COMMONWEALTH OF AUSTRALIA.

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DEPARTMENT OF NATIONAL DEVELOPMENT.

# BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

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RECORDS.

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1960/85



# THE 1960 INSTITUTION OF ENGINEERS' CONFERENCE, CAIRNS. QUEENSLAND.

by

G.M. Burton.

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TABLE OF CONTENTS

## SUMMARY

The 1960 Annual Conference of the Australian Institution of Engineers was held in Cairns, North Queensland, from 2nd to 9th May; I attended as one of the Department's representatives. A wide range of tropical engineering works, including two hydro-electric schemes, one irrigation project, harbour works and town engineering works, were visited and discussed. The discussions emphasized the effects of the tropics on construction and stability of structures.

On my return through Brisbane I visited the Moogerah Dam, a thin-arch structure near Ipswich, and the Queensland Geological Survey's Engineering Group.

## INTRODUCTION

The 1960 Conference of the Australian Institution of Engineers was held at Cairns, in north Queensland, from 2nd to 9th May. It was the first occasion on which the annual conference had been held outside a capital city or Newcastle (the only provincial city which is headquarters of a Division). Cairns was chosen so that engineers could examine the tropics and discuss the engineering problems associated with a tropical environment.

Approximately one-third of Australia lies north of latitude 23°27', the Tropic of Capricorn. Cairns, latitude 17°, is the most northerly city in Australia; it is 1250 miles by road, or 900 miles in a direct line, north of Brisbane. It is ideally placed for such a conference because of the varied surrounding tropical environment also, because of its excellent conference facilities and proximity to major current engineering works.

Cairns has a population of 24,000 and is the administrative centre for transport, electricity distribution and much commerce within the Cairns Division. This Division covers most of Cape York Peninsula and has a total population of 95,000. It has important agricultural, pastoral, timber and mining centres. The port of Cairns handles the greatest annual tonnage in Queensland, outside of Brisbane.

The tropical elements considered during the conference covered the high rainfall coastal belt near Cairns (Plate III), the high to moderate rainfall tropical highlands adjoining to the west, the low rainfall interior, including the centres of Mt. Isa and Mary Kathleen, and the medium rainfall coastal belt about Townsville (Plate I).

The Department of National Development was represented at the Conference by W.A. Wiebenga of the Geophysical Branch of the Bureau of Mineral Resources and myself of the Geological Branch.

A list of Kodachrome photos, taken during the conference and now filed in the Bureau collection, has been included at the end of this report.

## THE TROPICAL ENVIRONMENT

The main features of the tropics are:

1. High temperatures;
2. Summer, or monsoonal, rainfall;
3. Cyclone areas, with winds exceeding 100 m.p.h. and intense rainfall;

4. (a) For coastal area, high humidity and low evaporation;
   (b) For the interior, lower humidity and high evaporation.

These features differ greatly in degree and relative importance in the main geographic divisions of tropical Queensland, which are:

1. Tropical coast (Cairns Plain and Townsville).
2. Tropical highlands (Atherton and Evelyn Tablelands).
3. Tropical interior (Mt. Isa and north-western Queensland).

The engineering geologist is primarily concerned with the way in which these tropical environments affect:

1. Foundation strength and stability;
2. Geomorphology and weathering;
3. Groundwater-level and rainfall run-off;
4. Erosion and siltation.

Foundations must be strong enough to support the loads, and in some cases the uplift, imposed by the intense rains and winds.

The humid and arid tropical environments produce two land forms which differ in many respects from those found in the temperate areas of Australia, where most of the important engineering works have so far been built. The tropical humid environment produces deep dissection (given adequate relief), thereby exposing large areas of fresh rock side by side with large areas of deep soils and heavily chemically weathered rock. The soil and weathered mantle is preserved on many slopes, some as steep as 70°, by a thick cover of vegetation. In the dry tropical areas weathering is more physical than chemical, and vegetation is too sparse to protect the weathered material from erosion in the steeper country. The result is, in general, rocky hills, with light soil and thin weathered mantles, and nearby, in the lower country, areas of wash and soil which may be quite thick. Weathering is commonly deep along joints and shears.

The groundwater level is very shallow in the more humid areas but may be over one hundred feet in the arid areas. In both areas the piezometric surface may be subject to marked seasonal fluctuations. Both the depth of the piezometric surface and its fluctuation have a great effect on the stability and drainage of building foundations and excavations. The depth of the surface also is the deciding economic factor in the provision of a water supply in the early stages of development in many parts of tropical Queensland.

Erosion and siltation can be very great in the tropics. In the more arid parts it usually warrants careful consideration. In the more humid areas it is generally within acceptable engineering limits while the vegetation is maintained, but if this is removed the resulting erosion and siltation can be disastrous.

A knowledge of the mechanisms of weathering and erosion in the different tropical environments is very important in the selection of quarry and river gravel pit sites and in the planning of dam site foundation investigation programmes.

A paper on geological and geophysical engineering exploration in the tropics would have been a desirable addition to the proceedings.

## THE CONFERENCE

### GENERAL

The formal part of the Conference, consisting of technical sessions and short local excursions, was held in Cairns between 2nd and 6th May. Each of the seven technical sessions was divided into three sections, corresponding approximately to the three main divisions of engineering: civil, electrical, and mechanical; these three sections met simultaneously in three large halls. There were two half-day, and one full day, excursions to local engineering works and manufacturing plants. The usual General Meeting, Annual Dinner, and receptions were held also.

Post-sessional excursions in the Cairns and Mt. Isa regions followed on the week-end of 7-8th May. The Conference was adjourned to Townsville on 9th May where excursions and an official reception and a dinner were held.

### TECHNICAL SESSIONS

About 550 people were registered for the Conference. The large number meant crowding at some functions and prevented much useful informal discussion after some sessions. The lectures, however, were well organised and the freshness of the subject made up for any other weakness in the Conference. I attended technical sessions of the civil engineering group on all occasions.

### EXCURSIONS

The excursions covered a wide and interesting range of subjects. Unfortunately the control of the trips had been assigned to the Queensland Tourist Bureau and as a result the excursions were too long and did not permit detailed inspections of engineering works and discussions.

Many of the engineers and geologists who had been employed on the exploration and early construction of most of the projects visited had dispersed to new projects; their absence was felt by the Bureau officers when discussing the influence of geology at the different sites.

The use of Transhailers (megaphones containing small transistorised amplifiers) vastly improved those excursions on which they were used. Delegates were able to spread out and view the subject at ease and at the same time hear clearly everything said by the leader.

## ENGINEERING PROJECTS

### GENERAL

The major engineering works covered in the technical papers and excursions which I attended during the Conference were:

1. Mareeba-Dimbulah Irrigation Scheme;
2. Barron Falls Hydro-Electric Scheme;
3. Tully Falls Hydro-Electric Scheme;
4. Cairns Water Supply System;
5. Cairns Sewerage Scheme;
6. Mourilyan Harbour Development;

7. Mt. Isa and Mary Kathleen Rock Dams;
8. Townsville Harbour Works and Smelter.

All of these schemes have been built over the last ten years; they show the great efforts being made by the Queensland Irrigation and Water Supply Commission, Co-ordinator General's Department, State Electricity Commission, local government authorities and private companies to develop the tropical north of Queensland. Most of the schemes are only now beginning to yield large quantities of electricity and water; their influence on development should become very noticeable over the next five to ten years.

## MAREEBA-DIMBULAH IRRIGATION PROJECT

### The Project

The £20 million Mareeba-Dimbulah Project is designed to turn water from the east flowing coastal Barron River, at 2,200 ft. above sea-level, across the Great Dividing Range by means of channels and inverted siphons and into the north-westerly flowing Walsh and Mitchell Rivers. The additional water will irrigate large tracts of land in the basins of these two rivers.

The principal structure of the project is the Tinaroo Falls Dam, on the upper reaches of the Barron River, above the falls from which it takes its name. It is 25 miles south-west of Cairns. The dam will supply 378,000,000 gallons a day (10 times Brisbane's rate of consumption) to 1,000 farms over about 131,000 acres of land suitable for growing tobacco, cotton, maize, vegetables, fruit and pasture. The dam is the first large irrigation dam constructed in Queensland. The scheme is expected to lead to an increase in population of 16,000 and an added annual farm production of £6,000,000 in the Mareeba-Dimbulah area.

### Tinaroo Falls Dam

The salient facts about the Tinaroo Dam are:

Type: Concrete gravity
Height: 131 ft.
Length: 1750 ft.
Thickness: base - 120 ft.
crest - 12 ft.
Storage: 90,000 million gallons (320,000 acre feet)
Maximum design flood: 104,000 cusecs
Construction and design: Irrigation & Water Supply Commission, 1952-59.
Cost: £6,500,000.

It is a low, but very long, gravity dam with a direct overflow spillway. The wall contains the usual upper horizontal drainage and lower stepped grouting galleries. A subsidiary earth-fill embankment 820 ft. long and 21 ft. high had to be built at a low saddle ¾ mile south of the main dam to prevent over-topping during floods.

The dam is built on a coarse-grained biotite granite. It has a gently sloping left abutment: the right abutment, on the bank of the recent course of the river, is much steeper. The left abutment was covered by up to 50 ft. of alluvium, wash and weathered granite. This gives some idea of the deep chemical weathering in susceptible rock, like granite, in the tropics. In all 200,000 cub.yds. of material had to be excavated for a final placement of only 300,000 cub.yds. of concrete; practically all the material removed was taken from the left abutment.

The foundations were better than extensive exploratory drilling indicated and, mainly as a result of the saving in excavation and concrete, the job cost only £6,500,000 instead of the estimated £7,800,000. In all 12,000 ft. of diamond and percussion drilling was done in foundation exploration before and during construction.

An interesting feature of the left abutment was a deep narrow zone of weathering or "gullet" parallel to the dam wall which was not discovered in the exploratory drilling, although some holes were only 50 ft. apart. The treatment of this zone and a nearby transverse deeply weathered zone along a quartz vein is well described by Butler & Learmonth (1960).

The low permeability of the fresh foundations practically eliminated the need for blanket grouting and for the most part only 35 ft. deep BX drainage holes had to be drilled. The curtain grout holes were drilled to 70-80 ft. and were stage grouted. The curtain was drilled with a primary line of holes at 10 ft. centres and a secondary series of similarly spaced holes offset relative to the holes of the primary. Some additional holes were needed in places.

Butler & Learmonth's paper (loc.cit.) is an excellent, detailed paper on all elements of the design and construction of a gravity dam; it carries an excellent costing appendix which drew much praise during conference discussion. The paper is recommended highly for reading by all Bureau geologists interested in engineering geology.

The Commission's engineers pointed out that exploration could have been improved considerably and that a seismic survey preceding most of the drilling would have been most useful (to the geologist such a survey is considered imperative in view of the presence of an easily weathered rock in a climate conducive to deep chemical weathering). The engineers also said that they would consider the alternatives of an earth dam or pre-stressed concrete dam if building now. However when design of the irrigation project was in progress new topographical survey information caused the scheme to be suddenly and completely changed from a dam on the Walsh River to the present site. The engineers were called on to maintain the original time-table for the new scheme and as a result design and exploration time was severely restricted. The equipment available precluded an earth-fill dam.

Materials used in the concrete dam consisted of special low-heat cement from Townsville, a specially chosen sand, with low felspar and mica content, from Severin Creek, and aggregate from a quarry in a fine-grained granite near the dam site.

It is interesting to note that the aggregate was flakey particularly in the smaller sizes and that material smaller than $\frac{3}{8}$ inch had to be rejected. This required a higher cement content and consequently higher setting temperatures and placing difficulties.

The deep weathering at the quarry site required the removal of much overburden. This accounted for as much as 4/- out of the 15/- a ton cost of rock delivered to the crushers or an extra £20,000 for the dam.

The I. & W.S. Commission did much research into the mica content of sand during exploration for materials. This coincided with the period the Snowy Mountains Authority was investigating the same problem. The Commission found that up to 10% mica did not weaken appreciably the strength of the concrete.

Irrigation Chennels

The irrigation water from the dam passes through double outlet valves on the left abutment to concrete bench flumes following, with a very low down-gradient, the hillsides. About 400 miles of channels are needed to cover the full irrigation project; to date 75 miles of this programme have been completed. Water from Collins Weir on the Walsh River will be turned also into the same system at a later date.

The channel system consists of reinforced concrete bench flumes and pipes where topography demands, by trapezoidal concrete-lined channels where permeability or scour demands and earth channels where speed and permeability are not problems.

Some sections of the earth channel are being repaired by clay where permeability is greater than was expected.

Exploration for the channel lines consisted of a soil survey by the Department of Agriculture & Stock to assess permeability and hand-augering at 200 ft. intervals to test excavation difficulties. One officer commenced a study to compare the theoretical permeability obtained from auger holes with the losses in practice in the completed unlined channels but this work had to be discontinued because of lack of time.

No important geological problems have been encountered in channel construction. Most of the ground has proved suitable for immediate removals by ordinary medium-size earth moving plant or after ripping by the same plant.

BARRON FALLS HYDRO-ELECTRIC SCHEME

The Project

The Barron Falls Scheme consists of two sections: the existing system and the new system, now being started.

The existing scheme consists of a small underground power station operated by diverting the normal flow of the Barron River into a penstock tunnel at the top of the Barron Falls. The new scheme will use the same principle but will be much larger. As it will come into operation after the flow of the Barron River has been reduced by the Tinaroo Falls Dam diversion an additional pondage on Flaggy Creek, a lower tributary of the Barron River, will be necessary. The Flaggy Creek Dam site is being investigated by drilling.

Existing Hydro-Electric Scheme

The present hydro-electric scheme first produced electricity in 1935. A small intake channel just above the Falls diverts water into the penstock tunnel in which it is carried by two steel pipes to the turbines of the underground power station in the Barron Gorge 900 ft. below. This power station is interesting because it was the first underground power station built in Australia. The station turbines have a capacity of 3,800 kW and make use of only 40% of the 900 ft. of head available.

Later, in 1940, a small balancing pondage was built for the scheme by erecting a low 12 ft. high mass concrete wei across the river just above the Falls. This weir is V-shaped pointing downstream as it follows a line of sound metamorphic rock across the river.

All of the works of the existing and new scheme are in hard slate, phyllite, quartzite and metagreywacke of the Barron Metamorphics.

Hydro-Electric Extension Scheme

Exploration and designing of the extension scheme have been completed, except for the Flaggy Creek Dam site, and access roads and working areas are almost completed. Tenders are being sought for the initial major works.

The new works consist of raising the present weir by 13 ft., driving penstock tunnels, and excavating the new underground power station chamber and tailrace tunnels.

The raising of the weir is considered to be quite simple. The Barron River carries a large silt load at times but no great trouble is expected from silting. The present low weir has not silted because of the strong scouring flows in the narrow river course. Siltation studies are in progress at the upstream margin of the pondage.

Water from the new pondage will be diverted at new intake works on the right abutment of the weir and carried through a mile-long, 9½ ft. diameter concrete-lined tunnel to the surge chamber. Concrete lining was specified for the tunnel because it was feared the metamorphics would deteriorate.

The surge chamber will be excavated out of weathered rock and will consist of a silt extractor, surge tank and valve house. The inclined penstock tunnel from this chamber to the power house, 930 ft. vertical below, will be 1390 ft. long and 8½ ft. in diameter. The tunnel will be steel-lined and backed with concrete to meet the maximum 930 ft. of head.

The underground power house will be 138 ft. long, 32 ft. wide and 65 ft. high. It will house two generators with a total capacity of 60,000 kW.

Exploration of the works site has been simplified by experience gained in building the similar smaller existing scheme on the opposite bank of the river. The Co-ordinator General's Department, which is the constructing authority, has diamond-drilled much of course of the tunnel, power station and weir abutments. The Department is also driving an exploratory tunnel into the power station chamber site; this tunnel will ultimately be used for the power cables.

Sand and gravel supplies are no problem. Local contractors supplying Cairns are working large banks in the Barron River where it pours out to the coastal plain, a few miles downstream from the hydro-electric works. This material mainly consists of detritus from the Barron Metamorphics and is hard and clean.

TULLY FALLS HYDRO-ELECTRIC PROJECT

The Project

The Tully Falls Hydro-Electric Works were designed as the second stage of a scheme to provide electric power to the Cairns Regional Electricity Board. They were built to supplement the supply from the original Barron Falls Project and to provide for the electrical load of the early 1960's. The Barron Falls Extension is planned to meet the expected increase after this.

Recently the Townsville Regional Electricity Board and the Cairns Board have linked their two systems. The present surplus Tully power can now be used to supplement the base load of the Townsville Thermal Station which is heavily burdened by the recent great industrialisation of the Townsville area. It also lowers power costs by reducing the proportion of power from the Townsville Station, which is burning costly coal from the Collinsville Field (120 miles from Townsville). The Tully Scheme is also able to operate close to capacity by using part of its drought storage; if a long drought should occur it would be possible to feed Townsville power at certain times into the Cairns grid.

The complete Tully Scheme consists of the following works:

Koombooloomba Dam,
Tully Falls Diversion Weir,
Horizontal and Pressure Tunnels,
Kareeya Power Station,
Tully-Cochable Power Station,
Tully-Nitchaga Power Station.

The Koomboolomba Dam (Plate VIII) acts as a storage to control the flow of the Tully River for the hydro-electric works. A weir has been built across the river downstream from the dam and half a mile above the Tully Falls, to provide a balancing pond at the inlet works of the power station tunnels. Water diverted at the weir is carried by a horizontal tunnel through a ridge forming a major bend on the river and then by an inclined pressure tunnel to the Kareeya Power Station in the gorge below the Tully Falls.

This first section of the work has been built already by the Co-ordinator General's Department at a cost of £18 million. The Cochable and Nitchaga Power Stations are quite small and have not been started yet.

<u>Koombooloomba Dam</u>

This dam is a particularly interesting structure for the geologist. Its salient features are:

Type: Central concrete gravity section and rock-fill flanks.
Height: 115 ft.
Length of gravity section: 200 ft.
Storage: 152,000 acre-ft.
Construction and design: Co-ordinator General's Department.

The river bed at the dam site is of fresh well-jointed granite; however, in the abutments weathering persists almost right down to the level of the river. It was decided to overcome the difficulty created by unsound abutments by constructing a central concrete gravity section over the sound river bed and to join this to the valley wall by earth flanks. Before starting on the main dam it was decided to raise a low saddle on the margin of the storage by means of an earth-fill embankment. While building the embankment with weathered granite it was found that the permissible range of moisture content for an earth dam could not be maintained in this tropical area (100 inches of rainfall and 190 wet days per year). The flanks of the main dam were then re-designed to consists of a clay core and rock-fill shell. A small cut-off wall extends from the gravity section into the clay and rock fill section and the central ends of the fill sections are protected by large retaining wings on the concrete sections.

I was unable to gather any information on the grouting. Some water is being lost through a leak on the weathered left abutment, but the loss has not been assessed. It has been found that the heavy mantle of weathered rock in the catchment reduces the rate of rainfall run-off. It acts very much like snow in cold areas giving a lengthy controlled supply of water after precipitation.

An interesting feature of the dam is that it is the first major structure in Australia in which pozzolanic material has been used in the concrete.

It was noted in the early search for materials that many of the local sources of sand and aggregate contained reactive rocks and that the local water was corrosive after passing through the tropical humic soils. The engineers decided to search the volcanic rocks for pozzolana; suitable material was found ultimately in a weathered relatively uniform basaltic lahar. The need for a pozzolanic additive was overcome when a fine-grained granite aggregate source, and river sands that were only slightly reactive, were discovered. The pozzolan, however, was still used to reduce the amount of costly cement. It not only did this but saved considerable time because the resulting mix was more readily worked. The mix did not wash out as the normal mix does during pouring in rain (a vital factor in this tropical area where rain fell for 2/3 of the construction time), and the low setting-temperature, due to the presence of the pozzolan, permitted faster pouring in the extreme summer heat.

One speaker who had used power house fly-ash as a pozzolan on a small scale in the construction of Keepit Dam (Tamworth, N.S.W.) claimed that the resistance to rain of the pozzolanic mix was due not to any chemical reaction but rather to the physical action of the pozzolan as a filler. This question may be worth further investigation as the use of pozzolan or fillers may be desirable in any major works in the Territory of Papua-New Guinea.

Mr. R. Gipps, of the Co-ordinator General's Department, claimed that pozzolan is plentiful on the eastern side of the Dividing Range in North Queensland. He fired the imaginations of many engineers present and it is likely that Gipps & Britton's paper (1960) on pozzolan, which was keenly received, will increase rapidly the engineers' demands for pozzolan. Some serious errors may occur if materials are not tested carefully.

An illustration of the pitfalls that do occur even in a well-organized investigation is that all tests on the Koombooloomba pozzolan were done with a Victorian cement: in the actual construction Townsville cement was used and the concrete strength was considerably lower. Gipps may be right that pozzolana is more common in Queensland than thought, but the main question is whether other pollolanic deposits are as uniform as the Koombooloomba deposit, which is a lahar (Best, Appendix I).

## Tully Falls Diversion Weir, Tunnels & Kareeya Power Station

The water released by the Koombooloomba Dam is diverted by a low mass-concrete gravity weir into a steel-lined horizontal tunnel, 2210 ft. long and 9 ft. in diameter. The tunnel carries the water through the ridge that separates the upper reaches of the river from the lower gorge. At the end of the horizontal tunnel is an 18 ft. diameter surge chamber and valve-room. From the valve-room the water is dropped a vertical distance of 1400 ft. by an inclined pressure tunnel 3,300 ft. long, to the underground Kareeya Power Station. The pressure tunnel is steel-lined; the steel has a maximum thickness of $\frac{7}{8}$ inch.

The horizontal and pressure tunnels were driven in volcanics, with some basalt and granite intrusions. The tunnels are a mile long; by contrast the distance by river between the diversion weir above the Falls and the power station in the gorge below is two miles.

The underground power station was excavated out of rhyolite. It has a vaulted concrete roof and is 230 ft. long, 45 ft. wide and 42 ft. high. Generating capacity is 72,000 kW.

These works, including the dam weir tunnels and power house, have cost £18 million.

Cochable and Nitchaga Extensions

These two extensions still remain to be built.

The Tully-Cochable Extension will make use of a further drop in the Tully River below the Kareeya Power Station. It will have a capacity of 20,000 kW.

The Nitchaga-Tully Extension will use the head between the top of the Koombooloomba Dam and the diversion weir. It will have a capacity of only 5,400 kW.

## CAIRNS WATER SUPPLY

Cairns water supply comes from Freshwater Creek 7 miles west of Cairns. Three low weirs have been built on the Crystal Cascades to divert part of the flow into a steel pipe reticulation system, which supplies Cairns by gravity flow. Cairns' demand for water will soon exceed minimum river flow, and a storage dam will soon be needed. Suitable dam sites exist in the steep gorge upstream from the Cascades. The sites have already been inspected but not tested.

Many people in Cairns overcome the occasional water restrictions by sinking shallow spear-point pumps into the porous sands of the deltaic sediments on which Cairns is built (Plate IV).

## CAIRNS SEWERAGE SCHEME

The task of sewering Cairns is very difficult: the city is flat and underlain by water-saturated porous deltaic sediments. Various schemes have been considered over the last 38 years, but the present scheme, estimated to cost £1.5 million, was not started until 1958. It will service 3,500 premises - an average cost of over £400 a unit served.

The sewer lines cannot be laid until the water-table has been lowered beneath the proposed pipe-line and the sides of the trenches stabilized. The water-table is lowered by means of spear-point pumps sunk at 3 ft. intervals along lines parallel to and about 2 ft. back from the proposed sides of the trenches. The pumps are jetted into the soft sediments by means of high pressure water and then gravelled. As many as 80 pumps are linked to a centrifugal pump which has a capacity of 1200 gallons a minute (Plate V). This pump can de-water an area in from 2 to 4 days but it is necessary to continue pumping while excavating the trench so that the water-table will not rise again and flood the trench.

The sides of the trenches are protected from collapse during excavation by means of steel sheeting. The sheeting is driven into the ground by means of a rail-mounted pneumatic pile-driver before excavation commences and cross-braced immediately after the mechanical trencher has passed.

The sewer pipes are specially coated and are joined by rubber rings to prevent groundwater leakage into, and flooding of, the sewer system. The rubber rings require flexibility in the foundations of the pipes and so concrete mounting is avoided as far as possible. Keays and Traves (1960) give more details of the dewatering and mounting problems.

Mr. K.W. Jack mentioned to me that small scale problems like this may arise in the Canberra sewerage system near the Lakes. My impression is that the permeability would only be great enough to constitute a problem in the areas of alluvium and aeolian sand. Care, however, will always have to be taken in supporting trenches near the Lakes or where groundwater level has been raised, even well away from the Lakes.

## MOURILYAN HARBOUR

Mourilyan Harbour (McKay, et al. 1960) is the port for Innisfail; until recently it was partly blocked by a shallow rock bar. The harbour behind this bar is deep and silt free. Some authorities suggested that if the bar were removed a change would occur in the scouring currents and the harbour would silt up.

The University of Queensland built a tide synthesiser and harbour model to investigate the problem. Work on this model demonstrated that the bar could be deepened safely to nearly 30 ft. but below this the scouring currents started to lessen. The bar was subsequently lowered to nearly 30 ft. and the harbour is now a major sugar loading port.

The tide synthesiser places the University of Queensland in a position to study major coastal engineering problems, including silting, wherever they arise.

## MT. ISA AND MARY KATHLEEN DAMS

I also attended the presentation of the paper by Mr. G.I. Davey (1960), of Gutteridge, Haskins and Davey, Consulting Engineers, on rock-fill dams for Mount Isa and Mary Kathleen, on the Leichhardt River and Corella River respectively. Both dams are only about 80 ft. high and have side-cut spill-ways.

The rock fill for the dams came mainly from the spillway cuts and had a specified maximum of 15% of minus 6" sizes to reduce settling in the wall. The rock-fill for the Leichhardt Dam was quartzite and for the Corella Dam it was calc-silicate hornfels and granulite.

The upstream face of both dams consisted of hand placed rock supporting steel reinforcing and sprayed with about 4" of gunite (10:1, sand-cement mix). In the Corella Dam the gunite facing is a continuous sheet, into which shrinkage grooves were cut part-way and filled with bitumen.

In the Leichhardt Dam the facing was prepared in sections and the sections were joined by rubber dumbells. Each dam has a 3 ft. deep concrete cut-off wall sunk into the ground and bonded to the foundation rock and gunite facing by steel rods.

Both dam sites were curtain-grouted to a depth of 30 ft., but took little grout. The joints on the abutments of the Corella Dam leaked but the leakage was insufficient to warrant grouting.

## TOWNSVILLE HARBOUR WORKS AND COPPER REFINERY

### General

The visit to Townsville included inspections of the Bulk Sugar Loading Terminal and Townsville Copper Refinery. Both are built on deltaic sediments and alluvium, and the main engineering geology interest in them lies in the treatment of the foundations. These foundations have not only to resist compaction but in some cases must also be able to resist uplift caused by the overturning moments of cyclonic wind gusts in excess of 110 miles per hour.

### Harbour Works

The Townsville Sugar Bulk Loading Terminal is the most important item in the scheme to remodel the Townsville Harbour.

The Plant consists of a very large storage shed from which sugar is fed to a conveyor belt in the shed foundations. The sugar is carried by the belt to a complicated overhead loading system which runs the full length of a new 850 ft. concrete wharf.

Because of the size of the storage shed and overhead loading wharf great care has been taken to ensure that the foundations will withstand cyclones. The storage shed is 1000 ft. long and 90 ft. high. It is partly built on rock and partly on carefully prepared frankipiles. The wharf foundations consist of two H-section steel piles driven, inside a caisson, into the underlying sediments. The piles, after driving, were cut off several feet below the surface of the sediments and capped with concrete. Concrete piers were then formed on top of these caps, in the section exposed to air and sea water.

Considerable silting is taking place in the Townsville Harbour, and dredging is continuous. The authorities consider that the siltation problem must be faced some day but that in the meantime the main effort and the available funds must be directed towards developing productive facilities.

Most of the aggregate used for major works such as this in Townsville comes from the Council quarry in the granite of Castle Hill. I did not have the opportunity to visit this quarry.

### Townsville Copper Refinery

The Townsville Refinery treats "blister-copper" railed from the smelter at Mt. Isa. The blister-copper is oxidised in a furnace to remove sulphur impurities and is then cast into anodes. The anodes are then refined electrolytically, and the refined copper is cast into "wire bars" for sale.

The heavy equipment required in this refining needed very stable foundations and careful preparation of the alluvium (Saint-Smith, 1960). Over 1500 16 inch Frankipiles were used in the foundations of the casting house, tank house and heavier parts of the rod mill.

The foundations of other buildings were prepared by compacting the ground with 30-ton loaded Tournapuls and covering the consolidated ground with compacted gravel before laying thick concrete floors.

The plant roads have to bear fast-moving fork-lift vehicles smoothly. As the fork-lift vehicles have very high tyre loads it was decided that the only suitable roadways on the alluvium would be 7 inch thick reinforced concrete pavements.

## MOOGERAH DAM

On my return through Brisbane I visited Moogerah Dam Site with Mr. F. Learmonth, Chief Construction Engineer, and Dr. Fraser, Senior Design Engineer, of the Queensland Irrigation and Water Supply Commission.

The Moogerah Dam site is near Mt. Edwards, on Reynolds Creek; it is 35 miles south of Ipswich. The dam is being built to provide additional irrigation water and flood control for the Reynolds and Warril Valleys, which stretch from the dam site almost to Ipswich.

The main details of the dam are:

Type: Thin double-curvature concrete arch
Maximum height: 124 ft.
Length: 684 ft.
Thickness: maximum 16 ft.
minimum 6½ ft.
Spillway: Side-cut, 85 ft. long, 19 ft. deep
Storage: 73,000 acre-feet
Cost: £1.3 million.

The dam is built on trachyte, according to R. Tucker of the Queensland Geological Survey who surveyed the site originally. This report is to be found in Commissioner Haigh's (1958) report, which also contains details of the Moogerah Irrigation Scheme.

The most interesting geological feature of the dam site is the jointing. Tucker originally mapped the site and reported: "two main vertical (joint) systems occur which strike approximately 70° and 340°. There is also a system of horizontal to slightly inclined joints; and, "the only structural weaknesses are the joints which may by careful selection and test drilling be overcome."

The dam excavations now show these near horizontal joints clearly. Their inclination appears to follow the topography closely, but the reason for this is not clear. The relationship may be due to jointing inherited at the time of consolidation of the trachyte, or may result from exfoliation, or unloading, connected with the recent geomorphology. It may be brought about by a combination of geological factors.

The contrast between the jointing in the two abutments is striking. The right abutment is a low rounded spur, and both the vertical and horizontal joints (Plate IX) have opened up to a depth of 30 feet. The "horizontal" joints follow closely the shape of the ground surface. The left abutment is a steep valley wall; in it the "horizontal" joints are almost as steep as the slope and are open only to a depth of 5 to 10 ft.

A problem in the Moogerah Dam is that the spillway and part of the right thrust-block have been sited on the downstream face of the spur (Plate IX). In this place the "horizontal" joints dip, like the ground-surface, downstream and provide potential slippage planes. Consequently a considerable load has to be borne on a plane of weakness. The engineers say that if they had been able to determine this earlier they would have moved the right abutment slightly upstream so that the foundations would be on horizontal joints on the top of the spur.

The blanket grouting for the dam is relatively simple. All holes were drilled to 20 ft. and grouted in two stages 0-10 ft. and 10-20 ft. On the right abutment grout hole spacing was 10 ft. and maximum pressure used was 30 lbs./sq. in. For the right part of the river section the spacing was 20 ft. with a maximum pressure of 50 lbs./sq. in.; for the remainder 20 ft. spacings have been drilled but only every second hole has required grouting because the holes have taken only small quantities of grout and the intermediate holes have been tested satisfactorily.

Aggregate and sand are both obtained from gravel beds farther up Reynolds Creek. The gravel aggregate is yielding 50% reactive volcanic rock. Earlier sampling of the gravels neglected the larger gravel boulders and indicated only 30% reactive rock - this is a further warning on the care needed in sampling gravels. A low alkaline cement is being used and it is not thought that the aggregate will cause trouble. The possibility that chemical reaction might weaken the bond between the concrete of the structure and the trachyte foundations has also had to be considered.

A committee, consisting of the Chief Design Engineer (Mr. Butler), Senior Design Engineer (Dr. Fraser), and Chief Construction Engineer (Mr. Learmonth), approves all excavations before pouring. This committee calls on the specialized advice of the Commission's geologist when necessary. The geologist was on leave during my visit and so I did not meet him.

## CONFERENCE POINTS OF INTEREST

Points of interest in the Conference management which I noted, and which may be useful for the Bureau when running conferences were:

(1) The use of punch-cards for the registration of delegates added considerably to the efficiency of the whole Conference. These standard cards can be purchased from Sands & MacDougall, Melbourne, and can be used for any system of classification after the necessary headings have been printed on them.

(2) Slide projection was well managed. Screens were well placed high so that all could see. An interesting innovation was a small globe on the projectionist's table to indicate when a slide was to be changed; the globe was powered by a torch battery and controlled by a button on the speaker's lectern. The result was fast and smooth slide projecting. Spare projecting globes were available at each machine.

(3) The use of Transhailers (megaphones with small built-in transistorised amplifiers) proved invaluable on the Barron Falls and Copper Refinery excursions.

(4) Excursions should be short enough and the parties small enough, to permit a reasonable amount of detail.

## REFERENCES

BUTLER, N.J., and LEARMONTH, F.M., 1960 - Design and construction of Tinaroo Falls Dam. Inst. Eng. Aust. 1960 Conference, Preprint.

DAVEY, G.I., 1960 - Rock Fill Dams at Mary Kathleen and Mount Isa, ibid.

GIPPS, R. de V., and BRITTON, A.H., 1960 - Local pozzolana used in concrete for Koombooloomba Dam, ibid.

HAIGH, F.B., 1958 - Development of the water resources of Warril Creek. Qld. Irrig. Com. Rep.

KEAYS, J.F., and TRAVES, N.H., 1960 - Design and construction of a sewerage scheme for Cairns, Inst.Eng.Aust., 1960 Conference Preprint.

McKAY, G.R., FISON, E.C., TRANBERG, C.R., 1960, Mourilyan Harbour Development, ibid.

SAINT-SMITH, J.C., 1960 - Design and construction of Townsville Copper Refinery, ibid.

KODACHROME LIST

The following slides of engineering features seen during the Conference have been filed in the Geological Branch collection.

| Subject | Slide No. |
|---|---|
| Cairns - coastal plain and ranges from Trinity Bay | QE 55/2/1 |
| Green Is. - barrier reef off Cairns | /2 |
| Cairns canefield - coastal plain north of Cairns | /3 |
| Cairns park - coastal plain underlain by water table only 4 ft. below | /4 |
| Barron River mouth - on plain also showing aerodrome and Trinity Bay | /5 |
| Cairns sewerage - excavating between lines of pumps; in foreground is sheeting for trench sides | /6 |
| Cairns sewerage - ditto, close-up | /7 |
| " " - trench supported by sheeting and braces | /8 |
| Cairns sewerage - pneumatic pile-driver inserting sheeting | /9 |
| Cairns sewerage - jetting in spear-point pump casing | /10 |
| " " - ditto | /11 |
| " " - spear-pump screen and head | /12 |
| " " - surface house of underground pump chamber | /13 |
| Tinaroo Falls Dam - river-control valve open | QE 55/6/1 |
| " " " - from quarry site; earth dam in foreground | /2 |
| Tinaroo Falls Dam - irrigation outlet valve house | /3 |
| " " " - left abutment, deeply weathered zone | /7 |
| Tinaroo Falls Dam - irrigation outlet channel | /4 |
| " " " - right abutment | /5 |
| " " " - pondage from right abutment | /6 |
| Mareeba-Dimbulah Irrigation Scheme - concrete bench flume | QE 55/5/1 |
| Mareeba-Dimbulah Irrigation Scheme - concrete lined trapezoidal channel | /2 |
| Mareeba-Dimbulah Irrigation Scheme - flow dissipator at foot of steep channel | /3 |
| Mareeba-Dimbulah Irrigation Scheme - automatic steady-flow control | /4 |
| Barron Falls - weir and pond | QE 55/2/14 |
| " " - part of falls | /15 |
| " " - coastal scarp at Stoney Creek | /16 |
| " " - ditto | /17 |
| " " - gorge, power house bridge, coastal plain | /18 |
| " " - bridge foundations to withstand strong turbulent flow | /19 |
| Cairns Water Supply - weirs on Crystal Cascades | /20 |
| Cairns Canefields- on plains at mouth of Freshwater Creek | /21 |
| Koombooloomba Dam - gravity and rock-fill sections | QE 55/6/8 |
| " " - outlet valve and spillway | /9 |
| " " - earth-fill weir on saddle | /10 |
| Tully Falls - flow stopped by Koombooloomba | /11 |
| Townsville - Copper Refinery | QE 55/14/7 |
| " - bulk sugar shed | /8 |
| " - " " wharf | /9 |
| " - design of wharf piers | /10 |
| " - wharf piers, concrete section | /11 |
| " - dredging channel | /12 |
| " - Castle Hill granite | /13 |
| " - Magnetic Island | /14 |
| Moogerah Dam - model | H 56/2/1 |
| " " - batching plant and catchment | /2 |
| " " - pondage | /3 |

| Subject | Slide No. |
|---|---|
| Moogerah Dam - spillway and thrust block | H 56/2/4 |
| " " - jointing on right abutment | /5 |
| " " - jointing and excavations, right abutment | /6 |
| Moogerah Dam - thrust block, right abutment | /7 |
| " " - ditto | /8 |
| " " - jointing, near right thrust block | /9 |
| " " - diversion flume | /10 |
| " " - coffer dam | /11 |
| " " - foundations in bed of river | /12 |
| " " - " " " " " | /13 |
| " " - left abutment | /14 |
| " " - " " , excavations | /15 |
| " " - " " , jointing | /16 |

# APPENDIX I

The following comments on Gipps and Britton's paper (*loc. cit.*) were prepared before the Conference by J.G. Best and were tabled by me at the conference, for inclusion in the proceedings of the meeting.

APPENDIX I

## Comments on local pozzolana used in concrete for Koombooloomba Dam

by

J.G. Best

The Staff of the Co-ordinator-General's Department should be congratulated for the initiative displayed in recognising, testing and using a local pozzolan in the construction of Koombooloomba Dam.

The following comments are proffered in the belief that they are supplemtnary to the information contained in the paper and in the hope that they may help to round out the picture on this deposit.

### ORIGIN OF THE POZZOLAN

Mr. Britton has mentioned that two schools of thought exist among geologists on the origin of the pozzolan; as a geologist, I wish to pursue the matter a little further because:

(a) I believe a knowledge of the formation of the deposit will assit in search for other similar deposits, not only in Queensland but elsewhere in Australia.

(b) This pozzolan has in some respects proved to be atypical and consequently difficult to classify; it may be that a better appreciation of its genesis may assist in solving some of these problems.

One school of thought believes that the material was originally a thick basalt flow which has been almost completely decomposed by weathering; the second school favours a basalt pyroclast which is completely weathered in the lower horizons. I belong to the second school and propose to present evidence which I consider conclusively proves the pryoclastic origin of the Tully Falls pozzolan.

1. The deposit has been bored by hand auger to a depth of more than 70 feet; this could indicate either a completely weathered flow or an unlithified pyroclast.

2. The pozzolan pit is 15-20 feet deep and reveals several feet of red soil overlying 6-8 feet of red, oxidised, pozzolan which grades down into grey pozzolan. The deposit is massive with boulders of olivine basalt scattered sporadically through it: where dry, the material has a compact crumb texture; but apart from this there is no sign of structure. Columnar jointing and bedding are entirely absent.

(a) There are many basalt flows exposed throughout the Tableland area; all those I have examined, are closely columnar jointed and I find it difficult to envisage how weathering could erase all traces of such a well developed fracture pattern. There are excellent exposures of dissected basalt flows at Ravenshoe Falls, Millaa Millaa Falls, Malanda Falls and on the Tully River near Cardstone and should you feel sceptical about this I urge you to examine one or all of these exposures.

(b) The rare boulders found in the grey horizon of the deposit are quite fresh throughout; **had they** been of residual origin there would have been some sign of partly weathered exfoliated shells surrounding them.

(c) The grey colour of the lower horizon is significant; had weathering been as complete as is suggested by the hand augering tests, then the lower horizons would have been leached and pallid; as it is, there is little to choose in colour between this material and freshly ground basalt.

(d) The absence of bedding, the thickness of the deposit and the sporadic distribution of the boulders suggest that this is a lahar deposit. Lahars are concomitants of explosive volcanic eruptions, particularly in high rainfall areas; they are caused by water, usually heavy falls of rain, saturating thick ash deposits near the crater and the resultant mud, flows inexorably down depressions to form thick massive deposits, ranging from agglomerate to tuff, many miles from the vent; commonly sub-aerial deposits in the same area are thin and bedded, or absent.

Lahars can travel long distances and are not affected by prevailing winds;. both these factors are significant when considering a possible source for the Tully Falls deposit because the only likely vents are well to the north, on the Atherton Tableland. There, late stage explosive volcanic activity has reamed out four large explosion craters and mantled the Atherton and Evelyn Tablelands with up to 100 feet of basaltic pyroclasts and I am convinced the Tully Falls deposit is a distal portion of these pyroclasts.

3. Thin sections of the pozzolan have been prepared in the Bureau of Mineral Resources laboratory. Under the microscope the material is seen to consist of fine wisps of decomposed rock minerals, probably mainly clay, but there is some undecomposed finely comminuted rock mineral present; that is, the grey pozzolan is a weathered pyroclast.

Mr. Britton has inferred in Table IV that the pozzolan may not have been derived from olivine basalt; presumably this inference is based on the lower $SiO_2$ percentage of the pozzolan. Personally I think the figures in Table IV offer ample confirmatory evidence that the pozzolan is a weathered olivine basalt. For example, the loss in $SiO_2$ is 9.44% and the loss of MgO, CaO, $Na_2O$ and $K_2O$ totals 10.83%; most of these metals form soluble silicates, so it is a reasonable assumption that the silica was leached with these metals; the figures accord well with such an assumption. Also the total loss accords well with the total gain; silica plus the four oxides listed above aggregates 20.27%, and $Al_2O_3$ + $Fe_2O_3$, $TiO_2$ aggregates 20.3%; these figures show too much accord to be accidental.

All authors agree that basic volcanic rocks generally do not make good pozzolans; yet **here** is a material derived from olivine basalt which has pronounced pozzolanic activity. What is the reason for it? Mr. Britton has demonstrated that halloysite is probably the main reactive mineral, and that the material is a satisfactory pozzolan without sintering and fine grinding. Most clay minerals are pozzolanic but commonly require sintering and fine-grinding to produce a suitably reactive material. Could it be that its finely comminuted state, a relic of its pyroclastic origin, is in some way responsible? Possibly this is a line worth investigating.

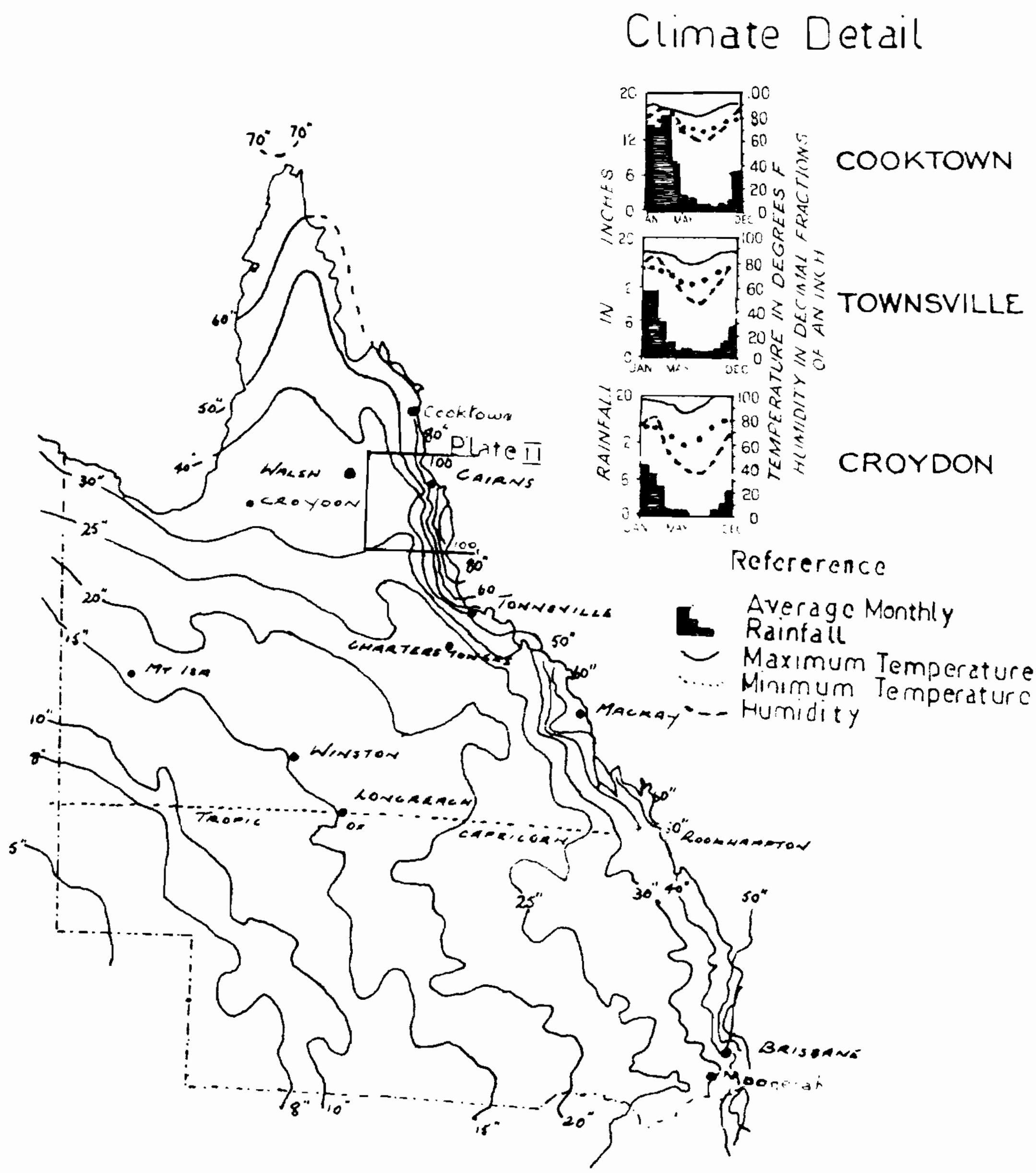
If the pyroclastic origin should prove to play a significant part in the pozzolanic activity, then the search for further basalt pozzolans is facilitated because pyroclastic basalts are much more restricted in area than effusive basalts.

In conclusion, I wish to express my appreciation of the paper; it records a pioneering venture and I hope it will promote further interest in the use of natural pozzolans in Australia.

Plate I

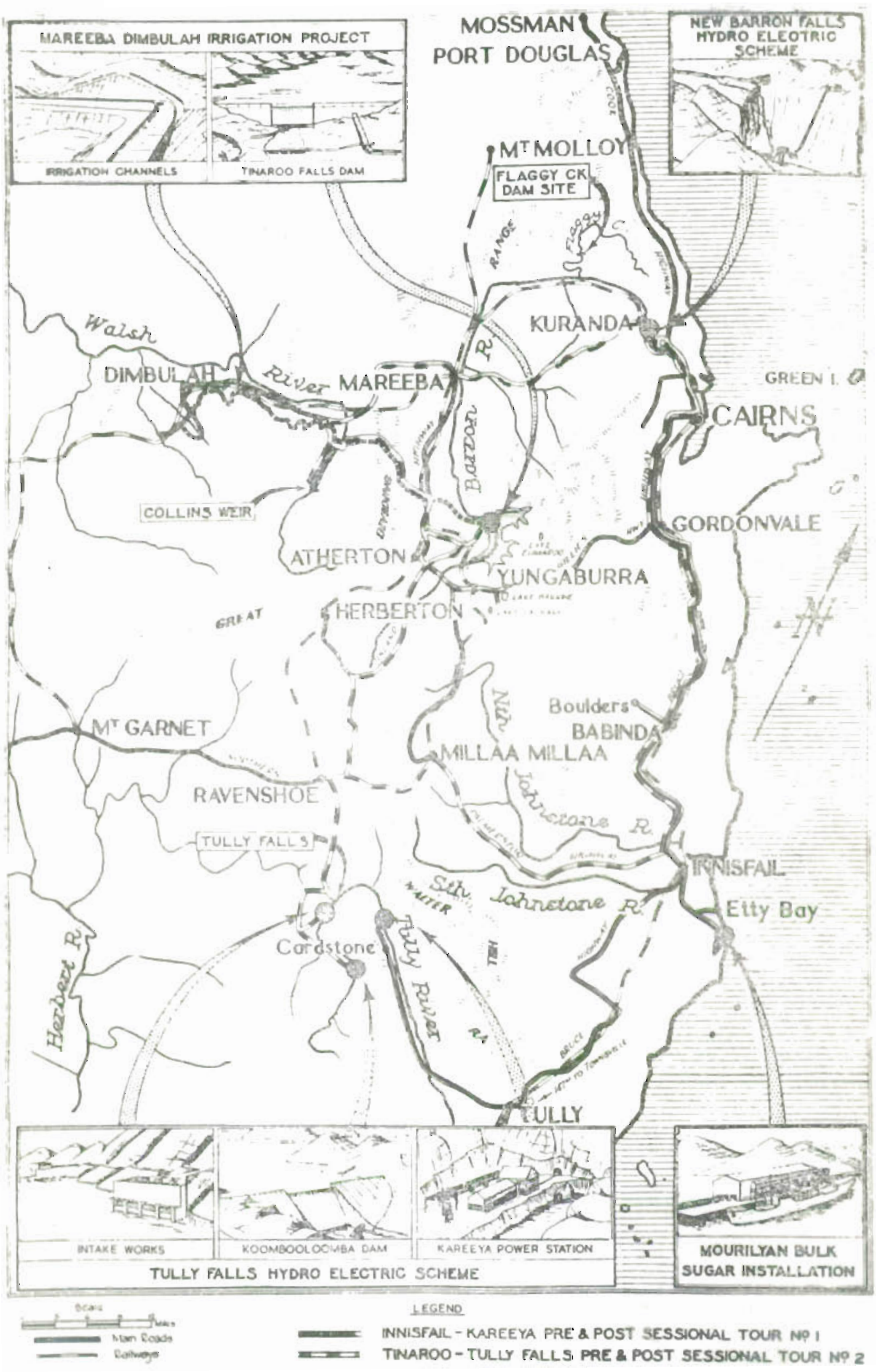
# LOCALITY MAP

## SHOWING TROPICS AND RAINFALL




Queensland Annual Rainfall

—5" Isohyets (Variable Interval)


MAREEBA DIMBULAH IRRIGATION PROJECT
IRRIGATION CHANNELS
TINAROO FALLS DAM
MOSSMAN
PORT DOUGLAS
NEW BARRON FALLS HYDRO ELECTRIC SCHEME
MT MOLLOY
FLAGGY CK DAM SITE
KURANDA
Walsh River
DIMBULAH
MAREEBA
Barron R.
GREEN I.
CAIRNS
COLLINS WEIR
ATHERTON
GORDONVALE
YUNGABURRA
HERBERTON
GREAT
Boulders
BABINDA
MT GARNET
MILLAA MILLAA
Nth Johnstone R.
RAVENSHOE
TULLY FALLS
INNISFAIL
Sth Johnstone R.
Etty Bay
Cardstone
Herbert R.
Tully River
TULLY
INTAKE WORKS
KOOMBOOLOOMBA DAM
KAREEYA POWER STATION
TULLY FALLS HYDRO ELECTRIC SCHEME
MOURILYAN BULK SUGAR INSTALLATION
LEGEND
Main Roads
Railways
INNISFAIL - KAREEYA PRE & POST SESSIONAL TOUR Nº 1
TINAROO - TULLY FALLS PRE & POST SESSIONAL TOUR Nº 2

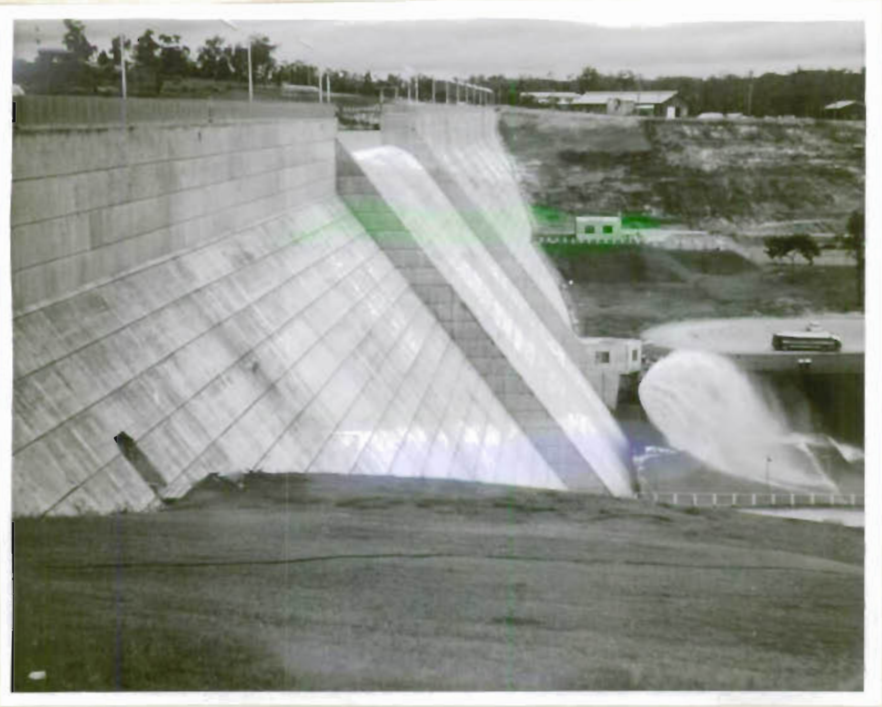
1. Cairns from Trinity Bay; Whitfield Range is seen rising behind city.

2. Coastal Plain at mouth of Barron River, Cairns Aerodrome and Trinity Bay in background.

1. Cairns park; park is watered by spear-point pumps pumping from water-table 4 ft. below surface.

1. Cairns sewerage, trench digger operating between lines of spear-point pumps

2. Cairns sewerage, jetting-in spear-point pump casing.



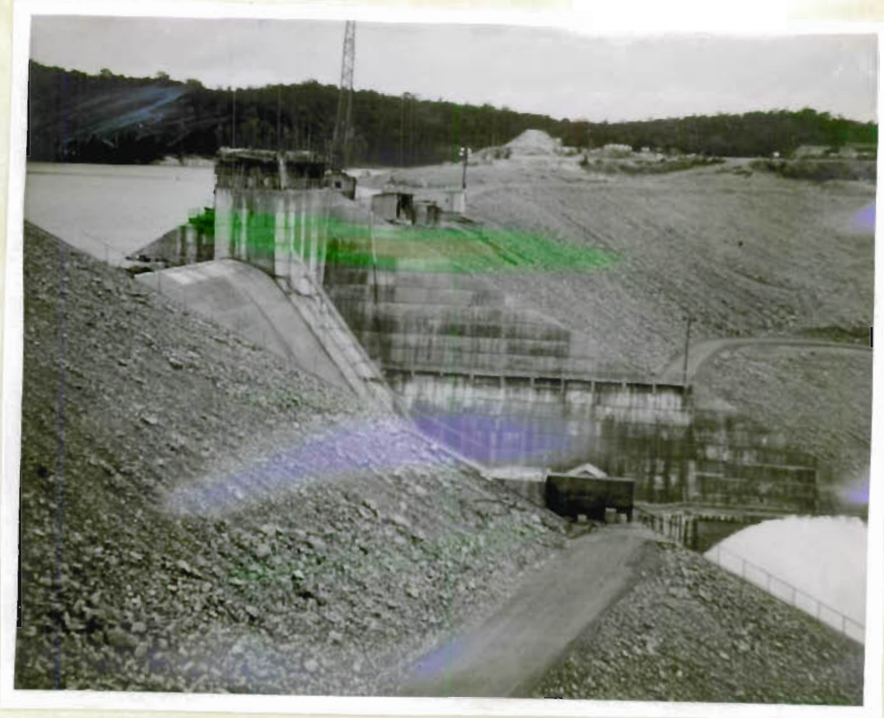
1. Tinaroo Falls Dam.

2. Mareeba-Dimbulah Irrigation Scheme, shewing concrete lined trapezoidal channels.

PLATE VII

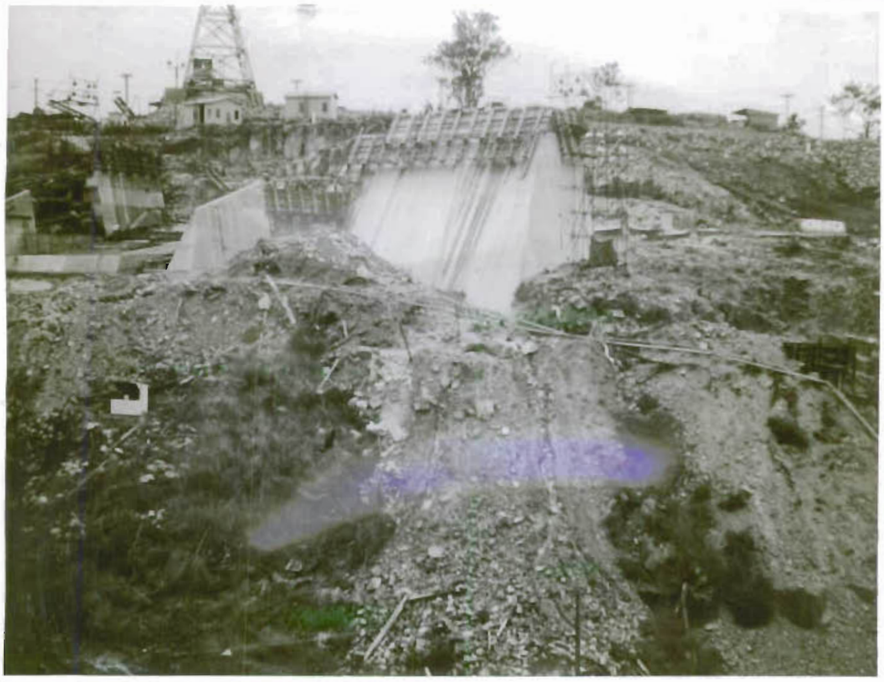
1. Barron Falls Weir.

2. Barron River Gorge and coastal plain; bridge to underground power house site on right bank can be seen in foreground.



1. Koombooloomba Dam, shewing central concrete gravity spillway section and rock-fill flanks.

PLATE IX



1. Moogerah Dam - right thrust block and spillway.

2. Moogerah Dam - Jointing on right abutment.