

WATER RESOURCES COMMISSION



ROCKHAMPTON FLOOD MANAGEMENT STUDY

PHASE 1 REPORT

**VOLUME 1
EXECUTIVE SUMMARY**



**CAMP SCOTT FURPHY PTY LTD
ACN 004 939 548**

APRIL 1992

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PHASE 1 REPORT

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ROCKHAMPTON FLOOD JANUARY 1991
Fitzroy River looking downstream to Rockhampton City



ROCKHAMPTON FLOOD JANUARY 1991
Depot Hill Area



ROCKHAMPTON FLOOD JANUARY 1991
Yeppen Crossing



ROCKHAMPTON FLOOD JANUARY 1991
Rockhampton Airport

ROCKHAMPTON FLOOD MANAGEMENT STUDY

PHASE 1

EXECUTIVE SUMMARY

INTRODUCTION

Rockhampton, the largest urban centre in Central Queensland, is built adjacent to the Fitzroy River. The Fitzroy River basin is one of the largest on the east coast of Australia, with a catchment area above Rockhampton of about 140,000 km².

The Fitzroy River at Rockhampton and adjacent areas and townships have been subjected to flooding on many occasions as a result of heavy rainfalls in the Fitzroy River basin. The worst flood since records commenced in 1859 was in 1918, when the river level at Rockhampton reached 10.11 m on the City flood gauge (8.65 m AHD). The second highest peak was 9.4 m gauge height (7.95 m AHD) in 1954. Rockhampton again suffered major flooding in January 1991 due to heavy rainfalls associated with Cyclone Joy. The peak flood level on this occasion reached 9.30 m gauge height (7.85 m AHD), but due to changes in the floodplain characteristics in recent years this level cannot be compared directly with that of previous major floods. In river discharge terms, both the 1991 and 1954 floods had peak flows of about 15,000 m³/s at Yaamba compared to about 18,000 m³/s in 1918.

Major flood flows cause flooding from Yaamba to downstream of Rockhampton including significant flooding of the lower lying parts of Rockhampton. A major flood breakout occurs upstream of Rockhampton at Pink Lily which results in significant flow in the floodplain which flows to the south of the city. These floodplain flows can result in the closure of Rockhampton Airport, the Bruce and Capricorn Highways and the North Coast Railway. Also the Bruce Highway and the North Coast Railway can be cut by floodwaters at the Alligator Creek crossing near Yaamba, some 30 km north of Rockhampton. In the 1991 flood, all of these links were cut for about two weeks, effectively isolating Rockhampton from the outside world for this period.

This disruption to all major traffic routes in and out of Rockhampton results in large indirect flood losses not only in Rockhampton but throughout the Queensland Coast. Significant direct flood damages resulted in the 1991 flood from about 160 properties being inundated above floor level, with a further 1200 properties being flooded to below floor level.

This Study was commissioned, following the 1991 flood, 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.

This report presents the findings of Phase 1 of the study which has comprised:

- Study of Fitzroy River flood characteristics;
- Flood damage assessment;
- Appraisal of options for flood management;
- Recommendations in regard to future flood management;
- Community consultation.

Phase 2 will comprise detailed investigation of those options identified in Phase 1 as having sufficient merit to warrant more detailed study.

A brief summary of the studies carried out, the recommendations for measures which can be implemented immediately, and those requiring further investigation in Phase 2 are given in this Executive Summary. It is emphasised that, in regard to those items to be studied in greater detail in Phase 2, the findings of this report are preliminary and do not constitute firm or final recommendations.

The Phase 2 report will be prepared to comply with requirements for funding applications under the Federal Water Resources Assistance Program (FWRAP), in order to facilitate a submission for funding of the recommended works. It should be noted that such applications are assessed on their merits, cost-effectiveness and priority relative to other State projects.

COMMUNITY CONSULTATION

Community consultation in Phase 1 comprised an initial call for written submissions together with a series of four public meetings. The public meetings were held both to inform residents of the Study and to enable public perception of the issues regarding flooding to be voiced and taken into account.

A total of 92 residents attended the public meetings, and a total of 11 written submissions were received. The one day workshop 'Effects of the 1991 Flood' organised by the Queensland National Parks and Wildlife Service at the University of Central Queensland on 27th September 1991 provided a further forum for exchange of ideas and experiences.

There will be a further round of community consultation early in Phase 2 of the study, when the findings of Phase 1 will be put on display and further public meetings held to explain the findings and recommendations of the study.

GENERAL DESCRIPTION OF FITZROY RIVER HYDROLOGY

The report includes a brief outline of the basic hydrologic regime of the Fitzroy River basin. This describes general catchment conditions, land use patterns, rainfall and river flow regimes, and includes a brief account of the influence of tropical cyclones on the flood hydrology of the Fitzroy River. Major floods in the lower Fitzroy River usually result from severe rainfalls over the northern subcatchments (Isaac River – Connors River System). There appear to have been few instances in which all major tributaries were in flood simultaneously.

In some instances, local runoff from tributaries such as Alligator Creek and Neerkol/Scrubby Creek can exacerbate flooding at Rockhampton, but generally runoff from local catchments has passed by the time floodwaters from upstream reach Rockhampton. The bankfull discharge of the Fitzroy River at Rockhampton is about 7,500 m³/s, above which a major breakout occurs in the vicinity of Pink Lily.

The report includes a brief description of the three largest recorded flood events at Rockhampton namely those of 1918, 1954 and 1991.

DESCRIPTION OF JANUARY 1991 FLOOD

The flood of January 1991 resulted from heavy rainfall over the northern part of the Fitzroy River basin caused by the passage of Cyclone 'Joy' which degenerated into a rain depression after landfall near Townsville on 26th December 1990.

Over the period 23rd December 1990 to 7th January 1991, several stations in the Mackay area recorded rainfalls in excess of 2,000 mm. Details of recorded rainfalls are given in the report.

There were two periods of heavy rain which resulted in two flood peaks at Rockhampton, the first reaching 9.15 m gauge height (7.7 m AHD) on 7th January, and the second 9.3 m gauge height (7.85 m AHD) on 12th January 1991. The corresponding peak discharge was at about 15,000 m³/s at The Gap and Yaamba, the most downstream recording points.

The volume of the 1991 flood was estimated to be over 17 million ML (compared to 32 million ML for the 1918 flood).

The flood caused widespread flooding in Rockhampton, particularly Depot Hill, Port Curtis, Fairy Bower, Pink Lily and areas of North Rockhampton close to the river. Properties were also flooded along the river downstream from Yaamba.

One of the most serious problems with the 1991 flood was the closure of all transport links and subsequent isolation of Rockhampton for about 2 weeks. The main durations of closure were:

- Bruce Highway South of Rockhampton (Yeppen Crossing) 11 days
- Bruce Highway North of Rockhampton (Alligator Creek) 15 days

- Capricorn Highway 20 days
- North Coast Railway South of Rockhampton (Yeppen) 11 days
- North Coast Railway North of Rockhampton (Alligator Creek) 12 days
- Rockhampton Airport – Main Runway 13 days

FLOOD FREQUENCY STUDIES

Considerable attention was given to flood frequency studies of peak discharge and peak river heights in order to enable the probability associated with the major floods of record to be estimated as closely as possible. The flood frequency curves were then used for the estimation of more extreme floods for flood management purposes and for use in flood damage studies.

Discharge data for the two primary streamflow recording stations at The Gap and Riverslea were analysed in this regard. The records for The Gap were combined with earlier records at Yaamba in order to provide the longest possible period of record (1911–1991). The records were analysed using annual maximum series and partial duration series approaches.

The records were analysed using a range of statistical distributions and it was found that the Gumbel distribution (Extreme Value Type 1) provided the best fit. Refinements such as adjustments for historic record periods (the 1918, 1954 and 1991 floods were known to be the three highest since 1859), and separation into two flood populations, one being due to the influence of tropical cyclones, were introduced. Peak height records were analysed for a number of stations using a partial duration series approach.

The final results adopted for use in the study are given in Table A. Values in Table A are given in terms of annual exceedance probability (AEP), which is the percentage probability of a flood of a given magnitude being equalled or exceeded in each and every year.

TABLE A
Adopted Flood Frequency Curves
Fitzroy River

Location	Type	Unit	Estimated value for AEP				
			2%	1%	0.5%	0.2%	0.1%
Yaamba/The Gap	Discharge	m ³ /s	14,200	16,400	19,000	22,500	24,000
Yaamba	Peak Level	m GH	16.3	16.9	17.5	18.3	18.9
		m AHD	17.6	18.2	18.8	19.6	20.2
Rockhampton	Peak Level	m GH	9.2	9.75	10.3	11.0	11.5
		m AHD	7.75	8.30	8.85	9.55	10.05

On the basis of this analysis, the 1918 flood has been assigned a probability of 0.6% AEP (170 year average recurrence interval (ARI)), and both the 1991 and 1954 floods have been assigned a probability of 1.8% AEP (55 year ARI).

EXTREME FLOODS

Significantly greater floods than those experienced since settlement could occur in the Fitzroy River basin as a result of more extreme rainfalls and/or high rainfalls occurring simultaneously over a larger part of the catchment.

Flood management should take account of these more extreme floods, as even though they may occur only rarely, the damage caused by such floods may be devastating.

Consideration is given in the report as to the likely magnitude of such extreme floods and whether estimation of the probable maximum flood (PMF) is warranted.

The procedures for estimating PMF have not been used for a catchment the size of the Fitzroy River basin; their use would be time consuming and the results obtained would still be subject to considerable uncertainty.

The report recommends that, for the purposes of the current flood management study, the approximate magnitude of extreme floods be estimated by extrapolation of the flow frequency curve, which gives an estimated 0.01% AEP flood of about 32,000 m³/s.

FLOOD MAPPING

Flood maps are one of the primary outputs of the study. Flood maps should show the extent of inundation from a range of flood magnitudes, and also delineate floodways and flood storage areas.

In Phase 1, it has only been possible to produce maps showing the extent of inundation in historic floods (mainly 1991, but with information for the main CBD area of Rockhampton only for the 1918 and 1954 floods).

This limitation in Phase 1 is due to inaccuracies and inconsistencies found in existing contour maps, and the necessity to better identify water surface variations over a range of flood heights. The latter requires hydraulic modelling which is part of Phase 2 activities. The inadequacies of the existing contour mapping will be addressed in Phase 2 by preparing better maps for the areas of most concern in this regard.

It is expected that flood maps will be prepared in Phase 2 for a range of flood probabilities. As little or no contour information is available outside the Rockhampton City Council area, it will be possible to produce flood maps only for the latter area.

FLOOD DAMAGE ASSESSMENT

General

The report contains three sections dealing with flood damage assessment. These are:

- a general section outlining the types of flood damages which occur and the terminology used to differentiate between direct and indirect losses, tangible and intangible losses etc.;
- damage estimation for the 1991 flood;
- flood damage modelling for a range of flood heights, including investigation of the effects of possible flood mitigation works.

Damages in 1991 flood

Damage assessment for the 1991 flood is summarised below:

• Residential sector	- direct damage estimated to be	\$1,000,000
	- indirect losses estimated to be	\$400,000
• Commercial/Industrial sector	- direct damage estimated to be	\$5,000,000-\$10,000,000
	- indirect losses estimated to be	\$26,000,000-\$71,000,000
• Public sector	- direct damage estimated to be	\$9,000,000
	- indirect losses estimated to be	\$2,000,000

These give a total estimated loss in the range of \$43 million - \$93 million. As there may be some double counting in the above the best estimate for total damages is about \$50 million, but this is clearly imprecise.

The largest component of the above, about \$30 million, is the estimated indirect loss to the commercial/industrial sector. This is due to costs to commercial and industrial enterprises resulting from delay or cancelled movement of goods and persons; and the cost of travel delays. As the range of estimates given above indicates, this component was the most difficult to estimate and is the least precise.

The total damage for the 1991 flood quoted above of about \$50 million is a best estimate within a likely range of about \$40 million to \$90 million.

This commercial sector value includes losses in the range of \$2 million - \$17 million for the tourism sector. Values at the lower end of the range are those relating to business losses in the Rockhampton area whereas the higher value is a statewide figure which takes account of the general reduction in tourist activity during and after a major cyclone event, and does not relate, in total, to flooding in Rockhampton.

Flood Damage Modelling

Flood damage modelling was undertaken using the ANUFLOOD computer model, which requires the establishment of a property database for both residential and commercial/industrial sectors. These property databases were produced following external survey of all premises in the flood liable areas of Rockhampton to note such characteristics as construction material, and floor height above ground. A total of 3365 residential properties and 789 commercial properties are included in the database. Properties outside of the urban area Rockhampton were not included due to the lack of ground height (contour) information.

Statistical summaries are presented which show that 93% of homes in Rockhampton are of lightweight construction and that 78% are raised, with 70% being raised 1.5 m or more. By way of contrast, 84% of commercial premises are of heavy construction, and 92% are unraised.

After first adjusting the model to allow for water surface variation, a reasonable degree of agreement was reached between the number of properties flooded in 1991 and the predicted number from the model. The model was then used to estimate potential direct damages for a wide range of flood heights and also to estimate the mean annual damage, the long term average damage taking into account the probability associated with flooding of different levels. The direct mean annual damage was estimated to be \$160,000 per annum for the residential sector and \$770,000 per annum for the commercial sector. The model does not include public sector loss but assuming a similar ratio to that in the 1991 flood, public sector mean annual direct loss would be expected to be about \$1.0 million per annum.

Allowing for indirect losses of similar ratio to direct losses as estimated for the 1991 flood, the total mean annual damage is believed to be of the order of \$5.2 million per annum.

The ANUFLOOD model was subdivided into 15 zones and flood damages estimated for each zone, so that the benefits of flood mitigation works could also be broken down for a number of separate areas within Rockhampton.

The ANUFLOOD model was used to estimate the effect on reduction of mean annual damage for the following flood mitigation measures:

- levees;
- house raising (including the benefit from already raised houses);
- flood proofing of commercial premises;
- floodplain clearing.

The most appropriate option for each location is identified in the report.

SOCIAL IMPACTS

From the data available, and from discussions with a number of residents and personnel responsible for post-disaster management, it appears that Rockhampton residents have displayed typical post-disaster physical and psychological reactions.

A proportion of Rockhampton flood victims are continuing to experience post-flood stress in the medium term.

As the 1991 flood receded, government and non-government welfare organisations worked together in 'Operation Recovery', which was designed to assist people in recovering from the effects of flood induced trauma.

The following recommendations are made in regard to minimisation of the social impact of future floods:

- That an 'Operation Recovery' type response be organised in regard to any major flood situations in Rockhampton;
- That in organising the above response, more experienced workers are targeted to work in the worst affected areas;
- That as part of 'Operation Recovery', government and non-government agencies seek to use a period of time before flood waters subside to organise wide-spread community response for flood clean up;
- That 'Operation Recovery' incorporate a medium term (six to twelve months after event) community outreach component;
- That flood mitigation measures such as raising houses, relocating electricity boards, and hot water systems be considered;
- That prevention measures such as information on flood resistant ways of enclosing and fitting downstairs parts of highset houses to be considered;
- That preparedness measures such as permanent street flood markers be part of any flood mitigation scheme;
- That preparedness measures designed to resource local communities eg. (local boatshed, local volunteer group) particularly in communities such as Depot Hill and Port Curtis be considered;
- That the Department of Family Services review its disaster subsistence scheme in such situations as the Rockhampton flood. An alternative response may grant every household below flood peak a subsistence amount;
- That relevant authorities ie. SES, Police and Council co-operate to consider ways of controlling sightseers;
- That preparedness measures designed to resource local communities be designed in consultation with those local communities.

ENVIRONMENTAL IMPACTS

Environmental impacts of flooding in the lower Fitzroy River are a combination of natural impacts and those induced by man's activity in the catchment and floodplain. In some instances, for example, soil erosion and the subsequent effect of transported sediment on coral mortality in Keppel Bay, these impacts relate to a natural process which has been exacerbated by man's occupation of the catchment.

A summary is given in the report of environmental impacts subdivided into land impacts; freshwater impacts; estuarine and marine impacts; and public health impacts.

Control of environmental impacts by means of the Integrated Catchment Management approach recently instigated by the Queensland Government is supported.

Recommendations are made in regard to assessing the hazard from operational and closed landfill sites within the floodplain with a view to control of leachate where warranted; and to the minimisation of storing of hazardous substances in the floodplain.

ISSUES RELATING TO CURRENT FLOODPLAIN MANAGEMENT

The report summarises the major issues which have been raised in regard to current flood management in the Rockhampton area. The findings in this section of the report are based largely on a review of previous hydraulic model studies, and need to be refined from model studies to be carried out in Phase 2.

A comparison was carried out between predicted flood levels in the 3 previous model studies, all of which were based on the 1954 flood, and actual levels in 1991. This was possible because of the high degree of similarity between these two events, although it should not be construed that these two floods were identical.

Flood level and velocity data collected by Dept of Transport at Yeppen Crossing during the flood, enabled the floodplain flow to be estimated at about 7,500 m³/s. This estimate is not regarded as being of a high level of accuracy and is likely to be an overestimate. It will be refined in Phase 2. Considering the other available evidence, the most likely range of floodplain flow was about 5,000 m³/s – 6,000 m³/s.

There has been considerable development in the floodplain in the period between the major floods of 1954 and 1991, notably construction of the Fitzroy River Barrage; reconstruction of Rockhampton Airport; reconstruction/realignment of the Capricorn Highway; and realignment of the combined Yeppen floodplain crossing of the Bruce Highway and North Coast Railway. The influences of these structures is summarised below, although it must be stated that it is not possible to separate the effects of individual structures with any accuracy.

Fitzroy River Barrage

The Fitzroy River Barrage was commissioned in 1970 to impound water for public water supply purposes. The barrier comprises 18 vertical lift gates which are lifted out of the water during flood so that the effect on the flood level is minimised.

The predicted effect of the barrage for a flood similar to that of 1954 was to raise flood level upstream of the barrage by 0.34 m, reducing to 0.06 m at Pink Lily. This prediction was confirmed by the actual level upstream of the barrage in the 1991 flood being 0.33 m higher than 1954. This increase in level upstream in turn increases the proportion of total flow which passes down the Pink Lily - Yeppen - Midgee floodway increasing flood levels along the floodway. Thus part of the increased water level at Yeppen is due to this effect.

Conversely, due to the reduced proportion of the flow remaining in the river, the level in the city reach was predicted to be 0.3 m lower, whereas in 1991 it was only 0.1 m lower than in 1954. This may indicate that the actual flow distribution between the river and the floodplain differed from that predicted.

Pink Lily Meander

Continuing erosion at the breakout location at Pink Lily, not only threatens the stability of the high bank at this major meander and the Rockhampton-Ridgeland Road which is in close proximity to the river bank at this point, but also will continue to reduce the threshold level at which breakout flows occur thus leading, over time, to a greater proportion of flow passing down the floodway. This could result, ultimately, in the river changing its course during an extreme flood event.

Recommendations are made in regard to stabilising the bank at Pink Lily to overcome this problem.

Erosion at Pink Lily can also change the distribution of flood flow between the river and the floodplain.

The Yeppen Crossing

The highway crossing at Yeppen and the adjacent railway crossings were reconstructed on a new alignment in the 1980's to improve flood immunity. The design flood immunity of the crossing is 8.5% AEP (12 year average recurrence interval). It is understood that the crossing did not overtop in the 1988 flood but was close to doing so. The flood frequency analysis carried out as part of this study showed that the 1988 flood was 8.5% AEP (12 year ARI) which indicates that the crossing performed as expected in this regard.

Flood levels in 1991 were about 0.5 m higher than in 1954 at Yeppen compared to a predicted increase with the realigned crossing, the barrage and other developments of 0.42 m. Taking account of differences between the modelled structures and those constructed, differences in flood flows and distribution, and other minor changes, the predicted increase in levels is broadly consistent with that observed.

Rockhampton Airport

Rockhampton Airport is constructed in the Pink Lily - Yeppen floodway and is protected by levees understood to have been designed to resist the 1954 flood. However, the levees and the runways were flooded in January 1991 resulting in the airport being closed for 13 days. The levees have since been reconstructed.

Rockhampton City Council is proposing to extend the main runway by about 800 m to the north west, across Lion Creek and across all or part of Lotus Lagoon. This development would cause further changes in the distribution of flows between the river and the floodplain and would cause some increase in flood levels.

It is recommended that the effect of the proposed development on flood levels be investigated as part of the hydraulic model studies to be carried out in Phase 2.

Rockhampton City Landfills

The Commonage landfill is situated within the Fitzroy River floodplain and was closed due to flooding in the 1991 flood. There are a number of previous landfills also in the floodplain. Previous hydraulic model studies have indicated that the landfill has little impact on flood levels. This should be checked as part of Phase 2 studies. The environmental and public health implications of the presence of landfills in the floodplain are considered in the report.

Scrubby Creek Diversion

A diversion channel was constructed on Scrubby Creek in the 1950's to divert high flows, in order to alleviate flooding adjacent to Scrubby Creek. Due to poor ground conditions, the diversion structure has failed on previous occasions and failed again during the 1991 flood. There has been considerable erosion in the diversion channel and downstream of the channel where floodwaters discharge onto the floodplain.

A number of options for the future management of Scrubby Creek have been identified. These include reconstruction of the diversion channel on the existing alignment; restoring conditions to those prior to the diversion being constructed; construction of a diversion structure and channel at a different location; control of upstream runoff by means of a detention storage.

Recommendations are made in regard to additional studies necessary to determine the most appropriate solution. However, due to funding constraints, this cannot be accommodated within Phase 2 of the current study.

Bruce Highway at Alligator Creek

The Bruce Highway at the Alligator Creek crossing near Yaamba is cut very frequently, with a current flood immunity of only 33% AEP (3 year ARI).

The crossing was cut for a total 21 days in the major 1991 flood including 15 consecutive days of closure during the passage of the main flood wave.

The Department of Transport has proposed realigning the Bruce Highway in this section at a cost of \$7.3 million. This will raise the flood immunity to about 2% AEP. An approximate benefit-cost analysis gave a benefit-cost ratio of 5.0 for this scheme. This proposal is supported.

STRUCTURAL FLOOD MITIGATION OPTIONS

A range of structural flood mitigation options were considered in regard to reducing flood damages. These are briefly summarised below.

Flood Mitigation Storage

A potential site for a major storage has been identified in previous studies at 'The Gap' upstream of Yaamba. Development of this storage for flood control purposes cannot be justified on economic grounds. The scheme would cost over \$200 million to develop at a benefit-cost ratio of only about 0.15. The dam would inundate about 10,000 ha of land and have significant environmental impact.

It is recommended that this scheme does not warrant detailed investigation.

Major Flood Diversions

The possibility of major diversions upstream of Rockhampton was briefly considered. These schemes would be prohibitive in cost due to the need to cross the coastal ranges and would have very significant environmental impact. They do not warrant further investigation.

The development of a stable floodway along the route of the Pink Lily - Yeppen - Midgee floodway was also investigated. This was estimated to cost about \$250 million to construct and would have significant environmental impact including draining most of the lagoons which form a significant wildlife habitat.

It is recommended that this scheme is not considered further in the study.

River Channel Enlargement Works

A number of measures in this general classification have been raised for consideration. These include dredging; elimination of 'The Rocks'; and truncation at Pirate Point. It is considered that none of these would be effective in reducing flood levels and would also have adverse environmental effects. Truncation of Pirate Point occurred naturally in the 1991 flood. None of these schemes is considered to warrant further investigation.

Improvement of Flood Immunity at Yeppen Crossing

Improvement of flood immunity of the Bruce Highway/North Coast Railway floodplain crossing at Yeppen has the potential for substantially reducing indirect losses, principally to commerce and industry caused by transport disruption, and also of reducing the impact of the current crossing on flood levels. To be effective in this regard would require increasing bridge length together with raising the embankment level. Bridging width would need to be sufficient to prevent this having an adverse effect on upstream flood levels. Estimated costs of increasing bridge lengths from the existing 420 m to 900 m and 1,200 m are about \$14.5 million and \$22.5 million respectively. These schemes have an approximate benefit-cost ratio of 1.0. This would not normally be regarded as being sufficiently high to warrant the expenditure under National Arterial Road criteria, but a lower benefit-cost ratio may be acceptable in regard to flood mitigation criteria. It is considered that enhancement of the Yeppen Crossing has sufficient merit to warrant detailed investigation in Phase 2.

A major reconstruction of the highway and railway to avoid the Yeppen crossing was briefly investigated. However, the cost of this was estimated to be in the order of \$75 million with a benefit-cost ratio of about 0.8. Such a scheme would also have significant environmental impact. It is considered that this scheme does not warrant further investigation.

Levee Banks

It would be possible to protect at least some of the most flood liable parts of Rockhampton by means of levee banks. The economics of these were considered on the basis of sub-division of the City area into 15 zones set up for the ANUFLOOD model.

The increase in flood level which would result from any of the levee proposals will need to be estimated in Phase 2.

The only areas which appear to warrant further investigation are:

- a combined levee to protect Port Curtis, Depot Hill and the lower part of the Central Business District. This would run from near the Yeppen 1 bridge to Quay Street, and has a benefit-cost ratio with protection to 1% AEP of 0.95 and a capital cost of \$9 million. Increasing levee height to 0.5% AEP and 0.2% AEP increases capital costs to \$11 million and \$15 million respectively, with benefit-cost ratios of 1.08 and 1.15;
- a levee bank to protect the airport in conjunction with the adjacent residential areas. This has only a low benefit-cost ratio, but the continued operation of the airport is a significant intangible benefit which should be taken into account.

It is recommended that these be subject to detailed investigation in Phase 2.

Flood Proofing

Flood proofing of commercial premises and raising of houses was considered along with structural options as it is a high capital cost measure. 78% of houses in Rockhampton are already highset, as a result of which residential mean annual damage is only 33% of what it would be if all houses were low set.

Raising of houses appears to be beneficial in the Splitters Creek area (benefit-cost ratio 1.65). Other areas in which the benefit-cost ratio for house raising approaches one are Lakes Creek Road (0.6) and Pink Lily (0.75).

Flood proofing of commercial premises has been briefly investigated but requires more detailed study on a property by property basis to enable costs to be estimated more closely before recommendations can be made in this regard. It is usual for such works to be undertaken by business owners rather than by Government funding.

Flood proofing of commercial premises has an overall benefit-cost ratio of about 0.4 with a broadly estimated cost of \$47 million. Benefit-cost ratios greater than one were found in Gladstone Road (1.85), Port Curtis (2.3), Depot Hill (1.3), south bank downstream of barrage (2.8), and north bank downstream of barrage (1.1) zones.

It is considered that further investigation of flood proofing is outside the scope of Phase 2 of the current study, but is recommended that a pilot study be undertaken to consider flood proofing requirements for selected premises.

Removal of Flood Liable Properties

Consideration was given to the cost and damage reduction of all houses and business premises below, say, the 1% AEP flood level being removed. Whilst this would substantially reduce flood damages, the social cost would be high particularly in Depot Hill and Port Curtis, where large proportions of the communities would be affected. The benefit-cost ratio for the residential sector are all low, the highest being about 0.1. The situation is very different in regard to the commercial sector, with approximate benefit-cost ratios of 1 or higher in Crescent Lagoon, and Gladstone Road/Lower Dawson Road. The latter figures are based on very approximate resumption and relocation costs and would need further investigation for individual properties.

It is not recommended that this course of action be considered further.

NON STRUCTURAL FLOOD MANAGEMENT MEASURES

These measures include, for example, planning controls, flood warning and community response thereto; improvements to public and commercial flood preparedness.

These measures are of a relatively low cost nature.

Planning Controls

The use of planning controls to reduce the impact of future floods relates to the application of such controls to limit or modify proposed development in flood liable areas. A necessary pre-requisite is the availability of flood maps showing the areas inundated for a range of flood magnitudes. The preparation of these maps is seen as an essential part of Phase 2.

This consideration should include identification and delineation of floodways and preparation of development guidelines.

Flood Warning

The provision of accurate, timely warnings of forecast flood height which are subsequently clearly and unambiguously disseminated to the public, allows the damages from imminent floods to be reduced. In Rockhampton, accurate flood warnings are available 4-7 days in advance, providing adequate time for significant reduction in flood damages to be achieved.

The Fitzroy River basin has one of the most extensive flood warning systems in Queensland, which together with the long lead time, puts Rockhampton residents in a good position with regard to reducing flood damages. However, it appears that these benefits are not being fully realised, mainly due to difficulties in relating forecast heights to flood levels at each property, together with some problems regarding the passing of appropriate information to the public.

The report has investigated these issues in detail and makes the following recommendations:

- **Flood maps** should be available to the public in order to raise awareness of limits of the flood liable areas;
- **Permanent flood markers** showing the height reached by the 1991 flood should be erected at strategic locations throughout the city and suburbs. Warnings for future floods can then be given relative to the 1991 level;
- **Telephone Telemetry.** It is recommended that rainfall telemetry be added to river level telemetry stations from Riverslea downstream and that telephone telemetry be installed to monitor river level and rainfall in Alligator Creek and Neerkol Creek catchments;
- **Floodway reference gauge.** It is recommended that Rockhampton City Council establish a reference gauge in the Fitzroy River upstream from the barrage at a location that will provide accurate information regarding flows in the floodway. This should be fitted with telephone telemetry;
- **Rockhampton Flood Warning Gauge Telemetry.** It is recommended that telephone telemetry be installed at the Rockhampton flood warning gauge.

Dissemination of Warnings

The following recommendations are made in regard to improving the dissemination of flood warnings:

- **Recorded telephone messages** – Rockhampton City Council should set up one or more telephone recording services in relation to providing flood warnings, and instructions to the public in the event of flood;
- **Local and District Emergency Operations Centre** – The scope and responsibilities of each should be reviewed and clarified and the public informed that the Local Centre is the single point of contact.

Counter Disaster Planning and Operations

It is understood that both the District and Local Counter Disaster Plans are under review. Whilst it is beyond the scope of this study to comment in detail in regard to these plans, the following comments and recommendations are made in the spirit of maximising the efforts of both DEOC and LEOC to minimise danger, disruption and damages during major floods;

- the respective roles and responsibilities of District and Local organisations and the means of communication between them should be clarified in their respective operations manuals, thus enabling improved co-ordination;

- the establishment of SES groups at Gracemere, Alton Downs and Yaamba is supported;
- local residents with flood experience in fringe areas of Rockhampton eg. Depot Hill and Port Curtis should be encouraged to become SES volunteers and that appropriate SES equipment should be stored locally in these areas;
- both Local and District Emergency Operations Centres should be maintained in a permanent state of readiness;
- the public should be better informed in regard to whom to approach for assistance (LEOC) with the LEOC being the single point of contact;
- recorded telephone messages equipped to provide the basic flood warning information should be installed as outlined above with the information being updated as frequently as possible. This will reduce the number of other telephone calls with which LEOC staff have to deal;
- counter disaster pre-planning should consider the consequences of a flood more severe than the 1991 flood in detail;
- business operators should be urged to prepare 'flood action plans'.

Community Flood Preparedness

Raising of public flood awareness between floods should be carried out by making the following widely available:

- flood maps;
- a flood awareness/preparedness leaflet;
- a magnetic card, to be kept for example on each household's refrigerator door containing a few key points and contact telephone numbers;
- a flood awareness page in the Rockhampton telephone directory to augment the 'Disaster Survival Guide', and along the lines of the page on cyclone warnings;
- flood markers as previously discussed;
- business operators in flood liable areas, should be made aware of the risk of their property being flooded, or its access route being cut, and should be encouraged to develop 'flood action plans'.

In addition to the above, in the period when a flood is imminent, it would be valuable to publish in the local print media:

- copies of the flood maps, and flood awareness literature;
- reminders of the appropriate contact numbers and advice regarding damage minimisation, evacuation procedures etc.

Strategies for Minimising Transport and Industrial Disruption

This aspect is considered in the report, which concludes that transport and industrial disruption will be minimised by:

- improving the flood immunity of existing transport links or the provision of alternative routes;
- improving the accuracy and timeliness of road closure reports given by the RACQ to minimise vehicles and occupants being stranded;
- increase in raw material stocks and finished product storage facilities during the wet season to minimise disruption to production during flood periods.

RECOMMENDATIONS REGARDING FURTHER INVESTIGATION OF FLOOD MITIGATION MEASURES AND FLOODPLAIN ISSUES

This section of the report brings together the economic analysis of various options and measures with consideration of social and environmental impacts using a matrix approach.

The following measures are considered to warrant further investigation in Phase 2:

- improvement of highway/railway flood immunity at Yeppen Crossing;
- levees – Depot Hill, Port Curtis, Lower Central Business District and around Rockhampton Airport only;
- planning controls – requiring the completion of flood mapping.

The report details the requirements for further investigation in regard to each of the above. Each of these options requires hydraulic modelling studies to be carried out. The report outlines the objectives of the hydraulic model studies, together with the data requirements which relate to topographic survey, hydrologic data, historic flood levels, and floodplain structures.

A range of other issues have been identified in the report which warrant further study. However, due to budgetary and time constraints it is not possible to include these in Phase 2. These are:

- Estimation of probable maximum flood;
- Scrubby Creek Diversion;
- Hydrological modelling for flood forecasting;
- Development of a geographic information system for counter disaster planning and operation;
- Provision of storage on Alligator Creek and Neerkol Creek;
- Detailed investigation of erosion and siltation in the lower Fitzroy River;
- Investigation of leachate from operational and closed landfills in the Fitzroy River floodplain and subsequent remediation if warranted;
- Flood proofing of commercial/industrial premises – pilot study.

It is recommended that consideration be given to funding of these studies by the appropriate authorities.

RECOMMENDATIONS REGARDING IMPLEMENTATION OF FLOOD MANAGEMENT MEASURES

Selection of a Flood Standard

The report lists the issues relevant to selection of a flood standard for planning purposes, and recommends that the 1% AEP flood be adopted.

Draft Floodplain Management Policy

It is recommended that Rockhampton City, Fitzroy Shire and Livingstone Shire Councils each develop and adopt a floodplain management policy. It is desirable, although not essential, that the policies of the three Councils be similar in regard to principles and major criteria such as the adopted flood standard. It is recommended that the Councils develop their policies in a co-operative and co-ordinated manner.

The policies should be developed in accordance with the delineation of floodways and flood storage areas, with compatible uses listed for each. As hydraulic model studies in Phase 2 are necessary before this delineation can be carried out, it is proposed to hold over preparation of a draft policy until Phase 2. The Phase 1 report lists the main points to be covered by a floodplain management policy.

Measures for Immediate Implementation

The following are recommended for immediate implementation without requiring further action in this study:

- Realignment of the Bruce Highway at the Alligator Creek crossing as currently proposed by the Department of Transport
- Flood warning
 - installation of river level and rainfall telephone telemetry stations on Alligator Creek and rainfall telemetry in the Neerkol Creek catchment;
 - installation of telephone telemetry at Rockhampton Flood Gauge;
 - installation of river level telephone telemetry station in the Pink Lily area to give warning regarding flows in the floodplain;
 - installation of street markers.
- Flood Warning Dissemination
 - installation of recorded telephone message service at the Local Operations Emergency Centre which should be the single point of contact for the public;
 - discussions with local media to clarify the flood warning system and their role within it.
- Counter Disaster Planning and Operations
 - clarify respective roles of the District and Local counter disaster organisations, and maintain both centres in a permanent state of readiness;
 - the recent establishment of SES groups at Gracemere, Alton Downs and Yaamba is supported. Consideration should be given as to how best to ensure adequate SES presence in Depot Hill and Port Curtis;
 - counter disaster pre-planning should consider in detail the consequences of a flood more severe than that of 1991.
- Increasing Public Flood Preparedness and Community Flood Response
 - preparation and issue of pamphlet explaining flooding in the area, what to do in the event of flooding to minimise damage, how to use street markers to estimate flood level at individual properties, contact telephone numbers;
 - preparation of summary information similar to the above for publication in the Rockhampton District Telephone Directory;

- when flooding is imminent publish flood maps, flood awareness/preparedness information in the local print media;
- business operators should be urged to prepare 'flood action plans'.
- request Department of Family Services to review its disaster subsistence scheme with a view to making it more equitable in such situations as flooding in Rockhampton;
- improvement to 'Operation Recovery' type response.

FLOOD MANAGEMENT OF THE FITZROY RIVER AND FLOODPLAIN

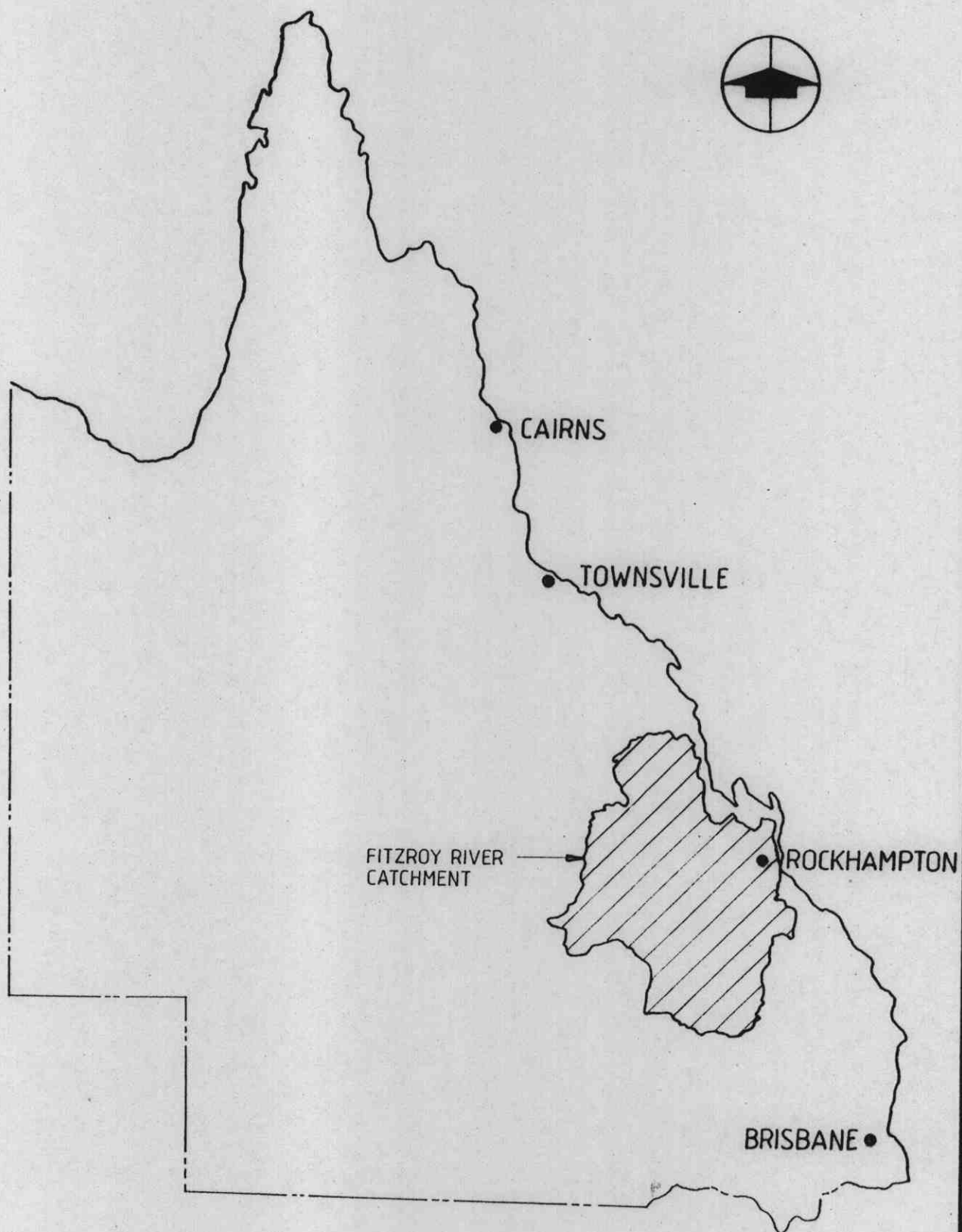
At present, a number of Commonwealth, State and Local Government authorities have an interest in management of the Fitzroy River and its floodplain, together with a number of community based groups.

These inputs are not always co-ordinated and it is believed that better co-ordination and co-operation between agencies would encourage better flood management.

The recent Queensland Government Strategy regarding Integrated Catchment Management provides an appropriate vehicle by which this co-ordination may be achieved.

It is recommended that as soon as a Fitzroy River Catchment Co-ordination Committee is constituted under the above, that a Floodplain Management Sub-Committee be established, with representation on the main committee. Alternatively, in the period until a Catchment Co-ordinating Committee is formed, it may be appropriate to establish a Lower Fitzroy River Improvement Trust.

Whichever of the above is formed, it should be broadly based and include representation of the three local Authorities, the major Government Departments with an interest in floodplain management, community groups, land use groups and local landowners.



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**ROCKHAMPTON FLOOD MANAGEMENT STUDY
LOCATION PLAN**

FIGURE 1

