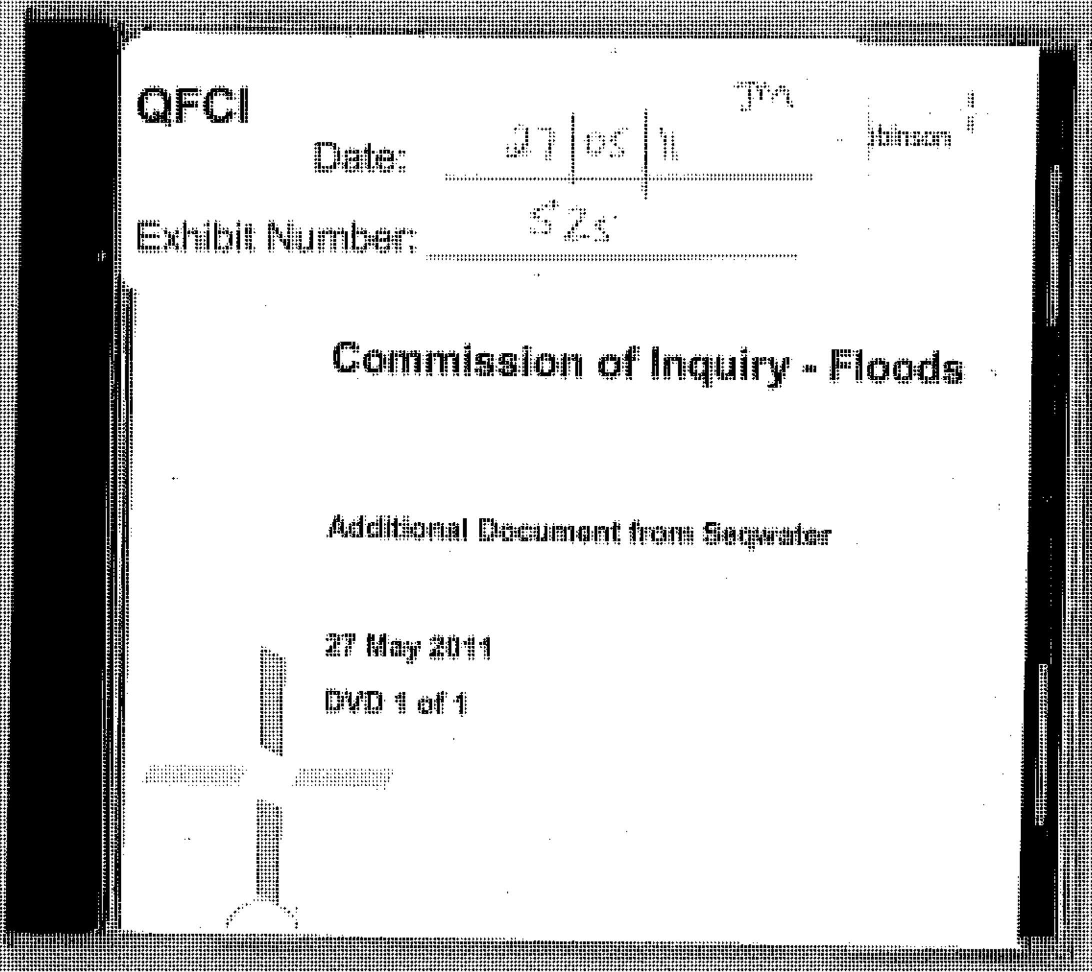


QFCI
JM
Date: 27 | 05 | 11
Exhibit Number: 525
Commission of Inquiry - Floods
Additional Document from Seqwater
27 May 2011
DVD 1 of 1

THE INSTITUTION OF ENGINEERS, AUSTRALIA
QUEENSLAND DIVISION
AUGUST, 1974

Proceedings of Symposium

JANUARY 1974 FLOODS
Moreton Region

HELD AT JOHN KINDLER MEMORIAL THEATRE
QUEENSLAND INSTITUTE OF TECHNOLOGY
3 & 10 APRIL, 1974

Proceedings of Symposium

JANUARY 1974 FLOODS
Moreton Region

HELD AT JOHN KINDLER MEMORIAL THEATRE
QUEENSLAND INSTITUTE OF TECHNOLOGY
3 & 10 APRIL, 1974

THE INSTITUTION OF ENGINEERS, AUSTRALIA
QUEENSLAND DIVISION
AUGUST, 1974

Photograph on Front Cover
by Courtesy of Courier Mail

Registered for Posting, Category C.

CONTENTS

		PAGE
Foreword	- T. L. Piggott Chairman, Water Engineering Branch	3
Opening Address	- Sir Charles Barton Co-ordinator General Queensland	4

HYDROMETEOROLOGY AND FLOOD WARNING SYSTEMS

Synoptic Meteorology of Flood Period (and Discussion)
- A. J. Shields 7

Hydrology of the Floods (and Discussion)
- J. K. G. Ward 39

Flood Forecasting and Warnings, Moreton Region
- G. Heatherwick 56

Flood Forecasting in the Brisbane River (and Discussion on both Forecasting papers)
- G. Cossins 81

Social Aspects of Flood Warnings (and Discussion)
- A. L. Quinnell 134

Interpretation of Flood Forecasts (and Discussion)
- I. Fairweather 141

FLOOD MITIGATION

Flood Mitigation in the Brisbane River (and Discussion)
- G. Cossins 151

Flooding in Brisbane Metropolitan Creeks
- I. G. Cameron 190

Flooding in Enoggera - Breakfast Creek Catchment (and Discussion on both Creek Flooding papers)
- K. J. Morris 197

CONTENTS (CTD.)

PAGE

FLOOD MITIGATION (contd.)

Flood Insurance (and Discussion)
- J. L. Irish 214

EFFECTS ON FLOOD ON SERVICES

Water Supply Maintenance in Brisbane
- W. G. S. Huxley 224

Brisbane Sewerage System
- J. J. Corbett 235

The Mount Crosby Problem (and Discussion associated with three previous papers)
- T. G. Reid 237

Electricity Distribution System - J. C. Oberthur 241

Telecommunications - P. L. Dubois 245

Roads and Highways - W. J. Cock 252

Are Trains Afraid of Floods? - G. H. Gore 255

Port of Brisbane (and Discussion associated with five previous papers)
- W. Chorley 261

ETHICS

The Ethical Position of the Engineering Profession
- J. F. Keays
Chairman Queensland Division 267

SYMPOSIUM SUMMARY 274

FOREWARD

1974 was heralded by the worst flood situation in the Moreton Region this Century. With the floods of 1893 in living memory, the Engineering Profession was, on the whole, not surprised by this event, although some individuals were taken unawares. The public, and some public utilities, were not so aware.

The Committee of the Water Engineering Branch agreed that the Engineering Profession should be advised of the facts of the flood situation as quickly as possible after the event. The areas of interest were considered to be:- cause; dissemination of information; effects on people; properties and services; lessons learned; prospects for the future and ethical role of the engineer.

The outcome was a two session symposium held on the 3rd and 10th April 1974, at which attendances of over 300 on the first night and over 200 on the second were recorded. The large numbers of speakers and the range of topics covered is reflected in this document.

The success of the symposium was due, in the main, to the efforts of Mr. Geoff Cossins and Mr. Geoff Heatherwick who undertook the mammoth task of arranging the speakers at short notice, despite their deep professional involvement with the aftermath of flooding, and of editing this publication.

Thanks are due to the following:

Sir Charles Barton for opening the Symposium,

Mr. John Andrews for chairing the first meeting,

The Queensland Institute of Technology for making the John Kindler Memorial Lecture Theatre available for the Symposium and

The Department of Civil Engineering for providing the backup facilities.

T. L. Piggott B.E., M Sc.,M.I.E. Aust.
Chairman
Water Engineering Branch
August 1974

OPENING ADDRESS BY SIR CHARLES BARTON B.E. F.I.E. Aust.
CO-ORDINATOR GENERAL OF QUEENSLAND

Flooding of serious proportions began in Queensland on December 18th, 1973, when flooding in the Dawson River caused trouble in that area and necessitated the intervention of the State Disaster Relief Organisation. A helicopter was obtained from the Army for use in the area and made several flights to ferry out people as well as to take in food and to make reconnaissances.

There was an easing of the situation over the Christmas, New Year period, but the end of the first week in 1974 saw things hotting up with floods on the coast and inland.

The major flooding in the north and west was at its worst with evacuations of hundreds of people by air in progress when the troubles of the Moreton Region began with the flooding of the creeks in the city area.

There is probably no need for me to point out to this audience the nature of Brisbane's dual flooding problems which arise firstly and most frequently from local flooding in the creeks traversing the city area; this flooding has become more serious as housing development with its increased areas of impervious surfaces has extended in the creek valleys and unfortunately even in the creek flood plains.

Secondly there is the flooding of the main river, which occurs less frequently. This main river flooding causes flooding also in the first mentioned creeks due to backwater extending up the creek valleys.

The flooding of the main river is of course much more serious in its results if it rises above certain levels but we must not underestimate the severe effects which the creek flooding can cause or the frightening spectacle to the householder of being surrounded by fast flowing flood water.

In fact in January of this year we had both types of flooding, the main river flood occurring while the effects of the creek flooding were still in the process of being dealt with.

There can be no doubt that the flooding experienced created a wave of shock in the community and we can be very thankful that the 1893 pattern of two major floods in a fortnight was not repeated.

Resulting from the effects of the flood there has been the normal reaction of trying to apportion blame; in the main to try to pin blame on to various authorities.

Among the authorities there has been examination of the problems as they saw them and of their deficiencies in dealing with them. The Police Department, for instance, has had two seminars to study their shortcomings and to find solutions for their many problems.

One constant criticism is that people should have been told what might happen and have been warned how river heights would affect the various areas of the city. This information was available, it is said, and not used.

The lesson from this is, I think, that there must be strenuous efforts to get information about flood prone areas across to people.

In Brisbane many people suffered from what I call the Somerset Dam Syndrome. They knew about the 1893 flood and the heights reached but now that we have Somerset Dam it won't happen again. I believe many of you here would have told people of flood possibilities to find them unbelieving.

Mr. Shields, who will contribute to this symposium, has made some very definite statements on flooding possibilities over a number of years. He it was, I think, who organised a striking T.V. session to drive home the message that flooding danger had not been eliminated. On occasions there have been articles and flood maps in the local papers. The critics have not seen these and they are probably more interested than most. As engineers, therefore, we should all help to keep the facts before people. When Wivenhoe Dam is built, don't let us have a Wivenhoe Syndrome develop in the Community; for Wivenhoe Dam, while it will greatly reduce the flooded areas, will still leave areas subject to severe flooding.

Let me now turn to what sort of organisation we have to deal with the effects of flood and to what is being done at Government level to reduce the effects of flooding in the Moreton Region.

Firstly let us take the organisation available to deal with the effects of floods.

In 1971 the government set up a Disaster Relief Organisation to deal with natural disasters throughout the State. This organisation consists of a Central Control Committee and a number of local groups each under a District Controller. Because of the need for such an organisation to have regular personnel and good communications it was based on the Police Department.

In general the Central Control was there to provide policy, authorise expenditures and generally to study requirements and take action to build up and improve the organisation. The District Controllers are the Police Inspectors in charge of the police districts throughout the State. They have built up around them advisory and liaison groups and meet several times a year to review their organisation and their plans for action.

Groups such as Civil Defence, Army, Red Cross etc. work to tasks specified by the District Controller but under their own leaders.

Communications are through liaison officers, telephone, police wireless and arrangements with the media. An Operations Room is set up where possible.

As would be expected, communications are the main problem and are being gradually strengthened.

This organisation was first tested by Cyclone "Althea" in Townsville not long after it had been set up. It worked fairly well in this operation, and steps were taken after this to make use of the lessons learned.

The operation during the Brisbane and Gold Coast flooding was carried out in Brisbane by the districts involved and in Ipswich and Brisbane by the district in Ipswich and the combined districts in Brisbane.

These operations were more complicated than the Townsville exercise and a good many points were noted for improvement.

At Government level the problem of the Brisbane Creeks was brought to the fore by their unwelcome and frequent flooding. In April 1972 the Co-ordinator-General's Department was instructed to have the problem investigated and to suggest mitigation proposals.

The work was carried out by consultants who were briefed and whose activities were co-ordinated by the Department and who produced reports which were made available to the Lord Mayor of Brisbane last year.

Representations are being made to the Commonwealth Government for help in this project which will cost some $15 million but no help is so far forthcoming. Commonwealth officers have inspected the proposed projects and are reporting back.

In the meantime, in view of the urgency the State has offered the Council loan funds with a 33-1/3% subsidy and work is, I understand, in hand on design.

So far as the Brisbane River itself is concerned the Moreton Regional Water Advisory Committee which had for some time been investigating future water sources for Moreton area completed its report in June 1971. The report dealt with a proposed dam on the Brisbane River at Middle Creek or alternatively at Wivenhoe and with flood mitigation for Brisbane and Ipswich. The committee recommended, and the Government accepted its recommendation, a dam at Wivenhoe be built to a full supply level of from R.L.215 to R.L.220 and having a gated spillway designed for flood control.

One of the main conclusions of the report was stated as follows:

> "There is still a very grave flood risk threatening Brisbane and Ipswich and this can be greatly reduced by a suitably designed dam at Middle Creek and Wivenhoe. The proposal has a high benefit-cost ratio; our estimate of the possible savings in the actuarial mean annual value for flood damage could exceed $1 million."

As a water source the dam will be needed in about 1981 or 1982. Work has started on the acquisition of land for the project. In view of the flood, steps are now being taken to see if the completion of the dam can be expedited.

Other measures being taken involve the collection of as much flood data as possible and the introduction of legislation to help in the control of flood plains.

Your seminar is a timely one and one which will help us all to understand the situation. Your speakers are men who are well versed in knowledge of their subject combined with knowledge of the conditions in the Moreton Region.

I am sure this symposium will be both interesting and fruitful and have much pleasure in declaring it open.

SYNOPTIC METEOROLOGY OF FLOOD PERIOD

by *A. J. Shields B.Sc.**

INTRODUCTION

Before discussing the meteorological situation which resulted in the extreme rainfalls and flooding in the Moreton Region in January 1974 it may be as well to comment briefly on two matters - the responsibilities of the Bureau in relation to flood warnings and the personnel required to carry out this role.

Under the Australian Government Meteorology Act of 1955 the Bureau is given responsibility, among other things, for

> "the issue of warnings of gales, storms and other weather conditions likely to endanger life and property including weather conditions likely to give rise to floods or bush fires".

This rather broad and imprecise definition of responsibilities in relation to flood warnings was clarified in a Cabinet decision of April 1957. This decision specified five precise areas of Bureau responsibility and included the functions of a National Authority for collating, treating and storage of hydrological data and the development of systematic flood forecasting services.

To achieve the latter role a separate hydrometeorological section was established consisting mainly, at first, of Meteorologists who were given specialist courses in hydrology at the University of New South Wales and later, as they became available, engineers with hydrological training or experience were included in the establishment.

There is no specific University course in Australia which directly produces a graduate in hydrology, and therefore special training in hydrology and hydro-meteorology is required for basically trained civil engineers or meteorologists. Either professional meets the requirements of the Bureau but with the emphasis now going towards the Engineer mainly for organisational reasons.

The meteorologist engaged in rainfall forecasting is working primarily in that part of the hydrological cycle which commences with the evaporation of water from the moist surfaces on the earth (and in the air) through the lifting, cooling and condensation process, the organisation of cloud systems and the production of rainfall which reaches the ground. The hydrologist now takes over and is responsible for assessing the resultant run-off and river behaviour from fallen rain as well as from the rainfall predicted over the river forecast period. It is obvious therefore that any flood warning or river prediction service can only be effective if the closest co-operation exists between the meteorologist and the hydrologist.

It is also necessary to emphasise the limitation placed on the Bureau in relation to the provision of a detailed interpretation service of flood

* *Regional Director Bureau of Meteorology, Queensland*

warnings and river prediction services at the local levels. Because of the State-wide responsibility of the Bureau in relation to these warnings which may be required simultaneously over practically all major river systems, local authorities have generally accepted the need for providing a local detailed interpretation of the warnings and where necessary supplementing these with additional local information and advices.

II. SEASONAL CONDITIONS IN JANUARY 1974 OVER QUEENSLAND

The wet season proper in far North Queensland normally is not well established until early January. In 1973 by mid-December the Intertropic Convergence Zone (ICZ) (or monsoonal trough) had penetrated well down over the Peninsula and Gulf Country and continued a steady net southward progress with only minor northward retreats. In addition to this, the north-west and south-east monsoonal flows were well established and stronger than normal over the Arafura and Coral Seas respectively. Fairly frequent strong surges of equatorial air moved well into Queensland during December.

The abnormalities in the general circulation over the Australian region are well illustrated in Fig. 1 which shows the striking variation between the mean January 1974 9 a.m. 850 mb contour heights and the normal for January (Fig. 2). The significantly increased strength of the January 1974 circulation, the greater southward penetration of the mean position of the monsoonal trough and the displacement of the southern high pressure system are very evident.

The January rains in the northern tropical inland and the far west in particular were excessive and many stations received record January falls with some stations recording record monthly totals for any month and exceeding their annual average rainfall by the end of January. January rainfall totals exceeded 1000 millimetres at some Carpentaria Stations.

A very approximate estimate of the rainfall over the State for January gives a figure of 900,000 million tonnes of water, and it is little wonder that most Gulf and far Western rivers reached their highest flood levels in recorded history, with all river systems except for a few in the eastern inland recording major floods.

III. SYNOPTIC SITUATION OVER SOUTH-EASTERN QUEENSLAND IN JANUARY 1974

SURFACE FEATURES

The main rain mechanism responsible eventually for the Moreton Coast floods had its beginning as a low pressure wave on the I.C.Z. on 21st January. This wave developed to the south of Willis Island in the wake of cyclone VERA which had moved steadily away from the area during the previous few days. The new wave gradually developed a closed circulation and also moved south eastward to be about 600 km east of Mackay on 23rd January. The low deepened slowly to become cyclone "WANDA" and recurved to a south-westerly track late on 23rd. The centre crossed the coast between 6 p.m. and 9 p.m. on 24th January between Maryborough and Double Island Point with a central pressure below 998 millibars and mean surface wind speeds mostly between 70/80 km/hr (40/45 knots) south of the centre with some higher squalls up to 100 km/hr (55 knots). The central eye mechanism of the low had not developed sufficiently to produce a mature cyclone before it crossed the coast. After crossing the coast, "WANDA" weakened rapidly and continued on a south-westerly track to be just north of Dalby by 9 a.m. on Friday 25th January and subsequently disappeared as a surface feature of the chart. The track of "WANDA" and the progressive southward movement and retreat of the surface position of the monsoonal trough are shown in Fig. 3.

The second important system was the intense high pressure which persisted over the Tasman Sea during the period. During 24th January this high moved north-east from a position east of Tasmania into the South Tasman Sea and intensified from 1026 mbs to 1030 mbs. The system then became quasi-stationary and was responsible, at least in part, for the recurvature of cyclone "WANDA" to a south-westerly track and for maintaining a very strong easterly gradient flow to the south of the cyclone centre. Between 9 a.m. on 24th January and 3 p.m. on 25th January the winds at Brisbane were mostly in the 80-100 km/hr range at 1000 m.

During 25th January the Tasman Sea high moved slightly further east-north-east and weakened with moderate pressure falls occurring along the New South Wales coast south of the cyclone centre which had now moved inland and weakened. During 26th January the approach of a new high pressure system from the Tasmanian region with its associated weak frontal system along the south coast of New South Wales caused a reversal of this pressure trend and a gradual strengthening of the ridge from the Tasman Sea high. As a result of this rearrangement of the southern pressure field together with the collapse of cyclone "WANDA" now well inland, the steady southward retreat of the monsoonal trough was halted over the Brisbane region. The oscillatory movement of the trough together with its final slow northward retreat and the development of a complex double-shear-line structure was responsible for the three separate intense rainfall periods over the Brisbane Valley region. It was the third of these intense rain periods on the night of Saturday 26th January which changed what would have been a relatively minor main river flood into one of major proportions.

The amalgamation of the two southern high pressure systems on 28th January, the further northward retreat of the monsoonal trough and the advection of drier and more stable southern maritime air from the southern system as a diffuse frontal zone by 9 a.m. 28th January led to a cessation of the protracted rain period.

The surface features of the synoptic situation are illustrated in Figures 4 and 5.

IV. THE RAIN PRODUCING MECHANISMS

A number of rain producing mechanisms operated during the five day period and resulted in most Stations in the Moreton region receiving rainfall in excess of 400 m.m. with totals in the higher country exceeding 1300 mm. The main rain production was due at various times to -

(a) mass convergence in a strong on-shore stream of tropical air coupled with orographical effects.

(b) convergence in the lower and middle troposphere at the monsoonal shear line between tropical easterly to north-easterly air and equatorial northerly to north-westerly air.

(c) upslide of the middle and higher level northerly to north-westerly flow with underlying easterlies to north-easterlies.

(d) convergence and uplift of tropical maritime air by southern maritime air at the northward moving frontal zone.

The highest rainfall intensity rate of 250 mm in 6 hours was recorded at New Beith and was associated with vigorous convectional cells which developed along the monsoonal trough. In areas where strong orographical effects operated, maximum rainfall intensity rates were of the order of 150/200 mm in 6 hours.

The erratic movement of the trough together with its vigorous migratory convective cells presented a difficult task in rainfall prediction except for short periods and added to the problems of precise prediction of the intermittently serious flash flooding in the creeks in the Brisbane and Ipswich areas. Similarly the prediction of longer periods in the main river flood situation proved to be a difficult task in the early stages of the flood.

The density of the rainfall reporting network is insufficient to provide an adequate representation of the rain field and frequent radar surveillance, providing estimates of current rainfall intensity rates was used. Digitized presentation of rainfall rates and automatic computation of areal values were not available. Manual estimates of areal rainfall using radar data, although valuable were generally in excess of the actual recorded rates.

The Brisbane airport radar rainfall distribution and intensity data schematically presented and transmitted by facsimile to the Regional Forecast Centre are given in Figure 6.

V. UPPER AIR SITUATION

The 700 mb streamline analyses are shown in Figures 7 to 11. At 9 a.m. on 25th January the Brisbane area was covered by a deep strong north-easterly stream of typical tropical maritime air at all levels. The shear line between this air and the north to north-westerly equatorial maritime air was lying to the north of Brisbane and moving slowly southward in a position abnormally far south.

By 3 p.m. on 25th January the 700 mb trough line had passed just to the south of Brisbane and a marked temporary cessation of the rain and breaking of the middle and high overcast occurred. On the surface the trough line was still to the north of Brisbane.

By 9 p.m. on 25th January the 700 mb trough had retreated to the north of Brisbane with the renewal of intense rainfall over the area. However, by 3 a.m. on 26th January the trough line had made a southward advance with the heaviest rainfall areas being located southward from the Brisbane area. A second northward retreat of the 700 mb trough occurred during the night of the 26th January causing the most intense rainfall of the period. It was not possible to obtain upper air data at 9 p.m. on 26th January or at 3 a.m. on 27th January because of local intense rainfall but by 9 a.m. on 27th January a strong northeasterly flow at 700 mb was again in evidence and persisted as the trough continued northward and finally was replaced by air of southern origin.

Although the final northward retreat of the trough can be related to the resurgence of the southern pressure field, the trough oscillations and the rapid changes in direction of a strong circulation to considerable depths of the atmosphere in the Brisbane area are difficult to explain. There is some suggestion of the presence of a mid-troposphere secondary closed circulation in the area but the critical missing data and the sparsity of the upper air network prevent any positive conclusions.

VI. RAINFALL

Figures 12 to 14 give the 9 a.m. 24 hour rainfalls in millimetres over the Moreton Region for 25th 26th and 27th January 1974.

The strong orographical rain influences over the range country in the north-east of the Brisbane River catchment and in the south-eastern border Highlands inland from Coolangatta are very evident in each of the daily rainfall patterns. The steady southward progression of the monsoonal trough from the Noosa-Esk region on 24th to the Caloundra-Ipswich area on 25th are reflected in the daily rainfall totals to 9 a.m. for 25th (Fig. 12) and 26th (Fig. 13) respectively.

The oscillation of this trough in the Brisbane-Ipswich area on 26th and its eventual northward retreat are reflected in the rainfall distribution for 9 a.m. on 27th January (Fig. 14). There are only minor orographical influences in the Brisbane-Ipswich area and the intense rainfall was due largely to vigorous convective activity in the strongly convergent area of the monsoonal trough.

Figure 15 shows the total storm rainfall for the five-day period ending at 9 a.m. on Tuesday 29th January 1974 but for the greater part of the Brisbane Catchment area this represents very close to 84 hour totals as little rain fell outside the period 9 a.m. 24th January to 9 p.m. on 27th January. A comparison with figure 16 which gives the total storm rainfall for the four-day period of the February 1893 record Brisbane flood, shows a significantly different rainfall distribution. The rainfall in the 1893 flood resulted from a decaying quasi-stationary tropical cyclone which moved inland over the northern parts of the Brisbane Catchment and produced the Australian record 24 hour rainfall of 907 mm at Crohamhurst on the headwaters of the Stanley River. The record monthly rainfall for February 1893 was 2998 mm at this station with a four-day storm total of 1964 mm.

It can be seen that the rainfall in the 1893 flood in the Brisbane-Ipswich area was relatively minor compared with the January 1974 flood rainfall. In the Ipswich area (Bremer River) the January 1974 totals show rainfall which was approximately three times greater than any previously recorded flood rainfall.

A judicious temporal and areal combination of the 1974 and 1893 rainfall distribution patterns which is certainly a meteorological possibility, could produce a significantly higher flood in the Brisbane area than any yet recorded and there is some geological evidence that such floods have occurred. It is also necessary to note when examining flood mitigation schemes for the upper and middle Brisbane River that significant inundation of the Brisbane city area could occur from extreme flood rainfall over the lower reaches of the Brisbane River and its tributaries only.

In Table 1 the 6 hourly rainfalls for Brisbane city (with Brisbane Airport in brackets) are listed with the associated 1000m wind at Brisbane Airport. Whilst the low level and surface wind fields indicate only one southward passage of the trough and subsequent retreat, the higher level winds clearly show a double transit over the Brisbane area. A comparison of the Brisbane City and Brisbane Airport rain totals indicates the great variability of rainfall intensity over a distance of 8 km.

VII. RADAR DATA

Fig. 17 shows the radar presentation of the rainfall associated with Cyclone WANDA at 10.15 a.m. on 25th January 1974. At this stage WANDA had crossed the coast to the north of Brisbane and was situated about 158 km inland in the Dalby area. Although well developed convective cells were evident in the radar data there was an almost complete absence of any discrete rainfall banding. Fig. 18 shows the radar coverage of Cyclone Zoe just offshore to the northeast of Brisbane on 12th March 1974 and is typical of a decaying cyclonic rainfall pattern in the latitudes of Brisbane with well defined spiral rain bands and partial eye formation which are absent in cyclone Wanda.

VIII. SATELLITE DATA

A comparison of the Essa 8 satellite photographs in Fig. 19 (cyclone Wanda) and Fig. 20 (Cyclone Pam) 12 days later clearly illustrates the difference between a true tropical cyclone with a well defined eye mechanism and a tropical low on the monsoonal front without warm core development. Cyclone Pam was located at 9 a.m. on 5th February 1974 about 700 km off the south coast of Queensland at latitude 24^{o} south. This major cyclone with estimated central pressure about 930 mbs was heading for the already flood devastated Brisbane area some five days after the Brisbane River had receded below flood level. Instead of recurving southward as predicted it could quite easily have crossed the coast to the north of Brisbane and undoubtedly had the potential to produce a flood of greater magnitude than cyclone Wanda. In extreme wet year circulation types there is a marked tendency for a fairly frequent succession of cyclonic rain disturbances. Such a sequence as that which occurred in 1893 presents a serious problem for effective use of flood mitigation storages which are already holding excess water.

Table 1.

Time EST	Date	Brisbane Airport 1000 m Wind Degree/ km/hr.	*Brisbane Rainfall past 6 hours mm	Remarks
0300	24/1/74	100/50	0	) Dry southern) maritime air) and anti-clonic flow.
0900	24/1/74	120/100	2.6	
1500	24/1/74	090/70	13.0	) Transition to) tropical) maritime and) cyclonic flow.)
2100	24/1/74	Norep	14.2	
0300	25/1/74	110/110	18.2	
0900	25/1/74	085/100	61.6 (83.8)	)
1500	25/1/74	070/50	129.8 (112.4)	Passage of monsoonal trough at 700 mb.
2100	25/1/74	070/47	35.6 (37.4)	
0300	26/1/74	005/56	118.2 (113.2)	Surface trough passage
0900	26/1/74	350/32	77.2 (61.2)	
1500	26/1/74	005/43	14.2 (15.0)	
2100	26/1/74	Norep	43.6 (28.2)	
0300	27/1/74	Norep	91.4 (62.2)	
0900	27/1/74	070/47	30.2 (15.4)	Northward retreat of monsoonal trough
1500	27/1/74	070/56	17.4 (13.6)	
2100	27/1/74	075/56	12.8 (11.8)	Advection of drier southern air commences.

* Brisbane Airport Rainfall figures (8 km from Brisbane) given in brackets.

IX. CONCLUSIONS

Any attempt at post-analysis of a meteorological situation which involves meso- and micro-meteorological elements, by reference to a rather sparse macro-network of upper air data always presents considerable problems and the January 1974 episode is no exception.

The two main problems facing the meteorologists were (a) the difficulty in predicting short period intensities of very localized rainfall more than an hour or two ahead for use in flash flood prediction in local creeks, and (b) the lack of useful predictors to cope with the oscillation of the monsoonal trough in the Brisbane area which resulted in the second and third critical heavy rain periods which transformed a minor flood to one of major proportions. Whilst this meteorological difficulty presented problems for local flood prediction it did not prevent the hydrologist from giving an accurate 30 hour prediction of the ultimate flood peak in the Brisbane River but did prevent the issue of any reliable longer period main river flood trends in the early stages of the flood.

Fully automated continuous radar coverage of metropolitan creeks with digitized and computerized rainfall intensity analyses supplemented by an adequate autumated ground rainfall-creek reporting network, are essential for short period warnings of flash flooding in densely populated areas. The complexity of rainfall producing mechanisms in areas where decaying tropical cyclones interact with temperate latitude systems will undoubtedly continue to present a difficult forecast problem even with markedly improved data and will no doubt prevent the issue of any reliable flood trends in any future Brisbane River flood beyond a 24-36 hour period.

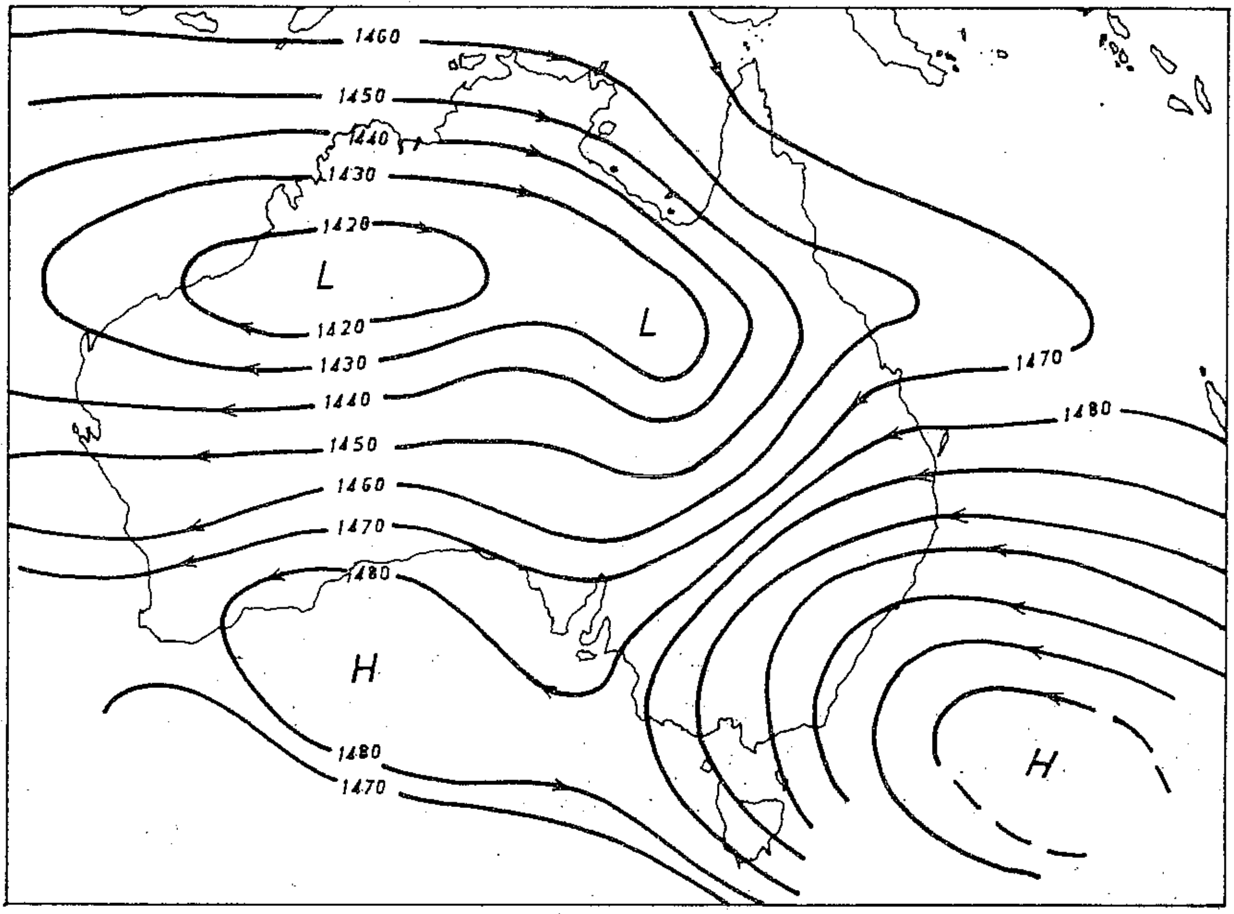


Fig 1   850mb Mean Geopotential Height in Geopotential Metres.
9am January 1974

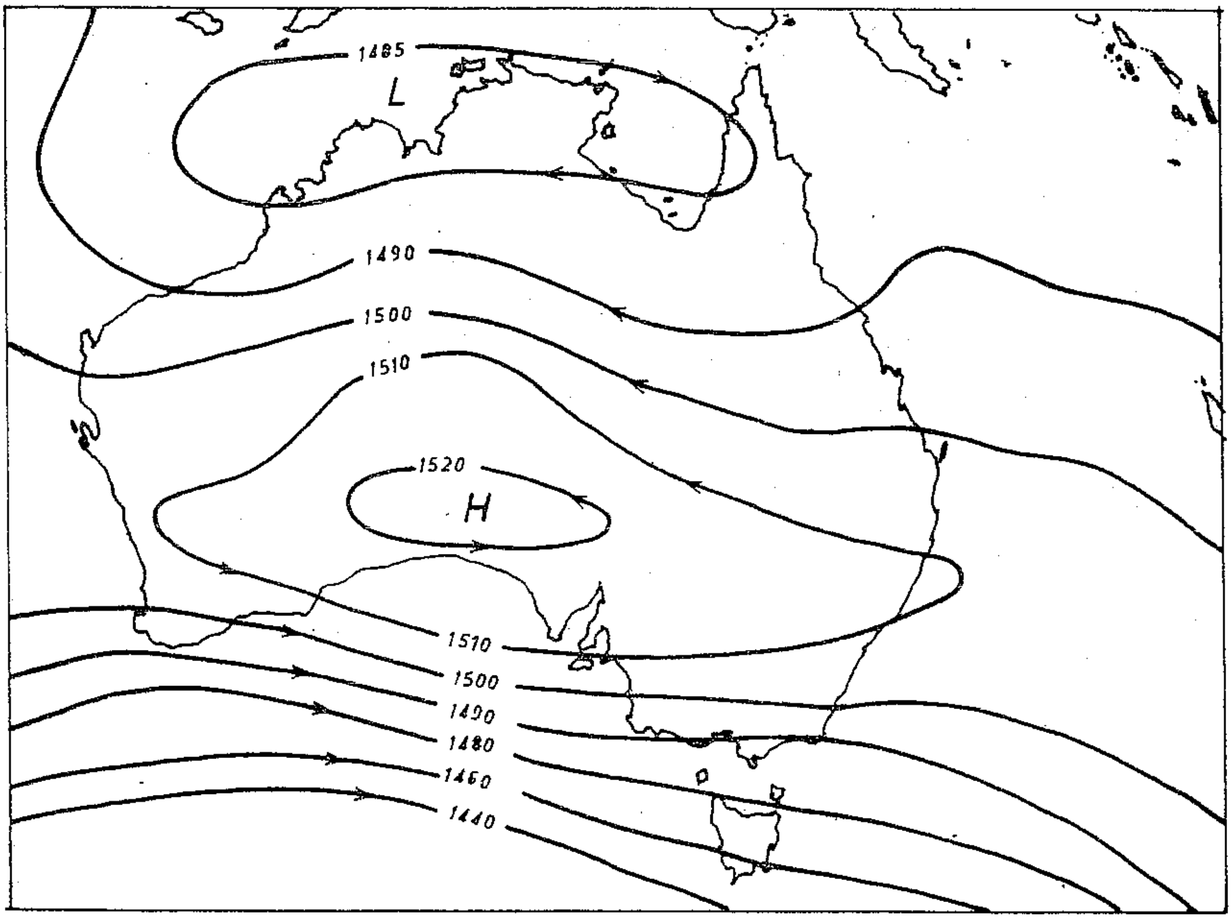


Fig 2   850mb Normal Geopotential Height in Geopotential Metres
9am January

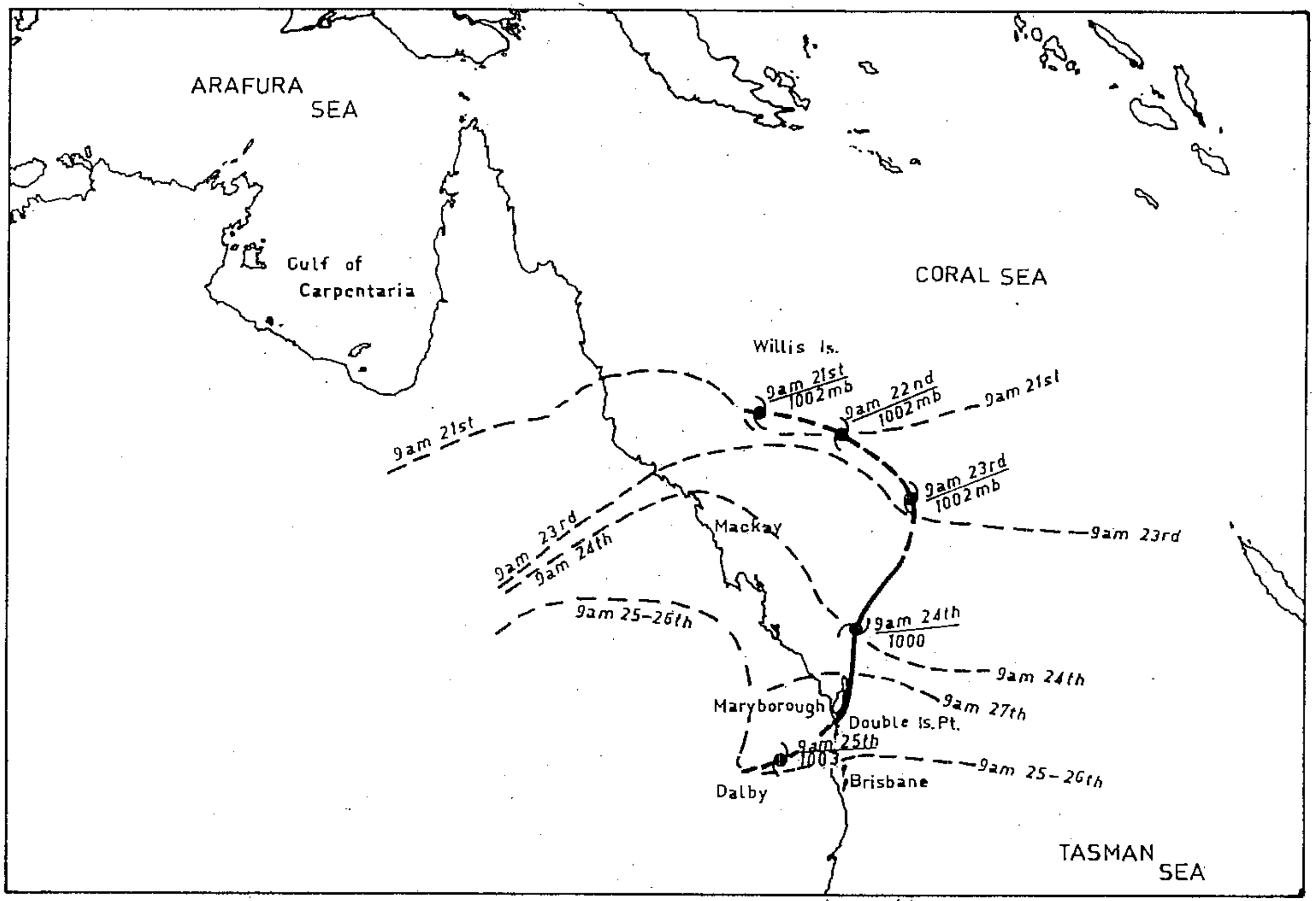


Fig 3 Track of Cyclone Wanda and Surface Movement of ICZ 21–27th January

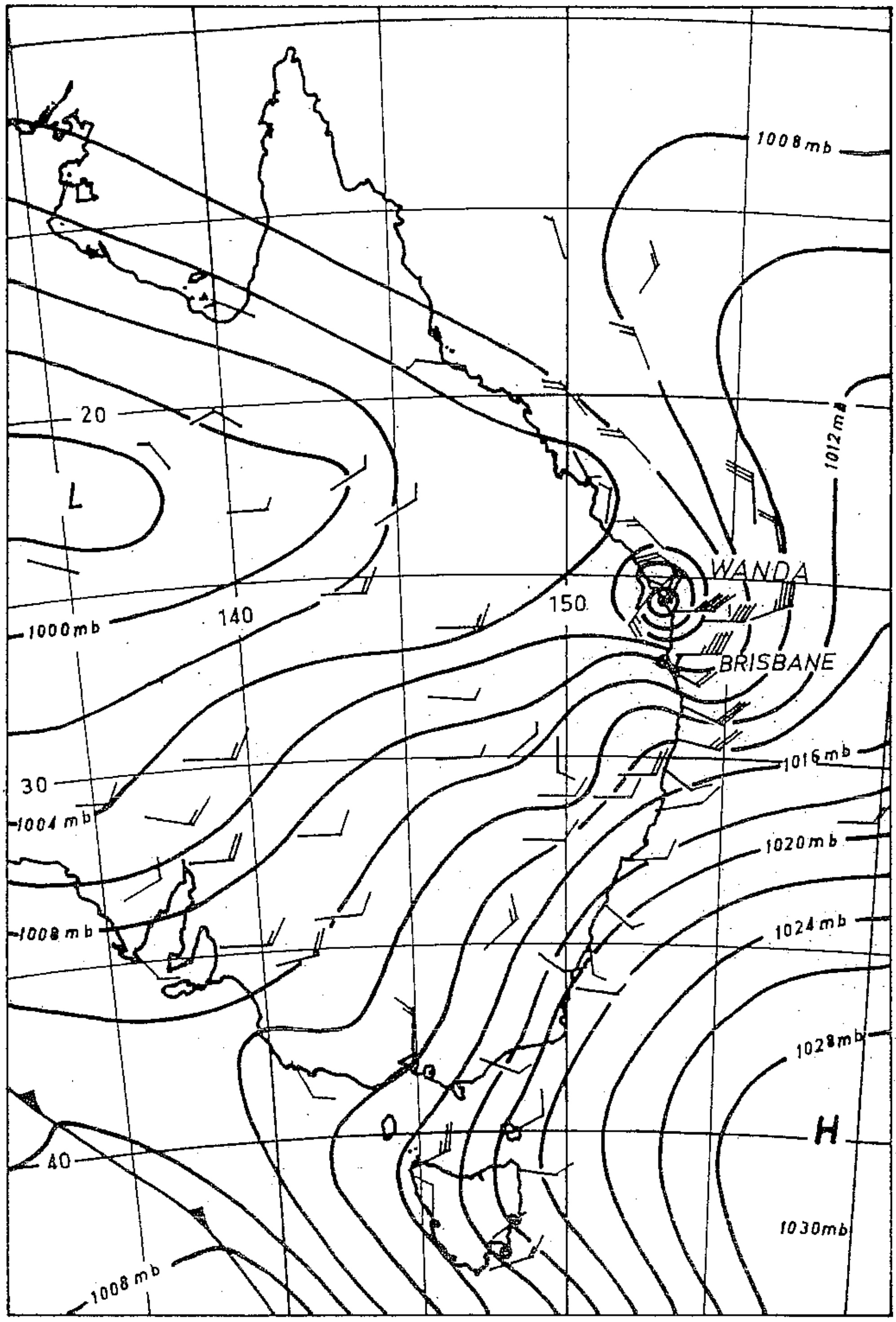


Fig 4   Surface Chart 6pm 24 January 1974 Wanda Prior to Landfall

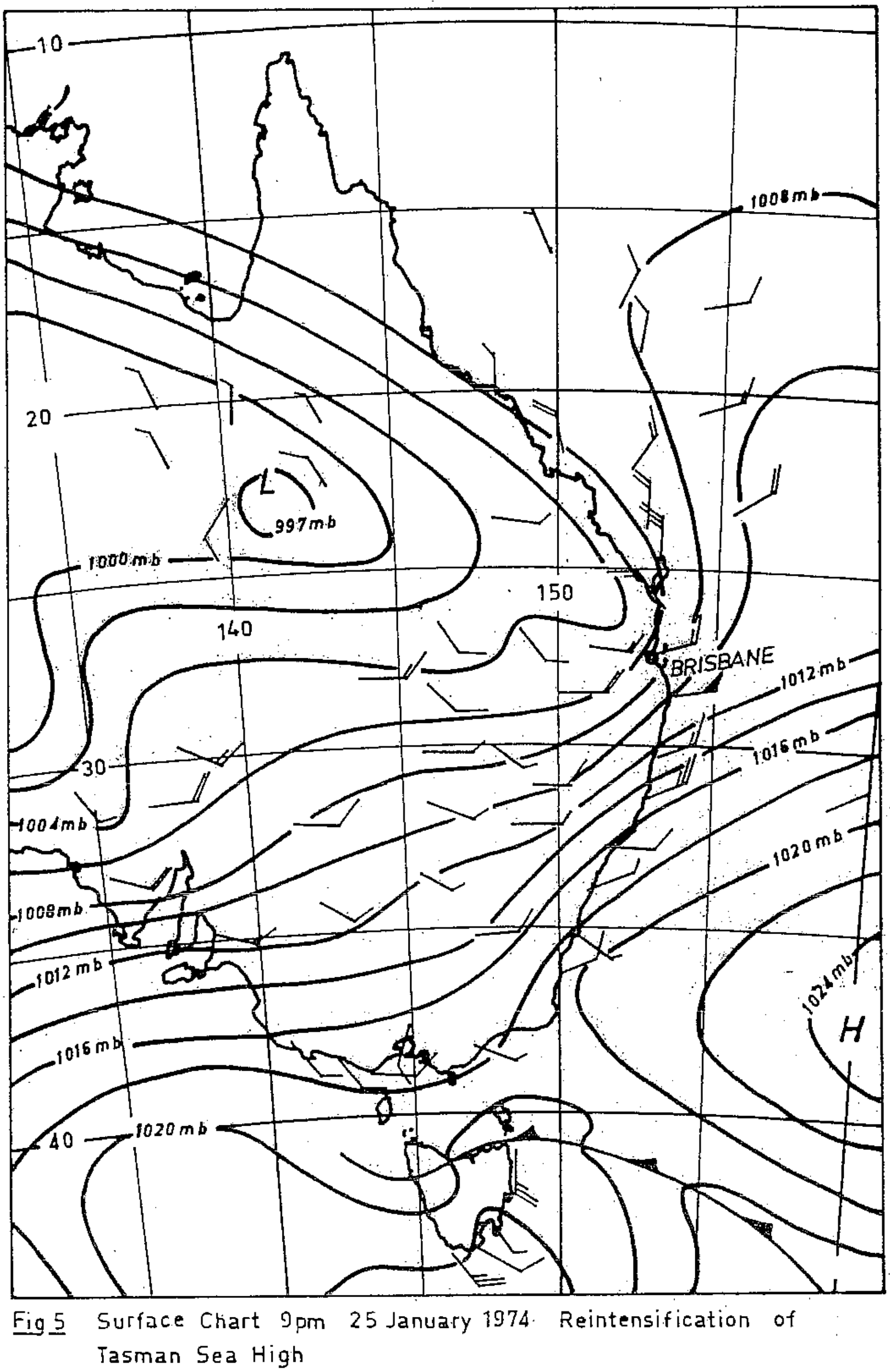


Fig 5 Surface Chart 9pm 25 January 1974 Reintensification of Tasman Sea High

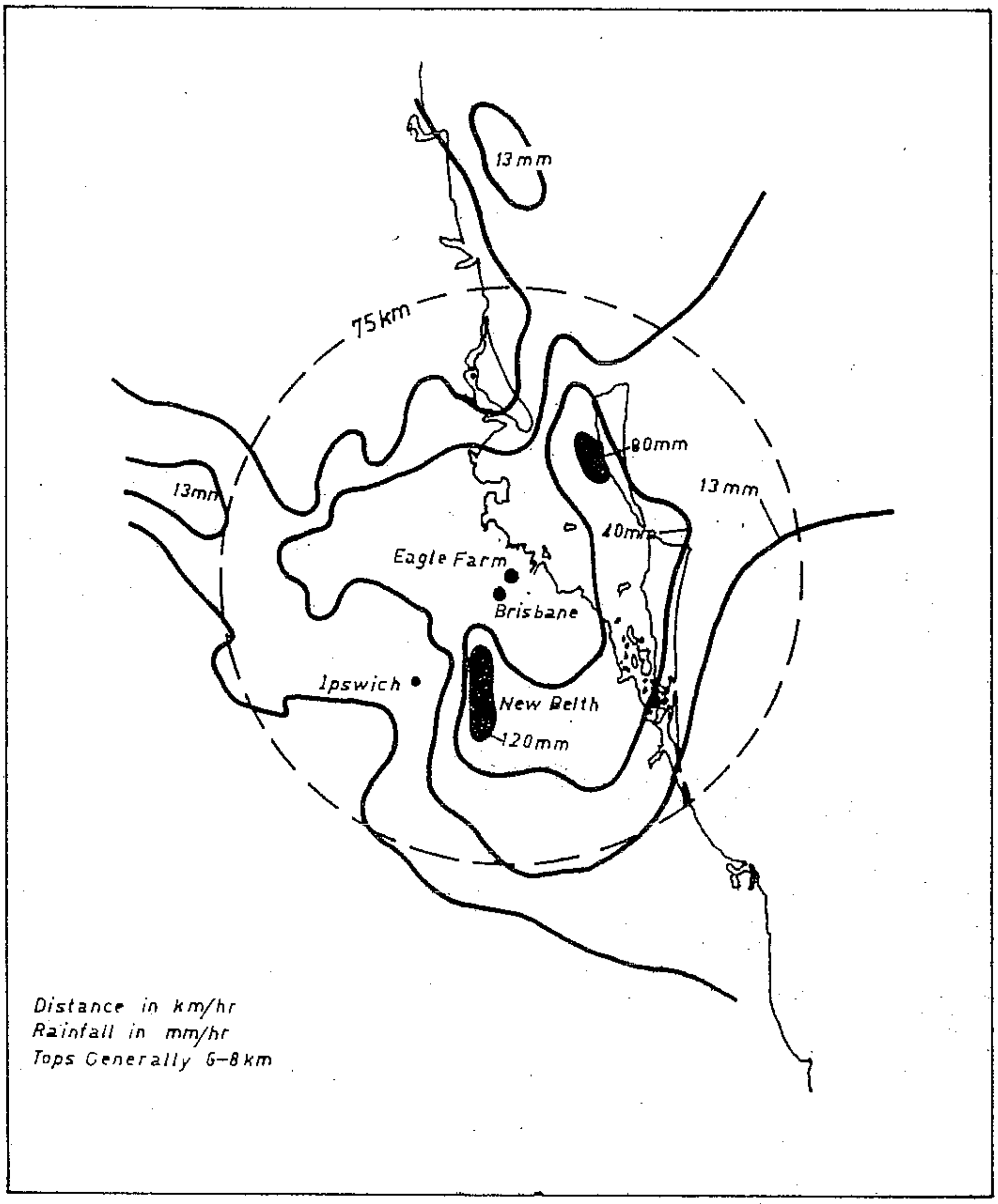


Fig 6   Brisbane Rainfall Intensity Schematic Presentation of Radar Rainfall Data 3am 25th January. Rainfall Rates in mm/hr

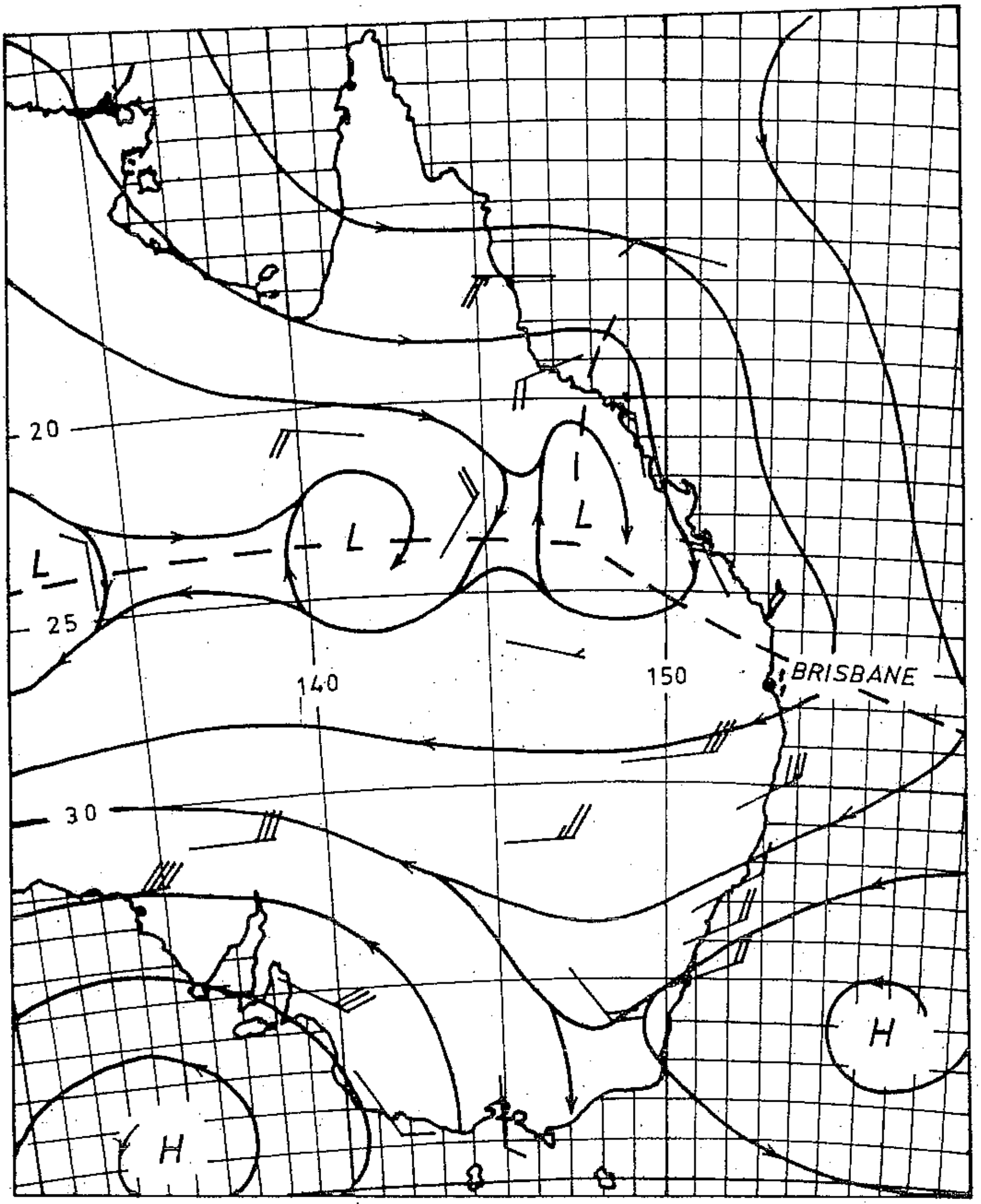


Fig 7 700 mb Streamline Analysis 9 am 25 January 1974

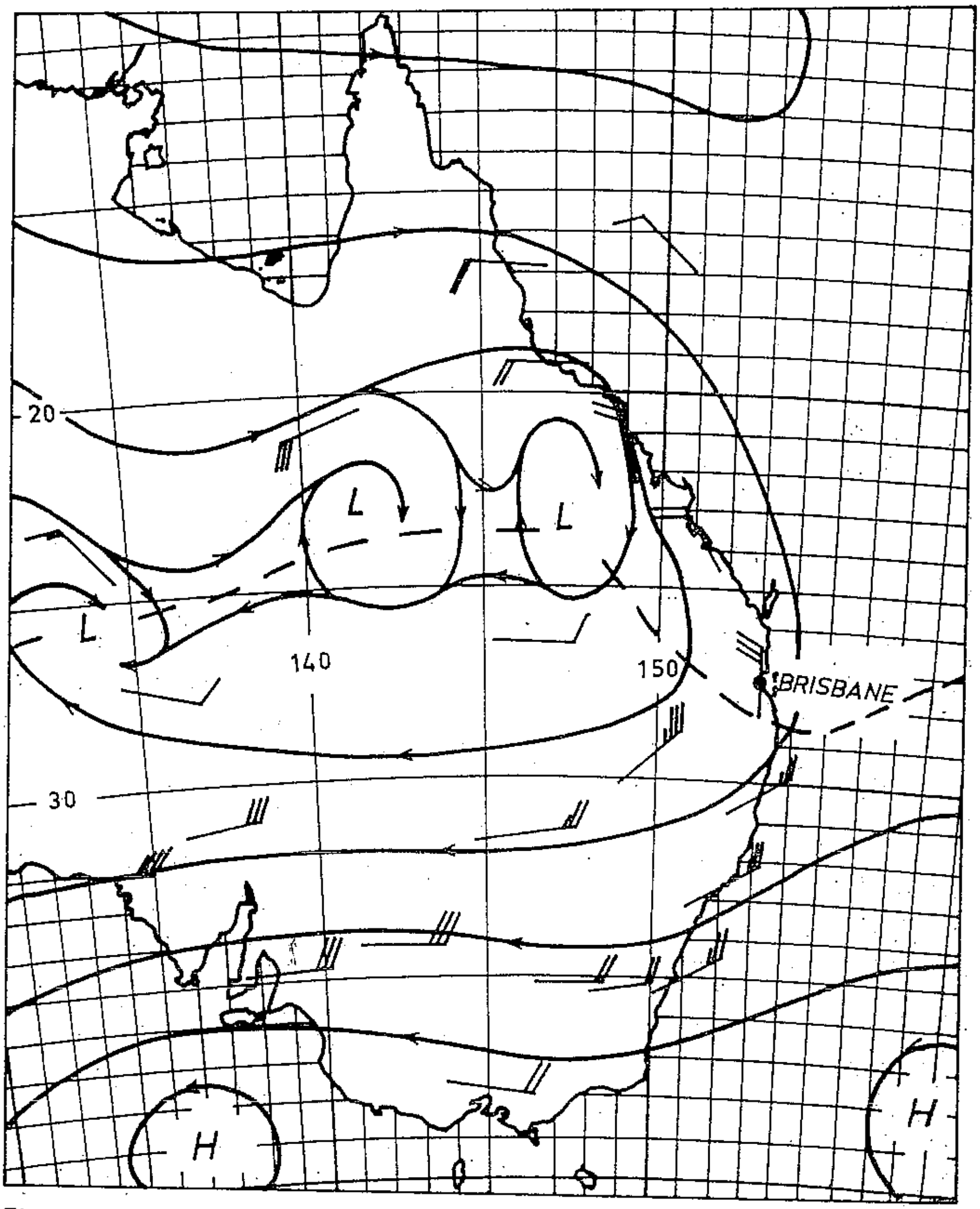


Fig 8 700mb Streamline Analysis 3 pm 25 January 1974

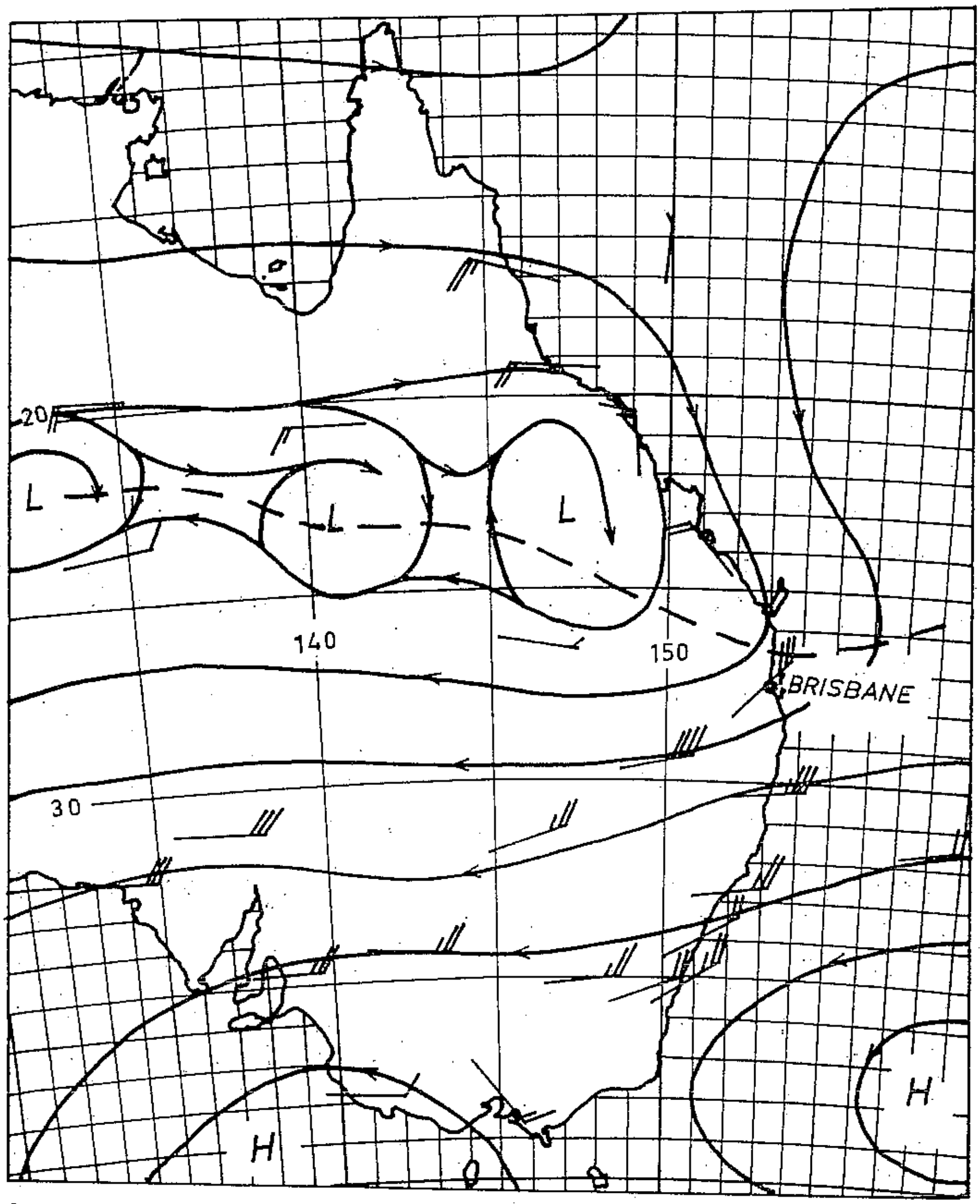


Fig 9 700 mb Streamline Analysis 9 pm 25 January 1974

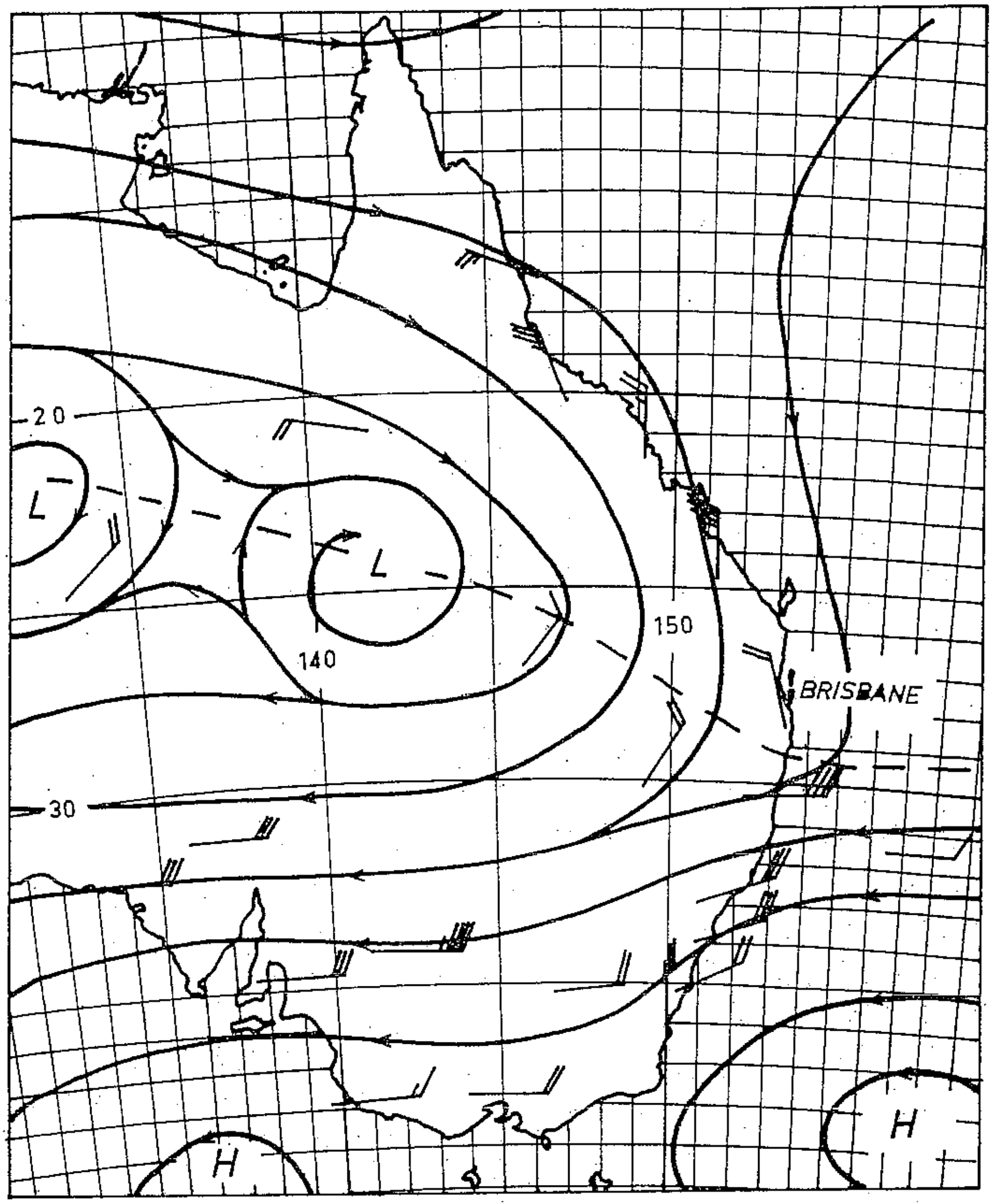


Fig.10 700 mb Streamline Analysis 3 am 26 January 1974

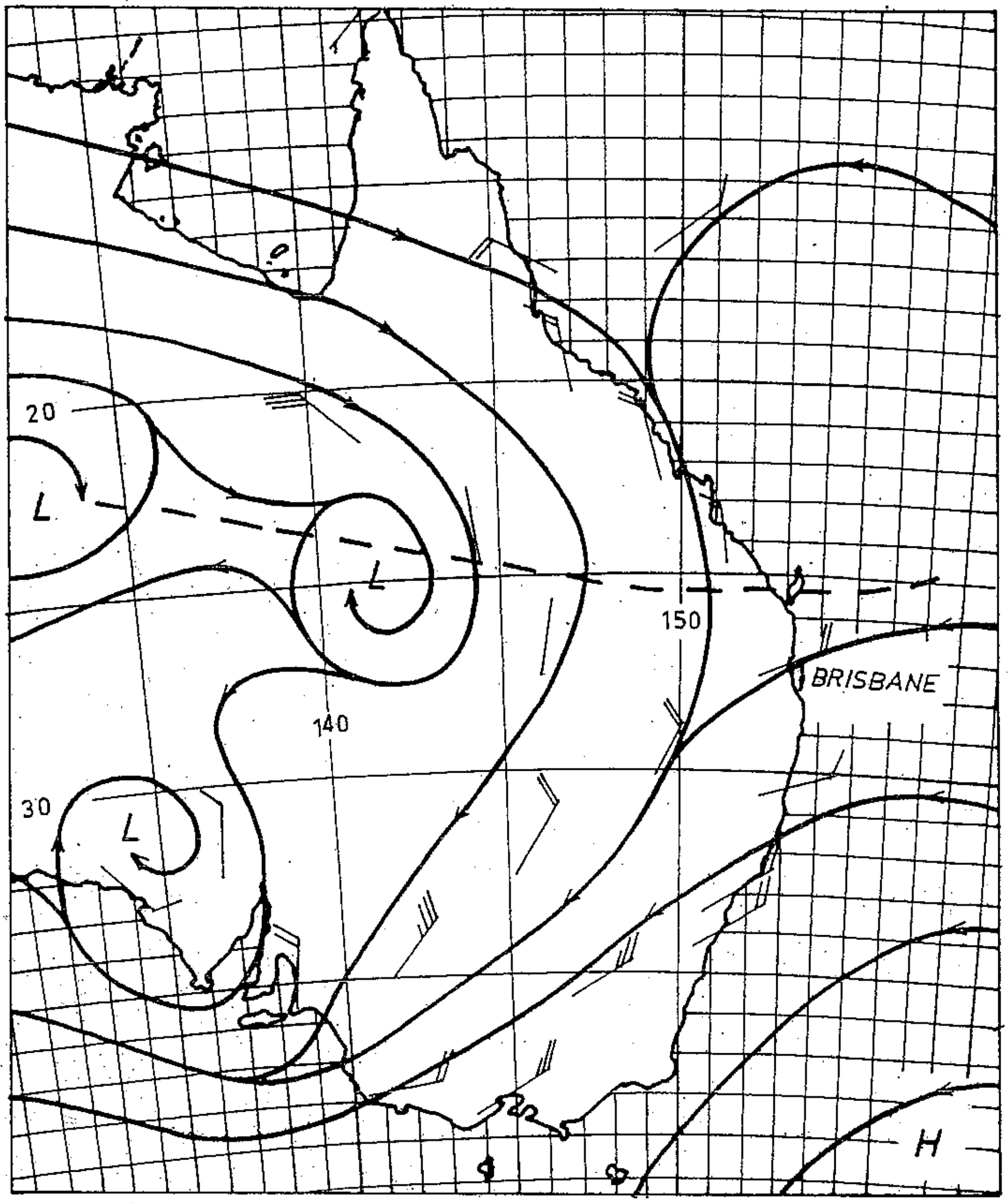


Fig 11 700 mb Streamline Analysis 9 am 27 January 1974

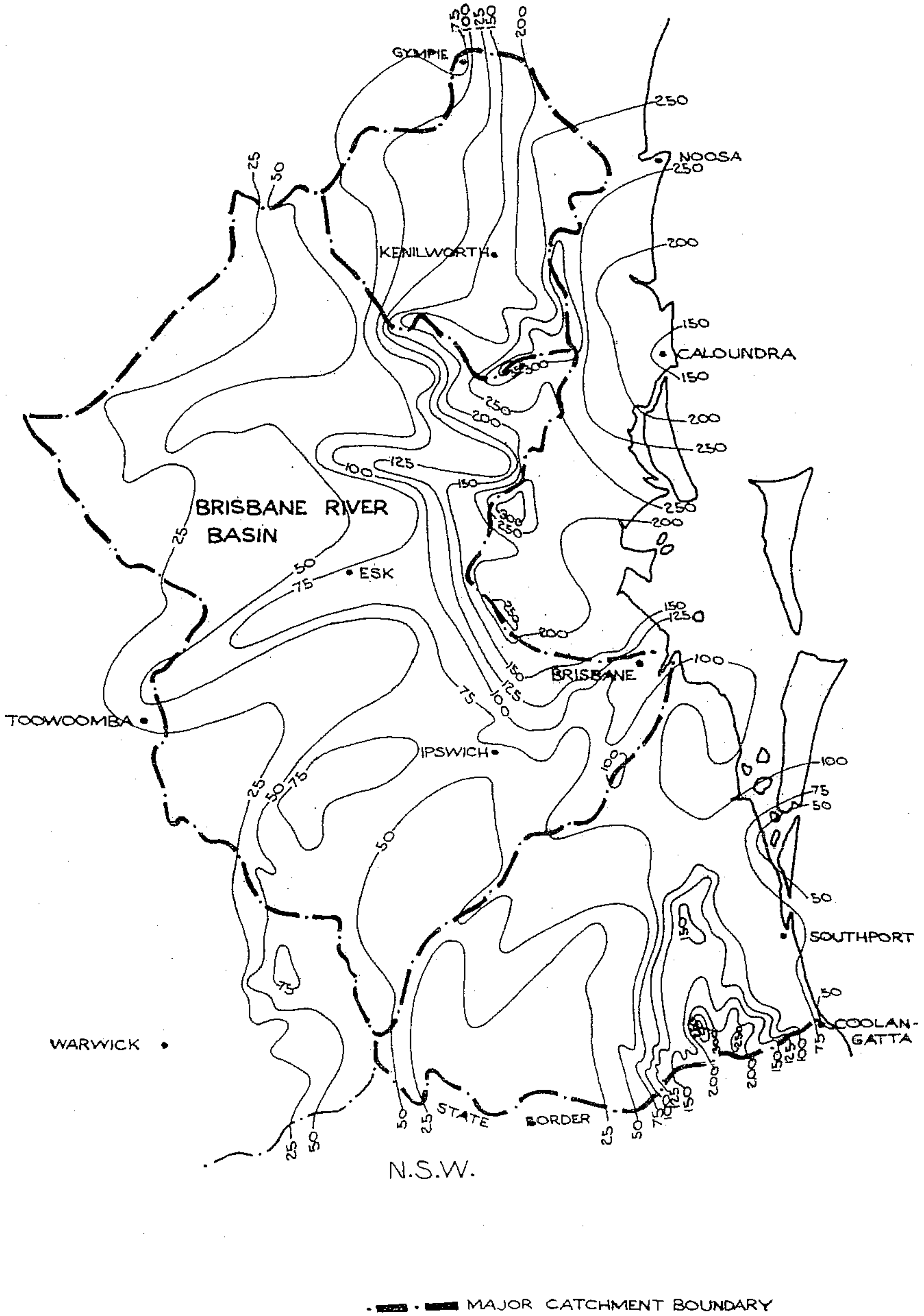


FIG. 12 BRISBANE RIVER BASIN AND ENVIRONS
PRELIMINARY 24 HOUR ISOHYETS ENDED 9 AM FRI 25-1-74

Rainfall in Millimetres *Scale 1cm = 12 km (Approx)*

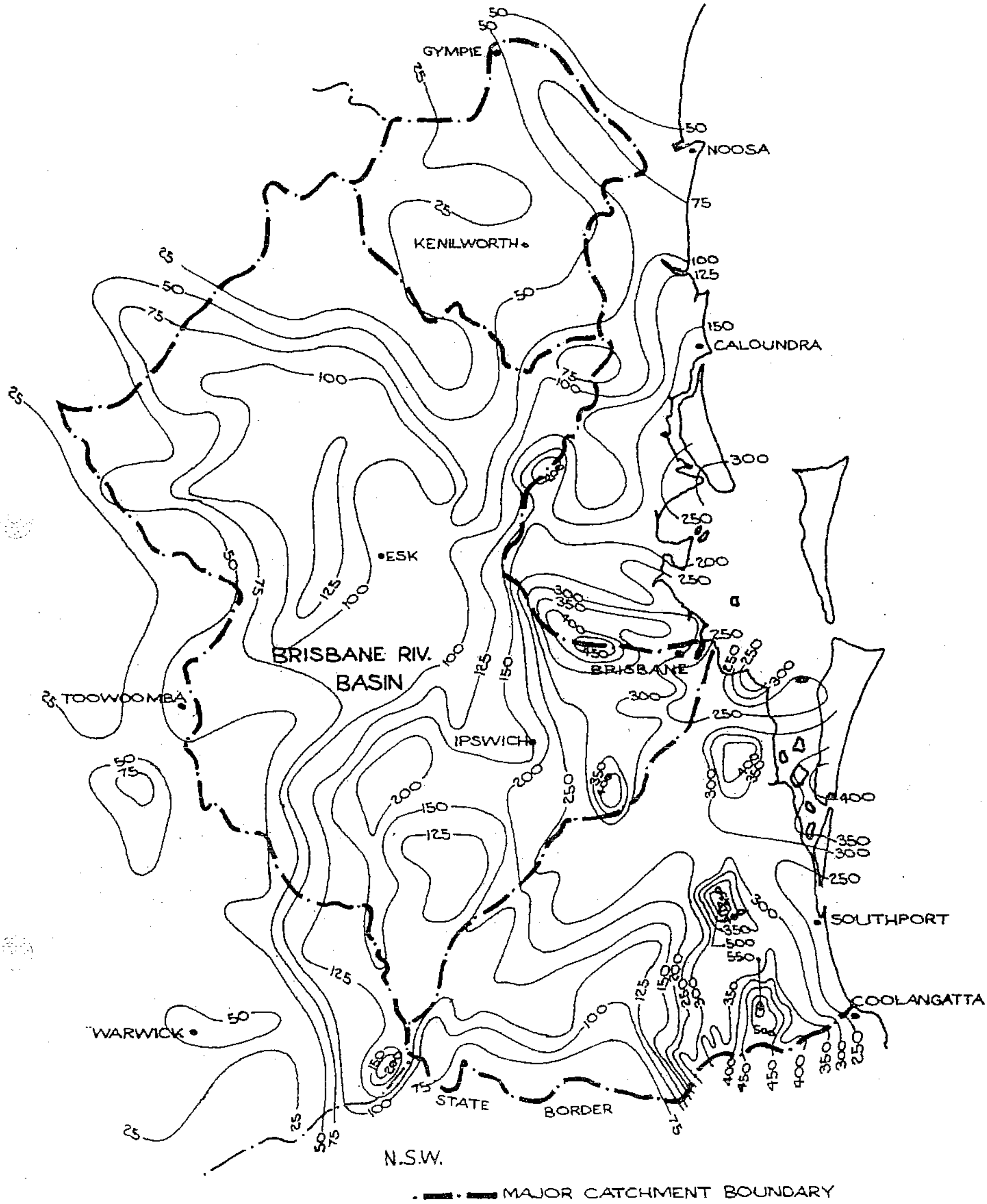


FIG. 13 BRISBANE RIVER BASIN AND ENVIRONS
PRELIMINARY 24 HOUR ISOHYETS ENDED 9AM SAT 26-1-74

Rainfall in Millimetres Scale 1cm = 12 km (Approx)

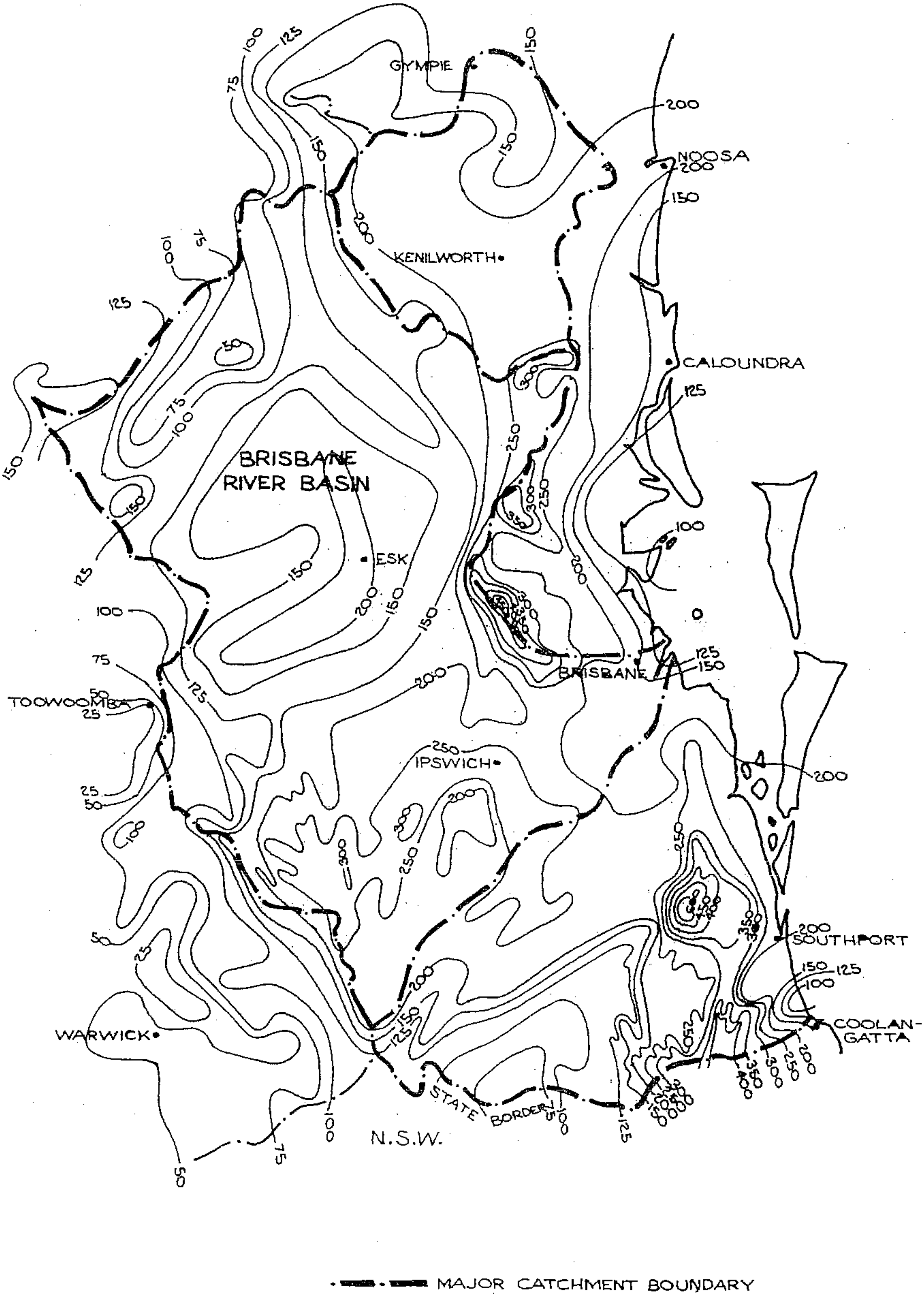


FIG.14 BRISBANE RIVER BASIN AND ENVIRONS
PRELIMINARY 24 HOUR ISOHYETS ENDED 9AM SUN 27-1-74

Rainfall in Millimetres *Scale 1cm = 12 km (Approx)*

Fig. 17 Brisbane Radar, Cyclone Wanda 10.15 am 25/1/74
Range 120n.mi. Elevation 0°. Video 1.

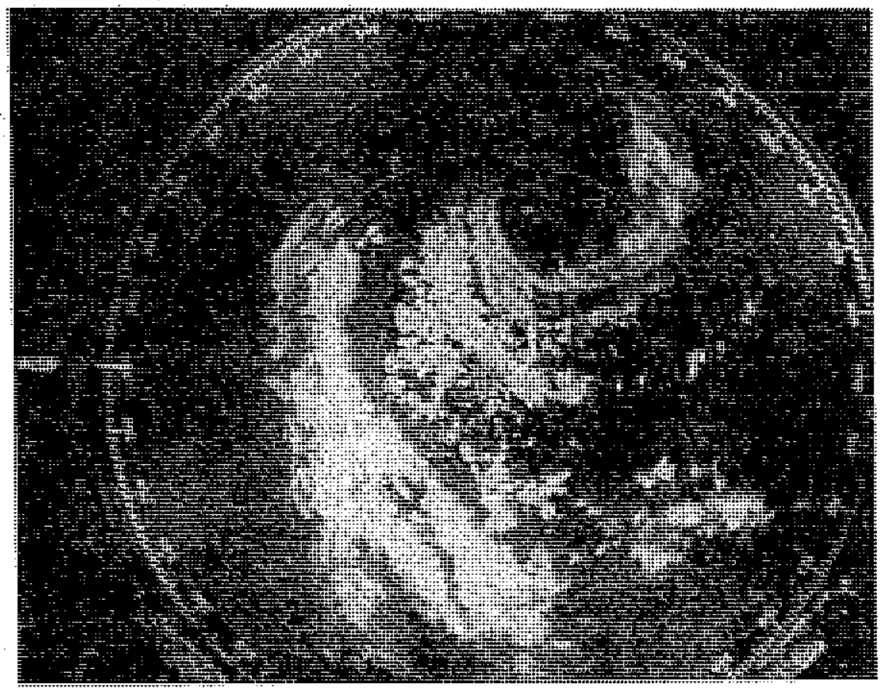


Fig. 18 Brisbane Radar, Cyclone Zoe 12.44 pm 12/3/74
Range 120n.mi. Elevation 0°. Video 1.

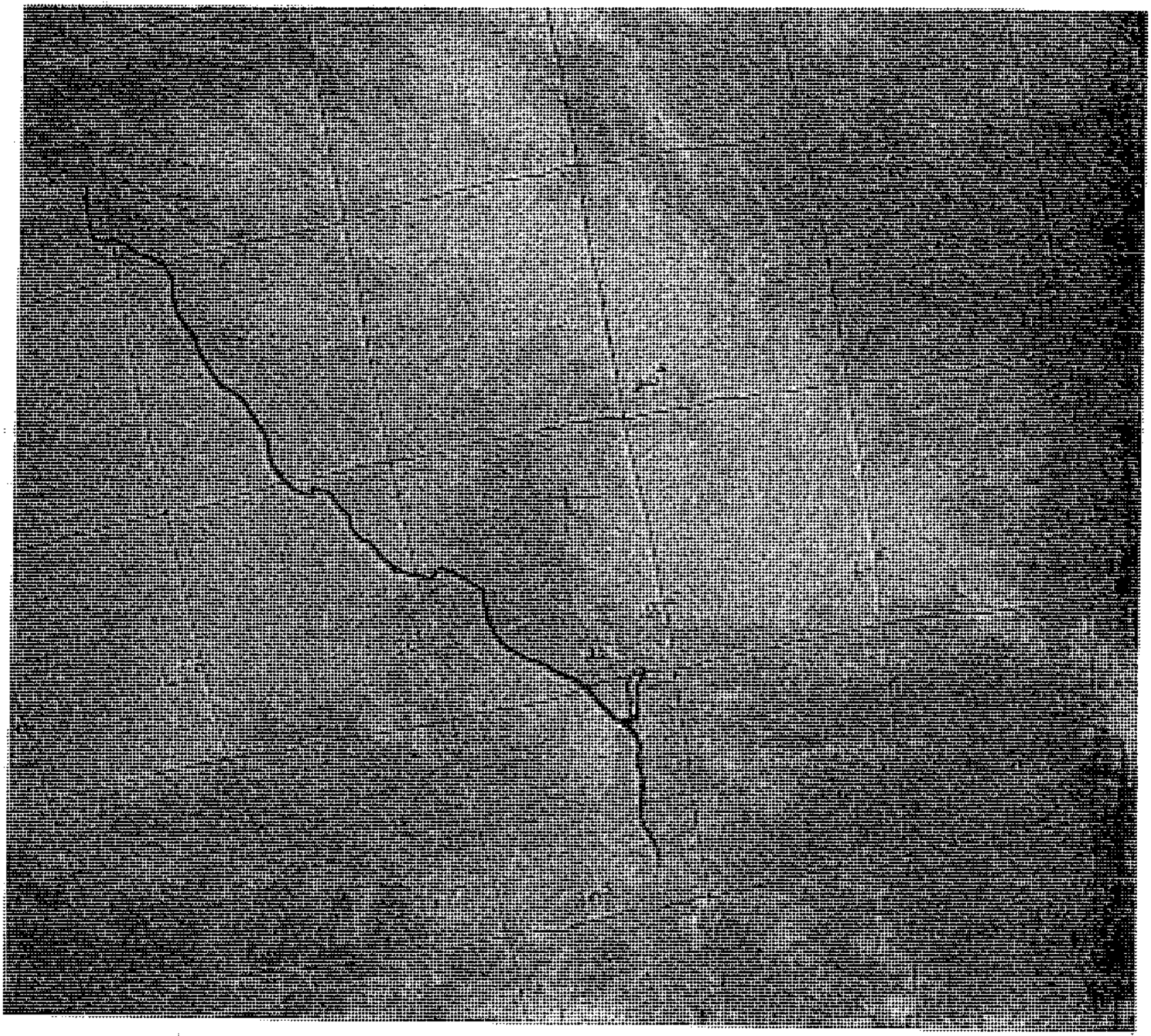


Fig. 19 Satellite, Photograph Cyclone Wanda 9 am 24/1/74
U.S.A. Essa 8.

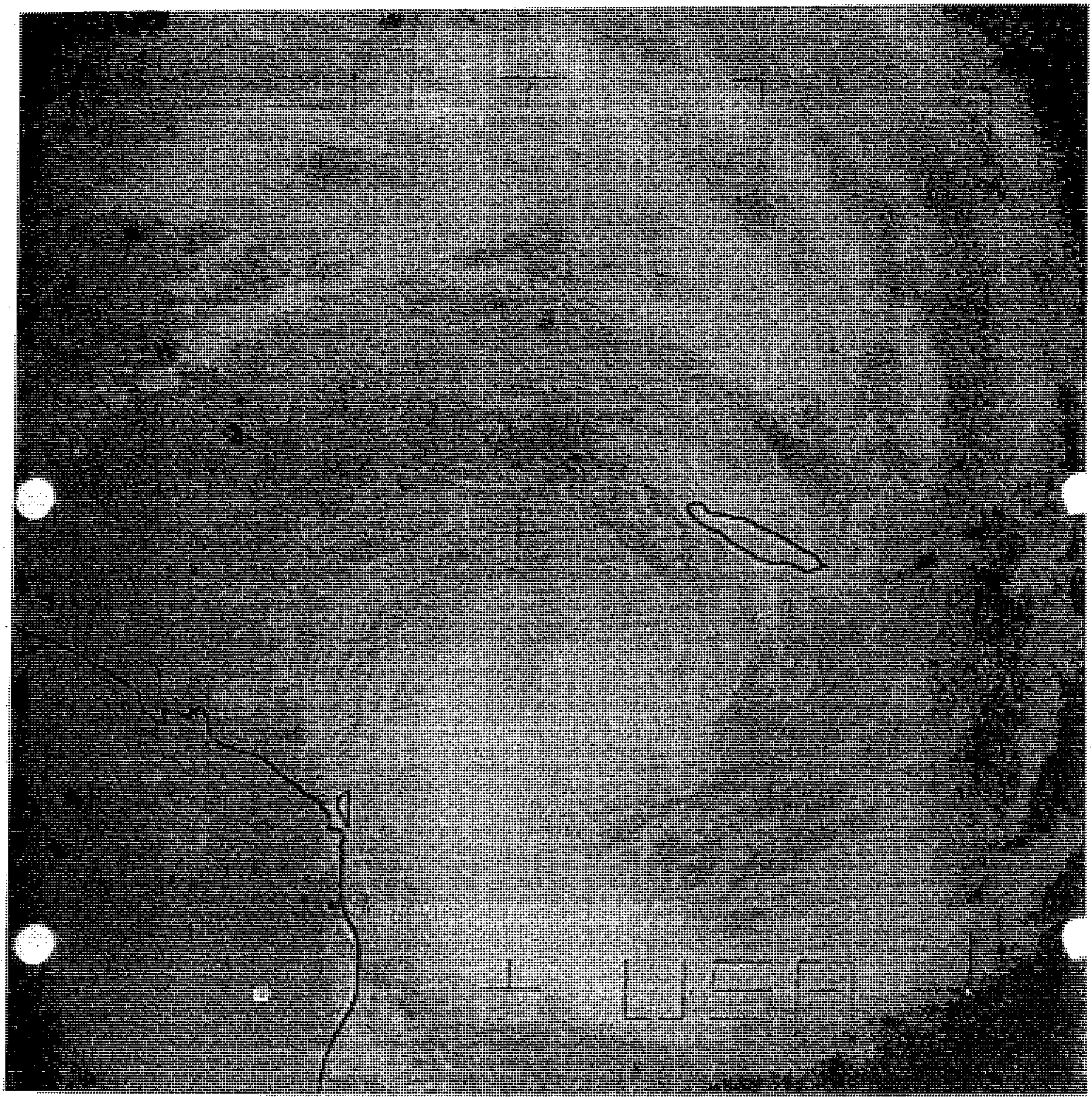


Fig. 20 Satellite Photograph Cyclone Pam 9 am 5/2/74
U.S.A. Essa 8. Cyclone Centre at Latitude 24° South.

DISCUSSION

G. Cossins B.E., M.I.E. Aust.

Criticism of the Weather Bureau for the alleged failure of forecasts has, unfortunately, become fashionable even with people who, otherwise, are most responsible citizens. The main feature of the criticism is the bitterness with which it is made. Yet, considering the overall performance of the Bureau in making forecasts, the criticism is not all warranted. Perhaps the phenomenon is another manifestation of the psychic ills that plague mankind in high pressured, affluent societies.

The criticism is particularly bitter from the city dwellers. This may be a reflection of the fact that it is necessary, in city life, to surrender much of the decision making which is vital in country areas, where the individual property owner's survival depends on correct and unsupported decisions. Many decisions are made for city dwellers on a mass scale and they are easily able to divorce themselves from the process. The city dweller is inclined to develop a blind faith (or a pious hope) that some father figure of authority will give the necessary advice and directions to cope with the situation. By way of compensation for this surrender of independent decision making to a central authority (which is largely an illusion as the events of January 1974 showed), the city dweller indulges in this grumbling and carping criticism which inevitably seems to arise in the circumstances but, in this process, isolates himself from any responsibility of understanding the factors involved in the situation. It is popularly believed that the technology of the situation is too difficult for anyone but the narrow experts to understand. In the final analysis, this attitude is completely negative and is of no benefit to the consumer of forecasts except, perhaps, as a means of venting some of the hostility he does not allow himself to show towards other clearly dishonest aspects of the society in which we live.

The attitude of the public towards this aspect of weather forecasting is annoying. In effect the public wants a forecast in no more than three or four words whilst good news forecasts of one word, such as "fine" are greatly prized. The brief weather forecast in a small panel on the front page of a daily newspaper seems to suit the requirements of the public - short, authoratitive, admitting of no other alternative and so easy to abuse if wrong.

All the manuals on management insist that the manager must assess all the available data and advice in terms of his specific problems and then make a decision after weighing the consequences of alternative courses of action to maximise the return for his organisation with the full understanding of some probability of failure of the outcome. Yet when it comes to weather forecasts even the most responsible managers forget their training and join the public in demanding absolute, unconditional predictions from the forecasters. The forecasters of flood levels are permitted the phrase "unless further heavy rain falls" to qualify their estimated flood levels. This privilege is not extended to the meteorologists.

The present state of the art and science of weather forecasting does not allow flat unqualified forecasts to be made. Understanding of the complex phenomenon involved is not complete and there is some suggestion that it may never be completely solved. Larger investments in equipment and staff would undoubtedly produce improvements but the additional costs have to be carefully weighed against the benefits. Weather forecasting must, therefore, be subject to some probability of error. We must learn to live with the situation, not just fight blindly against it.

The inherent possibilities in a weather situation are more important than any absolute statement of forecast. It is certainly important for flood forecasters to be aware of all the possible developments that can take place from a weather situation that threatens potential floods. Flood forecasters should have more than a nodding acquaintance with meteorology and particularly those synoptic situations that can result in prolonged heavy rainfall. It is therefore necessary for the public to be aware that a forecast is only the most probable outcome of the weather trend in the circumstances and that various factors can cause the situation to change. The best public service in this respect is given by the Australian Broadcasting Commission in its weather forecasts section of the evening television news programme. The announcer, having consulted at the Bureau with the forecasters, is able to give a simple but lucid explanation, aided by clear diagrams, of the weather patterns influencing the whole continent. He is able to point out how the possible development of various features, clearly shown on the map, can influence the weather in the viewing area. Although the forecast is largely confined to surface features the explanations are invaluable to the public.

After the cyclone which devastated holiday resorts on Hayman and Daydream Islands, the Bureau embarked on a successful campaign of educating the public about cyclones. There is a very great need for this type of campaign to be extended at least to the major flood rain producing types of weather situations. Weather forecasts will not become more informative and reassuring to the public unless the public first accepts the responsibility for understanding the full implications contained in weather forecasts, including what can go wrong as well as what can go right. In turn the public must have some means of gaining this necessary understanding. The obvious source of instruction is the Bureau of Meteorology.

Flood forecasters need to have a considerable understanding of the weather processes that can cause flood producing rain. It is not suggested that they become amateur weather forecasters in their own right. In fact the flood forecasters should be firmly discouraged from attempting to forecast the weather. Both weather forecasting and flood forecasting are extremely specialised affairs and should be left to the relevant specialists. At the same time the flood forecasters must be capable of taking an intelligent interest in the weather processes that cause floods, and, in particular, the flood possibilities inherent in any potentially dangerous situation.

The flood potential of some weather structures is obvious. The possible modes of behaviour of fully developed tropical cyclones are moderately well known even to the public. A good exposition of this subject is given by Brunt (Ref 1). On the other hand some potentially dangerous weather situations are not well understood by flood forecasters. One has only to notice how the mention of a "cut-off low" will cause a scatter among meteorologists to realize that some innocent seeming situations contain a major threat of severe flooding. The flood forecaster cannot do better than form a close link with his nearest official meteorologist for frequent discussions on the possible development of all rain producing weather situations. Discussion of this situation as an event is developing is of mutual benefit to both meteorologist and flood forecaster, the former so that he may be aware of the type of advice the flood forecaster needs and the latter so that he may be aware of the way in which the rainfall pattern could develop so, in the terms of a popular song of a generation ago, he can "watch the doughnut and not the hole". It is all too easy for a flood forecaster to convince himself of the pattern of rainfall he thinks will develop over a catchment to the extent of disregarding or disbelieving contrary data. Every forecaster does this sooner or later. Regular discussions with an independently minded weather forecaster are therefore essential.

In the immediate post flood period when scapegoats were being eagerly sought, the Bureau of Meteorology was strongly criticised for failing to forecast the resumption of the rain on the Friday night of the flood which caused the record flooding in some of the suburban creeks of Brisbane and Ipswich. It is believed that all the available data indicated a cessation of rain and that no other forecast was possible in the circumstances.

Another factor is also important. Forecasts are made in time for the most popular news broadcasts of the day. If there is any reason to change the forecast after the news has been broadcast, there seems to be no way of advising the public. Allegedly wrong forecasts are frequently due to the problem of gaining the attention of the public outside the recognised news times to advise them of the changed circumstances.

At various debriefings held after the flood the Bureau readily confessed its shortcomings in the belief that it was the duty of all public organisations to openly discuss the deficiencies of their performance in the flood so that a comprehensive plan could be drawn up to deal with future emergencies. The Bureau found, however, that it had committed the unpardonable sin of transgressing the Eleventh Commandment and were publicly criticised for having let down the citizens of Brisbane. This criticism was all the more unjustified when the efficient performance of the Bureau is compared with many other organisations, particularly the Police and the Civil Defence Organisations which frankly were badly disorganised at the critical part of the flood although individual officers and members showed considerable initiative in the absence of supportive directions and carried out much rescue work at considerable personal danger. Yet these very organisations have subsequently claimed that their own performances were efficient. Their attitudes are all the more surprising in view of the dry run of a 1893 type flood arranged for them in 1973 by the Queensland Disaster Organisation. All parties professed themselves to be satisfied with the outcome of this exercise.

It does not matter that such organisations, and there are many of them, have sought to save face in this manner. The great danger lies in the tendency to believe their own propaganda and thus entrench themselves in a hardened attitude towards the whole problem which will not allow the necessary flexibility of mind to deal with a future emergency except in terms of the practices of the 1974 flood. The failure of the Queensland Government to set up a judicial inquiry to examine all aspects of this flood problem, including the performance of all bodies with a public responsibility in the matter has perturbed many people who feel that too many major deficiencies have been glossed over hastily and any reorganisation of the emergency services will not cover the problems that will inevitably arise in future emergencies.

The January 1974 flood in Brisbane and Ipswich provides an interesting study of different organisations under stressful emergency conditions. For some, including the Bureau of Meteorology, it was largely an extension and intensification of their normal routine in flood periods. Other organisations such as the Water Supply and Sewerage Department of Brisbane City Council marshalled their resources in an orderly fashion to meet each emergency as it arose but many organisations were faced with situations they had never before contemplated. In all too many cases the few people who realised what should be done dashed off to do it leaving hundreds of willing and available helpers without any directions to follow.

There are some striking similarities between the January 1974 storm and the first major storm of February 1893. The latter has been described by Brunt (Ref 2). It started with tropical hurricane (cyclone) which seemed to degenerate into a persistent trough over the Mary and Stanley River catchments. Unfortunately no upper air data could be collected in those days so that it is not possible to say whether the intertropical convergence made one of its rare southward adventures into the Brisbane River Catchment.

References

1. BRUNT, A.T. Time Space Relationships of Cyclone Rainfall in the North Eastern Australian Region. Trans. Civ. Engg., I.E. Aust., Vol. C.E.1, April 1968.

2. BRUNT, A.T. The Crohamhurst Storm of 1893. Proc. Conference on Estimation of Extreme Precipitation Bureau of Meteorology, Melbourne, December 1958.

The Author in Reply:

Mr. Cossins' comments are pertinent and perceptive. No Meteorological Service however efficient can hope to provide precise and accurate forecasts of meteorological events on all occasions because of the highly complex and finely balanced state of the atmosphere in some situations. The micro-meteorological networks required to provide the fine-scale sampling of the atmosphere at frequent intervals as a basis only for the explanation of what is currently happening are not economically practicable. Prediction of the future state of the atmosphere under these conditions must therefore be subject to occasional error. The test of efficiency of a meteorological service should not be made on the basis of the occasional error of prediction but on the basis of the superior benefits of a forecast service as opposed to a non-predictive system. Of course, even the accurate reporting of existing weather without a predictive bonus has considerable practical application and benefit.

To obtain a true assessment of the performance of the Bureau in the January flood episode requires a broader examination than the critical assessment of one particular phase of the service. In the first instance, the detection, reporting and prediction of the behaviour of cyclone WANDA and the initial warning of the prospects of heavy to flood rain over south-eastern Queensland were both timely and accurate and represented a considerable achievement in terms of public service. The incorrect prediction of the rainfall trend on the Friday evening the 25 January to a "rain easing situation" instead of "a resumption of heavy rain" was based on a considerable amount of strong synoptic evidence. Careful post-analysis of the situation substantiates the decision made. What were the real immediate consequences of this decision as far as the public was concerned? A resumption of heavy rain produced another substantial creek flooding but did not appreciably increase the total community damage to any real extent. The prediction of the later continuation of heavy rains over the subsequent period of the main flood development stage to a large degree counteracted the earlier incorrect prediction and still allowed the major Brisbane River flood event to be accurately predicted by the hydrologists well in advance of its occurrence and with a warning time which would have enabled a substantial community flood damage avoidance programme to be undertaken had there been the desire and the organisation available to so do.

The very real problem of credibility of forecasts arises here. Any system with inbuilt predictive errors is not readily acceptable to a large part of the less informed community. Unless a reasonable reversal of this attitude to the acceptable level of predictability can be achieved by school and public education the maximum effectiveness of Bureau services generally will not be achieved. The Bureau of course has the continuing task of improving the standard of its services by improving facilities at a level which the community can afford, by greater research effort into forecasting techniques, and by a determined effort to retain an experienced and competent team of meteorologists and hydrologists for the difficult and often thankless task of prediction.

Mr. Cossins' comment about the difficulty in reaching the public with up-to-date amendments to previously issued forecasts has a number of aspects which are important. The first is that a large proportion of the community make little effort to keep themselves informed of the latest meteorological situation even when available and base their criticisms on the material of which they had prior knowledge. This might be a small part of what was available due either to incomplete distribution by the media or because of failure to listen or read. Secondly the Bureau provides a continuous service and it is difficult to reach the public when some of the media are not operating, when set recorded programmes are in operation or when communication systems are occupied or disrupted. However a prompt amendment service is provided by the Bureau at all times and is especially effective for the meteorological warning services when most of the media make special efforts to provide a continuous up-to-date service.

HYDROLOGY OF THE FLOODS

by J.K.G. Ward B.E. M.I.E. Aust. *

INTRODUCTION:

Even though January 1974 will be remembered as the time when some of the largest floods this century occurred in many parts of Queensland, and all of them are worthy of investigation, this paper will only concentrate on the ones that occurred in the Moreton region.

This region is bounded by the Caboolture River in the North, the Queensland/New South Wales border in the South, the Darling Downs in the West and the Pacific Ocean in the East. Figure I shows part of the region as well as some other pertinent information.

This paper will present the factual data that has been collected for the surface run-off phase of the floods.

SEQUENCE OF EVENTS:

On Thursday 24th January, 1974, the hydrographic staff of the Irrigation and Water Supply Commission were placed on the alert as cyclone 'Wanda' headed towards Brisbane.

Friday 25th January saw Brisbane deluged and all the local creeks in high flood. Stream gauging measurements commenced to assess the flow in these creeks.

On Saturday 26th January it became obvious from the rainfall totals being relayed from throughout the Moreton Region that it was time to leave the local creeks and concentrate on the larger streams.

In January 1968, 3,400 cumecs (some 120,000 cusecs) was measured in the Brisbane River at Jindalee. Late on Saturday predictions indicated that a flow in excess of this would occur in the next few hours.

At dawn on Sunday 27th January a team of hydrographers was stationed on the Centenary Bridge at Jindalee measuring the Great Brisbane Flood of 1974. Continuously during the daylight hours from that time until the river subsided some four days later stream gauging measurements were made.

During the time that measurements were being taken on the Brisbane River other measurements were being made on the Albert River at Lumeah.

HEIGHT TIME RECORDS:

Table 1 presents the gauging stations in the Moreton Region and some information relating to them. These stations have Recorders which give a continuous record of height versus time at one location on a stream. In addition to these Automatic Recorders a number of people recorded heights at various times during the flood at numerous points in the Moreton Region. These extra records have proved very valuable in assessing what occurred

* *Senior Engineer, Surface Water Resources Branch, Irrigation and Water Supply Commission, Q'land.*

during the flood. Many people noted the peak height reached by the flood and this has helped in inundation studies.

Of the 59 Automatic Recorders in the area it will be noted that 42 of them worked satisfactorily during the flood event. Six Floatwells were overtopped and two Gas Electric Recorders were inundated. The other nine recorders failed to work due to malfunctions of the instruments.

Figures 2 to 4 show some of the recorded height and discharge versus time hydrographs for the Brisbane River. Similar hydrographs could be drawn for most of the gauging stations in the Moreton Region.

DISCHARGE MEASUREMENTS:

Due to the limited number of hydrographic staff available to measure the floods in the Moreton Region it was only possible to measure some of the flooded streams. Table 2 presents the measurements that were made during the period in the Moreton Region.

As well as the problem of limited staff available for measurements it was extremely difficult to travel from one place to another during the flood period. Consequently, only a few stream gauging stations were manned and as many measurements as possible were made at these stations.

The equipment used for flood measurements is also suitable for flood rescue work and so whenever possible flood measurements were combined with flood rescue work.

Measurements were made from bridges, boats and travellers. In most cases Ott current meters were used. In certain cases, it was possible only to obtain surface velocity measurements, due to the extremely high river velocities and the considerable drag on current meters.

It is understood that Oceanics Australia also took a series of surface measurements at a number of locations along the Lower Brisbane River.

VELOCITY PROFILES:

From the stream gauging measurements taken during the flood, enough data was collected to draw velocity profiles both in the vertical and horizontal direction.

As an indication of the speed with which the streams flowed, velocities of up to 3.7 metres per second (12 feet per second) were recorded in the Brisbane creeks and of the order of 3.1 metres per second (10 feet per second) in the main Brisbane River.

TIME OF TRAVEL OF FLOOD PEAKS:

In the Brisbane River enough height hydrographs were recorded at a number of locations along the length of the stream to enable assessments to be made of the time of travel of the peak flow.

Information on the times of travel is used in flood predicting work.

FLOOD SLOPE SURVEYS:

Following the flood, the hydrographic staff surveyed the peak flood levels upstream and downstream of the stream gauging stations in order to provide flood slope data at every stream gauging station in the Moreton Region.

To augment the information obtained during the Centenary Bridge measurements, a local resident in the Jindalee area was requested to take height measurements some distance upstream from the bridge during the flood and these have been used in order to assess flood slopes during the flood.

Figure 5 presents flood survey data that was computed many years ago for the Brisbane River.

INUNDATION STUDIES:

Inundation surveys were commenced immediately after the flood for the majority of streams in the Moreton Region. The surveys were undertaken by the Irrigation and Water Supply Commission, the Surveyor-General's Department, the Brisbane City Council, the Ipswich City Council, and some other organisations.

Maps have been drawn by the Irrigation and Water Supply Commission indicating the areas that were inundated in these floods and these maps cover the majority of the Brisbane River and its tributaries, the Logan, Albert, Coomera and Nerang Rivers and several other streams.

ANALYSIS OF FIELD DATA:

It is essential that immediately after a significant flood event such as the one of January 1974 that all field data be collected, assembled and assessed for accuracy.

An initial check on the reliability of the field data can be obtained by making a volumetric water balance. A water balance of the Brisbane River Catchment based on the mean catchment rainfalls obtained from an isohyetal map produced by the Bureau of Meteorology and the flood volumes determined from the discharge hydrographs has been undertaken. Table 3 outlines the results of this analysis to date and indicates that there is quite a significant range in the percentage of runoff to rainfall over different parts of the area.

This water balance has also assisted in the extrapolation of existing rating curves.

It is hoped that eventually the hydrograph recorded at the Port Office gauge will be able to be subdivided into the portion resulting from the Bremer River catchment, the portion resulting from the Upper Brisbane etc.

GENERAL COMMENTS:

The stream heights recorded during the January 1974 floods are by no means unique. Figure 6 shows past flood data for the Brisbane Port Office from which it can be seen that floods of similar magnitude have occurred in the past in the Moreton Region and they will certainly occur in the future. The construction of dams such as Wivenhoe Dam will no doubt modify the magnitude of future floods, but it would be false to assume that they will eliminate floods from that time onwards.

A City, such as Brisbane, situated at the mouth of a river which has a catchment of some 13,600 square kilometres (5,300 square miles) should devise a warning system that allows everyone to assess what is likely to happen in their area, based on the official information relayed over news media.

It is believed that the information collected from January 1974 flood will allow various re-assessments to be made of the great 1893 flood and consequently will permit further consideration to be given to the best operating procedure for Somerset Dam during a flood crisis. In addition, it should help forecasters by providing more factual data.

ACKNOWLEDGMENTS:

I wish to acknowledge the permission given by the Commissioner of the Irrigation and Water Supply Commission, Mr. Haigh, M.B.E., M.E., F.I.E. Aust., F.A.I.M., to present this paper and the Staff of Surface Water Resources Branch who contributed so significantly to collection of data in the field and analysing it in the office.

TABLE 1

IRRIGATION AND WATER SUPPLY COMMISSION

Stream Gauging Stations in Moreton Region

G.S. NUMBER	STREAM	STATION NAME	LATITUDE	LONGTITUDE	A.M.T.D. (km)	CATCHMENT AREA sq.km	TYPE	PERIOD	REMARKS
142001	CABOOLTURE RIVER	UPPER CABOOLTURE	27 06	152 53	31.4	98	GAS	1965	
142101	NORTH PINE RIVER	YOUNG'S CROSSING	27 16	152 57	17.1	357	FLOAT	1956	
142202	SOUTH PINE RIVER	NEAR DRAPERS CROSSING	27 21	152 55	20.6	158	GAS	1965	MALFUNCTION
142203	CABBAGE-TREE CK.	S.15 MILES	27 21	153.02	8.4	18	FLOAT	1972	
142204	SCHULZ CANAL	NUDGEE ROAD	27 24	153 05			FLOAT	1973	
142205	CANNERY DRAIN	CROCKFORD STREET	27 24	153 05			FLOAT	1973	
142901	KEDRON BROOK	OSBORNE ROAD	27 24	152 59	28.7		GAS	1972	
142902	KEDRON BROOK	TEACHERS COLLEGE	27 25	153 02	19.5	54	FLOAT	1972	
143001	BRISBANE RIVER	SAVAGES CROSSING	27 26	152 40	130.9	10179	GAS	1958	MALFUNCTION
143007	BRISBANE RIVER	LINVILLE	26 48	152 16	282.4	2007	GAS	1963	
143008	BRISBANE RIVER	MIDDLE CREEK	27 16	152 35	187.2	6708	GAS	1962	MALFUNCTION
143009	BRISBANE RIVER	GREGOR CREEK	26 59	152 24	251.7	3885	GAS	1962	
143010	EMU CREEK	BOAT MOUNTAIN	26 59	152 17	10.1	920	GAS	1965	
143011	EMU CREEK	RAEBURN	27 04	152 00	74.0	443	GAS	1965	
143013	CRESSBROOK CREEK	36.4 MILES	27 16	152 12	58.6	324	GAS	1965	
143015	COOYAR CREEK	DAMSITE	26 44	152 08	12.2	958	GAS	1969	
143019	OXLEY CREEK	BEATTY ROAD	27 35	153 01	16.3	155	FLOAT	1971	OVERTOPPED
143020	MOGGILL CREEK	MISTY MORN	27 31	152 56	3.7	62	FLOAT	1972	OVERTOPPED
143022	STABLE SWAMP CK.	INTERSTATE RAILWAY	27 34	153 01		21	FLOAT	1971	OVERTOPPED
143027	BLUNDER CREEK	KING AVENUE BRIDGE	27 36	153 00			FLOAT	1973	OVERTOPPED

TABLE 1 contd.

G.S. NUMBER	STREAM	STATION NAME	LATITUDE	LONGTITUDE	A.M.T.D. (km)	CATCHMENT AREA sq.km	TYPE	PERIOD	REMARKS
143028	ITHACA CREEK	JASON STREET	27 27	153 00		9	FLOAT	1972	
143094	BULIMBA CREEK	14.1 MILES	27 32	153 06	22.7	52	GAS	1971	
143099	OXLEY CREEK	ROCKLEA	27 33	153 00		184	GAS	1971	
143107	BREMER RIVER	WALLOON	27 36	152 41	37.2	622	FLOAT	1961	OVERTOPPED
143108	WARRILL CREEK	AMBERLEY	27 40	152 42	8.7	920	FLOAT	1967	
143110	BREMER RIVER	ADAMS BRIDGE	27 50	152 31	77.1	130	GAS	1969	
143111	REYNOLDS CREEK	MOOGERAH DAM	28 01	152 33	15.6	225	FLOAT	1961	
143113	PURGA CREEK	LOAMSIDE	27 41	152 44	6.9		FLOAT	1973	
143114	BUNDAMBA CREEK	MARY STREET	27 36	152 48	4.4	31	FLOAT	1972	OVERTOPPED
143208	FIFTEEN MILE CREEK	DAM SITE	27 27	152 06	2.3	36	FLOAT	1956	MALFUNCTION
143209	LAIDLEY CREEK	MULGOWIE	27 44	152 22	30.9	179	FLOAT	1967	MALFUNCTION
143210	LOCKYER CREEK	LYONS BRIDGE	27 27	152 31	27.2	2538	GAS	1963	OVERTOPPED
143211	BUARABA CREEK	9.8 MILES	27 25	152 25	15.8	251	GAS	1967	
143212	TENTHILL CREEK	HOTEL	27 38	152 13	14.7	453	GAS	1968	MALFUNCTION
143293	LOCKYER CREEK	HELIDON NO 2	27 32	152 07	96.6	378	FLOAT	1966	
143932	ENOGGERA CREEK	BANCROFT PARK	27 27	153 00	9.3	67	FLOAT	1971	
								1962-66	
145003	LOGAN RIVER	FOREST HOME	28 12	152 46	166.5	176	GAS	1966-	
								1967-69	
145008	LOGAN RIVER	ROUND MOUNTAIN	28 04	152 56	124.7	1269	GAS	1969 -	
145010	RUNNING CREEK	3.6 MILES	28 15	152 54	5.8	155	GAS	1956	
145011	TEVIOT BROOK	CROFTBY	28 09	152 34	84	83	GAS	1966	

TABLE 1 contd.

G.S. NUMBER	STREAM	STATION NAME	LATITUDE	LONGITUDE	A.M.T.D. (km)	CATCHMENT AREA sq.km	TYPE	PERIOD	REMARKS
145012	TEVIOT BROOK	THE OVERFLOW	27 56	152 52	22.5	505	GAS	1965	
145013	CHRISTMAS CREEK	7.3 MILES	28 10	152 59	11.8	174	FLOAT	1967	
145014	LOGAN RIVER	YARRAHAPPINI	27 50	152 59	77.8	2404	GAS	1969	OVERTOPPED
145018	BURNETT CREEK	20.1 MILES	28 13	152 36	32.4	83	GAS	1969	MALFUNCTION
145020	LOGAN RIVER	RATHDOWNEY	28 13	152 52	150.2		GAS	1973	
145099	BURNETT CREEK	MAROON DAM TAILRACE	28 11	152 40	23.5		FLOAT		
145101	ALBERT RIVER	LUMEAH NO 2	28 04	153 03	76	171	GAS	1966	
145102	ALBERT RIVER	BROMFLEET	27 55	153 06	47.5	544	GAS	1963	
145103	CAINBABLE CREEK	6.2 MILES	28 05	153 05	10.0	41	GAS	1962	MALFUNCTION
145104	CANUNGRA CREEK	20.2 MILES	28 03	153 07	32.2	75	GAS	1965	MALFUNCTION
145107	CANUNGRA CREEK	MAIN ROAD BRIDGE	28 00	153 10	19.0	98	FLOAT	1973	
145196	ALBERT RIVER	WOLFFDENE	27 47	153 11	19.0	725	GAS	1969	
146009	LITTLE NERANG CK.	2.5 MILES	28 04	153 18	4.0	57	GAS	1969	
								1962-66	
146010	COOMERA RIVER	ARMY CAMP	28 02	153 12	45.2	96	FLOAT	1966-	
146011	NERANG RIVER	28 MILES	28 05	153 15	45.1	124	GAS	1965	
146012	CURRUMBIN CREEK	NICHOLLS BRIDGE	28 11	153 26	10.3	36	FLOAT	1970	
146014	BACK CREEK	BEECHMONT	28 07	153 11	16.3	13	FLOAT	1971	
146092	NERANG RIVER	GLENHURST RECORDER	28 00	153 19	23.0	238	GAS	1968	
146095	TALLEBUDGERA CREEK	7.9 MILES	28 09	153 24	12.7	60	GAS	1970	

TABLE 2

Stream Gauging Measurements in Moreton Region

25 - 30 January 1974

STREAM	GAUGING STATION	DATE	MEAN GAUGE HEIGHT (m)	DISCHARGE (Cumecs)	TYPE OF MEASUREMENT
Albert R.	Lumeah	25.1.74	4.13	102.2	Traveller
		25.1.74	4.57	124.6	Traveller
		25.1.74	4.90	139.9	Traveller
		25.1.74	5.02	148.4	Traveller
		26.1.74	7.90	380.3	Traveller S
		27.1.74	4.33	126.3	Traveller M.P
		27.1.74	4.18	120.1	Traveller M.P
		27.1.74	4.01	111.0	Traveller S
		27.1.74	3.92	107.3	Traveller S
		28.1.74	2.74	60.9	Traveller S
		28.1.74	2.24	40.5	Traveller S
Kedron Bk.	Osborne Rd.	25.1.74	2.95	96.3	Boat
		25.1.74	4.00	169.9	Float
Kedron Bk.	Gympie Rd.	26.1.74	3.54	56.6	Boat
		26.1.74	3.26	46.4	Boat
Enoggera Ck.	Bancroft Pk.	25.1.74	5.40	351.1	Bridge
		25.1.74	4.90	266.2	Bridge
Moggill Ck.	Misty Morn	25.1.74	4.72	218.1	Boat
		25.1.74	4.475	178.4	Boat
Stable Swamp Creek	Interstate Rly.	26.1.74	3.725	Affected by back-water	Boat
Brisbane R.	Jindalee	27.1.74	11.58-11.89	Measurements rejected. Barge against bridge	Bridge
		28.1.74	15.10	9401	Bridge
		28.1.74	15.24	9514	Bridge
		29.1.74	14.46	8778	Bridge
		29.1.74	14.11	8467	Bridge
		29.1.74	13.76	8070	Bridge
		30.1.74	10.10	5387	Bridge
		30.1.74	9.19	4842	Bridge

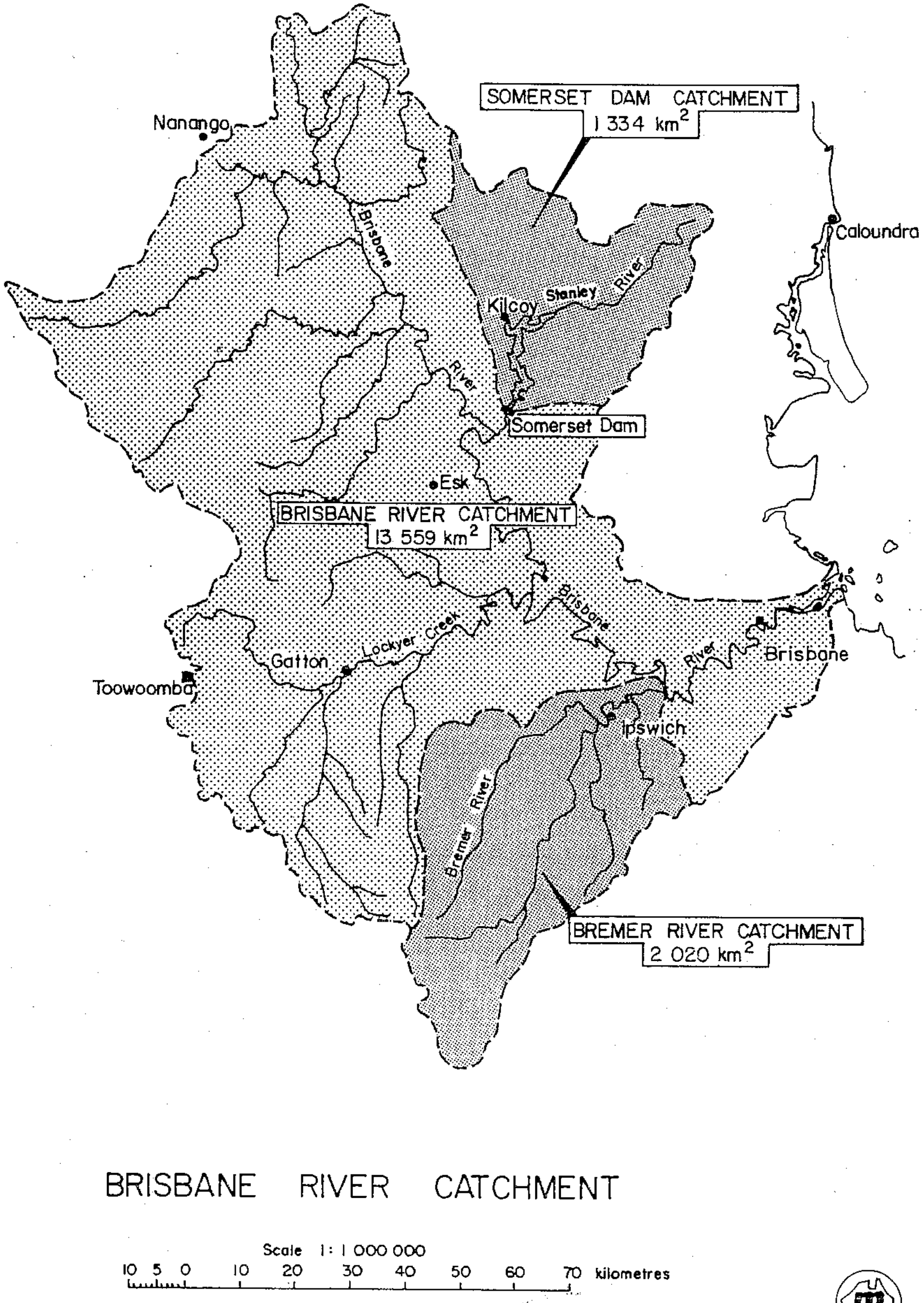
TABLE NO. 3

LOCATION	AMTD (km)	CATCHMENT AREA (sq.km)	PEAK DISCHARGE (cumecs)	TIME OF PEAK DISCHARGE Hour (Day) January 1974	FLOOD VOLUME $m^3 \times 10^6$	FLOOD VOLUME Mean Depth of Runoff (mm)	5 DAY MEAN CATCHMENT RAINFALL ENDING 9.00 29.1.74 (mm)	RUNOFF RAINFALL (%)
Brisbane R. at Jindalee	49.1	12 950	9540	2000 (28)	3579 (a)	277	390	71
" " less Somerset Catchment		11 616			2971 (b)	256	384	67
Brisbane R. at Savages Crossing	130.8	10 178	7650	0400 (28)	2532 (a)	249	364	68
" " less Somerset Catchment		8845			1926 (b)	218	343	64
Brisbane R. at Gregors Ck.	251.7	3885	5660	1100 (27)	766	197	283	70
Brisbane R. at Linville	282.4	2007	2440	1030 (27)	246	123	239	51
Cooyar Ck. at Damsite	12.2	958	1590	0830 (27)	144	150	250	60
Lockyer Ck. at Lyons Bridge	29.3	2460	1100	0800 (27)	295 (c)	120	360	33
Warrill Ck. at Amberley	8.7	919	2180	0300 (27)	335	364	459	79
Stanley R. at Somerset	7.2	1334			608	455	500	91
Albert R. at Wolfdene	19.0	725	1950	2200 (26)	315	435	615	71
Nerang R. at 14 Mile	22.4	238	1350	1500 (26)	179	753	1020	74

(a) Includes releases from Somerset Dam

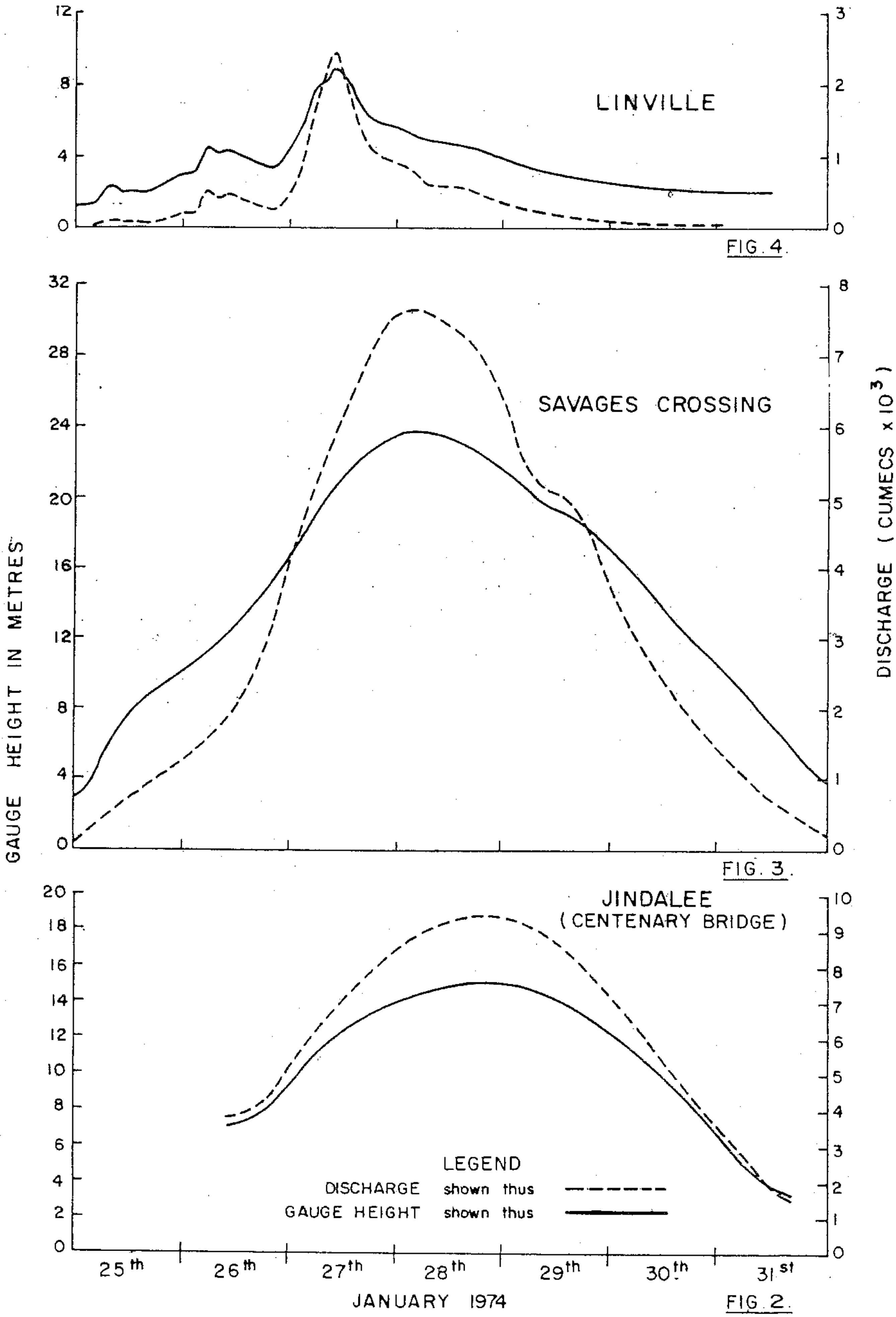
(b) Excludes releases from Somerset Dam

(c) Volume most likely greater as creek broke its banks.



BRISBANE RIVER CATCHMENT

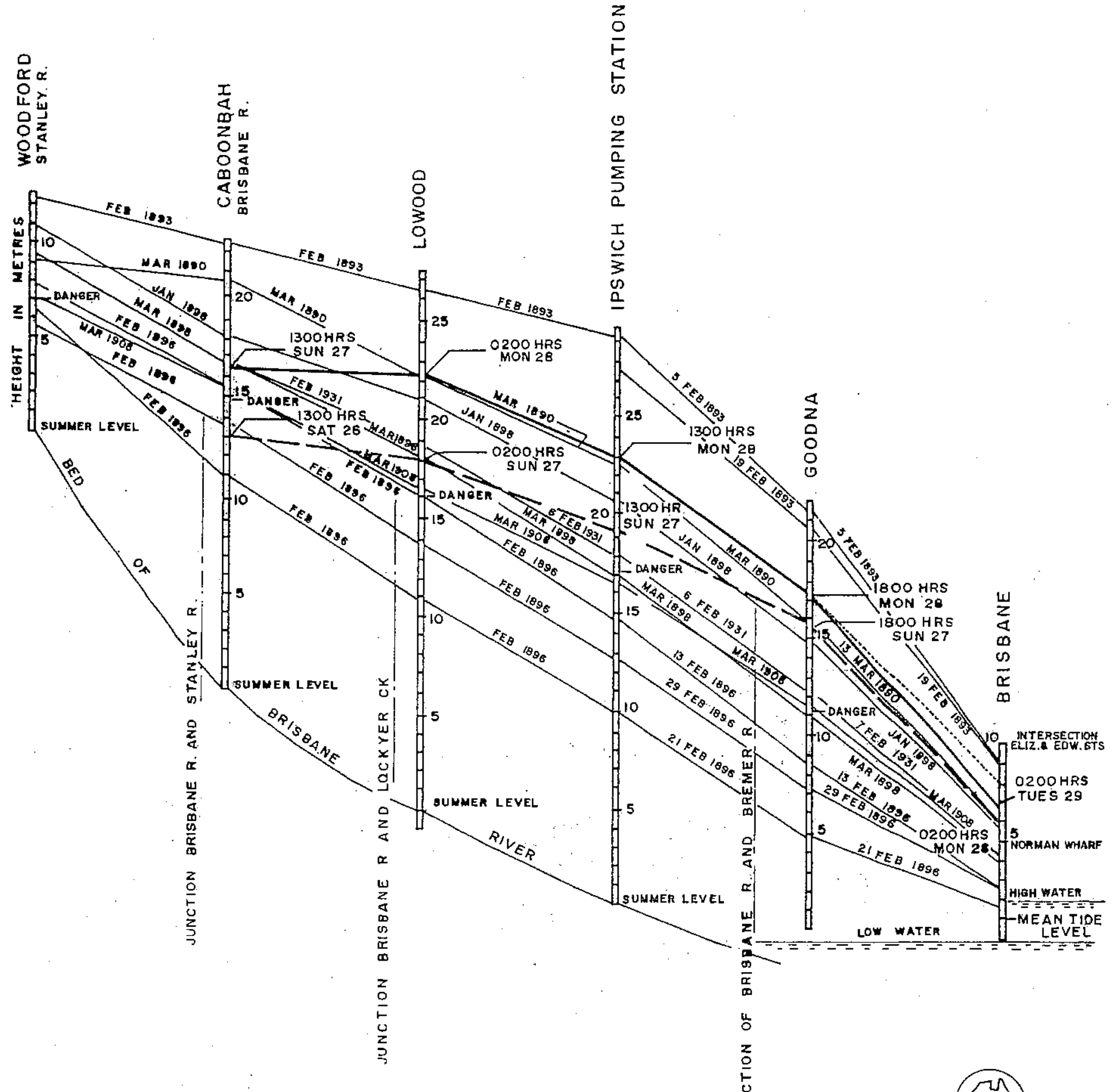
Fig. 1



BRISBANE RIVER
SELECTED HYDROGRAPHS

A4 - 38782

BRISBANE RIVER FLOOD HEIGHTS TO JANUARY 1974



NOTE FLOOD LEVELS PRIOR TO 1901 ARE REFERRED TO A DATUM 254 mm ABOVE THE PRESENT POST OFFICE GAUGE

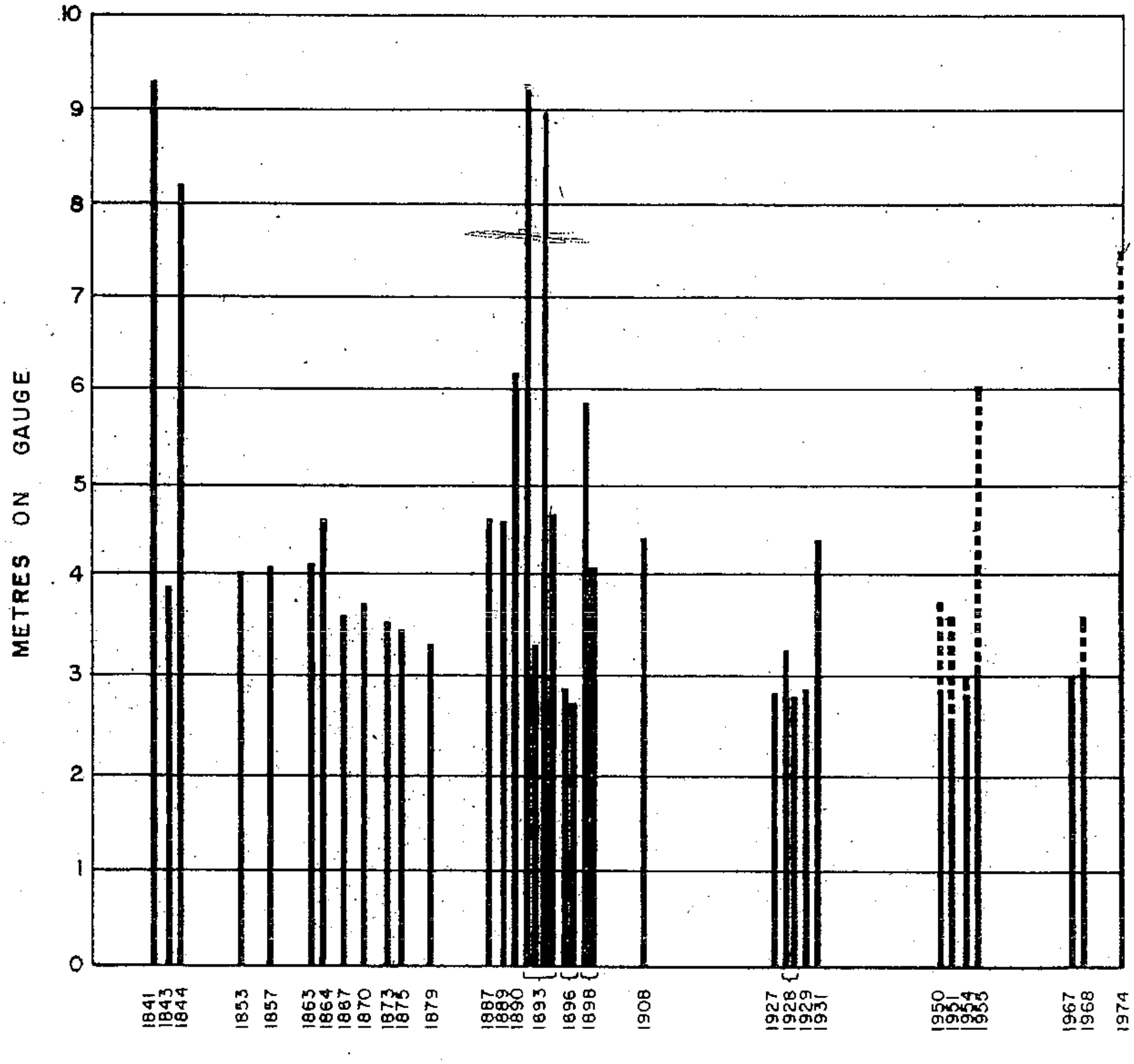
LEGEND

PROFILE JANUARY 1974 FLOOD HEIGHT	SHOWN THUS	———— (solid line)
PROFILE SYNCHRONISED WITH TIME OF PEAK BREMER RIVER CONTRIBUTION TO BRISBANE RIVER	" "	— — — (dashed line)
PROBABLE JANUARY 1974 FLOOD HEIGHT WITH RIVER CONDITIONS SIMILAR TO 1893 IN CITY REACHES, BUT INCLUDING SOMERSET DAM MITIGATION	" "	- - - - - (dotted line)

FIG.5.

Flood heights taken at Port Office Gauge, Brisbane.

Estimated height without flood mitigating effect of Somerset Dam shown thus ....



BRISBANE RIVER FLOOD HEIGHTS 1841 - 1974

FIG. 6.

DISCUSSION

J. Clerke, B.E., M.I.E. Aust.

Mr. Ward is to be complimented for his thorough documentation of the activities of the Irrigation & Water Supply Commission during the flood and the listing of the performance of the Commission automatic stream height recorders.

Flow gauging and river heights measured at Jindalee on the Brisbane River and on the local Brisbane creeks will prove to be invaluable in assisting future flood mitigation studies for the City of Brisbane.

The problems of trying to assess a flow hydrograph without any rating measurements are clearly illustrated by the attached diagram for the broad crested spillway at Enoggera Creek. The original assessment (curve "O") was based on the weir formula $Q = 2.7 \times 1 \times h^{3/2}$. The next assessment (curve "M") was based on model studies, while the amended "M" curve was based on detailed studies of several storms on the catchment. The adopted curve was derived by Mr. R. Black of the Queensland Institute of Technology following successful rating measurements over the spillway with a water depth of two feet.

The Brisbane City Council's Flood Control Centre was also fully operative over the long, (very long!) weekend. Besides controlling the operation of Somerset Dam, the Flood Centre carried out accurate predictions 12 to 24 hours in advance of flood heights for all locations on the river in the City reaches and for Mt. Crosby. The Flood Control Centre also directed the reading, often on an hourly basis, of 16 staff gauges on the Brisbane River, within the City limits and the data from these observations will considerably assist future computer studies of the interaction of flood flows, tide and surge in the river. It is of interest to note that 11 of the staff gauges were read by private individuals and the staff from the S.E.A.Q. power houses, the Q'ld. Cement & Lime Ltd., the Military Police and the Salvation Army Boys' Training Farm.

The Flood Control Centre also supervises the operation of nine pluviometer stations in the catchment. Breakdowns occurred in two of these installations - one failure being due to the back-up of flood waters from Somerset Dam!

The Council has four automatic lake level recorders on its four dams. Due to previous mechanical breakdown only three were operating during the flood period.

The staff gauge at Mt. Crosby was damaged by wash-aways on Tuesday, the 29th January and, as a result, river heights were not measured for about 12 hours after this event. The position was remedied by conveying a surveyor (by helicopter) to Mt. Crosby. Due to mechanical and electrical obsolescence, the Council's automatic river height recorder installation at Vernor was not operating during the flood period. However, the police at the nearby Lowood gauge obtained and transmitted (despite poor communications) good river height data.

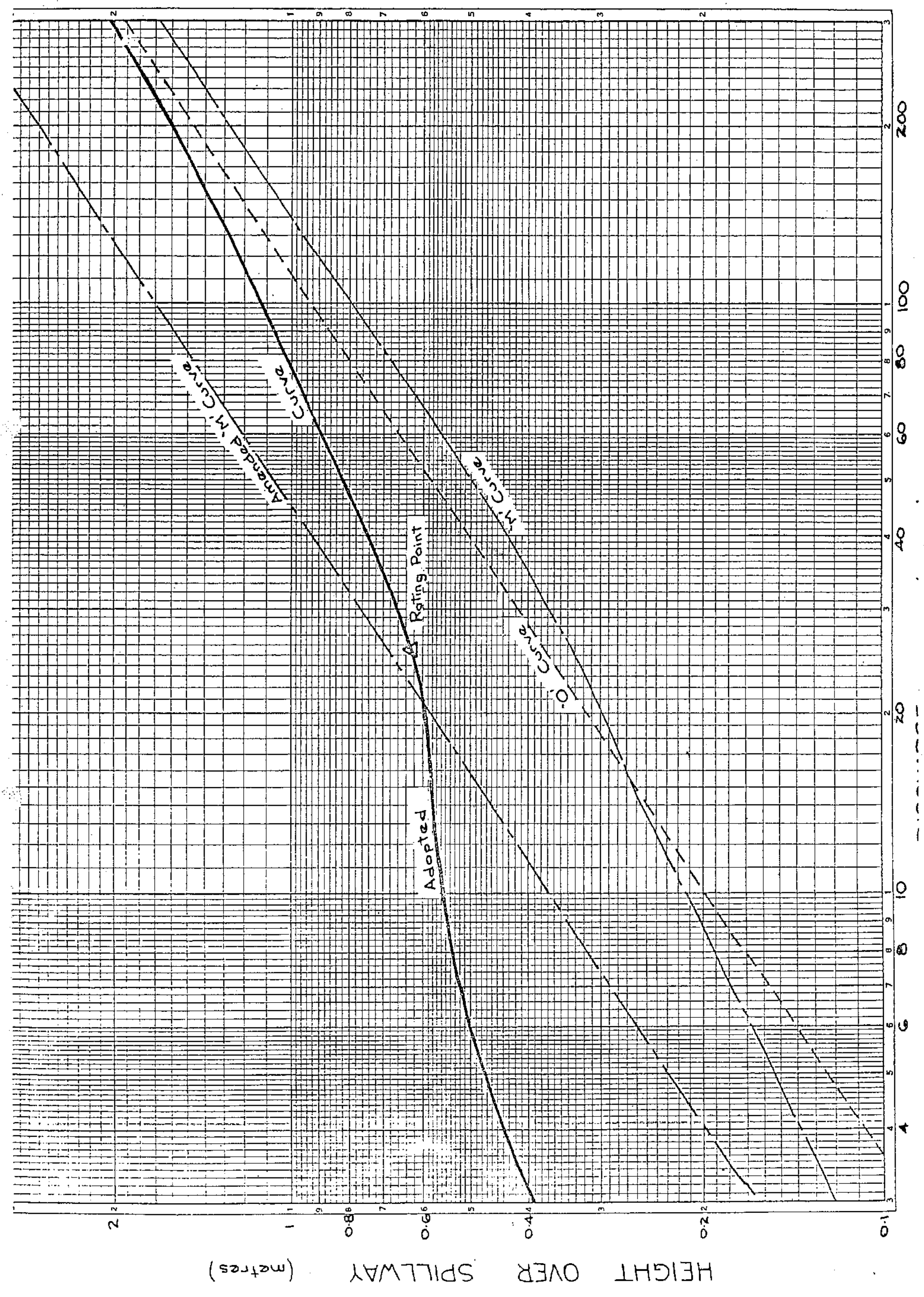
With regard to the I.W.S. automatic river gauge height recorders, it is regrettable that so many of the breakdowns were due to overtopping. In view of the importance of recording the major flood event, perhaps overtopping of an automatic gauge could be called the "unpardonable sin" - perhaps Mr. Ward may like to comment on this point.

It is of interest to note that the only available estimates of the flood run-off of the 1893 flood for the total Brisbane catchment give a figure only slightly less than that listed in Table 3 of Mr. Ward's paper for the 1974 flood (viz. 277mm run-off). However, the flood run-off in the Stanley River at the Somerset Dam location in 1893 was just slightly more than twice that occurring in the January 1974 flood (vix. 455mm).

The variation in spatial rainfall over the Brisbane catchment for the two flood events was also quite different. For example, in 1893 the rainfall at Crohamhurst and Ipswich was 2100 and 240mm respectively whereas for the 1974 flood, the respective figures were 700 and 600mm, thus illustrating the considerable increase in flood run-off that was contributed from the middle and lower reaches of the Brisbane River for this flood event.

With regard to the accuracy of extrapolation of rated stream gauge data, Mr. Ward may like to comment on say, the tolerance factor on the estimated peak flood flow of 7650 cumecs (270,000 cusecs) for Savage's Crossing that is given in Table 3.

ENOGGERA RES. SPILLWAY DISCHARGE RATING



The Author in Reply:

I thank Mr. Clerke for the comments on my paper and the additional information provided.

Mr. Clerke's first question relates to overtopping of automatic stream height recorders. It is the general practice of the Irrigation & Water Supply Commission to position the actual instrument several feet above the maximum known flood level at the recorder site. Where no previous flood height data exists an assessment is made of the level expected from a large discharge based on a Myer's formula calculation and the instrument is placed above this level.

If all instruments had to be sited above the probable maximum flood level then the costs of stream gauging installations would rise dramatically and most probably fewer installations could be financed. In addition the Irrigation and Water Supply Commission has a charter to assess the water resources of Queensland and this means measuring and observing the low flows as well as the high flows.

Due to the above it is inevitable that some recorders will be overtopped at some time.

Mr. Clerke's second question relates to the reliability of the extrapolated rating curve for Savage's Crossing. As actual stream gauging measurements have been made up to a discharge of 3360 cumecs (118,500 cusecs) at Savage's Crossing a considerable degree of confidence can be placed on the extrapolated rating curve. However until measurements are made in the range 7085 to 8300 cumecs (250,000 to 300,000 cusecs) at Savage's Crossing, the extrapolated portion of the rating curve must be regarded as provisional.

FLOOD FORECASTING AND WARNINGS

MORETON REGION

by G. Heatherwick M.I.E. Aust. *

SUMMARY

Since the disastrous floods in the Moreton Region during the last week of January, an investigation has been made into the warning procedures used during the period. This paper briefly describes some of these procedures together with a review of the development of flooding through the rainfall runoff phase for some of the major rivers.

1. INTRODUCTION

The Bureau of Meteorology has issued warnings of flooding since its establishment in 1908. The present Meteorology Act of 1955 renewed Bureau responsibility for the issue of warnings of floods likely to cause damage or loss to property and stock, and risk of loss of life. In 1957 the Australian Government Cabinet directed the Bureau of Meteorology to establish an Hydrometeorology Section, with responsibility for among other things, systematic flood forecasting.

Flood forecasts and warnings constitute a direct means for the reduction of flood damage and loss of life. Advance warning of an approaching flood permits evacuation of people and removal of livestock and equipment with little loss except the cost of removal. Warnings of course do not in general prevent damage to crops or structures. Regular broadcasts of flood warnings and interpreted information, keep the public well informed and assist in minimizing personal anxiety. The relatively low ratio of cost to benefit for a flood forecast and warning service makes it an ideal flood protection measure in many areas where physical means cannot be economically justified. This is particularly the case for river systems in Queensland where a wide range of weather extremes is experienced.

2. QUEENSLAND RAINFALL JANUARY 1974

The rainfalls of January 1974 were essentially associated with the North Australian Monsoon which moved further south than it had for many years. The monsoonal trough was also of unprecedented strength and persistence in January 1974 as well as in its southward penetration.

As a result, Queensland rainfalls for January were the highest ever recorded in a number of districts. A preliminary examination of the district averages for the month indicated that of the 19 districts, 15 rate as tenth decile rainfalls, six of which are record totals for any month, two districts totals are in the ninth decile with the remaining two in the eighth and sixth decile.

In general, rainfalls for the coastal and adjacent districts ranged up to three times normal, the Peninsula being just above normal, with most of the inland districts ranging from four to six times normal, to peak at

* *Senior Engineer, Hydrometeorology Section*
Queensland Regional Office, Bureau of Meteorology, Brisbane.

eight times normal in the Upper Western district which includes areas between Mount Isa, Longreach and Windorah.

Rainfalls in the Upper Carpentaria district exceeded 1000mm in the Gilberton and Forsayth areas. These rainfalls are equivalent to the third and fourth highest recorded annual totals. In the far southwest of the state, Nappa Merrie on the South Australian border recorded 467 mm which is 27 times the normal for January and exceeds the second highest annual total previously recorded.

Down the east coast, south from Ingham, rainfalls generally exceeded 600 mm. In the Moreton Region most rainfalls exceeded 500 mm for the month and along the Blackall and D'Aguilar Ranges rainfalls varied from 1200 to 1600 mm. At Springbrook, west from Coolangatta on the New South Wales border, 2314 mm were recorded.

Isohyets for Queensland for the month of January are shown in Fig. 1. Shields (Ref. 1) presents preliminary isohyets for the storm period which caused the Moreton Region floods.

3. QUEENSLAND FLOODING

Widespread major flooding occurred in almost all areas of the state. Few areas had no flooding at all. One of these was the Dumaresq River upstream from Texas, where by comparison, drought conditions prevailed.

Record flooding occurred in the Bulloo and Paroo Rivers, Cooper Creek, Diamantina and Georgina Rivers, Eyre Creek, middle and lower reaches of the Flinders River, Norman and Gilbert Rivers and tributaries, lower reaches of the Nerang and Logan Rivers and the lower reaches of the Bremer River and Warrill Creek in terms of flood discharge. In the Brisbane and Ipswich area, Bundamba, Woogaroo, Deebing, Sandy, Ironpot, Oxley, Moggill and Enoggera - Breakfast Creeks and Kedron Brook all had record flash floods during the Australia Day weekend. Flooding occurred in the remaining creeks in the Brisbane area, but record levels were not reached. Fig. 2 shows the rivers in Queensland affected by record and major flooding during January.

Flooding in the Mary River was amongst the highest on record. Maryborough had its third highest flood with a peak of 10.95 m (35.92 feet). Walkers Shipyard, a major employer in Maryborough has decided to close, since the flood.

On the Gold Coast, record flooding in the Nerang River and other local streams caused much damage through inundation of canal residential developments and nearby commercial areas.

On the Logan River, the record flooding inundated a number of houses and properties in the Waterford-Beenleigh area. Although at Macleans Bridge (Jimboomba) the peak was slightly less than the record height in January 1887, the peak downstream at the Pacific Highway was slightly higher. Although the 1893 flood produced record flooding in the Brisbane River, the flood of 1887 recorded higher levels in the Logan River, with rainfalls in the order of 450 mm for 24 hours. The Bremer River also had severe flooding in this storm and the Brisbane record 24 hour rainfall of 458 mm was produced.

In the Ipswich area, record flash flooding in the creeks followed by record flood discharges through the city from the combined Bremer River and Warrill Creek runoff, accompanied by very high velocities, again followed by Brisbane River backwater, caused disastrous flooding in the city. Approximately 40 houses were washed away and 1800 homes and premises were severely damaged by total or partial inundation.

In the Brisbane area approximately 6700 householders had their living area either totally or partially inundated. Some houses were washed away in the creek flooding and others collapsed into the Brisbane River. Fig. 3 shows the Moreton Region area affected by flooding.

4. FLOOD WARNINGS AND FORECASTS

During January, the Bureau of Meteorology issued 262 flood warnings for most rivers in the state. Of these, 102 warnings were issued in the period 24 to 31 January. For catchments in the Moreton Region, warnings were issued as follows: Nerang 9, Logan 13, Mary 20, (including 5 flood forecasts for Gympie and 6 for Maryborough), Metropolitan Creeks 10, Brisbane Valley 23, (including 16 forecasts for the Brisbane Port Office and 2 for Ipswich). The remainder of the 102 warnings were issued for rivers elsewhere in the state.

Flood warning river height and rainfall data are received at 0300, 0900, 1500 and 2100 E.S.T. for most rivers, however on some of the smaller catchments data are received at three hourly intervals. All times stated below refer to Eastern Standard Time. Warnings and forecasts have to be prepared to coincide where possible with the issue of general weather forecasts at 0500, 1200, 1700, 2200. This means that during the period 0900 to 1200 data for all catchments in the state have to be received and analysed for the formulation and issue of flood forecasts and warnings to meet fixed times of issue. In some cases as many as 12 flood warnings are prepared for 12 different river basins and of necessity, where flooding is not so serious the texts of warnings must be brief. Warnings issued for other times do not always include all catchments in flood, since on some western rivers one warning per day is sufficient.

Flood warnings are qualitative in nature and give details of recorded rainfalls and river heights, forecast rainfalls and expected flooding in terms of minor, moderate and major flooding. The position of flood peaks and the expected time of flood peaks through key areas is also stated together with expected road traffic disabilities. Although the Bureau of Meteorology is not responsible for road trafficability reports, this information is included in the flood warnings when the data are available.

Flood forecasts provide forecast heights for key river gauges together with the expected time of occurrence, usually within a time range, and are generally included in the flood warning text.

Flood warnings and forecasts are issued to the public through the media, (press, radio and television), and to local organisations such as police and municipal Councils.

To date flood forecasting systems have been developed and are in operation for the Brisbane, Mary and Macintyre Rivers and forecasts are prepared for specific gauge locations including the Brisbane Port Office, Ipswich, Gympie, Maryborough and Goondiwindi. With present facilities, hydrological investigations associated with the development of flood forecasting systems can take from six months to three years for a river basin. After the introduction of the first stage of a forecasting system, the techniques used are subject to review using data from new floods. In this manner the system is progressively refined over a period of years dependent upon the frequency of flooding.

5. NERANG - LOGAN RIVER FLOODS

On the Nerang River, two major floods occurred in January. The first, on 12 January, was caused by exceptionally heavy rainfalls locally in the Numinbah Valley, Beechmont and Advancetown areas. Rainfalls of approximately 200 mm in four hours fell in this area. Springbrook, at the head of the Nerang catchment, had, by comparison, much less than would normally be expected.

Runoff from the Advancetown-Numinbah area caused a sharp rise at Nerang Township, with a peak of approximately 10.36 m (34 feet) at about 0800 on 12 January, with major flooding. The height at Nerang remained above minor flood height of 6.1 m (20 feet) for only seven hours. Although peak discharge would have coincided very nearly with high tide on the rising stage in the canal developments, no significant flooding occurred. In this case the tides were not abnormally high and, because the rainfall at Springbrook was less than that in the Advancetown area, and not notable for that station, Mudgeeraba Creek, which enters the Nerang River via the southern section of residential canal developments, was not a major contributor. Considerable reduction in flood height due to natural storage and attenuation of the peak also occurred between Nerang and the Southport Broadwater.

Three flood warnings were issued for this flood, the first at 0500, the second at 0800 at the time of the peak at Nerang and the final warning at 1200. Little warning was possible because thunderstorm rainfalls of such intensity were not forecast. Runoff from the Numinbah Valley area takes four to six hours to reach Nerang. Fortunately, another two to three hours are available before the peak discharge reaches the lower Nerang River so some useful warning time is available for residents to take protective measures.

The second and damaging flood commenced on Thursday, 24 January with heavy rains over the catchment with the most intense rainfalls, as usual, at Springbrook. Nine warnings were issued between 1100, 24th and 1900, 27th. The degree of flooding was upgraded with each warning until 0645, 26th when major flooding was expected "around midday on the high tide around the Nerang-Southport-Surfers Paradise area, in conjunction with higher than normal tides." The height at Nerang peaked at approximately 9.14 m (30 feet) at about 1100, 26th. This was approximately 1.22 m (4 feet) lower than the peak on 12 January. However the combination of larger flood volume, large contribution from Mudgeeraba Creek and higher than normal tides were responsible for the extensive flooding in the canal estates. In addition, the flood peak coincided near high tide on the ebb. Fig. 4 shows the Nerang stage hydrographs and Springbrook hyetographs for the two floods.

The official flood warning station at Nerang is the Irrigation and Water Supply Commission gauging station several miles upstream from the town. The Bureau of Meteorology has installed a Stevens Telemark at the gauging station. Although the telephone number is not listed, it is available to local authorities so that local action may be taken on the basis of observed river heights at Nerang. To improve qualitative warnings and enable quantitative forecasts for the canal developments on the Nerang River, stream heights from Mudgeeraba Creek and tide heights from the Southport Broadwater will be required operationally and additional investigation will be necessary.

For the Logan River, flood warnings commenced at 1100, Thursday 24th. Thirteen warnings were issued up to 1100, Tuesday 29th. The initial contribution to flooding in the Logan River downstream from Macleans Bridge came from Scrubby, Sandy and Woolaman Creeks, all with their headwaters in the vicinity of New Beith which recorded 413 mm in the 24 hours to 0900, 26th, and completed a five day total with 819 mm. The most intense rainfall at New Beith produced 250 mm in the six hours to 0300, 26th.

The rainfall amounts quoted for New Beith were not known operationally and were only determined from study of the pluviograph chart after the event. However the Eagle Farm radar was used extensively during the flood period and very intense rainfalls were detected in the New Beith area during the Australia Day weekend.

Minor flooding commenced in the Macleans Bridge area at about 0500, 26th, and river levels increased steadily until the peak of 21.68 m at R.L. 24.92 m A.H.D. (71.13 feet at R.L. 82.06 on State Datum). The major contribution to the peak at Macleans Bridge came from Teviot Brook and northern tributaries of the Logan River. The Albert River was a significant contributor to flooding at the Pacific Highway.

Since the January flood a new flood warning river height reporting station has been established at Beaudesert. A new station is expected to be established on the Logan River near its junction with the Albert River in the near future.

Considering the projected closer development in the future in the Logan River valley, this area has an urgent need for a detailed flood forecasting system.

6. MARY RIVER FLOOD

On the Mary River, 20 flood warnings were issued, commencing with a preliminary warning at 1100, Thursday 24th. The final warning was issued at 1100, Thursday 31st.

At 0900 24th the Mary River had an initial loss of 23 mm. The initial loss is equivalent to that amount of rain required within a 24 hour period from 0900 to wet the catchment and produce significant runoff. By 1500, the initial loss was satisfied and by midnight the height at Gympie had reached minor flood height and was rising fast.

Flood forecasts were issued for Gympie at 0900, 1100, and 1700 on Friday, 25th. The 0900 and 1700 warnings included a forecast height of 19.5 m (64 feet) to occur between 0900 and 1200 Saturday, 26th. The first Gympie peak was 17.53 m (57.5 feet) at 1100. Forecast rainfall in the 24 hours following the peak at Kenilworth is a highly significant parameter for the accurate forecasting of flood heights at Gympie. Although forecast rainfall was higher than that observed, had an accurate precipitation forecast been given, the Gympie height would still have been overpredicted by an unacceptable amount.

Following a general easing of rainfall over the Mary catchment between 0900 Friday, 25th and 1500 Saturday, 26th, a renewal of very heavy rain occurred. During the next 18 hours, 186 mm of rain, averaged over the catchment to Gympie, were recorded. At 0900, Saturday, a further 300 mm of rain were forecast for the following 24 hours. Based on the observed heights at Kenilworth, Cooran and Imbil and the 300 mm forecast rain, a new flood forecast of 23.16 m (76 feet) was issued at 1030, 26th. A sharp reduction in rainfall intensities occurred after 0900 and at 1500 the forecast rainfall for the next 24 hours was amended to 75 mm. The warning issued at 1730 amended the Gympie forecast peak to 20.57 m (67.5 feet) to occur at about 0400, Monday, 28th.

A peak of 20.73 m (68 feet) was recorded at 0500 and was within 0.13 m (0.5 feet) of the amended forecast height.

The present technique for forecasting heights at Gympie employs co-axial correlation of river heights at Kenilworth, Cooran and Imbil on the three major tributaries and forecast rainfall for the catchment, 24 hours in advance. A unitgraph for the catchment was developed 18 months ago. However the forecast accuracy using unitgraphs was not superior to the method currently used. It was therefore rejected on the grounds that operational computations were more time consuming and there was a greater chance of mathematical error when working under conditions of stress. As is normal practice following major floods, the two methods will be re-assessed to determine any modifications that may be required.

Late on Saturday, 26th, minor flooding commenced at Maryborough. Forecasts for Maryborough commence when a height in excess of 6.10 m (20 feet) is expected. This height is 1.22 m (4 feet) above minor flood height. Forecasts for Maryborough were issued at 1030 and 1730 Sunday 27th, and 0500, 1530 and 2230 on Monday 28th. All forecasts for the rising limb and the peak at Maryborough were highly accurate and a maximum advance warning time of 22 hours enabled protective measures to be taken. A peak height of 10.95 m (35.9 feet) was observed at 0900 Tuesday 29th, with a forecast error of less than 0.01 m.

Since the flood forecasting system was introduced for Maryborough, the forecasts for a number of floods have been very accurate. The Maryborough flood forecasting system employs co-axial correlation techniques similar to the Gympie system and indicates that excellent forecasts can be made using relatively simple procedures. However to date, the Maryborough floods have not had a large contribution from the local area. A large contribution from the Maryborough local area in the future, although a rare event, is difficult to handle satisfactorily because advance warning times are considerably reduced and accurate precipitation forecasting is necessary. The Gympie and Maryborough stage hydrographs and mean catchment hyetograph to Gympie are shown in Fig. 5.

7. METROPOLITAN CREEK FLOODING

Heavy rains commenced over the Brisbane Metropolitan creek catchments at 0200 Friday 25th and continued until approximately 1400. In that 12 hour period, rainfalls varied from approximately 197 mm at the Brisbane Bureau to 236 mm at Enoggera Reservoir and 280 mm at Mount Nebo. Intense rainfalls eased in the seven hours to 2100. The second burst of intense rain commenced at 2100, 25 January and continued until 2400. In this period, approximately 80 mm were recorded at the Brisbane Bureau and 192 mm at Enoggera Reservoir Although it rained continuously in the Brisbane area between midnight and 1700 Saturday 26th, there was a general easing of rainfall in this period. The third burst of intense rainfall occurred between 1700 and 2400 26th. However the intensities were not as high as the first two bursts. In the six hours to 2400, the Brisbane Bureau had approximately 98 mm and Enoggera Reservoir 130 mm.

Lesser rainfalls were recorded in creek catchments on the south side of the Brisbane River east from Oxley Creek and these, including Norman, Bulimba, Wynnum and Lota Creeks, did not reach record levels.

Three flash floods occurred in creeks in the Brisbane area. Record levels were reached in Enoggera Creek and Kedron Brook in the middle flood and in Moggill Creek in the first flood. In Enoggera Creek and Kedron Brook the first flood was generally similar to the April 1972 flood and the third, slightly less. The stage hydrographs and hourly temporal pattern for several stations on Kedron Brook are shown in Fig. 6. They clearly demonstrate the three flash floods and the rainfall causing them.

Oxley Creek behaves in an entirely different manner to other Metropolitan Creeks. On a very flat catchment of approximately 259 km^2 (100 square miles), one major flood was recorded which reached record levels. In the 48 hours to 0900, Sunday 27th, New Beith near the head of Oxley Creek recorded approximately 684 mm, which included a burst of 250 mm in the six hours to 0300 Saturday 26th, and another of 131 mm approximately in the six hours to 2100, 26th. As stated earlier, although quantitative rainfalls from New Beith were not available operationally, radar detected the intense rainfall in this area during the flood period. This enabled the provision of useful warning of major flooding for Oxley Creek.

Only limited rainfall and creek height data are available operationally for analysis and the formulation and issue of flood warnings. During the Australia Day weekend, operational rainfall reports were available from the Brisbane Bureau, Eagle Farm, Amberley, Mt. Crosby, Lake Manchester, Gold Creek Reservoir, Enoggera Creek Reservoir and Mount Nebo. Spillway heights over Gold Creek and Enoggera Creek reservoirs were the only streamflow data available.

On the basis of this information together with radar observations, flood warnings were prepared for the creeks. Specific attention was given to Oxley, Moggill, and Enoggera-Breakfast Creeks and Kedron Brook.

Between 0800, 25th and 2130, 26th, 10 flood warnings were issued for Brisbane Metropolitan Creeks, including Kedron Brook and Enoggera-Breakfast, Moggill and Oxley Creeks. Warnings were qualitative only, however they were considered most useful as an alert to authorities as well as the general public to pinpoint where major flooding was expected and when the critical periods were likely.

During the 1974 winter it is planned to install telemetry equipment to telemeter continuously, using P.M.G. landlines, rainfalls from seven selected stations in the Brisbane area. This will enable closer monitoring of the rainfalls over all the major creeks in Brisbane. Although radar is used extensively in a qualitative manner to locate the areas of most intense rain and the extent of rainfall variability, further development of its quantitative application should make substantial improvement in the assessment of rainfall in the Brisbane area. Brisbane has the greatest need of any capital city in Australia for the introduction of quantitative assessment of rainfall by radar and digitization of data for input into the computer for operational flash flood warning.

It is expected that within the next two to three years, creek heights from selected gauging stations already established on Brisbane creeks will be telemetered into the Bureau using P.M.G. landlines and Stevens Telemarks or similar equipment. The completion of the two telemetry installation programmes will enable satisfactory analysis of the minimum amount of data required to provide significant improvement in flood warning services for flash flooding in Brisbane Creeks. However staffing levels would need to be adequate to enable rapid processing of data at hourly intervals or less, for periods up to 36 or 48 hours, at the same time as routine flood forecasting and warning operations are being carried out for other catchments.

8. IPSWICH AREA FLASH FLOODS

Several flash floods occurred during the Australia Day weekend in creeks in the Ipswich city area. Record floods occurred in Deebing, and Bundamba Creeks which enter the Bremer River from the south, Sandy and Ironpot Creeks which enter the Bremer River from the north and Woogaroo Creek which joins the Brisbane River through Goodna.

No specific flood warnings were issued for these creeks, as the problems of creek flooding in Ipswich to such a magnitude had not previously been recognised. Although several small floods have occurred in recent years in these creeks, little or no data are available from the catchments to indicate the magnitude of some of the previous floods, such as January 1887 which may have produced record or near record levels. Development of satisfactory rainfall and streamflow networks are now an urgent requirement so that data can be collected in future events. This is an area of concern which will require close study in the future.

9. BRISBANE VALLEY FLOODS

The highest floods since 1893 in most reaches of the Brisbane River commenced with the onset of heavy rain over the Stanley River, late on Thursday 24th. At 2100 on that day, cyclone WANDA was located 40 km (25 miles) northeast from Gympie and moving southwest at 20 km/h (12 m.p.h.) This was a most favourable path to produce flood rains in the Brisbane Valley and in particular the Stanley and Upper Brisbane Rivers. Detailed discussion of the synoptic meteorology of the flood is given by Shields (Ref. 1).

The initial warning for the Brisbane Valley was issued at 2230 Thursday 24th and 23 warnings were issued in the ensuing seven days until the final warning at 0530 Thursday 31st. Of the 23 warnings issued 16 included flood forecasts for the Brisbane Port Office.

By 0900, 25th, 24 hour rainfalls in the Stanley River included Woodford 231 mm, Peachester 250 mm and Mount Mee 324 mm. At this stage major flooding was occurring in the upper reaches of the Stanley River.

Lesser rainfalls were recorded in the other Brisbane River tributaries, namely the Upper Brisbane River, Lockyer Creek and the Bremer River and at 0900 initial losses had not been satisfied and no significant runoff was occurring, although local runoff had commenced in the lower reaches of the Bremer River.

By 1500, 25th, rain had saturated the total Bremer River catchment and by 2100, significant runoff had commenced in the Upper Brisbane River and Lockyer Creek. The operational mean catchment mass curves for the storm are shown in Fig. 7. The subcatchment mass curves are determined operationally during flooding from a network which generally consists of three, four or five stations. Data from the minimum number of reporting stations required to produce reasonable estimates are therefore analysed. Post analysis has revealed that the operational temporal patterns differed from those derived from isohyetal and pluviograph analysis by less than five percent. The exception was in the Stanley River catchment where the operational estimate was 16 percent higher than the isohyetal estimate at the end of the three day period given in Figure 7. The corrected curve is shown as a dotted line. A heavy rainfall centre was located over Mt. Mee, one of the Stanley River network stations, during most of the storm period, and this caused a gross over-estimate of the areal rainfall over the Stanley River subcatchment. The accumulated mass curve for New Beith, based on recorded pluviograph data, is shown also.

Heavy rains continued in all tributaries overnight and this included the Brisbane and Ipswich areas. The warning issued at 0500 Saturday 26th, warned of moderate to major flooding later that day in the Bremer and Upper Brisbane Rivers, and Lockyer Creek, and moderate flooding in the Brisbane River in the Brisbane city reaches on the high tide at midday, 26th. The 0700 warning on Saturday 26th, included among other things a forecast of 4.27 m (14 feet) at the Port Office Brisbane on the midday high tide, that height being similar to the February 1931 flood. The storm surge, or wind set up in this case was over-estimated by 0.43 m (1.5 feet) and as a result the observed Port Office height was approximately 0.61 m (2 feet) below that forecast.

There was a general easing of rainfall over the sub-catchments after 0900 Saturday 26th until heavy rain commenced again between 1500 and 2100. This is clearly shown in Fig. 7, and reflected in some of the stage hydrographs shown in Fig. 8.

The marked increase in rainfall intensities over the Brisbane Valley which commenced between 1500 and 2100, became apparent following the receipt of the 2100 rainfall reports. The rainfall in the 24 hour period following, was responsible for converting what would have been only a minor flood generally throughout the valley, to one of major proportions.

(a) The Ipswich Problem

The reports received at 0900 Saturday 26th provided the first opportunity for all data to be processed to enable Ipswich forecasts to be made. Correlations using stream heights from Harrisville, Rosewood and Mount Crosby are currently used operationally to determine Ipswich forecast heights, 8 to 12 hours in advance for a Bremer River flood. Harrisville and Rosewood heights have been correlated with Amberley and Walloon gauging station discharges respectively. The combined Amberley and Walloon discharge and Mount Crosby heights have been correlated with the Ipswich data. The success of this system depends upon runoff from the local area between Harrisville, Rosewood and Ipswich, being approximately a constant ratio of the runoff from above Harrisville and Rosewood. This is because adequate data for local area runoff are not available, and usually local area runoff is not significant when compared with the combined discharge from Harrisville and Rosewood. The Ipswich forecasts were determined, but because of unprecedented local runoff from the record flash flooding in the Ipswich area creeks and increasing local area runoff from the lower Bremer River and Warrill Creek catchments, the heights forecast eight hours in advance were already exceeded and the forecast 12 hours in advance was exceeded within a few hours. The situation did not improve as increasing runoff from the total Bremer River catchment, particularly in the lower reaches, exceeded the previous highest recorded discharge of 1642 cumecs (58000 cusecs) by 1500. Two forecasts for Ipswich were issued and were exceeded within a matter of hours. Since no data were available to enable accounting for local runoff of such magnitude no further forecasts were issued, however qualitative warnings for Ipswich continued.

Subsequently, a peak of 19.70 m (64.6 feet) was recorded at Ipswich at about 1500 Sunday 27th, but a height of 19.35 m (63.5 feet) was reached by 0600 which was essentially Bremer River, Warrill Creek and local runoff. The height at the Ipswich city gauge remained above 19.20 m (63 feet) for approximately 39 hours. Brisbane River backwater increased in this period to compensate for the recession of the Bremer flood. However upstream from the city gauge there was greater fall in river levels following the initial peak and the Brisbane River backwater peak was further below the Bremer River flood peak as the distance upstream from the city gauge increased. On the other hand, downstream from the city gauge flood levels continued to increase following the passage of the Bremer River flood peak, as the Brisbane River backwater increased, until the Brisbane River flood peak passed the Bremer River junction at Moggill. The velocities however during these later stages of the rise were minimal compared with those when the major contribution to flood heights east of the city centre came from the Bremer River. This behaviour is demonstrated in Fig. 9. The problem of interpreting flood forecasts for the Ipswich gauge in terms of areas to be flooded in Ipswich is therefore very complex as a flood event could either be a Bremer River flood, a Brisbane River backwater flood, a creek flash flood or any combination of the three. It is a most difficult problem therefore to determine a flood profile through the Ipswich city area given Ipswich city gauge forecast heights. The Ipswich town gauge stage hydrograph is shown in Fig. 8. The total Bremer River peak discharge was approximately two and one half times the previous highest recorded discharge of 1642 cumecs (58000 cusecs) observed in February 1971.

Heavy rainfalls over the Bremer River generally show a marked gradient with the heaviest falls over the southern and western ranges on the catchment boundary. Another notable feature of the January flood was that the heaviest rainfalls were in the northern section or local area around Ipswich. The January flood in the Bremer was therefore a rare type of Bremer River flood. Bremer River floods with significant discharges are rare events in any case and little data have been previously available. The flood in January 1887 was probably the next highest Bremer River flood but not enough factual data are available to substantiate this.

The natural storage area at the junction of the Bremer River and Warrill Creek provides detention pondage,hence reduction of flood peak for a flood of this magnitude,and as a result prevented even higher flood levels through Ipswich. A similar pondage occurs at the junction of the Bremer and Brisbane Rivers. Both pondages and their flood routing characteristics require detailed study as they are a major factor in the flood hydrology of the lower reaches of the Brisbane Valley and provide a degree of natural protection for the city of Brisbane.

Table 1 lists the rainfall totals for some of the better known floods over the main subcatchments of the Brisbane River. In particular, the three day and five day total rainfalls for the January flood are given for comparison. Although the Bremer River catchment recorded 307 mm for the 48 hours ended 22 January 1887, the three and five day totals for the January 1974 flood are far higher than any previously recorded.

It should be recognised that higher Bremer River floods are possible in the future at Ipswich with the combined Bremer River and Warrill Creek discharges higher than those in January. Preliminary maximization of rainfalls for the January storm over the Bremer River catchment indicate that in the future an extreme type of storm event could produce rainfalls as much as 60 percent higher than those observed during the Australia Day weekend.

TABLE 1 BRISBANE RIVER SUBCATCHMENT RAINFALLS FOR SOME PREVIOUS FLOODS IN mm.

Subcatchment Flood	Stanley	Upp.Brisbane	Lockyer	Bremer	Metrop.	Middle Reaches
1-4 Feb. 1893	939	358	237	137	288	446
16-18 Feb. 1893	430	252	266	260	406	414
14-15 Mar. 1908	225	154	185	225	326	319
4-6 Feb. 1931	452	219	192	163	433	337
27-28 Mar. 1955	344	199	153	138	208	203
*25-27 Jan. 1974	410	252	297	446	593	417
*25-29 Jan. 1974	507	280	350	461	656	481

* Note subcatchment rainfalls above are from isohyetal analysis and differ from those in Fig. 7 because of different duration and assessment method.

(b) Brisbane Port Office Forecasts

In Brisbane, the imminence of a major flood, higher than any recorded since 1893, was not apparent during the daylight hours of Saturday 26th. Following the minor flood peak of 3.56 m (11.8 feet) at the Port Office on the high tide at about midday, 26th, of which the major contribution was essentially local Brisbane creek runoff and storm surge, the warning issued at 1730 included a forecast Port Office height of 3.96 m (13 feet) at 2400 and 4.57 m (15 feet) at 1200 Sunday 27th on the high tides. This warning also included a forecast height of 8.53 m (28 feet) at Darra by late Sunday morning. This was a key warning which stated that major flooding was occurring in the Bremer River, Lockyer Creek and Upper Brisbane River and further rises were expected. The forecast of 4.57 m (15 feet) by midday

Sunday 27th gave 18.5 hours warning of a Port Office height in excess of the 1931 flood peak of 4.45 m (14.62 feet).

The forecast of 4.57 m (15 feet) was repeated at 0100 Sunday 27th and upgraded to 5.18 m (17 feet) at 0500 for the high tide at about midday. With the issue of the 0500 warning, forecast heights for Darra and Tennyson were included which detailed the heights expected on the midday high tide relative to levels experienced at midday the previous day. These levels were 4.57 m (15 feet) and 3.55 m (11 feet) higher respectively.

The next significant warning was issued at 1330 Sunday 27th, when a height of 5.94 m (19.5 feet) to be reached by 2400 and a height of 6.40 m (21 feet) by mid morning Monday 28th were predicted. The forecast 6.40 m (21 feet) was provided 21 hours in advance.

At 2100, 27th, a Port Office height of 6.71 m (22 feet) was forecast to occur at 1200 on Monday 28th. At 0500 Monday 28th, the warning reduced the Port Office forecast to 6.40 m (21 feet) for the 1200 high tide and forecast the peak of 6.71 m (22 feet) to occur early on Tuesday morning.

The warning issued at 1400, 28th included a Port Office forecast peak not exceeding 6.71 m (22 feet) on the high tide between 0100 and 0200 Tuesday 29th. This was 12.5 hours in advance.

The observed peak at the Port Office was 6.60 m (21.67 feet) at 0215.

Accurate forecasts were also made to coincide with high and low tides on the gauge at the Port Office on the falling limb of the flood hydrograph. These continued until the river fell below flood height in the Brisbane city reaches at 0530 Thursday 31st. The Port Office stage hydrograph and forecasts are shown in Fig. 10.

The procedures used by the Bureau of Meteorology for flood forecasting for the Port Office are those derived by Piggott (Ref. 2).

Piggott assumed that the Port Office height could be forecast from the following equation:-

$$H_P = H_M + f_T \, h_T + H_Q$$

where

H_P is the predicted level of the flood on the Port Office gauge

H_M is a term which includes an allowance for mean sea level and for changes due to meteorological effects on Moreton Bay.

h_T is the predicted amplitude of the tide at high and low water.

f_T is an empirical tidal attenuation factor which is assumed to be a function of flood discharge.

H_Q is the contribution to the flood stage due to flood discharge past the Port Office.

Piggott used sketchy data from floods in the last century plus data from the floods of 1931 and 1955 which peaked at the Port Office at 4.45 m (14.62 feet) and 3.51 m (11.5 feet) respectively.

Since the major floods of the 1890's, considerable changes to the hydraulic characteristics have occurred downstream from the Port Office due to channel improvements and dredging.

There was a tendency to overpredict the Port Office height in the January flood for heights in excess of 4.57 m (15 feet). This overprediction is not considered to have been a serious error. In fact it gave greater warning time for which forecast heights were reached. This was recognised during the forecasting operation and was considered to have been caused by the channel improvement mentioned above, since the floods of the 1890's from which data were used to derive the system. An additional term ΔH was introduced, and the trend in the change of ΔH was predicted with each forecast.

Cossins (Ref. 3) has described procedures used by the Brisbane City Council in flood forecasting for Brisbane for the operation of Somerset Dam.

The city of Brisbane is fortunate to have forecasts for the Port Office determined by two independent methods. Before each forecast is issued there is detailed consultation between flood forecasters in the Bureau of Meteorology and the Brisbane City Council. Any differences of opinion are resolved with hydrologic argument and one figure adopted for dissemination. This is absolutely essential since both authorities have entirely different organisational structures and under no circumstances should conflicting forecasts be issued to the public or privately to other organisations. This arrangement worked ideally during the January flood.

10. CONCLUSIONS

A highly satisfactory flood forecasting performance was achieved for the Brisbane River Port Office during the January 1974 flood. The warning times were the best that could be given in a situation where a major contribution to the flood came from local creeks between Brisbane and Ipswich, and the Bremer River itself.

The data collected from this flood will require detailed study to quantitatively determine the effect of river channel improvement in the Brisbane River. A method of quantitatively forecasting local runoff from the Brisbane creeks and its contribution to the Brisbane Port Office heights has to be developed.

The problems of satisfactorily forecasting floods at Ipswich are well recognised. Since February 1971, when a combined Bremer River and Warrill Creek flood produced a peak discharge of 1642 cumecs (58000 cusecs) and a height of 10.67 m (35 feet) at Ipswich, the Bureau of Meteorology has been conducting investigations into forecasting discharges in Warrill Creek and the Bremer River from rainfall using unitgraphs. Because the peak discharges do not always occur simultaneously and some are sharp narrow hydrographs, it is necessary to forecast accurately both the rising and falling limbs of the hydrograph, so that an accurate combined discharge hydrograph can be forecast. This is the case for a Bremer River flood. For a Brisbane River backwater flood affecting Ipswich, the combined Bremer River discharge still has to be forecast, but this is usually on the recession limb. The problem has yet to be solved. However little advance warning time beyond the present 8 to 12 hours can be expected for Ipswich for a Bremer River flood unless precipitation can be forecast accurately in advance. The preparation of precipitation forecasts for smaller catchments becomes more difficult, when forecasts for short periods in advance are required for periods of very heavy rainfall.

For a Brisbane River backwater flood affecting Ipswich, the velocities through the city are minimal, and Ipswich heights can be forecast accurately provided the Bremer River flow is small.

The detailed texts of each flood warning and forecast issued in the 1974 flood have not been listed. Examination of these is required to ensure that warnings in future serious flooding have sufficient impact.

It is not the purpose of this paper to detail the problem of interpretation of flood forecasts and warnings, however for forecasts and warnings to be fully utilized, this is an area where major improvements are required. The Bureau's forecasts throughout Queensland are related to specific locations in cities and towns. It requires organisations with local knowledge and manpower to effectively carry out the functions of interpretation and preparation for evacuation. The problem has no easy solution. It is a statewide problem, but in Ipswich and Brisbane it is most complex.

For Brisbane Metropolitan creeks significant improvements in flood forecasting and warning services are unlikely until improved data acquisition techniques for the receipt of rainfall and discharge data are introduced. In this regard, the further development of radar as an operational tool for rainfall assessment will in future have a significant influence on the overall operation of flash flood warning systems. Little warning time is available to take protective action in flash flood situations, however forecasting precipitation would assist if the problems presently experienced could be overcome. Since the major parts of the creek catchments in Brisbane are in built up areas, there is a requirement for interpretation of forecasts and warnings along a major length of the creeks. Because the time available is short for the receipt of data, analysis, formulation and issue of forecasts and warnings, interpretation, and protective action such as evacuation to be made, although forecasting techniques are available, it is unlikely that flood forecasting techniques could be successfully introduced on Brisbane creeks. Instead, improved qualitative warnings, seem to be a more feasible proposition.

More investigations are required for the Mary River at Gympie using the data collected in recent floods to improve the accuracy of forecasts. Although forecasts for Maryborough have been accurate, continual review of techniques and data are required and difficulties may be encountered at Maryborough where local runoff is a major contributor to flooding.

On the Gold Coast, in the Nerang, Albert and Logan River areas, quantitative flood forecasting systems are required.

The January 1974 floods throughout Queensland, particularly in the Moreton Region and Brisbane River, have demonstrated that flood warning and forecasting services are essential. However only time and money will enable significant improvement in services on all the rivers in Queensland which have an urgent requirement.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. W.J. Gibbs, Director of Meteorology for permission to publish this paper, and also the staff of the Brisbane Regional Office, Bureau of Meteorology, Hydrometeorology Section who assisted with the preparation of material.

REFERENCES

1. Shields, A.J. - Synoptic Meteorology of Flood Period - Symposium on Moreton Region Floods - January 1974 I.E. Aust., Queensland Division.

2. Piggott, T.L. - Some factors affecting the forecasting of floods at Brisbane. Civ. Eng. Trans. I.E.Aust., Vol. CE8, No. 1, April 1966, pp. 47-59.

c. Cossins, G. - Hydrology without tears and other stories. Technical Papers, Queensland Division. I.E. Aust., Vol. 10, No. 7, July, 1969.

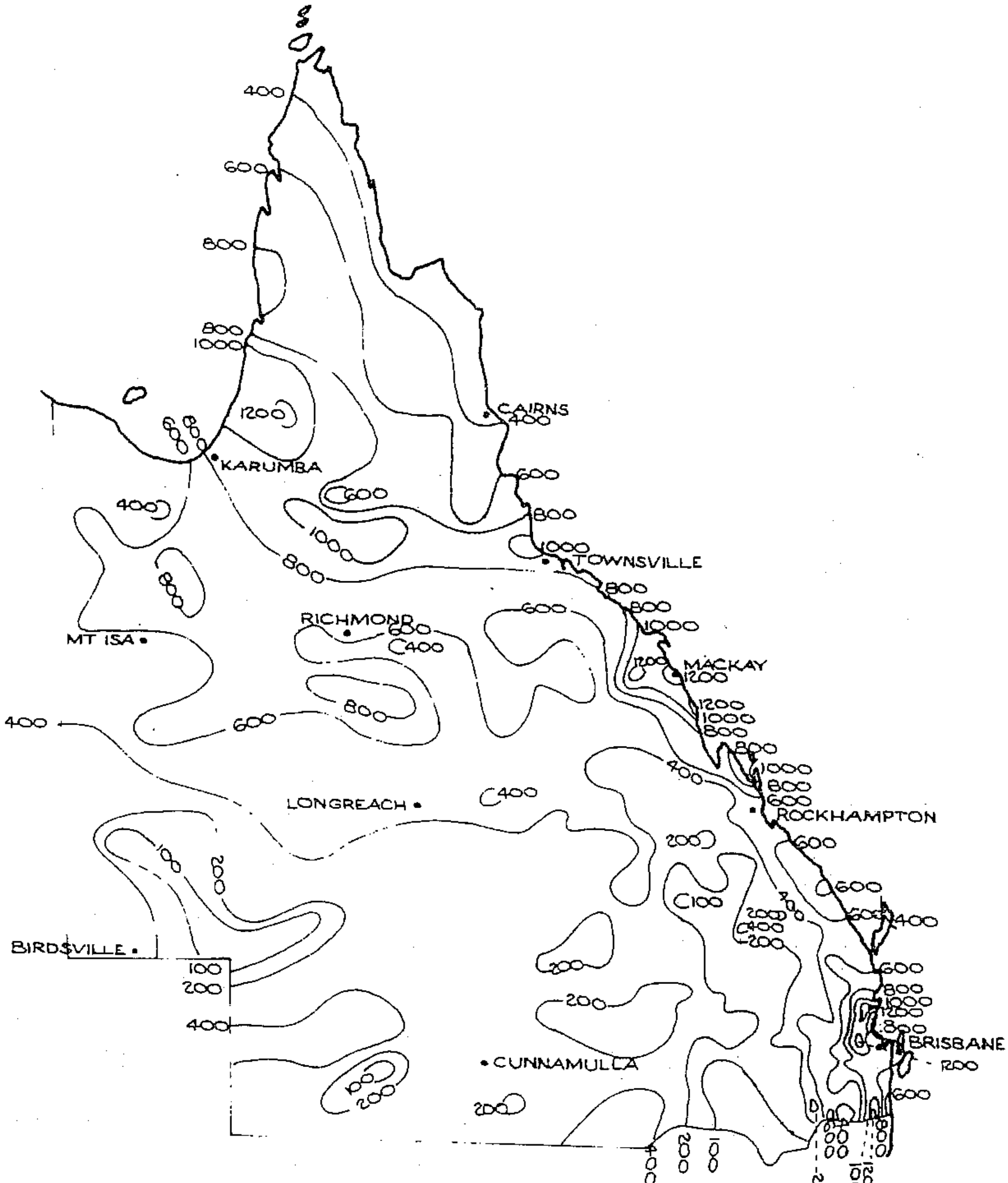
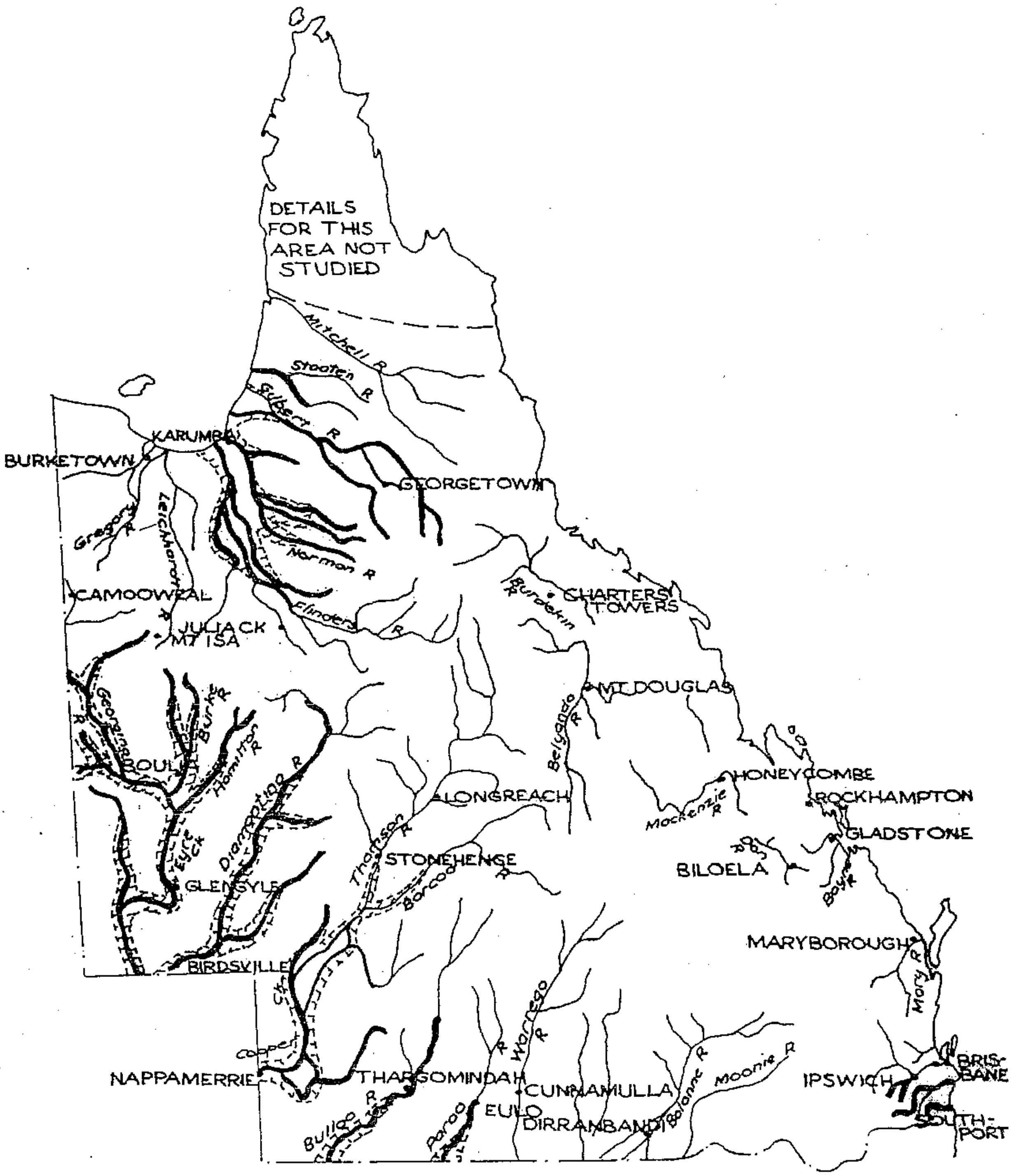


FIG. 1. QUEENSLAND PRELIMINARY ISOHYETS FOR MONTH JANUARY 1974

Rainfall in Millimetres Scale 1 cm = 120 km (Approx)



Scale 1cm = 110 km (approx)

FIG 2. AREAS OF RECORD AND MAJOR FLOODING IN QUEENSLAND FOR JANUARY 1974

Record Flooding
Major Flooding
Approximate Boundaries of Inundation

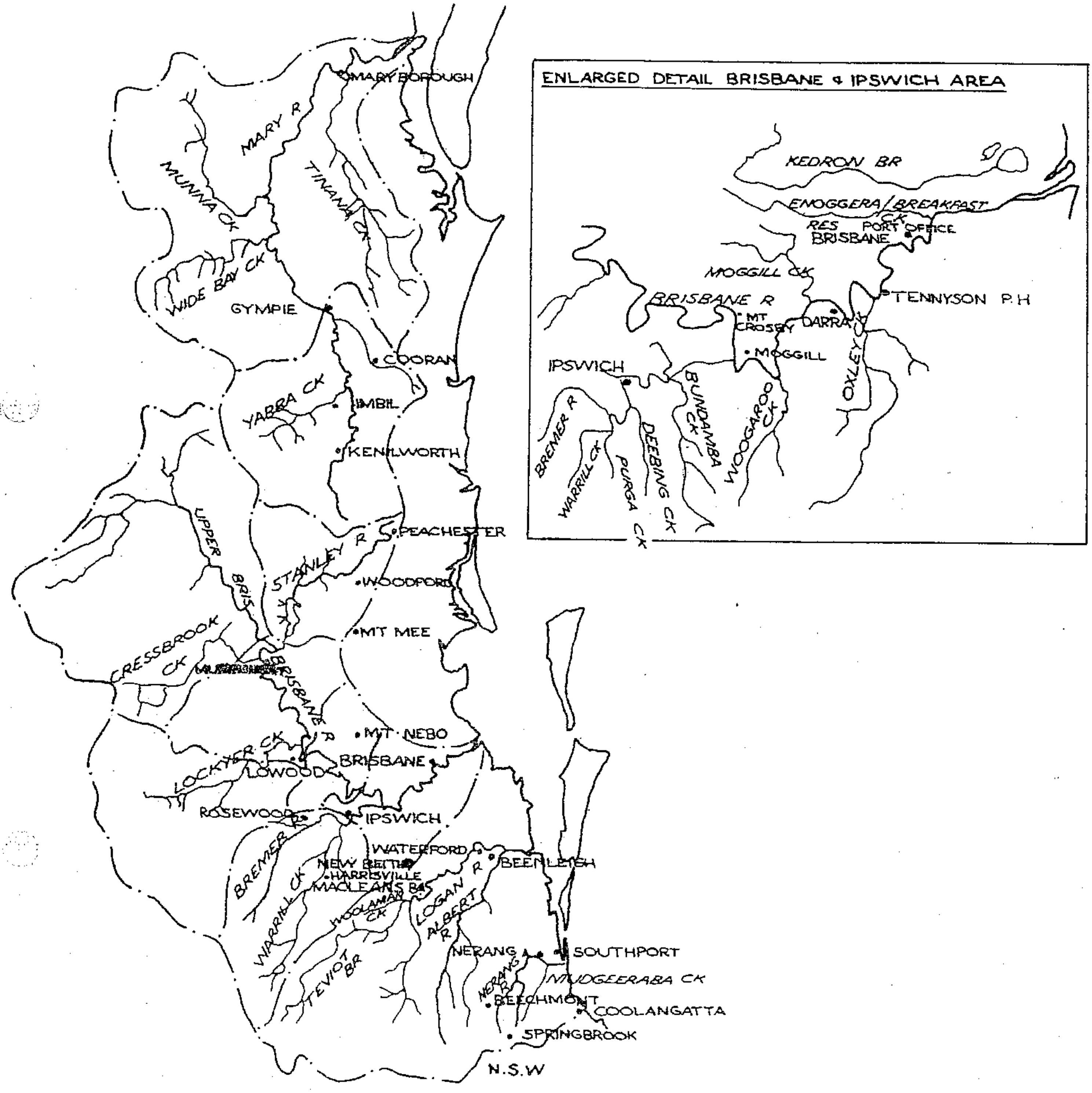


FIG 3. LOCALITY MAP

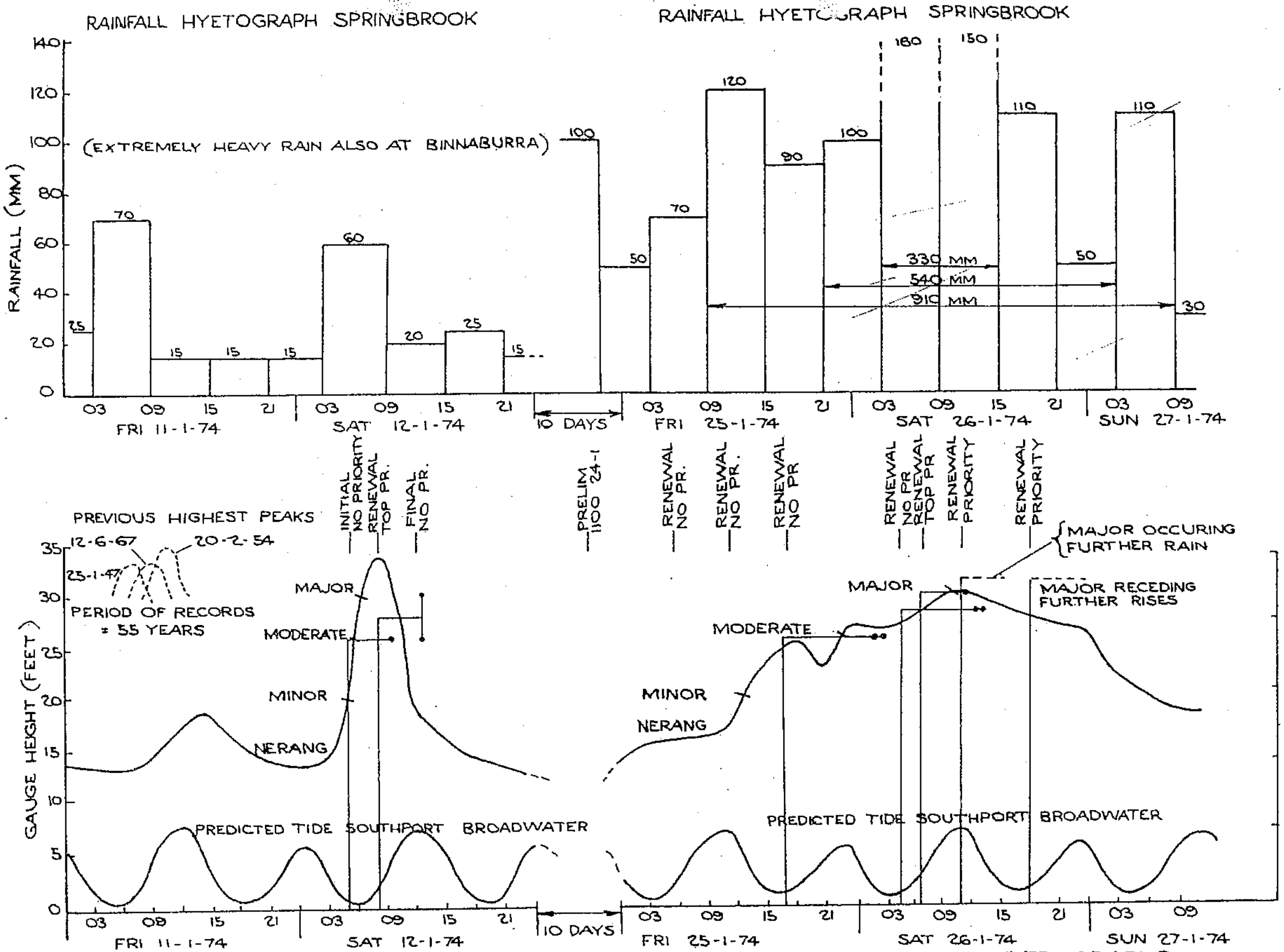
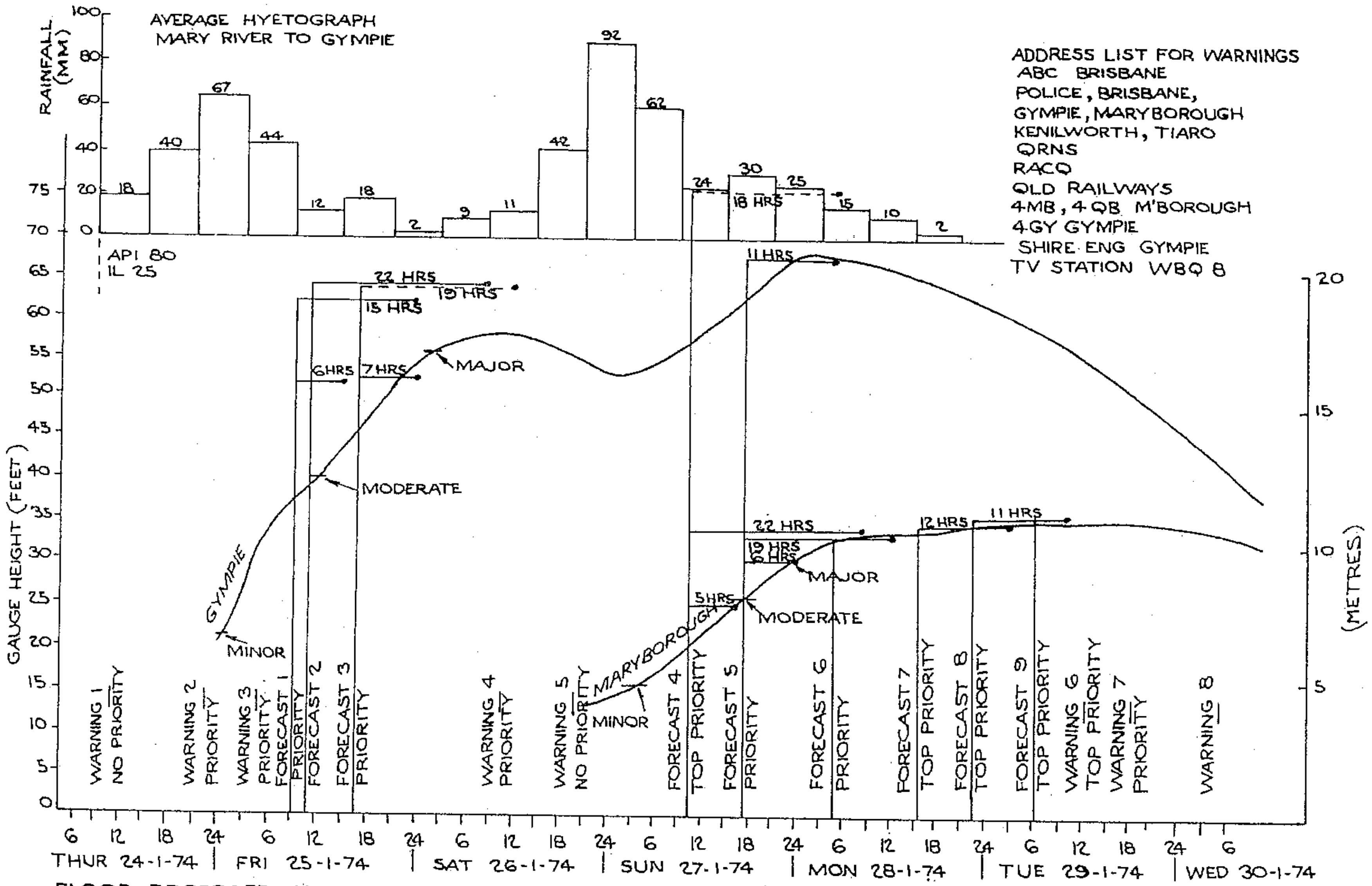


FIG 4. COMPARISON OF FLOOD STAGE HYDROGRAPHS AND SPRINGBROOK HYETOGRAPHS
FLOODS OF 12TH AND 26TH JANUARY 1974



FLOOD FORECASTING PERFORMANCE MARY RIVER AT GYMPIE AND MARYBOROUGH

FIG 5.

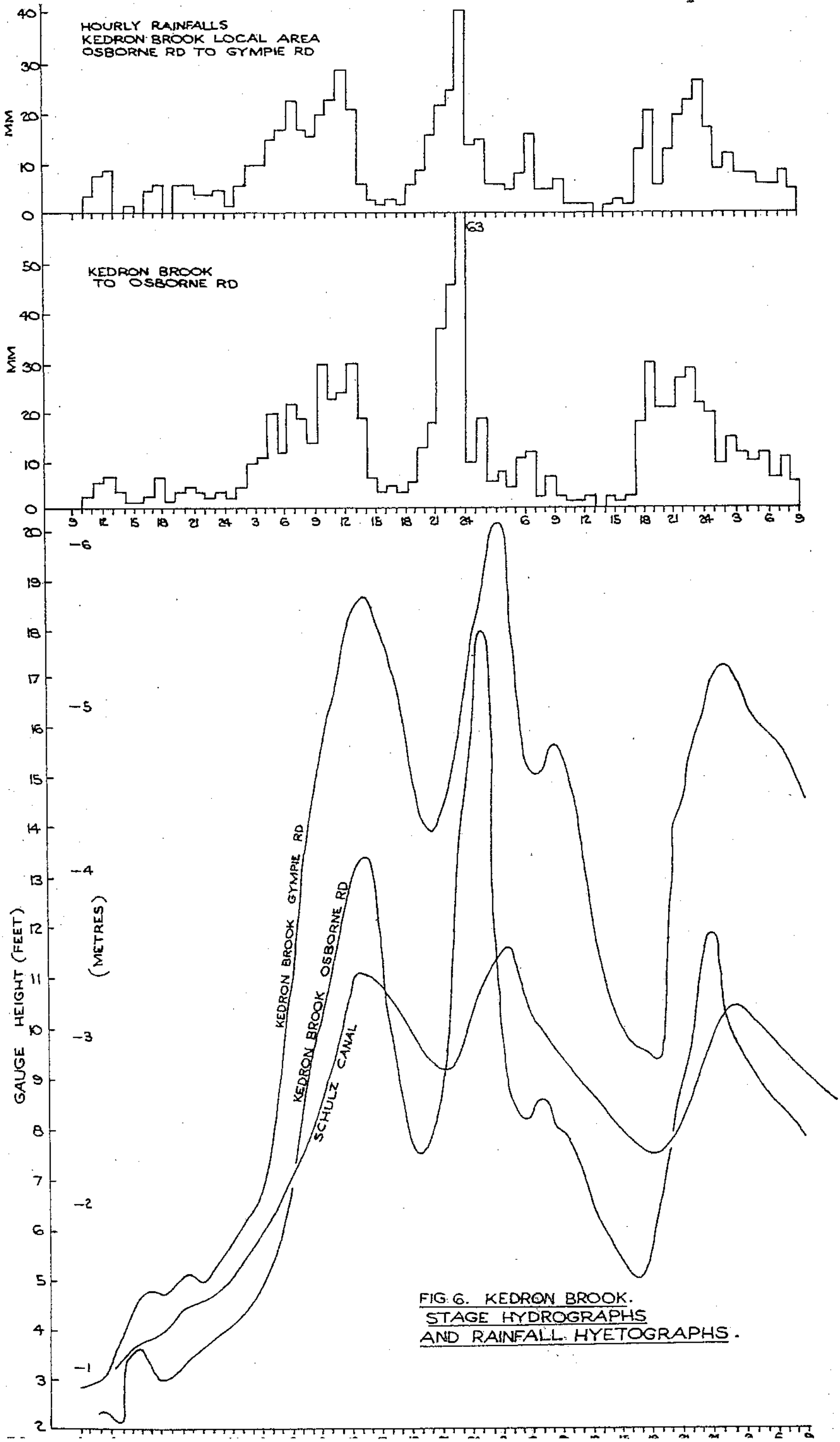
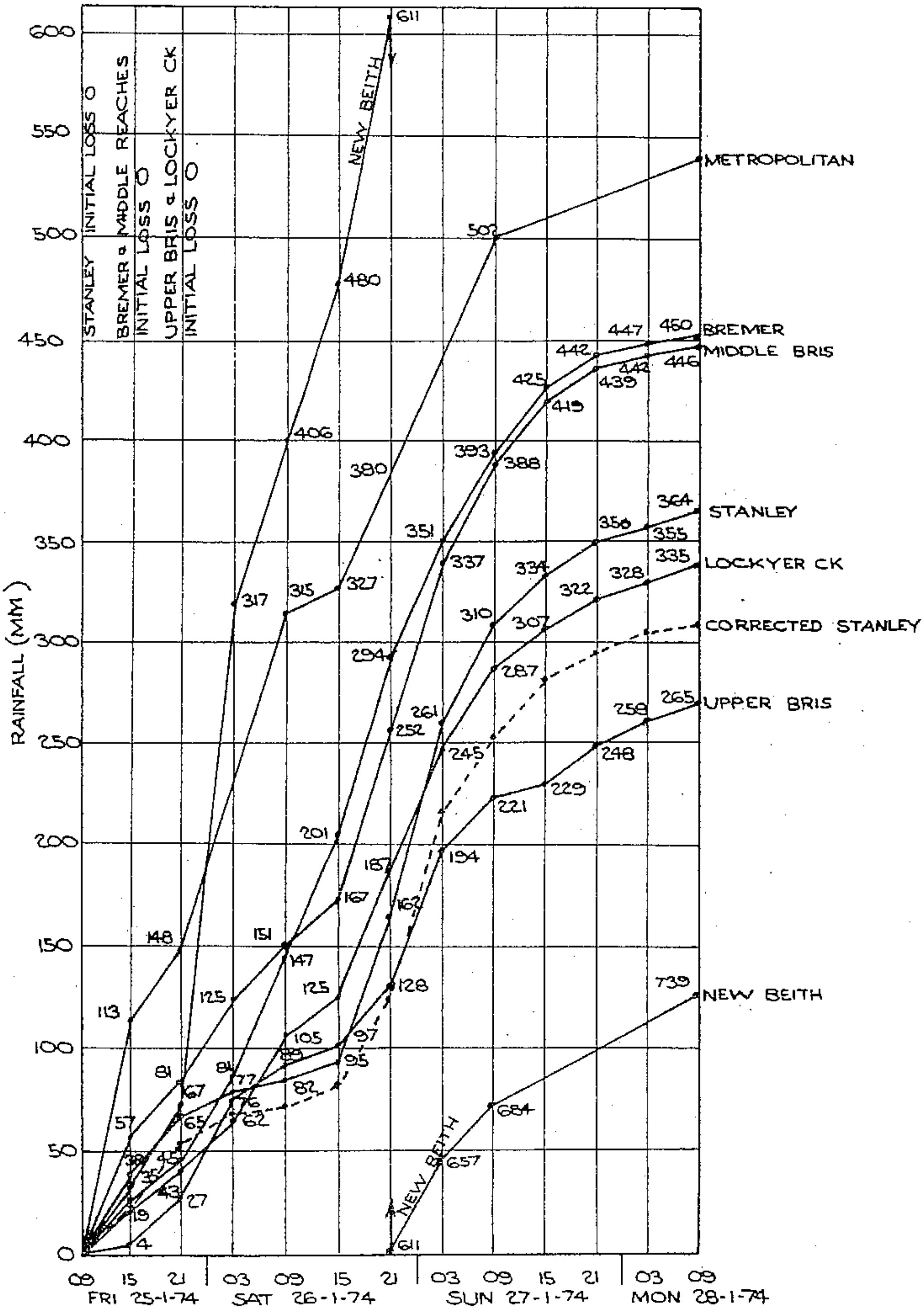
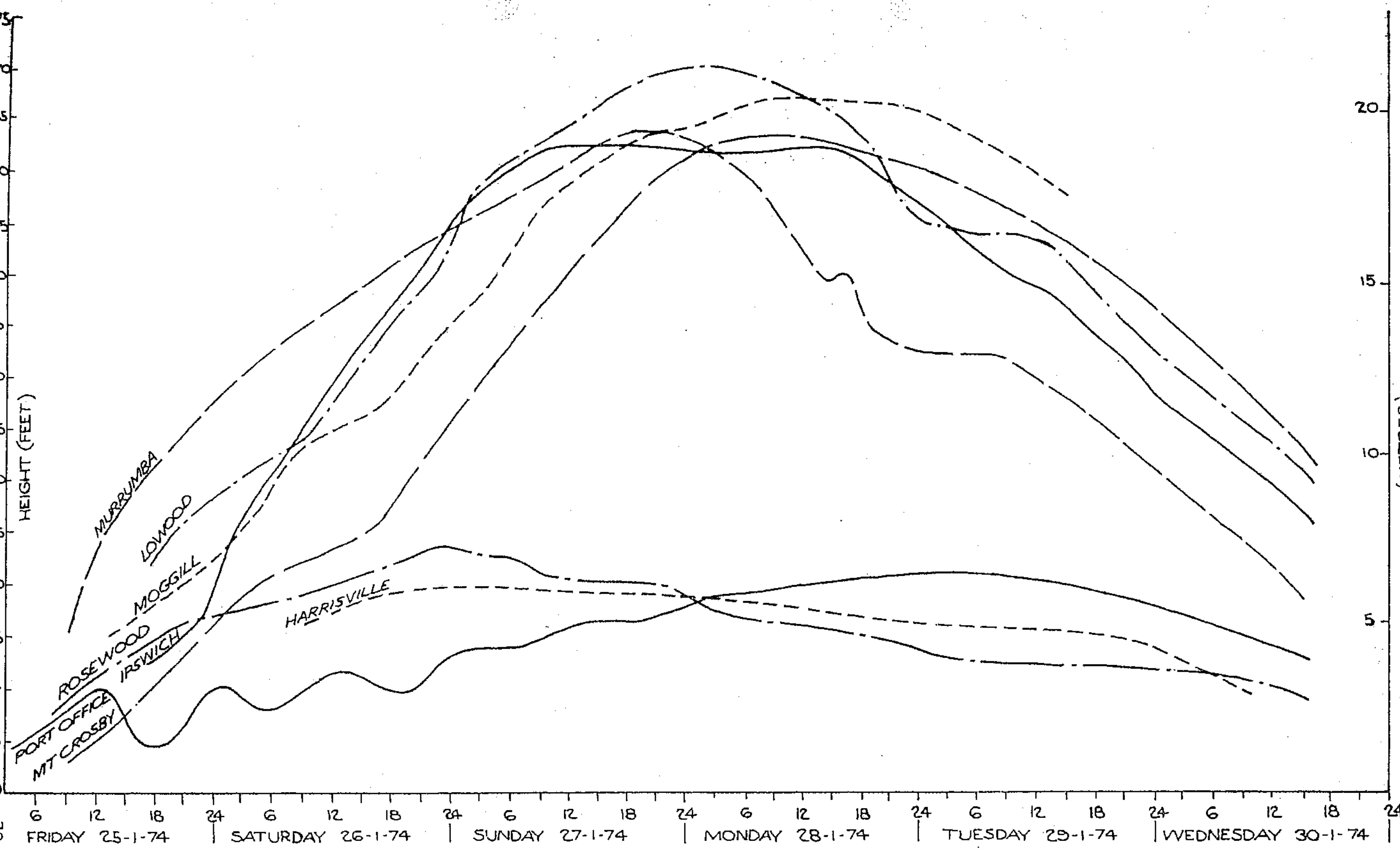


FIG 6. KEDRON BROOK.
STAGE HYDROGRAPHS
AND RAINFALL HYETOGRAPHS.



OPERATIONAL MEAN CATCHMENT MASS CURVES IN MM FIG 7.



SOME BRISBANE RIVER FLOOD STAGE HYDROGRAPHS JANUARY 1974 — FIGURE 8

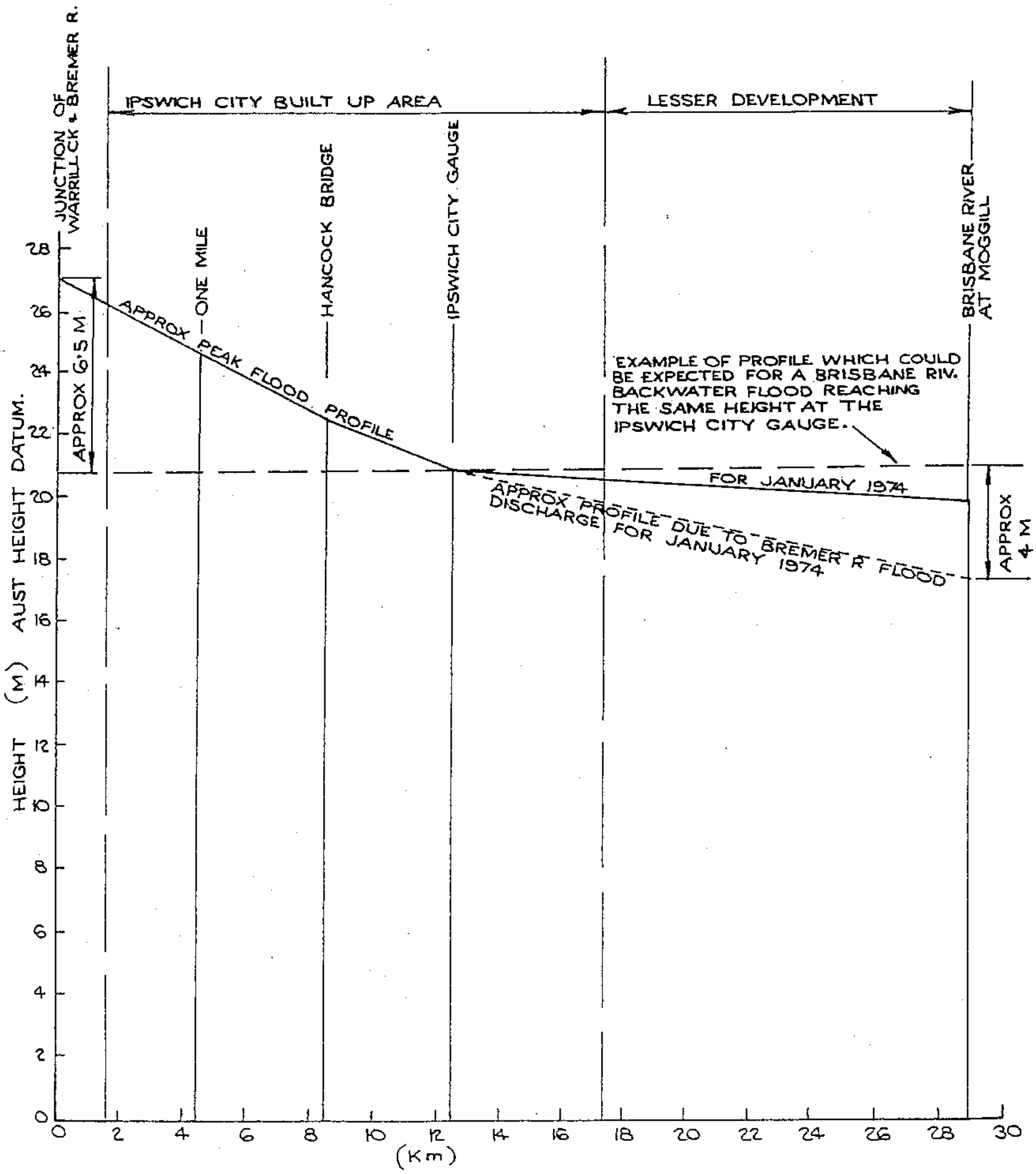
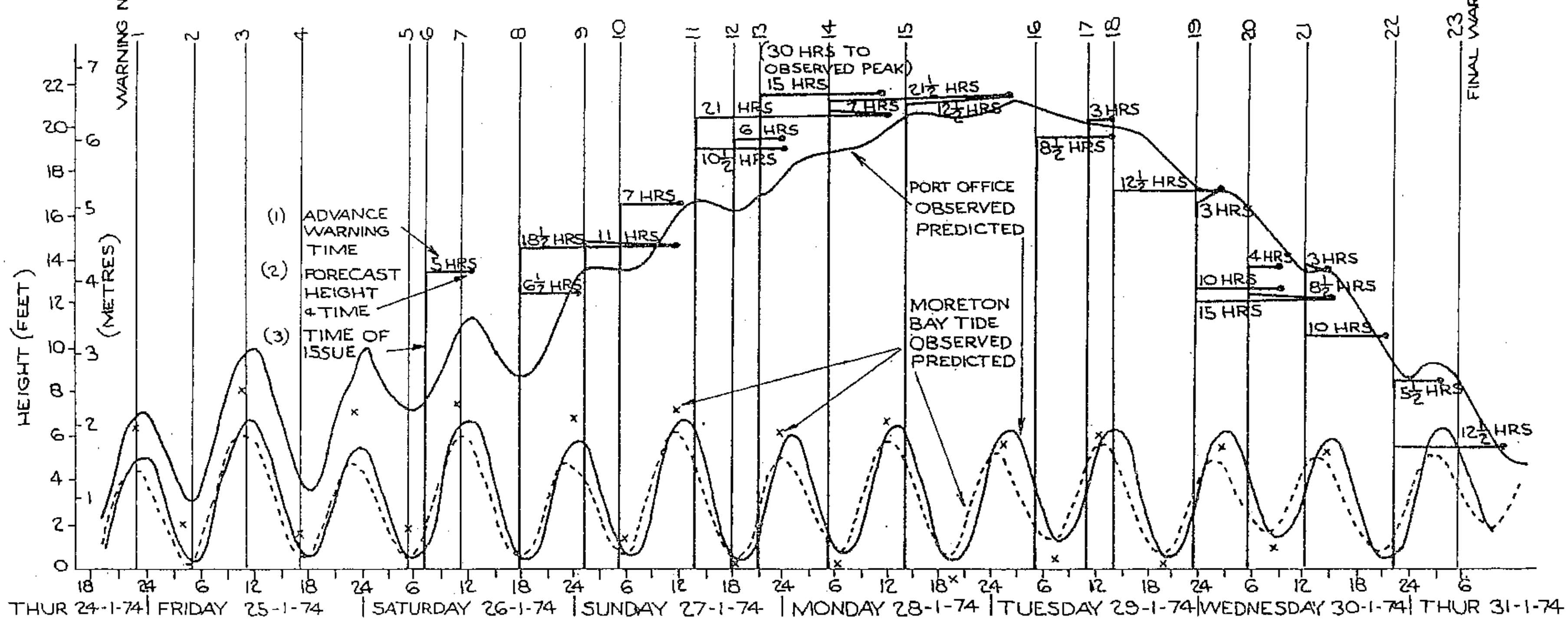


FIG 9. IPSWICH FLOOD GRADIENTS FOR BREMER RIVER FLOOD AND BRISBANE RIVER FLOOD.

FIG. 10. FLOOD FORECASTS FOR BRISBANE RIVER AT THE PORT OFFICE



FLOOD FORECASTING IN THE BRISBANE RIVER

by G. Cossins B.E. M.I.E. Aust. *

Any dam with a fixed spillway automatically mitigates floods to some extent without any human intervention. This comes as a surprise to most people, including many engineers, and is usually dismissed as one of those ridiculous lies which the technologists insist on perpetrating against all commonsense. However, it is so. The explanation is simple and involves the relationship between inflow, outflow and storage which is outlined in the simple text books on hydrology. On the other hand, when a dam is fitted with gates it can be operated, deliberately, to achieve a greater degree of flood mitigation than a fixed spillway dam. This is something the public can credit although, when it comes to a flood, they do not want to be persuaded that the gates were not wrongly operated and that the dam in fact did not cause the flood. Somerset Dam on the Stanley River is one such dam. It is operated in a planned fashion to mitigate flooding in the Brisbane River (Figure 1).

In order to achieve the maximum degree of flood mitigation with a controllable dam it is necessary to forecast flood levels throughout the whole river basin. A further inducement to the operating authority is the accumulation of data and evidence to refute the inevitable charges of inefficiency and mistaken operation of the dam that arise during a flood. The controlling authority is therefore in the position to offer a comprehensive flood warning service to the public. Somerset Dam is controlled by Brisbane City Council. As this dam is the most flexible of its kind in Australia in terms of the high discharge capacity in relation to inflow, the operators are able either to mitigate floods successfully by careful operation or to create a large flood by inefficient operation. The forecasting of flood levels in the Brisbane Valley by the Council is of major importance in the interests of operating the dam to best advantage.

The ability of the Council to forecast flood levels introduces a conflict with the Bureau of Meteorology which is the statutory body charged with the making of flood forecasts and the issue of forecasts and flood warnings to the public. This problem has been resolved by agreement. The forecasting staffs of the Bureau and the Council reach agreement on the forecasts for the key flood gauges, as described by Heatherwick (Ref. 1), following which the Council prepares detailed forecasts along the Brisbane River in the metropolitan area of Brisbane.

The generation of a flood hydrograph in the Brisbane River system is described by Cossins (Ref. 2 & 3 but in more detail in Ref. 4). The purpose of this paper is to describe the methods used by Brisbane City Council to forecast the flood of January 1974. Basically, a simple mechanical method of peak flood height oorrelation has been found to be effective in the past. Reference to Figure 1 shows the division of the whole Brisbane River catchment into the major sub-catchments, i.e. the Upper Brisbane above the Stanley River junction, Somerset above Somerset Dam on the Stanley River, Lockyer for the whole Lockyer Creek, Bremer for the whole Bremer River, Metropolitan below the Bremer Junction and Middle

* *Investigating Engineer, Department of Water Supply and Sewerage, Brisbane City Council*

Reaches for the remainder of the Brisbane River between the limits of the other sub-catchments. Figure 1 also shows the location of various flood gauges discussed below.

Correlation Methods

Rainfall provides the data on which the earliest flood warnings can be made but involves the use of complicated mathematical relationships and a large amount of computation. On the other hand, the simplest form of flood forecasting relies on the correlation between upstream and downstream peak flood levels. Figures 2 & 3 show the peak levels at Murrumba, Lowood, Mt. Crosby and Goodna respectively plotted against the peak levels at the Port Office in Brisbane for a series of floods; the locations of these gauges being shown on Figure 1. It will be noted that the scatter of points about the correlation line improves as the selected gauge is moved downstream from Murrumba to Goodna. This factor is due to the variable contributions of the major tributaries between the flood gauges. The higher the upstream gauge is located in the catchment, the longer the warning time but the less the accuracy of the forecast peak level.

This method allows a rapid, rough, assessment to be made of expected peak levels at downstream locations provided that peak levels are available for the upstream stations, the accuracy of the forecast increasing as the flood hydrograph moves downstream. Forty-eight (48) hours warning can be given for the centre of Brisbane under favourable conditions by this method and thirty-six (36) hours in advance under less favourable circumstances. In 1974 a 36 hour warning was issued for the Port Office by this method based on the Murrumba peak level and turned out to be accurate within a few inches. A 46 hour warning with an accuracy of 1 foot was used internally within the Council system. The principal disadvantage of the method lies in the possibility of a late contribution by a tributary low in the catchment to the peak of the flood. The users of this method must be alert for any departure from previous patterns of behaviour. The principal problem in early warnings of peak levels for Brisbane in the January 1974 flood was the loss of communications with the upstream gauges. The highest gauge that could reliably be used for this purpose was Murrumba below the junction of the Brisbane and Stanley Rivers. Longer warning time would have been available in January 1974 if communication had remained open to the Gregor Creek gauge on the Brisbane River above the Stanley junction (Fig. 7).

A detailed study of Figures 2 & 3 shows that the plotted points are randomly distributed and give no hint that the conditions of either the river or the catchment have changed significantly in the 80 years since reliable records began in 1893. The wide scatter of points below 2 metres Australian Height Datum (10 feet on Port Office Datum) in the above diagrams is due to the influence of the tide in the estuary of the Brisbane River; the normal high tide ranging from 0.2m A.H.D. (4'6" on Port Office Datum) to 1.3m A.D.H. (8'2 Port Office Datum). Tidal correlations in the estuary are discussed below.

The above method can be applied only to peak flood heights when a lengthy warning time is required. The distribution of run-off from the various tributaries prevents this method from being used to forecast the early part of the rising limb of a flood in Brisbane with any accuracy and, in this respect, the 1974 flood was the worst of all the recorded floods. The unusual distribution of rainfall during the flood and the unfamiliar sequence with which the various catchment areas contributed to the rising flood level in Brisbane, as discussed below, ensured that the above method could give a meaningful result only for the peak of the flood.

In any case, the lead time of a forecast cannot exceed the time of concentration of the catchment causing the flood. The early flooding in the metropolitan reaches of the Brisbane River was due, initially, to the suburban creeks of Brisbane with concentration times of only hours and this was followed by contributions from the Middle Reaches catchment and the Bremer River which have concentration times of about 1 day. A lengthy warning period is therefore not feasible in the early part of a Brisbane River flood in the metropolitan area.

Reach Correlations

Reference to Figure 1 shows that the main Brisbane River below the Stanley Junction consists of three long reaches located between the junctions of major tributaries. The catchment areas of the three reaches are relatively small and the tributary creeks are short. These are the Upper Middle Brisbane River between the Stanley and Lockyer junctions, the Lower Middle Brisbane River between the Lockyer and Bremer junctions and the Lower Brisbane River from the Bremer junction to Moreton Bay. Figure 4 shows the peak height relationship between Lowood and Mt. Crosby flood gauges at virtually the extreme ends of the Lower Middle Brisbane River reach. No significant tributaries enter the Brisbane River between these two gauges which accounts for the small scatter of points about the mean line. On the basis of past records the peak level at Mt. Crosby can be forecast within ± 0.25m from the peak level at Lowood; the time of travel of the flood peak being 9 hours. Such diagrams are suitable for more accurate flood forecasting than the correlation diagrams, Figures 2 & 3, for widely spaced gauges. Moreover, Figure 4, plotted from numerous data, allows both the rising and the falling limb of the downstream hydrograph to be determined with a fair degree of accuracy. Vernor is located just downstream of Lowood. The hysteresis effect in Figure 4 is due to the larger contribution to the reach between the gauges of the run-off from the intermediate catchment on to the rising limb of the hydrograph compared with the falling limb; the streams in the intermediate catchment being short with low time of concentration. This effect is not related to the hysteresis diagram of discharge rating obtained from the rising and falling limbs of flood hydrographs at a flood gauge.

The techniques of Figure 4 can be utilised for accurate forecasting if the problem of the contribution from the major tributaries can be solved. Although the length/width ratio of 2 for the Brisbane River catchment makes the flood response less sensitive to storm patterns than, say, Breakfast/Enoggera Creek with a ratio of 7, the variable contribution of the major tributaries, such as Lockyer Creek and the Bremer River, both in quantity and time, introduces a wide uncertainty into forecasting methods unless some allowance can be made for these factors.

River Junctions

The contribution by major tributaries to the peak flood heights in the Brisbane River is estimated by co-axial correlation as shown in

Figure 5 for the junction of the Brisbane and Bremer Rivers; the flood gauges being Mt. Crosby on the Brisbane River and Ipswich on the Bremer, both above the junction, and Moggill on the Brisbane River below the junction. The principal correlation is made between Mt. Crosby and Moggill on the main stream as the flood hydrograph of the Brisbane River is the main concern of the forecast. The contribution from the Bremer is considered to "modify" the Brisbane River flood. The flood peak takes 4 hours to travel from Mt. Crosby to Moggill, and, in this instance, Ipswich is equidistant with Mt. Crosby from the junction. The peak heights at Mt. Crosby are entered into the diagram but the gauge height at Ipswich occurring at the time of the Crosby peak is entered into the diagram. In those cases, i.e. Lockyer Creek, in which the upstream gauges are unequal distances from the junction, the time of travel from the tributary gauge to the junction is taken into account, i.e. the level on the tributary gauge N hours before the main stream peak is expected at the junction is entered into the diagram; the principal requirement being the simultaneous arrival at the junction of water from the main stream and the tributary.

Stage Routing Method

The above two techniques allow a complete flood forecasting system to be built up for the Brisbane River based only on staff gauge heights and times of travel of the flood hydrographs. Once a flood peak is established in the Upper Brisbane River the forecast peak levels can be brought downstream, progressively, reach by reach, taking account of the tributary contributions at the stream junctions. This method requires a similar method to be applied to each of the major tributaries so that the maximum length of warning can be given by using data from the most upstream gauges in both the main stream and the tributaries. If this data is available, a 48 hour warning can be given for Brisbane with an accuracy of ± 0.25 m. The forecast levels are, naturally, checked as the flood hydrograph passes each gauge in turn, and, as it does so, the long time forecast is amended. As the main flood hydrograph progresses downstream the forecasts for the lower river gauges are progressively improved until an accuracy of inches can be achieved at Brisbane with as much as 12 hours warning. The technique permitted by the use of Figure 4 can be used to forecast the whole downstream hydrograph although the accuracy on the rising and falling limbs of the hydrograph is not comparable with the accuracy of the peak height forecasts.

The loss of communications over the Australia Day week-end in January 1974 did not allow the whole of the above forecasting technique to be utilised for the Brisbane forecasts. At the most critical part of the flood no information could be obtained from the Upper Brisbane River as only three gauges were able to report above Mt. Crosby, i.e. Lowood, via the police radio, Murrumba, by some miracle via telephone (although the messages were relayed in a round about manner, sometimes via the R.A.C.Q. and sometimes via the Toogoolawah Ambulance) and finally Somerset Dam via Brisbane City Council radio. No data could be obtained from Lockyer Creek and the data from the Bremer River was not capable of interpretation, as pointed out by Heatherwick (Ref. 1).

The major problem faced by the forecasters in determining a peak level for Brisbane was the detection of a peak flow in an upstream reach of the Brisbane River. The time of the peak in the Upper Brisbane River above the Stanley junction was deduced from rainfall data and, finally, was detected at the Stanley River junction by closing down the whole discharge from Somerset Dam and observing the backwater level of the Brisbane River, 8 kilometres distant, in the dissipator of the dam. This action was necessary, in any case, to mitigate flooding in the Brisbane River as much as possible but it served both purposes. A similar technique was adopted by the Co-Ordinator General's Department during the 1955 flood. An accurate forecast for Brisbane however could not be made until the flood peak reached Murrumba.

In the absence of data from Lockyer Creek the peak level forecast for Brisbane could not be amended until the flood peak reached Lowood 5 hours later. This however still gave a warning time of 24 hours for Brisbane. The next major check was made at Mt. Crosby, 15 hours ahead of Brisbane and then at Moggill 10 hours ahead of Brisbane. Moggill is regarded as the final gauge on which the forecast for Brisbane is based.

Sufficient staff gauges and sufficient data from past floods allow a remarkable accuracy, well in advance of the event, in the flood forecasting for Brisbane by a purely geometrical method using only regular readings from the flood staff gauges. One of the main problems in establishing this system of forecasting lies in the selection of the highest gauge on the main stream; the higher the gauge the longer the warning time. However, the very highest gauges have small catchment areas. These respond very rapidly to each successive increase in the rainfall intensity in the storm pattern and produce a series of short individual peaks which cannot readily be used to start the forecasting process. Usually a compromise is necessary and a catchment area must be chosen that will produce an even shaped hydrograph with a well defined peak that can be used as a starting point for the forecasting process. Reference to Figure 6 shows that Gregor Creek is the highest suitable gauge on the main Brisbane River for this purpose.

Figure 7 shows the location of the stream gauges in the Brisbane Valley used for flood forecasting as and when communications permit. The majority of these report to the Bureau of Meteorology at regular intervals; the data being passed on to the Council. Data from the Council stations is in turn supplied to the Bureau. In addition to these manually read staff gauges the Irrigation Commission operates automatic water level recorders at the locations shown on Figure 7 as described by Ward (Ref. 5). The data from these automatic gauges is used for the post analysis of floods. Figure 8 shows the location of the rainfall stations used for flood forecasting. These stations report directly by telegraph to the Bureau of Meteorology.

The above description infers that the contribution of the Stanley River and Somerset Dam to the hydrograph of the Brisbane River flood are estimated by a correlation diagram of flood levels. This could be done but, as the releases from Somerset Dam are always considered in terms of flow, the correlation is carried out in flow terms for convenience and then converted into heights for the most convenient gauge downstream of the Stanley junction.

Flood Forecasting in Tidal Estuaries

The Brisbane River is tidal to Colleges Crossing 86km from its mouth in Moreton Bay. The tide introduces a further problem as the scatter of low points on Figures 2 & 3 shows. The effects of both tides and storm surges can be taken into account by a height diagram shown in Figure 8. This particular diagram was derived for forecasting the level at the Port Office in Brisbane using the height data from Moggill on the Brisbane River below the junction of the Bremer River and taking into account the sea level in Moreton Bay into which the Brisbane River flows. Figure 9 is essentially a diagram of the type of Figure 4 and is repeated for each different level that can be expected in Moreton Bay due to tides plus storm surges. If, for any uniform flow in the Brisbane River, the level of Moreton Bay is considered to vary over the whole possible range, it will be appreciated that the varying levels at a point on the river, such as Port Office, can be treated as a backwater problem. The lines representing different levels in Moreton Bay therefore converge towards a single line for high floods. It should be noted, however, that a tidal variation of 0.2m (7") was still detectable at the Port Office in the 1974 flood around a reading of 5.5m A.H.D. (21 feet Port Office Datum) and at a flow of some 9,650 cumecs (340,000 cusecs).

Figure 9 was derived for high and low tide conditions only from a study of floods in 1967, 1968 and 1974. The diagram can be used only for predictions at high and low tide at the Port Office and not for intermediate times. To use the diagram a high or a low tide is selected. The predicted tide level is corrected for storm surge and the time of the tide is noted from tide tables published by the Department of Harbours and Marine. The tide takes approximately one hour to travel from the mouth of the river to Port Office. The level that occurred 10 hours before the Port Office tide time is ascertained from the readings of the Moggill gauge and is entered into the diagram and traversed horizontally until the appropriate level for Moreton Bay (predicted tide plus storm surge) is reached. An ordinate then gives the predicted level for the Port Office.

A diagram of this nature can be derived by a backwater approach as outlined below.

The Bureau of Meteorology uses a different method to forecast Port Office levels as described by Heatherwick (Ref. 1). The methods are basically the same in the final analysis and, not surprisingly, produce very similar results.

Storm Surges

The storm surge component of the level of Moreton Bay has, so far, proved to be the most troublesome factor in the forecasting of levels at the Port Office in Brisbane. Figure 10 shows the variation in the storm surge operating in Moreton Bay during the January 1974 flood. The rapid variation of the surge could not be forecast and upset the levels predicted for the Port Office on 26th and 27th January considerably. After the 27th the magnitude of the surge diminished and even became negative. A subsequent analysis by the Bureau of Meteorology shows that the storm surge correlated well with the wind, thus raising the hope that future storm surges will be predictable and will thus remove one of the final factors that, hitherto, has prevented accurate flood forecasting along the metropolitan reaches of the Brisbane River.

An extreme surge of more than 10 metres occurred in Princess Charlotte Sound in North Queensland at the end of the last century but the probability of high surges decreases with increasing latitude. Townsville had a 3 metre surge in 1971 but a little over 1 metre appears to be the limit so far experienced in Brisbane. The Bureau of Meteorology is installing a remote indicating sea level gauge in Moreton Bay. Hourly readings of this gauge will enable a check to be kept of the trend of storm surges in future floods against the approximations that are presently possible only at high and low tide.

Further reference to Figure 9 shows that tidal and storm surge variations are damped out increasingly as the flood flow increases until they finally disappear. Similar considerations apply to any point in the tidal regime of a river. On further reflection it will be realised that no flood of any magnitude can damp out the tidal variations at the mouth of a river. It therefore follows that, for every flood flow, there must be some point on the river at which the tidal variation is damped out. The same conclusion can be reached by a backwater approach to the problem. The tidal variations are damped out furtherest upstream for small flood flows. The point of tidal damping moves downstream as the flood flow increases. Experience on the Brisbane River in its present (1974) condition shows that the tidal variations are damped out at approximately 7 to 8 metres on Australian Height Datum at any point in the tidal section of the river.

Errors in storm surge estimation have the maximum effect upon a flood forecast at small flood flows. The effect is most marked in the early stages of a flood. The storm which causes the flood rain also causes the storm surge but, whilst the storm surge may die away in hours, there can be a delay of days before the flood peak arrives in the tidal section of the river. The storm surge is therefore most likely to be at its maximum in the early part of a flood before the flood flow has risen to any extent. However, this is not necessarily always the case. It is possible to imagine circumstances in which the storm surge could occur at the peak of the flood or even at the end. Storm surges can usually be expected to be a problem in forecasting the early part of the rising limb of a flood in a tidal estuary.

Rain on the Intermediate Catchment

The flood forecasting methods outlined above are almost purely geometrical in that they rely on forecasting diagrams based on gauge heights and derived from observations made on historical floods. These methods become effective only when the major part of a storm has fallen and the flood waves are beginning to take definite shape in the upper tributaries of a river system. It is quite evident that late rainfall, particularly in the intermediate and lower parts of the catchment will upset the geometrical method and leave the forecaster without any reliable guidance. This, in fact, occurred in the January 1974 flood in the Brisbane River. The forecast for Ipswich based on the Harrisville gauge on Warrill Creek and the Rosewood gauge on the Bremer River was upset by the unusually heavy rain in the eastern part of the catchment which caused record floods in the suburban creeks of Ipswich. The same rain also caused record floods in Oxley, Woogaroo and other creeks which enter the Brisbane River. Reference to Figure 9 shows the hydrograph that must be added to the Moggill hydrograph to give an equivalent height at Moggill for the correct use of the main diagram to forecast Port Office levels accurately at high and low tide for the January 1974 flood. Reference to Figure 11 shows that this additional hydrograph is almost identical with the hydrograph of the contribution of the Metropolitan creeks to the Brisbane River which was derived by an independent method.

Attempts have been made to introduce modifying factors which will take into account the effects of late rainfall on the intermediate and lower catchments but such systems are complex and clumsy and introduce complications into what is, after all, a very simple system. It is clear that further improvements in the forecasting system for the Brisbane River will involve the use of flows derived, in turn, from unitgraphs or other hydrological models. Computerised calculation will be necessary in view of the limited time available and the large amount of data to be processed.

Velocity of Flood Hydrographs

Figure 6 shows a selection of height hydrographs for the Brisbane River during the January 1974 flood plotted on Australian Height Datum and Figure 12 shows the hydrographs in the Brisbane Metropolitan area in more detail. Figure 13 shows the envelopes of the maximum levels of a series of floods, including 1974, reached along the course of the Brisbane River.

From Figure 6 it is seen that the peak levels at the various gauges lie on a straight line as far downstream as Moggill at the junction of the Bremer and Brisbane Rivers. Reference to Figure 13 shows that this is not surprising as the flood peak grows in a regular fashion as it progresses downstream by additions from tributaries both large and small, reaching its greatest extent (in vertical rise above the normal low flow level) at Mt. Crosby. As the crest of the flood hydrograph travels at close to 5 k.p.h. in the Brisbane River, regardless of the magnitude of the flood, it is not surprising that the linear relationship of the flood peaks is preserved on a large scale.

A flood hydrograph, or wave, is a complex phenomenon that defies rigorous mathematic modelling. As a hydrograph progresses down a reach, such as between the Stanley Junction and Lockyer Junction it receives a virtually steady contribution of water from the short tributaries entering the reach of the river and the flood flow increases accordingly. However, the front of the hydrograph is continually being carved away to fill the valley storage with the overall result that the peak of the hydrograph travels at a lower velocity than the water in the stream. Many velocities have been quoted for the flood hydrographs in the Brisbane River but these should be viewed with suspicion unless the full circumstances of the measurements are known. Research shows that many of the peak levels quoted for past floods are not, in fact, the peak but highest observed level. Flood peaks on the Brisbane River generally last from two to three hours so that a single time does not adequately describe the peak unless, again, it is qualified. There is the further problem created by some gauge readers who observe from debris marks in the morning that a peak has occurred during the previous night, but instead of marking the observation D.N. (during night) place a fictitious time against it. The favourite time for this activity is the witching hour of midnight.

Careful and critical observations indicate that the flood wave velocity is constant at 5 k.p.h. in the reaches of the Brisbane River between major tributaries. The conjunction of the flood wave from a tributary can upset the apparent time of travel in the main river. This is best understood by considering the river valleys at the junction as a reservoir with two input hydrographs and one output hydrograph.

Conventional reservoir routing will show an apparent time displacement, either an acceleration or a slowing down, of the main stream flood hydrograph depending on the time relationship of the two input hydrographs.

Half way between Mt. Crosby and the Bremer junction the gorge, in which the Brisbane River has been contained since Lowood as it flows through the foothills of the D'Aguilar Range, suddenly opens out on to extensive flood plains flanking the tidal estuary of the Brisbane River. In this reach the height of the flood rise diminishes almost linearly to zero at the mouth of the river as shown on Figure 13. These effects, together with the fact that the contribution of the local catchments below Moggill have usually died away before the peak of the main river flood passes through, delays the time of the flood peak in the Brisbane River estuary and makes it appear to slow down as shown by the change in slope in Figure 6.

In actual practice the peak of the flood wave travels at 3 k.p.h. in the estuary of the Brisbane River; the drop in velocity being due, largely, to the increased valley storage in the estuary. Another reversal is shown in the line of the peaks from about Toowong to the mouth of the river. The peak level appears to go backwards in time down the river. This phenomenon occurs in the area of the river in which the tidal influence is effective. The high tide nearest to the time of the peak flood flow causes the highest level during the flood at any given point of the river under tidal influence. As the tide wave travels upstream at 27 k.p.h. and the flood wave downstream at 3 k.p.h., the peak level in the tidal reach of the flooded river appears to recede at 24 k.p.h.

This set of phenomena is characteristic of a tidal stream and, unless understood, results in complications in the interpretation of the observed data.

The Brisbane Forecasts

The accuracy of the forecasts for the Port Office in Brisbane during the January 1974 flood has been described by Heatherwick (Ref. 1). The Bureau of Meteorology limited its forecasts to one key station i.e. Port Office. Brisbane City Council then prepared forecasts for the full length of the metropolitan reaches of the Brisbane River from Moggill near the Bremer River junction to the mouth of the river, a length of 71km. The forecasts were made in a graphical form and represented the instantaneous flood profile or gradient expected at a specific time. Figure 14 shows a selection (not necessarily the best or the most accurate) of forecasts made on the rising limb of the flood and Figure 15 shows the falling limb. The lines, alternately, full and broken for clarity, are actual forecast gradients and the symbols mark the actual levels reached at the forecast times. Forecasts were made for times of high and low tide at the Port Office. This was done for several reasons. In the first place the public is familiar with tide times and is inclined to over exaggerate the effect of the tide. Forecasts based on tide times is therefore a psychological necessity. In the second place the river levels downstream of the Port Office are increasingly dominated by the tide and forecasts based on tide times are meaningful. The forecasting of a flood profile involves the separate forecast of flood levels at Moggill and the Port Office as well as the storm surge in Moreton Bay for the desired forecast time. If the forecast "lead" time is greater than the 10 hours required for the flood wave to progress from Moggill to the Port Office it then becomes necessary to forecast the Moggill level from which to deduce the Port Office value. The forecast levels for Moggill, Port Office and the West Inner Bar are then joined by a flood gradient. In the early stages of the 1974 flood a series of straight lines were drawn for want of a better understanding of the behaviour of the river. The first forecast was made at 1800 on Saturday 26th January for midnight on Saturday/Sunday (lowest line on Figure 14). The flood was already higher than any flood since 1931 and the forecasters simply had no experience on which to draw. The Port Office level was forecast accurately but the Moggill level was 2 metres low due to the unexpected contribution of the Bremer River. The forecast for noon on 27th made at the same time as the first forecast was even more seriously in error due to the same factors. This latter forecast was vastly improved on recalculation at 0300 on Sunday 27th i.e. 9 hours in advance of the actual time (See Figure 14). The forecasts steadily improved towards the peak of the flood as the unusual contributions by the Bremer River and the Metropolitan Creeks diminished and the forecasters gained experience in the shape of the flood profile for a range of flood flows. The envelope of peak heights for the Metropolitan Reaches was forecast at 1800 on Monday 28th. This should not be confused with the instantaneous gradients as the envelope shows the successive peak levels reached as the flood peak moves downstream. The different points on the envelope therefore occurred over a range of 15 hours. The envelope was accurate at Port Office, Jindalee and Goodna but the error varied from 1 metre high at Moggill to 1 metre low at St. Lucia, the errors being due to lack of experience of the details of the river gradient at such flows. The Brisbane River had not been at comparable levels since 1898 and many deepenings and widenings had been carried out in the intervening 76 years.

The accuracy of the forecast flood gradients improved immensely on the falling limb of the hydrograph as shown on Figure 15. This was due to two factors. All flow contributions to the Metropolitan Reaches of the river were subsiding evenly and it was found that the shape of the instantaneous profile is reasonably close to the shape of the envelope profile at any discharge with the exception that the Moggill end is higher on the rising limb and droops on the falling limb of the hydrograph. Furthermore, six hourly forecasts showed clearly the trending change of shape at more frequent intervals thus allowing corrections to be made promptly. Except for the last forecast the maximum error on the falling limb was 0.2m.

The contribution of each part of the whole catchment to the flood height at the Brisbane Port Office is shown in Figure 16. The contribution of both storm surge and tide is also shown. The diagram is plotted on the basis of low tide, the dotted line showing the hydrograph that would have occurred had Moreton Bay remained at low tide throughout the flood. The contribution of tide and storm surge is seen clearly from this diagram. Storm surge was the main factor in the sharp rise on the midday tide on Friday 25th January, the flow contribution at this stage being small. The declining storm surge and rising flood flow largely compensated for each other over the next 24 hours by which time the level was equal to the 1955 flood peak at midday on Saturday 26th.

The falling tide late on Saturday night misled many people into believing that the peak of the flood had been reached in spite of the fact that the Weather Bureau had forecast higher levels for Sunday. The rapid rise of the flood level on Sunday morning, 27th January to above the 1931 flood level inundated a large number of houses in Brisbane taking the inhabitants completely unaware.

Communication of Forecasts

Incredible as it may seem the accurate forecasts prepared by the Flood Control staff of the Water Supply and Sewerage Department of the Brisbane City Council were not transmitted to the public. The initial blame must be taken by the Commissioner for Police who issued a directive, early in the flood, that only the forecasts prepared by the Bureau of Meteorology for the Port Office were to be used and transmitted to the public. The Commissioner's decision was probably based on a misleading forecast issued from an official Brisbane City Council source. This forecast was issued in good faith but was so long delayed by the cumbersome Council machinery for issuing statements that the forecast levels were exceeded hours before the statement was issued. This incident serves to emphasise that the traditional methods of issuing information are hopelessly inadequate to cope with a flood situation. The Council forecasters regularly passed their forecasts to both Police and Civil Defence Headquarters but the flood was past its peak before the forecasters received any feedback that the forecasts were being disregarded. The 1974 flood in Brisbane clearly showed that the ability to forecast the flood greatly outstripped the ability of the community to transmit the forecasts in a meaningful form to the people who need most to receive them i.e. the people in the flood areas.

The forecasts made by the Investigation Section of the Water Supply and Sewerage Department operating as the Flood Control Section of Brisbane City Council to direct the operation of Somerset Dam and forecast flood levels in the Brisbane River were passed on to the Works Design Office of Council. The Works Design Office provides a service to the public. The forecast profiles are used in conjunction with contour plans of the City to advise the inquirers, in the best detail possible, to what extent their particular properties will be affected by the flood. Through an unfortunate series of oversights this particular service was not widely publicised. Nevertheless several thousand inquiries were dealt with.

The Forecasters

The sequence of meteorological events in the January 1974 flood has been outlined by Shields (Ref. 6) and the hydrological events by Heatherwick (Ref. 1).

Flood forecasting for the Queensland Regional Office of the Bureau of Meteorology is carried out by the Hydrometeorological Section headed by the Senior Engineer-Hydromet with a second Hydromet engineer who alternate with each other in working shifts during major flood events supported by a staff of four technicians, each shift staff comprising one engineer and two technicians. The Hydromet Section covers the whole of Queensland and is therefore physically limited in the detail to which forecasts can be carried except for the Brisbane/Ipswich area; the other centres are so small that one key flood gauge provides adequate reference for warning the whole population of possible inundation. It is not practicable for the Bureau to advise individuals on their particular flood predicament as this would involve detailed knowledge of every area of population. As Local Authorities have detailed knowledge of levels and layouts of their populated areas, the Bureau considers the detailed interpretation of flood forecasts to be a Local Authority responsibility.

The Investigation Section of the Water Supply and Sewerage Department of Brisbane City Council acts as the Flood Control Section during flood times both to direct the operation of Somerset Dam and to forecast the flood profiles along the Metropolitan reaches of the Brisbane River in detail. The Section is headed by the Investigating Engineer and the Assistant Investigating Engineer, both of whom have wide experience in the operation of Somerset Dam and in flood level prediction. In particular, the Investigating Engineer has been associated with Somerset Dam and flooding in the Brisbane River since 1944, having been tutored by the late Dr. Nimmo and also by Mr. E. M.Shepherd, both of whom worked on the early detailed hydrology of Somerset Dam and Brisbane River flooding. The Council staff is therefore in the direct episcopal succession of Somerset Dam operation stretching over 40 years since the systematic study of the problem started in 1933.

The overall flooding problem was first studied long before 1933. Henderson (Ref. 7) and Pennycuick (Ref. 8) reported on flood mitigation proposals after the record 1893 flood and the problem was again raised in the 1920's in connection with the amplification of the water supply to Brisbane, being considered by the Gutteridge Royal Commission (Ref. 9) which recommended, in 1928, the adoption of a dual purpose dam for both water supply and flood mitigation. The investigation was carried a stage further in 1930 by Bush (Ref. 10) and focused on Somerset Dam. A Special Committee of the Bureau of Industry, including as hydrologists, W. Nimmo, then of the Main Roads Department, and D. Fison of Harbours and Marine Department, recommended the construction of Somerset Dam (Ref. 11). Nimmo, with extensive hydroelectric experience in Tasmania, became the Chief Engineer of the Stanley River Works Board which designed and constructed the dam. He was joined by E.L. Richard, also from Main Roads, and who now holds the position of Engineer in Charge, Special Projects Section of Works Department of Brisbane City Council. In this position he is concerned with flooding in the suburban creeks and the works for flood mitigation.

E.M. Shepherd later joined the staff as Design Engineer, ultimately becoming Deputy Chief Engineer of the Co-Ordinator General's Department, the successors to the Board.

The Investigating Engineer and the Assistant Investigating Engineer alternate with each other on shift in flood situations supported by a permanent staff of two junior engineers, four draftsmen and a tracer. When a flood situation becomes sufficiently serious the staff of the Flood Control Section is augmented by drawing upon the personnel of the Design Branch and the Water Supply Reticulation Section of the Water Supply Maintenance Branch of the Water Supply and Sewerage Department of the Council both for forecasting and flood control calculations and also for reading flood gauges along the Metropolitan Reaches of the Brisbane River. In the 1974 flood the staff was temporarily augmented in this way to a peak of 16 in the control forecasting area and a further 20 reading flood gauges in the City, working irregular shifts as the exigencies of the situation, fatigue etc. dictated. This arrangement worked satisfactorily, the newcomers being used to carry out the more routine receiving, logging, posting, plotting and calculations which they were quickly taught, leaving the permanent staff to carry out the more specialised interpretation of the data. A senior engineer acted as O/C

Staff to relieve the hydrologists of the task of drawing up rosters and registering overtime etc. The main problem lay with the two seniors of the section who are virtually the only two hydrologists with sufficient experience to be able, on demand, to take command of the operation of Somerset Dam and the attendant flood forecasting. It was necessary for them to alternate shifts and, whilst it was decided, at the outset, that 12 hour shifts were the desirable limit, it was necessary, for various reasons, for them to work 27 and 26 hours respectively on occasions. Sickness or other disability on the part of either would have created an almost impossible situation as it is essential to have an experienced officer in control of the dam at all times to make major decisions and to deal with the continual crises that arise. In an emergency, it would have been possible to bring in an experienced, retired engineer for limited shifts. Nevertheless, the area remains vulnerable.

The Bureau of Meteorology had to deal with such a situation. Sickness, following a motor accident some months earlier, forced the assistant hydromet engineer to cease work early in the flood and the Senior Hydromet engineer worked a 60 hour shift before he was first relieved. The assistant hydromet engineer provided this relief over one night but worked under considerable physical difficulties, but this enabled the senior engineer to continue the next day and work until his predecessor was flown in from Melbourne to assist. The whole process was extremely exhausting for the senior hydrologists of both the Bureau and the Council and the senior meteorologists of the Bureau. All suffered, virtually, from battle fatigue, in the week following the flood. The older personnel were, predictably, affected for a much longer period. It is difficult to estimate how these meteorologists and hydrologists would have withstood the conditions of February 1893 when two major floods peaked a fortnight apart with a minor flood in the interval.

Flood forecasting for Ipswich is carried out by the Deputy City Engineer relying heavily on the Bureau of Meteorology for forecasts of the Ipswich Town Gauge and on both the Bureau and Brisbane City Council Flood Control Section for advice. In fact, the flood forecasting for the two Cities of Brisbane and Ipswich is a triangular affair with a complete exchange of all relevant information. It is understood that some reorganisation is to be carried out in the flood warning organisation for Ipswich and more staff gauges are to be constructed along the metropolitan reaches of the Bremer River to provide more data for improved forecasts.

Flood Level Recording in the Metropolitan Reaches

The location of flood gauges along the metropolitan reaches of the Brisbane River is shown on Figure 17. Eighteen staff gauges are read manually and the readings transmitted by telephone whilst a further two - Victoria Bridge and South Brisbane Gas Works - have been temporarily removed during the construction of roads and will be restored. The Port Office staff gauge reports to the Bureau and the remaining staff gauges to the Council. In addition the Department of Harbours and Marine has automatic tide level recorders at Newstead Park, Cairncross Dock and the West Inner Bar near the mouth of the river. The Newstead recorder, however, is limited to 2.15 metres A.H.D. and was not able to record the peak of the 1974 flood. Most manual gauges were read once an hour on the hour, this frequency being necessary to define tidal movements where applicable. Four of these gauges were read by the shift staff from the adjacent installations and another one partly so, whilst five were read by private citizens. The remainder were read either by Council maintenance and operation workers or by the draftsmen outlined above working in shifts. In addition to the regular staff gauges, a flood bound engineer made systematic marks on bitumen roads at Bellbowrie and Pullen Creek which were later surveyed to give almost complete hydrographs and a retired engineer achieved the same result at West End by observing the submergence and emergence of definite features which were later surveyed. A number of other residents made limited numbers of similar observations which have since been surveyed to give valuable corroborative evidence of the shapes of the hydrographs. All in all, a total of 1500 separate staff and similar observations were made in the metropolitan reaches of the River during the flood. The Ipswich Town Gauge on the David Trumpy Bridge was read each hour and a number of flood levels marked at the One Mile Bridge were subsequently surveyed. Observations at even more locations in the metropolitan areas of both Brisbane and Ipswich are required in future floods to enable the changing characteristics of the river to be analysed as a guide to improved forecasting.

A major problem in observing flood levels in the metropolitan reaches of the Brisbane River was posed by the continual oscillation of the river, as shown in Figure 18. This is a direct copy of part of the Cairncross Dock recorder chart. The oscillations are regular with a main period of about 20 minutes and a maximum amplitude exceeding 0.1m, although some smaller harmonics seem to be present. These oscillations were recorded on the automatic tide charts at the West Inner Bar and Cairncross Dock and on the Newstead Park tide recorder until its upper limit was reached. The oscillations were also observed at Indooroopilly and Bellbowrie by impeccable witnesses. These oscillations are clearly distinct from the short period surface waves and surging that accompanies a river in flood and they lasted for three days over January without abating. The main period of 20 minutes fits the natural frequency of Moreton Bay in an east-west direction in which the wind was mainly blowing. It is therefore suggested that the phenomenon was due primarily to a wind induced seiche in Moreton Bay. Instead of being damped out in an upstream direction like the tide, it was transmitted up the Brisbane River by resonance from reach to reach. The observation of future floods calls for more automatic recording equipment to study this phenomenon.

The main importance of the oscillation is the uncertainty it introduces into the reading and recording of flood levels from manual staff gauges. The observers normally watch for a minute or so to estimate a mean reading from all the short term waves and other oscillations yet it is clear that honest observations can be in error by more than 0.1 m over a period of 10 minutes. This has been observed by the surveyor measuring detailed flood levels along the course of the river. Observations of peak levels, including debris marks, occupy a band about 0.1 m thick rather than a line. This has lead to near neighbours almost coming to blows as they each described to the surveyor where the maximum water level was seen to come on their respective properties.

Is the oscillation significant in recording flood levels? From the point of view of causing damage, the highest peaks of the oscillations are the relevant levels in a flood, yet, as far as flow is concerned the mean value of the oscillations represents the true value level of the river. It is tempting to wonder if this phenomenon has occurred in all major floods of the past and, if so, whether some of the extreme accuracies with which past flood levels have been reported are, in fact, unwittingly fictitious. The observations on most of the city gauges were started on Friday 25th January and continued until Thursday 31st January when the river fell below flood level and the thick mud on the river banks made further observations both difficult and dangerous.

Some of the gauge readers had narrow escapes. The reader at Riverview managed to escape to higher ground as a landslip carried away the gauge board he was reading. At other times gauge readers have been bitten by snakes and one had a possum land on his head in the middle of the night. One private reader made a heroic solo effort, waking to an alarm clock every hour of the night and another was able to observe the Robert Miller incident as well as watching other vessels sailing majestically downstream. Telephone communications failed only near the mouth of the river and were difficult at Moggill where the reader had to drive two miles on a tractor to reach a workable telephone. One gauge reader was evacuated and two ran out of gauge boards to read whilst one gauge was hastily erected in a backyard on the river bank at the beginning of the flood to replace one that had become inaccessible. One gauge reader had to use a boat to reach his gauge and another had to wade. One gauge could not be reached at all.

Superelevation

Detailed surveys since the flood have confirmed observations made in 1893 that the water on the concave (outer) bank at a sharp bend in the river is superelevated with respect to the water on the convex (inner) bank. A maximum superelevation of almost a metre has been measured but, as these observations are subject to the usual oscillations uncertainty, it is too early to be definite about the magnitude of the superelevation. However, it is clearly a factor that will introduce complications into future, more detailed forecasts particularly if the forecasters have the temerity to claim an accuracy of centimetres. The problem will arise in transmitting meaningful flood warnings to the people in areas affected by superelevation on the outsides of banks as the areas concerned are relatively small. One exception is the Breakfast Creek area. The creek enters the river at a bend and the consequent superelevation will affect a large area along the creek.

The Flood Map

After the flood it was popularly held that had the flood map been available much of the hurried evacuation of houses etc. could have been avoided and much criticism implied that "They" had deliberately kept the public in ignorance. The much discussed flood map was in fact the one published by the Bureau of Industry in 1933. It was a product of Nimmo's team that afterwards became part of the staff of the Stanley River Works Board. The map shows the areas of Brisbane that would be inundated by floods rising to 10, 15, 20, 25 and 30 feet (B. C. C. Datum & Harbours and Marine Datum). The map is limited to the stretch of the river between Oxley and Cairncross Dock. In the 40 years between the publication of the map and the 1974 flood the Brisbane River has been deliberately widened and deepened whilst large amounts of gravel have been dredged from the reaches upstream of the William Jolly Bridge. On the other hand, the central city reaches have been abandoned for port purposes in the period and maintenance dredging is no longer carried out above Newstead. As pointed out by Piggott (Ref. 12) the hydraulic mean depth at Port Office has steadily decreased since 1925. It is therefore pertinent to ask if the 1933 flood map is sufficiently accurate to be used for 1974 conditions.

Figure 19 shows the flood profiles adopted by the Stanley River Works Board as broken lines; the full lines being actual recorded profiles for the 1893, 1931, 1968 and 1974 floods. Of these only the 1968 and 1974 profiles can be considered to be representative of the modern conditions of the Brisbane River. The 1968 flood peaked at 1.95m A.H.D. (10'2") at the Port Office and the 1974 flood at 5.45m A.H.D. (21'8"). The Bureau of Industry 20 ft. profile is therefore as much as 0.9m high at Indooroopilly whilst being correct at Toowong. In general, it is some 0.6m high. On the other hand, the 10 ft. profile varies from correct at the Port Office to 2.5m high at Indooroopilly.

Figure 20 shows the same actual flood profiles as full lines compared with computer simulated profiles based on an analysis of the 1968 flood. It will be noted that the actual 1931 flood closely approximates the 200,000 cusec simulation over the area of the flood map. It would therefore appear that any reduction due to the widening and dreding carried out in the 1930's has largely been cancelled by the subsequent abandonment of dredgings. As the 1931 flood peaked at 3.31m A.H.D. (14'7½") it can be seen that the 15 ft. profile of the Bureau of Industry is 1.5 to 1.8m high over much of the map whilst being more accurate below Port Office. A comparison of Figures 19 and 20 shows that the Bureau of Industry profile was close for 30 feet at the Port Office gauge. The Bureau of Industry profiles are accurate at the highest levels but increasingly exaggerate the flood levels for smaller floods, being 0.6m high for the 1974 flood and up to 2.5m high for the 1968 flood.

On the other hand, the area inundated at any Port Office level is found by the intersection of the flood profile line with the ground contours. The accuracy of the available contour plans is, therefore, a major factor in the overall accuracy of the flood map. The only contour plans of Brisbane available when the map was compiled in 1933 were the preliminary contours of the Brisbane sewerage scheme feasibility study surveyed in 1911. Subsequent detailed surveys have shown the old contours to be in error by as much as 2.5m. in some places. The overall accuracy of the flood map can be judged from the edition reprinted by the Surveyor-General's Department in March 1974 on which the outline of the 1974 flooded area is marked in red. The 1933 map is considerably in error in some flat areas but, by and large, is a good representation of the 1974 conditions. Considering all the circumstances under which the map was originally produced, its utility for present-day conditions is remarkable. Nevertheless, in view of the enormous losses suffered in Brisbane and Ipswich during the flood it is desirable that the map be revised in the light of present-day survey and hydrological data.

The revision of the map is being carried out jointly by the Queensland Government through the Co-Ordinator-General's Department, the Surveyor-General's Department and the Department of Harbours and Marine, by the Australian Government through the Cities Commission and Snowy Mountains Engineering Corporation, by Brisbane City Council through the Departments of Works and of Water Supply and Sewerage and through Ipswich City Council. The whole flooded area from the mouth of the Brisbane River to Ipswich will be covered in three maps. In order to produce these the detailed sewerage surveys of both Brisbane and Ipswich are being converted to Australian Height Datum with a vertical interval of 1 metre and a missing gap will be contoured from existing aerial photos. The flood profiles shown on Figure 21 have been prepared by the Flood Control Section of Brisbane City Council on the basis of the data recorded in the 1974 and 1968 floods. The revised maps are planned to be available before the 1974-75 flood season.

Simulation of Flood Envelopes

Figure 20 shows the envelope profiles simulated for the metropolitan reaches of the Brisbane River on the basis of data obtained in the 1968 flood as described by Cossins (Ref. 3). The peak discharge of this flood was measured by the Surface Water Resources Branch of the Queensland Irrigation and Water Supply Commission at Centenary Bridge under ideal conditions. The envelope profile of the river was recorded accurately during the flood but the cross-sectional data was largely approximate. The 1968 flood was simulated closely as a simple backwater function and using the constants derived from this study the envelope profiles for floods of 100,000, 200,000, 300,000, 400,000 and 500,000 cusecs were simulated as shown by the broken lines on Figure 20. The full lines show actual flood profiles. The good fit of the actual and simulated profiles leads to a good deal of confidence in the diagram when it was first produced in 1969 although it inferred that the peak flow of the 1893 flood was of the order of 500,000 cusecs as opposed to the 350,000 cusecs adopted by the Special Committee of the Bureau of Industry and the Stanley River Works Board.

On the basis of Figure 20 the Flood Control Section of the Council placed the 1974 flood at approximately 350,000 cusecs. In fact, the Irrigation Commission measured a peak of 338,000 cusecs at Centenary Bridge. This, naturally, has increased confidence in the simulation process which is to be repeated, using the 1974 flood data but with much improved cross-section data which will be available both from the Harbours and Marine detailed survey of the river channel and from the metric contours being produced by the Surveyor-General's Department for the flood maps. In addition to this a detailed survey was started after the flood to measure energy losses at bends in the river. The overall result is expected to be a much more accurate simulation that can be extrapolated with confidence to cover all possible levels of flooding in the Brisbane River. The new simulation will allow the profiles of Figure 21 to be corrected. Considering that the vertical interval on the flood map will be 2 metres at Port Office rising to 5 metres at Moggill the errors of Figure 21 will be small by comparison, except, perhaps, for the 10 metre profile.

Port Office as a Reference Gauge

The Port Office gauge is located in the area of the Brisbane River most affected by widening and dredging. The river works of the middle to late 1930's, as part of the flood mitigation project which included Somerset Dam, had the most effect on the Port Office gauge. This improvement is rapidly being offset by cessation of maintenance dredging above Newstead since World War II. On the other hand, the major river improvements in the last decade, have been near the mouth of the river for the oil terminal. The recently announced policy of moving the Port of Brisbane to the Fisherman Islands at the mouth of the Brisbane River over a period of some 30 years will mean that maintenance dredging will gradually cease between Newstead and Luggage Point with a consequent rise of flood levels. The new profile simulation will enable the effects of this move to be predicted as far as flood levels are concerned. It will also be possible to evaluate the economics of a maintenance dredging programme for flood mitigation alone.

From the above it is clear that the characteristics of the Brisbane River Town Reaches will change and that flood levels will rise at the Port Office gauge. In future years any map based on the 1974 characteristics of the Port Office gauge will overstate the flood levels to be expected upstream. Revisions of the map will therefore be necessary from time to time. It is suggested that the interval for revision should be less than the present 40 years. A continuous watch should be kept on the changing characteristics of the river by measuring the peak flow at Centenary Bridge and by observing the profile, in detail, at an amplified number of staff gauges. In this way any incipient changes in the characteristics can be detected from the profiles of the frequent minor floods.

Flood Forecasting in the Suburban Creeks

The safety of Enoggera, Gold Creek and Lake Manchester Dams is the concern of the Department of Water Supply and Sewerage of the Council. Levels from these dams are reported to the Flood Control Section of the Council. Although flood forecasting in the suburban creeks of Brisbane is not included in the terms of reference of the Flood Control Section, some early work was done on the problem that is of interest. Figure 22 shows the peak height over the spillway of Enoggera Dam plotted against the level just upstream of Bowen Bridge. The points are widely scattered due to the sensitivity of the catchment with a length/width ratio of 7 to the temporal and areal pattern of storms, an error of ± 1.5 metres being possible at Bowen Bridge based on the Enoggera Dam levels. However, observations have shown that once the pattern of a flood is established, the progressively plotted points tend to lie on one side or the other of the mean line reducing the error to less than one metre. The warning time available by this method does not exceed 2 hours although Morris (Ref. 13) has developed a forecasting method based on rainfall intensities which will allow the warning time to be extended somewhat.

Conclusions

Experience in the January 1974 flood showed that flood levels can be forecast for the metropolitan reaches of the Brisbane River with a high degree of accuracy but that there is a serious deficiency in the mechanism for conveying the forecasts from the forecasters and interpreting it in a meaningful fashion to the public in the areas likely to be flooded.

The main factors causing the errors of forecasting the metropolitan river flood levels, i.e. the contributions of the Bremer River and of the metropolitan creeks to peak flow and the storm surge in Moreton Bay will be evaluated in the near future leading to improved forecasts. There is no guarantee that the transmission of meaningful forecasts to the public will be considerably improved although some improvement is surely inevitable.

The effect of the tide on flood levels is greatly exaggerated by the public. Tidal variation is entirely damped out when the flood level at any point in the metropolitan reaches of the Brisbane River reaches 8 metres on Australian Height Datum. For this reason, the river below Newstead will never be free from tidal influence in any imaginable flood whilst the tide is damped out in the upper reaches from Goodna to Moggill by floods that are not noticed in the City reaches by the majority of the public.

Flood profile simulations based on the 1968 flood were shown to be satisfactory and a simulation to be based on the higher 1974 flood with improved cross-sectional data and bend loss measurements is expected to give a high degree of accuracy in simulating flood profiles over a great variety of conditions and will allow the effects of further river improvements as well as the results of the abandonment of maintenance dredging to be estimated.

The 1933 flood map, although many feet in error in some places, was the most comprehensive single document that could have been used for general flood warnings based on Port Office forecasts. On the other hand, the Flood Control Section of Brisbane City Council forecast extremely accurate flood levels for the metropolitan reaches of the Brisbane River and the Works Design Office of the Council interpreted these flood profiles in detail to provide a service for those members of the public who enquired of the Council. This service was available to other public authorities had they cared to enquire.

Flood forecasting for the key gauge at the Port Office is carried out jointly by the Bureau of Meteorology and the Flood Control Section of Brisbane City Council. Except for one early forecast at a low flood level which was upset by the unexpected decay of the storm surge, the forecasts were accurate both in time and level.

REFERENCES

1. HEATHERWICK, G. — Flood forecasting and warning, Moreton Region - Proc. Symposium, January 1974 Floods - Moreton Region. Q'ld. Div. I.E.Aust. August, 1974.

2. COSSINS, G. — The Operation of Somerset Dam - a Multipurpose Project. Technical Note No. 92 - Hydrological Forecasting, W.M.O. No. 228. T.P. 122, 1969.

3. COSSINS, G. — Hydrology Without Tears and Other Stories. Q'ld. Div. Technical Papers I.E. Aust. Vol. 10, No. 7 July, 1969.

4. COSSINS, G. — Flood Mitigation in the Brisbane River. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust., August, 1974.

5. WARD, J. K. G. — Hydrology of the Flood. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust. August, 1974.

6. SHIELDS, A. J. — Synoptic Meteorology of the Flood Period. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust., August, 1974.

7. HENDERSON, J. B. — Report on Floods in the Brisbane River and Schemes for the Abatement of their Disastrous Effects. Government Printer, Brisbane, 1896.

8. PENNYCUICK, J. — Report on Schemes for the Abatement of Floods in the Brisbane River. Government Printer, Brisbane, 1899.

9. GUTTERIDGE, A. G. — Report of Commission of Enquiry, Brisbane Water Supply, Government Printer, Brisbane, 1928.

10. BUSH, W. E. — Report on Water Supply Extensions and Flood Mitigation. Brisbane City Council, 1930.

11. BUREAU OF INDUSTRY SPECIAL COMMITTEE — Report on Recommendations - Brisbane Water Supply and Flood Prevention. Government Printer, Brisbane, 1934.

12. PIGGOTT, T. L. — Some Factors Affecting the Forecasting of Floods at Brisbane. Civ. Eng. Trans. I.E. Aust. Vol. C.E.8, No. 1 April 1966 p.p. 47-59.

13. MORRIS, K. J. Flood Mitigation in Breakfast Creek. Proc. Symposium, January 1974 Floods - Moreton Region, Q'ld. Div. I.E. Aust. August, 1974.

BRISBANE RIVER CATCHMENT

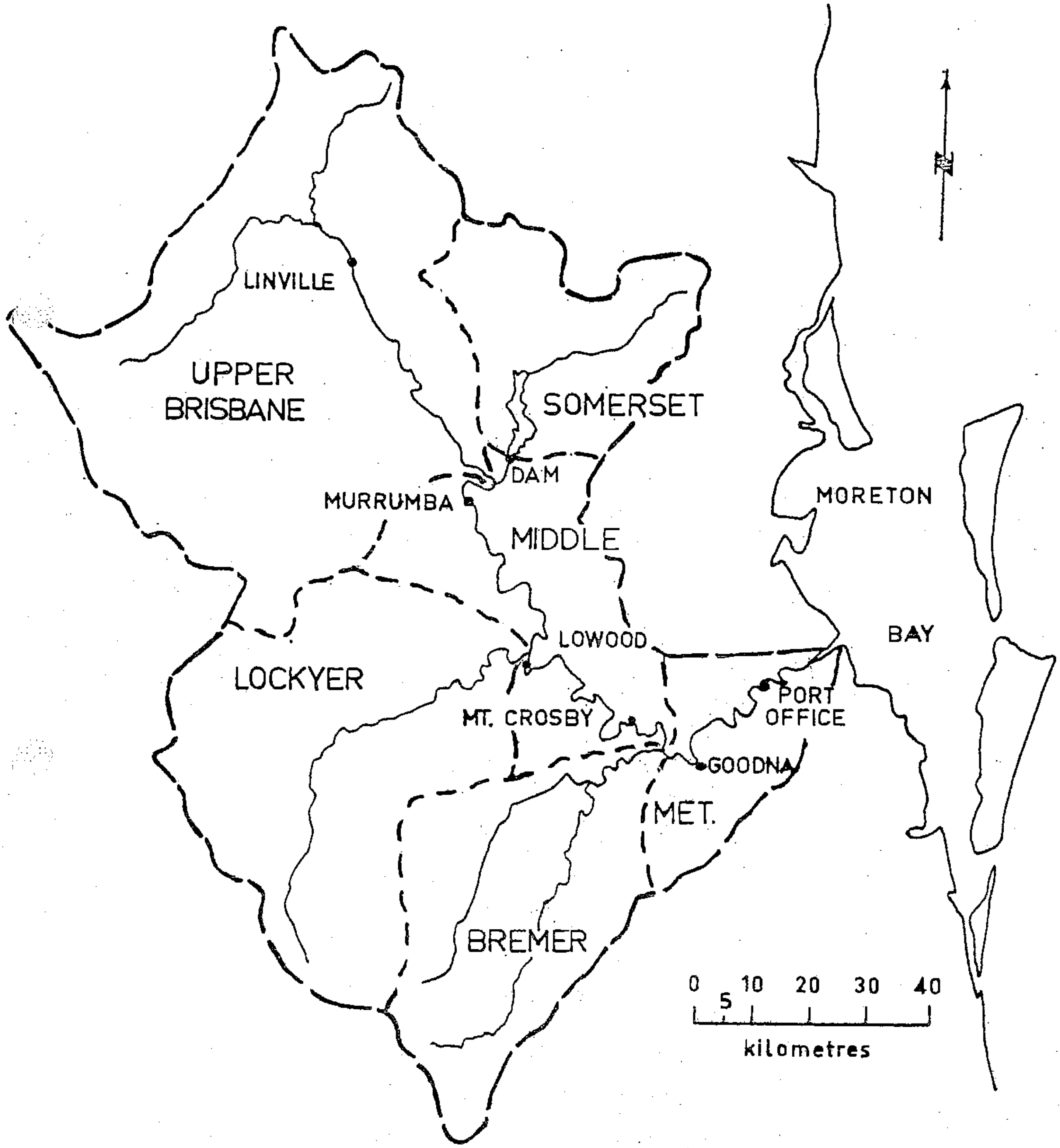


FIG. 1

PEAK STAGE RELATIONSHIPS

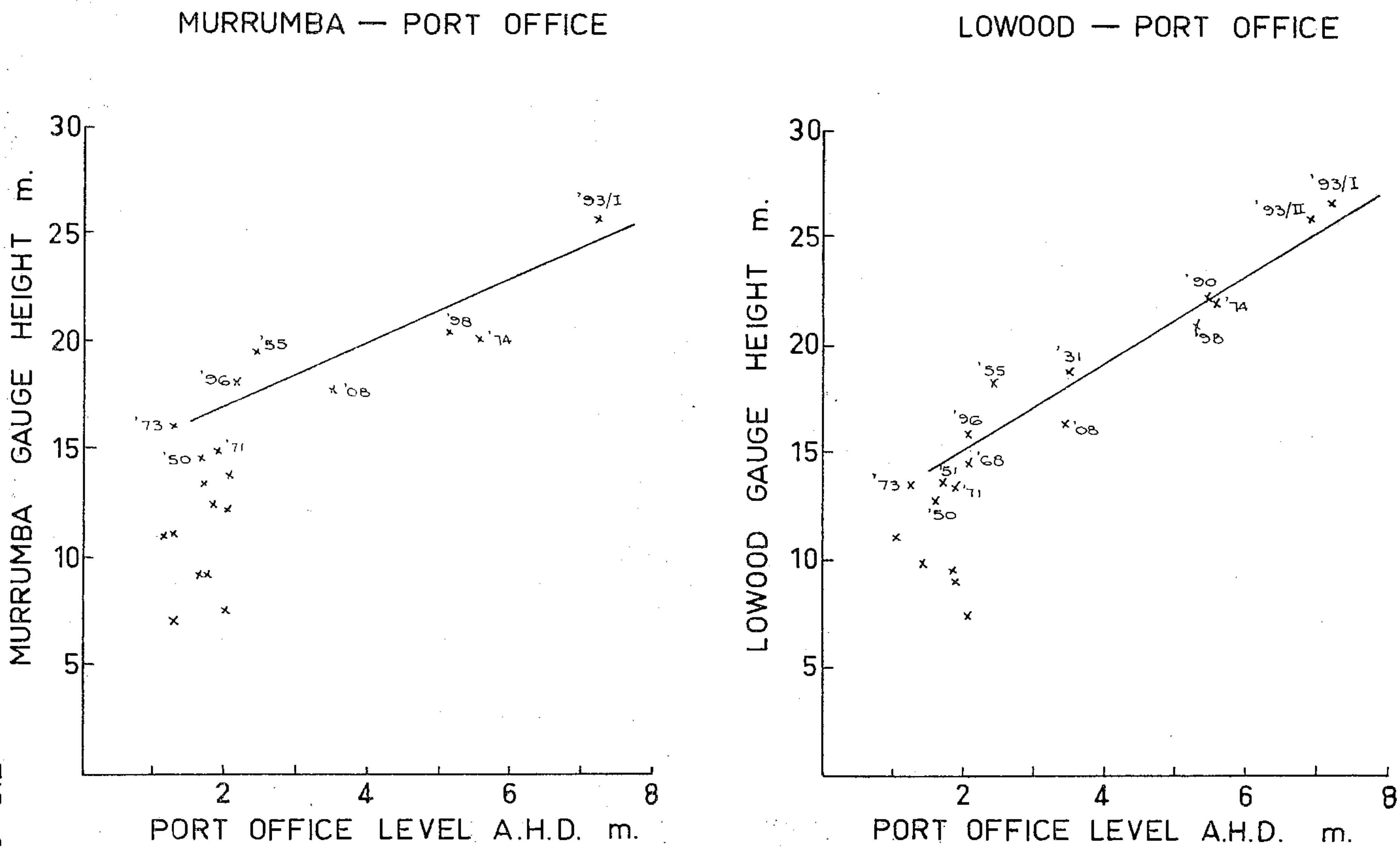


FIG. 2

PEAK STAGE RELATIONSHIP

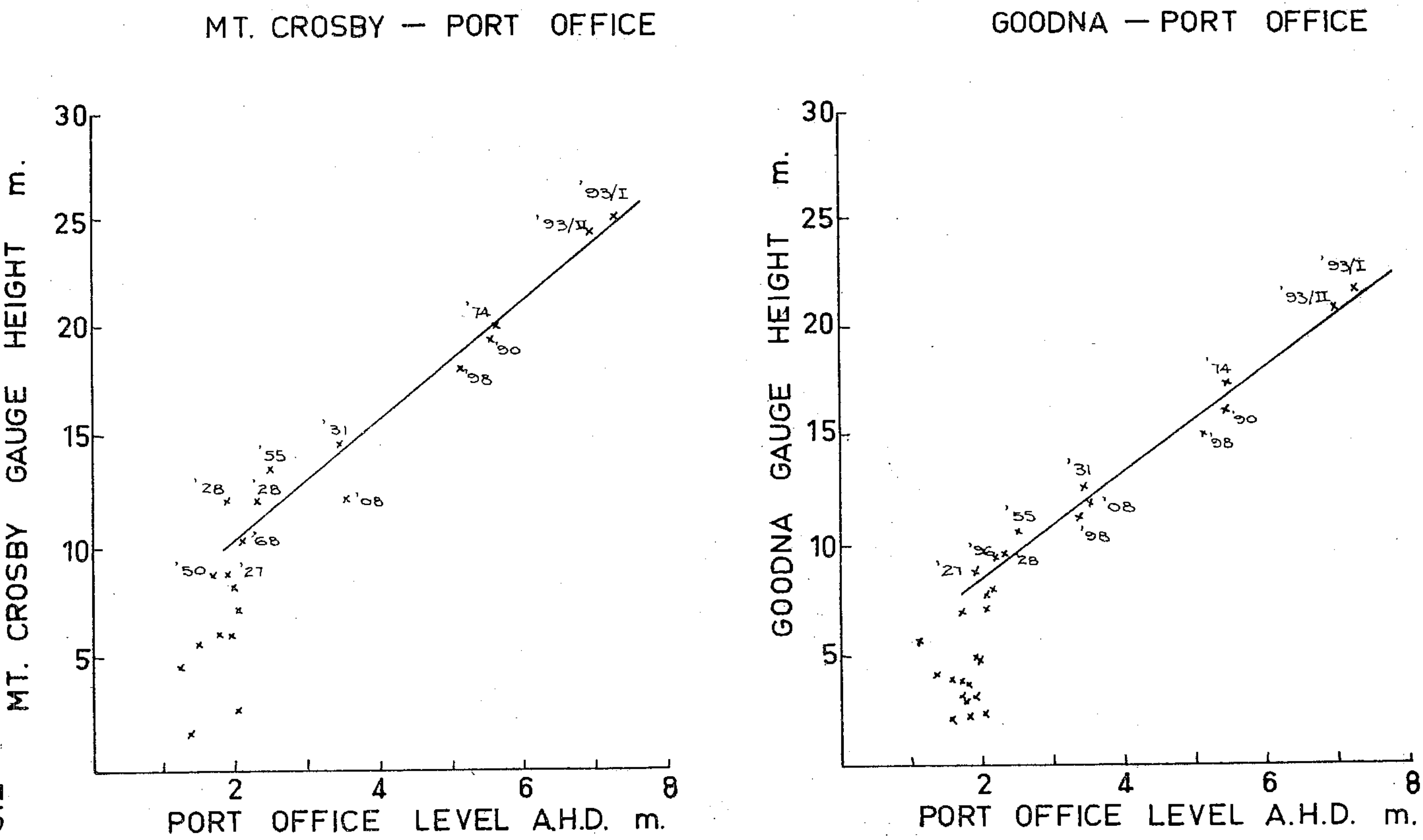


FIG. 3

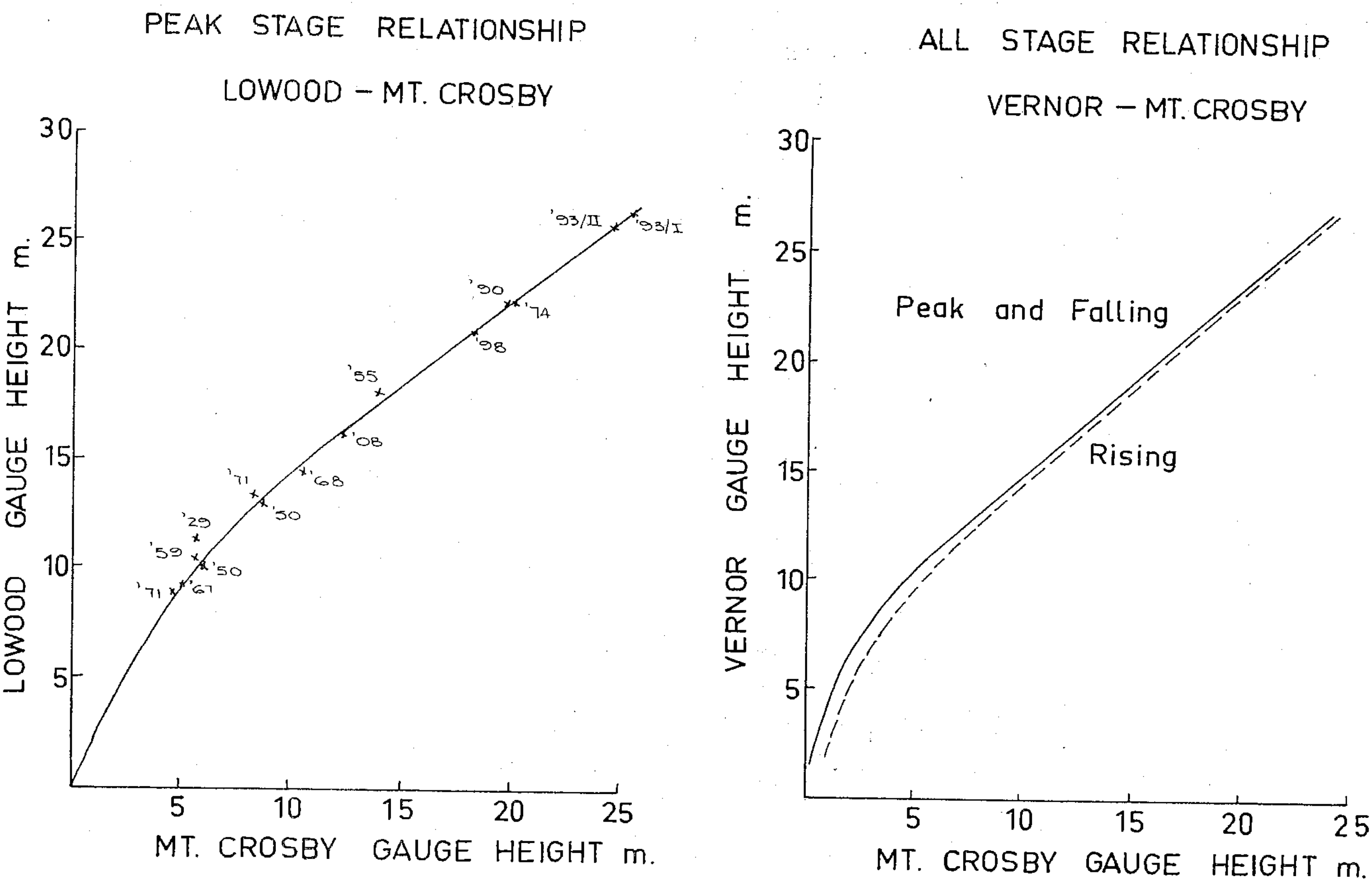
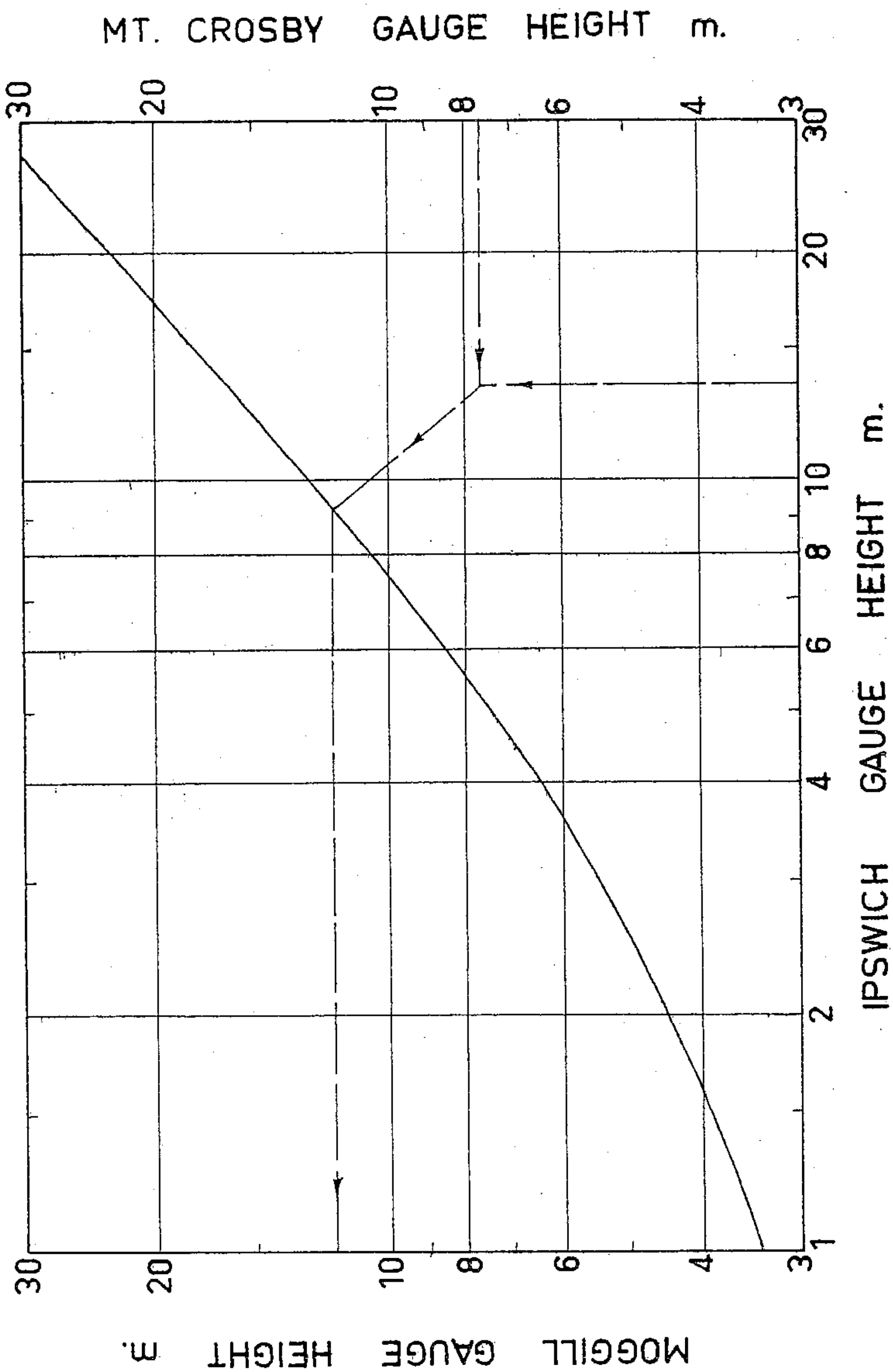

PEAK STAGE RELATIONSHIP
LOWOOD – MT. CROSBY
LOWOOD GAUGE HEIGHT m.
MT. CROSBY GAUGE HEIGHT m.
ALL STAGE RELATIONSHIP
VERNOR – MT. CROSBY
VERNOR GAUGE HEIGHT m.
Peak and Falling
Rising
MT. CROSBY GAUGE HEIGHT m.

FIG. 4



MT. CROSBY GAUGE HEIGHT m.
IPSWICH GAUGE HEIGHT m.
MOGGILL GAUGE HEIGHT m.
30
20
10
8
6
4
3
2
1

FIG. 5

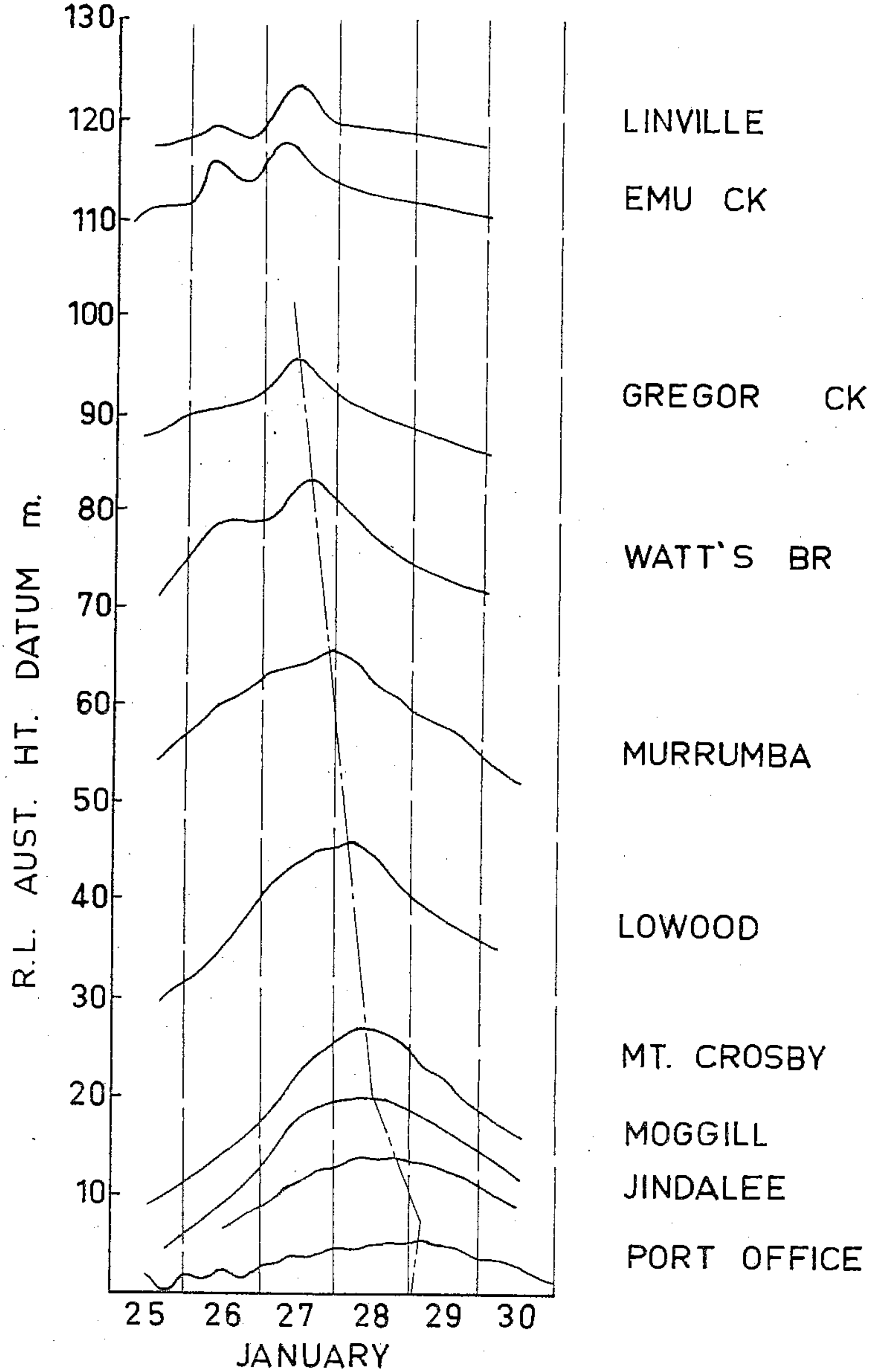

130
120
110
100
90
80
70
60
50
40
30
20
10
R.L. AUST. HT. DATUM m.
25
26
27
28
29
30
JANUARY
LINVILLE
EMU CK
GREGOR CK
WATT'S BR
MURRUMBA
LOWOOD
MT. CROSBY
MOGGILL
JINDALEE
PORT OFFICE

FIG. 6

BRISBANE RIVER CATCHMENT
FLOOD GAUGES AND RECORDER STATIONS

FIG. 7

BRISBANE RIVER CATCHMENT
RAINFALL STATIONS

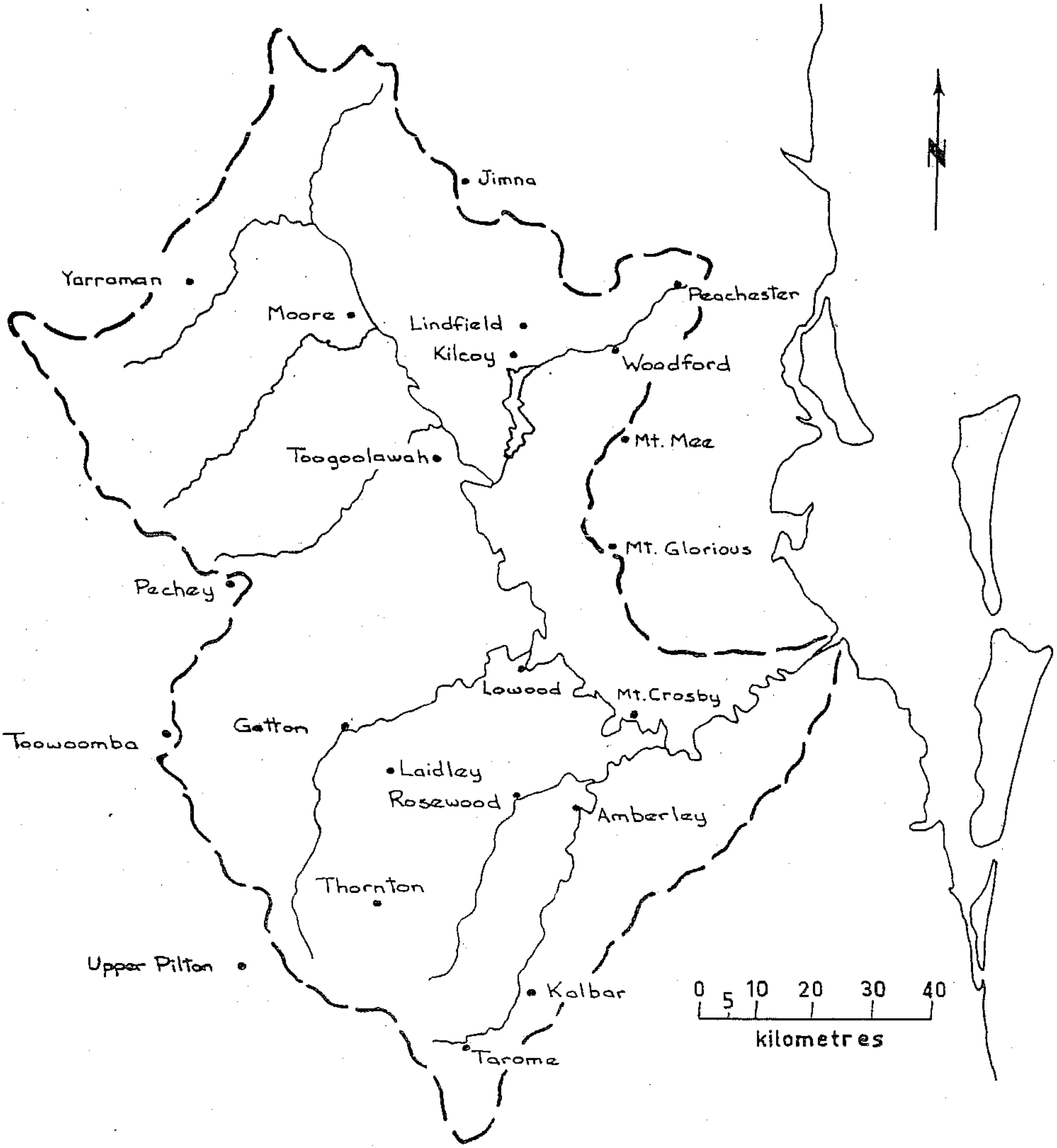


FIG. 8

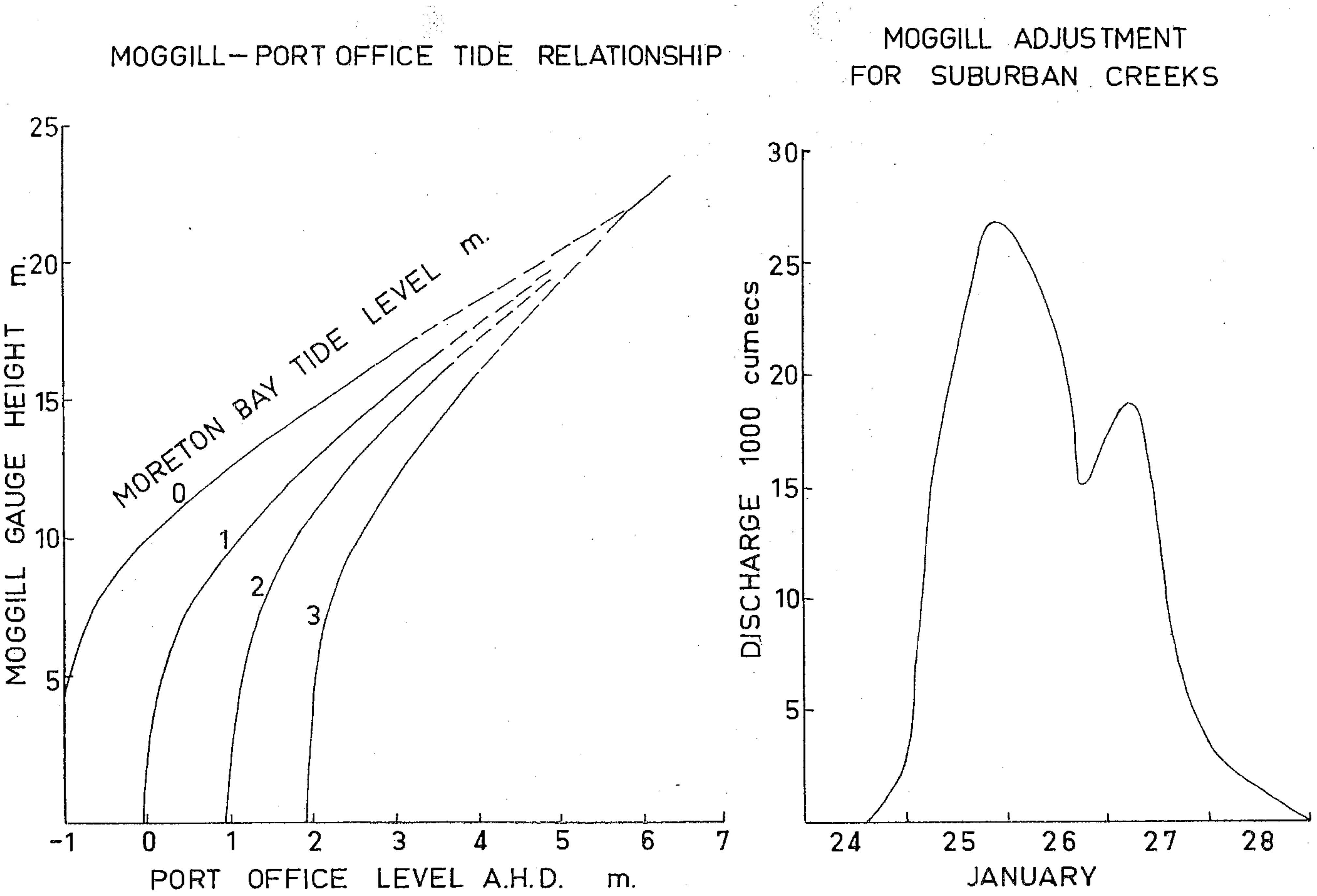

MOGGILL – PORT OFFICE TIDE RELATIONSHIP
MOGGILL GAUGE HEIGHT m.
25
20
15
10
5
MORETON BAY TIDE LEVEL m.
0
1
2
3
-1
0
1
2
3
4
5
6
7
PORT OFFICE LEVEL A.H.D. m.
MOGGILL ADJUSTMENT FOR SUBURBAN CREEKS
DISCHARGE 1000 cumecs
30
25
20
15
10
5
24
25
26
27
28
JANUARY

FIG. 9

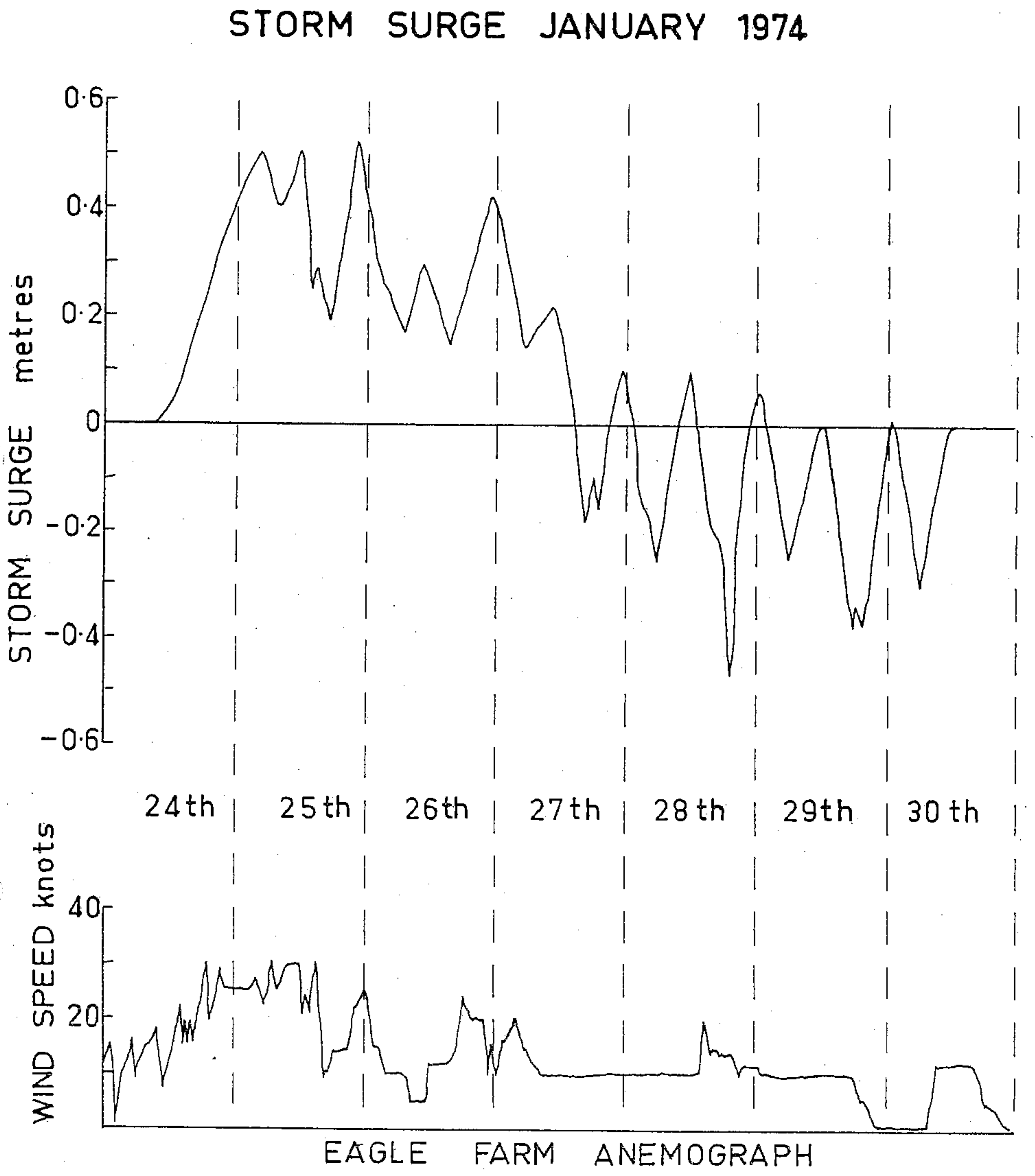

STORM SURGE JANUARY 1974
STORM SURGE metres
0·6
0·4
0·2
0
-0·2
-0·4
-0·6
24th
25th
26th
27th
28th
29th
30th
WIND SPEED knots
40
20
EAGLE FARM ANEMOGRAPH

FIG. 10

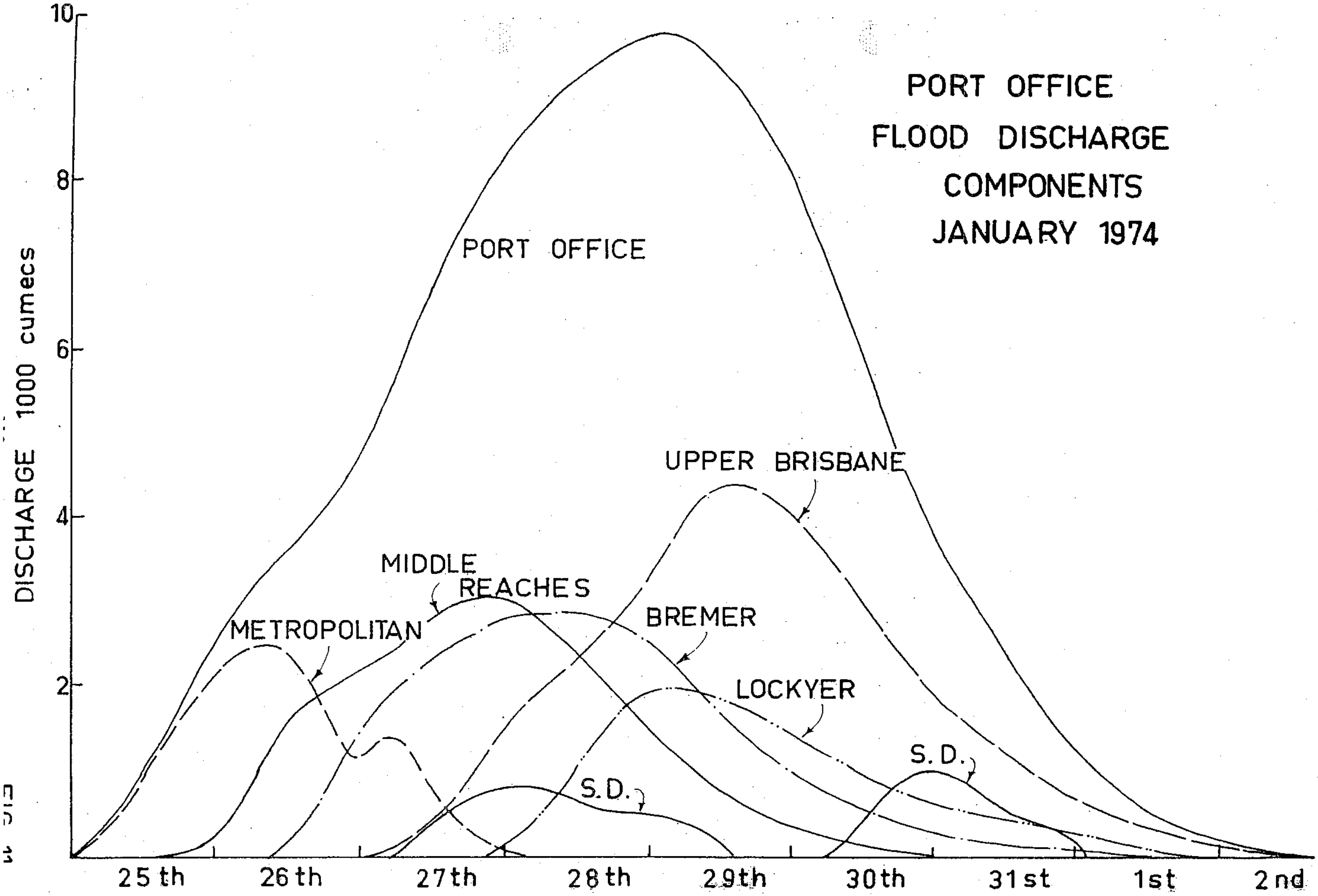

PORT OFFICE
FLOOD DISCHARGE
COMPONENTS
JANUARY 1974
PORT OFFICE
UPPER BRISBANE
MIDDLE
REACHES
METROPOLITAN
BREMER
LOCKYER
S.D.
S.D.
DISCHARGE 1000 cumecs
10
8
6
4
2
25 th
26 th
27th
28th
29th
30th
31st
1st
2nd

FIG. 11

BRISBANE FLOOD HYDROGRAPHS

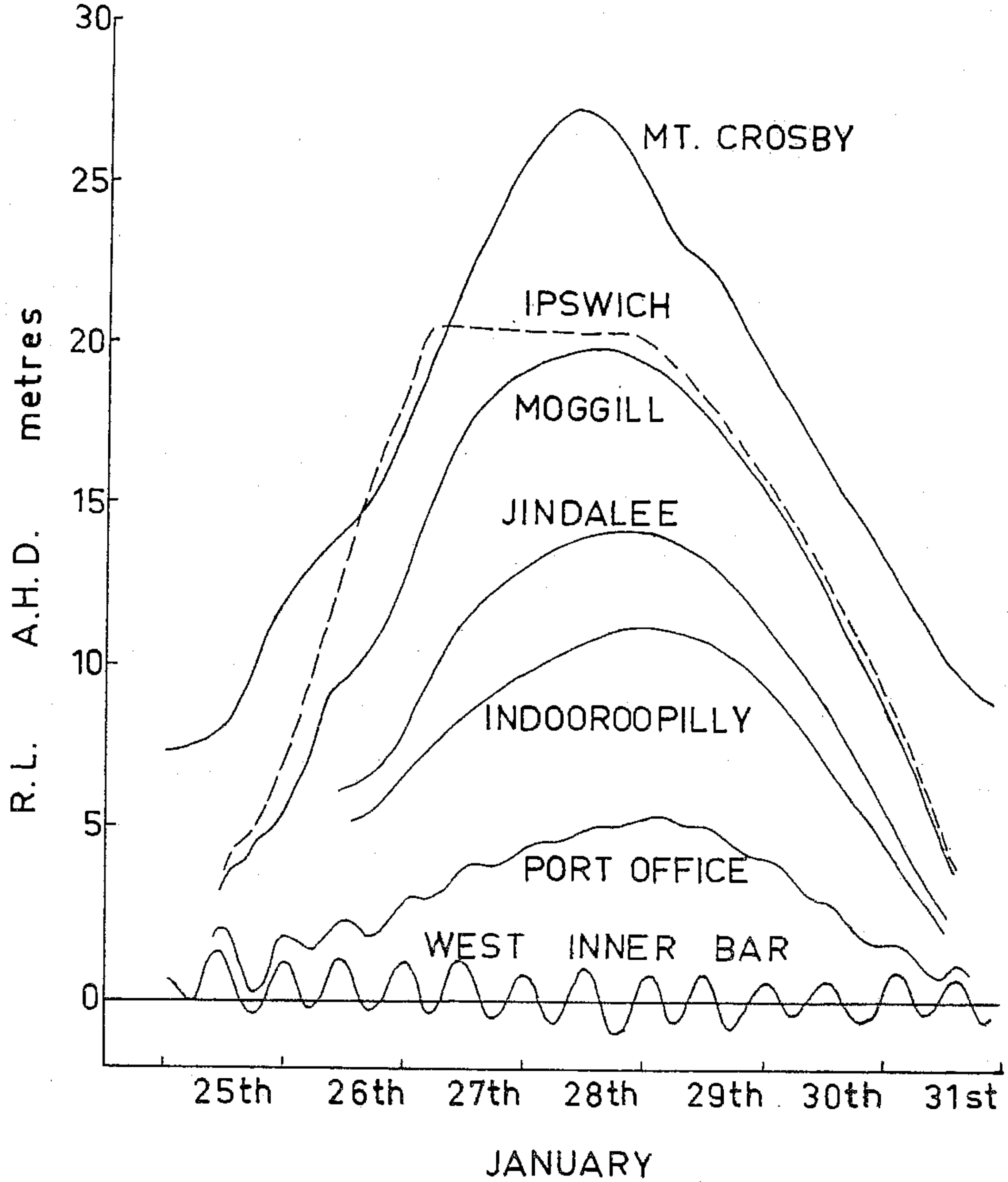


FIG. 12

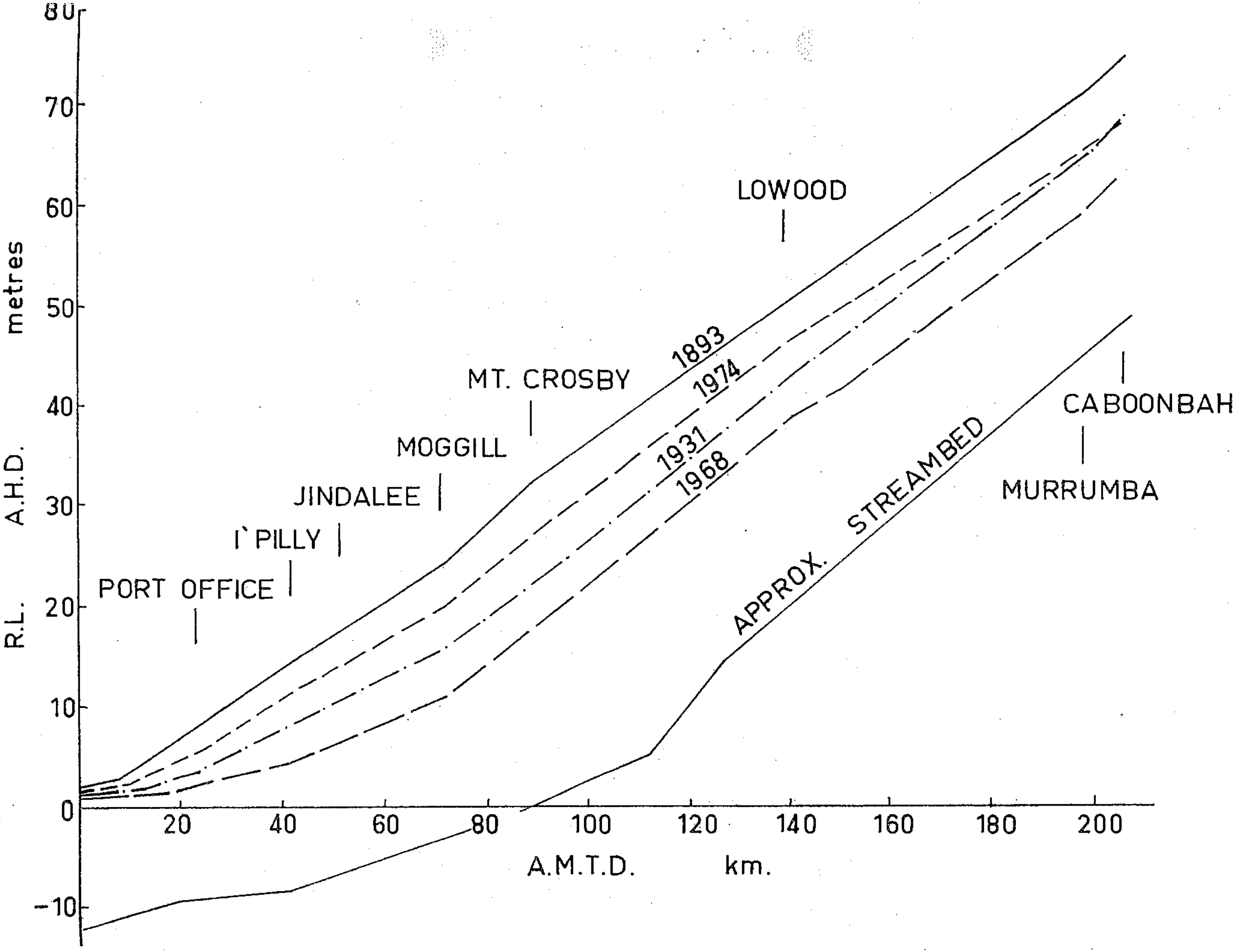

R.L. A.H.D. metres
80
70
60
50
40
30
20
10
0
-10
20
40
60
80
100
120
140
160
180
200
A.M.T.D. km.
PORT OFFICE
I`PILLY
JINDALEE
MOGGILL
MT. CROSBY
LOWOOD
MURRUMBA
CABOONBAH
1893
1974
1931
1968
APPROX. STREAMBED

FIG. 13

JANUARY 1974 FLOOD
PREDICTED PROFILES
(FALLING)

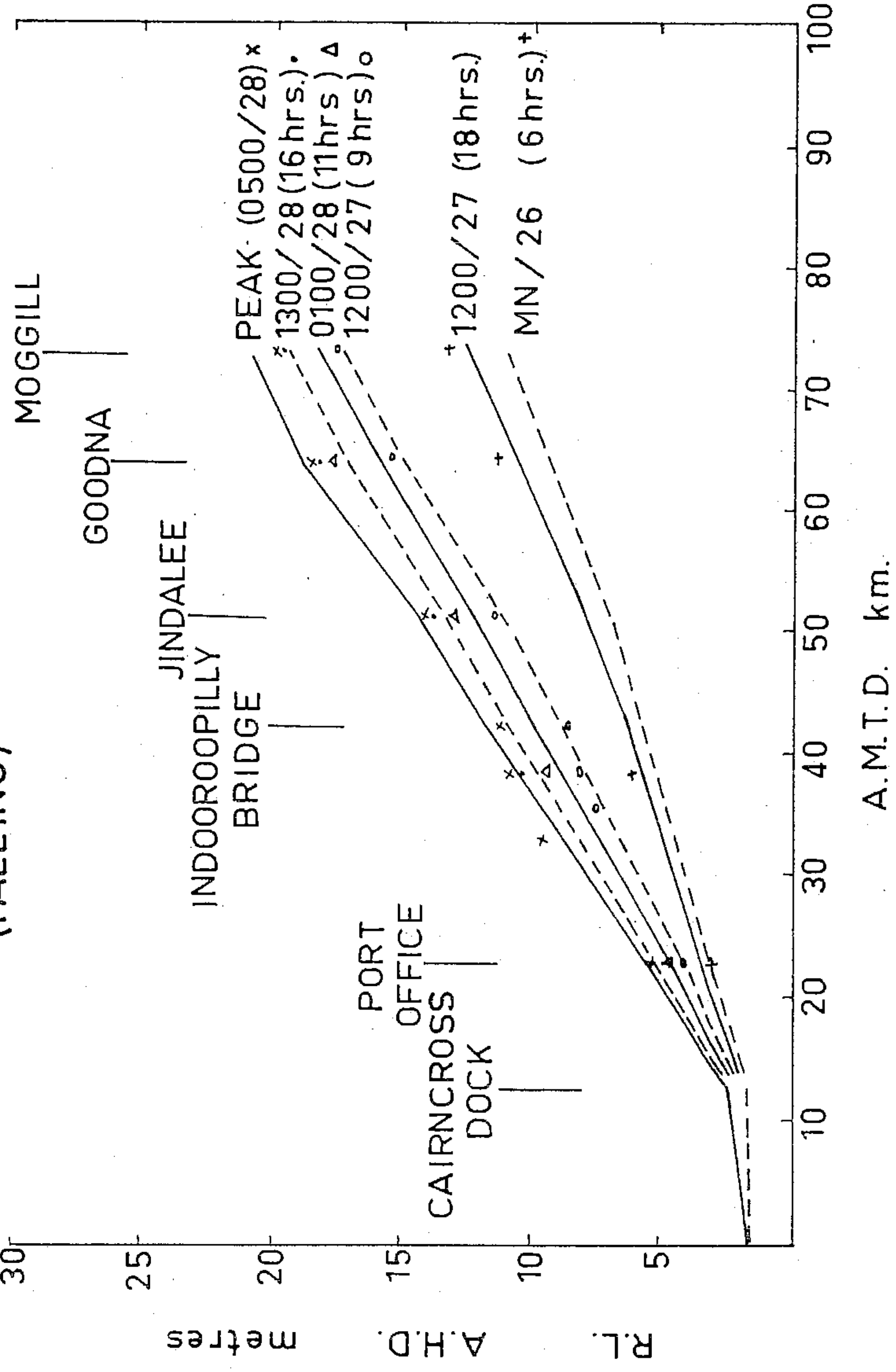


FIG. 14

JANUARY 1974 FLOOD PREDICTED PROFILES (FALLING)

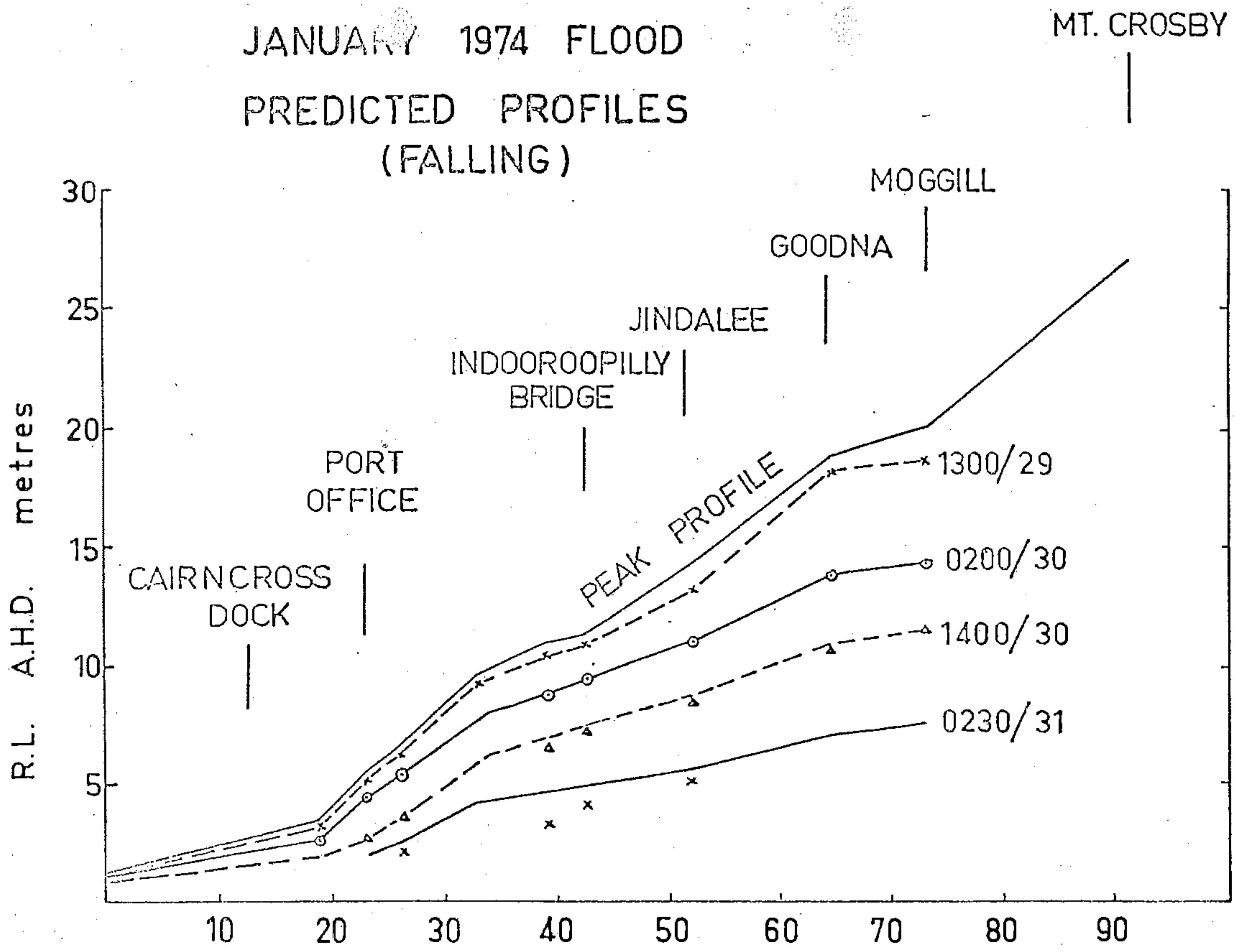
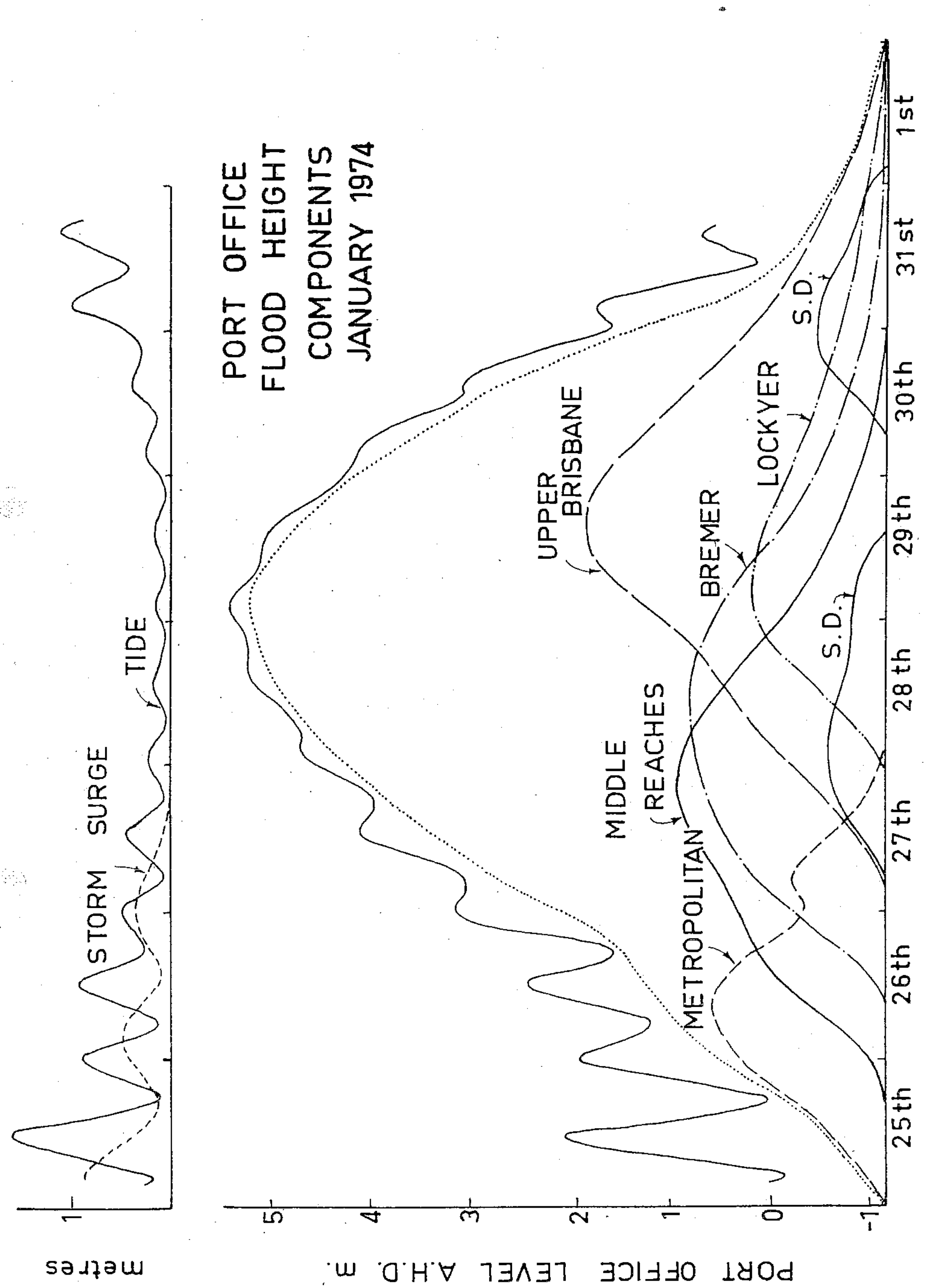
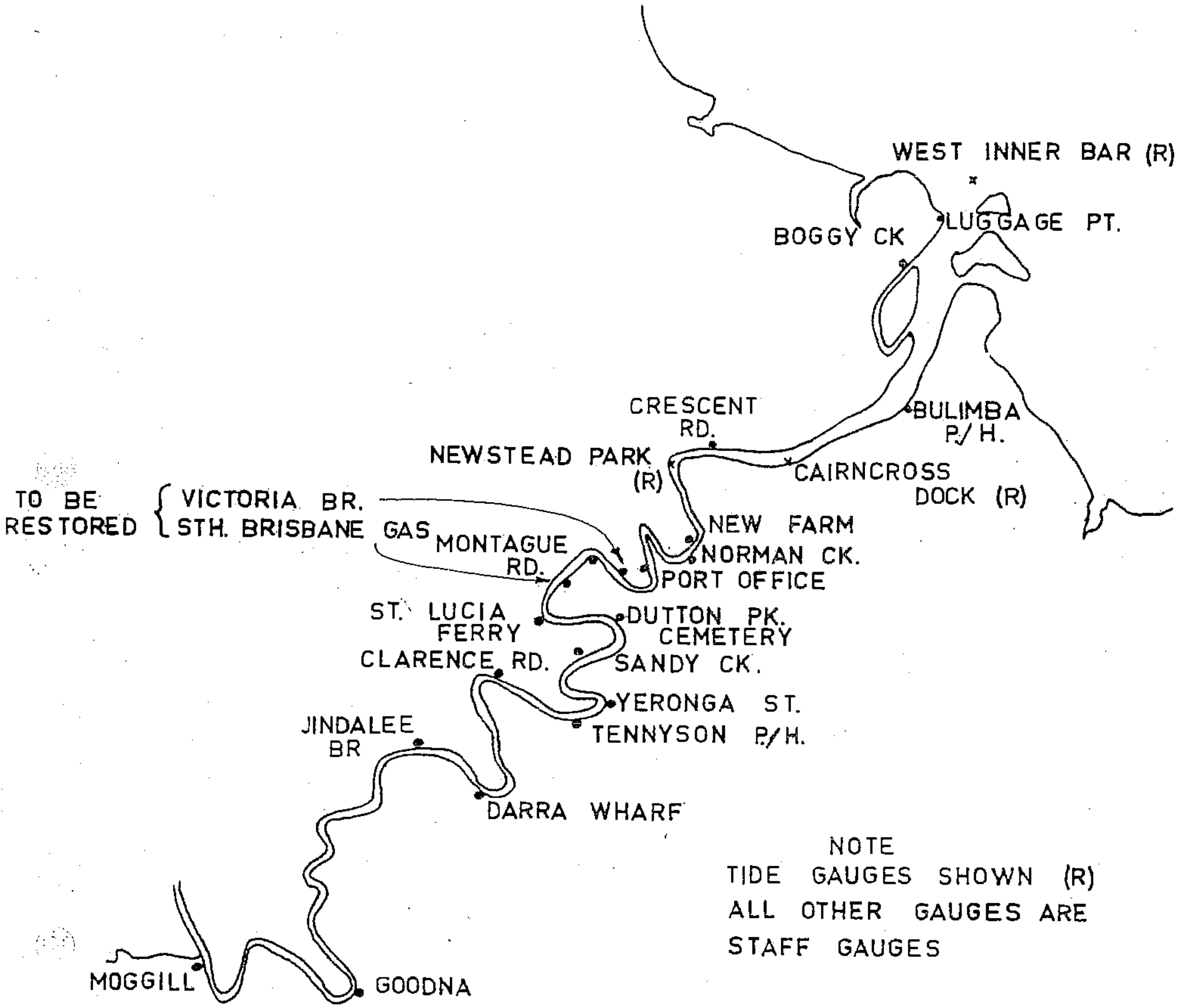


FIG. 15



PORT OFFICE
FLOOD HEIGHT
COMPONENTS
JANUARY 1974
STORM SURGE
TIDE
UPPER BRISBANE
BREMER
LOCKYER
MIDDLE REACHES
METROPOLITAN
S.D.
S.D.
S.D.
25th
26th
27th
28th
29th
30th
31st
1st
metres
1
PORT OFFICE LEVEL A.H.D. m.
5
4
3
2
1
0
-1

FIG. 16



METROPOLITAN RIVER GAUGES

FIG. 17

CAIRNCROSS DOCK TIDE CHART

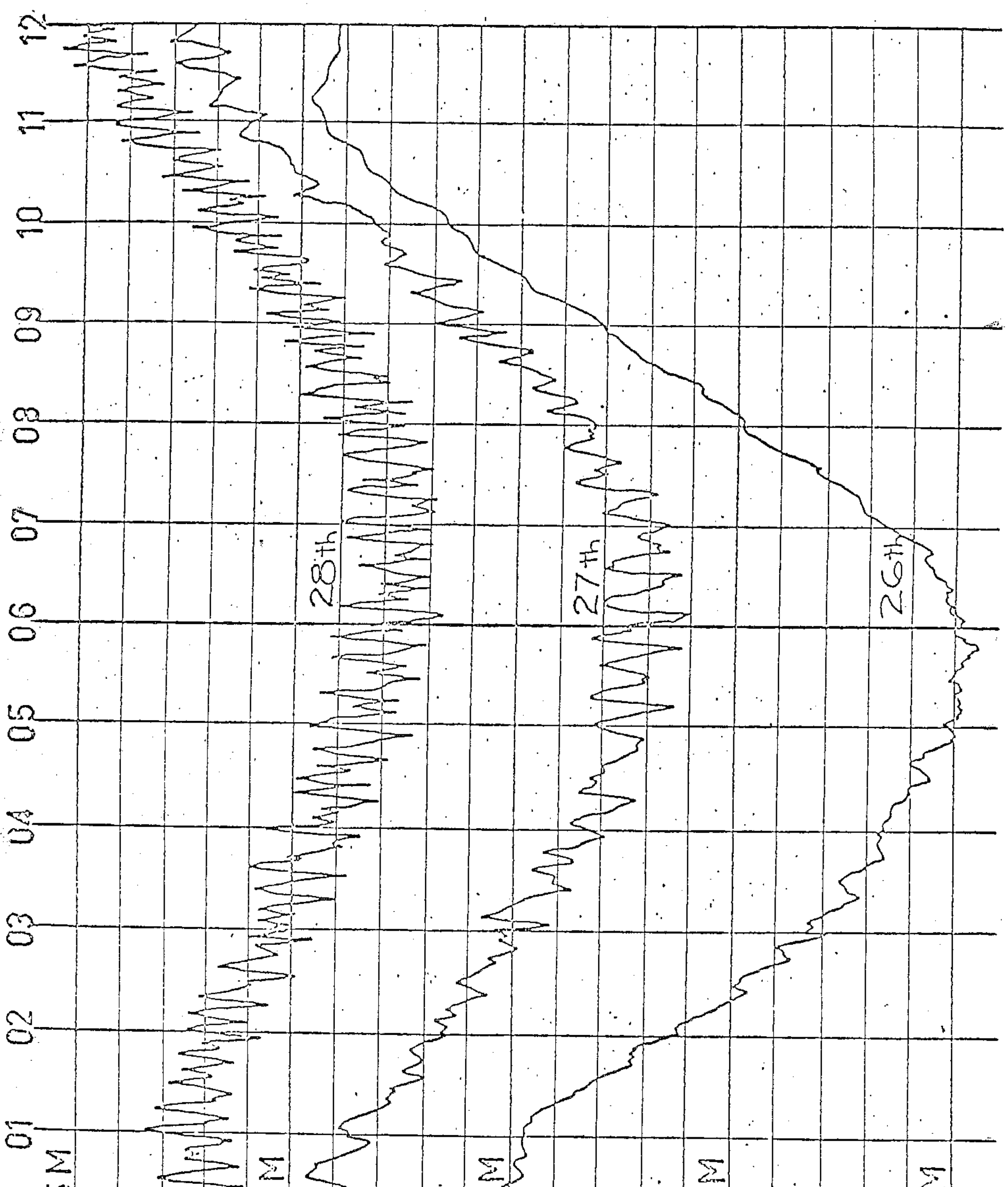


FIG.18

ACTUAL AND SIMULATED FLOOD PROFILES

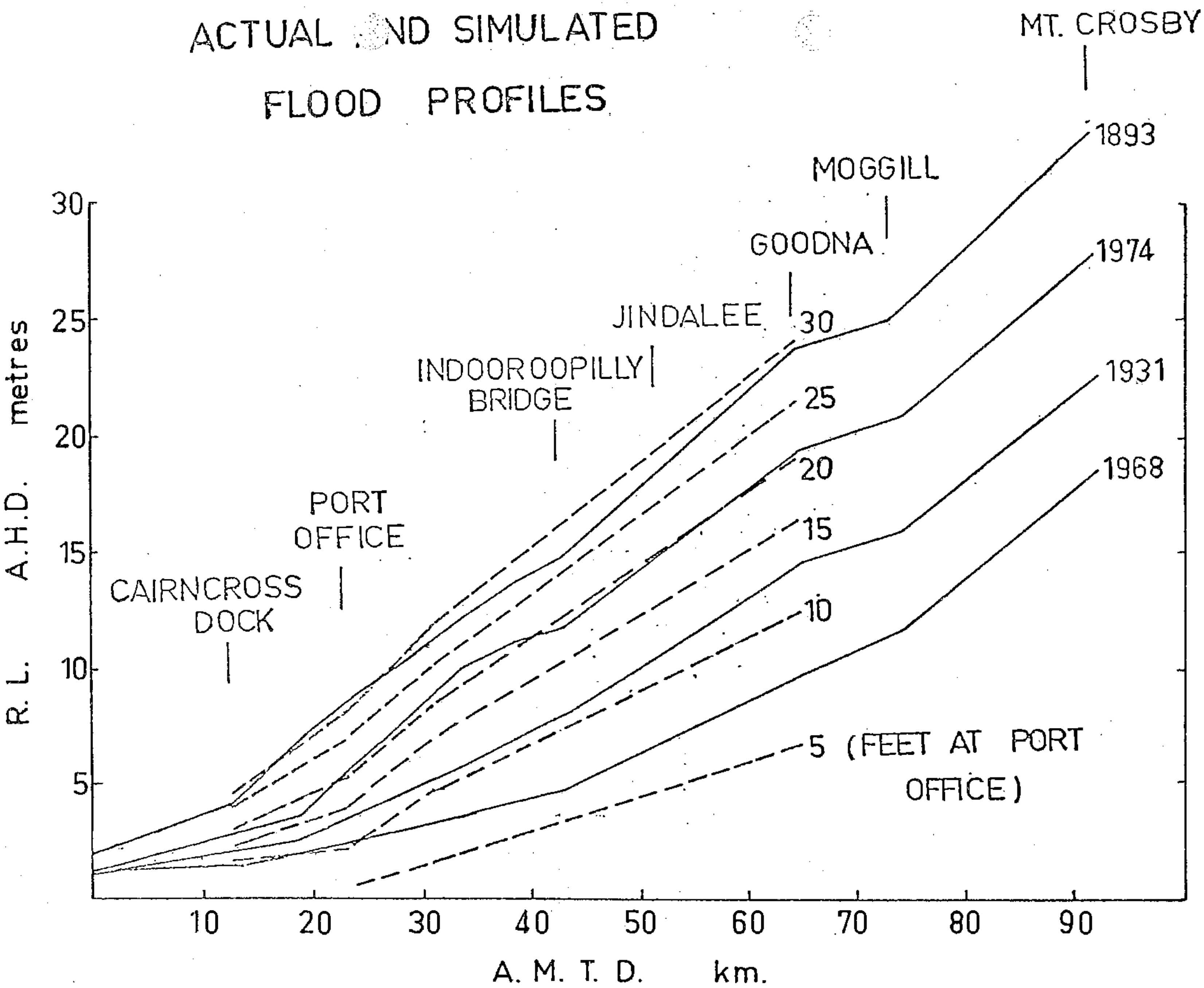


FIG. 19

ACTUAL AND SIMULATED FLOOD PROFILES

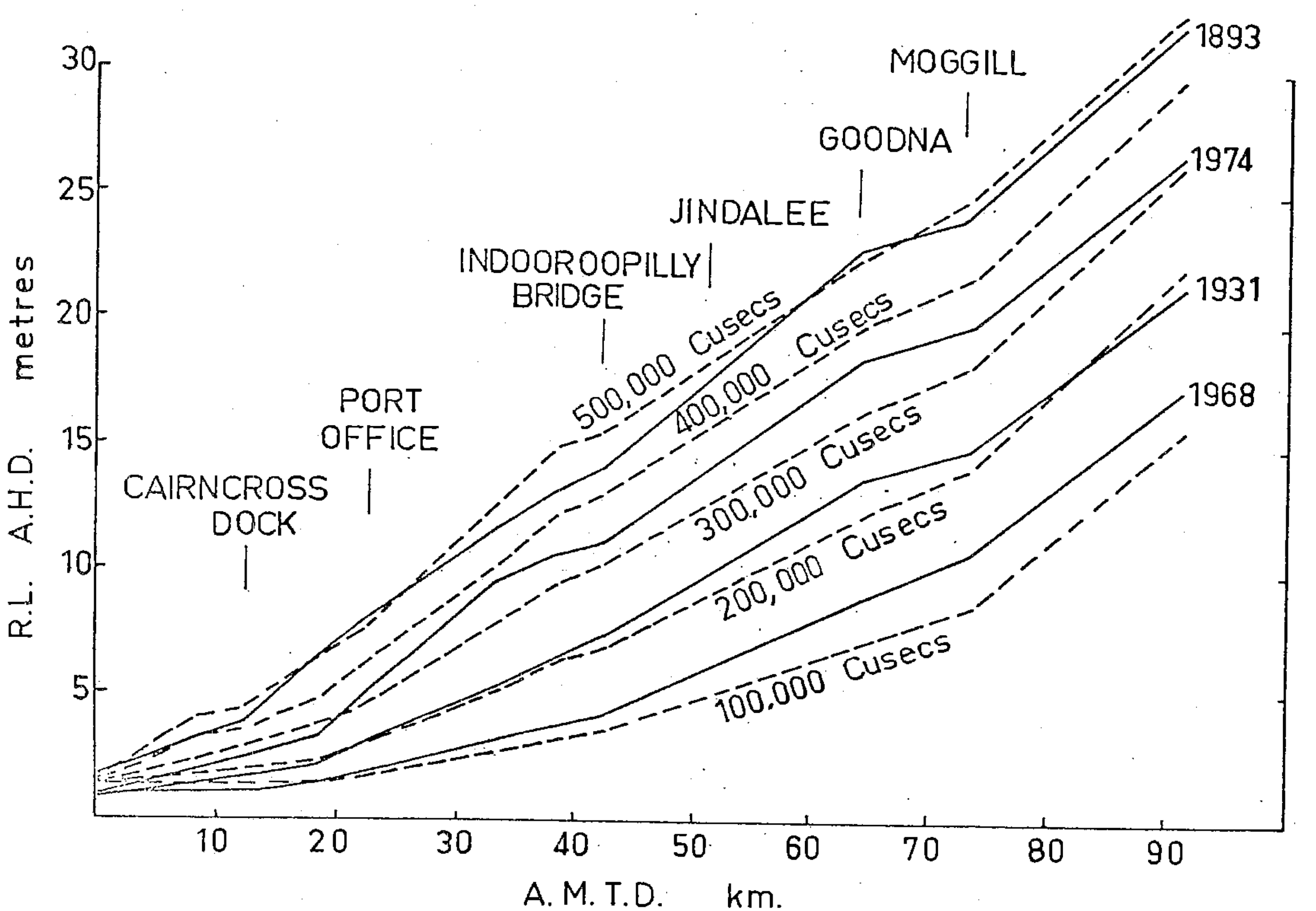


FIG. 20

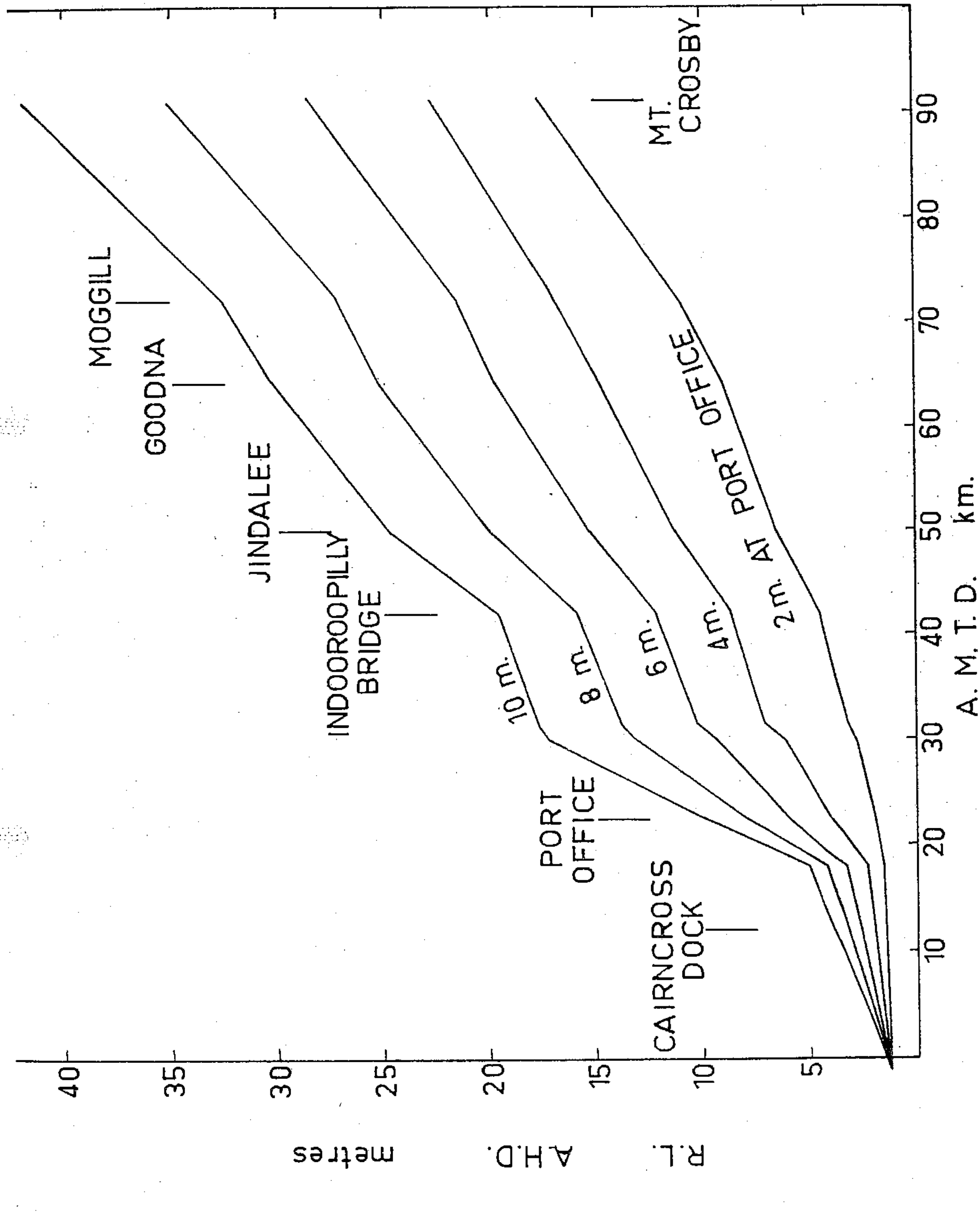
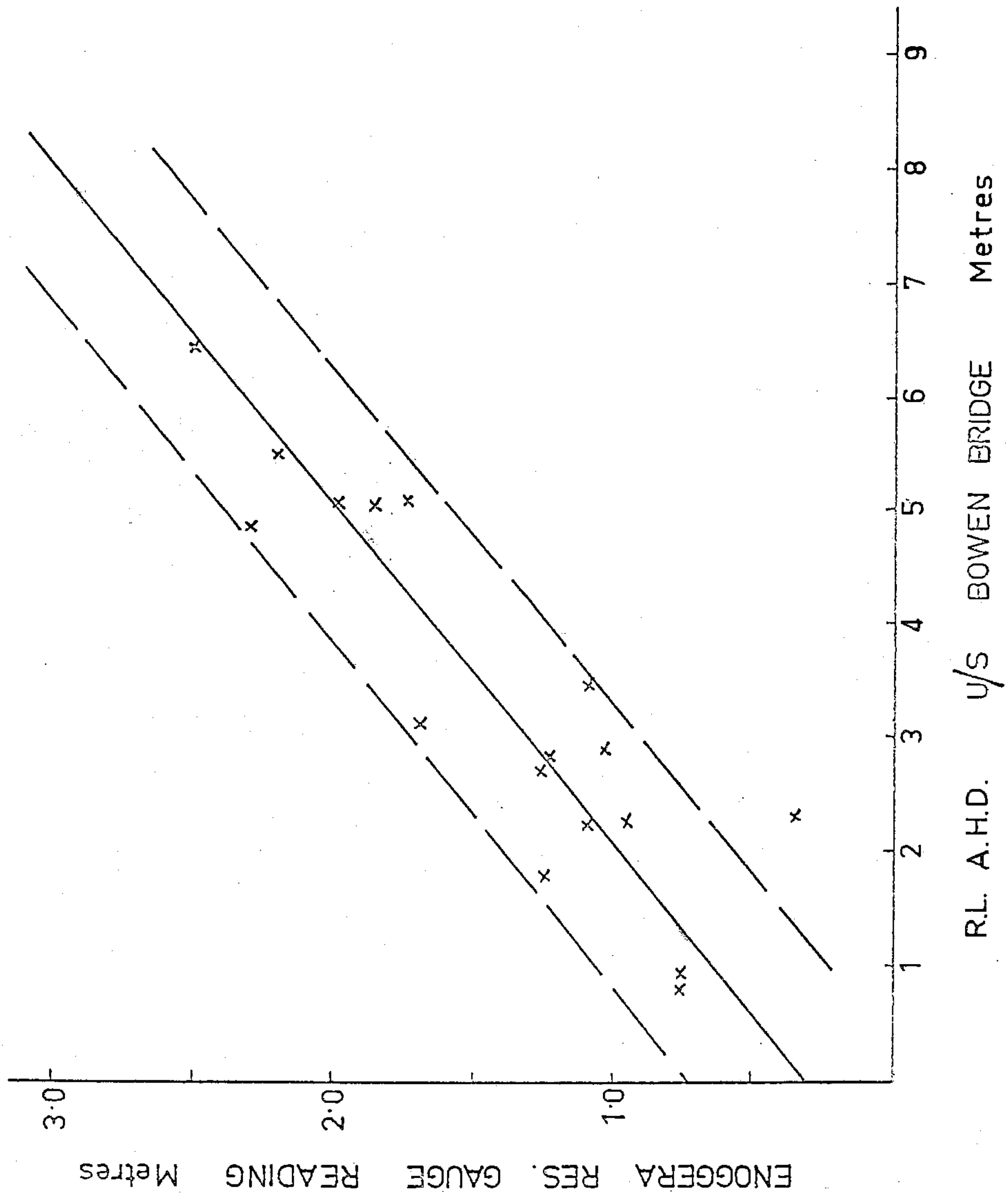

MOGGILL
GOODNA
JINDALEE
INDOOROOPILLY BRIDGE
PORT OFFICE
CAIRNCROSS DOCK
MT. CROSBY
10 m.
8 m.
6 m.
4 m.
2 m. AT PORT OFFICE
R.L. A.H.D. metres
40
35
30
25
20
15
10
5
10
20
30
40
50
60
70
80
90
A. M. T. D. km.

FIG. 21



R.L. A.H.D. U/S BOWEN BRIDGE Metres
1
2
3
4
5
6
7
8
9
ENOGGERA RES. GAUGE READING Metres
1·0
2·0
3·0

FIG. 22

DISCUSSION

R. F. Gamble M.I.E. Aust.

The writer congratulates the previous two authors on the comprehensive papers presented. The fields that these two gentlemen have covered are indeed of major significance to the people residing in the Moreton Region particularly to those residing in close proximity to the river systems contained therein.

Regarding Mr. Heatherwick's apology concerning the inaccuracy of the forecasts made for Ipswich in the flood, I have to reassure him that the Council is not distressed and we will be looking to his assistance in the next flood situation.

Mr. Cossins has demonstrated the records and data which have been collected by Brisbane City Council in the past and the accuracies in forecasting achieved from this information. Ipswich without a doubt wishes that it possessed but a portion of this information.

Having worked with these authors during periods of stress and strain when floods were upon us, the writer knows that they understand their subject very well and the issues covered in the papers represent only a portion of their knowledge of the subject under discussion.

People have said in the past that Ipswich in certain respects is a "problem child". There is no doubt that this was proven correct during the flood following "Wanda". The general lack of records and data for the Bremer River and associated tributaries gave cause for considerable concern in Ipswich.

As a result of 200mm of rain on Thursday night and on Friday, severe flooding, which rose to some 3½ metres above the recorded 1967 and 1971 floods, was experienced throughout the suburban creeks of Ipswich. A further 250mm of rain on Saturday caused a second peak in the suburban streams and a dramatic rise in the Bremer River which eventually led to the local streams being backed up by the Bremer River.

The Bremer River reached a peak on the Ipswich town gauge at 8 a.m. Saturday and remained at this peak for 30 hours until 2 p.m. Monday.

In the period leading up to the peak, the Bremer River destroyed 41 dwellings, completely submerged 620 and caused moderate to heavy damage to a further 974. An additional 200 dwellings, industrial installations and commercial enterprises were partially or completely inundated.

It has been assessed that the Bremer River reached a peak level of 0.3m above the 1893 level at the One Mile Bridge at Leichhardt to the west of the City and 3.8m below the 1893 level at the Town Gauge.

At Goodna, at the eastern end of the City, the flood was 4.9m below the 1893 flood level.

Of particular concern to the technical members of the Flood Control Centre of the Ipswich City Council is the issue which was raised by Mr. Heatherwick with regard to forecasting. Ipswich can be subjected to several types of flooding. In the past, three types have been recognised as major problems, these being, a Brisbane River flood with back up to Ipswich, a Bremer River flood or a combination of the two rivers in flood. The fact that the rain received in Ipswich was confined fairly close to the lower part of the Bremer and tributary catchments has shown that local streams play a significant part.

The authors are requested to answer the following questions:-

1. To Mr. Cossins -

Taking due account of the complexity of the type of flood situation which can be experienced in the Ipswich City area and the concise information held by Brisbane City Council on the Brisbane River, is it possible to extend the Brisbane information to the Ipswich area?

2. To Messrs. Cossins & Heatherwick -

With regard to flash flooding in the local streams and also forecasting for the Bremer River, is it considered that a regional network of pluviometers could be installed as a matter of urgency and would this network together with suitably sited flood gauges assist in the general management associated with flood forecasting?

3. To Mr. Heatherwick -

Taking due account that past data and records have been collected based on official gauges at Rosewood and Harrisville and the relatively short time of concentration from these centres to Ipswich, is it felt that the unitgraphs which have been developed by the Weather Bureau will assist in forecasting for the Ipswich area?

Directed to G. Heatherwick -

N. M. Ashkanasy B.E. M.Eng.Sc. M.I.E. Aust.:

It seems to me that the Bureau of Meteorology is deluding both itself and the public in attempting to predict specific flood heights at specific times in the future. Of course it is logically impossible to exactly predict any future event. The accepted scientific technique is to indicate a statistically evaluated range of expected values at a certain level of confidence. There are a number of well recognised methods for evaluating the, say, 95% and 99% confidence limits of expectation for predictions based on past knowledge and experience. Clearly the most realistic prediction would be the 95% and 99% confidence limit of expected values.

Does Mr. Heatherwick agree? Is he aware of these techniques? Is data available for such estimation? If so, why aren't predictions made on this basis? If not, why not?

J. Church B.Sc.:

It seems your initial Brisbane River predictions were out because of poor surge data. What surge data are available? What additions are contemplated? For example Meteorological Stations and tide gauges in Moreton Bay. What studies on surges are contemplated to improve these predictions?

K. Morris B.E. M.I.E. Aust.:

I have found in analysing rainfall records for some 20 flood events in Enoggera Creek that reasonable correlation between the volume of rain that fell during a storm event and peak flow existed. The volume of rain was totalled for durations far in excess of the time of concentration for the creek and that no reasonable correlation existed for intensities and/or the time in which the rain fell. Addition time of rainfall started and ended when the rainfall fell below a nominal rate (10 points/15 minute period). I have also heard of similar correlations in various rivers.

Can you comment on this method and its obvious advantages in flood forecasting?

Regarding the problems of joining the various creeks and rivers to find a cumulative flood flow and height, has any thought been given to setting up a mathematical model of the Brisbane River system?

Directed to G. Cossins

R. J. Gourlay:

Marigrams show that 41 storm surges have occurred at the Brisbane Bar from 1886 to 1972. With one exception (February 1934) they display the characteristics of forerunners rather than surges, having a gradual change in water level beginning several hours before the arrival of the storm, with an increase to peak height and subsequent decay maintained for several tidal oscillations. The forerunner, discussed by Hill M.N. (The Sea Vol. 1, 1962) is the first of three possible successive stages, i.e. the forerunner, cyclone surge and resurgence.

Where the storm was a maritime tropical cyclone, the peak occurred near the time of closest approach in the case of "down coast" cyclones, or at landfall for those crossing the coast. However two extra-tropical systems crossed from New South Wales to the Tasman Sea and generated surges which increased in height as their centres moved away to the east.

The writer therefore concludes that the latter two were internal and due solely to wind stress on Moreton Bay, while the former were external and due to surges entering from the open sea where the generation area is many orders greater.

Sufficient data are now available to develop a method to predict the time and height of peak surge on the Bar in the event of the approach of a mature, maritime tropical cyclone, (the general case).

"Wanda" was atypical in that the peak storm surge occurred more than a day after it crossed the coast and in this regard is analogous to the two extra-tropical cyclones mentioned previously; i.e. the surge height increased with the cyclone's departure; resurgences associated with the tidal oscillations are also significant.

A preliminary examination seems to indicate that variability in the Eagle Farm anemograph is reflected in the storm surge derived from West Inner Bar Marigrams for the period in question. Factors to be considered should include the lag due to response (probably variable and non-linear), reduction to surface from anemometer head, and the changing roughness. It is felt that this case represents the rare and more difficult type to contend with because, should this perturbation prove to be sensitive to the short period with wind fluctuations, it will present a problem which does not obtain with the general case.

At 6 a.m. February 6th, the West Inner Bar storm surge peaked at (0.7m), on the rising limb of H.H.W.S. tide, following a gradual rise over the preceding 12 hours as cyclone "Pam" closed on Cape Moreton to bear E.S.E. at 600 km; subsequently the surge decayed at a regular note as "Pam" moved away to the south. This pattern is reminiscent of previous mature tropical cyclones but quite different from the "Wanda" experience.

The quoting of the 1899 Bathurst Bay surge as 10 metres is interesting and an improvement on some that have offered more than 12 metres. However, the literature nowhere suggests that storm surges of this order have elsewhere been recorded or reported. Consideration of the wavelengths involved and the generating mechanism may well require some cut-off level for storm surge peaks. In 1918 Mackay had a storm surge of 3.8 m. Regional experience does suggest that surges generated by tropical cyclones are lower to the south but surges are virtually unknown in low latitudes while the North Sea (50-60^{o}N) surges generated by Atlantic cyclones are notorious.

L. Callaghan - A.Q.I.T., Grad. I.E. Aust.:

As the levels at the Port Office only are broadcast by the media how does a member of the public relate this to a level in his suburb or street? If he cannot, then who does, the police, the Council or the Civil Defence?

The Author, G. Heatherwick in reply:

To Mr. Gamble:

A carefully planned network of pluviographs in the creek catchments in the Ipswich City Council area would provide a basis for studying rainfall intensities for future flash floods. At least one automatic stream level recorder could be installed in each creek which would enable the flash flood problem to be studied in detail, particularly if rating curves are developed. This could lead to improved planning or zoning of development in creeks, the assessment of the feasibility of flood mitigation works and flash flood warning systems.

The use of unitgraphs for flood forecasting on the Bremer River and Warrill Creek has been studied since 1971. It is essential to forecast accurately the rising and falling limbs of the discharge hydrographs on both streams. This is because for a Bremer River flood the peak discharges of both do not usually occur at the same time, and for a Brisbane River backwater flood affecting Ipswich, the recession of the combined Bremer River and Warrill Creek discharge has to be forecast in advance. The problem has yet to be solved, but data from the January flood will of course be most valuable.

For a Bremer River flood however, little additional warning beyond 8 to 12 hours should be expected unless more accurate precipitation forecasting can be achieved. Delays in the receipt and processing of data should be minimized in the near future with the commissioning of the Brisbane Valley Radio Telemetry Scheme. Site works have been completed to telemeter data from 9 rainfall and 11 river height stations which comprise a minimum network. Data will be received by radio link via a number of repeater stations at the base station at the Brisbane Regional Office of the Bureau of Meteorology and a slave station at the Flood Control Section of the Brisbane City Council. The network is shown in figure D1. The final cost of the system is likely to be in excess of $400,000. The Brisbane City Council is to contribute about one-quarter the cost.

Considering the disruption to communications in the Moreton Region during the January flood, early consideration should be given to expanding the system to include more stations not only in the Brisbane Valley, but also in surrounding catchments, such as the Albert, Logan, Nerang, Pine, Mary and Condamine Rivers.

To Mr. Ashkanasy:

The proposition to use confidence limits for flood predictions is quite sound and the Bureau has in fact used 95% confidence limits in maximum probable flood studies carried out for clients.

Usually in flood forecasting, the Bureau forecasts a specific height within a time range. For the Port Office, forecasts have been made to coincide with high and low tide.

There are several problems associated with the use of confidence limits in operational flood forecasting. Firstly, as frequently happens, forecasting systems are developed from the minimum of data. In the specific case of the Port Office, data from only eight floods were used in sections of the analysis. The variation of the parameters used for flood forecasting at the Port Office in most cases has been evaluated from only three or four events. We have not had sufficient floods to have been able to assess the accuracy of forecasts from events other than those used in the analysis, and the January 1974 flood data must of necessity be used in determining certain changes. The effect of channel improvements and dredging downstream from the Port Office was unknown prior to this flood and metropolitan runoff contribution has been subjectively estimated as was the storm surge values 12 to 24 hours ahead.

At Ipswich we have had only one flood of any significance, that of February 1971, which has provided data for analysis for the development of the Ipswich forecasting system. The January 1974 flood discharges were two to three times the 1971 flood discharge at Ipswich and the runoff distribution was totally different. Now, few flood forecasting systems are designed to be operated purely from objective analysis. If this were the case, there would be no need for experienced engineers to operate flood forecasting systems. Usually only the minimum amount of data are available and in developing systems, assumptions have to be made such as runoff from ungauged areas being a constant ratio of runoff from gauged areas. It therefore leads to the development of systems which can cope adequately with "average" conditions, but much subjective judgement and adjustment to forecasts is required to cope with the unusual.

The January 1974 flood was a most unusual flood. Runoff from the local Ipswich area was beyond the experience of all engineers and those concerned with flood forecasting in particular.

Input data to flood forecasts will unfortunately continue to have considerable subjective content for some considerable time in the future.

In the development and operation of flood forecasting systems, engineers have to weigh the benefits to be derived from considerable time consuming research and development, often with inadequate data, to ensure satisfactory objective flood forecasting to cope with all eventualities, bearing in mind the additional time taken to process data and issue forecasts. Against this we have to consider simpler procedures which cope with "average" conditions but require greater subjective assessment from time to time, and the requirements for flood forecasting in other areas. It should be borne in mind that often, a large number of flood forecasting and warning systems are operated simultaneously with only limited staff.

Secondly, there is a problem of the public and operational agencies understanding and applying a range of forecast heights in an operational phase. In the January 1974 flood, various agencies suffered from what has been aptly termed "information overload". The Bureau would also suffer loss of credibility with a very critical public if a range of forecast heights were given to the public. Very serious consideration would have to be given before a decision was made to complicate forecasts with additional data other than the mean expected height.

To Mr. Church:

The variation of Moreton Bay tide heights at high and low tide was due to wind set up and it is believed that studies incorporating surface wind data from Eagle Farm could provide some of the answers. The main problem will be one of forecasting the wind field on Moreton Bay for the forecast period which could be up to 36 hours in advance.

The Bureau has negotiated with the Department of Harbours and Marine to install a telemetered tide gauge in Moreton Bay. This should be operational during the winter of 1974.

The Bureau has been studying storm surges in Moreton Bay over a number of years. This has involved the extraction of surge data from all available tidal records during periods of cyclone activity in south east Queensland. A working paper is due to be published in the near future.

To Mr. K. Morris:

Rainfall volumes are equivalent to rainfall rates and duration over an area. However for simplified flood forecasting in streams which have a short time of concentration, hence short warning time, rainfall intensities become a very significant parameter which can be quickly and easily applied. This is the case for flashing flooding in Brisbane and in the Nerang River.

There seems to be no reason why accumulated rainfalls above a nominal rate should correlate with peak discharge when the total duration is far in excess of the time of concentration. Of 35 storms on Enoggera Creek, studied by the Bureau, only six had average rainfalls in excess of 10 mm per hour for more than six consecutive hours. Therefore the duration for most storm data would not be greatly in excess of the time of concentration. Correlations of this type are found to be useful from time to time for one stream but do not necessarily produce acceptable accuracies on others. Obviously, the simpler the model the better, when time is the most important factor.

Where flash flooding occurs as in Brisbane creeks the problem is however not one of suitable techniques. The major problem here is the limited time available for receipt of data from say, five or six creeks, from efficient and reliable data acquisition facilities, (manual reporting is of limited value), analysis of data, the preparation and dissemination of forecasts for specific locations in the creeks and interpretation along the full lengths of the creeks in suburban areas.

This information has to be available to individual residents and business premises in time for evacuation and protective measures to be taken.

With regard to mathematical modelling of the Brisbane River system, the Bureau is interested in digital simulation models such as the Stanford Model and the Sacramento Model used by the U.S. Weather Bureau in California. It is proposed to apply these to Australian catchments in the future but their operational application will have to wait the installation of a remote terminal on line to the Bureau's computer in Melbourne.

The Author G. Cossins in reply:

To Mr. Gamble:

The Brisbane data can be used to forecast the level of backwater flooding in Ipswich from the Brisbane River. The level in Ipswich due to this cause is given by the level in the Brisbane River at the Bremer junction. The Moggill flood gauge, 1 km below the junction, is a good indication of this. The revised flood map will show hybrid backwater levels in Ipswich corresponding to the different heights on the Port Office gauge in conjunction with significant Bremer River flows. Depending on circumstances this could be misleading. Separate maps for Bremer River and Brisbane River flooding are required for satisfactory forecasting.

Sufficient data is available to set up a system for forecasting floods occurring in the Bremer River alone but the problem of combined Bremer River floods together with Brisbane River backwater will be more difficult to solve. It may be possible to examine this as a backwater problem but much more data will be required from flood observations before a complete forecasting system can be set up.

A major requirement for Ipswich is more flood height observing stations. Staff gauges are the cheapest to install but the problem of obtaining suitable observers is often difficult. A gauge every two miles from the One Mile Bridge to the Brisbane River junction would seem to be the minimum requirement for the Ipswich area to collect enough data for future analysis.

To Mr. Callaghan:

During the January 1974 flood it was not clear how a member of the public could obtain critical information and from which authority. Furthermore, it has not been made clear since the flood which authorities will, in future, accept the responsibility for these matters.

Works Design Branch of Brisbane City Council provides a flood advice service to the public during floods. This service obtains the forecast flood profiles for the metropolitan reaches of the Brisbane River from the Flood Control Section of the Council and uses the available contour plans of the City to interpret the significance for any individual inquirer. If an individual wishes to assess his own situation from forecast levels for Port Office it would first be necessary to determine the critical level involved (street level, house, floor etc.) and then find the level for the Port Office gauge for which the critical level would be exceeded. The latter advice can be obtained from the Flood Control Section of the Council.

The Flood Map shows the same information in a broad fashion. The old (1933) map shows areas of Brisbane affected for every five feet rise in the Port Office level. The revised maps will show equivalent information at two metre vertical intervals and will be much more accurate. The map, however, will be difficult to interpret at the fringes of the contour bands.

The 1974 flood showed a great need for regional flood centres in the suburbs where detailed information and detailed interpretation of flood advice can be obtained within easy walking distance of the threatened areas.

To Mr. Gourlay:

These comments are extremely interesting and helpful although it seems, from the explanation, that surges due to wind stress on Moreton Bay, as in January 1974 are likely to prove difficult to forecast. The general relationship between wind and surge shown on Figure 10 should be of some help in the future but it is clear that Mr. Gourlay is warning the amateurs to avoid rushing to conclusions when in the throes of flood forecasting.

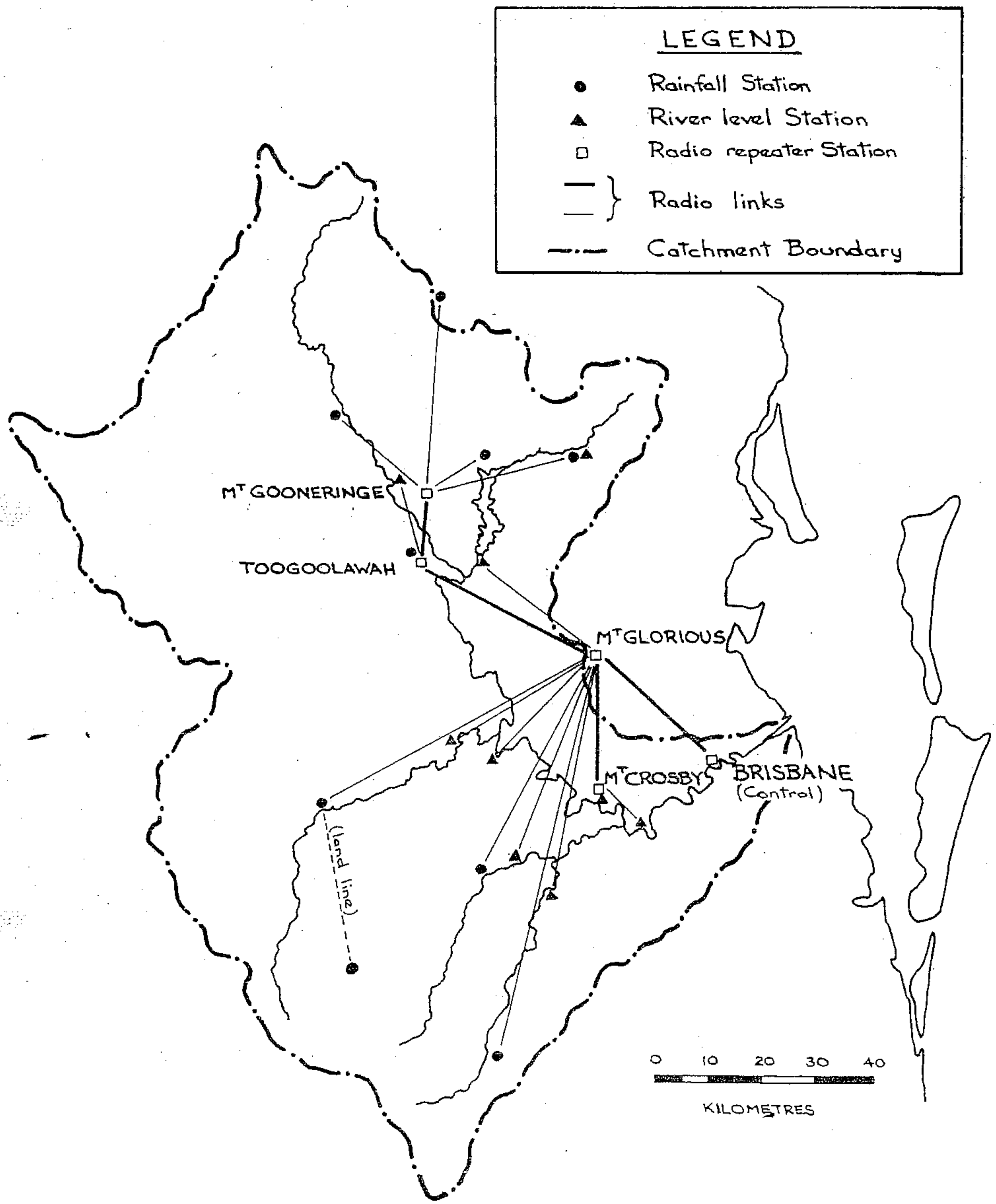


FIG. D1. CATCHMENT AREA SHOWING RADIO TELEMETRY NETWORK

SOCIAL ASPECTS OF FLOOD WARNINGS

by A.L. Quinnell B.Soc. Stud. M.A.A.S.J. *

It is practical to start by considering warning as a system, keeping in mind that it is the first phase of generally agreed upon disaster phases, i.e. warning, threat, impact, emergency and recovery and since warnings are designed as a public service, make some comment on the social aspects of warning. It seems logical to suppose that warnings are designed to elicit a certain kind of response, i.e. they are a call to action for the recipient of the message in relation to the threat. This assumes detection of environmental changes which could result in danger, collation of information about the changes, decisions on who should be warned and in what way, transmission of the warning, interpretation and action by recipients, feedback to the issuer of the warnings, and the issuing of new warnings, corrected, if necessary, in terms of responses to the first warning message. Obviously the detection of environmental changes, collation of information about these and decisions on who should be warned are solely within the realm of technical services. However, it seems that there is information about certain social behaviour which is of importance to deciding in what way people should be warned. The fear that a community or groups within the community will panic when warned of the threat of impending disaster is largely unfounded. There are recorded instances of panic causing disaster and also of panic within a community whose exits to safety have been closed. However, it does appear that very precise warnings of the nature of the threat can be issued with resultant organised responses by the recipients of the warnings.

Transmission of the warning involves, obviously, decisions by the issuer of the warning in respect to what the transmission points will be. In the present instance, use is made of multi-channels of communication - Police, City Council, recorded phone messages, press, radio and TV. Whilst with that spread the warning appears likely to reach a large percentage of the population, the issuer of the warning has no control on the way in which the warning is transmitted, i.e. whether additions or deletions are made to the warning or the context in which the warning is transmitted.

The following illustrates the importance of context - if a warning is sandwiched between an ad for Coca-Cola and an ad for Omo it would tend to lose its impact. However, if it is placed between film of Niagara Falls in full flood and film of a dam wall bursting, it may have an impact out of all proportion to its content. There would appear to be the need for very close co-operation and collaboration between the issuer and transmitter of flood warnings especially in relation to media transmission.

Interpretation of and reaction to the warning is a complex process and if time and a group of people are involved, usually a highly social one. The way in which a person responds to a warning most often depends on the way in which he defines the situation. Included in this definition are the following: how likely is the danger to eventuate and what are the likely losses if it does; what is the length of time likely to be before a decision about action has to be made; what is the likely cost of action and can the individual do anything to stop the danger eventuating. Whilst there may not be a coldly calculating process, on the whole, people would rather believe they are safe than in danger.

* *Executive Officer Queensland Disaster Welfare Committee*

It is most likely that a number of individuals will attempt to confirm the warning by contacting the source of the warning, discussing the warning with officials of various organisations and trying to establish whether certain disaster organisations are themselves responding to the warning.

It would seem that some organisations whilst still transmitting a warning have also to respond to the warning to prepare for the third and fourth phases of the disaster, i.e. impact and emergency. This would seem to indicate the necessity for a highly efficient organisation. The organisations most likely to have this dual function are the Police, Civil Defence and Brisbane City Council.

Another important information input in the decision making about the response are informal social communication networks. This process of interaction involving the gathering of opinions of, information from and probable action by neighbours, friends, relatives and workmates may cause the warning to be totally ignored. The importance of the use made of these informal networks can not be underestimated and the use of these sources of information, either correct, or incorrect, points to the necessity for education about the kinds of responses necessary in relation to warnings of different kinds of dangers. In relation to the Australia Day weekend flood, the probable lack of information about flooding in the Brisbane River among informal social contacts may be one of the decisive factors in the ignoring of flood warnings. If this was the case, how effective might a community education programme be to provide this kind of information? Again, how effective might this kind of programme be in providing knowledge of effective counter measures to take when a decision is made to respond positively to the warning? The use of the media for this purpose may have been underestimated.

The possibility that the community may have had no knowledge of the counter measures to take in relation to the threat again indicates the necessity along the same lines as the cyclone films. The experience of the community recently does not seem to negate the necessity for this education.

The clarity and consistency of the warnings influence the response as does the credibility of the source issuing the warning, for instance, is it possible to define more clearly locations in warnings - where are the Upper, Middle and Lower reaches of the Brisbane River? The credibility issue may be more appropriately considered in the next section on feedback.

The process of organisational response to the warning is a very complex one, and outside the scope of this paper. However, the decision to respond to the warning by welfare organisations has important implications because of their heavy involvement particularly in the recovery phase of disaster and the time span over which the recovery phase occurs. The resources committed by welfare organisations to the recovery phase of disaster far outweigh the resources they commit to the impact and emergency phases. Obviously there needs to exist a pattern for the response to warning by these organisations.

The feedback process appears to be vital within the warning system, for without feedback about both individual and organisational response to the warning, the issuer of the warning has no idea at all whether the warnings are effective, i.e. have they been received, how have they been interpreted and what response have they caused. While it is extremely difficult to gather feedback in a disaster situation, it is possible to elicit necessary information about the disaster and evaluate the warning system in the light of that information. Usually both the issuers and the transmitters of the warning receive unsolicited feedback. One assumes that the Weather Bureau, City Council, Police, Civil Defence and the media have received this kind of feedback in relation to the Australia Day weekend flood.

One questions the bias of this feedback and the validity of evaluating the warning system on this kind of information. It is very seldom that a person who is happy with a service rings to say so. The reverse situation is obvious. Perhaps the Australia Day weekend flood has provided a real opportunity for both the issuers and transmitters of the warning to systematically gather feedback and evaluate the service they provided. Whilst this symposium is part of the evaluation process, it would seem to be rather pointless if this kind of evaluation happened in isolation and no machinery existed anywhere for the recipients of the warning to feed into the system their interpretation of and response to the warning. Both the issuers and transmitters of the warning are providing a service which is aimed at eliciting an individual and organisational response. If the warning proved ineffective in eliciting an appropriate response, then both the issuers and transmitters of the warning need information to evaluate their role in the warning system. This would seem to be as necessary for the Weather Bureau as for the Police, City Council, Civil Defence and the media. The credibility of the issuer of the warning can also be elicited within the feedback process and is important in relation to how the recipient interprets and acts upon the warning. It would appear to be as important to know, if the credibility of the source is high, how that was achieved, as it is to know if and why the issuer has a low credibility. Obviously there is also an area for research.

The feedback process, i.e. information from the recipient of the warning to the issuer, from the recipient to the transmitter, and from the transmitter to the issuer converts the warning system from a linear process to a circular communication process.

Feedback therefore may result in a new warning being issued if an earlier warning has not elicited an appropriate response. Obviously the collection of new data may also result in a new warning. An inbuilt feedback mechanism therefore is important to the warning system, especially if it becomes necessary to issue corrected warnings.

There is a lot of evidence to suggest that it is difficult to warn people successfully of impending danger if they have not experienced the predicted danger for some years. The fact would obviously be relevant in relation to the Australia Day weekend flood and may have contributed greatly if a breakdown in the warning system occurred.

The original subject of this paper was to be the role of the media in flood warning. It seemed more important to place the media within the context of the warning system at the transmission and feedback points. However, it is obvious that the media has a role in flood warnings and the use of the media in a community education programme in relation to both flood and cyclone warnings is important. It would be unfortunate if the media did not place themselves within the framework of the warning system, as that would seem to place some tension in the relationship between the media and the Weather Bureau, the Police, Civil Defence and the City Council, if the media felt that they had no responsibility for the effectiveness of the warning system in a disaster situation.

It would seem to be important to regard flood warnings as a system and a circular communication process. The knowledge of certain social behaviour and its application is important if one regards warning as a call for action by both individuals and organisations. The warnings system indicates very clearly the inter-relatedness of the technical, media and social sciences. Certain processes in the warning system - the detection of environmental changes, collation of data about these, the decision on who should be warned and about what danger are very clearly solely within the areas of skills and knowledge held by the technical services.

Decisions on what people should be warned, how the warning should be transmitted, how people are likely to interpret the warning and the kind of response they are likely to make and the feedback process fall within the areas of skill and knowledge held by the technical, the media and social sciences. It is hoped that the need for the combination of these areas of knowledge has been illustrated.

1. Horace D. Beach - "Management of Human Behaviour in Disaster". Publication of the Department of National Health and Welfare, Canada.

2. Meg Davies, Rick Elliot, Judy Chapman - Australia Day Washout. Unpublished report. March 1974.

3. G. Grosser, H. Weschler, M. Greenblatt (eds) - "The Threat of Impending Disaster - Contributions to the Psychology of Stress". The M I T Press, Massachusetts, 1964.

4. Richard I. Shader and Alice J. Schwartz - "The Management of Reactions to Disaster", Social Work, April 1966.

5. E.L. Quarantelli and Russell R. Dynes - "When Disaster Strikes (It isn't much Like What You've Heard and Read About)". "Psychology Today, Vol. 5, Feb. 1974.

6. R.L. Wettenhall and J.M. Power
"Bureaucracy and Disaster - Part I - Prelude to the 1967 Tasmanian Bushfire". Public Administration Dec. 1969.

"Bureaucracy and Disaster - Part II - Response to the 1967 Tasmanian Bushfires". Public Administration June 1970.

DISCUSSION

G. Heatherwick M.I.E. Aust.

Miss Quinnell has given an insight into an area which is commonly neglected by engineers and those concerned with the various phases associated with natural disasters. For warnings to have the maximum impact there should be considerable feedback to the warning authorities to enable modification of future warnings.

Her example of an official warning being broadcast between two commercials and two films related to the subject matter clearly indicates the vital role which the media must play.

Would Miss Quinnell give her views on what the ideal arrangements should be, between the warning agencies, those concerned with the issue of factual bulletins, the media and the public and should greater controls be imposed on the media during emergencies?

F.W. Grigg B.E. M.Eng.Sc. M.I.E. Aust.

Would it not be essential for a recipient to know that a warning or information relating to a warning would be available at a specific time from a specific source, e.g. 4QR at 5 minutes to and 25 minutes past the hour?

I ask the question knowing that people considering or preparing for evacuation are extremely busy and generally unable to listen for warning given at random intervals from random sources.

The Author in Reply:

To Mr. Heatherwick - The transmission of factual bulletins takes place, obviously, at several levels. The Bureau of Meteorology, largely through mechanical means, takes responsibility for making warnings available to several agencies who then further broadcast the warnings to the public as well as activating emergency services in relation to the warned of threat. As the situation now stands, the Bureau of Meteorology has no control over whether the warning is broadcast, in what form, how often or whether the warning is further broadcast even though the Bureau considers it has become inoperative.

Without legislative controls, such a system rests on mutual understanding and co-operation, both of which may be insufficient in ensuring that the public has access to what are, in effect, public warnings. In combination with rare events, mutual understanding and co-operation might well prove to be no basis for the transmission of warnings.

Within the Broadcasting Act, it may be possible to ensure that the media broadcasts warnings immediately upon receipt, in the form they are received and with stated minimum times between broadcasts. It should be possible anyway to include a media representative on the State Disaster Relief Organisation or at least to introduce formal discussions between the media and the various warning organisations of the Bureau of Meteorology. One wonders if it is possible to include the media in any "dummy" runs which may be undertaken from time to time, for training purposes, by Civil Defence.

One wonders what inbuilt evaluation system is possible within the Bureau of Meteorology to assess the response to warnings within the area of threatened danger. While it is important to assess organisational response to a warning, it is also important to gauge individual response to a warning. Such knowledge may cause changes in transmission points for warnings and may emphasise the importance of some transmission points over others as a method of warning the public.

To Mr. Grigg - Without legislation it would seem that any arrangement to broadcast warnings at specific times during the period they are current relies on the goodwill of media distribution points and their perception of the importance and relevance of the warning. It could be possible to ensure with legislation that weather warnings take precedence over all other broadcas t material and be broadcast at least at hourly intervals.

INTERPRETATION OF FLOOD FORECASTS

*by I. Fairweather, B.C.E., F.I.E. Aust.**

This part of the symposium deals with the problem of transmitting the flood predictions into information easily understood by the public at large.

In the case of the Brisbane River, this presents problems that do not always occur elsewhere. The Brisbane River, within the boundaries of the City, floods over a length of 71 km and in the case of the recent floods the height ranged from 2m to 17m A.H.D. The time lag from the higher reaches to the lower reaches is in the order of 12 hours.

The other factor that makes it difficult is that the event is a rare event so that for each flood different personnel are usually involved.

In the early stages of the flood, the predictors could not give final flood height. This means that it is only possible to give information a limited number of hours ahead and until it stops raining and the river stops rising in the upper reaches, it is not possible to give the ultimate height.

Nevertheless, although there are problems, some action has to be taken to keep the public informed.

The recent experience of floods in Brisbane shows that there is room for improvement in the communications between the people making the predictions and the public.

During the recent flood, a continuous service was operative at the City Hall where people could ring up and be given reasonably accurate information as to what level the water would rise in a particular place consistent with the latest predictions made regarding the flood in the river. Many thousands of calls were handled in this way. This is time consuming and only gives information to people who phone in and is obviously not sufficient as a means of flood warning for the public. Nevertheless, this sort of service must always be maintained and in addition to this, more general information must be given out.

The problem is how to do this so that information is concise, clear and easily understood. There have been several suggestions made -

1. Paint flood heights on posts etc. in the street in different colours and then refer the flood bulletins to the flood height. This I do not like because -

   (a) It creates a continuous maintenance problem

   (b) Will probably only last until the first sale of a house in the street

   (c) With a long time between floods, there would need to be a continuing education programme to keep the people informed of what the marks mean.

* *Chief Engineer and Manager, Department of Works, Brisbane City Council*

2. Mark on each house in a prominent position the level of the floor with the flood height being given by reduced level for each reach of the river. This has some attractions but would be a very time consuming process and would need constant education of the people to keep newcomers aware of the significance of the reduced level marked on their house.

3. Have maps prepared for different flood heights for showing on T.V. The disadvantage of this is that a map which would show sufficient detail would have to be on a small scale resulting in so many maps that it would take a long time to show the lot with the result, that the T.V. stations would be reluctant to show them at frequent intervals. In any case, T.V. stations don't seem to remain on the air for 24 hours a day and most people would not be prepared to sit and watch T.V. waiting for the flood information and once the power failed, people would not be able to watch T.V.

   Also, no two floods are identical and one must be careful in publishing maps such as this as a difference of 6" in level could mean a difference between carpets being ruined and not.

4. By means of radio bulletins. I think this is the most effective means of communicating with the public as almost everybody has a radio at home and most people have portable transistors by which they can easily keep in contact. Simply, this would be done in this fashion -

   (a) Have charts prepared which show the level at which the river starts to break its banks in various reaches.

   (b) Prepare inundated area maps for various stages of the river.

   (c) Have prepared statements as to what the situation in relation to flooding will be at various levels of the river, defining the areas to be inundated by street and the depth of water at well known inter-sections.

   (d) When the official flood warning is issued, the relevant bulletin explaining what this means in terms of areas flooded, be released, the bulletin being related to the official warning.

   (e) Copies of the maps and bulletins be left at Police Headquarters and during the emergency, Council staff who are conversant with the information and who are able to interpret it, to be stationed there on a 24 hour basis.

   (f) At the same time, maintain a 24 hour service at the City Hall to give personal advice to those who require it.

I do not think that the issuing of flood information in terms of levels on the river means very much to the public. To say that by midnight tomorrow night the level at the Port Office gauge will be 20 and the level at Jindalee Bridge would be 54, this to my mind, means nothing to the public, but I think if you can say to the public that by say, midnight tomorrow night the area of say, South Brisbane bounded by Glenelg, Hope and Peel Streets would be inundated with water at the intersection of Grey and Melbourne Streets, 5 ft. deep, this would be meaningful and would be of great assistance.

It is planned to prepare such information and keep it updated so that the next time the river floods, we will be in a better position to keep the people informed.

DISCUSSION

G. Cossins B.E., M.I.E. Aust.

The major deficiency of the January 1974 flood in the Brisbane and Ipswich areas was the lack of any effective mechanism for conveying the accurate forecasts produced by the flood forecasts of both the Bureau of Meteorology and Brisbane City Council to the consumers, i.e. the public in the flood affected area, in a meaningful fashion.

After the flood there were many complaints that people were not aware that they were in any danger of being flooded and that authorities had not attempted to warn them of the potential danger. Alas for this comfortable view which sheds responsibility from the individual flood victim on to the mysterious, impersonal, uncaring but useful "they". Officers of Brisbane City Council, the Bureau of Meteorology, the Co-Ordinator General's Department and the former Stanley River Works Board have bitter experiences of trying to make members of the public aware of flood dangers. Prior to the flood a number of prospective purchasers of property near the Brisbane River either decided themselves to check up on the flood situation or were persuaded by friends to do so. However, it has always been amply clear to the officers advising them that they were seeking a comfortable reassurance that there was no bar to the purchase of the property. Advice on the probability of flooding to different levels was received as "bad" news and it was always clear from the tenor of the conversation that most people quickly convinced themselves that a 1 in 10 risk of flooding would be personally acceptable.

The few hydrologists and meteorologists willing to speak publicly on the risks of high flooding in Brisbane were regarded as semi harmless cranks and one, at least was rebuked in a public meeting by a civil engineer, in a position to know better, for spreading such misleading stories. Police Inspectors and Town Clerks alike listened to their rantings with polite incredulity whilst they privately assessed whether the speakers should be restrained in the public interest.

The mental lack of preparation among both public and authorities alike can be attributed to four factors. In the first place, the developers and the associated real estate fraternity have unblushingly claimed for the last 40 years that the construction of Somerset Dam had removed all possibility of flooding in Brisbane. There are already clear indications of the development of a similar Wivenhoe Dam mentality. The activities of the first group were abetted by the public which was only too willing to believe the "good news" as exemplified by the experiences related above.

Also there was the unwillingness of official bodies, both State and Local Authority, to undertake any campaign of educating the public to these risks. The official attitude, as in so many matters, is that all queries will be answered truthfully (but maybe not fully) but that the public must of itself seek out the right authority and pose the question. In the process it is known that some misleading advice was given in all good faith by public servants of all types who, themselves, did not understand the problem.

Finally, the engineering profession as a whole withdrew itself from any responsibility of informing the public on such issues, taking an extreme position of being willing to discuss such matters only on a client/specialist basis. There are, fortunately, some indications of a change of heart on the part of the Institution.

It is not possible to place a finger on the definite "they". However, if any improvement is to be obtained the demand will have to come from the public, and the public, in turn, will have to be prepared to accept the responsibility of understanding the problem as well as requiring various authorities to carry out their part of the programme. This, however, does not solve the problem of transmitting meaningful flood advice to the public.

Before moving on to the detailed machinery required to transmit the flood forecasts, it is necessary to consider the requirements of the consuming public. A bewildering variety of demands exist and it is clear that it will not be possible to devise a single system that will satisfy everyone. The requirements range all the way from the individual who requires enough data on which to make his own decision about evacuating and then proceeds to organise the move himself without being concerned with mass rescue and evacuation organisations. At the other extreme of the range is the individual who, for various reasons, is only willing to take action when advised by a clearly defined (uniformed) representative of a constituted authority and is not only willing to comply with any arrangement made on his behalf by authority but feels that it is right and proper that such a service should be provided.

The different public authorities have their own requirements for flood advice. These vary from the Police, Civil Defence and other rescue authorities who need to be advised of flood forecasts over a wide spectrum so that they, in turn, can both act on the information and transmit it to the public. The public utilities such as electricity supply, Australian Post Office, Railways etc. need the information to safeguard their own systems so that they can maintain the best service through the crisis and restore the system as rapidly as possible afterwards. These authorities need direct access to the forecasters and require lengthy discussions to understand the full implications of the flood from their own point of view.

The requirements and limitations of the forecasters must also be considered. During the 1974 flood the forecasters were extended to their limit and certainly need relief to be able to face an extended flood crisis in the future. A considerable amount of the forecasters' time and attention was taken up with answering queries from individual householders and representatives of businesses and factories etc. The forecasters should be relieved as much as possible of these enquiries. In the case of the Flood Control Section of Brisbane City Council, this is already achieved to a considerable extent by the Design Branch of Works Department of the Council which provides an advisory service for the public based on an interpretation of the flood gradients forecast by the Flood Control Section. A number of queries require specialised interpretation and are referred on to the Flood Control Section.

The Bureau of Meteorology receives queries from a wide range of interests, including householders. The Bureau is not equipped either with staff or detailed knowledge of local contours and flood gradients to answer these queries satisfactorily. The queries are dealt with as best possible and many are referred to Brisbane City Council. This all takes up the time of the forecasters who would be better employed on specialised business of forecasting.

The Works Design Branch of Brisbane City Council is equipped with contour plans which enable individual properties to be identified so that a reasonable assessment of probable flooding can be made in answer to telephone queries. During the 1974 flood this service answered many thousands of queries. However, had all the property owners in Brisbane been aware of the service, it is certain the facilities would have been overwhelmed with queries. A large number of genuine enquirers would never have been able to obtain an inwards telephone line whilst many thousands of queries would have been received from people well above any flood level but who require reassurance. After all, reassurance is as important to the public as positive advice on certain flooding. It is a genuine need of the public and any arrangement of flood warning services must take this into account. The Council advisory service has the disadvantage of working from the City Hall. Whilst the essential services to the City Hall to keep the advisory system in operation are relatively secure, the loss of communications to a flooded suburban area did effectively isolate a large number of people from the service.

One of the requirements of a reorganised and amplified flood information advisory service is decentralisation. This has several advantages. Firstly, it would spread the load of enquiries which already is potentially far greater than capacity of the existing centralised facilities. Secondly, it would overcome the problem of interruptions to long range telephone communications between individuals and the central advisory service. Thirdly, it would overcome the problem of the remote interpretation of local problems from maps and allow more detailed local problems to be taken into account. Fourthly, it makes on-site inspections feasible and allows much more meaningful dialogue on the spot between rescue services and advisory services. Finally, it allows for integrated advice to be held in regional centres in the suburbs for the use of all services on a local area basis.

The obvious location for each suburban information centre is in the integrated flood relief centre that is so obviously required in each affected area to replace the multitude of separate centres that operated in 1974 to the fury of public and helpers alike. Such a centre would require reliable communications, probably by radio to the various central control rooms of the authorities concerned in the flood operation. A study of the controversial flood map of Brisbane (Surveyor General's Department $1.00) shows that high floods leave flood free peninsulas projecting out into the flood waters. A central location in each peninsula would command a large flooded area and would still be relatively close to the flooded and potentially flooded properties so that on-site inspections would be feasible. Other factors, such as power supply and road communications, would have to be taken into account and some relocations of essential services on a long term basis could be considered to enhance the reliability of the centre as a functioning unit.

The staffing of the suburban centres for the interpretation and dissemination of flood information would pose a problem. Brisbane City Council would probably not have sufficient staff to provide more than a supervisory service and would have to rely on the services of volunteers. On the other hand, a large number of engineers and other technologists and technicians with some hydrological experience were flood-bound and uncommitted during the 1974 flood and would be more than willing to serve in such a capacity. This is a matter that the Institution of Engineers could well investigate as a community project.

Experienced hydrologists were not consulted during the January 1974 flood by any of the bodies making major policy decisions. At the best, the hydrologists' opinions were relayed second hand by other civil engineers with a limited understanding of hydrology. Consequently, the hydrological viewpoint was understated and many decisions were made which contrary to sound hydrological practice. Only four hydrologists, two from the Bureau of Meteorology and two from the Flood Control Section of the Council, had sufficient information to give a full picture of the flood situation yet were not consulted directly. Such hydrologists should be taken into consultation at a high level in future floods to serve the best interests of the public.

The flood showed the need for hydrologists working in shifts to be available at the major central control rooms to be able to interpret the various flood forecasts at some length to the major responsible organisations. Such interpretations cannot be carried out successfully over the phone. It would be necessary to call upon volunteers for this service but sufficient experienced hydrologists are available in Brisbane for this to be done. Again, the Institution of Engineers could organise the service.

Ipswich presents a more difficult staffing problem. The city has a major requirement in this respect but possibly there are not sufficient resident specialists to provide the service. This problem could well be investigated by the Institution.

In the midst of this welter of organisation, the social work function of the system must not be forgotten. The ultimate consumers of engineering services are the public and it is more than reasonable that the engineering profession should take some trouble to understand the psychology of people for whom they work, however indirectly. Engineers badly need to abandon their lofty, arrogant attitude that they must necessarily know what is best for the public. If they cannot bring themselves to study the public they should do the next best thing and consult the considerable body of Social Workers who now operate in the community and who rose to both public and official notice during the 1974 flood. Social workers can now go almost anywhere without being regarded as the people who make tea and sandwiches. Engineers may well be dismayed to learn that some of their favourite solutions of problems are, after all, not in the best interests of the public. This consideration could well apply to the many proposals for advising the public on the risk of flooding.

This discussion, so far, has centred only on the hardware, so as to speak, of the dissemination of flood warnings. The major problems yet to be overcome in the flood warning organisation is the framing of flood advice in terms intelligible to the people in the threatened areas. Although reliable forecasts were blocked, for a variety of reasons, from reaching the public in the 1974 flood it is doubtful if many people would have been able to interpret them in any case. There is an appalling gulf in understanding between forecasters and public. Try as they may, the forecasters find it hard to realise that the simplest hydrological and hydraulic terms are meaningless to a public that has never before had to utilise such information.

A river cannot flow unless it has a hydraulic gradient i.e. the water upstream of the observer is physically higher than water in the observer's immediate vicinity. In fact, a stream has a gradient that falls continuously from its headwaters down to the sea. This basic fact is not understood by many of the public who tend to regard a flooded river rather like a flooded lake, i.e. as a horizontal plane of water rather than an inclined plane. Even more difficult to some people is the idea that its sideways spread over the flood plain follows the rule that water finds its own level. As one commentator put it after the flood:_

> "Most people can't tell the difference between vertical height and horizontal height."
> This slip of the tongue emphasises an important point.

People place most emphasis on the horizontal distance the flood has to spread before their own properties are affected and find it difficult to understand that the vertical rise of the flood water is the important factor. People are utterly bewildered by this phenomenon in flat country. In steep areas they had a clearer appreciation of what a rise in flood level would mean to them.

People living behind the natural levee bank of the Brisbane River have a further problem to understand in a number of areas such as the Chelmer bank of the river just downstream of the Indooroopilly Bridges, where they were sheltered from the flooded river by the natural levee bank. However, their drainage enters the river about half a mile downstream and naturally (to a hydraulic engineer) their flood levels were fixed by the gradient of the flood at the downstream location. The residents faced the amazing paradox of the river coming backwards to flood them and are divided in opinion as to whether this was a case of water running uphill or was caused by a blocked Council drain. The same problem exists in the Fairfield area. Because they could not see the flooded river over the natural levee bank, people believed (and want to keep believing) that their troubles were caused by blocked or inadequate Council drains.

Problems of understanding are particularly difficult in the downstream areas of the suburban creek flood plains. The heavy rainfall early in the January storm caused the suburban creeks to flood on Friday 25th and Saturday 26th. In the short streams, such as Breakfast Creek, which flood quickly after rain, the flood level quickly fell only to rise again as the main flood came down the Brisbane River. Many houses were flooded twice within a few days to the bewilderment of the owners.

In areas of double flooding the investigators find that people place the major emphasis on the direction from which the flood waters came towards their individual properties. Many people can see no pattern at all in the flooding mainly because they have emphasised the results rather than the causative factors.

The writer investigated an industrial establishment subject to both creek and river flooding. The staff were utterly puzzled by the behaviour of flood water which approached from one direction in some floods and from another direction in other floods. A few hours of personal explanation on the origin of the floods and the significance of hydraulic gradients left the senior staff feeling more confident that they understood the problem and could interpret the phenomenon for themselves in future floods.

Ipswich has a more complicated problem than Brisbane. Flooding can occur from local creeks followed by the flooding of the Bremer River and followed, again, by backwater from the flooded Brisbane River. The problem of understanding on the part of the public is correspondingly more complex.

The words and phrases used in flood warnings need to be studied carefully with the advice of social workers and psychologists. Many words commonly used by hydrologists have a different connotation, usually alarming, to the public. A flood wave to a hydrologist means a flood hydrograph which rises and falls at a smooth rate. However, to the public, a flood wave is an abrupt wall of water, as in the ocean, roaring down upon them at express speed. The media is fond of the expression "a wall of water" to describe any approaching flood. Unfortunately, the public take this quite literally. In an attempt to avoid using these terms the Police Commissioner, in a broadcast, used the term "a final surge of two feet" to indicate that the 1974 flood would rise a final amount before it reached a peak level in 12 hours time. The use of the word "surge" was unfortunate because it evoked the same response as "wave" and "wall of water". These responses are measured by the number of panic calls received by the flood forecasters after every announcement.

Flood advice must, somehow, be given in terms that will not cause an emotional over-reaction but will be sufficiently forceful to impress people into action. There are many instances from the 1974 flood of mildly worded warnings issued by officials fearful of causing a panic. Such messages had no impact and were largely ignored. All concerned in flood warnings should firstly take advice on the psychology of the public in flood situations and then should agree on some common terminology for use in warnings. The relative importance of positive and negative statements should be carefully studied.

Rumours fly thickly during any flood. These all have a fear content. Somerset Dam is always said to have developed a crack and, if not said to be in actual danger of collapse, the inference is clearly there. Such a rumour was taken so seriously in one flood that children were sent home from many schools. A phrase that always occurs in a flood is "Somerset Dam is running over". The controllers of the dam have no idea what this is supposed to mean. Every time the rumour sweeps round the dam is far from "running over".

Of a similar nature is the persistent belief that dams cause floods but never mitigate them. The public is ambivalant about flood mitigation dams. During normal times people will agree that flood mitigation dams will save them from flooding. During a flood, however, they are certain that the dam has been wrongly operated and in fact has caused the flood not mitigated it.

A dam is a handy whipping post for public opinion. It serves as a basis for a convenient rationalisation which neatly absolves the individual from any responsibility for having built or bought a home in a flood prone area. Any dam is regarded as fair game in this respect. Enoggera Dam, for instance, is popularly accused by the flooded residents as the cause of their troubles. They firmly believe that every flood is caused by the opening of the flood gates of the dam at the wrong time. The dam has no gates and only one 9" diameter scour pipe, but the public does not want to believe this and will not even see for themselves when invited. To add insult to injury the residents along the banks of Kedron Brook are also convinced that Enoggera Dam causes their floods although there is no connection between the two streams.

There is an enormous job ahead, firstly, to educate the public in the essentials of flood behaviour and, secondly, to make the hydrologists, controllers, administrators and all others concerned with flood warnings and rescue etc. aware of the psychological needs of the public.

FLOOD MITIGATION IN THE BRISBANE RIVER

*by G. Cossins B.E., M.I.E. Aust.**

THE GENERATION OF FLOOD HYDROGRAPHS

Before launching into the main subject of flood mitigation, it is necessary to draw a picture of the generation of flood hydrographs in a catchment.

An observer sitting on a river bank and equipped with a suitably graduated measuring stick could record the progressive rise and fall of the water surface during a flood. In practice, a staff gauge is used. This consists of graduated boards 2 metres in height (5 feet before metrication) on posts up the river bank so that the whole flood range can be observed. When the readings are plotted against time, as shown by the full line in Figure 1, a height hydrograph is obtained. This has a characteristic shape that can easily be recognised.

Over a series of floods, the Surface Water Resources Branch of the Irrigation and Water Supply Commission obtains discharge rating curves, such as the one shown right hand side of Figure 1, for particular flood gauges. This job is full of pitfalls and should be studiously avoided by amateurs. The rating curve allows the hydrograph of flows, shown in a broken line on Figure 1, to be deduced from the height hydrograph. It may, or may not, be appreciated (but it is so), that the area under the flow hydrograph is related, by a suitable scale, to the volume of the flood that has passed the flood gauge, a fact much used by hydrologists.

Figure 2 shows the principal tributaries of the Brisbane River with their catchment areas. A more detailed explanation of this aspect is given by Cossins (Ref. 1). In the great majority of storms a flood wave originated simultaneously in the Upper Brisbane and the Stanley River catchments as shown in Figure 3. Assuming the conditions that prevailed before Somerset Dam was built, the diagram traces the course of the flood as it progresses downstream.

The flood flow hydrographs from the two main streams having grown in the passage downstream by additions from various tributaries, join at the junction of the two streams as shown by the arrows. The broken line in the following diagram for the Wivenhoe Dam site is the algebraic sum of the individual hydrographs. However, the reaches of the river near the Stanley junction act as a reservoir with two inputs and one output. Valley storage reduces the peak flow and spreads it as shown by the full line in the diagram. The same effect occurs when Lockyer Creek joins the Brisbane River, as shown in the hydrograph for Mt. Crosby and this is repeated for the Bremer River and the metropolitan creeks of Brisbane. In this way the flood hydrograph progresses from its humble origins high in the catchment and receives contributions from tributaries large and small as it travels downstream, increasing in peak flow and volume as it does so. Successful flood mitigation is achieved by interfering with the orderly development of the hydrograph.

* *Investigating Engineer, Department of Water Supply and Sewerage, Brisbane City Council*

SOMERSET DAM

Somerset Dam on the Stanley River is a combined flood mitigation and water supply structure located 8 km from the junction of the Brisbane River. The catchment of Somerset Dam is only 322 sq.km out of a 3225 sq km at Brisbane or 10% of the total. However, Figure 16 by Shields (Ref. 6) showing the isohyets for the 1893 storm, is typical of the majority of floods in the Brisbane River system; the heaviest rain falling on the Stanley catchment. As much as 25% of the total volume of many floods originated above Somerset Dam and thus can be regulated. The dam is a concrete structure shown in section in Figure 4. It is equipped with eight low level sluice gates to give a high discharge capacity whilst the reservoir level is low and is fitted with sector gates on the spillway crest. Water can be retained up to the tops of the gates and the sector gates can be raised by winches located on the top deck to open the spillway. The relevant levels are shown on both State Datum (imperial) and Australian Height Datum (metric). Both the storage capacity of the dam, and the discharge capacity of the gates are shown on Figure 4 against relevant levels on the dam. The storage capacity of the dam is an exponential function of the depth; increasing rapidly at the upper levels of the storage as shown in the broken line on the right hand diagram. On the other hand, the discharge capacity of the sluices is proportional to the square root of the depth from the reservoir water surface to the centre of the sluice, whilst the discharge capacity of the spillway is proportional to the 3/2 power of the height of the flat water surface of the reservoir above the fixed concrete spillway. The sum of these two discharge capacities is shown as a full line on the diagram from which it is clear that the discharge capacity of the dam is limited until the spillway comes into action, i.e. the discharge capacity is greatest when the reservoir level is a maximum.

The lower 43% of the storage or 370,000 Ml (299,000 ac.ft.) is set aside for water supply purposes whilst the upper 57% i.e. 514,000 MI (417,000 ac.ft.) is kept permanently empty, except during floods, to store flood waters. The dividing level known as the permanent water supply level, is set at 99.00 m A.H.D. (R.L. 325 State Datum). After a flood the flood storage is emptied as quickly as reasonably possible, taking into account the level of the Brisbane River, until the permanent water supply level is reached. When the reservoir level is below the permanent water supply level, water is released only to meet the water supply requirements of the Brisbane conurbation. In basic English the flood storage of Somerset Dam is always kept empty in readiness for a flood and, in fact, was empty before the January 1974 flood started. This may be bad news to the large number of people who hope the flood storage was partly full before the flood so they can evade the responsibility of understanding what caused the flood. However, it is a simple fact that can easily be verified and it cannot be dismissed as an official lie.

Various amateur critics have implied that the level of Somerset Dam should be drawn down before the flood season to give adequate storage for flood mitigation. Presumably they are working on an analogy with British conditions where flood volumes are so small and the wet season so reliable that this form of operation is successful. On the other hand, the water supply storage of Somerset Dam is required to ensure the water supply of the Brisbane conurbation through a major drought, such as the 1901-03 drought which lasted almost two years. Under these circumstances, the drought is usually signalled by the failure of the wet season. Any artificial lowering of the water supply storage prior to this time would prejudice the water supply function of the dam and require water rationing to make the remaining storage last through the drought. Furthermore, the volume of a major flood entering Somerset Dam is so large by comparison with the small extra flood storage that could be gained by this process that the increased flood mitigation would not be worth the risk to the water supply.

Attention is now drawn to Figure 5 which is a simplified version of Figure 3 for the conditions that operated before Somerset Dam was built. This figure is included because the format will be followed in the following figures used to explain the operation of Somerset Dam in mitigating floods; the arrows, as before, showing the progression of the flood hydrographs.

Figure 6 shows the situation after the construction of Somerset Dam. Under ideal operating conditions in a major flood, water is released from Somerset Dam in the early part of a flood, the outflow being equated to the inflow so that no water is stored and the level of the reservoir does not rise, as shown in the diagram. Then, as the peak of the flood hydrograph from the Upper Brisbane River catchment approaches the junction of the Stanley and Brisbane Rivers, the discharge from Somerset Dam is reduced, as shown in the diagram and water is stored in the reservoir, causing the reservoir water level to rise. Depending on the volume of flood pondage available in Somerset Dam in relation to the flood hydrograph entering the dam from the Stanley River catchment the discharge of Somerset Dam is reduced as far as practicable as shown in the diagram. During small Stanley River floods the discharge from the dam can be shut down completely but this is not possible during major floods, otherwise the top water level of the dam would be exceeded. In this way a large part of the peak flow of the Stanley River is withheld from the peak of the Brisbane River hydrograph. The reduction in flow from the Stanley River is, naturally, the difference between the peak flow of the natural hydrograph and the simultaneous rate of discharge from the dam. This, basically, is the way in which Somerset Dam achieves flood mitigation in the Brisbane River, i.e. by with-holding the flow of the Stanley River, as far as practicable, from the peak of the Brisbane River hydrograph. In the case of the reduction of the flow of the Stanley River by Somerset Dam the valley storage effect operates in the reverse way to the addition of hydrographs from the Brisbane and Stanley Rivers discussed above. The reduction in the flood peak in the Brisbane River is some 20% less than the apparent mitigation achieved by Somerset Dam. This is all taken into account in the hydrological calculations.

When the peak of the Brisbane River hydrograph has passed the Stanley River junction, the discharge from the dam is again increased, as shown in the diagram until the discharge equals the inflow at which time the reservoir level ceases to rise. It will be appreciated that the hatched area in the diagram represents the amount of water that has been stored in Somerset Dam during the operation. The upper diagram shows how the reservoir level rises in response to the storage of water.

The subsequent sections of the diagram show the effects of the operation of Somerset Dam at Wivenhoe near Lowood and at Brisbane. In each case the broken line represents the hydrograph that would have occurred in the absence of Somerset Dam and the full line is the hydrograph resulting from the operation of the dam. In each case, the area between the broken and full lines is equal to the volume of water stored in Somerset Dam (hatched area). It will be noted that a "critical level" is shown on the Port Office diagram. The significance of this is outlined below.

The degree of flood mitigation achieved by Somerset Dam depends on the relative magnitudes of the flood hydrographs in the Upper Brisbane River and the Stanley River, bearing in mind that Somerset Dam can influence only the contribution of the Stanley River to Brisbane River flood peaks. For floods in the Stanley River up to a certain magnitude the dam can absorb the whole peak flow and thus achieve the maximum possible degree of flood mitigation. However, for Stanley River floods, less than the critical size, the flood pondage of Somerset Dam does not fill completely and, although the whole peak flow of the Stanley River is kept off the Brisbane River flood peak, Somerset Dam is powerless to mitigate the flood any further even though it has spare flood storage available. The January 1974 flood was of this type, although the flood in the Stanley River was close to the critical size above which water would have had to be discharged on to the Brisbane River peak to prevent the overflowing of the Somerset flood pondage. The second major flood of February 1893 was also of the same type. In both cases the major flood contribution came from the Upper Brisbane River.

When, on the other hand, the larger flood originates in the Stanley River catchment, as in the first major flood of February 1893, the reduction in the peak flow from the Stanley River is governed by the limitation imposed by the flood pondage available in Somerset Dam (514,000 ML = 514,000,000 cubic metres). It is therefore necessary to discharge water from Somerset Dam on to the peak of the Brisbane River flood. The resultant flood in the Brisbane River then depends on the magnitude of the Upper Brisbane River flood. If this is small then the resultant flood could still be harmless in Brisbane. The final outcome of any flood ultimately depends on the pattern of the major storm and the distribution of rain over the whole catchment of the Brisbane River.

EMPTYING OF THE FLOOD STORAGE

Having arrived at the position where the Brisbane River flood has been mitigated as far as circumstances will allow and more or less water has been stored in Somerset Dam it is now necessary to discharge the stored water to empty the flood pondage in readiness for another flood. This process is shown in Figure 7. No move is made to release the stored flood water until the peak of the Brisbane River flood has moved well downstream. The stored water is then released in the fashion shown in the Somerset Dam diagram. The area under the release curve must equal the hatched area, because, after all, we are talking about the same amount of water.

By the time the resultant hydrograph reaches Wivenhoe the full line shows the modification that has been achieved by comparison with the "natural" hydrograph shown in a dashed line. Once again the relative areas between the curves are equal and are equal to the hatched area on the Somerset Diagram. Note also, at Wivenhoe, the pronounced rise to the peak of the discharged water. By the time Brisbane is reached the combined effects of valley storage and the contribution of the lower tributaries causes the release from Somerset Dam to appear only as a temporary slowing down in the rate of fall of the falling limb of the hydrograph. The areas between the curves are again equal.

The net result of the operation of Somerset Dam to mitigate flooding is the reduction of the peak flood flow (and therefore level) downstream of the Stanley junction but, inevitably a prolongation of low level flooding as the water stored in the flood mitigation phase is later discharged. Crudely, the top of the flood is dropped off and added to the tail.

Considerable controversy arose during the January 1974 flood over the procedure for releasing the stored flood waters from Somerset Dam after the flood peak had passed the junction of the Stanley River. This can be accomplished in a variety of ways depending on the desirable speed of emptying the flood storage. The quickest emptying can be achieved by continually increasing the discharge after the flood peak has passed the Stanley Junction in such a way that the resultant flood hydrograph has a broad flat top. This would be done by successively opening all the gates at Somerset Dam to increase the discharge to match the falling contribution from the upper Brisbane River. This is not shown diagrammatically but can easily be imagined. The process has been described by Cossins (with suitable diagram) (ref. 2 & 3); the original form of operation having been devised by Nimmo for the Stanley River Works Board. On the other hand, the discharge can be prolonged by holding the level of the Brisbane River constant at a low value as was done in the January 1974 flood whilst the stored water is released over many days. It will also be appreciated that the rate at which the level of Somerset Dam returns to normal depends on the rate at which the stored water is discharged.

TIME OF EMPTYING AND CRITICAL FLOOD FLOW

At this point, the concept of a critical flood in Brisbane is introduced. It is a fact that Somerset Dam can be operated in such a way that the flood flow in Brisbane will subside, after the flood peak, to any chosen level as quickly as if Somerset Dam did not exist. Reference to the Somerset Dam diagram of Figure 7 shows that this can be achieved by equating outflow from the dam to the inflow once the storage of water in the dam has ceased. It is also a fact that the dam can be operated to maintain the chosen flow through Brisbane during most of the period of emptying the flood storage. On reflection, it will be seen that the higher the chosen level, or critical flood, is selected for Brisbane then the shorter will be the time taken to empty the Somerset flood storage. Conversely, the lower the critical flood flow in Brisbane, then the longer will be the time taken to empty the flood storage.

It has always been the practice to empty the flood storage of Somerset Dam in 2 to 2½ days. The practice was introduced by Dr. Nimmo for the Stanley River Works Board as a necessary requirement for the operation of Somerset Dam to cope with the double flood of February 1893. This form of operation is discussed by Cossins (ref. 2 & 3). In actual practice, there were three floods in February 1893 each a week apart - two major floods separated by a minor flood. With an emptying period of 2½ days, Somerset Dam would have barely finished discharging the water stored from the first major flood when the second flood would have been upon it and similarly, the third flood which was a major flood would have occurred almost immediately the stored water from the minor flood was cleared away.

The same pattern was repeated in 1896 but the floods were considerably smaller than in 1893. There have been other occasions on which floods followed each other a week apart. The January/February flood period in the Brisbane River very nearly followed the same pattern. Cyclone 'Pam' passed down the eastern coast of Australia a week after the storm of the Australia Day week-end in January. Fortunately, the cyclone kept out to sea. Had it been closer to the coast a second major flood could have followed the first at an interval of a week. Shields (Ref. 1) has commented on this.

There is a very good case for retaining the 2½ day emptying time of Somerset Dam. Ample historical evidence shows that major storms have occurred at weekly intervals on the Brisbane River catchment and that a 2½ day emptying time is just adequate to cope with a repetition of the February 1893 flood period. It would also have been just adequate had cyclone 'Pam' been closer to the coast early in February 1974 and caused a storm over the Brisbane River catchment.

EMPTYING TIME OF SOMERSET AND WIVENHOE DAM

The problems arising from the emptying of flood storages will become more acute with the completion of the proposed Wivenhoe Dam on the Brisbane River. This dam will have at least 1,000,000 Ml of flood storage or twice the amount available in Somerset Dam. The total flood storage to be emptied after a major flood will therefore be 1,500,000 Ml or three times the flood storage of Somerset Dam. If the critical flow in Brisbane corresponding to a 2½ day emptying time for Somerset Dam is retained then the emptying time for Somerset Dam and Wivenhoe Dam combined will be 7½ days. This would not be adequate to deal with a repetition of the February 1893 conditions with the result that the intermediate minor flood of the series would probably be converted into a damage-producing flood. Had Cyclone 'Pam' caused a storm on the Brisbane River catchment in February the combined Somerset and Wivenhoe flood storages would not have been emptied and the capacity of these two dams to mitigate the second flood would have been considerably reduced. There is no case for increasing the emptying time of Somerset Dam. On the other hand, there is a good case for an emptying time of less than 5 days for the combined Somerset and Wivenhoe Dams. This would involve a higher prolonged critical flood flow through Brisbane with, consequently, a higher sustained flood profile.

The critical flow through Brisbane, and for that matter, Ipswich, because the Ipswich levels are governed by backwater from the Brisbane River, will have a major effect on Town Planning and Development. It was quite clear during the 1974 flood that the public would not tolerate any avoidable extension of the inundation of houses. As the river flows would be prolonged for several days at, or just below, the critical flow it follows that it would be necessary either to resume and remove all homes and other critical buildings located below the critical flood gradient or be prepared to pay substantial compensation for the increased duration of submergence. A preliminary investigation suggests the peak flow of the 1968 flood (3,400 cumecs) as a suitable critical flow for the present condition of flood mitigation by Somerset Dam only but this limit would have to be raised considerably to ensure an emptying time of 5 days for the combined Somerset and Wivenhoe Dams. Essential services and communications could be affected and the subject should be given a great deal of attention. The hydrology of this problem, at least, is being investigated by the Flood Control Section of Brisbane City Council.

However, the investigation will be lengthy.

SOMERSET DAM IN THE 1974 FLOOD

The operation of Somerset Dam in mitigating the January 1974 flood is summarised in Figure 8. It will be noted that the large catchment of the Upper Brisbane River integrated the run-off from the successive storms described by Shields (Ref. 1) into a single, smooth, hydrograph whereas the inflow to Somerset Dam was double peaked. The Somerset inflow reached the first peak on Saturday 26th January and it appeared, at that stage, that the rain influence had gone leaving a flood of the order of the 1968 flood to be dealt with in the Stanley and Upper Brisbane Rivers. Somerset Dam was operated accordingly. The whole flow of the Stanley River was stored in Somerset Dam whilst the apparent peak of the Upper Brisbane River passed the Stanley junction. The release of stored flood waters was then started, as shown on the diagram.

When the intertropical convergence passed back, northwards over the Brisbane River catchment causing the storm which converted a minor flood into a major flood, the discharge from Somerset Dam was not increased further but was reduced slightly. The discharge, however, was maintained because it was greatly realised that the second inflow would overfill the flood storage unless water was discharged before the true peak of the Upper Brisbane River arrived at the Stanley Junction. In fact, the total volume of inflow to Somerset Dam for the whole flood was 646,125 Ml (523,100 ac.ft.) and 204,850 Ml (165,975 ac.ft.) were released before the discharge was ordered to shut down. The total flood storage available in Somerset Dam is 514,000 Ml. The dam would have been overtopped if water had not been discharged during the flood.

The series of storms over the Upper Brisbane catchment caused a near record flood in the Upper Brisbane River. At Cressbrook Station on the Brisbane River just downstream of Cressbrook Creek, and which is representative of the integrated flow of the whole Upper Brisbane River, the ranking order of historical floods is - second major flood of February 1893, 1955 flood, 1974 flood, first major flood of February 1893. The contribution from the Upper Brisbane River was among the highest recorded whilst, fortunately, the inflow to Somerset Dam, whilst the largest since the dam was started in 1935, was only 60% of the inflow in the first 1893 flood.

The second storm and the subsequent major flood disrupted all telephone circuits to the flood gauges in the Upper Brisbane Valley above the Stanley Junction. The main problem on the morning of Sunday 27th January was to assess the magnitude and time of the flood peak from the Upper Brisbane River so that Somerset Dam could be operated appropriately. The timing of the peak was calculated, as best possible, from the scanty rainfall data available and, on this basis, the discharge from Somerset Dam was shut down as shown in the diagram on Figure 8. When the discharge was shut down, the backwater from the flooded Brisbane River reached 8 km back up the Stanley River into the dissipator of Somerset Dam coming within 1 metre of the top of the dissipator retaining wall shown on Figure 4. The operation thus achieved two objectives, i.e. the removal of the Stanley River flow from the peak of the Brisbane River flood and the measurement of the size and timing of the Brisbane River peak flow.

The effect of the operation of Somerset Dam in reducing the peak height between the broken and the full line in each case is the actual flood mitigation achieved, not merely the reduction in discharge from the Stanley River. When the peak of the Brisbane River hydrograph had progressed downstream for several hours the release of water from the dam was recommended as shown on the diagram. It was intended to discharge water as indicated by the short broken lines on the diagram; the effect of this form of operation being shown in a similar line at Lowood and the Port Office in Brisbane. Note that it was intended to let the flow through Brisbane fall to the level of the 1968 flood peak before the effect of the release from Somerset Dam prolonged the duration of flooding. Observations made during the 1968 flood showed that virtually no dwellings were inundated at this level. Had this form of operation been followed, the flood storage of Somerset Dam would have been emptied in 2½ to 3 days after which the whole of the Brisbane River would have subsided to low levels clearing all lines of communication.

At this juncture, the Lord Mayor of Brisbane intervened and directed the closing of the gates. It was pointed out to the Lord Mayor that this action would not free houses in Brisbane and Ipswich any more quickly than the form of operation proposed by the Department of Water Supply and Sewerage but would leave Somerset Dam almost full of water and greatly reduce its capacity to mitigate a further flood should that occur within a week. In a press statement the following day the Lord Mayor is reported to have stated that he ordered the gates at Somerset Dam to be closed in order to free houses in Brisbane and Ipswich from flood waters as quickly as possible. The Lord Mayor acknowledged that he had acted against the advice of his senior engineers and he accepted full responsibility for his actions, whilst, at the same time, stating that the Department of Water Supply and Sewerage was empowered to re-open the gates in the event of further rain. The closure of the gates started at 1400 on Tuesday the 29th. Previous experience had shown that a rapid shut down of the discharge from Somerset Dam causes failures in the banks of the river downstream of the dam. The bank material can't drain rapidly enough to resist slumping when the river level falls rapidly and stops supporting the bank. A schedule of gate closures was drawn up to ensure that the river level would fall more slowly than the slump limit. Another heated dispute then arose over what was regarded as an unnecessarily slow closure of the gates; the view being put that the gates should have been closed as rapidly as the operating mechanism would permit. The Department, however, was adamant on this point and the gates were closed according to the schedule.

A major point missed here and one which the public does not seem to understand is the time taken for water to reach Brisbane from Somerset Dam. It takes a day and a half for the effect of the operation of Somerset Dam to reach the Bremer junction and start affecting the built up areas of Brisbane and Ipswich and a further half day to reach the centre of Brisbane. These changes, both increases or decreases of flow, have been timed to travel at the same speed as the crests of flood hydrographs. This fact was confirmed by observations made in the January 1974 flood.

The effect of closing the gates at the dam can be seen from Figure 9. This shows the contributions from the various tributaries to the height at the Port Office in Brisbane. The full significance of the diagram will be discussed below but it will also serve our present purpose. The closure of the gates started at 1400 Tuesday 29th January when the flood level at the Port Office was 5.1m A.H.D. (20'7"). When the effect of the closure arrived at the Port Office, two days later on Thursday 31st, the level was down to the normal tidal range and well below any flood level. The same considerations apply to the junction of the Bremer and the Brisbane River except that the events here are 12 hours in advance of the Port Office. The closure of the Somerset Dam gates ordered by the Lord Mayor could not, and did not, affect flooding in Brisbane and Ipswich at a level where houses were affected. On the other hand, had the operation of Somerset Dam been allowed to continue as proposed by the Flood Control Section, the increased discharges from the dam to empty the flood storage would have started arriving at the Port Office in the evening of Wednesday 30th January when the level was 1.8 m A.H.D. (9'9") which is lower than the peak of the 1968 flood. No houses would have been affected.

The flood reached its peak at the Port Office at 0200 on Tuesday 29th January but the crest of the flow hydrograph (Figure 10) was so broad that the level did not drop significantly until Wednesday morning, 30th (Figure 9). At this stage Brisbane began to return to normal and by Thursday the flood was over in the river at Brisbane after being above the flood level for the previous five days. The Lord Mayor decided on Thursday morning to start the release of water from Somerset Dam at 1430 on Thursday and that it would be controlled to leave the Fernvale Bridge on the Brisbane Valley Highway clear of water. The operations of the dam to meet these conditions and to empty the flood storage as quickly as possible proved to be difficult. It takes 20 hours for the release from the dam to reach Fernvale. Frequent heavy showers caused the different tributaries to rise slightly but the rainfall reporting network was too coarse to allow the effects to be predicted in time to modify the operation of the dam. Fernvale Bridge was flooded by several inches of water a number of times.

The emptying of the flood storage of the dam took six days under these conditions. During this time the low level crossings on the Brisbane and Stanley Rivers were flooded and the residents in Esk Shire on the eastern side of the Brisbane River had no access for a total of 14 days, including the flood itself. Kilcoy Shire and the Town of Kilcoy were more seriously affected. Lake Somerset reached a record level of 106.74m (R.L. 350.11). The level of the dam had never before exceeded 103.54m (R.L. 339.60). At least six houses were flooded in Kilocy and the Town was isolated by road. The Central Burnett Highway was out at Mary Smokes Creek. It was known that all this would occur in the occasional large flood. With the operation proposed for the dam by the Department the houses at Kilcoy would have been brought out of water on Tuesday 29th January and the roads would have become trafficable on Wednesday 30th. In actual practice the lake took just over three days to fall to the former record level of 103.54m (R.L. 339.60) and Mary Smokes Bridges did not emerge until 3.00 on 5th February after being continuously flooded for 10½ days.

The disruption to the economy of both Kilcoy and Esk Shires caused by the directed operation of Somerset Dam was serious but the main danger threatened the citizens of Brisbane and Ipswich. The dam was virtually locked full of water for 6 days. Instead of being empty on Friday 1st February as proposed, it still held 410,000 ml of flood water, 80% of its flood storage capacity. This was one week after the first storm which started the flood period. Had the events of 1893 and 1896 been repeated, a second flood would have found the flood storage of the dam partly full of water and lacking the capacity to mitigate the flood completely. Five days later Cyclone "Pam" was located about 700 km off the south coast of Queensland as described by Shields (Ref. 1). Shields casually described Pam as a "major cyclone". In fact, it was the largest tropical cyclone ever experienced in the Australian area and one of the largest ever known in the world. It is not merely fortunate that "Pam" recurved away from the Queensland coast, it is a miracle for which Brisbane should be thankful. "Pam" would, undoubtedly, have caused a major flood producing storm which the full flood storage of Somerset Dam would have modified only to the dimensions of a record flood. If "Pam" had crossed the catchment the resultant flood would have found the flood storage of the dam still 26% full. The dam could well have been overtopped and endangered as discussed in a later section. In any case it would have been far less effective in mitigating the subsequent flood.

All in all, the Lord Mayor's intervention in the operation of Somerset Dam could not and did not reduce flood levels in Brisbane and Ipswich down to the critical value any more rapidly than would have happened had the proposed method of operation been carried out. On the other hand, the road access to large areas of Kilcoy and Esk Shires was flooded for an extra 6 days and the residents suffered considerable losses. At the same time the flood prone areas of Brisbane and Ipswich were subject to an increased risk of high flooding from a succeeding storm due to the slow emptying of the flood pondage of Somerset Dam.

The effect of Somerset Dam in mitigating the January 1974 flood in Brisbane is shown in Figure 8. The reduction in the envelope of maximum levels is shown in Figure 11; the reduction being 1m at Port Office increasing to 1.5m at Jindalee and 2m at Moggill. Figure 10 shows the contributions of the different parts of the whole catchment to the flood flow at the Port Office. The first contribution came from the Metropolitan Creeks which are short with low times of concentration. This was then followed by the Middle Reaches of the Brisbane River which received a heavy rainfall early in the storm. The effect of the two storms on the Middle Reaches catchment shows clearly. The Bremer River contributed next, having received little rain in the first storm but a large amount in the second. Lockyer Creek made a contribution from the second storm whilst the Upper Brisbane River made the major contribution in which the effect of the two storms is evident. The two contributions of Somerset Dam, as described above, are also shown.

Two points are worth noting in Figure 10. The discharge from Somerset Dam was not completely shut down until the peak of the Upper Brisbane River flow arrived at the Stanley Junction and Somerset Dam contributed to the peak of the flood at Port Office. The first event was due to the lack of flood height data from the Upper Brisbane River due to telephone failures, as pointed out above. The second, however, was due to the fact that the flow contribution from the Upper Brisbane River catchment, whilst the largest individual component at the Port Office, did not determine the time of the Port Office peak. The combined flow contributions from the Lockyer, Bremer and the Middle Reaches catchments caused the Brisbane peak to be early and thus included a contribution from Somerset Dam which raised the level by about 3 inches at the Port Office. Considering the unusual nature of the storms producing the flood and the failure of communications at a critical time on Saturday night and Sunday the operation of the dam was outstandingly successful. As pointed out above it was necessary to discharge water from the dam during the flood to stop the dam from overflowing. If the flood from the Stanley River had been much larger it would have been necessary to discharge a large amount of water on to the peak of the flood.

Figure 9 shows the equivalent contributions to the height at the Port Office, in this case taking into account the tide and storm surge as described by Cossins (Ref. 4). The point to notice is the period over which the river flow is close to the peak. In a flood of any consequence the peak is so broad that it straddles two high tides. A high tide invariably determines the peak height in the reaches still under the influence of the tide. The effect of the 1974 flood at the Port Office is evident although the tide was almost damped out. There is no possibility of a large flood peak being mitigated by coinciding with low tide or in the more popular phrase, "slipping down between the tides".

The Effect of Wivenhoe Dam

There has been much discussion since the flood of the possible effect of the proposed Wivenhoe Dam on flooding in the Metropolitan areas. There is already the danger of a "Wivenhoe mind" developing as the public eagerly listens to comforting misinterpretations of the possible effectiveness of the new dam.

Calculations have been made by the Flood Control Section of the Council of the mitigating effect of Wivenhoe Dam on the 1974 flood. Three alternatives were examined for Wivenhoe Dam, one with a flood storage of 800,000 Ml (600,000 acre feet) which was briefly examined by the Co-Ordinator-General's Department in its investigation of the future sources of water supply for Brisbane, one with a flood storage of 1,050,000 Ml (850,000 acre feet) which the Co-Ordinator General's Department favoured in the report and an alternative with a flood storage of 1,235,000 Ml. (1,000,000 acre feet) as a trial of the further mitigation that can be achieved. The operation of the two dams is shown in Figure 13. Some thought has been given to the operation of Somerset Dam in the circumstances and, clearly the matter must be studied in some detail before Wivenhoe Dam is built. However, except to control overflowing, the timing of the discharge from Somerset Dam will not be so critical as at present.

The upper part of the diagram shows that water must be discharged continuously from Wivenhoe Dam during a repetition of the 1974 flood and, for that matter, any flood of consequence. The volume of the 1974 flood inflow to Wivenhoe Dam, was 1,425,000 Ml. (1,155,000 acre feet) which is 1.15 times the flood volume proposed for the largest alternative considered for Wivenhoe. There can be no question of ever shutting down the discharge from Wivenhoe Dam in spite of all the Lord Mayors. Somerset Dam with a mass concrete main wall may be overtopped to a certain extent by flood waters. A rock fill or earth fill dam at Wivenhoe cannot be overtopped without the gravest danger of collapse. Figure 12 shows, finally, the combined effects of the two dams at the Port Office. Once again the respective areas between the curves represent the volumes of water taken into storage during the flood and later released. It also shows, as asserted above, that the increased mitigation provided by Wivenhoe Dam will require a prolonged period of discharge through the Metropolitan reaches of the Brisbane River below some adopted critical level. The effects of Wivenhoe Dam on the envelope of January 1974 peak levels in the Metropolitan area are shown in Figure 11. The reductions would be:-

Flood Storage at Wivenhoe	Reduction in Level of 1974 Flood at		
	Port Office	Jindalee	Moggill
800,000Ml (650,000 ac ft.)	1.3m	1.7m	2.4m
1,050,000Ml (850,000 ac ft.)	2.2	3.3	4.3
1,235,000Ml (1,000,000 ac ft.)	2.5	4.0	5.2

Wivenhoe Dam would be much more effective in mitigating floods of the 1893 type which originate largely above Wivenhoe Dam. In the January 1974 flood 45% of the total flood waters originated below Wivenhoe Dam and could not be controlled by it. In 1893 only 20% of the flood waters originated below Wivenhoe Dam improving the prospects for successful mitigation.

A further factor to be considered in the operation of flood mitigation dams is the effect of storage dams in modifying the dimensions of flood hydrographs. This is shown in Figure 13 for Somerset Dam. Once a dam is built the inflow must be deduced from the rate of rise of the reservoir water level and the controlled discharge from the dam. It is assumed that the storage characteristics of the reservoir are known. (If not, the exercise shades betwedn difficult and impossible). The indicated inflow, thus obtained, is characteristically more sharply peaked and is narrower than the hydrographs observed before the dam was built. The peak also occurs sooner. In the case of Somerset Dam the acceleration is some 12 hours.

This effect is caused by the water already in storage when the flood enters the dam. As a flood hydrograph moves down an unobstructed stream the front of the hydrograph fills up the flood storage of the river valley. If there is no flow contribution by tributaries the flood pondage of a valley will gradually mitigate a flood peak without any help from mankind. When a flood hydrograph enters a partly filled dam much of the flood pondage is already occupied by water and the valley storage effect is lost making the indicated inflow take the characteristic peaked shape.

It has been argued that the indicated inflow is an illusion that should be disregarded in flood mitigation operations. On the other hand, the indicated inflow is the quantity that fills the flood storage and raises the water level causing the controller to think anxiously of discharging water to stop the dam from being overtopped. Indicated inflow is a real quantity which must be heeded in the operation of a dam. There is no point in calculating the shape of the natural hydrograph that would have occurred in the absence of the dam. The operators have no use for it.

At the same time, the difference between the indicated inflow and the controlled outflow is not the effect of the dam in mitigating the flood. For this purpose the natural inflow must be calculated.

In the case of Wivenhoe Dam the acceleration of the indicated inflow has been calculated by the Co-Ordinator General's Department to be 18 hours. This means in effect that the discharge from the dam will be accelerated by the same time. This can be an important factor in timing the releases from the dam in relation to the flood peaks in the lower tributaries. The operation of Wivenhoe Dam will need to be studied carefully. It cannot be assumed that a few simple calculations of flow and volumes will provide all the answers.

SOMERSET DAM IN THE 1893 FLOOD

The flood pondage and the outlets of Somerset Dam were designed to deal with the flood conditions of February 1893. The hydrology of the inflow to the dam in this period was worked out by the Stanley River Works Board headed by Dr. Nimmo in the middle 1930's. The peak (natural) inflow to Somerset Dam in the first major flood of February 1893 was calculated at 4,250 cumecs (150,000 cusecs). At the same time the peak flow of the first major 1893 flood in Brisbane was placed at 9,920 cumecs (350,000 cusecs).

The accumulation of flood data since that time indicated that the Brisbane peak flow was higher than the accepted value. In its investigation of Wivenhoe Dam in 1971 the Co-Ordinator General's Department adopted a value of 11,335 cumecs (400,000 cusecs). However, the 1969 simulation described by G. Cossins (Ref. 3 & 4) suggested an 1893 flood peak flow of 14,170 cumecs (500,000 cusecs). This was confirmed by the measurement of 9,575 cumecs (338,000 cusecs) made at Centenary Bridge in January, 1974 (Ref. 5). Extrapolated to 1893 levels the Centenary rating gives 12,470 cumecs (440,000 cusecs).

This immediately raises a query about the rating adopted by the Stanley River Works Board for the Silverton gauge just downstream of Somerset Dam. Discharge measurements were made here in 1931 but subsequent experience with the high backwater from the Brisbane River at Somerset Dam raises considerable doubts about the interpretation of the Silverton measurements. This problem has recently been examined with the aid of unitgraphs using the more positive values of discharge from Somerset Dam. The study shows clearly that the 1893 inflow to the dam was underestimated in the past. It is now considered that the peak flow of the Stanley River at Silverton in the first flood of February, 1893, was 6,235 cumecs (220,000 cusecs) against the previous 4,250 cumecs (150,000 cusecs) but the volume of the flood was 1,085,000 Ml (880,000 ac.ft.). This is the same as the volume previously calculated.

Although the inflow of the first flood of February 1893 to Somerset Dam has been revised upwards the flood storage volume remains fixed by the dimensions of the structure. It therefore follows that Somerset Dam will not be as effective in mitigating a repetition of this flood, as previously estimated. Fig. 14 shows the method of operation to secure the maximum degree of mitigation in the lower reaches of the river consistent with the limit of the available flood pondage. The discharge cannot be reduced any further at the time of the Upper Brisbane River peak due to the storage limitation. The resultant hydrograph for Lowood is also shown on Fig. 14. At the Port Office in Brisbane the resultant peak flood level would be 0.3 m (1 ft.) higher than the level calculated by the Stanley River Works Board, 0.7 m (2.2 ft.) higher at Jindalee and 0.8 m (2.6 ft.) higher at Moggill.

The three solutions to the problem of discharging the stored flood waters from Somerset Dam after a flood are shown on Figure 14 for the recalculated 1893 flood. The first solution is the method proposed by the

Stanley River Works Board. It consists, essentially, of cutting the top off the flood hydrograph and then discharging the stored water immediately at a high rate to give a broad flat topped hydrograph as shown in long dash line on the figure. The resultant flood in Brisbane would stay at a peak level for two or three days and then decline quickly. This method of operation would prolong the flooding at the peak level of the flood but would empty the flood storage quickly. It has been argued that once a building is flooded the continuant of flooding will not significantly increase the damage. It is not known whether the experience of the 1974 flood supports this view or not. This solution would not be popular with the people whose houses were subject to prolonged flooding.

The second solution is the one proposed by Flood Control Section of Brisbane City Council as shown in chain line on the figure. This method gives the same degree of flood mitigation as the Stanley River Works Board solution but then allows the flood to subside at the same rate as the natural hydrograph down to some predetermined critical level below the level of all houses. It empties the flood storage rapidly and frees all houses of flood waters as quickly as possible.

The third solution is that directed by the Lord Mayor of Brisbane in the 1974 flood as shown in short dash line in the figure. This also provides the same degree of flood mitigation as before but the stored flood water is retained until the flood is almost completely over and then is discharged at a slow rate. Houses are freed of flood water as quickly as possible but the emptying of the flood storage is prolonged and communications are disrupted for many days in the process.

The emptying of the stored flood water raises an interesting point. In order to empty the flood storage in 5 days as proposed by the Flood Control Section, Brisbane City Council (chain line in figure) it would be necessary to maintain a flow of 5,500 cumecs (194,000 cusecs) through Brisbane for 2 days. The resultant flood gradient through Brisbane would be equivalent to the levels that occurred at midnight 26/27th January, 1974 (Saturday/Sunday) just below the 1931 flood level at which major damage starts. The gradient would be equivalent to 3.1 m (14 ft.) on the Port Office gauge. This once again, emphasises the need to determine a critical gradient for the discharge of stored flood waters. This is a complex matter with many ramifications and it cannot be ignored, particularly when Wivenhoe Dam comes into operation.

Somerset Dam Maximised Flood

The possibility of even higher floods in the future has been raised by a number of Authors including Heatherwick (Ref. 6) and Brunt (Ref. 7). Larger flood producing storms have been postulated and a considerable amount of meteorological research has been carried out. This problem has been examined, briefly, for Somerset Dam mainly to see whether the flood storage could be exceeded.

The method of maximisation outlined by Brunt (Ref. 7) was used to examine the problem in conjunction with unitgraphs already derived for the indicated inflow to Somerset Dam. The maximised 24 hour rainfall was used to determine the peak inflow and the maximised 4 day rainfall to deduce the flood volume. The resultant hydrograph of the maximised storm has a 30% higher peak flow than the 1893 flood, i.e. 8,075 cumecs (285,000 cusecs) and a 50% greater volume, i.e. 1,627,500 Ml (1,320,000 cu.ft.).

The routing of this flood through Somerset Dam is shown in Fig. 15.

Two methods of operation were tried. In both cases the sluices were operated to make the discharge match the inflow as far as possible. In the first alternative, shown by a long dash line, the spillway gates were left open so that the discharge from the dam would depend only on the reservoir level once all the sluices had been opened. This arrangement was then continued until the sluices were closed, on the final day of discharge, to bring the reservoir back to the permanent water supply level.

As an alternative, shown by the short dash line, the sluices were opened, as before, but the spillway gates were kept closed until the peak of the Upper Brisbane River flood had passed the junction. The spillway gates were then opened over 12 hours. This alternative would give more flood mitigation at the peak of the Somerset Dam inflow but less at the reservoir peak height. It would possibly give more satisfactory flood mitigation for the lower river but the first alternative is favoured as having a greater margin of safety against overtopping in the event of a larger flood volume than assumed.

It is clear from Fig. 15 that the favoured method of reducing the discharge from Somerset Dam to coincide with the Upper Brisbane flood peak would be possible for a maximised flood only by doubling the sluice discharge capacity of the dam. The capital expenditure required to double the sluice capacity would be formidable. However, the problem should be examined in some detail taking into account the flood mitigation to be achieved in Brisbane and Ipswich.

Probability of Flooding

Several attempts have been made in the past to derive the probabilities of flooding, particularly for the Port Office in Brisbane. The earliest known calculation was made by Dr. Nimmo in 1933 for the Special Committee of the Bureau of Industry. Nimmo later revised the calculation for the Stanley River Works Board and arrived at a probability of 1 in 130 for the 1893 flood. In 1954 Cossins and Shepherd re-examined the problem for the Co-Ordinator General's Department in the light of subsequent floods and arrived at a value of 1 in 200. In 1970 Russo and Shepherd recalculated the probability in connection with the investigation of Wivenhoe Dam and derived a value of 1 in 120. The main difficulties in the examination of probabilities for the Brisbane River are, firstly, the inadequate data and, secondly, mixed flood populations.

The longest flood record has been kept for the Port Office in Brisbane. Flood levels have been recorded since 1841 although the accuracy of the first few flood levels is doubtful. No record can be found of minor floods in the 19th Century and this factor, together with the variable tidal contribution, means that various methods of analysis, such as Log Pearson III cannot be applied to the problem. Mt. Crosby has the longest continuous record of annual flood levels starting in 1894 and this is followed by Lowood starting in 1909.

The existing flood records contain a mixed population of floods which cannot be analysed satisfactorily without "adjustments". Somerset Dam came into operation in 1942 and has since mitigated flooding in the Brisbane River. The previous calculations attempted to overcome this problem by estimating the height to which the various floods would have risen in the absence of Somerset Dam. They then analysed the resultant population of "natural" floods. The distribution of such a population of floods will not necessarily coincide with the distribution for floods controlled by Somerset Dam, yet, to date, no one has attempted to reverse the problem. A further complication is the continually changing characteristics of the Port Office gauge due to channel widening and deepening for navigation and the subsequent abandonment as described above. Attempts were made in the past to allow for this factor but it is now believed that some serious errors may have crept into the work. In any case the whole flow basis for past floods was wrong and the problem must be re-examined.

It is now considered that the only satisfactory way to derive probabilities requires the re-creation of past floods from rainfall records using unitgraphs, together with all available stream height information, the routing of these floods through Somerset Dam and the estimation of the resultant levels at any point in the river for 1974 conditions of the channels. This study which is now under way, will allow the effects of Wivenhoe or any other dam on the probability of flooding to be examined. In conjunction with the simulation of peak flood level envelopes it will be possible to trace the change in probability of flooding of any proposed channel improvements, or, for that matter, disimprovements due to the abandonment of dredging.

REFERENCES

1. SHIELDS, A.J. — Synoptic Meteorology of the Flood Period. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust., August, 1974.

2. COSSINS, G. — The Operation of Somerset Dam - a Multipurpose Project. Technical Note No. 92 - Hydrological Forecasting, W.M.O. No. 228 T.P. 122, 1969.

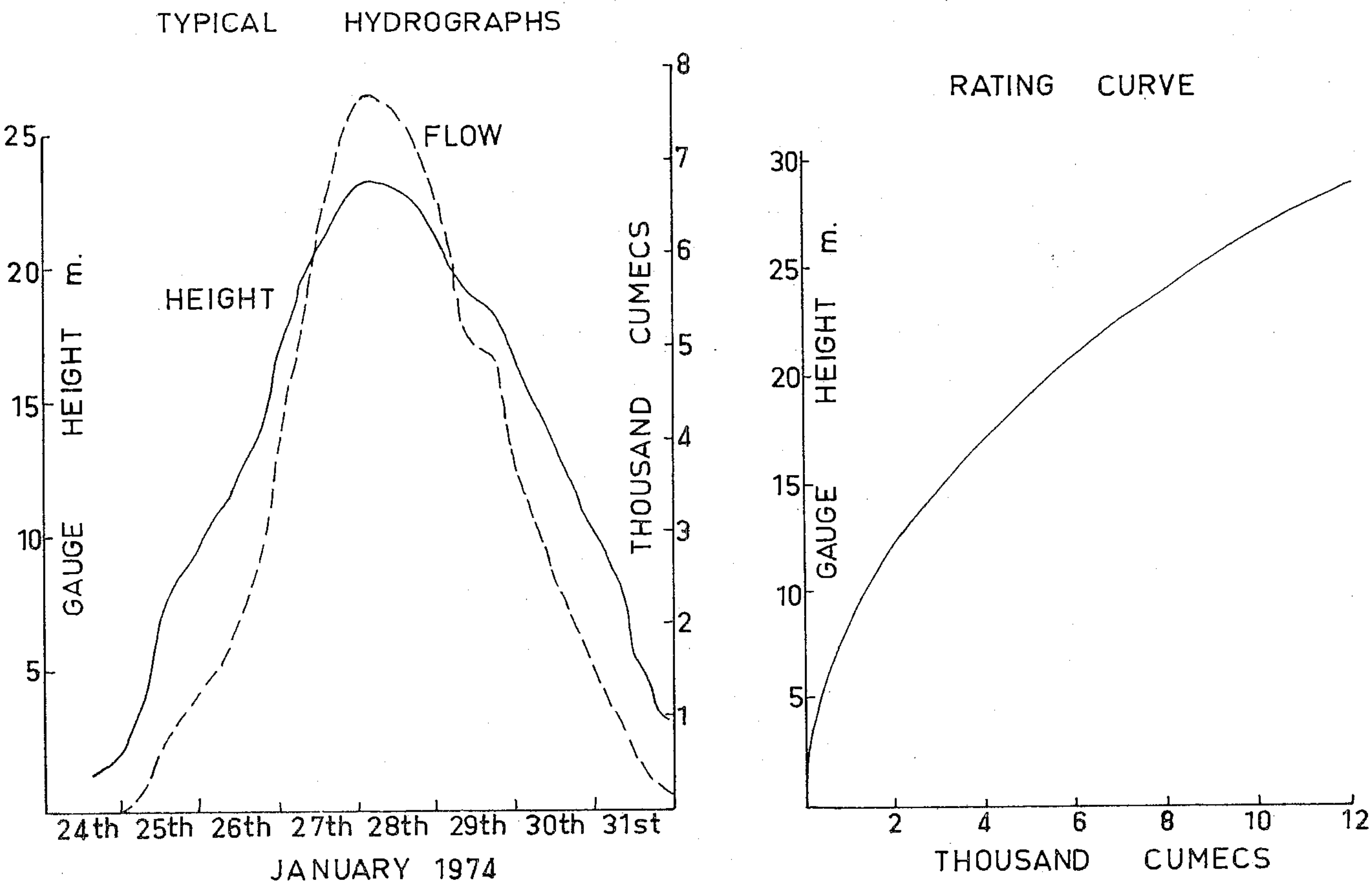
3. COSSINS, G. — Hydrology Without Tears and Other Stories. Q'ld. Div. Technical Pspers I.E. Aust. Vol. 10, No. 7 July, 1969.

4. COSSINS, G. — Flood Forecasting in the Brisbane River. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust., August, 1974.

5. WARD, J.K.G. — Hydrology of the Flood. Proc. Symposium, January 1974 Floods - Moreton Region Q'ld. Div. I.E. Aust. August, 1974.

6. HEATHERWICK, G. — Flood forecasting and warning, Moreton Region - Proc. Symposium, January 1974 Floods - Moreton Region. Q'ld. Div. I.E. Aust. August, 1974.

7. BRUNT, A.T. — The Crohamhurst Storm of 1893 Conference on Estimation of Extreme Precipitation, Bureau of Meteorology, Melbourne, April 1958, p191.



TYPICAL HYDROGRAPHS
FLOW
HEIGHT
GAUGE HEIGHT m.
THOUSAND CUMECS
25
20
15
10
5
8
7
6
5
4
3
2
1
24th 25th 26th 27th 28th 29th 30th 31st
JANUARY 1974
RATING CURVE
GAUGE HEIGHT m.
30
25
20
15
10
5
2
4
6
8
10
12
THOUSAND CUMECS

FIG. 1

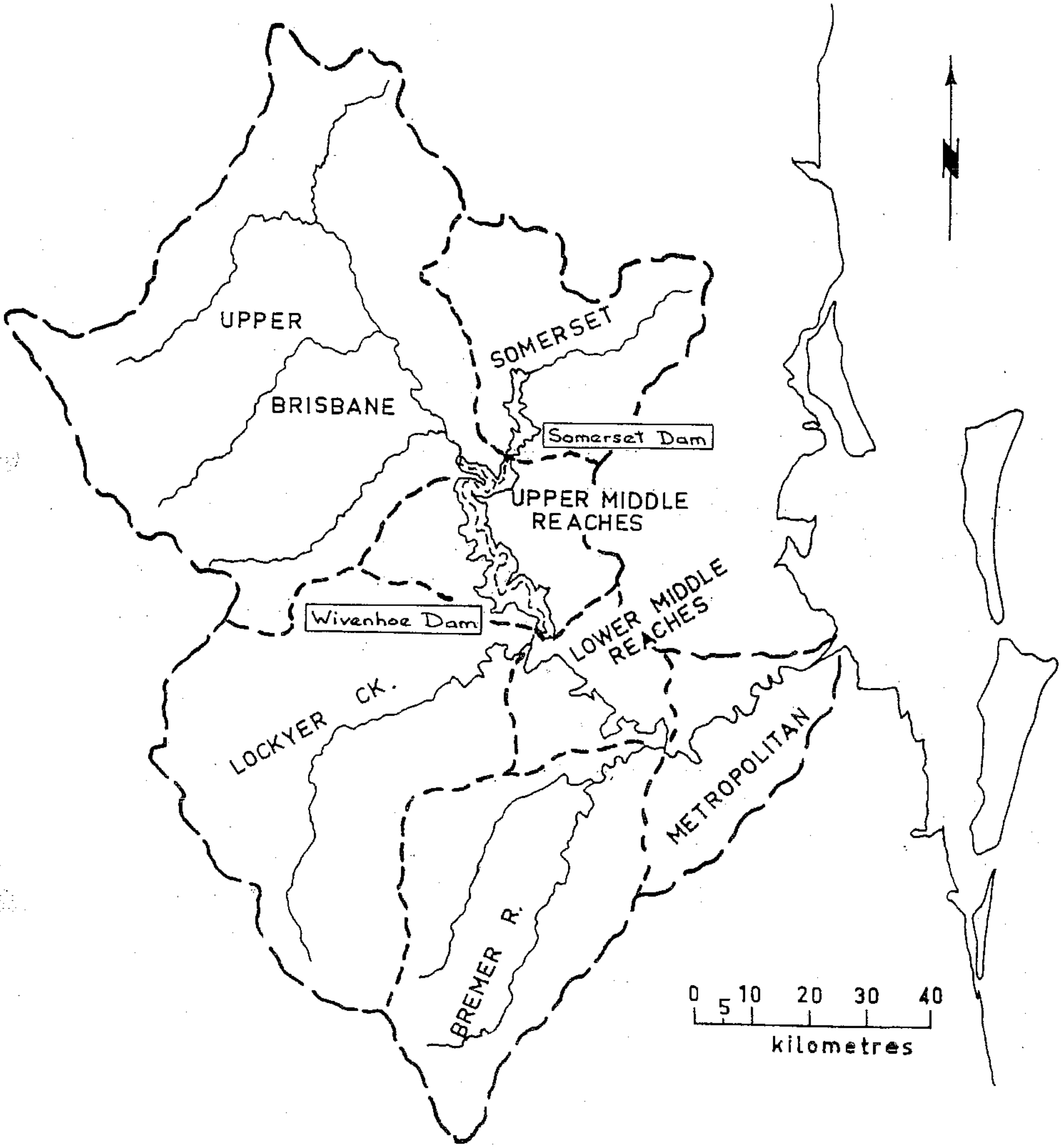
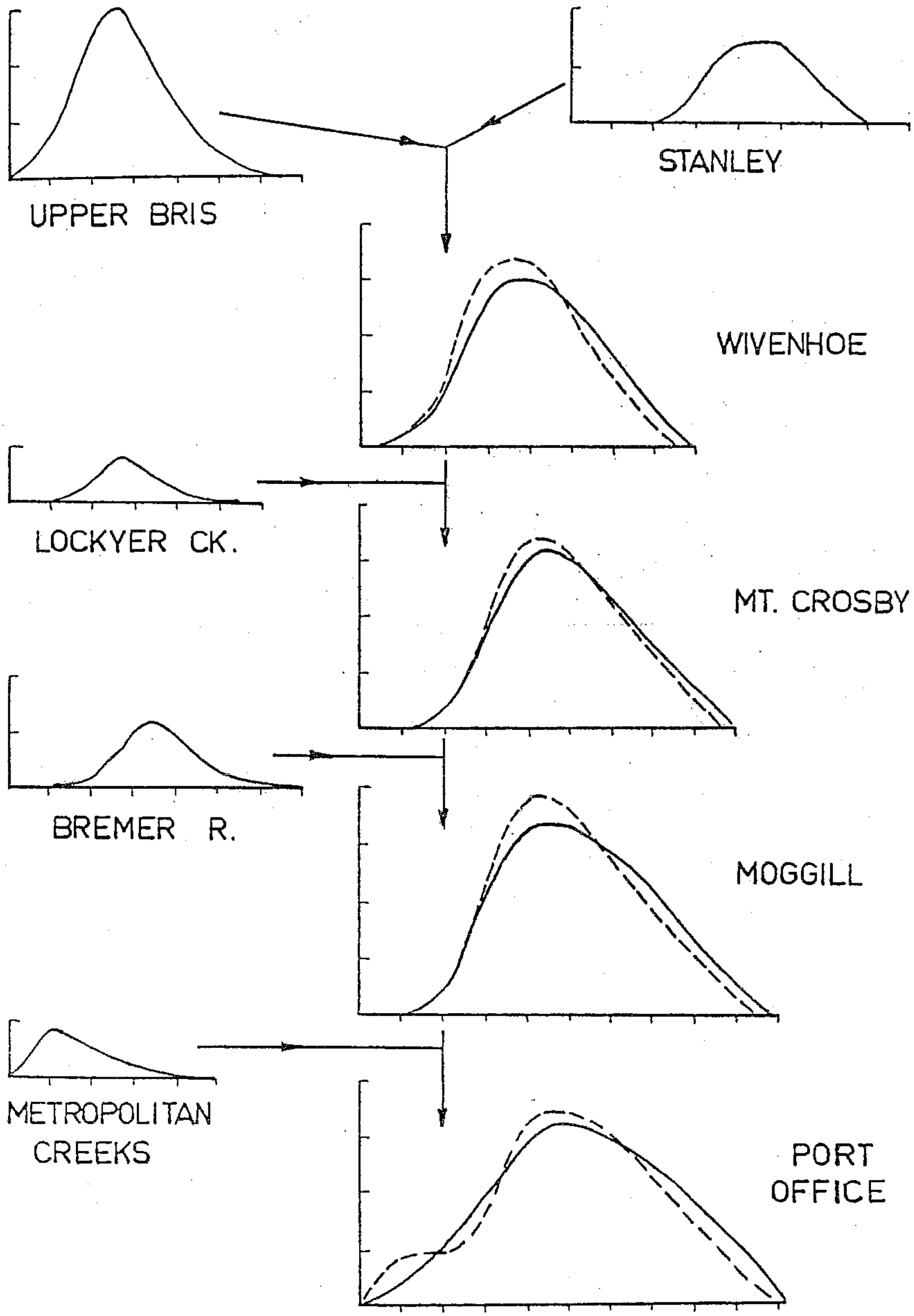
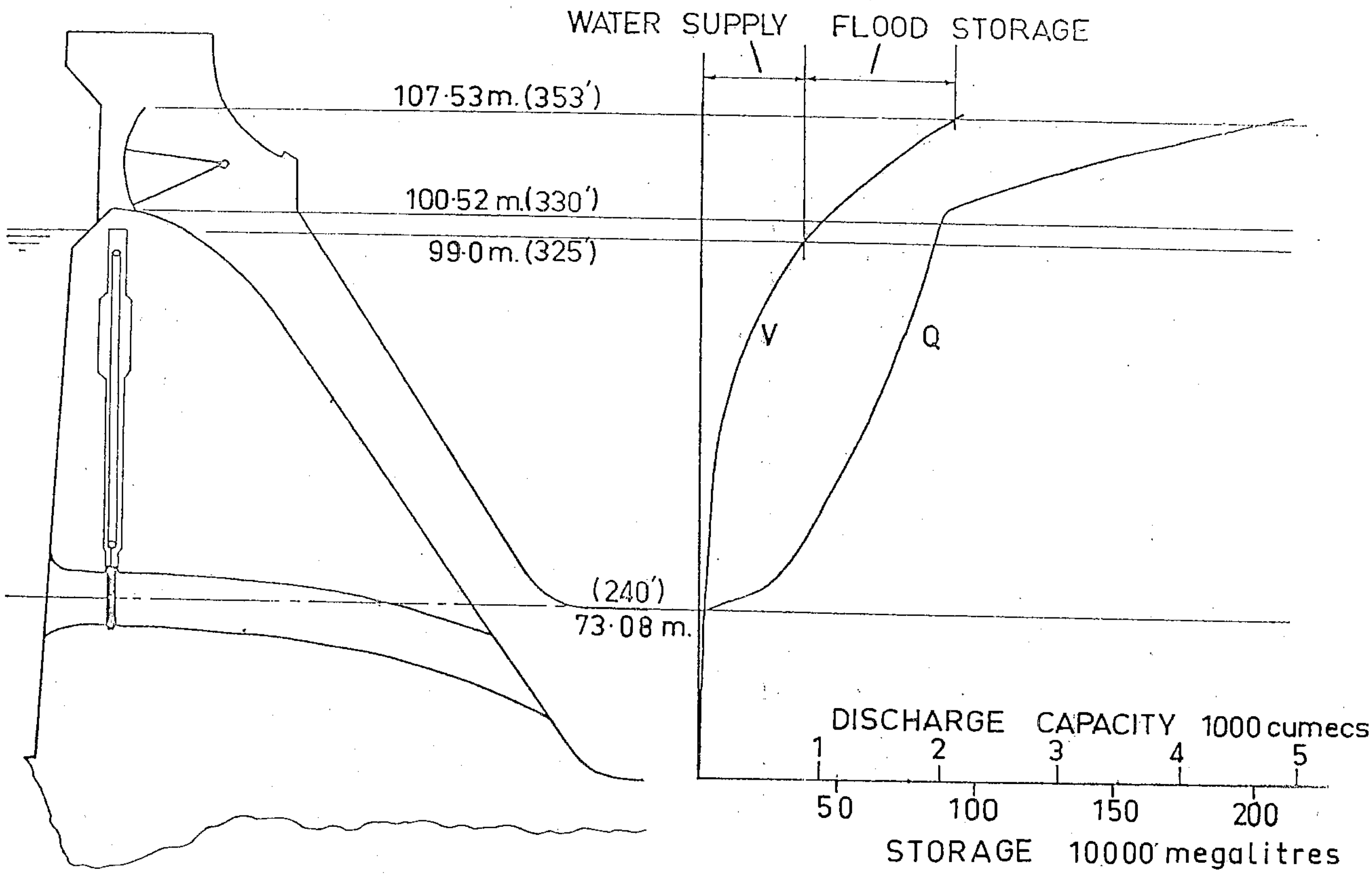

UPPER
BRISBANE
SOMERSET
Somerset Dam
UPPER MIDDLE
REACHES
Wivenhoe Dam
LOWER MIDDLE
REACHES
LOCKYER CK.
METROPOLITAN
BREMER R.
N
0 5 10 20 30 40
kilometres

FIG. 2



HYDROGRAPH GENERATION BRISBANE RIVER

FIG. 3



SOMERSET DAM CHARACTERISTICS

FIG. 4

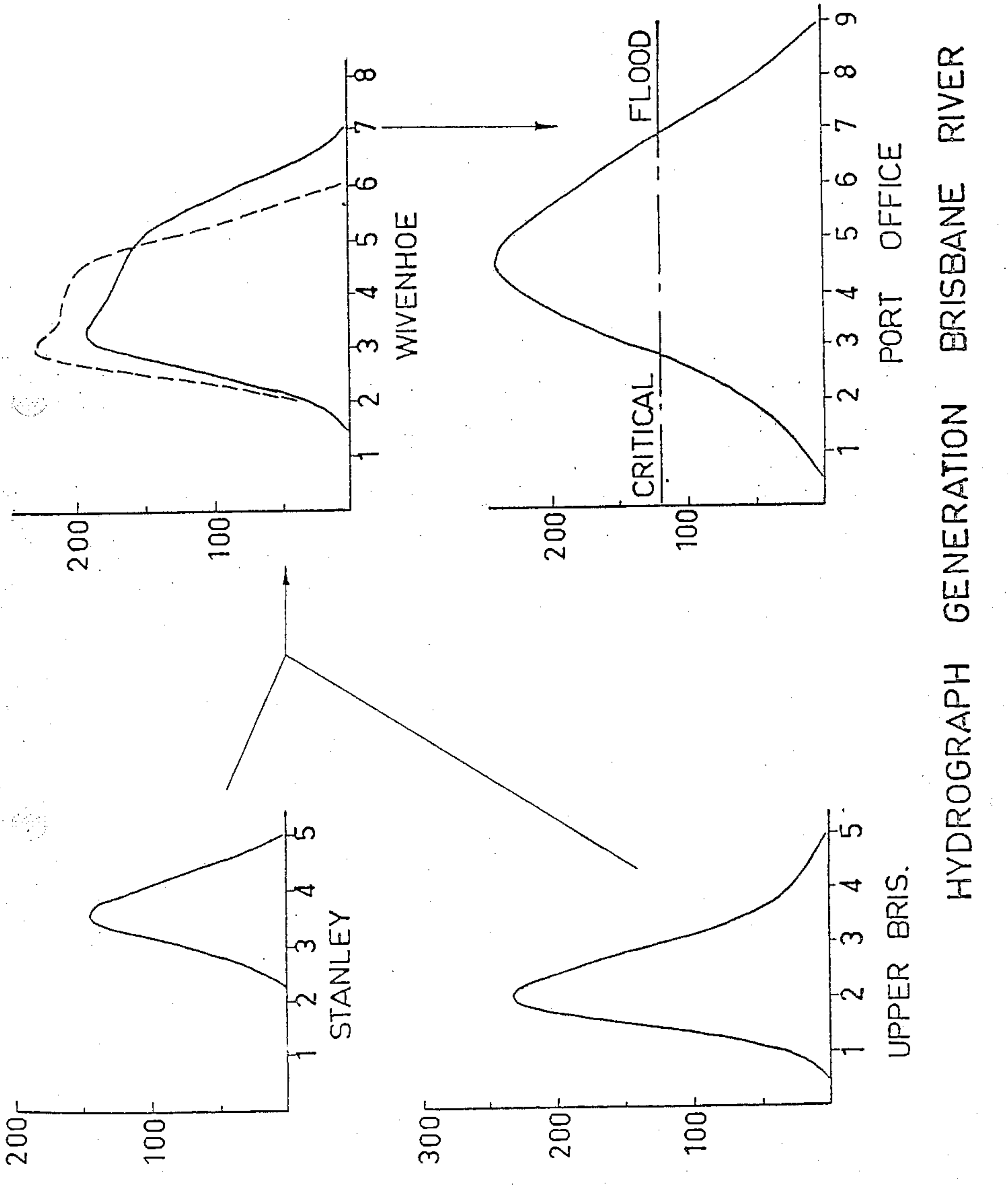
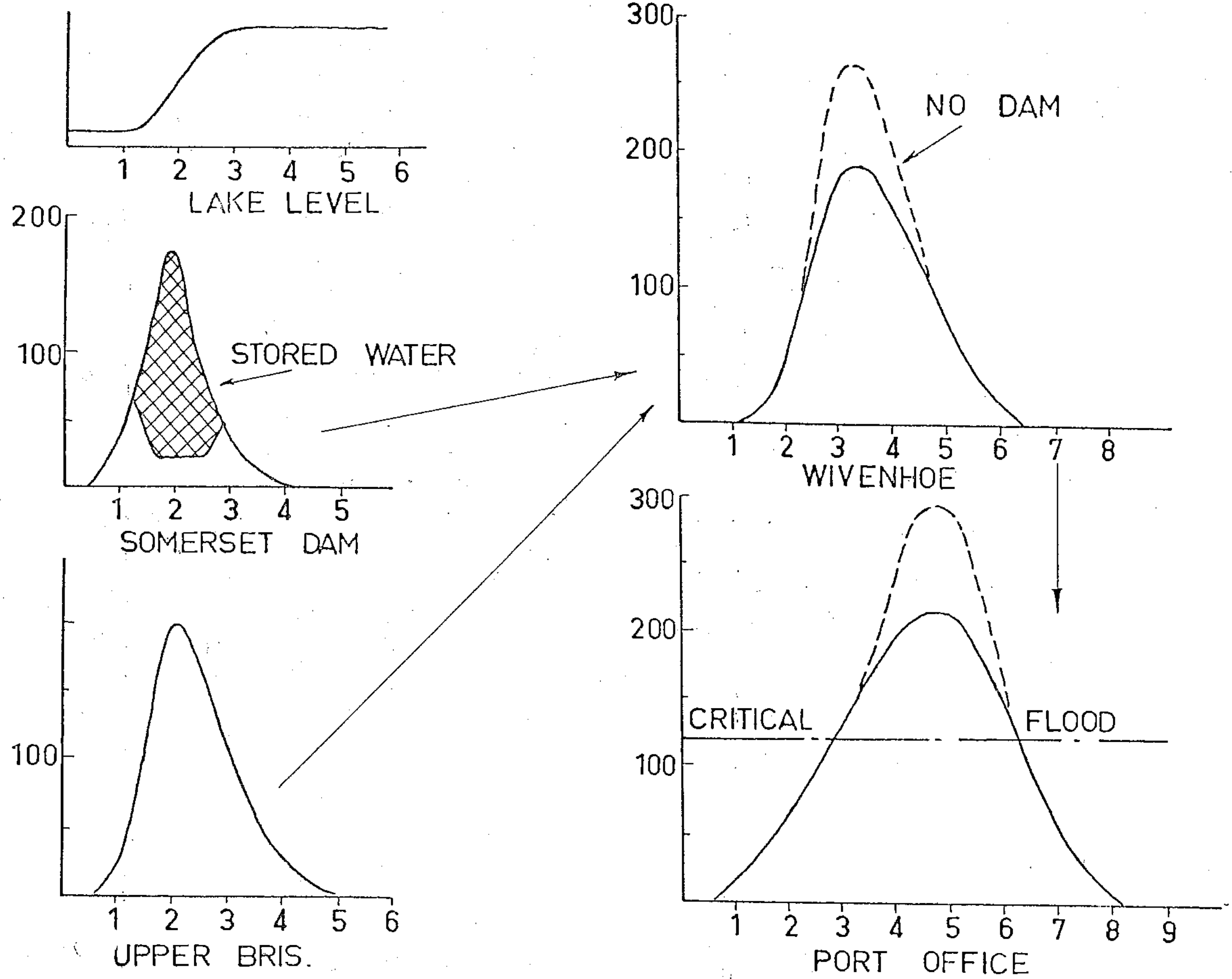
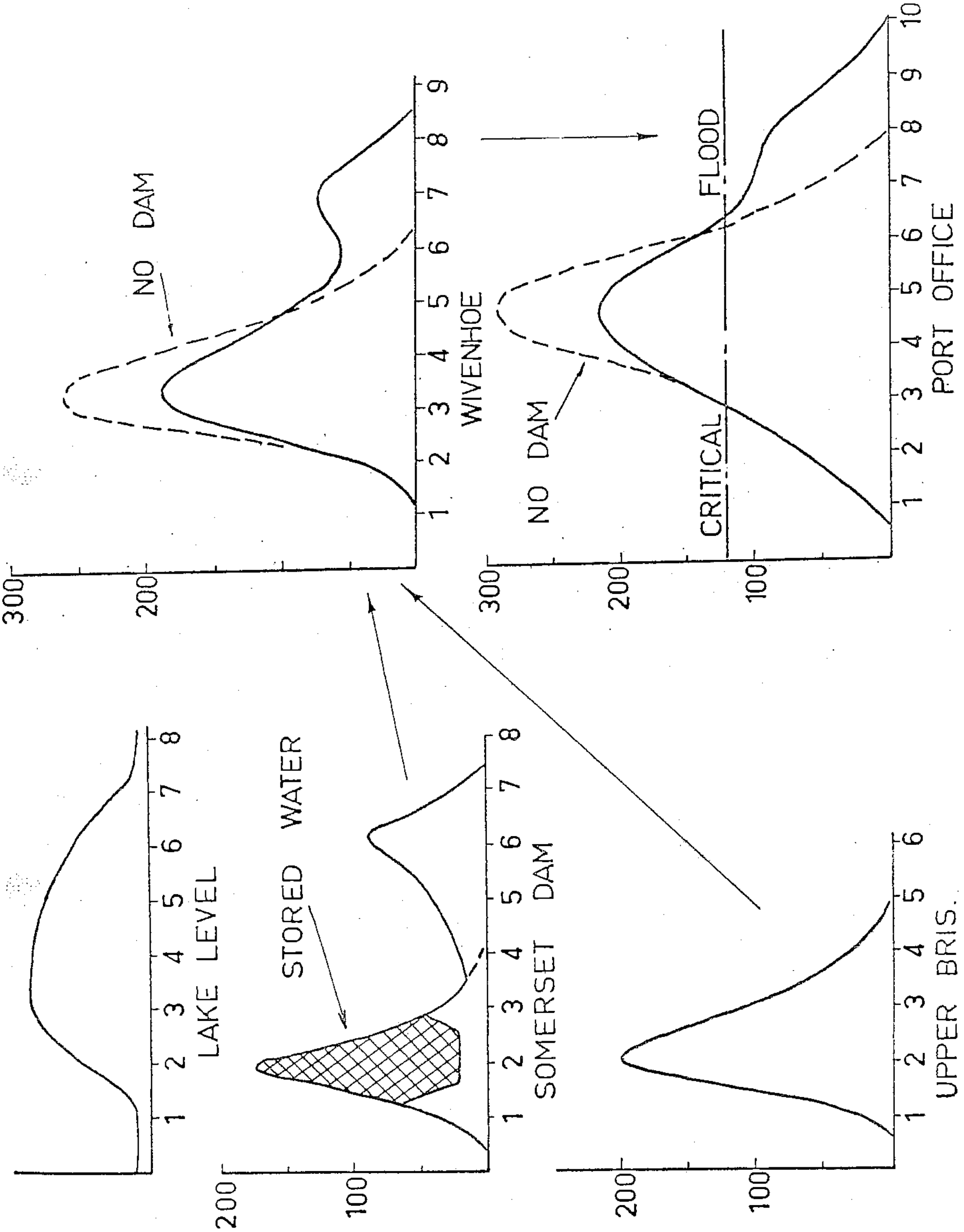

HYDROGRAPH GENERATION BRISBANE RIVER
STANLEY
UPPER BRIS.
WIVENHOE
PORT OFFICE
CRITICAL
FLOOD
200
100
300
200
100
200
100
200
100

FIG. 5



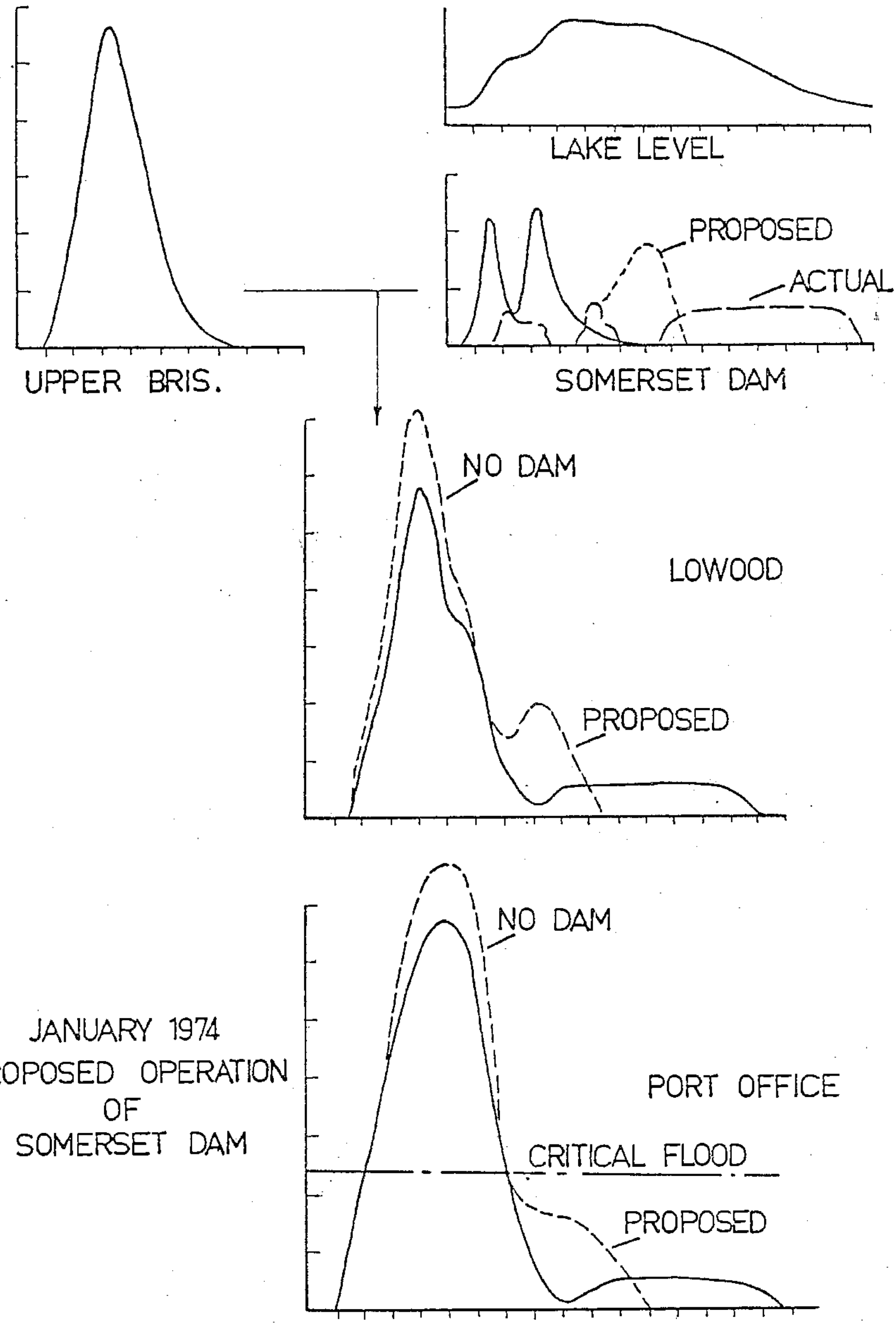
FLOOD MITIGATION SOMERSET DAM

FIG. 6



DISCHARGE OF STORED WATER SOMERSET DAM

FIG. 7



JANUARY 1974
PROPOSED OPERATION
OF
SOMERSET DAM

FIG. 8

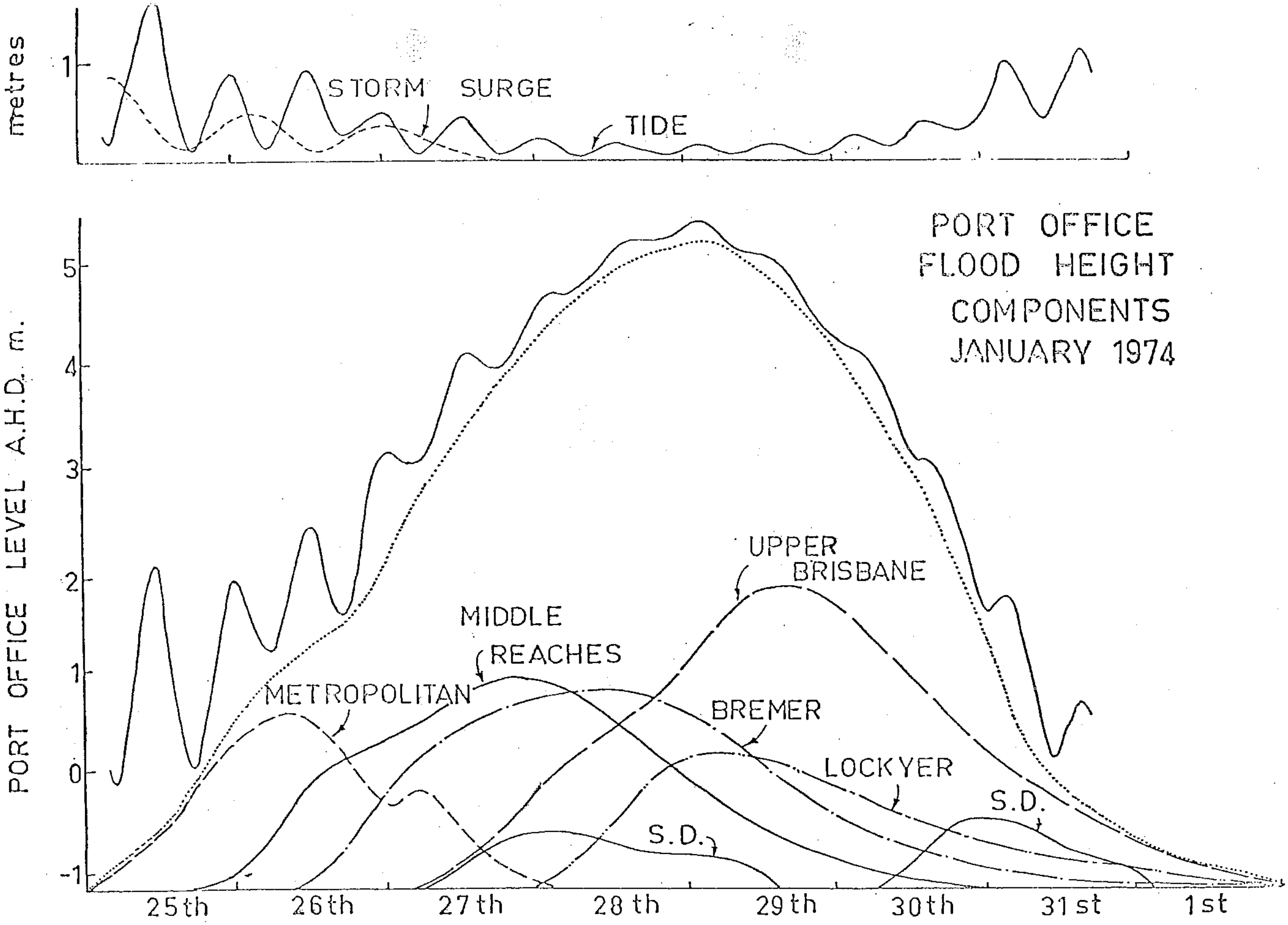
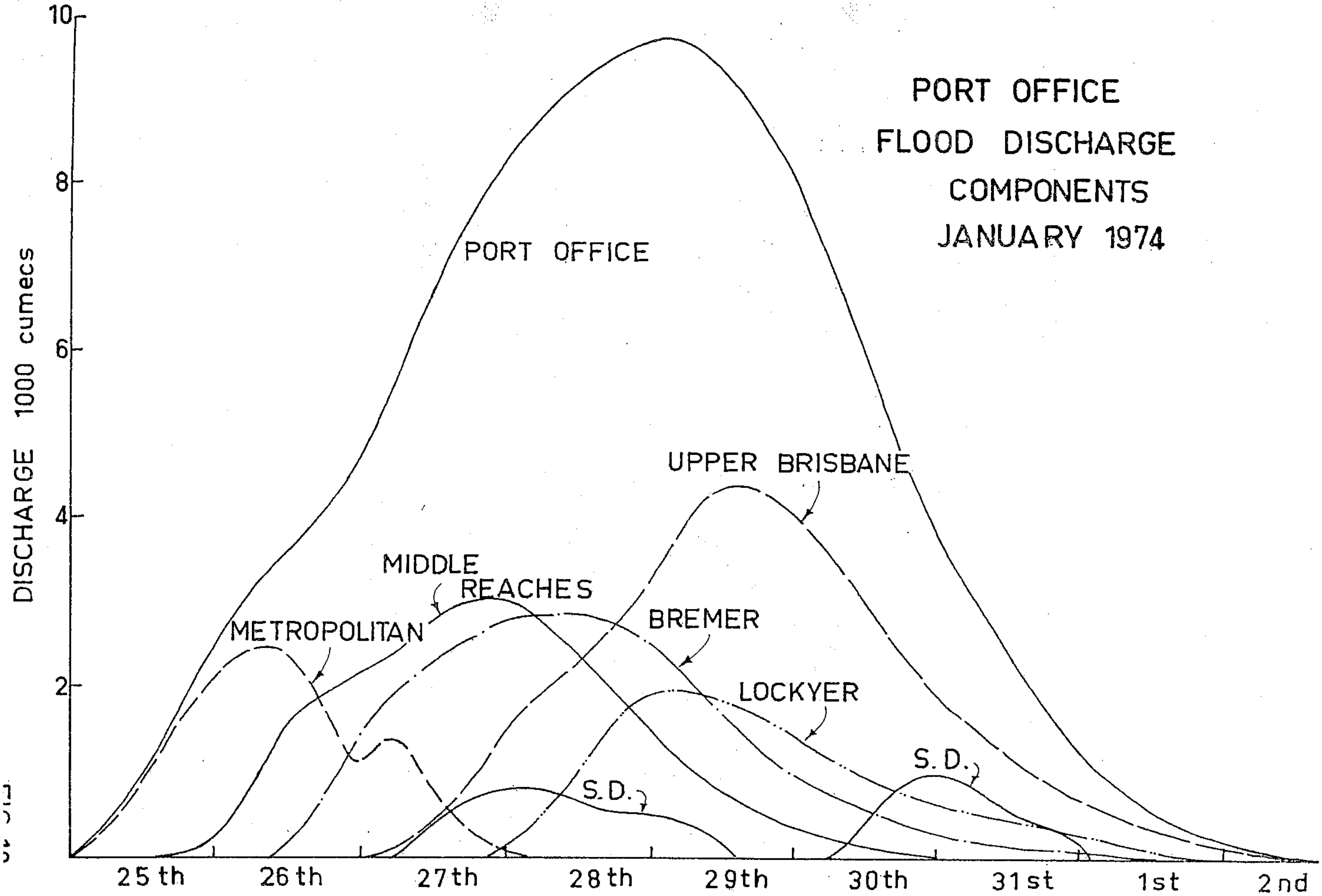
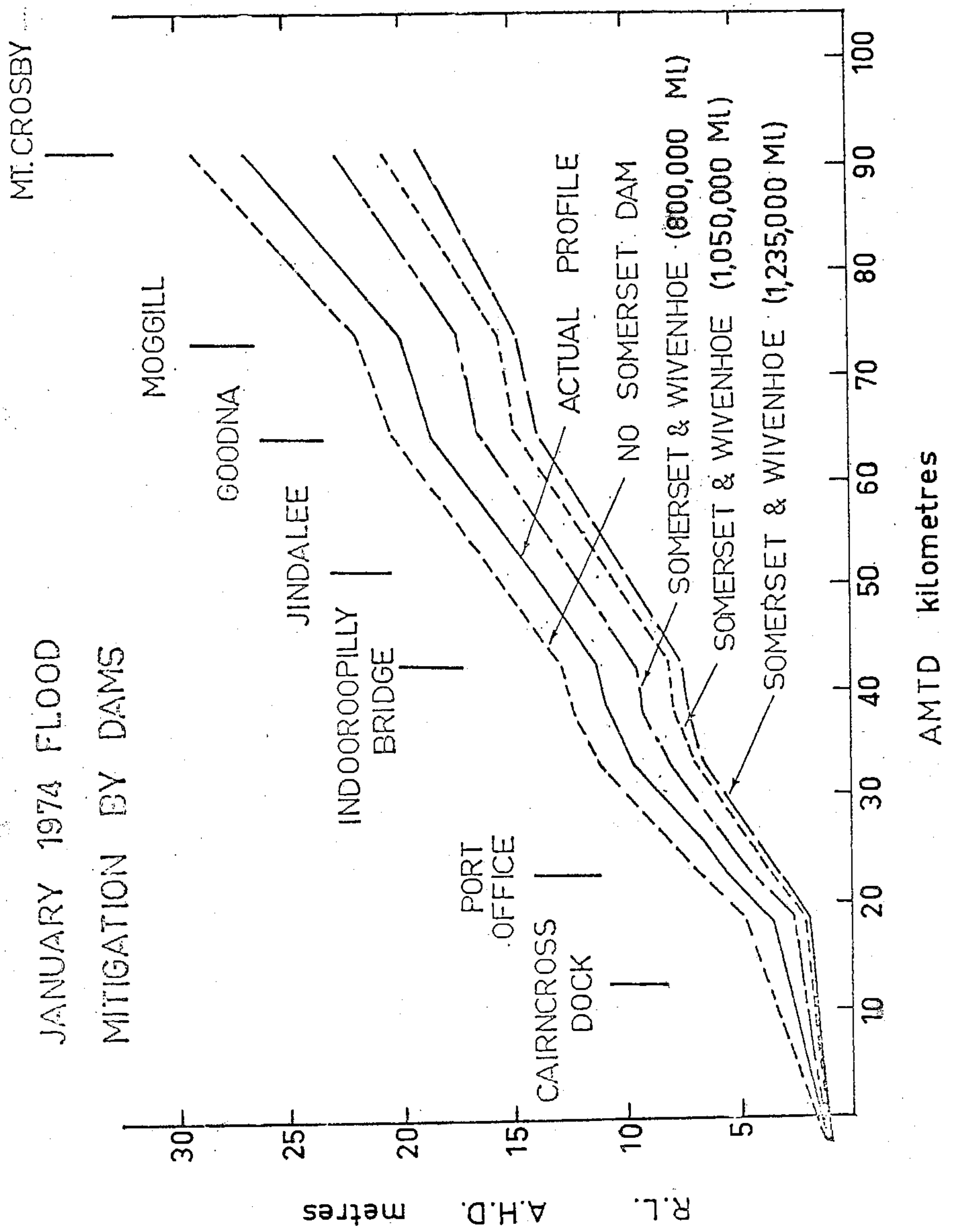

metres
1
STORM SURGE
TIDE
PORT OFFICE
FLOOD HEIGHT
COMPONENTS
JANUARY 1974
PORT OFFICE LEVEL A.H.D. m.
5
4
3
2
1
0
-1
UPPER
BRISBANE
MIDDLE
REACHES
METROPOLITAN
BREMER
LOCKYER
S.D.
S.D.
25th
26th
27th
28 th
29th
30th
31st
1st

FIG. 9


PORT OFFICE
FLOOD DISCHARGE
COMPONENTS
JANUARY 1974
PORT OFFICE
UPPER BRISBANE
MIDDLE
REACHES
METROPOLITAN
BREMER
LOCKYER
S.D.
S.D.
DISCHARGE 1000 cumecs
10
8
6
4
2
25 th
26 th
27th
28 th
29th
30th
31st
1st
2nd



JANUARY 1974 FLOOD
MITIGATION BY DAMS
MT. CROSBY
MOGGILL
GOODNA
JINDALEE
INDOOROOPILLY BRIDGE
PORT OFFICE
CAIRNCROSS DOCK
ACTUAL PROFILE
NO SOMERSET DAM
SOMERSET & WIVENHOE (800,000 Ml)
SOMERSET & WIVENHOE (1,050,000 Ml)
SOMERSET & WIVENHOE (1,235,000 Ml)
R.L. A.H.D. metres
AMTD kilometres
30
25
20
15
10
5
10
20
30
40
50
60
70
80
90
100

FIG. 11

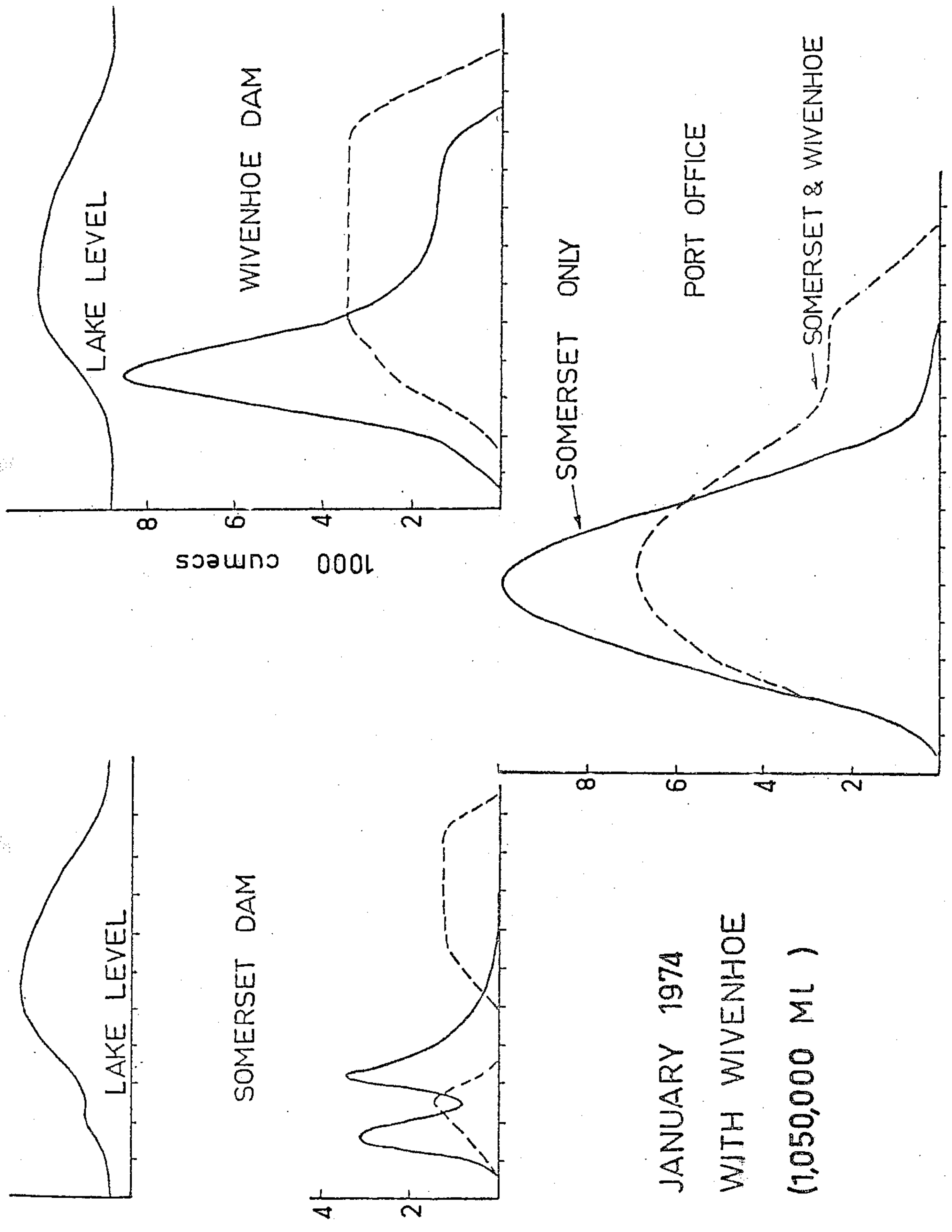

LAKE LEVEL
WIVENHOE DAM
SOMERSET ONLY
PORT OFFICE
SOMERSET & WIVENHOE
1000 cumecs
8
6
4
2
LAKE LEVEL
SOMERSET DAM
JANUARY 1974
WITH WIVENHOE
(1,050,000 ML)

FIG. 12

INDICATED AND ACTUAL INFLOW TO STORAGE DAM

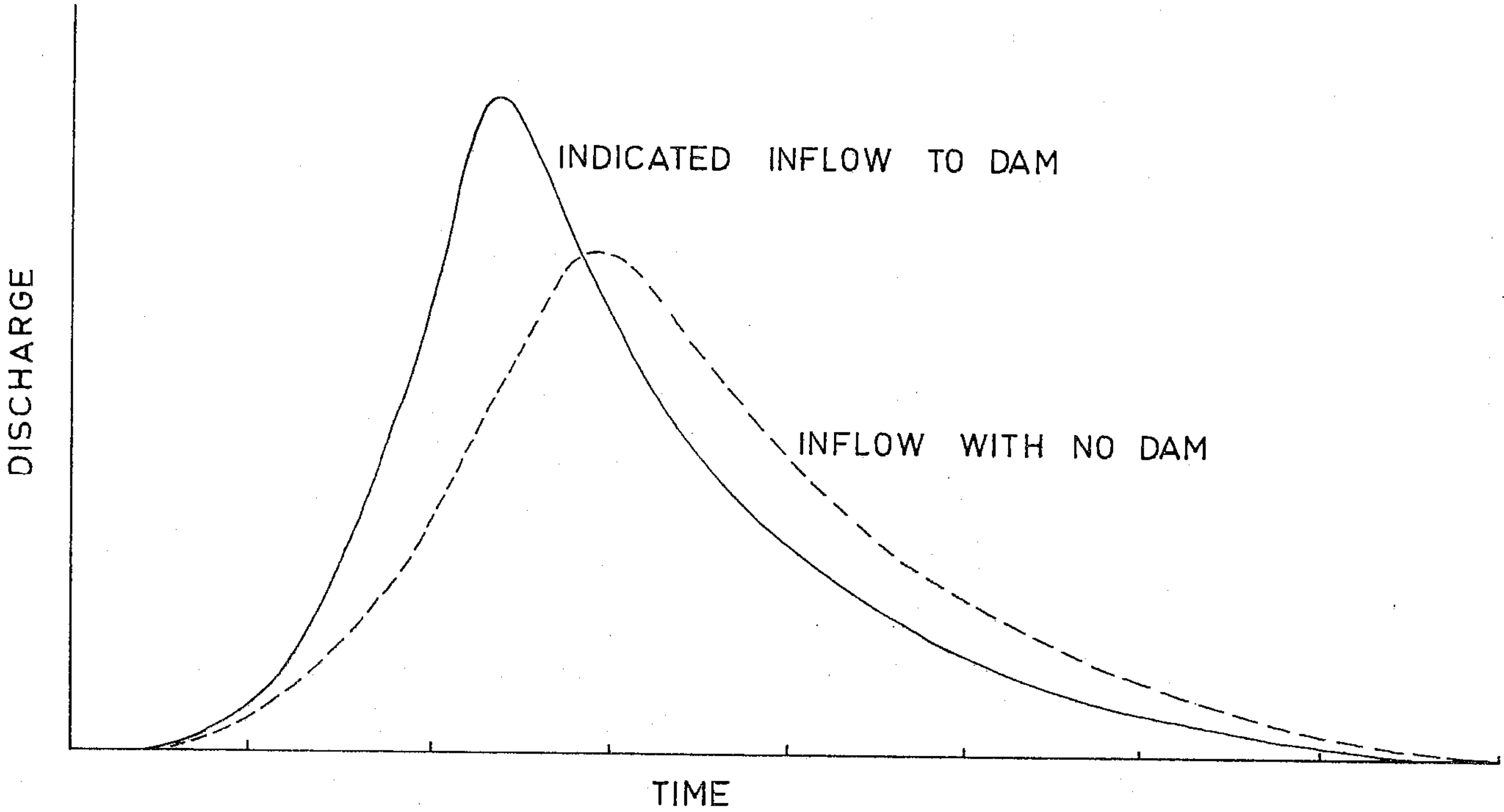
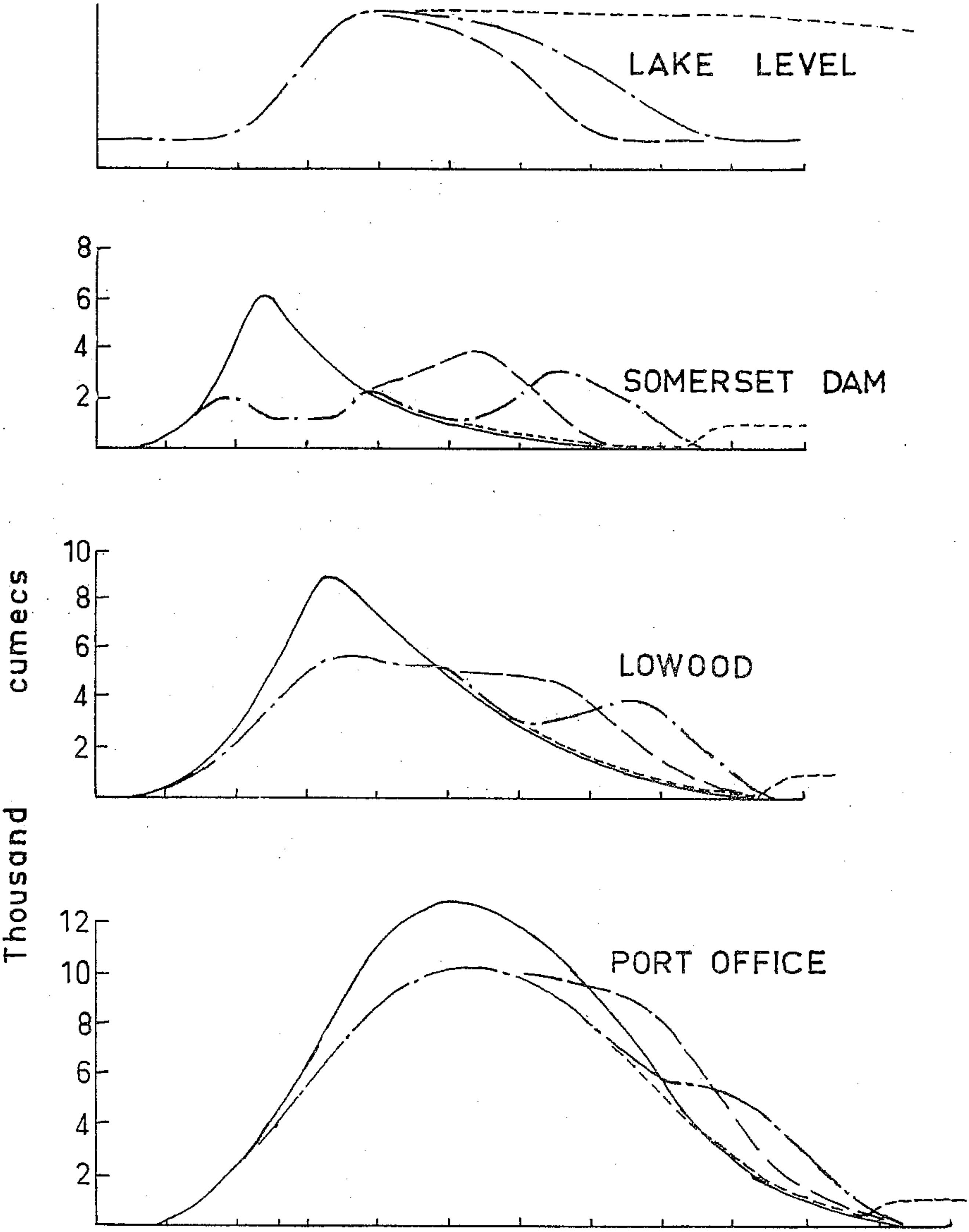


FIG. 13



1893 FLOOD WITH SOMERSET DAM

FIG 14

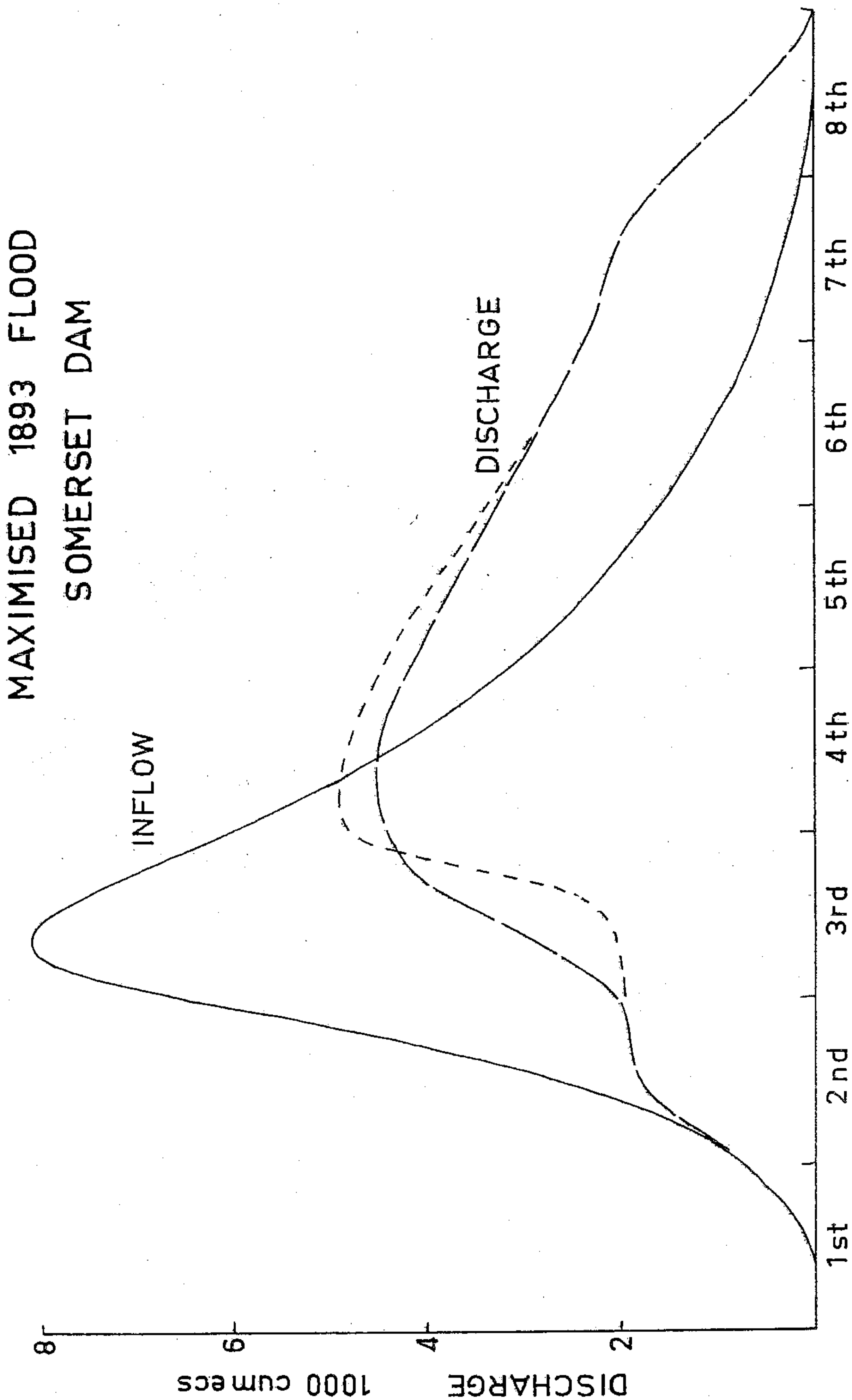

MAXIMISED 1893 FLOOD
SOMERSET DAM
INFLOW
DISCHARGE
DISCHARGE 1000 cum ecs
8
6
4
2
1st
2nd
3rd
4th
5th
6th
7th
8th

FIG. 15

DISCUSSION

E. M. Shepherd, M.E. F.I.E. Aust.

Following the last flood, two types of complaints were common. One was that the public had not been adequately warned of the flood risk in Brisbane, and the other that during the flood the predictions were quite inadequate to advise the public of the intensity of flooding to be expected in various parts of the City and suburbs.

In both cases the long fortuitous immunity from damaging flooding by the Brisbane River was probably a major contributing factor. It is a fact that few people will really heed warnings of phenomenon outside their own personal experience and a cynic might claim that any apparent lack of understanding of the risk was because the public did not want to face up to it and preferred to subscribe to the all too common flood philosophy of 'unlikely to happen in our time' comparable to 'when I win the casket'.

One speaker referred to a 'Somerset Dam Syndrome', and the flood mitigation provided by Somerset Dam has been exploited by certain irresponsible groups. However, the role of this dam has never been overestimated in official publications. It has always been clearly represented as providing flood mitigation only with its capacity outlined, but not flood prevention.

Whatever the basic cause, awareness of flood risks in Brisbane waned after the early 1940's and extensive building over the lower parts of the flood plain resulted.

In earlier years there were many in responsible positions - engineers and administrators - with personal experience of what had happened in the 1890's and there had been a few reminders, such as the Gutteridge Royal Commission in 1928 on water supply and flood mitigation, and particularly the 1931 flood which was then on the threshold of real damage. This flood frightened Brisbane without harming it very much and flood mitigation received serious attention shortly after with the formation of a Special Committee of the Bureau of Industry to examine the matter.

The recommendations of this Committee led to the construction of Somerset Dam.

The Committee examined the relative merits of dams at Middle Creek on the Brisbane River and Mt. Brisbane on the Stanley River for flood mitigation and water supply and recommended the latter, stressing its value for flood mitigation. The construction of the Somerset Dam as a combined purpose structure was the result.

The enabling legislation in 1932 covered action after its completion by the provision made for the creation of a 'Flood Board' when the Stanley River Works Board, created to build the Dam and other necessary work had completed its assignments.

This legislation of course, had to be repealed when Somerset Dam was handed over to the Brisbane City Council but it was originally intended that the Flood Board should plan and implement whatever action might be necessary for mitigation of the flood menace. The terms of reference to be inferred from the legislation were rather general, but the former Chief

Engineer of the Stanley River Water Board, W.H.R. Nimmo, perhaps best known to most as a former Commissioner of Irrigation and Water Supply, had clear ideas. The writer was the Designing Engineer for the Stanley Board Water Board and greatly admired Bill Nimmo's ability to think clearly and to think ahead, and he usually led his Board. The accepted conclusions were that it would be necessary for -

(a) Continued collection of data and appraisal of the hydrology and hydraulics of the Brisbane River System, then with many gaps since no really high flood had occurred since 1898. Hence there would be a need to collect all possible data from future floods. This policy was of course implemented firstly by the Office of the Chief Engineer, Stanley River Water Board then after its merger, by the Office of the Chief Engineer, Co-Ordinator General's Department and more recently by the Water Supply Department of the Brisbane City Council.

(b) Reliable means of communication to be established, both for the assembly of rainfall and hydraulic data, and for the efficient operation of Somerset Dam. This originally led to some mild disagreement with the Postmaster-General's Department who were then opposed to granting licences for radio communication and had an unjustified faith in their trunk telephone system.

(c) Clear knowledge as to how Somerset Dam might best be operated for efficiency in flood mitigation and safety, and organisation of the means to ensure this under all emergencies. In this respect Bill Nimmo was a little mistrustful of possible divided opinions from the anticipated membership of the proposed 'Flood Board' at critical times, considering that in an emergency the full responsibility for action should be given to one competent Engineer fully conversant with the problems of the Brisbane River catchment. Bill Nimmo trusted responsible and informed engineering judgement but mistrusted interference from personal or political motives. Many will agree with him.

(d) A very important adjunct to the planned operation activities in the preparation of a revised flood map, based on accurate contour and flood data, to replace the 1933 Bureau of Industry flood map.

This map was based on contour plans proposed in 1911, and the inadequate flood data, then available, but nevertheless had proved extremely valuable. In order to establish reliable flood profiles arrangements were made with Brisbane City Council for the establishment and reading of a series of flood gauges at suitable points in the suburbs, and what was referred to in the Office as 'Mr. Nimmo's tame flood' was awaited to establish reliable flood profiles, some preliminary work being carried out in the meantime.

There was quite a long wait, until the 1955 flood to a large extent conformed with the specification, but shortly after this Higher Authority decreed that the preparation of the flood map should be a Local Authority and not a Departmental activity. In about 1950 Mr. Nimmo had been appointed Commissioner of Irrigation and Water Supply.

The system of flood warning anticipated by the Stanley River Water Board office involved firstly predictions of the flood height in Brisbane, which had to be related to some key point, the Port Office gauge being the obvious choice.

The interpretation of this information for public understanding could then be made by medium of the revised flood map with flood profiles used for the more accurate predictions where actual ground or floor levels were available.

It was considered that the continued accumulation of flood data would progressively improve the accuracy of predictions. It was considered essential (in spite of some opposition) that the flood map should be a document widely available to the Public and not one for reference only in a central locality. This had been the aim of the 1933 flood map but it had become out of print too soon.

Research work on the catchment, the establishment of reliable flood height prediction, communications, and operational procedures have been considered under the direction of the Brisbane City Council and there are now no notable deficiencies here.

There have, of course, been the inevitable criticisms of actual operations of the dam, but the writer is not aware of an informed basis for any such claims.

Further to criticisms that local flood warnings during the recent flood were inadequate, the writer can not support criticisms of predictions being in the first instance related to the Port Office gauge. This he considers to be the essential first step. Means to predict the incidence of local flooding from the river should be a second step, which could be by medium of a widely available flood map, with far greater precision the establishment of clearly defined and visible level marks on the ruling datum (i.e. <u>not</u> related to Port Office levels, as indicated by the flood map, and not indicative of some given flood height on this guage). These level marks should be established in the flood prone areas.

The adoption of metrication makes a new flood map even more essential and to be in fashion it will almost certainly be required to be in metric units and with a new datum. This will probably be Australian Height Datum (A.H.D.) nearly one metre above present Port Office Zero. It is understood that the preparation of such a map with appropriate height intervals is under negotiation.

The setting up of local height marks would serve the additional purpose of publicising the new metric contour levels, and also serve for more accurate interpretations of local flood risks and predictions.

It would of course, have to be made clear that the figures on level marks were not directly related to flood heights or else there would be some wild predictions by the uninformed.

As to general communication by means of a flood map. In every group of the community there is almost certain to be some who could interpret it and the level marks correctly.

It may be of interest to include some of the relevant portions of the

1932 Bureau of Industry legislation with respect to the Flood Board although this is no longer operative and conditions are now very different. This reads -

> "The Governor in Council, may by Order in Council, vest the general supervision of operations including management of construction of works - in a Board to be called the 'Flood Board'".

Provision was made for its membership to comprise the City Engineers of Brisbane and Ipswich, the Chief Engineer Harbours and Marine Department, a representative of the Queensland Irrigation and Water Supply Commission, Chairman of the Works Board and the Director of the Bureau of Industry.

Provisions were further that -

> "It shall be the duty of the 'Flood Board' to make a continuous study and observations of the Brisbane River, its tributaries, and its and their catchment areas, especially in times of abnormal rainfall and such Board is hereby empowered and authorised to take such action as it shall deem necessary for all purposes of this section".

Perhaps it might be claimed that this could mean all or nothing, but certain future responsibilities were read into it in the 1930's.

Flood Mitigation by a Dam on the Brisbane River at Wivenhoe

Since the Australia Day weekend flood, there has been an upsurge of faith in a Wivenhoe Dam as a means to eliminate flooding in Brisbane. This can be a dangerous assumption. It must be appreciated that protection from floods is relative, and nature eventually will levy her toll on those who occupy flood plains although in some cases she may wait 1,000 years. This is not to say that a fatalistic attitude should be adopted. Far from it. It is a well established fact that the greatest aggregate of damage can normally arise from the more frequent floods in the medium to higher ranges, and if flooding can be effectively reduced, even if not eliminated, the benefit can be great in terms of money and human misery.

This is what a Wivenhoe Dam could do. The investigation made by the former Engineering Office of the Co-Ordinator General indicates that a Wivenhoe Dam could reduce the flood damage in Brisbane and Ipswich by some 20%. The 1974 flood originated in a different manner to any previously known with abnormal meteorologic conditions in the catchments below it, but it has also focused attention on the potential value of the flood mitigation function and it seems that any extra money needed to improve its flood mitigation capacity will be more readily available.

The method of control of the dam will be very important since it could make or amplify a flood if wrongly operated, and careful investigation will be required in its design to ensure that all conditions can be met. This could even involve building up a released discharge faster than the natural flood flow, and it will be essential for a decision - perhaps of a statutory nature - on the permissible flood flow at Brisbane.

By this it is meant that anyone who avoidedly builds below the equivalent level of such a flow would have to be regarded as having done so at his own risk, and it would be an obligation on authority to ensure that the acceptable levels along the flood plain were everywhere generally known.

A reservoir like Wivenhoe will completely change the flood run-off characteristic of the mid Brisbane Valley. No longer will a flood wave proceed rather leisurely down the valley from say, Stanley Junction to Wivenhoe, but the whole reservoir will respond to the flood inflow over this length in a small fraction of the old travel time and the rate of rise at Wivenhoe could be frightening to, and subject to misunderstanding by, any inexperienced operator.

River Dredging and its Influence on Flood Levels

The special Committee of the Bureau of Industry and the Stanley River Works Board, which to some extent took its place, expected that dredging of this river and improvements in some areas (such as at Kangaroo Point and the rock bar near the mouth of the river) would greatly improve the hydraulic properties of the river. Work prior to 1931 was believed to have improved conditions to the extent that an 1893 flood might have been four (4) feet lower at the Port Office and that the further improvements made in the 1930's would increase this to above seven (7) feet. It was anticipated that except for a minor drawdown this improvement would not extend much above the city bridges.

It would seem that silting has now largely nullified the 'improvements' of the 1930's, but the reaches below New Farm are probably better than anticipated with a very satisfactory depression of the profiles of high floods.

It seems too that the channel above the Bridges, up to the neighbourhood of Indooroopilly, may be hydraulically more efficient now than in 1931. The most logical assumption is that this has been influenced by dredging for gravel. Perhaps, however, in addition to the removal of gravel, some mud disturbed thereby has travelled downstream instead of resettling.

The shallowing of the City reaches and its results is an indication of what might happen if the Port of Brisbane changes from its present condition as a river port to a Moreton Bay port, for which cessation of dredging is claimed as a major benefit.

In such case, however, silting would be inevitable, with a considerable lift in the profiles of the higher floods with detriment to the City and riverside areas downstream.

Might I quote the following extract from an early report -

"As an interesting observation on the original condition of the Brisbane River, I mention that Captain Brennan, who has been in the Marine Department since 1866, informs me that in 1868 he waded at low water right across the river in the Quarries Reach upon a sand bar starting near 'Colmslie' and walked thence up to the Hamilton. The greatest depth on this bar was 3½ feet, which depth continued until 1873 when the flood of that year removed it to 6 feet".

What man has laboriously taken away could, in time, be restored by nature assisted by man-induced upstream erosion. The present need for continuous dredging to maintain shipping channels emphasises this point.

Flood Level Oscillations

Mr. Cossins commented on a certain degree of short period ebb and flow in the level of the flooded Brisbane River, which he considered might lead to erratic gauge height reading.

This is a common phenomenon in large rivers, very confusing when one is attempting to obtain a quick appraisal of conditions and rates of rise or fall.

In my young days in the country the bushman's method was to set two sticks, preferably in a backwater, to mark the two extremes and to watch them until a definite conclusion could be reached.

This ebb and flow phenomenon was noticable in sheltered little backwaters during the recent flood, and for example, at the end of Stanley Street it appeared of varying heights up to the order of 2 and 3 inches over about 10 minutes.

When flood peaks on gauges or elsewhere are picked up from well defined water marks or in particular, fine debris, the upper limit is commonly that which is recorded.

The phenomenon is thought to be some form of transverse oscillation travelling with the current rather than a series of low surge waves in the channel.

Prof. K.J. Bullock, B.E., Ph.D., M.I.E. Aust.

Mr. Cossins states that the catchment arwa of Somerset Dam represents 10% of the catchment area of the Brisbane system. What does the Somerset Dam Catchment Area represent on the total Brisbane River flow over the rive days on the January 1974 floods? What percentage of this volume of water was available for storage at Thursday evening (4 p.m.) 24th January, 1974?

The Author in Reply -

To Mr. Shepherd - The comments are extremely pertinent and reflect his long association with flood mitigation in the Brisbane River. He thinks that the oscillations discussed in the paper on Flood Mitigation are transverse oscillations generated upstream in the river and travelling down with the water. Mr. R.J. Gourlay of the Bureau of Meteorology is also of the same opinion. The only puzzling feature about this viewpoint is the similar record picked up by the recording tide gauge at the West Inner Bar. The author feels that this gauge may be far enough into Moreton Bay not to be influenced by the Brisbane River. A recording tide gauge in a remote part of the Bay may clear up the problem.

To Prof. Bullock - The volume of the inflow to Somerset Dam in the January 1974 flood was 646,000 Ml whilst the volume of the flood measured at Jindalee was 3,579,000 Ml, a ratio of 18% compared with the 10% ratio of the catchment areas. The flood storage of Somerset Dam was completely empty at 4 p.m. on Thursday, 24th January.

FLOODING IN BRISBANE METROPOLITAN CREEKS

*by I.G.Cameron, B.E., F.I.E. Aust., M.I.C.E.**

Brisbane has been built on both banks of the Brisbane River with the central city area some ten miles distant from the river's mouth in Moreton Bay. The river flows in a generally S.S.E. direction from its source and skirts the western flank of the D'Aguilar Range until it reaches a point just north of Ipswich where it turns to flow in a N.E. direction to its mouth in Moreton Bay.

The D'Aguilar Range terminates in a number of long ranges of hills which leave the main range with peak elevations of 1,500' - 2,000' and penetrate right into the suburban areas of North Brisbane. Taylor Range, for instance, ends in Mt. Coot-tha at an elevation of 800 - 900 feet only 3½ miles from the heart of the central business district.

The Urban Creeks of Brisbane

Between these ranges are deep, steep sided valleys with narrow valley floors. A series of major creeks with catchment areas up to 30 square miles flow in these valleys thence across the Brisbane River plain and coastal plain and discharge either into the river or Moreton Bay.

South of the river the country is generally flat to rolling and is drained by a number of creeks which flow north into the Brisbane River. These creeks generally have larger catchments than those to the north of the river and have much flatter profiles, wide flood plains and present quite different problems to those to the north of the river. Flood plains are more extensive and hence river storage modifies downstream discharge to a greater degree than happens in the Northern creeks.

The creeks both north and south of the River can be subdivided into two further categories:

Those creeks which flow into Moreton Bay or the Brisbane River downstream of the central business district experience maximum flood levels, in all but small areas around the confluences with the River, due to runoff from their own catchments.

Those creeks which flow into the river upstream of the central business district experience maximum flood levels over considerable lengths of their courses due to backwater from flooding in the river. This is not to say that large floods due to local runoff are not experienced, they certainly are, but in the flatter more economically important area river flooding can be considerably higher than creek flooding.

* *Principal, Cameron McNamara and Partners Pty. Ltd., Consulting Engineers*

TABLE 1

SIGNIFICANT BRISBANE METROPOLITAN CREEKS

	C.A. (sq.m.)	Location of Creek Mouth
1. North Side Creeks		
Pullen Pullen	12	) U/S of C.B.D.
Moggill	12	)
Breakfast/Enoggera	31	D/S of C.B.D.
Kedron Brook	27	) Moreton Bay
Nundah	13	)
Cabbage Tree	17	)
2. South Side Creeks		
Wolston	18	) U/S of C.B.D.
Oxley	100	)
Norman	12	) D/S of C.B.D.
Bulimba	43	)
Tingalpa	56	Moreton Bay

Flood Plain Development

The catchments of Breakfast, Kedron Brook, Nundah and Norman creeks are extensively urbanised and significant urbanisation is occurring in parts of the catchments of the other creeks.

By far the greatest flood damages occur in the Breakfast/Enoggera Creek catchment although in the Australia Day floods of 1974 extensive damage due to local runoff was caused in the catchment of most of the other creeks. Damage in the Breakfast/Enoggera Creek catchment has been estimated to exceed $3,500,000 in this one flood and the total damages since 1967 approach $10,000,000.

Even without the threat posed by the Brisbane River, Brisbane has a local flooding problem which would exceed that of most other cities of comparable size. Except in 1931 the first 66 years of this century were remarkably free of flooding and, as time passed, memories of major flooding experienced in the eighties and nineties of last century faded. Pressures to develop low lying land, which had previously been avoided, increased, and between the two world wars much of the flood plain of Breakfast Creek was built on. Since the early fifties there has been large scale development of Kedron Brook catchment and parts of Moggill, Witton, Bulimba and Oxley creeks have been developed both for residential and industrial purposes. Luckily the 1931 flooding prevented complete development of the Breakfast Creek flood plain and there are a large number of football parks and other playing fields occupying the lowest part of the plain. Nevertheless there was much development for residential purposes which in the light of recent experiences could only be called imprudent.

Dissemination of Knowledge

Until recently there has been little effort by the Government or Council to advise prospective purchasers of land in the flooded areas as to the likely flood experience. As previous speakers have shown there is a considerable body of knowledge of flooding in the Brisbane Metropolitan area. Inundation maps have been available in some form for more than forty years. Much better inundation maps for both river and creek flooding are essential. These should be printed in large numbers and be freely available to the public, not only immediately after a major flood, but at all times. On the reverse side of the maps there should be a simple description of past flood experience and some indication of probabilities of the exceedance of some key levels. (e.g. 5' above 1974 levels, 1974 levels, 5' below 1974 levels, 10' below 1974 levels). Inclusion of say 1974 peak levels would help in the general understanding of the information.

Recent History

In 1931, June 1967, February 1972 and April 1972 floods were experienced in many of Brisbane's creeks which were comparable in magnitude to the worst previously recorded. It seems almost certain that larger floods would have been experienced in the 1840's, 1880's and 1890's but due to lack of development on the flood plains no records of their magnitude have been kept.

The Australia Day weekend flood of 1974 exceeded by a generous margin those previously recorded in all the urban creeks except those with catchments confined to the east of the city such as Bulimba, Tingalpa, Nundah and Cabbage Tree creeks.

It is an unfortunate fact that for meteorological reasons the storms which produce flood runoff in metropolitan creeks nearly always peak at night with peak runoff and flood levels in the early hours of the following morning. Photographic records of peak flooding are therefore scarce and even accurate eye witness accounts covering a wide area are not plentiful.

Furthermore, it was not until 1972 that the first automatic water level recorder was installed in the Breakfast Creek catchment at Bancroft Park. It recorded the two 1972 floods and the 1974 flood. Another automatic recorder was installed on Ithaca Creek in time to record the 1974 flood. Without these recorders the certainty of calibration of the mathematical model of the Enoggera/Breakfast Creek catchment would have been difficult. Mr. Morris will give much more detail of the work that has been done and the checking that has gone on since January this year.

The Storm

The Australia Day storm was unusual in many ways. High intensity rainfall was maintained over a long period. It had three distinct peaks 12 and 18 hours apart. Intensities recorded at many stations during the Friday night peak were amongst the highest recorded for long duration storms. Figure 1 shows rainfall intensity-frequency-duration data for the Brisbane Regional Office of the Bureau of Meteorology and data for Enoggera Dam for comparison.

The rain on Friday and early Saturday morning was caused by strong onshore N.E. winds due to a steep pressure gradient between cyclone "Wanda" which crossed the coast near Double Island Point and a 'High' in the Tasman Sea. The rain on Saturday night and Sunday was caused by the monsoonal trough which had moved south with "Wanda" and then back north again to remain stationary just north of Brisbane. The areal distribution of rainfall was very variable even over comparatively small areas.

In 7 hours on Friday night the following rainfalls were recorded:

C.B.M. - Brisbane Bureau	:	528 points
Enoggera Reservoir (6 miles W. of C.B.M.)	:	995 points
Three catchments (12 miles W. of C.B.M.)	:	132 points

(peak 1 hour rainfall at Enoggera Reservoir = 363 points)

The area of maximum precipitation for the three days of heavy rainfall was a lozenge shaped area running N.W. - S.E. from the Mt. Glorious area to Enoggera Reservoir. Rainfall fell away in all directions from this area of high intensity. On Friday and Saturday there was another lesser centre of rainfall south of Brisbane near Clover Downs in the headwaters of Oxley Creek.

The following is a record of rain recorded at the Enoggera Reservoir pluviograph:

1st Storm	Friday,	25/1/74	0.00 hrs. - 16.00 hrs.	: 918 points
2nd Storm	Friday,	25th, 16.00 hrs. - Saturday, 26th, 3.00 hrs.		: 1,104 points
	Saturday,	26/1/74	3.00 hrs. - 17.00 hrs.	: 218 points
3rd Storm	Saturday,	26th, 17.00 hrs. - Sunday, 27th, 6.00 hrs.		: 917 points
	Sunday,	27/1/74	6.00 hrs. - 24.00 hrs.	: 281 points
			Total for 72 hours	3,438 points

The first peak was unusual in that it occurred during daylight hours and despite very difficult access, the peak flooding in Enoggera Creek was observed by the author and Mr. Morris, from St. Johns Wood to the mouth.

The second peak, and by far the largest, occurred during the first part of Friday night and brought peak flooding in most of the Metropolitan Creeks north of the river in darkness early on Saturday morning. The falling leg of this flood in Breakfast Creek was again observed between Normanby Bridge and the Brisbane River in the early daylight hours of Saturday. Peak levels in Oxley Creek at Ipswich Road (R.L.30.75) were not reached until Saturday afternoon.

Runoff

The model of urban runoff devised by Rao, Delleur and Sarma in the United States showed that in long duration very high intensity storms there is probably only 10% increase in runoff as a medium sized catchment is transformed from rural to urban conditions. This is so contrary to the long held belief of many that increasing urbanisation makes for a marked increase in runoff that some observations made during the height of the 1974 storm are worthwhile.

In both rural and suburban parts of the catchment a large proportion of rain was falling on flowing water and therefore was converted immediately to runoff.

The underground drainage systems were hopelessly surcharged and a large proportion of runoff in suburban areas was overland. The increased rate at which rain ran off impervious roofs and roads was to a degree mitigated by the retarding effect of fences, walls, houses, etc. The runoff from both rural areas and suburban blocks towards the end of Friday morning's peak rainfall, when rain had been falling at a rate of 100 - 150 points per hour for four hours with six hours at about 60 points an hour prior to this, was remarkable to see. Runoff on Friday night would have been even more extreme.

We believe that the Rao model gives an accurate picture of the runoff mechanism under the extreme precipitation conditions experienced in January as well as in the much more moderate conditions for which it was originally designed.

Effect of Tides on peak water levels

The effect of tides on peak water levels is generally over-estimated. For river levels above R.L. 20' at the Port Office fluctuations in water level due to tides was only of the order of 0.8 feet at the Port Office. Above Dutton Park there was no discernible fluctuation in water levels in the river due to tides.

Breakfast Creek discharges into the river in all but very small floods in an overfall type M2 backwater curve. Flood levels of about R.L.13'. recorded just upstream of the Breakfast Creek bridge at the mouth of the creek when river levels were at a maximum level of about R.L. 9'. It is impossible for tidal fluctuations in river levels to be reflected upstream under these circumstances.

In the 2 hours after midnight on Friday, 25th January, 1974 while Enoggera Creek at Kelvin Grove Road was rising three feet and at Northey Street was rising 4.0 feet the level of the Brisbane River fell 2.0 feet.

Despite this, Police, Radio and Television Stations were issuing warnings based on expected high tide times in the river. Decisions involving personal safety and very large possible financial losses were being made on the basis of these warnings. It is essential that the police and civil defence authorities be educated in this and other matters concerned with creek flooding.

Flood Warning

A question which has received much attention recently is "Is it possible to install a workable flood warning system on Brisbane Creeks?"

Northside creeks peak 4 - 7 hours after the commencement of heavy rain. However, 2 - 4 hours after the start of the storm, water levels in low lying parts of the flood plains can be high enough to make the removal of people and the safeguarding of property difficult.

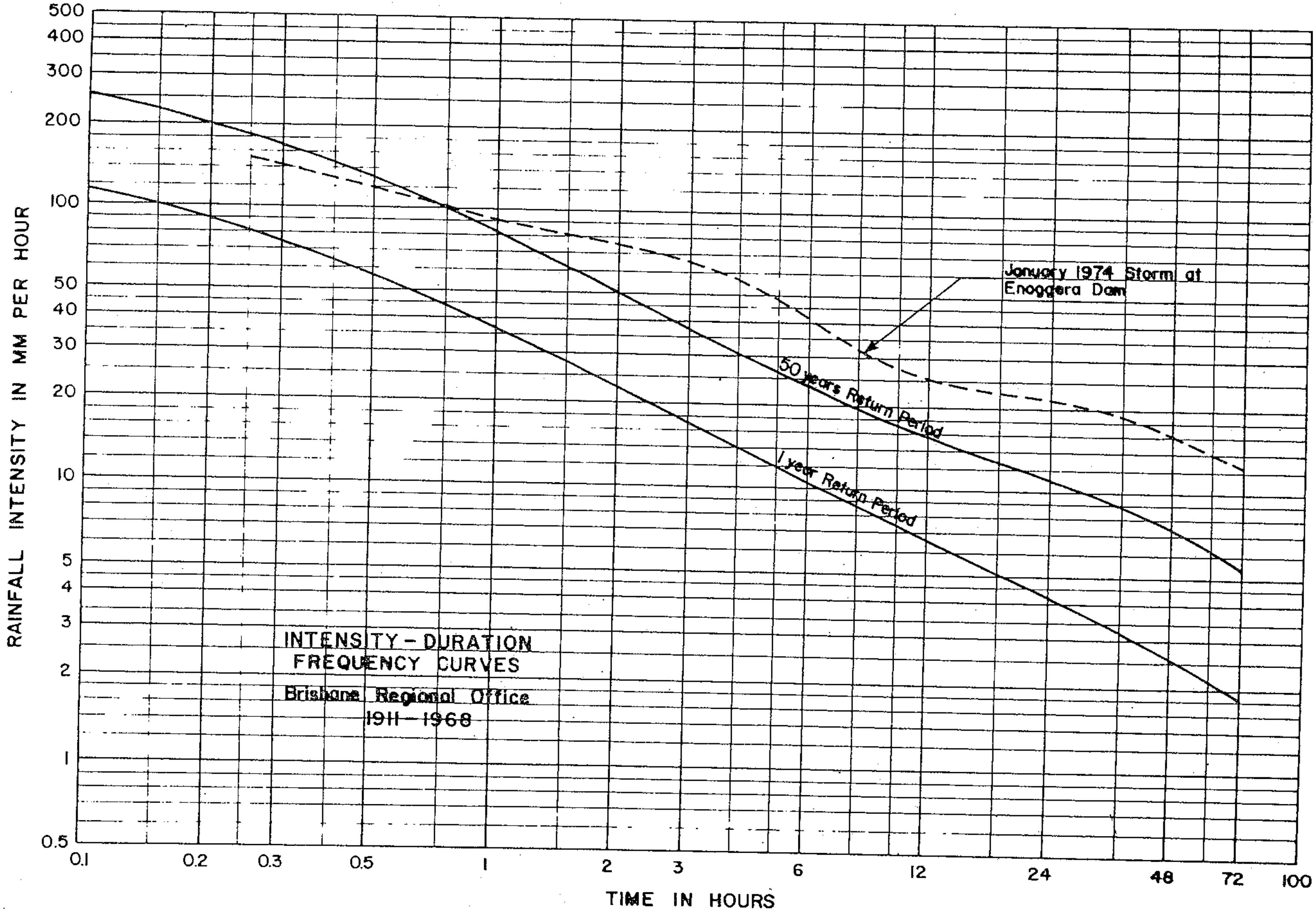
Southside creeks such as Oxley and Bulimba take longer to respond to rainfall. For instance in 1974 Oxley creek reached the level of Ipswich Road (R.L.16.6') at 6.00 p.m. on Friday. It reached a level of 29.00' at 8.00 a.m. and peaked at R.L.30.7' at noon on Saturday. Backwater from the Brisbane river subsequently exceeded this level.

By remote telemetering of pluviographs and water level recorders and inputting this information together with meteorological data on line into a computer, forecasts of flood levels in Northside creeks could be made for most floods with acceptable accuracy two to three hours in advance.

Could effective action to evacuate people and safeguard property be taken in that time?

Could the system live with forecasts which overestimate flood levels and initiated unnecessary evacuation?

These two questions must be answered before much effort is expended on a complex computerised warning system. Today's technology can provide answers so long as the answers are worth having.



500
400
300
200
100
50
40
30
20
10
5
4
3
2
1
0.5
RAINFALL INTENSITY IN MM PER HOUR
0.1
0.2
0.3
0.5
1
2
3
6
12
24
48
72
100
TIME IN HOURS
January 1974 Storm at
Enoggera Dam
50 years Return Period
1 year Return Period
INTENSITY - DURATION
FREQUENCY CURVES
Brisbane Regional Office
1911 - 1968

FLOODING IN THE ENOGGERA - BREAKFAST CREEK CATCHMENT

by K.J. Morris B.E. M.Eng.Sc., M.I.E. Aust. *

GENERAL

During 1972 the Co-Ordinator General's Department commissioned Cameron McNamara & Partners to study the Enoggera-Breakfast Creek catchment and make recommendations on the possibilities of mitigation of the numerous floods this creek system has experienced over recent years.

To this end a mathematical model of Enoggera-Breakfast Creek was developed. The model included the major tributaries of Ithaca and Fish Creeks, and extended along Enoggera Creek from its confluence with the Brisbane River up to and including Enoggera Reservoir, a distance of approximately thirteen miles.

The Creeks system was divided into seventeen reaches, of which the largest was that of Enoggera Reservoir. Enoggera Reservoir is situated approximately halfway along the length of Enoggera Creek, and controls approximately 41% of the total catchment area. It was chosen as the uppermost reach because the Brisbane City Council, in conjunction with the Queensland Institute of Technology, had developed a unitgraph for the area above the Reservoir, thus allowing inflows to Enoggera Reservoir to be calculated. For the remaining sub-catchment the inline and lateral inflows are calculated using the technique of Rao, Delleur and Sarma of which the only variables beside a rainfall hyetograph are simply the catchment area and its percentage of impervious area.

Flood routing is carried out using storage routing techniques, of which two are used by the model. These are:

(i) the Puls method, which is used for the routing of floodwaves through reservoirs or retention basins;
and,

(ii) the Muskingum method, which is used for the routing of floodwaves along open channel reaches.

Flood levels were calculated by using a series of backwater curves which were calculated by applying the standard step method to the cross-sections of the creek system.

The model was calibrated using the June 1967 storm which produced a high flood and the October 1972 storm which produced a low flood, only just breaking the banks of the Creek. Both of these events had sufficient pluviograph data. The documented flood levels, although concentrating on the lower reaches, were the best available at the time. Following calibration, the model was tested using the February 1972 flood. The model's reproduction of the I.W.S. automatic gauging station at Bancroft Park is shown in Figure 6.

THE JANUARY 1974 FLOOD

The January 1974 storm provided a great deal of data to further test

* *Engineer, Cameron McNamara and Partners Pty. Ltd.*
Consulting Engineers

the model outside the range for which it had been set up. The calculated flood flow of the largest of the three peaks was 27,000 cusecs at Bowen Bridge. This represents the largest flood ever recorded on the creek system, being some forty-five percent greater than the previously largest flood (April 1972) since 1911.

The available information for this storm and resulting flood consists of:

(i) Pluviograph traces of the storm at five of the six stations that control the catchment. The only station that did not work was that at Mt. Nebo, which experienced the highest manually read 6 and 12 hour totals of any of the other surrounding stations. However, by using the thiessen polygon method, this pluviograph station controls five percent of the area above Enoggera Creek Reservoir and its exclusion, normally, would not be serious.

(ii) Gauge height recordings at:

(a) Enoggera Dam - manual staff readings (B.C.C.)

(b) Bancroft Park on Enoggera Creek - Automatic I.W.S. recorder

(c) Jason Street on Ithaca Creek - Automatic I.W.S. recorder

(d) Butterfield Street on Enoggera Creek - manual staff readings (B.C.C.)

(iii) Numerous flood levels of the main or second peak of the flood.

Adjustment to Enoggera Dam

Before running the model the outflow from Enoggera Dam using the theissen polygon method was compared with the measured outflow. Marked differences were expected because of the heavy rain which fell on the lower part of the catchment above Enoggera Dam (1.5 inches in 15 minutes and 3.65 inches in one hour) compared with the much lower rainfall which occurred in the upper portion (0.2 - 0.4 inches/hour). Hence it is not reasonable to apply one unitgraph to a total average uniform hyetograph over the whole upstream catchment. Figure 2 shows the computed flows versus the measured.

As can be seen from Figure 2, the theissen polygon method of apportioning pluviograph records to form an average hyetograph is too coarse a method for this particular storm. Notice also that a secondary peak outflow at 17.00 hours on the 25th has not been represented, as no heavy bursts of rainfall were recorded on any of the stations around this time. To take account of the uneven distribution of rainfall, adjustments were made to the hyetograph to reproduce, where possible, the actual recorded event at the dam spillway. It was required to obtain a reasonable inflow hydrograph so that flood mitigation proposals could be properly analysed.

The outflow hydrograph of the existing dam, as produced from the adopted inflow hydrograph, is also shown on Figure 2.

January 1974 Flood Levels

Using pluviograph records only with an adjusted hyetograph to Enoggera Dam the results produced by the model represent the 1974 flood reasonably well. The comparisons are shown on the following figures:

(a) Figure 1 shows the model predictions in long section compared with surveyed flood marks.

(b) Figure 3 shows the comparison of the actual stage hydrograph at Bancroft Park on Enoggera Creek with that computed.

(c) Figure 4 shows the comparison of the actual stage hydrograph at Jason Street on Ithaca Creek compared with the stage hydrograph at the nearest reach end which is 920 ft. upstream of the gauging station. Adjustments have been made for flood slope. Note, the only variable input to obtain this result is a hyetograph, catchment area and percentage impervious area.

(d) Figure 5 shows the comparison of the actual stage hydrograph as manually read upstream of Bowen Bridge compared with the computed stage hydrograph at Bowen Bridge with adjustment for the floodslope.

There are three anomalies occurring from the results. The first is the higher afflux at Fraser's Bridge (approx. chainage 35,500 ft.). This was explained by a photograph taken of the bridge the following morning which shows a thick mat of debris covering the bridge to a depth of three to four feet above deck level. The second is the surveyed levels around the St. Johns Wood area which are very close to the June 1967 levels. Interviews with people in the area revealed that the main peak was four feet above the June 1967 level.

The third anomaly is the disagreement of the first peak at Bancroft Park where the computed levels are 1.5 feet higher than the measured values. The February 1972 level, both computed and measured, is directly in between these two. From an analysis of the pluviograph records of the first peak of the January 1974 storm and those of the February 1972 storm, i.e. by comparing the differences in the peak one, two and three hour totals, an increase of 9.8% above the February flood would be expected. The computed increase of 7.4% is consistent with this and thus does not explain the discrepancy. The uneven and patchy nature of the storm during the first peak could provide an explanation, in that the general rainfall could have been less than that shown on the point rainfall pluviograph traces.

Discharge Measurements

Two measurements were taken of the discharge at Bancroft Park by the I.W.S. The first measurement was taken between 14.30 hours and 16.10 hours on the 25th, of which the calculated mean discharge was 12,400 cusecs. The computed flows by the model during this time span varied from 15,000 cusecs to 12,800 cusecs with a mean of 14,200 cusecs, a difference of 15%. The second measurement was taken between 16.45 hours and 17.50 hours also on the 25th, of which the calculated mean flow was 9,400 cusecs. Again, during this time the computed flows by the model varied from 11,800 cusecs to 9,200 cusecs, with an average of 10,600 cusecs. The difference in this case is 13%. This is the first check of discharge since the model was set up. The differences of 15% and 13% are acceptable when considering the variation in flows during the time of measurement is 17% and 28% respectively.

Runoff Coefficient

Ithaca Creek is the only area within the Enoggera Creek catchment that has both a gauge recorder and is not affected by the increased storages of a dam. Hence, an estimate of the runoff coefficient is more accurate in this area than in any other in the catchment, especially if computed gauge heights are in reasonable agreement with those measured as is the case.

Using the average rainfall that occurred over the approximate time of concentration, the runoff coefficient is calculated to be 0.80. It should be noted that 62% of this catchment area of 3.4 square miles is rural.

Flood Forecasting

During the course of the study of Enoggera Creek the author has developed a preliminary flood forecasting graph which is based on the measured rainfalls over the catchment. Using approximately 15 different storm events and analysing the rainfalls and resulting flows it became apparent that the volume of rainfall was the only variable of significance.

Using this graph, the flood forecasts which could be made with the average Mt. Cootha and Enoggera pluviograph stations are:

(i) First Peak

Estimated flow from the graph = 17,500 cusecs, which converts to a level of R.L.20.6' at Bowen Bridge. The time of this estimate would have been 12.30 hours on 25th January 1974. The computed flow for this peak was 15,500 cusecs with a computed level of 20.2 feet (actual measured level was 19.2) at 15.00 hours.

(ii) Second Peak

Estimated flow from the graph = 24,500 cusecs, which converts to a level of R.L.22.2' at Bowen Bridge. The time of this estimate would have been 0.30 hours on 26th January 1974. The second peak reached a computed flow of 27,050 cusecs with a level both computed and measured of 23.2 feet at 2.30 hours on 26th January 1974.

Thus, using the most primary of data, the rainfall that has just fallen allows a prediction time of 2 to 2-1/2 hours. A longer time of prediction can only come from actually predicting the rainfall.

Flood Mitigation

Up until January 1974, the significant storms in the catchment have generally been of a single peaked nature, and the proposed alterations to the existing dam had been based on this observation. The January 1974 storm contained three peaks, the first of which would have filled the dam with the second and third arriving before significant drawdown of the water level had been achieved.

For lesser floods, for example the 1972 floods, the dam proposed prior to January 1974 would have achieved the anticipated mitigation and together with the proposed dredging of the downstream reaches the flooding of residential properties in this area would have been virtually eliminated (general flood level decrease was 8.5 to 9 feet).

The 1974 flood would have only been mitigated by approximately four feet at Bowen Bridge. Although this flood was a rare event, it has been decided to increase the capacity of the dam so that at peak flooding it can impound another 5 to 10 feet of water (20 to 25 feet above existing level). Larger sluice capacity will allow quicker drawdown should another multi peak storm occur. When the 1974 flood was run through the model including the modified works a mitigation of seven feet was achieved at Bowen Bridge.

It should be noted that economically feasible mitigation proposals do not eliminate flooding of the highly developed flood plains of the creek. They do turn a situation in which the highly destructive flooding experienced four times in the last seven years into one in which the 1967 and 1972 floods would be almost eliminated and the 1974 flood would be turned into a flood of moderate proportions. The need for flood forecasting, however, remains of utmost importance.

TIDE EFFECTS

The people of Breakfast Creek have been indoctrinated to believe that floods in this Creek are highest at high tide. This situation has occurred in June 1967 and in February and April 1972. Businessmen on the floodplain watch the tide closely; if the tide has reached its peak and is falling they cease all operations of raising stocks believing that the flood waters will come no higher. Decisions to prepare for flooding are made on the state of the tide. Even during the Brisbane River flood, radio stations were issuing bulletins that the flood would recede with the falling tide. This incorrect information should not be encouraged and the public should be informed as to the sensible tidal limits of the various creeks and rivers. The author interviewed residents upstream of Normanby Bridge in an attempt to establish flood levels. The most general surprising remark by the greater number of people interviewed was that the water rose after the tide had reached its peak. A number of people went to bed after midnight when the tide began falling only to be awakened one to two hours later by the sound of crashing trees, having time only to evacuate their house and leave possessions to the swirling floodwaters. It is surprising no lives were lost during those hours considering the creek was rising at the rate of four feet in one hour.

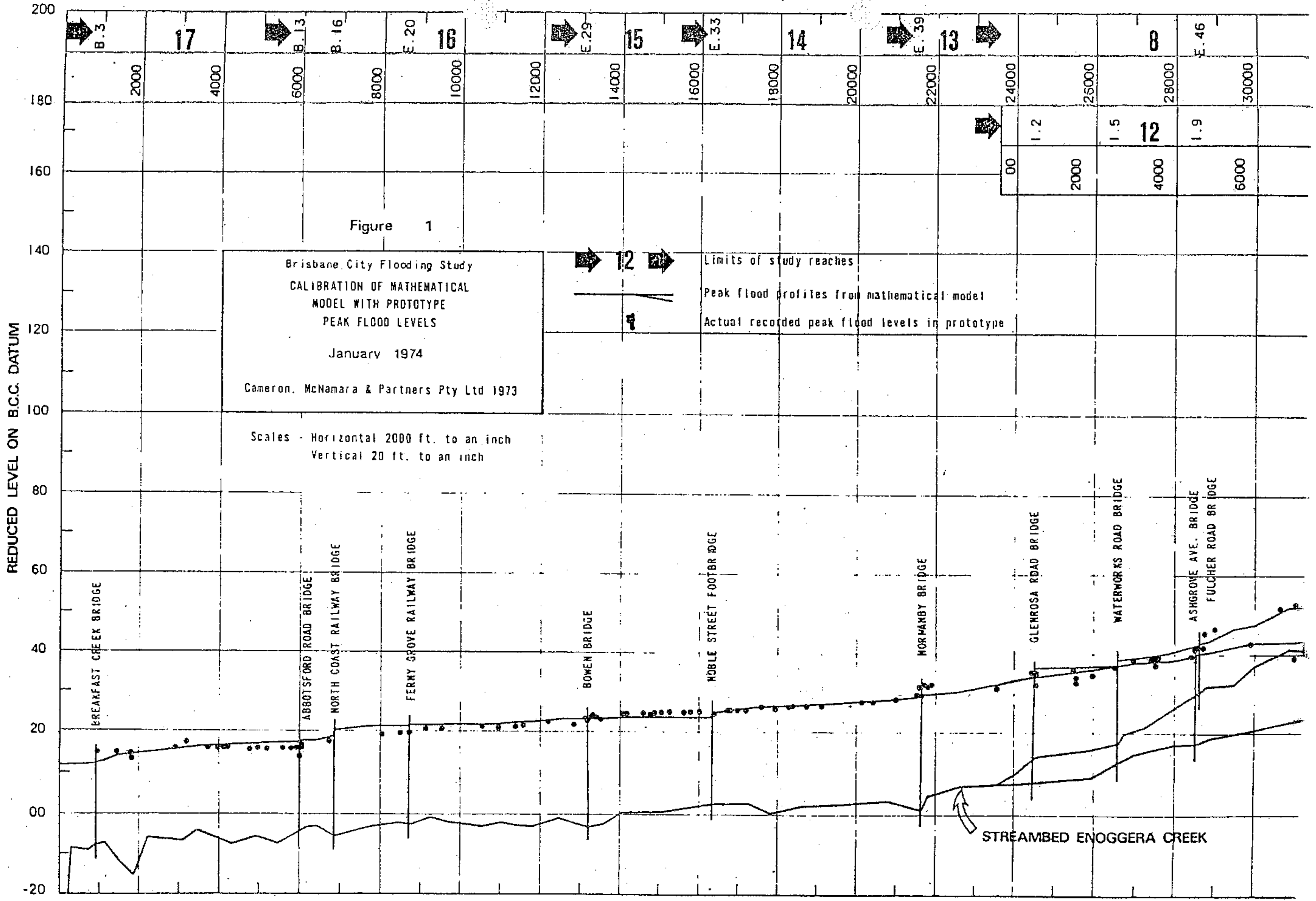


Figure 1

Brisbane City Flooding Study
CALIBRATION OF MATHEMATICAL MODEL WITH PROTOTYPE PEAK FLOOD LEVELS
January 1974
Cameron, McNamara & Partners Pty Ltd 1973

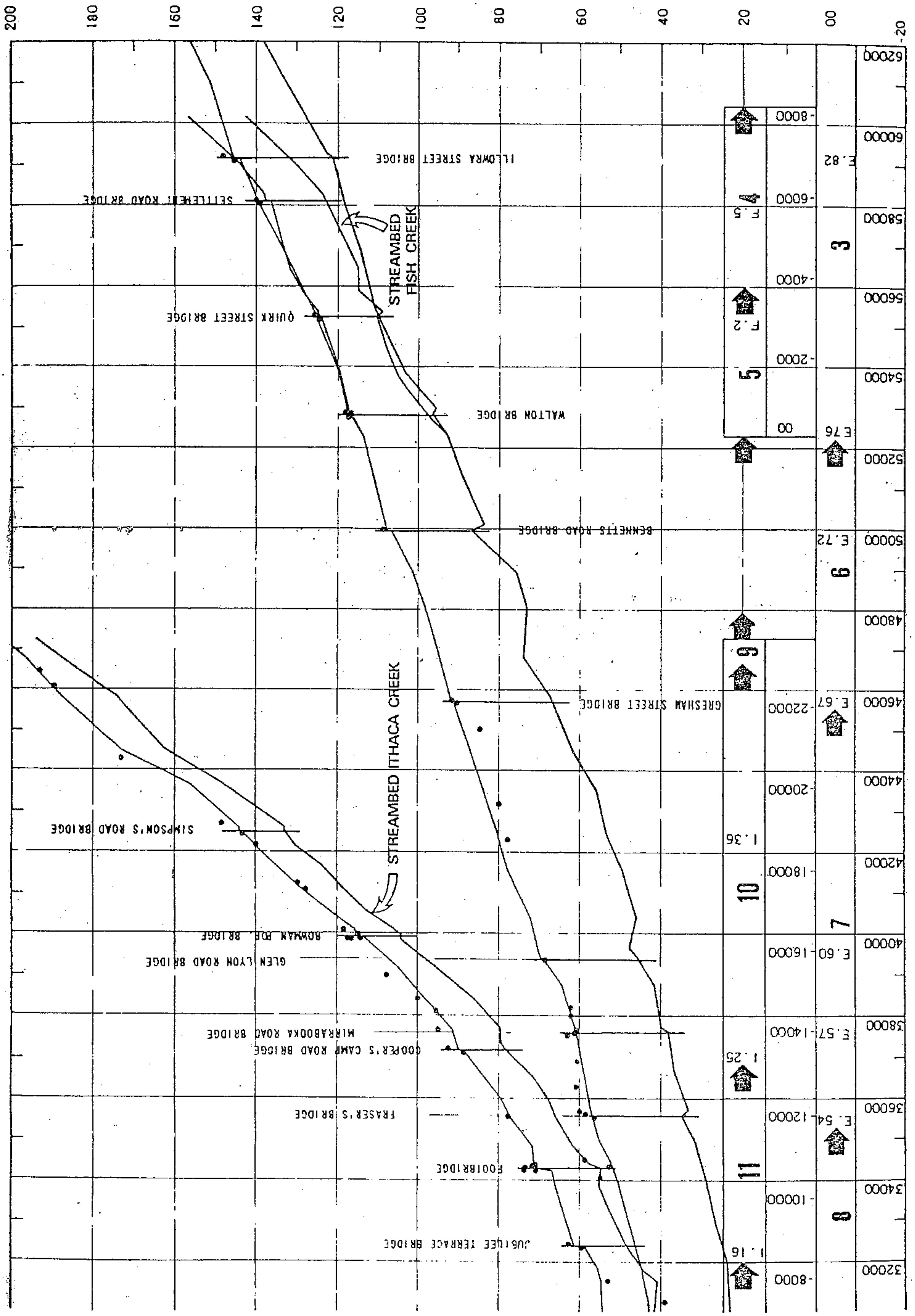
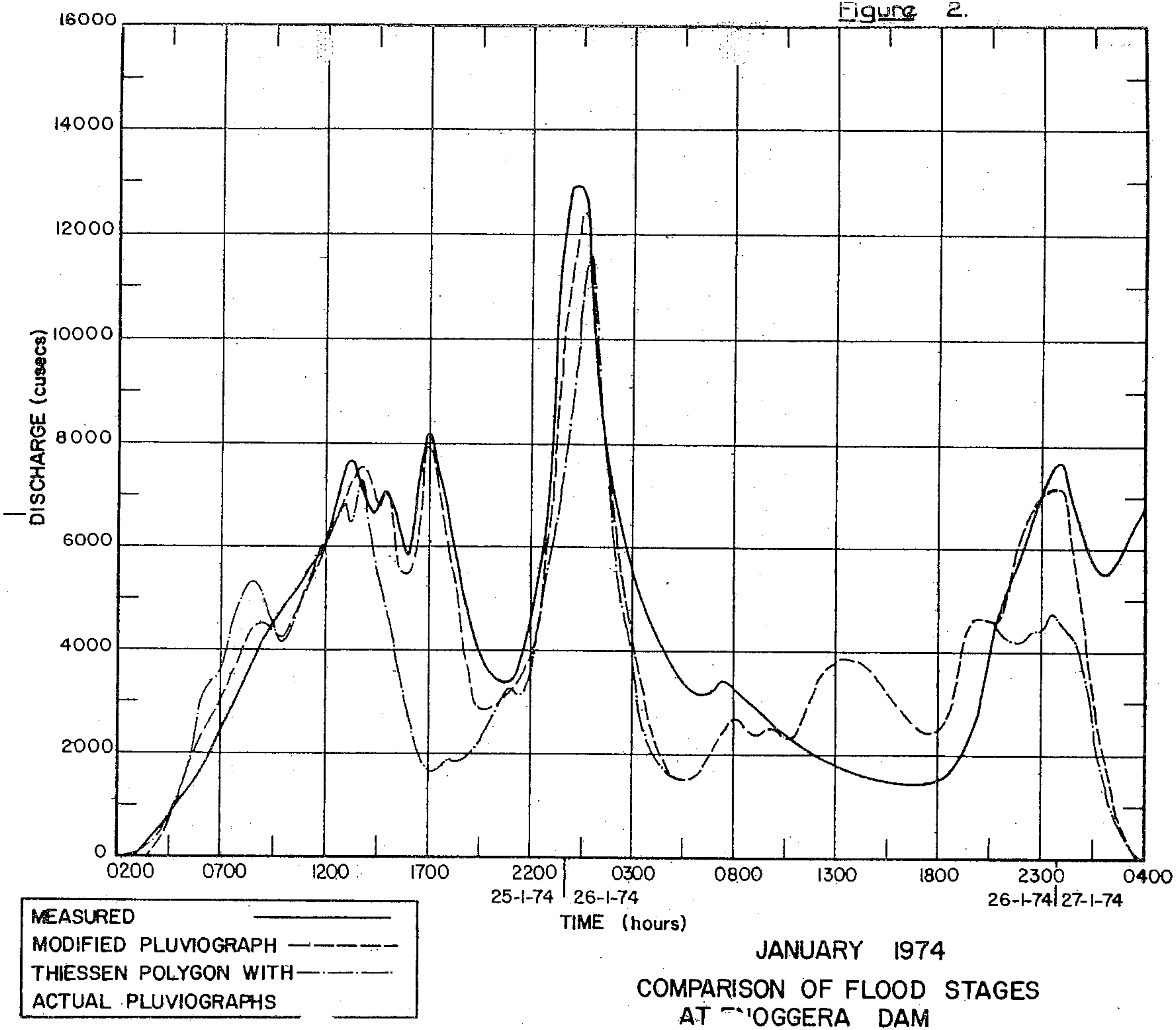

200
180
160
140
120
100
80
60
40
20
00
-20
62000
60000
58000
56000
54000
52000
50000
48000
46000
44000
42000
40000
38000
36000
34000
32000
-8000
-6000
-4000
-2000
00
-22000
-20000
-18000
-16000
-14000
-12000
-10000
-8000
E.82
E.76
E.72
E.67
E.60
E.57
E.54
F.5
F.2
I.36
I.25
I.16
3
4
5
6
7
8
9
10
11
ILLOWRA STREET BRIDGE
SETTLEMENT ROAD BRIDGE
STREAMBED FISH CREEK
QUIRK STREET BRIDGE
WALTON BRIDGE
BENNETTS ROAD BRIDGE
GRESHAM STREET BRIDGE
STREAMBED ITHACA CREEK
SIMPSON'S ROAD BRIDGE
BOWMAN PDE. BRIDGE
GLEN LYON ROAD BRIDGE
MIRRABOOKA ROAD BRIDGE
COOPER'S CAMP ROAD BRIDGE
FRASER'S BRIDGE
FOOTBRIDGE
JUBILEE TERRACE BRIDGE

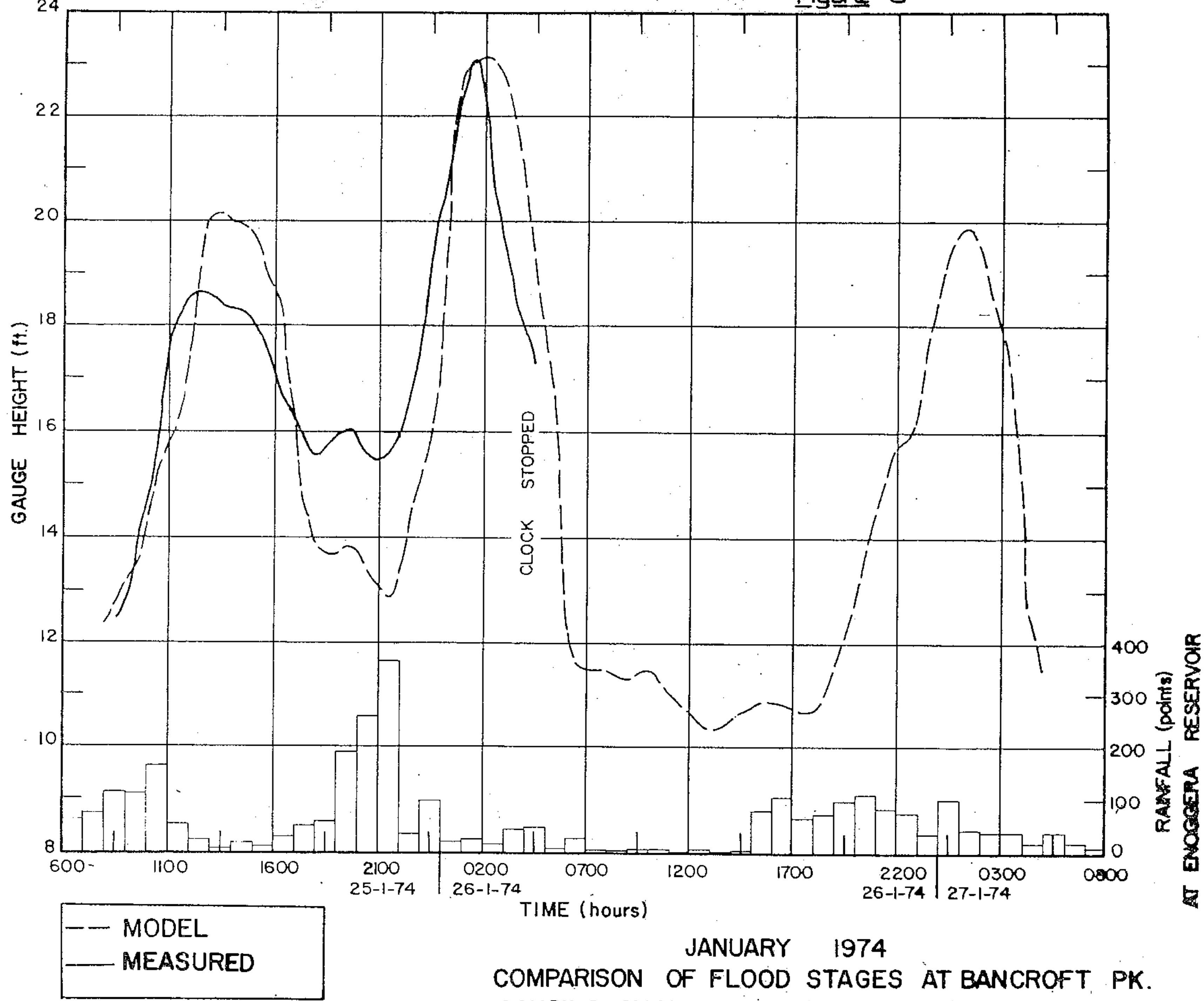
Figure 2.



JANUARY 1974

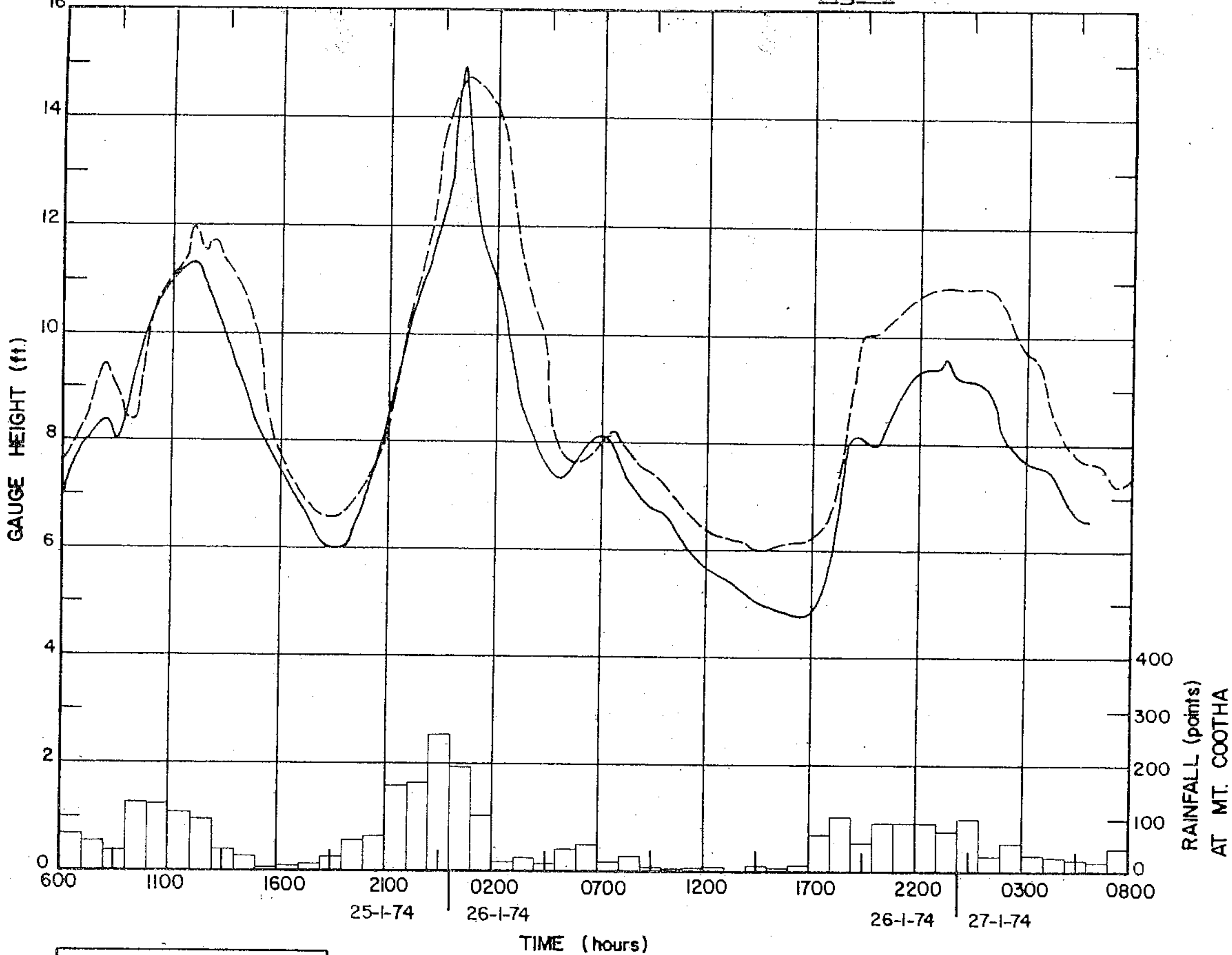
COMPARISON OF FLOOD STAGES
AT [illegible]OGGERA DAM

Figure 3



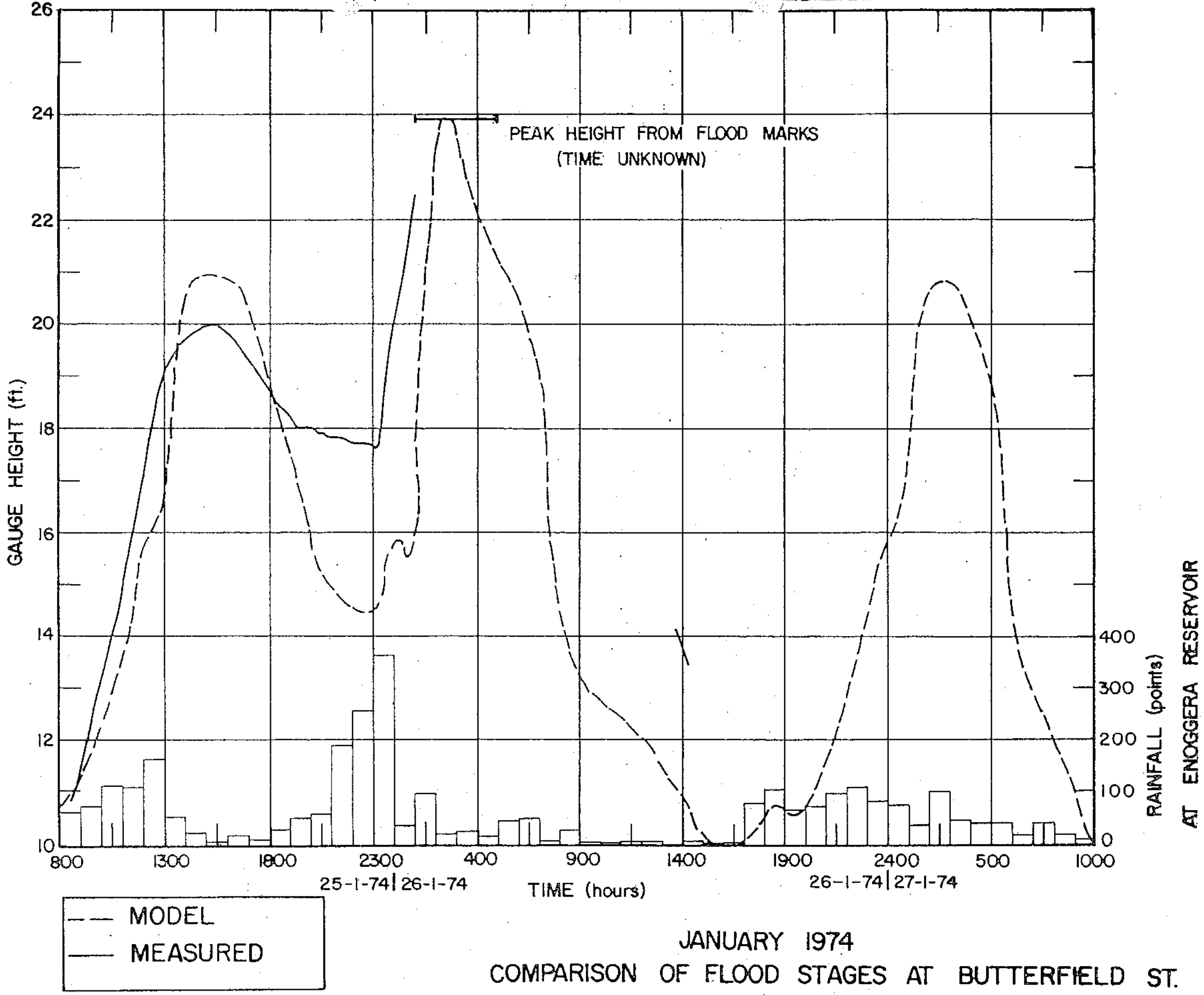
JANUARY 1974
COMPARISON OF FLOOD STAGES AT BANCROFT PK.
GAUGING STATION, ENOGGERA CREEK.

Figure 4.



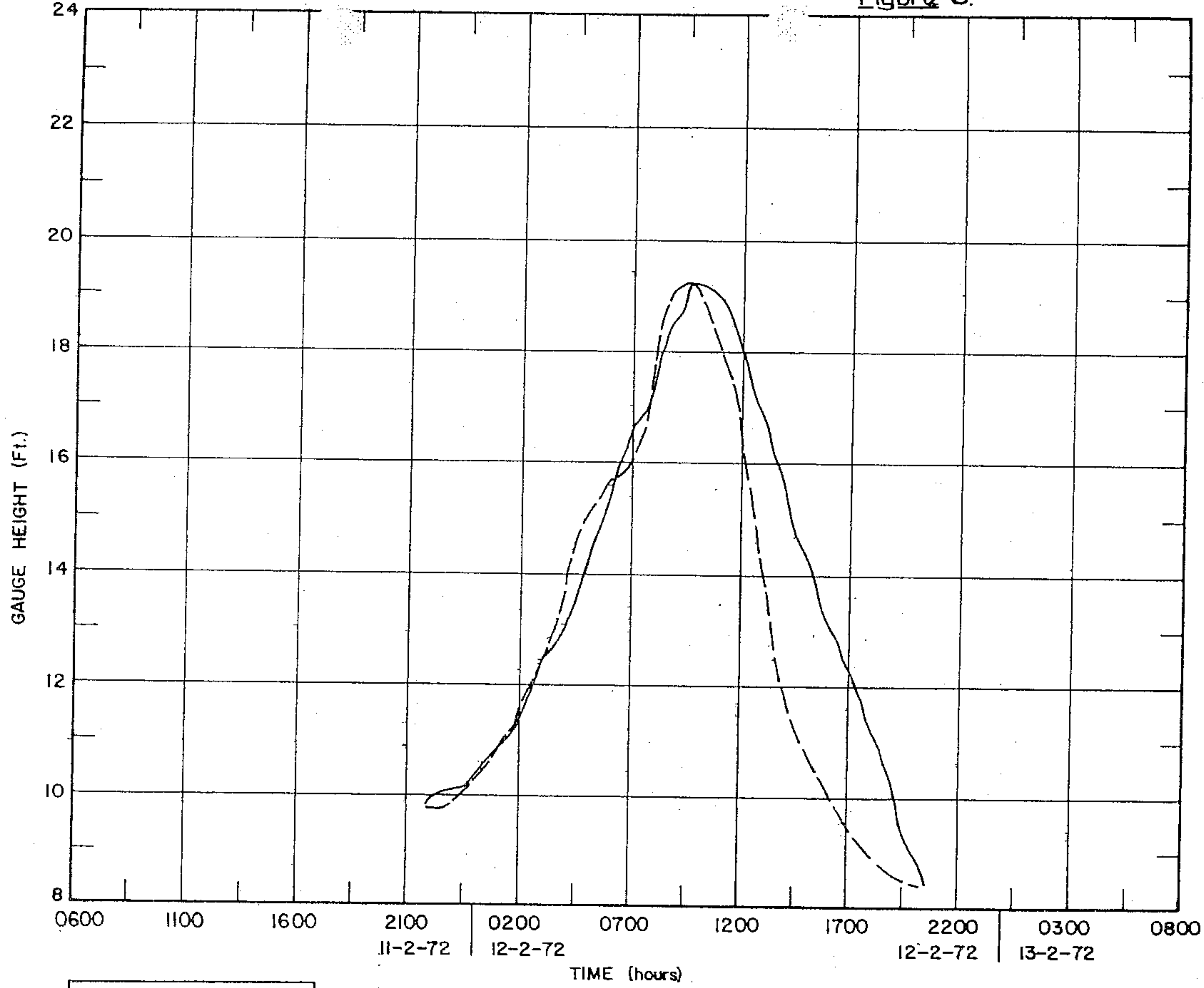
JANUARY 1974
COMPARISON OF FLOOD STAGES AT JASON ST.
GAUGING STATION, ˉHACA CREEK

Figure 5



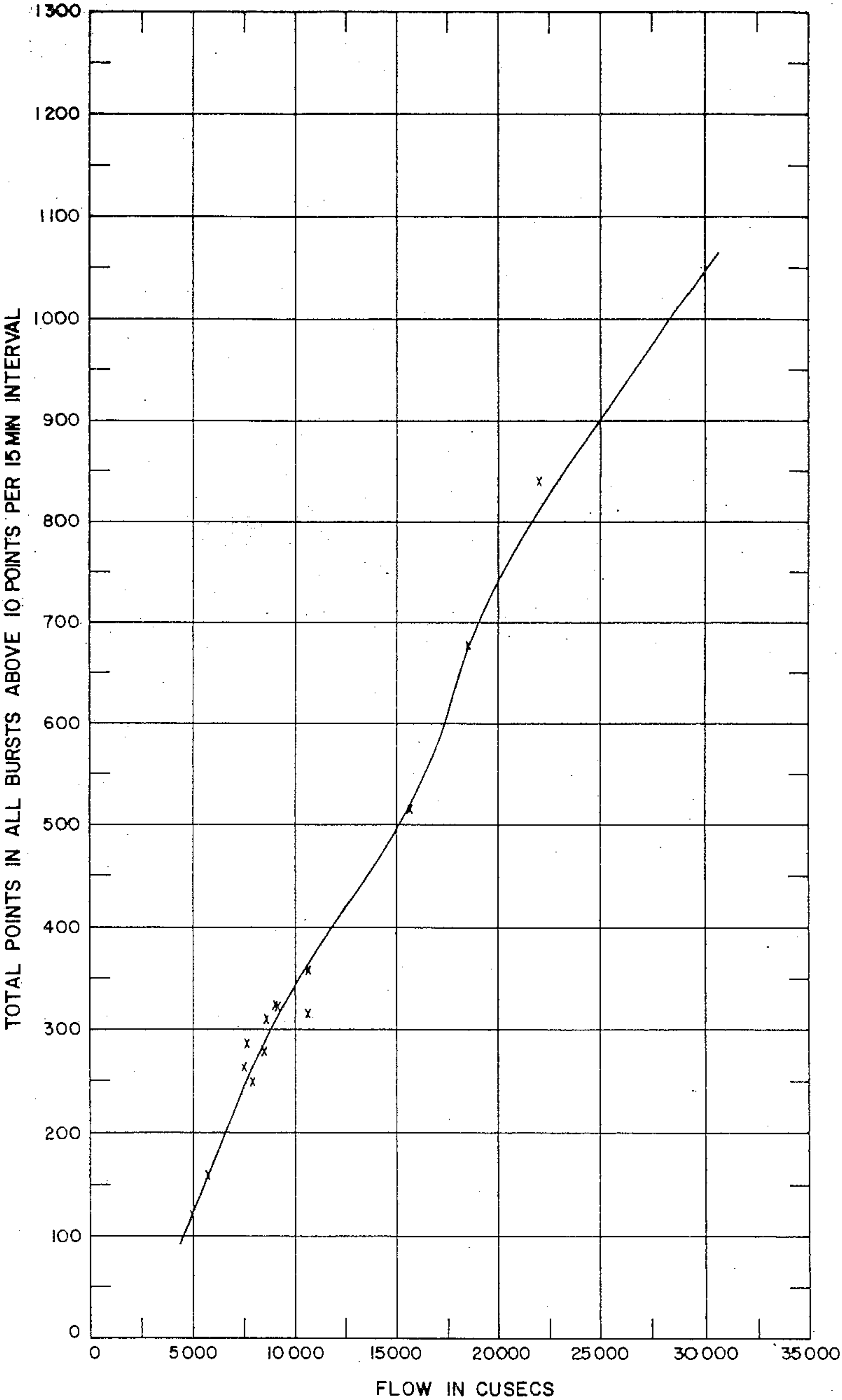
JANUARY 1974
COMPARISON OF FLOOD STAGES AT BUTTERFIELD ST.
MANUAL GAUGING STATION, ENOGGERA CREEK.

Figure 6.



FEBRUARY 1972 STORM
COMPARISON OF FLOOD STAGES AT BANCROFT PARK
GAUGING STATION ENOGGERA CREEK

Figure 7.



FLOOD PREDICTION,
ENOGGERA CREEK AT BOWEN BRIDGE.

MAXIMUM TIME SPAN OF ADDITIONS NOT TO EXCEED 8 HOURS

DISCUSSION

G.A. Johnson B.E., F.I.E.Aust.

Very shortly after the 1972 floods the State Government retained various Consultants to advise on flood mitigation measures for Brisbane Creeks. Munro, Johnson & Associates investigated half a dozen of the creeks but, due to various factors, only the study of Kedron Brook was brought to finality. A report on the feasibility study of Kedron Brook was submitted in February, 1973, and since that time Munro, Johnson & Associates have, on and off, been doing some preliminary design of retardation basins. On 29th January, 1974, Munro, Johnson & Associates were asked to prepare a report on the January 1974 flooding in Kedron Brook.

It is against this background that these comments are submitted.

First a summary of the geography of the Kedron Brook catchment. It lies immediately to the North of the Enoggera-Breakfast Creek catchment and has an area of some 28 square miles above Nudgee Road. Kedron Brook flows on through the Serpentine-Aerodrome area to the sea but when it was ascertained that the Federal Government was studying the lower reaches in connection with the design of a new Airport the study by Munro, Johnson & Associates was initially limited to the catchment above Nudgee Road. The stream above Sandgate Road is quite steep and is not unduly affected by the large flat area of the Serpentine; but the Sandgate Road-Nudgee Road reach itself is a somewhat "grey" area in the study because of this limitation.

An assurance was obtained from the Federal Government that their works would not make conditions any worse than now at Nudgee Road, but this was no great comfort as the State Government was trying to make conditions better than now.

Mr. Cameron has given you a good description of the rainfall at the time. Actually the Kedron Brook catchment is rather similar to the Breakfast Creek catchment and the rainfall on the two catchments is generally not dissimilar. This is extremely fortunate because in fact on Kedron Brook the measuring equipment did not work too well. The Weather Bureau has two pluviograph stations but both of these went out of commission. The Bureau also has several daily rainfall stations but all of these, except one, overflowed. The Irrigation Commission has three stream gauging stations and these did give a record of flood heights but unfortunately no velocity measurements could be obtained at peak height conditions and so there are no measured discharges. No discharges for flood flows have actually ever been measured in Kedron Brook. Good records were obtained of the actual flood levels experienced and this is, of course, the really important data for the flood mitigation measures proposed.

In the report of February, 1973, six different methods of flood mitigation were submitted for the consideration of the decisionmakers. These six options provided different methods of mitigating flood damage and also different degrees of protection. The degrees of protection offered were to prevent any damage from the 1967 flood (which was the highest previously recorded) and similarly from a hypothetical flood 2 feet higher than the 1967 flood. This latter protection arose generally from the Author's own experience, over a period of many years on similar work, that in a young country like Queensland there will always be a bigger flood than any previous. The six methods were each accompanied by a calculated benefit-cost ratio.

The Committee concerned initially favoured Method D, which was to protect against the 1967 flood by a combination of stream channel improvements, retardation basins and levees. In addition all unoccupied land not protected by levees were to be zoned open space.

As a matter of interest, Method E, using the same measures and giving protection against the hypothetical 1967 plus 2 feet flood, might well, due to the factors of safety provided, have ensured no damage or very little damage to the people along Kedron Brook from the January 1974 flooding. In the main damage zones this flood was 2 feet to 3 feet higher than the 1967 flood.

In actual fact the investigations show that, in the 1974 flood, water entered the upper living areas of over 200 homes and over 1,100 properties in all were affected by flood water. Fortunately no lives were lost but many homes had to be evacuated, some of them twice. (You will recall there were 3 separate and distinct peaks in 36 hours). A number of houses, sheds, etc., were washed away.

It should be realised, of course, that basically nothing is known about the probable frequency of this flood except that it is the highest since 1911; that is when detailed rainfall records started. More severe flooding could well have occurred in the 19th and other centuries.

While the engineering problems involved in flood mitigation can be quite complex, it is a fact that the social and political problems can be even more so. The major questions always seem to be:

(a) Who is going to pay for the work? The Federal Government, the State Government or the Local Authority - or should a benefitted area be declared, and payment be made by those who benefit?

(b) Who is going to be protected from floods, and who isn't going to be protected? Where is the dividing line?

(c) Why spend any public money anyhow to assist people who have been foolish enough to build on flood prone land?

In regard to the last of these three questions, before it is decided nothing <u>should</u> be done the following points are mentioned:-

1. Undoubtedly in many cases people who built homes, say 20 years ago, can say with some truth that the activities of others, including private citizens, Local Authorities and Government Departments have contributed to the flooding of land not previously flooded.

2. If we are prepared to instruct Civil Defence workers and Police that when a citizen rings up and wishes to be evacuated with his family because the water is rising around his home, he should be told to get himself and his family out of the mess himself - well go ahead.

But if we are not, we have to realise that a lot of public money is going to be spent evacuating people anyhow and Police and others are going to risk their lives helping the unfortunate victims.

3. As one final point, there is the question of flood warning systems. Mr. Cameron has posed a couple of questions on the subject. Engineers have always pointed out that flood warning is the cheapest form of flood damage mitigation.

It seems important to stress that flood warning systems start when the citizen is proposing to put his life time savings into the purchase of a house. It is suggested that it should be a legal requirement that flood information should be inscribed on the title deeds of every block of land. It is understood this is done in other parts of Australia.

What effort has really been made, up to the present, to advise citizens of flood hazards relative to the block of land he proposes to buy?

This seems to lead on to the question as to what are really the costs of floods to the community and what are really the benefits resulting from flood mitigation.

Reference has been made above to the benefit-cost studies carried out. In this case it was hoped to attract a Federal subsidy and therefore sophisticated benefit-cost studies were carried out in the form normally required by the Federal Government of the day. The costs of actual structural measures were easily quantified. Environmental considerations were also quantified after some investigation by Consultant Town Planner, Mr. Frank Costello. The main environmental benefits were of course the provision of more parks and playing areas. The figures for environmental benefits were not, however, included in the numerator. These could well have increased the benefit-cost ratios 2-3 times. In accordance with the information from Canberra at the time the human well-being or social benefits were not quantified. In the Feasibility Report of February 1973, Method D above was shown with a benefit-cost ratio of 2.35 and Method E with a ratio of 1.67.

It is a fact, however, that since the 1974 floodings citizens in general, and governments in particular, may be very conscious of the human well-being aspects and these aspects might well play a big part in deciding the answers to the 3 questions mentioned above.

In conclusion it is suggested that possibly the most important recommendation, in the report of February 1973, was that one authority must have the responsibility for flood mitigation for any stream, i.e. for carrying out flood mitigation works and, very importantly, for maintaining and operating these works, also for policing the associated legislation and for giving out flood information. In other States it is common to find such authorities which are autonomous and include representatives of the Local Authorities affected by the stream.

D. Stanaway, B.E., M.S.C.E., M.I.E. Aust.

Observations in Oxley Creek early in the morning of Saturday 26th January, 1974 showed an extremely high flood level at Ipswich Road and other points downstream.

The reason for this was established later when the pluviograph from New Beith was received. This indicated a burst of rain from midnight Friday to 3.30 a.m. Saturday when 250 mm fell. There had been a long period of rain preceeding this so that the catchment was saturated.

The resultant flood in Oxley Creek was the highest local flood that has ever been recorded, although in the lower reaches back-flooding from the Brisbane River lifted flood levels higher still.

With regard to the question of increase in runoff with urbanization of catchments we consider that while there is some small increase in local runoff, the major influence of urbanization is where natural storage is markedly reduced. This can have the effect of greatly increasing the flow in the creeks.

FLOOD INSURANCE

by J.L. Irish, B.Sc., B.E., M.I.E. Aust.

INTRODUCTORY REMARKS

FLOOD INSURANCE CURRENTLY AVAILABLE IN AUSTRALIA

Only a small proportion of houses flooded in the recent floods through the Moreton region were covered by flood insurance, although the position is still clouded by a legal challenge to the 'storm & tempest' clauses used by many companies. Most houses covered for flood appear to have been insured under the War Service Homes Scheme, which is compulsory for loans under this scheme. Premiums for war service type insurance is not fixed as a percentage of the cover; administrative costs are apparently kept low by the absence of the normal sales and valuation overheads. Some protection against adverse selection of risks would be inherent in the approvals mechanism for the home laon. The Minister for Defence has stated that the scheme is operating without government subsidy at extremely low premium rates.

A substantial number of motor vehicles are covered for flood damage, and it is also apparent that a considerable volume of flood cover existed for commerce and industry. This insurance is generally part of a package deal offered by the insurer to acquire all of a client's insurance business. Much of this insurance is reinsured overseas. Adequate local facilities for reinsurance would be necessary before flood insurance for commerce and industry becomes widely available at prices which are attractive, but it is true that cover is generally available. Most of the anticipated $100m. claims resulting from the recent floods throughout the State appears to be for commerce and industry and for motor vehicles.

The insurance industry is loath to offer flood insurance for small businesses and residential properties in Australia for a variety of reasons, including:

(i) poor experience with flood losses where flood cover has been sold, both in Australia and overseas; many local firms suffered badly in the June 1967 and February and April 1972 suburban creek floods. The first flood resulted in an upsurge in enquiries, and the later floods brought unprecedented claims; many firms declined to renew flood insurance policies;

(ii) adverse selection: It is commonly believed that only those subject to an obvious flood risk will desire flood insurance, and that the actuarial rate for these risks would make the flood insurance unmarketable, whereas those not subject to frequent flooding would not purchase flood insurance, even if available. The pool for meeting future claims would therefore be small;

(iii) interest in flood insurance is greatest immediately after a flood, and non-renewal of flood cover as time went by would lead to an unstable pool, with only high risks covered;

(iv) the nature of the risk (in common with earthquake and some other natural phenomena) implies that a large number of claims will arise from one event, whereas a year in which no large flood occurs will result in few claims. This means that the usual principle of insurance - the spreading of risks over time - is violated, and the flood insurance pool will be extremely volatile. (This problem can only be solved by a wide geographic spread of risks, both nationally and internationally, through improved reinsurance facilities);

(v) lack of knowledge of the risk. Most insurers have little knowledge of the flood risk in particular areas, or the sources of information on flood risk. Even if the risk is evaluated by an insurance inspector, it is usual to relate this to a particular historic flood rather than to flood frequencies and exposure to risk;

(vi) flood insurance as presently conceived in Australia is not likely to be a large profit earner, but could incur substantial losses. There is little incentive to offer flood cover to compete with other insurers - institutional restraints including tariff associations and government supervision limit competition through premiums. The volume of business would be small, and the high cost of inspecting each proposed risk to determine the premium rate compared to other classes of insurance with well-defined techniques of risk assessment and risk management mean that the overhead component of the premium would be unacceptably high.

All of these reasons are well founded for flood insurance sold under the existing arrangements. A new scheme must be found if flood insurance on a broad scale is to be introduced in Australia, and the scheme now operating in the U.S.A. is examined in the next section.

FLOOD INSURANCE IN THE U.S.A.

A successful scheme of flood insurance is being progressively extended in its coverage of flood prone areas of the U.S.A. The scheme was introduced in 1968, following studies by Fiering at Harvard University and the prestigous Travellers Insurance Company. A flood insurance study is carried out for each community joining the scheme, to determine actuarial rates for flood insurance, currently limited to 1-4 unit residential dwellings and small businesses. The premiums are determined from field studies of the actual number of dwellings of various types at particular elevations on the flood-plain, and a careful assessment of the average flood damage at various depths for each category of structure. These studies are carried out by the U.S. Army Corps of Engineers for the Federal Insurance Administration of the Department of Housing and Urban Development, and include a detailed study of the flood hydrology. Premiums are determined from the flood frequency curve and the depth-damage curve for each category of dwelling, based on living-area floor level; rates are adjusted to cover underinsurance, expenses etc. Cover is available separately for contents and structure.

The program is currently being expanded to allow more than 10,000 communities to join. The current program has been extended to 2,700 communities since its introduction, with about 300,000 policies in force, worth $5 billion. However, only 12% of homes and small businesses eligible for flood insurance have bought cover so far.

Flood insurance is compulsory for all property for which federal loan funds (e.g. Veterans' Administration) have been applied, and the new program extends this requirement to all federally guaranteed loans - e.g. building societies, banks etc. Extension of flood insurance to a particular community is tied to completion of a flood study and agreement by the local government authority to introduce adequate floodplain land-use regulations, including zoning. Policies in a particular area are sold by a licenced insurer who has agreed to sell flood insurance at the federally determined rates, and to lodge a sizeable bond. In return, reinsurance facilities are provided by the Federal Insurance Administration, designed to ensure a modest profit to the insurer. Claims are handled locally by the insurer or a loss assessor as agent. Subsidised flood insurance is available in some areas for existing development only, where the premiums would otherwise be unattractive. A subsidy may be cheaper in some cases than construction of a flood mitigation scheme with an adverse benefit-cost ratio, which the government might not otherwise be able to avoid because of political pressures.

ADVANTAGES AND DISADVANTAGES OF VARIOUS FORMS OF FLOOD INSURANCE

Many of the advantages of the U.S. scheme are immediately obvious; it is not compulsory, it has premiums which are proportional to risk, it is controlled by a government agency but operated by private companies, and it is tied to improved land-use planning in relation to floods.

The existing facilities for flood insurance for houses in Australia are inadequate and incapable of expansion by the private sector. Various proposals have been made which might lead to an expansion of flood insurance. One proposal has been to include flood cover in all householder policies in lieu of the existing restricted form of storm and tempest cover, and to levy a uniform rate to cover anticipated losses. This would operate much as fire insurance does, but is inequitable to those who are not subject to any flood risk. The only advantages of this method are that it gives a large and constant market and reduces the cost to the insurance companies of determining a separate premium rate for each risk, but it has the disadvantage that it would be difficult to fix the levy in advance, with little prior experience in this class of insurance. Unless the government compels all insurers to offer the same cover, insurers will, in time, offer policies without flood cover at reduced rates, and then adverse selection and a declining number of policies in force will result.

To encourage owners to take action to protect their own property in time of flood, there needs to be a sizeable incentive to remove contents where possible. This can be accomplished by paying actual damages less a deductible, i.e. applying an excess. Alternatively, there could be an agreed formula for claims in relation to depth of flooding, so that the occupier benefits if he removes his property to safety prior to flooding of the premises. This will also simplify premium determination.

A third suggestion, which has a great deal of merit, is to require insurers to offer flood insurance on all householder proposals. Once adequate facilities have been provided (based on the U.S.A. scheme or otherwise), it would then place the responsibility for declining flood cover on the householder. Instead of requiring the householder to find an insurer willing to provide flood cover, the onus should be on the insurer to offer it, and the insured to delete this option if not required. Persons who had declined flood cover could then expect little sympathy when flooded.

A natural disaster insurance or relief fund has also been proposed, but it is suggested that this would probably not operate as true insurance, but rather would require heavy government subsidies or other form of transfer payments.

FLOOD INSURANCE FOR JINDALEE - A CASE STUDY

The author has been co-opted onto the Jindalee Area Flood Relief Action Committee, as residents are concerned at the lack of flood cover. The Committee has carried out an assessment of the consequences of the recent flood in the Jindalee area, based on questionnaires completed by those suffering flood damage, (Report by Peter Swannell & Lewis T. Isaacs, Senior Lecturerers, University of Queensland, Department of Civil Engineering, on behalf of the Committee). Data from this report and results from a report by the author on flood frequencies at Jindalee prepared for Hooker Centenary Pty. Ltd. have been used to calculate mean annual damages for houses in the Jindalee area, based on the height of the January 1974 flood above or below the floor level of the main living area. It was widely reported in the press that Jindalee was 'devastated', so that one might imagine that flood insurance of houses in this area would not be feasible. The facts are that water entered 368 properties, out of 1,785 in the Jindalee area, of which 102 were flooded to the ceiling or above. About 210 houses had water entry in the main living area. Since larger floods than the January 1974 flood are possible, many more property owners would be interested in flood insurance if it were readily available. Whilst 95% of those flooded had a householders insurance policy on the structure and 86% held a policy for the contents, only 9% held flood cover, and, with only a few exceptions, these were policies arranged through the War Service Home Loan Scheme.

The January 1974 flood has been estimated to have a return period of 100 years. A stage-damage curve based on the average determined in the questionnaire for both high-set and low-set houses has been developed. The average value of the structure for low-set houses in the Jindalee area has been estimated at $25,000, and the average value of contents is estimated to be $5,000. The corresponding values of high-set houses are estimated to be $28,000 and $7,000. The damages estimated by respondents to the questionnaire appear to be reliable, and in any case represent the loss which respondents would expect to be covered by insurance had they held flood insurance. Stage-damage curves in other areas, e.g. Breakfast Creek, typically have much lower damages for various depths of flooding and particularly for total submergence; the difference is related to different standards of living. The following stage-damage curves were used:

Low-set Houses:

Depth of Flooding (feet above floor level main living area)	Damage Structure & Contents
-2	0
0	$ 500
+2	3000
4	5700
6	6500
8	7000
10	7500

High-set Houses:

Depth of Flooding (feet above ground-floor level)	Damage Structure & Contents
-2	0
0	$ 200
2	500
4	1000
6	2000
8 (floor level, main living area)	2500
10	4500
12	6000
14	6800
16	7500
18	8000

It should be noted that Jindalee is an upper middle class suburb of new brick houses. High-set houses generally have the downstairs area fully enclosed; timber flooring rather than concrete is not uncommon, together with wall partitions. Mean annual damages and the percentage rate (100 x mean annual damage ÷ value of structure + contents) have been calculated separately for both high-set and low-set houses, for houses flooded to a range of depths in the January 1974 flood (used as a reference level), and for houses at various heights above the January 1974 flood. The results are shown in the following tables:

Low-set Houses:

Depth of Flooding in January 1974 above floor level (feet)	Mean Annual Damage	Rate $/$100
18	$ 302	$1-01
16	263	0-88
14	226	0-75
12	194	0-65
10	163	0-54
8	132	0-44

Low-set Houses (contd.)

Depth of Flooding in January 1974 above floor level	Mean Annual Damage	Rate $/$100
6	$ 109	0-36
4	86	0-29
2	73	0-24
0	61	0-20
-2	54	0-18
-4	50	0-17
-6	41	0-14

High-set Houses:

Depth of Flooding January 1974, feet above -		Mean Annual Damage	Rate $/$100
Basement Floor	Floor Level Main Living Area		
18	10	$ 207	$ 0-59
16	8	170	0-49
14	6	143	0-41
12	4	117	0-33
10	2	97	0-28
8	0	82	0-23
6	-2	65	0-19
4	-4	57	0-16
2	-6	51	0-15
0	-8	46	0-13

Annual premiums would need to be higher to cover underwriting expenses, stamp duty, reserves and profit. The mean annual damages indicated above are by no means small for houses which were flooded to a major degree in the recent flood, but they indicate the degree of risk owners are already placed in. An insurer should only be willing to accept this risk at an actuarially fair rate; it is obvious that industry expenses would need to be carefully controlled by using cheap and effective systems for rate evaluation, and it would also be necessary for a single body to calculate actuarial premiums for each location.

The proposed dam at Wivenhoe would provide considerable flood mitigation to residents of Jindalee, but would not remove all risk of flooding. Premiums for flood insurance however could be drastically reduced. For example, the following mean annual damages have been estimated for a few cases, and are compared with the pre-Wivenhoe situation. (Data on the flood mitigation effect of Wivenhoe Dam has been obtained from the 1971 Report by the Co-Ordinator General's Department, although more conservative flood frequencies have been adopted).

Low-set Houses:

Depth of Flooding in January 1974 above floor level (feet)	Mean Annual Damage Without Wivenhoe Dam	Mean Annual Damage With Wivenhoe Dam
18	$ 302	$ 108
10	163	33
0	61	14

High-set Houses:

Depth Flooded above lower floor level January 1974 (feet)	Mean Annual Damage Without Wivenhoe Dam	Mean Annual Damage With Wivenhoe Dam
18	$ 207	$ 35
10	97	24
0	46	7

WHY FLOOD INSURANCE?

What are the advantages of flood insurance compared to structural flood mitigation works? Flood insurance certainly does not remove the personal anguish, the loss of treasured possessions or the danger to life. What flood insurance can do is to encourage wise use of the floodplain, especially when tied to land-use controls, alert prudent people to the risk long after a large flood, build up a reserve from which to cover repair work paid for by floodplain occupiers and remove the residual risk which exists even with structural flood mitigation projects. The environmental and economic implications of flood insurance are discussed in a paper by Irish and Burton presented to the 1973 Hydrology Symposium. The aspects of risk aversion are treated in a seminar paper and in a forthcoming paper by the author.

CONCLUSION

Flood insurance based on actuarial principles is feasible for houses in Brisbane not subject to extreme flood risk. Mean annual damages calculated for typical houses at Jindalee show that premiums would be relatively high prior to the construction of Wivenhoe Dam, but would be quite economical after this Dam is built. Premiums for contents and structures should be less than $1-00/$100 for most houses, and less than $0-30/$100 for those houses not severely flooded in the January 1974 flood.

Premiums will be even less further downstream, where the range of flood heights reached by the once in twenty and once in one hundred year return period floods is less, as well as in the suburban creeks.

DISCUSSION

G.P. Swannell B.Sc., Ph.D., C.Eng., M.I.C.E., M. We, L.D.I, M.I.E. Aust.

The Jindalee Area Flood Relief Action Committee was established at a public meeting of residents held on Tuesday, 5th February 1974, just a week after the peak of the 1974 flood. A questionnaire was sent to all residents in the flood affected area of Jindalee seeking information on the extent of damage to buildings and losses of personal belongings.

Between 1100 and 1200 homes existed in the Jindalee area during the flood. More than 800 of these were not affected by the immediate flood. Two hundred and eighty replies were received and these are considered to cover over 95% of all significantly affected houses.

The questionnaire gathered information on houses on the basis of being high set or low set and whether fully submerged or partly submerged and, in the case of the high set houses, whether the partial inundation affected the living area, the ground floor area or was only minor.

Other queries covered the loss of major furnishings and household contents, structural damage other than interior walls, ceilings and roof tiles, loss of personal possessions, valuables etc., damage to land and finally, loss of income. These items were each covered by a severity scale graduated from no loss to total loss in five steps.

The answers to the questionnaire are summarised in the attached table.

CONCLUSIONS

All statistics can be mis-interpreted. Those quoted above are no less susceptible to mis-interpretation than any others. With this in mind, it is, nevertheless, possible to make reasonable deductions concerning the impact of the Australia Day Flood. They are itemised below individually and should be read in the knowledge that they stem from conscientiously collected data given by people nearest to the event.

(i) Less than 20% of all the homes in Jindalee suffered water infiltration into the living area of the home. This is significantly less than would be deduced from Press and other media headlines which, during the flood crises, talked of "catastrophe", "total destruction" and other such expressions.

(ii) The number of homes totally destroyed is extremely small. Unquestionably, a modern suburb such as Jindalee with brick and well-constructed timber homes is fortunate in its ability to survive major flooding compared with other suburbs. There is no doubt that, catastrophic as the flood was to individuals, the general problem of 'flood survival' is not simply 'where' homes are, but 'what kind' of homes are there. Well-constructed homes recover substantially and relatively quickly. Residents who are fortunate enough to be able to live in a modern suburb, whether it be prone to very occasional flooding or not, are in an advantageous position relative to the rest of the community.

(iii) Notwithstanding the above, the total estimated damage (based on about 95% of significantly affected homes) of nearly $1.4 million dollars is massive. It is worth noting however, that average costs of rectification which vary from about $7600 (fully submerged homes) to about $1100 (relatively minor infiltration) do not give substance to rumours of consequential catastrophic loss of property values.

(iv) The rectification costs for recovery of house contents, furnishings, etc. represent about 44% of the total rectification cost. Bearing in mind that Federal Government Aid is directed towards structure cost this suggests a considerable residual burden of financial loss upon individuals. It makes nonsense of the view, heard sometimes, that a Government Relief scheme somehow unfairly makes other people pay for the misfortunes of those affected. The fact is that those affected suffer great personal loss irrespective of community action no matter how generous that action. And this is true in all suburbs, not just Jindalee.

(v) Damage to main structure and foundations is comparatively rare at this stage. It is, nonetheless, a serious problem, potentially extremely costly. There will be a continuing need to survey this type of damage, and remedial measures may have to be initiated in the long term.

(vi) By observation, rather than from the statistics, the advantages of a roof structure in which hip trusses are used rather than a single pitch were apparent during the flood crisis. The stabilising effect of the capping tiles across the main pitch, afforded by the hip-truss configuration, prevented displacement of main roof tiles on many lowset houses.

(vii) River-front properties present special problems. Home owners, generally from the higher income groups, suffered very severe financial loss, probably out of proportion to any (assumed) financially advantageous position they occupied prior to the disaster.

(viii) Insurance companies have to make profits. Nonetheless the question of Flood Cover must be investigated without delay. It is beyond the scope of this Report to comment on the possibilities open to the Insurers but the facts of the matter, from the insured's point of view, are clear. Only 8.6% of the survey sample had Flood insurance and these were virtually all War Service Homes.

House Category	Description	No. of Homes	LOSS OF FURNISHINGS & CONTENTS						TOTAL LOSSES					
			Severity of Loss (No. of Homes)						Struct. Costs $		Contents Cost $		Total Rectific. $	
			0	1	2	3	4	5	Total	Av.	Total	Av.	Total	Av.
1	Low-set home fully submerged	71	1	2	8	10	26	24	316,080	4,452	220,555	3,106	536,635	7,558
2	Low-set home, part submerged	51	3	0	12	17	8	11	127,340	2,497	139,245	2,730	266,585	5,227
All Lowset		122	4	2	20	27	34	35	443,420	3,635	359,800	2,950	803,220	6,584
3	High-set home, fully submerged	13	0	0	1	3	2	7	57,974	4,460	41,800	3,215	99,774	7,675
4	High-set home, water in living area	72	2	2	18	20	17	13	191,406	2,658	160,163	2,224	351,569	4,883
5	High-set home, substantial ground floor infiltration	61	12	6	26	11	4	2	76,905	1,261	53,676	880	130,581	2,141
6	High-set home, minor water entry	12	4	4	3	1	0	0	11,430	953	2,125	177	13,555	1,130
All High-set		158	18	12	48	35	23	22	337,715	2,137	257,764	1,631	595,479	3,769
All Homes		280	22	14	68	62	57	57	781,135	2,790	617,564	2,206	1,398,699	4,995

NOTES: (i) Split-level homes are included in categories 3 - 6.

(ii) Categories 1 - 4 imply flooding in main living areas.

NOTE: Categories other than "zero" imply re-painting and general interior redecoration at least in part.

STRUCTURAL DAMAGE OTHER THAN INTERIOR WALLS, CEILINGS AND ROOF TILES

Type	Description
0	No other reported damage.
1	Doors warped, glass broken.
2	Doors and fitted cupboards etc. warped.
3	As above and tiles/parquet floor damage.
4	As above to extreme extent.
5	Structural damage to main walls or fottings.

LOSS OF MAJOR FURNISHINGS AND HOUSEHOLD CONTENTS

Type	Description
0	No loss reported.
1	Minor articles only.
2	Floor coverings or part loss of furniture.
3	Part loss of furniture and most carpets.
4	All major articles including bulk of furniture.
5	Total loss
Note:	Categories (4), (5) represent very major losses.

WATER SUPPLY MAINTENANCE IN BRISBANE

by W.G.S. Huxley B.E., M.I.E. Aust. *

The Water Supply Maintenance Branch of the Department of Water Supply and Sewerage, Brisbane City Council is responsible for the operation and maintenance of the Water Supply System within Greater Brisbane (excluding mechanical and electrical installations). The system was severely affected during the January 1974 flooding.

FRIDAY, 25TH JANUARY 1974

At 5.30 p.m. the 915mm (36") diameter lock bar main, on the pipe bridge crossing of Moggill Creek, was displaced by the flood in Moggill Creek (Fig. 1). The actual time of the failure was pinpointed later from the automatic level recording gauge at the Mt. Crosby storage at Cameron's Hill Reservoir feeding the burst. A pipe end was angled out of its lead jointed collar, leaving a 9cm gap in the pipe line at the widest part (Fig. 2). This main was built in 1925. The joint failure caused the flow rate leaving Mt. Crosby Water Treatment Works for Brisbane to jump from 336.7 Ml/d (74 m.g.d.) to 746.2 Ml/d (164 m.g.d.).

All the Trunk Mains to the City of Brisbane, 1675mm 1525mm twin 1070mm 915mm and 610mm (66", 60" twin 42" 36" and 24"), pass through this locality, so until the actual broken main was identified, no shutting down procedures could start on either side of Moggill Creek. The burst was not completely shut down until 12.45 p.m. Saturday, 26th January 1974. Initially it was not possible to cross flooded creeks, either from the Brisbane or the Mt. Crosby end to identify the broken main and to isolate it by closing valves.

Acting on advice from a member of the public at 9.15 p.m., the Duty Officer and a Turncock walked across the slippery top of the 66" diameter trunk main in the dark with flooded Moggill Creek raging a foot below them and no handrail, carrying heavy valve keys to a maintenance crew who had been stranded earlier in the day by the rising flood. The creek then rose again and covered the access main so a second valve operating crew had to be turned out to close the valve on the City side of the Creek; the burst finally being isolated at 12.45 p.m. Saturday. This shut required the closing of two 750mm (30") diameter, one 610mm (24") diameter and two reticulation valves, spread over a distance of a mile on both sides of the flooded Moggill Creek. The 1675mm (66") pipe line was not clear of the flood again until 5.30 a.m. Saturday, the 26th January 1974, when everyone walked across to the Brisbane side of Moggill Creek.

Had the Water Supply Maintenance Branch not succeeded in isolating the main during Friday night, it is doubtful whether the Mt. Crosby Treatment Works would have been able to feed this burst and keep all pipe lines full. Had the trunk mains emptied they could have floated out of the water logged ground and ruptured themselves. This problem arose again during the flood.

* *Maintenance Engineer, Water Supply, Department of Water Supply and Sewerage, Brisbane City Council*

During Friday night, telephone contact with Gold Creek Reservoir was lost. Hourly contact was maintained during Friday night with the adjacent Enoggera Reservoir, where by 11.05 p.m., the depth over the spillway had already risen to the record level reached earlier in the afternoon and was rising rapidly with rainfall still intense. During Friday afternoon the depth over the spillway at Gold Creek had reached 1.45m (4'9"). It was believed that the effective crest level at Gold Creek was 1.68m (5'6") and, in view of the Enoggera Dam situation, it was feared that Gold Creek Reservoir could overtop. At 11.05 p.m. the Enoggera Reservoir Caretaker was sent to Gold Creek Reservoir to report on the situation. This required a three hour horse ride along the catchment ridge among fallen trees at the height of the storm when rain intensity was 95mm per hour.

Fortunately, Gold Creek Reservoir did not experience the same intensities as Enoggera and the highest level reached at Gold Creek was 1.45m (4'9½") above spillway crest. Subsequent investigations have shown that the effective dam wall height for overtopping approximates 1.83m (6'0") above spillway level and the spillway capacity used on the Friday night was only 68% of that available to cause overtopping. (There is a section of wall that is only 1.56m (5'1½") above crest level but this comes within the drawn down curve.

Enoggera Reservoir levels and rainfall were as follows:-

Time	Depth of Reservoir above Spillway		Rainfall in Preceding Hour
5.00 p.m.	1.94m	(6'4")	
8.00 p.m.	1.22m	(4'0")	
9.00 p.m.	1.18m	(3'10½")	
11.00 p.m.	1.41m	(4'7½")	47mm (1.85")
11.05 p.m.	1.85m	(6'1")	46.4mm
12.00 p.m.	2.5m	(8'2.4")	95mm (3.74")
12.30 a.m.	2.49m		11.6mm in ½ hr. (0.9" per hr.)
1.00 a.m.	2.26m	(7'5")	3.2mm in ½ hr.
1.30 a.m.	2.0m	(6'6-3/4")	7.0mm in ½ hr.
2.00 a.m.	1.8m	(5'11")	19mm in ½ hr. (1.5" hr.)
3.00 a.m.	1.57m		1.4mm for ½ hr.

The possibility of Gold Creek Dam being overtopped was discussed by telephone with the Acting Chief Engineer and Manager, the Investigating Engineer and Inspector Gwynne at Police Operations Headquarters around midnight and the following message was released at 1.05 p.m. for broadcasting by Police Headuqarters -

> "Because of what appears to be record rainfall in the Gold Creek-Moggill catchment, all residents in the Gold Creek and Moggill catchments are warned to immediately proceed to high ground till further notice.

Roads affected are Gold Creek, lower end of Savages Road, Adavale Street, Bundaleer Street, Rafting Ground Road, Wybelenna Street, Brookfield Road, lower areas in Misty Morn Estate, Fortrose, Darness, Kilkivan, Yarawa Street and Scenic Road."

When news came back from Gold Creek the following statement was 'phoned to Police Operations Headquarters for release by radio -

"The flow rate leaving Gold Creek Reservoir has decreased and immediate danger of flooding in the Upper Gold Creek and Moggill Creek has passed, but there will still be flooding in the lower reaches of Moggill Creek due to back up from the Brisbane River, levels of which are still rising."

SATURDAY, 26TH JANUARY 1974

By 1.05 a.m. the 300mm (12") and 400mm (16") diameter suction lines to the Enoggera Reservoir Pumping Station had been carried away by the flood in Enoggera Creek and the Pumping Station flooded. The feed to The Gap area was rezoned, resulting in only a relatively small area of high ground adjacent to the Reservoir and Paynes Road being without water when The Gap Reservoir emptied on Sunday afternoon, the 27th January 1974. The 400mm (16") diameter suction main was reinstated and pumps switched on again by 12.30 a.m. Wednesday, the 30th January 1974.

By Saturday morning it was known that water main crossings of five creeks had been lost, two 230mm (9") diameter, one 150mm (6") diameter and two 100mm (4") diameter. Two of these were important as they caused supply failure to reasonably large areas, namely, the crossing of Blunder Creek in Blunder Road where the bridge approaches were lost, with the attendant water main, resulting in supply failure to Pallara. A temporary supply was provided to this area by Friday, the 1st February 1974.

The crossing of Bullock Head Creek at Ipswich Road where the water main was carried away resulted in supply failures in the area to the west of this point. A temporary repair restoring partial supply was operative by Friday, 1st February 1974, and the final repair was done by 13th February, 1974.

SUNDAY, 27TH JANUARY 1974

Sunday morning was occupied in evacuating all vehicles and operating plant from the Water Supply Maintenance Branch's two operating Depots at Waterloo Street, Newstead and Harries Road, Coorparoo, and storing all plans, records and damageable stores above predicted flood heights. Predicted flood heighs were correct to within inches of the event and as a result no losses were sustained at either Depot and the Branch remained fully operative during the whole of the flood period. Emergency Operation Headquarters were established at the Maintenance Engineer Water Supply's offices at the City Hall.

By Sunday morning a further seven creek crossings or installations adjacent to creek banks were known to be lost. None of these was serious except a 300mm (12") diameter main that was carried away at Inala Avenue, resulting in Inala Reservoir emptying. This burst was isolated that afternoon and reservoir levels restored. Apart from the creek crossings and installations adjacent to creek banks, there were very few burst mains during the flood period or after, and these were repaired as they occurred provided they were not below flood level.

Difficulties were anticipated at Mt. Crosby Pumping Station during Sunday night - Monday morning, due to the infiltration of river water; Superintendents and Turncock crews were alerted to standby at reservoirs and on trunk main valves, ready to shut off the trunk mains leading from the Mt. Crosby Treatment Works' storages to the City and to back feed the inner city reservoirs towards Mt. Crosby. The trunk main shut off point was to be at Kenmore, the commencement of the urbanised area for the north side of the river and essentially, the river itself for the south side. This action was necessary in the event that Mt. Crosby could not maintain a supply of water to Brisbane. Such an occurrence would mean that the trunk mains would empty and then float out of the waterlogged ground, off piers, etc. Many of the above ground sections of the pipe lines were, in fact, inundated during the flood, confirming the necessity of this action.

At 10.30 p.m. with Mt. Crosby without power since 8.37 p.m. that evening, this being its third power failure for that day, instructions were issued to the Superintendents to commence shutting the trunk main system and back feeding the City reservoirs.

MONDAY, 28TH JANUARY 1974

By approximately 3.00 a.m. the trunk mains were shut and the backfeeding operation was completed. Reservoir storage in the Inner City at the commencement of the operation was approximately 382.2Ml (84,000,000 gallons), sufficient at the then current usage rates for approximately 24 hours.

During this shut it became apparent that there was a major main failure which, by 4.30 a.m., was proved to be the twin 450mm (18") diameter syphon crossing of the Brisbane River, Davies Park to Coronation Drive, laid in 1915. The specific syphon isolating valves, located adjacent to the banks of the Brisbane River, were by this time below the flood waters, requiring the shutting of other section valves beyond these points on major mains feeding to and from the river crossing. Three major valves, 610mm (24") to 915mm (36") diameter required shutting and four reticulation valves. It was necessary to use a boat to gain access to some of the valves on the Coronation Drive side of the river, and to wade through flood waters to others. This shut was completed by 10.00 a.m., Monday, the 28th January 1974 leaving a large area of South Brisbane without supply, essentially that area south of Vulture Street and bounded by the Brisbane River and Annerley Road. The size of the area involved was so large because the syphon isolating valves were, of course, open and below flood level with a break in the twin 18" diameter mains beyond.

Water carts were despatched to this area on Wednesday, the 30th January 1974, two at 4.00 p.m. and a further two later that evening. Supply to this area was further improved during Wednesday night when flood waters had receded sufficiently so that the syphon isolating valves could be shut down on the river bank and the area was rezoned to be fed from Tarragindi Reservoir instead of direct from Mt. Crosby as previously. Even so, elevated areas such as Dornoch Terrace, were still without water until late at night. This situation was not rectified until the 20th February 1974, by which time a booster pump and associated pipe lines had been installed and were operative in Hampstead Road.

Mt. Crosby Pumping Station experienced great difficulties during the day of Monday, the 28th January 1974, to maintain some pumping output. By midday, Monday, City water storage was down to approximately 182Ml (40,000,000 gallons). Between 4.00 and 5.00 p.m., the Superintendents (North and South) were instructed to proceed to re-open the trunk main valves. Due to difficulties still being experienced at Mt. Crosby, instructions were later issued to again shut the trunk main supply to the south side of the river and to throttle supply to the north side. The south side shut was completed by 10.45 p.m. but the throttling to the north side was only partially effective because of a cross-connection valve that was believed to be shut, but was next morning found to be open. North side valving was completed by 7.30 p.m.

By Monday evening, the following reservoirs were empty -

North Side:	Bartley's Hill
	The Gap
	Green Hill
South Side:	Tarragindi
	Inala
	Sunnybank
	Wellers Hill
	Highgate Hill

Inner City storage at this time would have amounted to approximately 136.5Ml (30,000,000 gallons) - approximately 8 hours' supply. This contrasts with the total Inner City available storage capacity of 527.8Ml (116,000,000 gallons), Mt. Crosby 141Ml (31,000,000 gallons), Pipe Line storage approximately 335.0Ml (73,750,000 gallons) consisting of trunk mains (16"-66") 265.5Ml (58,400,000 gallons) and reticulation network 69.5Ml (15,350,000 gallons).

TUESDAY, 29TH JANUARY 1974

During the whole of Sunday night, Monday, Monday night and Tuesday, the crisis at Mt. Crosby was followed on radio between the City Hall and the Resident Analyst, Mt. Crosby's radio car, anxiously following the fluctuating fortunes at the Mt. Crosby Pumping Station and on Monday night and Tuesday, anxiously awaiting sufficient improvement in the Mt. Crosby pumping capacity to permit supply once again being restored to the City of Brisbane via the trunk mains system.

During the night of Monday, all major consumers were contacted by 'phone by the Maintenance Engineer Water Supply or the Assistant Maintenance Engineer, Water Supply, and requested to shut off their supply. This included Redcliffe City Council who have an alternative supply from the Sideling Creek Dam, but did not include Ipswich City Council. By Tuesday morning, the 29th January 1974, the situation at Mt. Crosby Pumping Station had improved to the extent that storage levels had recovered to a depth of 2.4m (8'0") at Cameron's Hill Reservoir (current storage depth 7.15m (30'0"). Permission was accordingly granted to once again open supply lines to the south side of the river and this was put in hand at

5.30 a.m. Some reservoirs on the south side had been empty since the previous evening. To assist in maintaining storage at Mt. Crosby, the by-pass valve left open on the supply line to Sparkes' Hill Reservoir and areas beyond, was shut at approximately 6.00 a.m. Tuesday, the 29th January 1974 and distribution mains between Sparkes' Hill and Aspley Reservoirs were closed, roughly along the line of Hamilton Road. Aspley Reservoir, which up till this time had been shut, was then opened into the reticulation system north of this line to take load off Sparkes' Hill.

On Tuesday all burst water mains that were accessible were manned and repaired.

WEDNESDAY, 30TH JANUARY 1974

All plant and vehicles were returned to Newstead Depot, the Depot was hosed out and water supply maintenance activities on the north side of the river again operated out of this Depot. Temporary telephone installations for two lines and a temporary radio installation were activated at this Depot.

Harries Road Depot was also functioning for all operations on the south side of the river.

Areas still experiencing supply failure at this time were Highgate Hill, Hill End and parts of South Brisbane and Kangaroo Point, including Mt. Olivet Hospital, the Mater Hospital and Brisbane Gaol. Supply to this area was improved that evening as already mentioned. Large areas to the west of Bullock Head Creek, including the adjacent areas of Moreton Shire, were also still experiencing supply failure at this time, also the district of Pallara. At approximately 9.00 p.m. on Wednesday, the 30th January 1974, Mt. Crosby supply was again fed to Sparkes Hill Reservoir by opening the necessary valves previously shut on the distribution mains at Pickering Street, Enoggera.

THURSDAY, 31ST JANUARY 1974

Supply to South Brisbane was further improved by rezoning the Seven Hills, Morningside boosted area so that Tarragindi supply could be fed into the South Brisbane area via the 16"-24" diameter main Morningside to Vulture Street. Tarragindi feed was also fed into this main system at Cavendish Road. During the day zoning plans were prepared by the Water Supply Reticulation Office to bring the Mt. Crosby pressure along Ipswich Road to the Mater Hospital. This rezoning was carried out during Thursday night under the direction of the Assistant Maintenance Engineer, Water Supply.

FRIDAY, 1ST FEBRUARY 1974

Difficulties were still being experienced at the Mater Hospital so a pressure gradient check was run along the Ipswich Road - Annerley Road feed that had been rezoned the previous evening, to locate any shut valves or open scours. This check was completed by 1.45 a.m. Saturday, the 2nd February 1974. Two open scours and one shut valve were located and when these matters were attended to, supply to the Mater Hospital was again satisfactory.

SATURDAY, 2ND FEBRUARY 1974

The slip in Coronation Drive was causing concern, and in order to minimise shut down time should the slip continue, valving operations were carried out on the mains located in the slip, namely, the 24" diameter main which was shut at both ends, together with one end of the 12" diameter reticulation main; the main gate on the 36" diameter valve on the 48" diameter main near the Regatta Hotel and the feeds from the 48" diameter main at Skew Street, Boomerang Street, North Quay and Countess Street. Such throttling had a serious effect later on supply to Bartley's Hill Reservoir, and further valving operations were necessary. This really ended the crisis phase of the flood. From here on it was a matter of repairing outstanding damage.

CONCLUSIONS

The flood crisis tested the efficacy of the Water Supply Maintenance Branch's organisational structure, ability and capacity and it proved equal to the task. The Branch remained operative and effective throughout the flood crisis. Bursts were repaired as they occurred, provided that it was physically possible to reach them by conventional road transport. Creek crossings that were lost were shut down and temporary supply lines installed where necessary. The only areas that were without water for protracted periods were -

South Brisbane between Vulture Street, Annerley Road and the river, from Sunday night, the 27th January 1974 until Wednesday night the 30th January 1974 (as a result of the loss of the twin 450mm (18") diameter Davies Park to Coronation Drive river main crossing). After that time the only areas without water during daytime were the most elevated such as Dornoch Terrace and all areas including these received water late at night. There were some further intermittent daytime problems at the Mater and Mt. Olivet Hospitals and the South Brisbane Gaol, until the rezoning of Mt. Crosby supply to this area was finally completed during Friday night the 1st February 1974.

Supply to this area was normalised when the booster pump and pipework installed in Hampstead Road became operative on 20th February 1974.

Pallara was without water from Friday night, the 25th January 1974 to Friday, the 1st February 1974, when a temporary 50mm (2") diameter polythene hose was laid across Blunder Creek and connected into the 300mm (6") diameter mains either side. This loss was not all that critical in that town supply had only recently been made available to this area, and the residents would still have their own former alternative supply.

It was not possible to gain physical access to this area by conventional road transport until Thursday the 31st January 1974.

All areas west of Bullock Head Creek, including portion of the adjacent Moreton Shire and Wolston Park Hospital, experienced intermittent supply from Friday night, the 25th January 1974 until 4th March 1974.

This area was affected by the loss of the 230mm (9") diameter water main in Ipswich Road at Bullock Head Creek. This is the only main feeding outbound along Ipswich Road and the alternative feeds to the south-east were inadequate to maintain continuous supply to all this area. Once again, it was not possible to obtain physical access to this area by normal means until Thursday, the 31st January 1974. By Friday, the 1st February 1974, supply had been improved by the laying of a temporary 50mm (2") diameter G.W.I. line across Bullock Head Creek, connecting back into the 230mm (9") diameter main either side. Normal supply was fully restored to this area when a new 230mm (9") diameter line was laid across Bullock Head Creek and passed as satisfactory by the City Chemist on 4th March 1974.

The loss of various lines and the inability of the Mt. Crosby Pumping Station to maintain full continuous supply, necessitated a large number of rezoning operations with valve operations spread over a wide area.

These rezoning operations required field supervision at Superintendent or Assistant Superintendent level. There was physically available for such duty - one Superintendent, two Assistant Superintendents and two Technical Officers. During the flood, one Superintendent was absent on sick leave, one Assistant Superintendent became flood bound at Inala from Saturday evening until Thursday morning and was then used specifically to supervise valving operations in that general isolated area; one Technical Officer was on leave and one Technical Officer was flood bound at Booval until Thursday morning, the 31st January 1974. Engineer staff available from Friday, the 25th January 1974 to Thursday, the 31st January 1974 to supervise supply distribution aspects was the Maintenance Engineer Water Supply. The Assistant Maintenance Engineer Supply, one of whose normal responsibilities is distribution, was flood bound at Ipswich but his services were availed of per telephone for advice by the Superintendents and the Maintenance Engineer Water Supply, and for contacting major consumers, etc.

From Friday night, the 25th January 1974 until the Thursday morning, 31st January 1974, the task of planning and executing the rezoning of feeds, planning, organising and supervising the repair of broken mains; evacuation of the two Maintenance Branch Depots and their re-occupation; and organising the installation of temporary supplies was done by the Maintenance Engineer Water Supply, one Superintendent, one Acting Superintendent, one Assistant Superintendent and one Technical Officer. These officers had very little sleep over this period and worked in some cases to a stage of exhaustion. The Assistant Maintenance Engineer took over night time duties from the Maintenance Engineer Water Supply from the morning of Thursday, the 31st January 1974.

The normal complement of fifteen Turncocks or their Reliefs were used, but the bulk of the valving work was performed by nine who, in some cases also worked to the stage of exhaustion. It is pointed out that one of the services that a Turncock renders is to be able to walk straight onto a valve. It is one thing to see it on a plan, quite another to be able to walk straight onto it in the field.

The Department was well served by its Superintendents and Technical Officers who worked long hours on a multiplicity of duties and met each demand as it came without ever losing control of the situation. Their performance vindicated the basic requirements the Department has for officers to fill these positions, namely, qualified tradesmen who have completed, or are well advanced in their studies for, their Design Office Technician's Certificate or equivalent.

A Control Room would have been of considerable assistance during the crisis, mainly from the aspect of having one central establishment within the Water Supply Maintenance Branch where all valve operations are recorded, so that they are not overlooked. All valves that are planned to be shut as a zoning requirement, are indicated as such on Zoning Plans, copies of which are held by the Maintenance Engineer Water Supply's Office, the Water Reticulation Office, the Water Supply Maintenance Depots, and the individual Turncocks for their own and adjacent districts, but records are not kept at present of valves that are shut temporarily for maintenance reasons, or scours that are left open after mains are cement lined or laid as part of the water quality standard process. These operations are in the minds of Superintendents, Assistants, Technical Officers, Cement Lining Inspectors, Turncocks, etc. and are sometimes overlooked, with resultant inconvenience as was experienced in the rezoning of Ipswich Road.

The two scours running off the 400mm (16") diameter main in Ipswich Road, highlights the virtue of the policy never to discharge scours direct into stormwater pipes where they cannot be seen; always discharge them into gullies or above ground so that if they are overlooked, having been turned on, someone will observe them and they can then be shut off. The two scours at Ipswich Road discharged directly into stormwater drains.

All valve pits, especially butterfly valve pits, should be located where they will automatically drain and the necessary gravity drains provided. If this is impracticable, they should be sited in watertight valve pits so that the water entering them is only rain water so minimising corrosion. During the flood crisis, one set of valve gear teeth twelve years old, failed due to groundwater corrosion, and one critical butterfly valve pit had to be pumped out before it could be operated.

Because of this, and other previous flood experiences, it is obvious that all creek crossings by water mains should be in service ducts in the road bridge or be all welded steel lines on piled supports. Concrete piers set some depth into the creek bed have repeatedly failed. They must also be set either at a very low level or above flood level.

In the case of an all pumped supply, and with particular regard to present day terrorist activities and industrial disputes, I believe that it should be mandatory for all domestic dwellings to have drinking quality water stored on site to a very minimum of 2,275 litres (500 gallons) and preferably 4,500 litres (1,000 gallons), sufficient for a family of four for one week in the former and two weeks in the latter case. The Draft British Standard Code of Practice of Water Supply recommends on site storage to provide for interruption to supply.

Large consumers whose processes are such that they cannot shut down without serious damage to their plant, should be required to hold sufficient water in storage on site to cover their coming off line time.

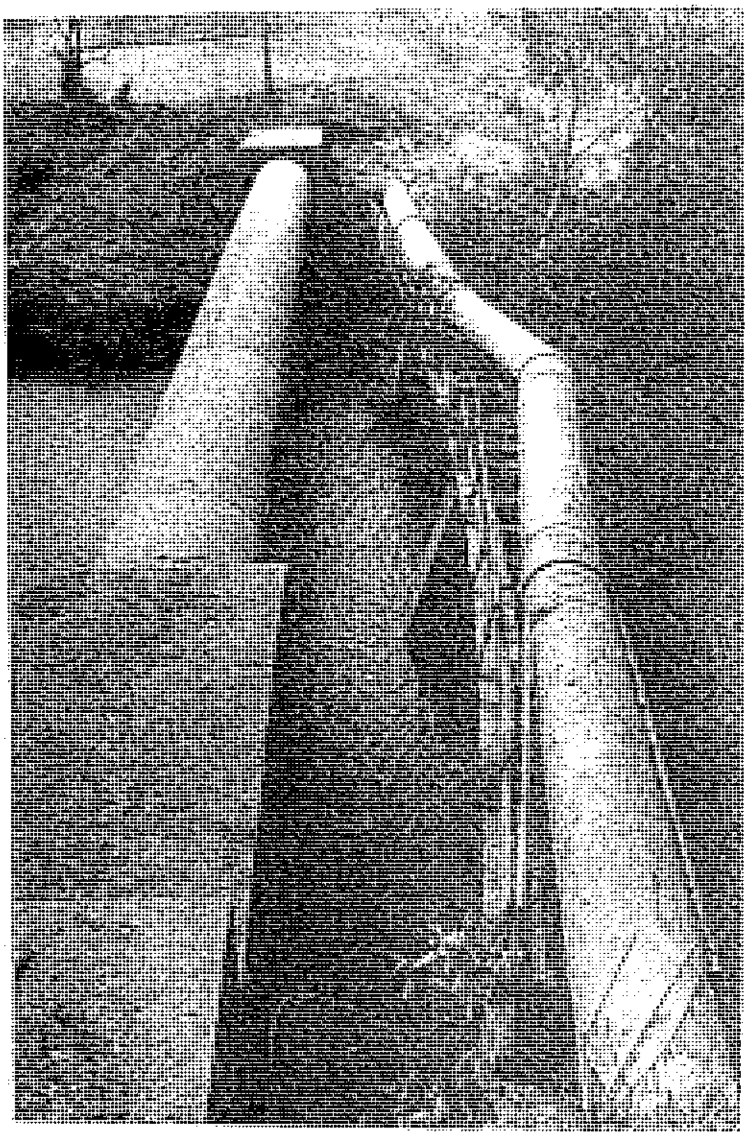
Water usage was particularly high after the flood, e.g. within the metropolitan area for the 24 hours ending 9.00 a.m. Sunday, the 3rd February 1974, it was 488.91 megalitres (107.45 m.g.) compared with the 24 hours ending 9.00 a.m. Friday, the 25th January 1974 of 363.91 megalitres (79.98 m.g.). Furthermore, this high usage was obviously concentrated in areas that had been flooded, and the increase in usage rates in these areas would have been much greater than indicated by the increase in the overall usage rate for Brisbane. In some areas, the high usage rate for washing down flood debris caused or aggravated already existing supply difficulties, for example, South Brisbane, Highgate Hill, Kangaroo Point, etc., where the feeds had already been dramatically weakened by the loss of the Davies Park syphon.

The Department, however, adopted a policy not to attempt to restrain people from hosing down, realising this was the only method to clear flood silt. Furthermore, people whose supply was affected in consequence, showed remarkable tolerance in accepting their own resultant difficulties.

One feature of the flood, compared with normal attitudes, was the readiness with which people accepted their supply failures with little or no complaint.

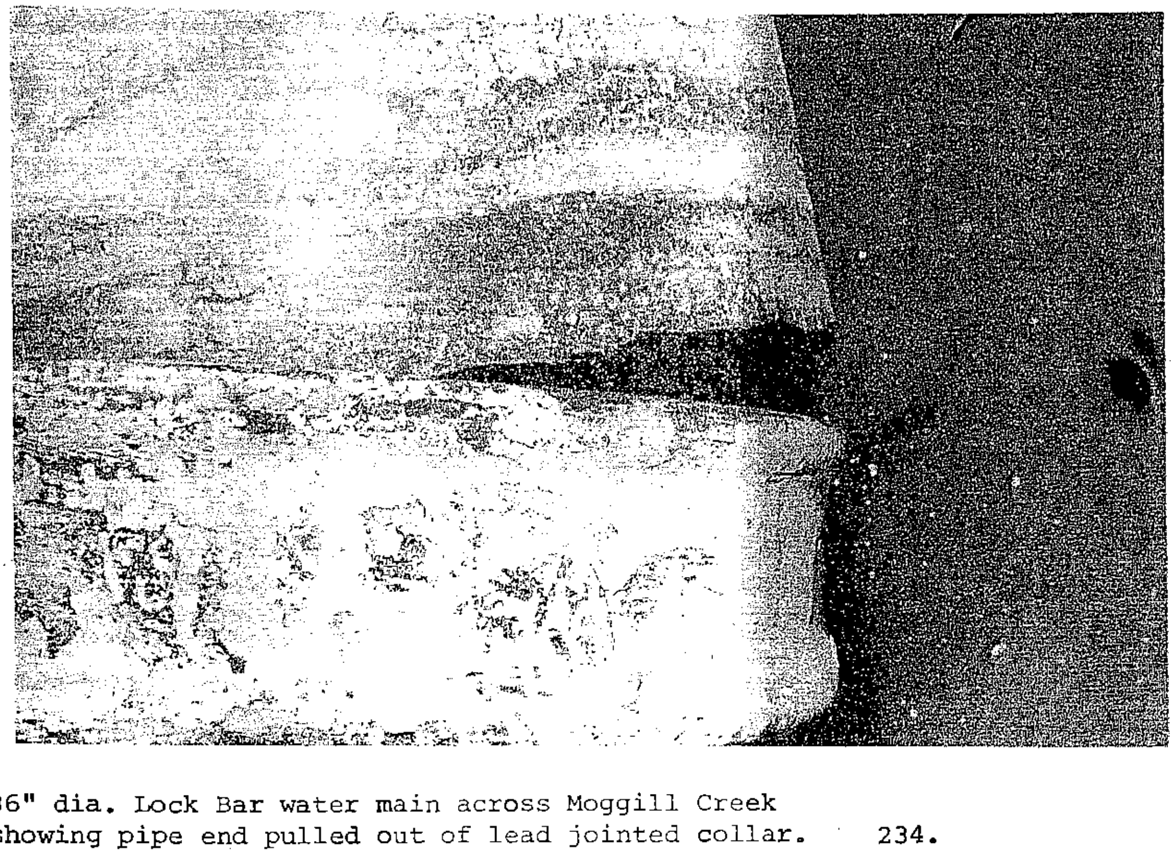
As Branch Head of the Water Supply Maintenance Branch, the author is proud of the way the Branch performed during this crisis. Personnel at all levels responded magnificently and did all that was asked of them.

The author is also proud of the Department. It did what it had to do quietly, and the help and advice that was required from time to time from other Branch Heads was available, effective and accurate.



36" dia. Lock Bar water main across Moggill Creek.

Displaced at approximately 5.30 p.m. on 25.1.74.
11.2.74. 35P/44/1.



36" dia. Lock Bar water main across Moggill Creek showing pipe end pulled out of lead jointed collar. 234.

BRISBANE SEWERAGE SYSTEM

*by R.J. Corbett, M.I.E. Aust.**

Brisbane, in common with many other large cities, has a sewerage surcharge problem. In times of heavy or continuous rain the system surcharges in many areas. Relief is obtained by the construction of overflows or by the use of reflux valves or anti-flooding devices on the individual house drain.

Although the system is separate from the stormwater system, much stormwater enters by way of cracked or faulty pipes, displaced manhole covers or illegal stormwater connections.

The inundation of vast areas of Brisbane in the January floods filled much of the system and many parts not previously affected were surcharged, the water entering through flooded house fittings, manhole lids, and many damaged or washed out sewers in flooded creeks. These damaged sewers included some submains as well as reticulation sewers and rising mains.

The overloaded system in many areas discharged into treatment plants or pumping stations either partly or wholly inundated and put these out of action. The extent of all sewer damage has not yet been fully established.

As soon as flood waters started to recede sewerage maintenance gangs together with construction gangs went into action. Surveys up flooded creeks and along the river banks located many trouble spots and these were temporarily repaired using mainly P.V.C. pipes. Reports of broken or damaged sewers also were received from the general public and were in most cases temporarily repaired in a matter of hours. Other breaks not so obvious are still being reported and attended to as soon as labour is available. Permanent repairs will continue for quite some time.

The degree of pollution in the water courses was thus kept to a minimum. The main breaks were repaired before the main flow in the creeks subsided and any sewage spillage was diluted and dispersed.

A very heavy flow in the main sewer continued after the main flood runoff had ceased. Three pumps at Eagle Farm were operating continuously and the level of the sewer could not be reduced. Fish and crabs on the screens initiated a search of all overflows and other previous trouble spots to no avail. Salinity tests along the length of the main sewer indicated higher readings along Coronation Drive. A search by divers along the twin 15" C.I. pipes under river syphon from Hocking Street, West End, to Coronation Drive revealed a break near Coronation Drive end. This has now been isolated and plugged so that repairs can be made.

**Assistant Maintenance Engineer, Sewerage, Department Water Supply and Sewerage, Brisbane City Council*

TREATMENT PLANTS

Eleven sewage treatment plants out of a total twenty-two were submerged by flood waters and put out of action. These were Bellbowrie, Centenary, Cubberla Creek, Fairfield, Inala, Keperra, Misty Morn, Mt. Ommaney, Oxley Creek, Ridgewood and Wacol. Some minor flooding occurred at other plants but did not affect their operation.

Restoration work on these plants proceeded as soon as flood waters would allow. Electric motors and switch gear were removed for drying out and a priority on order of repair was established. Primary treatment and chlorination by dosage with sodium hypochlorite was established at most plants as soon as possible. A high priority was given to pumps and motors where plants were dependant on pumping. A mobile alternator, by courtesy of the Sydney Water Board enabled primary treatment to be established at Oxley Creek Plant long before the plant's own motors were reconditioned.

The task of recommissioning the plants then included pumping out all tanks, primary, secondary chlorination, final settling and scouring out all the mud and silt. A combination of sewage sludge, silt and mud proved a very difficult mixture to remove. All inlet and outlet lines and channels were also cleaned and scoured. The air diffusers had to be completely dismantled and thoroughly cleaned. This work had to proceed while heavy flows were still entering the plants from overloaded sewer lines.

The stone media in the trickling filters at Misty Morn plant had to be completely removed and either washed down by high pressure hoses or replaced. Mud penetration into sludge drying beds where flood waters covered the beds resulted in the need to completely remove all sand and gravel and in most cases the relaying of the under drains.

Secondary treatment was brought back when air blowers, surface aerators, trickling filters etc. were reconditioned and put back into operation.

The whole process of bringing the sewerage system back into operation and obtaining a satisfactory effluent within days, played a major part in preventing any outbreak of disease in the community.

THE MOUNT CROSBY PROBLEM

*by T.G. Reid, M.I.E. Aust.**

Mt. Crosby pumping station is located on the bank of the Brisbane River 18km above the junction of the Bremer River. It supplies more than 99% of the water consumed in Brisbane and Ipswich. It was known for many years that the pumping station could be flooded by a rare large flood and various precautions were taken to make the installation as flood proof as the circumstances permitted. However, the situation which developed at the pumping station during the January 1974 flood was one of the most serious that the Cities of Brisbane and Ipswich faced during the whole flood.

On Monday, 28th January 1974 the Brisbane River rose to within 0.5 metre of the finished ground level outside the station. The river had only to rise a further 0.75m to flood the station and put it out of operation for days.

Most of the troubles experienced at the pumping station were due to the fact that the location of the station was fixed before the 1893 flood. The station location was originally chosen in 1889, but, before construction could start, the 1890 flood covered the site. The station was then relocated ten feet above the 1890 flood level but, no sooner had it been commissioned than the 1893 flood overwhelmed it to a depth of 13 feet. A series of enlargements took place over the years, the most recent being in 1940, all at the same level. Starting in 1948 the steam pumps were replaced with electrically driven centrifugal pumps and the pumping capacity of the station was again enlarged.

Mt. Crosby pumping station consists of a series of re-adaptions of former structures and the present station still uses some elements built in 1892. The majority of it was built before 1922 in the days before the concept of water/cement ratio was introduced into concrete technology. This proved to be a source of weakness in the January flood.

Boiler ash from the steam days of the pumping station had been dumped on the river side of the station and protected by material excavated from No. 2 sedimentation basin to form a useful working area and lookout. The gantry crane controlling the tunnel screens and gates was located on the ash bank.

On the advice of the Flood Control Section at 4 a.m. on Sunday, 28th January that the station could possibly be inundated, all possible precautions were taken. A sandbag dam was built around the most vulnerable part of the station and all openings were plugged. However, as the flood neared its peak a large section of the ash bank was washed away carrying with it the power poles for the gantry crane. The crane was left on the edge of a cliff.

When the ash bank collapsed, the old porous concrete allowed water to squirt into the pump wells, drenching the thrust and radial bearings of the long drive shafts with dirty river water causing bearings to fail.

** Mechanical and Electrical Engineer, Department Water Supply & Sewerage, Brisbane City Council*

The sump pumps were unable to cope with the inflow of water which was greatest on the river side and least on the bank side of the station. The situation was aggravated by three power failures in the critical period. Some of these blackouts were caused by the submergence of the supply lines by the Brisbane River which rose 19.75m at Mt. Crosby. During the longest blackout the sump pump motors were drowned and put out of action. Fortunately, two of the major pumps can be used as sump pumps and, when power was restored, one of the pumps had to be operated with its bearings under water to dewater the pump shafts.

At a critical stage the cover over an old strainer shaft was torn from the old concrete floor by the pressure of the river water. This let the river into the pipe gallery and then, by blowing out a temporary plug, the river water penetrated Well G which was constructed in 1940. The 1,600MW motors in Well G are located below the general station floor level and would have been flooded except for a fortunate accident. A watertight door between Well G and the other pump wells blew open from unknown causes. This saved the Well G motors as the main pumps were able to deal with the whole inflow. The situation was further eased by lowering a gate on the south suction tunnel and severely throttling the inflow to Well G.

Late on Sunday 28th it seemed to the Flood Control Section, due to a misinterpretation of flood levels from Lowood, that the Mt. Crosby pumping station would certainly be flooded. A start was made to hoist the motors for Wells A to D from their mountings and suspend them from the switchroom floor. Provision had been made for this some 20 years previously. Four of the motors were raised in this way before it was realised that the station would not be flooded.

The continued failure of bearings finally became the major problem at the station. Bearings were frequently flushed with oil to clear out the debris from the river water squirting into the wells. However, a combination of this and complete inundation during the power failures caused bearing failures. The stock of spare bearings and bearing oil held at the station was used up and the staff at the station became exhausted with the continuous demands made on them in the pump wells now made dangerously slippery with bearing oil floating on the water.

Stocks of bearings were air freighted from Melbourne and together with fresh supplies of oil were airlifted to Mt. Crosby by army helicopter. An engineer and several fitters were also airlifted to Mt. Crosby to relieve the resident staff and key personnel from the station were airlifted in from Ipswich. The last airlift was a draftsman equipped with level and staff to measure the river level after it had been discovered that part of the flood gauge was washed away.

As the river subsided the situation slowly improved. At one stage only three pumps were in an operable condition but others were slowly restored to use until the full capacity of the station was restored. Only one bearing was so severely damaged to warrant complete replacement.

The problems of water storage have been described by Huxley. The operators of the treatment plant at Mt. Crosby had a difficult time. The continual changing of pumping rate as pump bearings failed or as pumps were restored meant continual readjustment of the treatment process. The oil used to flush pump bearings had all to be pumped with the water supplied to the treatment plant and this added to the plant difficulties although all the oil was removed successfully from the water. In fact, the water dispatched from the Mt. Crosby plant to the consumers during the flood did not depart from the usual high standards of purity observed by the Council.

Communications were a major problem at Mt. Crosby. All telephone lines were quickly out of operation and the Council radio system was heavily overloaded with flood messages from all over the City. In any case, direct voice contact was not possible and messages had to be relayed. The radio despatchers did a magnificient job but the flood showed the necessity of direct voice to voice contact between senior personnel. Relayed messages are not adequate to convey the urgency of some situations. Use was also made of amateur radio to Mt. Crosby. This proved to be the only direct voice to voice link available and proved to be invaluable.

CONCLUSION

A major pumping station should have all weather access roads and reliable communications. It should also be built above all possible flood levels.

DISCUSSION

W.W. Solly, B.Sc.

The Brisbane City Chemist's laboratories are situated at Donaldson Road, Rocklea adjacent to the Waste Water Treatment Plant.

The laboratories were inundated to 18" above the first floor level, the entire ground floor and contents being submerged. Damage may be pictured when it is realised that island benches and their cupboard, shelf and contents floated to ceiling level, helping to destroy the latter. Basement-sited airconditioning plant was, of course, fully under water. An abortive attempt was made to remove portable equipment as the flood rose, but since this was transported in haste to supposed safety at first floor level, most sophisticated equipment received severe damage when this, too, was flooded. Salvaged equipment was removed to North Pine Water Treatment Works Laboratory, in the process of being established and urgent operations were resumed there.

The communications difficulties of all were shared by the Branch as well as road access difficulties. The Brisbane River Water Treatment Works Mt. Crosby was paradoxically, isolated by road not locally but at various points en route to Brisbane. The Resident Analyst remained on call or on the job for a continuous 160 hours since no other qualified technical personnel could reach the plant site. In addition to the anxieties of eking out supplies of treatment chemicals, there was the added one of recharging stocks for the comparatively long period of unfavourable water following.

By far the outstanding feature of our experience was that a highly trained, specialist team of chemists, microbiologists, technical assistants, laboratory attendants, samplers and plant operators carried us through the crisis of a lifetime with the remarkable record of no appreciable decrease in standards.

It has been equally important that members of this same technical staff have been available to rehabilitate services, virtually starting anew from a complete wipe-out of their essential, sophisticated working equipment.

The lesson was learned that maintenance of a staff of the highest ability was proved to be of inestimable value in a single short period which could have been disastrous to an extent embracing people far beyond, in number, those directly affected by the flood - namely the whole greater Brisbane population.

The day by day safeguard of water supply and waste disposal of close to a million people was managed in chaotic conditions primarily because of the existence of a specifically able technical force, including laboratory staff and equipment as essential units of operational services of the Department. This is the incalculably valuable return for employing them and their equipment at all times.

ELECTRICITY DISTRIBUTION SYSTEM

*by J.C. Oberthur, B.E., M.I.E. Aust.**

PHASES OF THE DISASTER

The Department of Electricity was exposed to three sequential phases of disturbance during and after the movements of cyclone "Wanda":

(a) Cyclonic gusty winds, with showers, on Thursday, 24th January, causing fairly minor damage and loss of supply to a small number of customers.

(b) Flash-flooding of suburban creeks on Friday and Saturday, caused by local heavy falls in the catchment area, and resulting in washaways of poles and damage to cables over creeks.

(c) Extensive river flooding reaching an upstream peak on the evening of Monday 29th January, and a peak in the Commercial Centre in the early hours of Tuesday morning.

The final phase caused the most damage, and resulted in widespread interruptions to supply. Further, the rising floodwaters of this phase cut many roads required for access to areas damaged by the second phase only; similarly, creek-crossings rendered unusable by the second phase blocked plant-access to damage from (a).

The rest of these notes will deal solely with the third phase.

ACTIONS TAKEN

The first intimation of severe flooding was received in the morning of Saturday, 26th January, with advice that water had entered, and was rising, within Archerfield Substation. Access was obtained and relays removed by personnel working from a boat. This substation was eventually covered with 15 feet of water.

More manpower was mobilized and was directed into two primary activities:-

(a) Removal of critical equipment from sub-stations in advance of rising water. This was done on a priority basis, governed by predictions of flood-levels, but with the aim of keeping electricity supply available for as long as possible. These actions later facilitated speedy restoration.

(b) Disconnection of aerial circuits to allow rescue operations to proceed in safety. This activity did mean that supply was taken off in some areas which were not themselves actually submerged. In fact, a total of 480 distribution centres were off-line at the flood-peak, but only about 80 transformers had to be replaced later because of actual water-entry from submergence.

* *Planning & Construction Engineer, Department of Electricity, Brisbane City Council*

As the flood subsided, immediate action was taken to "follow the water down", and make supply available to the maximum number of customers, both in the suburbs and in the commercial centre. As a result, 90% of all suburban customers who had water in their premises had some supply available by the evening of Wednesday, 6th February; in most cases, supply was un-metered. In the City, South Brisbane and West End area, 95% of affected customers had some supply available by Sunday, 3rd February.

This activity of re-energising mains was carried out in parallel with visiting customer's premises, and energising services up to the main switchboard. Action was commenced on removing and replacing meters, current transformers, equipment etc. Switchgear and distribution transformers were sent to various centres where oven-drying facilities were available.

The objectives at this stage were -

(a) To restore some supply, even if limited in quantity, un-metered and of doubtful reliability.

(b) To remove damaged equipment as quickly as possible (particularly non-replaceable gear) so that the drying-out could be commenced.

(c) To replace metering apparatus in accordance with priorities and as determined by the availability of replacement apparatus.

Work is still continuing on restoration of the system; several submarine river crossings must be replaced, as well as some switchgear and protective equipment.

STATISTICS

Approximately 6,000 domestic premises were flooded to the extent of submergence of switchboards. Over 13,000 meters had to be replaced, as well as over 1,500 hot-water control relays.

At the peak of the flood, 480 transformer stations were off-line (due either to submergence or to facilitate rescue operations); this represents about 30,000 customers. Of this total, 160 transformers were re-energised immediately after the water subsided, and it was later found that only 80 of the remainder had to be replaced. Thirty two substations in City-building basements were flooded and damaged to some extent.

11,000 volt circuit-breakers were significantly affected; 113 of these units had to be removed, dried out and replaced.

OBSERVATIONS

With hindsight, problems encountered during the disaster seem easier of solution, and it is not difficult to ignore and minimize the urgencies of the situation in the subsequent atmosphere of calm.

Evaluation of organisational performance in any field can only be determined by comparison of attainments with objectives. Broadly stated, Departmental objectives are concerned with the provision of a safe, reliable and economical supply of electricity, which, for a disaster situation, can be translated into specific objectives as follows:-

(a) Safety at all times - both public and employees.

(b) Speedy restoration of adequate supply to customers.

(c) Prompt restoration of the network to its previous condition of reliability and adequacy.

(d) Resumption of normal operations as quickly as possible.

The whole exercise may be regarded as a project, but one in which speed and urgency dominate; resources must be applied effectively, but it will be appreciated that resource-requirements and resource-availability change rapidly.

This leads to the conclusion that effectiveness in a disaster situation depends upon the following factors:-

(a) Determining the magnitude of the disaster.

(b) Establishing an appropriate temporary organisation structure.

(c) Monitoring progress and amending the structure as required.

(d) Flexibility and speedy re-allocation of resources.

(e) Realignment of priorities as the programme progresses.

These require in turn attention to the following:-

(a) Accurate initial appreciation of the extent of the disaster.

(b) Communications.

(c) Feed-back on progress.

These elements were all handled adequately, but difficulties occurred in the following aspects:-

(a) Insufficient warning.

(b) Translation of flood-prediction data into meaningful information.

(c) "Hard" data on extent of submerged customer-installations.

FUTURE ACTION

The Department has made extensive reviews into the performance of its manpower, plant, communications, and equipment, and is currently determining future actions; however, in all these considerations, the Department has been careful not to over-react.

To some extent, there has been confirmation of present practices, whilst elsewhere there seems scope for improvements (which will satisfy normal operations) at fairly small expense.

Generally, the changes from this particular disaster will be examined and introduced in the light of their application and benefit to normal operations and to the more frequent "mini-disasters".

TELECOMMUNICATIONS

*by P.L. Dubois, B.Sc., M.I.E. Aust.**

THE EFFECT OF THE FLOODS

By Tuesday 29.1.74 it was estimated that approximately 30,000 telephone services had been affected by heavy rain and subsequent flooding in the Moreton Region.

Plant failures which occurred as a result of the flooding could be divided into two major categories:-

(a) Physical damage to cable and aerial plant due to swiftly flowing current from the great volume of flood waters.

(b) Immersion of subscribers equipment and minor distribution cables due to backup of floodwaters and overflow of sewerage and stormwater drainage systems.

Damage in category (a) above occurred mainly at creek and river crossings where the force of the runoff and scouring of creek beds and bridge approaches resulted in the washaway of conduits, cables, poles and in one case, a complete manhole.

By far the greatest number of plant failures occurred under category (b) when thousands of residences and commercial and industrial establishments were submerged for periods of up to one week. Telephones, switchboards, PABX's and other subscribers equipment in these premises were severely damaged.

Failure of telephone exchange equipment was minimal due to our continuing long term efforts to locate exchanges on safe sites and to provide good building security against wind and water damage. However at the height of the flooding the basement of the Edison Exchange Building was threatened by sewerage system backflow and the possibility of direct entry of flood water. Fortunately no plant damage occurred in the basement area, although we did have some anxious moments. One rack of trunk switching equipment on an upper floor of the Edison Building was damaged by seepage of rainwater, but rapid action by our staff allowed facilities provided by this rack to be diverted to available spare equipment.

Service to telephone exchanges in the Region was largely influenced by the performance of external plant which provided junction or trunk circuits between terminal exchanges and higher order switching centres. Apart from a few (though important) cases, junction and trunk networks retained their integrity. Most Brisbane Metropolitan and outer Metropolitan exchanges were telephonically accessible although congested. A few smaller exchanges in the Moreton Region became inoperative owing to their batteries being run down and no commercial or standby power being available owing to isolation of the exchange sites by floods.

* *Assistant Director, Engineering, P.M.G. Department, Queensland*

The trunk centres most affected by river and creek washaways were those in the Ipswich hinterland served by (a) one of the cable routes between Brisbane and Ipswich, which failed at a Brisbane River crossing near Moggill, and (b) an aerial trunk route which was affected by a washaway along the Brisbane River near Lowood. Restoration of normal trunk facilities between Brisbane and the affected centres was made as rapidly as possible by patching carrier systems via alternative routes, and by provision of an interruption cable to bypass the damaged section of pole route near Lowood.

Increased calling rates during the crisis heavily loaded the switching system and the public was requested to endeavour to restrict calls to essential needs only.

Major cable failures were remarkably few considering the magnitude and extent of the flooding. This can be attributed to the effectiveness of the gas pressure system which protects almost all main cables in the network. Faults occurred chiefly at river and creek crossings and bridge approaches where cable was physically damaged. It is significant that, other than at creek and river washaways it was necessary to replace only one section of large size cable in the Brisbane Metropolitan Area. This was a 400 pair cable at least 30 years old in Stanley Street, South Brisbane.

As far as secondary distribution cables are concerned, most faults occurred in the older lead sheathed paper insulated cables located mainly in the older settled residential and industrial areas which were severely affected by floodwaters. Most faults were caused by water entering the lead sheathed lead-in cable at the telephone terminal block (or distribution frame or box) and flowing through this cable to wet the joint in the paper insulated street cable.

The later plastic sheathed underground cables performed very well and very few failures occurred in sections or in joints. In most cases where plastic distribution cables existed in the submerged areas it was possible to restore service merely by replacing the telephone and terminal block.

Terminals and wiring on cable distribution boxes or frames located in flooded sections of Brisbane City buildings, or in basement areas affected by stormwater or sewerage system backup, corroded quickly and severely affected service. Such installations have to be progressively re-located in safer areas.

ACTION TAKEN TO DEAL WITH THE EMERGENCY

When it became evident that major flooding would occur in the Region, an Emergency Control Centre was established in the Edison Exchange Building. The Centre incorporated representatives of the major sections involved in our supply and repair organisation and became a key co-ordinating and information centre for the various organisational units in the office and the field.

During the development of the flood crisis the main efforts were directed towards maintenance of a viable trunk and local telephone service in the face of a rising number of plant failures. Alternative routes had to be set up where practicable for trunk circuits which had been affected by plant faults. It was necessary to clear equipment, stores, motor vehicles, records etc. from areas likely to be flooded and to generally ensure that staff and equipment would be available to commence repairs as soon as access to problem areas became possible.

As flood waters receded sufficiently, staff moved in to effect repairs to trunk and junction external plant and to restore communication to isolated exchanges. For example, new carrier cables were provided across the Brisbane River at Moggill to replace the two 24 pair Brisbane-Ipswich cables which had been swept away on Sunday evening (27.1.74). Additionally a 24 channel radio system followed by a 120 channel radio bearer system was provided on a temporary basis between Brisbane and Ipswich to parallel the work being done on the carrier cable restoration and to provide additional insurance against the possibility of further failures on the route.

As business premises became ready for re-occupation, temporary arrangements were made to bypass faulty subscriber's equipment (e.g. switchboards which had been inundated by flood waters) in order to restore communication as quickly as possible. High priority was given to essential services. Local installation and maintenance staffs were reinforced by staff from other sections of the Engineering Branch and later by staff from Interstate.

Similarly, as flood waters receded from inundated areas, faulty distribution cables were repaired or replaced and previously submerged equipment and internal wiring attended to as soon as practicable after the premises were in a suitable state for re-installation of new equipment.

LESSONS TO BE LEARNED FROM THE FLOODING

Our reporting, restoration and repair organisation is normally geared to handle the general day to day level of plant faults, together with a capacity to rapidly cope with the occasional "major" plant failure or isolated crisis. Hence the problems imposed by a major widespread disaster severely loads the capacity of the organisation in the short run.

Perhaps the major lesson to be learned from the Moreton disaster situation is the need to shape existing organisational units to allow them to be rapidly expanded and reinforced when faced with sudden and widespread emergencies, rather than to form up new organisational arrangements at times of crisis.

It is necessary that, at all times existing organisational units have the necessary information systems, plant records, and local knowledge to enable them to quickly obtain advice of plant failures, assess the overall implications of such failures and have sufficiently detailed contingency plans to allow quick effective action to be taken to restore vital communication links via normal routes or to make use of alternative routes. Ad hoc organisational units formed to deal with specific crises tend to require a settling down period and tend to be comparatively less efficient in the short run than regular units which can be reinforced to handle extraordinary loads.

Essential lines of communication must be kept open at all times and to this extent it is necessary to ensure that, for example, communication links to sound broadcasting stations must be given a high priority. Most people have transistor radios and broadcasting stations provide an essential service for communication with members of the public and staff of the various service organisations which may for a time be cut off from normal telephone communication. This is an important supplement to private mobile radio networks which are operated by some of these organisations.

If the public can be adequately informed of rapidly changing conditions, progress on restoration work etc., then perhaps the load on existing (and perhaps restricted) public communication facilities could be held to a level which will keep the system viable at all times.

Where practicable, communication equipment (including cable distribution boxes and frames) installed in subscribers premises should be located above flood level. City building basements, even when above flood level, are potentially susceptible locations in those areas where build up of overflow from sewerage and stormwater systems can occur during heavy rainfall or flooding. Hence there is a real need to locate distribution boxes and frames and other telephone equipment clear of such locations in heavy rainfall or flood areas. The co-operation of Architects and Building owners is needed to ensure that such hazards are clearly recognised in buildings being planned and that suitable alternative accommodation is provided in specific existing buildings to allow for relocation of Departmental distribution frames and other vital equipment.

The loss of commercial AC supply to a commercial building, as well as immobilising lifts, lighting, air conditioning etc., will also cut AC supply to telephone subscriber's switchboards (which are generally fed from 240V AC/48V DC eliminators), other intercommunication equipment and telex machines. This information should be recognised when the site for electrical switchboards and emergency generating plant is being considered.

Critical Departmental buildings such as Telephone Exchanges, Line Depots, Engineering Maintenance Centres, Car Pools, Fuel Supply Depots, Workshops etc., should be located well above expected flood levels and wherever possible served by all weather access roads which are above flood level.

This latter requirement is difficult to meet in the case of some of the smaller perimeter exchanges in the Brisbane Outer Metropolitan Area and in some country communities. If the commercial power supply fails for a long period under flood conditions and movement of mobile generating plant to the site is very difficult then local batteries discharge to failure point. Reconsideration of the amount of reserve battery capacity provided and/or provision of local standby generating plant appears to be necessary at some sites.

Cable and aerial routes at river and creek crossings are a special problem. Our techniques for installing and protecting cable crossings have improved significantly over recent years and modern major crossings fared very well. Cables and conduits have been laid in deep trenches in the river bed (sometimes in bedrock). But abnormal scouring of creek beds, erosion of creek banks etc. damaged some of the older major installations and minor crossings.

Although temporary restoration has been made in all cases, the question of permanent replacement or relocation of some of these cables is receiving special consideration to ensure that we have improved security in the event of future flooding of such magnitude.

CONCLUSION

The January 1974 floods provided a severe test of the integrity of our inter-exchange communications system in the Moreton region. It could be said that the system passed the test in a very satisfactory manner.

The standard of reliability of our public exchange plant was high. Water damage to exchange equipment was almost non-existent. Increased traffic during the critical period severely taxed the communication network but the system remained viable at all times.

Trunk and junction cable failures were relatively few and action was taken as quickly as possible to provide circuits on alternative routes and/or repair the actual faults.

Staff at all levels responded magnificently to the needs of the time. In the early stages when working conditions were difficult and even hazardous, restoration and repairs were handled with a maximum of initiative and a minimum of fuss. Excellent co-operation was obtained from other organizations, e.g. the Fire Brigade, the Army, the Civil Defence and other State, Commonwealth and local authorities. Our thanks for an excellent effort go to all concerned.

Appendix 1

MAIN CABLES DAMAGED AT CREEK AND RIVER CROSSINGS

Cable Size (Pairs)	Sheath Type	Use	Location	Remarks
300	Lead	Subs	Inala Avenue, Inala	Cable in PVC conduit attached to bridge. Damaged by floodwaters and burst water main.
200	Arm Lead	Subs & Jct.	" " "	Armoured cable attached to bridge.
200	Lead	Junct.	Ipswich Road, Wacol	Cable in conduits under creek bed. Scoured to depth of 3m.
74	Lead	Subs	Blunder Road, Inala	Cable in pipe. Bridge approaches washed away.
50	Lead	Junct.	Railway line Wacol	Cable; pipe and manhole washed away.
100	Lead	Subs.	St. Johns Wood	Cable attached to bridge. Damaged by tree.
Two 200	Arm Lead	Subs.	Sth. Pine Rd., Milton	Cables laid under creek bed. Hit by debris when bed scoured.
400	Lead	Subs.	Cashs Crossing	Cable in pipe. Bridge approaches washed away.
Two 300	Arm Lead	Junct.	Bulimba Ck., Tingalpa	Cables suspended across creek. Hit by debris.
Two 24	Arm Lead	Junct. (Carrier) (Type)	Brisbane River, Moggill	Cables laid on bed of river. Damaged in section.

NOTES:

1. Brisbane-Lismore Coaxial cable hanging above bed of Pimpama Creek - due to scouring of bed - No failure occurred. Cable replaced.

2. Brisbane-Lismore Coaxial cable exposed at Logan River - being covered by sand pumping. New crossing being prepared - no failure occurred.

MAIN CABLE FAULTS OTHER THAN AT CREEK AND RIVER CROSSINGS

Cable Size (Pairs)	Sheath Type	Use	Location	Remarks
1500	MB	Subs	Coronation Drive, Toowong	Faulty thermoshrinkable plastic sleeve. Joint remade.
1000	MB	Subs	Oxley Road, Oxley	Faulty thermoshrinkable plastic. Joint remade.
600	Lead	Subs	Pinkenba Exch. Tunnel	Hole in pothead joint above gas seal (obsolete type). Joint remade.
400	Lead	Subs ('O' side)	Stanley St., South Brisbane	Faulty between manholes. (Cable at least 30 years old). Section replaced.
400	Lead	Subs	Mirrabooka Road, Ashgrove	Bandaged joint work in progress. Joint remade.
300	MB	Junct.	Blunder Road, Inala	Faulty sleeve. Joint remade.
200	Arm Lead	Junct.	Mosquito Is., Hays Inlet	Manhole collapsed on cable. Cable repaired.
200	MBHJ	Junct.	Bullen Ck., Moggill	Faulty thermoshrinkable plastic sleeve. Joint remade.

ROADS & HIGHWAYS

*by W.J.Cock, Dip.C.E., M.I.E.Aust.**

To consider the Australia Day situation, the Moreton Region as defined by the Water Engineering Branch comprises 2 M.R.D. Engineering Districts plus parts of 2 others. The first 2 have Headquarters in Brisbane and the latter are at Gympie and Toowoomba. The Department directly maintains basically the highway system, e.g. Pacific and Gold Coast Highways. Mt. Lindesay Highway via Beaudesert, Cunningham Highway via Ipswich and Cunningham's Gap, Warrego Highway to Toowoomba and Bruce Highway via Petrie to Gympie. Local authorities principally maintain the balance road system with financial help for the declared roads and under general engineering supervision from the Department's District Engineers.

Current estimates of the damage caused by the flooding on the Australia Day weekend to the declared road system based on flood submergence only exceeds $1,500,000. In addition, major slip damage particularly in the mountainous areas that received extremely heavy rain will cost approximately another $1,000,000 to repair. To this must be also added the very extensive pavement and subgrade failures due to saturation by rain and which have required a major maintenance effort, generally in continuing poor weather, in order to keep the main arterial roads in anything like reasonable condition. This aspect, almost impossible to estimate, could well prove to be the most expensive of all, and its considerable long term effect will show up in the need for accelerated reconstruction and bitumen reseals for the next couple of years.

From the preceding it is seen that direct costs to the M.R.D. will approximate $3,000,000, but the effect on LA needs is far more disastrous. Preliminary surveys suggest restoration in Brisbane and Ipswich could exceed $13,000,000, with a further $2,000,000 in the remaining LA's not so seriously affected, on the roads under their control which approximate 90% of all public roads in the Region.

MAINTENANCE ORGANISATION

The Departmental Maintenance Organisation is largely decentralised into depots located along the highway system.

Because of expected problems with beach erosion at Kirra, that of No. 1 (Moreton) District had been placed on alert on Thursday, 24th January for the long weekend, and special arrangements made for radio control, material supply and standby staff. This fortuitous action greatly overcame communications and repair problems in that District. In other areas, use of mobile radios quickly brought emergency forces into action when telephone and road communications failed. The M.R.D. base station at Spring Hill functioned from Sunday on an emergency basis after the main transmitter at Tamborine Mountain was lost.

LA's throughout the region largely operated independently and because of their local knowledge of known trouble spots were able to make repairs promptly in all but major damage cases.

** Assistant Commissioner, Main Roads, South Eastern Queensland*

SPECIAL ASPECTS OF DAMAGE

In addition to the usual damage to structures and roads being physically washed away or undermined there have been some special aspects worthy of note. They are:-

(a) Road Pavement and Subgrade Failures

Probably more than half of the damage occurred in this category. Generally, flexible pavements submerged for 1 or 2 days with heavy traffic immediately they could be used, suffered considerable damage due to loss of strength of the subgrade and paving materials. As many main arterial roads were flooded, alternative routes built for relatively light traffic, were severely damaged by diverted traffic, e.g. for some days the Boonah-Beaudesert Road was the only western outlet for Brisbane to Warwick and Toowoomba.

Repair works are proceeding using total reconstruction with new materials, cement and bitumen stabilisation, deep lift asphalt for heavy traffic routes and by simply "drying out" pavement by tyning up and reworking prior to sealing.

(b) Loss of Bridge Approaches

There were a significant number of these failures primarily due to high water levels for several days during which the approach banks were saturated, with collapse occurring as floods receded e.g. the 4 approaches to the Albert River twin bridges near Beenleigh all failed necessitating removal of the RC relieving slabs so that failed fill could be removed and replaced.

(c) Land Slips

Massive land slips occurred in steep terrain in the high rainfall areas of the Lamington Plateau, D'Aguilar and Blackall Ranges. (These areas are significantly those receiving the highest rainfall as indicated last week by earlier authors. The slips varied from major falls of material on to the road to complete mountain side failures where the slip commenced above the road and swept to the foot of the mountain (even damming a creek in one instance). The former have been repaired quickly by conventional means, but the latter generally have necessitated road closure with the provision of alternative access to mountain communities, e.g. Tamborine and Mt. Mee.

Final engineering solution to the problems involved in restoring these roads is complex and will involve detailed geological surveys which are proceeding - total road relocation may be needed in some cases.

Lessons to be Learned

Generally, emergency repairs to restore road communications proved to be effective. However, with the advantage of hindsight, some lessons can be learned viz -

1. Maintenance organisations require more mobile radios with full time manning of base stations for emergencies.

2. Additional stocks of signs, lights, and repair materials are necessary at depots - the location of the latter in regard to their access and freedom from flooding needs checking.

3. Use of "closed face" signs at known trouble spots.

4. Improved communications to Public of traffic disabilities - this will largely be handled by the Police Department from their Emergency Control Centre.

From the design and construction viewpoint, more consideration is necessary in regard to:-

1. Road location in steep terrain particularly requires study of geological surveys to avoid slip prone areas.

2. In flood prone areas, special care is required in the selection of fill and paving materials to ensure their physical properties are such that wetting does not cause serious strength losses. Recent flood levels have been recorded to assist these assessments.

To summarise, the heavy rain of the Australia Day weekend, has resulted in a bill to the community approaching $20,000,000 for the restoration of road communications which will strain the resources of the road authorities of the Moreton Region.

"ARE TRAINS AFRAID OF FLOODS?"

*By G.H. Gore, Dip.C.E., Grad.I.E.Aust.**

Sunday 27th January, 1974.
8.00 a.m.
Any Radio Station:-

"No long distance passenger trains will operate in or out of Brisbane tomorrow. The northbound Brisbane Limited from Sydney is being held at Casino. A restricted suburban service will operate on the north side with trains from Central terminating at Darra. However, normal services are expected to operate South Brisbane to Lota".

Quite obviously, such news bulletins reveal that the Railways were adversely affected by the January 1974 flooding. The brief notes which follow, indicate the extent of this disruption under two headings:-

1. Railways : An engineering structure
2. Railways : A transport medium.

AN ENGINEERING STRUCTURE

(a) A look at the history of the Railways in South-east Queensland reveals, with the exception of the Ferny Grove and Pinkenba lines, that all lines in the Moreton area were constructed prior to 1893. Apart from the hydrological significance of this date, it is perhaps more pertinent to note that at this time, soil mechanics, compaction and earthmoving equipment as we know them today, were non-existent. The selection of suitable embankment material was a luxury while the long term costs of poor material were probably not appreciated.

The Moreton region as defined for this Symposium incorporates approximately 450 miles of main, branch, and suburban track. This length of exposed face is largely an elevated embankment which crosses hundreds of water sheds throughout the Moreton region. The development which has occurred in many of these catchments, both rural and urban, has had far reaching effects on the discharges, and their times and locations of concentration, to be passed under the permanent way. Although there is some evidence to suggest that for prolonged heavy rainfall, the extent of urbanisation of a catchment has little effect on the co-efficient of runoff, it is considered that the time of concentration and certainly the locations of flows are adversely affected by development. Therefore, if one considers
(i) the number of catchments which have direct access to the railway
(ii) the probability of receiving localized exceptional rainfall in any one of these catchments
(iii) the highly variable structural nature of the formation and
(iv) the old adage to which the Railways fall easy prey, about the strength of chains and links, one can appreciate the inherent vulnerability of the high level railway formations which traverse the State.

* *Designing Civil Engineer, Bridge Section, Queensland Railways*

(b) In general, the major damage to the formation was caused by local flooding rather than the effect of the Brisbane River or other major flooding. Relatively major scour failures occurred on the Main Line in the Forest Hill - Laidley area over approximately 3/4 mile up to 7'0" deep. It appears that extensive flooding in this area is a comparatively recent development. In 1959, widespread damage of the same proportions as January 1974 occurred, and it is interesting to note that the investigation carried out by the Irrigation and Water Supply Commission after the 1959 damage, revealed that a principal cause of the high flood levels was the significant silting up of creek beds in the area, caused by soil losses from adjacent cultivated land. Downstream floodstone protection which had proved successful since its placement in 1959 was inadequate for the 1974 flows.

Other major scours occurred at a pipe culvert at Wacol, the North Coast Line at Mayne, culverts near Ferny Grove, the Brisbane Valley Line, and an old concrete bridge abutment near Rosewood.

Consistent with earlier statements concerning the economically enforced soil composition of the original railway embankments was the number of embankment failures which occurred. Despite the passage of time, weather, and trains, the outside three to four feet of embankments when saturated by the long and heavy rains of Cyclone Wanda, failed in several locations. Such failures, which are not exclusive to the rains of January 1974, often prevented the running of trains. The major falls were distributed: three locations on the N.C.L., five locations Brisbane to Ipswich, and four locations in the range between Grandchester and Yarongmalu. A slip failure which occurred on the North Coast Line was catalysed by the passing of a freight train which subsequently derailed. A major failure, which singularly took the longest time to repair of all damage occurred in a 30 foot high embankment at Goodna Creek near Redbank. Despite the height of the bank, water over-topped the formation by fourteen feet. Subsequently, the water level fell some forty feet in a matter of hours precipitating a rapid draw down failure which caused large portions of this bank to completely collapse.

Repairs to track damage by their nature and location, (which normally make it impossible for plant operate), are highly labour intensive and most unloading is performed by hand, e.g. the Rosewood to Forest Hill repair gang comprised 130 men and 140 shovels. Considering the continuous hours and conditions of this type of work, the effort given by all those involved in flood repairs was, as other organisations found in their emergencies, highly commendable.

The logistics of maintaining flood repair materials to the level of demand were hampered by three considerations
(i) the normal ballast and floodstone quarries of the Department were cut off by the track damage.
(ii) The stock of flood material normally held under load by each of the coastal Divisions during the wet season had been

depleted by quantities sent to assist the Central Division during their flood problems of December-January.
(iii) The flooding at Mayne and other major yards had caused damage to wagons resulting in a subsequent shortage.

However, material was obtained principally from the Brisbane City Council and a Departmental stockpile at Mayne until lines to the North and West allowed normal quarries to function. Material and wagons were subsequently received from Rockhampton, Maryborough and Toowoomba, and repairs were only slightly affected by supply problems. A total of 12,500 c.yds. of ballast and 22,000 c.yds. of floodstone was unloaded, largely by hand, in the two to three weeks following the flooding.

Figure 1 shows the locations of the railway lines in the Moreton area. The thickened sections indicate the regions and nature of significant damage.

(c) In terms of telephonic communications and control, the Railways employs both the P.M.G. and its own extensive system. The two services were affected causing great reliance to be placed on two-way radio, both hand held and through the Department's aerial on Mt. Coot-tha for vehicles, etc. Mechanical signalling damage occurred adjacent to track damage at Oxley, Wacol, Mayne, Clapham and other yards. Electric signalling was only slightly affected. A local power failure occurred when a Departmental 3000V HT hut at Tennyson was submerged. Electrolysis caused most damage in the battery room of level crossing lights, etc. Unfortunately, the location of signalling, and in the future the attendant equipment of electrification, is defined by the existing track levels. In virtually all cases, repairs in this regard were able to keep abreast of track repairs.

(d) To summarise, it can be said that while a large amount of damage was incurred, it was in relation to its potential and the size of the hydrological phenomena, comparatively moderate. The Railways easily suffered their worst damage in the Northern and Central Divisions.

A TRANSPORT MEDIUM

Regular experiences of flooding in other areas of the State have indicated that the Railways are usually the last form of land communication to fail. While many have benefited in the past from this fact, there are some who argue that the Railways should always be available in times of such emergencies. Considering the role of the Department in the Moreton region with both passenger and freight transport, two questions might well be asked:-

(i) how did the Railways, as a means of personnel transport and a freight service, survive the flooding?

(ii) how did the Railways contribute to the relief of the emergency?

(a) If the floods revealed an Achilles' heel to the Department, it was possibly the flooding of Mayne yard. Overnight, it is normal for about three quarters of the passenger rollingstock and locomotive fleet to be stowed at Mayne. A flash flood in Breakfast Creek on the Friday night prior to the Australia Day weekend, took Mayne completely by surprise and 95% of the stowed fleet was water damaged. A total of 35 diesel electrics (which aggregate a present market purchase price of about $12.5 million) 6 diesel hydraulics, 5 rail motors, a complete air-conditioned train, and 22 sets of suburban rail carriages were affected by water up to the floor boards. The sort of damage experienced below this level is to the axle boxes, batteries and generators on carriages, and traction motors on the diesels. Add to this list, a total of 722 wagons (about one third of the Brisbane fleet) under water at Mayne and elsewhere, and the repair problems is massive relative to time available.

At this time, it was still raining and it was necessary to repack the axle boxes under shelter. The goods sheds at Roma Street provided both shelter and light for this work. Wagons under load in the sheds had to be unloaded in the open to release them for flood material. The affected diesels could not be towed to Redbank for repairs owing to the track damage at Wacol and Redbank.

Several other station yards, notably Ipswich, Moolabin, Clapham, South Brisbane and Wacol were wholly or partially under water. At Ipswich, eighty per cent of the wagons and carriages were moved to higher ground west of Ipswich before the yard was submerged. A certain amount of goods freight including grain, was lost at Clapham.

(b) Nevertheless, the Departmental emergency operations centre instructed that services were to be run as far, as often, and as close to timetable as possible with the remaining 19 diesels. These nineteen were later supplemented by coal line diesels from Rockhampton. The immediate goal of meeting with the demand of 40,000 commuters on the first working day was achieved, and maintained.

However, the damage to the batteries and generators of the carriages made running of the night service difficult. Because completed repairs to wagons and diesels increased while the demand for flood material decreased, a restricted freight service was possible from Monday, 4th February.

Overall, full service was lost on the North Coast Line for five days (includes the long weekend), Central to Darra three days, Darra to Ipswich nine days, and Ipswich to Toowoomba fourteen days, (although some light diesel passenger services were run earlier than these times.) Albion to Shorncliffe and Petrie, and South Brisbane to Lota were virtually unaffected.

The Department made its services available free for the passage of flood relief materials anywhere in the State.

(c) To the question of should the Railways be a mighty all-weather link open to service at all times, it can be said that it is not practical to convert formation levels throughout the State to the 1/1000 year flood levels (whatever they are), but rather to design on basically economic grounds for periods of inundation, where necessary. It is matching the time of loss of service to only the time of inundation using flood protection works, which is not yet achieved. A perusal of the actual duration of inundation of the rails reveals that the maximum period was two to three days which would not be critical to industry or essential services such as, for example, coal to Swanbank powerstation.

The problem of Mayne is a real one which has not been considered previously e.g. even the "1 in 100 year" unmitigated flood levels of the Cameron and McNamara report of March 1973 indicated that Mayne Yard would be free from flooding at this frequency. Also it is probably fortunate that the flash flood occurred at a time when the river, less than 4000 feet away, was not in flood. Evacuation schemes have now been prepared for Mayne, Moolabin, and Clapham yards and these schemes have in fact been subsequently used for Cyclone "Zoe". However, until proposed flood mitigation works are completed, the decision to evacuate Mayne must be highly predictive since the process takes about four hours to effect while the time of concentration of Enoggera Creek below the Enoggera Reservoir is about three hours (giving a probable warning time of about two hours).

CONCLUSION

In terms of engineering lessons learnt from this flooding, two facts, although previously appreciated, were emphasized:-

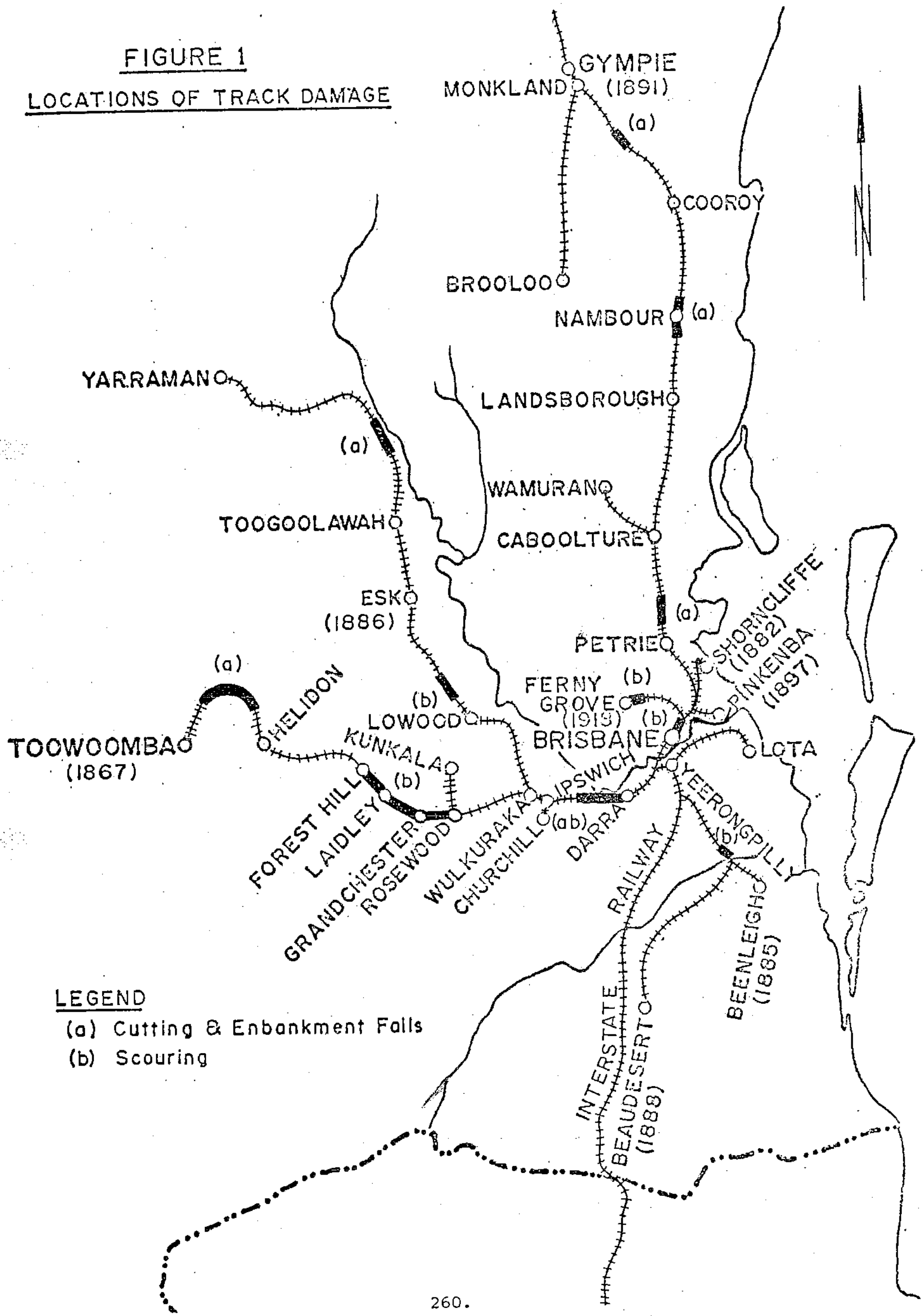
1. Care should be taken when providing waterways for apparently minor catchments that the watersheds remain discrete during heavy flows. Possible overflow and branch effects should be considered even on smaller catchments although this is probably easier said than done.

2. Local authorities should not underestimate the value of channel improvements.

Finally, it is perhaps an example of the Railway tenacity to carry on against all difficulties to relate the confirmed report of rescue workers who on occasions moored their boats to the top of a level crossing flashing light pole at Bundamba. The lights, although completely under water for some time, faithfully continued flashing, perhaps indicating that the trains would definitely be coming and not to lose hope.

FIGURE 1

LOCATIONS OF TRACK DAMAGE



PORT OF BRISBANE

*by W. Chorley B.Sc.Tech.**

THE PORT OFFICE GAUGE

Included with this paper is the record of the hourly heights of water at the Port Office Gauge. The datum is Low Water or Port Datum below which the tide rarely falls; it is the same as the Brisbane City Council Datum. Records from the old tide tables indicate that the datum was lowered by 10 inches between 1899 and 1903. It would seem that to compare the recorded heights of floods prior to 1903 with the present one 10 inches should be added to their heights. The reason for the change in datum which is related to navigational requirements is that deepening of tidal rivers increases the range of tide.

DREDGED CHANNELS LOWER REACHES

The Department was extremely apprehensive concerning the effect of the flood on the downstream dredged channels. Floods occurring within living memory and previous records indicated that major silting would take place particularly in the wide lower reaches of the river and outer bar cuttings. The flood flow surface velocity was estimated to be 8 knots (4.0 metres/second) in the Town Reach. An enormous quantity of sand had been kept in suspension, deposited on the banks of the river and submerged wharves.

The first task was to carry out a centre-line hydrographic survey from the Town Reach to the Outer Bar Beacons. This was done on Wednesday, January 30, 1974. The worst affected reaches were obvious from examination of the Echo Sounder records but generally the loss in depth was much less than anticipated. The average reduction in depth was of the order of 0.6 metre, some channels had scoured leaving sections deeper than before the flood.

Some channels, whilst maintaining depth, shifted towards the southern side of the river. The changes can be observed in Diagrams 1 and 2. In the particular case of Eagle Farm Flats Cutting were moved to conform with the newly scoured channel thus obviating costly dredging.

It is now apparent that medium floods will cause much greater siltation in the wider and deeper lower reaches than major ones.

No evidence is yet forthcoming as to where the material brought down by the floods has been deposited in Moreton Bay.

Within one week the whole port between Humbug Reach and the Outer Bar Beacons was surveyed in detail. Some 300 miles of hydrographic survey lines were run and plotted. By careful navigation the first major vessel left the port on Friday, February 1, 1974.

To re-establish the depot of the Port to pre-flood condition will cost approximately $1,000,000.

* *Manager, Engineering Services Division Department of Harbours & Marine*

UPPER BRISBANE RIVER

Nobody anticipated the problems, or perhaps it is better to say that a lot of people were complacent when building homes on riverside allotments. Property owners should very obviously now take steps to obtain technical advice on the location and design of homes or buildings. Very major slips occurred through scour and super saturation of loamy or clay foundations. The next major flood cannot be predicted.

The Department of Harbours and Marine is presently surveying the underwater slopes of the whole of the Brisbane River at 100 metre intervals. The resulting information will be made available to anyone concerned with bank stability and protection of waterfront properties.

The task of producing plans will take some months.

SEARCH FOR UNDERWATER OBSTRUCTIONS

One of the most notable slips occurred along Coronation Drive which is a major access road from the Western Suburbs to the City. The idea to use "Side Scan Sonar" to investigate this came from the Geology Department, University of Queensland. On realising the usefulness of this equipment it was decided to use it to search for underwater obstructions which could endanger small craft such as ferries and also large vessels.

Side Scan Sonar operates similarly to an Echo Sounder except that the transducer and receiver are contained in a "fish" towed behind the vessel. The impulses scan through 180° underwater. The trace produced is planometric at a distorted scale. A trained interpreter can determine the size and shape of underwater objects, slope of the banks etc. On one section of the tract, the roof of a building on the bottom of the river is clearly delineated.

In five days, the whole of the river from St. Lucia downstream was investigated; no objects which would affect the safety of vessels were found.

PORT OPERATION - COMMUNICATIONS

The radio communication system at the Port Office transmits from Mount Coot-tha tower and is received at Mount Gravatt tower by land lines and works on mains supply. On Saturday, January 26 power was disrupted and the communication system was maintained by handsets used by the Pilots. The following day a powerful battery operated set was flown from Townsville and installed on the upper floor of the building. It was estimated by this time that some 2'6" of water would inundate the ground floor.

All the Department's small craft were engaged in emergency situations at a lot of risk from floating debris. Fuel, extra mooring lines, food, etc. were delivered to vessels tied up in the river but were inaccessible by land.

"ROBERT MILLER" AND "PATRIS"

On Sunday, January 27, the 60,000 DWT bulk carrier "Robert Miller" broke away from its moorings where it was being fitted out. It had been

moored bow downstream, luckily the vessel also
vessel swung around on the anchor, the river was
flood waters to allow this to happen. The anchor h
was attached forward and steamed continuously ahead t
Another tug was stationed upstream to manoeuvre large i
away from the "Robert Miller" to prevent collision damage
objects included small craft, floating cranes, barges etc.
broken adrift upstream. Pilots were stationed on the ship du
whole period.

The vessel could not be remoored at the fitting out wharf as a
bollards had been carried away. The vessel would have to be towed downstream to a suitable berth.

Apart from the problem that the vessel might again break away, two other aspects caused concern. One was that having such a large freeboard the ship could swing across the river and go aground should winds of sufficient force arise. Coupled with falling flood waters, this could have been catastrophic. A tug was actually used to prevent this happening.

The other problem was that if the flood tide effect occurred a similar event could happen. This meant that the vessel had to be moved downstream at a selected time with a calculated risk. A decision was made to move the vessel to Cairncross Fitting Out Wharf on Thursday, January 30, 1974, after establishing that there was an adequate depth of water in the main shipping channels. There was obviously some risk as not enough time was available to thoroughly survey the river for underwater obstructions. The whole fleet of 6 tugs each with a pilot were used, two on each side, one ahead and one astern. The movement was accomplished with a minimum of fuss yet it was a major achievement in the narrow upstream reaches of the river.

The passenger vessel "Patris" moored at Cairncross Fitting Out Wharf broke her moorings on the night of Sunday, January 27. The vessel was manned, the anchors when dropped held and she was towed to another wharf.

PORT OFFICE

Being in the most fortunate location in knowing with reasonable accuracy what the height of flood waters would be, no records and an insignificant amount of equipment were lost at the Port Office. Staff who could get to the Office and/or alternatively staff who remained in the office for 2-3 days responded magnificently in shifting everything above flood level.

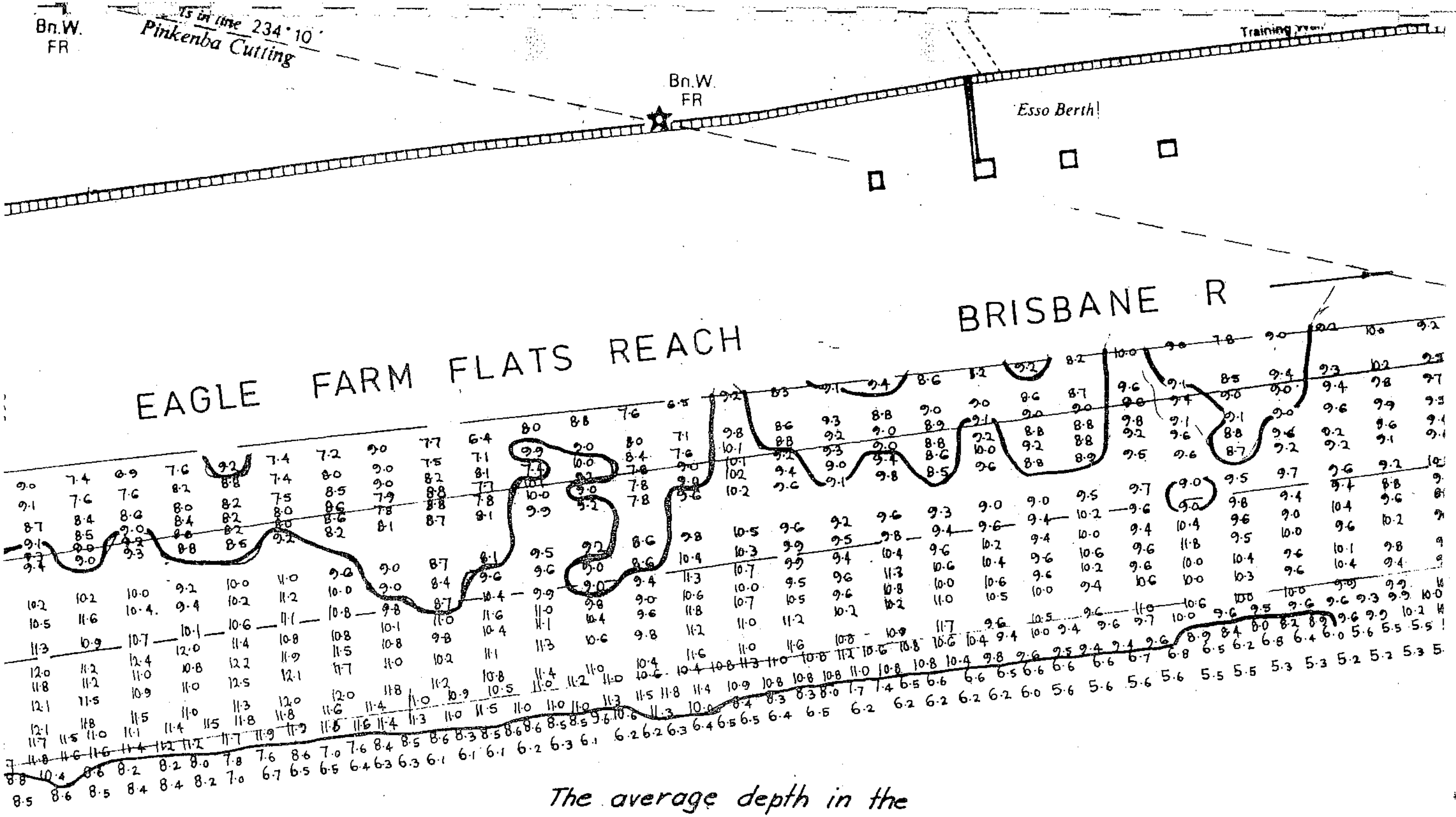
E TIDE GAUGE

RY 1974

(PORT OFFICE DATUM)

				27TH	28TH	29TH	30TH	31ST
					5.72	6.55	5.38	2.87
					5.79	6.59	5.38	2.95
					5.83	6.58	5.33	2.95
					5.82	6.53	5.23	2.87
					5.83	6.50	5.08	2.64
0600		1.26	[illegible]		5.84	6.43	4.93	2.39
0700		1.63	2.42	4.27	5.89	6.40	4.78	2.08
0800		2.07	2.67	4.37	5.92	6.32	4.60	1.88
0900	2.08	2.49	3.00	4.54	5.94	6.32	4.44	1.70
1000	2.35	2.93	3.28	4.76	6.06	6.30	4.34	1.63
1100	2.42	3.16	3.52	4.93	6.17	6.30	4.27	1.57
1200	2.29	3.19	3.61	5.11	6.25	6.30	4.22	1.70
1300	1.93	2.88	3.53	5.18	6.35	6.30	4.27	1.88
1400	1.54	2.37	3.36	5.17	6.40	6.27	4.27	2.01
1500	1.17	1.93	3.10	5.13	6.43	6.20	4.14	2.08
1600	0.84	1.74	2.93	5.11	6.43	6.12	4.01	1.98
1700	0.72	1.39	2.79	5.07	6.43	6.02	3.81	1.75
1800	0.77	1.20	2.74	5.03	6.37	5.94	3.56	
1900	1.12	1.26	2.84	5.07	6.35	5.82	3.36	
2000	1.49	1.71	2.96	5.18	6.35	5.66	3.15	
2100	1.89	2.27	3.25	5.21	6.35	5.56	2.92	
2200	2.22	2.57	3.60	5.33	6.37	5.49	2.82	
2300	2.31	2.90	3.87	5.46	6.43	5.44	2.75	
2400	2.15	3.11	4.00 (2330)	5.61	6.48	5.41	2.79	

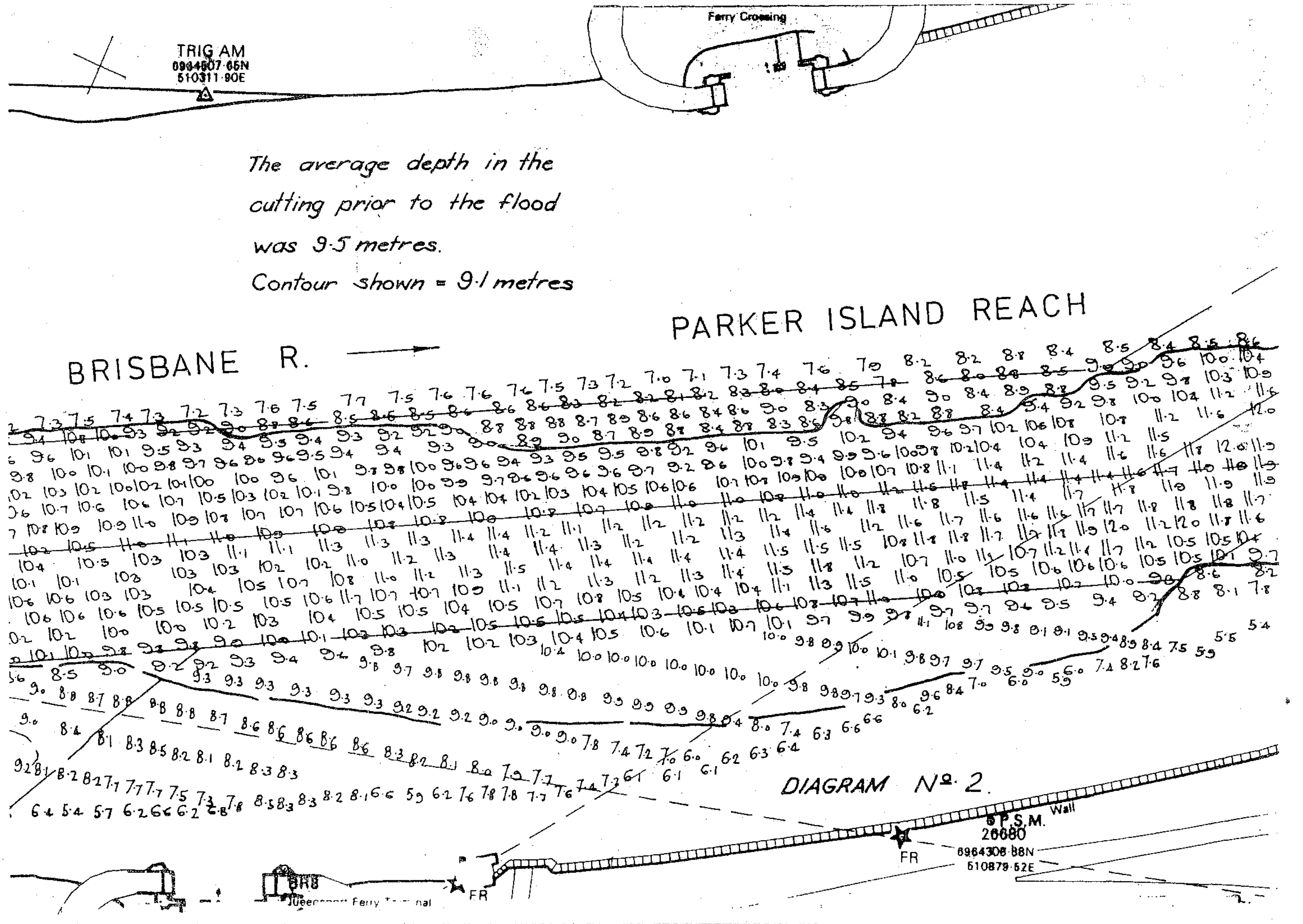
had anchors down. The
by now deep enough due to
eld. Immediatley a tug
throughout the flood.
floating objects
. The floating
which had
ring the
ll



The average depth in the cutting prior to the flood was 9·5 metres.

Contour shown = 9·1 metres.

DIAGRAM Nº 1


TRIG AM
6964607·65N
510311·90E
Ferry Crossing
The average depth in the cutting prior to the flood was 9.5 metres.
Contour shown = 9.1 metres
BRISBANE R.
PARKER ISLAND REACH
DIAGRAM Nº 2
P.S.M.
26680
6964306·88N
510879·52E
Wall
FR
FR

DISCUSSION

R.F. Bange, B.E.(Hons.), M.Eng.Sc., Grad.Dip.Bus.Admin., F.I.E.Aust., M.A.S.C.E. *

Faced with the prospect of leading the discussion following the previous five authors, one has an impossible task in attempting to condense their major points within the space available. This is somewhat like a "streaker" who has to show the most possible in the shortest possible time. Because of this, remarks will be confined to matters of broad principle, and thereby comments made on factors which seem to give a common thread linking the presentations of the previous speakers.

Firstly, if we look at the Concise Oxford English Dictionary, we find the following: "Communication - art of imparting (especially news) information given; intercourse; common door or passage or road or rail or telegraph or other connexion between places." In reviewing the January Floods, the whole matter on communications and organisation is one of prime concern. If one were to look at the links or chains involved during emergency procedures, you could imagine that they may be somewhat of the following form.

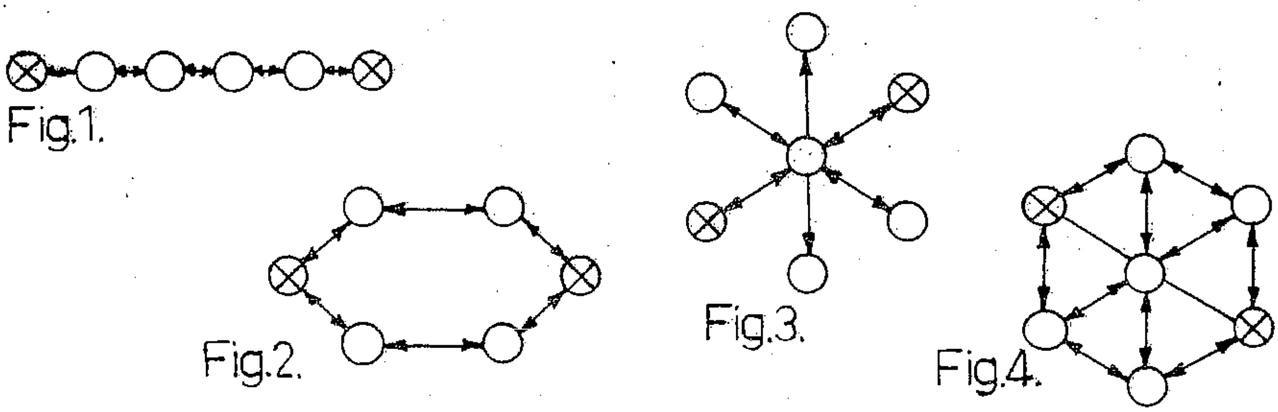


Fig.1. Fig.2. Fig.3. Fig.4.

From inspection of the first diagram, we see that the information flow from the point of interest through to the final operational centre or reaction area, is linked by a single chain of communication that has certain disadvantages, for example, it is a tenuous link relying as it does on a single mode of communication which can be broken under adverse conditions. Secondly, there is no feedback or verification system to ensure that the information received is valid. Again, the linear communication link brings with it the possibility of a long reaction time for the information to flow sequentially from one point to the next.

Turning briefly to the second concept, we see that this is somewhat like a wheel and the comments that applied in the first case, do not necessarily apply here. There is an alternative backup facility which provides verification, (which may in fact confuse the issue at times if the information given is a different form or complex). There is the safety factor of two communication chains, but of course the fairly lengthy process of information transfer still exists in an unco-ordinated manner.

In the third diagram, we see the development of a central co-ordinating centre with the information sources and operation areas linked together somewhat in the form of a spoke structure by a central co-ordinating agency which assesses the information and filters spurious data so that the operational centres should receive factual information on which to act. This of course, has several advantages, but is dependent upon the establishment of such a centre and its recognition as a competent disaster agency.

In the final diagram, a combination of the wheel and spoke structures is shown. In this case, one can visualize the central agency providing the basic data and information for the operational centres, but each centre being linked in some way with its own data collection arrangement, and having backups and verification of particular aspects to suit its own operation. This would provide a three way communication path and provided the information did not swamp the operations area, would seem to have many advantages.

The authors in various ways have shown where their organizations have particular strengths or weaknesses in these areas, and where new initiatives and changes will be evolved, based on their experience in the January floods.

Still on the topic of communications, it is clear that it involves all means of communication, road, rail, air, radio, T.V., newspapers, the telecommunication service and others. At the same time, it has involved a number of different government agencies, or semi-government agencies at all levels of our three tier system of Federal, State and Local Government. Thus, if we look at it in terms of organization, there was overall, a massive combination of widely differing systems (albeit this may be somewhat of an advantage for backup) operating under a number of different agencies, and it is gratifying to the level of co-ordination and rapid response that these people achieved in the circumstances.

Communication is a process in both time and place, and this has not been fully successful in Brisbane. In terms of time, considering the past, the present and the future, it could be said that we have been remiss in not learning the lessons of the past. Too often one hears of information that has been readily available, but which has not been used from the 1893 flood, the 1931 flood and so forth, all of which are a communication with past experience. What lessons did we learn from them?

Then we have the present. The January 1974 floods have been a traumatic experience and the shock, dismay and indignation raised by the losses incurred at this time, has communicated itself effectively throughout the community. Seminars such as this are helping to put the problem in perspective, but serve more as indicators for the future. If we look at the problem of communicating during the event, we have to look at the immediate real time reaction of people to a disaster, and it is true to say that the community was not aware of the magnitude of the disaster as rapidly as it should have been.

The speakers have also referred to gaps in their knowledge of the situation and the rapidity with which they were able to obtain the information they considered necessary to carry out their functions. From what we have heard, it seems that considerable efforts will be made to improve the collection of real time data. This brings us to the future. Here, the lesson is simple and plain. Somehow, we shall have to ensure that the lessons from the January flood are hammered home, that the necessary organizational changes are implemented and maintained, and that planning for disasters is improved by all means possible, including if necessary, re-zoning of flood plain land, resettlement and re-housing programs, regionalization of planning and so forth.

Looking at the other aspect of location, it is appropriate to mention only briefly that what we have seen this January is minor compared to floods in other places such as America and India, to mention two very diverse community living patterns. What did we learn from their experience?

In this area of communications, a variety of methods was employed in January, and one of the serious questions that we must ask is, "whose responsibility was it to inform the public of what was happening?" Certainly, reports came from such bodies as commercial radio stations and T.V. stations, from on the spot road reports and from R.A.C.Q. bulletins. In many cases however, these gave conflicting information and information that was behind the time of the event, anything upwards of 2 to 3 hours or more.

Turning now to the kind of process that would be desirable in a situation such as this, a broad outline can be put down somewhat as follows:

Data Collection	- Magnitude of the Problem, Location of the Problem Areas Type of Disaster that has Occurred.
Data Co-ordination	- The combination of the data into a meaningful whole.
Data Verification	- Verifying that what has occurred is the real situation.
Data Dissemination	- Ensuring that the information reaches the correct sources for action.
Alternative Plans	- Development of plans and alternatives to meet the situation. Selection of contingency planning solutions.
Implementation	- Undertaking the necessary steps to implement the corrective actions.
Feedback	- A continuous and reliable flow of information back, so that the effectiveness of actions can be assessed and/or modified.

This of course is a fairly simple process when we see it set out as shown and there are other sub systems of course, involved in the operation. If we examine each of these areas, we can establish avenues by which our actions could have been better tackled. To mention just a few, the idea of failsafe communications and alternative backup systems to ensure that sufficient data was collected and that it was reliable data. In terms of disseminating the information, it has been said, and seems to be true, that the dissemination was not effective enough, perhaps more so in the technical areas, but certainly not in the public area. It also seems true to say that few people in the Civil Defence, police or engineering fields have the experience or knowledge of group and mass psychology on which to make decisions regarding the release of information on safety grounds.

When we look at all of this information process and feedback, there are strong grounds for the establishment of priority systems in such circumstances, whether it be through some state of emergency or other legislation, so that under times of stress, priorities on telecommunications channels, on radio and T.V. and other media sources, can be allocated to ensure the operational groups have the best facilities possible at their disposal.

A much greater lesson can be learnt and we must look further afield than the January floods to see the potential problems which may arise in a city such as Brisbane. To mention some other potential disasters, one would note the prospect of - flood, fire, cyclone, earthquake. All of these have a potential for inflicting very severe damage. Perhaps the worst of these is the cyclone, which may exist in conjunction with a flood, and which could conceivably affect the whole of the Brisbane area, and not simply the lower regions. This could effectively destroy power, communications, roads, rail and other communications systems, and would greatly compound the problems experienced in the January floods. The writer has not been able to calculate the severity of a one in a hundred earthquake, but I am sure the one in a thousand earthquake would be a very severe shock to our system.

To comment further on the matter of responsibility and priorities. The question may be asked as to whether emergency services are the province of the police, Civil Defence or the various service authorities. It is believed that all of these must retain a measure of autonomy in grappling with their own problems and must, of necessity, be deeply involved in solving these problems. On the other hand, is it not time for us to think in broader terms of a new form of disaster centre and organization, an established program of disaster relief (material, financial and social) and is it not time for us to review the whole concept of organization and co-ordination within such a system?

Certainly, as engineers, we must learn one very important lesson, and that is for the establishment of clearly defined contingency plans to meet the foreseeable circumstances that can arise in engineering operations. In some cases, this means we will have to develop plans almost from scratch, whilst fortunately in a large number of cases, it will mean a re-look and review of existing plans in the light of experience. The holding of seminars and symposiums such as this should help to make us more aware of the need for such forward planning. In conclusion, the writer refutes the rumours that the Civil Engineering Department arranged a deal with anyone, to organize the floods as a part of the publicity program to advertise our forthcoming Flood Hydrology Course.

THE ETHICAL POSITION OF THE ENGINEERING PROFESSION

by J.F. Keays, M.B.E., B.C.E., F.I.E. Aust.
- Division Chairman

It is appropriate that we should, having heard and discussed the technological aspects of the January 1974 floods in Brisbane, consider the ethical position of the profession. The Institution as a professional body has its Code of Ethics which is a dignified and sound document. Clause 1 is entitled "Duty to the Community" and reads 'An Engineer's responsibility to the community shall at all times come before his responsibility to the profession, to sectional or private interests or to other Engineers'.

This clearly establishes our prime responsibility to the community at large but what does this mean and have we performed our duty? During this Symposium our authors have given us a detailed explanation of what happened and what was done on the technologist side. We know now that many Engineers and their support staff who were concerned with the prediction of flood levels and with the maintenance of essential services gave amazing service to the community and great credit is due to those dedicated people who performed so well and saved the community from what could have been disastrous after-effects.

However, we must admit that there was a break-down in communications and the people generally were not well informed and many suffered needless loss and damage. How many of you like me were isolated in our homes, listened to radio and watched television and wondered when someone was going to explain in layman language the significance of hydraulic gradients? Why did we not have a system by which predicted flood levels could be related to say, street levels at a series of street intersections, so that people could at local level get some understanding of areas that would be flooded?

We know that Lismore, Grafton, Kempsey and Taree have warning systems with flood levels tied to well-known local spots and these systems have been devised by and in the main are controlled by Engineers. It has been established that accurate flood levels were predicted before and during the long weekend.

As members of the Institution, we have a duty to the community to use our engineering knowledge to assist in setting up an improved system of communication and warning, and it must be one that is understood by the people.

As Engineers we apply basic scientific principles, our experience and engineering judgement to the problems that arise and we pass our advice to the political and commercial decision makers. In general they appreciate our efforts and seldom go against our recommendations, but much of our good work is perused and quietly filed. It is pleasing the Engineers who understood and knew what could and did happen have not adopted a 'we told you so' attitude and there has emerged a clear message that we must be more active in our assistance to the community on occasions of national disaster.

* *Principal, Gutteridge Haskins & Davey, Consulting Engineers*

We must make a determined effort to see that our voice is heard and that our good reports are not lost in filing systems. We live in a changing and in some ways enlightened age in which the public is becoming much more interested in environmental matters and these floods are just another of these environmental problems. Because we are not heard, we are saddled with much of the blame when things go wrong or something happens that the public has not anticipated. Our duty to the community demands that we keep them informed and we must set out to educate society in engineering matters that will affect them.

How do we go about this education and how do we get to terms with the people?

Under our system of Government, the decision makers and the moulders of public opinion are the elected representatives whom I fear only pass on what is of political benefit to them. We need more Engineers active in the political arena and in areas where we can voice our opinions.

I was interested during a visit to New Zealand last year to meet two Engineers who were members of their Parliament and to find that because of his regular contact with these Engineers, their Deputy Prime Minister knew and understood our thinking.

Brisbane, because of its single Local Authority and the complete lack of local pride and interest in the affairs of suburban communities, does not present many opportunities but maybe we should be stirring local interest.

In Melbourne, opportunities exist in the suburban Councils and in recent years three leading Engineers have held the office of Mayor in different Councils, and through such activities have been able to present the Engineers' view to the people.

Our Governments tend to set up committees of politicians and public servants to consider environmental matters of public interest. Institution members serve on the committees as Departmental representatives and do good work, but we need representation in the name of the profession so that our members can speak as members of the community.

There is much to be gained from the analysis and consideration of these floods and much work has been done and will be done. Our duty under our Code of Ethics is to see that the community is informed. We must be heard, then clearly understood and finally heeded and believed.

SYMPOSIUM SUMMARY

The January 1974 floods, particularly in the Brisbane River have dispelled the myth that no further major floods would occur in Brisbane, following the construction of Somerset Dam. The flood mitigation potential of Somerset Dam should now be more widely understood by those at least who have either attended this symposium or read the proceedings. Following the construction of Wivenhoe Dam, the flood risk in Brisbane will be further reduced but it should be well recognised that occasional flooding will occur in Brisbane in the future which could have equally serious consequences. In the period 1840 to 1900 there were a number of major floods, some very close to each other, only a week or two apart. A similar wet period could occur again.

The need for detailed flood forecasting and warning systems for most rivers in the Moreton Region has been well demonstrated. On the Brisbane River, a computer model and real time computer facilities would greatly relieve the pressures placed on flood forecasters during these events. Continuing development and evaluation of systems is required for some troublespots such as Ipswich.

In Brisbane city, very reliable flood forecasts can be provided. However until a complex system can be devised to interpret the flood forecasts into areas to be flooded and an organisation developed to efficiently and systematically arrange for this information to be disseminated to property owners street by street for evacuations in advance of being flooded, losses to the community will be higher than they should. The overall concept of a flood warning system should be closely studied. This includes the above and also planning welfare relief for evacuees, food, clothing and so on and also areas for furniture storage.

This symposium has touched on the problems with communications. Communications broke down rather badly during the January flood. This was not so much at telephonic or telegraphic level where priority and other channels were kept open under arduous conditions, but occurred beween and within organisations and authorities which were intimately associated some of which were involved in discharging their official responsibilities. The greater responsible involvement of the media should be studied so that the public at large are kept fully informed on what is happening and what Governments are doing about it.

To minimize the problems and losses associated with rare events such as flooding, continuing education programmes should be initiated so that the public at large know and understand better the problems which they occasionally have to face.

We have seen how essential services fared during the January flood, what breakdowns occurred, where and how some of these were rectified. Engineers have a tremendous amount of new data to analyse which should enable revised planning which could involve the relocation of key installations to reduce the degree of vulnerability in future flood events of this magnitude.

All of the above are responsibilities of Governments at all levels and if the public are fully informed and aware of the problems a greater degree of preparedness should exist. If the facts and risks involved are widely known the politicians will be better placed to make decisions to cope with future events.

The 1974 floods should not be forgotten as easily as those in the past. In this regard engineers should play their part.

G. Cossins

G. Heatherwick

<u>Editors</u>

ISBN 0 85814 102 7