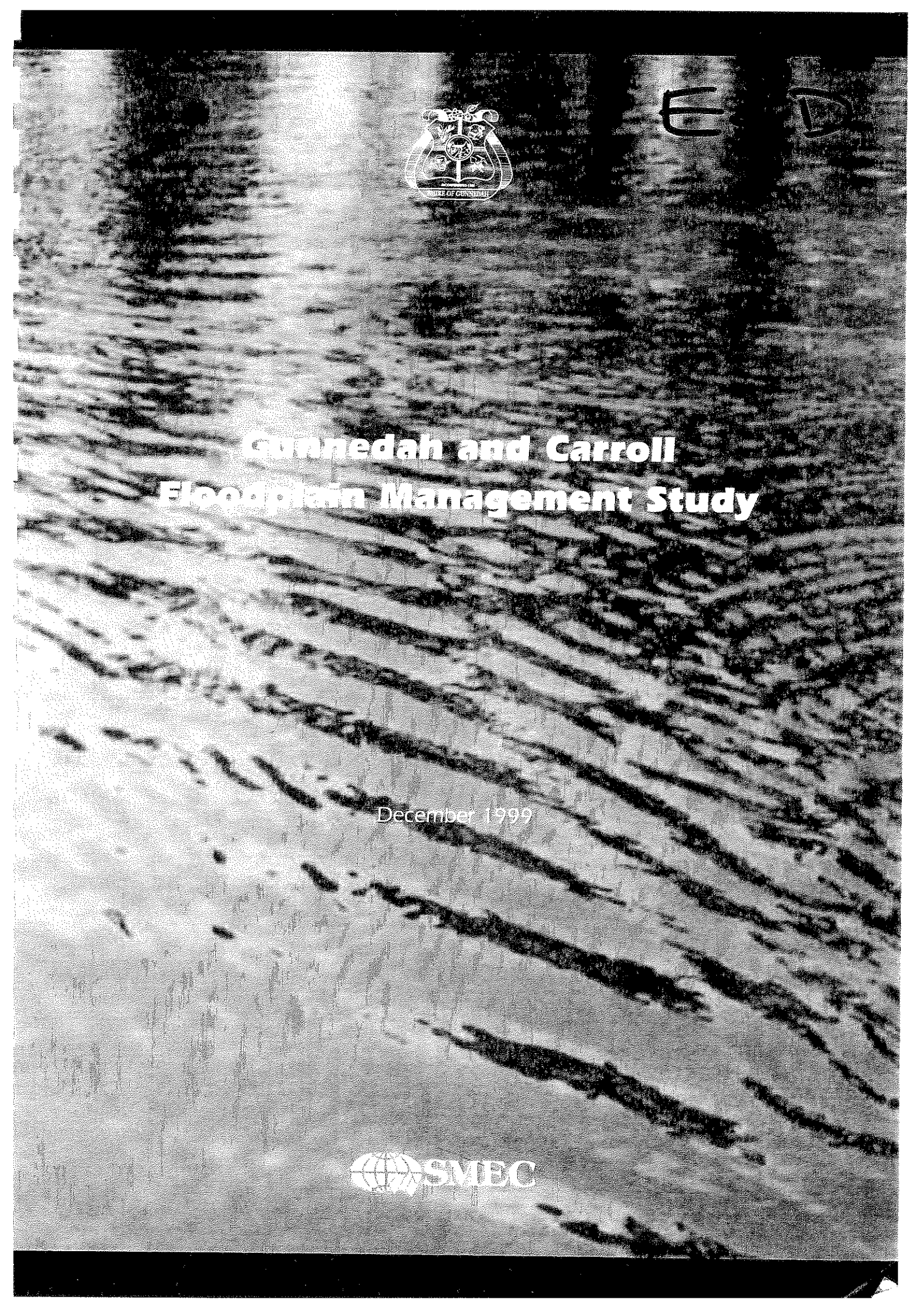

Gunnedah and Carroll Floodplain Management Study

December 1999

SMEC

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PREPARATION, REVIEW AND AUTHORISATION

Project Name:	*Gunnedah and Carroll Floodplain Management Study - Executive Summary*	Project No.:	*31923.001*
Prepared by:	*Anna Sherriff*	Signature:	
Position:	*Senior Environmental Planner*	Date:	15/6/00
Reviewed by:	*David Tow*	Signature:	
Position	*Manager – Environment & Planning, NSW*	Date:	15/6/00

This report was prepared in accordance with the scope of services set out in the contract between SMEC Australia Pty Ltd (SMEC) and the Client. To the best of SMEC's knowledge the proposal presented herein reflects the Client's intentions when the report was printed. In preparing this report, SMEC relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations referenced herein. Except as otherwise stated in this report, SMEC has not undertaken further verification regarding the accuracy or completeness of these information sources.

EXECUTIVE SUMMARY

Introduction

Flooding is a frequent occurrence in Gunnedah and Carroll. Periodically waters from the Namoi, Peel and Mooki Rivers sub-catchments flow into the northern section of Gunnedah and into Carroll from the west.

In response to the impact of flooding on these communities, Gunnedah Shire Council and the Department of Land and Water Conservation (DLWC) have recognised the need to undertake integrated floodplain management to manage flood hazard in the communities of Gunnedah and Carroll.

In 1996 DLWC completed the flood study for Carroll and Gunnedah, being Stage 1 of the floodplain management process. Drawing on the information from Stage 1, the next stage of the process has involved the preparation of a Floodplain Management Study (FPMS) and Floodplain Management Plan (FPMP), which identifies the flood hazard and recommends appropriate flood mitigation measures. The Study and Plan have been prepared in accordance with the principles and guidelines in the NSW Flood Prone Land Policy and its attendant Manual. This report is the FPMS, and presents background data and analysis used in the preparation of the FPMP.

Methodology

The Study process has followed five basic stages consisting of:

Stage One:

- Document Review
- Meetings with clients and other agencies
- Initial Community Consultation
- Data Collection and Review

Stage Two:

- Flood Definition and Mapping
- Flood Damage Assessment
- Assessment of Land Use Measures
- Assessment of Social and Environmental Issues
- Preliminary Identification of Floodplain Management Options

Stage Three

- Further community consultation
- Modelling/Assessment of Selected Management Options
- Review Flood Forecasting and Warning Requirements
- Assessment and Recommendation of Flood Planing Levels and Management Options
- Draft clauses for LEP, DCP
- Preparation of Floodplain Management Study Report

Stage Four

- Public Display and Comments, and assessment of comments

Stage Five

- Finalisation of Report and Plan.

The Study Area

Gunnedah Local Government Area (LGA) is situated in the Northern Statistical Division of NSW and has an area of 5,100 square kilometres. Gunnedah, its largest town, is located at the heart of the Gunnedah LGA, with Carroll situated 25 kilometres to the east of Gunnedah. Sydney is located 480 kilometres south-east of Gunnedah, while Tamworth is approximately 70 kilometres to the east of Gunnedah.

Both Gunnedah and Carroll lie on the floodplains of the Namoi River Valley, as illustrated in *Figure 1.1*. Carroll is upstream of Gunnedah, approximately 17.5 kilometres from the junction of the Peel and Namoi Rivers, and Gunnedah is approximately 4 kilometres downstream from the confluence of the Mooki and Namoi Rivers.

The study area outlined by Council in its brief for this project encompasses the northern portion of the town of Gunnedah, and the village of Carroll. In Gunnedah the study area is bounded by the Mungindi Railway to the south, the Mooki River to the east, and the one lane road leading to the property "Wirringulla" to the west. The northern study boundary incorporates a number of different landmarks, as illustrated in *Figure 1.2*. The study boundary in Carroll follows the village boundary, as shown in *Figure 1.3*. The Namoi River forms the western boundary of the study area in Carroll.

The nature of flooding in the study area cannot be assessed in isolation from the surrounding rural areas. Accordingly, the mathematical hydraulic model of the floodplain encompassed the floodplain of the Namoi River from Carroll to Boggabri and the floodplain of the Mooki River from the confluence with the Namoi to a point upstream of the village of Breeza. The base data for the model was established in great detail for the towns so that flooding could be modelled with the accepted degree of accuracy; the rural areas did not contain the same level of base data. The hydrologic input to the model (the flood flows) was taken for the catchment as a whole, covering the Namoi, Peel and Mooki Rivers.

Social and Ecological Issues

Demographic Characteristics

In determining the most suitable floodplain management options it is important to understand the specific characteristics of the population. This enables a merit assessment of each option based on its suitability for a particular population. The information presented below is built upon within the social impact assessment, chapter six of this Study. The population of the study area has the following characteristics:

- The study area comprises 18.3% of the total population of Gunnedah Shire LGA, which was 12,798 people at the 1996 census.
- Gunnedah Shire LGA shows a general decline in population, and especially in the proportion of its population aged between 10 and 34 years. The overall population is aging, influencing emergency response measures and evacuation procedures.
- Incomes both in Carroll and in the Gunnedah study area are lower than those in Gunnedah Shire as a whole, while the unemployment rate is higher than the Shire average, which is

slightly higher than the NSW State average. This lessens the ability of people in the area to recover from flood events.

- The majority of dwellings in the study area are detached, with a high rate of home ownership.

Biological and Physical Environment

It is equally important to examine aspects of the biological and physical environment, to determine which floodplain management options can be supported by the surrounding terrestrial and aquatic environments. Briefly, the physical and biological environment in Gunnedah and Carroll exhibits the following characteristics:

- The Namoi River Valley catchment is flat to undulating, and situated within the Gunnedah Basin. Black soil plains comprise a large proportion of the catchment.
- The region has a dry sub-humid climate, with the majority of rainfall typically occurring in summer.
- Much native vegetation in the area has been cleared for cropping and grazing purposes.
- The Plains Grass community has been identified as having high conservation status.
- Three vulnerable and one endangered species of flora may potentially occur within the Gunnedah area.
- Fauna habitats have been significantly altered from their natural condition, due to agriculture.
- Porcupine Reserve, situated south of Gunnedah township, contains a high diversity of flora and fauna species including several threatened species.
- The riverine corridor and the floodplain are likely to be utilised by a range of species. It is important to retain as much natural vegetation as possible, to allow movement of fauna between areas of higher habitat quality.
- Local flora and fauna would benefit from enhanced native vegetation along riverine corridors.

Existing Planning Controls

A review of the current planning and development controls for floodplain management in Gunnedah and Carroll revealed that provision for general flooding controls has been made for Gunnedah and Carroll within the *Gunnedah Local Environmental Plan (LEP) 1998.* No specific provisions have been made for flooding in Carroll, while the LEP and the *Interim Policy for Development on Flood Prone Land* provide local controls for Gunnedah.

There are a number of matters which have been found to warrant amendment to Gunnedah LEP 1998, and the creation of a Flood Prone Land Development Control Plan. These matters are:

- The flood study completed by DLWC in 1996 together with the maps produced within the floodplain management plan needs to replace the flood inundation map 1978 as the technical basis for the LEP.
- There is a need to define floodways and zone them accordingly, incorporating appropriate objectives for these zones.
- Zoning in Gunnedah generally does not respond to flood risks. For example, major commercial development along that portion of Conadilly Street zoned Business 3(b) may significantly increase potential flood damages.
- Definitions will need to be incorporated into the LEP which reflect the definitions in DLWC Draft Floodplain Management Manual, released for public comment by the NSW Government in March 1999.
- Specific controls and zones for the village of Carroll will be required within Gunnedah LEP 1998.
- Appropriate management options will need to be formulated into a development control plan and as amendments to the LEP.
- Flood planning levels, building and development controls will need to be implemented, for the area.
- Greater emphasis needs to be placed on access and evacuation issues for existing and future developments.

Consequent amendments to Gunnedah LEP 1998, and a Floodprone Land Development Control Plan, have been prepared to address these matters. They form *Appendix A* and *Appendix B*, respectively, of the FPMP that accompanies this Study.

Flood Damages

A major component of the Study was the estimation of flood damages, both social and economic, and a calculation of the Annual Average Damages. The results of these calculations are summarised in the Tables 1 and 2 below.

It should be noted that these calculations provide potential damage estimates and do not necessarily reflect actual damages that may occur during a flood. The actions of emergency services, the evacuation of residents and their property and, most especially, the evacuation of commercial properties in the flood affected areas will significantly reduce the level of flood damages.

Table 1 Flood Damages – Existing – Residential

Event	Damage ($)	Number of Houses Affected
10% AEP flood	689,488	77
5% AEP flood	1,225,609	127
1% AEP flood	3,256,385	277
3 x 1% AEP flood	8,249,733	476
Average Annual Damage	220,634	

Table 2 Flood Damages – Existing – Commercial

Event	Damage ($)	Number of Properties Affected
10% AEP flood	1,143,000	10
5% AEP flood	3,605,480	27
1% AEP flood	15,268,467	47
3 x 1% AEP flood	74,189,252	149
Average Annual Damage	818,026	

In addition to its economic impact, flooding has significant social impacts. These are not easily quantified or valued, however their impact on people's lives and livelihoods can be equally significant. Survey results showed that the major social impacts of flooding in Gunnedah and Carroll include high emotional impact (for example distress, depression, fear, panic); damage to homes, gardens, and possessions; loss of irreplaceable possessions; and disruptions caused by evacuation and isolation during flooding.

Floodplain Management Measures

There are three generally recognised ways of managing floodplains to reduce flood losses:

- by modifying the behaviour of the flood itself (Flood Modification);
- by modifying (e.g. house raising) or purchasing existing properties and/or by imposing controls on property and infrastructure development (Property Modification); and
- by modifying the response of the population at risk to better cope with a flood event (Response Modification).

The first two activities are generally referred to as "Structural Measures" and "Non-structural Measures" respectively. The need to include flood preparedness and response measures in the overall floodplain management plan is a new, and warranted concept, since floodplain management measures should address the flood situation as a whole. The range of floodplain management measures available for consideration are shown in Table 3 below:

Table 3 Floodplain Management Measures

Flood Modification Measures	Property Modification Measures	Response Modification Measures
flood control dams	zoning	flood prediction and
retarding basins	planning levels	warning
levees	building and development	flood plans
bypass floodways	controls	community awareness
channel improvements	voluntary purchase	community preparedness
velocity deflectors	house raising	evacuation arrangements
	flood proofing buildings	recovery plans
	flood access	

Flood modification measures are a common and proven means of reducing damage to existing properties at risk. Property modification measures, such as effective land use controls, are essential if the growth in future flood damage is to be contained. Response modification measures, such as flood awareness, are the most effective means of dealing with the continuing flood problem, which is the risk that remains from floods after other measures are in place.

A fundamental principle of sound floodplain management is that management measures should not be considered either individually or in isolation. They should be considered collectively so that their interactions, their suitability and effectiveness, and their social, ecological, environmental and economic impacts can be assessed on a broad basis.

The Gunnedah and Carroll Floodplain Management Study and Floodplain Management Plan have considered all three types of management measures and adopted an integrated and effective mix that is appropriate to the specific circumstances of the flood prone community. Adopted options included the provision of **detailed land use planning and development control measures** in the flood prone areas, and the continued application of **flood response measures** such as flood warning and public awareness programs.

Two other major measures were also considered, a levee and a combined house raising/voluntary purchase program. Both measures would apply to the flood prone northern portion of Gunnedah and, while each has its positive and negative aspects, it is SMEC's recommendation that the negative aspects of the levee would outweigh the positives.

Accordingly, it is considered that of the two active floodplain management measures – levee and/or voluntary purchase/house raising – the latter measure offers the most appropriate response to the flood situation faced by Gunnedah.

It is held that the most appropriate of the active floodplain management measures for Carroll are velocity deflectors and house raising.

The final decision on flood management measures has been made by Gunnedah Shire Council and the Gunnedah Floodplain Management Committee, after public consultation and consideration of this report. The Floodplain Management Committee and Gunnedah Council resolved to reject the option of a levee for Gunnedah or Carroll, and to adopt a combination of alternative management measures.

The options for floodplain management are discussed in detail in Chapter 8 of the Report and the recommendations are summarised in Tables 4 and 5 below.

Impacts of Proposed Measures

While the majority of measures proposed will have a positive impact on the communities of Gunnedah and Carroll, some may potentially have a harmful impact on the surrounding environment. It is recommended that the following factors be considered when implementing management measures, to reduce any likely impact:

- regard to the visual impact of house raising on adjacent properties, the streetscape, and views from significant view sheds;
- regard to the location of Aboriginal archaeological sites, and consultation with the NSW National Parks and Wildlife Service prior to disturbance of any sites;
- regard to the location of heritage sites, their significance and curtilage;
- protection of existing koala habitat areas; and
- consideration of the potential for soil erosion and increased turbidity due to flood or property modification works.

Our detailed conclusions with regard to each of the potential flood management measures are outlined in Tables 4 and 5 below.

Table 4 Summary of Potential Management Measures - Gunnedah

Measure	Recommendation
Flood Modification	
Flood Control Dams	Reject
Retarding Basins	Reject
Levees	Reject
Bypass Floodways	Reject, although it is noted that the 'pig-hole' currently performs this function and should be maintained as such.
Channel Improvements	Reject
Velocity Deflectors	Reject
Property Modification	
Zoning	The Local Environmental Plan should be used to support and provide weight to a Flood Prone Land Development Control Plan. Zoning amendments are recommended to protect floodways and restrict further commercial development at the eastern end of Conadilly Street. The existing 'no building line' should be maintained.
Planning Levels	Floor levels for new residential development should be 500mm above the flood contour of the 1% AEP event. No flood planning level should be set for commercial properties, but these should be constructed from flood compatible materials.
Voluntary Purchase	Supported.
House Raising	Supported.
Building and Development Controls	Supported for incorporation into the draft DCP.
Flood Proofing	Supported for new commercial properties in the 1% AEP area. Recommended for other commercial properties existing and within the extreme flood event.
Flood Access	No works recommended.
Response Modification	
Community Awareness	Supported - ongoing publicity needed, utilising this project as a first step.
Community Preparedness	Supported
Flood Prediction and Warning	Supported - refer to FPMP for proposals
Flood Plans	Supported - refer to FPMP for proposals
Evacuation Arrangements	Supported - refer to FPMP for proposals
Recovery Plans	Supported - refer to FPMP for proposals

Table 5 Summary of Potential Management Measures - Carroll

Measure	Recommendation
Flood Modification	
Flood Control Dams	Reject
Retarding Basins	Reject
Levees	Reject
Bypass Floodways	Reject
Channel Improvements	Reject
Velocity Deflectors	Support
Property Modification	
Zoning	Development should be permissible in the High Hazard area. The Local Environmental Plan should be used to support and provide weight to a Flood Prone Land Development Control Plan.
Planning Levels	Floor level for new residential development should be 500 mm above flood contour for 1% AEP event.
Voluntary Purchase	Reject
House Raising	Supported
Building and Development Controls	Supported for incorporation into the draft DCP.
Flood Proofing	Recommended for any new commercial development
Flood Access	
Response Modification	
Community Awareness	Supported - ongoing publicity needed, utilising this project as a first step.
Community Preparedness	Supported
Flood Prediction and Warning	Supported - refer to FPMP for proposals
Flood Plans	Supported - refer to FPMP for proposals
Evacuation Arrangements	Supported - refer to FPMP for proposals
Recovery Plans	Supported - refer to FPMP for proposals

Floodplain Management Plan

A floodplain management plan forms the heart of an effective floodplain management process. It is based on a comprehensive and detailed evaluation of all factors that affect and are affected by the use of flood prone land. It represents the considered opinion of the local community on how to best manage its flood risk and flood prone land; and it provides a long-term path for the future development of the community.

In formulating such a plan, three specific flooding problems need to be addressed:

- the control of flood damage and hazard to the existing community and properties at risk (the existing problem);
- the control of flood damage and hazard in areas yet to be developed (the future problem); and
- the control of flood damage and hazard associated with mitigation measures being overwhelmed by a larger than the design flood and/or those areas outside the "protected" area (the continuing problem).

A floodplain management plan should aim to achieve an appropriate and integrated mix of control measures that address each of these three problems.

The primary objectives for the Floodplain Management Plan for Gunnedah and Carroll are:

- to reduce the social and economic impact of flooding on individual owners and occupiers of flood prone property; and
- to reduce private and public losses resulting from floods.

Within these overall objectives, Council's specific objectives are:

- to mitigate the impacts of flooding on essential service infrastructure;
- to minimise adverse economic impacts on the commercial centre of Gunnedah;
- to maintain the urban/rural lifestyle of Gunnedah;
- to maintain the rural residential lifestyle in Carroll;
- to utilise ecologically sustainable methods for flood mitigation where possible; and
- to retain the social and environmental benefits to the residents resulting from the proximity of both towns to the Namoi River.

A fundamental principle of this management plan is to ensure that flood management measures are not considered individually or in isolation. Measures must be considered collectively so that their interactions, their suitability and effectiveness, will ensure that a holistic approach to floodplain management is achieved.

With these constraints in mind, a detailed Floodplain Management Plan has been prepared for the township of Gunnedah and the village of Carroll. This Plan is presented as an accompaniment to this Report.

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1 INTRODUCTION

Flooding is a frequent occurrence in Gunnedah and Carroll. Periodically waters from the Namoi, Peel and Mooki Rivers sub-catchments flow into the northern section of Gunnedah and into Carroll from the west.

In response to the impact of flooding on these communities Gunnedah Shire Council and the Department of Land and Water Conservation (DLWC) have recognised the need to undertake integrated floodplain management to manage flood hazard in the communities of Gunnedah and Carroll.

In 1996 DLWC completed the flood study for Carroll and Gunnedah, being Stage 1 of the floodplain management process. Drawing on the information from Stage 1, the next stage of the process has involved the preparation of a Floodplain Management Study (FPMS) and Floodplain Management Plan (FPMP), which identifies the flood hazard and recommends appropriate flood mitigation measures.

This report has been divided into two sections. The Floodplain Management Study presents, and assesses the impact of, floodplain management measures. The Floodplain Management Plan identifies how the preferred management measures can be implemented.

1.1 DEFINITION OF STUDY AREA

Gunnedah Local Government Area (LGA) is situated in the Northern Statistical Division of NSW and has an area of 5,100 square kilometres. Gunnedah, its largest town, is located at the heart of the Gunnedah LGA, with Carroll situated 25 kilometres to the east of Gunnedah. Sydney is located 480 kilometres south-east of Gunnedah, while Tamworth is approximately 70 kilometres to the east of Gunnedah.

Both Gunnedah and Carroll lie on the floodplains of the Namoi River Valley, which is illustrated in *Figure 1.1*. Carroll is upstream of Gunnedah, approximately 17.5 kilometres from the junction of the Peel and Namoi Rivers, and Gunnedah is approximately 4 kilometres downstream from the confluence of the Mooki and Namoi Rivers.

A considerable portion of the Namoi and Mooki River floodplains are utilised for irrigation, which has resulted in changes in land use and various earthworks which have influenced natural drainage and flooding patterns (Barrett Purcell & Assoc 1997:1).

The study area outlined by Council in its brief for this project encompasses the northern portion of the town of Gunnedah. The area is bounded by the Mungindi Railway to the south, the Mooki River to the east, and the one lane road leading to the property "Wirringulla" to the west. The northern study boundary incorporates a number of different landmarks, as it follows from the west, the rear of the lots to the north of the Namoi River, connects with Wean Road as it runs south to the aerodrome and then follows the Namoi River to the confluence with the Mooki River. This area is illustrated in *Figure 1.2*.

The study boundary in Carroll follows the village boundary, as shown in *Figure 1.3*. Carroll is divided by the Oxley Highway, which is known as Breeza Street, through the town. The Oxley

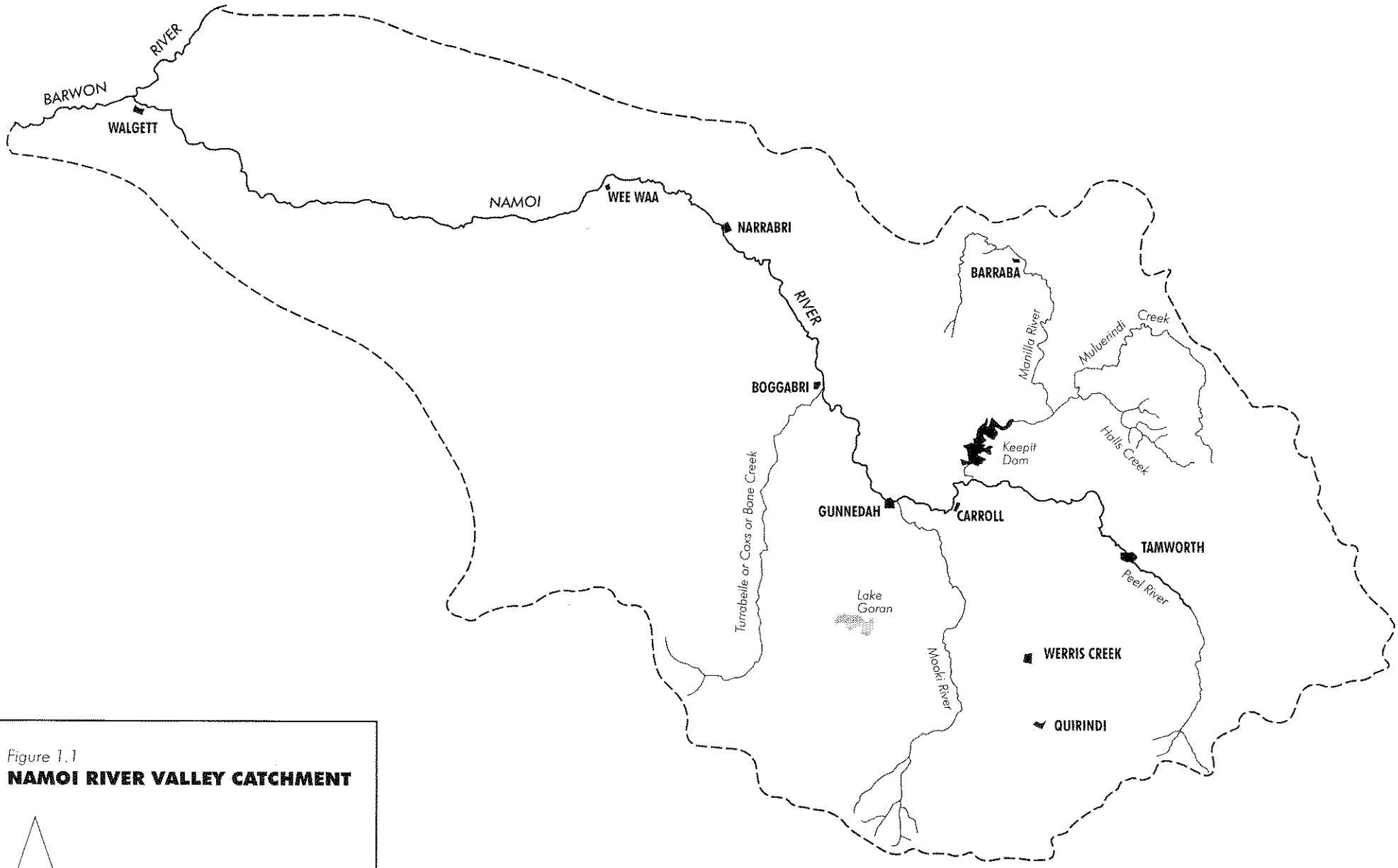


Figure 1.1

NAMOI RIVER VALLEY CATCHMENT

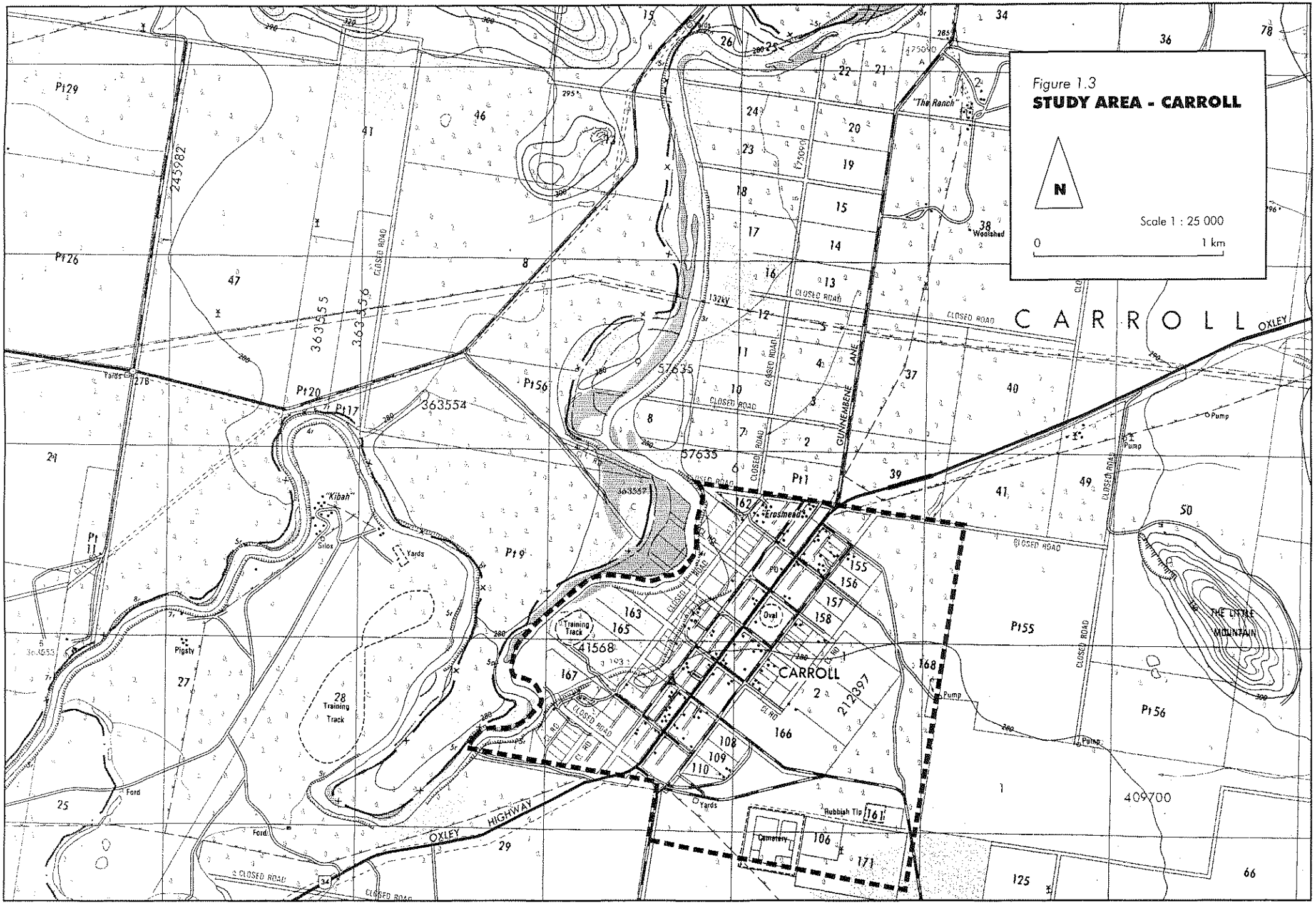


Figure 1.3
STUDY AREA - CARROLL
N
Scale 1 : 25 000
0
1 km
CARROLL
OXLEY HIGHWAY
GUNNEMBENE LANE
CLOSED ROAD
"The Ranch"
"Kibah"
"Erosmead"
Woolshed
Yards
Silos
Pigsty
Ford
Pump
Oval
Cemetery
Rubbish Tip
Training Track
THE LITTLE MOUNTAIN
Pt29
Pt26
Pt20
Pt17
Pt11
Pt19
Pt156
Pt155
363555
363556
363554
245982
57635
41568
212397
409700

Highway runs north-east to Tamworth and south-west to Gunnedah. The Namoi River forms the western boundary of the study area, with North Street to the north, James Street in the east and Namoi Street to the south.

The nature of flooding in the study area cannot be assessed in isolation from the surrounding rural areas. Accordingly, the mathematical hydraulic model of the floodplain encompassed the floodplain of the Namoi River from Carroll to Boggabri and the floodplain of the Mooki River from the confluence with the Namoi to a point upstream of the village of Breeza. The base data for the model was established in great detail for the towns so that flooding could be modelled with the accepted degree of accuracy; the rural areas did not contain the same level of base data. The hydrologic input to the model (the flood flows) was taken for the catchment as a whole, covering the Namoi, Peel and Mooki Rivers.

1.2 PROJECT METHODOLOGY

The methodology for preparation of the Flood Plain Management Study (FPMS) and Flood Plain Management Plan (FPMP) has involved several stages of documentation review, collection and analysis of data, modelling and consultation with the Flood Plain Management Committee (FPMC) and communities of Gunnedah and Carroll. The overall methodology for the project is summarised in *Figure 1.4* below.

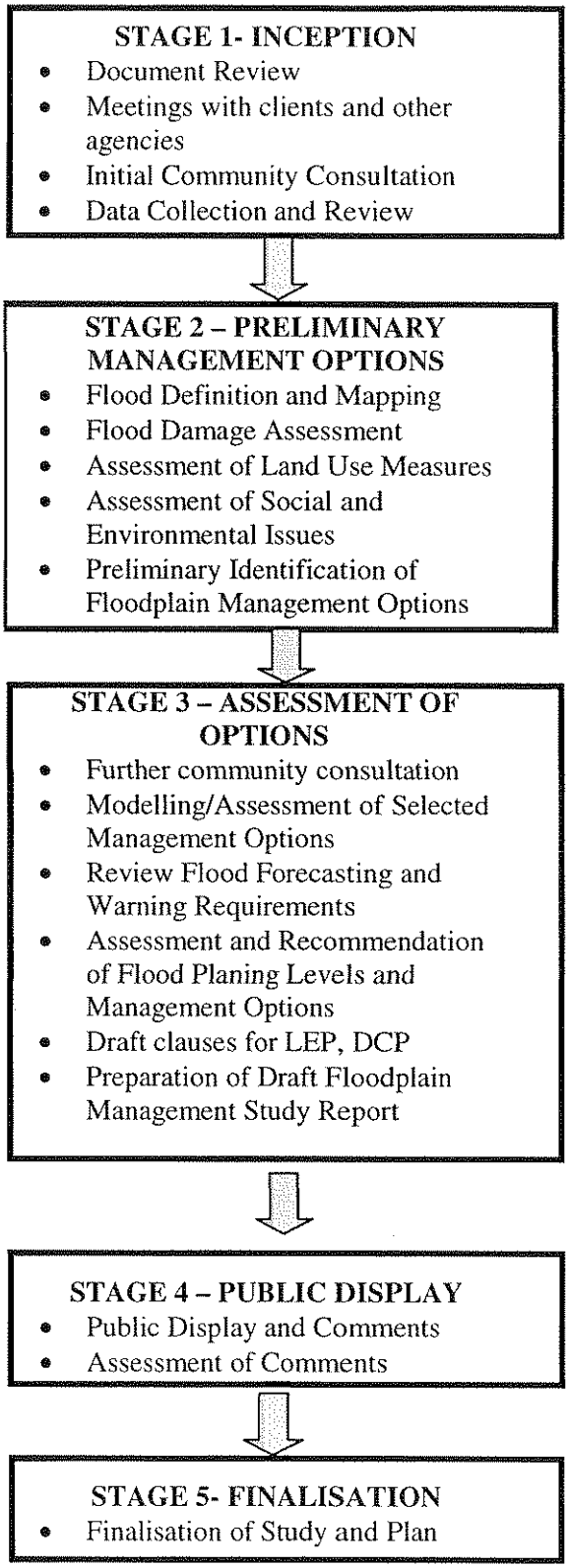


FIGURE 1.4 PROJECT METHODOLOGY

1.3 DOCUMENTATION USED

i Reports

The reports listed in *Table 1.1* were made available to SMEC for the purposes of the Gunnedah Floodplain Management Study.

Table 1.1 Reports

Document	Author	Date	Subject
Floods in the Namoi Valley	Water Resources Commission NSW (WRC)	1980	1955, 1962, 1964, 1971, 1974, 1976 floods
LEP No 1	Gunnedah Shire Council	1981	Environmental Planning Instrument
Circular No 31	Minister for Planning	1982	Environmental Planning Instrument
Namoi Valley Flood Plain Management Study	Laurie, Montgomerie & Pettit	1982	
Gunnedah Environmental Study	Planning Workshop	1982	Local Environmental Study
Flood Damages & Mitigation Options for Gunnedah, NSW	Smith & Greenaway	1984	CRES Working Paper
Local Environmental Plan 1986	Gunnedah Shire Council	1986	Environmental Planning Instrument
State Government Flood Prone Land Policy	State Government	1986	Government Policy
Namoi Valley Flood Report 1984	WRC	1986	1984 flood
Namoi River, Boggabri to Carroll	WRC		Photos, minutes
Flood Investigation	Department of Main Roads		Bridge over Mooki River near Gunnedah
Direction G25	Minister for Planning	1987	Section 117 Direction of the Environmental Planning and Assessment Act, 1979

Document	Author	Date	Subject
Circular C9 – Floodplain Development Manual	Minister for Planning	1989	Government Policy
Interim Policy for Development on Flood Prone Land	Gunnedah Shire Council	updated 1991	Council Policy
Alternative Power Station Locations – Lower Namoi Valley	Elcom Consultancy	1991	Streamflow records
NSW State Rivers and Estuaries Policy	NSW Water Resources Council	1993	Government Policy
SH11 Oxley Hwy, Option 2 Alignment, Design Report	RTA/Webb McKeown	1993	Hydraulic Assessment of Proposed Improvements at the Mooki River and Carroll Creek
SH11 Oxley Hwy, Hydraulic Assessment of Concepts	Webb McKeown	1993	Hydraulic Assessment of Proposed Improvements at the Mooki River and Carroll Creek
Floodplain Management on the Liverpool Plains	NSW Floodplain (Non-Tidal) Management Advisory Committee	1994	Executive Summary of the Burton Report
State Environmental Planning Policy No 44 – Koala Habitat Protection	Minister for Planning	1989	Environmental Planning Instrument
Circular F13 Total Catchment Management	Minister for Urban Affairs and Planning	1995	Government Policy
Gunnedah Local Flood Plan	SES	1995	Gunnedah Local Disaster Plan
Flood Investigation for Gabo, Breeza, NSW	Baiada Properties	1995	
Gunnedah Flood Study	DLWC	1996	FS Report – Gunnedah & Carroll (No. HO/16/96), Flood Maps, Hydrology and Hydraulics, Results, Data listings
Profitable & Sustainable Management of the Liverpool Plains		1996	Results of a Community Workshop
Introduction to Liverpool Plains Catchment	Liverpool Plains Land Management Committee	Undated	Information Brochure
Progress in catchment management: an update of research in the Liverpool Plains	LPLMC	1996	Proceedings of the Committee Workshop

Document	Author	Date	Subject
Floodplain Management in the Liverpool Plains	Scott Glyde	1997	Implementation of Part VIII of the Water Act (1912) Review of Landholder Perspectives
Review of Floodplain Management Procedures	DLWC	1997	Liverpool Plains
Guidelines for Namoi Valley Flood Plain Development	Barrett Purcell	1997	Battery Hill Group
Local Environmental Plan 1998	Gunnedah Shire Council	1998	Environmental Planning Instrument
Gunnedah Shire Integrated Area Plan	TBA Planners	1998	Strategic plan for the LGA
Guidelines for Namoi Valley Flood Plain Development	Barrett Purcell	1998	Carroll Group

ii Aerial Photography

The following aerial photography was made available for this study:

Table 1.2 Aerial Photography

Reference	Scale	Date	Source
Boggabri 3497-64	1:40 000	24/3/86	Gunnedah Shire Council (GSC)
Boggabri 3497-65	1:40 000	24/3/86	GSC
Boggabri 3497-66	1:40 000	24/3/86	GSC
Boggabri 2719-196	1:50 000	17/9/78	GSC
Boggabri 2327-49		30/7/75	GSC
Boggabri 2327-51		30/7/75	GSC

iii Flood Photographs

Flood photographs have been available from GSC, DLWC and local residents of Carroll and Gunnedah. The photographs provided by Council were taken on 22 July 1998. These photos show:

- extent of flooding around Carroll;
- flooding at the junction of the Namoi and Mooki Rivers;
- flooding on the Tabilah Flats;
- flooding around Cohens Bridge;
- flooding of Wolseley Park;
- flooding of Blackjack Creek and the effluent retention pond;
- flooding of Quia Road intersection;
- flooding at Ballyragan Bridge;
- flooding of Blue Vale Road Speedway;
- view of Gunnedah from the north during flood;
- view of the aerodrome during flood; and
- flooding of the Mooki River at the bridge.

The following photographs were provided by DLWC:

- photographs taken on 15 April 1994 of Curlewis Road and various homesteads outside of Gunnedah;
- photographs of Keepit Dam taken on 28 March 1995;
- photographs of the town of Gunnedah and the Oxley highway between Gunnedah and Carroll taken on 30 March 1995;
- photographs of Laundry Lagoon and Gunnible Lagoon taken on 30 March 1995;
- photographs of the speedway taken on 30 March 1995; and
- photographs of the Carroll flood gauge and the Namoi River at Carroll taken on 12 October 1995.

iv Maps

Maps used in this study:

Table 1.3 Maps

Map Name	Type	Scale	Source
Curlewis 8935-I-N	Topographic	1:25 000	CMA NSW
Gunnedah 8936-III-S	Topographic	1:25 000	CMA NSW
Emerald Hill 8936-III-S	Topographic	1:25 000	CMA NSW

Map Name	Type	Scale	Source
Gunnedah T1967-6	Orthophotomap	1:4 000	GSC
Gunnedah Airport T2867-4	Orthophotomap	1:4 000	GSC
Gunnedah (Sheets 1 to 4)	Local Environmental Plan 1998	1:10 000	GSC
Shire of Gunnedah – Sheet 2 and 3 of 5	Draft Local Environment Plan 1979	1:4 000	GSC
Parish of Gunnedah – Sheets 3 to 6	Cadastral	2 chains to an inch	Valuer General's Department Sydney NSW
Gunnedah Sewerage – Sheets 1 to 6	Sewerage Plans	50 feet to 1 inch	Department of Public Works
Flood Inundation Map Namoi River at Gunnedah	Flood inundation map	1:10 000	Water Resources Commission NSW

1.4 PROJECT OUTPUTS

The outputs of this project to date are set out in Tables 1.4 and 1.5 below. The content of the reports to date is largely reproduced in different sections of this report.

Table 1.4 Reports Produced

Report	Date Produced
Progress Report 1	4 February 1999
Potential Floodplain Management Measures	9 April 1999
Progress Report 2	20 May 1999
Assessment of Floodplain Management Measures	18 June 1999
Draft Flood Plain Management Study	30 June 1999
Draft Flood Plain Management Plan	30 June 1999

Table 1.5 Drawings Produced

Drawing List – Gunnedah Floodplain Management Study

Drawing Number	Title
31923-001	Gunnedah Inundation Map
31923-002	Inundation Map – Gunnedah 5% AEP
31923-003	Inundation Map – Gunnedah 1% AEP
31923-004	Inundation Map – Carroll 5% AEP
31923-005	Inundation Map – Carroll 1% AEP
31923-006	Inundation Map – Carroll 3x1% AEP
31923-007	Hazard Map – Gunnedah 1% AEP
31923-008	Hazard Map – Carroll 1% AEP
31923-009	Mitigation Options - Gunnedah
31923-010	Mitigation Options - Carroll
31923-011	Cross Sections & Property Locations - Gunnedah
31923-012	Cross Sections & Property Locations – Carroll
31923-013	Gunnedah Water Level Contour Map – 5% AEP
31923-014	Gunnedah Water Level Contour Map – 1% AEP
31923-015	Gunnedah Water Level Contour Map – 3x1% AEP
31923-016	Carroll Water Level Contour Map - 5% AEP
31923-017	Carroll Water Level Contour Map - 1% AEP
31923-018	Carroll Water Level Contour Map - 3x1% AEP

2 STUDY AREA

2.1 TOPOGRAPHY, GEOLOGY AND SOILS

The study area is located on the Liverpool Plains in the Namoi River Valley. The catchment is flat to undulating with slopes ranging from less than 1% along the floodplains of the Namoi and Mooki Rivers to 15% in the valleys separating the ridge systems.

The catchment is situated within the Gunnedah Basin, which forms the central depression in the Sydney-Gunnedah-Bowen Basin Region. The Gunnedah Basin extends from Bellata in the north to the Liverpool Ranges in the south. The Mooki fault system forms the eastern boundary of the basin with the western boundary lying in the vicinity of Coonabarabran.

A large proportion of the Liverpool Plains catchment is comprised of fertile black soil plains. Approximately 43% (538,840 ha) of the catchment has a slope of less than 2%. The soils on these plains are derived from alluvial outwash of the Liverpool Ranges, namely tertiary basalts and dolerites found in lava flows, dykes and colluvium. These soils, locally called "black soils", are generally very deep black earths, grey clays and brown clays (Banks 1995).

Rising above the plains are ridges and caps of volcanic and/or sedimentary origin. Soils derived from this parent material are locally called "red soils". Those derived from volcanic material, generally basalt flows and dolerite, include toposequences of lithosols on crests and trenches; and euchrozems, chocolate soils and black earths on sideslopes, footslopes and drainage lines. Ridges of sedimentary origin have highly variable parent material including quartzose and quartz lithic sandstone, silty sandstone, mudstone and polymictic conglomerate (Broughton, 1994). Soil toposequences are also highly variable and include earthy sands, lithosols and soloths on crests; red earths, red brown earths on sideslopes; and podzolic and solodic soils on lower slopes and drainage lines (Banks 1995).

2.2 CLIMATE

The region has a dry sub-humid climate. Winter rains in the Namoi Valley are generally low and unreliable, with only about 6 percent of the annual rainfall occurring in the months of May to August (WRC 1980). The summer months bring most of the rains to the valley, with cyclonic pressure systems producing very heavy rainfalls. It is usually the decaying cyclonic pressure systems that are the cause of the severe flooding that affects the valley from time to time. One quarter of the annual rainfall across the Valley is received during the months of December and January. However, floods can occur at any time of the year, as was evidenced by the 1998 floods.

The average annual rainfall at Gunnedah is 642 millimetres and the average annual evaporation is 1962 millimetres. In summer the average maximum temperature in January is 31.6 degrees Celsius with the average minimum being 18.5 degrees Celsius. In winter the average maximum temperature in July is 15.7 degrees Celsius with the average minimum being 4.5 degrees Celsius (Gunnedah Research Centre 1999).

2.3 FLORA AND FAUNA

2.3.1 Flora

Two distinct plant formations are identified within the Gunnedah local area. These are:

- open forest; and
- plains grass.

The open forest formation is comprised of two vegetation communities; the White Cypress Pine *(Callitris hugelii)* – tall woodland and shrub woodland community; and the Yellow Box/White Box/Bimble Box *(Eucalyptus melliodora – Eucalyptus albens – Eucalyptus populnea)* – tall woodland and savannah woodland community (Planning Workshop 1982:26).

The Yellow box/White box/Bimble box community is restricted largely to the lower slopes and alluvial plains of the Namoi and Mooki Rivers. Much of this community has been cleared and is used for cropping and grazing. The soil conservation service (now Department of Land and Water Conservation, DLWC) has identified the dominant and subdominant species within these communities in *Table 2.1* (Planning Workshop 1982:26).

Table 2.1 Dominant Species – Yellow Box / White Box / Bimble Box Community

	Botanical Name	Common Name
Yellow Box/White Box/Bimble Box		
Dominant Species	*Eucalyptus melliodora*	Yellow Box
	E. albens	White Box
	E. populnea	Bimble Box
Subdominant Species	*E.camaldulensis*	River Red Gum
	E. blakelyi	Blakely's Red Gum
	Angophora floribunda	Rough-barked Apple
	Casuarina cristata	Belah
	Brachychiton populneum	Kurrajong
	Geijera parviflora	Wilga
	Heterodendron oleifolium	Rosewood
	Acacia aneura	Mulga
	Acacia pendula	Myall

The Yellow Box/White Box/Bimble Box community incorporates a number of associations, the main ones within the Gunnedah area being the White Box *(E. albens)* and Bimble Box *(E. populnea)* associations. The White Box associations tend to dominate the basaltic slopes of the eastern part of the Gunnedah area while, the Bimble box associations occurs on the alluvial floodplains along the Namoi and Mooki Rivers. The main grass cover species are *Stipa* spp., *Aristida* spp., *Bothriochloa ambigua* (Red Grass), *Dicanthium sericeum* (Blue Grass), *Chloris* spp. (Windmill Grass), *Eragiostis* spp. and *Paniculum* spp.

The Plains Grass community is dry tussock grassland dominated by *Stipa aristiglumis*. This community formerly dominated the areas of heavy textured cracking black soils of the Liverpool Plains. The soil conservation service (now DLWC) has identified the major subdominant species within the community, which have been listed in *Table 2.2*.

Table 2.2 Subdominant Species – Plains Grass Community

Botanical Name	Common Name
Panicum spp.	Panics
Dichanthium sericeum	Blue Grass
Chloris spp.	Windmill Grasses
Aristida spp.	Wire Grass
Stipa spp.	Spear Grasses
Danthonia spp.	Wallaby Grasses

According to Greenwood (1982) the plains grasses grow to heights of about two metres, and ground cover is comprised mainly of fallen organic matter and small creepers.

Within the Gunnedah area, much of this community has been cleared and the areas used largely for cultivation and grazing of domestic livestock. Remaining uncleared areas are very small in size and have been infested by exotic weeds such as *Bassia birchii* (Galvanised Burr) and *Xanthium spinosum* (Bathurst Burr.).

The vegetation immediately adjacent to the Namoi and Mooki Rivers within the Gunnedah area is dominated by Mature River Red Gums (*Eucalyptus camaldulensis*) with occasional River Oaks (*Casuarina cunninghamiana*). In an undisturbed condition this vegetation would have an open forest structure and would provide habitat for fauna species along the riverine corridor. Much of this vegetation has been cleared for agricultural pursuits and it is often reduced to a thin band of trees present on the river bank.

The vegetation of the floodplains within the Gunnedah area is dominated by mature Bimble Box (*Eucalyptus populnea*) with a lesser occurrence of White Box (*Eucalyptus albens*). In an undisturbed condition this vegetation would have a woodland structure with a shrubby/grassy understorey. Much of this vegetation has been cleared or altered for agricultural pursuits, leaving scattered trees and a mixture of native and exotic grasses.

i Conservation Value

The Plains Grass community has been identified by a number of researchers, Specht (1974) and Urwin (1981), as being a community of high conservation status.

> *"Due to the intensity of agricultural land use, the Plains Grass community has decreased in size to a point where any remnant areas which still exist, though they comprise relatively common species, now would be considered uncommon to rare communities."*
>
> (Planning Workshop 1982: 28).

ii Threatened Species

The legislation protecting threatened species is the *Threatened Species Conservation Act, 1995*, which is administered by the NSW National Parks and Wildlife Service (NPWS). The Act protects certain classes of threatened wildlife including endangered species, endangered populations, endangered ecological communities and vulnerable species. The Act specifies that a Species Impact Statement is required if a development or activity will significantly affect threatened species, populations or ecological communities, or their habitats.

At the time of preparing this report no endangered populations or ecological communities relevant to the Gunnedah area were listed under the *Threatened Species Conservation Act, 1995*. However, three vulnerable species and one endangered species have been recorded on the NSW Wildlife Atlas database (NPWS 1998) for the Curlewis and Boggabri 1:100,000 map sheets, which have been listed in *Table 2.3*. These species have the potential to occur within the Gunnedah area.

Table 2.3 Vulnerable and Endangered Species

Botanical Name	Status
Swainsona murrayana	vulnerable
Bothriochloa biloba	vulnerable
Cadellia pentastylis	vulnerable
Hakea pulvinifera	endangered

2.3.2 Fauna

The Gunnedah Shire lies within the drainage basin of the Namoi River situated on the Liverpool Plains. The majority of the vegetation, and hence fauna habitats, have been significantly altered from their natural condition due to the history of agricultural pursuits in the area.

There have been relatively few studies undertaken on native fauna within and around the Gunnedah area, mainly due to the fact that the land has been predominantly cleared for agricultural pursuits. However, located just to the south of the township of Gunnedah is

Porcupine Reserve, which encompasses 198 hectares of timbered woodland. This reserve contains a town lookout and is used for recreation purposes. Porcupine Reserve contains a high diversity of flora and fauna species including several threatened species (Eckardt and Prager, 1998). Threatened species, which have been recorded on the NSW Wildlife Atlas database (NPWS 1998) for the Curlewis and Boggabri 1:100,000 map sheets are listed in *Table 2.4*.

Table 2.4 Vulnerable and Endangered Species

Scientific Name	Common Name	Status
Stictonetta naevosa	Freckled Duck	vulnerable
Neophema pulchella	Turquoise Parrot	vulnerable
Dasyurus maculatus	Tiger Quoll	vulnerable
Phascolarctos cinereus	Koala	vulnerable
Petrogale penicillata	Brush-tailed Rock-wallaby	vulnerable
Rattus villosissimus	Long-haired Rat	vulnerable
Ephippiorhynchus asiaticus	Black-necked Stork	endangered
Tyto novaehollandiae	Masked Owl	vulnerable
Nyctophilus timoriensis	Greater Long-eared Bat	vulnerable

The Planning Workshop (1982) states that the Gunnedah area appears to have quite a good population of koalas, and that there have been reports of koalas in close proximity to the town itself. A detailed study of Koalas in Gunnedah Shire, was undertaken by Curran (1997).

It has been identified in Curran (1997) that the following tree species were considered to be of high importance in terms of Koala utilisation in the Gunnedah Shire. These are listed in *Table 2.5* below.

Table 2.5 Tree Species for Koala Utilisation

Botanical Name	Common Name
Eucalyptus blakelyi x camaldulensis	-
E. populnea	Bimble Box
E. melliodora	Yellow Box
E. albens	White Box
Callitris glaucophylla	Cypress Pine
Angophora floribunda	Rough-barked Apple
Geijera parviflora	Wilga
Acacia homalophylla	Yarran

These conclusions lend some support to the conclusions of Smith (1992) that *E. albens, E. populnea* and *C. glaucophylla* are species important to koalas in the Gunnedah Shire, but also suggests other species, such as *E. melliodora, Angophora floribunda, Geijera parviflora* and *Acacia homalophylla* may also be important to koalas. However, the report identifies that further research is required (Curran, 1997).

Within the Gunnedah area, outside of Porcupine Reserve, there is limited potential for threatened species to occur mainly due to the disturbed condition of the habitat present. However, a range of other species may utilise both the riverine corridor and floodplain within the Gunnedah area. In particular, highly mobile species such as birds, may utilise the area for foraging and roosting. Retaining as much of the natural vegetation of the area as possible is important to allow for the movement of fauna between areas of higher habitat quality.

2.4 DEMOGRAPHIC PROFILE

2.4.1 Population

i Gunnedah Local Government Area

The total population of the Gunnedah Local Government Area was 12,798 people at the 1996 census. Gunnedah Shire has experienced a 4% decline in population between the 1986-1996 census period. This appears to be a general trend in Northern NSW as the Northern (NSW) Statistical District has experienced a 1.5% decline during the same period. Regional NSW has experienced an increase of 12% between the 1986-1996 census period.

Gunnedah has a higher percentage of children and youth aged between 0 to 17 years than regional NSW. Between 1986-1996 census periods there has been an increase in children aged between 0 to 9 in the Gunnedah Statistical District. However, this trend is inconsistent with the general trend across regional NSW, which is showing a decline in this proportion of the population.

Gunnedah has shown an approximate 40% decline in the population aged 18 to 24. While regional NSW has also experienced this decline it has not been as dramatic as Gunnedah being only a 2% decline. Similarly there has been a 20% decline in the 25 to 34 age bracket while regional NSW has experienced a 2% decline.

The general trend shows a 10% increase in the age groups 35 to 44 and 45 to 54 over the ten year census period, which is a lot lower than the 25% and 40% increase respectively for these age groups in regional NSW.

There has been a slight increase in the proportion of the 55 to 64 age bracket which reflects the marginal increase in regional NSW.

The 65+ age group represents the greatest increase in population over the last ten years in Gunnedah. There has been a 20% increase in the 65 to 74 age group compared with 30% in

regional NSW, a 30% increase in the 75 to 84 age group compared with 57% in regional NSW. In the 85+ age group there was a 90% increase which is significantly more than the 70% increase across the ten year period in regional NSW. Therefore it can be concluded that Gunnedah has a significant aging population.

ii Carroll

At the 1996 census the population of Carroll was 174 people, contributing 1.3% of the population of the Gunnedah Local Government Area. Of these, 95 were male and 79 were female. This equates to a majority of 55% male population. 28% of Carroll's population were aged between 35 and 54, and 57% of these were male. The over 55 age bracket made up 21% of the population, and was relatively balanced in gender. The age bracket 0-14 occupied 25% of Carroll's population (43 people), and was 70% male (30 males). Females comprised 60% of the 15-34 age bracket, which made up 26% of Carroll's population (45 people).

iii Gunnedah Study Area

The Gunnedah study area is broken into six collector districts by the Australian Bureau of Statistics. Detailed information on one of these collector districts has not been available for this Study, however, data from the remaining five has been compiled. The five collector districts are thought to be representative of the study area.

The population of the Gunnedah study area at the 1996 census was 2,187 people. The Gunnedah study area contributed 17% of the population of the Gunnedah Local Government Area. Of these, 1108 were male (51%) and 1079 were female (49%).

Those aged 55 and over were the largest group and made up 30% of the population, numbering 666. The majority of these, 57%, were female. The 15-34 age group was the next largest, comprising 26% of the population (561 people), of whom 55% were male. Next was the 35-54 age group, proportionately 24% of the population (527 people), followed by the age group 0-14, with 433 people making up 20% of the population. Of those aged between 35 and 54, 54% were male. In the 0-14 age bracket, 53% were male.

2.4.2 Income and Employment

i Gunnedah Local Government Area

The employment sectors showing key growth in the period 1991-1996 were the utilities sector (30% growth), 25% growth in recreational services and 20% growth in finance and businesses services. Due to the closure or scaling down of a number of mines in the area there has been a 35% drop in employment in the mining sector. There has been less than a 15% shift in all other sectors.

The weekly individual income for the Gunnedah Local Government Area is $200-$299, while the median weekly family income is $500-$599.

The unemployment rate has declined in the Gunnedah Local Government Area from the 1986 census to the 1996 census. In 1996 the unemployment rate was 9.5% compared to the NSW average of 8.8%.

ii Carroll

According to the1996 Census, the working population of Carroll totals 43 people. Of these, 12 (28%) are female, and 31 (72%) are male. The main industries employing Carroll's workforce are manufacturing (10 people, 23% of workforce), and agriculture, forestry and fishing (9 people, 21% of the workforce). Retail trade, accommodation, cafés and restaurants, and health and community services each employ 6 people, taking up 14% of the workforce each. Lastly, mining and education each employ 3 people, that is, 7% of the workforce each.

The median individual income is $160-$199 per week, while the median weekly family income is $300-$499. These incomes are substantially lower than the average income of the local government area as a whole.

The unemployment rate for Carroll is 26.4%. This rate is extremely high when compared with the local government area as a whole and regional NSW.

iii Gunnedah Study Area

The median individual income is $200-$299 per week, while the median weekly family income is $300-$499. The weekly family income is generally lower in the study area than the local government area as a whole.

The unemployment rate varies across the collector districts with a range of 6.7% to 22.1%. All collector districts have a higher unemployment rate than the shire average except for the area bounded by Elgin to the east, the railway line to the south, Conadilly Street to the north and Warrambungle to the west. This may be explained by the fact that this area is the retail and commercial district of the town.

2.4.3 Dwelling Structure and Tenure

i Gunnedah Local Government Area

At the 1996 census there were a total of 4,633 dwellings in the local government area (LGA). There is a high rate of home ownership in Gunnedah, which is comparable with the state average. Of all housing stock 45% is owned while 20% is being purchased. Twenty eight percent of the housing stock is rented while the remaining 7% are under some other form of occupancy.

There is a mixture of family types in the Gunnedah LGA. Of these families 14% are one parent families, 33% couple only families, 51% couple families with children and 2% other families. These rates are comparable with the NSW average.

ii Carroll

At the 1996 census there was a total of 78 dwellings. Of these dwellings 86% are separate houses, 4% were attached to a shop or office and the remaining 10% did not have a dwelling structure listed. Home ownership is very high in the town, as a total of 56% of homes are fully owned while a further 15% of homes are currently being purchased. A total of 12% of homes were rented at the 1996 census while 13% were unoccupied. There were 4% of cases where the tenure was not stated.

The occupancy rate of the separate dwellings was 2.6, while the occupancy rate of the alternate housing types was 1 at the 1996 census.

There is a mixture of family types within Carroll. There are 32% couple households with children, 22% couple households without children, 19% one-parent households and 27% lone person households.

iii Gunnedah Study Area

There are a total of 1,025 dwellings within the five collector districts in the study area, at the 1996 census. Home ownership is slightly lower than the average for the shire with an average across the five collector districts of 42%. An additional 16% are being purchased and 31% being rented which is comparable with the LGA average. The remaining 11% form the 'other' category.

Occupancy rate across the five collector districts averages 90%. The large majority of houses in this area are separate houses (72%), with 5% attached to a shop or office, 15% classified as flats/units or apartments and the remaining 8% caravans or other forms of housing. There is a slightly greater variety of housing choice within the Gunnedah study area than there is in Carroll.

The average breakdown of family types across the collector districts include 10% of one parent households, 33% lone persons households, 24% couples with children and 23% couples without children. The remaining 10% were classed as other. It appears that there are a greater proportion of 'single parent' and 'couples with children' households in Carroll than there are in the Gunnedah study area.

2.5 EVALUATION AND CONCLUSIONS

Key issues of relevance arising from this overview of the Study area are:

- although very little rainfall occurs in the area between May and August (6% of annual average), flood events may occur at any time;
- local riverine vegetation corridors provide for limited amounts of remnant native vegetation in the area, which are of significance to native fauna species. Local flora and fauna would benefit from enhanced native vegetation along riverine corridors;
- incomes and employment levels are generally lower in flood affected areas, lessening the ability of people in these areas to recover from flood events; and

- there has been significant population loss from the local area over time, especially in the 15-24 age group. This coincides with a substantial growth in the 65+ age group. This has implications for emergency response measures and evacuation needs in flood events and also underlines the importance of flood management strategies which support local investment and job creation.

3 PLANNING AND REGULATORY REVIEW

3.1 BACKGROUND TO PLANNING PROVISIONS

On 27 August 1980 the Minister issued Direction 7(i)(a) under Section 117 of the *Environmental Planning and Assessment Act, 1979* requiring Councils to provide provisions for the protection of or development controls relating to flood liable land and water catchment areas. Since this time, Councils, in preparing planning documentation, have had to have regard to the impacts of flooding. This chapter provides an overview and evaluation of all relevant State and Local Government planning instruments and policies of relevance to this Study.

3.2 STATE PLANNING INSTRUMENTS AND POLICIES

3.2.1 State Government Flood Prone Land Policy

i Primary Objective

The State Government Flood Prone Land Policy 1984 has the objective to "reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding" (NSW Government 1986:33). There are three main aspects to this objective:

1. The reduction of flooding and flood liability impacts on existing developed areas will generally be attained by flood mitigation works, the removal of unnecessary development controls, and property acquisition where necessary.

2. The application of effective planning and development controls will contain the potential for flood losses in new developed areas.

3. Broad consideration of social, economic, and ecological, as well as flooding matters, will be made for all development decisions, based on a "merit approach".

ii Implementation

Implementation of the above objectives was planned to occur at Federal, State and Local government levels.

The Flood Prone Land Policy identified various local government responsibilities for the management of flood prone land. To assist local governments in their role, the State Government developed a program of technical and financial assistance to councils for the undertaking of flood mitigation works and property acquisitions, and for the reinforcement of emergency and relief services.

In addition to this program, the State Government passed legislation providing indemnity to councils for decisions made in relation to flood prone land. This legislation is contained in section 733 of the *Local Government Act, 1993.*

3.2.2 Floodplain Management Manual

In March 1999, the NSW Government placed a draft "Floodplain Management Manual" on public exhibition. This Floodplain Management Study and Plan have been prepared in accordance with SMEC's understanding of the draft Manual.

The draft Manual is a significantly revised edition of the Floodplain Development Manual published in December 1986. The draft edition is understood to incorporate the results of a series of public reviews of floodplain management issues in New South Wales, changes to policy and practice introduced by successive governments and increased emphasis on the integrated management of floodplains, both urban and rural.

The draft Manual aims to present general principles and a process to be worked through to enable Councils through their floodplain management committees to:

- define floodplain management strategies; and
- formulate floodplain management plans.

To satisfy the legislative requirements that are associated with the Manual (Section 733 of the *Local Government Act, 1993*), the resulting floodplain management plans are required to:

- be effective in the management of the existing, future and continuing flood hazards; and
- take into account social, economic and ecological factors, together with community aspirations for the use of flood prone land.

The first requirement is a new statement of an underlying principle of the 1986 Manual; the second requirement is not changed at all.

Based on a comparison between the 1986 Manual and the draft Manual, the changes and new areas incorporated into the draft edition are listed below.

The amendments are:

- an emphasis on the importance of developing floodplain management plans that address existing, future and continuing flood risks for flood prone land and to assess proposed developments in line with the relevant floodplain management plan, on a strategic basis, rather than on an ad hoc or individual proposal basis;
- more explicit recognition of the need to consider the full range of flood sizes, up to and including the extreme flood event (3 x 1% AEP);
- recognition of the need for flood plans that address preparedness and response;
- recognition of the importance of house raising as a floodplain management measure;
- inclusion of rural flooding and local overland flooding in the management process;

- an emphasis on maintaining and enhancing the riverine and floodplain environments, including the needs of threatened species, populations and ecological communities, as part of flood mitigation measures;
- incorporation of the principles of Ecologically Sustainable Development in the floodplain management process;
- an increased emphasis on catchment considerations including a requirement for a local catchment management committee representative to serve on Council floodplain management committees;
- recognition of the potential implications of climate change on flooding behaviour (global warming); and
- the introduction of new terminology so that "Flood Planning Level" replaces "standard flood" and "flood prone land" replaces "flood liable land".

The amendment that will have the greatest impact on Gunnedah Council is the introduction of the concept of Flood Planning level. This concept is described briefly below and is addressed further in Section 10.

Flood Planning Levels

It is understood that the concept of Flood Planning Levels (FPLs) will replace that of the standard or designated flood, used in the 1986 Manual. Our understanding is that the FPL will be used as a planning tool, to set development controls on flood prone land.

Essentially the FPL is a result of balancing two risk factors:

- the potential damage to property and risk to human life, which may occur as a result of flooding; and
- the value of the use of the floodplain for development and occupation.

FPLs attempt to strike a balance between these two factors, according to land use needs and certain physical factors that vary across the floodplain. If the FPL is set too low, it will result in excessive damage to property, but if set too high unnecessary restrictions will be placed on land which is capable of development, and uneconomic use of the land will result.

While a FPL will not generally define the full extent of flooding, it will take into account the full range of floods, the likelihood of their occurrence, and the related consequences for development.

3.2.3 Section 117 Direction – No G25

On 1 June 1987 the Minister for Urban Affairs and Planning issued a direction under section 117 of the *Environmental Planning and Assessment Act, 1979*. Direction G25 sets out provisions which regulate Local Environmental Plans (LEPs). It aims to ensure that, where relevant, the objectives of the Flood Policy are reflected by LEPs. The Direction provides a statutory basis for the planning principles in the Floodplain Development Manual.

Draft LEPs generally must not rezone flood liable land for development, and must not permit development in flood liable land, or anything which would cause the need for government to increase spending on mitigation, infrastructure, or servicing. Any flood liable land which

presents high hazard, or land in a floodway, must be zoned "special uses – environment protection" or similar, by a draft LEP.

Development for agricultural purposes, or minor alterations and additions to existing development, may be permitted without development consent in low hazard, flood fringe, and flood storage areas.

It is understood that Direction G25 is currently being revised by the Department of Urban Affairs and Planning, parallel to the revision of the Floodplain Management Manual

3.2.4 Circular C9 – Floodplain Development Manual

Circular No. C9 – Floodplain Development Manual was issued on 17th March 1989. It works in conjunction with the Floodplain Development Manual, liability legislation made by the *Local Government (Flood Liable Land) Amendment Act, 1985*, and the Section 117(2) Direction, No. G25. Circular C9 aims to assist councils by relating the Floodplain Development Manual to the *Environmental Planning and Assessment Act, 1979*, and also by indicating the approach of DUAP to implementation of the Flood Policy.

While the Manual establishes that Floodplain Management Plans should be prepared by councils, and that LEPs should be based on the implementation of those Plans, Circular C9 acknowledges that there is some delay in the preparation of the plans. For the interim period, the Circular identifies matters which are to be considered in the preparation of a draft LEP. Among these is the consideration of "any relevant floodplain management plan or interim policy", and also any further information on the extent or impacts of flooding. This highlights the need to consider Gunnedah's Interim Flood Policy in the determination of any development applications, and in the preparation and execution of LEPs.

The Circular also emphasises the need to consider the impacts of development, and of flooding, in adjacent local government areas. There must be consultation between councils to ensure that their floodplain management plans support consistent standards. Cumulative impacts of the various aspects of development and flooding should also be considered. The Circular also highlights the need to consider certain matters of state and regional significance, such as those contained in State Environmental Planning Policies (SEPP) and Regional Environmental Plans (REP), any diversion or retention of floodwaters, or reduction of catchment storage capacity.

It is understood that Circular C9, and related planning documents, are currently being revised by the Department of Urban Affairs and Planning, parallel to the revision of the Floodplain Management Manual

3.2.5 Part VIII of the *Water Act, 1912*

Land with a slope less than 2% within the Liverpool Plains region was gazetted as floodplain under Part VIII of the *Water Act, 1912* in December 1994. Any landholder wishing to develop the floodplain must apply for a licence from the Department of Land and Water Conservation under Part VIII of the *Water Act, 1912*. The floodplain between Carroll and Boggabri has been declared a floodplain under this section of the Act.

3.3 LOCAL PLANNING INSTRUMENTS AND POLICIES

3.3.1 LEP No 1 – Shire of Gunnedah

Local Environmental Plan No. 1 – Shire of Gunnedah gazetted on 27 November 1981 was the first planning instrument to place the whole of the Gunnedah Shire under town planning control. In response to this directive the LEP contained a provision relating to flood liable land and water catchment areas. It stated:

> *"8. In respect of any application for approval to erect a dwelling-house or a residential building, the Council shall take into consideration the likelihood of floodwaters entering any such building and may attach conditions to any such approval requiring the floor to be erected at a height sufficient, in its opinion, to obviate the frequent flooding of the building."*
>
> (Planning Workshop, 1982:130).

3.3.2 Gunnedah Environmental Study

In 1982 the Gunnedah Environmental Study was conducted by Planning Workshop, forming the basis for the preparation of Gunnedah LEP 1986. The recommendations of the study were to:

- incorporate the provisions outlined in Circular No 31;
- prohibit development on flood prone land unless concurrence is granted by the Water Resources Commission;
- not consider the option of removing development from flood prone land as this solution is not practical; and
- prevent government, semi-government or government assisted or subsidised work being located within a floodway (defined as 1 in 20 year flood) or on flood prone land (1 in 100 year) in accordance with the Circular No. 31.

3.3.3 Gunnedah Local Environmental Plan (LEP) 1986

Local Environmental Plan (LEP) 1986 was gazetted on 4 July 1986. The LEP contained one clause dealing with development on flood-prone land. Clause 27 identified flood-prone land as land horizontally hatched on the zoning map. This hatching followed the 1 in 100 year flood event, delineated in the Department of Water Resources map of 1978. All development on this land required Council consent.

Clause 27(3) outlined the matters to be considered by Council when dealing with applications on this land. These were:

> *(3) The council may consent to the carrying out of development on land within a flood-prone area only if it is satisfied that-*
>
> *(a) adequate measures will be taken in the structural design of the proposed development to prevent flood damage;*
>
> *(b) adequate precautions will be taken to prevent waste pollution; and*

(c) the carrying out of the development proposed and of other development in the locality will not increase the likelihood of flooding on existing development.

The 1986 LEP thereby gave Council some control, which was limited to the prevention of flood damage:

- to proposed development through structural design;
- to the environment through waste disposal; and
- to existing development through assessment of impacts of proposed development.

The 1986 LEP was repealed on 25 September 1998.

3.3.4 Shire of Gunnedah Interim Policy for Development on Flood Prone Land

In 1984 Council recognised the deficiency in controls for flood liable land and adopted an Interim Policy for Development on Flood Prone Land. This policy was subsequently amended in 1991.

The Interim Policy defines the terms: floodways; flood storages; and flood fringe land. It also maps an approximate 1 in 10 year flood line which is termed the "no building" line. Development between the river and the 1 in 10 year flood line is generally prohibited, with provisions applying to development between the 1 in 10 year and the 1 in 100 year flood line. Main provisions contained in the policy are summarised below.

- No development is permissible in floodways (defined generally as the main paths of water flow during floods).
- No building or filling above 300mm may take place between the "no building" line and the Namoi and Mooki Rivers, unless proof of satisfactory hydraulic or other flood mitigation works can be given. No residential buildings are permitted in this area.
- Certain provisions apply to any residential building (or portion of such) which is between the "no building" line and the 1 in 100 year flood line. Building construction must be able to withstand inundation stresses, and floor levels must be 0.5m above the 1 in 100 year flood level. Similar restrictions apply to commercial and industrial buildings in this area. However, floor levels are required to be above the 1 in 20 year flood and buildings must be erected so that any materials or fixture that could be damaged by floodwaters are 0.5 metres above the 1 in 100 year flood.
- Any buildings to be erected in areas subject to inundation must be built on land, which is filled to at least 300mm above its natural level and such filling be extended to a distance of at least 3 metres beyond the perimeter of the building.
- Minor extensions and renovations to occupancies existing as at 15 December 1986 shall not be prohibited by the policy. These minor extensions and renovations are permitted within the application of this policy, so long as these do not substantially extend the life of the dwelling.

This policy relates only to Gunnedah and does not apply to Carroll.

3.3.5 Gunnedah Local Environmental Plan (LEP) 1998

The Gunnedah LEP 1998 contains more detailed provisions relating to flood-prone land, and applies to the entire Gunnedah Local Government Area including Carroll.

i Zoning Provisions

a Gunnedah

The Gunnedah study area falls under several different zonings in the 1998 LEP. The zonings of the Gunnedah town centre are identified in *Figure 3.1*. The complete study area zoning is described below. Generally, the area closest to the railway is zoned either Residential 2(b) – Residential (Higher Density), or Industrial 4(a) – Industrial (General). Zone 4(a) prohibits residential and commercial development, and hazardous or offensive industry. It allows for light industrial uses.

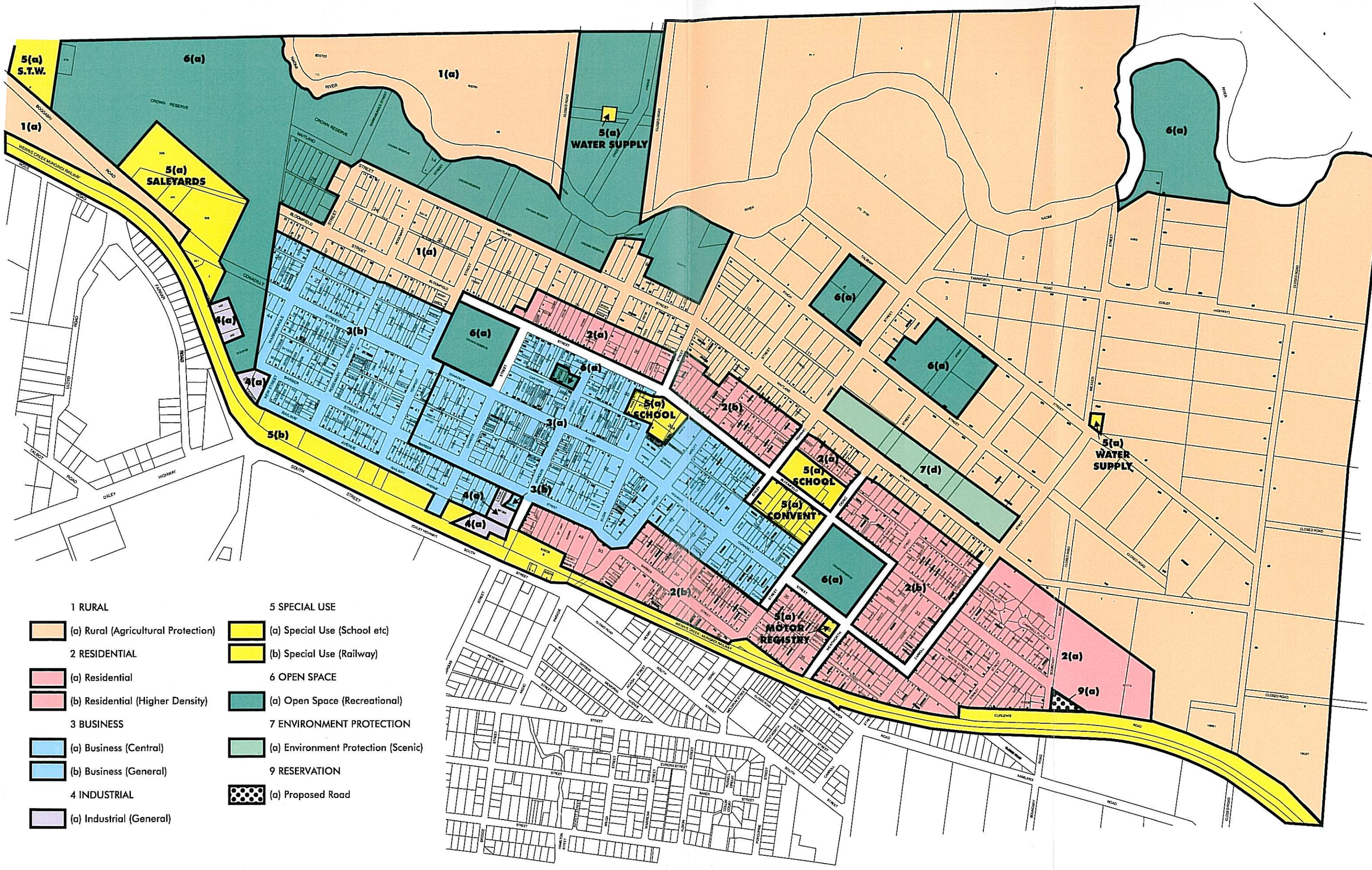
Immediately adjacent to, and north of this area is a business strip centred on Conadilly Street. To the east, this strip is zoned 3(a) – Business (Central). West of Tempest Street, it becomes 3(b) – Business (General). Zone 3(b) is more flexible than 3(a), allowing development such as warehouses, bulk stores, and recreation areas with development consent. Zone 3(a) encourages the development of core business uses which are associated with a central business district.

It is understood that the 3(b) zone was first introduced under LEP 1, 1981 and provided for a commercial zoning, in part, to reduce flood risk to residential properties that may have been developed in this flood affected part of Conadilly Street.

Further north, and adjacent to the business strip are the residential and outlying rural areas. Those closest to the school and central business areas are zoned Residential 2(b) – Residential (Higher Density). Zone 2(b) allows higher density residential development than zone 2(a), encouraging a variety of housing forms. Both zones 2(a) and 2(b) prohibit most commercial and industrial development, and zone 2(b) allows residential flat buildings and motels with consent. Zone 2(a) aims to provide low density residential development.

The majority of land north of these residential areas is zoned Rural 1(a) – Agricultural Protection. Zone 1(a) aims to protect agricultural use of the land. Recreation facilities, medium density residential, and retail and commercial development are all prohibited. This is broken by some areas of 6(a) – Open Space (Recreational), along the banks of the Namoi River. Zone 6(a) allows the development of facilities for active and passive recreation, with consent. All other uses are prohibited.

Outside of the town centre and west of Warrabungle Street, vast swathes of land are zoned Rural 1(a), either side of Boggabri Road. An industrial development, zoned 4(a) – Industrial (General) is located adjacent to the railway and at the intersection of Boggabri and Quia Roads. Immediately west of Warrabungle Street and south of the Namoi, zoning of the land changes to 6(a) – Open Space (Recreation). Between this space and Boggabri Road are the saleyards, zoned 5(a) – Special Use (Saleyards). All uses other than saleyards are prohibited in zone 5(a).



This map should be used for illustrative purposes only.
It is not a legal document

Figure 3.1
ZONING MAP - GUNNEDAH

All land within the study area and north of the Namoi is zoned 1(a) – Rural (Agricultural Protection).

b Carroll

Two zonings apply to the study area at Carroll, under LEP 1998. Residential 2(v) – Village zone applies to the blocks around Breeza Street (Oxley Highway), as identified in *Figure* 3.2. The zone allows a variety of uses, including dwelling houses, agricultural development and home occupations, without development consent. It prohibits development for heavy industrial purposes, though allows commercial development subject to development consent.

Zone 1(a) – Rural (Agricultural Protection) applies to all land outside of zone 2(v), within the study area. This zone is identical to the 1(a) zone applying in the outlying areas of Gunnedah.

ii Flood Provisions of the LEP

Clause 3(7) of the LEP outlines the following objectives relating to flooding:

> *(a) to reduce the incidence of damage and level of hazard to areas subject to flooding by managing development in the floodplain and in floodways, and*
>
> *(b) to allow more detailed controls on development in the floodplain and in floodways to be provided in the Council's Interim Flood Prone Lands Policy.*

The LEP provides specific definitions for the terms flood hazard, floodplain, flood prone land, flood proofing, and floodway. These definitions are largely identical to those in the Draft Floodplain Management Manual, released for public comment by the NSW Government in March 1999.

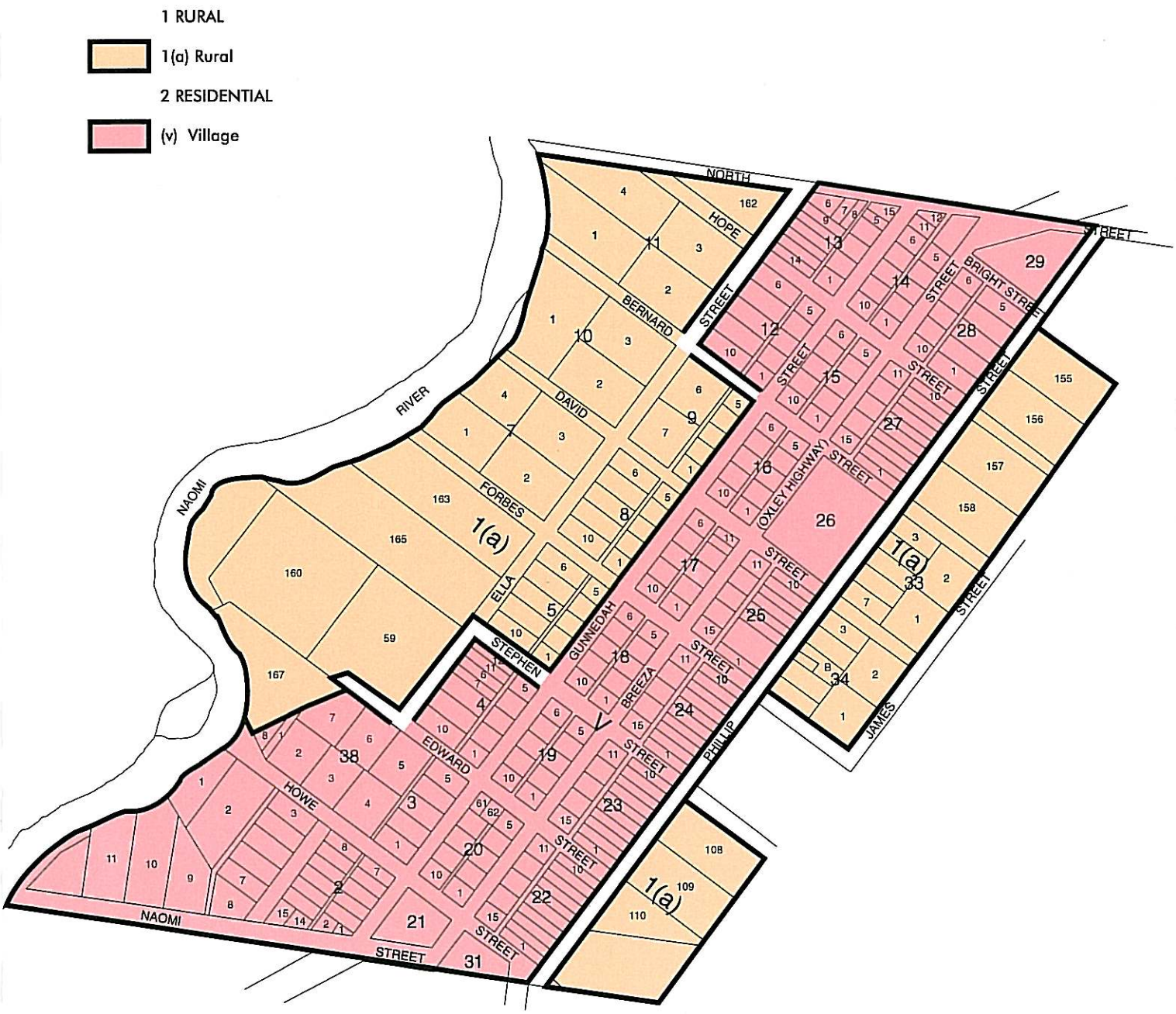
Under clause 26 of the LEP Council consent is needed for any development on flood prone land. Flood Prone Land is defined as:

> *"land identified as being in a flood prone area on the Flood Inundation Map dated 1978 related to the Council's "Interim Policy on Development on Flood Prone Land" and available at the office of the Council and includes land that would be affected by the 1% probability flood." (Page 9)*

To grant consent, Council is required to ensure that the factors outlined under clause 26(2) will be addressed by the proposed development. These include that:

a) the building or work does not restrict flow characteristics of flood waters;
b) it does not increase the degree of flooding on nearby land;
c) the structural characteristics are such that it can withstand flooding; and
d) the building is adequately flood proofed.

Subclause 3 contains matters which Council must consider before approving any development on flood-prone land. These include the cumulative effects of development on flood levels, the risk of water pollution from development, and how the building or work may be accessed for evacuation during a flood. Council is also given power under subclause 4 to set requirements



This map should be used for illustrative purposes only.
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Figure 3.2
ZONING MAP - CARROLL

for the height of habitable building floors on flood prone land, so that flooding impacts on living areas may be mitigated.

3.3.6 Gunnedah Shire Integrated Local Area Plan – January 1998

The Gunnedah Integrated Local Area Plan (ILAP) Final Report was produced in January 1998. Its purpose is "to establish a framework of action initiatives for the improvement and coordination of development of the Shire and the provision of services by Council and other government bodies" (TBA Planners 1998:1). It identifies, and sets out actions to remedy, the key development issues faced by the community of Gunnedah. Relevant sections to flood-plain management are discussed below.

i Aims

The ILAP aims to respond to both the external and internal forces influencing change in the Gunnedah community. Within land and water resource management, the environmental quality of water was identified as one factor over which the community may have some influence. The community could address the problem of water provision, and the quality and quantity, rehabilitation, monitoring, and conservation of water resources. The ILAP targeted a community response of "increasing awareness that the long term sustainability of the land/water resource base is a major issue and the current practices will have to change" (ibid: 32).

ii Management of Flooding

Section 3.1 addresses the management of natural resources. The issues highlighted for consideration included:

- the increasing reliance of agriculture on surface and ground water;
- ongoing depletion of water supply from the artesian water table; and
- the need for water management, as a component of total ecosystem management, to sustain the quality and quantity of region's natural resource base.

The suggested directions are:

- promote consideration of land capability, and thereby the sustainable management of land and water resources;
- ensure acceptable levels of water quality are maintained;
- protect the natural condition of watercourses;
- adopt an integrated catchment management approach;
- ensure comprehensive consideration of effects on water in the development assessment process (a function of the LEP); and
- encourage in all areas the participation and education of the community.

3.3.7 Community Charrette Handbook Review

The Gunnedah Community Charrette was undertaken on 17-18 May 1997, involving citizens, businesses and civic leaders of Gunnedah in an endeavour to define goals for the town and

Shire, and identify means of achieving them. The Community Charrette Handbook was compiled as a result of this exercise, and outlines the ideas that were raised in the process of the Charrette.

Issues related to flood-plain management include:

- long term protection of natural resources, including water;
- monitoring and regulating the quality, quantity and usage of water;
- assessing the impacts of urban run-off in the catchment; and
- managing areas subject to flood hazard.
  (The Community Partnership 1997:22)

Other ideas relevant to flooding and flood mitigation techniques are discussed below.

a Green Belt/Natural Corridor

A proposal was made to implement a "Green Space and Drainage Corridor System". This would make primary links to areas such as the Mullibah Lagoon and Blackjack Creek Corridors and a new tourist centre, and would link passive recreation areas around and through Gunnedah via a continuous green belt. The green belt would be designed to address problems of salinity and drainage, as well as providing a way to manage animal habitats. A strategy for surface drainage would be created as a component of the green belt.

b Blackjack Creek Corridor

Mining along the Blackjack Creek Corridor has resulted in erosion and saline-sodic soils. Various proposals were made, including:

1) The development of several shallow basins along the corridor, increasing the corridor's capacity for storm water retention from hillside run-off and town storm sewer discharge.

2) Improvement of the water quality and ecosystems downstream.

3) Refoliation of hillsides north-west of Gunnedah to increase their absorption of surface drainage.

4) Planting of additional vegetation to absorb surface water and filter pollutants from run-off, also improving aesthetic quality.

These suggestions were to be integrated into the overall design of the "continuous green space plan". The primary purpose of this was for environmental improvement, however, it also provides recreational linkages to south-western Gunnedah and the koala habitat.

c Mullibah Lagoon Corridor

The primary purpose of the corridor, due to its enclosure within a floodplain, is the mitigation of flood impacts. Specifically, this would be achieved in the corridor by holding stormwater,

cleansing it through wetland filters, and allowing it to drain slowly into the floodplain of the Namoi River. The corridor was also deemed capable of supporting multiple uses, so long as these could inter-relate in an environmentally sensitive fashion. One of the corridor's uses would be as a passive recreational area.

Implementation of stormwater management will involve the use of:

- aquatic plants (filtering street and stormwater run-off);
- silt traps and regrading restrictions; and
- biomass filter systems (filtering constructed wetland).

It is understood that the Mullibah Lagoon Corridor is now proceeding.

3.4 OTHER RELEVANT PLANNING POLICIES

3.4.1 State Environmental Planning Policy (SEPP) No 44 – Koala Habitat Protection

This policy, which commenced on 13 February 1995, aims to protect the habitat of koalas. It applies to land with an area of more than one hectare. The Gunnedah Local Government Area is one of the LGAs covered by this policy.

Before a consent authority may grant development consent on land, it must decide whether or not the land is "potential koala habitat". The definition of potential koala habitat is "an area of native vegetation where the trees or the types listed in schedule 2 (koala feed trees) constitute at least 15% of the total number of trees in the upper or lower strata of the tree component" (clause 4).

The application of this policy to the study area relates to the review of vegetation in section 2.3 and opportunities that may arise to mitigate flood impacts through revegetation strategies.

3.4.2 Regional Environmental Plans (REP)

There are no REPs relating to the study area or its catchment.

3.4.3 Total Catchment Management (TCM) and Planning

Circular F13 was issued on 21 August 1995 and introduces the Department of Urban Affairs and Planning (DUAP) document entitled *Total Catchment Management and Planning*. This document promotes an understanding of the relationship between TCM and planning legislation, and encourages councils to integrate TCM into their works and practices.

TCM aims to promote the sustainable use of natural resources, through involvement of all levels of government agencies and individuals. It involves the integrated management of environmental components including land, water, vegetation, fauna and other natural resources.

The document highlights specific land use planning issues which relate to flooding, helping to identify ways in which legislation can accommodate these issues. The issues are:

- risks to human life, property and stock;
- debris, litter, chemicals and fuel entering and polluting rivers during floods; and
- conservation of wetlands, flood plain vegetation and native fauna which are threatened when water flows are modified and water quality declines.

These issues should therefore be considered in a floodplain management plan and the relevant planning documents.

3.4.4 NSW State Rivers and Estuaries Policy

The NSW State Rivers and Estuaries Policy sets out a framework for the consideration of issues affecting rivers, estuaries and their adjacent riverine plains. Factors such as vegetation, water chemistry and geomorphology are to be considered within the overall framework of total catchment management.

The objective of the Policy is:

> *"To manage the rivers and estuaries of NSW in ways which*
> *~ slow, halt or reverse the overall rate of degradation in their systems,*
> *~ ensure the long-term sustainability of their essential biophysical functions, and*
> *~ maintain the beneficial use of these resources."*

Certain management principles will be employed in order to achieve that objective. The principles are aimed at encouraging the sustainable and non-degrading use of rivers and estuaries. Where areas of estuaries or rivers are currently degraded, the policy encourages their restoration and rehabilitation. Where there are areas of particular significance, the policy provides for their protection. These management principles are combined under an ethos of sustainability.

The Policy is based on the development and review of strategies for sustainable resource management. Sustainable resource management is defined as:

> *"that which ensures resource use is consistent with the long term biological and physical function of the natural system."* (NSW Water Resources Council 1993:23)

Regional Estuaries Reports will be produced for each region every two years, to monitor the improvement and/or degradation of resources. Every four years, these regional reports will be compiled into a State of the Rivers and Estuaries Report. The Policy also initiates development of ten component policies by certain nominated agencies. The key components are wetlands, riparian zones, riverine plains, streams and estuaries.

Implementation of the Policy and its components was previously overseen by the Water Resources Council. The Coastal Rivers and Estuaries Advisory Committee, and the Inland Rivers Advisory Committee also assisted in overseeing implementation. Implementation is now the responsibility of the Department of Land and Water Conservation (DLWC).

3.5 EVALUATION OF PLANNING INSTRUMENTS AND POLICIES

This chapter presents the background to the development of floodplain management in the Shire of Gunnedah and an overview of current controls.

At the present time it can be concluded that no specific controls exist for Carroll apart from the general provisions within the LEP. The LEP and the Interim Policy for Development on Flood Prone Land provide local controls for Gunnedah. However, a number of discrepancies have been identified that warrant amendment to the Gunnedah LEP 1998 and creation of a Flood Prone Land Development Control Plan. Examples of these discrepancies are outlined below.

- The flood study completed by DLWC in 1996 together with the maps produced within the floodplain management plan needs to replace the flood inundation map 1978 as the technical basis for the LEP.
- There is a need to define floodways and zone them accordingly, incorporating appropriate objectives for these zones.
- Zoning in Gunnedah generally does not respond to flood risks. For example, major commercial development along that portion of Conadilly Street zoned Business 3(b) may significantly increase potential flood damages.
- Definitions will need to be incorporated into the LEP which reflect the definitions in DLWC Draft Floodplain Management Manual, released for public comment by the NSW Government in March 1999.
- Specific controls and zones for the village of Carroll will be required within LEP 1998.
- Appropriate management options will need to be formulated into a development control plan and as amendments to the LEP.
- Flood planning levels, building and development controls will need to be implemented, for the area.
- Greater emphasis needs to be placed on access and evacuation issues for existing and future developments.

4 COMMUNITY INPUT

4.1 DEVELOPMENT OF THE CONSULTATION PLAN

Community input to the development of this Floodplain Management Study and Plan has been guided by a Consultation Plan, submitted to Gunnedah Shire Council in November 1998. The aims of the consultation plan are to:

- clearly articulate the study's aims and objectives to the community;
- establish and maintain the interest and enthusiasm of the community in the study;
- ensure that the community has ownership of the study by involving them in the decision making process;
- ensure that views of all target audiences are heard;
- utilise established community networks and links to disseminate information to the wider community;
- ensure that all material presented is in a clear and concise plain English manner; and
- establish clear lines of communication between the community and the consultants (and therefore the FPMC) at the outset of the project.

The key elements of this Consultation Plan have been:

a) collection of data and community input through direct surveys;
b) maintaining public awareness of the Study through a newsletter and regular newspaper articles;
c) utilising the membership of the Floodplain Management Committee (FPMC) as a conduit for community views throughout the Study;
d) obtaining informal community input through public forums in Gunnedah and Carroll following the development of mitigation options; and
e) finalisation of the Study following public exhibition in Gunnedah and Carroll for 28 days.

4.2 STAGE 1 CONSULTATION

The key objective of the first stage of the consultation process was to collect information from the community. In order to assist in the collection of data three survey forms were devised. These are provided in *Appendix A*. The focus of the information collected is to assist in the flood loss analysis and the social impact assessment. A description of the information collected is provided below.

4.2.1 Residential Floor Level Surveys and Condition Reports

For the estimation of the flood damages caused by potential floods, information on property type and value information needs to be assessed for each individual dwelling, as well as an estimate made of the floor level.

All residential properties affected by the extreme flood event in both Carroll and Gunnedah were surveyed. In Gunnedah, this involved 354 residential premises and in Carroll, there were 79 residential properties.

The data collected for each residence was:

- Type of Property (house, unit, etc);
- Height to Floor;
- Construction Type;
- Number of Storeys;
- Footprint of Building;
- Condition of Building; and
- Condition of Garden.

Real estate agents and valuers were contacted to ascertain the local values of properties. From this assessment, four value codes were established, which will be used in the establishment of damage curves.

4.2.2 Commercial Surveys

All businesses in the study area were surveyed to identify the potential impacts that various flood events, including the extreme flood, would have on the business in terms of physical damage and loss of trade. A measurement of all properties above ground level was also taken. A total of 189 commercial surveys were distributed, and 152 were completed and returned. A total of four commercial properties were surveyed in Carroll while the remaining 148 surveys were undertaken in Gunnedah. The data collected for each commercial survey comprised:

- business details;
- heights from ground level to floor level;
- flood history;
- cost of damage to stock and premises as a result of flooding;
- effect on trading as a result of flooding;
- likely future impacts in the event of an extreme flood;
- details of any future expansion of business; and
- any other impacts.

4.2.3 Social Impact Assessment

Random door knocking of one residential property in each street block was undertaken within the study area. Additional surveys were left at the Carroll General Store for distribution. A total of 71 surveys were completed. There were 19 responses from the residents of Carroll and 52 responses from the residents of Gunnedah. The aim of the social survey was to ascertain the following:

- resident information;
- flood history;
- flood warning and evacuation;

- impacts of flooding;
- impacts of post flooding;
- impacts of evacuation; and
- general impacts.

4.2.4 Individual Interviews

The SMEC team spent one week in Gunnedah between 7 and 11 December 1998 to undertake surveys and collect data. During this week members of the Consultant's team had discussions with Gunnedah Shire Council, the SES and DLWC regarding the behaviour of the flooding experienced in Gunnedah and Carroll. This allowed an understanding of the nature of the flooding to be developed. There were also a number of interviews with local residents who had experienced several floods and could provide vital information about the flood patterns experienced in the region.

4.3 STAGE 2 CONSULTATION

Potential flood plain management measures were the subject of a meeting of the Floodplain Management Committee on April 15 and public workshops in Carroll and Gunnedah on the same day. A Community Comment form was distributed at the two public workshops and 16 responses received, as well as two additional written responses. A summary of the feedback provided at these various forums is set out below.

Please note that the feedback obtained for various flood management options (set out below) should be read in conjunction with the overview of these options in Chapter 8.

4.3.1 Community Comment Forms

Community comment forms were distributed at both Gunnedah and Carroll to allow more detailed feedback once meeting participants had considered the various options. A copy of this form is provided at *Appendix A*.

Responses provided by way of community comment forms are summarised below for each of Carroll and Gunnedah under the headings of flood modification measures, property modification measures and response modification measures. A full summary of each response can be found at *Appendix B*.

4.3.2 Carroll Community Input

i Workshop, 15th April 1999

Residents of Carroll expressed substantial concern that isolation and increased flood levels would impact those houses outside the proposed levee. It was stated that the priority should be to upgrade warning systems, and it was difficult to gain flood information from the radio. Residents were also concerned that there was no gauge between Keepit Dam and its junction with the Peel River, where floodwaters meet. Also, culverts were needed along the Oxley

Highway to assist in "evening out the floods" and keeping flood waters on the eastern side lower.

ii Written Feedback

Six responses commenting on potential flood response measures for Carroll were received.

a Flood Modification Measures

Respondents were generally not in favour of flood modification measures, with a particular adverse focus towards the ring levee concept. The reasons cited for this lack of support were:

- a large number of properties that would need to be outside the levee would be isolated;
- exacerbated flood conditions outside the levee;
- environmental impact; and
- uneconomic cost.

The one flood modification measure that received support was enhanced drainage under the Oxley Highway so that floodwaters are more quickly and evenly dispersed.

Improvements to the river bank and Hass's causeway were also suggested.

b Property Modification Measures

Of the property modification measures suggested, development controls and building material requirements were most strongly supported. The introduction of zoning restrictions to Carroll was seen as both undesirable and inappropriate given the limited amount of development likely to occur.

House raising was seen as uneconomic and given the comparative property values in the area voluntary house purchase was seen as a more appropriate response where necessary.

Enhanced evacuation access towards Tamworth was seen as more viable than towards Gunnedah.

c Response Modification Measures

The prevailing view was that flood awareness is very high across the Carroll community, provided there is adequate warning of flood events. There was seen to be room for improvement in flood warning systems and ongoing community education.

The concept of an enhanced refuge during floods was strongly supported, with a prevailing view that the school is not adequate.

d Other Comments

A number of responses expressed a concern that irrigation and levee works on surrounding farms had significantly altered flood flow patterns in the area, possibly causing extended flood

events. There was also concern that the construction of a levee at Gunnedah would adversely affect Carroll.

Other matters raised included a need to work with nature, rather than against it in designing flood response measures, enhanced local communication with the SES and more local consultation prior to finalisation of the study.

4.3.3 Gunnedah Community Input

i Workshop, 15th April 1999

Residents of Gunnedah who attended the workshop were generally supportive of a levee, although there was substantial concern about the impact on properties that would be left outside the levee to the north of the town. It was suggested that a levee could be built to the level of the extreme flood event, or alternatively to one metre over the 1864 flood level. Protection of the Sewage Treatment Plant was considered critical. For those living outside the town, warning systems were also an issue. Mitigation measures could include an education package for local schools. The need for a land line to the Ruvigne gauge was highlighted, to enhance communications.

It was suggested that Gunnedah Airport could improve their tie-downs, which hold planes during flooding. Also the emergency airstrip could be upgraded to take commercial flights during floods.

Further information was desired regarding the cost of undertaking commercial property modifications, and also inclusion of the industrial zoned land west of Gunnedah.

ii Written Feedback

Ten survey forms and two letters were received with regard to potential flood management measures for Gunnedah.

a Flood Modification Measures

A mixed response was received with regard to the concept of a levee along the northern boundary of Gunnedah, with particular concern about the impact on properties outside the levee and to the north of the river. Although extreme views for and against the levee were expressed, most responses supported more investigation and modelling of impacts. One response suggested that a levee capable of handling an extreme flood event be investigated and others suggested that the levee should be integrated with a flood bypass. Integration with a Gunnedah heavy traffic bypass was also raised.

A number of responses sought attention for the 'pig-hole', keeping it clear of vegetation and preserved as a floodway.

With the exception of some support for river clearing, most other flood modification measures were not supported.

Such suggestions should be read in conjunction with the discussion of flood modification measures in section 8.1 of this report.

b Property Modification Measures

Property modification measures generally received a very high level of support. Some key issues raised include:

- the need to incorporate responses for houses outside any levee;
- voluntary purchase has previously failed; and
- what happens to houses not suitable for raising?

A number of responses believed that property modification measures would not be necessary if a levee was constructed.

The emergency airstrip was seen as satisfactory as a back-up during flood events, although some upgrading for night-time use would be beneficial.

Improved or dedicated boat access facilities for flood periods were seen as desirable.

These suggestions should be read in conjunction with the discussion of property modification measures in section 8.2 of this report.

c Response Modification Measures

Many responses noted that there was always room for enhanced emergency response measures, including:

- improved local communication prior to and during flood events;
- better use of the local radio for updates;
- improved measuring equipment; and
- ongoing community education, so that flood awareness is maintained.

One response suggested that response modification measures would not be required if a levee was constructed.

These suggestions should be read in conjunction with the discussion of response modification measures in section 8.3 of this report.

4.4 STAGE 3 CONSULTATION

Following comment on this report during the 28 day exhibition period, a summary of community input and an updated Floodplain Management Study and Plan prepared for the consideration of the Gunnedah Floodplain Management Committee and Gunnedah Shire Council.

5 FLOOD INFORMATION AND MODELLING

5.1 CATCHMENT

The Namoi River Basin is located west of the Great Dividing Range in northern NSW, forming part of the Barwon-Darling River system, as was shown in *Figure 1.1*. It is bounded by the Nandewar Range to the north, The Great Dividing Range to the east and the Warrumbungle Range to the south. Extending over 350 kilometres (km) from the head of the MacDonald River westward to Walgett, the basin covers 43,000 square kilometres (km^2).

The Namoi River rises in the New England Plateau of the Great Dividing Range. The main headwater tributaries of the basin include the Manilla, Peel and Mooki Rivers. The Manilla River joins the Namoi upstream of Keepit Dam and the junction of the Peel and the Namoi Rivers is approximately 13 km downstream of Keepit Dam. This is approximately 17.5 km upstream of Carroll. The Mooki River joins the Namoi just upstream of Gunnedah. Downstream, at Boggabri, the Cox's River joins the Namoi River. The catchment and the main rivers are also illustrated on *Figure 1.1*.

Gunnedah and Carroll are both situated on the left bank of the Namoi River and have catchment areas of 17,100 km^2 and 10520 km^2 respectively. The catchment of the Mooki River is about 7,200 km^2, and the Peel River at Carroll Gap 4,670 km^2.

There are four storages located on the Namoi River and its tributaries upstream of Carroll. These are Split Rock Dam (397,000 megalitres) on the Manilla River, Keepit Dam (425,000 megalitres) on the Namoi River, Chaffey Dam (62,000 megalitres) on the Peel River and Dungowan Dam (6,000 megalitres) on Dungowan Creek (Barrett Purcell & Assoc 1998). The dams have a combined catchment area of 6,215 km^2, which is approximately 59% and 35% of the catchment area to Carroll and Gunnedah respectively. The combined catchment area for Split Rock and Keepit Dams is approximately 54% and 33% of the catchment area to Carroll and Gunnedah respectively (DLWC 1996).

The catchments of the Mooki River, Cox's Creek and the Namoi River between Keepit Dam and Boggabri (LPLMC undated) from the region known as the Liverpool Plains, which has an area of approximately 12,000 km^2. The town of Gunnedah and the village of Carroll both lie within this region, with Gunnedah being the major town centre.

5.2 LAND USE

Considerable land use changes have taken place over the years due to a variety of factors. The most significant change in land use patterns has been over the plains areas. From the early 1800's, there was extensive stocking sheep and cattle in the region. The 1880s saw the conversion of some areas to wheat cropping, alternated with pasture. However, prior to the 1950's, grazing remained the predominant land use. Gradually, with the introduction of farm machinery, this was replaced with grain cropping, predominantly sorghum and wheat. In more recent years, large-scale irrigation has accompanied the change to cotton cropping. This has meant that much of the plains areas have had a series of irrigation canals and levee banks built across them.

This recent change has been of concern to the community, as the construction of irrigation infrastructure has often been carried out in an ad hoc manner, without due concern for impacts beyond each individual properties. In many cases, natural flow paths have been altered or block, impacting the natural flood and drainage patterns.

The upper valley has been traditionally grazing country, raising both sheep and cattle. The numbers of each have varied in response to various upsurges in wool and cattle profitability from time to time. This has in turn led to additional areas of slope country being cleared for additional grazing.

To address these land use changes and their possible impacts on flood behaviour, the DLWC has engaged SMEC Australia to investigate the hydraulic regime in the rural floodplains. These investigations will utilise the hydrologic and hydraulic models developed for this Study, amended to incorporate the various agricultural developments that have occurred and are likely to occur (the existing and future flood problems). This information will then be used to develop a management plan for the rural areas.

5.3 FLOOD BEHAVIOUR

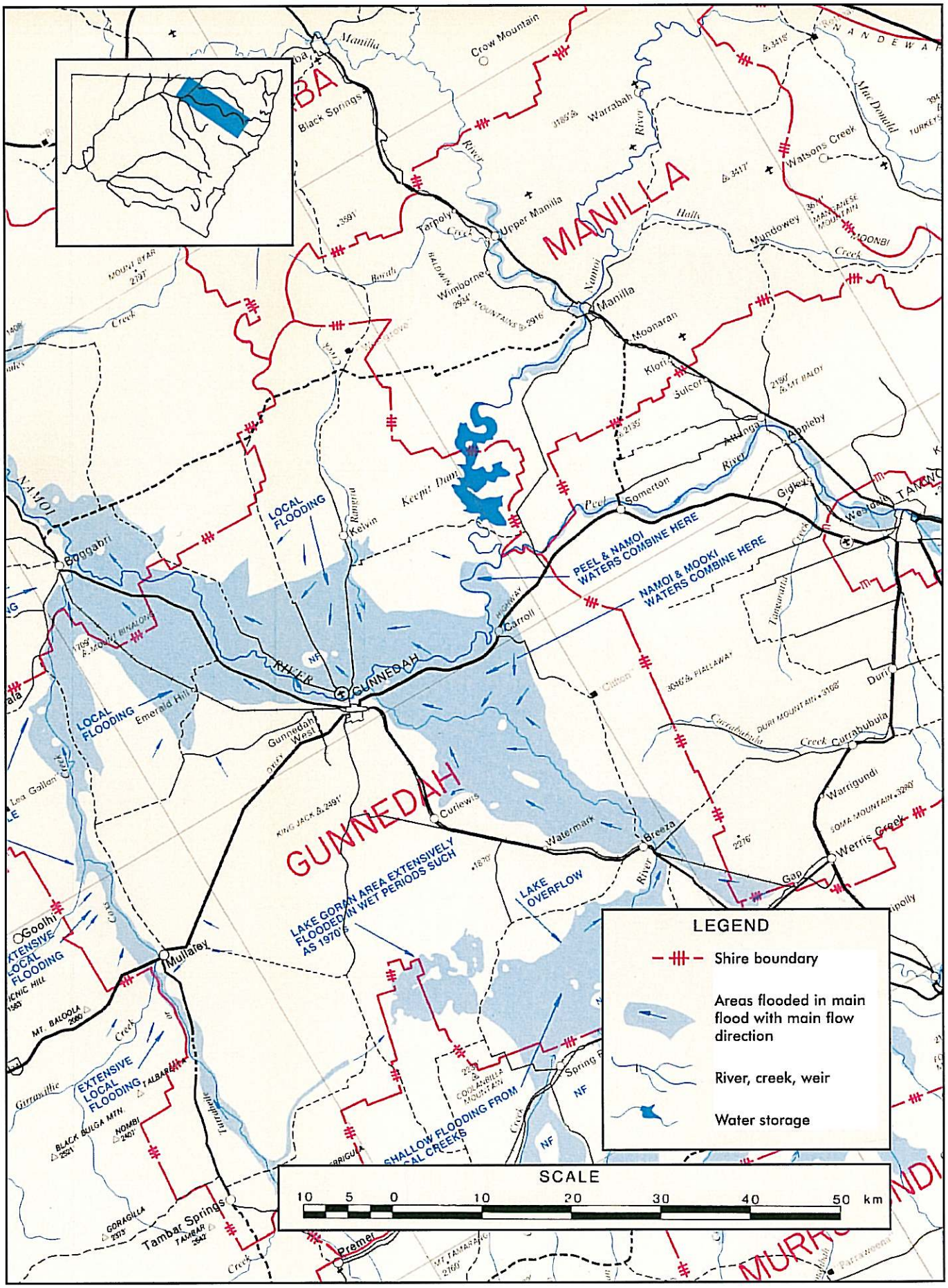
i General Flood Behaviour

There is no consistent pattern to the flooding experienced at Gunnedah and Carroll. This is due to the large catchment area upstream and the variability that is experienced across it, in terms of the location of storm cells and the many sources of floodwaters. Changes in flood behaviour has also been observed from flood to flood as the course of the river bed is altered. The following is a generalised description of the flooding experienced.

The tributaries to the Namoi River upstream of Carroll are the Manilla and the Peel Rivers. At the confluence of the Namoi and Peel, both streams are in relatively narrow valleys with little overbank storage. About six kilometres downstream of this confluence, the valley opens out to form the eastern limit of the western plains. Below this point, in major floods the river spreads extensively out over the plains on both sides. Major breakouts occur from both sides of the Namoi River in the vicinity of the village of Carroll, 16 km downstream of the confluence. *Figure 5.1* shows a generalised map of the floodplain, with arrows indicating the general direction of flows or inflows. *Figure 5.1* is not a flood extent map and should not be used as such.

A breakout of floodwaters occurs onto the relatively narrow floodplain immediately upstream of Carroll, from which a significant portion of floodwaters flow over the Hoss Causeway and onto the Mooki River floodplain to the south west. The Hoss Causeway will also be carrying a significant amount of local floodwaters if the storm centre is over the Carroll region. Downstream of Carroll, the Namoi River breaks where it approaches the Oxley Highway about 1.5 km south-west of the village. At slightly higher river levels, flows in the Namoi break out through the middle of Carroll. In addition, Ginnagulla Creek inflows from the east to join the high level breakouts to flow in a southerly direction from Carroll.

The higher level water breaking from the Namoi River through the village of Carroll flows due south and spreads on a broad front as it crosses the Carroll to Breeza (via Clifton) road to the



Source: *NSW Inland Rivers Flood Plain Management Studies - Namoi Valley, Laurie, Montgomerie & Petit, 1992.*

Figure 5.1

NAMOI RIVER FLOWPATHS

east of the Carroll to Long Point Road. The deepest flow is towards the eastern end. This water tends to stay east of the Carroll to Long Point road until it begins to cross the road at a number of places at the properties of Yeovil and Warilda.

Downstream of Carroll the Namoi Valley widens considerably, with extensive flat alluvial floodplains becoming a major characteristic. Major breakouts of floodwaters from the Namoi River occur between Carroll and Gunnedah. Some of the floodwaters move to the Mooki River floodplain, to the south. One of the major breakouts from the Namoi River occurs at Tommy Swamp, immediately downstream of Carroll. At this point a considerable portion of the Namoi River flow is redistributed onto the Mooki River floodplain via this floodway. This indicates that the carrying capacity of the Namoi River is limited, typical of western NSW rivers.

The Mooki River joins the Namoi River just upstream of Gunnedah. Extensive flooding is common along the lower Mooki and it can be a significant factor in the flooding of Gunnedah.

The floodwaters moving in a southerly direction from the Namoi River to the Mooki River floodplain combine with the floodwaters originating from the Mooki River. The combined floodwaters flow in a north-westerly direction and rejoin the Namoi River flood waters immediately upstream of Gunnedah.

The floodwaters that leave the Namoi River and flood the northern floodplain flow in a westerly direction, towards Gunnedah. Just upstream of Gunnedah, these floodwaters move along clearly defined floodways. These floodways cross Kelvin Road, flowing past both sides of Gunnible Mountain to rejoin the Namoi River.

Floods in the Mooki River in the Battery Point area, which is upstream of Gunnedah, break first into low lying flood runners adjacent to the river. Floods with a return period exceeding about once in six or seven years at Breeza then break over both banks of the river, causing more extensive flooding. Flood heights at the downstream end of Battery Hill may be further influenced by floodwaters arriving from the Namoi River.

ii Significant Historical Floods

The 1864 flood is considered to be the largest flood to have occurred at Gunnedah since white settlement, however there is no confirmation of the source of the recorded flood height which was 9.85 metres (m). Official records commenced in 1892, when the DLWC installed a gauge on Cohens Bridge, Gunnedah. The February 1955 flood is the second largest flood that has occurred at Gunnedah and the largest since official records commenced, with a gauge height of 9.6 m.

The SES installed a staff gauge in the township of Carroll in 1962, which is only read during flood periods. Prior to 1962, records of flood heights were maintained by the late H W Weakley and his son W L Weakley. Since 1962, the January 1964 event is the largest flood recorded at the Carroll SES gauge, with a height of 9.6 m, which was similar in terms of magnitude to the 1955 and 1910 flood events. In Gunnedah, the gauged height of the 1964 flood was 8.79 m.

The February 1955 flood was the result of intense rainfall over a three-day period. There had been several periods of moderate to heavy rains during January and early February, thus the catchment was very wet prior to the flood causing rains. The highest rainfall was recorded in the Mooki catchment, particularly the upper catchment, and the Manilla catchment, and both made a high contribution to the flood. The Peel River catchment also received high rainfall, and contributed 34% of the total volume of the flood to pass Gunnedah, while having only 27% of the area. At the confluence of the Peel and Namoi Rivers, the peaks did not coincide, thus the flood peak was lower at Gunnedah than might otherwise have occurred.

The January 1964 flood originated in the Namoi River catchment upstream of the junction with the Peel River. The 1964 flood exceeded the magnitude of the February 1955 in Carroll, both in terms of gauge height and peak discharge. However, the flood had a relatively small volume and rapid attenuation, therefore had little impact further downstream.

After 1955, the next event that had a major impact across the Namoi River Basin was the January - February 1971 event. This recorded a peak gauge height of 8.98 m at Gunnedah and 9.45 m at Carroll. This flood was very damaging because of its long duration, approximately three weeks, marked by two separate flood peaks. Most of the high rainfall was recorded along the south-western regions of the catchment, and the catchment was wet prior to the flood rains, giving high runoff in the upper Manilla and Peel River catchments. During this flood, Keepit Dam was operational, and where possible was used to attenuate the flood, with releases being made such that they mitigated peak flood flows at downstream locations.

The January 1974 flood resulted from relatively even runoff from all parts of the upper catchment, with the maximum runoff from the Manilla and Mooki River systems. The volume at Gunnedah was only one third of that of the 1971 flood, although the Mooki River contribution was about the same in both floods. In this flood, the Mooki River catchment contributed about 38% of the total flow passing Gunnedah. The gauge height at Gunnedah was 8.59 m and at Carroll was 8.43 m.

In January 1976, as in earlier major flood events, the catchment of the Namoi Valley was well watered before the onset of the flood rains that caused the January-February 1976 flood. The highest runoff for this was recorded from the Peel and Macdonald River catchments, with the Peel River system contributing 44%. There was considerably lower runoff from the Mooki and Manilla Rivers. The flood volume passing Gunnedah was similar to that recorded during the 1974 flood, but the gauge height was higher, with a peak of 8.78 m. At Carroll the gauge height was 8.97 m.

Prior to the January-February 1984 flood, there had been above average rainfalls which had wet the catchment, and promoted rapid rates of runoff when the flood producing rains occurred. The storm cell producing these rains was centred over both the Mooki and Peel Rivers, with the Peel River contribution at Gunnedah for this event being approximately 50%. The peak discharge upstream of Chaffey Dam was the highest on record. However, as Chaffey Dam was empty, it had a significant effect on the flood, reducing the peak by about 95% (WRC, 1984). The flood peak upstream of Keepit Dam was well below the highest recorded flood peaks of 1964 and 1955. This peak was reduced by some 35% by the operation of Keepit Dam.

It can be seen from the historical floods in the upper Namoi River catchment that there is no consistent pattern of flooding. The catchment area is large, and storms are usually centred over only a portion of the catchment. This results in flood peaks being generated from some of the many sources of floodwaters and tributaries are often not in flood simultaneously. Should there be an instance where the whole of the catchment is subject to high rain falls and flood peaks arrive downstream simultaneously, towns and properties in the flood plain could potentially have a flood significantly in excess of any flood yet experienced. The probability of occurrence of such an event would be very low, with such an event being what is termed an "extreme event".

iii 1998 Floods

The 1998 flood is the first major flood that had been experienced in fourteen years. The flood was unusual in there was a series of five peaks recorded, between 24 June and 7 September. The peak height reached in Gunnedah was 8.84 m on 22 July, which was the second peak to pass through Gunnedah. Properties in Carroll were not inundated during this flood. Using information presented in the DLWC flood study (1996), the gauge height of 8.84 m in Gunnedah corresponds to an event with a 5% AEP.

Carroll village did not flood until 6 September, as the last flood peak moved down Namoi River. The peak of 9.1 m recorded at this time corresponds to an event with an AEP of less than 10%. This peak arrived in Gunnedah on 7 September and recorded a peak height of 8.5 m, corresponding to an AEP of slightly greater than a 10%.

Throughout these floods, Keepit Dam was being operated to attenuate the flooding, with releases being calculated so as to minimise the flood peaks where possible. There were minimal releases during the July 1998 flood. However, by September, several floods had moved through the valley, thus the dam was full. It became necessary to release large volumes of water to protect the integrity of the dam and these releases in conjunction with rising floodwaters from the Peel River system, resulted in flooding Carroll village.

iv Gunnedah Historical Flood Heights

The SES classifies a major flood as having a gauge height of greater than 7.9 m at the Namoi River at Gunnedah gauge at Cohens Bridge (419001). A major flood is defined as the gauge height at which extensive rural areas are flooded, with properties, villages and towns isolated and/or appreciable urban areas flooded. A total of 20 floods have exceeded this gauge height between 1892 and 1998. The gauge heights of the major historic floods in Gunnedah are shown in *Table 5.1* (DLWC, 1996). The Namoi River breaks its banks in Gunnedah at a gauge height of 6.6 m.

Table 5.1 *Gauge Height (419001) of Major Historical Floods in Gunnedah Gauge zero = 254.885m AHD*

Year	Date	Height (m)
1864	-	9.85
1900	25/7	8.96
1908	18/3	9.65
1910	16/1	9.40
1920	30/6	7.93
1921	3/7	8.23
1942	12/7	7.93
1950	24/7	8.38
	23/11	8.10
1955	26/2	9.60
	26/10	8.47
1956	11/2	8.84
1962	14/1	8.05
1964	15/1	8.69
1971	2/2	8.98
1974	9/1	8.59
1976	25/1	8.78
1977	17/5	8.00
1984	31/1	8.84
	29/7	8.00
1998	22/7	8.84
	29/7	8.55
	9/8	7.98
	7/9	8.50

The peak discharges and volumes for the 1995, 1971 and 1984 events in Gunnedah are presented in *Table 5.2*.

Table 5.2 Peak Discharge and Volumes, Gunnedah (419001) (Source: DLWC, 1996)

Event	Discharge (m^3/s)	Volume (ML)
February 1955	9160	2 000 000
February 1971	4750	2 170 000
January 1984	3960	835 000

v Carroll Historical Flood Heights

The observed and recorded flood heights for Carroll are shown in *Table 5.3*. The Namoi River breaks its banks at Carroll at a gauge height of 8.4 m.

Table 5.3 Observed and Recorded Flood Heights in Carroll
Gauge zero = 271.10 m AHD

Year	Gauge Height (m)
1910	9.60
1950	9.09
1955	9.60
1962	8.99
1963	5.84
1963	5.92
1964	9.60
1968	7.62
1970	5.94
1971	9.45
1971	9.09
1974	8.43
1976	8.97
1977	6.63
1984	9.30
1998	9.10

During the flood study undertaken by DLWC (1996), a flood frequency analysis was undertaken on the Cohens Bridge gauge (419001) at Gunnedah and the SES gauge at Carroll. The results of this analysis are shown in *Table 5.4*. The study noted that the results obtained

compared favourable with the flood frequency results presented on the Gunnedah Flood Inundation Map, 1978.

Table 5.4 Flood Frequency Analysis Results

Gunnedah (419001)		Carroll (SES Gauge)	
Year	**AEP (%)**	**Year**	**AEP (%)**
1864	1.0 – 0.7	February 1955	1
February 1955	1.4 – 1.0	1964	2
February 1971	4	February 1971	4
Jan-Feb 1984	5	1984	10

As part of the flood study, DLWC (1996) derived and modelled an extreme event for both Gunnedah and Carroll. The estimation of the Probable Maximum Flood (PMF) was not feasible due to the size and complexity of the catchment upstream. For Gunnedah, the extreme event was estimated using a regional method based on plots of maximum flood discharge against catchment area. An extreme flood discharge of 30,000 m^3/s was obtained, which is approximately three times the record floods of 1864 and 1955. A gauge height reading for this flood in Gunnedah would be approximately 11.6 m.

For Carroll, an extreme flood was estimated as three times the February 1955 flood. This gives a peak discharge of 27,000 m^3/s. A gauge height reading for this flood in Carroll would also be approximately 11.6 m. DLWC considered this extreme event estimation suitable for detailed emergency management planning.

5.4 FLOOD IMPACTS

i Extent of Inundation

The work undertaken on the flood study (DLWC, 1996) included the development of a MIKE 11 hydraulic model. This was used to estimate design flood profiles for the 1%, 5% and 10% AEP and an extreme event for the detailed study areas of Carroll, Gunnedah and the environs of Gunnedah and for the 2% AEP at Carroll. The results indicated that the extent of flooding for the 10%, 5% and 1% AEP events, as depicted by Gunnedah Flood Inundation Map 1978, is still appropriate for Gunnedah. A discussion of the MIKE-11 model is included under section 5.8.

Carroll village is extremely flood liable, with the entire village population requiring evacuation in major floods. Under the modelled 1% AEP flood conditions, flood depths are in the order of 2.0 m and overland flow velocities were 0.5 to 1.0 m/s, which are extremely hazardous conditions. Under extreme flood conditions (3 * 1% AEP) flood depths are generally 0.5 to 1.0 m higher than the 1% AEP flood.

At Gunnedah the extent of the 1% AEP flood varies from Maitland Street in the eastern part of Gunnedah to Little Barber Street in the western part of the town, similar to what is shown in the Gunnedah Flood Inundation Map, 1978. Average flow velocities in the lower part of the township, in the vicinity of Maitland Street, are in the order of 0.5 to 1.0 m/s and flood depths approximately 2.0 to 2.5 m, which are considered hazardous conditions. The extreme flood (3 * 1% AEP) is generally 1.5 m to 2.0 m higher than the 1% AEP flood.

Please refer to the drawings accompanying this Study to view these flood impacts.

ii Properties

In their study, Smith & Greenaway (1984) noted that in Gunnedah there are 216 residential and 52 commercial properties at risk from the 1 in 100 year flood. The following levels are taken from the SES Flood Intelligence Card (1998), which shows the levels at which properties are inundated as the flood waters begin to rise:

Table 5.5 Property Inundation Levels

Height	Consequence
7.5	Water enters the yard of the house at 103 Chandos Street, occupants are evacuated
7.6	Talibah Flat soccer fields are inundated and water enters the sports centre canteen there. 6 houses on the Talibah Flat are surrounded by water.
7.7	Water enters the shed at 48 Maitland Street and there is water under the elevated houses at 52 and 80 Bloomfield Street.
7.8	Water surround the elevated house at 71 Maitland Street
	Water enters the garage at 14 Little Conadilly Street
7.92	The house at 169 Marquis Street has water over the floor
8.0	Water under the elevated houses at 45 and 85 Bloomfield Street
	Water enters the houses at 40 Rosemary Street, 34 Little Conadilly Street and 86 Bloomfield Street
8.10	Water enters the house at 163 Marquis Street and 44 Tempest Street. Water under the elevated house at 77 Bloomfield Street.

As the flood continues to rise, more properties become affected. An example of the Flood Intelligence Card held by Gunnedah SES is included in *Appendix C*. We understand that this Card has been upgraded since the 1998 floods.

iii Roads

Once the flood water is above 7 m, roads in lower lying areas are cut. This affects roads between Gunnedah and other centres, as well as properties within Gunnedah, which become isolated. The following levels are also taken from the SES Flood Intelligence Card (1998):

Table 5.6 Road and Aerodrome Inundation Levels

Height	Consequence
7.2	A breakout occurs and water starts to flow over the road at the "Pig Hole" approximately 500 m north of Cohens Bridge.
7.3	Water starts to cross the low areas of Kelvin, Bluevale, Wean and Orange Grove Roads. Roads may close with short notice above this height. The rural properties on the northern side of the river will become isolated once all of these roads are closed. Alternative routes are available via Manilla.
	Water starts to encroach on the western end of Maitland Street.
	Access from Maitland Street into Warrumbungle Street is restricted.
7.32	The Gunnedah to Kelvin Road is closed at Cohens Bridge. A shuttle service is operated using high clearance emergency vehicle. Normal road access to the aerodrome is lost, alternative access is available via the Ballyreagan Bridge.
7.5	Water over the northern approaches of the Ballyreagan Bridge. There is no vehicular access to the aerodrome from Gunnedah
7.6	About 12-18 hours after this height is recorded, water will flow over the Gunnedah to Boggabri road (MR72) at Barlows Corner, about 25 km west of Gunnedah.
7.8	The shuttle service across the "Pig Hole" by high clearance vehicle ceases and is taken over by flood boats.
	Water over the road at the intersection of Bloomfield and Rosemary Streets restricts access to the workshop of Sansons Power Coating.
7.92	Water over the road restricts access to 107 and 109 Maitland Street and 92 Bloomfield Street.
8.10	Water covers part of Runway 11/20 at the western end of the Gunnedah aerodrome. The aerodrome is closed at this time.
8.38	The Tamworth Road (Oxley Highway) may be closed by water flowing over the road between the McDonaugh Bridge over the Mooki River and the Weakley Bridge over the Mooki Deviation Channel.

Once the Gunnedah to Kelvin road closes, properties to the north of Gunnedah are isolated. While there is alternative access via Manilla, travel to places of work or school in Gunnedah becomes difficult or impossible. The closure of this road also restricts access to the Gunnedah Airport. Road access via the Ballyreagan Bridge or use of high clearance vehicles can be continued, up to a gauge height of 7.8 m. After this, the Gunnedah Bush Fire Brigade runs a ferry service across the river, using flood rescue boats. Beyond 8.1 m, the runway is closed and the Gunnedah Shire Council operates an emergency airstrip. The emergency airstrip is on the Pullaming Stock Route off Main Road 72 (Gunnedah to Quirindi) about 9 km south of Gunnedah.

The Oxley Highway between Carroll and Gunnedah was closed when the Carroll gauge was reading 9.1 m during the 1998 flood. There were three sections at which it was cut, being the breakout point just south of Carroll, Tommy's Swamp, which is approximately half way between Gunnedah and Carroll, and Boggabri, which is approximately 5 km from Gunnedah.

Good information on what level on the Carroll gauge indicates a road closure is not available, but it is estimated to be 8.8 m.

The Hoss Causeway, on the Tamworth side of Carroll is another place at which the Oxley Highway closes. Carroll becomes completely isolated once both the Gunnedah to Carroll and Carroll to Tamworth roads have been cut as described above.

1984 Flood Impacts

The February 1984 with a recurrence interval of 1 in 14 years entered the grounds of 70 residential properties and exceeded floor height in 60 cases. A further 15 commercial premises sustained over-floor flooding.

Following this event, damage estimates were undertaken by Smith & Greenaway (1984). They found that the combined direct and indirect potential damages for the residential sector from the February flood was $371,000 and for the commercial sector was $190,800. The corresponding estimates for direct and indirect actual damage were $55,650 for the residential and $63,600 for the commercial sector. Amounts given are the 1984 figures.

Based on these two data sets the recommended ratio of actual to potential damage are 0.15 and 0.30 for the residential and commercial sectors respectively. The large differences between actual and potential values are due to the efficiency of flood reduction measures undertaken by the affected community.

Average annual damage estimates for the combined direct and indirect actual damages are presented. These are $10,700 and $16,870 for the residential and commercial sectors respectively (Smith & Greenaway 1984). These values closely match those obtained in an earlier and completely independent study undertaken by Laurie *et al.* (1982).

1998 Flood Impacts

During the 1998 floods, 30 families in Gunnedah had to be evacuated and had their property moved to the Showground pavilion. There were three families from Gunnedah put into motels, for a length of stay of up to one week. A further 99 houses were affected by floodwaters. These were raised houses with water around them or houses surrounded by floodwater, which required boat access. A total of 32 business premises were inundated and a further 15 were affected due to restricted access and the subsequent loss of business. The Department of Community Services provided support and assistance to 186 families in the Gunnedah area (SES 1998).

In Carroll, there were 6 properties evacuated, with people generally moving in with friends or neighbours whose houses were above flood level. Property which was endangered was put up on drums. There were 30 properties in Carroll which were inundated by floodwaters.

Road closures occurred on the Gunnedah to Kelvin Road, the Gunnedah to Boggabri Road at the Ballyreagan Bridge and Barlows Corner, and the Oxley Highway between Gunnedah and Carroll and Carroll to Tamworth. During the 1998 floods, these roads were each closed several different times for 2 to 3 days each time.

b Gunnedah Local Emergency Operation Controller

It is the responsibility of the Gunnedah Local Emergency Operation Controller to:

- monitor flood response operations;
- coordinate support to the SES Local Controller if requested to do so;
- evacuate persons at threat of inundation, as required by the SES Local Controller; and
- control flood emergency operations if required to do so.

c Gunnedah Shire Council

The Gunnedah Shire Council has a responsibility to:

- maintain a plant and equipment resource list for the Council area;
- deploy manpower and resources for flood related activities, at the request of the SES Local Controller;
- provide manpower, plant and transport resources, if available, to assist the SES conduct evacuations;
- provide radio communications if required;
- close and reopen roads affected by flooding and advise the SES Local Controller; and
- operate the emergency airstrip on the Pullaming Stock Route if required.

The Gunnedah Bush Fire Brigades maintains access to the airport by operating a shuttle service across Cohens Bridge and its approaches, using high clearance vehicles, until floodwaters are deep enough for flood rescue boats to take over the service.

The NSW Police Service is responsible for providing manpower for evacuations, controlling roads, ensuring all evacuees are registered and securing evacuated areas.

The NSW Fire Brigades provides pumping facilities if required.

The various Service Clubs within Gunnedah assist in conducting evacuations, sandbagging operations, and the registration of evacuees and the Gunnedah Disaster Welfare Service controls and manages evacuation centres as required by the SES Local Controller. Gunnedah Shire Council maintains a supply of sandbags, with backup supplies available from the Namoi SES Headquarters.

Generally it is only feasible to sandbag commercial properties, due to the differences in construction and type of property being protected.
The Gunnedah SES Local Controller is also responsible for the education of the community on the flood threat in their area and how they can protect themselves against it. This includes being made aware of the stage their property might be inundated (if applicable), evacuation arrangements and the general contents of the Emergency Plan. The SES has distributed the evacuation procedures section of the plan to affected residents, and have carried out flood evacuation surveys of the community. Only 19% of those surveyed responded positively to receiving this type of information, as discussed in Section 3.3.1 (ii).

In 1998, prior the floods, as part of the education process, the SES distributed brochures advising of the flood risks present and what action could be taken by the community to mitigate those impacts. However, as the community perceived the risk of flooding to be remote, the responses were often apathetic. Then, following the floods, there were members of the community who then felt that as the floods had already hit and damage had been done, it was now too late to take appropriate action to prepare against floods.

d Communications

The SES Local Controller obtains flood information on river heights and flood predictions from the Bureau of Meteorology, Namoi SES Headquarters and the stream gauge monitoring system.

Pump and stock warnings for landholders are issued by the Namoi SES Headquarters through regional radio and television stations and newspapers. They also organise the distribution of the Bureau of Meteorology flood warnings through these media outlets.

There is a local phone-in information service to the public in relation to river heights, flood behaviour, road closures and advice on temporary mitigation. The SES believes that everybody has access to telephone to access assistance. During the 1998 flood, most lines remained in service. For areas which did lose telecommunications, Telstra distributed free mobile telephones.

e Evacuations

The general arrangements for evacuations are as follows:

- If only a small number of evacuations are required, the Gunnedah SES Local Controller organises them. If Carroll needs to be evacuated or if 20 or more residences in Gunnedah need to be evacuated, the evacuations are controlled by the Gunnedah Local Emergency Operations Controller.
- Field teams conduct doorknocks. They report back to the Evacuation Controller on:
  - street name and house number;
  - number of occupants;
  - details of support required (such as transport, medical evacuation, assistance to secure house and/or property); and
  - time of actual inundation, if available.

The primary means of evacuation is by private transport, although assistance is arranged for those who do not have their own transport.

Evacuees are directed or moved to evacuation centres, where they are registered, medically checked and provided with their immediate welfare needs.

For the village of Carroll, evacuees are directed to the Somerton Hall. Facilities at the Hall are limited, being only a kitchen and toilets. The options for accommodation are:

- if evacuees have alternative accommodation, they are encouraged to use it;

- evacuees with their own bedding may stay at the Hall; and
- others are evacuated to Tamworth, where accommodation is arranged for them.

Furniture and effects may be stored at the Hall.

In Gunnedah, an evacuation centre is established at the Gunnedah Showgrounds. Those having alternative accommodation are encouraged to use it, otherwise accommodation is arranged for them in motels/hotels. Furniture and effects are shifted to the Showgrounds and stored there in pavilions. There is also a caravan park with facilities at the Showgrounds, which can be used by caravan parks requiring evacuation.

5.6 LOCAL AND REGIONAL ISSUES

i Development on Mooki and Namoi River Floodplains

The change in land use to high value, irrigated cropping has been accompanied by large-scale private construction of levee banks and raised canals on the Mooki River plain upstream of Gunnedah. This construction was initially undertaken without regard for the overall effects of the work, and in numerous cases banks caused, or had the potential to cause, serious disruption to previously existing flood flow patterns.

In December 1984, DLWC brought all land in the Liverpool Plains with a gradient of less than two percent under Part VIII of the *Water Act, 1912*, which requires all earthworks to be authorised and located so as not to materially or prejudicially affect the distribution of floodwaters.

However, there remained serious problems in the licensing procedures, with landholders being concerned about delays in processing applications and unlicensed works continuing to be constructed.

The initiative to improve floodplain management on the Liverpool Plains arose largely because of landholder conflict caused by ad hoc earthwork development. For floodplains to serve the dual role of agricultural production and effective catchment drainage there needed to be cooperation between landholders for the success of both floodplain schemes and recommended land management practices.

To this end there have been a number of steps taken. In September 1993, the Minister for Land and Water Conservation established the NSW Floodplain management (Non-tidal) Advisory Committee. The Committee's first task was to examine floodplain management issues on the Liverpool Plains region. The Committee's final report, which has become known as the Burton Report, was delivered to the Minister in 1994.

The Burton Report reviewed the administrative arrangements which were in place for the resolution of land and water management issues in the Liverpool Plains, identifying areas of deficiency or overlap and presented a list of preferred options for better coordination and efficiency of effort.

The body primarily charged with implementing the recommendations of the Burton report is the Liverpool Plains Flood Management Task Force (LPFMTF). An Advisory Committee was also set up to advise the Task Force on floodplain issues.

Since the Burton Report was submitted, there have been a number of other studies which have reviewed the management of the Liverpool Plains catchment and the implementation of the recommendations from the Burton report. The DLWC review (1997) found that there were still difficulties being experienced in the areas of licensing and conflict resolution, and made a series of recommendations on how the process can be improved.

In more recent times, there have also been a number of community workshops which have examined catchment issues and how sustainable management of the region can be achieved.

One of the bodies with a key role in this process is the Liverpool Plains Land Management Committee (LPLMC). The LPLMC was formed in February 1992 with a clear direction from the local community to coordinate and manage research, development and extension in natural resource management issues.

It originated out of community concerns regarding the threat of rising saline water tables, however, this focus has been expanded to deal with a myriad of environmental sustainability issues as expressed by its constituent stakeholders. It is now the umbrella organisation for some 35 Landcare/Rivercare groups in the Liverpool Plains catchment.

A study carried out by Barrett Purcell & Assoc (1998) identified all of the irrigation works on the floodplain between Carroll and the junction of the Namoi and Mooki Rivers. It was found that most of this area has been covered in a network of low height irrigation channel banks. Most of the banks range between 0.4 m and 0.8 m high.

During the flood study a broadbrush sensitivity analysis was undertaken (DLWC 1996) of this development using the January-February 1984 event. This analysis indicated that the current level of development is not likely to cause significant changes to peak flood levels at Gunnedah and Carroll for the range of floods considered in this study, particularly for the larger to extreme events.

SMEC understands that DLWC is implementing a series of flood plain management studies over the rural floodplains across the State to address land use changes and their possible impacts on flood behaviour. The DLWC has engaged SMEC Australia to investigate the hydraulic regime in the rural floodplains in the Carroll to Boggabri reach of the Namoi River. These investigations will utilise the hydrologic and hydraulic models developed for this Study, amended to incorporate the various agricultural developments that have and are likely to occur (the existing and future flood problems). This information will then be used to develop a management plan for the rural areas that will integrate with this study and resultant plan.

ii Transport infrastructure

Road closures are frequent on many of the major routes, particularly the Oxley Highway and the Gunnedah to Kelvin Road, north of Cohens Bridge. These closures isolate many rural properties, making travel to places of work or school difficult or impossible. This situation becomes more dangerous if there is a medical or other emergency during the time of isolation.

The village of Carroll becomes completely cut off once the Oxley Highway is closed on both sides of the village. Carroll is then dependant on helicopter drops of supplies from the SES.

Within Gunnedah there are also a number of low lying areas that suffer localised isolation, as the local roads become flooded. This impacts on both residential and commercial premises. While access from the township of Gunnedah to other major centres is not completely cut, travel times may be significantly increased, dependant on road cuts.

There are also problems experienced with the Gunnedah Airport. The main one is that the access between the airport and the town is lost quite early during flood times. After this, a shuttle service, then ferry service, is operated until the airport is closed as flood waters inundate the western end of Runway 11/29. The shuttle service requires a high clearance emergency vehicle, while the ferry service is run using flood rescue boats. Once the aerodrome is closed, the Gunnedah Shire Council operates an emergency landing strip with flood-free access to the town.

5.7 PREVIOUS FLOODPLAIN MANAGEMENT MEASURES

In late 1995 construction of the deviation of the Oxley Highway crossing of the Mooki River and the Carroll Creek floodplain was completed. This involved the construction of a 2 km bypass from the Oxley Highway west of Ruvigne Road to TR 72 east of Gunnedah, and three new bridges. The bridges now cross the Mooki approximately 1,400 m upstream of the old bridges, and incorporated three new crossings, one bridge spanning 140 m and two culvert crossings, over the Mooki Overflow Channel and Carroll Creek. The new alignment was built to a 1 in 10 year flood level. Following the opening of the new bypass, the old timber bridges over the Mooki River were removed.

The hydraulic impact of the completed works on flood behaviour was reassessed as part of the flood study (DLWC 1996). It was found that maximum impacts occur immediately upstream of the road alignment. Maximum afflux caused by the new alignment over the full range of floods considered is approximately 0.14 m and occurs under January-February 1984 flood conditions. The impact of this afflux is felt, in a continually decreasing manner, for approximately 2 km upstream and up to 0.5 km downstream, of the new bridge works.

During the 1998 floods, the new bridges were not overtopped, however, the approaches to the Ruvigne Bridge were flooded on both sides.

In Carroll, following the 1955 floods, the Oxley Highway was raised, by up to 0.5 m in some places (DLWC 1996). During SMEC's visit to Carroll, it was noted that some residents on the western side of the highway felt that this had exacerbated cross-drainage problems, with floodwaters not being able to drain away until the highway was overtopped.

There are still many roads in and around Gunnedah which experience closures during times of flood and these are discussed in Chapter 8 below. The priority areas are seen as the provision of flood free access for as long as possible to the Gunnedah Airport and rural properties to the north of Gunnedah and the isolation which the village of Carroll experiences once the Oxley Highway on both sides of the village is flooded.

Once the floodwaters inundate the Gunnedah Airport, the Gunnedah Shire Council operates an emergency landing strip with flood-free access to the town. It has been noted by the FPMC that this facility, though adequate, would benefit from some upgrading to better handle emergency situations.

During the 1955 flood, about 171 houses and businesses were flooded. Since 1955, there have been about 10 houses in Gunnedah that have been raised (SES Flood Intelligence Card, 1998). This is seen as an important and effective flood mitigation measure for suitable houses which are in low hazard areas. The use of this option is also discussed in Chapter 8 below.

i Flood Mitigation by Large Dams

The dams that are upstream of Carroll, particularly Keepit Dam, are operated where possible for flood mitigation purposes. However, they are not big enough to provide reliable attenuation of all floods which move through the Valley. The catchment area upstream is large, and the sources of floodwaters varied. If the dams are full or near full when flooding occurs, the dams can have only a minor impact on the flood as it moves through.

A matter raised in many discussions relates to the passing of information regarding the levels and expected releases from the dams operation centres to the SES Headquarters, to ensure the SES is as informed as possible of the situation upstream.

A related issue raised by the Gunnedah SES is the amount of information available through the stream-gauging network. To assist in developing an accurate and efficient flood warning system, the SES needs access to timely and accurate information. In previous flood events, predictions have suffered in accuracy due to a lack of gauge height and gauged stream data. During 1998, a number of new gauges have been installed by DLWC in the upper catchment, which will go some way towards alleviating this situation. In addition, the SES have made an application to have the Carroll gauge hooked into telemetry and connected to the DLWC network.

There is a low flow gauge on the Mooki River known as the Ruvigne Gauge, which is operated by DLWC. The SES would like to see this upgraded to telemetry to provide additional information on the flows and flood levels in the Mooki River. Recommended gauging improvements are discussed in Chapter 8 below.

ii Community Education

Another area that has been pursued in the past is community education, in the areas of flood liability and preparedness, for both residential and commercial properties. It was noted during discussions with members of the community that there were instances in which they need to be aware of the extent to which properties could be inundated, and what action they could take to minimise the impacts on their properties. The SES has distributed a copy of the evacuation procedures section of the plan to affected residents, but there has been no education on emergency supplies or securing property. Some houses have their power lines running under the floor, which presents a dangerous situation when water levels rise above floor levels. This is a matter that should be addressed for new buildings and included in any education campaign.

There have also been instances where the Gunnedah SES has offered advice and material to business so as their properties could be flood proofed, prior to the 1998 floods. The flood proofing required some simple preparations to be made. However, there was an unwillingness to take these precautions, and consequently, substantial damage was suffered. Following the floods, the SES made the same offers, however, these were still not taken up. Education programs that outline the flood threat and encourage the community to take simple measures to reduce flood exposure will be investigated. The community needs to be more aware of the ongoing risk of flooding in the region.

5.8 MODELLING

As part of the flood study, DLWC (1996) established a MIKE-11 hydraulic model. The area covered by the model included the areas of Gunnedah township, the floodplain immediately downstream of Gunnedah, and the village of Carroll. It covered the section of the Namoi River and its tributaries from the junction of the Namoi River and Peel Rivers, the Mooki River from the Breeza gauging station upstream of Gunnedah, to Boggabri downstream of Gunnedah.

This model was calibrated and validated against a range of historical flood events. For the study area of Carroll the MIKE-11 model was calibrated against the January 1964 event and validated against the February 1955, January-February 1971 and January-February 1984 events. For the detailed study area of Gunnedah and the environs of Gunnedah the model was calibrated against the February 1955 event and validated against the January-February 1971 and the January-February 1984 events.

This MIKE-11 model has been made available to SMEC for this study. It was installed and the full range of floods were run. The results from these runs have been compared with those presented in the flood study. There was good agreement in Carroll and Gunnedah for the 1% AEP flood and in Carroll for the 3 * 1% AEP flood.

5.9 FLOOD MAPPING

Inundation maps and hazard maps have been produced using MapInfo GIS software. This has required the production of a digital base map for Gunnedah and for Carroll, including a digital terrain model and cadastral information.

The topographic information has been digitised from the 1:4000 orthophoto maps for Gunnedah and from a series of spot heights for Carroll. The Carroll information has been supplemented by the cross sections from the flood study (DLWC 1996) and the 1:25 000 topographic map. For copyright reasons, the cadastral information for Gunnedah has been digitised from the 1:4000 Draft Local Environment Plan while Carroll has been taken from the Local Environmental Plan 1998.

The locations of cross sections have been digitised from the schematic layout of the MIKE-11 model presented in the flood study report (DLWC 1996).

Using the spot heights given for Carroll, contours and a three dimensional model of the topography were generated. The location of all properties was assigned, and the ground level for each property extracted from the model, allowing the floor level to be calculated.

Table 1.5 (Chapter 1) lists the 18 maps and drawings that have been produced as part of this Study.

5.10 FLOOD MAPPING AND HAZARD ASSESSMENT

Detailed "flood maps" for Gunnedah and Carroll have been prepared for the 5%, 1% and 3x1% AEP flood events. The flood maps provide a convenient means of assessing flood behaviour and the hazards associated with flooding. The maps show the extent of inundation, depth of flooding and water level contours. Hazard categorisation was undertaken for the 1% event. Identification of flood hazards within Gunnedah and Carroll was determined in accordance with the NSW Floodplain Development Manual (FDM), 1986. A list of the maps is to be found in Table 1.1 (Chapter 1). Preliminary versions were presented at the Floodplain Management Committee meeting on 15 April 1999 and final versions on 22 June 1999.

The FDM defines flood zones into three categories, namely, "floodways", "flood storage" and "flood fringe". Floodways are areas with significant flow paths that should be kept free of obstructions, else upstream flood levels may increase. Flood storage areas hold significant volumes of water during floods and should not be filled (for development) else downstream flood discharges may increase. Flood fringe areas are inundated but pass no significant amounts of flood and hold no significant storage. These areas can be developed and filled without adversely affecting flooding.

The FDM also categorises flood liable areas into two hazard categories, namely, "high hazard" and "low hazard". These are assessed on the basis of flow depth, flow velocity and access or evacuation opportunities. Flood hazard ratings were assessed in accordance with *Figure 7, Appendix B* of the Floodplain Development Manual. In the case of Gunnedah, a flood warning and evacuation procedure is in place, therefore, the areas at the transition between the high hazard and low hazard categories may be downgraded to low hazard. While flood warning and evacuation procedures are also in place, almost the entire village of Carroll is subject to deep flooding, and may become isolated in all but the lowest of floods. This is a potentially dangerous situation so the hazard rating has not been downgraded from high.

There are no significant flood storage areas in Gunnedah or Carroll, so there are only four flood categories, namely:

- low hazard floodway;
- low hazard flood fringe;
- high hazard floodway; and
- high hazard flood fringe.

The flood hazard boundaries were determined using the MIKE 11 cross sections and results in conjunction with the digital terrain model developed in MapInfo, and a computer program developed by SMEC. The program used the MIKE 11 results as input and computed velocities and velocity depth products at regular grid points. The final maps were prepared using MapInfo.

6 FLOOD DAMAGES – SOCIAL IMPACT

6.1 SOCIAL COSTS

The social damage caused by a flood cannot be overestimated. It includes the increased levels of psychological and physiological stress imposed on flood-affected people. While loss of life is the most extreme social cost of flooding, there are also a number of lesser social costs. The term "intangible", which is associated with social costs, reflects the difficulty in measuring social costs rather than their relative significance.

During the Brisbane floods of 1974, a number of residents reported feelings of "adventure" and "excitement" as they attempted to cope with the situation and evacuate their possessions. In the weeks immediately following the flood, however, these feelings tended to be replaced by feelings of depression and insecurity as people faced up to the realities, difficulties, financial costs and general inconvenience of repairing, replacing or discarding flood damaged items. Increased levels of marital stress were also reported in a number of cases (Cameron, McNamara & Partners, 1977).

A major flood causes a great deal of havoc to people's lives and even if there is no loss of life, the lesser social "costs" are a very real consequence of flooding. Property owners and residents affected by flooding often report a feeling of intrusion and future dread of an event over which they have no control. Social costs include the heartache and hurt associated with the loss of family photos, family heirlooms and other damaged items whose value lies with emotional attachment more than financial value. These items are often described as priceless because they can not be adequately replaced. As a result the feeling of loss felt by those affected by flooding often exceeds the monetary value that can be attributed to flooding. In some instances the accumulated flood damage to the business community may be modest, but included in that may be sufficient loss to close a number of marginal businesses. In this case the social cost far outweighs the financial cost.

Interviews with local residents and business operators indicate that the 1998 floods in Gunnedah had a serious social impact. This was mainly due to the duration of flooding experienced, rather than the flood levels, which were relatively low.

6.2 SOCIAL IMPACT FINDINGS

A total of 72 residents were surveyed. Of these participants, 27% resided in Carroll and 73% in Gunnedah. Various questions were asked in the survey which covered issues such as flood history, extent of flooding, flood warning and education received, emotions felt during floods and major impacts of flood.

6.2.1 Extent of Flooding

A large majority of respondents, 47 (67%), said their properties were affected by flooding. Of these, 30% were in Carroll and 70% were in Gunnedah. Based on the number of properties which were affected by flooding, the streets which seemed to be most affected were Breeza

Street (6 surveyed properties affected), Maitland St (4), and Tempest St (3). Streets where people commonly said their properties had not been affected by flooding were Barber Street (4), and Little Barber Street (3).

The vast majority of those surveyed (85.7%) had experienced at least one flood and 44% had experienced more than five floods, largely due to the recent passing of the 1998 set of floods. Several residents were even able to remember the flood of 1955.

6.2.2 Flood Impacts

The main forms of flood damage for residences, was damage to gardens, equipment, floor coverings and building structure. Of those residents whose properties had been affected by flooding, 27% suffered inundation of water in their home.

Out of those properties affected by flooding, 36% (17) were forced to evacuate their premises. Approximately half of these respondents said they were unable to carry on normal activities during the evacuation period. Also of those whose properties were affected by flooding, 44.6% said it took a month or longer to complete the clean up, and 21% said it took six months. At the time this survey was taken (December 1998), some respondents still did not have their property returned to the state it was before the 1998 floods. The majority of respondents who were evacuated (58.8%) stayed with their families during the evacuation period. Only 23.5% of evacuees used the accommodation provided for evacuees.

During the flood, the most common emotions felt were distress, worry and panic. A majority of respondents (57%) were able to identify some of the greatest impacts of flooding on their lifestyle. Of these respondents, 20% said the greatest impact of flooding was isolation. A further 15% said the greatest impact was that they missed work. Other impacts which more than one respondent identified were: missed school (8%), health (8%), and property damage (5%). Exactly half the total number of respondents identified a second impact of flooding on their lifestyle. Of these, missing work (17%); property damage (17%); missing school (11%); and isolation (6%) were identified as the second greatest impacts on lifestyle.

Nine people provided suggestion regarding how impacts of floods could be minimised in the future, these included:

- being provided with more warning;
- being provided with better information on preparation for floods; and
- practicing better management of dams.

6.2.3 Emotion

Table 6.1 below lists the emotions felt during and after flooding, as conveyed by the people surveyed. These emotions have been categorised as having low, moderate or high negative impact of people. There is also a category for other emotions that people conveyed that would not be defined as having negative emotional impact.

Table 6.1 Emotions Felt During and After Flooding

Category	Emotions A	Emotions B	Emotions C	Emotions D
Level of Negative Emotional Impact	Low	Moderate	High	Other
No. of People Expressing These Emotions	23	26	41	20
Emotions Conveyed	Nuisance (3)	Sadness (4)	Fear (8)	Patience(1)
	Bored (3)	Worry (11)	Collapsed with Hypothermia (1)	Acceptance (1)
	Felt Sorry for Others (1)	Tense (1)	Scared(1)	Confident(1)
	Concerned (1)	Lonely (1)	Distress (16)	Calm (8)
	Not Sure What to Expect (2)	Wanted to Help Terrified Stock (1)	Angry (2)	Interesting, Kids Excited (1)
	Frustrated (5)	Stress (1)	Panic (10)	Happy(1)
	Used to it (1)	"Down and Out" (1)	Depressed (2)	Fine (5)
	Worried about water pump (1)	Sick (2)	Claustrophobic(1)	Excitement (2)
	Don't know(1)	Shock (2)		
	Wanted to Help People(1)	Disgust (1)		
	Inconvenience	Anxiety (1)		
	(2)			
	Disappointing(1)			
	Wonder how much higher(1)			

Note: The categorisation of information above is an interpretation made after talking to local residents and various authorities.

Out of the 72 people surveyed, 22 people did not give any response to the questions regarding emotions felt. 37% of emotions felt could be classified as having a high negative emotional impact, while 24% where of a moderate impact and 20% of a low impact.

Emotions conveyed that were of a high impact included: fear, panic, distress, scared, angry, as well as medical conditions such as depression, claustrophobia and hypothermia. The other impacts of the floods on the people experiencing these emotions was correlated with other survey results to attempt to find any particular impacts that may have cause this high negative emotional impact.

It was found that the people experiencing high negative emotional impact reported the major impacts of flooding to be isolation, property damage and missing work or school. 40% of people these people reported that isolation was a major impact, 78% reported that property damage was a major impact and 36% reported that missing work or school was a major impact. Other major impacts reported were lack of food and supplies, hard work to clean up, fear of looting, evacuation and having to stay at other peoples place. 67% of people who were evacuated experience high levels of negative emotional impact.

Other emotions that people experienced that were not of a negative impact were also interesting. 13 people said they felt calm or fine which is surprising given the extent of the floods. It may be assume that these people were not affected but after making a correlation with the impacts experienced by these people it was found that the extent of impact ranged from none to isolation, evacuation and losing crops. This could be explained by the age of respondents and their physical ability to cope with an emergency such as a flood. 38% of people experiencing high levels of negative emotion were over 55 with the average age being 45. Amongst the 3 people that said they experienced excitement there were also various negative emotions experienced such as fear, being scared and distress.

6.2.4 Community Awareness and Education

i Amount of warning people were given about pending flood

From the people surveyed, 13.9% reported that they had at least 2 days warning before the highest flood that they had experienced arrived. The majority of people said they received 1 day warning (20.8 %) or a few hours to half a day (20.9%). The percentage of people stating that they had less than a few hours was slightly lower (16.7%) and 8.3 percent stated they received no warning. (A further 18.1 percent did not respond to the question).

ii How people were advised of flood

The radio station 2MO was reported as a good source of flood information and warning, with 40% of the people surveyed stating that they were notified via the radio. A further 18% were notified by the SES and 16% by neighbours, friends or family. Other forms of media notification were the newspaper (3%) and the TV (2%). Otherwise 8% of people reported that they were not notified or they saw the flood themselves.

iii Information received regarding advice on preparing for a flood

Out of the total of 72 people survey, only 14 respondents reported that they regularly received information about what to do in a flood. From these 14 people, 7 read the information and 7

didn't read the information. The remaining 58 people stated that they have not received any information or could not recall receiving any information.

Half of the people that reported receiving information regarding what to do in a flood, said that the information came for the SES (7), while 3 said the Council, 1 person said the Department of Land and Water Conservation, 1 person said flood relief and 4 people didn't know where the information came from.

iv Preparation made in advent of a flood

From the 72 people surveyed a total of 42 people prepared for pending floods by moving valuables to a high place, however, only 6 of these people had read any material sent to them regarding how to prepare for floods. A total of 7 people placed sandbags around their house or property and none of these people had read any preparation material.

Those who had experienced between three and five, or more than five, floods, generally gave a more detailed response to the question "what preparations would you make in the advent of a flood?" Out of these more experienced respondents, 65% chose "move valuables to a high place", while 12% of those who chose that answer had experienced less than three floods. The other common preparations were "evacuate premises" and "ensure that the house always has emergency supplies". Again, very little response was gained from those who had experienced only one or two floods. Most people who had experienced flooding also said their current property had been affected by flooding.

13 respondents reported that they evacuated their premises and 8 commented that they had secured any property affected by fast flowing waters. 15% of the people that evacuated and 13% of the people that secured property had read preparation material. Furthermore, 13 respondents stated that they ensured that their house always had emergency supplies. Of these 13 people, 15% had read preparation material.

Amongst the 7 people that had read material regarding the preparations needed in the advent of a flood there were several reports of the correct preparation not being carried out. These included 5 people not ensuring that the house always has emergency supplies, 7 people not placing sandbags around their property, 1 person not moving valuables to a high place, 6 people not securing property affected by fast flowing waters and 5 people not evacuating. These may have been people not significantly affected by flooding therefore there would be no need to undertake some of the above preparations.

Other preparations that people made that were beyond the categories suggested included: moving cattle/machinery (6); cutting off electricity (2); dropping fences (1); packing gear (2); cleaning gutters (1); calling family members (1); raising bore (1); pulling up carpet (1); and placing cars on high ground (5).

v Problems with Services

During flooding 13.9% of people had the electricity supply cut off from their homes and 2.7 % were made aware that the electricity could be cut off.

Out of the 72 people surveyed 5 people reported sewerage problems, 3 people reported water supply problems and 2 people reported that their gas supply was cut off.

6.2.5 Living in a Flood Prone Area

Residents were asked why they choose to live/ rent a property in areas affected by floods. 31.9 % of respondents didn't answer the question, however, 23.6 % of those that did said they lived in an area affected by flooding because there was affordable housing. 16.6% percent of people surveyed said they live in the area because it had always been their home, while 13.9% felt the flood effects were minor and 8.3% like to live close to the river.

38.9% of people survey gave various other responses beyond the categories suggested. Some of the other reasons people chose to live in areas affected by flooding include: it's quiet (2); inherited from parents (2); close to Gunnedah (3); were unaware of flood effects or thought they were minor (6); like the area (4); it's away from the city or they needed space (3); fertile land (4); work commitments (3); and family live in the area (2).

6.2.6 Maitland Street

Maitland Street, Gunnedah, is being examined for possible acquisition of homes on the northern side. A total of six Maitland Street residents were interviewed in social surveys. Five of the six property owners surveyed said their property had been directly affected by flooding and all were affected by the 1998 floods. All had experienced between two and five floods during their time at the property. The average time spent at that address was 18 years.

Flood impacts included damage to houses, belongings and property. Substantial damage was sustained in the area as the highest floods have knocked over walls and fences in the past. The dept of the floodwaters above the ground at fences averaged at 0.9 metres. There was reported damage to equipment, furniture, gardens, irreplaceable personal items and floors and the structure of houses. 4 out of the 6 people surveyed reported that fences were knocked over by floods.

The average age of people in Maitland Street is 59 calculated from the five people that provided their age. These people were 70, 80, 37, 65 and 42. Residents were asked what were the greatest impacts of flooding on their lifestyle and their answers included: isolation, damage to personal items, inconvenience of evacuation, fear of driving through water and hard work to clean.

The average warning given to the people of Maitland Street was 1 day, and 3 out of the 6 people surveyed reported that they were evacuated. They were advised via radio, the SES or friends and neighbours. The electricity was not cut off and no other services were reported to be affected. The people in Maitland Street seemed reasonably well prepared despite the fact that only 2 out 6 people had received any information and no one had read any information regarding flood preparations. Generally it took a few days to a week to clean up, and several months before life was "back to normal". When asked why they chose to live in a flood-affected property, answers were "has always been my home"; "own it"; "affordable"; and the general statement that they were unaware of the potential flood impact when purchasing the home.

3 out of the 6 people surveyed said that they had family, neighbours and friends helping with clean up while the other 3 had no one. One person reported life-threatening experience during flooding. Common emotions felt during flooding were distress, fear, and worry, as well as excitement and a general acceptance of flooding. Severe physical health impacts were also experienced. 50% of people surveyed in Maitland Street said that community spirit was high, however, there was a feeling that the attitude of Gunnedah people towards flood victims could be improved.

silt staining, silt is removed from the houses and irreparably damaged items are taken away for disposal. Similarly, volunteers and employees help in the clean-up operations at commercial establishments affected by the flooding.

The cost of immediate post flood clean-up operations is essentially the value of the time of those engaged in the clean-up process plus the cost of removing and dumping flood damaged materials, together with loss of business for commercial establishments.

7.3 INDIRECT DAMAGE

A flood can severely disrupt the goods and services provided by commercial establishments in the community. It may take many weeks for a community to regain their pre-flood levels of productivity. The indirect flood damages to the community includes the loss of production, revenue and wages, which occurs during the flood and the post-flood recuperative phase. Indirect damages also arise in a number of other ways. For example, the disruption and diversion of traffic, both during and immediately after a flood, represents another indirect loss.

7.4 ACTUAL AND POTENTIAL DAMAGES

Damage estimates based on the costs arising from an actual flood event are referred to as *actual* flood damages. Actual damages are often less than potential damages due to actions taken to reduce flooding after flood warnings are issued. The data available for an actual damages study are in general more reliable than those used in a potential damages study. In the actual damage situation the areas, depths and duration of flooding and the number of properties inundated can usually be estimated reliably. Financial costs are more accurate when based on damage sustained during an actual event.

For the purposes of calculating the commercial damages for the current study local property owners and business operators were interviewed, to ascertain the actual level of damage experienced in recent floods. It is noted that damages given in this report are based on actual damages.

For the residential properties, it was necessary to derive estimates of potential flood damage for a range of flood magnitudes. In addition, it was necessary to take account of community "flood awareness" and their experiences in coping with floods, that is, the higher the awareness and experience, the lower the ratio of potential damages to actual damages will be.

The data obtained from actual flood damages was extended to include potential damages incurred in larger floods. The extension was based on information obtained from interviews and from floods experienced in other centres, such as Nyngan (1990) and Ganmain (1997).

7.5 FLOOD DAMAGE ESTIMATES DERIVED IN THE PRESENT STUDY

This study estimates the flood damage likely to occur in Gunnedah for the following two major damage categories:

- the *direct financial costs* of damage to property; and
- the *indirect financial costs* associated with the disruption of social, community, industrial and commercial relationships during the post-flood period.

Direct damage estimates represent the sum of the structural, contents and clean-up cost components.

The indirect damage estimates derived in this study are calculated as a percentage of the direct damages. The estimates also include consideration of the flood warning system and the reduction in potential flood damages which may be achieved with the warning system installed and adequate emergency procedures in place. The equations used to calculate the potential damages that incorporate these factors are discussed further in *Appendix D*. The indirect damages were estimated at 20% of the direct damages, however, a reduction of 15% was allowed for the flood warning system being in place. These factors were based on a review of previous studies i.e. River Torrens (SMEC 1980), Tamworth (PPK 1993) and Ganmain (SMEC 1997) and an assessment of the conditions which existed in Gunnedah during the 1998 floods.

7.6 ESTIMATION OF FLOOD DAMAGE

A variety of factors affect the flood damage caused to a particular piece of property. In this study the following three factors have been used to predict direct, potential flood damages:

- the use to which the land is put (hereinafter referred to as land use);
- the "size" of the buildings and other improvements associated with the land use; and
- the depth of flooding.

Land in the flood-prone areas of Gunnedah and Carroll is used for a variety of purposes, such as residential, commercial, utility services and recreation. Flood damage varies with land use.

The amount of damage that occurs on a particular piece of land tends to increase with the "size" or "scale" of the operations undertaken there, other factors remaining constant. Measures of property size can include annual assessed value ($) as the measure of size for residential and recreational property and floor area (m^2) for all other types of property.

For this study damages for commercial properties were based on information obtained from extensive interviews with individual owners/operators. This information was analysed and estimates of damage for various components of each business was made e.g. stock, fittings, fixed or moveable machinery, etc and a flood level at which this damage would be sustained was assigned. All commercial properties were divided according to a business category, and by summarising the above data, an estimate of average damage made for each category based on a flood level.

During the commercial surveys, some business gave indications of reduced turnover and/or number of days during which their business were closed as a result of flooding. However, analysis of this data to determine an average reduction /loss in turnover which could then be applied to damages estimates proved to be difficult, due to:

(a) only a minimal amount of data being supplied, thus and "average" figure was not meaningful; and

(b) the reduction/loss of business can not necessarily be predicted on any one indicator e.g. level of inundation or time of inundation. Some business e.g. a nursery, may be closed for a long period of time after only a low level of inundation, whereas another may continue to trade at normal levels as orders are received by phone and stock is effectively unaffected by inundation, requiring only a wash down.

The damage estimates applicable to residential properties were based on published data relating to flood damage and the nature of the individual property. During the study a survey was carried out where vital information was obtained for each residential property to assist in assessing potential flood damages. Information obtained included type of construction, age, size and height above ground. This allowed a stage damage curve to be individually assigned to each residential property. For the purposes of the study four curves were used for residential properties relating to different levels of potential flood damage.

7.7 AVERAGE ANNUAL POTENTIAL DAMAGES

In order to compute the Average Annual Potential Damage (AAD), taking account of the annualised cost contribution from the full range of possible floods, it was necessary to plot the damages for each flood return period against the probability of its occurrence and evaluate the area under the curve.

Flood damages for existing conditions in Gunnedah and Carroll to residential properties are given in Table 7.1, and damages to commercial properties are given in Table 7.2. Average annual damages for the variety of flood events are illustrated as graphs at *Appendix D*.

Table 7.1 Flood Damages – Existing - Residential

Event	Damage ($)	Number of Houses Affected
10% AEP flood	689,488	77
5% AEP flood	1,225,609	127
1% AEP flood	3,256,385	277
3 x 1% AEP flood	8,249,733	476
Average Annual Damage	220,634	

Note: For calculation of AAD the 3 x 1% flood was assumed to have an ARI of 700 years.

Table 7.2 Flood Damages – Existing – Commercial

Event	Damage ($)	Number of Properties Affected
10% AEP flood	1,143,000	10
5% AEP flood	3,605,480	27
1% AEP flood	15,268,467	47
3 x 1% AEP flood	74,189,252	149
Average Annual Damage	818,026	

Note: For calculation of AAD the 3 x 1% flood was assumed to have an ARI of 700 years.

These figures provide a basis for the Cost Benefit Analysis set out in section 9.2 below.

8 FLOODPLAIN MANAGEMENT MEASURES

There are three types of flood risk that affect flood prone areas:

- the **existing risk** faced by existing developments on flood prone land;
- the **future risk**, which any new development will face; and
- the **continuing risk** that remains after flood mitigation action has been completed.

A balanced floodplain management plan must address all three types of risk. However, different management measures may be appropriate for each of the three problems.

There are generally three recognised categories of floodplain management activities that may reduce losses associated with flooding:

- by modifying the behaviour of the flood itself (Flood Modification);
- by modifying (e.g. house raising) or purchasing existing properties and/or by imposing controls on property and infrastructure development (Property Modification); and
- by modifying the response of the population at risk to better cope with a flood event (Response Modification).

The first two modification activities were previously referred to as "Structural Measures" and "Non-structural Measures" respectively. The inclusion of response modification measures such as flood preparedness and response planning in the overall floodplain management plan is a new, if warranted, concept as floodplain management measures should address the situation as a whole, not as individual measures.

Flood modification measures are a common and proven means of reducing damage to existing properties at risk. Property modification measures are essential if the growth in future flood damage is to be contained. Response modification measures are the most effective means of dealing with the continuing flood risk, the risk that remains after other measures are in place.

This approach, that management measures should not be considered either individually or in isolation, is a fundamental principle of sound floodplain management. Measures should be considered collectively so that their interactions, their suitability and effectiveness, and their social, ecological, environmental and economic impacts can be assessed on a broad basis.

All three "risk modification" categories are considered in the development of the Gunnedah and Carroll Floodplain Management Plan. To be successful, the Plan must incorporate measures from all three categories and adopt an integrated and effective mix that is appropriate to the specific circumstances of the flood prone community of Gunnedah and Carroll.

This Chapter provides an overview of the measures that may be utilised. The following Chapter 9 provides a detailed assessment of their application to Gunnedah and Carroll.

8.1 FLOOD MODIFICATION MEASURES

The purpose of flood modification measures is to modify the behaviour of a flood by reducing flood levels or velocities or by excluding floodwaters from areas at risk. Flood modification

measures, by their structural nature, may have environmental and ecological impacts (positive or negative) and so any proposal for such works must be subject to strict and detailed assessment in accordance with the existing planning and environmental assessment legislation.

8.1.1 Flood Mitigation Dams

Flood mitigation dams reduce downstream peak flood discharges. As the flood wave passes through the dam, the dam is progressively filled to the point of overflow, trapping a portion of the floodwaters. The full dam then provides temporary storage for floodwaters subsequently passing through it as the storage level rises above the spillway level.

The mitigating effects of a large dam on a major flood may be surprisingly small for the following reasons:

- the volume of water in a major flood may be much greater than the storage capacity of even a large dam;
- the dam may be nearly full at the start of a flood; and/or
- floods may result from rainfall in parts of the catchment that are not commanded by dams.

Consequently the benefits of flood mitigation dams are generally limited to mitigating the effects of a flood generated in only one portion of the catchment.

For flood mitigation dams to be effective, it is essential that adequate air space be retained to store water when a flood occurs. While compromises are possible, this generally limits and possibly precludes their use for other purposes, such as town water supply or irrigation.

Gunnedah and Carroll are in close proximity (downstream) of Keepit Dam, a major water supply storage on the Namoi River. Keepit Dam has no flood mitigation air space and is generally operated to ensure the safety of the structure and ensuring the maximum water storage after the passage of the flood. Consistent with these objectives, DLWC is understood to currently operate the dam to mitigate the impacts of flooding.

It is understood that there are no fixed rules to this operation with each flood being treated on its merits. The operational policy is generally subject to the prevailing circumstances. It is also understood that the Department of Land and Water Conservation (DLWC) makes every effort to manage outflows during floods so that the impact downstream is minimised. Based on discussions with DLWC staff, this management approach has two main objectives; to ensure that outflow does not exceed inflow and to pre-release or manage outflows to attempt to avoid the co-incidence of peak flows from the Namoi and/or Peel Rivers. The DLWC also communicates its activities to the State Emergency Service (SES) so that the latter is aware of releases from Keepit Dam and suitable warnings can be issued. It is understood that DLWC can predict such releases up to approximately eight hours before actual release.

There are very few if any suitable sites for flood mitigation storages upstream of Carroll and Gunnedah and it is considered that any such storage, without a complementary water supply purpose, is not economically feasible. Environmental considerations may also preclude the construction of another storage.

The establishment of protocols for advising the SES of releases from Keepit Dam is a further issue for consideration and is discussed in below.

8.1.2 Retarding Basins

A retarding basin is a small dam that provides temporary storage for floodwaters. It behaves in the same way as a flood mitigation dam, but on a much smaller scale. In urban areas, retarding basins are most suitable for small streams that respond quickly to rapidly rising flooding.

Retarding basins have a number of inherent disadvantages that should be carefully evaluated for each particular situation, for example:

- they require a substantial area to achieve the necessary storage;
- where they involve multi-purpose uses, safety aspects during flooding need to be addressed;
- long duration or multi-peak storms (when the basin is filled from a previous peak) can increase the risk of overtopping or breaching and the resulting hazard and damage; and
- they provide little attenuating effect when overtopping occurs.

As the flooding that affects Carroll and Gunnedah is from river sources, retarding basins are not a viable flood modification measure within the context of this study and floodplain management plan. Retarding basins may have some use in the developing areas of Gunnedah however that is outside the scope of this study.

8.1.3 Levees

Levees are frequently the most economically attractive measure to protect existing development in flood prone areas. The height or crest level of a levee is determined by a variety of factors including:

- the economics of the situation (including the nature of development requiring protection);
- the physical limitations of the site; and
- the level to which floods can rise relative to the ground levels in the area (important in safety considerations).

A levee may rarely be called upon to achieve its design requirements. If it fails at this time because of poor design, improper construction or poor maintenance, the money spent on its construction has largely been wasted and the flood damages that had been "saved" were, in all probability, significantly increased. Even if design, construction and maintenance is exemplary, all levees will ultimately be overtopped by an 'overwhelming' flood (unless designed for the extreme flood event). It is not a question of if overtopping will occur, but of when and what the consequences will be.

In using levees for flood mitigation, the following precautions need to be noted:

- the likelihood and consequences of catastrophic damage and unacceptable hazard levels when the levee is overtopped;

- appropriate design of the levee and provision of spillways to avoid uncontrolled high velocity flows or even failure when the levee is overtopped;
- proper maintenance of the levee crest level, grass cover and spillways, and the avoidance of damage from traffic or animals;
- development control measures for protected development behind the levee;
- provision for local runoff from behind the levee into the main stream;
- emergency response plans for levee overtopping and evacuation;
- analysis of flow conditions that may develop when overtopping occurs and the flood continues to rise. In some situations high hazard conditions can develop in protected areas;
- on-going community education to ensure that the population is aware of the risk of overtopping, is informed about emergency response plans and does not suffer a false sense of security simply because a levee has been constructed; and
- levees may prevent the flow of water to valuable ecological areas, such as wetlands. The consequences of this need to be considered especially for threatened species and the ecological community as a whole.

Some of the foregoing precautions do not apply when the probable maximum flood is adopted as the design event for levees. In such cases, important factors to consider include the maintenance of the levee and the provision of adequate freeboard against wave action and subsidence.

There are possibilities for levees to protect both Gunnedah and Carroll. Preliminary alignments are shown on *Drawings 31923-009* and *31923-010*.

Option 1 at Gunnedah would start at the high ground near the saleyards, follow Bloomfield Street to the corner of Tempest Street, then travel to the corner of Maitland and Chandos Streets and follow the Maitland Street road reserve to high ground at Boundary Road. This levee would be approximately 3.1 km in length and could be designed for either a 1% AEP event or a 5% AEP event. To accommodate the 1% AEP event it would need to be up to 3m high in parts.

An alternative levee would start at the high ground near the saleyards, travel north to Maitland Street and follow Maitland Street to the high ground at Boundary Road. This would allow better use of Crown land, but would be approximately 3.5 km in length and require a structure generally 2.5-3.0 m in height to accommodate the 1% AEP flood.

Carroll has the potential for a ring levee running along the route comprising: the lane between Ella and Gunnedah Streets, Howe Street, Phillip Street, Forbes Street, James Street, Bright Street and North Street. Such a levee could accommodate a 1% AEP event and would be approximately 3 km in length.

8.1.4 Bypass Floodways

Bypass floodways redirect a portion of the floodwaters away from areas at risk, and may reduce flood levels on the floodplain by increasing the capacity for in-channel flows. However, bypass floodways may exacerbate downstream flood problems and their construction is likely to have significant environmental impacts both at the site and downstream.

For example, the construction of a bypass floodway would require the total loss of existing vegetation, including mature trees, and there would be increased siltation of the river system until the bypass was stabilised, probably requiring rapid growth exotic grasses and trees. This impact would be spread over a significant distance and would require control over the land to be vested in Council. Because of its intended purpose to carry floodwaters efficiently, the land would effectively be sterilised for future agricultural development.

Because of the topography of the area, economic, environmental and ecological considerations and the limited availability of land, the construction of bypass floodways at either Carroll or Gunnedah is not a recommended floodplain management option.

8.1.5 Channel Improvements

The capacity of a river channel to discharge floodwater can be increased by widening, deepening or re-aligning the channel, and by clearing the channel banks and bed of obstructions to flow. The effectiveness of channel improvement depends upon the characteristics of the river channel and the river valley.

As a mitigation measure, channel improvements have several potential disadvantages. First, like bypass floodways, they facilitate the transfer of floodwaters downstream and can accentuate downstream flooding problems. Other disadvantages include the cost of maintenance, the destruction of riverine habitat and the visual impact of replacing naturally varying channel sections with a section of more uniform geometry.

Channel improvements are likely to be most effective (including reducing the need for other structural works) on steeper smaller streams with overgrown banks and narrow floodplains. Channel improvements would have a minimal effect in flooding situations where there are extensive areas of over-bank flooding, such as at Carroll and Gunnedah. Accordingly, these measures are not recommended as part of the Floodplain Management Plan.

8.1.6 Velocity Retarding

In open floodplains, such as that at Carroll and Gunnedah, there may be benefits to affected properties by reducing velocities through built-up areas. Such retarding agents could be of two forms, low earth mounds or vegetation. Road reserves and riverine corridors would appear to be the most appropriate sites for such measures.

Flow velocity is not a significant issue in the flood affected developed areas of Gunnedah; the main issue there is the depth of flooding. The area covered by this study to receive the greatest benefit from velocity retarding is Carroll, principally because the entire village area is affected by flooding. Earth based deflectors, if not carefully sited and maintained, may lead to adverse flood impacts on adjoining properties and when overflowing, may result in increased localised velocities.

The use of suitable native vegetation as a velocity retarding agent would have a number of benefits besides reducing velocities, particularly in floods where the depth of water is not great. The visual amenity of the streetscape would be improved through the introduction of a broad range of native vegetation, the native fauna would be encouraged to return and have suitable corridors for movement and there would be increased shade for residents and visitors.

The removal of exotic species and replacement with indigenous flora along the riverine corridor adjacent to the towns may also provide some broader environmental benefits.

8.2 PROPERTY MODIFICATION MEASURES

8.2.1 General

Property Modification Measures refer to modifications to existing development and/or development controls on property and community infrastructure for future development. These measures are aimed at shepherding inappropriate development away from high risk areas, and ensuring that potential damage to developments at risk is limited to acceptable levels by means of minimum floor levels, flood proofing requirements, etc. Appropriate land use control measures are an essential part of a floodplain management plan and are essential if the rate of growth of future flood damage is to be limited.

8.2.2 Zoning

The NSW Flood Prone Land Policy does not support the use of zoning to unjustifiably restrict development simply because land is flood prone. The division of flood prone land into appropriate land-use zones is therefore an effective and long-term means of limiting flood damage to future developments. Moreover, any flood-related zonings should be incorporated in a local environmental plan or development control plan in conjunction with the floodplain management plan.

Zones over flood prone land should be based on an objective assessment of hazard, environmental and other factors, for example:

- the objectives of the Floodplain Management Plan;
- whether the land is in the high hazard or floodway category;
- potential for future development to have an adverse impact on flood behaviour at existing developments, particularly the cumulative effects of on-going development;
- whether or not adequate access is available during floods;
- whether certain activities should be excluded because of additional or special risk to their users, e.g. accommodation for aged people, hospitals and the like;
- existing planning controls; and
- the requirement under Sections 26 and 27 of the *Environmental Planning and Assessment Act, 1979,* for a public authority to own land which is reserved for a public purpose.

The main opportunity for zoning changes in Gunnedah to better reflect flood risk relate to better definition and protection of floodways and consideration of changing the Business 3(b) zone in Conadilly Street to lessen the risk of increasing flood damages to commercial development.

8.2.3 Building and Development Controls

Building and development controls are the appropriate means of implementing detailed aspects of Council's Floodplain Management Plan, particularly when addressing the future flood hazard.

In this preliminary assessment of building and development controls, the following considerations were addressed:

- land use;
- access to and from the site during flood events;
- any fill or excavation in the floodplain;
- flow of floodwaters across the site;
- freeboard;
- floor levels;
- structural soundness when flooded;
- fencing;
- building materials;
- the impact of the development on other users of the floodplain;
- the impact of floods on services such as power, potable water, sewerage and drainage;
- the impact of floods on some activities such as fuel storage or galvanizing workshops;
- cumulative impact of similar development;
- need to, as far as practicable, maintain flooding regimes necessary to maintain riverine and floodplain species and ecological communities; and
- flood awareness.

Development Control Plans prepared under Section 72 of the *Environmental Planning and Assessment Act, 1979* may appropriately implement such land use and general development controls.

8.2.4 Potential Controls over Development for Carroll and Gunnedah

The primary planning instrument currently governing development in flood prone land in Gunnedah is Council's Interim Policy on Flood Prone Land (reviewed 19.6.91), supported by enabling provisions in the Gunnedah LEP 1998. It would appear that the Interim Policy does not apply to Carroll.

This Study recommends that the Interim Policy be replaced by a Flood Prone Land DCP.

The Interim Policy is currently limited in the 'tools' used to manage development on flood prone land, with reliance on building restrictions, floor levels and general construction requirements. We would recommend the implementation of a more sophisticated development control regime through a Flood Prone Land DCP and update to LEP 1998, dealing with the following issues:

- a zoning relationship between land uses and location within the Outer Floodplain, Flood Fringe and Floodway;
- floor level controls;

- building components and materials;
- structural soundness of buildings;
- flood effect of works;
- evacuation and access;
- flood awareness (including restrictions on title and use of s.149 certificates); and
- building management and design (especially for commercial activities).

The matters that a DCP should address are set out in points i – viii below.

i Zoning Relationship Between Land Uses and Flood Classification

The DCP should provide for an identification of land uses and building types that should be restricted in certain flood category areas. For some types of land use the type of restrictions that should apply are clear. For example, essential community facilities and critical utilities should not be permitted in 1% AEP affected areas except possibly above the level of the extreme flood event. The rules that should apply to other land uses require more detailed consideration. For example, Council's current Interim Policy prohibits any development within a floodway. This may be achievable for Gunnedah where only a small proportion of the town is within the floodway (refer to Gunnedah 1% AEP Hazard map). Carroll, however, presents greater difficulty with virtually all of the town within the High Hazard Floodway. In Carroll it may be desirable to replace the floodway development prohibition with a series of other development control measures, enhanced community education and flood modification response measures. The DCP therefore needs to be tailored to the circumstances of each location.

ii Floor Level Controls

The DCP should provide for a variation in floor levels across different development types. Generally speaking, it is recommended that habitable areas of residential development be built with 500mm freeboard above the 1% AEP flood. Floor levels for commercial development need greater flexibility to respond to streetscape and access considerations.

iii Building Components and Materials

A schedule of flood compatible building materials can be found at *Appendix E*. The DCP should provide for these to be used below the 1% AEP flood level plus 500 mm (freeboard) or below the extreme flood level where there is no minimum floor level (e.g. commercial properties).

iv Structural Soundness of Buildings

This includes requirements for engineers' certification or applicants' demonstration of the structural soundness of proposed buildings.

38.9% of people surveyed gave various other responses beyond the categories suggested. Some of the other reasons people chose to live in areas affected by flooding included:

- it's quiet (2);
- inherited from parents (2);
- close to Gunnedah (3);
- were unaware of flood effects or thought they were minor (6);
- like the area (4);
- it's away from the city or they needed space (3);
- fertile land (4);
- work commitments (3); and
- family live in the area (2).

ii Carroll

Carroll is largely classified as a high hazard floodway, however the purchase of the entire village would not be viable, socially and/or economically. Other flood modification or property modification measures are considered more suitable and are discussed in other sections.

iii Gunnedah

The most flood prone area in Gunnedah may benefit from a voluntary purchase program. Twelve (12) properties on the northern side of Maitland Street between Elgin and Marquis Streets and the two properties on the north-west side of the intersection between Tempest and Bloomfield Streets, shown on drawing 31923-009 have been identified for possible voluntary purchase. These properties are in the highest hazard category and are also those exposed to the most regular flooding. There are also eleven (11) properties in the "rural-residential" area generally north-east of Maitland and Henry Streets that are in the high hazard zone and may be considered for voluntary purchase.

There are a number of other properties also in the high hazard floodway in Little Conadilly Street. In this location the high hazard category derives primarily from water depth rather than velocity and house raising may be a more appropriate response.

It is estimated that the cost to purchase the fourteen identified properties in the town area would be $980,000, assuming an average value of $70,000. The eleven "rural-residential" properties may cost more due to their larger land area, however, the same average price is used to estimate the cost should voluntary purchase be pursued in this area. It is estimated that the "rural-residential" properties would cost $770,000 to purchase.

Details of the properties identified for voluntary purchase are in *Appendix F*.

8.2.6 House Raising

i General

House raising has long been a traditional response to flood risk in New South Wales, as demonstrated by the number of raised houses in frequently flooded urban areas such as Lismore and Fairfield.

Avoidance of flood damage by house raising achieves three important objectives:

- a reduction in personal loss;
- a reduction in risk to life and limb and in the costs of servicing isolated people who remain in their homes to protect possessions; and
- a reduction in stress and post-flood trauma.

Not all houses are suitable for raising. Houses of single or double brick construction or slab-on-ground construction are generally either impossible or very expensive to raise, however, the decision on this latter issue is very site specific. The principal issues to be addressed with such houses are the quality of the foundations and the state of the brickwork. Houses best suited to raising are timber-framed and clad with non-masonry materials.

While raising a house may achieve the objectives described previously, care must be exercised in implementing this measure by considering the implications of a slightly higher than design flood. The new construction may be isolated for long periods during floods, necessitating an increased load on emergency services should they be required. The isolated house would also have to be capable of "self support during flooding", e.g. adequate food supplies. Thus it is essential that both the benefits and dis-benefits of house raising are considered in the floodplain management planning process and any subsequent community education campaign.

House raising is considered a viable floodplain management measure for Carroll and for extensive areas of Gunnedah, generally within the high hazard fringe area.

ii Carroll

In Carroll, there are 79 houses that could be subject to house raising. Of these, 69 houses are less than 2.0m above ground level and thus at the greatest exposure to flood damage and only three (3) are brick walled and difficult to raise. Based on the average cost of house raising in Fairfield ($40,000), the comprehensive implementation of this measure in Carroll would cost up to $2.76M for houses less than 2.0m above ground level. An additional $0.18M should be allowed for raising those that are brick walled.

iii Gunnedah

In Gunnedah, there are 115 houses in the identified area that are less than 1.5m above ground level and thus at the greatest exposure to flood damage. Of these houses, six (6) are brick or stone walled and would be very difficult to raise. Based on the average cost of house raising in Fairfield ($40,000), the comprehensive implementation of this measure for those 109

properties most at risk would cost up to $4.36M. An additional $0.36M should be allowed for raising those that are brick or stone walled. There are also 37 properties in the proposed house raising area that are already raised more than 2.0 m above the ground and further raising may either be not viable or they would be unsuitable for raising from their existing support structures.

Details of the houses involved are in *Appendix G.*

8.2.7 Flood Proofing of Buildings

Flood proofing refers to the design and construction of buildings with appropriate water resistant materials such that flood damage to the building itself (structural damage) and possibly its contents is minimised should the building be inundated.

At best, flood proofing is an adjunct to other management measures. Whilst flood proofing can minimise structural and possibly content damages to flood-affected buildings, the occupiers of flood-affected buildings still suffer the social and economic disruption of flooding.

To prevent or minimise structural damage from flooding, developments should be designed to withstand inundation, debris and buoyancy forces. Particular methods of construction and certain types of materials are better able to withstand inundation. For example, plasterboard and chipboard, both materials commonly used for the internal wall linings and cupboard fittings of a house, can be badly damaged on inundation and may have to be replaced. In contrast, double brick construction can withstand inundation and may only require a hose and scrub down when the flood subsides. In commercial buildings the adopted floor level is also affected by economic and commercial risk-taking considerations.

A flood proofing code or an enhancement of the planning matrix may be a viable option for the CBD of Gunnedah, particularly for the commercial development. This would need to be developed in consultation with the commercial operators and could include building requirements such as use of toughened glass, sealable door frames and other higher order construction methods.

The Flood Prone Land DCP could provide a basis for the flood-proofing of new commercial buildings. With regard to existing commercial buildings, it may be necessary for the Floodplain Management Committee to include in any community education campaign, information regarding flood-proofing.

8.2.8 Flood Access

i General

Flood access can be partly dealt with as a building or development control. However, it also needs to be addressed on a broader scale than the layout of new sub-divisions. In the situation in Carroll and Gunnedah, in which complete isolation of residences during a flood is not

unusual, and alternative routes are generally not available, the question of access routes for evacuation and/or emergency use is a special concern.

Two specific access issues were identified in the preliminary listing of floodplain management options; access to and from Carroll and access to Gunnedah airport. The main method of providing the access was road raising and detailed modelling of the impacts of both proposals would have been required. However, the Floodplain Management Committee determined that these options should not be investigated in detail due to the very extensive nature of work that would be required.

Access during flood events is not only by roads. The Floodplain Management Plan must reflect the requirements of the Local Flood Plan so that areas where boats can be launched or berthed in quiet floodwaters and where helicopters can safely land are known and incorporated in both Plans (and the LEP). The Plans also need to establish what rail services are likely to be available, or unavailable in flood time.

Access to critical facilities and the impact of flooding on critical facilities can also be a matter of concern. Facilities such as water and sewerage treatment plants, communications centres (telephone) and electricity and gas distribution centres require special consideration in the floodplain management plan. Other essential facilities include Police, Ambulance and Fire Services and SES offices.

ii Carroll

Access to and from Carroll is a major floodplain management issue, especially if evacuation is required. Without major road reconstructions at Tommy's Swamp and Hoss' Causeway, road access to Carroll will be cut for the 10% AEP and greater floods. The flood warning system and the Local Flood Plan (see below) must have specific rules relating to access and evacuation responses for Carroll. These rules would have to relate to decision heights to evacuate or not, depending on the predicted flood heights and the time of cutting of the road.

In the situation that faces Carroll, where the whole village is affected by flooding to significant depths, there needs to be provision for emergency evacuation. The most appropriate location for emergency helicopter access is the relatively high ground at the corner of Phillip and Stephen Streets. However, this site, and any other site in Carroll, would be restricted to light aircraft with subsequent increases in evacuation time.

iii Gunnedah

In Gunnedah, access to the town is cut from both Boggabri and Tamworth by flows over the Oxley Highway. There remains, however, both road and rail access to the south through Breeza. Any resident evacuated can be accommodated in the town itself and helicopter evacuation would only be required for out-lying properties. Access to the airport is progressively more difficult as flood levels rise on the northern floodplain, particularly at Pig Hole until access is no longer an issue when the landing strip is inundated. Air access is then limited to the emergency strip south of the town.

The main infrastructure issues are the protection of the Sewerage Treatment Plant (STP) and the location of the Police and SES offices. The STP is currently protected to a flood height just

above the estimated 1% AEP flood and there would be overtopping of the protective measures in a greater flood. The ability to shut down this critical facility by physical presence at the site or by remote control is an issue that needs to be addressed by Council. Increasing the protection level to the STP would be warranted to protect against a flood greater than the 1% AEP event.

Both the present SES and Police offices will be affected by a 1% AEP flood or higher. If the facilities are to remain where they currently are, there is a need to flood proof these structures and the communications equipment therein. It would be more prudent, however, to either relocate the offices to flood free locations or to have alternative locations to which SES and Police could relocate during a flood.

8.3 RESPONSE MODIFICATION MEASURES

8.3.1 General

Flood response measures encompass various means of modifying the response of the population to the flood threat. Such measures include flood warning, plans for the defence and evacuation of an area, for the relief of evacuees and for the recovery of the area once the flood subsides. Planning for these measures is incorporated in the local Flood Plan for the area, which is prepared under the auspices of the SES and is complementary to the Council floodplain management plan.

The importance of flood preparedness and response measures has become apparent in recent years, and was recently confirmed by the Nyngan experience. Unless the probable maximum flood is adopted as the design flood, all flood and property modification measures will ultimately be overwhelmed at some time by a flood event larger than that designed for. The development and implementation of effective flood response plans are a means of reducing the damage associated with this risk.

Response measures, such as flood warning and evacuation procedures, can be of substantial benefit in their own right. Flood warning and evacuation plans can be very cost effective. In fact, they may, in some cases, be the only economically justified management measures.

8.3.2 Flood Prediction and Warning

The purpose of flood warning is to enable and persuade the community to take the appropriate actions to increase safety and reduce the damages associated with flooding. When properly developed and communicated, accurate and timely flood warnings are one of the most effective tools in the management of flooding, the reduction of damage and the maintenance of safety of the community.

A Total Flood Warning System, as described in "Flood Warning: An Australian Guide" comprises the following stages:

- prediction of flood severity and time of onset of particular levels of flooding;
- interpretation of the prediction to determine flood impacts on the community;

- construction of warning messages describing what is happening, the expected impact and what action should be taken;
- the dissemination of such messages;
- response to the warnings by the agencies involved and the community; and
- review of the warning system after flood events.

These components, as they apply to Gunnedah and Carroll, are discussed below and recommended actions within the Floodplain Management Plan are highlighted.

i Prediction of flood severity and time of onset

Flood prediction is concerned with establishing in advance the vertical extent or level of expected flooding. The Bureau of Meteorology (BoM) has a system of weather data collection that allows flood levels to be predicted after the rain has fallen. For this activity to be effective f or Carroll and Gunnedah, the BoM depends on a series of rain gauges throughout the Namoi Valley and a series of stream gauges operated by the Department of Land and Water Conservation (DLWC).

Within the area of concern, the BoM issues flood warnings for Carroll Gap, Breeza, Keepit Dam and Gunnedah. No predictions are made for Carroll.

The flooding in 1998 (the first floods of consequence since 1984) revealed a number of shortfalls in the prediction service, particularly the need to account for local area run-off within the Mooki River catchment. There are no real-time rain gauges covering the lower Mooki catchment and only a limited number in the upper catchment. The present coverage is inadequate to address local area run-off and additional rain gauges are required if the prediction service is to be more effective.

The majority of the stream gauges serving Carroll and Gunnedah are modern, telemetered gauges and there is ready access to these gauges during flood events. There are two exceptions that do require addressing; an existing telemetered gauge on the Mooki River at "Ruvigne", between Gunnedah and Breeza, and the SES gauge at Carroll.

The issue at "Ruvigne" relates to electronic access, currently limited due to the method of connection. For regular and emergency uses, the telephonic connection needs to be by ground-line, rather than the present "on/off" system; the latter is not always on when required and accordingly, significant local flood inflows are not accounted for in the prediction process. The Carroll gauge, currently a series of height plates, provides little information on rising flood levels before a level of 6.88m is reached and requires personal monitoring by the gauge reader. This situation could become extremely hazardous in major flooding. The installation of a telemetered gauge at Carroll would limit that hazard, provide a better record of flood levels at Carroll and would assist the prediction service by providing an accurate picture of flood flows coming from the combined Namoi and Peel Rivers.

The **Recommendations** for the Prediction process are:

Rain Gauges	A minimum of two additional real-time rain gauges in the Mooki catchment area at Breeza and in the vicinity of Battery Hill. An additional rain gauge at Somerton would assist local area run-off prediction in the lower Peel River system.
Stream Gauges	The existing gauge at "Ruvigne" be connected to a landline. A telemetered gauge be installed at Carroll.

It is important to stress here that the BoM does not, and cannot, effectively work in isolation to produce flood predictions. The BoM must work in close co-ordination with the local response agency, the SES, if predictions are to be as accurate and effective as possible. Reports from the area of concern can and must be used to validate and verify predictions. This is not to say that local agencies should devote significant time and effort in duplicating the prediction process; the local agency should identify its concerns regarding a prediction and work with the predicting agency to produce the best estimate, not compete for absolute accuracy.

Flood releases from Keepit Dam are also an issue when predicting flood severity. As indicated in 2.1 above, the DLWC operates the Dam to ensure its safety and the maximum storage after the event. It is essential that protocols be established between DLWC, the SES (local and regional) and the BoM so that there is clear and unambiguous advice of release rates, times and duration. While it is appreciated that operational decisions are made within relatively short time frames, both Carroll and Gunnedah are within an immediate impact zone for flood releases. The warning and response activities must be allowed the greatest time possible to react to releases so as to ensure that adequate measures are taken to mitigate their impact over and above the flood impact being addressed.

ii Interpretation of the prediction

Even if the prediction of a flood event's level is accurate (or as accurate as could be expected), the prediction is without real value to the community if the community does not clearly understand what the prediction means. In other words, the prediction must be interpreted into plain language to describe what impacts the predicted flood level will have on the community.

To adequately interpret the meaning of a prediction, it is essential that the SES (as the flood combat agency) have adequate information on flooding and its impacts. This is known as "Flood Intelligence" and can be drawn from many sources – past flood events, flood studies and the current Floodplain Management Study.

It is understood that the SES has recently reviewed the "Flood Intelligence" for Carroll and Gunnedah in light of the 1998 experience. It may be necessary to carry out a further review of the intelligence data in light of the damages study and mapping of an extreme event in this report; i.e. the "Flood Intelligence" for Carroll and Gunnedah can be upgraded to identify individual properties from the information in this report.

It is **recommended** that the SES "Flood Intelligence" for Carroll and Gunnedah be reviewed and updated based on the flood hazard mapping produced in this study.

iii Construction of warning messages

A "warning message" converts the technical information of the prediction and its interpretation into news and advice for the community at risk. It is the critical step between flood prediction and interpretation on the one hand and protective action by the community.

The Gunnedah Flood Plan, discussed below, contains guidance on the content of an evacuation warning message but does not address more common flood warning messages.

Flood Warning: An Australian Guide provides a guide for effective message design that can be summarised as:

The message should:

- describe the flood;
- say what is happening currently, what is expected to happen and when it will occur; and
- indicate how people should act.

As Gunnedah Council is closely involved with the SES and its response to flooding, it is essential that Council also be aware of the constraints that should be placed on flood warning messages. It is also essential that Council works in co-operation with the SES in the design of the messages.

It is **Recommended** that the Flood Plan for Carroll and Gunnedah be updated to include pro-forma messages based on the checklist provided in *Flood Warning: An Australian Guide*.

iv The dissemination of messages

There are two general categories that describe message dissemination methods, general and specific. General methods are usually the "mass media", in particular the broadcast media. Specific methods provide information and warnings to particular, pre-identified individuals, groups or organisations. These two methods should be complementary, with specific warnings reinforcing the general.

In Carroll and Gunnedah, both methods are used and no significant problems have been identified in passing the message from agency to agency. The response to the messages is discussed below.

The major issue facing the communities of Carroll and Gunnedah in message dissemination is not the message content nor its interpretation, it is the ability to make the best use of the broadcast media, particularly radio and television. Both local radio, 2MO, and television are remotely networked and, in 1998, the SES had significant difficulty in arranging a break in to the networks to properly broadcast the warning messages. While the networking situation continues, there is no reason why this issue will not occur again, unless specific agreement can be reached between the SES, the Council and the broadcasters to allow emergency messages to be broadcast either across the network or specifically for the affected areas.

It is **recommended** that the SES and Gunnedah Shire Council seek a specific undertaking from the broadcast media that in the event of a flood situation at Carroll and Gunnedah, quick and effective action can be taken to organise the broadcast of warnings into the local area.

As indicated above, specific messages must be used to complement the general messages that are sent on the broadcast media. In the case of Carroll, a "flood warden" arrangement is in place so that all residents are warned on an individual basis. While this arrangement worked during the 1998 flood, it appears that there are no written arrangements in place should one or both of the "flood wardens" be absent for whatever reason when an event occurs. In addition, it appears that the Carroll warning is general for all residents. Given the flood prone nature of Carroll, this may well be appropriate. However, it is considered that those at the greatest risk should be the first targeted and a special plan be in place to organise evacuation, if required, before the road to Somerton, the only viable refuge, is cut.

In Gunnedah, as a result of the broadcast media problems described above, it was essential that a specific message was conveyed to those already identified as being at greatest risk. This was organised by the local SES and the message was successfully passed, although it did require a labour intensive, house to house procedure. Again, the response was not always what was generally considered appropriate. Consideration should be given to the installation of an automated telephone dialling system or "telephone tree" that would allow a small number of SES to contact the necessary members of the community in a short period of time.

The area identified in the Gunnedah Flood Plan to be the subject of these specific messages is very general in nature and requires considerable resources to cover adequately. With the mapping available in this Report, the Flood Plan could now identify specific sections of streets to be warned, allowing other necessary actions to be undertaken at the same time by other members of the SES.

It is **recommended** that the Gunnedah Flood Plan be amended to include:

Carroll	Defined "flood warden" arrangements, with nominated deputies and specifically identified targets for warning messages.
Gunnedah	The SES identify target zones within Gunnedah for specific messages in relation to flooding and its likelihood. An automated telephone system be developed to allow the targeted population to be notified of the warning in the shortest time.

Flood Warning: An Australian Guide provides more detailed advice on the dissemination of flood warnings that is beyond the scope of this Report.

v Response to warnings

The response to flood warnings by both the community and the relevant government agencies was tested in real life during 1998 when five floods occurred in a four-month period. The response of all parties was, generally, more than satisfactory once some early problems were overcome.

The 1998 floods have also revealed some special response issues that do require attention:

- community "apathy" or lack of knowledge;
- suitability of Somerton community hall as an evacuation centre;
- the passage of flood information, especially road closures, to travellers; and
- delayed response by some agencies to the flood situation.

Of these issues, addressing community apathy is the most pressing. Gunnedah had not had a significant flood since 1984 and many of the residents in the most hazardous areas were either unaware of the risks faced or, for many and varied reasons, were "in denial" that a risk existed. This "denial" state has resurfaced after the 1998 flood with some residents of the opinion that "nothing can be done", "it will never get higher than 1998" or simply ignoring the risk, placing a great burden on the local SES to repeat rescue and recovery activities.

While it may not always be 100% effective – there will always be some community resistance – it is essential that a community awareness campaign be instituted to raise the awareness of the community to the risks of flooding. The elements of such a campaign are detailed in Section 8.3.4 below.

Somerton Community Hall is the principal evacuation point for residents of Carroll if evacuation is required. While the Flood Plan specifies that the Hall would not become a "permanent" refuge, it is understood that the facilities at the hall (kitchen and toilets) are not adequate for a sudden influx of evacuees. Consideration needs to be given to upgrading these facilities or having, as part of the Flood Plan, contingency plans to supplement the facilities from Tamworth.

The problem of communicating with travellers regarding traffic hazards and road closures, reported as a recurring problem during the long period of flooding, consideration should be given to using a dedicated message line for such information. A dedicated line would allow regular updating of a taped message and allow SES and other emergency services to concentrate their efforts on their flood response and recovery responsibilities.

Delays in agency response can usually be put down to a lack of preparedness or, as was likely with the broad scale of the 1998 flood, the time lag needed to marshal the necessary staff to deal with the situation. The Flood Plan and its overarching Disaster Plan provide details of the response required by the various agencies. It is essential that the response be regularly rehearsed, both as realistic responses and desktop exercises, so that all likely participants in a flood response are aware of the Plans and their roles in implementing the Plans.

It is **recommended** that:

Community Awareness	A detailed community awareness plan, as discussed below, be developed and implemented as part of the Gunnedah Floodplain Management Plan.
Evacuation Facilities	The facilities at the Somerton Community Hall be upgraded to accommodate the likely evacuee requirements for Carroll. Alternatively, the Flood Plan should include the provision of temporary facilities from Tamworth.

Hazard Communication	A dedicated information line, with taped messages dealing with the flood situation, be established and activated during flood events.
Agency Response	All elements of the Flood Plan be reviewed and rehearsed regularly.

vi Review of the warning system after flood events

A post-flood review of the warning system and the response of all parties is an essential part of an effective floodplain management plan. Its aim is not to criticise or shift blame for problems that may arise. Rather, the purpose of the review is to allow constructive discussion of issues and to seek and implement improvements in the existing plans.

The review process has occurred after the 1998 floods; indeed it is continuing. The findings of this Report will complement the review, leading to a more precise Flood Plan, as discussed below.

8.3.3 Gunnedah Local Flood plan

The SES, in association with the community through the Local Emergency Management Committee, has prepared a detailed Flood Plan for those areas of Gunnedah Shire that are prone to flooding. The plan describes the various preparedness, response and recovery measures to be undertaken before, during and after a flood, including evacuation procedures.

The Floodplain Management Committee needs to ensure that the floodplain management measures adopted in the floodplain management plan are compatible with the Local Flood Plan.

As indicated in the discussion above regarding the Warning System, a number of issues for the Flood Plan have been identified. The discussion will not be repeated here however the specific recommendations are:

- that the SES "Flood Intelligence" for Carroll and Gunnedah be reviewed and updated based on the flood hazard mapping produced in this study and incorporated in the Local Flood Plan as part of the "Specific Risk Areas";
- that the Local Flood Plan be updated to include pro-forma messages based on the checklist provided in *Flood Warning: An Australian Guide*;
- that protocols regarding releases from Keepit Dam are established between DLWC, the SES (local and regional) and the BoM so that there is clear and unambiguous advice of release rates, times and duration (see section 8.3.2(i));
- that the Local Flood Plan contains procedures that allow quick and effective action can be taken to organise the broadcast of warnings into the local area.
- that the Local Flood Plan be amended to include:
  - defined "flood warden" arrangements for Carroll, with nominated deputies and specifically identified targets for warning messages; and

- identified target zones within Gunnedah for specific messages in relation to flooding and its likelihood. An automated telephone system be developed to allow the targeted population to be notified of the warning in the shortest time;

- a detailed community awareness plan, as discussed below, be developed and implemented as part of the Gunnedah Floodplain Management Plan.
- the facilities at the Somerton Community Hall be upgraded to accommodate the likely evacuee requirements for Carroll. Alternatively, the Flood Plan should include the provision of temporary facilities from Tamworth;
- a dedicated information line, with taped messages dealing with the flood situation, be established and activated during flood events; and
- all elements of the Flood Plan be reviewed and rehearsed regularly.

In addition to these issues relating to the flood warning system, the Local Flood Plan should also include:

- details of flood heights at which evacuations will be required in Carroll, especially the heights at which road access is cut;
- measures and operations to secure critical infrastructure such as the Sewerage Treatment Plant and any telecommunications equipment; and
- detailed plans of action should the SES offices be affected by flooding.

8.3.4 Community Awareness and Preparedness

A first step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain. This must be done purposefully because awareness of flooding and its consequences cannot be assumed.

Flood awareness can be enhanced by various simple means such as:

- advice about flooding to ratepayers from time to time;
- articles in local newspapers;
- displays of flood photographs and newspaper articles in the Council Chambers or in shopping centres;
- videos of historic floods in the area; and
- erecting signs showing where flood waters have come to in previous flood events.

The major factor determining the degree of flood awareness of a community is usually the frequency of moderate to large floods in the recent history of the area. The more recent the flooding, the greater the community flood awareness is likely to be. This would be the general case at present in Gunnedah and Carroll, however, there are instances in the surveys done for this study where residents not affected by the 1998 floods remain convinced that they will never be flooded. These properties are well within the area covered by the 1% AEP flood, let alone the extent of the 1955 historical flood.

Even when residents have a high level of flood awareness, there will always be people moving into an area who have not experienced flooding even in the areas from which they originated. Such people must be expected to be unaware of basic flood preparedness activities as well as

of the nature of the flood hazard in their new location. Awareness raising activities must be devised to ensure that the newcomers become aware and the long-term residents do not forget. These activities must be repeated from time to time to maintain consciousness of the hazard.

Sustaining an appropriate level of flood awareness is not easy. It involves a continuous effort by Council in cooperation with the SES.

Community awareness of floods needs to be used to create community preparedness for floods. Effective flood plans need to be developed, and the community must be made aware - and remain aware - of the role of each individual in mitigating flood impacts.

Flood preparedness is the ability of flood-affected people to defend their communities from flood threat by appropriate preparatory and evacuation measures. Preparedness involves deciding, or at least considering, what goods and possessions to move, and how, and where to put or take them.

It is important that preparation should not be solely for the more common and/or less severe floods. The community needs also to be prepared for the flood that is quite outside the experience of anyone in the floodplain. Eventually, there will be a flood which overwhelms the access routes used at flood time, overtops levees which have not been overtopped before and which inundate areas, both rural and urban, that have not previously been affected.

The first step in creating preparedness is always creating awareness. Other steps will follow which may be specific to particular areas. These may include the development of warning services, flood plans and planning for the recovery from flooding.

Strategies to facilitate community education and awareness raising need to be implemented on a systematic basis and targeted towards particular sections of the community, with a focus on commercial property owners, affected residents and school children.

Although regular newspaper features and general information circulation are important, these traditional approaches have been found to be wanting in the past. For example, of 72 affected residents surveyed as part of this Study, only 14 recalled regularly receiving information on what to do in the event of a flood, of which only 7 actually read the information (refer to section 6-4). This also underlines the risk of depending on strategies that may be perceived to remove flood risk, such as a levee.

It is recommended that a systematic flood awareness strategy be implemented, having regard to the following potential initiatives:

a) development of a local schools campaign, run at both primary and high school levels;
b) occasional major events, possibly based around the anniversary of a major flood (e.g. 45 years since the 1955 flood). Such events have been very successful elsewhere and provide an opportunity for a multi-faceted approach, which could include an 'awareness day/week', parade or festival. competitions and general information distribution; and
c) some focus on property management initiatives, for both commercial and residential properties, including the development of flood plans for individual properties, flood proofing initiatives for commercial properties and review of property safety (e.g. under-house wiring problems).

9 ASSESSMENT OF FLOODPLAIN MANAGEMENT MEASURES

9.1 INTRODUCTION

This chapter is an assessment of the impact of the proposed floodplain management measures on social, economic and ecological aspects of the environment. Attention is primarily given to floodplain management measures that propose flood or property modification, since these have the greatest potential to directly impact the environment. Specifically, the impact on the following environmental aspects has been assessed:

1. Flood behaviour. Some modification measures may alter the course and velocity of floodwaters. The likelihood of this is discussed, especially in relation to the proposed levee.
2. Cost-benefit. To assess the cost-benefit relationship of modification measures, a cost-benefit analysis was conducted for levees, house raising and voluntary purchase.
3. Visual environment. The impact of levees, vegetated velocity deflectors, and house raising on the landscapes and streetscapes of Gunnedah and Carroll is assessed.
4. Social environment. Modification measures have potential for a positive or negative social impact. These factors are discussed.
5. Archaeological sites. Four known areas of Aboriginal archaeological significance exist in proximity to the study area. The potential impact of mitigation measures on each site is identified.
6. Heritage items. Items of non-Aboriginal heritage in the area were located, and the potential impact of modification measures on these items is assessed.
7. Ecology. Ecological impacts are related to both flora and fauna. These are assessed for both aquatic and terrestrial environments. The impact of modification measures on the achievement of ecologically sustainable development is also discussed.

9.2 FLOOD BEHAVIOUR - HYDRAULIC MODELLING OF LEVEES

To assess the impacts of the levees, the MIKE11 model was used. Adjustments were made at relevant cross sections in either Gunnedah or Carroll to reflect the changes in topography should a levee be constructed. The possible alignments of the levees in Gunnedah are shown in *Drawing 31923-009* and for Carroll in *Drawing 31923-010*. Before the flood protection levees were modelled, the hydraulic model was updated to allow for the levee around the STP and the proposed saleyards levee. The proposed saleyards levee is the subject of a separate report.

The impact of the proposed levees in Gunnedah was assessed for three flood scenarios, 5% AEP, 1% AEP and the 3x1% AEP for both Alignment One and Alignment Two. The results in areas where the model indicated flood levels were affected by the levees are tabulated in the Floodplain Management Study. The results have been compared with those levels adopted previously in the DLWC Flood Study. In other areas, the impact of the levees is negligible.

Alignment One and Alignment Two refer to the two alignments shown for Gunnedah in Drawing 31923-009.

The impact of the proposed levee in Carroll was assessed for the 1% AEP flood, and the results obtained compared with those reported for Carroll in the DLWC Flood Study.

9.2.1 Flood Levels

Analysis of Levee Alignment One showed an increase of 0.2 m in the vicinity of the Saleyards and Warrabungle Street for the 5% AEP flood, increases of 0.2 m to 0.3 m in the same area for the 1% AEP flood and, subject to not being overtopped by a flood equal to or greater than a 3*1% AEP flood, significant and generally unacceptable increases in flood level across the floodplain for the 3*1% AEP flood.

Similar results occurred for Levee Alignment Two, with only slightly less significant level increases for the 3*1% AEP flood.

At Carroll, flood levels were significantly affected by the introduction of a ring levee, which would increase flood levels by an average of 0.7 m in the 1% AEP flood event. This result arose from the disruption or complete blockage of a number of flood runners that cross or adjoin the village. These flood runners are essential to the passage of floodwaters either within the Namoi River floodplain or towards the Liverpool Plains. For this reason, a levee at Carroll is not favoured on hydraulic grounds.

9.2.2 Velocities

The impact on floodplain velocities resulting from the introduction of levees at Gunnedah is not as marked as that witnessed for flood levels. Generally, the resulting velocity variations are less than 0.8 m/s with the majority of variations less than 0.4 m/s. The most significant increase in velocity, in the 1% AEP flood event, is at chainage 30.21. Without the levee, the velocities at this section were 0.1 m/s on the left and right banks, and 0.4 m/s in the main channel. This increased to 0.4 m/s on the left bank, 0.5 m/s on the right bank, and 1.0 m/s in the main channel with the construction of a levee. As none of the estimated velocities approach a high hazard rating, these variations are considered acceptable.

Flood flow velocities were not calculated in detail for the Carroll situation, as these would be meaningless given the highly adverse flood level reaction described above.

9.2.3 Conclusions

The results for Gunnedah indicate that at lower floods, and even in the 1% AEP event, the impact of the levees is not significant, with the greatest increase in the 5% AEP event being 0.2 m, and in the 1% AEP flood it is 0.3 m. However, in the 3x1% AEP event, there is a significant increase in flood levels, of up to 0.6 m for Alignment One and 0.5 m for Alignment Two. These increases in levels occur from beyond the downstream end of the levees to upstream of Cohen's Bridge and beyond, across the overall Namoi River floodplain. With this increase in levels, there has been a decrease in velocity at some cross sections, in particular around Cohen's Bridge.

In Carroll, the results indicate that a levee would cause a widespread increase in water levels, both upstream and downstream of the levee as flood runners are dramatically altered or destroyed by the introduction of the embankment. The adverse impact of this levee would indicate that it is not a feasible option to be considered for flood mitigation in Carroll.

The MIKE11 hydraulic model used for this study is also being used to assess the rural floodplains between Carroll and Boggabri. It would be prudent to review the levee results as reported once the rural development scenario, both existing and in the future, has been assessed in detail.

9.3 ECONOMIC ASSESSMENT

An economic assessment by way of preliminary Cost-Benefit Analysis (CBA) has been conducted for the following:

- Gunnedah levee;
- Gunnedah house raising and voluntary purchase scheme;
- Carroll levee; and
- Carroll house raising and voluntary purchase scheme.

Please note that this CBA has only accounted for quantifiable economic considerations and does not provide guidance regarding social and environmental costs and benefits, nor guidance on flood behaviour impacts.

A cost-benefit ratio of 1 usually means that the works would have a neutral economic effect. Greater than 1 represents a positive economic effect and less than 1, a negative economic effect.

9.3.1 Data and Assumptions Used

The following economic data has been used for these calculations:

i Economic Damages

Chapter 7 and *Appendix D* of this Study provide a detailed description of the methodology and assumptions used to calculate damages for Gunnedah and Carroll. The combined results are shown as Tables 7.1 and 7.2 in Chapter 7 above. *Appendix D* also contains figures illustrating the Average Annual Damages used in CBA calculations.

ii Potential Flood Measures - Implementation Costs

Table 9.1 below provides a summary of the other economic assumptions used. Greater detail regarding these for each CBA can be found at *Appendix H.*

Table 9.1 Implementation Costs

Gunnedah levee construction cost including purchase of 12 houses	$5,800,000
Carroll levee construction	$2,395,000
Annual levee maintenance (each levee)	0.5% construction cost
Gunnedah house purchase	
• Average per house	$70,000
• Total (14 houses)	$980,000
Gunnedah house raising	
• Average per house	$40,000
• Total (113 houses + 6 masonry)	$5,160,000
Carroll house raising	
• Average per house	$40,000
• Total (59 houses)	$2,360,000
Evacuation Facility for Carroll	$300,000
Culverts under Highway at Carroll (assuming 5 culverts and substantial road reconstruction. It has been assumed that the RTA would bear this cost)	$750,000

The following economic variables have not been included in the CBA, due to uncertainty regarding their value:

1. Increased economic value of public land within the High Hazard areas if a levee was to be built. This largely depends upon Council's attitude to future development in this area.

2. The damages saved to public infrastructure such as roads and tennis courts from a levee. Although Council has estimated damages to roads from the 1998 floods at $2.3M, the majority of this damage would appear to have occurred outside the area that would otherwise be protected by a levee. The 1998 damages were also significantly worsened by the length of time that roads were saturated.

9.3.2 Gunnedah Levee

The Gunnedah levee options as described in section 8.1.1 and shown on *Figure 31923-009* would have a cost benefit ratio of **1.54**. *Appendix H* contains details of the assumptions used for this calculation and *Appendix I* contains specifications assumed for construction of the levee.

9.3.3 Gunnedah House Raising and Voluntary Purchase

Voluntary purchase and house raising of all 'eligible' properties in the area shown in *Figure 31923-009* would have a cost benefit ratio of **0.21**.

'Eligible' properties have been defined as those which currently have a floor level less than 2m above ground level. We have calculated that there are 119 properties that meet these criteria, including 6 of masonry construction. There are 14 properties nominated for voluntary purchase.

Appendix H contains details of the assumptions used for this calculation.

9.3.4 Carroll Levee

The Carroll levee option as described in section 8.1.1 and illustrated on *Figure 31923-009*, would have a cost benefit ratio of **0.89**.

Appendix H contains details of the assumptions used for this calculation and *Appendix I* contains specifications assumed for construction of the levee

9.3.5 Carroll House Raising and Voluntary Purchase

It has been suggested that the cost of house raising and house purchase in Carroll would be comparable. For the purposes of this assessment an average figure of $40,000 has been used for both house raising and voluntary purchase. It should be noted that there are likely to be differing social implications for house raising and voluntary purchase and these are discussed below in section 9.4.

We have also included the cost of upgrading the Somerton evacuation facility in this analysis.

Voluntary purchase and/or house raising (of 'appropriate' properties) in the area shown on *Figure 31923-009* would have a cost benefit ratio of **0.85**.

'Appropriate' properties for house raising have been defined as those which currently have a floor level less than 2 m above ground level and which are of building materials suitable for lifting. We have calculated that there are 59 properties that meet these criteria.

9.4 VISUAL ASSESSMENT

A number of the potential flood management measures will have a visual impact upon the communities of Gunnedah and Carroll.

9.4.1 Levees

Of all potential measures, the greatest visual impact would arise from the proposed levees in both Carroll and Gunnedah.

The Carroll levee would be a 'ring levee' and by definition fully encircle the township. Its height would be in the vicinity of 2.5 m-3.0 m for the majority of length if it were to be designed for a 1% AEP flood with 500 mm freeboard. The overall base of the levee would require a width of up to 15 m to accommodate the slopes necessary for stability and maintenance. This substantial structure would have a significant visual impact on the township of Carroll and dominate views from all locations within the town. The relationship of the town to surrounding rural areas and the river would be diminished.

The Gunnedah levee would be of similar dimensions, that is, 2.5-3.0 m in height for the majority of its length and up to 15 m wide at the base. The visual impact of this levee would be less severe than Carroll, but would still be a dominant feature in the northern districts of Gunnedah. As with Carroll, the relationship between the town and the river would be diminished and the current outlook towards rural and vegetated areas would be replaced with a homogeneous grass slope.

The Gunnedah levee would probably run on the northern side of Maitland Street for the majority of its length, necessitating demolition of 12 houses on that side of the street. Alternatively, it may be possible to construct it behind those houses with the use of an easement, though this has not been investigated in any detail.

There is also a significant avenue of trees along the central portion of Maitland Street, which may be at risk along the northern side of the street. Whichever route is selected, it is safe to say that any levee in this vicinity will have a significant effect on the visual amenity of the northern part of Gunnedah, and on Maitland Street in particular.

9.4.2 Vegetated Velocity Deflectors

One management option for Carroll is the construction of substantial vegetated corridors through the town to act as velocity deflectors for floodwaters. Given the relatively limited extent of vegetation that currently remains in the town, it is considered that this response would provide a significant visual improvement.

An assessment of the damage reduction resulting from the introduction of vegetated velocity deflectors would be highly subjective. Damage calculations are based on depth of flooding and the impact of flood water on contents, etc. No assessment was made of the structural soundness of the properties in Carroll and without this, no accurate measure of likely structural damage through velocity impacts could be made.

The introduction of additional vegetation to Carroll would have significant ecological and social benefits to the village. These cannot be quantified, however it is considered that these non-flood benefits positively supplement the flood benefits.

9.4.3 House Raising

House raising in both Carroll and Gunnedah will have some visual effect on the towns, especially where houses are raised in the vicinity of heritage items and where significant streetscapes exist. One area that may require some closer scrutiny is the raising of residential properties amongst commercial properties at the western end of Connadilly Street, although this may be an insignificant impact in relation to the flood risk that exists.

9.5 SOCIAL COSTS

A full and detailed assessment of the social costs of flooding in Gunnedah can be found in Chapter 6.

In summary, interviews with local residents and business operators indicate that the recent floods had a serious social impact. This was mainly due to the duration of flooding experienced rather than flood levels, which were relatively low.

The majority of affected residents surveyed (41/73) experienced emotions that could be categorised as 'high impact', including fear, distress, panic and anger as well as medical conditions such as depression, claustrophobia and hypothermia. Virtually all respondents suffered some level of emotional impact.

The greatest flood impacts were felt by Maitland Street residents, including life-threatening incidents. All Maitland Street respondents had experienced between 2-5 flood events.

Isolation and property damage were also identified as major social impacts, with the majority of respondents taking between 1-6 months to complete the clean-up. In many instances property damage cannot be valued, particularly with the loss of family photos, heirlooms and other items with an emotional value. As a result, the feeling of loss felt by those affected by flooding often exceeds the monetary value that can be attributed to flooding.

In some instances, the accumulated flood damage to the business community may be modest, but included in that may be sufficient loss to close a number of marginal businesses, which in a relatively small town such as Gunnedah, can have significant negative flow-on impacts.

With regard to the proposed flood management measures, the great majority would have a positive social impact by alleviating flood risks. There is, however, a need to give close consideration to the appropriate mix of measures for Carroll, given the relatively marginal existence of this settlement. For example, a prohibition on further development would eventually lead to the death of the town. Similar consideration needs to be given to the appropriate use of voluntary purchase and house raising for Carroll. The economic cost of both schemes is very comparable, but the social impact may be quite different. A voluntary purchase scheme may undermine the ongoing viability of the town in a manner similar to a prohibition on development, whereas house raising may provide an incentive for further investment in the town. We would be keen to obtain further input from the FPMC and Carroll community on this issue.

An additional social impact that may be caused by the construction of a levee is the creation of an undue sense of security. At the moment, the residents of Gunnedah and Carroll are acutely aware of flood risk and well informed regarding appropriate behaviour and actions during a flood event. Over time, a levee can substantially diminish this awareness, eventually leading to significant increase in property and personal damages when the levee is overtopped by a flood greater than the 1% AEP event. For this same reason, we recommend the maintenance of planning levels above the 1% event even if a levee is constructed.

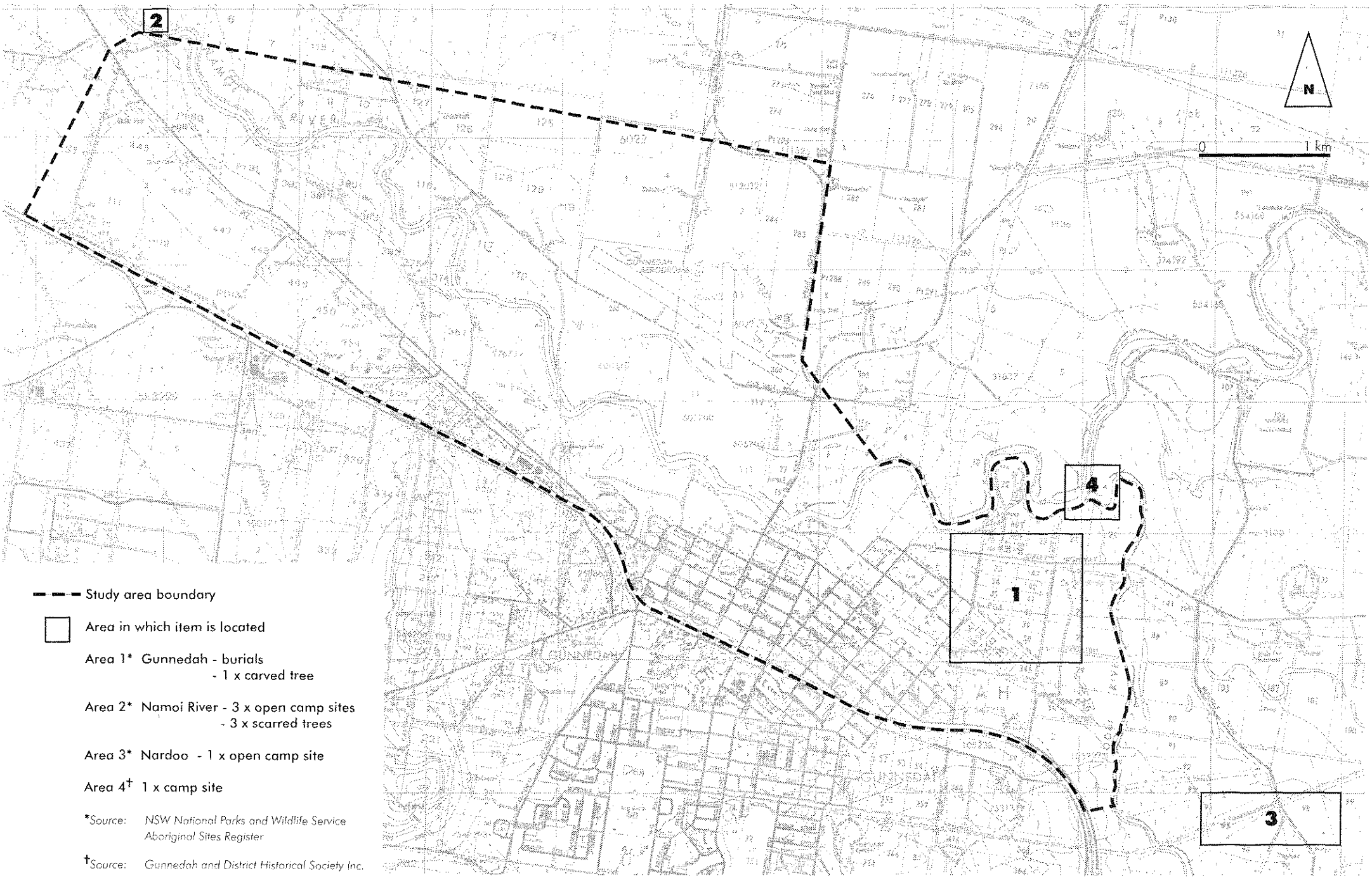


Figure 9.1
ITEMS OF ABORIGINAL ARCHAEOLOGICAL SIGNIFICANCE

9.6 ARCHAEOLOGY ASSESSMENT

9.6.1 Methodology

In total, four areas of Aboriginal archaeological significance were found in close proximity to the Gunnedah study area. No sites were recorded in or near Carroll. The four areas contain a total of ten sites, comprising burials, carved trees, scarred trees, and camp sites.

The NSW National Parks and Wildlife Service was consulted for a listing of all recorded sites in or near the study area. They reported three locations where Aboriginal sites occurred, at those areas named Gunnedah, Namoi River, and Nardoo. The Gunnedah and District Historical Society provided information on a fourth area.

The area locations are shown in *Figure 9.1*. *Table 9.2* below gives approximate inundation and velocity values, used to determine the flood impacts for a range of flood events. Values were calculated from a representative cross section which was thought to be representative of the area, taken from the *Flood Study Report Gunnedah and Carroll* (DLWC 1996) and supplemented as necessary with data from the MIKE-11 hydraulic model. Due to the limited amount of topographic information and inexact location of sites, values given are approximate only. Inundation depths were calculated from height contours on topographic maps, supplemented with cross-sectional data from the MIKE-11 hydraulic model.

An additional area along the proposed levee route in the vicinity of Mullibah Lagoon had been identified as a significant Aboriginal archaeological site. However, no Aboriginal archaeological sites in the immediate vicinity of the proposed levee were identified in our searches.

9.6.2 Flooding and Flood Mitigation Impacts

i Area 1

Area 1 is located within the north-western part of the study area. It contains an unknown number of burials, and a carved tree. It is situated away from the proposed mitigation works, and would not be affected by the levee or any other works.

Given the indefinite nature of its location, the area would need to be more closely surveyed to determine the precise impacts of flooding on individual sites. However, approximate levels of various flood events in Area 1 are shown in *Table 9.2 below*. The area is south of the Namoi River, west of the Mooki River, and is dissected by the *Mooki-2* floodway, which flows to the Mooki. Generally the ground surface is flat, and the approximate surface level is 263 m AHD. Velocity over the range of floods is relatively slow, at between 0.2 and 0.4 m/s. However, in an extreme (3*1% AEP) flood event, inundation could potentially reach a level of 4.8 metres. In a 1% AEP flood event, inundation is estimated at 3.5 metres, and in a 10% AEP flood event, at 1.4 metres.

The carved tree and burial(s) in the area are not likely to be damaged by any one flood event. Effects of flooding such as erosion and siltation could have an adverse impact on the archaeological sites over a period of time, potentially washing away cover over the burial site/s.

ii Area 2

Area 2 is located to the north east of the study area, on the north bank of the Namoi River. It consists of three open camp sites, each with a scarred tree. These border on the study area, but are distanced from proposed mitigation works such that the sites will be unaffected, directly or indirectly, by any proposed works.

The area is on the northern bank of the Namoi River, south of Landry and Gunnible Lagoons. Its approximate elevation is 258 m AHD. Velocity of floodwaters in the area ranges from an estimated 1.4 m/s in a 10% AEP flood event, to 2.9 m/s in an extreme (3*1% AEP) flood event. This faster flow combines with inundation levels in the order of two to four metres deep, or more. Scarred trees in the area are likely to survive the range of flood events, though suffering erosion over a period of time. Open camp sites would be adversely affected if they are not protected by sufficient vegetation. Affectedness will also vary according to the relative exposure of the camp sites to the flow of floodwaters. Any relics and marks of the camp sites may be washed downstream by floodwaters.

iii Area 3

Area 3 is located outside the study area, east of the Mooki River. It contains one open camp site, which will be unaffected by any of the proposed flood mitigation works.

The estimated elevation of the area is 266 m AHD. A floodway transects the area, meeting Carroll Creek to the north. The approximate velocity of floodwaters in the area is relatively low, ranging from 0.1 to 0.8 m/s. Inundation ranges from approximately 0.4 to 4 metres. Inundation at the 1% AEP flood event is approximately 2.2 metres. Again, relics of the open camp site could potentially be washed downstream by floodwaters, in a flood of high velocity.

iv Area 4

Area 4 is partially within the study area, positioned at the intersection of the Namoi and Mooki Rivers. The proposed flood mitigation works will not impact the camp site in the area.

The area has an elevation of approximately 263 m AHD. Velocity of floodwaters through the area is approximately 1.3 metres/second during a 10% AEP flood event, with inundation at approximately 1.4 metres. In an extreme (3*1% AEP) flood event, velocity is approximately 2.6 metres/second and inundation estimated at 4.8 metres. Relics and other items which may mark the location of the camp site are likely to be swept away by a flood of high velocity and high inundation.

v Summary

Four areas containing Aboriginal archaeological sites were identified in Gunnedah, and none in Carroll. It was noted at the FPMC meeting on April 16 that an area along the proposed levee route in the vicinity of Mullibah Lagoon had been identified as a significant Aboriginal archaeological site. This site has not been recorded or identified in any of our heritage searches, including those undertaken with the National Parks & Wildlife Service who are responsible for such sites. No Aboriginal archaeological sites in the immediate vicinity of the proposed levee were identified in our searches.

The table below summarises approximate inundation and velocity for the range of flood events, for each of the identified areas. Cross sections used as the basis for these estimates were:

- Area 1: Mooki-2, chainage 54.350 km
- Area 2: Namoi 95, chainage 37.000 km
- Area 3: Carroll-2, chainage 26.350 km and 27.250 km (for height data) and chainage 26.710 km (for inundation and velocity data)
- Area 4: Mooki, chainage 55.050 km

Table 9.2 Flood Affectedness

Area	Approx. elevation (m AHD)	1% AEP		5% AEP		10% AEP		3*1% AEP	
		Inundation (m)	*Velocity (m/s)*	*Inundation (m)*	*Velocity (m/s)*	*Inundation (m)*	*Velocity (m/s)*	*Inundation (m)*	*Velocity (m/s)*
1	263	3.5	0.4	1.9	0.4	1.4	0.2	4.8	0.4
2	258	3.2	2.2	2.5	1.8	1.9	1.4	4.6	2.9
3	266	2.2	0.5	1.1	0.2	0.4	0.1	4.0	0.8
4	263	2.8	2.3	1.9	1.9	1.4	1.3	4.8	2.6

None of the areas in which Aboriginal sites are recorded are close to the proposed levee, and it is unlikely that they would be impacted by any proposed structural flood mitigation works. It is possible that further unrecorded sites could exist in the vicinity of the study area. All Aboriginal sites, whether or not they are recorded, are protected under the *National Parks and Wildlife Act, 1974*. Permission is required from the Director-General of the National Parks and Wildlife Service, prior to any disturbance of Aboriginal sites.

A full summary of heritage items and flood impacts can be found at *Appendix J*.

9.7 HERITAGE ASSESSMENT

9.7.1 Methodology

In the assessment of non-Aboriginal heritage in or near the study area, reviews were undertaken of:

Figure 9.2

HERITAGE ITEMS - GUNNEDAH STUDY AREA

0 250 m 500 m

Metres

N

Figure 9.3

HERITAGE ITEMS - CARROLL STUDY AREA

0 250 m 500 m

Metres

N

- Gunnedah Local Environmental Plan 1998 *Schedule 1 – Heritage items, archaeological sites and potential archaeological sites;*
- Australian Heritage Commission's *Register of the National Estate* database;
- Department of Urban Affairs and Planning's *State Heritage Inventory;*
- *National Trust* database; and
- Register of the *Gunnedah and District Historical Society.*

A database was formed as the result of these reviews, and those heritage items within the study area were investigated for the potential impacts of flooding and flood mitigation measures. The complete listing of heritage items is appended at *Appendix J*. Heritage items within the study area are tabled in *Appendix J* and are located on *Figures 9.2 and 9.3*. *Appendix J* also details the potential impacts of flooding, and of mitigation measures, on heritage items within the study area.

9.7.2 Heritage Items

In total there are 21 non-Aboriginal heritage sites within the Gunnedah study area, and one in the Carroll study area. Eight of these are likely to be affected in some form by the proposed mitigation measures, as described below.

i Cohen's Warehouse

Cohen's Warehouse, the old John Affleck building, is at 82 Maitland Street. It is shown as ID 25 on *Map 9-2*.

The levee option as currently proposed transects the property of the Warehouse. The property has therefore been nominated for voluntary purchase, and under normal circumstances buildings would be demolished to improve flood flow paths. Council may believe it is warranted to demolish the property in the interests of better flood management. However, due to its heritage significance other options need also be considered.

Even with the levee option, the warehouse could be retained for some "low-risk" use, such that when flooded no significant damages would be suffered. For instance, it could be used as a community hall or similar. Alternatively, it may be possible to route the levee behind the property, protecting it up to the 1% AEP flood event. The construction of a levee as proposed is likely to have major detrimental impacts on the Maitland Street streetscape, and would affect the appearance of the building and potentially its heritage significance. If the levee were constructed to the south (Maitland Street side) of the warehouse, it would visually and physically cut off the warehouse from the Gunnedah township.

If the levee option is not carried out, alternate flood mitigation options such as house raising would also impact on the streetscape, and care should be taken to carry out these measures in a sensitive fashion, so as not to decrease the heritage significance of the warehouse.

ii Cohen Bridge

The Cohen Bridge crosses the Namoi River at Chandos Street, and is shown on *Map 9-2* as ID 36. It was built as a rivet bridge in 1885, by Mr Royce.

The bridge would be affected by the proposed raising of the access roads to Gunnedah Airport, and any structural alterations should be carried out sympathetically so as to ensure that its heritage significance remains. The proposed planting of native species along the Namoi foreshores may improve the appearance of the bridge.

iii Original Convent for the Sisters of Mercy

The original convent is a brick building located at 93 Maitland Street. It is shown as ID 29 on *Map 9-2*.

The proposed levee would protect the building up to the level of the 1% AEP flood, however both the levee and house raising in the surrounding area are likely to have an adverse aesthetic impact on the old convent. It is possible that the aesthetic impact could be lessened by vegetation screening.

iv Roseneath Manor

Roseneath is located next door to the original convent, at 91 Maitland Street. It is a two storey brick house, formerly George Cohen's residence, built approximately 1878-79. The house is now used as a residence and the base for two home businesses. It is shown as ID 31 on *Map 9-2*.

As for the convent, Roseneath is likely to be affected by the aesthetic impact of both the levee and house raising.

v Original Methodist Church

The original Methodist Church is located at 44 Abbott Street, and is shown on *Map 9-2* as ID 27. The property is at the corner of Abbott and Barber Streets, and as such may suffer some aesthetic impact from the raising of houses on the opposite side of Barber Street. House raising in the vicinity should be considerate of heritage significance. The construction of a levee would protect the church from flooding up to the 1% AEP flood event.

vi School

The brick school at 48 Elgin Street also shares a boundary with Barber Street. It is shown as ID 30 on Map 9-2. House raising on the opposite side of Barber Street should be sensitive to the school's heritage significance and have consideration for the overall streetscape. The proposed levee protects this property from flooding up to the 1% AEP flood event.

vii Reveree Homestead

The Reveree Homestead is located on Block 38 in Carroll, and is a federation style home once inhabited by George Weakley (c.1896). It is shown as ID 40 on *Map 9-3*. The property is located beyond the proposed levee as it is close to the Namoi River. It is likely that the proposed levee will cut the homestead off from Carroll township. Flood behaviour on and around the property is also likely to change, because of the levee.

viii Flour Mill

Meggitt Ltd flour mill is located on New Street, shown as ID 17 on *Map 9-2*. The positioning of a levee north of the property may have impacts on the property.

9.7.3 Summary

A number of non-Aboriginal heritage sites exist within the flood-affected areas of Gunnedah and Carroll. On the whole, these would not be affected by any of the proposed flood management measures. The main exception relates to Cohen's Warehouse (Old John Affleck building) at 82 Maitland Street, which is nominated for voluntary purchase and is on the route of the proposed levee.

Properties purchased under a voluntary purchase scheme are usually demolished to improve flood flow paths. In this instance it may be warranted to retain the building for use in a manner that would not expose it to significant flood damages (by using the ground floor as a community hall or similar).

If the levee was favoured, it may be possible to route the levee behind the property. Alternatively, Council may believe it is warranted to demolish the property in the interests of better flood management.

Situated on the opposite side of Maitland Street, the original convent for the Sisters of Mercy (93 Maitland Street) and Roseneath Manor (91 Maitland Street) may also be affected by the proposed flood mitigation works. The levee and house raising are likely to have an adverse aesthetic impact on these properties.

9.8 ECOLOGICAL ASSESSMENT

9.8.1 Impacts of a Gunnedah Levee

A proposed mitigation measure for flood protection of the Gunnedah Township is to construct a levee which would be located within the northern residential areas of the township, predominantly along the route of Maitland Street. Due to the already highly modified nature of the habitats present within this area, it is unlikely that the proposed levee would have a significant effect on flora and fauna species of the area.

As no threatened flora species were observed within the study area, the construction of the levee would have no impact upon these species. As the area for the proposed levee is already

substantially cleared it is anticipated that few native trees would require removal. Therefore, construction of the proposed levee would have no significant impact upon flora within the study area.

During a flooding event, the proposed levee would alter the natural flow of water so that it is diverted around the township. Flood waters usually carry seeds and propagules onto the floodplain where they are deposited and may germinate if suitable conditions exist. After construction of the proposed levee, flood waters carrying seeds and propagules may not inundate as extensive an area of the floodplain as they would have prior to the construction of the levee. This gives rise to the potential that less native seeds will be deposited within the study area and hence there will be less germination and recruitment of native tree species. However, due to the current land uses within the study area, such as grazing, it is unlikely that there would be a significant impact on the number of germinating seedlings surviving to become established trees. Flood waters also carry weed seeds and propagules so there is the potential for a positive impact in that less weed seeds and propagules may be deposited in the study area.

The proposed levee would be constructed on the southern side of Mullibah Lagoon. This would result in no change to the number of times the lagoon is inundated during flood events. However, as the levee would contain the flood waters, there is the potential for the lagoon to be inundated for a longer period of time. This would only be in the order of one or two days and would not significantly affect the lagoon.

Construction of the proposed levee is unlikely to affect fauna species due to the lack of habitat present along the proposed route. As the threatened species known to occur in the local area (Table 2.3) are all mobile, the levee will not act as a barrier to the movement of these species should they be present in the area. In particular, Koalas have been known to occur in the local area. The levee, which would be grassed and maintained, would not pose a significant barrier to the movement of Koalas should they be present within close proximity to the town.

9.8.2 Impacts of Mitigation in Carroll

i Flora

The vegetation present within and around the township of Carroll is very similar to that of Gunnedah. Within the township itself, the vegetation consists of street trees and ornamental plantings associated with dwellings, as well as some remnant River Red Gum (*Eucalyptus camaldulensis*) trees. Much of the land surrounding the township of Carroll has been cleared for agricultural pursuits, however, some native vegetation is present within the study area. To the west of the township of Carroll is open forest along the Namoi River, while to the east is open woodland vegetation.

The open forest vegetation is very similar to that described for the Gunnedah study area, consisting of River Red Gums (*Eucalyptus camaldulensis*) up to 25 metres high with a projective foliage cover of 30-70%. Willows (*Salix babylonica*) are also present along the river bank. There is no shrub layer within this community and the ground layer is dominated by exotic weed and pasture species.

The open woodland to the east of Carroll consists of White Box (*Eucalyptus albens*) 15-20 metres high with a projective foliage cover of 15-30 %. There is no shrub layer within this community, but some young regenerating trees are present. The dense ground cover is dominated by weed and pasture species.

ii Fauna

The fauna habitat present within the Carroll study area is similar to that of Gunnedah. The vegetation present may provide some foraging habitat for threatened species (Table 2.3) if they are present within the local area. The grazing of stock and the presence of domestic cats and dogs may limit the potential for some threatened species to occur within the study area.

iii Potential Impact of Flood Mitigation Measures

One of the proposed mitigation measures for flood protection for the township of Carroll is the construction of a ring levee encompassing the majority of the residential dwellings. As this area is already cleared and developed, the construction of a levee would not significantly impact upon native flora or fauna. It is expected that the change in the movement of flood waters caused by the levee would not impact upon ecological processes in the local area. Any levee which is constructed must incorporate adequate drainage structures to ensure that there is no adverse impact on stormwater drainage in the towns. This would be considered in detail at the design stage.

Velocity deflectors have also been suggested as a flood mitigation option for Carroll. Velocity deflectors would consist of densely planted vegetation corridors that would act to slow the flood flow. The utilisation of velocity deflectors would have a positive impact on the ecological characteristics of the area. The use of indigenous native species for planting would restore some of the naturally occurring flora species and provide habitat for fauna species. The local Landcare group could assist in the selection of appropriate species for this purpose. The velocity deflectors have the potential to provide foraging habitat, and act as fauna corridors for species moving from the riverine corridor to the east of Carroll.

9.8.3 The Aquatic Environment

The major waterways in the Gunnedah district are the Namoi and Mooki Rivers, Cox's Creek and Keepit Dam. Gunnedah Shire Council's State of the Environment Report (1997) states that there is a growing awareness and concern about the degradation of these systems. To maintain and improve the quality of the aquatic environment the factors contributing to the degradation of waterways must be managed and controlled.

Two factors that effect the aquatic environment include effluent discharge and surface water runoff. Gunnedah Shire Council operates a secondary sewerage treatment which is discharged into the Namoi River. Most urban stormwater runoff in Gunnedah is also eventually drained into the Namoi River (Gunnedah Shire Council, 1997). These factors result in the input of nitrogen and phosphorus into the aquatic environment. Increased nutrient loading can lead to excessive algal growth which prevents sunlight from reaching aquatic plants. Aquatic plants help stabilise the river bank and bed and produce oxygen for other aquatic organisms. The mitigation measures suggested for the townships of Gunnedah and Carroll will not contribute

to nutrient loading, and proposed levees may potentially reduce the urban stormwater runoff reaching the Namoi River.

Another factor contributing to the degradation of the aquatic environment is turbidity. Turbid waters prevent light penetration, which affects the ability of aquatic plants to photosynthesize and produce oxygen. Reduced dissolved oxygen levels can have a negative impact on the overall biodiversity of an aquatic system (Gunnedah Shire Council, 1997).

The removal of trees and intense grazing results in increased soil erosion. Soil from eroded sites is ultimately washed into the river system. The use of densely planted vegetation corridors as velocity deflectors would have a beneficial effect by binding the soil and reducing the potential for erosion. During the construction of proposed levees there may be the potential for increased erosion. Management procedures and controls would need to be implemented to prevent soil erosion during construction.

9.8.4 Ecologically Sustainable Development

Ecologically sustainable development (ESD) seeks to achieve the integration of environmental and economic considerations into the decision-making process. Ecologically sustainable development has been defined by the Commonwealth Government (1990) as 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'. The concept of ESD has developed from the concern that insufficient weight has been placed on environmental considerations when making decisions about resource use.

The principles of ESD defined in the *Protection of the Environment Administration Act, 1991* and the *Environmental Planning and Assessment Regulation, 1994*, are described below.

The precautionary principle: This principle states that if there are any threats of serious or irreversible environmental damage, lack of scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Intergenerational equity: This principle states that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.

Conservation of biological diversity and ecological integrity: This principle is not described in the Regulation, although it means that the diversity of genes, species, populations and the communities, as well as the ecosystems and habitats to which they belong, must be maintained or improved to ensure their survival.

Improved valuation and pricing of environmental resources: This principle is not described in the Regulation, although it is described in Harding (1990) as:

> *Traditionally pricing and resources have not reflected their scarcity, replacement costs in the long term, or future cost of irreversible and cumulative damage to natural systems. This principle requires that the true costs to the environment be factored into the cost of production or use of the resource. Those who pollute or degrade the environment should be held accountable for the restoration of the environment to its previous natural condition.*

The proposed flood mitigation options presented for the towns of Gunnedah and Carroll are consistent with the objectives of ecologically sustainable development. The construction of levee banks or velocity deflectors would provide benefits to the area through a reduction in flood damage and increased human safety. The construction and operation of the flood mitigation options would not negatively impact upon the biodiversity of the area or on ecological processes. The use of densely planted vegetation corridors as velocity deflectors will enhance the local environment by establishing indigenous flora species and providing habitat for fauna species.

9.9 SUMMARY

There are both positive and negative impacts which may result from implementation of the proposed floodplain management measures. The impacts have been explored in this chapter, and are summarised in the following table.

Table 9.3 Summary

Aspect	*Assessment*
Flood Behaviour	A levee in Gunnedah would increase flood levels downstream of the levee in large flood events. This would decrease the velocity of floodwaters at some cross-sections. A levee in Carroll would significantly increase water levels outside the levee.
Cost-Benefit	Operating on the assumptions outlined in *Appendix H* and section 9.2, it is calculated that a Gunnedah levee would have a positive cost-benefit relationship, with a ratio of 1.54. House raising and voluntary purchase schemes in Gunnedah would have a cost-benefit ratio of 0.21, indicating a negative economic effect. A levee around Carroll would have a cost-benefit ratio of 0.89, also a negative economic effect. House raising and voluntary purchase schemes in Carroll would also have a negative economic effect, with a cost-benefit ratio of 0.85.
Visual Environment	A levee around Carroll would have a significant visual impact on the town due to its bulk and scale, and would dominate views within the town. The Gunnedah levee would have slightly less impact on views and vistas throughout Gunnedah, however it would impact the visual amenity of the northern part of Gunnedah township. Vegetated velocity deflectors in Carroll would have a positive impact on visual amenity in the town House raising in both Gunnedah and Carroll would have visual impacts, especially on the adjacent properties and streetscape, and need to be considered on a case by case basis.
Social Environment	The majority of modification measures would have a positive impact on the social environments of Gunnedah and Carroll, substantially alleviating the social impacts and risks of flooding. An important consideration is to protect the sustainability of the community in Carroll against any measures that may discourage development there. A levee may have negative social impacts by isolating people left outside it. It may also encourage a false sense of security, thereby decreasing flood awareness over time.
Archaeological Sites	None of the identified sites would be affected by the proposed mitigation measures, given their distance from affected areas. However, there is potential for other unrecorded sites of Aboriginal archaeological significance to exist in this area.

Heritage Items	Within the study area there are 22 non-Aboriginal heritage items. Of these, eight are likely to be impacted by the proposed mitigation measures. The majority of the items impacted would suffer aesthetic impacts to the streetscape due to proposals for house raising and for levees. One item (Cohen's Warehouse in Gunnedah) would be subject to voluntary purchase due to its location on the levee path. Consideration needs to be given to the future use of this building if voluntarily purchased.
Ecology	The proposed levee in Gunnedah would have minimal impact on flora and fauna, due to the cleared and highly modified environment along its route. The proposed levee may cause erosion to the watercourses during construction, and appropriate measures should be taken to avoid this. The use of vegetated velocity deflectors is likely to decrease erosion and sedimentation of watercourses, resulting in a positive impact on the aquatic environment. The proposed mitigation measures as a whole are consistent with the principles of ecologically sustainable development.

10 RECOMMENDATION FOR FLOOD PLANNING LEVELS

10.1 FLOOD PLANNING LEVELS

This section has been prepared having regard to the 1999 Draft Floodplain Management Manual, released for public comment by the NSW Government in March 1999.

The concept of a "Flood planning level" (FPL) supersedes the "standard flood" of the 1986 Manual. It should be noted that many of the references to an FPL in the draft Manual include the (s) to indicate that there can be number of FPLs for a range of land uses.

There is a detailed discussion of FPL in *Appendix K* of the draft Manual, indicating its importance in the overall process. The Appendix lists and discusses a range of factors that require consideration in determining an FPL; these are listed below:

- long term strategic planning;
- existing and potential land use;
- impact of local floodplain management objectives on existing and future development;
- current flood level used for planning purposes;
- changes in potential flood damages caused by the selection of a particular FPL;
- consequences of floods larger than the FPL flood;
- ecological issues;
- flood warning, emergency response and evacuation issues;
- community flood awareness;
- creation of a false sense of security; and
- land values and social equity.

The concept of the FPL is based on a trade off between risk to the community and community amenity and expectations. Council's selection of a flood planning level involves consideration of the risks associated with all levels of floods, up to and including the Probable Maximum Flood. The process of establishing an appropriate flood planning level is one of determining an acceptable level of risk for each category of development, since the consequences of flooding vary depending on the type of development. The flood planning level selected is one which achieves a satisfactory balance between retaining the economic, social and ecological benefits of development on the floodplain, and minimising the risk to human life and property.

It should also be noted that the FPL is not tied to **any** AEP, it is a flood level. This is, it is understood, an attempt to overcome the problems that may arise when re-calculation of frequency means that the 1% AEP flood has a new level, be it an increase (the usual scenario) or a decrease.

Put simply, residents do not care whether the flood is an AEP of 1.5% or 1.8%, they simply require a level to develop above that will reduce the risks to themselves and emergency services to acceptable levels.

10.2 INFORMING THE PUBLIC

The two key issues in relation to the Flood Planning Level are determining the level and advising the residents of that determination. The requirement to consider an extreme flood event in floodplain management has significant implications for the second issue.

The activity of advising residents and landowners of the affected nature of a property is one of the responsibilities of a Council, and also one of its major burdens. This will be doubly so with the introduction of the extreme event as part of the information available to a Council. With regard to possible legal implications in respect of the consequences of future floods, Council needs to provide clear and factually correct flood information. To this end, the following should be noted:

- the need to explicitly inform flood prone property owners and others living and working in flood prone areas of their risk of flooding;
- the need to clearly and objectively inform townspeople of flood emergency arrangements to deal with residual risk;
- the need to recognise the difference between flood prone land and land under the Flood Planning Level; and
- the need to be factually correct on all written notifications to ratepayers, property developers, etc. concerning flood information.

By way of example, the following example is adapted from the recently published *"Floodplain Management in Australia – Best Practice Principles and Guidelines"* (referred to earlier):

> *"On the basis of present information available to council, estimated flood levels at your property are as follows:*
>
> | *Annual Exceedance Probability (AEP)* | *Flood Level (m AHD)* |
> |---|---|
> | *5%* | *5.7* |
> | *2%* | *6.1* |
> | *1%* | *6.6* |
> | *Probable Maximum Flood* | *8.5* |
>
> ***Note (a)***
> *The Flood Planning Level for your property is 6.6m AHD. Council has a specific flood Development Control Plan that covers your property (DCP No. XX) and you should contact Council's Planning Department to obtain details such as but not limited to, a specified freeboard to be added to the flood planning level and requirements on building materials.*
>
> ***Note (b)***
> *Flood levels at your property can rise significantly higher than the flood planning level. The probable maximum flood level is an estimate of the highest possible flood level that could occur at your property. The probable maximum flood is an extremely rare event. The chance of a probable maximum flood occurring in any year is 1 in 100,000 or greater. Nevertheless, such events have occurred in the past on 2-3 occasions in Australia. Council does not have a DCP that affects the use of land above*

the flood planning level but still subject to the PMF. Emergency plans are in place and you should contact Council or the local SES for further details.

Note (c)
The above flood level estimates may be revised from time to time as additional information comes to hand."

10.3 JUSTIFICATION FOR FLOOD PLANNING LEVELS

Whilst flood prone land includes all land within the PMF, it is not physically feasible, nor economically desirable to adopt the PMF as a flood planning level in Gunnedah or Carroll. This would result in massive restrictions to residential and commercial development. However, critical utilities, including emergency services, should be located above the PMF (plus freeboard) where possible, since flooding of these facilities has great social and economic consequences. The selection of a FPL must balance the risk of flood damage with the economic and social benefits of using the floodplain.

Development in Gunnedah and Carroll has been planned along the line of the 1% AEP for so long that to adopt a FPL below this level would drastically alter the flood damage curves. The 1% AEP flood line is a common flood standard in Australia. While other levels of risk must be investigated, the 1% AEP flood line (plus freeboard) is considered an appropriate FPL for residential development and rural dwellings in Gunnedah and Carroll.

The selection of a FPL for commercial and industrial development is considered a decision made more appropriately be the owner / occupier, who should determine the level of risk and potential damages acceptable to their business, and factor these risks into their business costs.

Recommended flood planning levels are set out below.

10.4 GUNNEDAH FLOOD PLANNING LEVELS

Residential – A minimum floor level of 500mm above the flood contour levels shown for the 1% design flood on Drawing 31923-014 (please note that these levels vary across the flood prone areas), assuming retention of the existing 'no building line'.

Commercial – No minimum floor level if built with flood compatible materials and in accordance with provisions of the Flood Prone Land DCP (refer to section 8.2.4).

10.5 CARROLL FLOOD PLANNING LEVELS

Residential – A minimum floor level of 500 mm above the flood contour levels shown for the 1% design flood on Drawing 31923-017 (please note that these levels vary across the flood prone areas), assuming retention of the existing 'no building line'.

Commercial – No minimum floor level if built with flood compatible materials and in accordance with provisions of the Flood Prone Land DCP (refer to section 8.2.4).

11 CONCLUSIONS

This Floodplain Management Study has aimed to identify and assess the various options for floodplain management against their suitability for Gunnedah and Carroll. The options for floodplain management range from options for flood modification such as a levee, property modification such as house raising or voluntary purchase, and response modification, such as raising community awareness. Consideration has been given to the full range of options, resulting in the assessment of each option as outlined in sections 11.1 and 11.2 below.

Central to discussion of management options is the consideration of a levee for Gunnedah. It is SMEC's recommendation that the negative aspects of the levee would outweigh the positives. This is based on the following considerations:

- The levee would protect the majority of the town from floods up to the 1% AEP flood level, however, floods greater than that would have a significant economic and social impact on the town when the levee is overtopped. It is therefore necessary that other planning, building and response measures be implemented as stand-alone strategies.

- Although the hydraulic impact of the levee is generally not significant, the levee would have the effect of dividing the town from its rural and rural/residential areas to the north, and could be seen as isolating those residences between the levee and the river. Those residents may even feel a sense of abandonment by the town.

- The levee would create a false sense of security in the town's residents, leading to pressure on Council to develop the low lying land along Maitland Street, increasing the potential flood damages in the event of an overtopping flood.

- The presence of a levee may result in what could be termed the "Nyngan Syndrome" - all efforts are put into a perceived need to protect and raise the levee in the event of a flood, while at the same time forgetting to protect and evacuate those properties and possessions most at risk should failure occur.

- The levee would also result in considerable visual intrusion between the town and the riverscape, being an earthen embankment of up to 3.5 metres in height.

The option of a levee for Carroll has also been considered and is not recommended for similar reasons.

A combined house raising / voluntary purchase program was also considered. This measure would involve a voluntary purchase scheme for properties in the Gunnedah High Hazard area, and house raising for properties in the Flood Fringe area. Despite having both positive and negative aspects, this measure is considered preferable to a levee.

The provision of **detailed land use planning and development control measures** in the flood prone areas and the continued application of **flood response measures**, such as flood warning and public awareness programs, will also be fundamental to floodplain management.

Figure 1.2

STUDY AREA - GUNNEDAH

N

Scale 1 : 25 000

0 1 km

The options were presented to the communities of Gunnedah and Carroll for comment. Following the consultation period, the Floodplain Management Committee and Gunnedah Council considered these options and resolved to accept voluntary purchase and house raising as property modification options, along with a number of other property and response modification measures. Council and the Floodplain Management Committee also resolved not to pursue flood modification options, including a levee, for Gunnedah or Carroll.

Our detailed conclusions with regard to each of the potential flood management measures are as follows:

11.1 GUNNEDAH

11.1.1 Flood Modification Measures

Measure	Recommendation
Flood Control Dams	Reject
Retarding Basins	Reject
Levees	Reject
Bypass Floodways	Reject, although it is noted that the 'pig-hole' currently performs this function and should be maintained as such.
Channel Improvements	Reject
Velocity Deflectors	Reject

11.1.2 Property Modification Measures

Measure	Recommendation
Zoning	The Local Environmental Plan should be used to support and provide weight to a Flood Prone Land Development Control Plan. Zoning amendments are recommended to protect floodways and restrict further commercial development at the eastern end of Conadilly Street. The existing 'no building line' should be maintained.
Planning Levels	Floor levels for new residential development should be 500mm above the flood contour of the 1% AEP event. No flood planning level should be set for commercial properties, but these should be constructed from flood compatible materials.
Voluntary Purchase	Supported.
House Raising	Supported.
Building and Development Controls	Supported for incorporation into the draft DCP.

Flood Proofing	Supported for new commercial properties in the 1% AEP area. Recommended for other commercial properties existing and within the extreme (3 * 1% AEP) flood.
Flood Access	No works recommended.

11.1.3 Response Modification Measure

Measure	Recommendation
Community Awareness	Supported - ongoing publicity needed, utilising this project as a first step.
Community Preparedness	Supported
Flood Prediction and Warning	Supported - refer to FPMP for proposals
Flood Plans	Supported - refer to FPMP for proposals
Evacuation Arrangements	Supported - refer to FPMP for proposals
Recovery Plans	Supported - refer to FPMP for proposals

11.2 CARROLL

11.2.1 Flood Modification Measures

Measure	Recommendation
Flood Control Dams	Reject
Retarding Basins	Reject
Levees	Reject
Bypass Floodways	Reject
Channel Improvements	Reject
Velocity Deflectors	Support

11.2.2 Property Modification Measures

Measure	Recommendation
Zoning	Development should be permissible in the High Hazard area. The Local Environmental Plan should be used to support and provide weight to a Flood Prone Land Development Control Plan.
Planning Levels	Floor level for new residential development should be 500 mm above flood contour for 1% AEP event.
Voluntary Purchase	Not recommended.
House Raising	Supported
Building & Development Controls	Supported for incorporation into the draft DCP.
Flood Proofing	Recommended for any new commercial development
Flood Access	

11.2.3 Response Modification Measure

Measure	Recommendation
Community Awareness	Supported - ongoing publicity needed, utilising this project as a first step.
Community Preparedness	Supported
Flood Prediction and Warning	Supported - refer to FPMP for proposals
Flood Plans	Supported - refer to FPMP for proposals
Evacuation Arrangements	Supported - refer to FPMP for proposals
Recovery Plans	Supported - refer to FPMP for proposals

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APPENDICES

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1.0 Introduction

SMEC Australia has been commissioned by Gunnedah Shire Council to undertake a floodplain management plan for Gunnedah and Carroll. As you would be aware, the recent floods in July 1998 caused extensive damage to properties and community assets, resulting in disruptions to normal activities. For a variety of reasons, organisations are sometimes forced to put off repairs, renovations or delay purchase of new equipment after the events. These are the indirect impacts of flooding.

The following survey aims to obtain information from you on how the flooding has affected your organisation and any premises that it owns and/or uses. In completing this survey we need you to consider the impact of the recent floods as well as more extreme flood events. So, while the recent floods may not have affected you, please consider how your organisation's property or normal activities would be affected in a more extreme flood. It is important to list both direct and indirect impacts of flooding in your response.

Some organisations may not actually own any premises, however, please give details regarding any buildings, facilities (such as playing fields) or premises that your organisation regularly uses. (Give address details of these premises).

All responses to this questionnaire are entirely confidential and will not be published in any form.

2.0 Organisation Details

2.1 Organisation Name: _____

2.2 Organisation Type: _____

2.3 Street Address of Organisation: _____

2.4 Contact Name: _____

2.5 Contact Numbers: _____

3.0 Facility Details

3.1 Type of Facilities and Address (e.g. storage shed, gymnasium, club house, class room, playing field/court, chapel):

_____

_____

_____

3.2 Building Materials - Floors: _____

Walls: _____

_____

3.3 Type of Playing Fields/Courts (e.g. grass, asphalt, clay):

_____

_____

_____

3.4 Heights of floors or playing courts/fields above natural ground level:

_____

_____

_____

4.0 Flood History

4.1 Please describe the previous experience of flooding for your organisation:
(List the years of the flood and the extent of the flooding in relation to your organisation).

_____

_____

_____

_____

_____

_____

_____

_____

4.2 Describe the damage to premises, equipment, playing fields, etc previously affected by flooding, and the approximate value (e.g. playing surfaces, sporting equipment).

_____

_____

_____

_____

_____

_____

_____

_____

4.3 *Describe damage to building structures and fittings from floods, and value:* (Particular items likely to need replacing are carpets, metal filing cabinets, lighting, plaster walls which may warp or need repainting, particle board and masonite furniture which disintegrates).

4.4 *Length of time before the organisation's normal activities resumed?* (This includes the time during the flood and the time taken to clean up after the flood).

4.5 *Is this level of damage likely to occur after future flood events?* (Think about this in terms of the July flood (1 in 20 year event), a flood that is approximately one metre higher than the July flood (i.e. 1 in 100 year event) and a flood that is approximately three metres higher than the July flood (ie an extreme flood). These flood levels are shown on the attached map).

4.6 *Potential damage to equipment, premises, playing fields, etc in the event of a larger flood:* (Note that in a 1 in 100 year flood the flood level is approximately one metre higher than the 1998 flood, and the extreme flood event is approximately three metres higher).

4.7 Did your organisation have any plans for improvements to property or to purchase new equipment this year or next? If so what were they?

4.8 Does the impact of the recent floods deter you from carrying out the works listed above? Please give reasons.

4.9 Other Details:
(e.g. other results of floods, details of restricted access to facilities, etc).

Any additional information such as plans of buildings, surveys, etc would be greatly appreciated.

It would be greatly appreciated if you could return this survey by Tuesday 29 December 1998 even if you have been unable to answer all questions. Please return to:

Anna Sherriff
SMEC Australia
PO BOX 1052
North Sydney NSW 2060

Thank you for your assistance

GUNNEDAH FLOODPLAIN MANAGEMENT STUDY

Page No. ___

Consultant : SMEC

Collected By : _____

Street : _____

Date : _____

House No.	Unit No.	Resid. Code	Comments	Floor Levelling			Construction Type (Ground Floor)					Storeys	Footprint of Bldg			Condition of Building			Garden		Value Code A,B,C,D
				Ground Level	Height to Floor	Floor Level	Floor Timber	Conc	Walls Fibro	Brick	Other		S	A	L	P	A	E	A	E	

Residential Code = A.Detached House B.Dual Occ D.Duplex E.Terrace F.Other (details) U.Units

Non-Residential Code = 1.Retail 2.Warehouse 3.Office 4.Industrial 5.Educational 6.Health Care 7.Public Utility 8.Other (state)

SMEC

GUNNEDAH FLOODPLAIN MANAGEMENT STUDY

Social Survey for Residential Premises

Details

Name:_____ Date:_____

_____ Telephone:_____

Address:_____ How long at this address?_____

_____ How long in the area?_____

Tenure?_____

Flood History

1 Has your property been affected by flooding? If no please go to question 32.

Yes	No

2 How many floods have you experienced?

One	Two	Three - five	Five +

3 Please state the dates/year of these floods:

_____

4 How deep was the highest flood water level?

Location	Depth (approx millimetres)	Did Not Enter
Above floor of main building		
Above floor of other buildings		
Above ground at fences		
Above grounds		
Above road adjacent to property		
Other		

5 Was the highest floodwater travelling

Fast?	Slow?	Still?

6 Did the highest flood:

Action	Fences?		Walls?		Buildings?	
Knock over	Yes	No	Yes	No	Yes	No
Build up against	Yes	No	Yes	No	Yes	No

7 Flood damages or losses from the highest flood

Did the Highest Flood Cause:	No	If Yes		
Damage to your gardens?		Considerable	Moderate	Minimal
Damage to your equipment?		Indicate approximate cost		
Damage to your house?		Floor/Structure	Walls	Furniture
Loss of irreplaceable items		What were these items:		

8 Did the flood ever threaten your life or the life of a family member?

Yes	No

9 Why do you choose to live/rent a property that is flood affected?

Has always been my home	Affordable housing	Flood effects are minor	Like to live close to the river

Other_____

Flood Warning and Education

10 How much warning did you have of the highest flood?

2 days or more	1 day	Half a day	A few hours	Less than a few hours

11 Who advised you of the flood?

SES	Radio	Newspaper	Council	Neighbours/ Friends	Other

12 Do you regularly receive information in the mail about what to do in the event of a flood?

Yes	No

13 If yes who prepares this information?

SES	Council	DLWC	Other Government Departments

Other_____

14 Do you read it?

Yes	No

15 What preparations would you make in the advent of a flood?

Move valuables to a high place	Sandbag around house/property	Evacuate premises	Ensure that the house always has emergency supplies	Secure property affected by fast flowing waters

Other _____

16 During the floods were electricity supplies etc cut off to residential properties?

Yes	No

17 If yes, were you made aware that this might occur?

Yes	No

During the Flood

18. What emotions did you feel during the flooding experience? (You may circle more than one)

Excitement	Sadness	Panic	Distress	Fear

Other _____

Can you list the five greatest impacts that flooding had on your lifestyle?
(i.e. isolation, damage to property, emotional distress, missing work, children missing school, health, possessions being stolen etc)

a_____
b_____
c_____
d_____
e_____

19 Was there any way these impacts could have been minimised?

_____
_____
_____
_____
_____

20 Were you forced to evacuate your premises?

Yes	No – Go to Question 26

21 How long was it before you could return to your home?

One day	A few days	One week	Two weeks or more

22 Where did you stay during the evacuation period?

Family	Friends	Accommodation provided for evacuees

Other _____

23 Were you able to carry out any normal activities during this time?

Yes	No

24 If yes, what were these activities?

_____
_____
_____
_____

25 How did you feel during this time?

Sad	Angry	Frustrated	Distressed	Happy

Clean Up

26 How long did the clean up take?

One day	One week	Fortnight	One month	Six months

Other_____

27 Did you have to take time off work for the clean up?

Yes	No

28 How much time did you have to take off work?

One day	A couple of days	One week	One month

29 How long did it take until your lives were back to normal?

One day	One week	Fortnight	One month	Six months

Other_____

30 Was community spirit high during the floods?

Yes	No

31 Who assisted you in your clean up?

Family	Friends	Community Volunteers	SES	Council

Other_____

Note: If answered no to Question 1, complete Questions 32-35 and then Questions 2, 3, 10, 11, 12, 13, 14, 15, 16 and 17.

32 Did the floods disrupt any of the following activities?

Activity	Yes	No
Access to shopping		
Access to friends		
Access to school		
Access to work		
Access out of Gunnedah		
Access to sporting activities		

33 What were the main effects of the disruptions?

Longer travel times	Taking time off work	Children missed school	Less variety in convenience goods	Missed sporting activities

Other _____

34. How long did the disruptions last?

One day	A few days	A week	Fortnight	Month or longer

35. Would you be prepared in the event of a larger flood?

Yes	No

GUNNEDAH FLOODPLAIN MANAGEMENT STUDY

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The following survey aims to obtain information from you on how the flooding has affected your organisation and any premises that it owns and/or uses. In completing this survey we need you to consider the impact of the recent floods as well as more extreme flood events. So, while the recent floods may not have affected you, please consider how your organisation's property or normal activities would be affected in a more extreme flood. It is important to list both direct and indirect impacts of flooding in your response.

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*2.2 Organisation Type:*_____

2.3 Street Address of Organisation: _____

*2.4 Contact Name:*_____

*2.5 Contact Numbers:*_____

3.0 Facility Details

3.1 Type of Facilities and Address (e.g. storage shed, gymnasium, club house, class room, playing field/court, chapel):

_____

_____

_____

*3.2 Building Materials - Floors:*_____

*Walls:*_____

3.3 Type of Playing Fields/Courts (e.g. grass, asphalt, clay):

3.4 Heights of floors or playing courts/fields above natural ground level:

4.0 Flood History

4.1 Please describe the previous experience of flooding for your organisation:
(List the years of the flood and the extent of the flooding in relation to your organisation).

4.2 Describe the damage to premises, equipment, playing fields, etc previously affected by flooding, and the approximate value (e.g. playing surfaces, sporting equipment).

4.3 Describe damage to building structures and fittings from floods, and value:
(Particular items likely to need replacing are carpets, metal filing cabinets, lighting, plaster walls which may warp or need repainting, particle board and masonite furniture which disintegrates).

4.4 Length of time before the organisation's normal activities resumed?
(This includes the time during the flood and the time taken to clean up after the flood).

4.5 Is this level of damage likely to occur after future flood events?
(Think about this in terms of the July flood (1 in 20 year event), a flood that is approximately one metre higher than the July flood (i.e. 1 in 100 year event) and a flood that is approximately three metres higher than the July flood (ie an extreme flood). These flood levels are shown on the attached map).

4.6 Potential damage to equipment, premises, playing fields, etc in the event of a larger flood: (Note that in a 1 in 100 year flood the flood level is approximately one metre higher than the 1998 flood, and the extreme flood event is approximately three metres higher).

4.7 Did your organisation have any plans for improvements to property or to purchase new equipment this year or next? If so what were they?

4.8 Does the impact of the recent floods deter you from carrying out the works listed above? Please give reasons.

4.9 Other Details:
(e.g. other results of floods, details of restricted access to facilities, etc).

Any additional information such as plans of buildings, surveys, etc would be greatly appreciated.

It would be greatly appreciated if you could return this survey by Tuesday 29 December 1998 even if you have been unable to answer all questions. Please return to:

Anna Sherriff
SMEC Australia
PO BOX 1052
North Sydney NSW 2060

Thank you for your assistance

APPENDIX B

SUMMARY OF COMMUNITY FEEDBACK – STAGE 2 CONSULTATION

SUMMARY OF COMMUNITY COMMENT FORMS
(DISTRIBUTED APRIL 15 MEETINGS)

Carroll

Respondents

1. RD Lang, PO Box 597 Gunnedah
2. Liz Turner, 70 Breeza St Carroll
3. Kevin Wilkinson, 24 Edward St Carroll 2340
4. Maxine & Kevan Kiellor, 'Kiellors Keep' Carroll 2340
5. W & M Weakley
6. Joyce Robinson, 10 Breeza St Carroll

	Flood Modification	Property Modification	Response Modification	Other
1	• does not support flood modification measures generally, especially levees	• generally supportive, but zoning difficult for Carroll • building and development controls should be used	• should be part of the solution and always room for improvement	• should work as much as possible within the constraints of the landscape and nature
2	• flood control dam not viable • levee could be suitable but isolates town, requires home purchases and could cause some local panic • river banks need attention	• generally supported • many homes unsuitable for raising • flood period access to Tamworth more viable than to Gunnedah	• enhanced awareness an local communication necessary • school not adequate for emergency situations	• a local community committee would help local communication and knowledge and provide a point of contact for the SES • changes to farm levels and levees mean that

				there are different flow patterns every flood
3	• generally not supported due to environmental impacts and isolation of several residences	• development controls, materials, etc should be enforced for new residences • new community hall as a refuge a good idea	• good awareness of flood issues in Carroll, as long as adequate warning is provided • better communication between authorities required	• irrigation canals and levees on farms causing abnormal and prolonged flood patterns
4	• flood control dam, retarding basin and levees not supported due to environmental impact and social isolation • bypass floodway may assist with small floods, esp Hass's causeway (?) • better sub-road drainage to allow for flood waters to drain away from the town	• flood prone houses could be purchased, but aren't suitable for raising due to low value • bridge at Hass's causeway and Tommys swamp to improve evacuation access • zoning not applicable	• prediction and awareness good, however, dam water release information very poor	• farm levees need to be looked at • Gunnedah levee could affect Carroll • more community input needed
5	• levee feasibility doubted	•	• improved Carroll refuge would benefit the community	•
6	• enhanced culverts under the main road to drain floodwater	•	• better and more information about local flooding would be beneficial	•

Gunnedah

Respondents

1. Margaret Hood, Lodge Farm, Wean Rd Gunnedah
2. Anon
3. RD Lang, PO Box 597 Gunnedah
4. Geoff McNair, Lot 1, Peppergrove Lane Gunnedah
5. Bryan Smith, 56 Connadilly St Gunnedah
6. Kevin & Una Gardner, 'Hatari', Old Wean Rd Gunnedah
7. Colin Douglas, 183 Marquis St Gunnedah
8. Leonie Studdy, Kareela Gunnedah
9. Roy & Lillian Simpson, 30 Tempest St Gunnedah
10. W & M Weakley

Written Letter

11. G & M Hood, Lodge Farm, Wean Rd Gunnedah
12. Gunnible Landcare Inc, PO Box 714, Gunnedah 2380

	Flood Modification	Property Modification	Response Modification	Other
1	• Levee impacts on others must be investigated • Pighole must not be allowed to overgrow	• Support purchase of houses near playing fields • Houses outside levee may require raising or separate levee	• Use of local radio with regular updates • Better communication between SES, affected residents and other assistance agencies	• If a levee is to be built consideration should be given to the PMF
2	• Possible to combine	• Many properties not suitable	•	•

	levee with heavy vehicle route • False sense of security had built in 14 years since 5% flood	for raising – what happens to them?		
3	• does not support flood modification measures generally, especially levees	• generally supportive • believes that voluntary purchase has previously failed to be supported • building and development controls should be used	• should be part of the solution and always room for improvement	• should work as much as possible within the constraints of the landscape and nature
4	• People on north side of river need to be given due consideration	• Possible house raising north side of river	•	• Need to consider effect on levels on north side of river
5	• Levee the only option • Clear river of debris	• Not necessary if levee installed • Upgrade secondary airstrip	• Not necessary if levee installed • More regular warning updates	• 3.5m levee would solve all local problems
6	• Does not support flood control dams • more study of levee option needed • pighole needs to remain free of vegetation and river cleared	• business premises should be built above 1955 flood • house raising north of river • support measures generally • better access through pighole	• more use of radio and media – two hourly updates • SES to provide advice to affected persons, including other assistance available in recovery	•
7	• Levee only viable solution	• not necessary if levee constructed	• upgrade measuring equipment	• strongly supports levee

	• clear river of fallen trees	• emergency airstrip OK, possibly some upgrading warranted		• levee may be better suited to an alignment along northern bank of STP, inside corner for runoff or possible dam
8	• a levee would act as a deflector for surrounding areas • deflectors dangerous with so many converging waterways	• house raising and property restrictions should continue • SES strip should be maintained	• community awareness should be maintained at all times, ongoing reminders with rate notices for at risk properties • use of local knowledge for flood events and warnings	• all combinations of events and possible eventualities need to be considered, especially for people on the northern side of the river • believe that STP dam caused greater flows and velocities to north
9	• levee should include a Gunnedah bypass • flood control dam may be viable	• house raising and flood proofing supported, but not other measures	• excellent job done to date, ongoing improvement needed	• support levee but all options should be considered
10	• levee needs thorough modelling and discussion	• decision on these measures should follow levee decision	•	•

11	• need to consider all houses in high risk areas, including north of river • pighole should be 'manicured' as preserved as a floodway • modification to southern bridge access ramp and playing field fences to limit debris build up and levee effect • extreme flood levee should also be costed • excavation may be needed between levee and the river to enhance flows • a very small culvert under Kelvin Rd in pighole main channel cuts the road during low floods • a boat access route from north side of river should be created for emergency situations • Cohens Bridge approach could be realigned and raised to meet levee crossing • levee design should provide for a heavy vehicle route
12	• landholders to north of river should be considered in any levee consideration • flood affected land near the junction of the Mooki and Namoi Rivers should be mapped as part of the study • more consultation with those north of the town is required • flood response planning and measures needed for affected properties north of town

APPENDIX C

FLOOD INTELLIGENCE CARD

DRAFT FLOOD INTELLIGENCE CARD
GUNNEDAH - GAUGE NUMBER 419001
AS AT 19 NOVEMBER 1998

Height	Consequence
	DHQ will advise property owners of the need to move livestock and machinery when there are significant rises in the river. Historical records indicate that the most common months for flooding at Gunnedah are January, February, March and July. Many of the effects on houses and properties listed in this card were recorded during the floods of July/August 1998.
6.7	Check for campers along the riverbanks in the area of Cuchans Reserve and near Cohens Bridge and arrange for their relocation.
7.2	A breakout occurs to the north and wter starts to flow over the road at the 'Pig Hole' (GR 378701) approximately 500 m north of Cohens Bridge. Low areas on river flats on the northern side of the Namoi River are inundated. Livestock and machinery has to be moved.
7.3	Water starts to cross the low areas of Kelvin, Bluevale, Wean and Orange Grove roads. These roads may close at short notice from this height. The rural properties on the northern side of the river will become isolated once all of these roads are closed. Alternative routes are available via Manilla. Water starts to encroach on the Woolshed Reserve, the Donnelly playing fields and the western end of Maitland Street near Benevolent Park. Access from Maitland Street into Warrumbungle Street is restricted.
7.32	The Gunnedah to Kelvin road is closed at Cohens Bridge to all but high clearance vehicles. Normal road access to the aerodrome is lost; alternative access is available via the Ballyreagan Bridge and Bluevale Road. A shuttle service by high clearance emergency vehicle is provided to ferry people and stores across the 'Pig Hole' during daylight hours. It is too shallow to operate flood boats with safety at this height.
7.5	Water over the northern approaches of the Ballyreagan Bridge, which closes Bluevale Road. There is no vehicular access to the aerodrome from Gunnedah. Water enters the yard of the house at 103 Chandos Street; occupants are evacuated.
7.6	The soccer fields at Talibah Flat are inundated and water enters the sports canteen located there, notify the owners before this to enable them to make appropriate preparations. About 6 houses on the Talibah Flat are surrounded by water but there are no evacuations needed. About 12-18 hours after this height is reached, water will flow over the Gunnedah to Boggabri Road (MR72) at Barlows Corner about 25 km north west of Gunnedah.
7.7	Water enters the shed at 48 Maitland Street and the outside toilet at 20 Warrumbungle Street. Water under the elevatd houses at 52 and 80 Bloomfield Street.
7.8	The shuttle service across the 'Pig Hole' by high clearance vehicle ceases and taken over by flood boats. Water surrounds the elevated house at 71 Maitland Street. Water over the road at the intersection of Bloomfield and Rosemary Streets restricts access to the workshop of G Sansons Powder Coating. Water enters the garage at 14 Little Conadilly Street.
7.9	11/2/92 Peak height. The house at 103 Chandos Street was evacuated.
7.92	The house at 169 Marquis Street has water over the floor. Water over the road restricts access to 107 and 109 (Dot Fleming - Flood post in front yard) Maitland Street and 92 Bloomfield Street.
8.0	Continuing breakout causes water to spread towards the south, away from the river, inundating the lower portions of Gunnedah. Water under the elevated house at 45 and 85 Bloomfield Street. Water enters the houses at 40 Rosemary Street, 34 Little Conadilly Street and 86 Bloomfield Street.

8.05	14/01/62 Peak height. In this event, a total of six families were evacuated. The majority of these evacuations were from the houses that have since been raised or removed.
8.10	Water enters the house at 163 Marquis Street and 44 Tempest Street. Water under the elevated house at 77 Bloomfield Street. Water covers part of runway 11/29 at the western end of the Gunnedah Aerodrome. The Aerodrome is closed at this time.
8.15	Water enters Wolseley Park and inundates the lower courts of the Gunnedah Tennis Club. This restricts the possible use of the park as a helipad.
8.16	13/2/76 peak height. This was the result of a secondary flood following the major flood of 8.78 metres on the 25 Jan 76 caused by follow up flood rains falling on an already saturated catchment.
8.20	Water enters the houses at: a. 16 and 18 Warrumbungle Street, b. 30 Conadilly Street, and c. 27 and 55 Little Conadilly Street. Water enters the yard at 45 Bloomfield Street. Water surrounds the resudence of the caretaker of the Gunnedah Common (The 'Common House') located near the racecourse entrance.
8.30	Water flows over the retaining wall at the Tourist Caravan Park (51 Henry Street). Water enters the basement of the RSL Club at 94 Bloomfield Street. There is a gymnasium and a lower bar area (The 'Snake Pit') in the basement that requires to be prepared. Water enters the workshop of G Sansons Powder Coating on the corner of Bloomfield and Rosemary Streets and the house at 77 Bloomfield Street. Water under the house at 44 Rosemary Street and in the yard of Graham Harrison's Truck Depot in Elgin Street.
8.33	23/7/50 Peak height
8.38	The Tamworth road (Oxley Highway) may be closed by water flowing over the road between the McDonaugh Bridge over the Mooki River and the Wheakly Bridge over the Mooki Deviation Channel. Note: This occurred on the 29/7/98 but it may be attributable to the influence of the Mooki River and requires further investigation. An alternative route may be available via Qurindi. 10% AEP flood level (200,000 ML/d); source DLWC Flood Study of Gunnedah and Carroll, August 1996.
8.40	The tarmac of the Gunnedah aerodrome is inundated and closed to all aircraft. The emergency airstrip; located on the Pullamin Stock Route, 8km south of Gunnedah and on the Quirindi Road (MR72) (CURLEWIS, 8935-1-N, 1:25,000, GR410622) is activated and controlled by the Gunnedah Shire Council. This airstrip is 1,100 metres long and is suitable for use by twin engine aircraft up to and including Caribou. Rotary wing aircraft tasked by the SES will use the helipad at the Gunnedah District Hospital. The river flats area in the vicinity of the aerodrome (Peppergrove Lane, Bluevale Road, Campbells Lane, Wean Road and Kelvin Road) is inundated. The homes and occupants are not at risk but livestocka nd machinery needs to have been relocated by this height. Water in the shed of 19 Conadilly Street. Water enters the main hanger at the Gunnedah aerodrome. Water enters the house at 78B Maitland Street. Water under raised house at 153 Marquis Street. The lower end of the Gunnedah Tourist Caravan Park is inundated. Water across Warrumbungle Street denies access to houses in Warrumbungle Street below Conadilly Street and the entrance to the Overland Motel on the corner of Warrumbungle and Conadilly Street.
8.50	Water over the floor of the house at 18 Warrumbungle Street. Water enters the Gunnedah Ag-Ware P/L shop at 68 Conadilly Street and the rear of the St Vincent De Paul shop at 146 Marquis Street. Water under the raised house at 71 Maitland Street. Water under the house at 24 Little Conadilly Street and 110 Chandos Street.

8.53	9/1/74 Peak height. The volume of this flood was only one third of that of the flood of 1971 although the Mooki contribution was the a\same in both. The Mooki catchment contributed about 38% of the total flow passing Gunnedah. In this event, there was a total of 50-60 houses evacuated. Note: Since then a number of the affected houses have been raised or relocated.
8.60	Water covers the machinery display area of Peel Valley Machinery at 73 Conadilly Street (on north side of road). Water under the house at 96 Maitland Street. Water enters the houses at 19 Little Conadilly Street and 97 Maitland Street. Water overtopped the levee at 'Bimbi' inundating the house (Jul 98).
8.70	Water enters the houses at 53 Wentwprth Street and 91 Little Conadilly Street. Water enters the business premises of Lawrences Garage at 60 Conadilly Street, Gunnedah Autoelectrics at 66 Conadilly Street and Light Engineering at 62 Bloomfield Street.
	Water threatens the houses at 104 Chandos Street, 46 Little Conadilly Street and the business premises of Gunnedah Workshop Enterprises at 71 Conadilly Street and 'Focus on Fitness' at 30 Tempest Street.
8.76	Peak height 1976. In this flood there was a total of about 55 houses/businesses flooded.
8.80	Water entered the premises of Brown's tyre service at 70 Conadilly Street, the Old Freezing Works at 94 Maitland Street, 'The Fitness Factory' at 34 Tempest Street and the aerodrome maintenance shed. Water enters the houses at 38 Rosemary Street, 55 Little Conadilly Street, 85 Chandos Street, 78B Maitland Street, 94 Maitland Street and 7 Warrumbungle Street. Water under houses at 62 Conadilly Street, 107 Maitland Street and 34 Tempest Street.
8.845	22/7/98 Peak height. 30 houses were evacuated due to over floor inundation. A further 99 houses were flood affected by floodwater (ie.; raised houses with water around them or houses surrounded by floodwater which required boat access). A total of 32 business premises were inundated and a further 15 were affected due to restricted access and the subsequent loss of business. The Department of Community Services provided support and assistance to 186 families in the Gunnedah area. Peel Valley Showroom sandbagged - water just up to front door. Water entered the workshop of Gunnedah Hydraulics at 65 Conadilly Street.
8.82	5% AEP flood level, 340,000 ML/d; source DLWC Flood Study of Gunnedah and Carroll, August 1996.
8.84	31/1/84 Peak height. It is estimated that a total of 96 premises may be flooded.
8.90	Anecdotal evidence indicates that the effects listed from this height occurred in the 1955 flood and may occur at similar heights in future. Water enters the terminal building at the Gunnedah aerodrome.
8.92	Water enters the house at 58A Abbott Street.
8.98	2/2/71 Peak height. High discharges in both the Peel and Mooki Rivers combined with releases from Keepit Dam to produce major flooding at Gunnedah. The total volume measured during this event was the greatest of all the major floods in the Namoi Valley in 1971. During this flood about 80 houses/businesses were flooded.
9.0	Water in Scott Mayne's house on Bluevale Road and Fred Ramien's house on 'Thornleigh'. Water threatens the houses at 134 Little Conadilly Street, 143 Marquis Street and 104 Chandos Street. These houses may experience overfloor inundation at any stage from this height.
9.35	2% AEP flood level, 600,000 ML/d; source DLWC Flood Study of Gunnedah and Carroll, August 1996.
9.60	26/2/55 Peak height. Although both the Peel and Namoi systems contributed very high flows, their peaks did not coincide at the Peel-Namoi junction thus producing a smaller peak at Gunnedah than might have occurred otherwise. The Peel River contributed about 34% of the total volume estimated to have passed Gunnedah. During this flood about 171 houses/businesses were flooded. Since then about 10 houses have been raised. A similar height today may result in about 161 houses/businesses being flooded. Water in the houses at 20 and 30 Little Barber Street.

APPENDIX D

DAMAGES COSTING METHODOLOGY AND ANNUAL AVERAGE DAMAGES

D1. INTRODUCTION

Flood damages for residential properties in Gunnedah were computed using a suite of computer modules developed by SMEC. The modules can also be used to compute damages for commercial, industrial and public utility properties, but for the Gunnedah Study damages for these properties were computed on a property by property basis using information provided by the property owners. This is usually the best approach, but the generalised procedure is used for studies that involve many commercial, industrial and utility properties where large surveys are not practical. A description of the modules used to compute damages is given below.

D2. GENERALISED PROCEDURE FOR DAMAGES

The procedures use information obtained from a detailed site survey. For the Gunnedah study the survey included all residential buildings located on land inundated by floodwaters from a 3x100 year ARI flood. This survey was designed to establish the data necessary to establish the location and damage to property occupied by buildings, due to a particular storm event. Consequently, the following data is usually obtained:

- addresses of buildings comprising street number and street name as per site visits and Council records
- provision of a building description, ie flat, house, unit
- designation of building types between:
  - residential
  - commercial
  - industrial
  - public institution
  - public utility
- a determination of the damage category within which each building falls as per site visits, ie low, medium or high
- an estimate of building size
- identification of the type of material used in the construction of external walls and floors (residential only)
- estimation of floor level of each building within the flood zone by measuring the height above ground with a staff
- estimation of ground level at each building location, from topographic information taken from orthophoto maps
- identification of the water course responsible for causing possible flood damage to the building
- an identification chainage to locate the building at a point along the designated water course

The value of damages to all property occupied by buildings can be computed for the following categories for particular flood events:

- existing conditions

- proposed design conditions with different flood mitigation options

An additional cost allowance for Council repairs and clean-up of the local infrastructure is also included. Vacant land is considered to contribute negligible damages overall and is normally excluded from the study. For each category above, total damages resulting from all flood events are plotted to produce a damage/frequency curve from which the Average Annual Potential Damage (AAD) is derived. For calculation of AAD the 3 x 1% flood was assumed to have an ARI of 700 years. This was calculated using the flood frequency curves presented by DLWC in their flood study (DLWC 1996).

D3. DATA PRESENTATION - MAPINFO (GIS)

A building data base was established using Access which was linked to a digital cadastral plan of Gunnedah. The information held within the database was tied to individual blocks by geocoding and street addresses enabling retrieval of specific data by pressing the mouse pointer within the appropriate boundary.

D3.1 Building Database

The information held within the Building database is tied to an icon of a house/business located at the centroid of the title block. This database comprised the following:

Floor level
Building type (residential, commercial, industrial, public institution, public utility)
Building description or Business type (house, unit, etc or industrial, retail, etc)
Material type (commercial and residential)
Number of stories
Footprint of Building
Condition of Building and Garden (residential only)
Value Code (residential only)
Estimates of building, contents and turnover (commercial only, not comprehensive)

D3.2 Building Damage Assessment

The value of damages to residential buildings is evaluated by incorporating the equations described in the following section into the Access database. Commercial properties were assessed using actual damage data collected through surveys of commercial property owners. Damage curves were developed for low, medium and high levels of flooding.

In the Gunnedah study, damages were computed for all residential and commercial buildings subjected to floodwaters of 1 in 10 year, 1 in 20 year, 1 in 100 year and 3x100 year ARI floods for presently existing conditions and a range of proposed flood mitigation schemes (design conditions).

D4. PROPERTY DAMAGE

D4.1 Building Type

Damage evaluation to individual properties is based on a designation of building type corresponding to a Landuse number, ie:

Residential	-	Landuse 1
Commercial	-	Landuse 2

Industrial	-	Landuse 3
Public institution	-	Landuse 4
Public utility	-	Landuse 5

Each landuse type, except for residential, is further categorised as either a low, medium or high damage category in an attempt to estimate more accurately the direct potential damage to individual properties.

In evaluating property damage for residential landuse types the following equations are used:

Depth of over floor flooding (H) < 1 m

$$D = D_2(0.06 + 1.42H - 0.61H^2)\ R\ (1 + ID) + D_{CLEAN} \quad (1)$$

Depth of over floor flooding (H) ≥ 1 m

$$D = D_2\ (0.75 + 0.12H)\ R\ (1 + ID) + D_{CLEAN} \quad (2)$$

Where D = Value of damage to property ($)
D_2 = Assessed value of residential property damage at 2 m depth of flooding (H) or "size" ($)
H = Depth of over floor flooding (m)
R = Reduction factor by virtue of a flood warning provision. 0.85 was adopted in this study.
ID = Indirect damage factor. 0.2 was adopted for the Gunnedah study.
D_{CLEAN} = Clean-up cost ($)

D4.2 Measures of "Size"

One measure of size is adopted for the evaluation of residential damages and another for the evaluation of the remaining landuse category damages.

For properties other than residential the floor plan area of the building is adopted as the size (A).

For residential landuse an assessed value of residential property damage at a height of 2 m above floor level was adopted as the size based on the table of values as adopted by PPK, 1993 in their Tamworth study, with adjustments to account for the different land values in Gunnedah. The values adopted for the current study are given below:

	Internal	External	Structural
Low value property	$ 7 750	$ 850	$ 4 220
Medium Low value property	$ 9 690	$ 1 050	$ 5 630
Medium High value property	$11 240	$ 1 230	$ 7 050
High value property	$13 370	$ 1 470	$9 150

Based on extensive site survey the medium value property category was adopted as representative of the residential property within the Gunnedah flood zones. Thus the size (D_2) of residential property became the summation of the internal, external and structural amounts of the medium value property category.

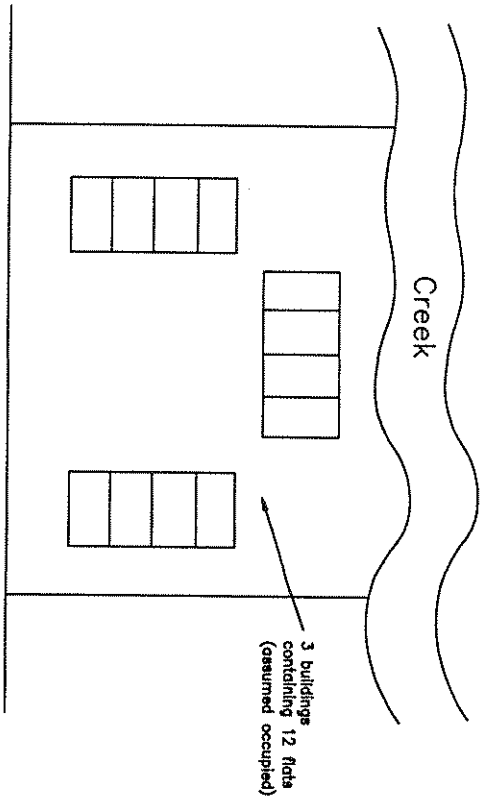
To make an allowance for the difference in comparable "size" between houses, flats and units, the following formulation was derived:

$$D_2 = X\,(Int + Ext) + (Y \times Struct) \qquad (4)$$

D_2	=	Annual assessed value of residential property at 1 m depth of flooding (H) or size (S) ($)
X	=	Total number of units/flats located on title block
Y	=	Total number of buildings which contain X
Int	=	Internal property value ($)
Ext	=	External property value ($)
Struct	=	Structural property value ($)

An example of the use of Equation 4 is the case illustrated in the sketch where 12 flats are assumed to have internal and external values of $16 000 and $1 750, respectively, and there are three buildings having a structural value of $10 000 each.

Thus $D_2 = 12\,(16\,000 + 1\,750) + 3 \times 10\,000 = \$243\,000$



D4.3 Flood Level Interpolation

The MIKE-11 hydraulic model only provides estimates of flood levels at specific cross sections along the creeks being modelled. Intermediate flood levels are therefore computed by interpolation, based on chainage. This was done using an inhouse SMEC program written for the MapInfo package.

D4.4 Reduction Factor Due to Flood Warning

The reduction factors or actual damage factors were determined from a review of previous studies i.e. River Torrens (SMEC 1980), Tamworth (PPK 1993) and Ganmain (SMEC 1997) and an

assessment of the conditions which existed in Gunnedah during the 1998 floods. A reduction factor of 15% was adopted.

D4.5 Indirect Potential Damages

The indirect potential damages expressed as a percentage of direct damages were determined with the aid of previous studies, as listed above, and accounting for conditions in Gunnedah. A factor of 20% was allowed for this component.

D4.6 Potential clean-up costs

As potential clean-up costs were allowed for in the indirect potential damages factors for all landuse types other than residential, a clean-up equation was adopted as used in the 1980 SMEC study, River Torrens, Adelaide and adjusted to suit Gunnedah conditions:

$$D_{CLEAN} = \text{Daily rate} \times Z \times \ln\left(\frac{H}{0.023}\right) \quad (5)$$

Where D_{CLEAN} = Potential clean-up costs ($)
Daily rate = Earnings per day of one worker ($/day)
H = Depth of over floor flooding (m)
Z = Factor accounting for sediment load and deposition

After consideration of other studies, Tamworth (PPK, 1993) and River Torrens (SMEC, 1980) and recent ABS data for Gunnedah, a value of Z = 10 was adopted to account for sediment load and deposition and a daily rate of $55/day. This gave:

$$D_{CLEAN} = 550 \ln\left(\frac{H}{0.023}\right) \quad (6)$$

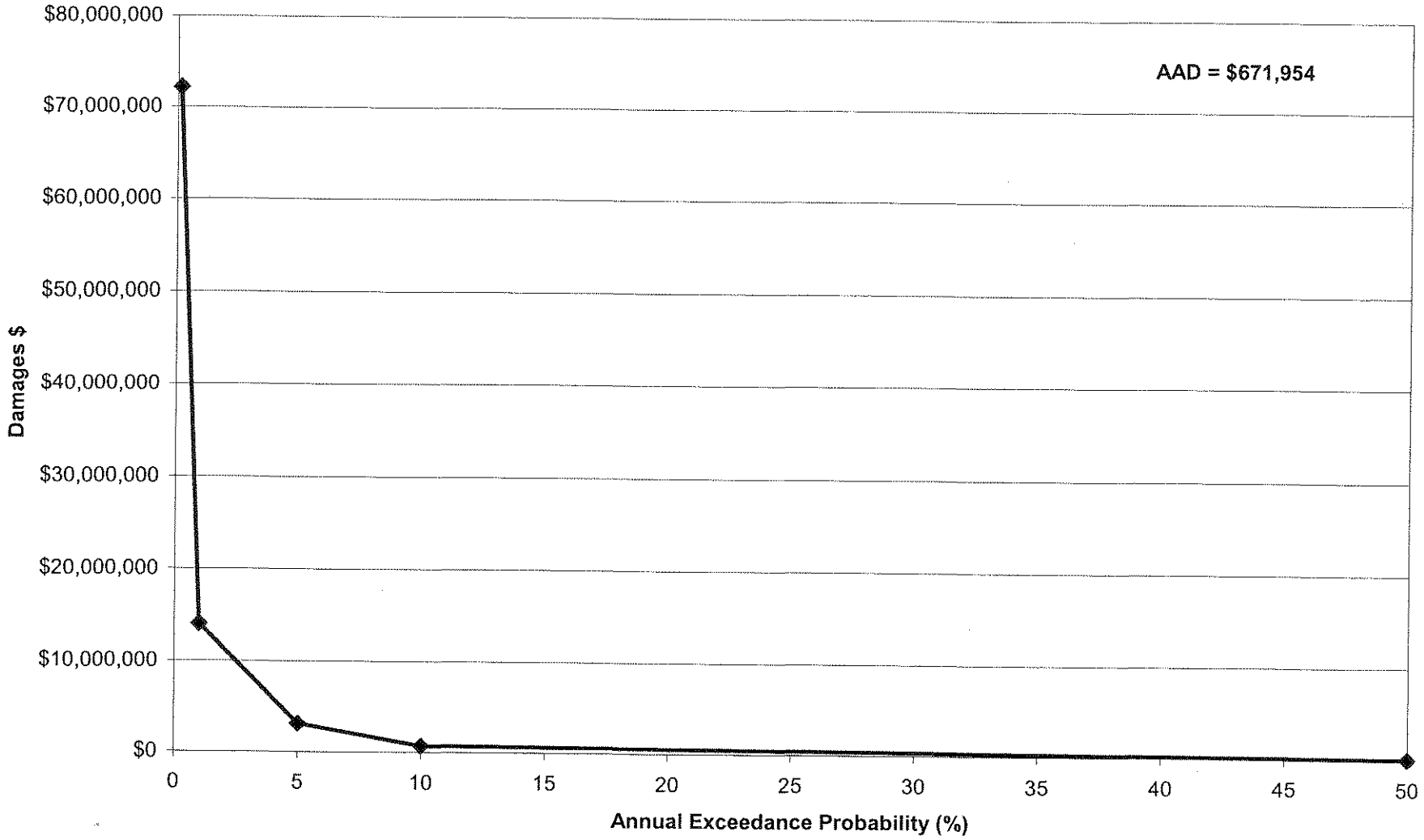
D4.7 Special conditions

Due to the inclusion of the natural logarithm function ln(A) in all equations used to evaluate damages, a value of 'A'< 1 would result in negative values creating instances of negative damages for small depths of over floor flooding ranges. Considering D_{CLEAN}, if D_{CLEAN} is to be greater than zero, h must be greater than 0.023 m.

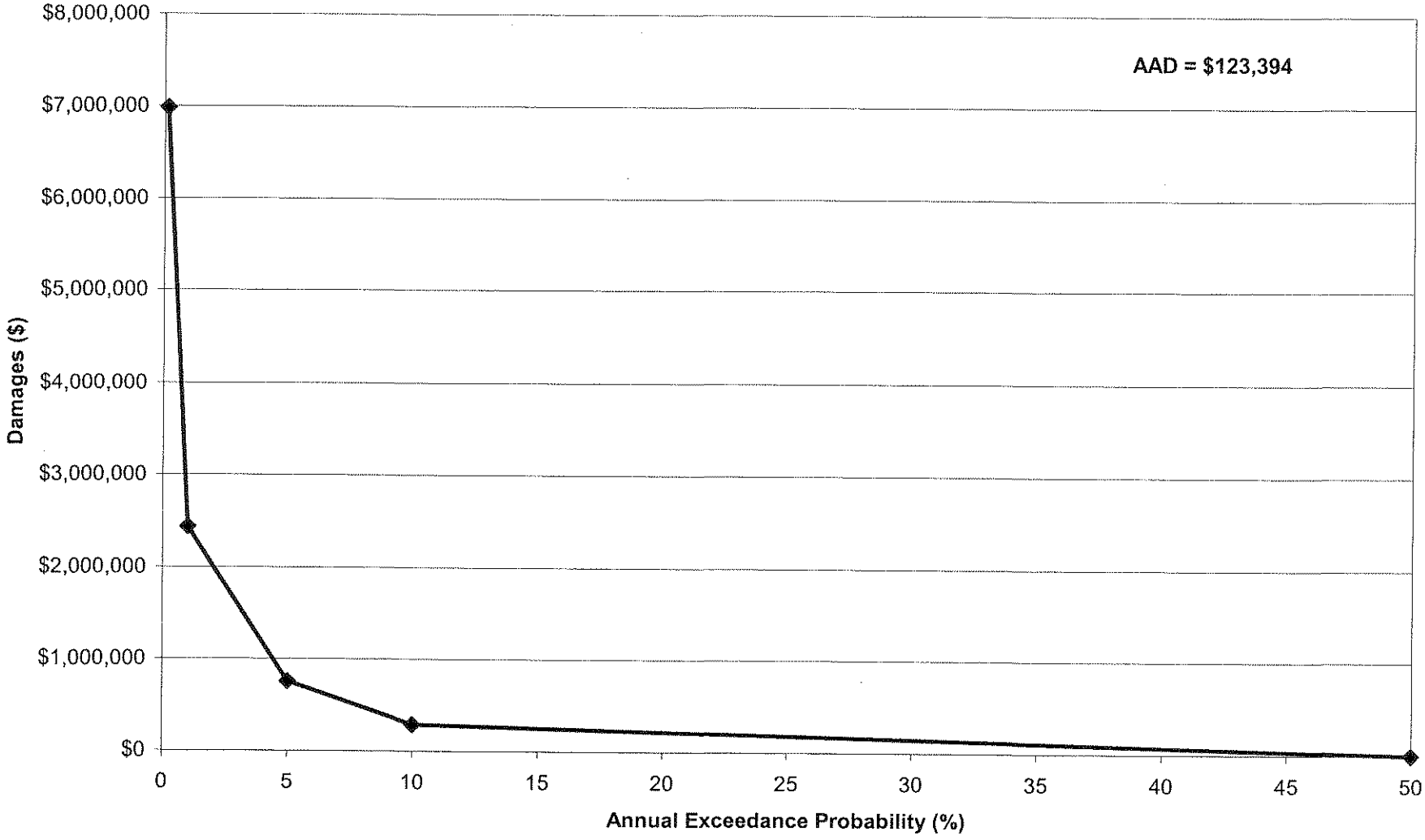
Accordingly, for depths of flooding between zero and (0.023 + 0.01) m (=0.033 m), D_{CLEAN} was estimated from Equation (6) as if the depth, H, was in fact 0.033 m:

$$D_{CLEAN} = 550 \ln(0.033/0.023) = \$198.56$$

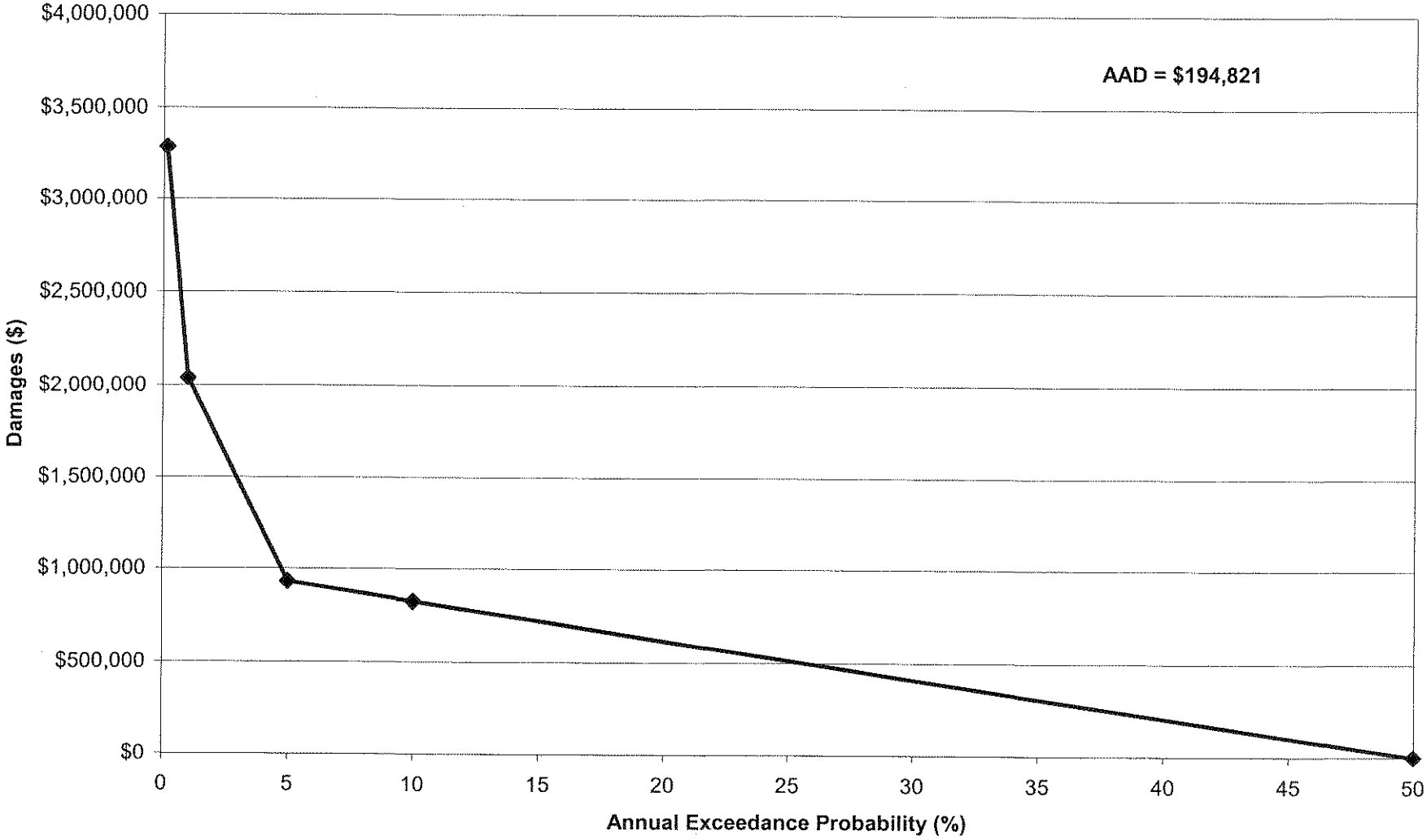
Flood Damages
Gunnedah Commercial Properties



Flood Damages
Gunnedah Residential



Flood Damages
Carroll Residential & Commercial Properties



APPENDIX E

FLOOD COMPATIBLE BUILDING MATERIALS

SCHEDULE 1 FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub-Floor Structure	• pier and beam construction, or • suspended reinforced concrete slab	**Doors**	• solid panel with water proof adhesives • flush door with marine ply filled with closed cell foam • painted material construction • aluminium or galvanised steel frame
Floor Covering	• clay tiles • concrete, precast or in situ • concrete tiles • epoxy, formed-in-place • mastic flooring, formed-in-place • rubber sheets or tiles with chemical set adhesives • silicone floors formed-in-place • vinyl sheets or tiles with chemical-set adhesive • ceramic tiles, fixed with mortar or chemical set adhesive • asphalt tiles, fixed with water resistant adhesive • removable rubber-backed carpet	**Wall and Ceiling Linings**	• asbestos-cement board • brick, face or glazed • clay tile glazed in waterproof mortar • concrete • concrete block • steel with waterproof applications • stone, natural solid or veneer, waterproof grout • glass blocks • glass • plastic sheeting or wall with waterproof adhesive
Wall Structure	• solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• foam or closed cell types
Windows	• aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• galvanised • removable pin hinges

Electrical and Mechanical Equipment

For dwellings constructed on land to which this Policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main power supply -

Subject to the approval of the relevant power authority, incoming electricity mains, service equipment and meters shall be located 1m above the flood planning level. Means shall be available to easily disconnect the building from the main power supply.

Wiring -

All wiring, power outlets, switches, etc, should, to the maximum extent possible, be located 1m above the flood planning level. All electrical wiring installed below the relevant flood level should be suitable for continuous submergence in water and should contain no fibrous components. Only submersible-type splices should be used below the relevant flood level. All conduits located below the relevant flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment -

All equipment installed below or partially below the flood planning level should be capable of disconnection by a single plug and socket assembly.

Reconnection -

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Heating and air conditioning systems should, to the maximum extent possible, be installed in areas and spaces above the flood planning level. When this is not feasible every precaution should be taken to minimise the damage caused by submersion according to the following guidelines.

Fuel -

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

Installation -

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage thanks should be vented to an elevation of 600 millimetres above the flood planning level.

Ducting -

All ductwork located below the flood planning level should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, the ductwork should be protected by a closure assembly operated from above the flood planning level.

Services

All sewer connections to buildings on flood prone land are to be fitted with reflux valves to prevent backflow of sewage in a flood event.

APPENDIX F

VOLUNTARY PURCHASE PROPERTIES

Gunnedah				
Houses Subject to Voluntary Purchase				
ID	House No	Street	Height to floor	100 yr Flood Level*
99	100	Maitland St	0.1	2.6
85	80	Maitland St	0.2	2.4
416	169	Marquis St	0.25	2.4
89	84	Maitland St	0.48	2.1
87	1/82	Maitland St	0.8	2.1
86	2/82	Maitland St	0.77	1.9
96	94	Maitland St	0.58	1.8
82	78b	Maitland St	0.91	1.7
88	3/82	Maitland St**	0.9	1.7
97	96	Maitland St	2.24	0.2
170	60	Tempest St	2.3	0.0
98	98	Maitland St	2.43	0.0
81	78a	Maitland St	2.71	0.0
221	52	Bloomfield St	2.57	0

* This is the height of the 100 year flood above the floor level

APPENDIX G

POTENTIAL HOUSE RAISING PROPERTIES

Gunnedah - Properties for House Raising							
ID	House No	Street	Height to floor	Floor - timber	Walls - fibro	Walls - other	100 yr Flood Level*
179	12	Little Conadilly St	0				2.3
109	135	Maitland St	0.1	Y		timber	2.1
190	34	Little Conadilly St	0.1	Y		timber	2.1
84	73	Maitland St	0.52	Y	Y	timber	1.8
189	30	Little Conadilly St	0.39	Y		clad	1.8
192	36	Little Conadilly St	0.4	Y	Y		1.7
389	84	Elgin St	0.5			timber	1.7
181	18	Little Conadilly St	0.4	Y		timber	1.7
414	106	Chandos St	0				1.7
391	80	Elgin St	0.3	Y		clad	1.7
411	103	Chandos St	0.1		Y		1.6
107	129	Maitland St	0.6	Y	Y		1.5
305	40	Rosemary St	0.15	Y		timber	1.5
174	16	Warrabungle St	0.5	Y	Y		1.5
188	29	Little Conadilly St	0.47	Y	Y		1.5
171	20	Warrabungle St	0.89	Y	Y		1.4
173	18	Warrabungle St	0.7	Y	Y		1.4
237	86	Bloomfield St	0.1	Y	Y		1.3
184	19	Little Conadilly St	0.53	Y	Y		1.3
166	46	Tempest St	0.07	Y	Y		1.3
306	44	Rosemary St	0.55	Y		clad	1.3
172	22	Warrabungle St	1.1	Y		timber	1.3
387	83	Elgin St	0.62	Y		timber	1.3
419	152	Marquis St	0.77	Y	Y	timber	1.3
162	36	Tempest St	0.05			timber	1.3
420	1/146	Marquis St	0.5	Y	Y	timber	1.3
199	52	Little Conadilly St	0.35	Y		timber	1.2
100	99	Maitland St	0.65	Y	Y	timber	1.2
245	104	Bloomfield St	0.13	Y		timber	1.2
392	75	Elgin St	0.35	Y		clad	1.2
421	2/146	Marquis St	0.5	Y	Y	timber	1.2
165	44	Tempest St	0.15	Y	Y		1.2
388	79	Elgin St	0.6			timber	1.2
317	36	Conadilly St	0.32	Y		clad	1.1
422	144	Marquis St	0.45	Y	Y	timber	1.1
394	76	Elgin St	0.75	Y		timber	1.1
371	61	Abbott St	0.45	Y		timber	1.1
235	84	Bloomfield St	0.4	Y		timber	1.1
198	51	Little Conadilly St	0.55	Y		timber	1.1
227	60	Bloomfield St	0.15	Y		timber	1.0
435	1/157	Marquis St	0.7	Y	Y		1.0
316	34	Conadilly St	0.4	Y		timber	1.0
250	110	Bloomfield St	0.2	Y		timber	1.0
393	73	Elgin St	0.46	Y		timber	1.0
436	2/157	Marquis St	0.7	Y	Y		0.9
395	74	Elgin St	0.7	Y		timber	0.9
390	77	Elgin St	0.7	Y		timber	0.9
256	120	Bloomfield St	0.05	Y	Y		0.9
335	62	Conadilly St	0.56	Y		timber	0.9
315	32	Conadilly St	0.2	Y		timber	0.8
249	108	Bloomfield St	0.4	Y		timber	0.8
304	38	Rosemary St	0.74	Y		timber	0.8
160	28	Tempest St	0.25	Y		timber	0.8
229	66	Bloomfield St	0.38	Y	Y		0.8
91	89	Maitland St	1.43	Y	Y		0.8
396	71	Elgin St	0.51	Y		clad	0.8
369	60	Abbott St	0.7	Y		timber	0.7
193	42	Little Conadilly St	1.26	Y		timber	0.7
115	50	Henry St	1.48	Y	Y		0.7
195	43	Little Conadilly St	0.96	Y		clad	0.7
328	52	Conadilly St	0.76	Y		clad	0.7
397	70	Elgin St	0.6	Y		timber	0.7
326	46	Conadilly St	0.65	Y		timber	0.7

196	46	Little Conadilly St	1.23	Y		clad	0.6
268	60	Osric St	0.95	Y		timber	0.6
255	118	Bloomfield St	0.4	Y		timber	0.6
409	102	Chandos St	0.78	Y		cladding	0.6
348	132	Little Bloomfield St	0.2	Y		timber	0.6
225	54	Bloomfield St	1.06	Y		clad	0.6
410	104	Chandos St	0.93	Y		timber	0.6
398	69	Elgin St	0.65	Y		timber	0.6
257	122	Bloomfield St	0.27	Y	Y		0.6
370	58a	Abbott St	0.55	Y	Y		0.5
201	55	Little Conadilly St	0.77	Y		clad	0.5
370	58a	Abbott St	0.55	Y	Y		0.5
354	142	Little Bloomfield St	0.2	Y		timber	0.5
200	53	Little Conadilly St	1.05	Y		timber	0.5
372	59	Abbott St	0.6	Y		timber	0.5
329	54	Conadilly St	1.08	Y		timber	0.5
161	34	Tempest St	0.7	Y		timber	0.5
259	128	Bloomfield St	0.16	Y		timber	0.4
359	152	Little Bloomfield St	0.1	Y		timber	0.4
423	142	Marquis St	1.05		Y		0.4
244	102a	Bloomfield St	1.2	Y		timber	0.4
239	94	Bloomfield St	0.9	Y		clad	0.4
254	116	Bloomfield St	0.7	Y	Y		0.4
258	126	Bloomfield St	0.33	Y		timber	0.4
241	98	Bloomfield St	0.9	Y		timber	0.4
243	102	Bloomfield St	1			timber	0.4
350	136	Little Bloomfield St	0.25	Y		timber	0.3
267	58	Osric St	0.46	Y		timber	0.3
327	50	Conadilly St	1.15			clad	0.3
252	114	Bloomfield St	0.9	Y		clad	0.3
358	150	Little Bloomfield St	0.15	Y		timber	0.3
373	58	Abbott St	0.4	Y		timber	0.3
374	56	Abbott St	0.3	Y		timber	0.2
379	50	Abbott St	0.15	Y		timber	0.2
360	154	Little Bloomfield St	0.1	Y		timber	0.2
238	92	Bloomfield St	1.13	Y		timber	0.2
377	52	Abbott St	0.25	Y		timber	0.2
349	134	Little Bloomfield St	0.47	Y		timber	0.1
356	146	Little Bloomfield St	0.1	Y	Y		0.1
233	82	Bloomfield St	1.42	Y		clad	0.1
376	54	Abbott St	0.39	Y		timber	0.0
353	140	Little Bloomfield St	0.6	Y	Y		0.0
357	148	Little Bloomfield St	0.2	Y		timber	0.0
355	144	Little Bloomfield St	0.45	Y		clad	0.0
266	56	Osric St	0.35	Y	Y		0.0
260	130	Bloomfield St	0.58	Y		clad	0.0
203	132	Bloomfield St	0.58	Y		clad	0.0
251	112	Bloomfield St	1.21	Y		clad	0.0
242	100	Bloomfield St	1.42	Y		timber	0.0
242	100	Bloomfield St	1.42	Y		timber	0.0
204	134	Bloomfield St	0.62	Y		timber	0.0
314	28	Conadilly St	1.26	Y		timber	0.0

* This is the height of the 100 year flood above the floor level

Gunnedah - Concrete floor properties								
ID	House No	Street	Height to floor	Floor - concrete	Walls - brick	Walls - fibro	Walls - other	100 yr Flood Level*
418	163	Marquis St	0	Y		Y	and timber	2.0
108	131	Maitland St	0.2	Y	Y			1.7
182	17	Little Conadilly St	0.2	Y			sheet metal	1.6
226	56	Bloomfield St	0	Y			tank + shed	1.4
93	93	Maitland St	0.9	Y	Y		stone	1.2
330	56	Conadilly St	0.36	Y			clad	1.2
92	91	Maitland St	1	Y	Y			1.2
248	106	Bloomfield St	0.1	Y	Y			1.2
164	42	Tempest St	0.11	Y		Y		1.2
228	62	Bloomfield St	0.15	Y			sheet metal	1.0
116	48	Henry St	0.52	Y			stone	0.6
117	46	Henry St	0.7	Y		Y		0.0

* This is the height of the 100 year flood above the floor level

Carroll - Properties for House Raising							
ID	House No	Street	Height to floor	Floor - timber	Walls - fibro	Walls - other	100 yr Flood Level*
34	10/15	Gunnedah St	0.5	Y	Y		2.1
28	6/5	Forbes St	0.6	Y	Y		2.0
12	5/20	Breeza St	0.75	Y		timber	2.0
49	9/18	Gunnedah St	0.15	Y	Y		1.8
44	11/20	Gunnedah St	1	Y	Y		1.7
64	1/23	Phillip St	0.2	Y		timber	1.7
47	7/19	Gunnedah St	0.5	Y		clad	1.6
13	5/16	Breeza St	0.5	Y		timber	1.6
38	10/14	Gunnedah St	0.37	Y		timber	1.5
41	11/14	Breeza Lane	0.46	Y		clad	1.5
39	9/14	Gunnedah St	0.35	Y	Y		1.5
21	5/18	Breeza St	0.15	Y		timber	1.5
26	2/19	Breeza St	0.6	Y	Y		1.5
31	7/16	Gunnedah St	0.3	Y		tin and timber	1.4
69	3b/33	Bernard St	0.2	Y		tin	1.4
67	1/27	Bernard St	0.37	Y		timber	1.3
11	15/23	Breeza St	0.85	Y	Y		1.3
20	11/24	Breeza St	0.2	Y		timber	1.3
33	2/12	Gunnedah St	0.9	Y		timber	1.3
35	9/13	Ella St	0.51	Y		timber	1.2
40	6/14	Breeza Lane	0.84	Y	Y	timber	1.2
3	8/28	Breeza St	0.15	Y		timber	1.2
79	10/8	Forbes St	0.65	Y		brick clad	1.2
10	11/22	Breeza St	1.24	Y	Y		1.2
36	14/13	Ella St	0.43	Y	Y	and timber	1.2
48	6/19	Gunnedah St	0.9	Y	Y		1.2
43	8/20	Gunnedah St	1.2	Y	Y		1.1
16	11/25	Breeza St	0.92	Y	Y		1.1
78	8/4	Ella St	0.34	Y		timber	1.1
15	3/16	Breeza St	0.24	Y		timber	1.0
80	10/25	David St	0.84	Y	Y		1.0
71	3/28	Lane A	0.59	Y		timber	1.0
73	8/23	Lane A	0.16	Y	Y		0.9
54	6/27	Phillip St	1.14	Y	Y		0.9
66	lot110	Phillip St	0.75	Y	Y		0.9
61	5/34	Phillip St	0.2	Y		timber	0.9
29	6/18	Gunnedah St	0.95	Y	Y		0.9
51	4/28	Phillip St	0.73	Y		timber	0.9
55	2/27	Phillip St	0.85	Y	Y		0.8
1	6/28	Breeza St	0.65	Y	Y		0.8
30	9/17	Gunnedah St	1.1	Y		clad	0.8
72	10/23	Lane A	0.2	Y		timber	0.8
18	15/25	Breeza St	0.65	Y		timber	0.8
25	3/19	Breeza St	1.18	Y	Y		0.7
42	9/20	Gunnedah St	1.17	Y		clad	0.7
8	14/22	Breeza St	1.1	Y		clad	0.6
24	13/23	Breeza St	1.1	Y	Y		0.5
53	10/27	Phillip St	1.35	Y	Y		0.5
52	2/28	Phillip St	1.24	Y		timber	0.5
19	1/17	Breeza St	1.25	Y	Y		0.4
27	14/23	Breeza St	1.48	Y	Y		0.3
14	4/16	Breeza St	1.41	Y		clad	0.3
63	7/34	Phillip St	0.91	Y	Y		0.3
77	7/38	Edward St	0.8	Y		timber	0.1
62	6/34	Phillip St	1.1	Y		brick clad	0.1

* This is the height of the 100 year flood above the floor level

Carroll - Concrete floor properties							
ID	House No	Street	Height to floor	Floor - concrete	Walls - brick	Walls - fibro	100 yr Flood Level*
68	3a/33	Bernard St	0.8	Y		Y	1.1
17	12/25	Breeza St	0.79	Y		Y	0.9
32	6/16	Gunnedah St	0.05	Y	Y		2.2
56	4/33	Phillip St	0.6	Y		Y	0.9
58	7/33	Phillip St	0.1	Y	Y		0.7

* This is the height of the 100 year flood above the floor level

APPENDIX H

COST BENEFIT ANALYSIS – ASSUMPTIONS AND SENSITIVITY ANALYSIS

Cost benefit Analysis

Gunnedah Levee

Capital Cost for construction of levee	$	5,800,000
Variation in cost		0%
Actual Cost used in the analysis	$	5,800,000
Annual maintenance Cost %		0.50%
Annual Inspection, Monitoring Cost		
Average Annual Damage	$	795,348
Variation in AAD		0%
Actual Benefits used in the analysis	$	795,348
Discount Rate		7%
Construction period		2 yrs
Maintenance period commences from		3 rd yr
Benefits from levee commences from		3 rd yr
Work to be carried out in 1st yr (% capital cost)		60%
Work to be carried out in 2nd yr (% capital cost)		40%

Assumptions:

1. Future costs and benefits were converted to the present values using 7 % discount rate.
2. Construction take 2 years with maintenance commencing the third year.
3. Benefits is commencing after completion of Levee.(ie 3 rd Year)
4. Estimated value of costs and benefits are based on 1999 values.
5. The useful life of the levee is assumed to be atleast 30 yrs given proper maintenance.
6. Construction cost splits into 60%, 40% for the first and second year respectively.
7. Only the reduction in flood damage (AAD) due to levee is considered as benefits for the analysis.
8. Recurrent expenses (maintenance, monitoring and inspection) of the levee is 0.5 % of capital cos

Cost Benefit Analysis

Gunnedah Levee

Sensitivity Analysis

Capital Cost Vaiation	Benefits Variation (Annual Average Damage)	Benefit Cost Ratio at assumed Discount Rate (%)		
		4%	7%	10%
Capital Cost + 20 %	AAD + 20%	2.15	1.54	1.16
	AAD	1.78	1.27	0.96
	AAD - 20%	1.41	1.01	0.76
Capital Cost	AAD + 20%	2.60	1.86	1.40
	AAD	2.15	1.54	1.16
	AAD - 20%	1.70	1.22	0.92
Capital Cost - 20 %	AAD + 20%	3.27	2.34	1.76
	AAD	2.71	1.94	1.46
	AAD - 20%	2.15	1.54	1.16

Cost benefit Analysis

Gunnedah - House Purchase and Raising Option

Capital Cost for construction of levee	$	-
House Purchase	$	980,000
House raising	$	5,160,000
Total Cost	$	6,140,000
Variation in cost		0%
Actual Cost used in the analysis	$	6,140,000
Annual maintenance for heritage properties	$	20,000
Average Annual Damage (AAD)	$	123,394
Variation in AAD		0%
Actual Benefits used in the analysis	$	123,394
Discount Rate		7%
Construction period		10 yrs
Maintenance period only for heritage building commences from		1 st yr
Benefits from reduction of flood damage (linear up to 10 yrs and full amount thereafter)		2 nd yr
Work to be carried out in 1st yr (% capital cost)		10%
Work to be carried out in 2nd yr (% capital cost)		10%
Work to be carried out in nth yr (% capital cost)		10%
Work to be carried out in 10 th yr (% capital cost)		10%

Assumptions:

1. Future costs and benefits were converted to the present values using 7 % discount rate.
2. Construction take 10 years with no maintenance to residential property.
3. Benefits is commencing from 2nd year and increases gradually upto 11 yr and constant AAD up to 50 yr
4. Estimated value of costs and benefits are based on 1999 values.
5. The useful life of the works is assumed to be atleast 50 yrs given proper maintenance.
6. Construction cost splits equally for 10 yrs.
7. Only the reduction in flood damage (AAD) due to construction is considered as benefits for the analysis.
8. No maintenance to residential properties, However $ 20000 allowed for a heritage property.

Cost Benefit Analysis

Gunnedah - House Purchase and Raising Option

Sensitivity Analysis

Capital Cost Vaiation	Benefits Variation (Annual Average Damage)	Benefit Cost Ratio at assumed Discount Rate (%)		
		4%	7%	10%
Capital Cost + 20 %	AAD + 20%	0.34	0.22	0.15
	AAD	0.27	0.17	0.12
	AAD - 20%	0.20	0.13	0.09
Capital Cost	AAD + 20%	0.41	0.26	0.19
	AAD	0.33	0.21	0.15
	AAD - 20%	0.25	0.15	0.11
Capital Cost - 20 %	AAD + 20%	0.52	0.33	0.23
	AAD	0.41	0.26	0.18
	AAD - 20%	0.31	0.19	0.13

Cost Benefit Analysis

Carroll - Levee option

Sensitivity Analysis

Capital Cost Vaiation	Benefits Variation (Annual Average Damage)	Benefit Cost Ratio at assumed Discount Rate (%) 4%	7%	10%
Capital Cost + 20 %	AAD + 20%	1.24	0.89	0.67
	AAD	1.02	0.73	0.55
	AAD - 20%	0.80	0.57	0.43
Capital Cost	AAD + 20%	1.51	1.08	0.81
	AAD	1.24	0.89	0.67
	AAD - 20%	0.98	0.70	0.53
Capital Cost - 20 %	AAD + 20%	1.90	1.36	1.03
	AAD	1.57	1.13	0.85
	AAD - 20%	1.24	0.89	0.67

Cost benefit Analysis

Carroll - Levee option

Capital Cost for construction of levee	$	2,395,000
House Purchase	$	-
Easement Costs	$	-
Total Cost	$	2,395,000
Variation in cost		0%
Actual Cost used in the analysis	$	2,395,000
Annual maintenance Cost %		0.50%
Annual Inspection, Monitoring Cost		
Average Annual Damage (AAD)	$	194,821
Variation in AAD		0%
Actual Benefits used in the analysis	$	194,821
Discount Rate		7%
Construction period		2 yrs
Maintenance period commences from		3 rd yr
Benefits from levee commences from		3 rd yr
Work to be carried out in 1st yr (% capital cost)		60%
Work to be carried out in 2nd yr (% capital cost)		40%

Assumptions:

1. Future costs and benefits were converted to the present values using 7 % discount rate.
2. Construction take 2 years with maintenance commencing the third year.
3. Benefits is commencing after completion of Levee.(ie 3 rd Year)
4. Estimated value of costs and benefits are based on 1999 values.
5. The useful life of the levee is assumed to be atleast 30 yrs given proper maintenance.
6. Construction cost splits into 60%, 40% for the first and second year respectively.
7. Only the reduction in flood damage (AAD) due to levee is considered as benefits for the analysis.
8. Recurrent expenses (maintenance, monitoring and inspection) of the levee is 0.5 % of capital cost.

Cost Benefit Analysis

Carroll - House Purchase and Raising Option

Sensitivity Analysis

		Benefit Cost Ratio at assumed Discount Rate (%)		
Capital Cost Vaiation	Benefits Variation (Annual Average Damage)	4%	7%	10%
Capital Cost + 20 %	AAD + 20%	1.33	0.87	0.62
	AAD	1.09	0.70	0.50
	AAD - 20%	0.84	0.54	0.38
Capital Cost	AAD + 20%	1.60	1.04	0.75
	AAD	1.30	0.85	0.60
	AAD - 20%	1.01	0.65	0.46
Capital Cost - 20 %	AAD + 20%	2.00	1.30	0.93
	AAD	1.63	1.06	0.75
	AAD - 20%	1.26	0.81	0.58

Cost benefit Analysis

Carroll - House Purchase and Raising Option

Capital Cost for construction of Evacuation Centre	$	300,000
House Purchase/raising	$	2,360,000
Oxly Hwy culvert + Velocity Deflectors	$	40,000
Total Cost	$	2,700,000
Variation in cost		0%
Actual Cost used in the analysis	$	2,700,000
Annual maintenance of evacuation centre	$	20,000
Average Annual Damage (AAD)	$	194,821
Variation in AAD		0%
Actual Benefits used in the analysis	$	194,821
Discount Rate		7%
Construction period		10 yrs
Maintenance period only for evacuation centre commences from		2 nd yr
Benefits from reduction of flood damage (linear up to 10 yrs and full amount thereafter)		2 nd yr
Work to be carried out in 1st yr (% capital cost)		10%
Work to be carried out in 2nd yr (% capital cost)		10%
Work to be carried out in nth yr (% capital cost)		10%
Work to be carried out in 10 th yr (% capital cost)		10%

Assumptions:

1. Future costs and benefits were converted to the present values using 7 % discount rate.
2. Construction take 10 years , 1st yr evacuation cetre & balance residential. (from 10 % of cost)
3. Benefits is commencing from 2nd year and increases gradually upto 11 yr and constant AAD up to 50 yr
4. Estimated value of costs and benefits are based on 1999 values.
5. The useful life of the works is assumed to be atleast 50 yrs given proper maintenance.
6. Construction cost Isplits equally for 10 yrs.
7. Only the reduction in flood damage (AAD) due to construction is considered as benefits for the analysis.
8. No maintenance to residential properties, However $ 20000 allowed for a evacuation centre.

APPENDIX I

LEVEE COSTINGS AND SPECIFICATIONS

SNOWY MOUNTAINS ENGINEERING CORPORATION

Project: Gunnedah Floodplain Management **Contract No.**

Preliminary Cost Estimate for: Gunnedah Levee

Drawing:

Item	Description	Unit	Quantity	Rate	Amount $
1	Site Establishment and Disestablishment	Item			50,000
2	Stripping Of Top Soil in Foundations	m^3	10,500	6.00	63,000
3	Trench Excavations	m^3	9,750	2.00	19,500
4	Compacted Fill with Stabilised Soil	m^3	81,500	15.00	1,222,500
5	Compacted General Fill	m^3	137,000	5.00	685,000
6	Establishment of Vegetation Cover	m^2	9,700	2.00	19,400
7	Soil Testing	Item			100,000
8	Construction of Drainage Culverts	No	4	30,000.00	120,000
9	Construction of Crib Walls at Swamps	Item			250,000
10	Main Access Crossing Chandos Street	Item	1	350,000.00	350,000
11	Access Ramps Old Oxley Highway	Item	1	150,000.00	150,000
12	Land Acquisition Houses	No.	14	70,000.00	980,000
13					
	Sub-Total				4,009,400
12	Survey, Geotechnical, Design and Supervision (15%)				601,410
13	Contingencies (30%)				1,202,820
	TOTAL				5,813,630

SNOWY MOUNTAINS ENGINEERING CORPORATION

Project: Gunnedah Floodplain Management **Contract No.**

Preliminary Cost Estimate for :Carrol Levee

Drawing:

Item	Description	Unit	Quantity	Rate	Amount $
1	Site Establishment and Disestablishment	Item			50,000
2	Stripping Of Top Soil in Foundations	m^3	10,400	6.00	62,400
3	Trench Excavations	m^3	14,100	2.00	28,200
4	Compacted Fill with Stabilised Soil	m^3	61,300	15.00	919,500
5	Compacted General Fill	m^3	55,000	5.00	275,000
6	Establishment of Vegetation Cover	m^2	8,200	2.00	16,400
7	Soil Testing	Item			100,000
8	Construction of Drainage Culverts	No	4	20,000.00	100,000
9	Main Access Crossings Oxley Highway	No	2	150,000.00	100,000
	Sub-Total				1,651,500
10	Survey, Geotechnical, Design and Supervision (15%)				247,725
11	Contingencies (30%)				495,450
	TOTAL				2,394,675

APPENDIX J

HERITAGE ITEMS AND IMPACTS

HERITAGE IMPACTS

NO	ID	NAME	LOCATION	SHI	LEP	RNE	NTA	HS	POTENTIAL FLOOD IMPACTS	POTENTIAL MITIGATION IMPACTS
1	4	Carinya	113 Barber Street, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
2	5	Convent of Mercy Group (incl Chapel and Central Wing)	151-163 Bloomfield Street cnr Henry Street, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ north corner of property inundated by 3*1% AEP flood - water level contour is 267.25	None
3	6	Courthouse	322-324 Conadilly Street cnr Abbott Street, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ property inundated by 3*1% AEP flood - water level contour is 267	None
4	10	Gunnedah Railway Station	45-47 Railway Avenue, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
5	11	Gunnedah Railway Station Group	Werris Creek-Moree Railway, Gunnedah	✓					▪ town side of proposed levee; beyond no building line and house raising line ▪ parts of the railway line are affected by flooding, though the frequency and extent of flooding is unknown.	None
6	14	House	18 Henry Street cnr Little Barber Street, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
7	15	House	136 Barber Street, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
8	17	Meggitt Ltd flour mill (formerly Brunton's Flour Mill); including adjoining land	New Street opposite Railway Avenue, Gunnedah	✓	✓	✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ property inundated by 3*1% AEP flood - water level contour is 266.25	Close to existing levee. New levee may change flood behaviour, potentially changing the impact of floodwaters on the property.
9	18	Mumalong incl picket fence	14 Henry Street cnr Barber Street, Gunnedah	✓		✓	✓		▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None

HERITAGE IMPACTS

NO	ID	NAME	LOCATION	SHI	LEP	RNE	NTA	HS	POTENTIAL FLOOD IMPACTS	POTENTIAL MITIGATION IMPACTS
10	24	Christ Church Anglican Church	117 Barber Street cnr Elgin Street, Gunnedah	✓	✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
11	25	Brick building (formerly Cohens Warehouse / John Affleck Building)	82 Maitland Street, Gunnedah	✓	✓	✓	✓		▪ river side of levee; within no building line and house raising line ▪ high hazard floodway ▪ property inundated by 5% AEP flood - depth 1.5->2.5 m ▪ inundated by 1% AEP flood - depth >2.5m ▪ inundated by 3*1% AEP flood - water level contour 267	Positioned on the river side of the proposed levee, there is significant potential for damage to be caused to the building during flooding. One option to acquire the property and demolish the building, to allow better flood flow paths, may be pursued. Alternatively, a low risk use may be adopted for the building, such as a community hall, though residential use is inappropriate. Such alternative use of the building may aid its preservation.
12	26	House	129 Barber Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
13	27	Brick building (formerly original Methodist Church)	44 Abbott Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ northern half of property low hazard flood fringe ▪ northern half of property inundated by 1% AEP flood - depth >0.0-0.5m ▪ property inundated by3*1% AEP flood - water level contour 267	Buildings at the opposite side of Bloomfield St are subject to house raising. Aesthetic impact of this on the heritage significance of the building should be considered. Proposed levee would protect the building from flooding up to the level of the 1% AEP flood event.
14	28	Brick building (formerly original Catholic Church)	356 Conadilly Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None

HERITAGE IMPACTS

NO	ID	NAME	LOCATION	SHI	LEP	RNE	NTA	HS	POTENTIAL FLOOD IMPACTS	POTENTIAL MITIGATION IMPACTS
15	29	Brick building (original convent for Sisters of Mercy)	93 Maitland Street, Gunnedah		✓			✓	▪ town side of proposed levee; beyond no building line ▪ within house raising line ▪ high hazard flood fringe ▪ inundated by 5% AEP flood - depth >0.5-1.5m ▪ inundated by 1% AEP flood - depth >1.0-2.0m ▪ inundated by 3*1% AEP flood - water level contour 267	The levee is proposed to pass at the front of the property, significantly impacting on the appearance of the building. Surrounding houses are also subject to house raising. This adverse aesthetic impact may act to decrease heritage significance of the building. Proposed levee would protect the building up to the level of the 1% AEP flood event.
16	30	Brick school (formerly primary school)	48 Elgin Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ low hazard flood fringe ▪ inundated by 1% AEP flood - depth >0.0-1.0m ▪ inundated by 3*1% AEP flood - water level contour 267	The aesthetic impact of house raising (opposite side of Bloomfield St) on heritage significance of the school should be considered. Proposed levee would protect the building up to the level of the 1% AEP flood event.
17	31	Roseneath (2 storey brick house; formerly George Cohen's residence)	91 Maitland Street, Gunnedah		✓			✓	▪ town side of proposed levee; beyond no building line ▪ within house raising line ▪ high hazard flood fringe ▪ inundated by 5% AEP flood - depth >0.5-1.5m ▪ inundated by 1% AEP flood - depth >1.0-2.0m ▪ inundated by 3*1% AEP flood - water level contour 267	Surrounding houses are subject to house raising. This and the levee passing at the front of the property are likely to have an adverse aesthetic impact on the building and premises, potentially decreasing heritage significance. Those businesses run from the building (B&B and hairdressers) would be adversely affected, which may also affect the preservation of the building. Proposed levee would protect the building up to the level of the 1% AEP flood event.

HERITAGE IMPACTS

NO	ID	NAME	LOCATION	SHI	LEP	RNE	NTA	HS	POTENTIAL FLOOD IMPACTS	POTENTIAL MITIGATION IMPACTS
18	32	Public clock and clock tower	148 Conadilly Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ low hazard flood fringe ▪ inundated by 1% AEP flood - depth >0.0-0.5m ▪ inundated by 3*1% AEP flood - water level contour 266.75	No adverse impact. Proposed levee would protect the building up to the level of the 1% AEP flood event.
19	34	Cenotaph Monument	Conadilly Street cnr Elgin Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ property inundated by 3*1% AEP flood - water level contour is 267	None
20	35	Namoi Flour Mills	74 Marquis Street, Gunnedah		✓				▪ town side of proposed levee; beyond no building line and house raising line ▪ not affected by 3*1% AEP flood	None
21	36	Cohen Bridge	Intersection of Namoi River and Chandos Street, Gunnedah					✓	▪ river side of levee; within no building line and house raising line ▪ high hazard floodway ▪ property inundated by 5% AEP flood - depth >2.5m ▪ inundated by 1% AEP flood - depth >2.5m ▪ inundated by 3*1% flood - water level contour 266.75 ▪ access road to airport to be raised ▪ exotic plants along river to be replaced with natives	Raising of the access road may entail structural alterations to the bridge. These should be carried out in a sympathetic manner, so as to preserve the heritage significance of the bridge. The replacement of exotic plants with native species along the river foreshore has potential to improve the appearance of the bridge.
22	40	"Reveree" Homestead (George Weakley home - 1896)	Carroll					✓	▪ part of property is beyond limit of information ▪ river side of levee ▪ high hazard floodway / flood fringe ▪ inundated by 5% AEP flood - depth >0.0-2.0m ▪ inundated by 1% AEP flood - depth >0.5-2.5m ▪ inundated by 3*1% AEP flood - depth >2.0->2.5m	The proposed levee is likely to cut the property off from the Carroll township, and have an adverse aesthetic impact. Behaviour of flood waters on the property may also change.

ABBREVIATIONS: SHI – State Heritage Inventory; LEP – Local Environmental Plan; RNE – Register of the National Estate; NTA – National Trust of Australia; HS – Gunnedah and District Historical Society.