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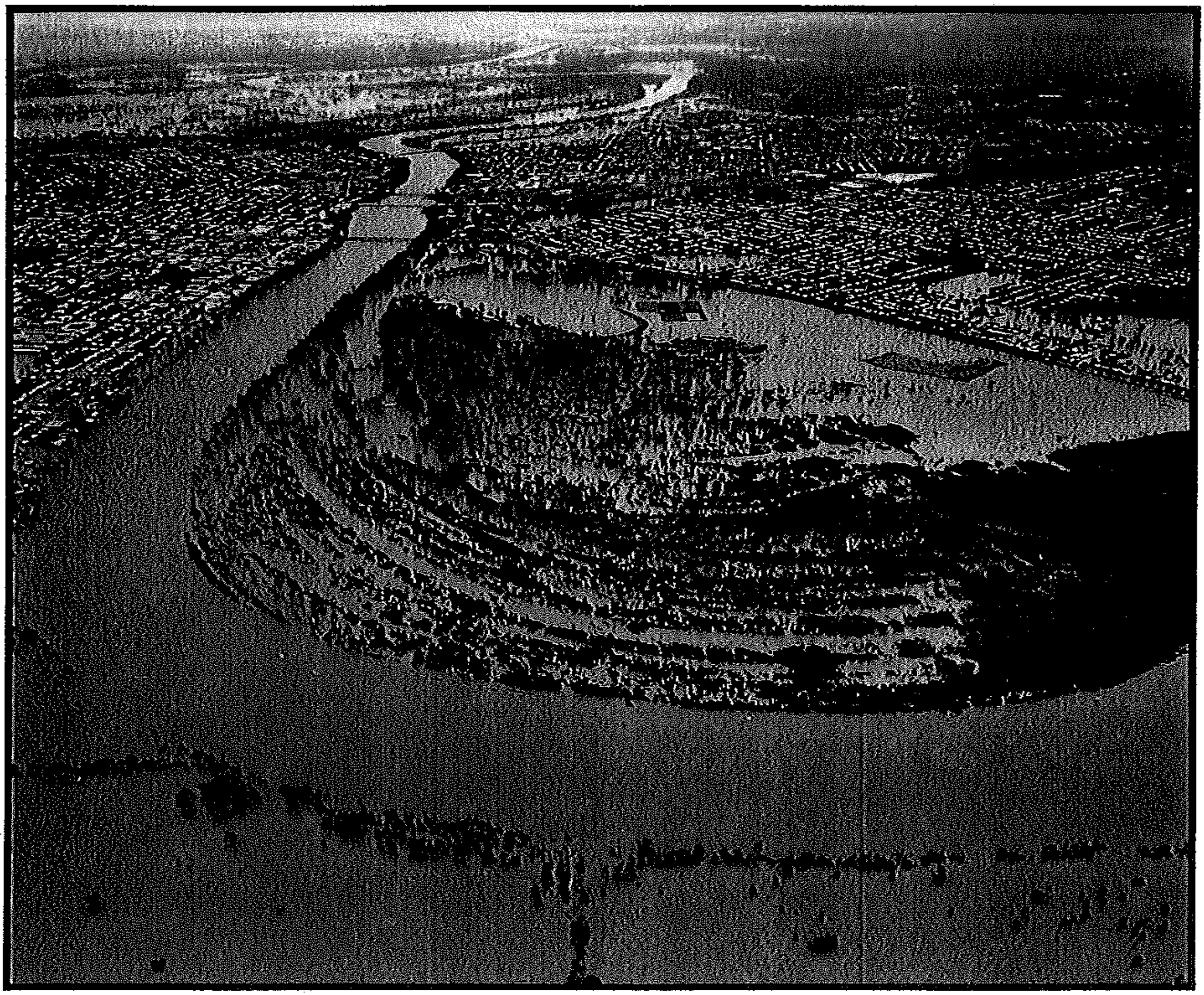

ROCKHAMPTON FLOOD MANAGEMENT STUDY

PHASE 2 REPORT

VOLUME 2
REPORT

CMPS&F

CAMP SCOTT FURPHY PTY LTD
ACN 004 939 548

NOVEMBER 1992

CMPS&F.
Rockhampton Flood Management Study
:Phase 2 report.

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VOLUME 1 EXECUTIVE SUMMARY

VOLUME 2 REPORT

VOLUME 3 APPENDICES

ROCKHAMPTON FLOOD MANAGEMENT STUDY

PHASE 2

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ROCKHAMPTON FLOOD MANAGEMENT STUDY

PHASE 2

VOLUME 3 – APPENDICES

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NOTE: Appendices unchanged from Phase 1 not included.

GLOSSARY OF TECHNICAL TERMS USED IN THIS REPORT

Term	Abbreviation	Meaning
Afflux		The increase in water level caused by the introduction of a constriction, such as a bridge, into a stream or channel.
Australian Height Datum	AHD	National Mapping datum used throughout Australia. Australia wide average of mean sea level.
Annual exceedance probability	AEP	The probability (chance) of an event (eg. flood of a given size) being equalled or exceeded in each and every year, usually expressed as a percentage.
Average recurrence interval	ARI	The reciprocal of AEP – the average period between exceedances of an event of a given magnitude, usually in years eg. 100 year ARI is equivalent to 1% AEP. This term is often misinterpreted as the actual period between exceedances rather than the average period.
Benefit-cost ratio	BCR	The ratio between economic benefits of a proposal scheme and its cost, both expressed in terms of net present value. A BCR of 1 or greater demonstrates economic viability. This is rarely achieved with flood mitigation schemes, which typically have a BCR of 0.4 – 0.7. These schemes are justified on the basis of social and other intangible ie. non monetary benefits.
Direct Flood Damage		That loss or damage caused by the physical contact of floodwaters with buildings and their contents or with other property.
Indirect Flood Damage		That loss or damage consequent upon direct flood damages. Caused by the interruption/disruption of economic or social activities as a result of direct flood damage.
Floodplain		The portion of a river valley, which is covered with water when the river overflows during floods.

Term	Abbreviation	Meaning
Levee		Embankment structure designed to protect property from damage by floodwaters by excluding flood waters from the protected area. These are usually earth embankments but may include sections of retaining walls and spillway structures.
Mean annual damage or Average annual damage	MAD AAD	The long term mean (average) of annual flood damages taking into account the probability distribution of flood magnitude and the resulting damage caused.
Net Present Value	NPV	The difference between the sum of the present value of benefits and the sum of the present value of costs. The present value of a stream of costs/benefits spread over time is their equivalent value should they be expended at the present time ie. the value of a benefit or a cost in the future discounted to a base date.
Probable Maximum Precipitation	PMP	The depth of precipitation (rainfall) which for a given area and duration can be reached but not exceeded under known meteorological conditions.
Probable Maximum Flood	PMF	The flood produced as a result of a catchment experiencing probable maximum precipitation (rainfall). Usually taken as the highest of such floods resulting from PMP of a range of durations.

SECTION 1

1. INTRODUCTION

1.1 BACKGROUND

Rockhampton is the largest urban centre in Central Queensland. The city is built on the banks of the Fitzroy River just north of the Tropic of Capricorn and some 55 to 60 km from the Fitzroy River mouth at Keppel Bay.

The Fitzroy River at Rockhampton has a catchment area of 140,200 km^2 and the Fitzroy River basin is one of the largest on the east coast of Australia.

The general location of the catchment is shown in Figure 1-1.

The basin can experience heavy rainfall, particularly in the summer months (December - March) from a variety of atmospheric conditions and synoptic processes. Major floods in the Fitzroy River are usually associated with tropical cyclones or easterly trough lows. The northern most part of the catchment inland from Sarina receives the highest rainfalls.

The Fitzroy River at Rockhampton and adjacent areas and townships have a long and well documented history of flooding. Flood records at Rockhampton date back to 1859. The worst flood since that date was in 1918 when flood levels in Rockhampton reached 10.11 m at the City gauge (8.65 m AHD). The second highest flood peak was 9.40 m gauge height (7.95 m AHD) in 1954.

Rockhampton again suffered major flooding in January 1991 due to rainfalls from Cyclone 'Joy'. The peak flood level reached 9.30 m gauge height (7.85 m AHD) in the recent flood, but due to changes in floodplain characteristics since 1954, the relativity of the 1954 and 1991 floods cannot be directly compared. In discharge terms, the 1954 and 1991 floods were almost identical with peak flows (at Yaamba) of 15,000 m^3/s compared to 18,000 m^3/s in 1918.

Major flood flows cause flooding from Yaamba to downstream of Rockhampton, and a major breakout occurs upstream of Rockhampton at the Pink Lily meander. This breakout flow can result in flooding and closure of Rockhampton Airport, the Bruce and Capricorn Highways, and the North Coast Railway. Also, the Bruce Highway and North Coast railway are cut by floodwaters at fairly high frequency at the Alligator Creek crossing near Yaamba. In the 1991 flood, all of these links were cut for about two weeks, effectively isolating Rockhampton from the outside world. This disruption to all major traffic routes in and out of Rockhampton results in large indirect flood damages not only in Rockhampton but throughout the Queensland coast. About 160 properties were inundated above floor level and 1200 to below floor level in the 1991 flood, with significant direct flood damages.

The aim of this Study is to consider all aspects of current flood management and options for future flood management in order to make recommendations aimed at reducing the impact, both tangible and intangible, of future floods.

The Study has been funded under the Federal Water Resources Assistance Program (FWRAP) and the Study reports have been prepared to facilitate application for further FWRAP funding for the recommended works.

1.2 PHASE 2

Phase 2 of the Rockhampton Flood Management Study comprises the detailed investigation of those options short listed from Phase 1, together with the formulation of final recommendations.

The following flood management measures, shortlisted for further study in Phase 1, were investigated in further detail in Phase 2:

- construction of levees to protect the flood liable areas of Port Curtis, Depot Hill and lower Central Business District (CBD);

- construction of levees to protect Rockhampton airport together with consideration of the effect of the proposed runway extension;

- selection of a control level for initiation of floodplain flows at Pink Lily;

- raising the flood immunity of the Yeppen highway/railway crossing by a combination of raising and bridge widening;

- the preparation of flood maps for a range of flood magnitudes for the urban area of Rockhampton.

Further to the round of community consultation following the publication of the Phase 1 Report, the following were added to the issues to be investigated in Phase 2:

- development of a major floodway from Pink Lily to Gavial Creek. This had been dismissed in Phase 1 on the grounds of costs and environmental impacts but has been reconsidered after being raised by members of the community;

- the effect of the Capricorn Highway on flood levels in the Fairybower area.

Fundamental to investigation of all the above was the development of a comprehensive hydraulic model to represent both existing floodplain conditions and to enable the impacts of the various measures to be studied. The hydraulic model studies formed the major component of Phase 2.

Other activities in Phase 2 included:

- preparation of new base mapping in the North Rockhampton area where Phase 1 studies had shown significant anomalies in the available contour maps;

- refinement of concept level designs for the above range of flood mitigation measures;

- refinement of cost-benefit analysis for the above;

- delineation of floodway areas and advice regarding preparation of Local Authority Floodplain Management Policies.

1.3 COMMUNITY CONSULTATION

The Phase 1 Report was published in April 1992 and a series of public meetings were held in early May 1992 to elicit the community response. These were attended by a total of 53 residents. The opportunity for further written submissions was also made at this time. Only 2 written submissions were received.

Public response to the Phase 1 report was generally positive. A summary of comments received is given below. Notes from the public meetings are given in Appendix B.

There was general support for the proposed non-structural measures, namely upgrading of the flood warning system, the installation of flood markers, provision of a recorded telephone service, flood preparedness leaflets/telephone directory entries.

There was general agreement that further consideration to upgrading the flood immunity of the Yeppen Crossing was warranted.

There was concern expressed in regard to levees, particularly property resumption impacts and flood level impact upstream. The positive effect on property values within the protected area and the potential for development of land currently liable to flooding were recognised.

Fairybower/Gracemere residents were vocal in their adverse reaction against levees both around Port Curtis/Depot Hill and the airport. Their view was that they had been disadvantaged by previous works eg. the Fitzroy River Barrage and Yeppen crossing and did not want to be further disadvantaged. Furthermore they are against contributing (by way of rates/charges) to any works which will disadvantage them.

The main issues raised which require attention are summarised below:

- **Alligator Creek Crossing**

  The Department of Transport (DOT) was requested to provide design information regarding the proposed new Alligator Creek crossing both to the Consultant and to community representatives ie. basis of design, design discharge, design afflux, assumed tailwater conditions, design drawings to show bridge length crest RL's.

  This information was subsequently provided by briefing the relevant Livingstone Shire Councillors. This has not been considered further in the study.

  The action of the Department of Transport in including upgrading of the Alligator Creek crossing in its current work program is recognised as a significant contribution to improving access northwards of Rockhampton.

- **Flood Warning Information**

  It was suggested that the proposed recorded telephone messages include Tartrus, Riverslea, The Gap, Yaamba, new floodway gauge and Rockhampton levels; the messages to be run continuously so that a repeat of the message is available. These suggestions are supported.

- **Levees**

  The following points were raised in regard to the consideration of levee options:

  - levees to be considered on an easement rather than a resumption basis where practicable;
  - local drainage within levee systems;
  - source of levee material;
  - scour protection requirements;
  - effect on flow distribution, flood levels and velocities (from hydraulic model studies).

- **Capricorn Highway**

  The hydraulic model should consider the effects on flood levels of the Capricorn Highway. The question as to why the highway is raised above general ground level was raised, as a low level crossing is acceptable because of the existence of an alternative flood free route.

- **Major Floodway Pink Lily – Midgee**

  This was raised in written submissions subsequent to the meeting as well as at one of the meetings. In summary, these submissions suggested:

  1) building a navigable canal from Lion Creek round to the Woolwash (Gavial Creek) to provide flood mitigation and a tourist facility. As proposed this would have only a small flood mitigation capacity;

  2) Construction of a floodway from Pink Lily via Murray and Yeppen Lagoons, through Yeppen crossing to the woolwash, together with levees around the airport and Depot Hill/Port Curtis/lower CBD.

  This option had been discounted previously on cost and environmental grounds. However, as a major floodway has the potential to provide substantial flood mitigation, and because of the submissions outlined above, this was given consideration in Phase 2.

A further round of community consultation will take place following publication of the Phase 2 Report.

1.4 FEDERAL WATER RESOURCES ASSISTANCE PROGRAM

This Study has been funded under the Floodplain Management Sub-Program of the Federal Water Resources Assistance Program (FWRAP).

The Study Reports have been prepared so as to facilitate submission for funding of the recommended flood management measures under this scheme.

The terms and conditions governing FWRAP funding include the following:

- completed flood maps delineating floodways and flood fringe areas are made available to the public;
- land use controls and building regulations are in operation at the local government level to prevent unwise development in identified floodways, and that all new development in flood fringe areas is above the designated flood, or is flood proofed.

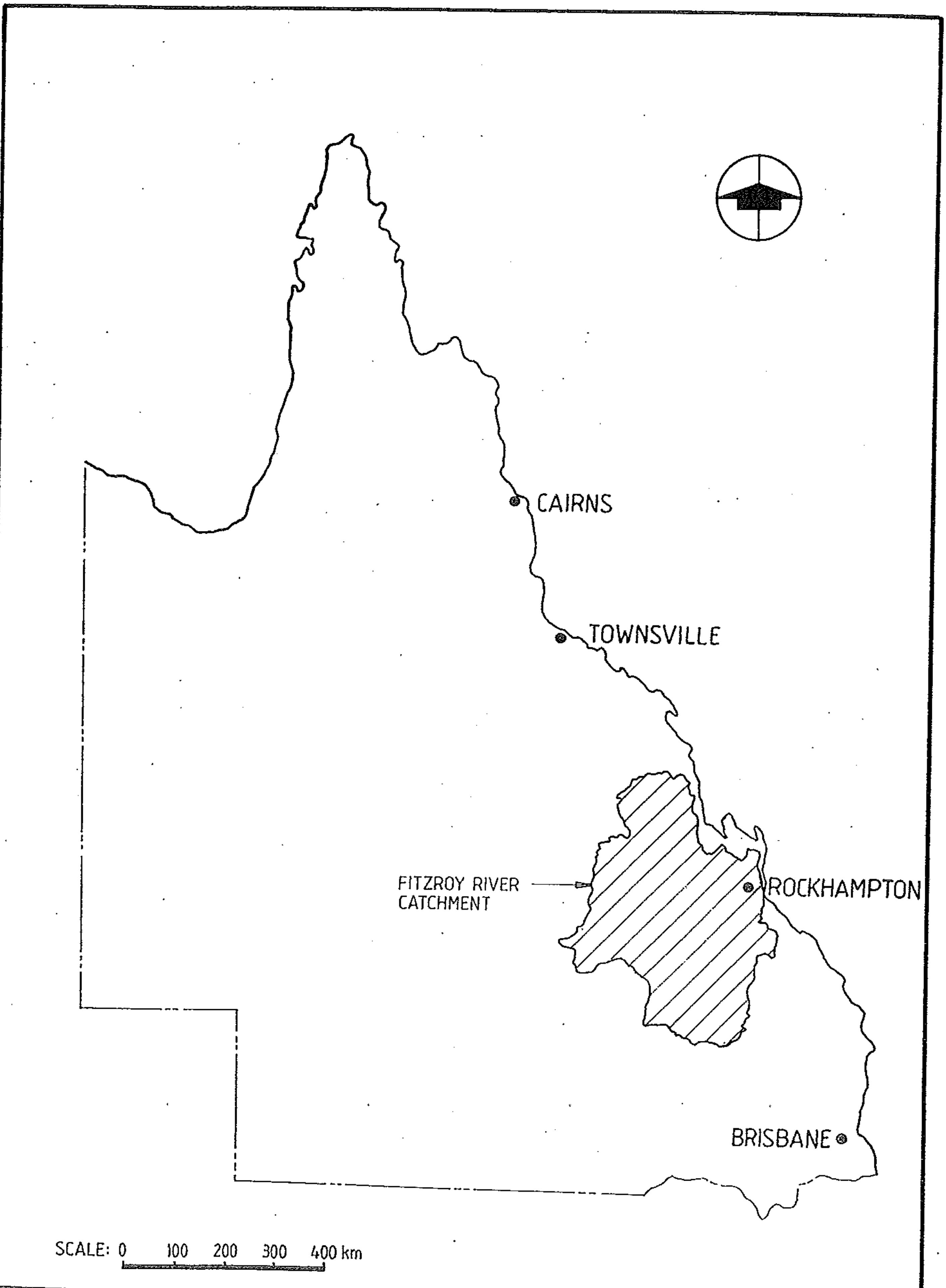
These conditions have been taken into account in formulating the recommendations presented in this Report.

The final report will be prepared to comply with the requirements for FWRAP funding applications. It should be noted that submissions for funding under FWRAP are considered on their merits and cost-effectiveness and also on priority relative to other state projects.

1.5 ACKNOWLEDGMENTS

The co-operation of officers of the Water Resources Commission, Rockhampton City Council, Livingstone Shire Council, Fitzroy Shire Council, other Commonwealth and State Government Officers, local interest and business groups and members of the public in providing input to and data for this Study is acknowledged with appreciation.

A list of the principal contributors was given in Appendix C of the Phase 1 Report.



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ROCKHAMPTON FLOOD MANAGEMENT STUDY
LOCATION PLAN

FIGURE 1 – 1

SECTION 2

2. HYDRAULIC MODEL STUDIES

2.1 GENERAL

This section describes the setting up and calibration of a mathematical model to simulate flood behaviour of the lower Fitzroy River and its associated floodplain.

This model was the single most important component of the Phase 2 studies, as the satisfactorily calibrated model was utilised for the following:

- prediction of flood levels for a range of design floods for current floodplain conditions for the preparation of flood maps;

- prediction of the effects on flood levels and flow distribution of the flood mitigation options short listed in Phase 1 of the Study.

As discussed at length in the Phase 1 Report (section 13), the previous hydraulic model studies had some shortcomings. The physical models have been broken up, hence their further use was not an option. Due to perceived shortcomings in the 1987 mathematical model, it was determined that a new model independent of previous studies was required. This section describes the objectives of the hydraulic model studies; the data available for model calibration and validation; model calibration and validation; the use of the model for flood map preparation; and consideration of flood mitigation options.

2.2 OBJECTIVES

As stated above hydraulic modelling was the single most important component of Phase 2. It was required in order to provide information in regard to the following:

- determination of the distribution of flood flows between the river and the floodplain;

- estimation of flood levels throughout the floodplain resulting from a range of flood magnitudes with existing conditions, to enable flood maps to be prepared;

- modelling of the effect on flood levels in the river and in the floodplain of those levee schemes which have merit on an economic basis;

- modelling of the effect on the distribution of flood flows and flood levels resulting from the proposed runway extension at Rockhampton Airport;

- modelling of the effect on flood levels, and duration of submergence of the Yeppen Crossing, for various combinations of increased bridge waterway area and raised embankment heights;

- modelling of the effect on flood levels of the Rockhampton City commonage landfill;

- simulation of a range of control levels at Pink Lily in order to establish the appropriate level for construction of bank stabilisation works.

2.3 DATA REQUIREMENTS AND AVAILABILITY

In order to enable the model to be calibrated, validated and used for predictive purposes the following data were required:

- topographic survey data to enable river and floodplain cross-sections to be generated;

- hydrologic data for floods used in calibration, validation and predictive modes;

- flood level data for historic floods for use in calibration and validation modes;

- details of structures in the floodplain.

These requirements are discussed in more detail in the following paragraphs.

a) Topographic Survey

One limitation of the previous models has been their limited downstream extent. Ideally, the model should extend to the ocean, with tidal levels used for model tailwater. No topographic survey information suitable for modelling purposes is available more than about 10 km downstream of the City. Field survey to obtain cross-section information from the current limits to the ocean would have been prohibitively expensive, and it was felt that this expenditure was not warranted as the modelling of the flood levels in the main area of interest was not expected to be sensitive to even broad assumptions regarding conditions in the lower section of the river. Conditions in the lower reaches were approximated by estimation of cross-sections on the basis of the available spot height information and published nautical charts. This approach enabled the model to be extended to the ocean.

In the Rockhampton City area, improved base mapping was required for flood mapping purposes. This mapping together with available river cross-sections formed the basis of cross-sectional information in the city area.

In the Yeppen floodplain, data available from previous surveys was utilised.

Topographic survey, in the form of river cross-sections, for the Pink Lily to Yaamba reach was provided by the Yaamba Oil Shale Joint Venture, whose co-operation in this regard is acknowledged.

River cross-sections in the city reach were provided by Rockhampton City Council, and in the Barrage to Pink Lily reach by the Water Resources Commission.

b) Hydrologic Data

Hydrologic data required for the model study comprised main river and tributary discharges in hydrograph form.

Historic discharges for major floods were available at Yaamba and/or The Gap. Hydrographs for The Gap for the 1991, 1988, 1983 and 1978 floods were converted to equivalent hydrographs at Yaamba by the WRC. Flood frequency curves for use in design were presented in section 4 of the Phase 1 Report. These, however, give peak discharge only. For predictive purposes, design hydrographs were prepared, based on scaling of historic hydrographs, to match the magnitude of design flows.

There are currently no data available on inflows from Alligator Creek except that measured for Hedlow Creek in 1983. A discharge hydrograph for Neerkol Creek was available for the 1991 flood, but no design hydrographs are currently available. Due to the relatively small magnitude of these inputs, these were ignored for modelling purposes except for the input of the Neerkol Creek hydrograph for modelling of the 1991 flood.

The model was calibrated using discharge hydrographs and flood levels for the 1991 and 1988 floods, as these are the only floods on record consistent with current floodplain conditions. Validation was based on the 1978, 1983, 1954 and 1918 floods. Predictive runs were based on a range of design floods (eg. 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP). Floodplain conditions under assumed extreme flood conditions were also simulated.

c) Historic Flood Levels

Peak water levels for the 1991 flood were available at a number of points along the river and in the floodplain and many of these have been utilised in the calibration of the hydraulic model. The sources of information available were:

- Rockhampton City Council;
- Department of Transport;
- Water Resources Commission.

Subsequent field survey of flood marks in the floodplain area was carried out as part of the study to supplement the above.

A number of flood levels were also available for the 1988 flood from information supplied by the Rockhampton City Council.

Historic tidal information at Port Alma was obtained from the Department of Transport for the 1978, 1988 and 1991 flood periods, for use as downstream boundary condition hydrographs.

TABLE 2-1

Summary of Model Flow Paths

Description	Flow Path Specifications			No.of Cross-sections
	Name in Model	Upstream Chainage km	Downstream Chainage km	
Fitzroy River Yaamba – Ocean	FITZROY	100.000	203.124	61
Main floodplain Pink Lily – Gavial Creek	FP MAIN	0.000	19.042	35
Gavial Creek	FP GAVIA	0.000	6.066	8
Minor flow path Lakes Creek Road	LAKESCK	0.000	2.930	9
Minor flow path across Pink Lily meander	PLILY2	0.000	1.069	7
Minor flow path across Pink Lily meander	PLILY3	0.000	1.670	8
Breakout flow path Pink Lily	FP 1	2.600	6.900	8
Breakout flow path Pink Lily	FP 2	0.000	3.200	6
Subsidiary flow path Lotus Lagoon	FP 3	0.000	4.800	7
Scrubby Creek flood flow path	FP SCRUB	0.000	5.150	14
Flood flow Port Curtis/Depot Hill	FP CURTI	0.690	4.200	8
Lion Creek	FP LION	0.000	5.300	10
Flood flow north side of airport	AP NTH	0.000	2.600	10
Flood flow south side of airport	AP STH	0.000	3.000	12
Road/rail overflow Yeppen 1	YEPPEN1	0.000	0.170	4
Road/rail overflow Yeppen 2/3	YEPPEN2	0.000	0.120	4
Spill over Capricorn Highway	CAPRICORN	0.000	0.020	2
Spills from AP Sth to AP Nth	SP AP1	0.000	0.020	2
Spills from AP STH to AP NTH	SP AP2	0.000	0.020	2
High level spill from River to FP3	SPFITZROY	0.000	0.020	2
Spill from FPMAIN to FP3	SPFPMAIN1	0.000	0.020	2
Spill from FPMAIN to FP3	SPFPMAIN2	0.000	0.020	2
Spill from FP3 to Lion Creek	SPFP3 1	0.000	0.020	2
Spill from FP3 to Lion Creek	SPFP3 2	0.000	0.020	2
Spill from AP STH to FP MAIN	SP AP3	0.000	0.020	2
Spill from FP MAIN to FP CURTIS	SPCURTIS	0.000	0.020	2
Spill from FP SCRUB to FP MAIN	SPSCRUB	0.000	0.020	2
Yeppen 2 bridge flow	BRUCEY2	0.000	0.300	7
Yeppen 3 bridge flow	BRUCEY3	0.000	0.300	7
Spill into Splitters Creek area	SPLITTERS	0.000	2.360	11
	TOTAL			258

2.5 MODEL CALIBRATION AND VALIDATION

2.5.1 Approach

In order to develop a robust model suitable for design purposes it was necessary to produce a model which performed adequately over a range of floods for which flood flow and level data were available. Performance was judged principally on the reproduction of observed water levels, within acceptable limits, and also on the timing and sequence of events such as the initiation and cessation of breakout flows.

The approach comprised two stages, namely calibration and validation. In the calibration stage, model parameters such as channel roughness were varied systematically to give reasonable agreement for the calibration events. Calibration was based on the 1991 and 1988 events. These events were chosen for a number of reasons:

- they are the two most recent events and are the only events fully representative of current conditions;
- they have the most data available in terms of flood levels together with some information regarding floodplain flows or velocities;
- they represent a reasonable range of flood magnitudes, with AEP of 8.5% and 2% respectively. The 1988 flood caused a relatively small flow in the floodplain whereas the 1991 flood caused major floodplain flow.

Once calibration was completed to a satisfactory level, the process of validation was carried out whereby the model was run with further historic floods with no further manipulation of model structure or parameters. The degree of agreement or disagreement between observed and estimated flows for these events gave an indication of the acceptability of the model, within the limitations of the available data.

Validation was carried out using the floods of 1983, 1978, 1954 and 1918. The first two of the above are post-barrage but predate reconstruction of the Yeppen crossing. The 1918 flood was included as it is the highest on record, but of course conditions in the river and floodplain have changed significantly since that time. The same comment applies to the 1954 flood, which was very similar in magnitude to the 1991 flood.

The process of calibration and validation, and the results obtained therefrom are outlined in the following paragraphs.

2.5.2 Calibration

Model calibration consisted of varying model parameters such as channel roughness, weir coefficients and, where justified, section geometry in order to achieve a satisfactory level of agreement in terms of water levels and discharge (where known) throughout the modelled area. Attention was also paid to trying to ensure coincidence of timing of peaks and overflows.

As discussed above, calibration was based on the 1991 and 1988 flood events. The approach taken to calibration was to vary the model parameters firstly in regard to the 1988 flood, whereupon the performance with 1991 conditions was assessed. Parameters were then varied as necessary and a number of iterations were required to obtain parameters giving reasonable performance for both calibration events. Further model refinement was necessary for the more severe 1991 flood, in relation to spills between the various floodplain flow paths.

Channel roughness values used in the model (Manning's n) to give the above results are given in Table 2-2.

TABLE 2-2

Model Values of Channel Resistance (Manning's 'n')

Flow Path	Location	Chainages km	Mannings 'n'
Fitzroy	Yaamba – u/s Pink Lily	100–137.2	0.047
Fitzroy	Pink Lily – Barrage	137.2–149.27	0.041
Fitzroy	Barrage – The Rocks	149.27–151.5	0.050
Fitzroy	The Rocks – Gavial Creek	151.5–154.87	0.022
Fitzroy	Gavial Creek – Edinda Lane	154.87–165.02	0.035
Fitzroy	Edinda Lane – Keppel Bay	165.02–203.12	0.042
FP Main	Yeppen – Gavial Creek	13.95–19.04	0.100
FP Scrub	Yeppen – FP MAIN	4.14–5.15	0.100
FP Curtis	Yeppen – Gavial Creek	0.91–4.2	0.100
AP NTH	Airport – North Side	0 – 2.6	0.070
AP STH	Airport – South Side	0 – 3.0	0.070
FP1	River – Lotus Lagoon	2.6 – 6.9	0.060
FP2	River – Lotus Lagoon	0 – 3.2	0.060
FP3	FP Main – Lotus Lagoon	0 – 4.8	0.060
All other Sections			0.080

The performance of the model for these two events is summarised in Tables 2-3 and 2-4 and in Figures 2-3 to 2-12. Figures 2-3 shows observed and estimated levels throughout the model in plan form. Figures 2-4 to 2-7 give modelled and observed hydrographs at key locations for the 1991 flood to enable comparison of relative hydrograph shape and timing as well as peak levels. Figures 2-8 and 2-9 show longitudinal profiles of observed and estimated flood levels along the Fitzroy River and along the main floodplain flow path (FP-MAIN) for the 1991 flood.

The corresponding diagrams relating to the 1988 flood are given in Figures 2-10 to 2-14.

Geometry of some control sections in the floodplain, where the only ground level information was the 1960 Department of Local Government (DLG) survey, were varied by a maximum of ±0.3 m to maximise agreement of observed and modelled flood levels. Discrepancies of this order exist between the DLG survey and the Australian Survey Office (ASO) surveys where these overlap in the vicinity of the Rockhampton Airport were noticed during the preparation of contour mapping in Phase 1 of the study. Hence this was believed to be justified in physical terms.

Weirs to represent overtopping of the Bruce Highway at Yeppen were based on road levels plus 200 mm to allow for kerbing/median strips. The corresponding railway crossing weirs were based on top of rail level.

The results obtained for the 2 events are discussed below.

a) Model Calibration 1991 Flood

Reference to Table 2-3 and Figure 2-3 shows a maximum discrepancy between the observed and estimated flood levels of 0.23 m. At key points, agreement is better than this, with estimated values being +0.01 m at the City flood gauge, -0.09 m at the Barrage and -0.02 m at Yaamba. Flood levels at these locations are given the greatest weight as recorders and/or staff gauges are erected at these points. Other flood levels have generally been obtained by subsequent levelling of flood markers, and are subject to a greater level of uncertainty.

Key locations in regard to floodplain flows are where breakout flows cross the Rockhampton-Ridgelands Road, where levels were estimated within 0.15 m of observed levels and at the Yeppen crossing. Estimated levels were in close agreement with observed levels on the upstream side of the crossing and within 0.04 m on the downstream side of the crossing.

This level of agreement is regarded as being satisfactory especially considering the known limitations of some of the topographic information, and the difficulty of actually recording flood levels under very bad conditions.

TABLE 2-3

Summary of Model Calibration 1991 Flood

Flow Path	Location	Chainage km	Flood Levels			Peak Discharge		Comments
			Observed Level m AHD	Modelled Level m AHD	Difference m	Observed m³/s	Modelled m³/s	
Fitzroy River	Yaamba	100.0	17.95	17.93	-0.02	14,200	14,200	Yaamba discharge input is upstream boundary condition
	u/s Pink Lily	134.0	12.36	12.26	-0.10		14,140	includes flow in Pink Lily overbanks
	start of FP2	139.2	*11.6	11.48	-0.12		13,000	includes flow in Pink Lily overbanks
	start of FP Main	140.1	*11.4	11.42	+0.02		10,200	includes flow in Pink Lily overbanks
	near Water Treatment Works	144.78	*11.2	10.98	-0.22		10,000	
	Barrage	149.27	9.59	9.50	-0.09		10,250	335 m³/s from Lion Creek
	d/s Barrage	149.47		9.27			10,250	
		150.17	8.83	8.56	-0.23		10,250	
	Railway Bridge	150.67	8.53	8.36	-0.17		10,250	
	Fitzroy Street Bridge	151.57	8.03	8.03	0.00		10,250	
	City Flood Gauge	152.57	7.85	7.84	-0.01		10,180	approx 75 m³/s in Lakes Creek flow path
	Gavial Creek	154.27	*7.5	7.59	+0.09		7,300	approx. 3,150 in Gavial Creek overflow path
	Edinda Lane	165.02		6.1			14,140	single flow path adopted from this point
		173.00	*5.6	5.44	-0.16		14,120	
FP MAIN	J/w Fitzroy River	0.0	*11.4	11.42	+0.02		1,500	total outflow FP MAIN, FP1, FP2: 4,125 m³/s
	Rockhampton-Ridgelands Road	1.75	10.9	11.04	+0.14		750	
	Lotus Lagoon	4.56	*10.8	10.99	+0.19		3,665	includes 1,970 m³/s FPI, 675 m³/s FP2 less spills to Airport area
	Nine Mile Road	6.63	*10.4	10.55	+0.15		3,412	includes input from Lion Creek
	Start FP SCRUBBY	11.0	9.32	9.44	+0.12		3,445	u/s of junction, 1,600 m³/s downstream
	Junction with AP-STH	13.0	8.98	9.16	+0.18		2,060	d/s of junction
	u/s Yeppen Crossing	13.6	8.64	8.64	0.00		1,420	spill of 640 over Capricorn Hwy to FP SCRUBBY
	d/s Bruce Highway	13.84	8.32	8.39	+0.07		1,420	bridge flow 950 overflow north of bridge 290, south 180
	d/s Yeppen Crossing	14.0	8.06	8.10	+0.04		950	
	Old Burnett Highway	15.15	*7.8	7.97	+0.12		3,150	net of spill to FP CURTIS, FP SCRUBBY
	Old Bruce Highway	16.98	*7.3	7.25	-0.05		3,150	includes FP SCRUBBY, but not to FP CURTIS
	J/w FP GAVIAL	19.04	*7.1	7.09	-0.01		3,150	
FP SCRUBBY	Start	0	9.32	9.44	+0.12		1,845	
	d/s Capricorn Highway	1.3	8.88	9.01	+0.13		1,845	
	u/s Bruce Highway	4.0	8.55	8.64	+0.09		2,510	bridge flow 1,550 m³/s, overflow of 960 m³/s
	d/s Railway	4.3	*8.1	8.11	+0.01		2,190	spill to FP MAIN 320 m³/s
	J/w FP MAIN	5.15	*7.9	7.97	+0.07		2,190	
FP CURTIS	u/s Bruce Highway	0.69	8.64	8.47	-0.17		290	
	Port Curtis Junction	1.4	*7.78	7.73	-0.05		290	
	Depot Hill	2.1	7.55	7.69	+0.14		290	
	Gavial Creek	4.2	7.55	7.57	+0.02		750	includes spill from FP MAIN
FP LION	J/w FP MAIN	0	*10.4	10.55	+0.15		250	
	J/w AP STH	2.2	10.44	10.44	0.00		255	
	J/w AP NTH	3.35	10.48	10.25	-0.23		185	
	Fitzroy River	5.3	9.59	9.50	-0.09		245	
Airport North	J/w FP LION	0	10.48	10.25	-0.23		75	
	New Terminal	2.12	9.33	9.45	+0.12		200	
	J/w AP STH	2.6	*9.0	9.16	+0.16		200	
Airport South	J/w FP LION	0	10.45	10.44	-0.01		385	
	Opposite Terminal	1.3		9.62			255	
	J/w AP NTH	2.3	9.0	9.17	+0.17		255	
	J/w FP MAIN	3.0	8.98	9.16	+0.18		460	d/s AP-NTH
Lakes Creek Road	near Fitzroy River Bridge	0	8.03	8.04	+0.01		75	
	Lakes Creek Road (STW)	1.5	7.39	7.34	-0.05		75	
	Lakes Creek Road (Landfill)	2.0	7.39	7.27	-0.12		75	
	J/w Fitzroy River	2.93	7.29	7.22	-0.07		75	
Gavial Creek	Fitzroy River	0	*7.5	7.59	+0.09		3,050	
	J/w FP CURTIS	1.03	*7.55	7.57	+0.02		372	d/s FP CURTIS
	J/w FP MAIN	4.21	*7.1	7.09	-0.01		6,770	d/s FP MAIN
	Edinda Lane	6.06	*6.6	6.43	-0.17		6,770	
Splitters Creek	Fitzroy River	1.34	9.67	9.51	-0.16		66	
	Fitzroy River	2.36	9.59	9.50	+0.09		66	

In terms of river discharge, of the total peak flow at Yaamba of 14,200 m^3/s, the model indicates 10,250 m^3/s remaining in the city reach of the river. The total estimated breakout flow at Pink Lily was 4,125 m^3/s of which 335 m^3/s returns to the river upstream of the barrage via Lion Creek. About 480 m^3/s flows through the airport area with 3,400 m^3/s passing down the main floodway across Nine Mile Road. Of this total flow, 1,300 m^3/s was estimated to pass through the Yeppen 1 flow path and 2,500 m^3/s through the Scrubby Creek flow path. The Yeppen 1 flow is broken down into 950 m^3/s through the bridge and 470 m^3/s over the road/rail embankments between the roundabout and Jellicoe Street. The combined flow through the 3 southern bridges was estimated as 1,550 m^3/s with 950 m^3/s overflowing the embankment south of the roundabout. The bridge flows are in good agreement with those estimated from velocity measurements taken during the flood which gave estimates of 1,020 m^3/s for Yeppen 1 bridge and 1,500 m^3/s for the 3 southern bridges (as given in Appendix E of the Phase 1 Report) and theoretical flows based on measured water levels of 925 m^3/s and 1,580 m^3/s respectively. The weir flows are, however, substantially less than the preliminary estimates in Phase 1, as those estimates did not allow for the effect of the high tailwater levels.

It was concluded that the model performed very well at the Yeppen Crossing as it reproduced both flood levels and flows to a high level of agreement with observations.

In regard to hydrograph shape and timing (refer Figures 2-4 to 2-6) there is good agreement in respect of the main river hydrographs, except that the early rise due to inputs from Alligator Creek and other local catchments has not been taken into account. As these flows were receding by the time of arrival of the main flood wave, and as they could not be quantified, their exclusion was not of concern.

The hydrograph at Yeppen crossing has a good shape in relation to the observed hydrograph, but is about 18 hours late. This is due to the model floodplain storage needing to be filled prior to flow occurring in the lower section of the floodplain, whereas in reality the heavy local rain and local runoff would have filled these storages. The overflow at Pink Lily occurred in the model early on 4th January, as it did in reality, but whereas overtopping at Yeppen occurred early on 5th January, this did not occur in the model until early on 6th January. However, the overflow duration is well modelled at 10.5 days. This delay is not believed to be a serious impediment to the operation of the model. As will be noted later, this delay did not occur in the model for 1988 in which the floodplain was dry.

The hydrographs at the airport are in good agreement (within ±0.15 m) with the records from temporary flood markers erected there, especially given that these markers do not coincide exactly with the location of cross-sections in the model.

Hydrographs from the lower reaches of the Fitzroy River show that tidal influence is negligible at the height of the flood in the area of interest, see Figure 2-7.

Longitudinal profiles along the river and the main floodplain flow path are given in Figures 2-8 and 2-9.

b) **Model Calibration 1988 Flood**

Reference to Table 2-4 and Figure 2-10 shows that the peak flood level at Yaamba was underestimated by 0.18 m for this event, with underestimation of 0.13 m at the Barrage, but with good agreement at the flood gauge. At the junction of Lakes Creek Road flow path with the river, the flood level was overestimated by 0.25 m. However, this was a low accuracy observation. Other discrepancies of ±0.2 m occurred at minor points.

However, a significant discrepancy of 0.62 m occurred at the Yeppen crossing, where the estimated level was 7.45 m compared to observed values of 6.83 m. The latter were taken in connection with gauging of the floodplain flow. However, these measurements show virtually the same level, on both upstream and downstream side of the highway of 6.83 m and 6.82 m respectively. This is inconsistent with the measured flows, which must have created greater afflux than 0.01 m. These levels may have been taken within the drawdown zone. As the flows were well modelled, as discussed in a later paragraph, this discrepancy is not believed to invalidate the model. On the southern side of the floodplain the estimated levels were 0.09 m high.

The total discharge for this event was 9,420 m^3/s at Yaamba. The WRC measured the discharge at Yeppen during this flood (see Appendix E2, Phase 1 Report), and recorded a peak discharge of 640 m^3/s for Yeppen 1 and a combined total of 76 m^3/s for the 3 southern bridges. Thus in this event, a total floodplain peak flow of 716 m^3/s was measured, the bulk of which stayed in the main flow path. No overtopping of the road/rail embankment occurred. The WRC report states that these flows are expected to be accurate within about ±20% due to the difficulties associated with gauging of flood flows.

In the model, the peak floodplain flows for this event were 705 m^3/s at Yeppen 1 and 110 m^3/s for the 3 southern bridges, giving a total of 815 m^3/s. This total is within 14% of the measured total, and the flow at Yeppen 1 within 10%. These values are within the noted tolerance of ±20% reported by WRC. In the model, as in reality, no overtopping of the embankments occurred. Hydrograph shape and timing was acceptable throughout, as can be seen in Figures 2-11 and 2-12. The delay in the latter which occurred in the 1991 event was not experienced in the 1988 event.

Longitudinal sections along the Fitzroy River and the main floodplain flow path are given in Figures 2-13 and 2-14.

c) **Conclusion**

The fitted model was able to represent floods of 9,400 m^3/s and 14,200 m^3/s (8.5% AEP and 2% AEP respectively) with predicted levels mostly within ±0.15 m at key points and generally within ±0.2 m. Floodplain flows in the 1988 flood were within 14% of measured flows, and bridge flows in 1991 were in very close agreement with those estimated from measured levels and velocities.

TABLE 2–4

Summary of Model Calibration 1988 Flood

Flow Path	Location	Chainage km	Flood Levels: Observed Level m AHD	Flood Levels: Modelled Level m AHD	Flood Levels: Difference m	Peak Discharge: Observed m³/s	Peak Discharge: Modelled m³/s	Comments
Fitzroy River	Yaamba	100.0	16.52	16.34	–0.18	9,420	9,420	Yaamba hydrograph input as upstream bordering condition
	u/s Pink Lily	134.0		11.11			9,170	include flow in Pink Lily 3 overbanks
	start of FP2	139.2		10.15			8,280	include flow in Pink Lily 2 & 3 overbanks
	start of FP Main	140.1	10.41	10.36	–0.05		8,280	include flow in Pink Lily 2 & 3 overbanks
	near Water Treatment Works	144.78	9.60	9.69	+0.09		8,280	
	Barrage	149.27	8.59	8.46	–0.13		8,365	approx 90 m³/s from Lion Creek
	d/s Barrage	149.47		8.10			8,365	
		150.17	7.76	7.57	–0.19		8,365	
	Railway Bridge	150.67		7.44			8,365	
	Fitzroy Street Bridge	151.57	7.09	7.11	+0.02		8,365	
	City Flood Gauge	152.57	6.95	6.95	+0.00		8,330	approx. 30 m³/s in Lake Creek Road flow path
	Gavial Creek	154.27	6.74	6.73	–0.01		6,150	approx. 2,200 Gavial Creek overflow
	Edinda Lane	165.02		5.32			9,030	single flow path from this point
		173.00		4.67			9,000	
FP MAIN	J/w Fitzroy River	0.0	10.41	10.36	–0.05		560	
	Rockhampton-Ridgelands Road	1.76	9.69	9.67	–0.02		340	
	Lotus Lagoon	4.56		9.45			890	includes flows from FP1, FP2
	Nine Mile Road	6.64	9.19	9.19	0.00		810	reduced by overflow into Lion Creek
	Start FP SCRUBBY	11.0		8.02			790	upstream of junction 710 downstream
	Junction with AP–STH	13.0		7.54			705	
	u/s Yeppen Crossing	13.6	6.83	7.45	+0.62		705	
	d/s Bruce Highway	13.84		7.10			705	
	d/s Yeppen Crossing	14	6.82	6.71	–0.11		705	
	Old Burnett Highway	15.52		6.67			810	
	J/w FP GAVIAL	19.04		6.16			810	
FP SCRUBBY	Start	0		8.02			110	
	d/s Capricorn Highway	1.3		6.73			110	
	u/s Bruce Highway	4.0	6.63	6.72	+0.09		110	combined flow 3 bridges
	d/s Railway	4.3	6.62	6.71	+0.09		110	
	J/w FP MAIN	5.15		6.67			110	
FP CURTIS	u/s Bruce Highway	0.69		7.45			0	no flow
	d/s Railway	0.91	*6.83	6.71	–0.12		0	
	Depot Hill	2.1	*6.55	6.71	+0.16		24	tidal backwater
	Gavial Creek	4.18		6.71			36	tidal backwater
FP LION	J/w FP MAIN	0		9.19			–24	flow reversal occurs
	J/w AP STH	2.2	9.25	9.08	–0.17		90	flow reversal occurs
	J/w AP NTH	3.35		8.74				flow reversal occurs
	Fitzroy River	5.3	8.59	8.46	–0.13			flow reversal occurs
Airport North	J/w FP LION	0					0	no flow
	New Terminal	1.54					0	
	J/w AP STH	2.6	7.52	7.72	+0.20		0	
Airport South	J/w FP LION	0					0	no flow
	Opposite Terminal	1.3					0	
	J/w AP NTH	2.3	7.52	7.72	+0.20		0	
	J/w FP MAIN	3.0		7.54			0	
Lakes Creek Road	near Fitzroy River Bridge	0	7.09	7.11	+0.02		30	
	Lakes Creek Road (STW)	1.0		7.10			30	
	Lakes Creek Road (Landfill)	2.0		6.42			30	
	J/w Fitzroy River	2.93	6.15	6.40	+0.25		30	
Gavial Creek	Fitzroy River	0	6.74	6.73	–0.01		2,200	
	J/w FP CURTIS	1.03		6.71			2,200	
	J/w FP MAIN	4.21		6.15			2,940	
	Edinda Lane	6.05		5.72			2,940	

Given the limitations on available topographic and cross-section data, and the expected accuracy of flood levels and flows, it was concluded that the model accurately reflects current conditions, over at least this range of flows.

Further evidence of this was sought from model validation runs for a wider range of flood flows, as outlined in the next paragraph.

2.5.3 Validation

Validation runs were carried out with the 1983, 1978, 1954 and 1918 floods. The results obtained are outlined in the following paragraphs and summarised in Tables 2–5 to 2–8.

Typical hydrographs for these events are given in Figures 2–15 to 2–18. These model runs have been carried out with no change to model structure or parameters from that giving the calibration results discussed above.

It should be noted that none of these floods are representative of current conditions.

The model calibration runs had shown that the floodplain flows were controlled primarily by the configuration at the breakouts in the Pink Lily area together with the level in the river only and not by backwater from the lower reaches of the floodplain except possibly under extreme flood conditions. Hence recent changes to the lower section of the floodplain would not impact on these aspects of model performance. Of course, modelled levels in the lower floodplain in particular will not be directly comparable to levels observed in these historic floods.

Model performance with each of these events is discussed in the following paragraphs.

a) 1983 and 1978 Floods

These floods will be considered together as they are very similar in magnitude. The 1983 flood reached 16.27 m AHD at Yaamba and 6.80 m AHD at Rockhampton. Corresponding values for the 1978 flood were 16.05 AHD and 6.70 m AHD. Discharge hydrographs at Yaamba for these events were estimated from those for The Gap by WRC. These had almost identical peak flows of 7,860 m^3/s and 7,850 m^3/s respectively. The higher level in 1983 probably results from local runoff, which is not modelled. This was expected to result in some discrepancies in levels downstream. Flows at The Gap were measured during these floods and have high reliability. The estimated flows at Yaamba are based on maintaining the measured flood volume, with some adjustments to the rating curve being required.

In both of these floods, which are smaller than either of the calibration floods, the peak level at Yaamba was significantly underestimated, by 0.59 m and 0.35 m respectively for the 1983 and 1978 events. However, it is understood that there may be errors in the recorded flood levels for these events as apparently some of the gauge boards had been replaced off the station datum.

At the Barrage, the underestimation had reduced to 0.25 m and 0.18 m respectively, and to 0.14 m, and 0.03 m at the flood gauge.

The only other location for which levels were available was for the 1978 flood in the floodplain at the Rockhampton-Ridgelands Road, where the estimated value was 0.08 m high.

It appears that flood levels were underestimated for these events, to an acceptable degree in the Rockhampton area, but an unacceptable degree at Yaamba.

A report on the 1978 flood (Dept of Transport, 1988) quoted rough estimates of floodplain flow of 225 m^3/s to 400 m^3/s. The model estimated 220 m^3/s at Pink Lily reducing to 185 m^3/s at Yeppen.

These estimates are thus in broad agreement with the approximate values available, although the significant underestimation at Yaamba was of concern.

This underestimation of flood levels may be due to any or all of the following:

- error in the fitted model;
- error in discharge hydrographs;
- observation error in observed flood levels;
- variation in channel characteristics over time ie. main river channel cross-section area less than used in the model.

b) 1918 and 1954 Floods

In order to simulate the 1918 and 1954 floods the barrage was removed from the model structure. No tidal records were available for these events, so a constant tailwater was assumed. Initially, the tailwater was set at the mean sea level (0 AHD). A sensitivity check with a constant tailwater of 3 m AHD produced only a very small difference in estimated level at Rockhampton (0.02 m at the city flood gauge for the 1918 flood).

For the 1954, the model gave reasonable agreement, overestimating the level at Yaamba by 0.28 m, overestimating by 0.15 m at Pink Lily, 0.15 m at the barrage site, with agreement within 0.05 m at the flood gauge. In regard to flows, with a peak discharge at Yaamba of 15,080 m^3/s, the model had a peak of 10,760 m^3/s in the river at the site of the barrage and a total breakout flow at Pink Lily of 4,620 m^3/s.

Considerable variation between observed and modelled levels occurred in the floodplain section, particularly upstream of the Yeppen Crossing but this was expected because of the significant changes which have occurred since 1954. In the Depot Hill area, the estimated level was within 0.2 m of that observed.

Within the limits of available data, and with recognition of the substantial changes in river and floodplain conditions, the model gave a good representation of the 1954 flood.

In regard to the 1918 flood, the estimated level at Yaamba was 0.23 m high but was 0.21 m low at the city flood gauge. In this event, with a modelled flow of 17,800 m^3/s at Yaamba, the total breakout flow at Pink Lily was estimated to be 6,370 m^3/s, with 11,600 m^3/s in the city reach of the river.

The discrepancy between observed and estimated levels at Rockhampton may be due to any or all of the following:

- model error;
- error in discharge hydrograph input to the model;
- observation error in recorded flood levels;
- variation in river cross-section with time;
- variation in control level at Pink Lily due to progressive erosion.

c) **Discussion**

In regard to levels at Yaamba, these were overestimated by 0.28 m and 0.23 m for the higher flood magnitudes of 15,000 m^3/s and 18,000 m^3/s but underestimated for the smaller floods of about 8,000 m^3/s. This suggests that the current model has relatively too great a cross-section area in the within-bank section which is counteracted at higher flows. As higher flows are the main interest, this was not a severe problem. There may also have been significant change in cross-section over the years. As discussed above, there is some doubt as to the accuracy of the recorded flood levels at Yaamba in the smaller events.

In regard to levels at Rockhampton, the validation runs have differences in the range +0.06 m to -0.21 m. Figures 13-11 and 13-12 of the Phase 1 Report show that between surveys taken in 1950 and 1989/90, bed levels in the reach from upstream of the barrage to Pink Lily (AMTD 61.16 km to 70.50 km), have lowered by as much as 3 m. Whilst no detailed data are available in regard to conditions at the time of each flood, it would be expected that each major flood would result in further degradation (erosion), possibly with some aggradation (deposition) taking place between major floods. This ongoing erosion is consistent with the change of river course in recent geological time to the current channel through the city, possible as recently as 8,000 years BP (Cameron McNamara 1981). This could account for some of this discrepancy.

Similarly, the ongoing erosion at Pink Lily has been reported to be lowering the level of the natural levee controlling the threshold of overbank flow in this area. If this were higher during the 1918 flood than it is now, a greater proportion of the flow would have remained in the river channel than predicted by the current model, hence the current model would predict lower levels for a given flood magnitude than occurred previously.

In regard to the peak flow for the 1918 flood, this has recently been revised by WRC to about 18,000 m³/s, whereas previous estimates were about 25,000 m³/s. Whilst the revised value is regarded as being accurate, the size of this revision, which results from reassessment of the Yaamba stage discharge rating curve, may mean that this figure is of low accuracy. A 10% underestimation in flow, for example, would probably result in a difference in water level equal to the modelled error. For example, using design flows of 19,000 m³/s and 22,500 m³/s see section 2.6, predicted levels at Rockhampton flood gauge were 8.59 m AHD and 9.04 AHD respectively compared to the 1918 recorded peak level of 8.65 m AHD. Thus a flow of about 20,000 m³/s with the model would give a flood level in good agreement with the recorded 1918 level.

The main area of change appears to be related to the river cross-section information. The cross-sections for the Yaamba to Pink Lily reach used in the model are those obtained in relation to the Yaamba Oil Slate Project and are dated 1982. There has apparently been significant accretion of sand bars in the upper Barrage storage since it was commissioned in 1970. This accumulation of material and its subsequent movement during floods indicates that the stage - discharge relationship in this reach is not stable over time. As the model has a fixed geometry, it cannot reflect these transitory effects and will subsequently not adequately reflect historic flood levels in the Yaamba area.

The above discussion suggests that there have been changes in river and floodplain characteristics, since the earlier major historic floods, together with possible errors in their magnitude, which explain, to a large extent, the discrepancies between observed flood levels and those estimated using the model which has been set up to represent current conditions as closely as possible.

It was concluded from the above, that the model performs within the acceptable limits for the range of validation floods.

As such, it was concluded that the model may be utilised with acceptable confidence in the estimation of flood levels for a range of design floods for current conditions, and for consideration of the effectiveness and impact of a range of flood mitigation options. It is reiterated, that the model applies to current conditions and not to specific historic flood events other than the 1988 and 1991 events.

TABLE 2-5

Summary of Model Validation 1978 Flood

Flow Path	Location	Chainage km	Flood Levels			Peak Discharge		Comments
			Observed Level m AHD	Modelled Level m AHD	Difference m	Observed m³/s	Modelled m³/s	
Fitzroy River	Yaamba	100.0	16.05	15.70	-0.35	7,860	7,860	'The Gap' hydrograph used for flow at Yaamba
	u/s Pink Lily	134		10.57			7,800	
	start of FP2	139.2		9.96			7,760	Includes overbank flow at Pink Lily
	start of FP Main	140.1	9.61	9.86	+0.25		7,520	Includes overbank flow at Pink Lily
	near Water Treatment Works	144.78		9.19			7,520	
	Barrage	149.27	8.23	8.05	-0.18		7,590	
	d/s Barrage	149.47		7.71			7,590	
		150.17		7.23			7,590	
	Railway Bridge	150.67		7.09			7,590	
	Fitzroy Street Bridge	151.57		6.82			7,590	
	City Flood Gauge	152.57	6.70	6.67	-0.03		7,570	20 m³/s in Lakes Creek Road flow path
	Gavial Creek	154.27		6.47			5,760	2,015 m³/s in Gavial Creek overflow path
	Edinda Lane	165.02		5.12			7,730	single flow path
		173.00		4.48			7,730	tidal influence
FP MAIN	J/w Fitzroy River	0.0	9.61	9.86	+0.25		220	
	Rockhampton-Ridgelands Road	1.76	9.04	9.12	+0.08		105	
	Lotus Lagoon	4.56		8.92			260	Includes FP1, FP2
	Nine Mile Road	6.64		8.83			185	75 m³/s into Lion Creek
	Start FP SCRUBBY	11.0		6.76			185	
	Junction with AP-STH	13.0		6.42			185	Note changed since 1978
	u/s Yeppen Crossing	13.6		6.22			185	
	d/s Bruce Highway	13.84		6.07			185	
	d/s Yeppen Crossing	14.0		5.99			185	
	Old Burnett Highway	15.15		5.96			185	
	J/w FP GAVIAL	19.04		5.79			185	
FP SCRUBBY	Start	0		6.76			0	no flow u/s Yeppen
	d/s Capricorn Highway	1.3		5.97			0	Note changed since 1978
	u/s Bruce Highway	4.0		5.97			0	
	d/s Railway	4.3		5.97				tidal flows – downstream of Yeppen
	J/w FP MAIN	5.15		5.97				
FP CURTIS	u/s Bruce Highway	0.69		6.22				tidal backwater flows only
	d/s Railway	0.91		6.45				
	Depot Hill	2.1		6.45				
	Gavial Creek	4.18		6.45				
FP LION	J/w FP MAIN	0		8.83				
	J/w AP STH	2.2		8.69			-15	flow reversal occurs
	J/w AP NTH	3.35		8.33			to	
	Fitzroy River	5.3	8.23	8.09	-0.14		75	
Airport North	J/w FP LION	0					0	no flow
	New Terminal	1.54					0	
	J/w AP STH	2.6					0	
Airport South	J/w FP LION	0					0	no flow
	Opposite Terminal	1.3					0	
	J/w AP NTH	2.3					0	
	J/w FP MAIN	3.0					0	
Lakes Creek Road	near Fitzroy River Bridge	0		6.82			20	
	Lakes Creek Road (STW)	1.0		6.80			20	
	Lakes Creek Road (Landfill)	2.0		6.20			20	
	J/w Fitzroy River	2.93		6.16			20	
Gavial Creek	Fitzroy River	0		6.47			1,825	
	J/w FP CURTIS	1.03		6.45			1,825	
	J/w FP MAIN	4.21		5.79			1,985	
	Edinda Lane	6.06		5.43			1,985	

TABLE 2-6

Summary of Model Validation 1983 Flood

Flow Path	Location	Chainage km	Flood Levels			Peak Discharge		Comments
			Observed Level m AHD	Modelled Level m AHD	Difference m	Observed m^3/s	Modelled m^3/s	
Fitzroy River	Yaamba	100.0	16.27	15.68	-0.59	7,850	7,850	Yaamba discharge input is upstream boundary condition
	u/s Pink Lily	134		10.56			7,765	includes flow in Pink Lily overbanks
	start of FP2	139.2		9.95			7,765	includes flow in Pink Lily overbanks
	start of FP Main	140.1		9.85			7,560	includes flow in Pink Lily overbanks
	near Water Treatment Works	144.78		9.18			7,560	
	Barrage	149.27	8.30	8.04	-0.26		7,570	70 m^3/s from Lion Creek
	d/s Barrage	149.47		7.70			7,570	
		150.17		7.22			7,570	
	Railway Bridge	150.67		7.08			7,570	
	Fitzroy Street Bridge	151.57		6.81			7,570	
	City Flood Gauge	152.57	6.80	6.66	-0.14		7,550	approx 20 m^3/s in Lakes Creek flow path
	Gavial Creek	154.27		6.47			5,750	approx. 1,800 in Gavial Creek overflow path
	Edinda Lane	165.02		5.11			7,720	single flow path adopted from this point
		173.00		4.49			7,720	
FP MAIN	J/w Fitzroy River	0.0		9.85			210	
	Rockhampton-Ridgelands Road	1.75		9.10			105	
	Lotus Lagoon	4.56		8.91			250	includes 30 m^3/s FPI, 15 m^3/s FP2
	Nine Mile Road	6.63		8.81			180	includes input to Lion Creek
	Start FP SCRUBBY	11.0		6.74			180	u/s of junction, 1,860 m^3/s downstream
	Junction with AP-STH	13.0		6.40			180	d/s of junction
	u/s Yeppen Crossing	13.6		6.20			180	spill of 890 over Capricorn Hwy to FP SCRUBBY
	d/s Bruce Highway	13.84		6.06			180	
	d/s Yeppen Crossing	14.0		5.98			180	
	Old Burnett Highway	15.15		5.95			180	
	J/w FP GAVIAL	19.04		5.79			180	
FP SCRUBBY	Start	0		6.74			0	no flow u/s Yeppen
	d/s Capricorn Highway	1.3		5.96			0	
	u/s Bruce Highway	4.0		5.96			0	
	d/s Railway	4.16		5.96			0	
	J/w FP MAIN	5.15		5.95			0	
FP CURTIS	u/s Bruce Highway	0.69		6.20				no flow
	d/s Railway	0.91		6.45				tidal backwater
	Depot Hill	2.1		6.45				
	Gavial Creek	4.18		6.45				
FP LION	J/w FP MAIN	0		8.81			70	
	J/w AP STH	2.2		8.67			70	flow reversal occurs
	J/w AP NTH	3.35		8.32			70	
	Fitzroy River	5.3		8.04			70	
Airport North	J/w FP LION	0					0	no flow
	New Terminal	1.54					0	
	J/w AP STH	2.6					0	
Airport South	J/w FP LION	0					0	no flow
	Opposite Terminal	1.3					0	
	J/w AP NTH	2.3					0	
	J/w FP MAIN	3.0					0	d/s AP-NTH
Lakes Creek Road	near Fitzroy River Bridge	0		6.81			20	
	Lakes Creek Road (STW)	1.0		6.80			20	
	Lakes Creek Road (Landfill)	2.0		6.19			20	
	J/w Fitzroy River	2.93		6.15			20	
Gavial Creek	Fitzroy River	0		6.47			1,820	
	J/w FP CURTIS	1.03		6.45			1,820	d/s FP CURTIS
	J/w FP MAIN	4.21		5.79			1,980	d/s FP MAIN
	Edinda Lane	6.06		5.43			1,980	

TABLE 2-7

Summary of Model Validation 1954 Flood

Flow Path	Location	Chainage km	Flood Levels			Peak Discharge		Comments
			Observed Level m AHD	Modelled Level m AHD	Difference m	Observed m³/s	Modelled m³/s	
Fitzroy River	Yaamba	100.0	17.89	18.17	+0.28	15,080	15,080	Yaamba discharge input is upstream boundary condition
	u/s Pink Lily	134		12.40			15,080	includes flow in Pink Lily overbanks
	start of FP2	139.2		11.59			15,030	includes flow in Pink Lily overbanks
	start of FP Main	140.1	11.34	11.53	+0.19		13,700	includes flow in Pink Lily overbanks
	near Water Treatment Works	144.78	10.82	10.91	+0.09		10,400	
	Barrage site	149.27	9.27	9.42	+0.15		10,800	360 m³/s from Lion Creek
	d/s Barrage	149.47		9.39			10,800	
		150.17	8.90	8.77	-0.13		10,800	
	Railway Bridge	150.67		8.55			10,800	
	Fitzroy Street Bridge	151.57		8.21			10,800	
	City Flood Gauge	152.57	7.96	8.02	+0.06		10,730	approx 80 m³/s in Lakes Creek flow path
	Gavial Creek	154.27		7.74			7,660	approx. 3,800 in Gavial Creek overflow path
	Edinda Lane	165.02		6.21			15,000	single flow path adopted from this point
		173.00		5.54			15,000	
FP MAIN	J/w Fitzroy River	0.0	11.34	11.53	+0.19		1,620	total breakout flow of 4,500 m³/s
	Rockhampton-Ridgelands Road	1.75		11.14			770	
	Lotus Lagoon	4.56		11.10			3,910	includes 2,125 m³/s FPI, 755 m³/s FP2
	Nine Mile Road	6.63		10.65			3,640	includes input from Lion Creek
	Start FP SCRUBBY	11.0	8.65	9.55	+0.90		3,670	u/s of junction, 1,620 m³/s downstream
	Junction with AP-STH	13.0	8.56	9.27	+0.71		2,200	d/s of junction
	u/s Yeppen Crossing	13.6	8.28	8.74	+0.46		1,505	spill of 720 over Capricorn Hwy to FP SCRUBBY
	d/s Bruce Highway	13.84		8.48			1,505	bridge flow 980, overflow north of bridge 220, bridge-roundabout
	d/s Yeppen Crossing	14	8.14	8.18	+0.04		1,505	
	Old Burnett Highway Old Bruce Highway	15.15 16.98	8.06	8.04 7.34	-0.02		3,280 3,280	includes FP SCRUBBY, spill of 655 to FP CURTIS
	J/w FP GAVIAL	19.04	7.26	7.20	-0.06		3,280	
FP SCRUBBY	Start	0	8.65	9.55	+0.90		2,010	
	d/s Capricorn Highway	1.3	8.32	9.13	+0.81		2,010	
	u/s Bruce Highway	4.0	8.32	8.73	+0.41		2,730	bridge flow 1,570 m³/s, overflow of 1,180 m³/s
	d/s Railway	4.30	8.06	8.18	+0.12		2,270	spill to FP MAIN 460 m³/s
	J/w FP MAIN	5.15		8.04			2,270	
FP CURTIS	u/s Bruce Highway	0.69	8.28	8.74	+0.46		335	
	d/s Railway	0.91	7.95	8.49	+0.54		335	
	Depot Hill	2.1	7.68	7.87	+0.19		335	
	Gavial Creek	4.18	7.51	7.72	+0.21		985	includes spill from FP MAIN
FP LION	J/w FP MAIN	0		10.65			265	
	J/w AP STH	2.2		10.54			190	
	J/w AP NTH	3.35		10.38			285	
	Fitzroy River	5.3		9.44			285	
Airport North	J/w FP LION	0		10.38			105	
	New Terminal	1.54	9.43	9.78	+0.35		210	
	J/w AP STH	2.6	8.94	9.28	+0.34		235	
Airport South	J/w FP LION	0		10.54			460	
	Opposite Terminal	1.3	9.43	9.78	+0.34		320	
	J/w AP NTH	2.3	8.94	9.28	+0.34		530	
	J/w FP MAIN	3.0	8.56	9.27	+0.71		530	d/s AP-NTH
Lakes Creek Road	near Fitzroy River Bridge	0		8.21			85	
	Lakes Creek Road (STW)	1.0		8.20			85	
	Lakes Creek Road (Landfill)	2.0		7.38			85	
	J/w Fitzroy River	2.93		7.36			85	
Gavial Creek	Fitzroy River	0		7.74			3,175	
	J/w FP CURTIS	1.03	7.51	7.72	-0.10		4,130	d/s FP CURTIS
	J/w FP MAIN	4.21	7.26	7.20	-0.15		7,370	d/s FP MAIN
	Edinda Lane	6.06		6.52			7,370	

Note: Barrage deleted, otherwise represents 1991 conditions, hence levels in flood plain section do not represent 1954 conditions.

TABLE 2-8

Summary of Model Validation 1918 Flood

Flow Path	Location	Chainage km	Flood Levels			Peak Discharge		Comments
			Observed Level m AHD	Modelled Level m AHD	Difference m	Observed m³/s	Modelled m³/s	
Fitzroy River	Yaamba	100.0	18.62	18.85	+0.23	17,750	17,750	Yaamba hydrograph used as upstream boundary condition
	u/s Pink Lily	134	13.54	13.35	-0.18		17,720	
	start of FP2	139.2	11.84	12.08	+0.24		15,300	2,500 in FP1
	start of FP Main	140.1		12.03			11,960	
	near Water Treatment Works	144.78		11.49			11,240	barrage deleted to model 1918 conditions
	Barrage site	149.27		9.99			11,750	includes flow from Lion Creek
	d/s Barrage site	149.47		10.03			11,750	
		150.17	9.59	9.19	-0.30		11,750	
	Railway Bridge	150.67	9.31	9.00	-0.31		11,750	
	Fitzroy Street Bridge	151.57	8.80	8.64	-0.16		11,750	
	City Flood Gauge	152.57	8.65	8.44	-0.21		11,600	160 m³/s in Lakes Creek Road flow path
	Gavial Creek	154.27	8.53	8.15	-0.38		8,260	4,020 m³/s in Gavial Creek flood flow path
	Edinda Lane	165.02		6.54			17,700	single flow path
		173.00		5.84			17,700	
FP MAIN	J/w Fitzroy River	0.0		12.03			2,400	total breakout flow 6,370 m³/s
	Rockhampton-Ridgelands Road	1.76	11.40	11.56	+0.16		1,710	
	Lotus Lagoon	4.56	11.28	11.53	+0.25		4,660	includes FP1, FP2 less spills to Lion Creek
	Nine Mile Road	6.64		11.14			4,600	includes flow input via Lion Creek
	Start FP SCRUBBY	11.0		10.10			5,130	upstream of junction, 2,150 downstream
	Junction with AP-STH	13.0		9.81			2,940	940 m³/s spills across Capricorn Highway
	u/s Yeppen Crossing	13.6		9.16			2,010	overflow across road/rail of 970 m³/s
	d/s Bruce Highway	13.4		8.88			2,010	
	d/s Yeppen Crossing	14		8.53			1,310	
	Old Burnett Highway	15.51		8.39			4,030	spill 720 m³/s to FP CURTIS
	J/w FP GAVIAL	19.04		7.56			4,030	
FP SCRUBBY	Start	0		10.10			3,000	
	d/s Capricorn Highway	1.3		9.68			3,000	
	u/s Bruce Highway	4.0		9.16			3,940	bridge total 1,610 m³/s
	d/s Railway	4.3		8.54			3,940	overflow across road/rail 2,330 m³/s
	J/w FP MAIN	5.15		8.39			2,720	
FP CURTIS	u/s Bruce Highway	0.69		9.16			540	
	d/s Railway	0.91		8.93			540	
	Depot Hill	2.1		8.44			540	
	Gavial Creek	4.18		8.13			1,900	includes spill from FP MAIN
FP LION	J/w FP MAIN	0		11.14			225	
	J/w AP STH	2.2		11.14			190	
	J/w AP NTH	3.35	11.28	11.12	-0.16		440	
	Fitzroy River	5.3		9.94			440	
Airport North	J/w FP LION	0		11.12			375	
	New Terminal	1.54		10.37			355	spills to AP STH
	J/w AP STH	2.6	9.88	9.82	-0.06		355	
Airport South	J/w FP LION	0		11.14			960	
	Opposite Terminal	1.3		10.38			475	spills to FP MAIN
	J/w AP NTH	2.3	9.8	9.88	-0.05		795	
	J/w FP MAIN	3.0		9.81			795	
Lakes Creek Road	near Fitzroy River Bridge	0		8.64			165	
	Lakes Creek Road (STW)	1.0		8.62			165	
	Lakes Creek Road (Landfill)	2.0		7.82			165	
	J/w Fitzroy River	2.93		7.74			165	
Gavial Creek	Fitzroy River	0	8.53	8.15	-0.38		3,360	
	J/w FP CURTIS	1.03		8.13			5,250	
	J/w FP MAIN	4.21		7.56			9,280	
	Edinda Lane	6.06		6.80			9,280	

Note: Barrage deleted, otherwise represents 1991 conditions, hence levels in flood plain section do not represent 1918 conditions.

2.6 DESIGN FLOODS

2.6.1 General

Following completion of the calibration/validation stage, the hydraulic model was used to simulate water levels resulting from a range of design floods.

This served the following purposes:

- estimation of water levels for a range of flood magnitudes for the development of flood maps;
- estimation of velocities for the delineation of floodways;
- to enable a comparison of water levels under existing conditions with those pertaining to a range of flood mitigation options.

2.6.2 Design Inputs

The required design inputs are:

- flood discharge hydrographs at Yaamba;
- water level hydrographs at the ocean;
- model structure for existing conditions as per model calibration runs.

The design hydrographs were based on the peak discharges given in Table 4-8 of the Phase 1 Report. For floods of 5%, 2% and 1% AEP the shape of the 1991 hydrograph was adopted and scaled to give the appropriate peak discharge. For the more extreme floods (0.5%, 0.2% and 0.1% AEP), the same principle was adopted but the longer duration 1918 flood hydrograph was used. The design hydrographs are plotted in Figure 2-19.

As the calibration runs had shown that, in the area of interest, the model was not sensitive to or influenced by the tidal levels, the design runs were based on a constant tailwater level of 0 m AHD (mean sea level). Sensitivity testing with levels as high as 3 m AHD produced insignificant effect in the region of interest.

2.6.3 Modelled Flood Levels

The results of these runs are shown in Tables 2-9 and 2-10. Table 2-9 shows the distribution of flows between the river and the floodplain over a range of flood discharges of 11,500 m^3/s to 24,000 m^3/s (5% AEP to 0.1% AEP). The 2% AEP flood is almost identical to the 1991 event.

The lower floodplain flow at Yeppen compared to that breaking out of the river at Pink Lily reflects the small proportion returning to the river via Lion Creek, relative timing and storage effects.

TABLE 2-9

Summary of Peak Discharges in Design Runs

Flow Path	Location	Peak Discharge (m^3/s) for AEP of					
		5%	2%	1%	0.5%	0.2%	0.1%
Fitzroy River	Yaamba	11,500	14,200	16,400	19,000	22,500	24,000
	Barrage	9,150	10,250	11,100	12,100	13,400	14,000
Floodplain	Breakout at Pink Lily	2,435	4,130	5,600	7,400	9,810	10,850
	Yeppen Crossing						
	– bridge flow	2,100	2,500	2,650	2,670	2,675	2,680
	– overflow	200	1,410	2,600	4,420	6,920	7,920
	– total	2,300	3,910	5,250	7,090	9,595	10,600

Comparison of this distribution of flows between the river and the floodplain with those from the previous model studies (Table 13-1 of the Phase 1 Report) shows these to be consistent with the two physical models but with substantially greater floodplain flow than the 1987 mathematical model.

Figure 2-20 presents the flow frequency curve from Table 2-9 in graphical form. From this figure it can be seen that the proportion of breakout flow to the total flow increases with the severity of the flood. Data from the previous model tests have been added to this figure. These have been plotted to match the frequency curve for total flow and also show the flow distribution in the earlier models. This illustrates that the current model is broadly consistent with the previous physical models but not with the earlier mathematical model. As the latter was found to give inconsistent results in the review carried out in Phase 1 the latter does not detract from the current model.

Table 2-10 summarises the peak flood levels at a number of locations in the river and the floodplain for the range of flows considered. Levels for floods more extreme than 1% AEP should be regarded as tentative as they may exceed the levels of topographic information.

Comparing the range of levels at Yaamba and at the City Flood Gauge with those given in Table 4-8 of the Phase 1 Report shows that modelled levels at Yaamba are generally above those estimated directly from the sequence of flood level records, converging to a similar value at 0.1% AEP. The figures for Rockhampton are higher than those in Table 4-8 for the less extreme floods but lower for the more extreme floods. As stated in the Phase 1 report, the validity of the values for Rockhampton especially given in Table 4-8 was questionable due to changes in the floodplain characteristics over the years which were reflected in levels reached by certain floods.

A frequency curve based on the modelled values is included in Figure 2-20.

TABLE 2-10

Summary of Peak Flood Levels for Design Runs

Flow Path	Location	Chainage km	Peak Flood Levels (m AHD) for AEP of					
			5%	2%	1%	0.5%	0.2%	0.1%
Fitzroy River	Yeamba	100.0	17.11	17.93	18.52	19.14	19.88	20.18
	u/s Pink Lily	134.0	11.74	12.26	12.69	13.14	13.72	13.96
	start of FP2	139.2	10.97	11.48	11.90	12.32	12.87	13.10
	start of FP Main	140.1	10.88	11.42	11.84	12.27	12.82	13.05
	near Water Treatment Works	144.78	10.23	10.86	11.32	11.77	12.34	12.57
	Barrage	149.27	8.93	9.49	9.91	10.35	10.90	11.13
	d/s Barrage	149.47	8.58	9.17	9.60	10.07	10.65	10.89
		150.17	8.02	8.55	8.96	9.39	9.91	10.13
	Railway Bridge	150.67	7.85	8.35	8.74	9.15	9.64	9.84
	Fitzroy Street Bridge	151.57	7.54	8.03	8.40	8.79	9.26	9.45
	City Flood Gauge	152.57	7.37	7.84	8.21	8.59	9.04	9.23
	Gavial Creek	154.27	7.13	7.58	7.94	8.30	8.73	8.91
	Edinda Lane	165.02	5.71	6.10	6.38	6.68	7.03	7.18
		173.00	5.05	5.43	5.69	5.97	6.30	6.43
FP MAIN	J/w Fitzroy River	0.0	10.88	11.42	11.84	12.27	12.82	13.05
	Rockhampton-Ridgelands Road	1.75	10.47	11.04	11.41	11.75	12.24	12.47
	Lotus Lagoon	4.56	10.37	10.99	11.38	11.73	12.23	12.46
	Nine Mile Road	6.63	9.93	10.55	10.95	11.39	11.92	12.15
	Start FP SCRUBBY	11.0	8.83	9.43	9.89	10.35	10.87	11.09
	Junction with AP-STH	13.0	8.48	9.15	9.60	10.04	10.54	10.74
	u/s Yeppen Crossing	13.6	8.06	8.64	9.00	9.32	9.67	9.83
	d/s Bruce Highway	13.84	7.83	8.39	8.71	9.06	9.48	9.64
	d/s Yeppen Crossing	14.0	7.60	8.10	8.36	8.75	9.24	9.42
	Old Burnett Highway	15.15	7.49	7.96	8.22	8.60	9.07	9.24
	Old Bruce Highway	16.98	6.73	7.24	7.47	7.83	8.27	8.47
	J/w FP GAVIAL	19.04	6.67	7.08	7.38	7.72	8.13	8.29
FP SCRUBBY	Start	0	8.83	9.43	9.89	10.35	10.87	11.09
	d/s Capricorn Highway	1.3	8.17	9.00	9.46	9.91	10.40	10.61
	u/s Bruce Highway	4.0	7.91	8.63	8.99	9.31	9.66	9.82
	d/s Railway	4.3	7.59	8.10	8.37	8.77	9.27	9.45
	J/w FP MAIN	5.15	7.49	7.96	8.22	8.60	9.07	9.24
FP CURTIS	u/s Bruce Highway	0.69	7.13	8.64	8.96	9.32	9.67	9.83
	Port Curtis Junction	0.91	7.26	8.37	8.76	9.10	9.49	9.66
	Depot Hill	2.1	7.12	7.67	8.19	8.67	9.19	9.37
	Gavial Creek	4.2	7.11	7.56	7.91	8.30	8.74	8.89
FP LION	J/w FP MAIN	0	9.93	10.55	10.95	11.39	11.92	12.15
	J/w AP STH	2.2	9.79	10.43	10.90	11.45	12.09	12.33
	J/w AP NTH	3.35	9.39	10.25	10.86	11.45	12.09	12.34
	Fitzroy River	5.3	8.93	9.49	9.91	10.35	10.90	11.13
Airport North	J/w FP LION	0	9.39	10.25	10.86	11.45	12.09	12.34
	New Terminal	1.54	8.64	9.61	10.15	10.64	11.20	11.43
	J/w AP STH	2.6	8.64	9.16	9.61	10.05	10.55	10.76
Airport South	J/w FP LION	0	9.79	10.43	10.90	11.45	12.09	12.33
	Opposite Terminal	1.3	8.59	9.61	10.15	10.65	11.20	11.43
	J/w AP NTH	2.3	8.48	9.16	9.61	10.05	10.55	10.76
	J/w FP MAIN	3.0	8.48	9.15	9.60	10.04	10.54	10.74
Lakes Creek Road	near Fitzroy River Bridge	0	7.54	8.03	8.40	8.79	9.26	9.45
	Lakes Creek Road (STW)	1.0	7.53	8.01	8.39	8.77	9.22	9.41
	Lakes Creek Road (Landfill)	2.0	6.84	7.26	7.61	7.99	8.48	8.69
	J/w Fitzroy River	2.93	6.80	7.21	7.54	7.88	8.29	8.45
Gavial Creek	Fitzroy River	0	7.136	7.58	7.94	8.30	8.73	8.29
	J/w FP CURTIS	1.03	7.11	7.56	7.92	8.28	8.71	8.89
	J/w FP MAIN	4.21	6.66	7.08	7.38	7.72	8.13	8.29
	Edinda Lane	6.06	6.12	6.43	6.65	6.92	7.25	7.39
Splitters Creek		1.1	8.93	9.51	9.92	10.54	11.16	11.42
		2.1	8.93	9.50	9.91	10.38	10.98	11.23

Note: Levels for floods of AEP < 1% are tentative.

Longitudinal profiles for the Fitzroy River and the main floodplain flow for the modelled range of design floods are given in Figures 2–21 to 2–23.

The values given by design runs of the model, whilst they include model error, do present a consistent set of values being based on 1991 conditions, as modelled.

2.6.4 Flood Mapping

The flood levels obtained from these design runs were utilised to produce flood maps for existing conditions as described in Section 4.

2.7 FLOOD MITIGATION OPTIONS

2.7.1 General

Following completion of the calibration/validation process the model was modified to simulate the impacts of a number of flood mitigation options on flood levels and flow distribution.

This section describes the use of the model in this context and is limited to a consideration of the hydraulic impacts of such options. A discussion of the flood mitigation options themselves including a summary of the hydraulic aspects but also considering costs, social and environmental impacts is given in Section 3 hereof.

Those options listed in section 1.2 were considered firstly on an individual basis and then in various combinations, as described in the following paragraphs.

The range of options and impacts considered was:

- levee construction: Port Curtis – Depot Hill – Lower CBD and Depot Hill – Lower CBD only;
- levee construction: airport including the effect of the proposed runway extension;
- levee construction: Splitters Creek;
- improving flood immunity of the Yeppen Crossing, together with lessening the impact on upstream flood levels;
- reduction in floodplain flows by raising breakout control levels in the Pink Lily area;
- construction of a major floodway to the south of the city, either in whole or in part;
- impact of Commonage Landfill;
- lowering the elevated section of the Capricorn Highway.

These options were considered principally in relation to 2% and 1% AEP floods. The following paragraphs discuss the findings for these options.

2.7.2 Levees Port Curtis - Depot Hill - Lower CBD (Options A1, A2)

a) Option A1 - Depot Hill - CBD Only

The proposed levee around Depot Hill and lower CBD (Option A1) but excluding Port Curtis (scheme 2 on Figure 14-5 in Phase 1 Report) would not have significant impact on flood levels as the area protected is primarily flood storage and not a high velocity floodway. This was borne out by modifying the model to account for reduction in flow cross-section in the FP-CURTIS flow path, the results of this and other runs being given in Appendix J (Table J-1).

The impact of this scheme would be to raise the peak level in the river by a maximum of 0.03 m at the City flood gauge for 2% AEP flood and 0.04 m for 1% AEP. Levels in the Port Curtis flow path adjacent to the levee would be raised by 0.08 m, 0.09 m for 2%, 1% AEP. Elsewhere in the floodplain modelled level differences are negligible. It is considered that the above increases are acceptable.

b) Option A2 - Port Curtis - Lower CBD

The combined Port Curtis - Depot Hill - Lower CBD levee (Option A2) has a significantly greater impact on flood levels as it effectively blocks the FP-CURTIS flow path. The impact of this levee option was modelled by removing this flow path, and its associated spills, from the model. The results for this option are given in Table J-2.

This levee scheme would raise the level in the main floodway downstream of Yeppen Crossing by about 0.6 m for 2% AEP flood and 0.9 m for 1% AEP. This, in itself, is not a problem as there is little development in this part of the floodplain. Of greater impact, is the increase in the flood level on the upstream side of Yeppen crossing of 0.30 m for 2% AEP, and 0.42 m at 1% AEP. This impact reduced to near zero at Nine Mile Road for 2% AEP but was still 0.14 m at 1% AEP. In the airport region, if this were not itself protected, levels would be raised by about 0.07 m near the terminal and 0.14 m at the southern end and in the Fairybower Road area for 2%, 1% AEP floods.

It is unlikely that the above would be acceptable without some compensatory works. The following were considered in this regard:

- lower levels downstream of (and hence also upstream of) Yeppen Crossing by removal of old embankments and/or channel works;
- lower levels upstream of Yeppen Crossing by means of works at the crossing itself to increase bridge waterway area;
- reduce floodplain flow by raising breakout levels at Pink Lily.

These combinations are considered in Section 2.7.11.

2.7.3 Levee Construction at Rockhampton Airport (Options A3, A4)

Two scenarios were considered in regard to Rockhampton airport, namely:

- levees to provide protection to the existing airport up to 1% AEP;
- as above, but allowing for the proposed runway extension to the north extending across Lion Creek.

a) Protection to existing airport (Option A3)

The effect of protection of the existing airport was modelled by removing the flow paths AP-NTH and AP-STH and their associated spills.

The effect of this would be to reduce the capacity of the floodway and increase the proportion of the breakout flow from the Pink Lily area returning to the river via Lion Creek. This results (see Table J-3) in increased levels in Lion Creek of up to 0.37 m for 2% AEP and 0.58 m for 1% AEP, and a small increase of 0.03 m for 2% AEP and 0.07 m for 1% AEP at the Barrage, reducing to 0.01 m, 0.02 m respectively at the City Flood Gauge. Between the Pink Lily breakout and Nine Mile Road, levels in the upper part of the floodway would be increased by up to 0.1 m and 0.2 m at 2% AEP and 1% AEP respectively. At the Yeppen Crossing, the level would be reduced by 0.04 m at 2% AEP and 0.08 m at 1% AEP due to a small decrease in floodplain flow which results from the greater return flow via Lion Creek mentioned above.

b) Protection of Extended Airport (Option A4)

The proposed extension of the main runway to the north-west along Lion Creek would have a more profound effect on floodplain flows. Whilst it is anticipated that low flows from Lion Creek would either be carried under the runway in a culvert, or diverted around the northern boundary, the capacity of such drainage works is likely to be limited. As no details are available of the works which would be required, the effect of these works has been modelled approximately by severely restricting the capacity of the centre sections of FPLION and FP3.

Results given in Table J-4 show very little difference from the previous case of protection of the existing airport with maximum increase of 0.37 m for the 2% AEP flood and 0.58 m for 1% AEP flood in Lion Creek due to the redistribution of flows.

2.7.4 Levee Construction – Splitters Creek Area (Option A5)

A levee along the left bank (looking downstream) of the Fitzroy River near Splitters Creek (scheme 9 on Figure 14-5 of Phase 1 Report) would prevent the overflow occurring in that area and hence reduce flooding of this mainly residential area.

The impact of this on flood levels in the river was modelled by removing the SPLITTERS flow path. The results are given in Table J-5 which show the effect of this to be minimal.

2.7.5 Yeppen Crossing (Options B1-B9)

Works at Yeppen crossing would have 2 potential impacts, namely:

- reduction in closure times of this major crossing and hence reduction of indirect flood damage for the whole area;
- reduction in flood levels in the Fairybower Road area.

The first could be achieved primarily by raising the level of the approach embankments, say to the bridge levels, and the second by increasing the bridge waterway area.

These were studied initially separately and then in combination, as outlined below:

a) Increased Waterway Area (Options B1, B6)

Increased waterway area was considered both from bridge widening and lowering of bridge inverts. The current bridging length is 420 m. Increasing the bridge waterway area to twice the current amount was considered (Option B1). Results from this run are given in Table J-6. It is outside the scope of the present study to provide final design data, so if this proposal is adopted further analysis will be required to finalise bridge dimensions.

With doubling of the bridge waterway area (assuming each bridge would be doubled in length), the flood level on the upstream side of the Yeppen crossing would be reduced by 0.27 m and 0.29 m in 2% and 1% AEP floods respectively. Times of submergence would be reduced by 1.85 days (to 9.75 days) and 0.72 days (to 11.95 days) respectively. At the airport, levels would be reduced by 0.08 m and 0.14 m at the terminal area and southern end of the runway respectively for both 2% and 1% AEP floods. Flood levels would be reduced by 0.06 m and 0.10 m at Depot Hill for 2% and 1% AEP events with corresponding reduction at Port Curtis of 0.1 m and 0.25 m respectively due to reduced flow in the FP-CURTIS flow path. Levels in the main floodplain flow path FP-MAIN would be increased marginally by 0.05 m, 0.08 m downstream of the Yeppen crossing. There was an insignificant effect on levels in the city reach of the river.

Discharges through the bridges would increase by about 30% only but the afflux caused by the bridges would be significantly reduced. Velocity through the various bridges would range from 1.2 m/s to 1.7 m/s at 2% AEP, compared to 1.9 m/s to 2.8 m/s under existing conditions.

An alternative means of increasing waterway area would be to lower the invert level (ie. the bed level) below each bridge. The feasibility of this is considered in section 3, this section reports only the hydraulic effects. This possibility was investigated assuming a reduction in bed level of 2 m. This reduction was assumed to continue between the road and rail bridges with transition back to existing surface levels upstream of the highway bridges and downstream of the railway bridges. The result of this run (Option B6) is given in Table J-10.

This was found to have as nearly a beneficial impact on flood levels as bridge duplication, but with rather less improvement in regard to time of submergence. Bridge velocities were reduced compared to existing conditions and were in the range 1.4 to 2.0 m/s at 2% AEP.

b) **Increased embankment height (Options B3, B4)**

The existing road and rail crossings are higher at the bridges than in between. The simplest way of increasing embankment height to reduce closure time would be to increase the level of the road/rail sections between bridges to that at the bridges themselves. This represents a maximum increase of about 1.0 m. An intermediate increase of 0.5 m was also considered. Greater increases were not considered due to the need then to raise the bridges.

The results from these model runs (Tables J-7 and J-8) showed that with embankment heights raised to give constant road and rail height across the bridges and embankments, but with no change to waterway area, there would be an increase in flood level on the upstream side of Yeppen crossing of 0.38 m for 2% AEP and 0.31 m for 1% AEP. The corresponding increases at the Airport (terminal area) would be 0.16 m and 0.11 m increasing to 0.23 m, 0.19 m at the southern end of the airport and in the Fairybower Road area. Time of submergence would reduce by 4 days to 7.6 days for 2% AEP and by 3 days to 9.63 days for 1% AEP.

The entire crossing including the bridges would be overtopped in both of the events considered.

c) **Combinations of the above (Options B5, B7)**

Following the above separate consideration of various measures, their combined effect was investigated.

The combined effect of embankment raising (to bridge level) and doubling of the existing bridge waterway area was modelled as Option B5, the results being given in Table J-9.

This combination would not be overtopped in a 2% AEP flood providing a continuous kerb is provided between bridge sections, and would have a time of submergence in 1% AEP flood of 6.82 days, a reduction of 5.85 days. This combination would also result in a reduction in flood levels upstream of the Yeppen crossing of 0.17 m for 2% AEP reducing to 0.05 m for 1% AEP. At the airport (terminal) the reductions would be 0.05 m, and 0.02 m respectively, increasing to 0.09 m, 0.03 m at the southern end of the airport and at Fairybower Road. Bridge flow velocities at 2% AEP would be in the range 1.2 m/s to 2.0 m/s.

Flood levels would also be lowered in the Depot Hill area due to reduced overflow in the FP-CURTIS flow path. This effect is greatest just downstream of the railway where levels would be 0.78 m, 0.63 m lower for 2% and 1% AEP floods compared to existing conditions. At Depot Hill these differences would be 0.08 m, 0.15 m respectively.

Slightly higher levels would result in the main floodway downstream of Yeppen crossing because of the reduced flow in FP–CURTIS. However, this is a maximum of 0.06 m, 0.11 m for 2% and 1% AEP floods immediately downstream of the crossing and is of little consequence.

The combination of raising embankment height to give constant level across the crossing, and reducing invert levels through the bridges was considered as Option B7. The results of this run are summarised in Table J–11. This combination would also result in the crossing not being overtopped at 2% AEP, but would have an increased submergence time at 1% AEP of 8.0 days compared to 6.8 days with Option B5. Bridge flow velocities would be in the range of 1.7 to 2.3 m/s for 2% AEP, thus scour protection would need to be provided.

Flood levels would be reduced upstream of Yeppen Crossing by 0.03 m for 2% AEP, but would be increased by 0.14 m for 1% AEP compared to existing conditions. Airport flood levels would be reduced by only 0.01 m for 2% AEP, but increased by 0.04 m for 1% AEP. Levels at Depot Hill would be reduced by 0.08 m, 0.12 m respectively for 2%, 1% AEP floods.

As Option B7 still had an adverse impact on levels upstream of Yeppen for 1% AEP, two further means of reducing these levels were considered, namely:

- removing the Old Burnett Highway bridge and causeway and the section of disused railway embankment adjacent to the Old Bruce Highway between Port Curtis and Roopes Bridge (Option B8);
- as above together with construction of 200 m wide channel from downstream of the Yeppen 1 bridge to continue the lowered invert to below Edinda Lane (Option B9).

The results from these runs are given in Tables J–12 and J–13.

Option B8 produced a substantial improvement over Option B7. Flood levels upstream of Yeppen Crossing were reduced by 0.41 m for 2% AEP and by 0.09 m for 1% AEP, with reductions at the Airport of 0.15 m, 0.25 m respectively. Time of submergence was again zero for 2% AEP and reduced to 3.7 days for 1% AEP.

Option B9 produced only marginal benefit over Option B8 and was clearly not worthwhile. This conclusion would be reinforced when costs were also considered.

2.7.6 Control of Breakouts at Pink Lily and Gavial Creek (Options D1 to D4)

The threshold level at which flows commence in the main floodplain is controlled by the bank levels along the right bank of the Pink Lily meander. As discussed in section 13.4 of the Phase 1 Report, stabilisation is required to limit the continuing erosion of the meander, both because of its lateral progression but also because the control level will reduce as erosion progresses.

Stabilisation works in this area would also provide the opportunity to alter the control level. Raising the control level and/or reducing the length over which breakout flow takes place would have the effect of reducing flow and hence flood levels in the floodplain, but at the expense of raising flood levels in the City reach of the river. Conversely, lowering the control level, which would require excavation, would increase flows and the incidence of flows occurring in the floodplain and reduce flow and flood levels in the City reach.

It was considered that increasing flows in the floodplain by this means would be unacceptable, as would significantly raising flood levels in the city reach. However, as varying the control level could be a means, for example, of compensating the effect on floodplain levels of levee construction at Port Curtis, the impact of raising the control levels by 1.0 m was investigated (Option D1). This was done by raising the inlet weir levels in floodplain flow paths FP-MAIN, FP1 and FP2 by these amounts. The results of this run is given in Table J–14.

Raising the control level by 1.0 m was effective in lowering the 2% AEP flood level on the upstream side of Yeppen crossing by 0.22 m but this effect reduced to 0.09 m for 1% AEP flood. Levels at the airport were lowered by a maximum of 0.45 m in the terminal area for 2% AEP and 0.14 m for 1% AEP. Levels at Port Curtis were lowered by 0.20 m and 0.08 m respectively for these 2 flood magnitudes.

Conversely, flood levels at the Barrage were raised by 0.32 m for 2% AEP and 0.14 m for 1% AEP, with corresponding values at the City flood gauge being 0.10 m and 0.04 m respectively.

Extension of this principle was explored by further raising the Pink Lily breakout levels by an extreme amount, sufficient to prevent breakout flow occurring under a 2% AEP flood (Option D2). This was found to require breakout control levels to be raised to about 13.2 m, corresponding to an embankment with maximum height of about 4.5 m. If this were acceptable, it would eliminate the need for improvements at Yeppen Crossing. The results of this run (Table J–15) show that this would be effective in the latter regard, with Yeppen Crossing flood free at 1% AEP, and flood levels upstream of Yeppen being reduced by 1.57 m for 2% AEP and 1.29 m for 1% AEP. However, this would also cause significant rise in the flood levels in the city reach of the Fitzroy River. Increases in level at Pink Lily would be 1.3 m, 1.66 m for 2% and 1% AEP floods. Corresponding increases at the Barrage would be 1.14 m, 1.35 m and 0.49 m, 0.51 m at the City Flood gauge. It was considered that such an increase in levels in the city reach would not be acceptable.

Levels in the Depot Hill area would be worsened because of higher flows in the river and the Gavial Creek flow path and these levels were estimated to be increased by up to 0.25 m.

A compromise between Options D1 and D2 was subsequently tested, Option D3 with breakout level raised by 2.5 m. The results for this are given in Table J–16. In this case levels upstream of Yeppen were reduced by 0.71 m for 2% AEP and by 0.49 m for 1% AEP, sufficient to reduce time of submergence to 6.5 days and 9 days for 2% and 1% AEP respectively. Flood levels in the river would be raised by a maximum of about 1.2 m at Pink Lily for both events, 0.71 m for 2% AEP and 0.55 m for 1% AEP at the Barrage and 0.27 m, 0.19 for 2%, 1% AEP at the City flood gauge.

None of the above were considered to be suitable as stand alone measures but they were considered further in regard to combinations of measures.

As a further means of reducing floodplain flow the effect of reducing floodplain tailwater level by increasing the level at which breakout occurs for the Fitzroy River near the Gavial Creek junction was briefly investigated as Option D4. The results of this run are given in Table J–17. This was found to be ineffective in producing a marked reduction in floodplain levels but did increase river level by up to 0.7 m (at Gavial Creek) for 2% AEP. This was not considered further.

2.7.7 Improving Hydraulic Capacity Downstream of the Pink Lily – Yeppen – Gavial Creek Floodway (Options F3, F4)

Improving the hydraulic capacity of the floodplain downstream of Yeppen Crossing was investigated in two stages, namely:

a) removal of the bridge and causeway on the Old Burnett Highway together with the removal of disused railway embankment adjacent to the Old Bruce Highway (Option F3);

b) as above, together with excavation of a channel 900 m wide with invert level at 4.2 m AHD to the junction of the FP–MAIN and FP–GAVIAL flow paths (Option F4).

a) Option F3

The results of model runs to test these options are given in Tables J–18 a, b from which it can bee seen that the effect on flood levels and times of submergence at Yeppen are minimal.

The maximum reduction in water level with Option F3 for 1% AEP would be 0.07 m upstream of Yeppen and 0.17 m downstream with a reduction of times of submergence of only 0.04 days for 1% AEP and 0.6 days for 2% AEP.

This options would reduce flood levels in Port Curtis and Depot Hill by about 0.1 m for both 2% and 1% AEP floods.

Whilst this option is not sufficient alone, it was considered further in regard to combinations of measures, as discussed in 2.7.5 c.

b) Option F4

In regard to Option F4, the scope for channel improvement is limited because of very flat gradients in this area. In order to give an indication of the potential for lowering tailwater levels at Yeppen by this means, a model run was carried out with a channel at constant bed level of 4.2 m from downstream of Yeppen Crossing to Gavial Creek and with a bed width of 900 m, thus representing a major channel. The effect of this was to lower the flood level on the upstream side of Yeppen Crossing by 0.11 m for 2% AEP and 0.09 m for 1% AEP which is only a marginal improvement relative to removing the Old Burnett Highway bridge and the disused rail embankments adjacent to the Old Bruce Highway (Option 3). Similarly, downstream of Yeppen Crossing the water levels were lowered by 0.28 m for 2% AEP and 0.23 m for 1% AEP compared to 0.17 m for 1% AEP for Option F3.

Time of submergence of Yeppen Crossing was only marginally reduced by 0.8 days for 2% AEP and 0.67 days for 1% AEP for Option F4. This option would reduce water levels at Port Curtis and Depot Hill by about 0.16 m for both 2% AEP and 1% AEP floods.

This option was not considered to be worth pursuing.

2.7.8 Major Floodway (Option E1)

The option of a major floodway had been discounted in Phase 1 because of limited effectiveness, high cost and high environmental impact. It was reintroduced subsequent to being raised in written submissions received as part of the community consultation process. It has, therefore, been investigated in Phase 2 using the hydraulic model.

The floodway was modelled as a major channel with 1,000 m wide base width and 1,000 m wide right overbank channel, on a constant grade from the upstream part of the Pink Lily meander to Gavial Creek. Due to the very large nature of such a channel, it was assumed that new bridging would be incorporated as necessary. The remainder of the Pink Lily meander would need to have levees constructed to prevent outflow outside of the flood relief channel.

The results are given in Table J–19.

Levels would generally be higher in the channel than would occur under existing conditions. The capacity of the modelled channel was 3,570 m^3/s at 2% AEP and 4,580 m^3/s at 1% AEP, which is insufficient to have any beneficial impact on flood levels in the city reach. This option did not warrant further consideration.

2.7.9 Commonage Landfill (Option M1)

The impact the commonage landfill has on flood levels was investigated by removing the LAKESCK flow path from the model, thus simulating the effect of completely blocking the flow path. The results of model runs are given in Table J–20.

These runs show that this have a negligible impact, raising flood level at the City Flood gauge by 0.01 m for both 2% AEP and 1% AEP.

This has no impact on flows and levels in the main floodplain.

2.7.10 Lowering Capricorn Highway (Option M3)

Parts of the Capricorn Highway between the Bruce Highway roundabout and the edge of the floodplain near Gracemere are raised above existing ground level by up to about 1.5 m. The effect of lowering the highway, in the raised sections, by 1 m was investigated, and the results given in Table J–21.

This was found to be ineffectual, lowering the level on the upstream side of the Capricorn Highway by a maximum of 0.1 m for 2% AEP with a subsequent increase in level on the downstream side due to flow redistribution. For a 1% AEP flood, the impact was negligible. Due to the ineffectual nature of the option, this was not considered further.

2.7.11 Other Combinations (Options C1 to C10)

In addition to the options discussed above the following combinations were tested. Comparison of these options on economic and impact grounds is held over until Section 3 hereof. All the combined options include upgrading of Yeppen Crossing in order to enable substantial reductions to be made in indirect losses. Options C1 – C5 are based on lowering the inverts under the existing Yeppen bridges as well as raising embankment levels to bridge height. Options C6 – C10 are based on bridge duplication and embankment raising.

Option C1

- combination of the Levee from Port Curtis to the CBD (Option A2) with Option B8 to upgrade Yeppen Crossing (raise embankment, lower inverts, demolish old highway bridge and remove old railway embankment).
- this would provide protection to the flood liable areas of Port Curtis, Depot Hill and the CBD and would also raise the flood immunity of the Yeppen Crossing to 2% AEP.
- the results for this run are given in Table J–23. The flood level upstream of Yeppen would be reduced by 0.03 m for 2% AEP, but increased by 0.24 m at 1% AEP. In the Fairybower area the corresponding figures were –0.05 m, 0.11 m respectively.
- time of submergence at Yeppen Crossing would be zero at 2% AEP, 8 days at 1% AEP.

Option C2

- as for C1 plus levee to protect Rockhampton airport and a levee to prevent overflow in the Splitters Creek area.
- substantially as above – see Table J–24. The presence of the airport levee reduces levels in the Fairybower – Yeppen section (as for Option A3), with this combination reducing levels upstream of Yeppen by 0.09 m for 2% AEP, but increasing level by 0.17 m for 1% AEP.
- levels along Lion Creek adjacent to the levee would be raised by a maximum of 0.36 m at 2% AEP and by 0.59 m at 1% AEP.
- levels along the Rockhampton–Ridgelands Road would be raised by 0.05 at 2% AEP and by 0.12 m at 1% AEP.
- time of submergence at Yeppen Crossing would be zero for 2% AEP and 7.8 days for 1% AEP.

Option C3

- as Option C1 but with Port Curtis excluded from the protected area. Obviously this is to the detriment of Port Curtis but still provides levee protection to Depot Hill and the Lower CBD including the area subject to backwater flooding from the main drain.
- this has a positive impact on flood levels in the main floodway for 2% AEP with a reduction of 0.24 m upstream of Yeppen Crossing (see Table J–25). For 1% AEP the level upstream of Yeppen is unchanged from current conditions.

- time of submergence of Yeppen Crossing would be zero at 2% AEP and 7 days at 1% AEP.

Option C4 – as Option C3 but with levees around the airport and to prevent overflow into Splitters Creek. The results given in Table J-26 show that levels at Yeppen would be further reduced compared to Option C3. Levels upstream of Yeppen would be 0.3 m lower for 2% AEP than under existing conditions, and 0.06 m lower for 1% AEP.
- time of submergence of Yeppen crossing would be zero for 2% AEP and 6.5 days for 1% AEP.

Option C5 – as Option C2 but with breakout threshold levels at Pink Lily raised by 1.25 m. This was modelled to compensate for the worsening of peak flood levels upstream of Yeppen Crossing in Option C2. Results are given in Table J-27. This would result in reductions in levels at Yeppen of 0.53 m for 2% AEP and 0.02 m at 1% AEP compared to existing conditions. However, levels in the river would rise, by 0.50 m and 0.33 m for 2%, 1% AEP near the water treatment works, 0.30 and 0.20 m at the Barrage and 0.17 m, 0.08 at the City flood gauge. This is the minimum raising at Pink Lily which would cause no worsening of levels upstream of Yeppen.

Option C6 – C10 are similar to options C1 – C5 in the combinations given below except that they are based on duplication of the Yeppen bridges instead of invert lowering.

Option C6
- as per Option C3, see Table J-28 for results.
- the peak flood level upstream of Yeppen was 0.16 m lower for 2% AEP and 0.07 m lower for 1% AEP.
- corresponding levels in the Fairybower road area would be 0.09 m, 0.03 m lower.
- time of submergence at Yeppen would be zero for 2% AEP, 6.9 days for 1% AEP.
- marginal increases in river level of 0.02 m maximum would occur.

Option C7
- as per Option C4, see Table J-29 for results.
- the peak flood level upstream of Yeppen would be 0.20 m lower for 2% AEP and 0.13 m lower for 1% AEP.
- corresponding levels in the Fairybower area would be 0.18 m, 0.19 m lower.
- levels along Lion Creek would be raised by 0.37 m, 0.55 m maximum outside the airport levee.
- levels in the river would be increased by a maximum of 0.04 m, 0.08 m for 2%, 1% AEP between the water treatment works and the barrage.
- time of submergence at Yeppen would be zero for 2% AEP, 6.4 days for 1% AEP.

Option C8
- as per Option C1, see Table J-30 for results.
- the peak flood level upstream of Yeppen was 0.28 m lower than for existing conditions for 2% AEP and 0.02 m lower for 1% AEP.

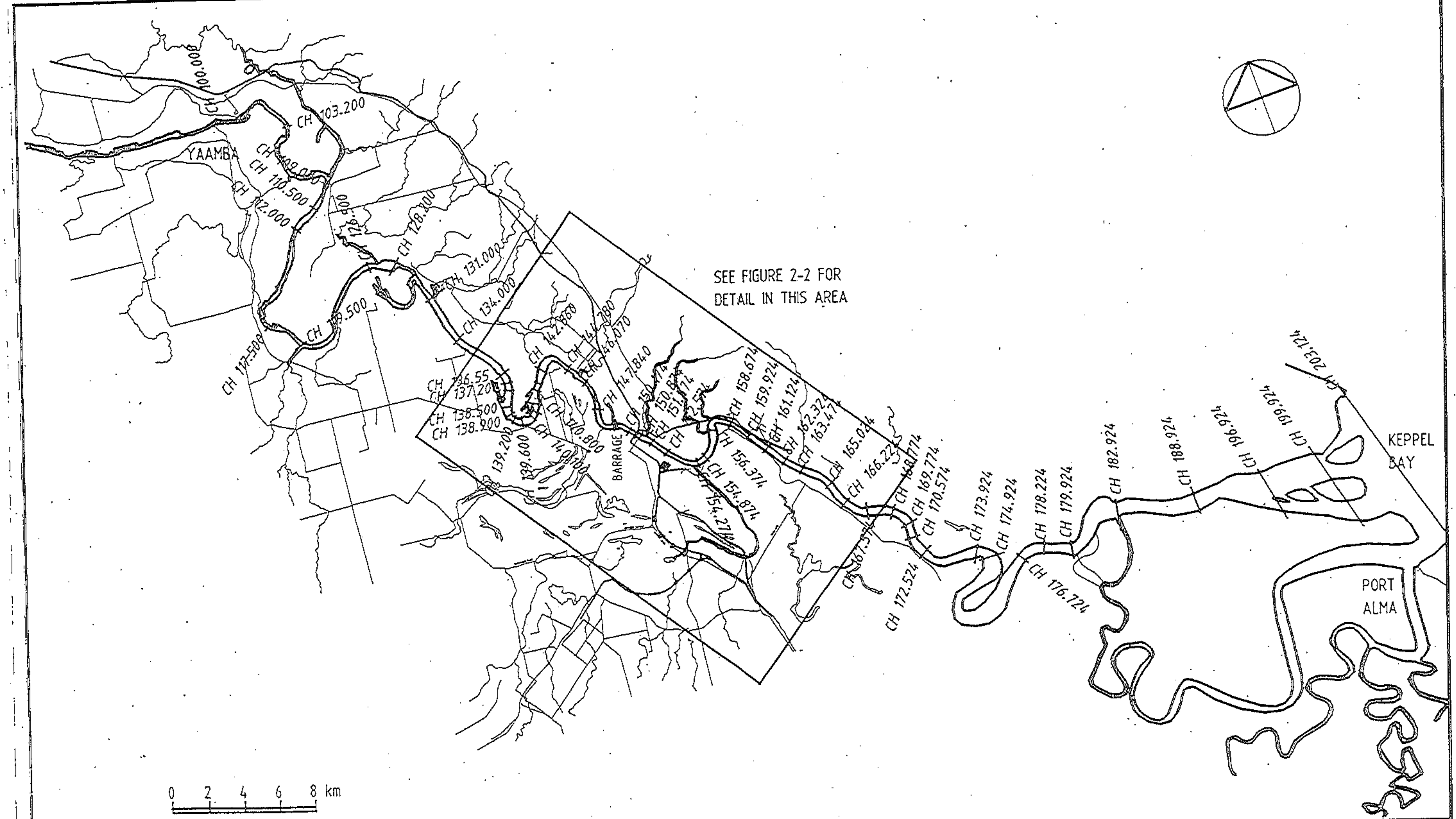
- Levels in the Fairybower area would be decreased by 0.15 m, 0.02 m for 2%, 1% AEP respectively.
- Time of submergence would be zero for 2% AEP, 6.5 days for 1% AEP.

Option C9

- as per Option C2, see Table J-31 for results.
- the peak flood level upstream of Yeppen would be reduced by 0.33 m for 2% AEP and by 0.09 m for 1% AEP.
- levels in the Fairybower area would be reduced by 0.25 m in 2% AEP and 0.17 m in 1% AEP.
- levels in the river between Pink Lily and the City would be raised slightly by a maximum near the water treatment works of 0.03 m for 2% AEP, 0.06 m for 1% AEP, and reduced marginally in the City reach (0.02 m, 0.06 m at the City flood gauge for 2%, 1% AEP).
- time of submergence at Yeppen would be zero for 2% AEP and 3.5 days for 1% AEP.

Option C10

- as per Option C9 but with threshold level at Pink Lily raised by 1.25 m, instead of removal of the old highway bridge and disused rail embankment, see Table J-32 for results.
- this would reduce the level upstream of Yeppen crossing by 0.44 m for 2% AEP and by 0.01 m for 1% AEP.
- Maximum increase in level in the river would be 0.45 m higher for 2% AEP, 0.27 m for 1% AEP at Pink Lily, reducing to 0.26 m, 0.15 m for 2%, 1% AEP at the barrage, and 0.10 m for 2% AEP, zero increase for 1% AEP at the City flood gauge.
- there would be small increases of 0.02 m, 0.01 m for 2%, 1% AEP at Yaamba.



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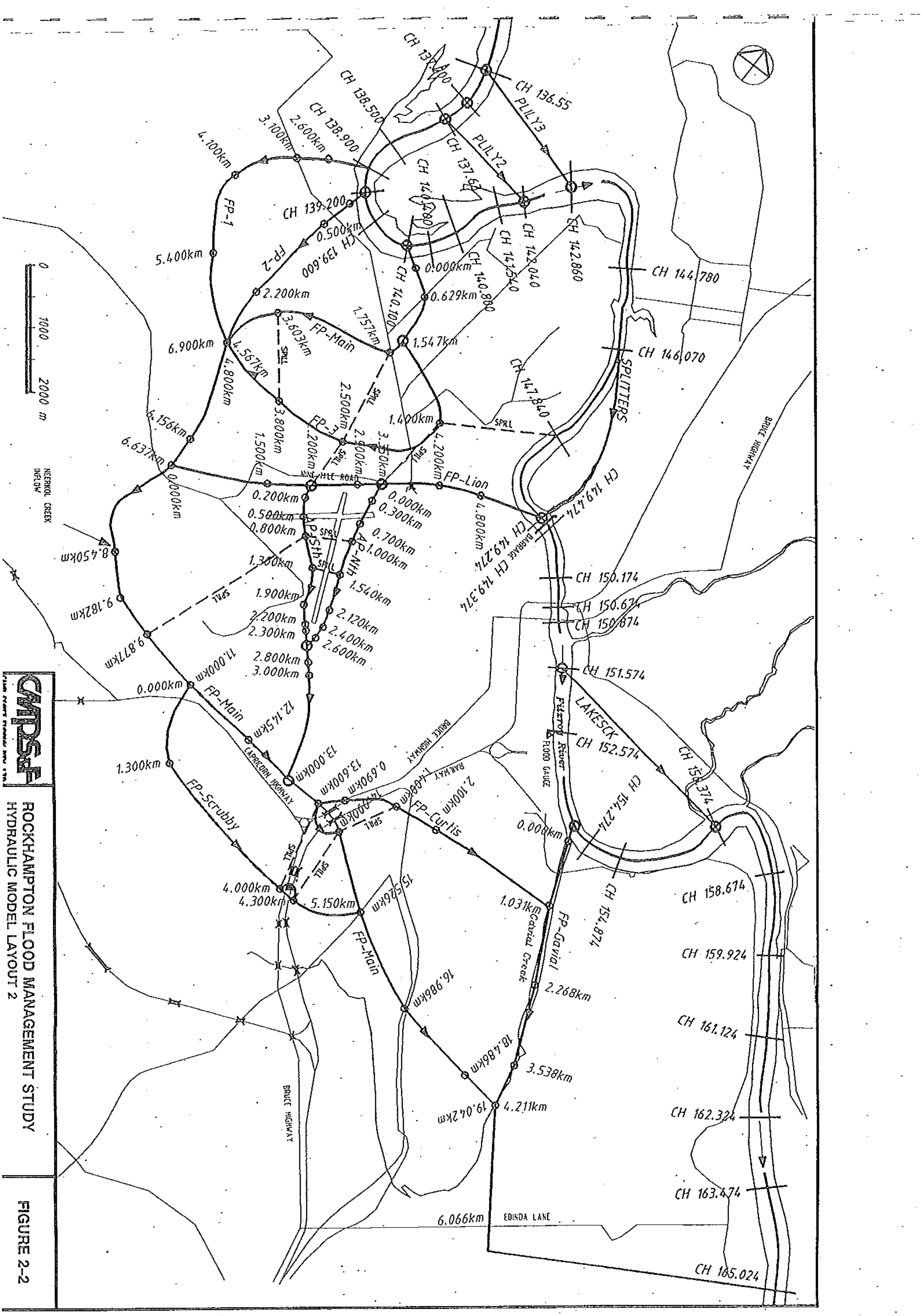
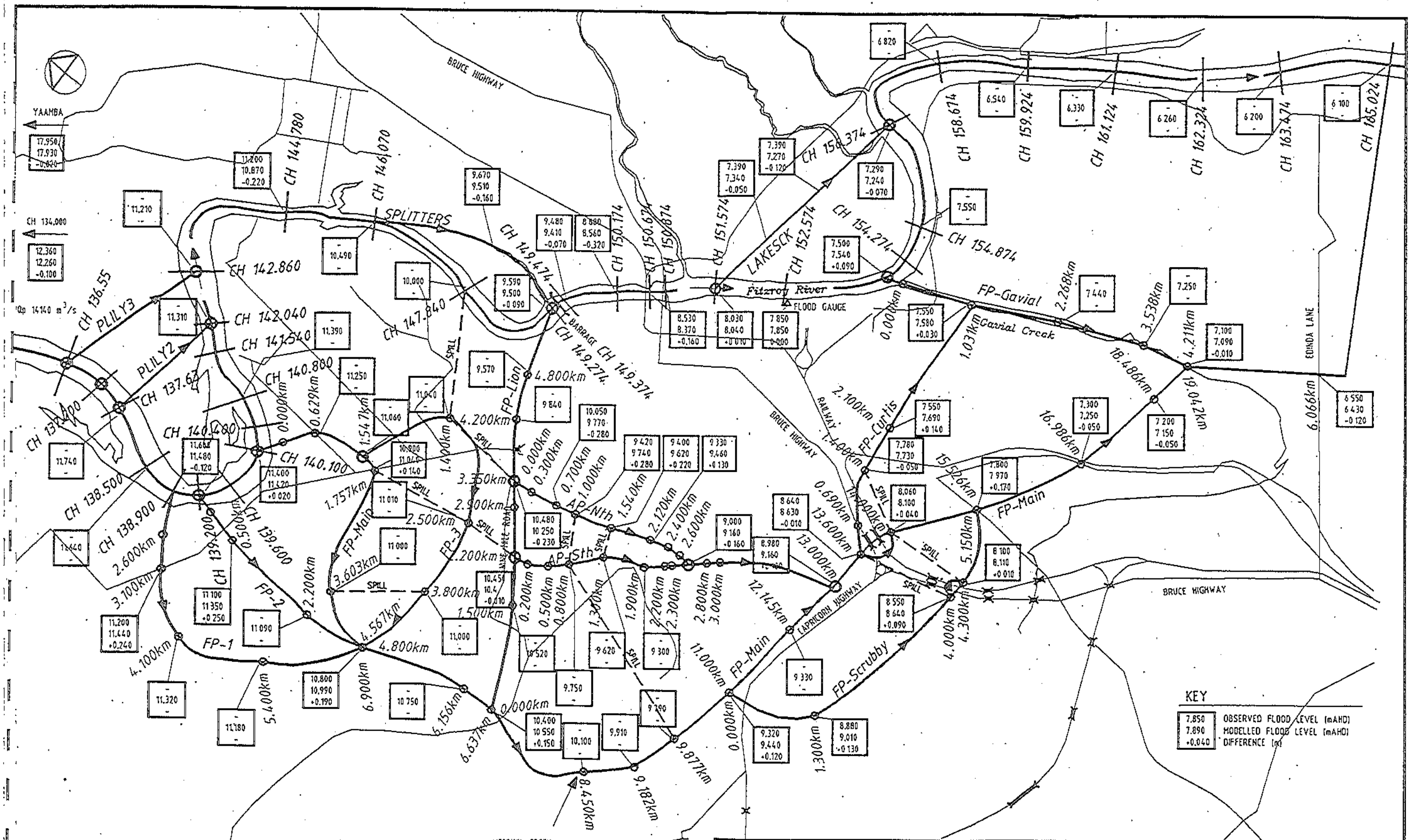
ROCKHAMPTON FLOOD MANAGEMENT STUDY
HYDRAULIC MODEL LAYOUT 1

FIGURE 2-1



ROCKHAMPTON FLOOD MANAGEMENT STUDY
HYDRAULIC MODEL LAYOUT 2

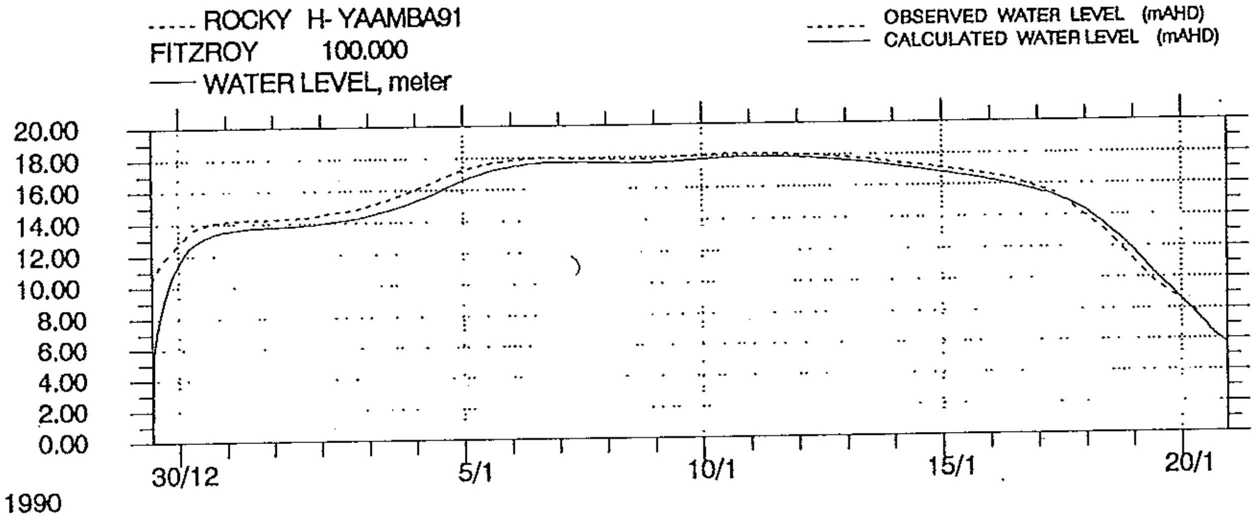
FIGURE 2-2



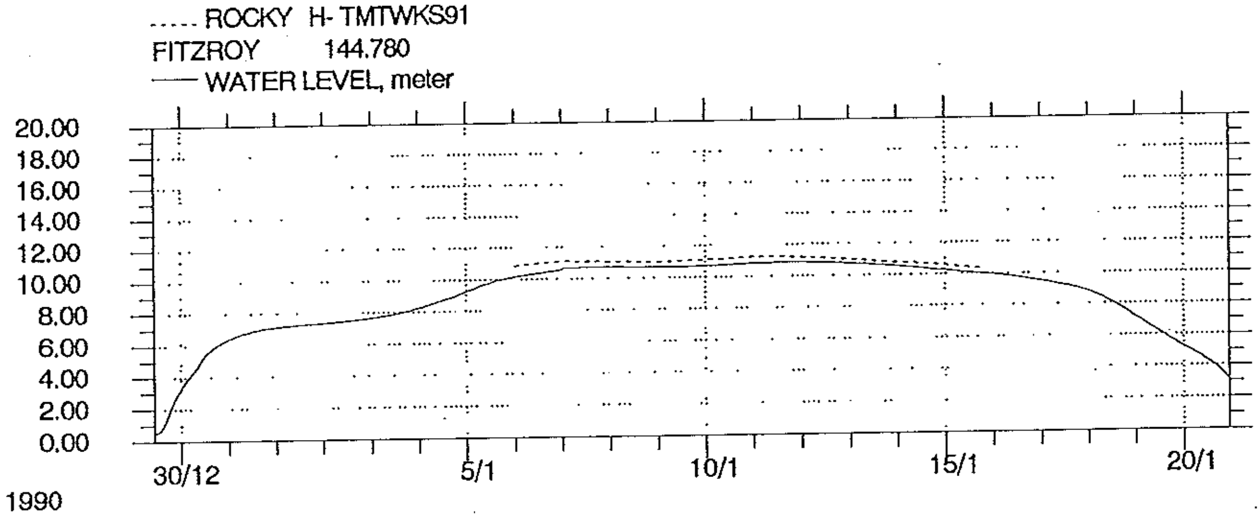
ROCKHAMPTON FLOOD MANAGEMENT STUDY
HYDRAULIC MODEL LAYOUT 2
CALIBRATION 1991 FLOOD

CMPS&F

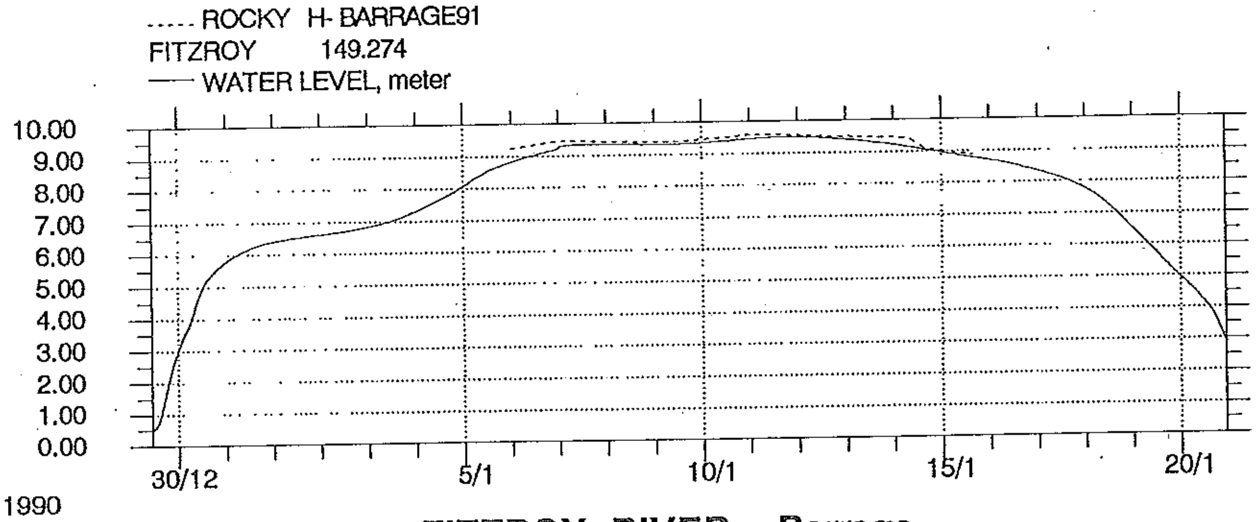
FIGURE 2–3



FITZROY RIVER - Yaamba



FITZROY RIVER - Water Treatment Works



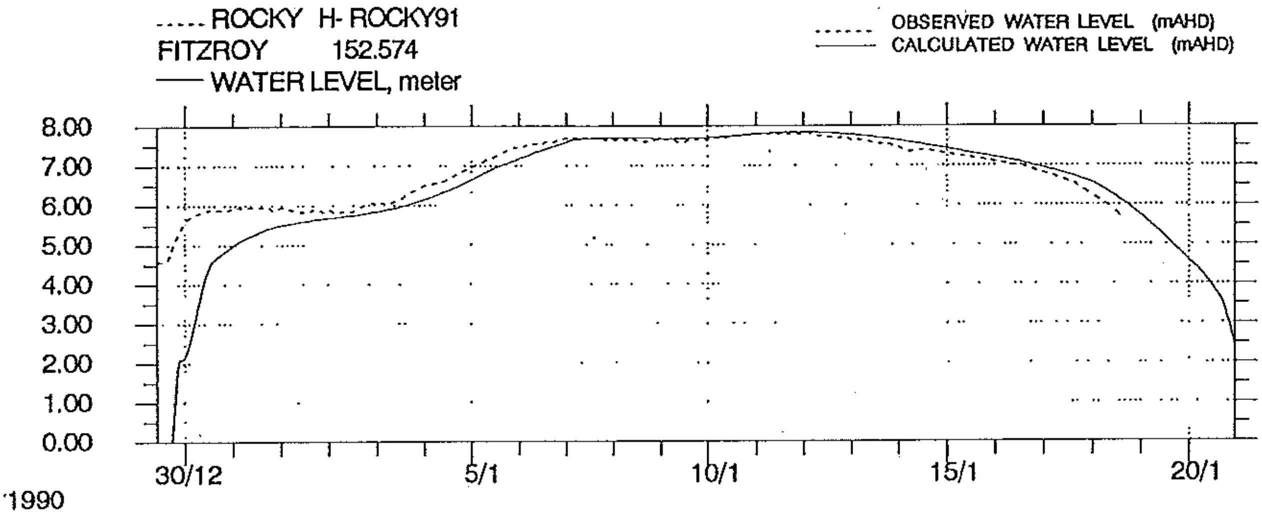
FITZROY RIVER - Barrage

CMPS&F

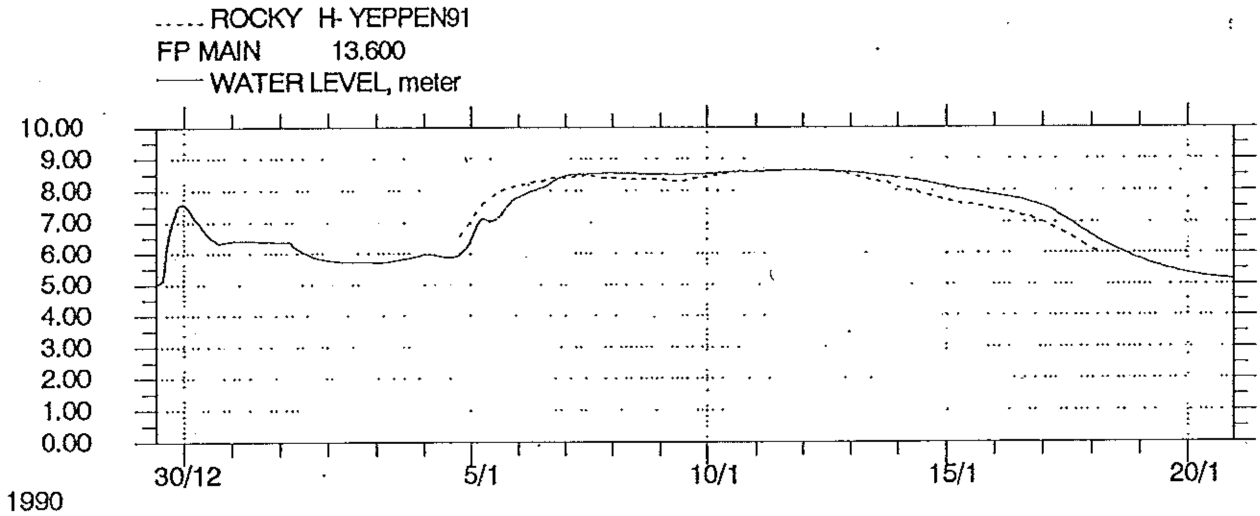
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1991 FLOOD CALIBRATION
FLOOD LEVEL HYDROGRAPHS AT YAAMBA, WATER TREATMENT WORKS AND BARRAGE

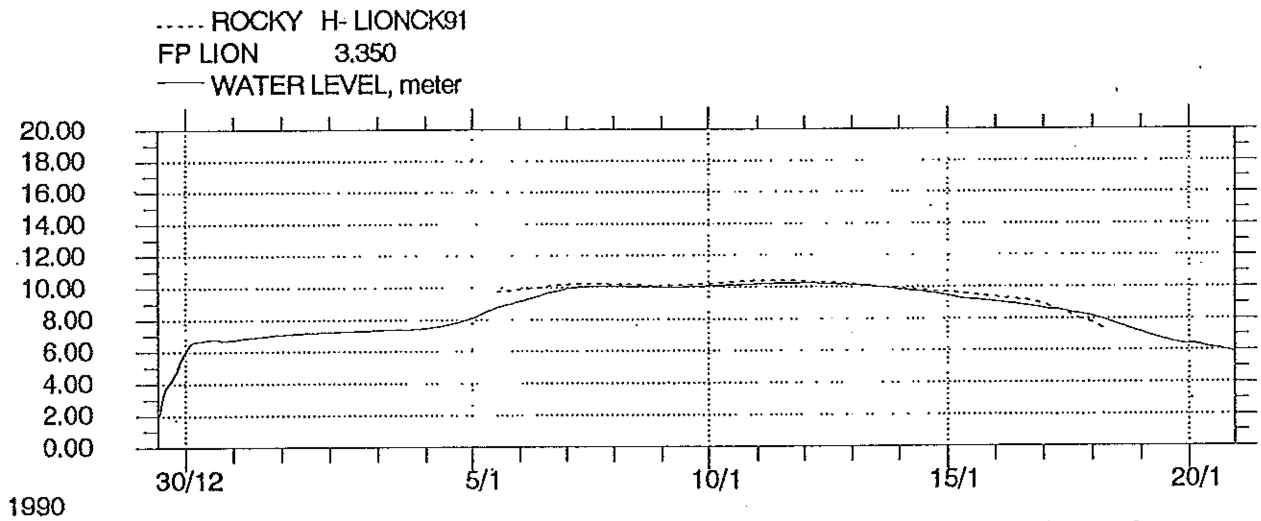
FIGURE 2-4



FITZROY RIVER - Rockhampton Flood Gauge

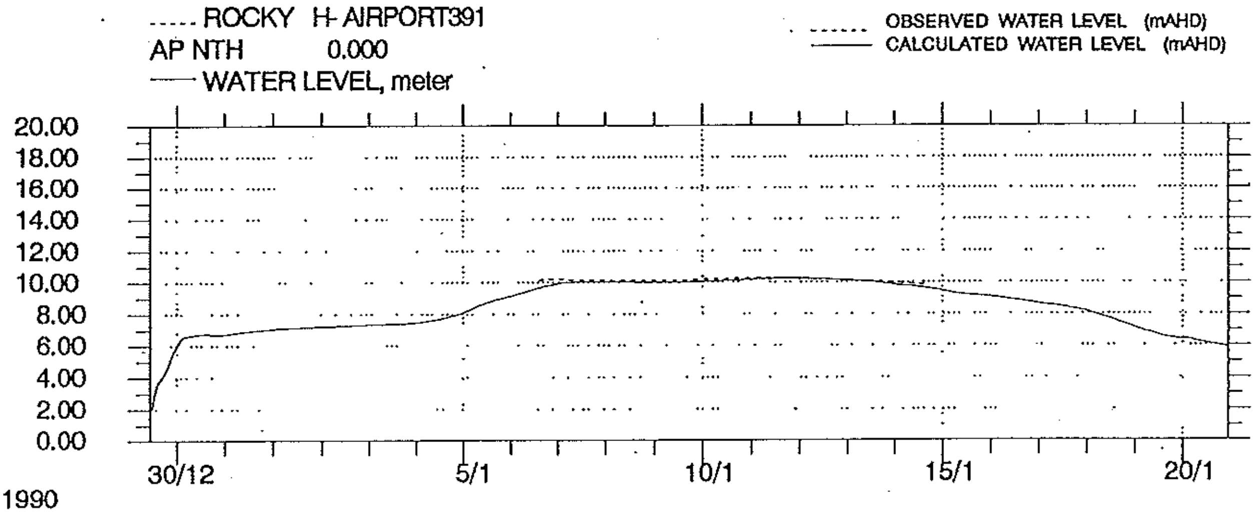


YEPPEN 1 BRIDGE (U / S) - Bruce Highway

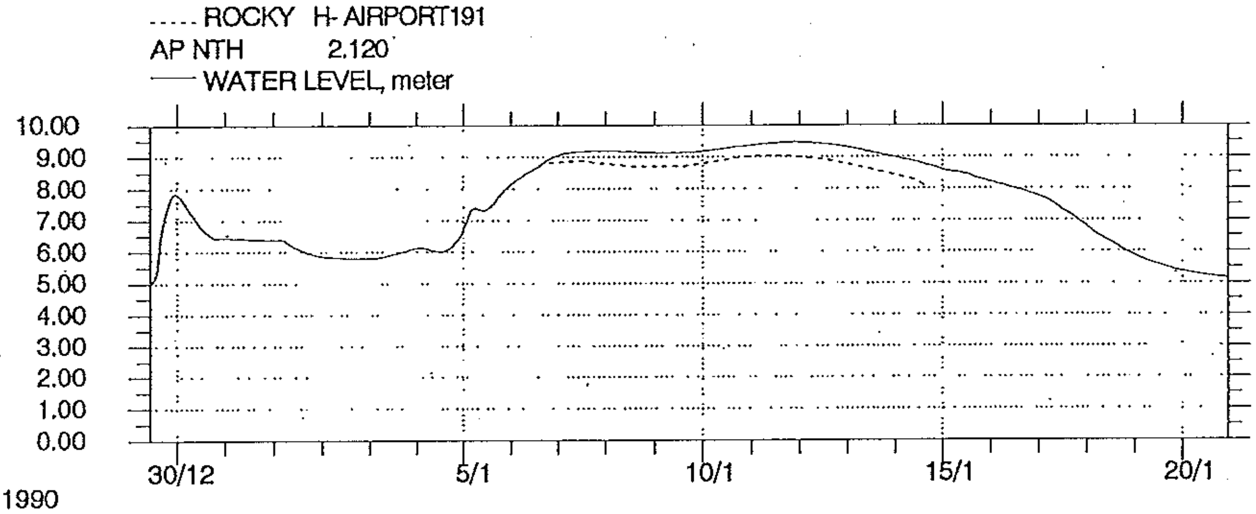


LION CREEK - Rockhampton - Ridgelands Road

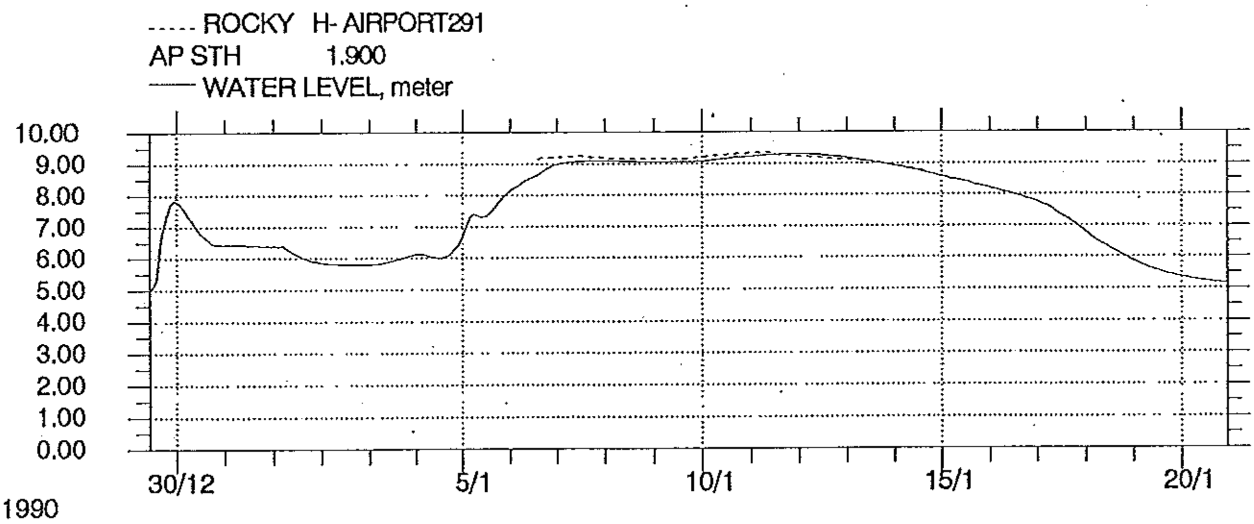
CMPS&F CAMP SCOTT FURPHY PTY. LTD.	**ROCKHAMPTON FLOOD MANAGEMENT STUDY** **1991 FLOOD CALIBRATION** **FLOOD LEVEL HYDROGRAPHS AT CITY FLOOD GAUGE, YEPPEN 1 BRIDGE & LION CREEK**	**FIGURE 2-5**



AIRPORT - Gauge 1



AIRPORT - Gauge 2

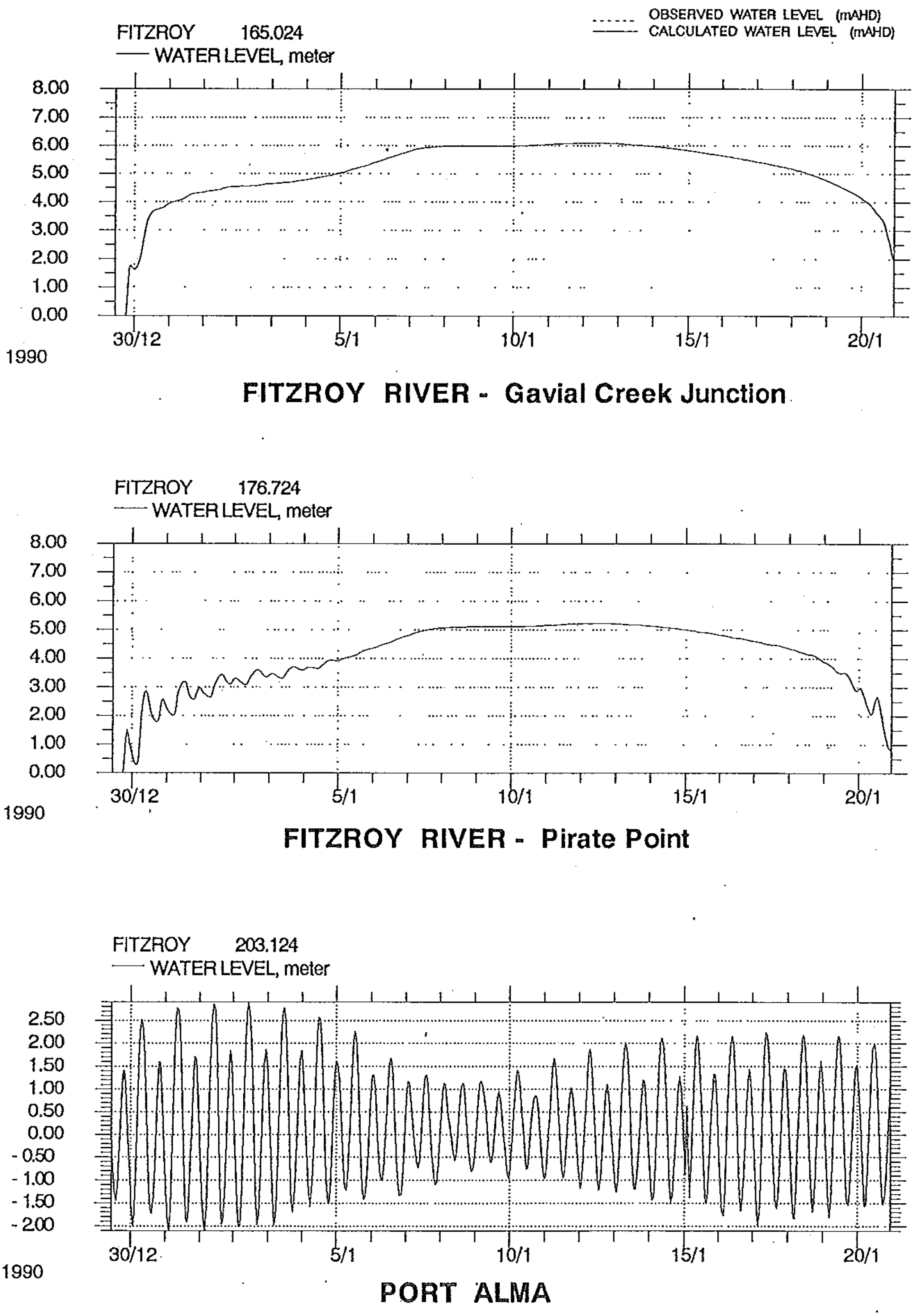


AIRPORT - Gauge 3

CMPS&F
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1991 FLOOD CALIBRATION
FLOOD LEVEL HYDROGRAPHS AT AIRPORT
GAUGES 1, 2 & 3

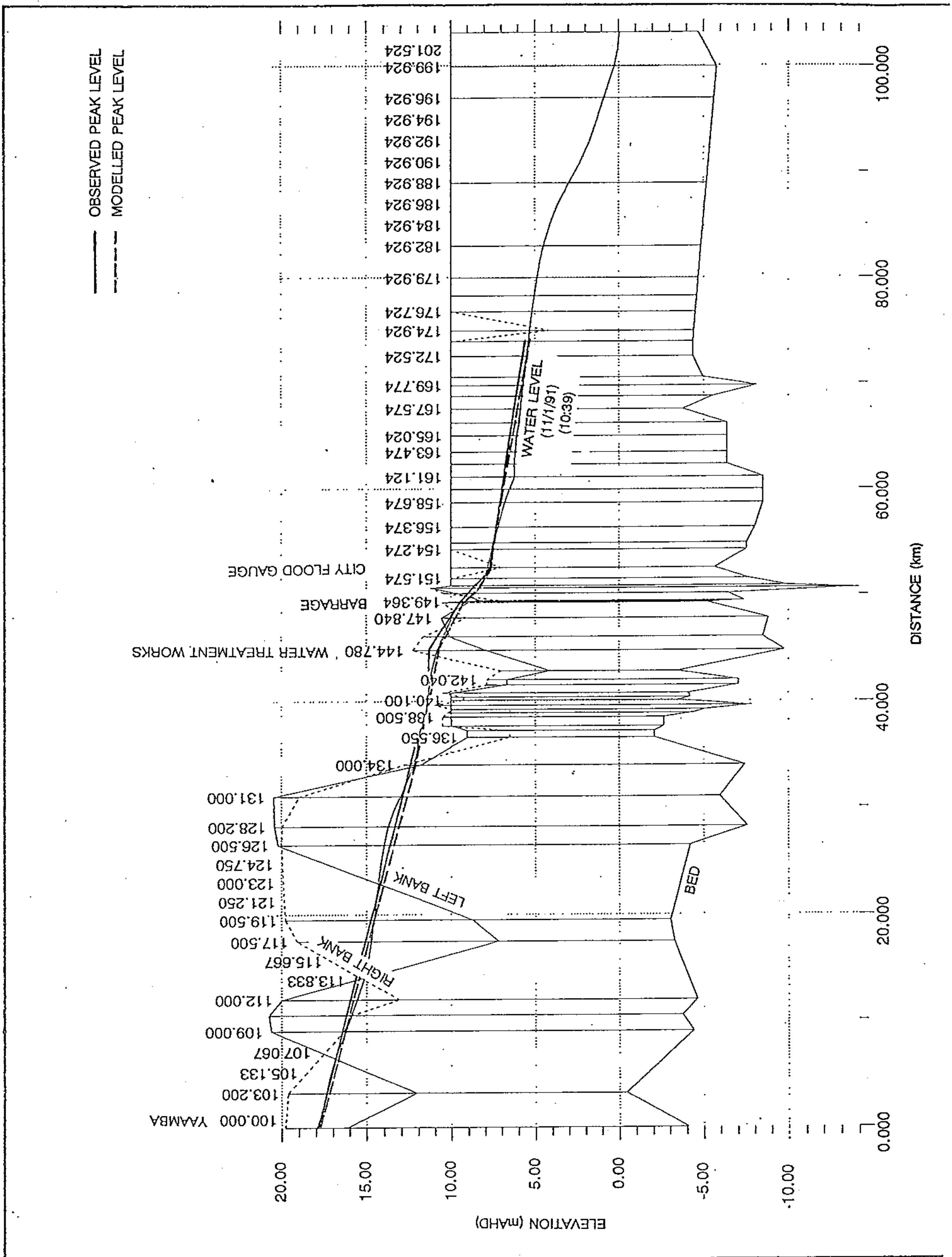
FIGURE 2-6



CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1991 FLOOD CALIBRATION
FLOOD LEVEL HYDROGRAPHS AT GAVIAL CK JUNCTION, PIRATE POINT & PORT ALMA

FIGURE 2-7



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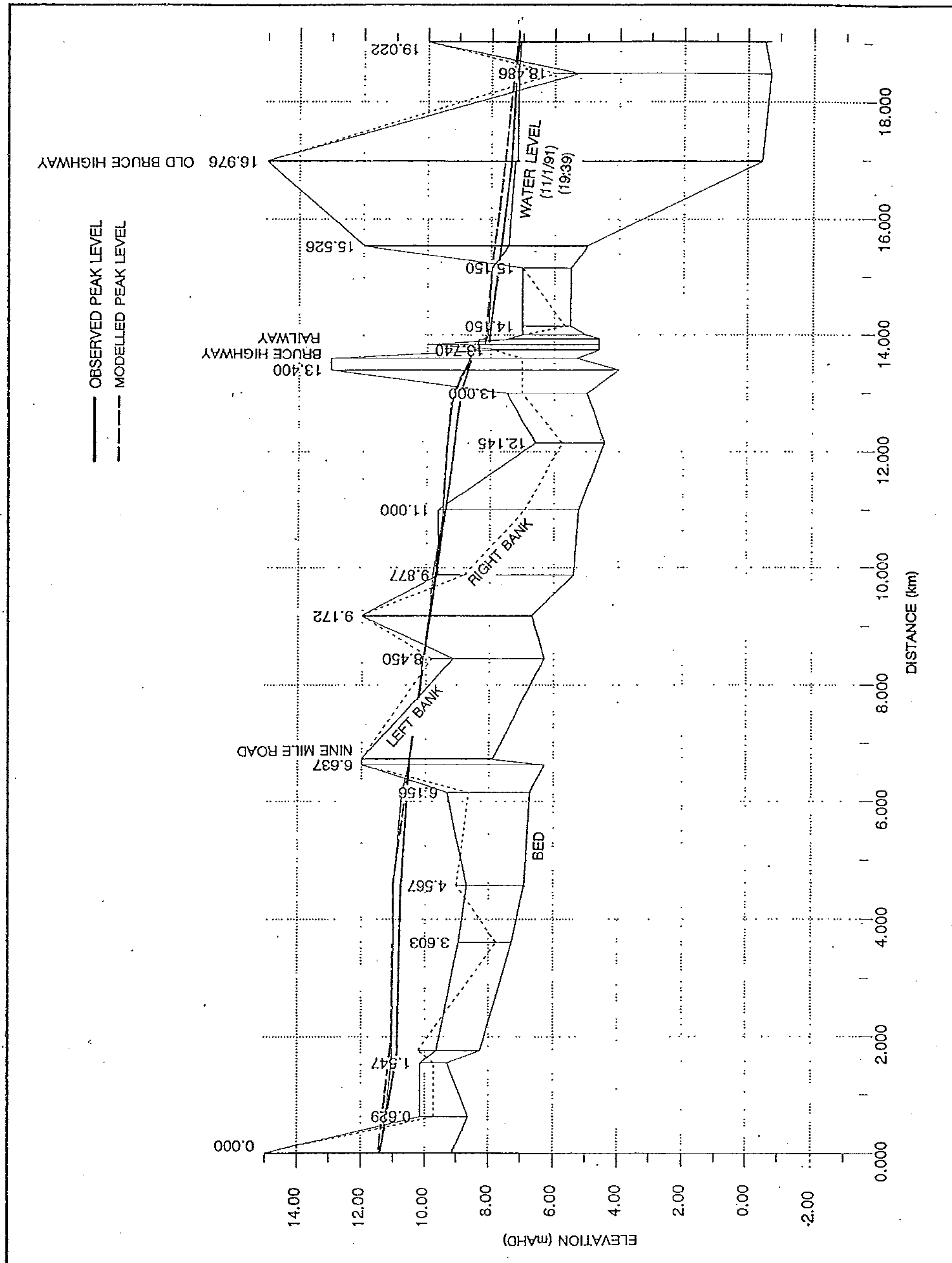
ROCKHAMPTON FLOOD MANAGEMENT STUDY
1991 FLOOD CALIBRATION
LONGITUDINAL PROFILE OF FITZROY RIVER

FIGURE 2-8



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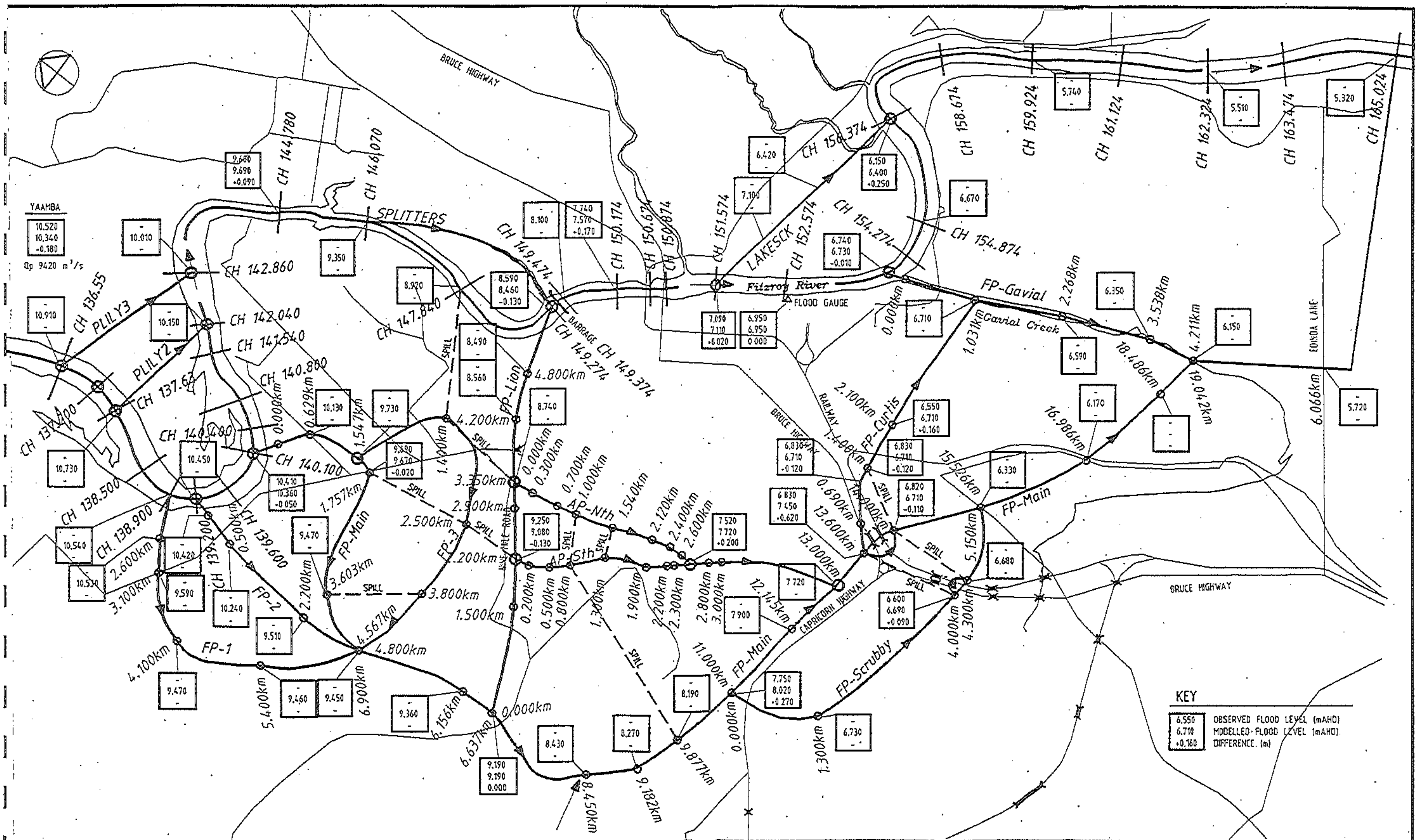
ROCKHAMPTON FLOOD MANAGEMENT STUDY
1991 FLOOD CALIBRATION
LONGITUDINAL PROFILE OF MAIN FLOODWAY
(FP–MAIN)

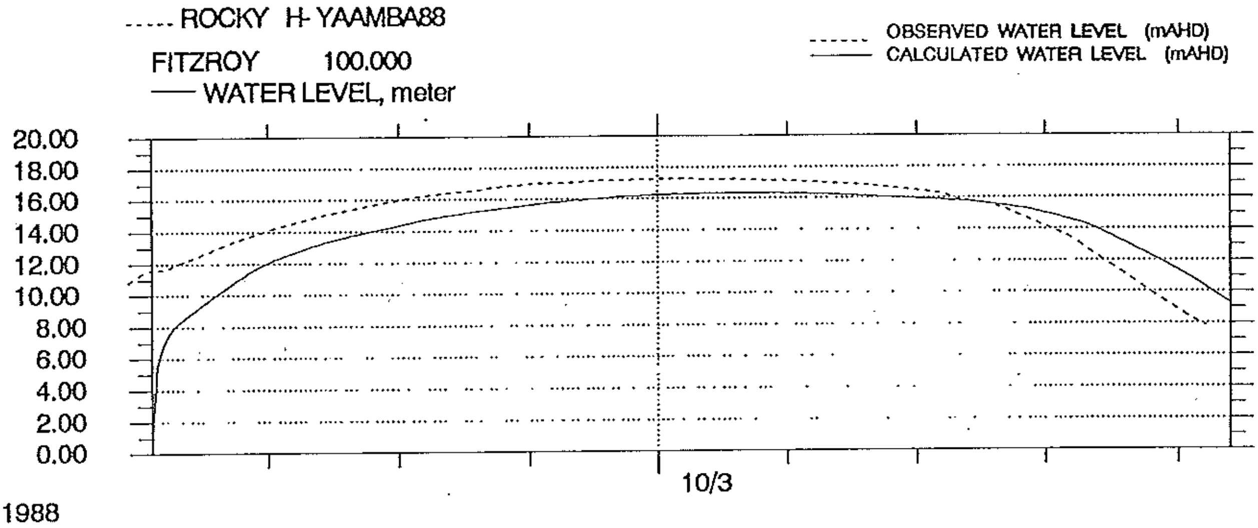
FIGURE 2–9



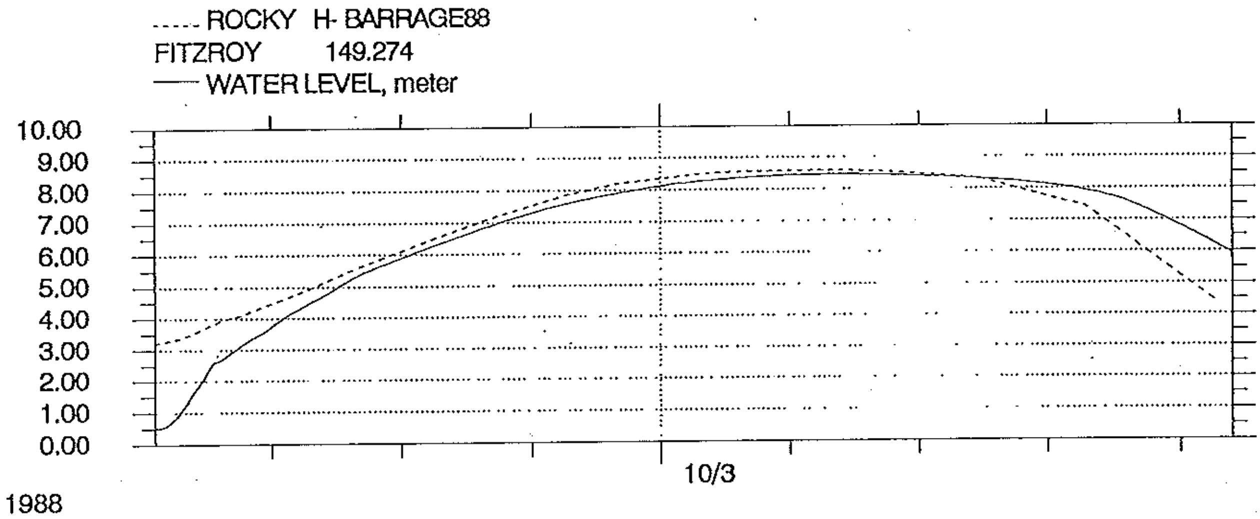
CMPS&F
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
HYDRAULIC MODEL LAYOUT 2
CALIBRATION 1988 FLOOD

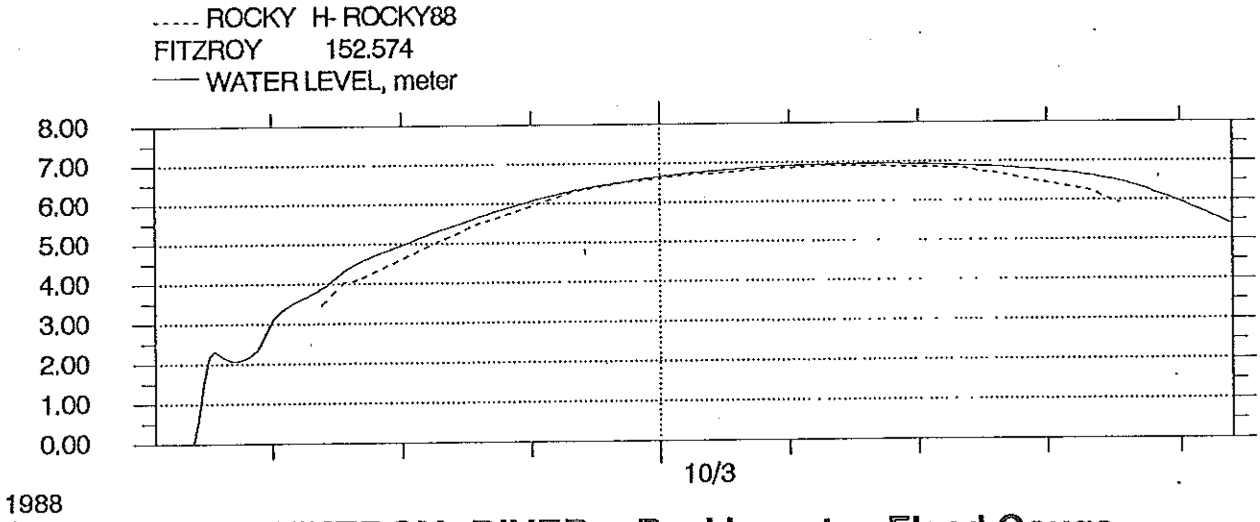
FIGURE 2-10



FITZROY RIVER - Yaamba

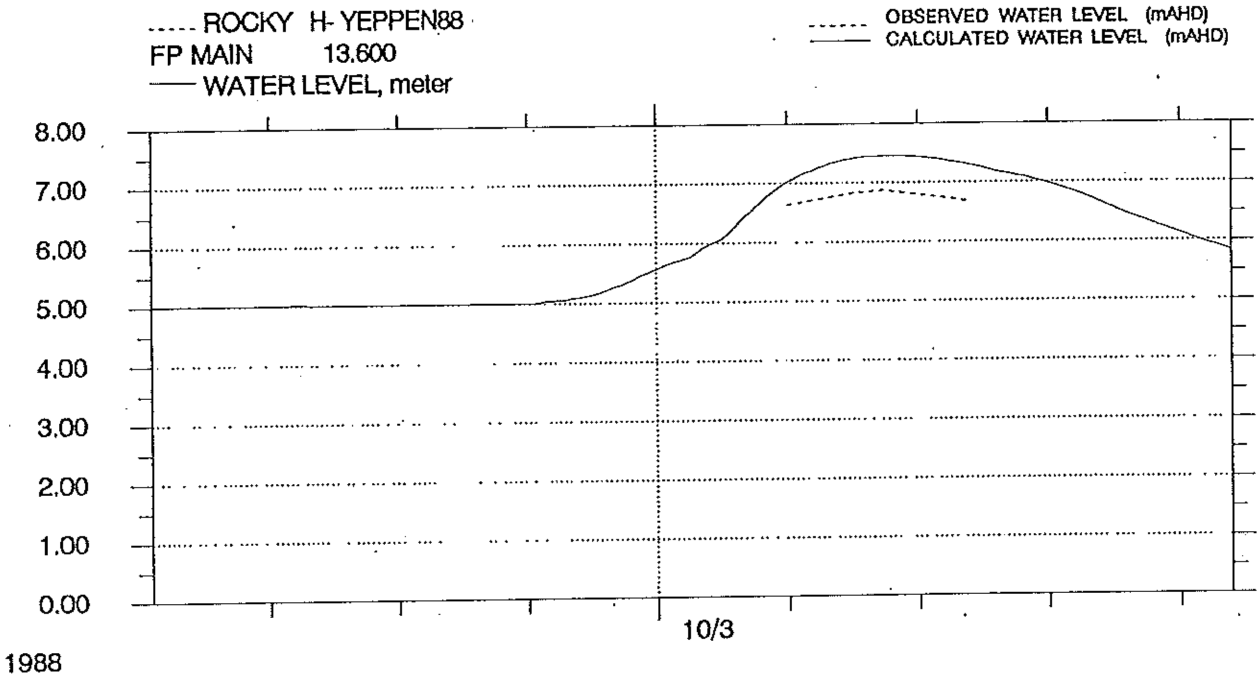


FITZROY RIVER - Barrage

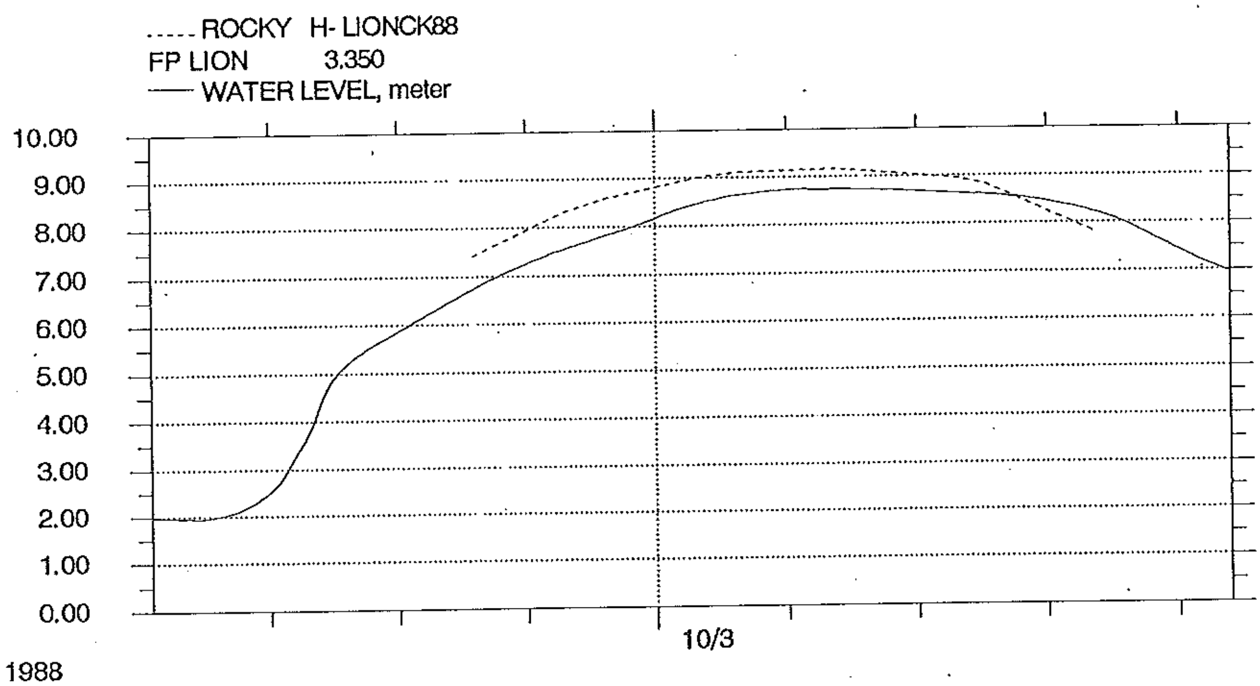


FITZROY RIVER - Rockhampton Flood Gauge

CMPS&F CAMP SCOTT FURPHY PTY. LTD.	**ROCKHAMPTON FLOOD MANAGEMENT STUDY** **1988 FLOOD CALIBRATION** **FLOOD LEVEL HYDROGRAPHS AT YAAMBA, BARRAGE & CITY FLOOD GAUGE**	**FIGURE 2-11**



YEPPEN 1 BRIDGE (U / S) - Bruce Highway

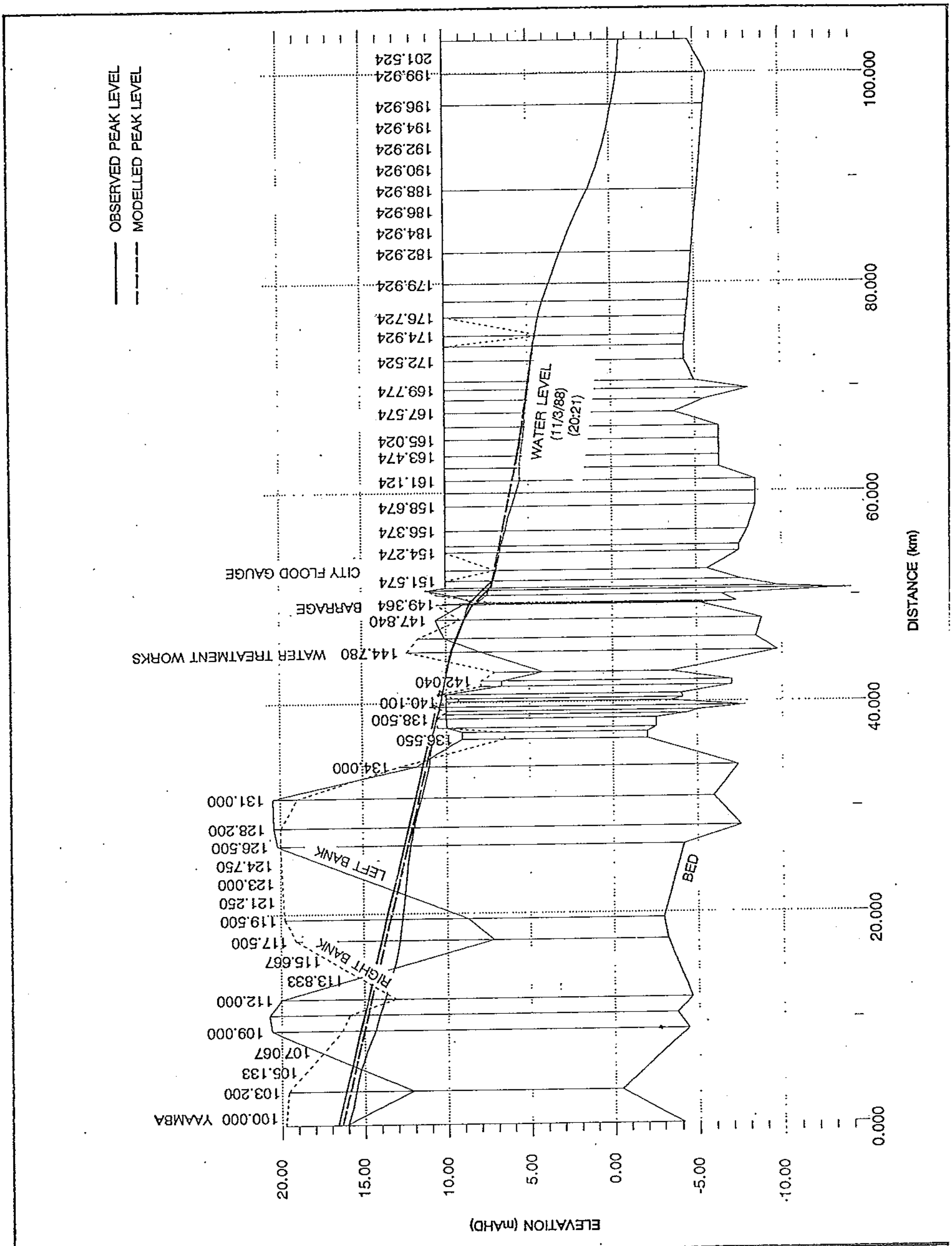


LION CREEK - Rockhampton - Ridgelands Road

CMPS&F
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1988 FLOOD CALIBRATION
FLOOD LEVEL HYDROGRAPHS AT YEPPEN & LION CREEK

FIGURE 2–12



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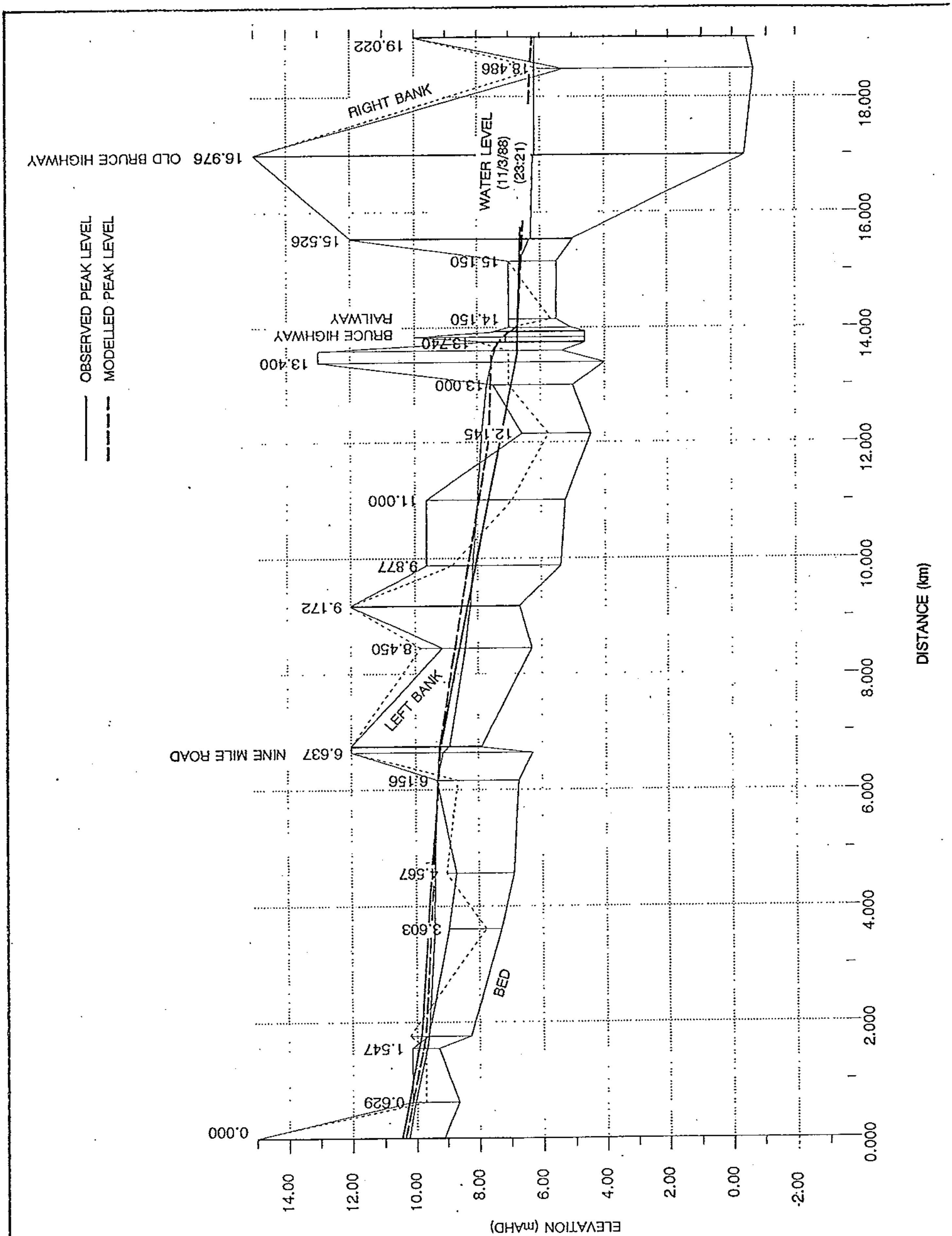
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1988 FLOOD CALIBRATION
LONGITUDINAL PROFILE OF FITZROY RIVER

FIGURE 2–13



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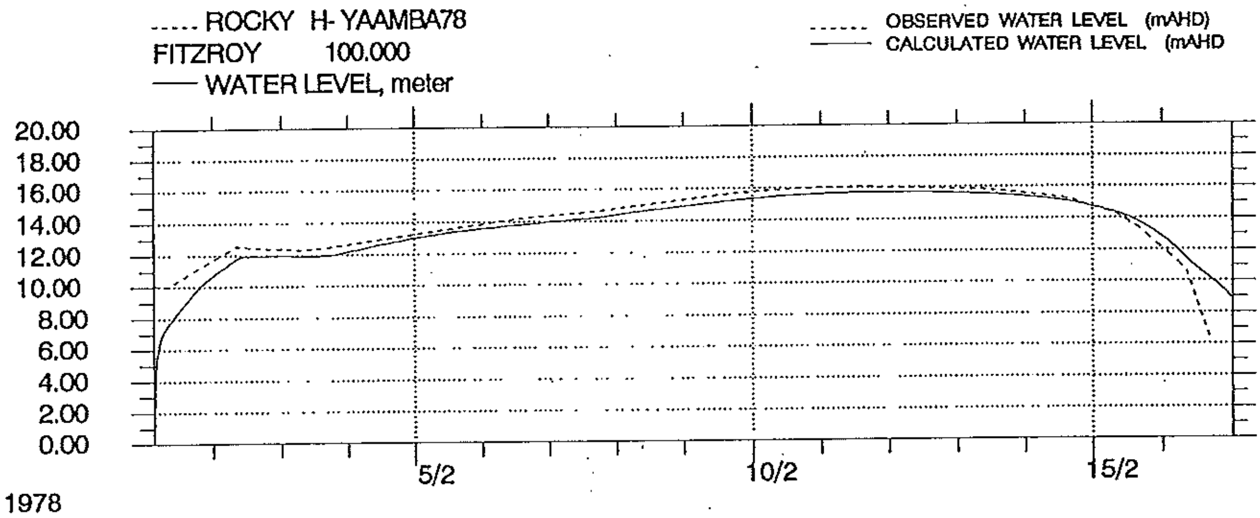
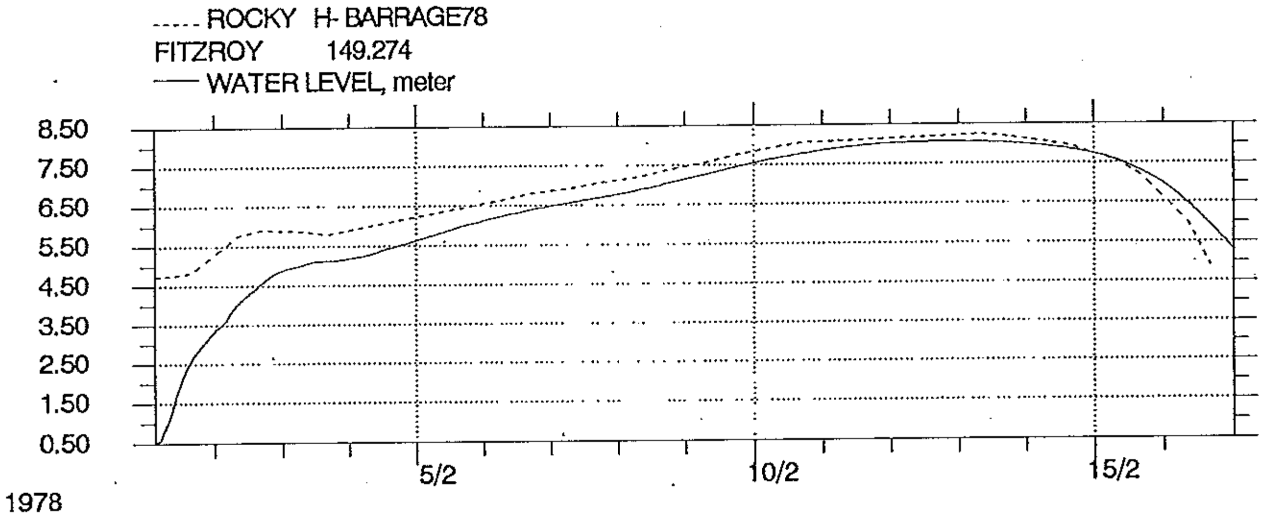
ROCKHAMPTON FLOOD MANAGEMENT STUDY
1988 FLOOD CALIBRATION
LONGITUDINAL PROFILE OF MAIN FLOODWAY
(FP–MAIN)

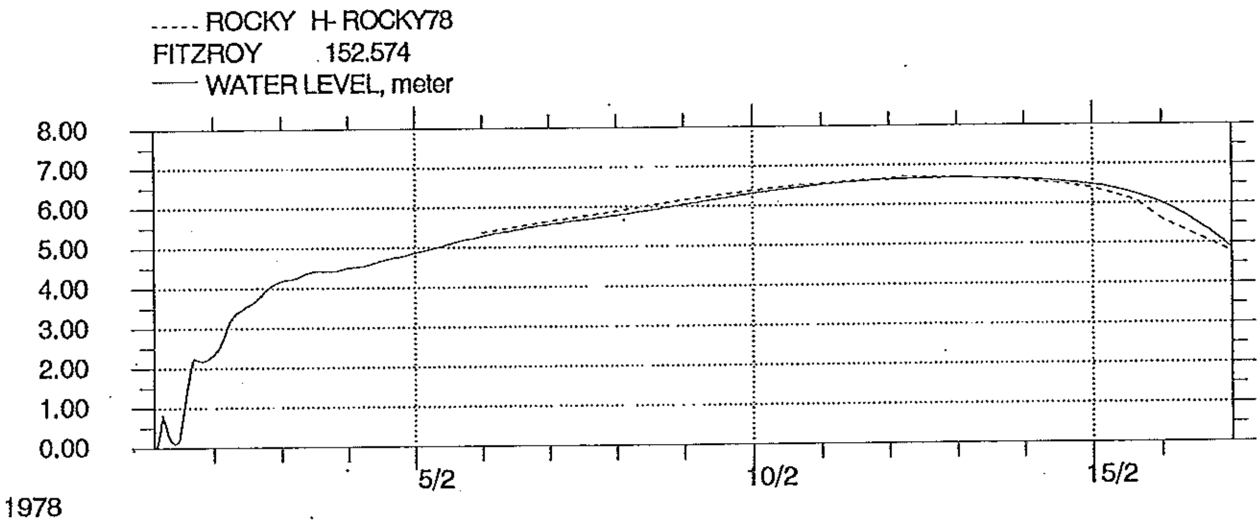
FIGURE 2–14



FITZROY RIVER - Yaamba

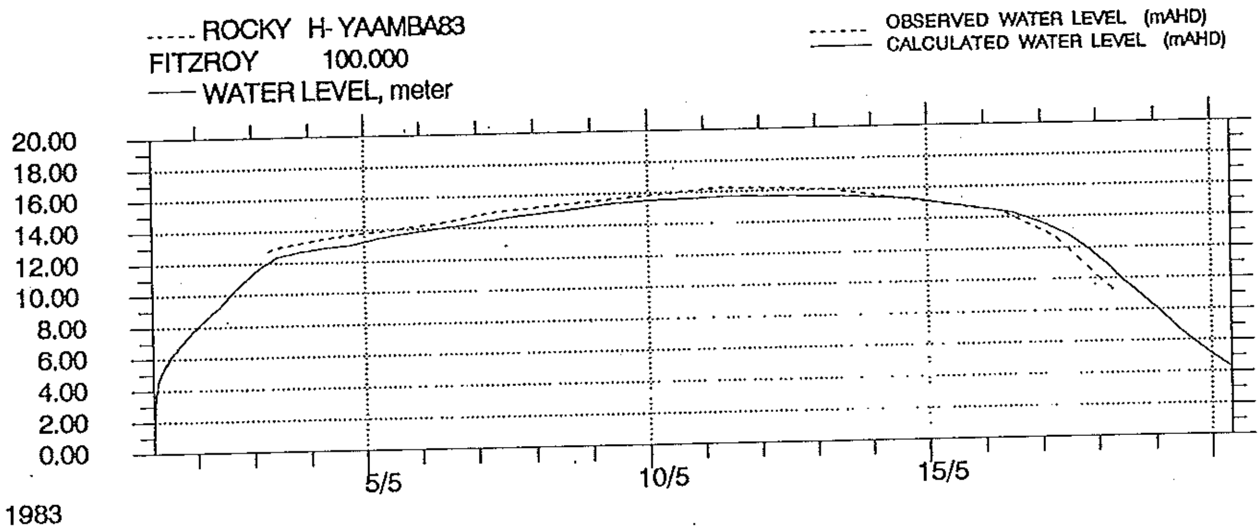


FITZROY RIVER - Barrage

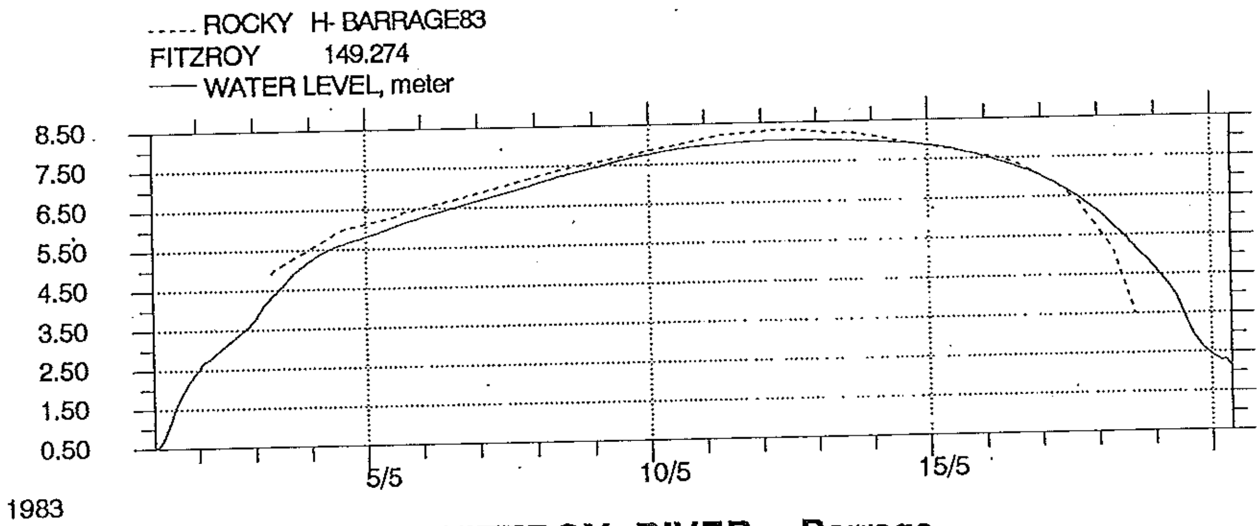


FITZROY RIVER - Rockhampton Flood Gauge

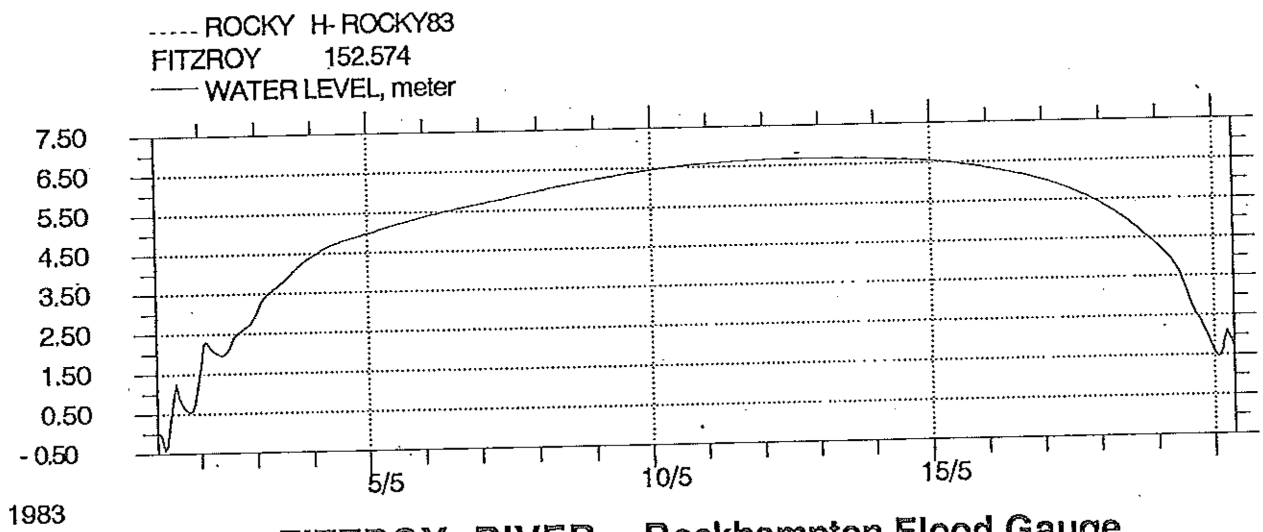
CAMP SCOTT FURPHY PTY. LTD.	**ROCKHAMPTON FLOOD MANAGEMENT STUDY** **1978 FLOOD VALIDATION** **FLOOD LEVEL HYDROGRAPHS AT YAAMBA, BARRAGE & CITY FLOOD GAUGE**	**FIGURE 2-15**



FITZROY RIVER - Yaamba

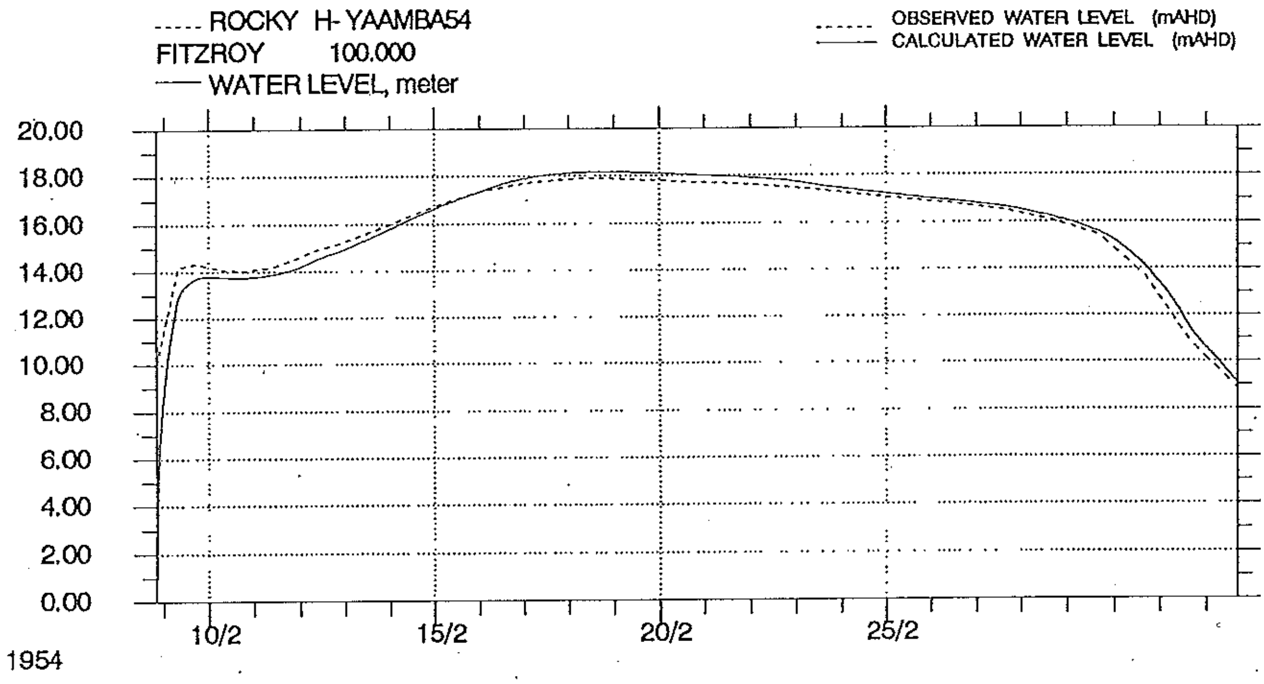


FITZROY RIVER - Barrage

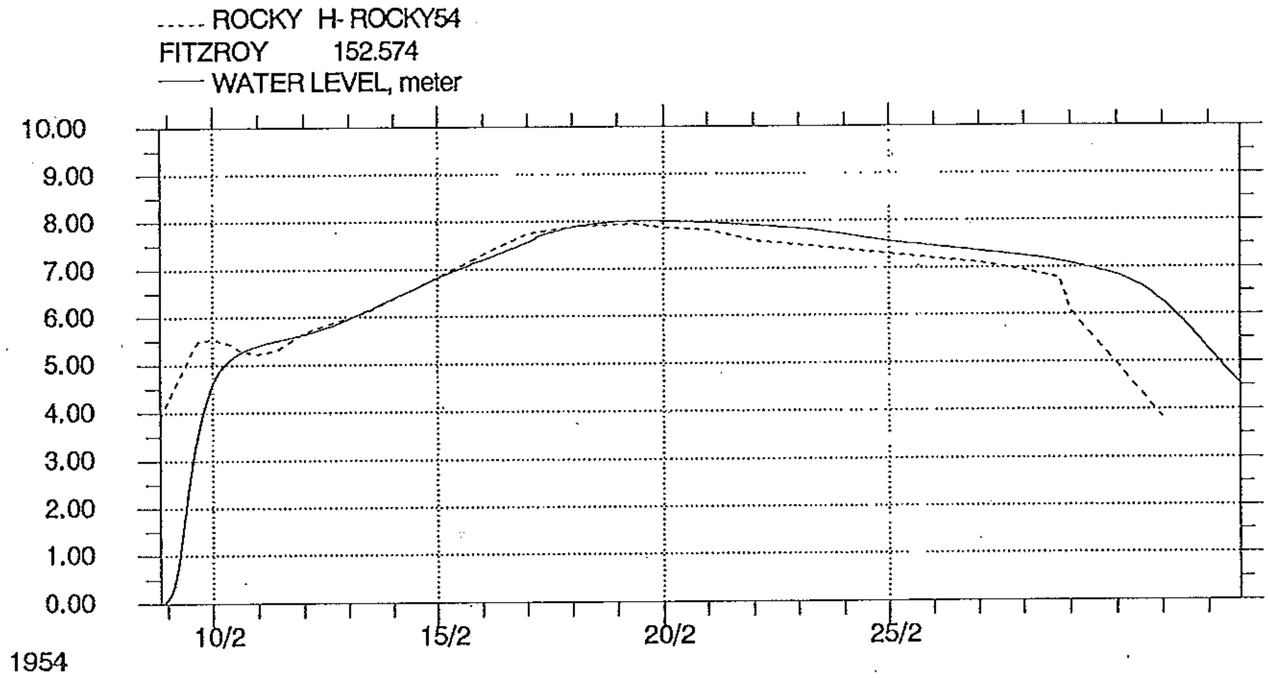


FITZROY RIVER - Rockhampton Flood Gauge

CMPS&F CAMP SCOTT FURPHY PTY. LTD.	ROCKHAMPTON FLOOD MANAGEMENT STUDY 1983 FLOOD VALIDATION FLOOD LEVEL HYDROGRAPHS AT YAAMBA, BARRAGE & CITY FLOOD GAUGE	FIGURE 2-16



FITZROY RIVER - Yaamba

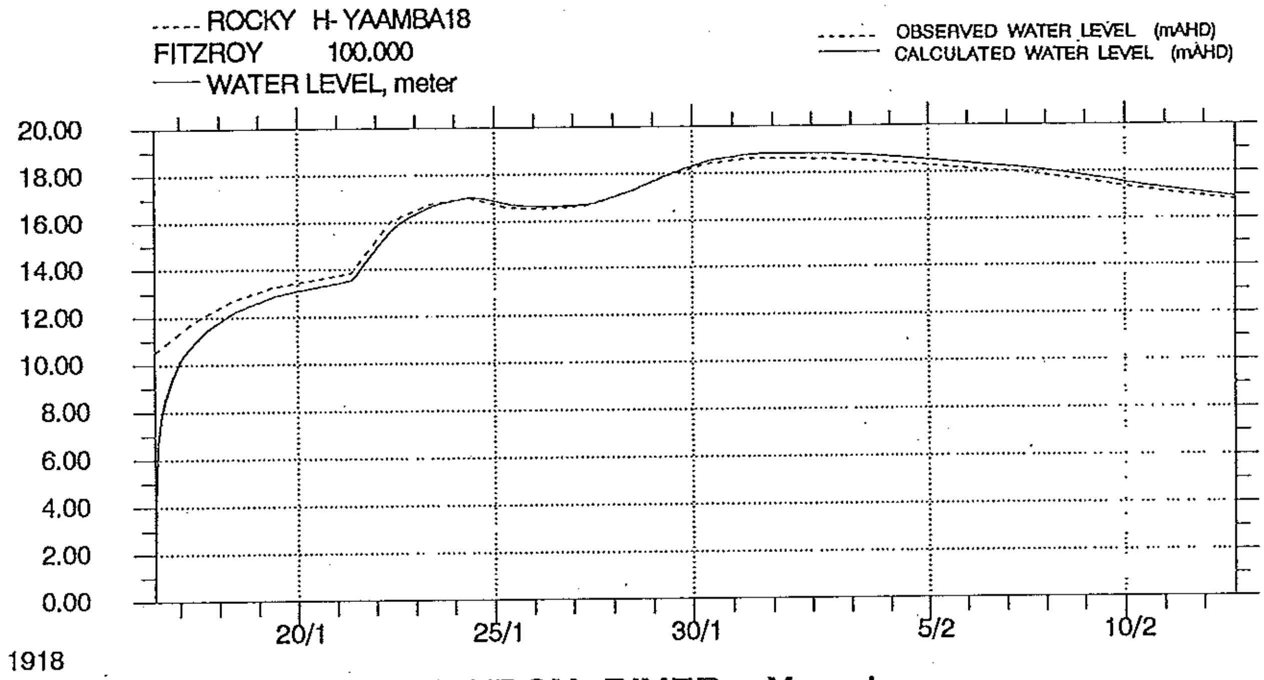


FITZROY RIVER - Rockhampton Flood Gauge

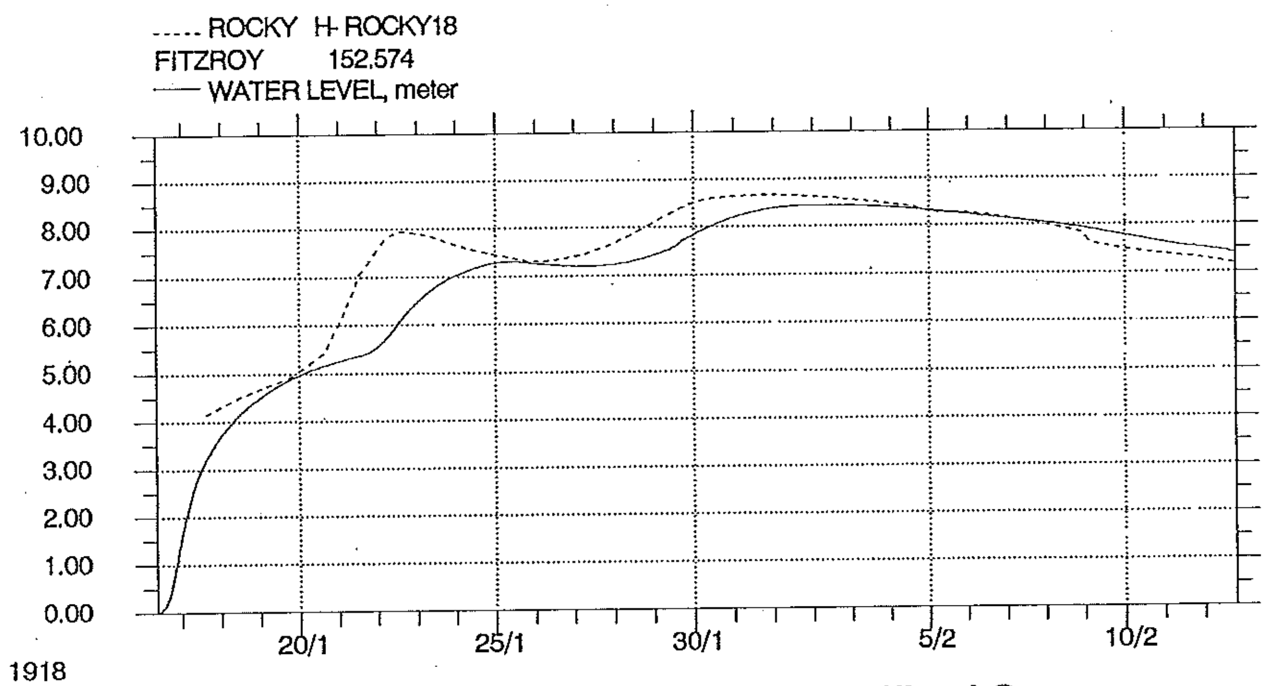
CMPS&F
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
1954 FLOOD VALIDATION
FLOOD LEVEL HYDROGRAPHS AT YAAMBA
& CITY FLOOD GAUGE

FIGURE 2–17

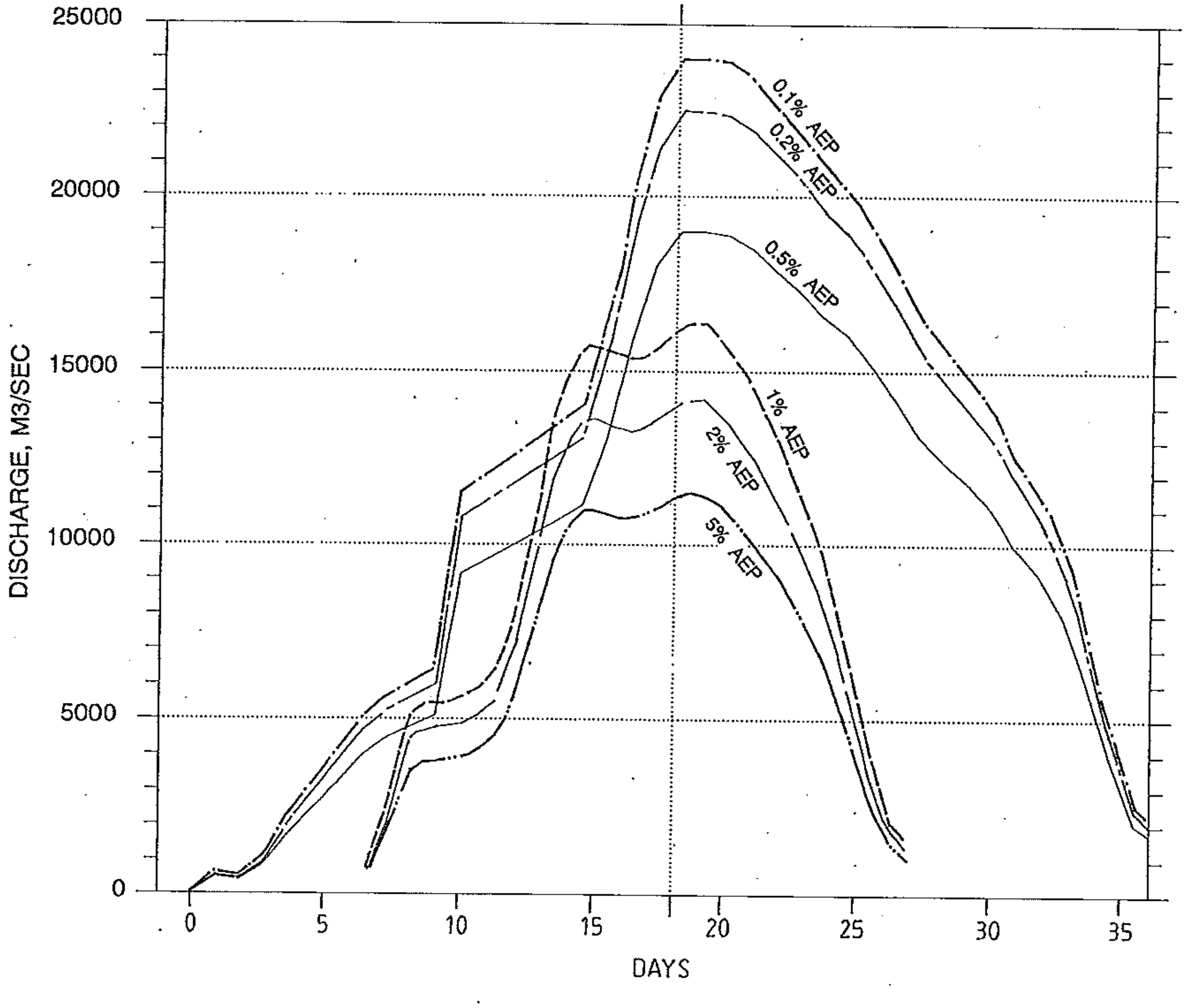


FITZROY RIVER - Yaamba



FITZROY RIVER - Rockhampton Flood Gauge

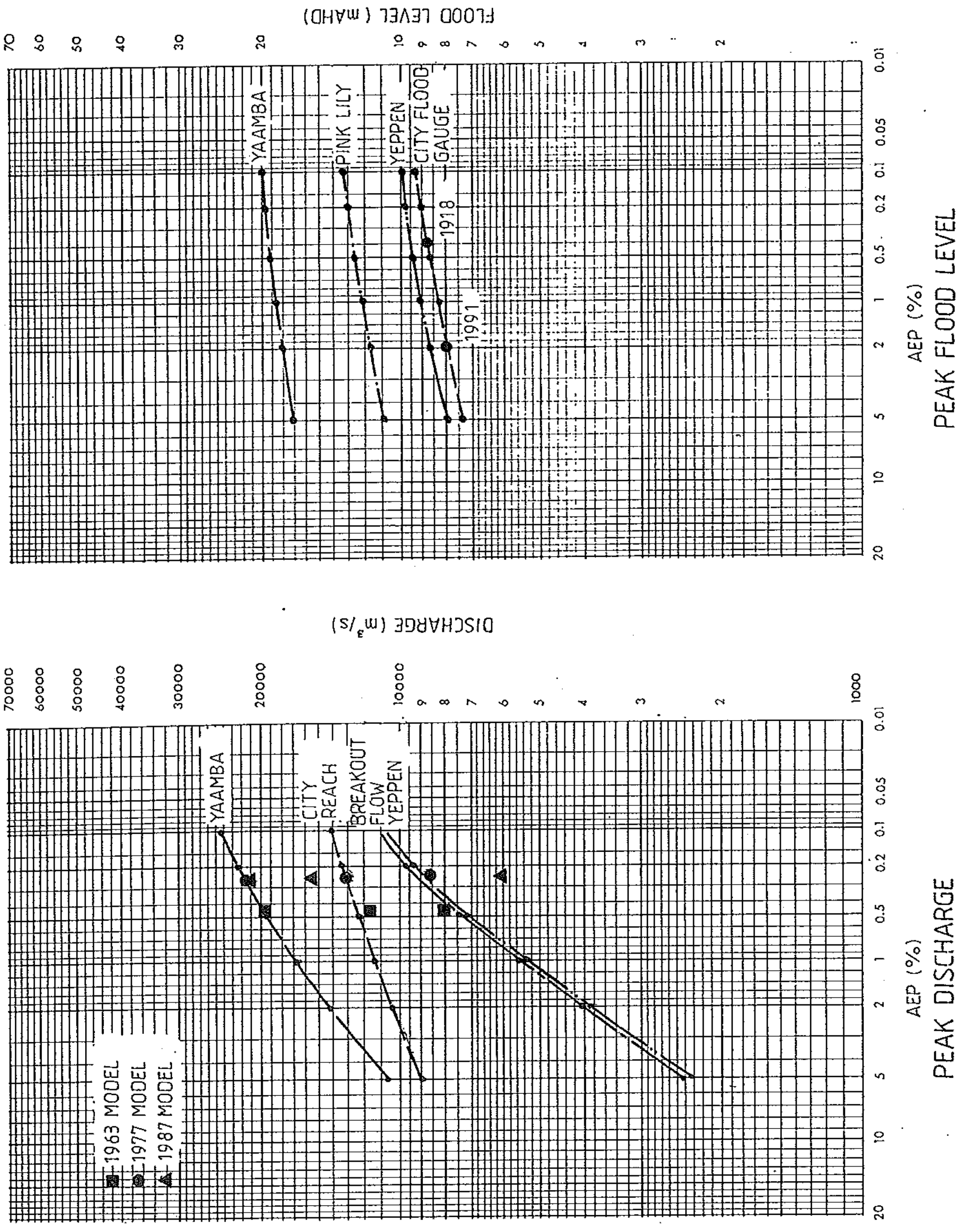
CMPS&F CAMP SCOTT FURPHY PTY. LTD.	**ROCKHAMPTON FLOOD MANAGEMENT STUDY** **1918 FLOOD VALIDATION** **FLOOD LEVEL HYDROGRAPHS AT YAAMBA & CITY FLOOD GAUGE**	**FIGURE 2–18**



CMPS&F
CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
DESIGN FLOOD DISCHARGE HYDROGRAPHS

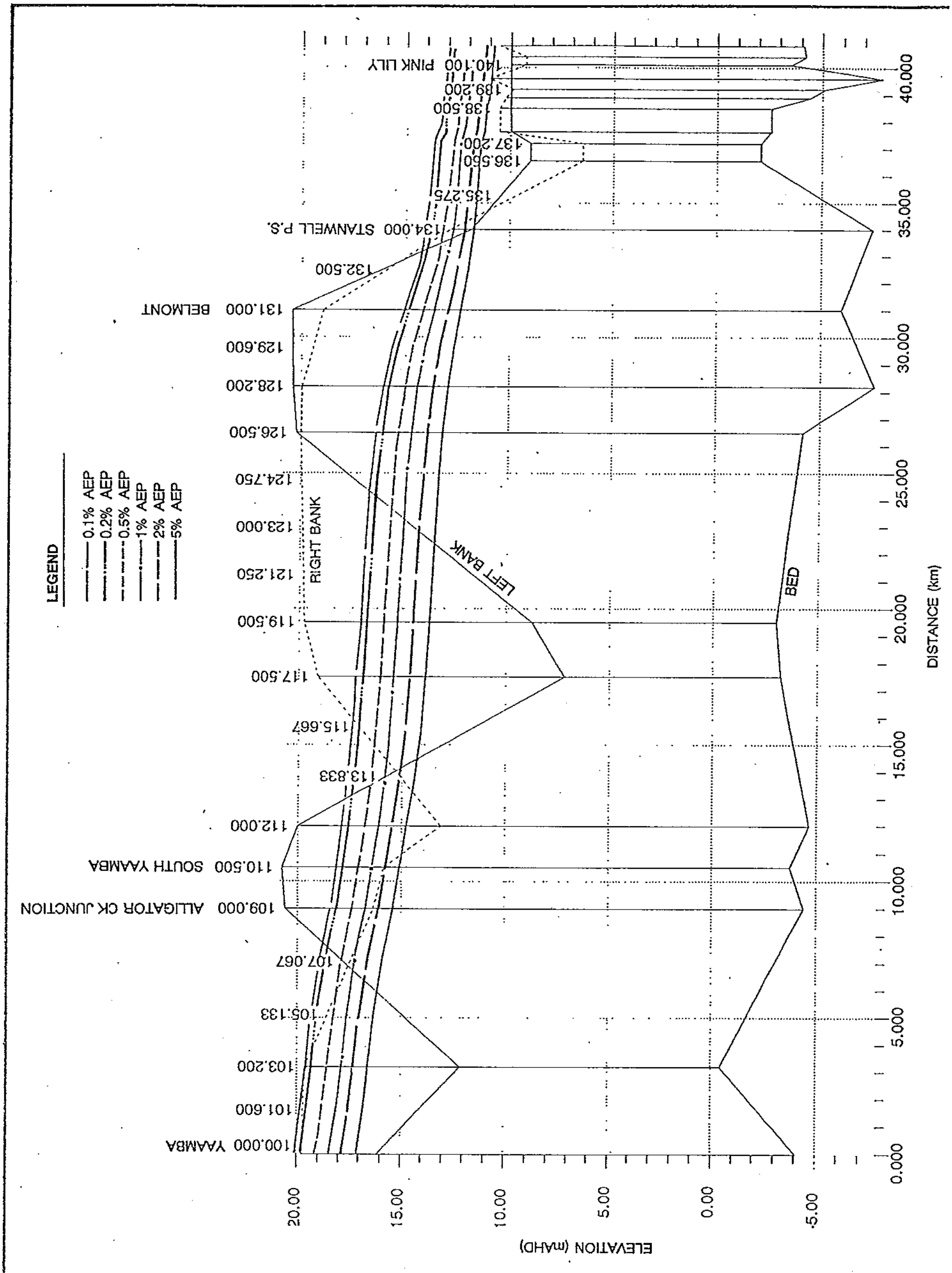
FIGURE 2–19



CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
DISCHARGE AND FLOOD LEVEL PROBABILITY CURVES

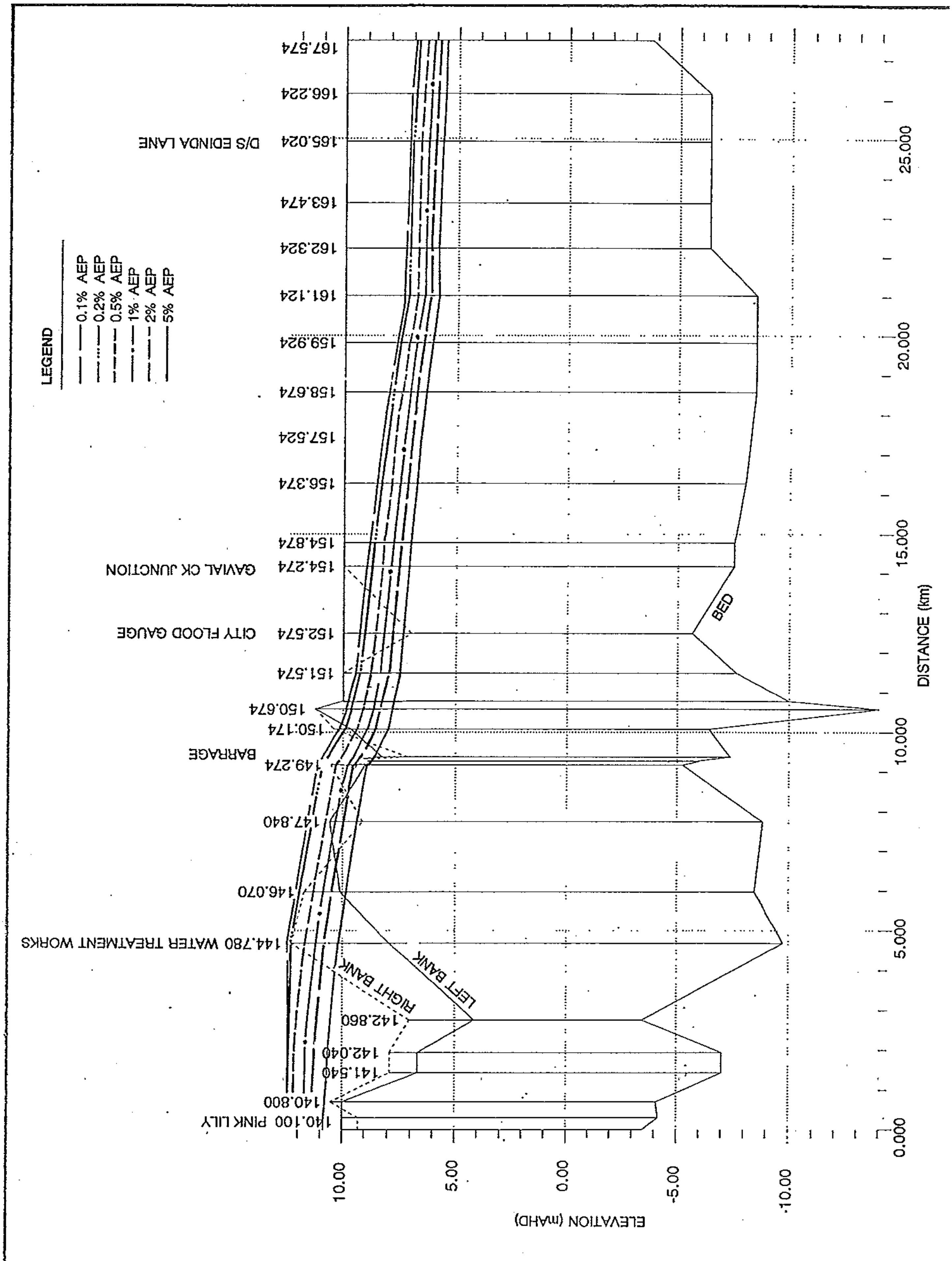
FIGURE 2-20



CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
LONGITUDINAL PROFILE FOR DESIGN FLOODS
FITZROY RIVER – YAAMBA TO PINK LILY

FIGURE 2–21



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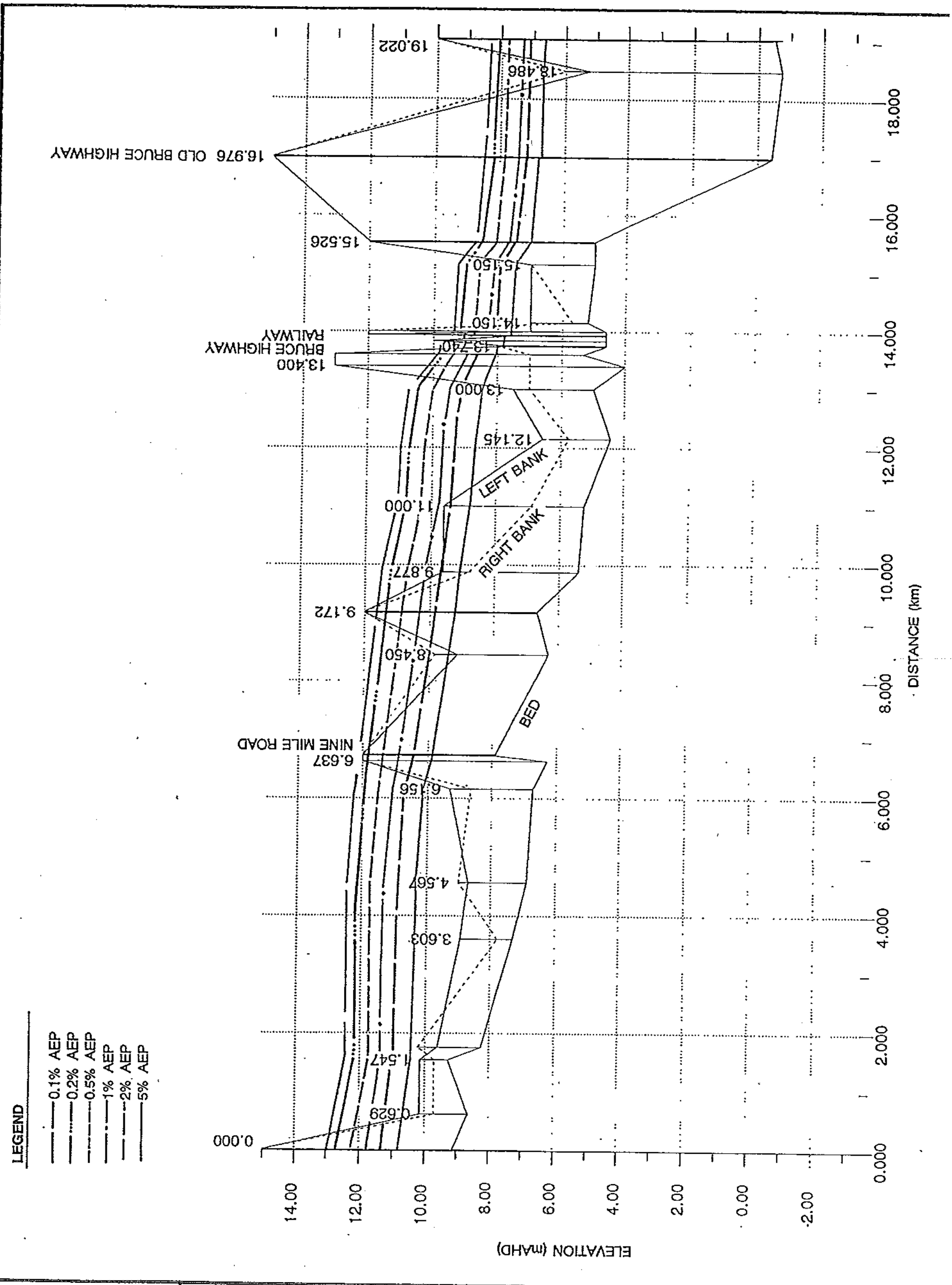
ROCKHAMPTON FLOOD MANAGEMENT STUDY
LONGITUDINAL PROFILE FOR DESIGN FLOODS
FITZROY RIVER - PINK LILY TO EDINDA LANE

FIGURE 2-22



CMPS&F

CAMP SCOTT FURPHY PTY. LTD.

ROCKHAMPTON FLOOD MANAGEMENT STUDY
LONGITUDINAL PROFILE FOR DESIGN FLOODS
MAIN FLOODWAY

FIGURE 2–23