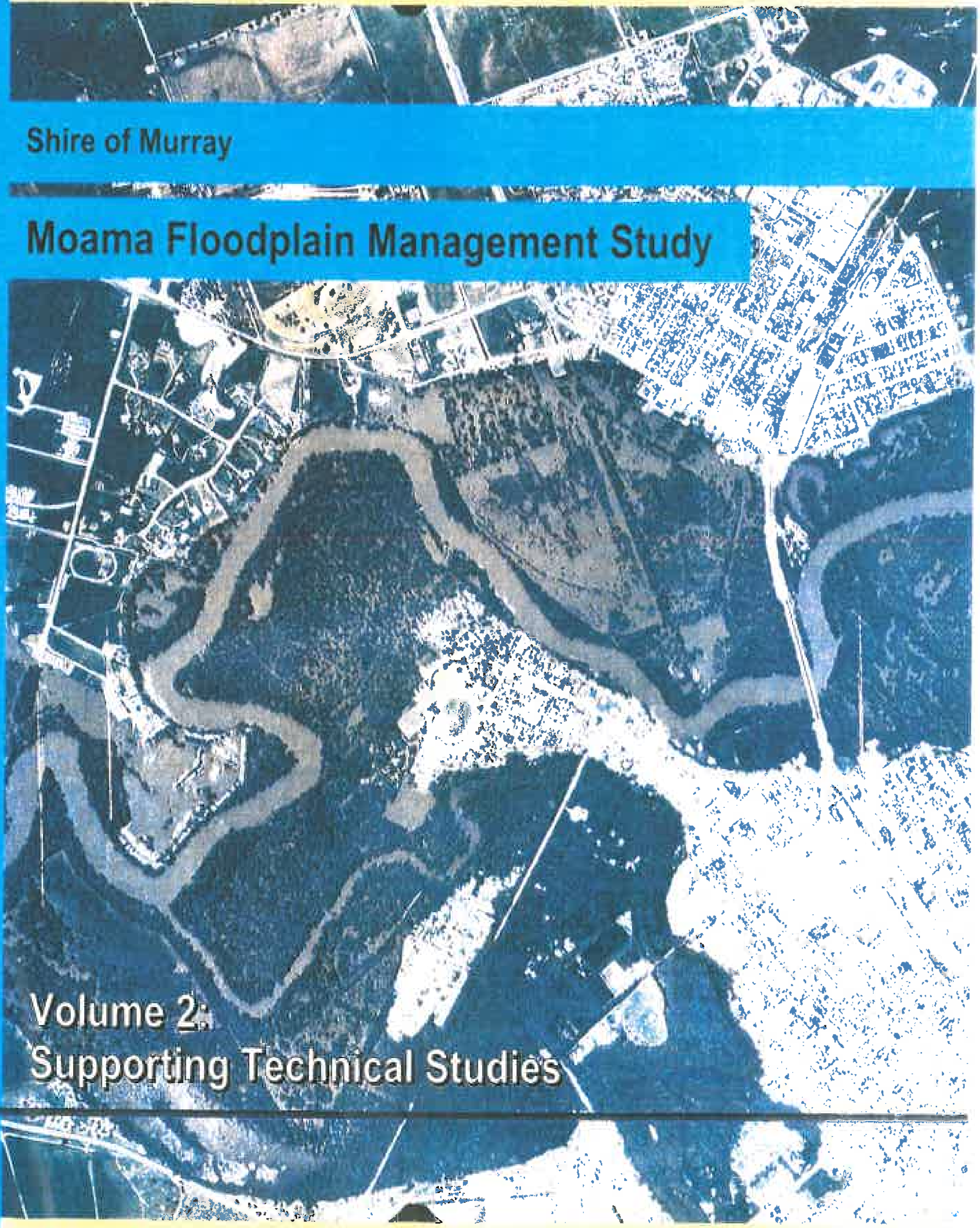
Shire of Murray

Moama Floodplain Management Study



Volume 2: Supporting Technical Studies

January 2001

SINCLAIR KNIGHT MERZ

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Moama Floodplain Management Study

Volume 2:
Supporting Technical Studies

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1. Introduction

1.1 Background

The towns of Echuca and Moama are situated on the floodplains of the Murray River, about 7 km downstream from its confluence with Goulburn River and about 4 km upstream from its confluence with Campaspe River. The approximate catchment area of the Murray, Goulburn and Campaspe Rivers in the vicinity of the towns are about 40,000, 18,000 and 4,000 km^2, respectively. The flood levels in the study area are caused by the complex interactions of floods in the three (3) rivers.

Following the near record floods in the vicinity of Moama/Echuca in 1993, the relevant departments in the Victorian and New South Wales Government and the local authorities undertook a detailed flood study of the Murray River and its floodplain in the area. The purpose of that study was to identify major flood impacts and hazards in the floodplain. The immediate objective of the study was to define the flood behaviour along the Murray River and its floodplain in the vicinity of Moama and Echuca. The long term objective was to develop an hydraulic model with sufficient details to be used later for evaluating floodplain management options.

Sinclair Knight Merz (SKM) carried out the flood study which was completed in 1997 (SKM, 1997). A Steering Committee comprising the New South Wales Department of Land and Water Conservation (DLWC), the Victorian Department of Natural Resources and Environment(DNRE), Shire of Murray and the Shire of Campaspe overviewed the flood study.

Subsequent to the flood study, Sinclair Knight Merz was commissioned to prepare the Moama Floodplain Management Study by Murray Shire Council, with the assistance of the Department of Land and Water Conservation (DLWC).

The purpose of this Study is to address flooding issues on the NSW floodplain from Gilmours Road, Barmah (upstream of the Goulburn River confluence) to Twenty Four Lane, Moama (downstream of the Campaspe River confluence with the Murray). Flooding issues addressed in the study will be developed into a Draft Floodplain Management Plan aimed at providing Council with specific management measures to guide future development and management of flood-affected land. A base map of the study area is shown on **Figure 1.1.**

1.2 NSW Flood Policy

The NSW Flood Prone Land Policy and its associated Floodplain Development Manual has established since 1986 the general principles for floodplain management throughout NSW, including urban and rural floodplains. This policy remains the overriding source of floodplain management principles in NSW.

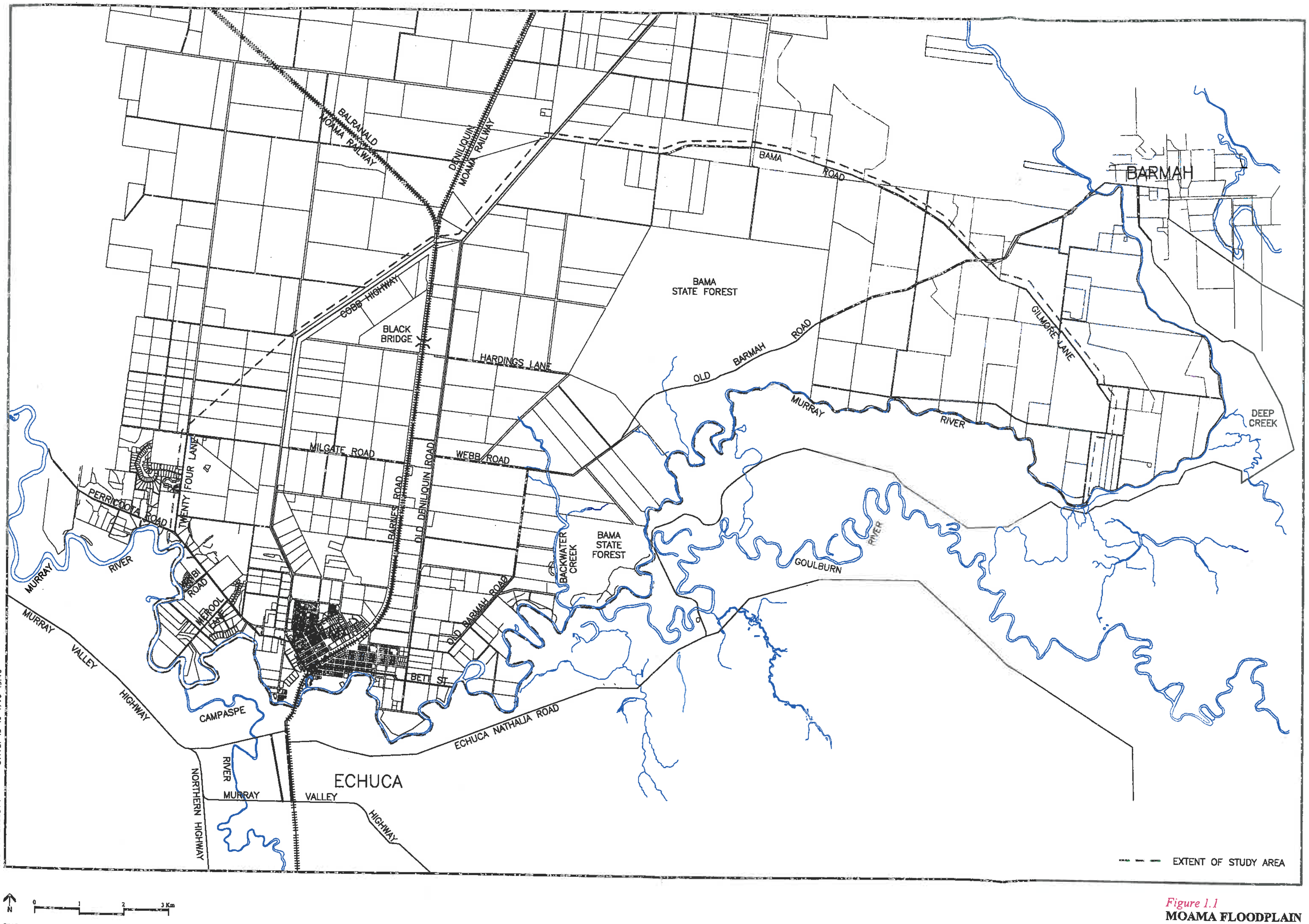

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Figure 1.1
MOAMA FLOODPLAIN BASE MAP

Central to the Flood Policy is the requirement that all floodplain development proposals are to be treated on their merits by regulatory authorities rather than on the application of rules under a prescriptive policy. Under this merit-based approach, flood liability is based on an understanding of the full range of flood behaviour and associated flood risk, taking into account the social, economic and ecological consequences of flooding.

The primary objectives of the policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers,
- to reduce private and public losses resulting from flooding.

At the same time, the policy recognises the benefits of floodplain occupation under appropriate conditions and the particular social, economic and ecological attributes of the floodplain.

Under the 1986 policy **flood liable land** is defined as land which would be inundated as a result of the standard flood. The 'standard' or 'designated' flood is defined as the flood selected for planning purposes through the floodplain management study process. The selection of the flood standard to describe flood liable land should be based on an understanding of flood behaviour and the associated flood risk, and should also take into account social, economic and ecological considerations.

The policy provides to Local Government, and other public authorities such as the Department of Land and Water Conservation (DLWC), immunity from liability in respect of floodplain planning and management advice and actions (provided they were undertaken in good faith).

A proposal to amend the current policy to place greater emphasis on the 'management', rather than 'development' of the floodplain, greater recognition of the ecological processes of the floodplain, and a greater emphasis on flood risk management is currently before the NSW Government. The Moama Floodplain Management Study and associated draft management plan has taken into consideration the principles of flood risk management identified in the new Draft Floodplain Management Manual.

The proposed new flood risk management approach includes additional policy provisions such as:

- Recognition of the need to consider the full range of flood magnitudes, up to and including the probable maximum flood (PMF) and the corresponding flood hazards associated with each flood.
- The implementation of Flood Planning Levels (FPL) rather than the previous concept of one "standard" or "designated" flood level defining flood liable land. Different FPLs may be appropriate for different

categories of land use and for emergency services planning. The proposed use of FPLs do not define the extent of **flood prone land** which is defined by the PMF, and management plans need to recognise that there will be flood prone land above that defined by the FPL.

- Allowing for the sustainable use of the floodplain as a natural resource with an emphasis on the need to consider ways of enhancing the river and floodplain environment.

1.3 Structure of the Report

Section 2 of this report provides background data and information about the study area in terms of geomorphology, social and environmental setting, land use and planning, and experience of flooding.

Section 3 then considers the flood hydrology and hydraulics, and concludes by confirming that the present flood levels used in planning are appropriate. This section draws heavily on the *Moama-Echuca Flood Study* (Sinclair Knight Merz, 1997).

Section 4 reports on results obtained from the hydraulic model of the floodplain, and discusses flood hazards and impacts in both rural and urban parts of the study area. Analysis of the damages incurred by flooding in Moama is included in Section 5.

Sections 6 deals with the planning context under which the Floodplain Management Plan is to be developed. This includes the formal legislative context, as well as discussions of the new risk management context for floodplain management and emergency response procedures. Section 7 proceeds to consider both non-structural and structural options for mitigating the impacts of flooding in Moama and surrounding rural areas.

Section 9 discusses the ecological factors which are relevant in making assessments of environmental impacts. The economic and social impacts of flooding in Moama are evaluated in Section 9, which also compares the benefits and costs associated with the main flood mitigation option.

The recommended draft Floodplain Management Plan and the measures required to implement it, together with a draft Development Control Plan, are included in Volume 1 of this report.

Documents prepared for the process of community consultation are presented in Volume 3.

2. The Moama Floodplain

2.1 Social and Environmental Setting

Moama is located in the Southern Riverina of NSW, some 800 km from Sydney and 200 km from Melbourne. Moama is situated on the Murray River opposite the major Victorian town of Echuca which is a strong influence on the development of Moama.

The Echuca-Moama riverine area is recognised as a major social and environmental asset to both Victoria and NSW. The region supports a growing urban population with a significant agricultural (sheep, cattle, rice and winter cereal), timber and transport base, together with popular tourist and recreational opportunities, particularly associated with the Murray River.

The region is an attractive place for holidays, day trips and retirement because it offers a range of recreational activities based on natural, historical and cultural resources. The development of motels, caravan parks and rural residential establishments have proliferated along or close to the river frontage. Bush camping and boating activities are also popular holiday activities.

2.1.1 History

The area surrounding Moama was originally occupied by the Yorta-Yorta Aboriginal people. The name Moama is believed to have originated from the aboriginal word "moammay, moammy, or moamay" which is said to mean "place of the dead". It is not surprising that the name of Moama is linked to aboriginal burials, given the large sand-hills which surround the area which provide flood free and easy digging burial sites. Descendants of the Yorta Yorta live throughout the area and also in the nearby Cummergunja village, which was originally established as a Mission in 1883 and is just upstream of the study area and close to the surrounding sand-hills.

The first European contact with the area was in 1838 when in the droving of cattle to Adelaide, Moama was deemed to be a suitable place to cross the River. Within five years squatters had established cattle stations in the region. With the cattle markets in Melbourne rather than Sydney, James Maiden, who took up Perricoota Station in 1843, established a punt service across the river in 1845. This crossing was the first cattle crossing on the Murray River and it became a major access route between Victoria and NSW. Moama became the largest cattle market outside Melbourne.

A hotel was established in 1846 by Maiden known as the Junction Inn on the corner of Victoria Street and Chanter Street. A town-site was reserved in 1848, (originally named "Maidens Punt"), with subsequent development of a laundry, blacksmith, shoemaker, carpenter and two carriers. The Maidens Inn Caravan Park, off Chanter Street, is now located in the area of the original inn. A post office was established and the town gazetted in 1851 as "Moama". The original Crown subdivision is in the area generally between Murray Street and Victoria Street, east of the present railway line, and is highly susceptible to flooding from overland and from the river.

A river port was established on the Victorian side of the River in the 1850s when Moama became the outermost port for the first trading paddle-steamer on the Murray River, the Mary Ann. Echuca became the dominant town and by 1856, as Maidens cattle business dropped, Echuca became the terminus of the Melbourne railway and the largest inland port in Australia.

A succession of floods from 1867 caused the complete abandonment of old Moama by 1870, the year of the largest flood on record, and buildings were moved to higher ground to the west (the site of the present town development). Perricoota station was subdivided for selection in 1875. In 1876 a private railway to Deniliquin was established above the 1867 flood. A new post office was erected in 1881 and Moama was incorporated as a municipality in December 1890, with Mr J.Chanter elected as first Mayor.

The railway was taken over by the Victorian Government and joined to the Victorian state system in 1923 at Echuca, when the line to Moulamein was also constructed. Moama has remained closely attached to Echuca, and for a century has been often described as a suburb of Echuca. The difference provided by State laws however has enabled Moama to provide attractions previously unavailable in Echuca, such as clubs with extensive gaming facilities.

While many of the residents of Moama and surrounding areas today are still engaged in mixed farming ventures, the tourism industry, centred on the River and its immediate surrounds, has emerged as a major economic and social force. Moama is also being developed as an ideal town for retirement.

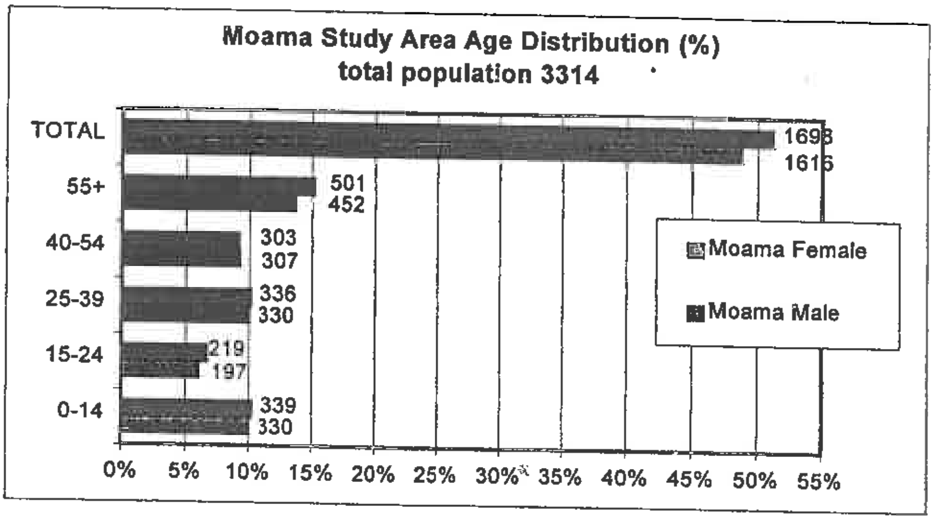
2.1.2 Population

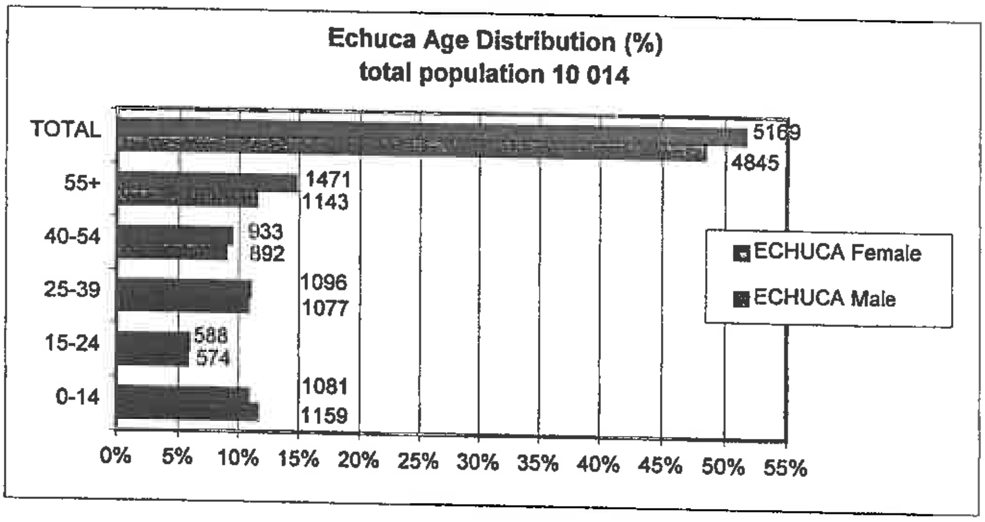
Approximately 13 000 people live in the wider region between Barmah and Torrumbarry Weir, mostly in Echuca or Moama or the smaller river town of Barmah in Victoria.

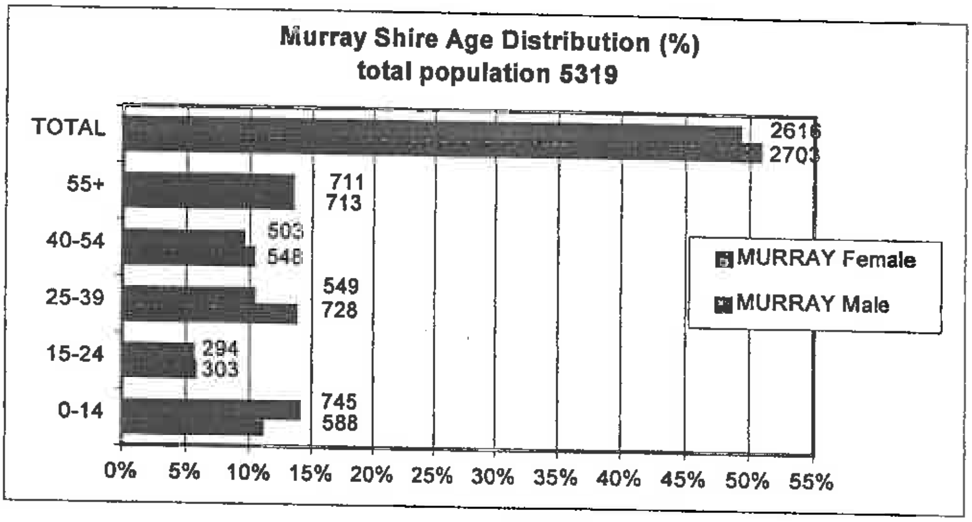
The population of the Moama study area is 3 314. This is approximately one quarter of the population of Echuca (10 014) and almost half of the Murray Shire population (5 319). These population figures have been taken from the 1996 census and a combination of collector districts for the study area.

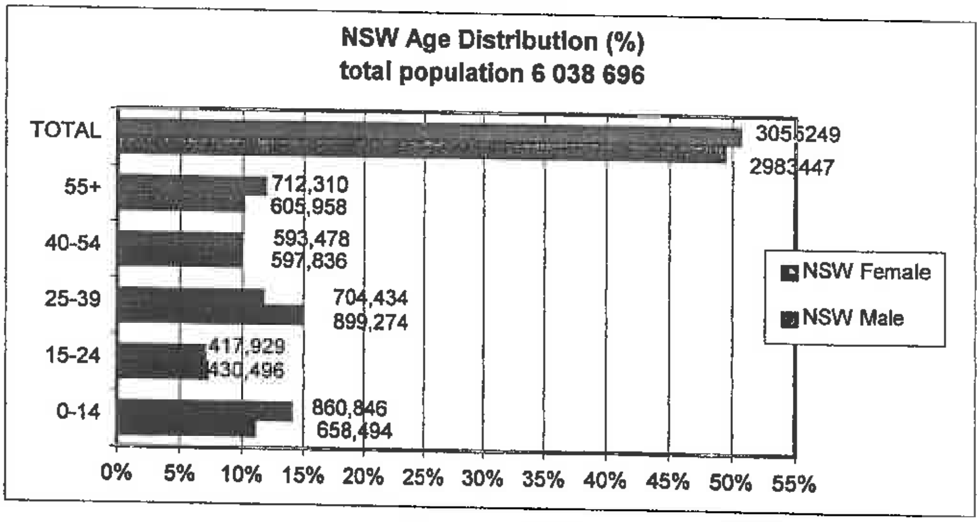
There is a predominance of retired and elderly people (approximately 30% of the population is 55 years and above) within the Moama area. The population is distinctly weighted towards the elderly in comparison with age distributions for Echuca, Murray Shire and also the NSW figures as shown in **Figure 2.1.**

Figure 2.1: Population and Age Distributions





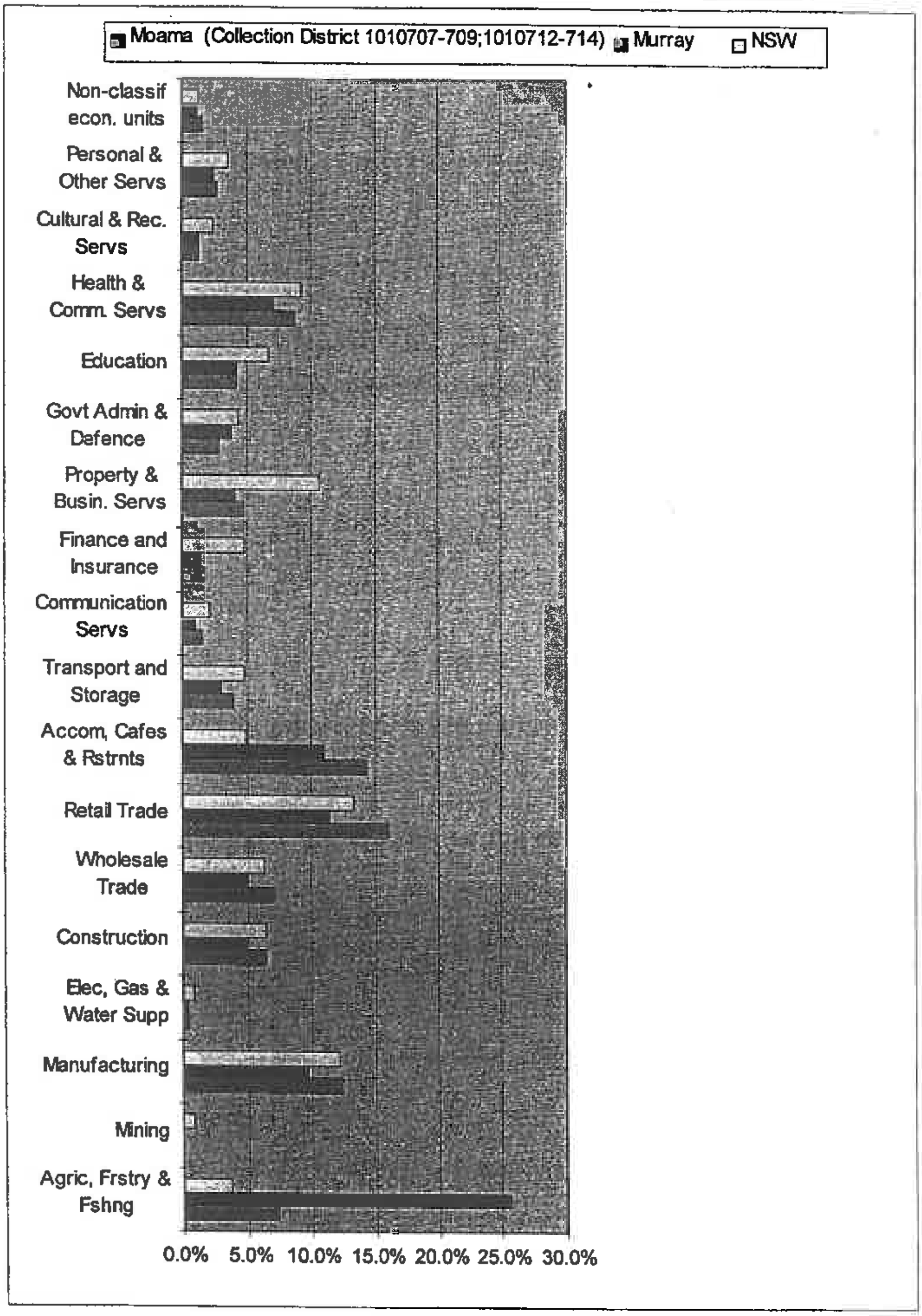




A high proportion of the study area's working population is employed in the tourism or holiday service business including accommodation, cafes and restaurants. Combined with those employed in the general retail trade, the figure rises to some 30% of the working population, significantly higher than for both Murray Shire generally and the total NSW figures. Conversely only 7% of the working population is employed in the rural sector, which, while still double the percentage for NSW is significantly below the figure of 25% for Murray Shire.

Industry employment figures for the study area from the 1996 census are shown in **Figure 2.2.**

Figure 2.2: Industry Employment for the Study Area



These figures support the accepted importance and development of tourism and associated holiday recreation activities within the study area. While rural industries are a significant feature for the whole of the Murray Shire, the important feature of this study area is the focus on tourism.

2.1.3 Land Use and Facilities

The Floodplain Development Manual and the Draft Floodplain Management Manual recognise six general types of land-use to be used by Councils in the development of a Floodplain Management Plan. Each of these categories, and there extent or implications for the study area is discusses briefly below.

Residential

Includes houses, flats, units and homes for the aged which could be occupied in times of flood and may need to be evacuated. Household effects are also highly susceptible to flood damage. Motels, caravan parks, mobile homes, and rural residential development are all generally regarded as a residential land use for the purpose of the Floodplain Development Manual.

Detached housing is predominant within the village area of Moama and in surrounding rural residential areas upstream and downstream of the town where the river environment is highly valued. There are also a substantial number of long term, caravan-type occupied dwellings as shown in the 1996 census data for the study area in **Table 2.1**.

Table 2.1: Housing Types 1996

Occupied private dwellings in Study Area	
House	926
Flat, unit or apartment	197
Caravan, cabin, houseboat etc	91
Not stated	12
Total	**1226**

NB: House includes detached and semi-detached house
Flat includes: unit apartment and house or flat attached to a shop, office etc.
Caravan includes: cabin, houseboat, improvised home, tent, sleepers out

Table 2.1 shows that in 1996 there were just over 1 200 residential dwellings within the study area. Council advise that there are approximately 341 residential dwellings/units currently below the 1 in 100 year flood line with the potential for a further 364 dwellings/units below this flood line in the next 20-25 years.

There are a significant number of holiday villas and apartments generally within the village area, and also west of Moama adjacent to Perricoota Road. Some holiday/cottage accommodation is also available in the eastern extremity of the study area adjacent to Gilmour Road (Morning Glory River Cottages).

Land adjacent to the river has been used extensively for caravan parks and associated camping grounds, which include some permanent or semi-permanent structures. Statistics have shown that a larger proportion of visitors to the Murray region (11%) use caravan parks than for the Victorian (9.4%) and NSW (9.1%) State figures. Camping is also popular in the region, with 4.8% of visitors camping or using caravans outside of a caravan park. The study area contains six established caravan parks with a further one currently under development. Figures from Murray Shire Council identifying the number of sites within these caravan parks are shown in **Table 2.2**. Inspections indicate that the number of sites with semi-permanent structures is higher than implied by the figures for long stays in **Table 2.2**.

Table 2.2: Caravan Parks

Caravan Parks/Camping Grounds	Short Stay	Long Stay	Camping sites
Shady River Caravan Resort	129	1	0
Cottonwood Holiday Park	237	1	0
Horseshoe Lagoon Caravan Park	131	7	0
Maiden's Inn Caravan Park	118	30	33
Merool Caravan Park	316	10	56
Moama Riverside Caravan Park	90	10	0
TOTAL	**1021**	**59**	**89**

The SES considers that during the peak tourist season these parks can contain up to 5,000 people (equivalent to almost the entire permanent population of the Shire of Murray). All of the parks are on riverbanks or lower level flood terraces, while access to higher ground varies. A caravan park proposal for up to 400 sites on a low level flood terrace east of Moama, without flood-free access was considered by Council in 1991. Council approved the application for 200 vans.

Commercial

Commercial development refers to shops and general offices with the potential for high damage costs associated with loss of stock and trade, particularly in high hazard areas. It is considered that the major clubs, that are such an important part of the Moama economy, would fit within this definition of land-use rather than the residential use (as applied to motels), discussed above.

Commercial properties in Moama are predominantly along or near the main thoroughfare, Meninya Street. There are currently some 57 commercial properties below the 1% flood level with the potential for a further 30 commercial operations to establish within this area in the next 5-8 years.

There are two major clubs and a motel/conference centre. The Rich River Golf Club is along Twenty Four Lane, away from the River and just beyond the western boundary of the study area. Moama Motor Inn and Conference Centre is within the main commercial area of Moama off the Cobb highway (Meninya Street). The Moama Bowling Club is a significant property which the State Emergency Services recognise as requiring special attention, being in a specific hazard area east of the railway line and below the 1% flood level.

Industrial
An industrial area is located north-east of the town up to the "one-mile crossing" adjacent to Barnes Road and the railway line. The industrial area is below the 1% flood level and was protected by the town levee in 1993. The area is susceptible to overland flood flows coming from the north which helps to drain the extensive flood storage areas where water passes under the railway culverts north of Moama (the black bridge). Since 1993 the industrial area has been extended further to the east, within the path of this northern floodway.

Open Space
Open space, as a category of land use, is generally compatible with flooding provided the flood hazard associated with facilities, such as public amenities, is recognised. Developments which may include club houses and facilities with high damage costs or with possible adverse impact on flood behaviour, such as fencing, should be avoided.

There are extensive areas of open space, State Forest and State/Crown Reserves throughout the study area associated with low-lying red gum forests and riverbank/floodplain areas. These areas are not extensively developed and provide for a range of passive outdoor activities that pose little threat to flood behaviour or cost recovery. The Bama State Forest occupies extensive areas of low lying flood storage within a large flood basin upstream of the Echuca Bridge. Other smaller forest reserves upstream of the bridge include Fish Hook Reserve and Horseshoe Lagoon State Forest.

Horseshoe Lagoon Park is an extensive area of red gum forest and back-water lagoons south of Moama town between Berry Street and the River. This area has been developed with timber walkways and platforms which provide access to the river in a manner compatible with the flood threat.

There are also large areas of open space associated with the road and rail bridge crossings. On the western or downstream area of the bridge is the Moama Historic Precinct. This area encompasses the low lying forest and riverine area opposite the historic Echuca Wharf and includes the historic Barges and Slipway at the end of Ward Street on the Moama side of the river.

Most of the riparian land downstream of the bridge is privately owned and while still providing areas of forest and open space, is still subject to development pressure.

Rural/Non-urban

The majority of the study area is rural land, predominantly cleared and used for various mixed agricultural pursuits with extensive areas of cropping. Agricultural areas west of the Cobb Highway are generally flood free. The Cobb Highway and then Barmah and Gilmour Roads (which follow the edge of the sand-hills), define the northern boundary of a large basin (the Kanyapella Basin) which in times of flood can fill and store floodwaters for a considerable period of time. There has been an increasing use of rural levees within this basin to protect high value crops from inundation. The potential impact of these rural levees is considered in some detail as a specific aspect of this Floodplain Management Study in Section 3.

Special Uses

The floodplain is traversed by the railway and road bridge, which includes a high embankment across much of the floodplain on the NSW side of the river.

Principal Special Use facilities provided in Moama and in relation to those provided in Echuca are shown in **Table 2.3**.

Table 2.3: Community Facilities

Facilities	Moama	Echuca
High School		☐
Primary School	☐	☐
Hospital		☐
Nursing Home	☐	☐
Retirement Units	☐	☐
Ambulance		☐
Doctor	☐	☐
Post Office	☐	☐
Police	☐	☐
Court House	☐	☐
State Emergency Service	☐	☐
Railway		☐
Council Chambers		☐
Pre-School Kindergarten	☐	☐
Library		☐
Saleyards		☐
Airstrip		☐
Public Hall	☐	☐

A number of special use facilities can be used for emergency services during a flood, or their continued operation may be important in reducing social disruption during or immediately following the passing of a flood.

The Moama Public School in Simms Street and the Moama Private Nursing Home in Regent Street have been identified by the SES as areas requiring special attention within the township of Moama during a flood.

2.1.4 Natural Environment

The remnant native vegetation of the study area is dominated by *Eucalyptus camaldulensis* (Murray Red Gum), *E. largiflorens* (Black Box) and *E. micro-carpa* (Grey Box).

Red Gum is the most widely distributed eucalypt species in Australia and the most common tree species within the study area. Red Gum stands vary from tall forests with heights in excess of 35 metres to open woodland or scattered tress with heights of 12 metres or less. The extent of its occurrence and development is largely determined by the frequency and duration of flooding and access to groundwater. It reaches its maximum development on the River Murray floodplains between Tocumwal and Murrabit. It is the most important commercial timber species within the region. It also performs an important habitat function for a range of fauna particularly with maturity and the development of hollows (refer to section 6.1).

Black Box generally occurs on higher areas of irregular flooding and heavy soils. It frequently occurs in association with Red Gum and Grey Box. It is a species which commonly occurs in low-lying areas and depressions in the vicinity of watercourses within the Murray-Darling Basin. It is a small to medium sized tree with heights ranging from 10 to 20 metres.

Grey Box occurs on the higher reaches of the floodplain and beyond. It occurs on better drained or lighter soils in flood free or low duration flooding areas although it is also found on the dark coloured, heavy soils characteristic of the floodplain. It occurs in woodland formation in association with Red Gum or Black Box. The species is widespread in NSW, Victoria and southern Queensland, principally on the inland side of the Great Dividing Range.

The study area has been largely cleared for agriculture, urban / industrial and tourism / recreation development with the exception of areas of State Forests and public reserves. In addition, some roadside reserves remain relatively undisturbed and contain examples of native vegetation, as for example an area immediately downstream of the existing Echuca - Moama road bridge. In some riparian areas, including flood terraces, vegetation growth in previously cleared areas can be traced back to particular flood events.

In general terms, the flora of the State Forest and public reserve areas are dominated by Red Gum. The following examples illustrate the point:

- A substantial portion of the eastern section of the study area is occupied by Bama State Forest No. 584 which has an area of 3 092 ha. The vegetated areas of the forest consist of 2 131 ha of Red Gum, 180 ha of mixed Red Gum and Box and 730 ha of Black Box / Grey Box.

- Horseshoe Lagoon Centennial Park (previously Horseshoe Lagoon State Forest) is located on the floodplain area immediately upstream of the Echuca - Moama road bridge. It occupies an area of 15 ha which consists of 11 ha of Red Gum with no box species present (the remaining 4 ha is mostly open water).

- The area downstream of the bridge is largely dominated by Red Gum. It consists of scattered mature and semi-mature individuals with extensive areas of regrowth probably dating from significant floods in 1993 and 1974 and 1975.

There are no sites of totally undisturbed native vegetation within the study area. The State Forests and other public and private land have experienced timber removal for sawlogs, sleepers, fence posts, vineyard posts and firewood over many years. Consequently, most of the timbered areas contain trees with a range of sizes and ages from sapling regrowth to large mature trees with an abundance of hollows. Red Gum regeneration in particular tends to be related to flood events which provide the necessary conditions for seed to germinate and for growth of seedlings.

The dominance of Red Gum reflects the general location of the reserves at low levels on the floodplain and the consequent duration and frequency of flooding. In these locations Red Gum occupies the lowest elevation sites which experience the most frequent and longest duration floods. By contrast the vegetation of the roadsides tends to be dominated by Black Box / Grey Box with Red Gum present in much lower numbers.

In addition to the roadside reserves, there are a number of uncleared areas to the north and north-east of Moama. These areas are dominated by Grey Box and Black Box although Red Gum does occur on the lower elevation sites.

Scattered stands and individual trees of Black Box and Grey Box occur on the higher elevation cleared country. On these areas, Black Box is generally restricted to depressions which contain heavy textured dark soils. Grey Box, on the other hand, tends to occur on the lighter textured red and yellow soils.

The understoreys of Red Gum communities are generally lacking a shrub layer and consist mostly of grasses, sedges and other annual herbs. The ground cover of the most regularly flooded sites consists only of litter or occasionally *Pseudoraphis spinescens* (Moira Grass). Sites which are less frequently flooded contain *Exocarpus strictus* (Dwarf Cherry) and *Acacia dealbata* (Silver Wattle). Some areas of mixed Box communities contain *Muehlenbeckia florulenta* (Lignum) as an understorey species. Lignum is restricted to the periphery of Red Gum communities and rarely, if ever, occurs on the more frequently flooded low elevation sites. Other vegetation species occurring in the study area include *Acacia Hakeoides* (Western Black Wattle), and *Myoporum montanum* (Boobialla).

Section 6.1 describes some of the fauna which these habitats support.

2.2 Geomorphology and Flood Behaviour

Echuca and Moama are situated on the floodplains of the Murray River, about 7 km downstream from its confluence with the Goulburn River and about 4 km upstream from its confluence with the Campaspe River. The approximate catchment area of the Murray, Goulburn and Campaspe Rivers in the vicinity of the towns are about 40,000, 18,000 and 4,000 km^2, respectively. The flood levels in the study area are caused by the complex interactions of floods in the three rivers.

An important factor that determines the flooding pattern in the area is the geomorphology of the floodplain. Both Murray and Goulburn Rivers flow into a very large depression known as the Kanyapella Basin, in the floodplains upstream of the towns (see **Figure 1.1**). The system thus behaves like a large storage basin in the case of large flood events, with two inlets provided by the Murray and Goulburn Rivers and the outlet being the Murray River between Moama and Echuca.

The existence of this large basin, the incised nature of the Campaspe River in the vicinity of Echuca, the confined flow of the Murray River west of the town and the ridge that runs from Echuca to Deniliquin, are explained by the rising of the Cadell Fault, some 30,000 years ago (Currey and Dole 1978).

At that time, it is postulated that the Murray River was flowing further north and the Goulburn River well to the south of Moama/Echuca. A ridge of land running from south of Echuca to Deniliquin was uplifted by about 30 metres due to the Cadell Fault, blocking the former courses of both rivers and causing formation of a lake. The Murray outflanked the uplift to the north (the approximate course of the Edward River today), but later broke through the fault near where Moama is now located. The confined nature of the Murray to a considerable distance west of the town is explained by this mechanism.

There have been a series of developments carried out in the study area with the formation of the towns and their growth since last century. Structures such as railway lines, roads, town levees and rural levees have modified the flood regime in the floodplain within the study area. The lower Goulburn River has been confined by levees as well.

There have also been land use changes in the catchment area of the three rivers. The construction of the Eildon Dam in the Goulburn River in 1952 controls about 25% of that catchment, and the Eppalock Dam constructed on the Campaspe River in 1964 controls half the Campaspe catchment. These have altered the flow regimes of those rivers.

2.3 Flood Damage

2.3.1 General

Major flood level is defined by the Bureau of Meteorology when floods exceed 94.4 m on the Echuca Wharf Gauge.

The largest flood since European settlement was in 1870, when the peak was 96.2 m on the gauge. **Table 2.4** lists peak levels for some of the years in which floods exceeded the major flood level.

Flood behaviour is discussed in more detail in Section 3. Essentially, when the floodplain becomes inundated upstream of Moama, floodwaters must return to the river to pass under the bridge. Two main flood flow paths exist to return floodwaters to the river. One is Backwater Creek, which can affect outer parts of Moama East.

Table 2.4: Historical Major Floods

Year	Stage at Echuca Wharf (m AHD)
1867	95.35
1870	96.2
1916	94.8
1917	94.55
1939	94.4
1956	94.58
1974	94.52
1975	94.75
1981	94.27
1993	94.80

Floodwaters in the northern part of the upstream floodplain which pass under the Black Bridge to the western side of the railway must return to the river by flowing in a southerly direction between the railway and the Cobb Highway. This floodwater must pass under railway culverts in town and along a slight depression towards the river east of the main township. These floodwaters can cause problem flooding of residential and industrial properties on the northern and eastern edges of Moama.

Downstream of the town the floodplain is less extensive, and river flows are more confined between higher ground on either side. Some tourist developments, primarily caravan parks, are affected by floods in this area and closer to the river on the upstream side of town.

2.3.2 1993 Flood

In 1993, a major flood developed in response to unusually intense rainfall in north-east Victoria. Both the Murray and the Goulburn River were in flood, although river flows in the Campaspe were below major flood levels.

A moderate flood in the Goulburn in September was followed by the major flood in early October. Most floodplain storage was occupied by floodwaters remaining from the first flood when the October flood came through. As a result, the second flood reached high levels in the floodplain basin upstream of the town and bridge. Backwater effect from the Campaspe, which can be influential in some floods, was relatively minor in October 1993, allowing floodwaters passing through the Echuca-Moama bridge to pass downstream more freely.

High flood levels in the upstream floodplain basin caused flow through the railway to the north of the town. On this occasion, a private embankment traversing the flood-path between the railway and the Cobb Highway blocked the floodwater, but did not hold. Flooding of houses and industrial estates ensued to the north of the town, and road closures and residential flooding were also experienced in Moama East. A temporary levee was used to protect the lower portions of the industrial estate and residential area.

Substantial sand-bagging was also implemented to keep floodwaters out of Caravan Parks near the town. It is noted that this type of action may increase flood levels slightly in adjoining properties. While sand-bagging of permanent residences immediately adjacent structural walls and openings is acceptable practice to mitigate property damage, sand-bagging of large areas is undesirable and property within Caravan Parks should be removed during floods rather than be fortified. If sand-bags fail or are overtopped, damages would far exceed the cost of removal of portable equipment (*eg.* caravans, cabins and temporary housing). The potential hazard is increased by sand-bagging, but is reduced by temporary removal of property. All Caravan Parks should have prepared flood evacuation plans.

Damages incurred in the flood of 1993 are discussed in further detail in Section 5.

Results of hydraulic modelling reported in Section 3.2 indicate that upstream of the bridge flood levels in the floodplain approximated flood levels of ARI 50 years. Downstream of the bridge, flood levels in 1993 were closer to those for an ARI of 20 years. This can be attributed to the effects of the sequence of floods which lead to floodplain storage being occupied on arrival of the main peak upstream of the bridge, and the relatively minor backwater effect from the Campaspe in this particular flood downstream of the bridge.

3. Hydrology

The Moama/Echuca flood study was completed by SKM in 1997. Findings of this study are presented below in Section 3.2, hydraulic modelling.

3.1 Existing Flooding Pattern

The flooding pattern in the study area is the result of complex interactions of the floods in the Murray, Goulburn and the Campaspe Rivers. To use a very simple analogy, the floodplain upstream of the towns behaves like a large retarding basin in times of reasonably high flood events (see section 2.1). The inlets to the basin are the Murray and Goulburn Rivers and the outlet is the river between Moama and Echuca. This outlet, constricted by geographical features, controls the peak flows downstream of Echuca/Moama.

In general during major floods, the critical level at the Echuca Gauge as defined by the Bureau of Meteorology for flood warning purposes (94.4 m AHD) may be exceeded continuously for up to 2 months or more. This is due to the filling of the Kanyapella Basin upstream of Moama and the constricted outlet conditions described above. Peak flood levels in the study area are influenced by both the flood discharge peaks and flood volumes of the inflows from the Murray and Goulburn Rivers.

Peak flood levels in the two towns can also be influenced by the Campaspe River that joins the Murray River about 4 km downstream of the Echuca Wharf. From the study of past floods it is concluded that there is often some coincidence between Campaspe and Murray floods. The Campaspe flood in general reaches the Murray River before the arrival of the Murray flood peak at Echuca. The time difference can vary from 4 to 9 days for the floods studied. The backwater effect of the Campaspe River at the Echuca gauge raises the flood level for a given Murray flow. The significance of this effect obviously depends on the magnitude of the Campaspe flood and its time of peak in relation to the Murray River flood peak. In 1870 and 1916, the increase in peak flood level as a result of the impact of the Campaspe was 1.0 m and 1.5 m respectively (Currey and Dole, 1978).

The Goulburn River has been constrained by levees on both sides to a considerable length downstream of Shepparton (Sinclair Knight Merz, 1998). During significant floods there is a large right bank overflow near Loch Garry that flows into the Deep Creek system. This spill flows into the Murray River at a location between Barmah and Lower Moira shown in **Figure 3.1**.

The Kanyapella Basin fills up due to overflow from the Goulburn and Murray Rivers in the study area. The Goulburn River has a natural choke at Yambuna (see **Figure 3.1**). There is significant overflow on the Goulburn upstream of this choke, primarily on the right bank.

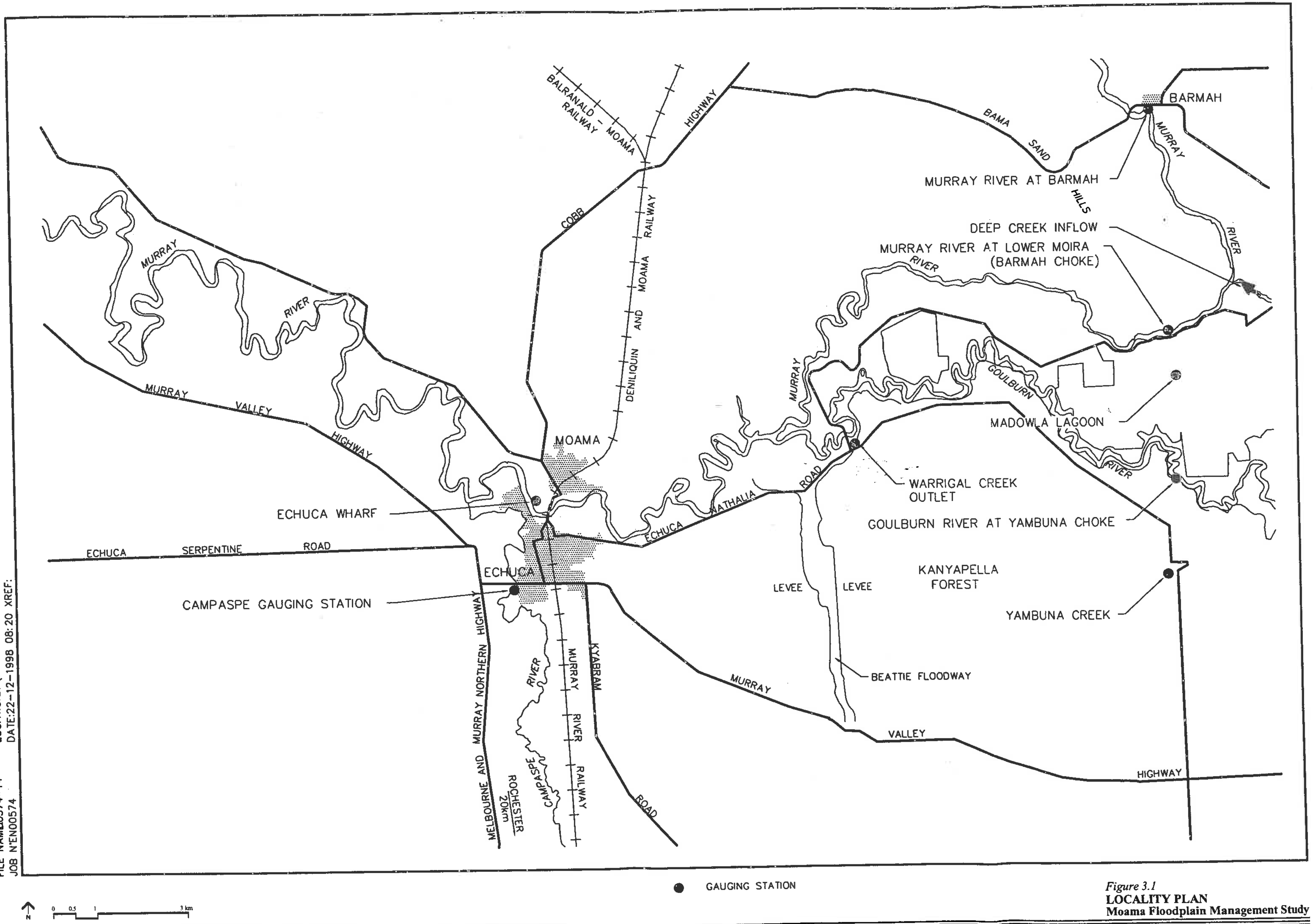


Figure 3.1
LOCALITY PLAN
Moama Floodplain Management Study

SINCLAIR KNIGHT MERZ

The sump of the basin on the Victorian side, Kanyapella Forest, is used as a disposal basin for irrigation return flows. If the Murray has experienced sustained high stage prior to the advent of a Goulburn flood the Warrigal Creek outlet must be closed and water may be stored in this sump, producing some minor reduction in the volume of flood storage which would otherwise be available.

A natural choke also exists in the Murray River downstream of Barmah, created by the natural sand ridge (lunette) which once bounded the ancient Lake Kanyapella (the Bama Sand Hills in NSW). This choke restricts the inflow into the study area to a value of about 350 m^3/s to 400 m^3/s. The excess flow during floods finds its way into the Edward River system to the north.

Note that the bridge at Barmah and the limited capacity of the river channel through the Barmah Swamp upstream of Barmah are often considered to be part of the 'Barmah Choke', however the natural physical feature which in combination with Goulburn River inflows causes the choke on flows and forces higher flows into the Edward River is the remnant lunette (Bama Sand Hills) associated with the ancient lake.

During some flood events there has been flow reversal on the Murray River, in the vicinity of Barmah. This can occur when major floods develop in the Goulburn and the Murray is already in flood. Goulburn River overflows into the Deep Creek system may then stop or even reverse the Murray flow upstream of the Barmah Choke.

Goulburn River right bank overflows can also enter the Kanyapella Basin through the Madowla Lagoon, shown in **Figure 3.1**. Private levees south of Madowla Lagoon can intercept low to medium flows before reaching this gap in the sand ridge, however larger floods overtop and breach that levee. The future of this levee is being addressed as part of current floodplain management planning by the Goulburn-Broken Catchment Management Authority in Victoria. Another gap in the ancient sand ridge existed at Yambuna Creek on the left bank of the Goulburn, but this has been blocked for many decades.

The flooding problems in Moama are primarily caused by the right bank overflow from the Murray River downstream of the Bama Sand Hills. Properties east of the railway line experience flooding due to the rise of the Murray River during floods. Flood flow crosses the Deniliquin-Moama railway through the existing culvert north of the town and returns towards the Murray River in a southerly direction west of the railway. It flows back through railway culverts in Moama. This flooding behaviour was experienced in the 1993 flood event.

3.2 Hydraulic Modelling

MIKE-11, a computer-based, one-dimensional numerical modelling system, originally developed by the Danish Hydraulic Institute, was configured to represent an hydraulic model of the study area. This discussion of the model and results is taken from the flood study report (SKM 1997).

Ideally, to configure and calibrate an hydraulic model for Moama/Echuca and their associated floodplains, the upstream model boundaries should extend from Shepparton on the Goulburn River, Barmah on the Murray River and Rochester on the Campaspe River. The reasons are as follows:

- Due to the very large and flat catchments with complex effluent systems, conventional rainfall-runoff methods of deriving design inflow hydrographs cannot be justified in this study. The possibility of partial area storms further vindicates this stand. Hence, design inflow hydrographs would have to be derived statistically, using historical flood hydrographs.

- It is only at the suggested model boundary locations that reliable long term records are available that could be used to derive the design inflow hydrographs.

- There are complex interactions between the Murray and the Goulburn Rivers, downstream of Barmah and Shepparton.

Notwithstanding the above, an hydraulic model of the magnitude suggested above would cover a very large area and be very costly to develop.

Furthermore, it would cover virtually all of the area subject to a very detailed hydraulic modelling project carried out in the 1980s for the former Rural Water Corporation. This project, the Lower Goulburn Floodplain Management Study (Cameron McNamara, 1987), modelled the area from Barmah on the Murray River and Shepparton on the Goulburn River downstream to Kanyapella, about 7 km upstream of Moama/Echuca.

It was therefore decided to configure, calibrate and validate the hydraulic model from Lower Moira on the Murray River and Yambuna on the Goulburn River respectively, to a location 50 km downstream of the towns of Moama/ Echuca. The Lower Goulburn Floodplain Management Study model outputs at these locations were used for the design inflow hydrographs.

Data from the flood event of October 1993 was used to calibrate the Moama/Echuca hydraulic model. Data from the flood events in 1992 and 1981 were used to validate the calibrated hydraulic model.

To simulate the 1974 flood event, model output from the Lower Goulburn Floodplain Management Study at Lower Moira and Yambuna for the 1974 flood were used as inflows for the validated Moama/Echuca model along with the observed flow in the Campaspe River. It was found that the observed flood behaviour was simulated adequately. This served as an independent check on the accuracy of the Lower Goulburn Floodplain Management Study hydraulic model outputs at Lower Moira and Yambuna.

3.2.1 Design Simulations

Having validated the results of the Lower Goulburn hydraulic model using the results for the 1974 flood event, design inflows at Lower Moira and Yambuna were accepted as inputs to the Moama/Echuca model for the events of Annual Exceedance Probability (AEP) 0.5%, 1%, 2%, 5% and 10%. Design inflows for the same events at the Campaspe River were evaluated from flood frequency analysis of the historical data at Rochester.

These inputs were used to run a series of design simulations to study the flood behaviour of the system to different combinations of inputs down the Murray, Goulburn and Campaspe Rivers. The results of the simulations along with the adopted design levels at the Echuca Wharf Gauge taken from a revised flood frequency analysis (see section 3.3) were used to derive design flood profiles along these rivers.

The design flood hydrograph inputs from the Lower Goulburn Floodplain Management Study were single-peaked and were derived considering 12-day flow volumes at Shepparton. However, the historical floods often have a double peak and last over 50 days, as during the 1993 flood. If the flood storage in the Kanyapella Basin is occupied by floodwaters from a preceding flood peak, the effects of a second peak are then aggravated.

Double-peaked 1% AEP design inflow hydrographs were therefore derived at Lower Moira on the Murray River and Yambuna on the Goulburn River. These used the design flood peaks from the Lower Goulburn Floodplain Management Study and the shapes of the observed 1993 flood hydrographs at these two locations.. These inflows, when used in conjunction with the 1993 inflow on the Campaspe River, were used to derive the 1% AEP design peak level at the Echuca Wharf Gauge.

3.2.2 Design Flood Profiles

Design flood profiles were presented for the 0.5%, 1%, 2%, 5% and 10% AEP events along the Murray, Goulburn and Campaspe Rivers. These used the results of the design simulation runs, and a revised flood frequency curve at the Echuca Wharf Gauge (see section 3.3).

Design flood profiles and flood contours indicate that the longitudinal slope of flood water surfaces is much flatter upstream of Moama/Echuca than downstream. This is not an effect of the bridge, and although observational data immediately upstream and downstream of the bridge opening does not exist to permit accurate model calibration, the hydraulic modelling shows that the head difference across the bridge alignment during floods is quite small (*e.g.* 0.05 m to 0.07 m). The important influences which create the fallter profiles upstream are:

(a) the natural basin referred to previously (*i.e.* Kanyapella Basin) – flood storage in this area upstream of the bridge creates a large ponding effect;

(b) the backwater from the Campaspe River.

Because of these effects which flatten the flood profile in the vicinity the effect of the bridge opening is diminished.

A Probable Maximum Flood (PMF) was not derived because of the size and complexity of the catchment upstream. Particularly notable is the diversion of flood flows from the Murray River into the parallel Edward River system, the magnitude of which would be virtually unpredictable in a massive flood such as the PMF. Estimation of the flow magnitude passing the gauge at Echuca and not diverted to the north would be merely speculative.

Instead, an extreme flood event was evaluated. This was nominated as a flood with peak discharge and volume twice that of the design flood of 1% AEP down the Murray, Goulburn and Campaspe Rivers. The resulting flood profiles along the Murray, Goulburn and Campaspe Rivers were also presented in the flood study report. This extreme event serves to demonstrate the impacts of a flood large enough to overwhelm the proposed mitigation measures, in order to assess residual risk and appropriate emergency response.

3.2.3 Limitations of the Hydraulic Model and Accuracy Limitations

The pattern of flood flow caused by the interactions of the three rivers with the existing geomorphologic and topographic conditions is a very complex one. It is also essentially two-dimensional in nature. The hydraulic model study carried out by SKM as described earlier was one-dimensional.

Over a long period of time, a large number of levees have been built in the floodplain to protect individual landholdings. Most of these have been licensed by DLWC, but not all. The cumulative effects of these rural levees have never been evaluated properly. However, it is inferred that they have the tendency to change the flood behaviour of smaller flood events.

An ideal solution to evaluate the complex flooding patterns and the effects of the rural levees would be to set up, calibrate and test a two-dimensional mathematical model. This could be used to evaluate the individual and cumulative effects of these rural levees. This information could lead to a management plan where the levees with the worst effects are removed from the floodplain.

In order to set up and calibrate such a two-dimensional model, more detailed hydrologic, hydraulic and topographic information would be required. Such an exercise would be extremely costly.

The flood model that was used in the original SKM flood study was a branched, one-dimensional model that was configured in a way to closely approximate the two dimensional behaviour, especially in the floodplain.

These limitations do not decrease the value of the results obtained from this model study with respect to its major findings or the final design flood recommendations for planning purposes. The model is effective for planning purposes.

However, it would be very difficult to simply extrapolate the results from such a one-dimensional model for floods of low return periods. This is especially true in the floodplain where complex two-dimensional flow patterns and the effects of rural levees dominate. The interpretation of flood behaviour at specific locations is also less precise with one-dimensional modelling, particularly for locations situated between cross-sections. Nevertheless, from the one-dimensional model studies it is certainly possible to infer information pertaining to the flood behaviour even for floods of low return period, and reasonable understanding of the effect of rural levees can be deduced.

3.3 Flood Frequency Estimation

Annual peak flood heights from 1865 have been recorded at the Echuca Wharf Gauge by the Bureau of Meteorology. This information is used by both Moama and Echuca as one of the key indicators of flooding. The former Rural Water Corporation derived a flow rating curve for this gauge in 1978 which ignored the backwater effects from the Campaspe River at the Wharf. This rating curve was used to convert the annual series of flood heights, and a flood frequency curve was derived at Echuca for the derived annual series of peak flows. The 1 % AEP flood level on that curve is 95.63 m AHD, and has been adopted as the current planning level.

It was part of the SKM study brief to re-evaluate the flood frequency curve for the following reasons:

- There is a definite change of slope in the flood frequency curve which is unusual. The reasoning for the discontinuity appears to be a belief in the existence in the record of a small sub-set of 'extreme' storm / flood conditions which arise only rarely. If there were two distinct populations of floods, a break in the slope of the curve could be a consequence. The analysis attempts to accommodate the data of the 1867 and 1870 floods, which were distinctly higher than other floods on record. The hypothesis of a small sub-set drawn from a different statistical population is open to debate, however.

- Using a rating curve which neglects all backwater effects from the Campaspe River could introduce errors. In fact, due to the reasonable degree of coincidence between the floods in the Murray and Campaspe Rivers, there will always be some effect from the Campaspe at the Echuca Wharf Gauge, but it varies from flood to flood.

The hydraulic behaviour of the 1974, 1981, 1992 and 1993 flood events at the Echuca Wharf Gauge were studied in detail to evaluate an "average rating curve" that includes the backwater effect of Campaspe River. The design simulation runs were taken into account in the derivation of this "average rating curve", as well as field measurements of discharge carried out at this gauge in 1886 and 1975.

This revised discharge rating was used to convert the annual series of flood heights at the Echuca Wharf Gauge to an annual series of flows. Several statistical distributions were fitted to the flow data to arrive at the flood frequency curve. The log Pearson type 3 distribution fitted as suggested by the 1987 edition of ***Australian Rainfall and Runoff*** was found to give the best fit.

The design flood levels at the Echuca Wharf Gauge adopted for this study are taken from this log Pearson type 3 distribution.

3.3.1 Revised Rating Curve and Flood Frequency

A flood frequency curve was constructed at the Echuca Wharf in the preceding Flood Study (Sinclair Knight Merz, 1997) using the revised rating curve that takes into account the backwater effect of the Campaspe.

The current planning levels in use in the Shire of Murray have been taken from the flood frequency curve developed in 1978. A comparison of the two curves using the historical flood level information is given in **Figure 3.2**. According to this figure:

- The heights predicted by the previous curve are higher for flood events greater than about ARI 70 years.
- The heights predicted by the previous curve are lower for flood events with ARI less than about 70 years.
- The height for ARI 100 years on the previous curve (equal to the existing planning level of 95.63m AHD) is equivalent to ARI 200 years using the revised curve.

Although the design results using the revised discharge rating are less conservative for larger floods, they have been determined by adhering to the guidelines for flood frequency analysis in *Australian Rainfall and Runoff* (1987). The judgements made in the analysis done in 1978 may have some technical basis, but these have not been adequately justified and the judgements are very open to debate (*i.e.* subjective).

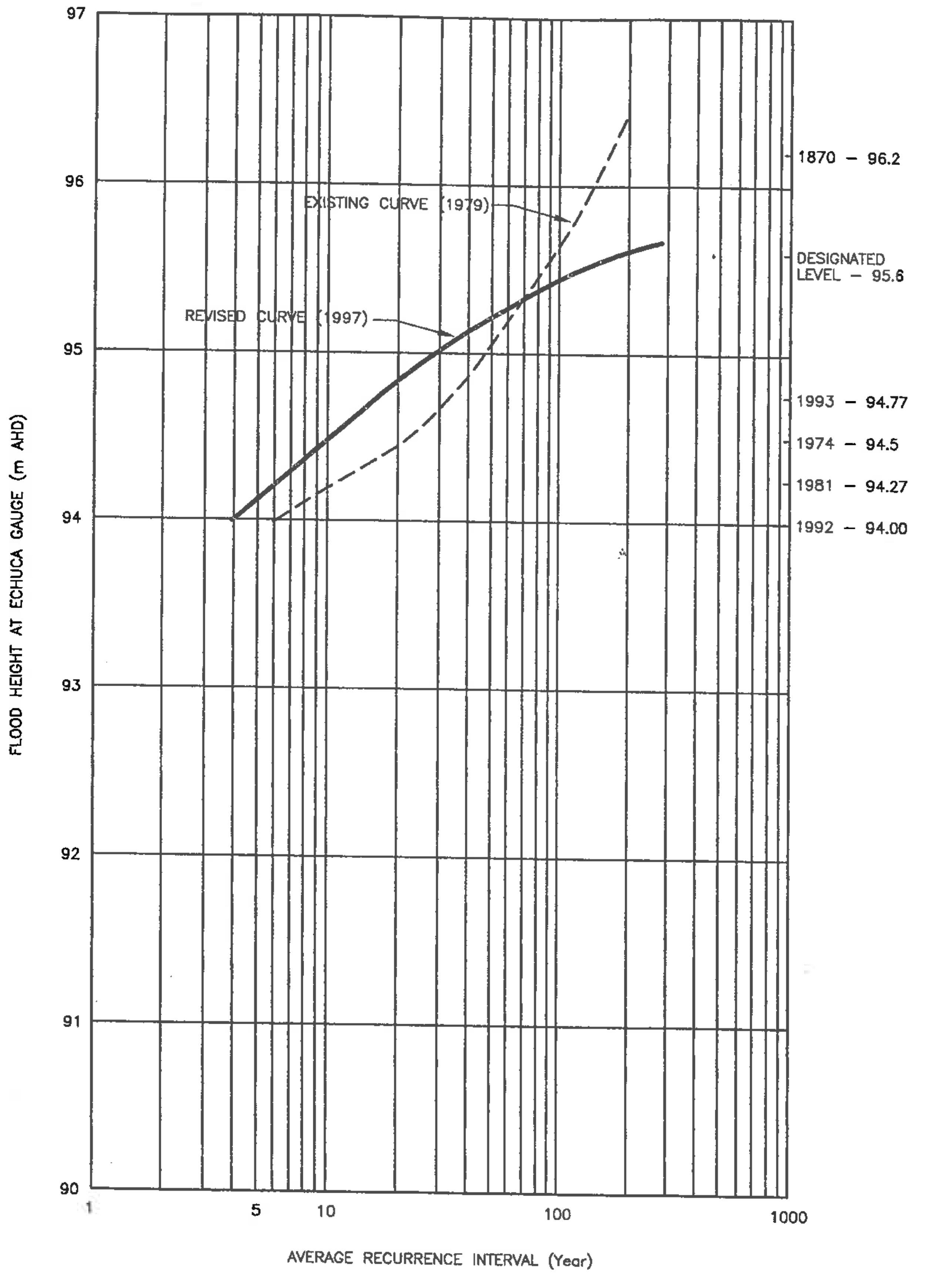


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Figure 3.2
COMPARISON OF FLOOD FREQUENCY CURVES
Moama Floodplain Management Study

It is also indisputably true that major changes to the river system have occurred since 1870, including extensive leveeing of rivers upstream. Land clearing and changes in land use have also taken place within the catchments. It is therefore proposed that the revised flood frequency curve should be the basis for future flood studies at Moama. It is based on extensive investigations, including the effects of the joint probabilities of the floods from the three rivers, as explained in the flood study (Sinclair Knight Merz, 1997), and is applicable to current river and catchment conditions.

At the Echuca gauge, the 1993 flood is determined to be close to ARI 20 years with the revised flood frequency curve (rather than approximately 30 years by the previous estimation).

The 1992 flood is approximately ARI 5 years according to both flood frequency curves. According to the revised, recommended curve, the 1974 and 1981 floods are approximately ARI 10 years and 7 years, respectively.

As discussed in Section 3.2, the preceding flood study produced design flood profiles for ARIs of 10, 20, 50, 100 and 200 years, and for an extreme design flood for the study area. They were estimated using single-peaked design floods for reasons discussed earlier. The Murray River flood profiles for these design events are presented in **Figure 3.3**.

The 1993 flood was a double-peaked event that lasted almost two months and is considered a 20-year ARI event at the Echuca Gauge. In order to evaluate future flood mitigation options a 100-year ARI double-peaked design flood hydrograph was simulated by trial and error in the original study.

The 1993 flood levels closely matched the 20-year ARI design flood profile from the downstream boundary, through the bridges up to the Goulburn River confluence. Upstream of this point, they more closely matched the 50-year ARI design flood profile. In the flood prone lands in the Bama Forest area and the area on the eastern and western sides of the railway line the 1993 flood levels were also closer to the 50-year ARI levels.

In the Lower Goulburn, the October 1993 flood peak was estimated to be of ARI 30 years, approximately (Sinclair Knight Merz, 1998). The ARI of the flood would have been greater in the Kanyapella Basin storage area because storage was occupied by floodwaters from the preceding peak, whereas downstream of the basin the ARI presumably decreased due to the relatively small backwater effect from the Campaspe in this particular event.

In the same manner the flood profile of the 100-year, double-peaked design flood profile matches the derived 200-year ARI profiles in the areas mentioned above, but matches the 100-year ARI flood profile in the Murray River from the Goulburn River confluence to the downstream study boundary.

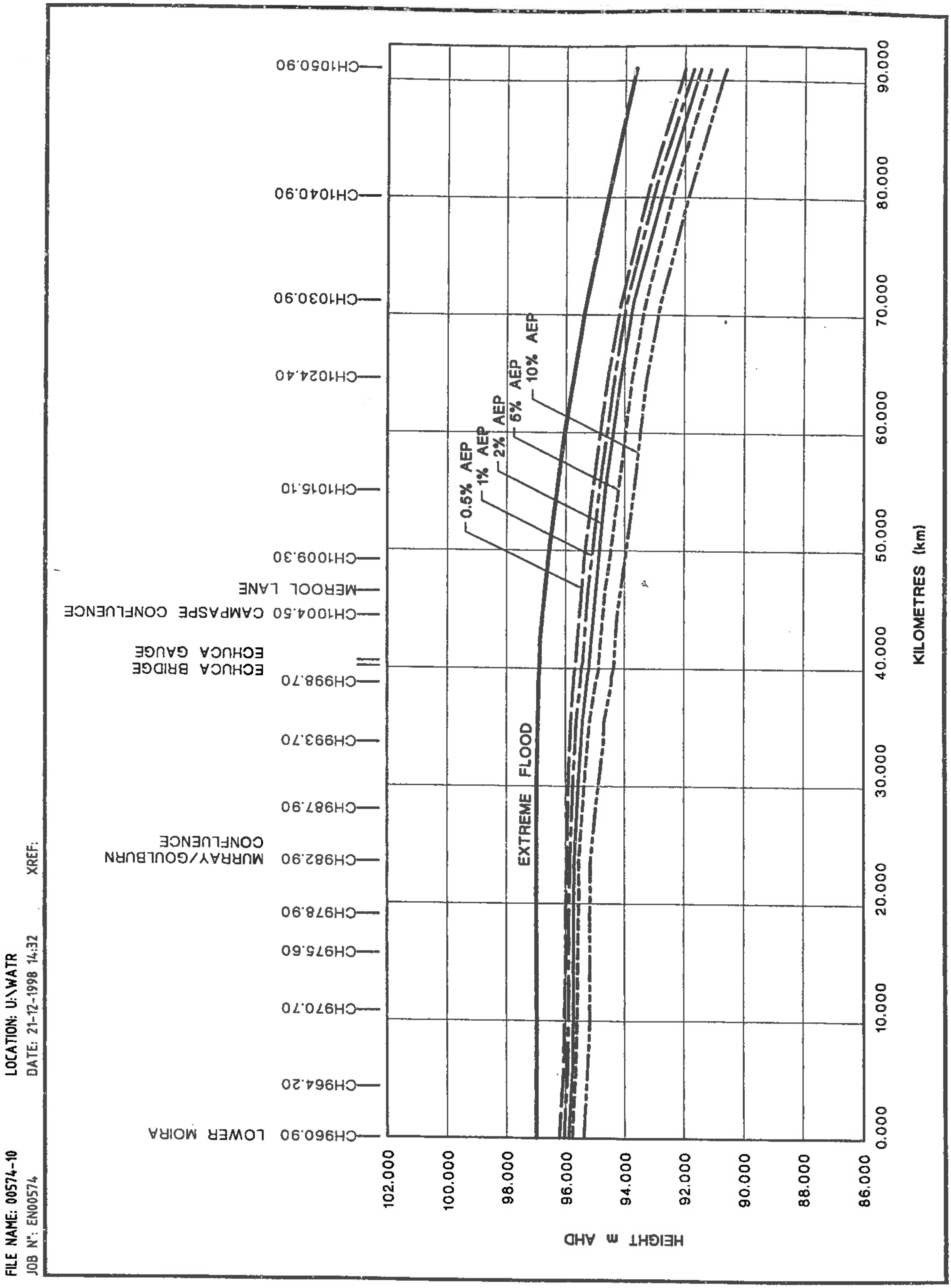


Figure 3.3
DESIGN PEAK HEIGHT PROFILES - MURRAY RIVER
Moama Floodplain Management Study

This behaviour is understandable as the first peak fills the flood storage areas and the second peak further increases the flood levels in the floodplain storage areas upstream of the bridge (Kanyapella Basin).

3.4 Flood Planning Levels

Even though it corresponds approximately to AEP 0.5% (ARI 200 years) with the revised discharge rating, it is recommended that the level of 95.63 m AHD given at the Echuca Wharf Gauge be adopted as the Flood Planning Level for planning purposes.

(a) It takes account of the higher levels experienced in 1867 and 1870.

(b) It allows for flood behaviour in which extended or multi-peaked floods may fill floodplain storage and influence peak levels in the basin upstream of Moama.

(c) It maintains the present planning levels. The current planning level, or the old 1% AEP level, is 95.63 m AHD. The revised level for the 0.5% AEP level is 95.60 m AHD.

It should be noted that this recommendation is made purely from a hydrological perspective. The standard of Flood Planning Level accepted may be varied from place to place based on an assessment of social, ecological and economic considerations as well as the hydrological considerations.

The Victorian Department of Natural Resources and Environment (DNRE) is presently undertaking studies to collate historical flood data and delineate the flood prone areas in Victoria. The level used for that study is 95.63 m AHD, as derived in the 1978 flood frequency analysis. This is the level presently used in Echuca for planning purposes, and assumed to be for 1% AEP. It should be noted that this study finds this level to be at 0.5 % AEP level, and is recommended as the Flood Planning Level on the NSW side of River Murray.

4. Outcomes of Hydraulic Modelling

The delineation of Flood Hazard categories has been determined for the design flood events, using:

- results of the hydraulic model runs undertaken in the *Moama Flood Study* (Sinclair Knight Merz, 1997) and described in Section 3,
- topographic information, and
- the recommendations of the Draft NSW Floodplain Management Manual.

4.1 The Draft Floodplain Management Manual

This manual recognises three hydraulic categories of flood prone land - floodway, flood storage and flood fringe - and two hazard categories - low hazard and high hazard. Subdivision of the floodplain on the basis of these two classifications produces the following six categories of flood prone land:

1. Floodway - High Hazard
2. Floodway - Low Hazard
3. Flood Storage - High Hazard
4. Flood Storage - Low Hazard
5. Flood Fringe - High Hazard
6. Flood Fringe Low Hazard

Floodways are those areas where a significant volume of water flows during floods. They are often aligned with obvious natural channels or depressions. Floodways are areas which, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

High hazard floodways would typically have either velocities in excess of 2 m/s or depths greater than 1 m. Flood depths could be less than 0.8m for low hazard floodways. However, for the low hazard floodways the impacts of new developments on flood behaviour need to be addressed in determining the management plan and development control measures.

Flood Storage Areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

In general, high hazard flood storage will have depths greater than 1m. The depth of flood water in the low hazard flood storage may be less than 0.8m, however the implications of new development on flood storage and flood behaviour need to be addressed in formulating planning controls.

Flood Fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have significant effect on the distribution of flood flows and/or flood levels.

The high hazard flood fringe areas are characterised by flood depths greater than 1m. The low hazard flood fringe areas have depth less than 0.8 m in general.

In determining appropriate hydraulic categories, it is important that the cumulative impact of progressive development be evaluated, particularly with respect to floodway and flood storage areas. Whilst the impact of individual developments may be small, the cumulative effect of ultimate development can be significant and may result in unacceptable increases in flood levels and flood velocities elsewhere in the floodplain. In these circumstances, precedents which allow individual developments should be avoided.

4.2 Delineation of Hazard Zones

The hazard categories for the 10, 20, 50, 100, 200 year ARI and an extreme flood are shown in **Appendix A** as **Figures A.1** to **A.6.** The hazard diagram for the 1993 flood event is given in **Figure A.7**.

Given the scale of these plans and the general lack of contour information in the flood plain, it is not possible to show the extent of the floods to a high degree of accuracy, and the extents of flooding shown on these figures are indicative only. However, it is possible to determine design flood levels and the flood extent in a particular area using the cross section locations shown in **Figure A.8** in conjunction with the design flood levels given in **Table A.1** in **Appendix A**.

A strip of land along the Murray River and Backwater Creek is marked as high hazard floodway in these figures. The width of the strip increases with the severity of the design flood. In general, for the floods under consideration the velocities in the river and the floodway zone are generally between 0.5 m/s and 1 m/s and the flood depths are high, being greater than 2 m in general for the designated flood (200-year ARI event).

Large areas of the Bama Forest and the flow paths along the eastern side of the railway line and the western side of the railway line through the town of Moama are delineated as high hazard flood storage areas in these figures. The velocities in these areas are quite small due to the large flow areas. However the depths of flow are quite high. In the case of the flow path through Moama and on the western side of the railway line, they are greater than 1 m for floods of ARI 50 years and greater. In most parts of Bama Forest the depth of flooding is up to 2 m for the design flood of ARI 10 years.

To either side of these zones, areas are shown to be low hazard storage areas where the depths are less than about 0.8 m.

4.3 Effects of Rural Levees

There are two natural flowpaths or floodways in the floodplain as shown in **Figure 4.2.** One overland path flows through the Bama State Forest to Backwater Creek. The other path flows through Black Bridge to the west of the railway, then south and parallel to the railway line north of Moama. It is recommended that rural levees blocking these natural flowpaths should be removed. As the levees in other areas of the floodplain have little impact on the distribution of flood flows in the floodplain during major floods when most levees would be submerged, they could remain. Analysis finds that, if the existing rural levees in NSW east of the railway were high enough not to be submerged during a flood of 1% AEP, over 10% of the floodplain storage available (140,000 ML) would be removed. As the floodplain storage in the basin is a key influence on the flood behaviour through Moama and Echuca, this should not be allowed to happen.

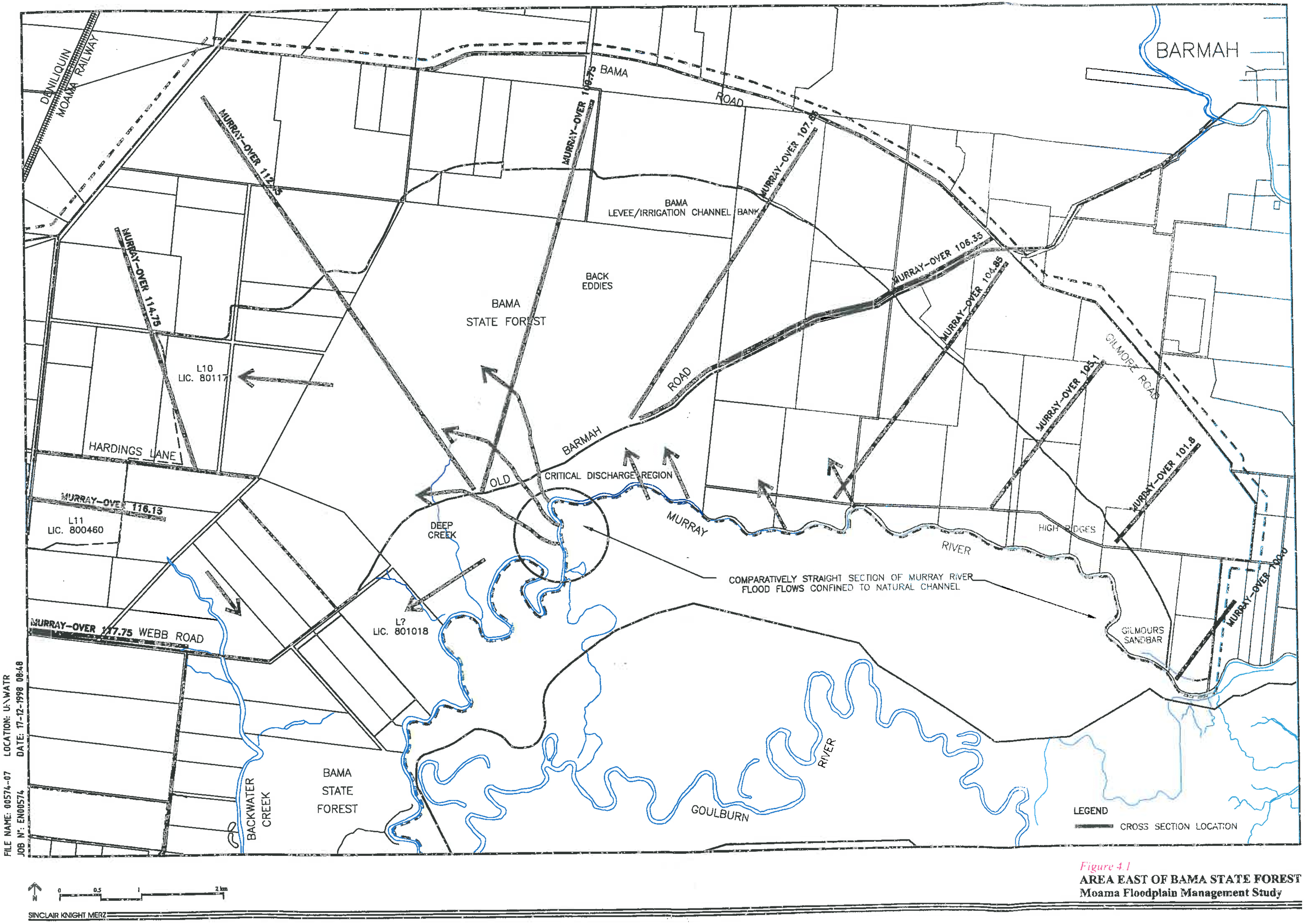
Accordingly, a restriction should be imposed on heights of all existing levees to ensure levees are not raised in future. No approvals should be given for new earthworks or for any modifications to existing earthworks, except as recommended to improve spacing between parallel levees.

The effects of the rural levees in the floodplain are considered geographically as follows:

- east of Bama State Forest to Gilmours Road area (**Figure 4.1**)
- east of railway line to Bama State Forest (**Figure 4.2**)
- north of Moama between Cobb Highway and the railway (**Figure 4.2**)
- East of Moama between the Railway Line Culverts and the Murray River (**Figure 4.3**)
- Merool Lane Area (**Figure 4.4**)

4.3.1 East of Bama State Forest

Flood levels and velocities for the overland flood flow path through Bama Forest to Backwater Creek shown in **Figure 4.1** are given in **Table A.1**. Also shown in **Figure A.8** are the locations of the cross sections for which the levels and velocities are presented.



SINCLAIR KNIGHT MERZ

Figure 4.1
AREA EAST OF BAMA STATE FOREST
Moama Floodplain Management Study

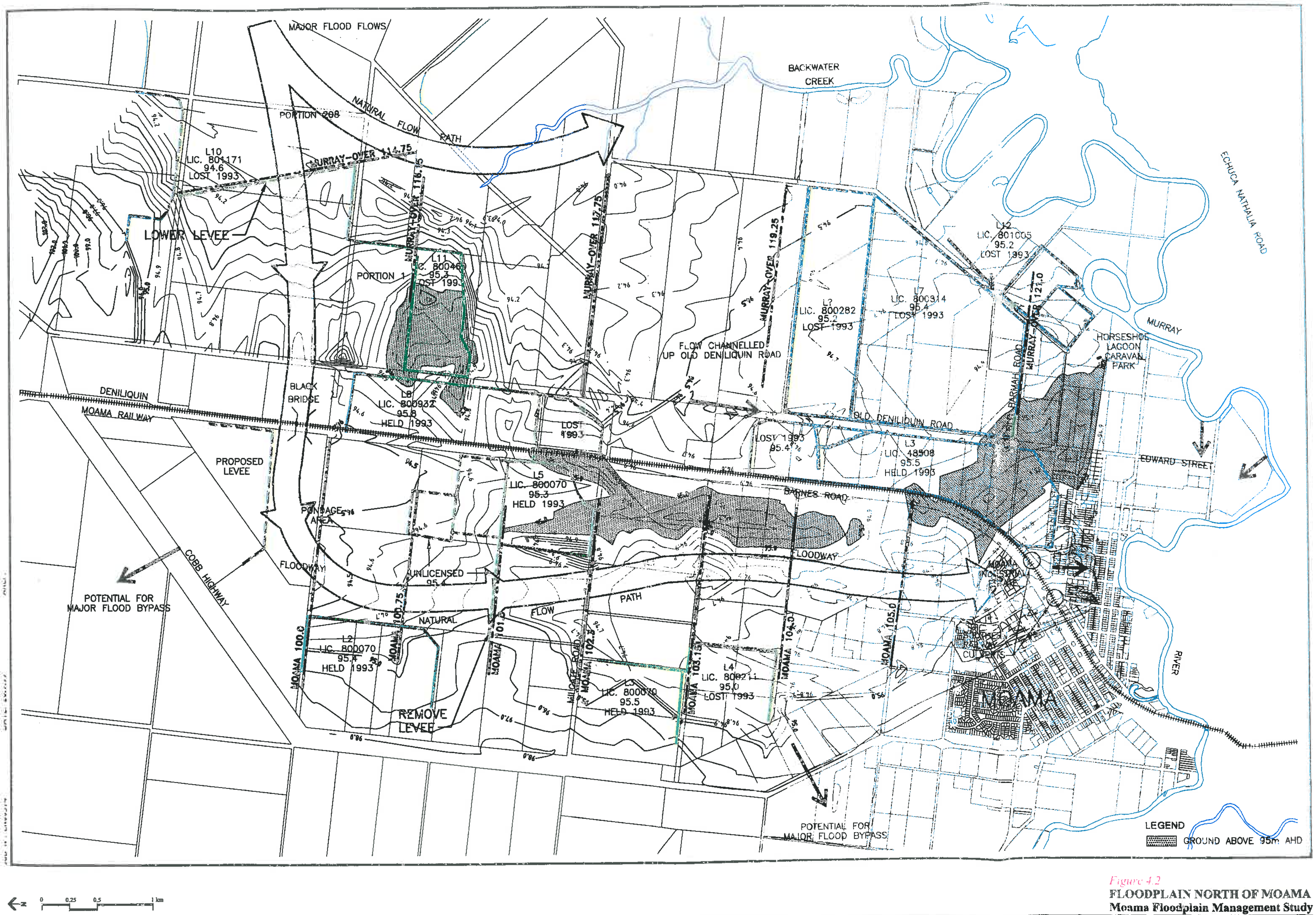


Figure 4.2

FLOODPLAIN NORTH OF MOAMA

Moama Floodplain Management Study

The velocities through this area are quite low but the flood depths are high. The overbank flows that overtop the right bank (concentrated between 4 km to 8 km downstream from Gilmours Sandbar) flow towards the railway line. They are constrained by the levee system north of Hardings Lane (L 10) [1]. Some of the floodwaters will flow over the levee parallel to the railway line and flow through the Black Bridge into the floodplain north of Moama. Some of the floodwaters will flow towards Backwater Creek in a southerly direction as shown in **Figure 4.2**. There will also be flows across Webb Road parallel to the railway line in a southerly direction.

The rural levees under consideration in this section include the ones on either side of Webb Road / Old Bama Road on the eastern side of Backwater Creek (Lic 801018).

As discussed above, these rural levees are not blocking main natural flowpaths and they do not affect the flood storage area significantly. As such, they can remain with a height restriction attached. Levee crests should be limited to their current heights or the 1993 flood level, whichever is the lesser. The 1993 flood level is chosen as an upper limit because:

- it is quite recent in memory,
- it corresponds approximately to ARI 20 years at the Echuca Gauge,
- it corresponds approximately to ARI 50 years in the floodplain area upstream of the railway.

This provides a relatively high standard of protection for rural land.

4.3.2 Area East of Railway Line to Bama State Forest

This area has numerous rural levees, as seen in **Figure 4.2**.

Floodwaters flow from the Bama Forest towards the railway line. They are constrained by the levee on an irrigation channel north of Hardings Lane, which is shown in **Figure 4.2** as L 10 near cross section 114.75. Some of the floodwaters will flow over this levee and flow through the Black Bridge into the floodplain north of Moama. Some of the floodwaters will flow towards Backwater Creek in a southerly direction. There will also be flows across Webb Road parallel to the railway line in a southerly direction. Although the flows conveyed through Black Bridge and across Webb Road may be only a small proportion of the total flow in the river and floodplain, these are natural flowpaths and their obstruction would raise flood levels elsewhere in the floodplain.

The levee L10 constructed on the irrigation channel bank near cross section 114.75 blocks a natural flow path and should be lowered to the approved crest elevation.

[1] There is an irrigation channel at this location. One of the channel banks has been raised to obstruct flood flows.

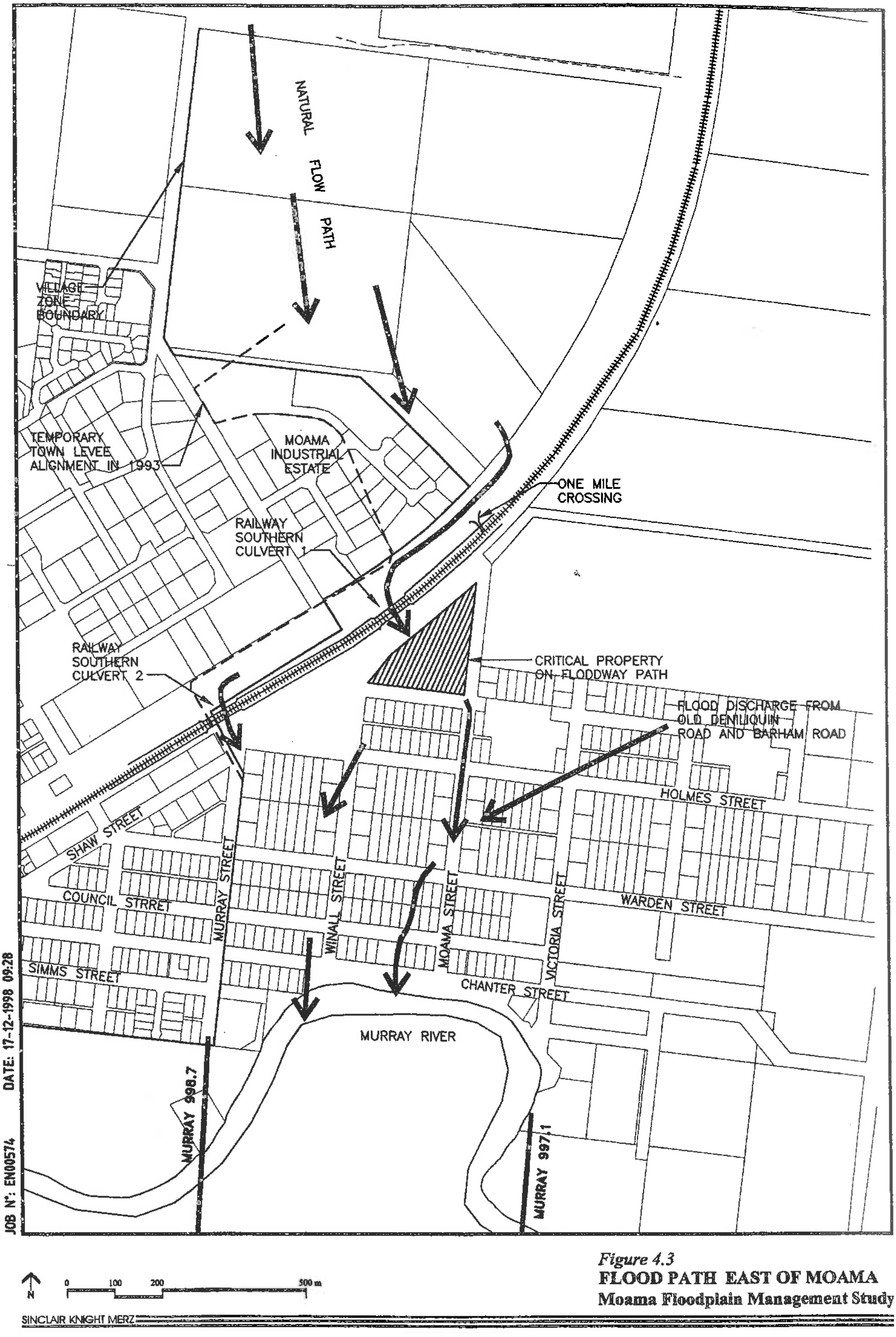


Figure 4.3
FLOOD PATH EAST OF MOAMA
Moama Floodplain Management Study

Other levees can remain as they only encroach slightly on the floodpaths and have insignificant effects on flood storage. It is recommended that other levees can remain with restrictions on levee heights attached. Levee crests should be limited to their current heights or the 1993 flood level, whichever is the lesser. It is also recommended that no further levee construction be permitted.

There are three levees north of the Horse Shoe Lagoon (L3, L7 and L12) that concentrate flows in road reserves and direct them towards Moama. The levee spacing between L3 and L7 (Old Deniliquin Road) is about 60 meters: the levee spacing between L12 and L7 is about 40 meters. It is recommended that these spacings be widened to 100 meters, which would reduce velocities by a factor of two or more. Minimum spacing between levees of 100 m should be imposed in future.

4.3.3 Area North of Moama between the Cobb Highway and Railway

There are numerous levee banks in this area as shown in **Figure 4.2**. During the extreme flood event (PMF) there will be breakaway flows across the Cobb Highway at two locations shown in **Figure 4.2**.

This area primarily receives flow through the Black Bridge. There also could be minor seepage through the railway embankment during floods. The floodwaters flow in a southerly direction to pass through the two railway culverts towards the Murray River. A levee constructed near cross section 101.5 blocks this natural flow path. It is recommended that this unlicensed levee be removed and the natural floodway restored.

Other levees only encroach slightly on this floodway. The other levees can remain with restrictions on levee heights attached. Levee crests should be limited to their current heights or the 1993 flood level, whichever is the lesser. It is also recommended that no further levee construction be permitted.

4.3.4 East of Moama between the Railway Line Culverts and the Murray River

This floodway area is shown in **Figure 4.3** and is on the right bank of the Murray River. It also forms the main discharge area from the northern floodplain, passing under the southern railway culverts. It also links with flood discharges from the east near the intersection of Old Deniliquin Road and Old Bama Road.

4.3.5 Merool Lane Area

As shown in **Figure 4.4**, the Merool Lane area is the subject of a number of levee developments that affect flood behaviour.

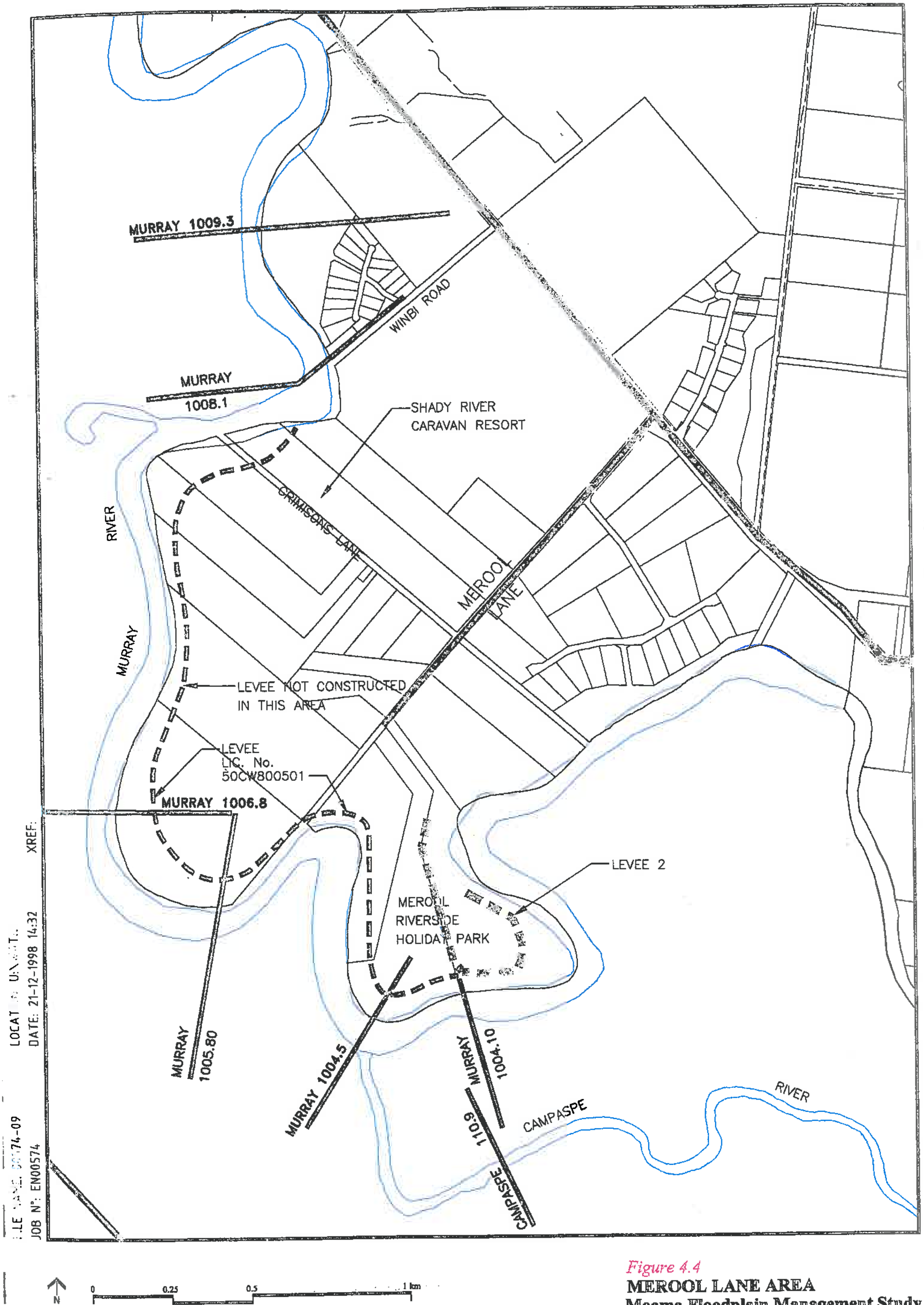


Figure 4.4

MEROOL LANE AREA

Moama Floodplain Management Study

SINCLAIR KNIGHT MERZ

There is a licence for a levee of unlimited height following the bank of the Murray River from the upstream end of Merool Riverside Holiday Park to Shady River Caravan Resort past Grimisons Lane. The levee to the western (downstream) side of Merool Lane has not been constructed, although there is one section around Shady River Caravan Resort that generally falls within the alignment of the licensed levee. The levee around Shady River Caravan Resort has recently been extended.

The licensed levee (shown as Levee 2 in **Figure 4.4)** has been constructed around the Merool Riverside Holiday Park to a level of about 94.5 m AHD, which is very close to the 1993 flood level.

The original hydraulic model was modified by inserting about six additional cross sections downstream of the Echuca Bridge to evaluate the effects of these developments.

The hydraulic model studies did not reveal any adverse impact on the Campaspe floodplain in Victoria from the existing Merool Riverside levee. It does increase the 100-year ARI flood levels by about 0.1 m at the Echuca Bridge. Flow velocities near the bend at Merool Riverside Holiday Park are also increased by this levee. The increase in average velocity was about 0.15 m/s (from 0.8 to 0.95 m/s) for the 1993 flood, and would be about 0.2 m/s (from 0.7 to 0.9 m/s) for the flood of ARI 100 years.

If raised higher, this levee would completely obstruct flows across the low-lying land in Merool Riverside Holiday Park. Aerial flood photography reproduced in **Figure 4.5** illustrates that this is part of the natural flow path of the main river flow during floods. The increase in velocities would become greater in larger floods if the levee were raised. It is strongly recommended that the existing levees should not be further raised.

In the same manner, if the levee which has been licensed to be built up to unlimited height is constructed, there would be substantial increase in velocities due to the restriction of flow areas. This would contribute greatly to river erosion and flood hazard.

It is recommended that no further levee construction be allowed in this flood-plain. Licences issued for which levee development has not taken place should be revoked.

4.3.6 Victorian Developments

Echuca levees

The main town levee in Echuca extends from Percy Street (the bridge) down past the Echuca Wharf and existed for many decades. It provides a level of protection approximately to the designated flood level (95.63 m AHD).

FILE NAME: 00574-23

JOB N°: EN00574

NOTE: MEROOL RIVERSIDE HOLIDAY PARK AT LOWER LEFT

Figure 4.3

OCTOBER 1993 FLOOD PHOTOGRAPHY

Moama Floodplain Management Study

Between 1989 and 1992, extensions to the levee system were made. These included a levee to protect Echuca East upstream of the bridge, a short length of levee along the river bank parallel to Dickson Street (downstream of Echuca Wharf), and two short levee systems on the Campaspe right (east) bank.

These levees were the subject of an audit for the Victorian Department of Natural Resources and Environment (Findlay Irrigation Services / BM Consulting, 1996). All of these levees protect developed urban areas of Echuca.

The levee system in Echuca East comprises four sub-sections of levee with a total length of 2 600 m. Apart from a very high level of protection surrounding a pump station and water treatment plant, the levee crests are generally below the designated flood level and provide standards of protection to between 3% and 2% AEP (*i.e.* ARI 33 to 50 years). The design crest level was intended to provide 600 mm freeboard above a flood of 3% AEP, but the constructed height is variable.

The Murray River levee downstream of the wharf area is 486 m in length. Higher ground exists naturally in this area, but the levee at the rear of properties fronting Dickson Street protects lower ground in those properties from inundation. The design crest level is 95.10 m AHD, which is intended to provide 600 mm freeboard above a 3% AEP flood level. Although there is a short section which is a little lower, the crest level is at approximately 2% AEP (or ARI 50 years).

The lengths of levee along the Campaspe right bank are well removed from the Murray River and are unlikely to have any potential effect on the NSW bank.

No further extensions or modifications to the levees in Echuca are planned at this stage.

Lower Goulburn River

A Floodplain Management Plan is also being finalised for the Lower Goulburn River (downstream of Shepparton) which could have some minor future influence on flood levels in Echuca and Moama (Sinclair Knight Merz, 1998). Extensive levee systems have flanked the Goulburn River on both sides from Coomboona and Bunbartha down to Wyuna and Kotupna since early this century. These have acted to isolate the river from floodplain storage areas in minor and moderate floods (up to about ARI 10 to15 years), and convey flows to the Yambuna Forest area upstream of the Yambuna Choke with less attenuation of flood flows than would occur without the levees.

Two proposals are under consideration for the Lower Goulburn:

(i) a strategy which adapts the existing levee system, and adds more controlled outflow points to distribute floodwaters to the adjoining floodplains during major floods (with ARI greater than about 15 years);

(ii) a strategy which would remove some levees on the north side of the river (right bank) at and downstream of Loch Garry, permitting floodwaters to escape to the Deep Creek system in floods of ARI greater than about 3 years.

The authority responsible for implementation of the Floodplain Management Plan is Goulburn-Broken Catchment Management Authority. The second option is favoured by the authority at this stage because of the opportunity provided for greater environmental and recreational benefits. This option is more expensive, however, and will depend upon attracting funding support and further consultation to engender community acceptance of the proposal.

During major floods of the magnitude which would affect Moama, either one of the proposals will utilise more of the floodplain storage available beside the Lower Goulburn and so no adverse downstream impacts are likely.

4.4 Other Proposed Developments and Issues in the Floodplain

4.4.1 Development in the Town Area Downstream of Echuca Bridge

There are several proposals which have been submitted to Council that affect the flood liable land west of the road and rail bridge embankment. There is a danger of setting a precedent for the filling of flood storage areas, but if this is explicitly restricted to a strip within the village area adjoining the main thoroughfare (Meninya Street) it would be acceptable. The filling of land close to river cross-section Murray 1001.70 where the floodplain flows are converging back to the river on the NSW bank could accelerate flood flow velocities in this part of the floodplain, increasing erosion potential and creating potentially hazardous conditions immediately adjacent to the proposed fill.

4.4.2 Vegetation Impacts Downstream of Echuca Bridge

Concern has been raised regarding the growth of vegetation in the area between Meninya Street and the river (as shown in **Figure 4.6**) and its effects on the flood levels at the bridges and upstream. Thick vegetation growth increases the roughness factor or resistance pertaining to general flow hydraulics in the floodplain and tends to increase flood slopes and levels upstream.

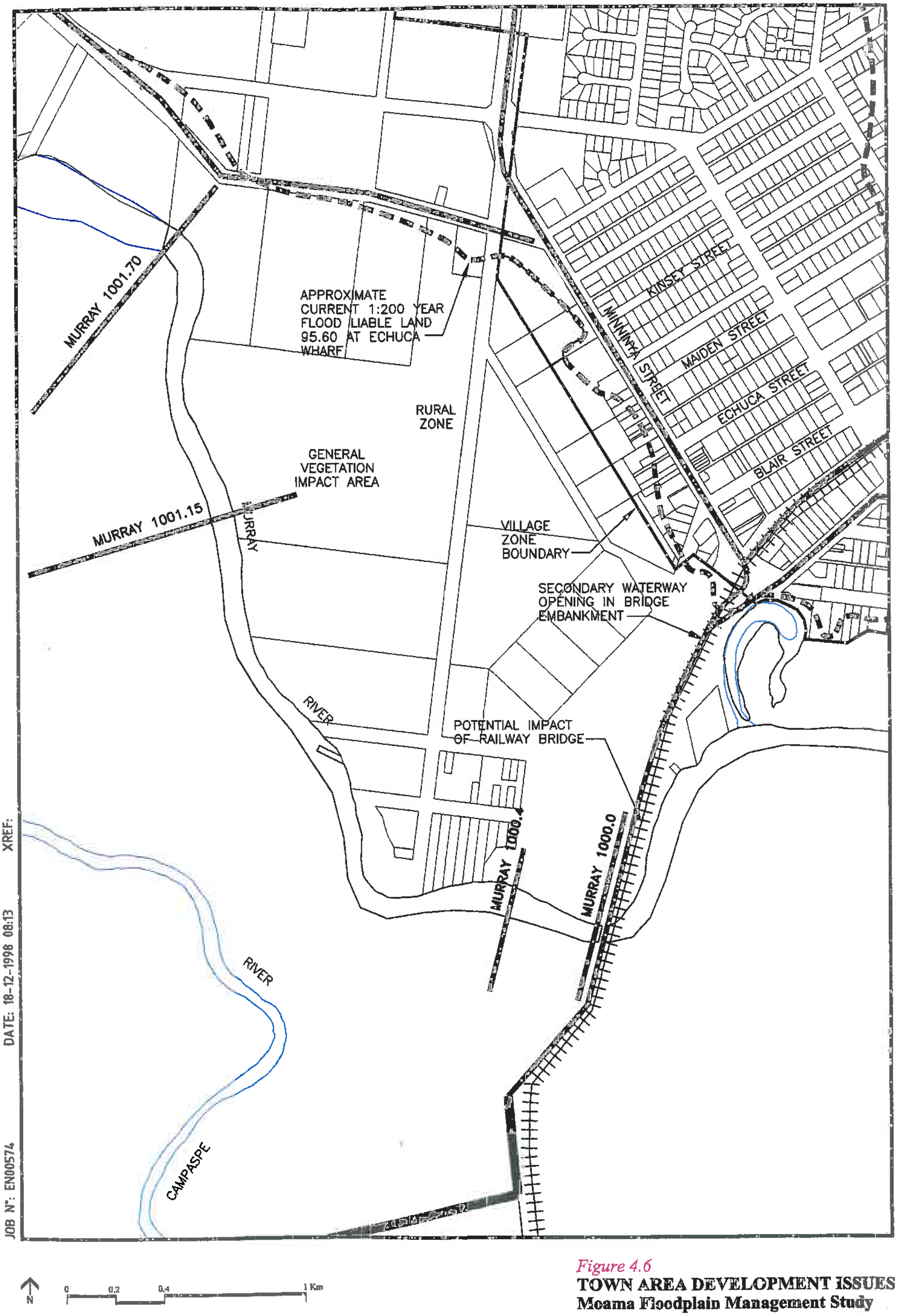


Figure 4.6
TOWN AREA DEVELOPMENT ISSUES
Moama Floodplain Management Study

However, the floodplains of the River Murray downstream of the bridges are wide and the thick vegetation does not entirely cover this area. There could be minor redistribution of flows within the floodplain due to variations in the thickness of vegetation growth, leading to a two-dimensional flow situation. As discussed before, the existing hydraulic model is one-dimensional, and simulating these effects would be very difficult. It is also difficult to know by how much roughness factors would increase without some means of model calibration.

It could be argued that redistribution of flows would tend to increase velocities and erosion potential in some areas, which is undesirable. Furthermore, thick growth immediately downstream of the bridge openings could temporarily block flows with the accumulation of trapped logs and debris carried during flood events. This would increase velocities and erosion potential quite substantially.

Due to these reasons, it is suggested that a program of vegetation management be maintained in flow-paths immediately upstream and downstream of the bridge openings.

This should be restricted to a confined area, because in general interference with native vegetation and its regeneration is undesirable. A management area of width extending to 30 m both sides of the bridge openings would be appropriate. The area should also extend up to 50 m upstream of the bridge openings (i.e. transverse to the rail or road crossings) and up to 200 m downstream. In the confined management area, no existing mature trees should be removed under the management program. A balance should be maintained between regrowth and understorey vegetation, and the hydraulic performance requirements of the concentrated flood flow-path.

The area immediately downstream of the main bridge opening on the NSW bank is a designated conservation area. Conservation objectives extend to the vegetation and the old slipway opposite the Echuca Wharf. Given this status, the application of the proposed vegetation management program should be very sensitive in this area, and only clearance of understorey vegetation with the potential to trap debris and create obstructions during flood flows should be permitted.

The other bridge opening nearer the town of Moama is a recreation area, and this use is very compatible with the hydraulic objectives of the proposed vegetation management program.

Vegetation management should be restricted to these limited areas. Effects of vegetation is just one influence on flood flows in this part of the floodplain. Other important influences are the bridge crossing itself and the backwater effect from the Campaspe.

In many floods, the Campaspe backwater can appreciably reduce the hydraulic gradients downstream of the bridge, and in these circumstances the effects of the floodplain vegetation will become almost insignificant.

The effect of the bridge, too, will have an effect similar to that of the floodplain vegetation. The embankment blocks approximately 410 m of the 980 m width of the floodplain on the alignment of the crossing. The effect of the bridge is also diminished by the backwater effects that arise from the Campaspe. Hydraulic modelling shows that the head difference across the bridge alignment is quite small during floods (*e.g.* 0.05 m to 0.07 m, although observational data available does not permit accurate model calibration).

Clearance of floodplain vegetation is also poor in principle. Quite apart from the important ecological roles played by riparian forest, and other aesthetic and recreational considerations, riparian vegetation mitigates the effect of floods downstream by slowing velocities and attenuating flood peaks. Widespread removal of floodplain vegetation aggravates flooding downstream and harms river health.

5. Flood Damage Assessment

5.1 Introduction

This section documents the flood damage assessment tasks undertaken for the Moama Flood Plain Management Study.

Specifically, the tasks in flood damage assessment were as follows:

- A full flood damage assessment for a range of design events from AEP 10% up to an extreme flood (refer section 3.2.2) for existing conditions, and for specific flood mitigation measures.
- Estimation of average annual damages in existing conditions and for mitigation options.

A detailed account of the flood damage modelling is provided. Existing conditions are evaluated in this section of the report, while damages under modified conditions are considered under section 7.

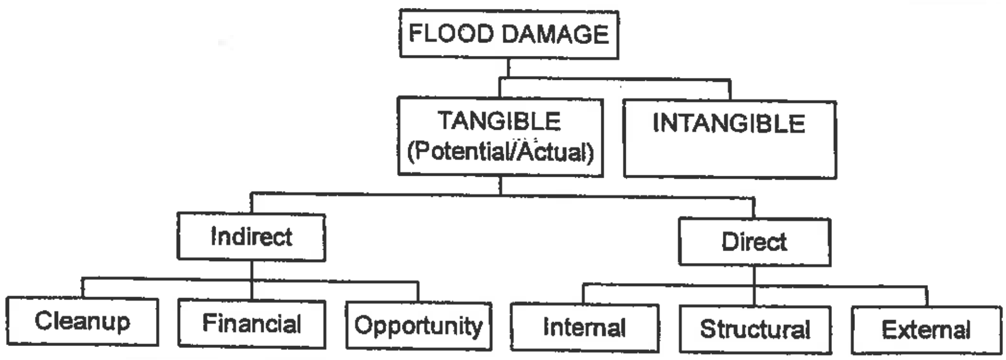
5.2 Flood Damage Assessment Procedure

5.2.1 Fundamentals

A flood damages assessment was undertaken for Moama to determine the scope of damages in existing condition and to assess the merits of a flood mitigation option in reducing those damages. The assessment is a key component in the determination of a preferred flood mitigation scheme, directly via estimates of damages and as input into a financial benefit-cost assessment.

Damages from flooding can be sub-divided into a number of categories. **Figure 5.1** shows the various categories commonly used in flood damage assessments.

Figure 5.1 - Categories of Urban Flood Damage



Tangible flood damages are those to which a monetary value can be assigned and include property damages, business losses and recovery costs. Intangible flood damages are those to which a monetary value cannot be readily assigned and include anxiety, inconvenience and disruption of social activities. Both are a function of flood magnitude. This flood damages assessment focuses on the tangible flood damages. Intangible damages are important and are considered, but only in the broader context of the acceptability generally of degrees of flooding in Moama.

Tangible damages can be sub-divided into direct and indirect damages. Direct damages are those financial costs caused by the physical contact of flood waters and include damage to property, roads and services. Property damages can be sub-divided into internal and external damages. Internal damages include damage to carpets, furniture and electrical goods. External damages include damages to cars, gardens and building exteriors.

Indirect damages are those additional financial costs generally incurred after the flood during clean-up and include the cost of temporary accommodation, loss of wages, loss of production for commercial and industrial establishments and the opportunity loss caused by the closure or limited operation of business and public facilities.

Tangible damages can also be treated as potential or actual damages. Potential damages are the maximum damages that could occur for a given flood event. In determining potential damages, it is assumed that no actions are taken (whether months or hours) prior to or during the flood to reduce damage by, for example, lifting or shifting items to flood free locations, shifting motor vehicles or sandbagging. Actual damages, in this context, are the expected damages for a given flood event. Their value – a proportion of potential damages – is based on the community's flood preparedness which is a function of community awareness and the lead time of flood warnings.

5.2.2 Assessment Methodology Overview

The flood damage assessment relies on the collection of property data for all potentially flood prone properties for the range of flood events being considered. Flood level data for each event of interest are applied to these data to determine flood depths and from this flood damages at each property. Total damages are simply a summation of damages for each property.

The damages considered in this flood damage assessment are tangible damages associated with property. Damages to roads and services, for example, are not considered. Furthermore, the assessment deals with potential tangible damages as worst-case damages.

The assessment was undertaken using a flood damage model developed by Sinclair Knight Merz. The model was constructed in a GIS environment using the ArcView GIS software package. The GIS environment provides a visual representation of the assessment. It can show property locations, flood extents and flood affected properties as well as listing property data and calculating resulting damages. The methods and damage data used in the model are those of a model called ANUFLOOD (1992) created by the Centre for Resource and Environmental Studies (CRES) at Australian National University.

The assessment involved determining total damages (both extent and cost) for each of a range of flood events under given floodplain conditions (*i.e.* existing conditions or some flood mitigation scheme conditions). The range of total damage estimates can be combined to determine an average annual damage (AAD) or annual damage cost to the community for accepting a given floodplain condition. It is commonly used in flood management studies as it is a useful single value indicator of the financial vulnerability of a community to flooding in existing conditions and of the benefit of proposed mitigation schemes.

5.3 Flood Damage Assessment Data

The data requirements for the flood damages assessment are significant. The types and sources of data are discussed in the following sections.

5.3.1 Property Data

Fundamental to the assessment is the compilation of property data for properties potentially affected by flood. The data of interest are predominantly building data. The data were collected from available cadastral and zoning plans and input into a property database within the GIS flood damage model. For the assessment methods adopted in this study, the following property data are required.

Property Location

The property location must be defined by ground coordinates used by the model to identify the flood level at each property.

A cadastral plan of Moama township showing building locations was used to define ground coordinates of the properties. The buildings were digitised and imported into the GIS environment (see **Figure B.1, Appendix B**).

Land Use

The land use for each property is a major factor in determining the expected damage for a given flood depth. Land uses include residential, commercial, industrial, public, open space and recreation. Clearly for a given flood depth damages will differ with land use. The flood damage model considers two land use categories, residential and commercial. The latter is used to cover a range of non-residential land uses (industrial, public, etc.).

A development control plan showing zoning for Moama township, was used to identify land use categories to assign to each property.

Property Damage or Value Class

Property value is an important determinant in flood damages. The flood damage model requires each property to be assigned to a damage or value class. The class determines which flood depth versus damage data are used for each property. Class categories differ for residential and commercial properties.

For residential properties damage class is a function of building size, material and condition. Each residential property can be assigned to one of three residential damage classes.

For commercial or non-residential properties value class is primarily a function of building contents, although building material and condition are also factors. It is the value of the business and its contents which determines its value class. There are five commercial value classes. Building size is also very important in commercial properties. For each value class, there are three size categories.

Given the limitations in data generally, a detailed assessment of each property could not be justified. Therefore, property damage values were based on the following assumptions.

Based on data obtained from flood damage assessments recently undertaken by SKM for several Victorian townships (e.g. Euroa, Wangaratta, Traralgon, etc.), all the residential properties of Moama were assigned to the median class (medium sized and in good condition). The commercial or industrial properties were considered as buildings with medium value class and medium size.

Ground and Floor Levels

In order to determine a flood depth at each property, ground and floor level data must be obtained. These data must be located by coordinates so as to identify the appropriate flood level for each property.

The ground information for each property have been extracted from a Digital Elevation Model (DEM) derived from available, albeit limited, information, namely benchmarks located inside Moama township and in the surrounding area. The resulting DEM reproduced the ground variability of the study area (see **Figure B.2, Appendix B**).

The floor levels for Moama properties were not available and consequently they have been derived from simplistic assumptions based on previous studies, in particular from the Euroa Flood Plain Management Study. An average difference between floor and ground levels for each land use class was determined for the Euroa township and applied to the Moama property database. Therefore, to determine floor levels to each property +0.35 m has been added to each ground level of the residential properties, while +0.20 m has been added for both commercial and industrial buildings.

5.3.2 Flood Level Data

Flood level data for Moama were determined using MIKE 11, a one-dimensional dynamic hydraulic model. One-dimensional hydraulic models represent rivers and creeks as series of cross sections. For each flood event of interest, the hydraulic model output is therefore in the form of a single flood level at each cross section.

By contrast, properties are scattered across the river and creek floodplains. Only rarely will a property location coincide with an hydraulic model cross section. The bulk of properties will lie between adjacent hydraulic model cross sections. In order to assign a flood level at each property some form of flood level interpolation between cross sections is required.

This was achieved in Moama by generating an interpolated flood surface for each flood event of interest, from a flood level at each hydraulic model cross section. The flood surfaces are input into the GIS flood damage model, where they are overlain onto the property data to determine flood depths at each property for each flood event.

5.3.3 Damage Data

Damage data provide the means by which flood depths can be converted into monetary damages. The data required must cover the different types or categories of damage relevant to this flood damage assessment. Specifically, damage data is required for both direct and indirect damages. Direct damages can be further sub-divided into internal and external damages. Following is a brief description of the damage data used for each damage type or category. All damage data are embedded in the GIS flood damage model.

Direct Damages (Internal)

Internal direct damage curves have been taken from the ANUFLOOD program. There are eighteen internal damage curves, three for residential properties (for 3 damage classes) and fifteen (for 3 size classes by 5 value classes) for commercial properties. Each relates flood depth above floor with monetary damage. As the damage data were initially calculated in early 1992, all damage values were adjusted to 1998 values using a Consumer Price Index (CPI) based factor of 1.12.

Figure 5.2 reproduces the CPI adjusted internal direct damage curves used for this flood damages assessment for residential properties.

Figure 5.2 - Residential Internal Damage Curves

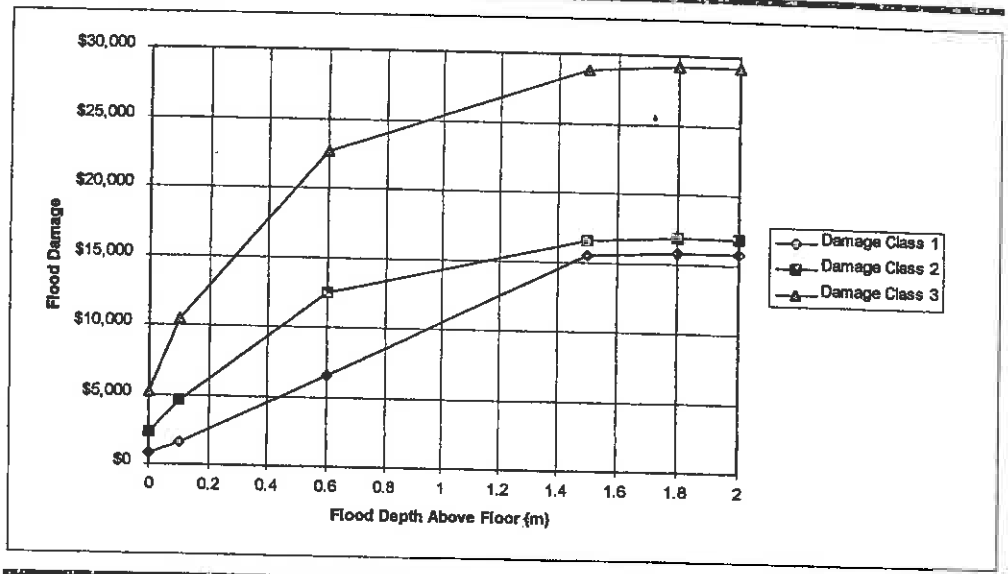
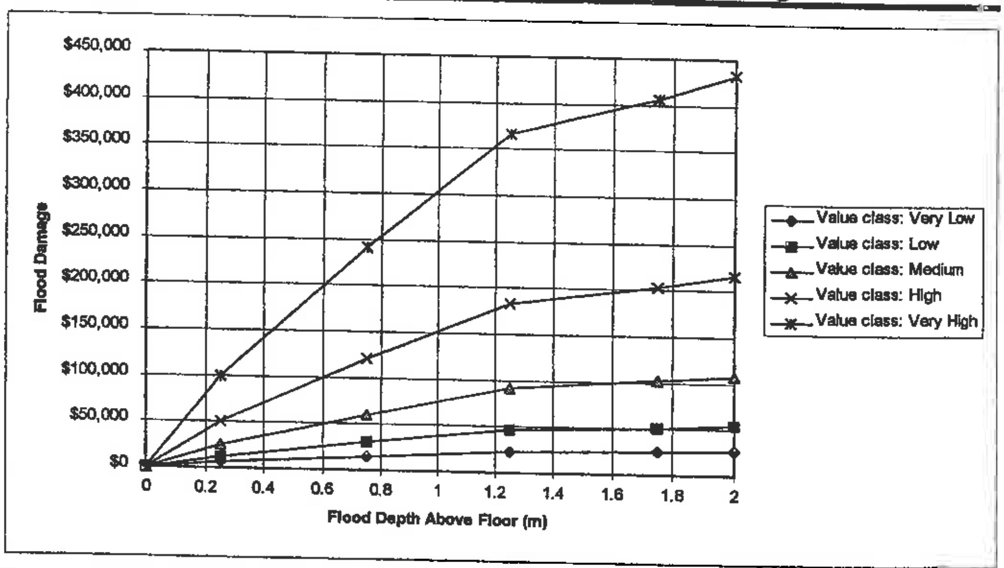


Figure 5.3 reproduces the CPI adjusted internal direct damage curves used for this flood damages assessment for the medium size class of commercial properties.

Figure 5.3 - Medium Commercial Class Internal Damage Curves

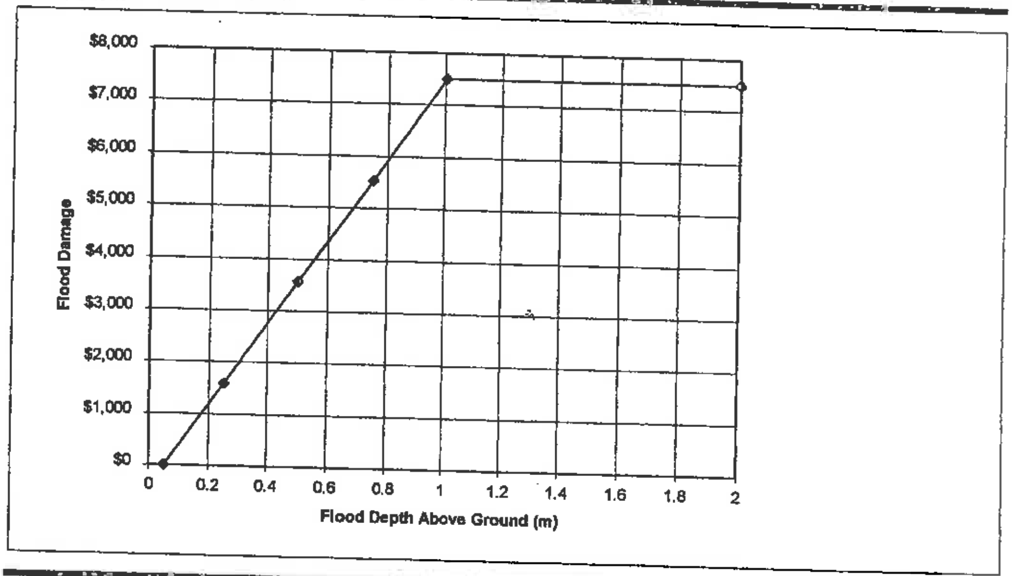


Direct Damages (External)

An external direct damage curve has been developed using data from Main Report, Volume 2, Floodplain Management in Australia (AWRC, 1989). It assumes that external damages commence at a flood depth above ground of 0.05 m and vary linearly to an upper limit of $7 500 at a flood depth above ground of 1 m. No distinction is made between residential and commercial properties.

Figure 5.4 shows the resulting external direct damage curve used for this flood damages assessment for all properties.

Figure 5.4 - External Damage Curve



Indirect Damages

Indirect damages are calculated as a percentage of total (ie. internal plus external) direct damages. The percentage values used are taken from the ANUFLOOD program. They are assumed as a function of land use only. **Table 5.1** lists these percentages.

Table 5.1 - Indirect Damages (as a percentage of Direct Damages)

Residential	Commercial	Industrial
15%	55%	70%

Note that as these indirect damages are a function of direct damages, they do not include the indirect damages imposed on flood free properties that rely on flood affected properties as a source or market for goods and services. As such, this method may underestimate the total indirect damages.

5.4 Flood Damage Analysis for Existing Conditions

The GIS flood damage model was first run to assess flood damages under existing conditions for a range of design flood events, namely the 10%, 5%, 2%, 1%, 0.5% AEP (*i.e.* ARI 10 years, 20 years, 50 years, 100 years and 200 years, respectively) events and an extreme event. **Tables 5.2** to **5.4** list the numbers of above-floor, flood-affected and the total affected properties and the resulting total potential property damages. The total affected properties includes properties flooded to a depth below floor level which would incur only external damages.

Table 5.2 - Above Floor Flooded Properties in Existing Conditions

Locations	10%AEP	5%AEP	2% AEP	1% AEP	0.5% AEP	PMF
Residential	3	3	94	175	256	875
Industrial	-	-	55	59	66	77
Commercial	-	-	-	-	-	20
TOTALS	**3**	**3**	**149**	**234**	**322**	**972**

Table 5.3 - Total Flooded Properties in Existing Conditions

Locations	10%AEP	5%AEP	2% AEP	1% AEP	0.5% AEP	PMF
Residential	3	18	226	291	364	1,069
Industrial	-	-	59	66	66	77
Commercial	-	-	-	-	-	27
TOTALS	**3**	**18**	**285**	**357**	**430**	**1,173**[1]

[1] Note that for the extreme event, the number of total affected properties (1,173) represents the whole township of Moama.

Table 5.4 - Total Flood Damages in Existing Conditions

Locations	10%AEP	5%AEP	2% AEP	1% AEP	0.5% AEP	PMF
Residential	0.08 m	0.104 m	1.256 m	2.665 m	4.728 m	18.292 m
Industrial	-	-	1.419 m	2.525 m	3.827 m	7.323 m
Commercial	-	-	-	-	-	0.366 m
TOTALS ($)	**0.08 m**	**0.104 m**	**2.676 m**	**5.190 m**	**8.556 m**	**25.981 m**

Tables B.1 to B.3, Appendix B show further details of the flood damage assessment results in existing conditions. **Figure B.3** shows the flood affected properties in a 1% AEP flood event.

With regard to the flood damage modelling the following comments are made.

The flood depths and extents were derived by converting the output (i.e. flood levels at cross-sections) of the one-dimensional hydraulic model to a flood surface and comparing it to an interpolated ground surface Digital Elevation Model. As the data sources for the hydraulic model cross-sections (and hence flood surfaces) and ground surface DEM were different, there exists potential for introduction of errors in estimation of the resulting flood depths and extents.

The modelling was based on a direct comparison of flood levels (in the form of a flood surface) with property data in the flood damage model's property database. For each property, if the flood level was greater than the property ground or floor level, the property would register in the model as flood affected.

The accuracy of the flood damage assessment is very dependent on the level of accuracy of the required input data. For Moama township most of the data has been derived from assumptions and hypothesis, due to a lack of more direct information. Such data inconsistencies limit the accuracy of the modelling processes. Consequently, the reliability of the results has to be considered as low. A detailed survey of ground and floor levels together with field investigations on property sizes and conditions would provide a higher level of reliability to this type of analysis.

Despite this, it is believed the flood damage model provides a reasonable representation of flood damages in Moama for the purposes of assessing the impact of flood damages in existing conditions and the benefits of flood mitigation options (see **Figure B.3, Appendix B**).

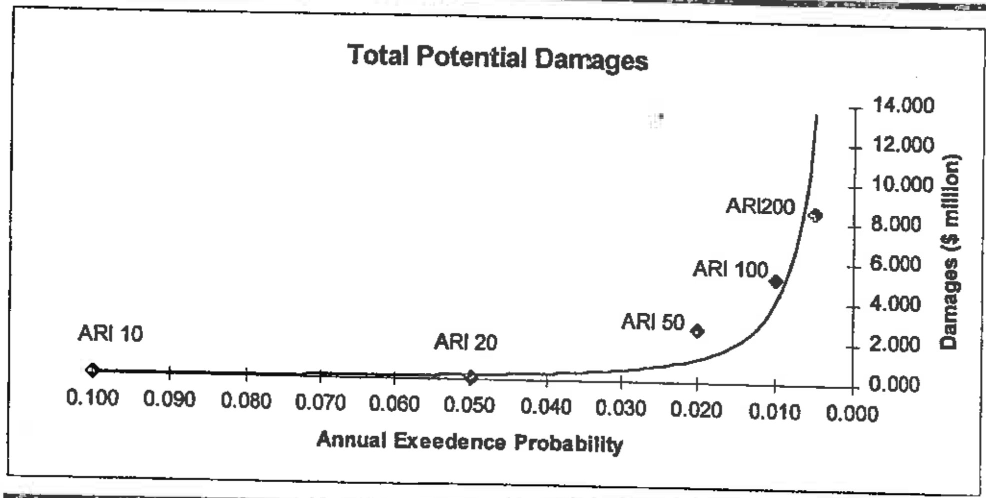
Average Annual Damages

Average annual damages (AAD) are calculated as the area under a curve of total monetary damages versus AEP. AAD are a standardised measure of damages used, for example, in economic evaluations. In this instance the curve is generated from data in **Table 5.4** above. **Figure 5.5** shows a plot of this data. Note that the smooth curve is a fitted curve only, and was not used for the calculation of areas.

In calculating average annual damages, the area of interest under the curve is up to the Flood Planning Level (0.5% AEP flood event). Whilst the total damages for greater events are relevant and important data, average annual damages are only calculated up to this Flood Planning Level for Moama. The calculation of AAD also assumes that there are zero damages for a flood event of 20% AEP (ARI 5 years).

The average annual damages for Moama up to the Flood Planning Level in existing conditions is $0.124 m or $124,000 per annum (see **Table B.4, Appendix B**).

Figure 5.5 - Total Potential Damages versus AEP



6. The Planning Context

6.1 Planning Framework

6.1.1 Background

Floodplain management is intimately related to issues of land use planning and associated development controls. This link, between floodplain management and the NSW environmental planning legislation (Environmental Planning and Assessment Act, 1979 (EP&A Act)), is fundamental to the NSW Flood Prone Lands Policy and the processes laid out in the Floodplain Development Manual and the Draft Floodplain Management Manual.

Land use planning within Moama and the rural areas of the study area is primarily regulated under the provisions of the EP&A Act (as amended), by Murray Local Environmental Plan 1989 (Murray LEP 1989), and also by Murray Regional Environmental Plan No 2 (REP No2).

The Water Act also plays a significant role, requiring the approval of works under either Part 2 or 8, which affect the flow and distribution of floodwater within a designated floodplain. The licensing of rural and caravan park levees under the Water Act has recently been formally integrated with the development control powers of Local Government. The Environmental Planning and Assessment Amendment Act, 1997, has established new processes for development control, including a category called "Integrated Development", where development requires "in principle" approvals from approval bodies such as the DLWC before development consent is granted. Such a system has operated informally under the consultation provisions in Murray REP No 2 prior to this latest amendment to the process.

6.1.2 Murray REP No 2

This REP provides a regional planning framework affecting floodplain management planning and development control along the River Murray. The REP requires consideration to be given in the land use planning and development control process to:

- the effects of development on the behaviour of floodwater and water quality,
- the effect of flooding on development,
- the design standards and maintenance requirements of flood mitigation works for the protection of new urban development.

The REP identifies flood liable land as land inundated in a 1 in 100 year flood as shown on a map marked 'Murray Regional Environmental Plan No 2 - Riverine Land' deposited in the office of the Department of Urban Affairs and Planning. It is expected that data derived from future flood studies will further refine current flood information as defined by this map.

The REP identifies a number of planning principles which should be considered by Murray Shire Council in the preparation of LEPs, determining development consent, and in considering activities which have the potential to adversely affect the riverine environment of the River Murray. Specific principles relating to land subject to flooding include:

- the benefits to riverine ecosystems of periodic flooding,
- the hazards involved in the development of that land,
- the redistribution effect of the proposed development on floodwater,
- the availability of other suitable land in the locality not liable to flooding,
- the availability of flood free access for essential facilities and services,
- the pollution threat represented by any development in the event of a flood,
- the cumulative effect of the proposed development on the behaviour of floodwater,
- the cost of providing emergency services and replacing infrastructure in the event of a flood,
- flood mitigation works constructed to protect new urban development should be designed and maintained to meet the technical specifications of the DLWC.

There is also the principle that new or expanding settlements (including rural-residential subdivision, tourism and recreational development) should not be located on flood liable land.

Typical planning control provisions in the REP affecting floodplain management include:

- Permanent facilities associated with caravan parks and camping grounds should not be on flood liable land. Caravan Parks and Camping Grounds require Council consent, are required to be advertised, and a range of public authorities consulted including DLWC, DUAP, EPA, MDBC, NSW Tourism Commission, Campaspe Shire Council, and VIC Department of Natural Resources.
- Development consent is required for chemical, fuel or fertiliser storage on flood liable land and consultation with DLWC, EPA and MDBC.
- Development consent and advertising is required for flood control works. Flood Control Works are defined as works which change the natural or existing condition or topography of land (such as the construction or alteration of levees, channels and mounds) and which are likely to affect the hydrology of the River Murray system. Consultation is required with the MDBC, DLWC and appropriate Floodplain Management Committee.

- Use of flood liable land for hazardous or offensive (or a potentially hazardous or offensive) industry, hazardous or offensive storage establishment, intensive livestock keeping, waste land-fill, and manufactured home estates is prohibited. Use of land for such works above the definition of flood liable land will require development consent and advertising.
- Road and rail undertakings (included in the definition of Public Utility Undertakings), are controlled as stated in LEPs (usually not requiring development consent). However they do require consultation with the Murray Darling Basin Commission (MDBC), Council and other relevant authorities.

Murray REP2 also places controls on the clearing of native vegetation and the management of wetlands. The clearing of any species of indigenous trees and shrubs mapped as native vegetation on the Murray REP No2 Maps requires Council Consent unless being carried out under specific Crown authority, or of a generally minor nature or being undertaken in accordance with a Vegetation Management Plan for the land. Consultation is also required with DLWC, State Forestry, MDBC and NPWS. Specific matters that must be considered by the Council as consent authority include:

- whether the development would contribute to soil erosion, land degradation, including rising water-tables
- the effect of the development on landscape
- the potential loss of wildlife habitat
- whether the development would endanger the species of vegetation, either locally or across its range.

These provisions can be relevant to the construction or alteration of particular flood control works. These provisions apply, as do provisions concerning flood liable land, to areas marked on maps.

Murray REP2 also provides for the making of River Management Plans which are to be taken into account in the planning and development control process. River Management Plans are defined as any development control plan, plan of management, study, strategy, guideline or the like, which has undergone a public consultation process, which is consistent with the aims, objectives and principles of Murray REP2 and which is endorsed by the MDBC.

In line with the wider strategic interest in the regional planning and management of the River Murray and its floodplain, the MDBC has issued a Floodplain Planning Guideline on *Camping Grounds and Waterfront Resorts*. Provisions of this Guideline include:

- no fixed infrastructure systems or buildings should be constructed in locations where they are liable to be jeopardised by periodic flooding;
- existing areas liable to flooding must have the ability to be evacuated at short notice in times of flooding;

- no new developments should be permitted in floodways for camping grounds, caravan parks and related activities;
- waterfront resorts and caravan parks with permanent facilities and structures such as power lines, rigid caravan annexes, mobile homes and amenity buildings should be located on flood free land (should not be located on flood liable land);
- subdivision of lots for separate occupation sites should not occur within the 1 in 100 year floodplain area unless it is part of an approved River Management Plan;
- levees, or other flood control works cannot be constructed within the 1 in 100 year floodplain areas without prior approval from the Interstate Levees Committee (or a delegate authority *eg.* DLWC or Murray Shire).

Murray REP No 2 and associated high-level guidelines relating to floodplain management (such as those provided by the MDBC) can either operate in isolation to Murray Shire's planning policy (while still requiring compliance), or can be integrated into the Draft Floodplain Management Plan.

6.1.3 Murray LEP 1989

Murray Local Environmental Plan (LEP) 1989 is the relevant local planning instrument that established the detailed decision making framework for the planning and control of land uses on and within the Moama floodplain and associated area. The general aims of Murray LEP 1989 include broad objectives to:

- Encourage the proper management, development and conservation of natural and man-made resources within the Shire of Murray (Clause 2a), and

- Help facilitate growth and development of the Shire of Murray in a manner which facilitates the efficient and effective delivery of amenities and services(Clause 2b(ii)).

There is currently a specific provision in the LEP regarding Flood Liable Land which states:

- A person shall not erect a building or carry out a work for any purpose on flood liable land except with the consent of the Council. (There is a general assumption that this does not apply to agricultural works within the rural zone of the floodplain because such works are ancillary to the use of the land for agriculture which is a conforming or permissible use without Council consent)

Apart from this specific provision and the identification of flood liable land as shown on the LEP Map, there is little further control, or consideration of floodplain management issues.

The EP&A Act provides for Ministerial Directions to Local Councils to include certain provisions in Draft LEPs specified in those Directions. Such Directions have been applied to flood liable land as defined in accordance with the Flood Prone Lands Policy.

The Flood Liable Land Direction states generally that Draft LEPs shall not:

- Rezone flood liable land to residential, business, industrial, special uses, village or similar high value use;
- Contain provisions which:
  - permit a significant increase in the development of that land,
  - are likely to result in increased Government spending on flood mitigation measures, infrastructure or services,
  - permit development to be carried out without development consent, except for agriculture (not including dams, drainage canals, levees, buildings or structures in floodways, high hazard flood fringe or high hazard flood storage areas) minor development and additions.

Land defined as high hazard flood liable land or as floodway in accordance with the Flood Prone Lands Policy is to be zoned accordingly in any Draft LEP, permitting uses such as open space, rural, conservation, environmental protection and similar non intensive land uses.

Flood liable land is defined with diagonally hatched black lines on the LEP map. The mapping of flood liable land is as identified in the 1986 Murray River Floodplain Management Study based on the 1 in 100 year flood event.

Amendments may need to be made to Murray LEP 1989 to reflect the definition of flood liable land and associated flood hazard categories arising from the recommendations of this Floodplain Management Study and associated Draft Plan.

6.2 Zoning

Murray LEP introduced five planning zones, as described below and indicated in **Figure 6.1**.

6.2.1 Zone No 1(a) - General Rural

The majority of the study area is zoned General Rural, including the area from the east of Murray Street and around the existing town levee. On the west of Moama the General Rural zone follows a line to the west of land fronting Meninya Street and then generally west of the Cobb Highway. The majority of the General Rural zone is cross hatched on the LEP map to indicate flood liable land.

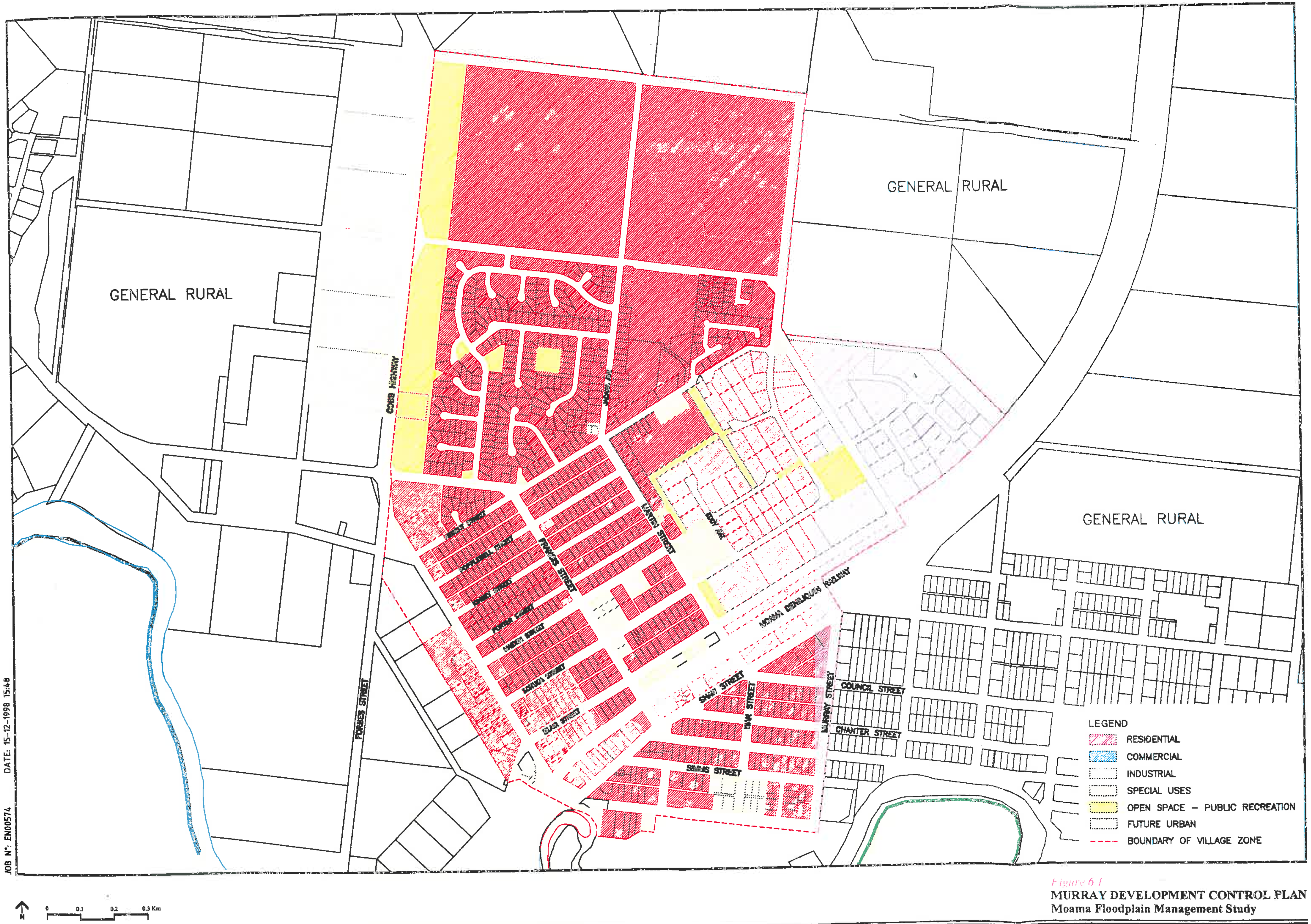


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Figure 6.1
MURRAY DEVELOPMENT CONTROL PLAN
Moama Floodplain Management Study

SINCLAIR KNIGHT MERZ

There are no planning objectives or general considerations for development control relating to flood management within the zone. Agriculture is permissible without development consent, although under Murray REP2, Flood Control Works require development consent and are also required to be advertised.

Such a clause would apply to the construction of rural levees, as would the flood liable land provision in the LEP for Council consent to be obtained for any work on flood liable land as defined by the planning map. The application of this provision in the LEP to rural levees, however, may be constrained due to the fact that such levees would be ancillary to the use of the land for agricultural purposes which does not require consent. The provisions of Murray REP2 override any such inconsistency, however.

The minimum subdivision for agricultural purposes is 40 hectares, and 120 hectares where there is a dwelling on the created allotment. There is an allowance for existing holdings to be subdivided only once to create an allotment of less than 120 hectares with an existing dwelling. Dwelling entitlements within the General Rural zone require a land area of not less than 500 hectares although they may be as small as 20 hectares where a licence to irrigate horticultural crops exist under the Water Act (1912). There are no special requirements to consider flood management issues and any special requirements that do exist relate generally to the protection of prime crop and pasture land.

Council currently requires any residential development to have a floor level equal to a 95.63m AHD flood level as measured at the Echuca gauge. This is the designated flood planning level. There are no special requirements for flood access, considering that there is sufficient flood warning time for preparation and the ability to boat in and out in generally slow-flowing waters east of Moama. Most rural inhabitants are generally well prepared for flooding and are also able to use high-level vehicles such as tractors for general access purposes if required.

6.2.2 Zone No 1(c) - Rural Small Holdings

The objectives of this zone are to enable the development of land for rural-residential or hobby farm development and also a range of industrial, storage or intensive livestock keeping purposes. The Small Holdings zones are to the west of Moama in the vicinity of Merool Lane, and have been approved in line with the Flood Liable Land Direction, on the basis that that they are not flood liable. There are therefore no planning objectives or general considerations for development control relating to flood management within the zone, although compatibility with the environmental capabilities of the land is required for industrial, storage or intensive livestock keeping purposes.

Rural residential subdivision within the Rural Small Holdings Zone is limited to an average allotment size of 0.8 hectares with off-site disposal of sewage and

2 hectares with on site disposal of sewage. Again there are no specific provisions for flooding issues to be considered although under clause 14(3)(a), Council is required to consider the natural hazards of the land to be subdivided in relation to the density of the allotments proposed to be created and (c), design of each allotment in relation to the economic provision of services.

6.2.3 Zone No 1(d) - Future Urban

The Future Urban area for Moama is identified north of Nicholas Drive and west of the Cobb Highway. There are no specific provisions for flood management and the area is above the designated flood planning level.

6.2.4 Zone 1(f) - Rural Forests Zone

This zone identifies areas of State Forest east of Moama and prohibits uses other than agriculture and forestry.

6.2.5 Zone No 2(v) - Village or Urban Zone

This zone identifies the urban area of Moama including associated industrial and commercial property. A separate Development Control Plan (DCP) identifies industrial, commercial and other sub zones within this area and provides details on Councils policies for their consideration of development within this zone. The DCP does not provide any specific direction in relation to flood management or protection.

6.2.6 Subdivision and Dwelling Entitlements

The subdivision of land within the study area requires Council consent. There are no special or specific requirements within the LEP to address flood management issues in the subdivision of land. The principal requirements are to avoid the fragmentation of rural land so that it can continue to be used for agricultural purposes and to allow for rural residential size subdivision in suitable areas.

There are many small allotments based on the original Crown subdivision of the Town of Moama within the General Rural zone to the east of Murray Street and within the current definition of flood liable land. Many of these lots remain undeveloped and may have building rights, depending on their position as 'existing holdings'.

6.2.7 Existing Use Rights

There is protection for existing uses such as for approved rural levees, under the EP&A Act, known as "existing use rights". An environmental planning instrument can not require development consent for the continuance of a work for a lawful purpose. (In other words, Murray REP2, which requires development consent for flood control works, cannot require development consent for flood works legally built prior to making Murray REP2.).

These rights for lawful works do not allow however for any alteration, extension, rebuilding, increase in area, enlargement, expansion or intensification of the use without obtaining development consent.

On the other hand, the Water Act discussed below is retrospective and provides the mechanism for dealing with existing works which are inappropriate or unacceptable.

6.2.8 Rural Flood Levee Approval and Licensing

The underlying approach of the NSW Flood Prone Lands Policy has been largely focused on urban and coastal flooding issues. The planning and management of rural floodplain works has been practised largely through the licensing powers available to the DLWC under Parts II and VIII of the Water Act, 1912, rather the EP&A Act, 1979, (although responsibilities to protect the environment still remain under Part V of the later Act).

Part II of the Water Act provides for the licensing of works which could affect the distribution of floodwaters flowing in, to or from, or contained in, a river or lake. In 1984 the Water Act was amended, via a new Part VIII, to control all private works, on the banks of rivers and lakes and on proclaimed floodplains, which could affect the distribution of floodwaters. A "controlled work" under Part VIII of the Water Act is defined as any earthwork, embankment, or levee (except those excluded by "prescription") constructed on a designated floodplain or on the bank of a river, or lake. This part of the Act also provides control over existing works and not merely future works.

Works excluded by "prescription" include railways and associated bridges vested in the State Rail Authority; and roads, associated bridges and works vested in a local government council or the Roads and Traffic Authority.

The DLWC may refuse an application or apply conditions where the controlled works are likely to affect the distribution of floodwaters in its vicinity. An approval (license) has effect for five years, with provision for renewal and there is also provision for the cancellation of approvals and for the DLWC to remove works or require them to be modified where an approval is not in force.

The Ministerial Water Corporation (under Part VIII of the Water Act), has designated the flood affected areas of the Central Murray region which include the rural areas of Moama. The provisions of the legislation allows for the preparation of coordinated floodplain management plans for the designated area in consultation with landholders and Local Government. No plans have been developed for this area of Moama, and the intention is to integrate the Moama rural floodplain management issues within the broader provisions and strategies of the Moama Floodplain Management Plan under the NSW Flood Policy.

6.3 Planning for Flood Hazard Categories

Guidelines for appropriate development considerations for the floodplain and hazard categories form an important part of the NSW Flood Policy and associated Floodplain Development Manual (and Draft Management Manual).

Six types of land use (residential, commercial, industrial, open space, rural, and special uses) are prescribed development considerations under six types of development condition (existing development, infill development, new development, redevelopment, major additions, and minor development and additions) according to the floodplain and hazard categories encountered.

6.3.1 Land Use Categories

The development types defined within the policy and as occurring within the Moama study area were described in Section 2.1.3.

Residential, Commercial and Industrial

Generally these uses are treated as one category, with a range of conditions from general floor level controls in low hazard areas through to the requirement for detailed engineering studies and effective evacuation procedures in low hazard floodways and high hazard categories throughout.

Open Space and Rural

These uses are also generally treated as one land use type with respect to development considerations. Development considerations are identical to the above category, apart from low hazard floodway considerations which could be applied only where warranted.

Special Uses

The guidelines specify that special uses such as for schools, hospitals, public halls, fire and police stations and infrastructure service buildings should be sited on flood free land.

6.3.2 Development Categories

In addition to these development types, the following development categories are required to be taken into consideration in determining the floodplain management plan.

Existing Development

Existing development is already at risk from flooding and is therefore not addressed within the development control guidelines. Potential future damage can be reduced by flood modification measures (such as the proposed town levee), property modification (including voluntary acquisition in high hazard areas), and by improved emergency response measures. Flood modification measures to protect existing development, such as by rural levees or levees around caravan parks, are not considered to be a favourable option in view of their cumulative impact on flood behaviour and their consequent impact on other land uses within the floodplain.

Infill Development
Generally refers to the development of vacant blocks in urban areas for uses consistent with the land use zone. Despite the apparent consistency with surrounding land uses, where existing development is already flood-affected due to past land use decisions, further infill would be inappropriate due to present understandings of the flood risk.

New Development
Generally refers to a change of land use such as the subdivision of rural land for new urban or rural residential development. New development proposals need to fully account for the present understanding of flood risk and associated design guidelines.

Redevelopment
Redevelopment refers to the demolition and reconstruction of existing land uses, often to a more intensive level. Generally redevelopment should be treated the same as for infill and new development.

Infill, new development and redevelopment are all treated as a single category for the application of development considerations in the guideline.

Major Additions
Includes such developments as major increases in floor area. Additions generally greater than 10% of the existing area or floor space require development consent and suitable control as for a new development.

Minor Additions
Refers to uses such as for swimming pools, fencing, storage sheds and minor additions. This form of development now falls within the general definition of "Exempt Development" under the Environmental Planning and Assessment Amendment Act (1997). The NSW Government is preparing a State Environmental Planning Policy (SEPP) that will declare minor development exempt from Council approval if it meets certain standards. Some forms of minor additions such as fencing could impact on the floodplain in sensitive areas such as floodways, and Council will need to incorporate such items into an LEP prior to December 1999 if control is to be ensured over such works.

6.3.3 Development Control Guidelines

Development guidelines from the Floodplain Development Manual are summarised below in **Table 6.1** as an outline of the recommended NSW Flood Policy with regard to appropriate considerations to be given to planning and development control matters within the floodplain.

These guidelines are later utilised to recommend an appropriate Draft Floodplain Management Policy for the control of land use and development contained in Section 10 of this Study.

Table 6.1: Development Control Guidelines

Development Considerations	Application
1. Any portion of a building below the FPL should be built from flood compatible materials	all development and land use categories in all hydraulic and hazard zones
2.Floor Heights (residential, industrial, commercial and special uses) to be 0.5m above FPL for freeboard or be flood proofed to this level. Generally applies to major residential extensions and or as considered by the merits of the individual case.	As above except for minor development and additions
3 Caravan Parks to be carefully assessed	as above
4 Minor developments and additions to existing developments are exempted from special controls although should be treated on their merits in specific cases	general exemption for minor developments except in floodways (either low or high hazard)
5. Developer/owner to demonstrate that any structure can withstand the force of flowing floodwaters in engineering report.	low hazard floodway and all high hazard hydraulic categories (except for minor development categories)
SPECIAL (flood Storage and Floodway) - where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour proponent will need to demonstrate proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS	generally for all flood storage and floodway hazard categories (except for some major and all minor development categories)
SPECIAL (high hazard areas) - the feasibility of effective evacuation is to be demonstrated to the consent authority including permanent, fail-safe, maintenance measures to ensure the timely, orderly and safe evacuation of people from the area. It is to be also demonstrated that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. Council should also consult the SES and be provided with a detailed engineering report and EIS.	For all high hazard categories.

6.4 Floodplain Land Use and Risk Assessment

There are both risks and benefits achieved from the use of the floodplain. These uses include those which have been developed over time through human occupation and settlement, and also the intrinsic use of the floodplain by natural ecosystems.

The NSW Flood Prone Lands Policy is based on the principles of risk management being applied to the management of land use within the floodplain in order to achieve the objectives of the policy including:

- to reduce the impact of flooding and flood liability on individual owners and occupiers,
- to reduce private and public losses resulting from floods,
- to protect the natural flood carrying capacity and flood storage functions of floodplains, and
- to sustain the natural ecosystems of floodplains.

There are many risk management issues which are relevant to questions of floodplain management. A risk management approach to floodplain management looks at such things as how often floods will occur, the consequences of floods, the vulnerability of the community, and the resilience of the community to recover from floods. Generally the approach considers the assessment of a level of risk based on a consideration of two primary factors:

- the likelihood of flooding, and
- the consequences of flooding.

The likelihood of flooding is a measure of the probability or frequency of flooding.

The consequences of flooding relate to the impacts of a flood of a given frequency on existing and potential development (including the intrinsic environmental values of the flooded area). In order to assess the consequences of floods of various frequencies the following broad categories of the numerous flood risk factors are considered:

- flooding characteristics,
- socio-economic factors, and
- environmental values.

6.4.1 Flooding characteristics

The accepted approach to define flood behaviour is through the delineation of flood hydraulic and hazard categories based primarily on the combinations of velocity of flood flow and flood depth which are considered to be hazardous to occupants of a floodplain. Other factors relevant to any consideration of flood hazard include the duration of flooding, the rate of rise and fall of the flood, effluent flow-paths and strategically significant flow exchange paths, areas protected by levees and their state of maintenance and associated spillway arrangements.

The NSW Flood Policy recognises three hydraulic categories of flood-prone land: floodway, flood storage and flood fringe – and two hazard categories: low hazard and high hazard. Flood hazard categories have been determined for a range of flood events using the results of the hydraulic model described in Section 3.2 of this report, and defined in Section 4.2.

6.4.2 Socio -Economic Factors

Socio-economic factors include measures such as the population at risk, numbers of properties affected, access to flood free areas, ease of evacuation, flood awareness and flood warning. All of these factors affect the consequences associated with particular flood events and the risks attached to the protection of people and property.

While flood behaviour may define particular hazard characteristics, the risks attached to particular hazards will be affected by the socio-economic characteristics of the area. Generally, in the rural areas, property managers and their families are intimately aware of flooding behaviour and are well prepared to cope with the events and also to assist others. They are more self-reliant than urban or hobby farm residents, and the risks associated with the more common flood events may be considered relatively minor.

6.4.3 Environmental Factors

The natural flooding of floodplains has important implications for the preservation of floodplain ecosystems and associated water quality. Consideration needs to be given to the beneficial flooding of areas to sustain wetlands, breeding of aquatic wildlife, nutrient exchange, and the sustainability of terrestrial flora and fauna.

These considerations are particularly important within the study area given:

- the ecological significance of floodplain forests and ecosystems;
- their dependence on the flood regime for regeneration, growth and environmental health.

The consequences of impeding flood flows and storage in natural areas can be significant and the risk assessment process may need to carefully balance the costs and benefits associated with works that alter natural flooding regimes.

6.4.4 Preliminary Risk Assessment

The outline in **Table 6.2** is developed as a basis for a qualitative risk analysis for various sectors of the Moama Floodplain Management Study area.

The proposed risk management model used in this study involves two interrelated activities:

- Risk analysis or assessment (using the flood risk matrix shown in **Table 6.2**)
- Risk management - implementing responses appropriate to the risk analysis. These may be based on strategies of risk prevention, impact mitigation, risk transfer, or, risk acceptance

Floodplain land use and specific risk areas have been divided into the following sectors that reflect both local knowledge and recorded flood behaviour within the study area. These areas include:

- east of Bama State Forest to Gilmours Road area,
- east of the railway line to Bama State Forest,
- north of Moama between the Cobb Highway and the railway,
- east of Moama between the railway line culverts and the Murray River,
- the town area downstream of the Echuca Bridge,
- the Merool Lane area west of Moama.

Table 6.2: Flood Risk Analysis Matrix

Likelihood (Frequency)	Consequences/Impacts			Risk Management
	Flood Characteristics	Socio-Economic	Environment	
10%; 5%; 2%; 1%; 0.5% Average Exceedance Probability (AEP) floods and also an Extreme Flood	Hazard and hydraulic definitions (floodway, flood storage, flood fringe: flood paths: duration; rate of rise; areas protected by levees	Population at risk; numbers of properties; access to flood free areas; ease of evacuation; flood awareness; flood warning	Preservation of floodplain ecosystems; consequences of impeding flood flows	Risk prevention through flood modification (levees, floodways); impact mitigation and assessment through better planning and development control: better emergency response measures and education

6.5 Emergency Response and Flood Preparedness

6.5.1 Role of State Emergency Service

Because emergency management has taken time to filter into the list of considerations in a developing society, we are faced with a legacy of past mistakes which mean that the community is often now exposed to hazards which, with benefit of hindsight, could have been avoided by sensible land use and development.

The State Emergency Services Act 1989 states that the SES is to act as the combat agency for dealing with floods (including the establishment of flood warning systems) and to coordinate the evacuation and welfare of flood-affected communities.

The SES and the volunteers who provide the response service to their communities during floods recognise that for a productive rural community to exist, people may need to live on their farmland despite being exposed to the hazard of floods. These productive farmers are often reasonably self-reliant and require a minimum of assistance during floods, and in most cases they are a relatively small and stable population.

In contrast, the experience of the SES is that individuals in rural residential communities are less well prepared for isolation and tend to quickly run out of food and basic supplies. Even relatively short periods of isolation can create a liability on the SES and Disaster Welfare Service to provide supplies of food and other essentials. In the case of weekenders and retreat homes, they are not occupied all the time and this adds another complicating factor to the warning process.

The SES has limited human and material resources and there is no direct mechanism by which SES capability can be increased as development expands into areas at risk. If the population exposed to potential flooding continues to grow in number, especially if poorly located development creates rescue and supply obligations in the process, these limited resources will ultimately be unable to cope. As the agency with the responsibility for dealing with floods and developing warning systems, the SES has a duty to inform the community about the limitations of emergency response in times of flood.

The Service has a further duty to consider the impact of flood response operations on SES volunteers who are increasingly being placed under an obligation to provide assistance under difficult and dangerous conditions.

The SES role in floods has been recognised in the State Disaster and Rescue Management Act 1989. This Act places a responsibility on the SES to develop and maintain Flood Plans for all flood affected communities. The Flood Intelligence Card for Moama is currently being updated prior to the 1999 flood season.

6.5.2 Local Flood Plan

A Local Flood Plan has been produced for the Murray Shire as a Sub-Plan of the Murray Local Disaster Plan (DISPLAN). The latest edition of the Local Plan is October 1993. It is noted that the Plan should be updated no less frequently than every three years. It is likely that this Plan will be updated following consideration of this Draft Floodplain Management Study and a current review by the SES of their Flood Intelligence Card.

The Local Plan covers such things as:

- responsibilities
- preparedness measures
- response operations
- coordination of immediate recovery measures
- details of flood threat

6.5.3 Public Education and Flood Awareness

Public Education regarding flood risk and behaviour is seen as a critical issue. Regular small flood events in much of the study area tend to cause residents to become complacent about floods. In these situations residents are likely to underestimate the likely impact of the less frequent, but more severe floods. Because of this lack of awareness, residents may be caught out by making a decision not to evacuate at the appropriate time.

The Murray SES Local Controller, with the assistance of the Murray Shire Council, is responsible to ensure that the residents of the municipality are aware of the flood threat in their area and how to protect themselves against it. This includes knowing (where applicable) at what stage their property might be inundated, appropriate evacuation routes, the location of evacuation centres, and the general contents of the Local Flood Plan.

The Local Flood Plan has allocated a specific responsibility to Caravan Park and Lodge Owners or Operators to:
1. Prepare a Flood Plan for their park.
2. Display that plan in a prominent location.
3. ensure that caravan owners/occupiers and residents of lodges are aware of any current flood and evacuation warnings.
4. Evacuate Parks as required.

6.5.4 Flood Warnings

The Bureau of Meteorology provides Confidential Flood Advice, Preliminary Flood Warnings and Flood Warnings including river height readings and predictions for river height gauges on the Murray and Edward Rivers. Flood Warnings are provided to the SES, media, police and other relevant organisations such as the Murray Shire Council. Official Bureau of Meteorology warnings are categorised as Minor, Moderate or Major with the type of warning issued determined by pre-defined depths at specific stream gauges.

Definitions of Minor, Moderate and Major are generally as follows:

- **Minor** flooding causes inconvenience. Low lying areas adjacent to watercourses are flooded, requiring removal of stock and equipment. Minor roads may be closed and low-level bridges submerged. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and/or towns-people begin to be flooded.
- **Moderate** flooding in addition to the above may require the evacuation of some houses. Main traffic routes may be closed and there may be substantial flooding in rural areas.
- **Major** flooding in addition to the above causes extensive flooding to both rural and urban areas, with properties and towns likely to be isolated and major traffic routes likely to be closed. Numerous evacuations may be required.

According to the SES Murray Shire Local Flood Plan the relevant flood warning gauges for Moama are located at Tocumwal, Echuca and Deniliquin as shown in **Table 6.3**.

The flood warning classifications for the Echuca gauge are based on flooding applicable to rural areas and riverside caravan parks in the Moama area and not town flooding.

Table 6.4 has been taken from elements of the SES Flood Intelligence Card for Moama. River heights are AHD on the Echuca gauge.

Table 6.3: Bureau of Meteorology Flood Warning Gauges

River	Station	Flood Classifications		
		MINOR	MODERATE	MAJOR
Murray	Tocumwal	6.4	6.7	7.3
Murray	**Echuca**	**93.1 (AHD)**	**93.6 (AHD)**	**94.4 (AHD)**
Edward	Deniliquin	4.6	7.2	9.4

Table 6.4: Moama Flood Intelligence

Classification	Height (m) (AHD)	Consequences
MINOR	92m	Rural flooding and the initial flooding of a number of caravan parks
MODERATE	94m	Old Deniliquin Road is closed and all roads in the area bounded by Old Deniliquin Road, Barmah Road and the Murray River are inundated
MAJOR	94.4m	Minor flooding in Moama township
MAJOR	94.5m	Flood water has moved west of the railway line (through the Black Bridge culvert) and inundated parts of Barnes Road and Milgate Road. Minor flooding across Chanter Street
MAJOR	94.6	Major flooding in Moama township. Water over roads causes significant flooding down Chanter Street, Tip and Water Ponds roads
	94.76	1993 flood peak height
	94.8	1916 peak height
	96.2	Flood of Record - 1870

At a river height of 94.4m (which is equivalent to the flood level of ARI 10 years or 10% AEP) it is reported that Moama township is only experiencing minor flooding. Major flooding within Moama is not reported until heights of 94.6m on the gauge.

Flood Warnings are distributed by the Murray SES Division Headquarters in Lavington. Flood Warnings are distributed, as considered appropriate to:

- Radio Stations
- Television Stations
- DLWC Regional Offices
- Victorian water resource authorities
- Police District Headquarters
- Newspapers
- SES Local Units
- NSW Ambulance Service
- Victorian SES
- NRMA (Albury)

On receipt of flood warnings which apply to the local area, such as Moama, the SES Local Controller (situated in Mathoura) will advise the Council plus the Murray Local Emergency Operations Controller.

Flood Bulletins are issued by the SES Division Headquarters which supplement the information contained in the Flood Warnings. These are also disseminated to appropriate media outlets listed above. The Murray Local SES Controller provides relevant information for such Bulletins, related to the estimated impacts of flooding at heights predicted by the Bureau of Meteorology.

SES warnings at the local level rely on the Local Controller who is in direct contact with the affected population. Besides direct contact with owners and occupiers most at risk, such as in caravan parks, the local controller will fax flood bulletins where possible or provide details by telephone.

There has been a recent move by the Bureau of Meteorology on advice from Councils and the SES to differentiate between rural and urban flood warnings. There is some difficulty however in deciding on the boundary between rural and urban. This is particularly evident in Moama with a number of residential properties located east of the town and susceptible to "rural" flooding. There is also a recognised problem in differentiating NSW flood warnings (provided by the NSW section of the Bureau of Meteorology and the NSW SES) from the Victorian warnings provided by the Bureau of Meteorology in Victoria and the Local Council.

It should be noted that the Victorian SES play a significantly different role during floods than the NSW SES. In Victoria the Local Council is responsible for much of the work (such as with flood warnings) that is carried out in NSW by the SES.

In 1993 the (then) Echuca Council made some high level complaints in NSW regarding the NSW SES flood warnings, which were said to be "scaring away the tourists". Echuca Council argued that as Echuca was not being flooded the SES should desist from what it considered to be alarmist flood warnings. Due to the nature of development in the rural areas, particularly to the east of Moama, the NSW SES have a duty to provide flood warning bulletins on the advice of the Bureau of Meteorology, that may not be relevant to the Victorian situation but are highly relevant to what could happen on the NSW side of the river.

6.5.5 Evacuation

The SES Flood Intelligence Card provides no detail regarding past flood evacuations. During the 1993 flood the SES was involved in the evacuation by boat of personal belongings from caravans caught in flood waters within the Merool Caravan Park.

Caravan Park owners/operators may independently decide to relocate vans or to evacuate their parks, based on Flood Warnings and other information provided to them or through the SES Local Flood Controller. Where temporary flood mitigation measures such as sandbagging are no longer considered practical, the SES Local Controller may decide that a caravan park has to be evacuated. The park owner/operator is responsible for evacuation, when and where ordered, under the control of the Local Emergency Operations Controller.

Evacuations when required from the township of Moama and its immediate surroundings are under the control of the Local Emergency Operations Controller. Field teams conduct house to house doorknocks to ascertain numbers and details of support required. All premises that have been evacuated are reported to the Moama Police who are then responsible for general security of the unoccupied premises.

The first stage evacuation centre is the Murray Shire Branch offices in Meninya Street. Short-duration evacuees can be accommodated at the Moama Sports Club or in Deniliquin, or will be encouraged to find alternative accommodation.

6.5.6 Post Flood

The Local Flood Plan also deals with flood recovery measures such as welfare, registration, 'all clear', recovery coordination and general de-briefing arrangements.

7. Potential Flood Mitigation Options

7.1 Introduction

A fundamental principle of good floodplain management is that management measures should not be considered individually or in isolation. Floodplain management is about identifying a total package of management measures (structural, non-structural and response measures) to reduce the adverse consequences of flooding, within a framework of environmental, social and economic constraints.

Table 7.1 provides an overview of the more common floodplain management measures and some assessment of their applicability in the Moama Study area. These measures are further discussed in Sections 7, 8 and 9 of this report.

Table 7.1: Floodplain Management Measures

Measure	Issues/Options
Measures which Modify Flood Behaviour	
Flood Mitigation Dams	There are a number of large dams within the catchment area of the Murray and Goulbourn Rivers which can mitigate effects of floods downstream. None of these dams are specifically flood mitigation dams. Because of the size of the catchments upstream, additional retardation through dams is not a feasible option.
Levees	can be an economically attractive measure to protect existing flood affected urban development. Consequences of overtopping a town levee need to be considered. Leveed areas should not be treated as completely flood free - unless designed to withstand the PMF. Environmental and social impacts need to be properly accounted for. Levees are becoming a significant issue in rural areas where intensive agricultural use of the floodplain is being protected by rural levees. A town levee is a likely measure for protection of Moama.
Bypass Floodways	are floodways designed to pass flood flows through an area to avoid developed areas and/or provide additional flood conveyance capacity. Environmental impact and the downstream implications of the floodway need to be accounted for.
Channel Improvements	increase the capacity of the river channel to discharge flood flows by opening up the channel area includes the clearing of obstructions to flow. Can accentuate downstream flooding, can incur recurrent maintenance costs and significant environmental impact. Not an option on the Murray for environmental reasons.
Retarding Basins	provide temporary flood storage upstream of the flood, similar to flood mitigation dam. Natural flood storage is provided by large basin including the Barna State Forest area immediately to the east of Moama. Issue for Moama is to protect the available volume of flood storage in this area which is currently being reduced in smaller flood events by extensive rural levees.
Floodgates	The strategic use of floodgates to control flows along particular flood paths can have beneficial effects depending on what flood conditions are being faced and by whom. It has been suggested that floodgates could be applied to the Black Bridge in order to protect Moama by the levee provided by the railway line. The railway line fill has not been designed as a levee and the environmental implication on the northern Moama floodplain and farming areas appears to preclude serious consideration of such an option. The provision of floodgates in the Chanter Street area to control flows from and to the river in this area is a more practical consideration.
Land Management	Modification or management of land influences runoff from that land and the hydraulic behaviour of floods which pass over it. Catchment management in upstream areas can mitigate the effects of floods, and management of riparian and floodplain vegetation and land use can influence flood levels and downstream impacts. Murray Shire not in a position to influence this adequately, given the extensive catchment areas and development upstream.

Property Modification Measures	
Land Use Zoning	Incorporated into Local Environmental Plan (LEP) or Development Control Plan (DCP). Need to be based on flood hazard. Best measure available to deal with cumulative impact of potential inappropriate development. Does not deal effectively with existing development. Could be appropriate for dealing with areas north of Moama and on the Murray floodplain.
Voluntary Purchase	where flood mitigation is impractical and existing people and property (including those sent for rescue) are exposed to unacceptable risks. Could be relevant to existing holdings within the floodway east of Moama and on Forbes Street near the slipway.
House Raising	is generally suitable only for low hazard areas of the floodplain and suitable structures.
Development on fill	will need to consider the effect on flood behaviour, risk of overtopping design level and isolation during floods. An option in Moama adjoining existing high ground within existing village zone.
Flood proofing of buildings	is the design and construction with appropriate water resistant materials to minimise flood damages. Only as an adjunct to other measures - social and economic costs remain. May impact on flood behaviour.
Flood access	Consideration needs to be given to access under flood conditions, including by road, boat and air. Access to critical facilities such as water, sewerage and hospitals.
Building and Development Control	control new development through local planning instruments in consultation with relevant authorities. Particularly relevant is the concept of "Integrated Development" in conjunction with Part 8 licensing of rural levees by the DLWC for the control of "flood works". General elements may include: □ access to site during floods □ fill or excavation in the floodplain □ freeboard □ flood works □ minimum floor levels □ building materials □ services □ impact on flood behaviour □ flood awareness - emergency plans
Response Modification Measures	
Flood awareness	Awareness of flooding and its consequences cannot be assumed. Requires public education and inculcation.
Section 149 Certificates	Information to property owners and occupiers on flood information and policies affecting the property. Could be issued to owners/occupiers on a regular basis.
Flood preparedness	The ability of flood affected people to defend their communities from flood threat by preparatory measures such as moving goods and possessions to higher ground. Some public education desirable.
Flood warning	Moama is well serviced by flood warning information however there may be inconsistencies between the NSW and the Victorian sides and the impact of warning on the economics of the tourism industry need to be considered.
Flood Plans	The SES has a detailed flood plan which needs to be integrated with the broader findings of the Floodplain Management Plan.
Recovery Planning	Besides general clean up activities and assistance following the flood peak, flood-related data and experience should be compiled to better deal with future flood planning and management.

7.2 Measures to Modify Flood Behaviour

7.2.1 Proposed Town Levee

Flooding problems in Moama are primarily caused by overflows from the Murray River. The Murray River right bank overflows cross the Deniliquin/ Moama railway line north of town, through the existing Black Bridge (1.61 m x 31.2 m). They flow towards the Murray River in a southerly direction parallel to the railway line and discharge through two railway culverts in town (0.93 m x 20.8 m, and 0.84 m x 19.2 m).

This was the flooding mechanism for the 1993 flood event. Murray Shire Council prepared a town levee to protect the inundated areas in 1996. The alignment of this levee is shown in **Figure 7.1** as the 1996 alignment. This levee alignment was studied for the Flood Study Report (Sinclair Knight Merz, 1997).

The alignment of the levee proposed now is slightly different to that proposed in 1996 downstream of the two railway culverts. The levee is now proposed to run down Winall Street instead of Murray Street, as shown in the alternative alignment in **Figure 7.1**. This includes more residences within the levee, and reduces the length of the narrow path for flood flow along the Barnes Road reserve. The railway culvert (southern culvert no.1 shown in **Figure 4.3**) must also be widened to increase the waterway area available for flow.

The levee is proposed to protect against the 0.5% AEP flood with a 600 mm freeboard.

The effects of this proposed levee were analysed using the hydraulic model. West of the railway, two possible floodways with different widths were taken into consideration. Floodways with base widths 34m and 60m and with three in one side slopes were assumed to convey the flows towards the railway culverts. These dimensions were taken from Council information.

The double-peaked inflow hydrographs for 20 and 100 year ARI flood events were used to evaluate the effects.

Effects of the Levee on the 20-Year ARI Flood Regime

Under existing conditions, the 20-year ARI flood profile inside the town is very flat. Flood levels rise gently upstream of the southern railway culverts and remain with very low gradients past the sewage treatment works.

With a 34m floodway in place between the railway and the proposed levee, the shape of the profile is similar, but the flood level upstream of the sewage treatment works is increased by 0.20m. With the 60m wide floodway, this increase is of the order of 0.10m. The peak flow in the floodway is about 27 m^3/s and the corresponding velocity is about 0.9 m/s with a 60 m wide floodway.

On the river side of the railway and upstream of the bridge crossing of the river, flood levels in the design flood of 20-year ARI increase by approximately 0.03 m. This effect extends upstream beyond the Goulburn River confluence, but diminishes to a negligible change in flood level at Gilmour Road. The effect of the proposed town levee also dissipates rapidly downstream of the Echuca-Moama bridge.

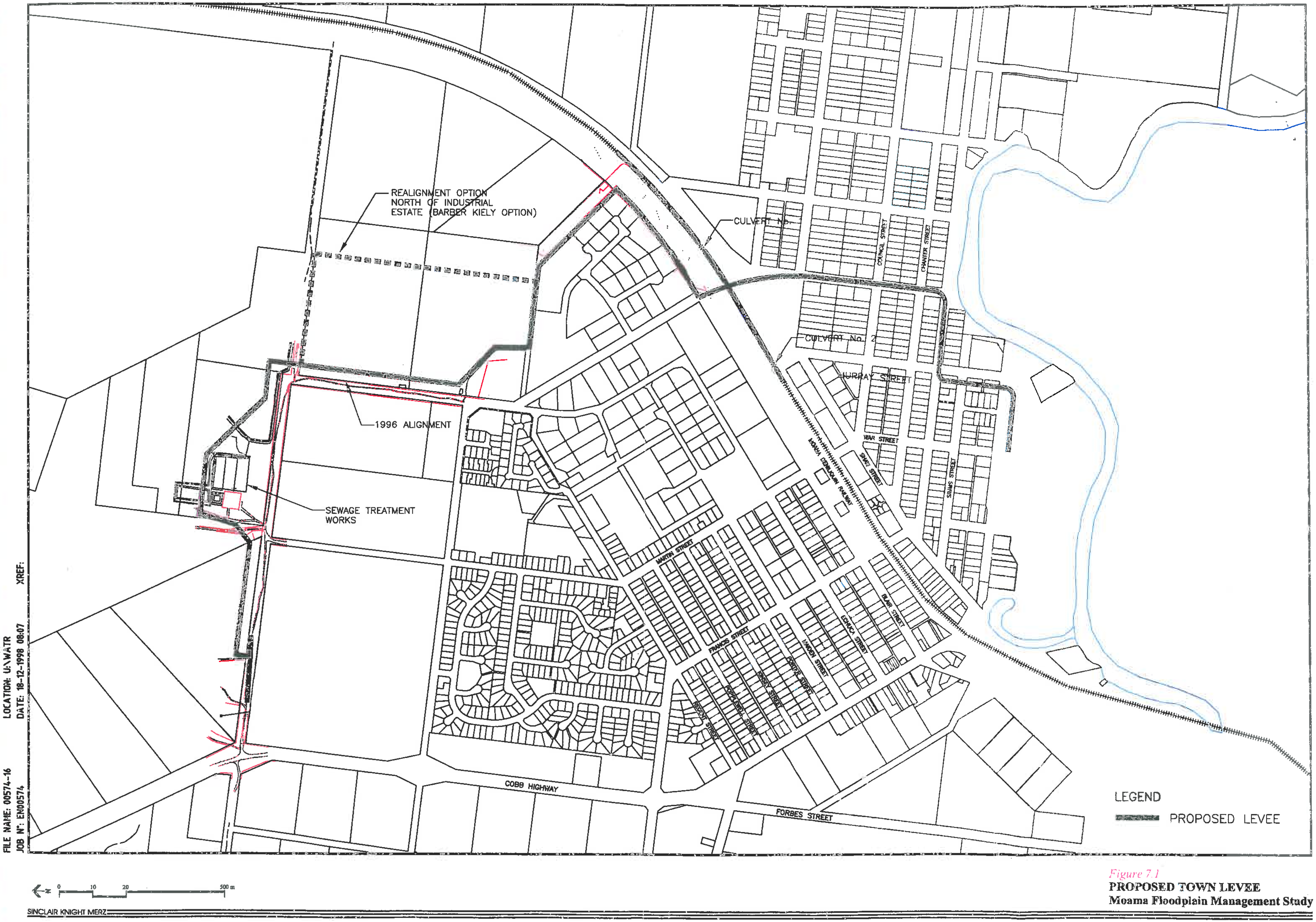

Figure 7.1
PROPOSED TOWN LEVEE
Moama Floodplain Management Study

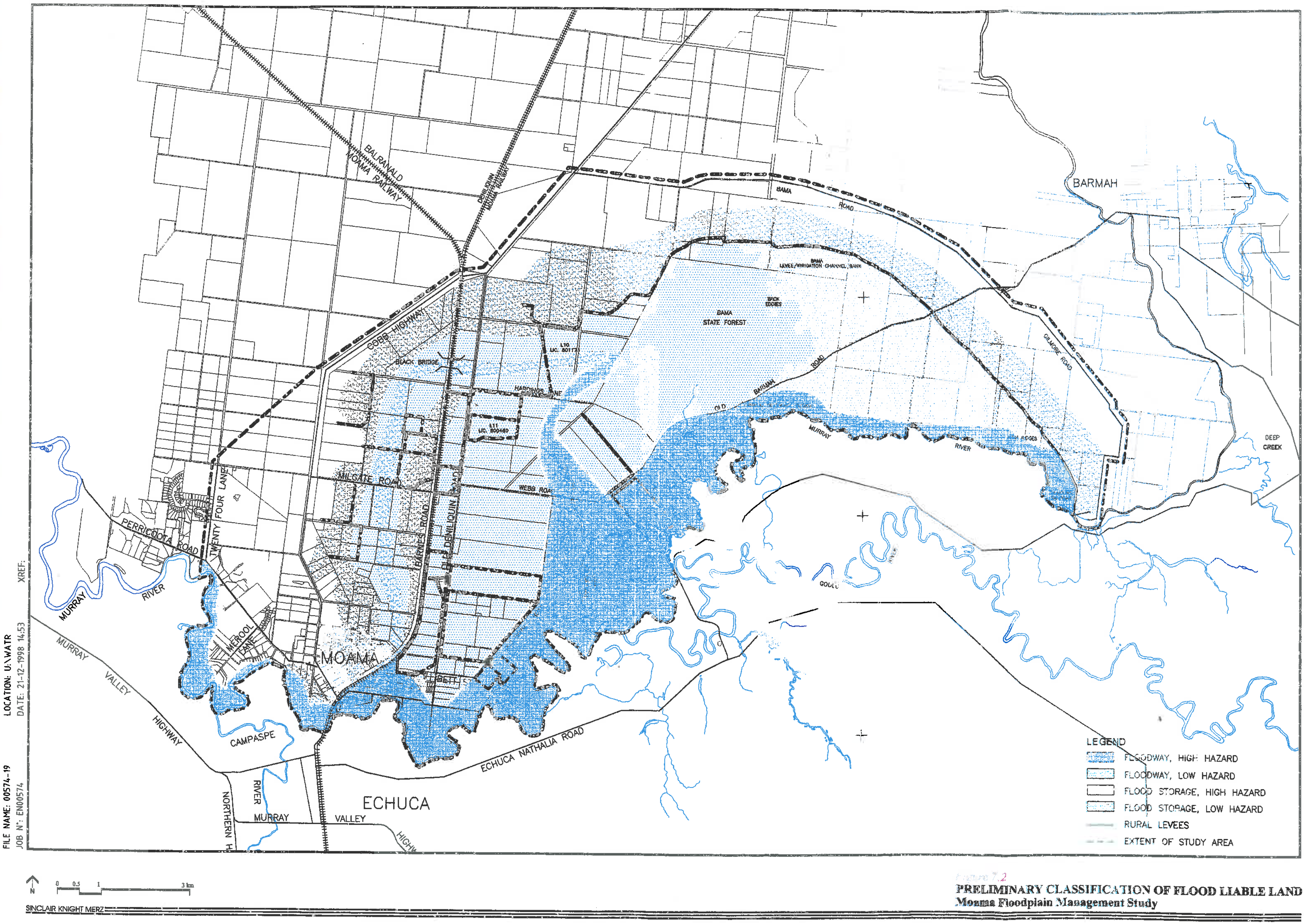

Figure 7.2
PRELIMINARY CLASSIFICATION OF FLOOD LIABLE LAND
Moama Floodplain Management Study

Effects of the Levee on the 100 year ARI Flood Regime
Under existing conditions, the 100-year ARI flood profile inside Moama rises very gently from the culverts up to the sewage treatment works and has very low gradients further upstream.

With the 34 m floodway in place between the railway and the proposed levee, the shape of the profile is similar, but the flood levels upstream of the sewage treatment works increase by 0.25 m. With the 60 m wide floodway, this increase is of the order of 0.10 m. The peak flow in the floodway is about 36 m^3/s, and the corresponding velocity is about 0.9 m/s with a 60 m wide floodway.

On the river side of the railway and upstream of the bridge crossing of the river, flood levels in the design flood of 100-year ARI increase by approx-imately 0.02 m. This effect extends upstream beyond the Goulburn River confluence, but diminishes to a negligible change in flood level at Gilmour Road. The effect of the proposed town levee also dissipates rapidly downstream of the Echuca-Moama bridge.

The Council is also considering a request to protect lands north of the Moama Industrial Estate by shifting a part of the levee to the east (also shown in **Figure 7.1** as the Barber-Kiely Option). This has some potential to shorten the levee alignment and reduce cost. The rest of the levee system remains the same.

The hydraulic model was modified to reflect this changed alignment. The results for the floods of 20-year and 100-year ARI show that this change of alignment does not significantly alter the affluxes north of Moama for either the 34 m or 60 m width floodways, reported above.

In conclusion, the levee as proposed by the Murray Shire Council is hydraulically feasible. The 60 m wide floodway is recommended near Barnes Road, as the increases in flood levels induced by the levee are significantly less than with a 34 m floodway. Some saving in the cost of the levee would also be gained since lower crest levels could be accepted.

7.2.2 Rural Levees
The situation and impacts of rural levees were discussed at some length in section 4.3. Within the flood storage areas of **Figure 7.2** future development of rural levees should be discouraged.

Most existing levees do not have a great effect on flood levels or flood storage, although they may influence the distribution of floodplain flows. Their influence diminishes in larger floods, since the crest levels of most existing levees are roughly to about 20-year ARI levels.

With a few exceptions identified below, existing rural levees may be permitted to remain subject to certain provisions. These provisions include a height restriction. Levee crest should be limited to the current height (as at December 31, 1998) or the 1993 flood level, whichever is the lesser. Levees with crest elevations higher than the 1993 flood level should be modified to reduce their crest elevations accordingly.

No extensions to existing levees should be permitted. Licences for rural levees which have not been constructed (as of December 31, 1998) should be revoked.

Spacings between levees roughly parallel (as on opposite sides of road reserves, for instance) should not be spaced closer than 100 m. Existing rural levees with spacings closer than this should be realigned to provide the minimum spacing above. This applies to levees flanking Old Deniliquin Road and Old Bama Road.

Two levees which obstruct proposed floodways should be removed. These are levee L10 located north of Hardings Lane, and an unlicensed levee north of and parallel to Milgate Road (see **Figure 4.2**). Assistance should be available for the removal or modification of licensed levees.

7.2.3 Cost Estimates

Cost estimates were prepared for the main works associated with the option including construction of the town levee and enlargement of the opening for the southern railway culvert no.1.

The estimated cost of the levee construction is $1.20 million. The assumptions involved in this estimate are summarised in **Appendix C**. It was assumed that suitable construction material will be available within 5 km. The length of the proposed levee alignment is 4,590 m. Whether or not the Barber-Kiely option is adopted makes very little difference to length or cost.

The cost of the railway culvert will depend on the manner in which this is done. A preliminary design has been undertaken in this regard and an amount of $372,500 was estimated. At this stage a provisional amount of $500,000 is made in economic analysis for this and other works to improve flows and drainage along the floodway. This will need to be determined more accurately at design stage.

Other costs of implementation of the Plan would be associated with the removal or modification of existing, licensed levees to comply with the requirements of section 7.2.2. These would be relatively minor, with the possible exception of realignment of parallel levees. As an approximate guide, the cost of removal of low rural levees is likely to be of the order of $10 to $15 per metre. Removal and reconstruction of levees (*i.e.* realignment) is likely to be of the order of $35 to $40 per metre. Naturally, these costs are dependent upon factors such as levee height, location of disposal site, realignment distance, *etc.*

7.2.4 Damage Reduction of Flood Mitigation Options

The flood damages data for existing conditions (see section 5.4) can be used to assess and compare the benefits of flood mitigation options for Moama township.

After the 1993 flood, the Murray Shire Council proposed a levee to protect the urban areas subject to inundation, and the effects of this levee on the existing flood situation are analysed in this section.

The alignment of the proposed levee is shown in **Figure 7.1**.

The levee crests have been set close to 96.30 m AHD south of the railway line, at 96.40 m AHD north and west of the railway. The levee crests will provide a level of protection of 600 mm freeboard above the 0.5% AEP flood surface (the Flood Planning Level) and will protect most properties (see **Figure B.4**). As the difference in flood levels between the 0.5% AEP and 1% AEP events is 150 - 200 mm, the proposed levee will protect the township from a 1% AEP flood event with up to 800 mm freeboard.

The extreme design event (refer section 3.3) would overtop the levee crest by 600 - 800 mm, inundating the nearest industrial and residential properties. In such an event, structural damage could be incurred by properties adjacent to any breach.

Table 7.2 and **Table 7.3** list the total affected properties and the total potential property damages with the Levee Option (See **Tables B.5 to B.7, Appendix B** for further details).

Table 7.2 - Total Flooded Properties with Levee Option

Locations	10%AEP	5%AEP	2% AEP	1% AEP	0.5% AEP
Residential	3	12	18	20	20
Industrial	-	-	-	-	-
Commercial	-	-	-	-	-
TOTALS	3	12	18	20	20

(*)No result can be provided by the flood damage model for the extreme event with the Levee Option.

Table 7.3 - Total Flood Damages with the Levee Option

Locations	10%AEP	5%AEP	2% AEP	1% AEP	0.5% AEP
Residential	0.080	0.099	0.206	0.321	0.431
Industrial	-	-	-	-	-
Commercial	-	-	-	-	-
TOTALS	0.080	0.099	0.206	0.321	0.431

Note that for all the events from AEP 10% to AEP 0.5%, no industrial or commercial property is affected by flooding.

Average Annual Damages (see **Table B.8, Appendix B**) are estimated to decrease from $124,000 per annum in existing conditions to $15,700 per annum a benefit of $104,300 per annum, as a result of implementation of the Levee Option.

7.3 Property Modification or Planning Measures

7.3.1 Murray REP2

Murray REP No 2 and associated high-level guidelines relating to floodplain management (such as those provided by the MDBC) can either operate in isolation to Murray Shire's planning policy (while still requiring compliance), or can be integrated into the Draft Floodplain Management Plan. The latter option is favoured as a basis for comprehensive and consistent floodplain planning and management within the Moama area.

7.3.2 Murray LEP and Zoning

Local planning directions from the State Government have quite specific implications in regard to local planning and zoning requirements of LEPs, such that:

- land uses on flood liable land are not to be intensified
- all development on flood liable land requires consent (apart from basic agricultural uses)
- high hazard hydraulic categories (floodway, flood storage or flood fringe) are only to contain non-intensive land uses appropriate to the flood hazard.

With overriding policies and directions being set by State and Federal Government (particularly along the Murray River) regarding the planning and control of land use within what is described as flood liable land, the real power of Local Government in floodplain management planning is in the definition of hazard and flood liability of the floodplain.

The planning options available to the Council relate specifically to the definition of what is "flood liable" and also what hazard and hydraulic definitions should be applied to the floodplain. These issues are central to the flood behaviour and associated modelling carried out as part of this Floodplain Management Study.

The option is available to amend Murray LEP 1989 to reflect the definition of flood liable land and associated flood hazard categories arising from the recommendations of this Floodplain Management Study and associated Draft Plan.

7.3.3 Flood Planning Levels

From the Murray REP2 it would appear that the flood standard or designated flood was selected as ARI 100 years, as mapped in the REP. The direction being taken in the draft NSW Floodplain Management Manual is to allow for separate "Flood Planning Levels" as designated floods for different types of land use and/or development categories.

It is proposed that the flood level of 95.63 m AHD on the Echuca Wharf gauge is continued to be used as the flood planning level for Moama. According to the revised flood frequency curve developed in the Flood Study (see section 3.3), this level is for AEP 0.5%.

7.3.4 Floodways and Flood Storage Areas

Accordingly, the floodway and flood storage zones shown in **Figure A.5** are appropriate for planning purposes. Flood Prone Land as defined by the draft NSW Floodplain Management Manual should extend to the flood extent shown in **Figure A.6** for the extreme flood simulation.

Although the depths and velocities of flows are not great enough to justify classification as floodway on hydraulic grounds alone, the importance of maintaining unobstructed passage for floodwaters justifies insertion of a nominated floodway zone upstream (north)of the southern railway culverts and extending to the east of the Black Bridge in the railway embankment. A small extension to the south-east of the southern railway culverts is included to allow for dissipation of flood flow velocities which would develop through the openings.

With these modifications taken into account, the proposed classification within the flood planning area is shown in **Figure 7.2**.

That part of Moama between the railway and Murray Street are shown as 'floodway' under current conditions in **Figure 7.2**. It should be noted and is acknowledged that there is high ground in this area which would not be flood liable. The topographic information available to this study however was inadequate to discriminate between this higher ground and land which would be inundated in the design flood (0.5% AEP). Detailed ground level data should be used to more finely classify land within this developed area, and residents are able to compare their constructed floor levels against estimated flood levels held by Council. In any case, if the proposed levee is constructed as recommended all of this area will benefit from higher levels of flood protection.

Within floodway areas, the types of restrictions described in **Table 6.1** should be imposed. All obstructions (*e.g.* earthworks above natural surface) should be removed.

7.3.5 Other Planning Issues

Caravan Parks/Camping Grounds

The issue of planning and approval for caravan parks/camping grounds and associated permanent facilities is not a favoured land use for flood liable land as supported by the Murray Darling Basin Commission (MDBC) in their "River Murray Floodplain Planning Guidelines". The Floodplain Development Manual and Draft Floodplain Management Manual provide no specific guideline for the approval of caravan parks - only to the effect that they should be carefully assessed as they are both difficult to evacuate and can create other hazards.

Public Utility Undertakings

Such works fall under Part V of the EP&A Act whereby environmental factors are required to be reviewed, and where considered by the relevant authority to be significant would require the preparation of an Environmental Impact Statement (EIS). The issue of public utility undertakings (including those of Councils) within or on the floodplain has been an area of general community concern. The option available is for such activities and works by public authorities to be better integrated with the same level of control as applies to private works within the floodplain,

Subdivision and Dwelling Entitlements

In line with flood planning directions and general good planning practice, flood liable land should not be further subdivided and in particular dwelling entitlements on flood liable land should not increase. In high hazard floodway or flood storage areas dwelling entitlements and existing dwelling may need to be acquired and the dwellings or dwelling rights removed. The land could then be returned to flood compatible uses such as for recreation or nature conservation. Any heritage buildings could remain in their original location and be available for community uses other than residential. Such a situation exists between Winall St and Moama Street.

Existing Use Rights

Apart from controlling the intensification of existing uses, land use planning has very limited powers to affect the continuance of lawfully approved uses, no matter how inappropriate in terms of potential property damage or risk to life or limb such developments are or have become. Under the EP&A Act, a development consent may be revoked or modified by a consent authority, however there is also provision for the recovery of compensation for expenditure incurred by a developer in carrying out works consistent with the development approval or consent. The immediate and real cost to the local community associated with revoking or modifying previous approvals in order to avoid future unknown costs (which may well be greater in terms of both life and property) are not directly comparable.

The options available to deal with poorly planned existing uses therefore tend to include physical protection, voluntary acquisition and removal (where the costs if justified, are supported by the State), and improved emergency response measures. These options are discussed elsewhere in this Study.

Rural Levees/Flood Control Works

The definition of, and the requirement for approval of flood control works within the Murray REP No2 affects most works throughout the rural areas such as levees, channels and the general filling and excavation of land. These works require licensing by DLWC under Part 8 of the Water Act and a process of integrating the Council and DLWC approvals has now been established.

The approval process for levees and other flood works by DLWC has now been integrated with the development consent process for flood control works by Murray Shire Council. The application for approval is made to the Council. Council refer the application to relevant approval bodies such as the DLWC (with the necessary fee). The DLWC either advises Council that they can issue an "in principle" approval for the DLWC licence, or they advise Council that they could not issue a licence. Council cannot issue a development consent for flood control works without an "in principle" approval from the DLWC for their licence.

All works that are currently unlicensed will either require separate integrated development approval (where not a lawfully existing use) and licensing, or licensing solely by the DLWC. Lawful works were constructed prior to 31 March 1994, being the gazettal date of Murray REP2. For works with existing use rights under the EP&A Act, a development application would only be required if the works were to be altered or modified. For works without existing use rights, (constructed after 31 March 1994) a development consent would be required.

There is a clear need for the DLWC, as expressed in the Burton Report, to take a more positive role in rural floodplain management including enhanced resourcing and a more focussed and pro-active approach. Some of the general recommendations of the NSW Floodplain (Non-Tidal) Management Advisory Committee (Burton Report) are relevant to the rural floodplain management issues in Moama. In particular:

(i) that additional staff be allocated to the Deniliquin regional office of DLWC for floodplain licensing and associated management activities

(ii) that consideration be given to providing financial assistance for the modification of existing public or private works shown to improve the overall flooding situation in the wider public interest

The following options, in line with the recommendations of the Wakool Land and Water Management Plan Recommendations, are also proposed to enhance rural floodplain management in Moama:

1. A register of all existing floodplain works in Moama be established and categorised as:

   (a) unlicensed and unacceptable
   (b) unlicensed but acceptable
   (c) licensed and acceptable
   (d) licensed and unacceptable.

2. The costs of dealing with categories (a), (b) and (c) should be borne by the individual landholder(s), whilst the costs for category (d) works should be borne by government.

3. All levees, earthworks and structures on the floodplain must conform to a standard accredited by Murray Shire. In the case of rural lands, referral should be made by the Shire to DLWC.

7.4 Flood Hazard Categories and Risk Assessment

The current division between 'flood liable' and 'flood free' land in the Moama area is based on the 1986 mapping of the extent of flooding in a flood of 1% AEP (ARI 100 years), which was previously estimated as the height of 95.63 m AHD at the Echuca Wharf Gauge. As noted earlier, a standard of 1% AEP has also been applied through the Murray REP No 2 and in Guidelines by the MDBC. This standard is also commonly used by the Victorian Department of Natural Resources and Environment (DNRE) to delineate flood prone areas.

The draft floodplain management approach being proposed in NSW is to amend the adoption of a single flood standard to a range of flood planning levels based on an understanding of risk. FPLs are used to determine the extent of land that is subject to flood-related building and development controls. FPLs may be different for different land uses. Murray REP2 has already established the FPL for a range of landuses and development types provided for in that plan. A similar approach has been adopted in Victoria (DNRE, 1998).

The selection of appropriate Flood Planning Levels (FPLs) is principally concerned with risk management. This Study has been asked to look at a range of flood events, up to and including the Possible Maximum Flood (PMF) in the general definition of 'flood prone land' and associated floodplain management options. While such a severe flood has not been recorded in living memory, it is important to recognise that floods greater than 1% AEP can and do occur, and that there is no clear separation between flood free and flood liable land delineated by the 1% AEP flood extent. Equally the risks to the community from increasingly rare flood events becomes negligible when balanced with the immediate benefits in developing such land.

In investigating risk associated with a range of possible flood events it is necessary to understand the consequences of the event in terms of flood behaviour, social and economic and also environmental factors.

An overview assessment of risk-related consequences and issues for the full range of flood events has been divided into the following sectors that reflect both local knowledge and recorded flood behaviour within the study area. These areas are:

- east of Backwater Creek to Gilmours Road area,
- east of the railway line to Backwater Creek,
- north of Moama between the Cobb Highway and the railway,
- south of Moama between the railway line culverts and the Murray River,
- the town area downstream of the Echuca Bridge,
- the Merool Lane area west of Moama.

7.4.1 East of Backwater Creek to Gilmours Road

Issues

This is a predominantly agricultural and forestry area with the opportunity for river and forest related camping and recreation. Floodwaters inundate the Bama Forest to completely fill the area to an embankment of levees and irrigation channels between the forest and paddocks south and west of Gilmour and Barmah Roads. These roads follow high ground formed by a sand hill defining the northern and eastern edges of the Kanyapella Basin.

As reported in Section 4, flood velocities through this area are generally very low. However, flood depths can be high, access restricted and property and people isolated. Rural development and associated development infrastructure is generally concentrated around the higher edge of the basin with an existing levee/channel bank protecting agricultural assets up to a 1:50 year flood as occurred in 1993. This levee is not blocking any natural flow path; its effect on flood storage is significant but not excessive at this time.

The key issue within this area is the importance of retaining the natural flooding regime and the ability to store flood waters within an extensive flood basin (refer section 4.3). The area is part of a significant flood storage area, the capacity of which should not be further reduced by future construction of rural levees or raising of existing levee heights.

The area is also a significant environmental resource, and natural flooding plays an important part in sustaining these values. Recreational use of the area should be limited to primitive camping with suitable flood awareness measures and evacuation procedures to be specified in any approval. Gilmour and Barmah Roads, which follow a natural high ridge around the edge of the flood basin, should be maintained to provide emergency access to and from the area up to extreme flood levels (approximately 97m AHD).

An overview of flood risk issues based on consequences is provided for this area in **Table 7.4**.

Table 7.4: Flood Risk Assessment, East of Backwater Creek

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	**Socio-Economic**	**Environment**
ARI 10 years - 10% AEP	High hazard floodway along main river channel and along Backwater Creek. High hazard flood storage for the forest areas due to depth of water, although low velocity. Flood waters rise gradually but can remain in area for up to 2 months. Levee around the north-east fringe of basin reduces flood storage, but does not interfere with flood flow paths. Some existing levees within storage area close to Backwater Creek are breached.	Rural area and state forest area; low, self-reliant population. Low risk to rural properties around fringes of the storage area. Flood free access to Barmah and Gilmour roads. Internal forest roads (Webb Road and Old Bama Road) flooded. Moderate risk to recreational users of the river and forest areas unless these areas evacuated prior to flood.	Significant environmental values associated with riparian and floodplain Red Gum forests. Risk to environmental values should natural flood flows be impeded
ARI 20 years - 5% AEP	As above with increase in high hazard flood storage area. Western area of fringing rural levee breached.	As above, with low risk to rural properties. Expect crop damage in areas of breached levees.	as above
ARI 50 years - 2% AEP	Equivalent to 1993 flood level. As above, with increase in low hazard flood storage in western fringe	as above	as above
ARI 100 years - 1% AEP	as above	as above	as above
ARI 200 years - 0.5% AEP	Increase in high hazard floodway through Bama State Forest and the Backwater Creek area. High hazard flood storage extends to area of fringing rural levee. Low hazard flood storage adjacent to Barmah and Gilmour Roads	Rural levee/irrigation channel overtopped. Damage to agricultural crops and associated infrastructure. There would be significant risk to any future development within the high hazard floodway or flood storage areas.	as above
Extreme Flood	Increase in high hazard flood storage area	Barmah and Gilmour Roads still accessible	as above

Risk Management Measures

The existing flood standard based on 95.63m at the Echuca gauge (representing a 0.5% AEP flood) is an appropriate Flood Planning Level (FPL) based on flood risk. The following planning policies should be applied:

- Aim/objectives - no intensification of development below the FPL which is likely to cause a significant reduction in flood storage capacity or change in flood behaviour
- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at

risk from flooding or generate demand for emergency services and placing other involved in evacuation at risk.

- Development above FPL and below extreme flood level to be assessed with particular consideration to flood evacuation using Gilmour and Barmah Roads.
- Tourism developments on land below the FPL limited to primitive camping grounds only, and as provided for in the Local Government (Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 1995.
- Existing rural levees in flood storage areas limited to current height or 1993 flood level (whichever is the lower), with new levees prohibited apart from those in low hazard flood storage areas adjacent to Cobb Hwy, and with a 5% AEP height limit.
- Council to consult the DLWC, MDBC, Goulburn-Broken CMA and Vic DNRE in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour, proponent will need to demonstrate proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with future similar developments). Need to also provide adequate compensating works for flood storage, together with engineering report and a detailed EIS
- In areas identified as high hazard, the feasibility of effective evacuation is to be demonstrated to the consent authority including permanent, fail-safe, maintenance measures to ensure the timely, orderly and safe evacuation of people from the area. It is also to be demonstrated that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. Council should also consult the SES, and be provided by the proponent with a detailed engineering report and EIS.

7.4.2 East of the Railway Line to Backwater Creek

Issues

The northern area along the eastern edge of the railway contains a number of rural properties and associated dwellings. These properties are associated with several rural levees isolating sections of the floodplain from minor flooding. Some of these levees can affect flood flows through Black Bridge and redistribute smaller floods affecting neighbouring properties and community infrastructure such as roads. If allowed to increase in height, the rural levees would infringe on flood storage available during major floods, as noted in section 4.3.

The southern area, to the end of Edward Street and the Murray River, contains some of the main flood affected areas of Moama with an increasing semi-urban and holiday-based population. This area contains a number of concessional dwellings, smaller subdivisions with associated dwellings, and existing and planned caravan park developments adjacent to the river. The number of permanent and temporary caravans associated with lower level flood terraces is of great concern.

Access to Moama in the north is generally along Old Deniliquin Road and across the railway line at Milgate Road. Old Deniliquin Road, is closed by floodwaters in less than a 1:10 year flood event. In 1993 this access to Moama was cut for a period of approximately six weeks.

In the south, Old Bama Road, Holmes Street, Bett Street and Chanter Street provide southern access to the eastern edge of Moama, and within the area of the proposed town levee. Both Holmes Street and Chanter Street are cut by floodway flows from the north of Moama and by overbank flows of the Murray. While there is some relatively high ground in the area of Old Bama Road and Edward Street, Chanter Street is cut by floodwater above a 1:10 year flood event and high ground in the east can be isolated.

The SES noted that in 1993 there were some 30 permanent structures and 500 vans in caravan parks within this area that during the peak tourist season can accommodate up to 2 000 people. All are on riverbanks or lower level flood terraces (river flats). The SES flood card notes that initial flooding of caravan parks occurs above 92.81m (gauge height) and by 93.24 m can reach the bottom of the Cottonwood Levee. This represents a level still approximately 1 m below the estimated flood level for ARI 10 years. The estimated level of 95.34 m (gauge height) for ARI 100 years would inundate these areas with over 2 m of water in a high hazard (fast-flowing) floodway.

Another caravan park has recently received development approval for 200 sites at the end of Edward Street within what this study identifies as a high hazard floodway. Council development approval conditions required that no filling other than the managers residence and amenities block be greater than 300 mm above the natural surface. The managers residence is required to have a floor level corresponding to the flood of ARI 200 years. This places such a development on a platform approximately 1.2 m above surrounding ground levels. The surrounds would be inundated even in minor floods by high velocity flood flows (0.8m/s), leaving the residence as a temporarily isolated island. Access to the property at the end of Edward Street is at approximately 93.4 AHD which is some 1.2 m below a flood of ARI 10 years at this site.

An overview of flood risk issues based on consequences is provided for this area in **Table 7-5**.

Risk Management Measures

As for other areas, the existing flood standard based on 95.63m at the gauge (representing a 0.5% AEP flood) is an appropriate FPL based on flood risk. The following planning policies should be applied:

Table 7.5: Flood Risk Assessment, East of Railway Line to Backwater Creek

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	Socio-Economic	Environment
ARI 10 years - 10% AEP	High hazard floodway along Backwater Creek and adjacent to river through Horseshoe Lagoon CP and the lower area of Edward Street. Flow velocities may be high. High hazard flood storage in areas to the north not protected by rural levees and up to Old Deniliquin Road. Flood waters in the north rise slowly and are of low velocity. Low hazard flood storage north of Black Bridge along fringe of higher ground. Flood flow path towards the Black Bridge culvert in the north blocked by rural levee. Rural levees protect significant areas along the railway line and either side of Old Bama Road.	No significant risk to small rural population in north which is self reliant and protected by rural levees. Old Deniliquin Road cut in the vicinity of Webb Road. Minor flooding of existing caravan parks with high risk to proposed caravan park in high hazard floodway at end of Edward Street with possible evacuation required. Low risk to existing dwellings and rural properties in the south although access to Moama may be restricted by flood water over Chanter Street.	Mostly cleared agricultural land although areas of natural forest and regrowth remain as important aquatic habitat during floods. Significant areas of riparian redgum forest.
ARI 20 years - 5% AEP	Equivalent to 1993 flood levels in the south of this area. As above with little change from 1:10 flood. Some rural levees breached in the north, east of Old Deniliquin Road becoming high hazard flood storage. Some high ground in the area of Old Barmah and Edward St flood free.	As above, with possibility of rural dwelling isolation and or evacuation east of Old Deniliquin Road and near Webb Road. Increasing risk to caravan parks. Access to Moama increasingly difficult.	as above
ARI 50 years - 2% AEP	Equivalent to 1993 flood level in the north of this area. As above with risk from high hazard floodway area along river increasing to cover Edward and Bett Streets and Horseshoe Lagoon CP area. Much of the area east of Old Deniliquin Road defined as high hazard flood storage. Most rural levees breached.	Access cut to properties east of Moama from Chanter, Bett and Old Bama Road. Evacuations required. Rural levees east of Old Deniliquin Road breached. High risk to population and properties east of railway line and proposed town levee.	as above
ARI 100 years - 1% AEP	As above. Area mostly either high hazard floodway or flood storage. Some areas of low hazard flood storage in the northern fringe	As above	as above
ARI 200 years - 0.5% AEP	As above	As above	as above
Extreme Flood	As above	As above	as above

- Aim/objectives - no intensification of development below the FPL which is likely to cause a significant reduction in flood storage capacity or change in flood behaviour

- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at risk from flooding or generate demand for emergency services.
- Existing flood control works and impediments to flood flows deemed by Council to be within flood flow path to Black Bridge from Goulbourn River to be removed and no future flood control works within this area to be permitted.
- Existing rural levees in flood storage areas limited to current height or 1993 flood level (whichever is the lower), with new levees prohibited apart from those in low hazard flood storage areas adjacent to Cobb Hwy, and with a 5% AEP height limit.
- Council should consider raising Old Bama Road (in the vicinity of Horseshoe Lagoon CP, between existing rural levees) to the level of the existing flanking levees, or 5% AEP, to provide for 5% AEP flood free access to/from Moama and to avoid the road becoming a channel for flood flows below this level.
- Implementation of Murray REP 2 and MDBC guidelines such that no more caravan parks and associated permanent facilities should be established on flood liable land as defined by the FPL.
- Tourism developments limited to primitive camping grounds only, and as provided for in the Local Government (Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 1995.
- Levees within existing caravan parks to be height limited to 5% AEP flood level protection.
- No new levees to be permitted within high hazard floodway and high hazard flood storage areas related to the 5% AEP flood.
- Council should investigate revoking the previous development consent for the Edward Street caravan park.
- Council to consult the DLWC, MDBC, and Victorian DNRE or relevant Catchment Management Authority in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour.
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour the proponent will need to demonstrate that the proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS
- In areas identified as high hazard, the feasibility of effective evacuation is to be demonstrated to the consent authority including permanent, fail-safe, maintenance measures to ensure the timely, orderly and safe evacuation

of people from the area. It is to be also demonstrated that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. Council should also consult the SES, and be provided by the proponent with a detailed engineering report and EIS.

- Floor Heights (residential, industrial, commercial and special uses) to be at FPL consistent with existing provisions. Generally applies to major residential extensions and or as considered by the merits of the individual case.

7.4.3 North of Moama between the Cobb Highway and the Railway

Issues

Water levels in the 1993 flood between the Cobb Hwy and the railway line north of Moama were held up to artificially high levels earthworks built directly across the flood flow. This rural area is generally low-lying and contains a number of natural pools or depressions (principally immediately west of the Black Bridge) where water can remain for many months following a flood.

There is a need for a designated floodway zone through this area to be cleared of existing obstructions and preserved from future development that may impede flood flows through this area.

The Moama Industrial Estate has been located immediately in the path of the flood water and now requires flood protection and training of flood flows from the north around this area.

Flood water levels in 1993 came quite close to the Cobb Hwy just north of the town. The possibility of the highway being breached should be permitted to allow controlled flows to pass to the north-west of Moama in extreme floods.

Table 7.6 provides an overview of flood risk issues based on consequences for this area.

Risk Management Options

As for other areas, the existing flood standard based on 95.63m at the gauge (representing a 0.5% AEP flood) is an appropriate FPL based on flood risk. The following planning policies should be applied:

- Aim/objectives - no intensification of development below the FPL which is likely to cause a significant reduction in flood storage capacity or change in flood behaviour

- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at risk from flooding or generate demand for emergency services.

Table 7.6: Flood Risk Assessment, North of Moama

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	Socio-Economic	Environment
ARI 10 years - 10% AEP	Low hazard flood fringe with flood flow path from Black Bridge to southern railway culverts. Several rural levees. Unlicensed levee across flood flow path. Natural ponding of water within northern area can remain for many months.	Rural properties with access to Cobb Highway or Barnes Road in the south. Milgate and Barnes roads cut by flood flow path from the north. Industrial estate in the south at risk without levee.	Some significant areas of remnant forest. Ponded areas can replenish groundwater and provide for the breeding of avifauna. Risk to environmental values should natural flood flows be impeded. There are also significant areas of natural vegetation along Barnes road south of the industrial area.
ARI 20 years - 5% AEP	As above, with gradual increase in low hazard flood storage and flood flow through the area from the north.	As above. Industrial area and nearby dwellings at risk.	As above
ARI 50 years - 2% AEP	As above. 1993 flood equivalent in this area. Most rural levees breached. Fringe levees adjacent to Cobb hwy unlikely to have significant impact on flood storage.	As above. Significant flooding of Barnes Road with associated loss of access. Northern edge of Moama adjacent to existing sewerage treatment area threatened.	As above
ARI 100 years - 1% AEP	As above. Rural levees breached. Significant floodway from the north. Still areas of low hazard flood storage adjacent to high ground along Cobb Hwy.	As above. Future urban area of Moama in significant flood risk without levee protection. Industrial area flooded without flood levee protection.	As above.
ARI 200 years - 0.5% AEP	As above.	As above. All rural properties flooded with levees having no impact Large areas of Moama at risk without levee.	As above
Extreme Flood	As above. Area of high hazard flood storage extends to edge of Cobb Hwy. Breakout over Cobb Hwy. Cobb Hwy forms natural levee which will overtop in lowest section. Lowest section of the hwy needs to be designed to provide for identified spillway in extreme flood. Town levee would be breached. Town area designated as high hazard flood storage.	As above. High property and personal risk to entire town area east of Cobb Hwy, regardless of levees.	As above

- Existing flood control works and impediments to flood flows deemed by Council to be within flood flow path from Black Bridge to One Mile Crossing to be removed and no future flood control works within this area to be permitted.

- Existing rural levees in flood storage areas limited to current height or 1993 flood level (whatever is the lowest), with new levees prohibited apart from those in low hazard flood storage areas adjacent to Cobb Hwy, and with a 5% AEP height limit.
- Council to consult the DLWC, MDBC, and Victorain DNRE or relevant Catchment Management Authority in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour.
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour the proponent will need to demonstrate that the proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS.
- Floor Heights (residential, industrial, commercial and special uses) to be at FPL consistent with existing provisions. Generally applies to major residential extensions and or as considered by the merits of the individual case.
- Survey of Cobb Hwy to establish flood spillway area for extreme floods.
- Access to either Cobb Highway or protected town area needs to be considered in emergency planning.

7.4.4 South of Moama between the Railway Line Culverts and the Murray River

Issues

This is a critical floodway zone that forms the main discharge area from the northern floodplain under the southern railway culverts and includes the majority of the original town subdivision. The area also links with flood discharge from the east near the intersection of Old Deniliquin Road and Old Bama Road. The area can be affected by both overbank flows from the river and overland discharge from the flood storage to the north and east.

While the area is zoned rural, there are still a significant number of residences and two caravan parks located to the east of Murray Street which required sandbagging or construction of individual levees during the 1993 flood (equivalent to 5% AEP in this area).

The flood path between the southern railway line culverts and the Murray River is poorly defined and can be affected in places by road works and other minor structures such as fences.

Water passing through the southern railway culverts and the floodway east of Moama, prior to re-entering the main flow of the Murray, should be regarded as a floodway with potential for strong flows as water drains from the northern flood storage area. There are four dwellings and a number of undeveloped existing holdings with possible dwelling rights in the direct path of the floodway. Voluntary acquisition of critical properties in this area is recommended given the frequency of flooding, potential velocities of water flow and the associated hazards to both life and property.

The proposed alignment of the town levee is along Winall Street, which will allow for internal drainage during floods to be collected in the existing low lying land between Murray and Winall streets, to be pumped from there over the levee to the river.

Roads crossing the floodway such as Holmes and Chanter Street provide critical access between Moama and development to the east. Council should investigate the provision of sufficient culverts under Chanter Street in the area of the floodway to allow for the northern flood flow and to provide for flood free access to the east up to the 5% AEP flood level.

An overview of flood risk issues based on consequences is provided for this area in **Table 7.7**.

Table 7.7: Flood Risk Assessment, South of Moama

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	Socio-Economic	Environment
ARI 10 years - 10% AEP	Flows from northern flood storage passing through railway culverts and meeting the river. High hazard floodway along river channel rising to the southern end of Murray Street.	Risk to existing and possible future residential properties in undefined floodway and along river channel. Minor flooding in Moama Village area. Minor flooding across Chanter Street.	There are significant environmental values within the floodway area between the railway culverts and the Murray River. Careful management of environmental values will be required in the construction of the town levee.
ARI 20 years - 5% AEP	1993 flood equivalent in this area. As above, with increasing floodway hazards.	Major flooding in Moama township with significant flooding across Chanter Street. Access routes to Moama from the east through this area flooded	As above
ARI 50 years - 2% AEP	As above. Area from Holmes St to Murray River covered by high hazard floodway.	As above	As above
ARI 100 years - 1% AEP	As above. Potential high hazard flood floodway east of railway line to be flanked by proposed town levee.	As above. Significant property and personal risk to much of the town area east of railway line unless protected by town levee.	As above
ARI 200 years - 0.5% AEP	As above	As above	As above
Extreme Flood	As above. Town levee would be breached. Town area designated as high hazard flood storage.	As above. High property and personal risk to entire town area east of Cobb Hwy, regardless of levee.	As above

Risk Management Options

As for other areas, the existing flood standard based on 95.63m at the gauge (representing a 0.5% AEP flood) is an appropriate FPL based on flood risk. The following planning policies should be applied:

- Provide for town flood levee protection up to the FPL with 600mm freeboard.
- Provide for floodway along eastern side(flood side) of levee to pass flood flow drainage from the northern area and allow for new culverts under the railway line and at Chanter Street to take the 0.5% AEP flow through this area.
- Increase flood awareness (of the full range of flood events, up to and including the extreme flood) of all landholders through general education, signage and issuing of regular flood certificates.
- Raise the level of Chanter Street to provide flood free access to the eastern area of Moama up to the 5% AEP level.
- Investigate the voluntary acquisition of properties between Winall and Moama Streets, to remove dwelling entitlements and to rezone to flood compatible land uses such as open space / nature conservation.
- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at risk from flooding or generate demand for emergency services.
- Council to consult the DLWC, MDBC, and Vic DNRE or relevant Catchment Management Authority in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour.
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour the proponent will need to demonstrate that the proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with past and future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS.
- Re-grading of Holmes Street within the floodway area so the street formation presents no obstruction to flows and causes no ponding on the north side.
- Floor Heights (residential, industrial, commercial and special uses) to be at FPL consistent with existing provisions. Generally applies to major residential extensions and or as considered by the merits of the individual case.

7.4.5 The Town Area Downstream of the Echuca Bridge

Issues

This section of the floodplain is immediately south west of the main commercial area of Moama along Meninya Street. Much of the town is on relatively high ground above the 0.5% AEP flood level. Significant issues within this area are seen to be the potential for obstructions or flow constrictions to raise upstream water levels, and also the potential for further town development along the high bank adjacent to Meninya Street.

As reported in Section 4, filling of land within the Village Zone adjacent to Meninya Street will have minimal impact on flood storage as it is located on the outer fringe of the flood storage area. The rural zoned floodplain area should remain largely undeveloped although commercial tourism opportunities may be possible with appropriate consideration, including that of access to flood free land.

Vegetation within this area has been substantially cleared in the past. There is now significant regrowth, particularly following recent flood events, and concern has been expressed regarding its impact on flood flows and associated hazards. Management of this issue is discussed elsewhere in this report.

An overview of flood risk issues based on consequences is provided for this area in **Table 7.8**.

Table 7.8: Flood Risk Assessment, Downstream of the Echuca Bridge

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	Socio-Economic	Environment
ARI 10 years - 10% AEP	High hazard floodway associated with the river, gradually increasing as floods become larger. Generally low hazard flood fringe/storage with backwaters rising slowly from the river along higher flood terraces	No significant risks given the largely undeveloped nature of the area. Access to flood free areas along Meninya street and Boundary Road	Significant environmental and cultural heritage resource. Impact of clearing to provide flood flow to be carefully managed
ARI 20 years - 5% AEP	As above	As above	As above
ARI 50 years - 2% AEP	As above	As above. Low-lying areas along Boundary Road threatened.	As above
ARI 100 years - 1% AEP	As above	Some low-lying residences threatened	As above
ARI 200 years - 0.5% AEP	As above	Commercial development along the edge of Menninya Street threatened	As above
Extreme Flood	High hazard floodway along Meninya Street.	Commercial development along Meninya St flooded	As above

Risk Management Options

As for other areas, the existing flood standard based on 95.63 m at the gauge (representing a 0.5% AEP flood) is an appropriate FPL based on flood risk. The following planning policies should be applied:

- Filling of land to provide for commercial or tourism developments could be allowed with Council Consent in low hazard flood storage areas within the Village zone and adjoining higher ground.
- Increase flood awareness (of the full range of flood events, up to and including the extreme flood) of all landholders through general education, signage and issuing of regular flood certificates.
- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at risk from flooding or generate demand for emergency services.
- Implementation of Murray REP 2 and MDBC guidelines such that - caravan parks and associated permanent facilities should not be established on flood liable land as defined by the FPL.
- Tourist development and caravan parks to be carefully assessed including demonstrating that any structure can withstand the force of flowing floodwaters in engineering report.
- Council to consult the DLWC, MDBC and Victorian DNRE or relevant CMA in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour.
- Acquisition of properties in Forbes Street which have been developed, and withdrawal or withholding of dwelling rights from other properties in the floodway zone.
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour the proponent will need to demonstrate that the proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with past and future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS
- Floor Heights (residential, industrial, commercial and special uses) to be at FPL consistent with existing provisions. Generally applies to major residential extensions and or as considered by the merits of the individual case.
- An ongoing program of vegetation management implemented for restricted zones immediately adjoining waterway openings in the main transport crossing of the Murray River. No existing mature trees should be removed under the management program, and only clearance of understorey vegetation with the potential to trap debris and create obstructions during flood flows should be permitted.

7.4.6 The Merool Lane Area West of Moama.

Issues

The Merool Lane area is a peninsular of land running off Perricoota Road which generally follows high ground to the west of Moama. The floodplain is generally well defined by a distinct high bank. Merool Lane runs along a central ridge, or spur of land to the Murray River, in the immediate vicinity of its junction with the Campaspe River. Land in the vicinity of Perricoota Road and Merool Lane junction is above the existing standard flood level (0.5%AEP). Approximately half of this area however can be cut off by high hazard flood flows in major flood events as the river cuts through from the east to the north placing major caravan parks and an isolated residence within the floodplain at risk.

The area is predominantly rural with small areas zoned and developed for rural residential uses on higher ground above the 0.5% AEP flood level. There are significant commercial and residential developments on the higher ground including the RSL Club.

There is a licence for a levee of unlimited height following the bank of the Murray River from the upstream end of Merool Riverside Holiday Park to A Shady River Caravan Resort past Grimisons Lane. Concern has been expressed regarding such a levee given its alignment directly opposite the junction with the Campaspe River, and what impact it would have on flood heights upstream. The section of this levee to the western (downstream) side of Merool Lane has not been constructed, although there is one section around Shady River Caravan Resort that falls within the general alignment of the licensed levee.

The section of the licensed levee around the Merool Riverside Holiday Park has been constructed to a level equivalent to 94.75 m at the Echuca gauge (*i.e.* just below the 5% AEP flood level). The position of this levee opposite high ground near Crofton Street, Echuca creates a constriction to flood flows.

Grimisons Lane, providing private access to a house adjacent to the river, also forms a significant obstruction to flood flows across the floodplain. There have been some local disputes concerning the function of culverts through the lane, which have been variously blocked and unblocked during flood events. Initially the river floods as a backwater in this area from downstream of Shady River and properties upstream of Grimisons Lane have blocked the culvert to protect their land from minor floods. When the riverbank breaks upstream the culvert is reopened to allow floodwater to pass through. Blockage of the culvert in the initial backwater flooding phase is seen by some to increase the flood effects downstream of Grimisons Lane - the unblocking of the culvert in turn causes properties upstream of the lane to be flooded in relatively minor flood events.

An overview of flood risk issues based on consequences is provided for this area in **Table 7.9**.

Risk Management Options

As for other areas, the existing flood standard based on 95.63m at the gauge (representing a 0.5% AEP flood) is an appropriate FPL based on flood risk. The following planning policies should be applied:

- Increase flood awareness (of the full range of flood events, up to and including the extreme flood) of all landholders through general education, signage and issuing of regular flood certificates.

Table 7.9: Flood Risk Assessment, Merool Lane Area West of Moama

Likelihood (Frequency)	Consequences/Impacts		
	Flood Characteristics	Socio-Economic	Environment
ARI 10 years - 10% AEP	High hazard flood way with areas of low hazard flood storage. Initial flooding of lower section of caravan parks. Over 1m of water through western section of Merool caravan park	Caravan Park evacuations. Isolation of dwelling at end of Grimisons lane. Flood free access to Moama along Merool Lane and Perricoota Road.	Significant areas of riparian vegetation and individual redgum specimens along flood terrace. Flood levees within floodways can increase surrounding flood velocities along river bank leading to erosion and tree decline/collapse.
ARI 20 years - 5% AEP	As above, with general increases in depth and velocity.	As above.	As above
ARI 50 years - 2% AEP	As above, with general increases in depth and velocity. Breaching of caravan park levees.	As above. Significant damages to caravan parks and emergency evacuations.	As above
ARI 100 years - 1% AEP	As above, with general increases in depth and velocity.	As above.	As above
ARI 200 years - 0.5% AEP	As above, with general increases in depth and velocity. Potential for high hazard flood way to reach intersection of Grimisons Lane. Breakout from near cemetery across Perricoota Road to west of racecourse.	As above. Potential for Perricoota Road to be cut by floodwaters.	As above
Extreme Flood	As above with general increases in depth and velocity. Entire Merool Lane area up to Perricoota Road becomes high hazard floodway.	As above. Perricoota Road cut by high hazard floodway with areas to the north high hazard flood storage. All development at risk.	As above

- Existing licensed levees to be height restricted to 5% AEP flood level.
- No further levee construction within the floodplain and existing licenses for unconstructed levees to be revoked.
- No intensification of development below the FPL which is likely to cause a significant reduction in flood storage capacity or change in flood behaviour.

- No intensification of development in high hazard areas below the FPL which is likely to place the owner or occupants (including their property) at risk from flooding or generate demand for emergency services.
- Implementation of Murray REP 2 and MDBC guidelines such that - caravan parks and associated permanent facilities should not be established on flood liable land as defined by the FPL.
- Tourist development and caravan parks to be carefully assessed including demonstrating that any structure can withstand the force of flowing floodwaters in engineering report.
- Council to consult the DLWC, MDBC and Vic DNRE in determining whether a development proposal is likely, either independently or in combination with other similar developments, to cause a significant reduction in flood storage capacity or change in flood behaviour.
- Where new development is likely to cause a significant reduction in flood storage capacity or change in flood behaviour the proponent will need to demonstrate that the proposal will not cause a significant increase in flood levels or flood hazard (including cumulatively with future similar developments). Need to also provide adequate compensating works together with engineering report and a detailed EIS.
- In areas identified as high hazard, the feasibility of effective evacuation is to be demonstrated to the consent authority including permanent, fail-safe, maintenance measures to ensure the timely, orderly and safe evacuation of people from the area. It is to be also demonstrated that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. Council should also consult the SES and be provided with a detailed engineering report and EIS.
- Floor Heights (residential, industrial, commercial and special uses) to be at FPL consistent with existing provisions. Generally applies to major residential extensions and or as considered by the merits of the individual case.
- Further investigation of the potential affects of the Merool Caravan Park levee and the high level access to Grimisons Lane residence adjacent to the river bank.

7.5 Flood Preparedness and Emergency Response Measures

7.5.1 Flood Warning

Key requirements for flood warning are provision of adequate advance warning to permit citizens to take appropriate actions to reduce damages and hazard arising from flood, and sufficient accuracy in forecast magnitudes for response agencies and informed individuals to understand the effects which are imminent.

Moama is in a fortunate position in that it is located on a major river with a very large catchment. Even though the greatest influence derives from Goulburn River floods and not Upper Murray floods, the Goulburn too is a very large river system. This means that advance warning times are good and the potential for accurate forecasts is relatively high. The influences played by upstream flood storage in successive floods and by tributary flows from the Campaspe River were described in section 3.1. Even so, forecasts of the peak river stage at Echuca will improve as the flood peak approaches and in most cases should be quite accurate in sufficient time for appropriate measures to be taken.

Where the main area for improvement lies is in the interpretation of flood effects. That is, given the forecast of an estimated peak stage in Echuca, what will be the effect in various parts of the floodplain?

The flood levels estimated for floods of different ARI have been estimated in the Flood Study, and these results are presented in Appendix A to this report. In particular, results presented in **Table A.1** may be interpreted using cross-section locations in **Figure A-8**. There are limitations to use of these results.

It must be understood that the model is one-dimensional, whereas the flood flow distribution is two-dimensional. This means that estimated flood levels are less reliable further away from the main flow paths (*e.g.* on the floodplain edges), and between the locations of cross-sections.

The influences of the Campaspe and successive floods from the Goulburn will also complicate interpretation downstream and upstream of the gauge, respectively.

The other key limitation is lack of ground surface data. However, if ground levels were known the results of the hydraulic model would be useful in predicting depths of inundation, and could be related to the forecast river stage at Echuca using **Table A.1**.

7.5.2 Public Education

It has been proposed by Bewsher (1998) that widespread distribution of flood certificates should take place to all owners and residents in a floodplain on a regular basis.

Raising flood awareness is recognised as a very cost effective means of reducing the impacts of flooding. This is the primary objective of this Study and associated Floodplain Management Plan. Raising flood awareness is about increasing the scope and effectiveness of communicating knowledge of flood risks, so that decisions such as where a person will live, what land uses are appropriate in certain parts of the floodplain, or how to design a new building can be undertaken on an informed basis.

The Local Flood Plan has allocated a specific responsibility to Caravan Park and Lodge Owners or Operators to:

1. Prepare a Flood Plan for their park.
2. Display that plan in a prominent location.
3. Ensure that caravan owners/occupiers and residents of lodges are aware of any current flood and evacuation warnings.
4. Evacuate Parks as required.

A further consideration would be the option to require flood indicators at all Caravan Parks and riverside accommodation be erected in prominent locations such as adjacent to the reception area and the amenities block. Flood indicators should show both AHD Datum and Flood Levels for the full range of flood events relative to the Echuca Wharf Gauge, with historical flood markings.

Both the SES and Murray Shire Council should work together to actively promote flood awareness through supply of flooding data and advice to property owners, residents, visitors, potential purchasers and investors. Such information should be provided on a regular basis in the form of Flood Certificates that would report information on flood levels (AHD) for all design floods as related to the Echuca gauge. Property owners would be advised of the inherent inaccuracies in the model that derives the estimate of these levels. Equally residents would be encouraged to feed back real flood data concerning flood levels during times of flood so that flood information could be continually upgraded and integrated into the Council's property data base.

7.5.3 Evacuation

The hydraulic modelling demonstrates that in extreme floods there are three main evacuation routes available from Moama. These are the Barmah Road along the line of the Bama Sand-hills, the Cobb Highway north towards Deniliquin, and the bridge across to Echuca.

Should a flood occur of great enough magnitude to threaten inundation of the town, the last two of these will be the most viable evacuation routes. The higher ground associated with the Cadell Fault (*e.g.* around Mathoura) would be safe, but it should also be appreciated that floods in excess of about ARI 200 years will commence to overtop the Cobb Highway just north of Moama, so timely evacuation would be required. In a flood of this magnitude, flooding would also be devastating in Echuca, so that would not be a safe haven.

In floods of lesser magnitude, there will be significant parts of Moama which are not inundated. Construction of the proposed levee would create a much larger area not inundated. In these floods, evacuation to Moama will be the main focus. There may be some residents more isolated in the floodplain who would prefer to use the Barmah Road route to evacuate to locations further north.

In smaller floods, the Old Bama Road and Chanter Street will be a key route, and the Old Deniliquin Road. However, it must be appreciated that these routes will start to be flooded between ARIs of 20 years and 50 years.

North of Moama, the best access will be the Cobb Highway. The Barnes Line of Road will play a secondary role for some residents, but will quickly be cut by floodwater in floods above ARI 10 years. Areas west of Moama are best served by either the Cobb Highway or Perricoota Road.

7.5.4 Post Floods

While there may be many issues clamouring for attention in the aftermath of a flood, it is important to keep records of these events. Information should be collected on houses and buildings which were flooded, roads which were cut and damages experienced.

Flood level data should also be collected to improve the knowledge of the relative flood heights in various parts of the floodplain study area. Flood levels should be pegged from debris marks or local advice within a few weeks at most. Survey to pick up these levels can be delayed, but the levels should be pegged before the marks or memories fade.

Photographic records should be made, particularly within developed areas. While it may be prohibitively expensive for the Shire to arrange aerial photography, if aerial photography has been obtained by other agencies (NSW, Victorian or Federal) copies should be acquired. Satellite imagery should also be purchased after major flooding.

8. Ecological Factors

The most significant ecological factors within the study area are those relating to the hydrological regime of the River Murray and its tributaries, and the resultant flooding patterns. The study area occupies part of the Murray River floodplain between the confluences of the Goulburn and Campaspe Rivers. Flooding patterns within the area may therefore be very complex. Many species of flora and fauna owe their presence within the study area to the flooding pattern and are uniquely adapted to it. The floodplain provides resources which support a significant proportion of the biological diversity within the study area.

8.1 Fauna of the Floodplain Forests

The forests of the study area provide habitat for a range of fauna species. The range of species includes large terrestrial mammals, small terrestrial mammals, arboreal mammals, bats, reptiles and amphibians, birds and fish and crustaceans.

8.1.1 Large Terrestrial Mammals

The most common large terrestrial mammal is *Macropus giganteus* (Eastern Grey Kangaroo). It is common and widespread throughout the floodplain forests of the study area and the surrounding region. *Macropus rufus* (Red Kangaroo) has occasionally been reported from the fringes of the forest areas.

The Eastern Grey Kangaroo is widespread throughout Eastern Australia from Bass Strait to the Atherton Tablelands in Northern Queensland. It is extremely common throughout its range and is a grazing animal with specific food preferences which are restricted to grasses and forbs. This preference is maintained even during times of drought. Regular flooding of the floodplain forests is required to maintain an adequate supply of natural fodder and thus restrict competition for fodder on grazing properties.

The Red Kangaroo is widespread thought the inland areas of mainland Australia. It subsists in low numbers in the deserts and is common in better watered plains country and low open woodlands.

8.1.2 Small Terrestrial Mammals

Fauna in this category which are known to occur within the study area or region include *Antechinus flavipes* (Yellow-footed Antechinus), *Hydromys chrysogaster* (Australian Water Rat) and *Ornithorhynchus anatinus* (Platypus).

Yellow-footed Antechinus is the most widespread species of antechinus. It occurs from the coastal regions of tropical Queensland and northern NSW through central western NSW to south-western Victoria and south-east South Australia. It occupies a range of habitats from tropical vine forests, through swamps to dry mulga country. Its diet consists mainly of insects although it may also include flowers and nectar as well as small birds and mice.

The Australian Water Rat is widespread throughout Queensland, tropical north Australia, all of NSW except for the far west, Victoria and southern South Australia. There are also occurrences in south-west Western Australia and off-shore islands. Its primary habitat includes permanent bodies of fresh or brackish waters and occasionally on coastal beaches. It is primarily an opportunistic predator on large aquatic insects, fish, crustaceans, mussels, frogs, lizards, small mammals, fresh carrion and water birds.

It has been suggested that population numbers have increased since the introduction of European Carp into the Murray-Darling system although swamp reduction and river regulation have reduced the area of available habitat.

The Platypus occurs throughout Tasmania and coastal Victoria, NSW and Queensland and has also been reported in the Murray River system. It tends to be somewhat discontinuous throughout its range . Its habitat is adversely affected by inappropriate fishing practices, and steam and river bank disturbances for agriculture or dam and weir construction. Its diet consists mainly of adult and larval aquatic invertebrates, small fish and amphibians.

8.1.3 Arboreal Mammals

Arboreal mammals which are found in the region in habitat similar to the study area include *Trichosurus vulpecula* (Brush-tailed Possum) *Pseudocheirus peregrinus* (Ring-tailed Possum), *Petaurus breviceps* (Sugar Glider) and *Petaurus norfolcensis* (Squirrel Glider).

The Brush-tailed possum is widespread throughout the better watered areas of mainland Australia and occurs throughout Tasmania. It occupies a vast range of habitats throughout its range and its abundance varies significantly. It is common throughout the region occupies by the study area. Within the study area it would occupy hollow dead branches, tree trunk hollows, or fallen logs. It may also occupy the space between the ceiling and roof of houses within the area. The bulk of its diet consists of leaves, the choice of which is determined by nutrient and fibre content. In addition, flowers and fruit form an important component particularly in arid and tropical areas.

The Ring-tailed possum occurs from south-east South Australia through Victoria, eastern NSW and eastern and northern Queensland. It also occurs throughout Tasmania. It occupies a variety of vegetation types including rainforest and woodlands. Within the region occupied by the study area it is mainly restricted to mature Grey Box stands where it nests in available hollows. Its diet consists primarily of eucalypt leaves for which it is anatomically specialised. However, the diet may be supplemented with flowers and fruits.

The Sugar Glider occupies a similar geographic range to the Ring-tailed possum. Throughout its range it is locally common where tree hollows are available for shelter and food supplies are adequate. The diet primarily consists of gum produced by acacia species, nectar and pollen, eucalypt sap and invertebrates and invertebrate exudates. Within the region occupied by the study area Sugar Gliders are widespread, although not generally found in large numbers.

The Squirrel Glider occupies a more restricted range than the Sugar Glider. It inhabits dry sclerophyll forests in south-eastern Australia and is generally absent from the dense forests of the coastal ranges. It does not occur in Tasmania. The diet of the Squirrel Glider is similar to the Sugar Glider although in central Victoria it also feeds on beetle and caterpillars. It is critically dependent on tree hollows for nest sites and its continued survival is threatened in areas where extensive clearing has reduced the number of available hollows. It occurs only in local patches within the region occupied by the study area. It is listed as a vulnerable species under Schedule 2 of the NSW Threatened Species Conservation Act 1995.

8.1.4 Reptiles and Amphibians

A variety of species of snakes. lizards, tortoises and frogs are known to occur within the study area. Their distribution and abundance is generally closely linked to the flooding regime of the area.

8.1.5 Birds

The region is particularly rich in avian fauna. More than 200 species have been recorded, of which more than 75% are known to breed within the region.

The floodplain provides critical habitat for many species which are dependent on the hydrological regime for all or part of their life cycle. Features to note include:

- Fifteen species can be characterised as common, although numbers increase significantly in flood years; while a further ten species are uncommon and only occur in the region in flood years.
- Waterbird species recorded within the region which are dependent on flooding for breeding include pelican, darter, egrets, herons, ibis, swans and ducks.
- Some recorded species nest in reeds or build floating nests. Examples include grebes, bitterns, ibis, swans, ducks, rails, crakes, water-hens, coots, grassbirds and cisticola.
- Some recorded species are hollow dependent. They include ducks, falcons, cockatoos, parrots, owls, kingfishers and treecreepers.

- One species from the region, *Xanthomyza phrygia* (Regent Honeyeater) is listed as Endangered under Schedule 1 of the NSW Threatened Species Conservation Act 1995.
- The following 13 species from the region are listed as Vulnerable under Schedule 2 of the Threatened Species Conservation Act 1995. They are;
  - *Botaurus poiciloptilus* (Australian Brown Bittern)
  - *Stictonetta* naevosa (Freckled Duck)
  - *Lophoictinia isura* (Square-tailed kite)
  - *Falco hypoleucos* (Grey Falcon)
  - *Grus rubicunda* (Brolga)
  - *Burhinus magnirostris* (Bush Stone-curlew)
  - *Polytelis swainsonii* (Superb Parrot)
  - *Lathamus discolor* (Swift Parrot)
  - *Ninox connivens* (Barking Owl)
  - *Grantiella picta* (Painted Honeyeater)
  - *Rostratula benghlensis* (Painted Snipe)
  - *Glossopsitta porphyrocephala* (Purple-crowned Lorikeet)
  - *Petroica rodinogaster* (Pink Robin)

8.1.6 Fish and Crustaceans

Nineteen indigenous species of fish and eight exotic species are known to occur in the Murray-Darling Basin and could be expected in waterways adjacent to the study area. Many of these species require flooding to provide conditions suitable for breeding and feeding offspring.

The three most significant species of crustaceans are Murray Crayfish, the Yabbie and the Shrimp. Crayfish have been heavily exploited. Yabbies are common and frequently occur in high numbers, and shrimps provide a food source for many other fauna species.

8.2 Vegetation Management Issues

As discussed in section 2.5.5, the study area has been substantially cleared for agriculture, urban / industrial and tourism / recreation development. The vegetation of the uncleared sections of the study area is dominated by Red Gum, Black Box and Grey Box communities. The most significant uncleared areas are Bama State Forest and Horseshoe Lagoon Centenary Park, and some peripheral timbered properties to the north and north-east of Moama. In addition, some relatively undisturbed roadside reserves have been identified as significant for conservation of native vegetation. These forests provide value as fauna habitat and are important for the continuing maintenance of biological diversity within the study area.

Given the extent of clearing which has already occurred within the study area, one of the significant issues for vegetation management is the minimisation of further clearing. Accordingly, any strategies for management of flooding within the study area should be based on this objective.

Other vegetation management issues within the study area include:

- Avoidance of removal of hollow bearing trees. Mature hollow-bearing trees provide habitat for a wide range of fauna. Hollows however are very slow to develop, particularly in Red Gum which is a relatively slow-growing species. Accordingly, any floodplain management strategy should adopt avoidance of removal of hollow-bearing trees as an objective. In the event that removal of such trees is unavoidable, a number of measures could be implemented to mitigate the impacts. The measures could include:
  - inspection by an ecologist prior to clearing to identify any current use of hollows;
  - attendance by a representative of a fauna care group when clearing is undertaken if hollow dwelling fauna are present;
  - replacement of hollows with artificial breeding / nesting boxes and / or salvage of hollows and attachment to suitable trees nearby.
- Red Gum has significant dependence on periodic winter - spring flooding regeneration and growth. In addition, it is not adapted to continuous flooding or to repeated summer floods. Accordingly, any floodplain management strategy should adopt an objective of maintaining or improving the current hydrological regime in this respect.

8.2.1 Vegetation Management Downstream of the Moama/Echuca Bridge

The vegetation community which occupies the high level floodway down stream of the Moama/Echuca bridge is primarily composed of Red Gum, with small patches of Black Box and extensive areas of Silver Wattle and Dwarf Cherry regeneration. The Red Gum community consists of widely-spaced mature and semi-mature trees with the gaps occupied by regeneration dating from the floods of 1974, 1975 and 1993. As is common with Red Gum, the older regeneration appears to have slowed substantially in growth due to the very high stocking levels and competition among individual stems for available moisture and nutrients.

It has been suggested that the very high stocking density of Red Gum and associated shrubby Acacia and dwarf cherry regrowth in this location has the effect of backing up floodwaters and exacerbating flooding impacts by trapping debris and creating a damming effect. The impact of the high stocking levels could be mitigated by undertaking a thinning exercise in the regrowth. Any thinning should be undertaken in accordance with the following prescription:

- Thinning should seek to reduce competition among individual Red Gum species whose growth has become stagnant and to be otherwise restricted to understorey vegetation (Silver wattle regrowth and Dwarf

Cherry regowth). The most healthy and vigorous red gum individuals should be retained.

- Only clearance of understorey vegetation with the potential to trap debris and create obstructions during flood flows should be permitted.
- Suppressed stems should be removed.
- Thinning of Red Gums should seek to obtain a final stocking of 500 regrowth stems per hectare.
- The thinning operation will be restricted to regrowth stems from the 1974, 1975 and 1993 floods. Mature or semi-mature trees will not be removed.
- The thinning operation will be restricted to the high water level for a flood event with a 1% annual exceedance probability.

The thinning operation should be managed by a forester or other appropriately qualified person.

9.1 Costs

A discussion of the types of costs to the community were included in section 5.2.1. Tangible damages are costs to the community upon which a monetary value can be attributable. These include direct damages and indirect damages.

There are also intangible costs to the community to which it is difficult or inappropriate to attach monetary values (although techniques have been devised to do so).

9.1.1 Direct Damages

Direct damages are costs which are immediate and directly imposed by the flooding. These include costs such as of repair to buildings and equipment, value of stock losses, *etc.*

In general, most direct damages can be readily quantified. One exception is loss of life, a direct damage and one which does have monetary value but is usually more valued as a personal loss.

9.1.2 Indirect Damages

Indirect, tangible damages are costs which become apparent or are incurred after the flood and as a consequence of flooding — such as loss of business in commercial districts, clean-up costs, alternative accommodation or agistment costs, loss of agricultural productivity, *etc.*

Loss of agricultural productivity may be incurred due to damage to land or pasture, crop loss or the loss of opportunity to crop.

Indirect damages also include medical costs, whether incurred by stress-related illness or by contaminated water supplies. There are also costs borne by government service departments and agencies in provision of recovery services.

After severe floods, depression of the regional economy can have medium to long term suppression of demand leading to reduced levels of business. In the short term, access difficulties may lead to customers going elsewhere.

In general, indirect damages can be valued in monetary terms, but many are quite difficult to quantify, particularly if the effects are longer lasting. Underestimation of flood damages often arises because of the difficulty of quantifying indirect (and intangible) damages.

9.1.3 Intangible Damages

Intangible damages are damages for which assignation of a monetary value is very difficult or inappropriate. These include trauma and distress induced by experiences during flood events. Human responses to the stress induced by severe natural events are unpredictable. While some may cope well, others suffer a sense of powerlessness and depersonalisation which can have lasting effects on health and personal relationships. Effects may be physical as well as psychological, and can require treatment over extended periods.

There is also a non-monetary value attached to removing or reducing the risk associated with floodplain occupancy, even for those who may recover readily.

After floods, the morale of communities is often subdued, manifested in various ways from a reduced feeling of well-being through to individual depression. Civic enterprise can sometimes be damaged by the realisation of vulnerability which succeeds a flood. Suppressed economic activity can lead to reduced morale and optimism, ramifications of which can include stresses placed on personal and community relationships. Family breakdown is a real cost to communities, and the stresses imposed by unexpected hardship can certainly contribute to this problem.

9.2 Economic Assessment -Quantified Assessment

9.2.1 Introduction

An economic evaluation, consistent with usual government guidelines, needs to examine all the significant costs and benefits of the project from the community perspective compared with the base case and other options (if relevant). This involves analysis of quantified impacts as well as unquantified impacts, with the overall evaluation combining the two impact groups.

In this assignment, the Moama levee option is only being considered against the "do nothing" base case. i.e. a comparison of the situation with, and without, construction of the levee.

The quantified assessment utilises a cost-benefit analysis using a discounted cashflow technique over a 30 year evaluation period. A series of indicators of economic worth have been derived, including net present value, net present value/capital cost ratios, and economic internal rates of return over their economic life. Because the results are dependent on the values of key parameters, the sensitivity of the results to variations in these key assumptions have also been tested for robustness and confidence.

9.2.2 Costs

Costs which have been quantified in the evaluation are capital costs and maintenance costs.

Capital Costs
Capital costs were provided using 1998 dollars and include costs for the levee including the freeboard. The capital costs and works associated with the levee are assumed to take place in year one of the evaluation, at a cost of almost $1.2 million for the levee. See **Appendix C**.

In addition to the levee construction costs, there are costs associated with construction of culverts under the railway and under Chanter Street. The cost of construction of the railway culvert is estimated at $372,500. Costs of raising Chanter Street to a 5% AEP flood level and installing culverts to accommodate the 5% flood flow from the floodway to the north were estimated as $260,000, but need not necessarily be undertaken as an integral component of the Flood Management Plan. No allowances have been made for land acquisition. It is assumed that the levee can be aligned along public land and existing easements, although details of parts of the alignment are still subject of negotiation.

Total capital costs directly associated with the levee construction are therefore estimated as $1,570,000.

Maintenance Costs
Maintenance costs are the costs associated with on-going maintenance of the levee. Maintenance costs are assumed to be constant over the evaluation period. Annual costs are $4,000 per annum (0.3% of the capital cost). Maintenance costs commence in the second year of the evaluation reflecting completion of levee construction in the first year. In addition to the regular maintenance costs, there are flood pegging and satellite imaging costs; these costs are estimated to be $1,700 per annum.

Total maintenance costs are therefore $5,700 per annum.

Property Acquisition and Easements
Estimates were subsequently made of the costs of acquisition of property or easement rights associated with construction of the levee and desirable for the designation of floodway zones. These are estimated to amount to $476,000, as itemised in **Appendix C**.

9.2.3 Benefits
The economic benefit measures quantified in this evaluation are:

- the avoided annual damage costs associated with flooding; and
- increased property values for potential development sites previously affected by floods.

Avoided Damage
The main economic benefit of flood mitigation is normally measured in the form of flood damage costs avoided. Flood damage costs are a function of

the depth and frequency of flooding and the damage caused at relevant flood depths. The damage estimates are based on empirical observations in the community under analysis and applied to the flood damage models described in Section 2 of the report.

The levee will offer protection at the I in 200 year flood level. Avoided damage benefits for the levee compared to the base case have been estimated at $108 300 per annum, being the difference between the average annual damage of $124,000 in the base case and $15,700 under the levee option. Benefits are assumed to begin in the second year of the evaluation and remain constant over the life of the evaluation.

Amenity Benefits

As a result of the levee construction, vacant land will be more likely to be used for residential and commercial purposes. A 10% increase in property values has been used as a proxy for the amenity benefits associated with construction on the vacant land after the levee has been built. The amenity benefits associated with the land development are the result of being able to build in a closer proximity to the central township and the increased conveniences associated with this development.

However, of the amenity benefits, not all of the benefit can be attributed the levee, since over time, as the population grows the land will be used regardless of levee construction, and land is also available outside the floodplain area for development. Therefore, it is assumed that 25% of the amenity benefits can be attributed to the levee and included in the evaluation.

It should be noted that increased land property values have been used as a proxy for measuring amenity. A possible alternative measure would be the avoided flood-proofing costs on constructed properties. This has not been estimated due to lack of available data.

Table 9.1 details the basis for the calculation of amenity benefits used in this evaluation (approximately $12,000 per annum). The numbers of properties used is based on information supplied by Murray Shire.

Table 9.1: Calculation Amenity Benefits

Measure	Result
Number of Residential Properties	364
Number of Commercial Properties	30
Residential Value per Property	$37 000
Commercial Value per Property	$32 000
Total Property Value	14 428 000
Annual Property Value Increase	$48 093
Annual amenity Benefit @25% attributable	$12 023

9.2.4 Evaluation Results

Figure 9.1 details the evaluation spreadsheet and **Table 9.2** details the results of the base evaluation using a 7% discount rate and an estimated capital cost of $1.56 million.

Table 9.2: Evaluation Results for 7% discount rate

Economic Measure	Result
Net Present Value at 7%	($152 692)
Benefit Cost Ratio	0.90
Net Present Value/Capital Cost	-0.10
Internal Rate of Return	5.99%

Figure 9.1: Evaluation Spreadsheet

Year	Costs		Benefits		Net
	Capital	Maintenance	Avoided Damage	Property Values	
1	1,560,000	-	-	-	- 1,560,000
2	-	5,700	108,300	12,023	114,623
3	-	5,700	108,300	12,023	114,623
4	-	5,700	108,300	12,023	114,623
5	-	5,700	108,300	12,023	114,623
6	-	5,700	108,300	12,023	114,623
7	-	5,700	108,300	12,023	114,623
8	-	5,700	108,300	12,023	114,623
9	-	5,700	108,300	12,023	114,623
10	-	5,700	108,300	12,023	114,623
11	-	5,700	108,300	12,023	114,623
12	-	5,700	108,300	12,023	114,623
13	-	5,700	108,300	12,023	114,623
14	-	5,700	108,300	12,023	114,623
15	-	5,700	108,300	12,023	114,623
16	-	5,700	108,300	12,023	114,623
17	-	5,700	108,300	12,023	114,623
18	-	5,700	108,300	12,023	114,623
19	-	5,700	108,300	12,023	114,623
20	-	5,700	108,300	12,023	114,623
21	-	5,700	108,300	12,023	114,623
22	-	5,700	108,300	12,023	114,623
23	-	5,700	108,300	12,023	114,623
24	-	5,700	108,300	12,023	114,623
25	-	5,700	108,300	12,023	114,623
26	-	5,700	108,300	12,023	114,623
27	-	5,700	108,300	12,023	114,623
28	-	5,700	108,300	12,023	114,623
29	-	5,700	108,300	12,023	114,623
30	-	5,700	108,300	12,023	114,623
Undiscounted	1,560,000	165,300	3,140,700	348,677	1,764,077
Discount Rate					
4%	$1,560,000	$96,807	$1,839,336	$204,201	$386,730
7%	$1,560,000	$69,983	$1,329,672	$147,619	-$152,692
10%	$1,560,000	$53,407	$1,014,728	$112,654	-$486,025

This shows that at a 7% discount rate the project returns a slightly negative NPV, with a benefit cost ratio of 0.9.

Sensitivity Tests

Sensitivity tests are concerned with variations in key assumptions in order to assess the economic robustness of the base evaluation. The following sensitivity testing has been undertaken:

- increased benefits under the joint probability approach to freeboard
- 4% discount rate
- 10% discount rate.
- 20% increase in capital cost
- 20% decrease in capital cost

Test 1: Increase Benefits - Joint Probability Approach

Freeboard accounts for uncertainties in analysis, localised anomalies in hydraulic flood behaviour, wave action during floods, levee foundation settlement and localised wear and tear. While communities should not be allowed or encouraged to believe that freeboard provides protection over and above the nominated Flood Planning Level or design flood probability, an innovative approach (Joint probability) examines the implications of added protection potentially provided by a freeboard. This sensitivity test accounts for this by increasing the avoided damage cost benefits. In order to accurately determine the additional benefits associated with the joint probability approach, further model application and analysis would be required. However, based on empirical evidence from similar studies, a 10% increase in annual avoided damage (to $119,130) has been used a proxy. **Table 9.3** details the results of the sensitivity test at a 7% discount rate.

Table 9.3: Joint Probability Approach Sensitivity Test

Economic Measure	Result
Net Present Value	($19 725)
Benefit Cost Ratio	0.99
Net Present Value/Capital Cost	-0.01
Internal Rate of Return	6.87%

At a 7% discount rate the additional benefits are not quite sufficient to generate a positive NPV.

Test 2: 4% Discount Rate

Table 9.4 details the results of evaluation using a 4% discount rate.

Table 9.4: Evaluation Using a 4% Discount Rate

Economic Measure	Result
Net Present Value	$386 730
Benefit Cost Ratio	1.25
Net Present Value/Capital Cost	0.25
Internal Rate of Return	5.99%

Test 3: 10% Discount Rate

Table 9.5 details the results of evaluation using a 10% discount rate.

Table 9.5: Evaluation Using a 10% Discount Rate

Economic Measure	Result
Net Present Value	($486 025)
Benefit Cost Ratio	0.69
Net Present Value/Capital Cost	-0.31
Internal Rate of Return	5.99%

Test 4: 20% Increase in Capital Cost

Table 9.6 details the results of evaluation with a 20% increase in capital costs. Such an increase in capital costs, would, we are advised, more than cover any remediation costs of environmental impacts. As the environmental impacts are identified, remediation costs will need to be measured in some way. This sensitivity test can used as a possible proxy to reflect the covering of remediation costs.

Table 9.6: 20% Increase in Capital Costs

Economic Measure	Result
Net Present Value	($464 692)
Benefit Cost Ratio	0.75
Net Present Value/Capital Cost	-0.25
Internal Rate of Return	4.33%

Test 5: 20% Decrease in Capital Cost

Table 9.7 details the results of evaluation with a 20% decrease in capital costs.

Table 9.7: 20% Decrease in Capital Costs

Economic Measure	Result
Net Present Value	$159 308
Benefit Cost Ratio	1.13
Net Present Value/Capital Cost	0.13
Internal Rate of Return	8.27%

Quantified impacts - Key results

The key results are:

- On a stand alone basis, the quantified evaluation does not result in a positive net present value at a 7% discount rate. The relatively low population being protected would appear a key factor in this result given the capital cost of the levee (i.e. there appears little access to "economies of scale" from levee protection here).
- At a discount rate of 4%, a positive NPV is recorded with a benefit cost ratio of 1.25
- A reduction of capital costs to a value of $1,407,308, or an increase in total measured benefits to a total of $132,760 per annum would result in a break even position (ie NPV=0) at the 7% discount rate.
- On an indicative analysis, the joint probability approach to measuring avoided damage costs, almost increases the avoided damage benefits sufficiently to generate a positive NPV (once amenity benefits are added).
- A 20% increase in project costs at the base level of benefits (a cost increase which could in part be covering environmental impact mitigation costs), implies a significantly negative NPV, with a benefit cost ratio of 0.75.

9.3 Economic evaluation - unquantified impacts

The following impacts of the levee have been identified in the course of the preparation of the Moama Flood management study. These impacts are sourced from the social assessment and environmental assessment sections of the report. Feeding them into the economic evaluation allows assessment of whether the impacts will alter the quantified results to a significant degree. In what follows the impacts are described and where possible qualitatively assessed, where this has been done in the source information.

Table 9.8 identifies the unquantified impacts and provides a simple significance rating on the following scale:

- No significant impact
- Low Significance
- Medium significance
- High Significance

The impacts identified are all cost impacts except the social benefit of reduced flood stress on the protected population. This benefit is over and above the long term social benefits for the community in terms of avoiding the impacts of flood, which are quantified in terms of avoided damage costs in the previous section.

On the information provided from other areas of the assignment, (i.e. no additional community consultation has occurred), it appears that the unquantified cost impacts are only likely to be of low significance, once mitigation measures have been implemented. The investigations of the proposed alignment for aboriginal heritage values did not identify adverse impacts.

The various mitigations required will involve a number of costs. Without estimates of what these costs may be, the quantified analysis has run a sensitivity on higher project costs.

On the positive side, the quantified estimates of benefit of avoided damage from flooding, does not fully account for the social benefit of the levee.

Table 9.8: Unquantified impacts

Impact	Significance rating	Mitigation measure
Environmental impacts		
Construction impacts - noise/dust	Low after mitigation	Yes
Locality transformation	None	
Vegetation clearing	Low (specific area)	Some clearing unavoidable
Threatened species impacts	None or low	Yes
Degradation of existing quality	None	
Safety hazards	None	
Pollution	None after mitigation	Prevention
Waste Disposal	Low, if any	
Social Impacts		
Cultural / Heritage	None (see note)	
Aesthetics – obstruction of views	Low	Choice of embankment type
Construction disruption	Low	
Reduced flood "stress"	Medium	n/a

Note: The proposed levee alignment has been investigated for aboriginal significance.

9.4 Economic Evaluation -Conclusions

Overall the economic evaluation concludes that the proposed levee cannot categorically be shown to provide overall net benefit to the community. For quantified impacts at a 7% discount rate, the project achieves a negative NPV of $153,000, essentially due to the relatively low protected population.

Any increase in project costs to cover mitigation measures for the low significance environmental impacts identified, would reduce the NPV further below the break-even line.

However, restricting the capital cost by 10% to $1.407 million does mean that a break even NPV could be obtained (at 7% discount).

Equally a lower discount rate (below 6%), representing a higher weighting for the social impacts on future generations, which have not been fully incorporated into the quantified analysis, does also result in a positive benefit being generated (but this excludes any mitigation costs that may be required).

Another way of expressing this is the benefits would have to be $12,000 per annum higher (excluding mitigation costs), for net benefit to result. This represents about $30 per protected current household. This could be regarded as an additional willingness to pay (WTP) requirement, reflecting the inter-generational benefits which have not fully been accounted for. Clearly this break-even level of required WTP would rise once mitigation costs are known and can be incorporated.

10. References

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Appendix A - Hydraulic Model Outputs

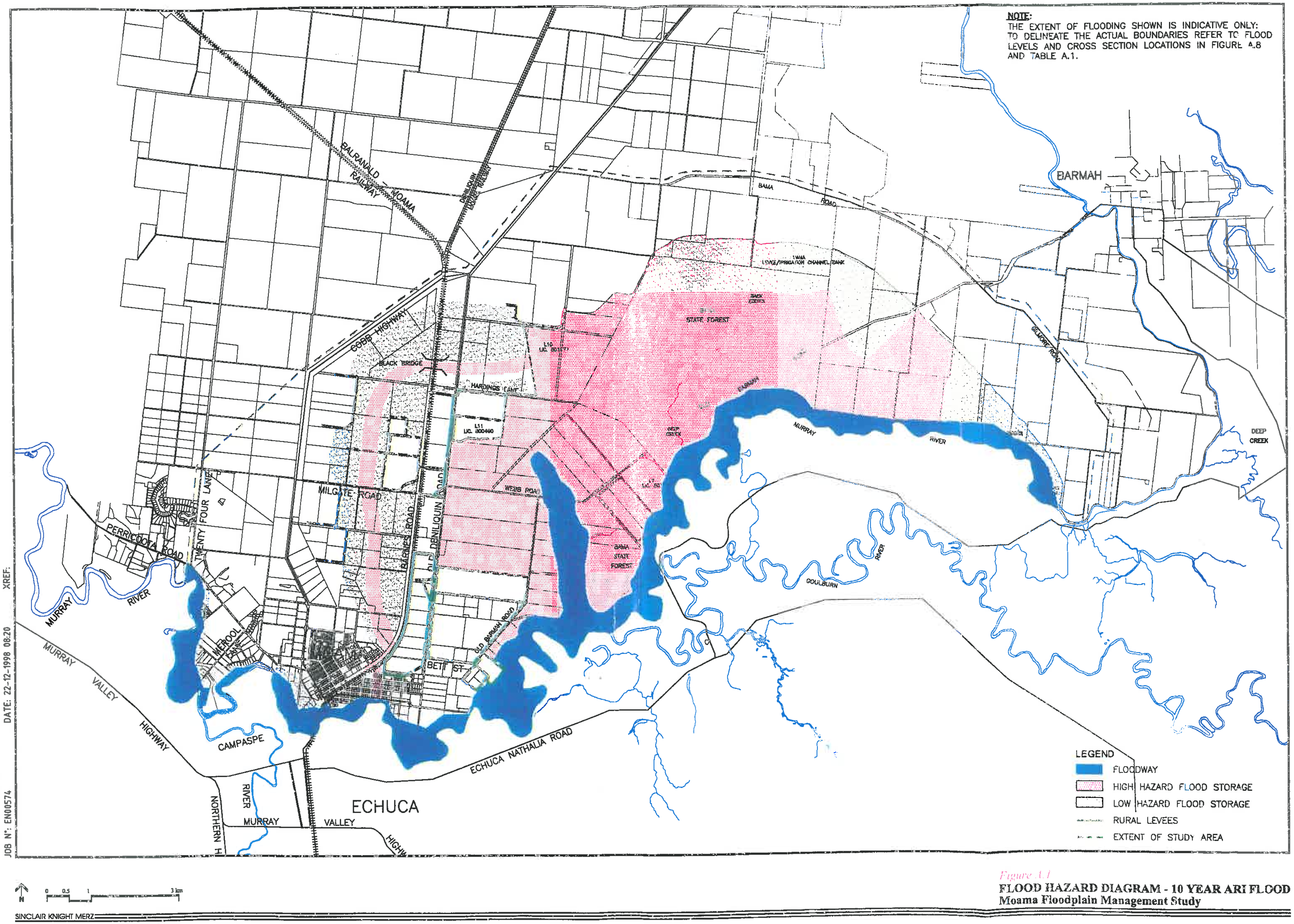
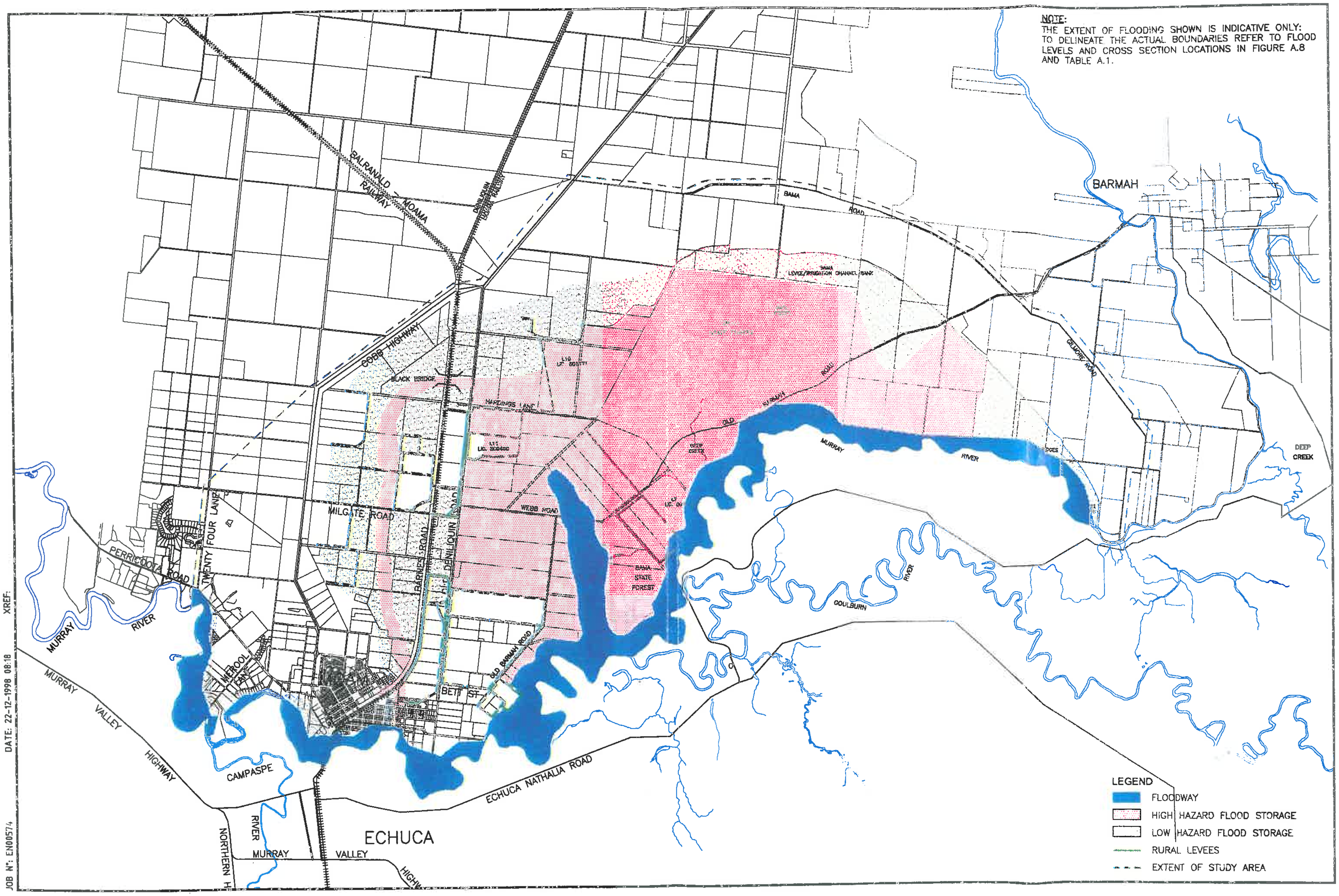


Figure A.1

FLOOD HAZARD DIAGRAM - 10 YEAR ARI FLOOD

Moama Floodplain Management Study



N 0 0.5 1 3 km

Figure A.2
FLOOD HAZARD DIAGRAM - 20 YEAR ARI FLOOD
Moama Floodplain Management Study

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JOB N°: EN00574 DATE: 22-12-1998 08:18

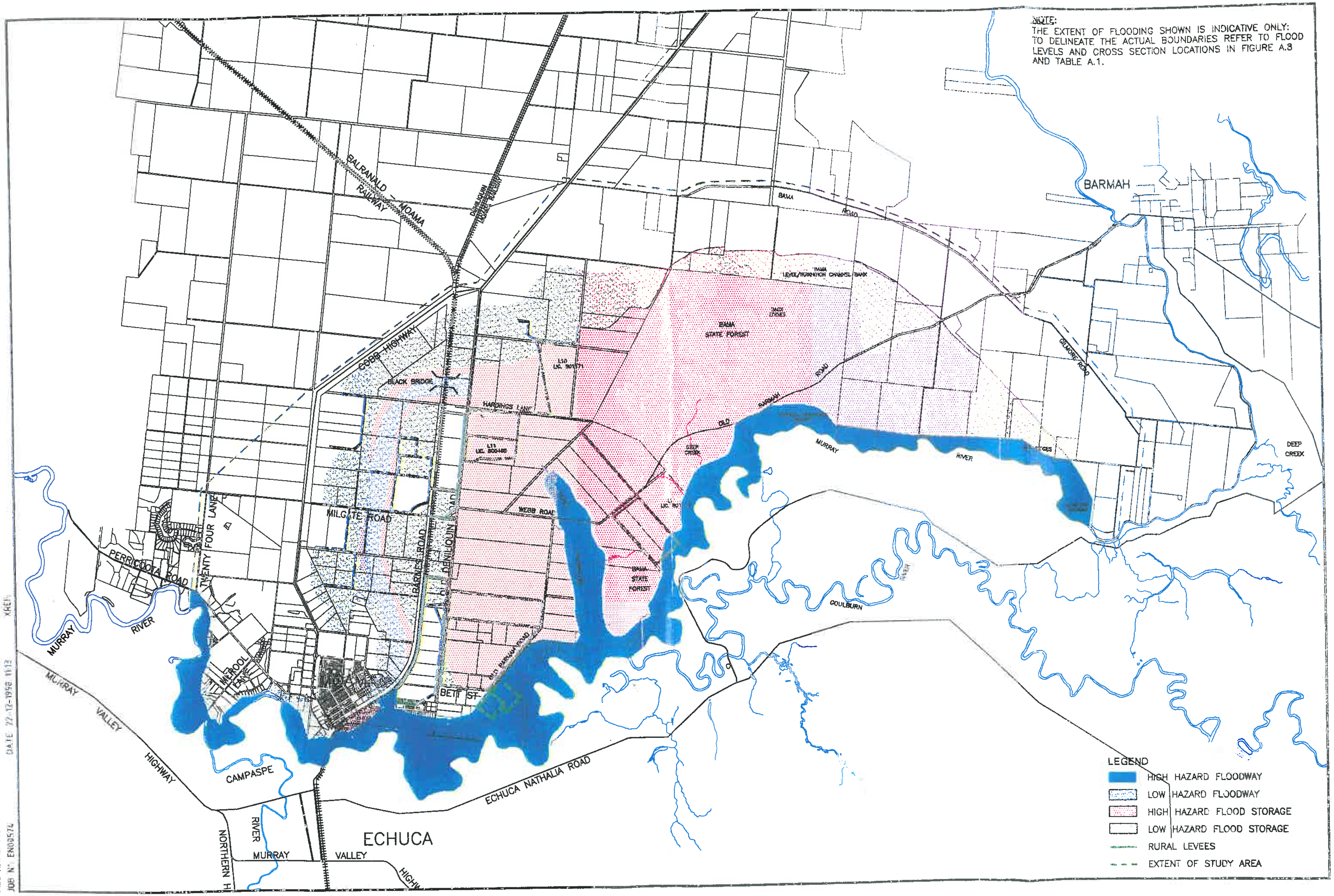
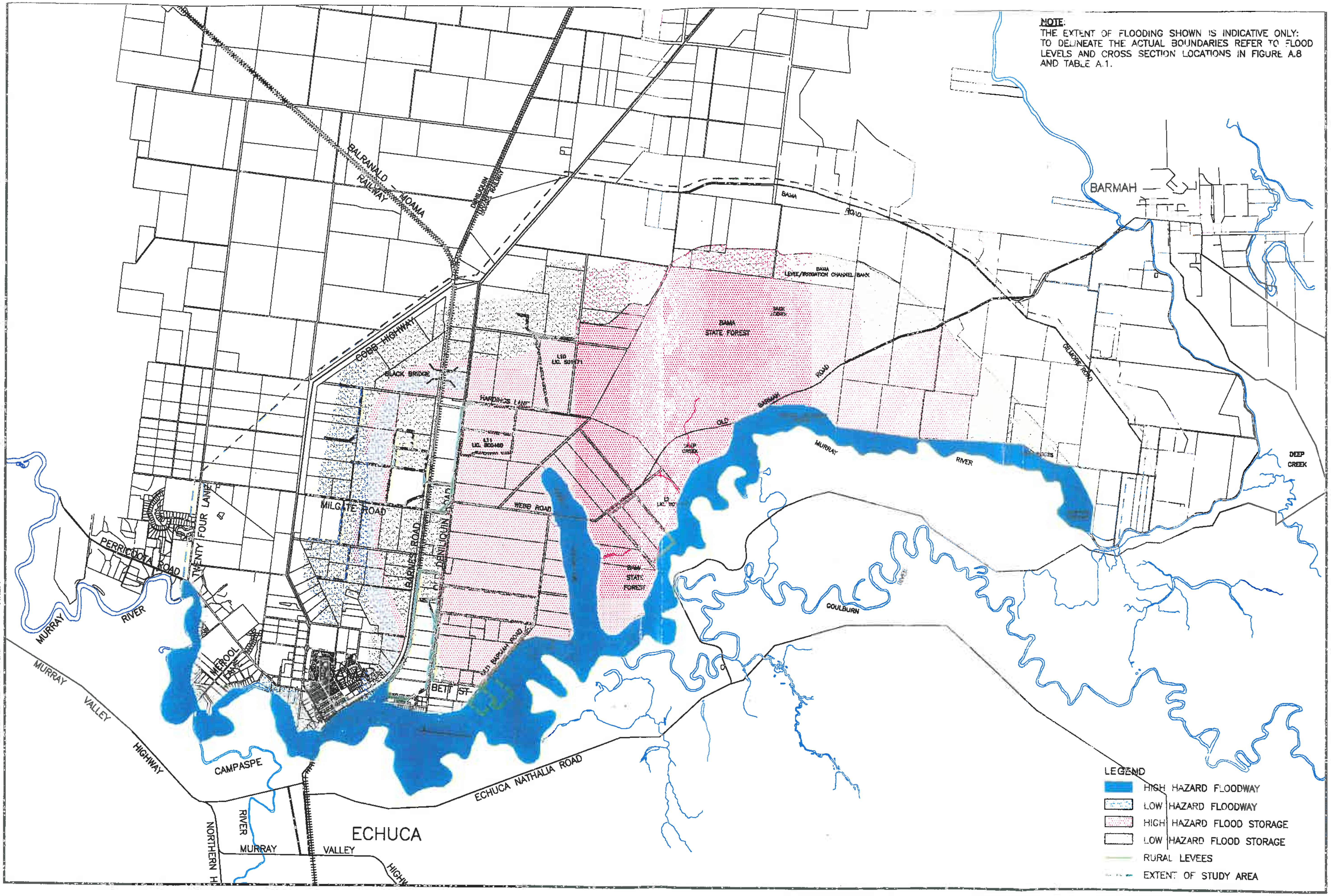


Figure A.3
FLOOD HAZARD DIAGRAM - 50 YEAR ARI FLOOD
Moama Floodplain Management Study



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JOB N°: EN00574 DATE: 22-12-1998 11:13

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Figure A.4

FLOOD HAZARD DIAGRAM - 100 YEAR ARI FLOOD

Moama Floodplain Management Study

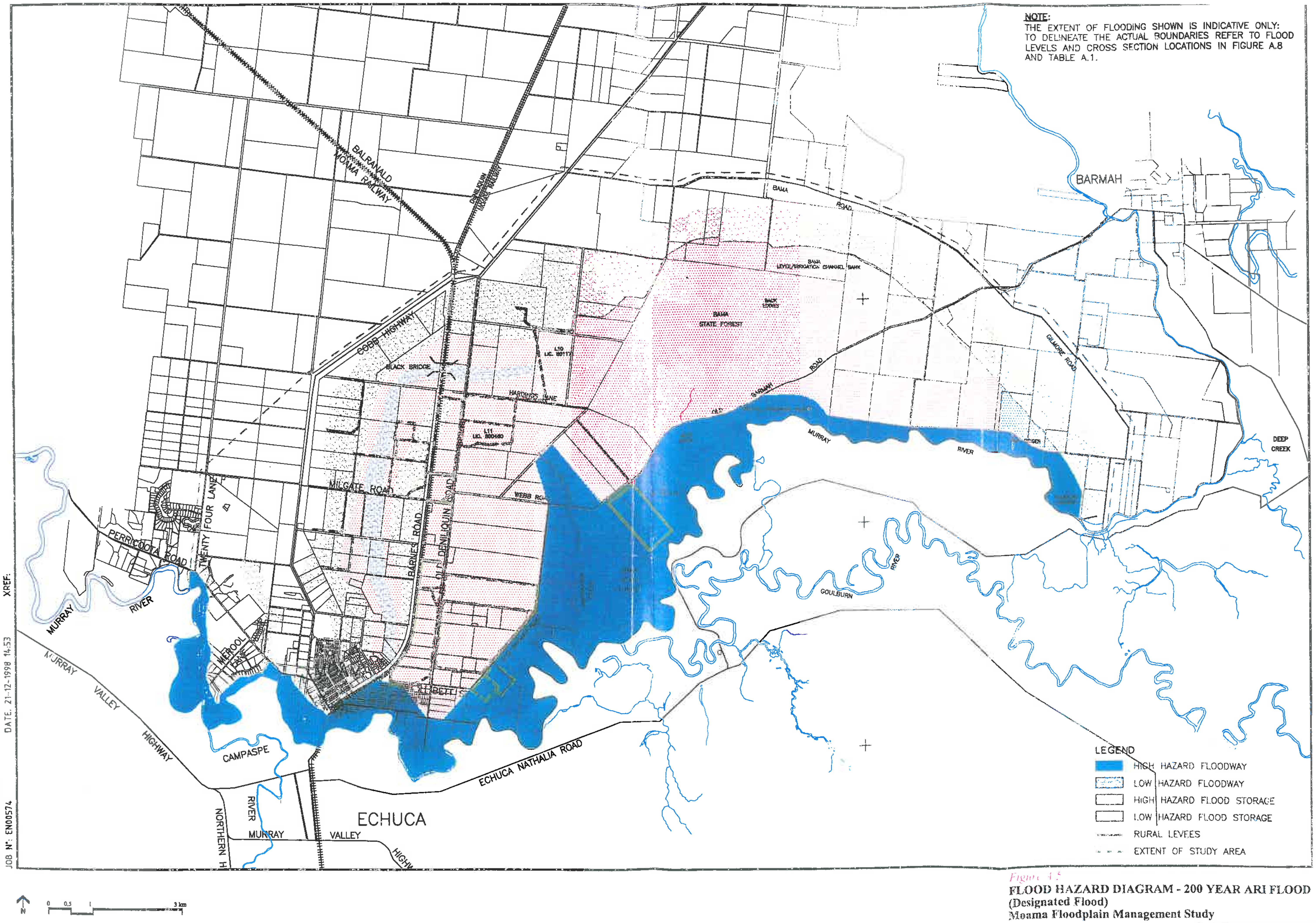
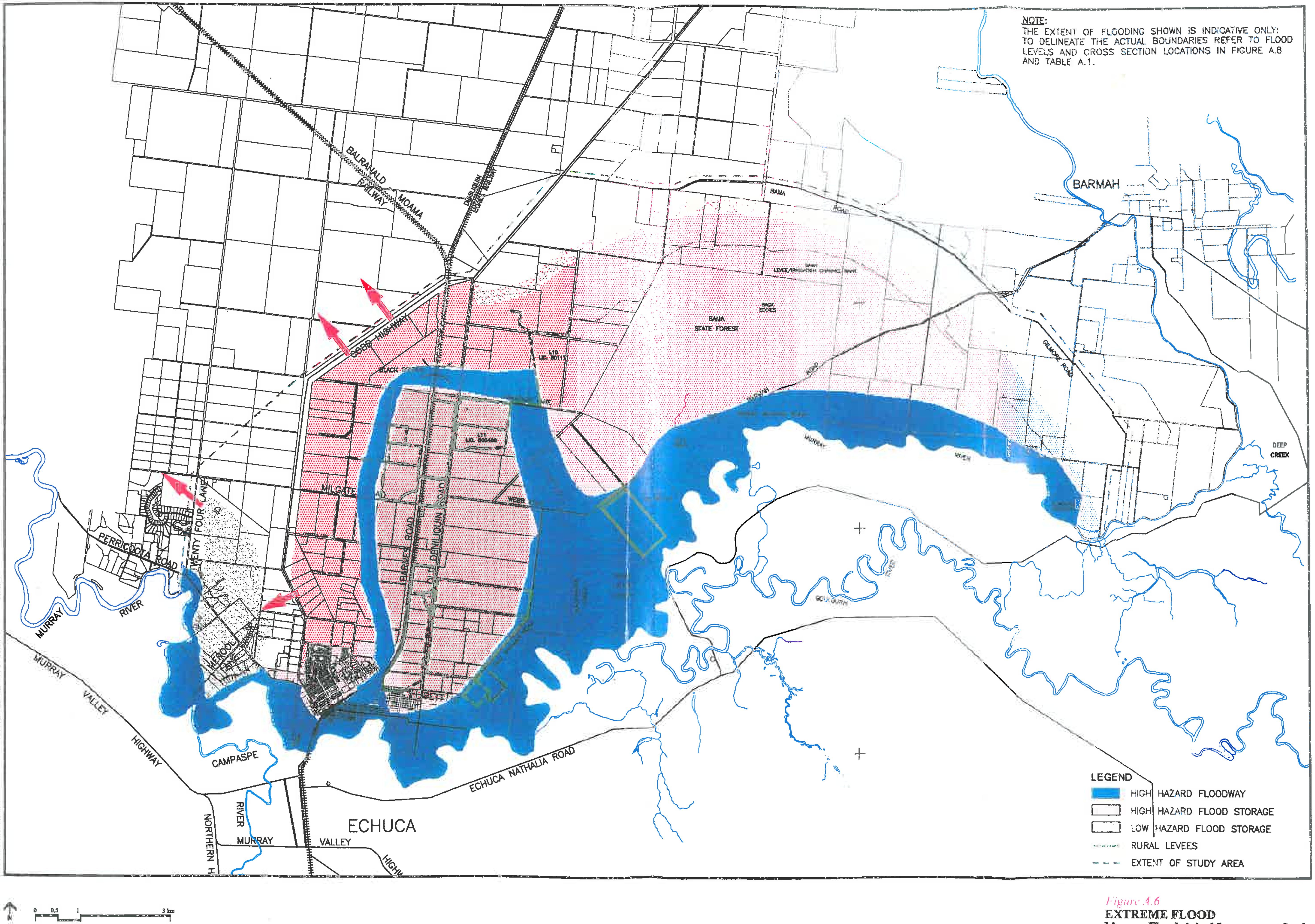


Figure 4.5
FLOOD HAZARD DIAGRAM - 200 YEAR ARI FLOOD (Designated Flood)
Moama Floodplain Management Study

SINCLAIR KNIGHT MERZ



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SINCLAIR KNIGHT MERZ

Figure A.6
EXTREME FLOOD
Moama Floodplain Management Study

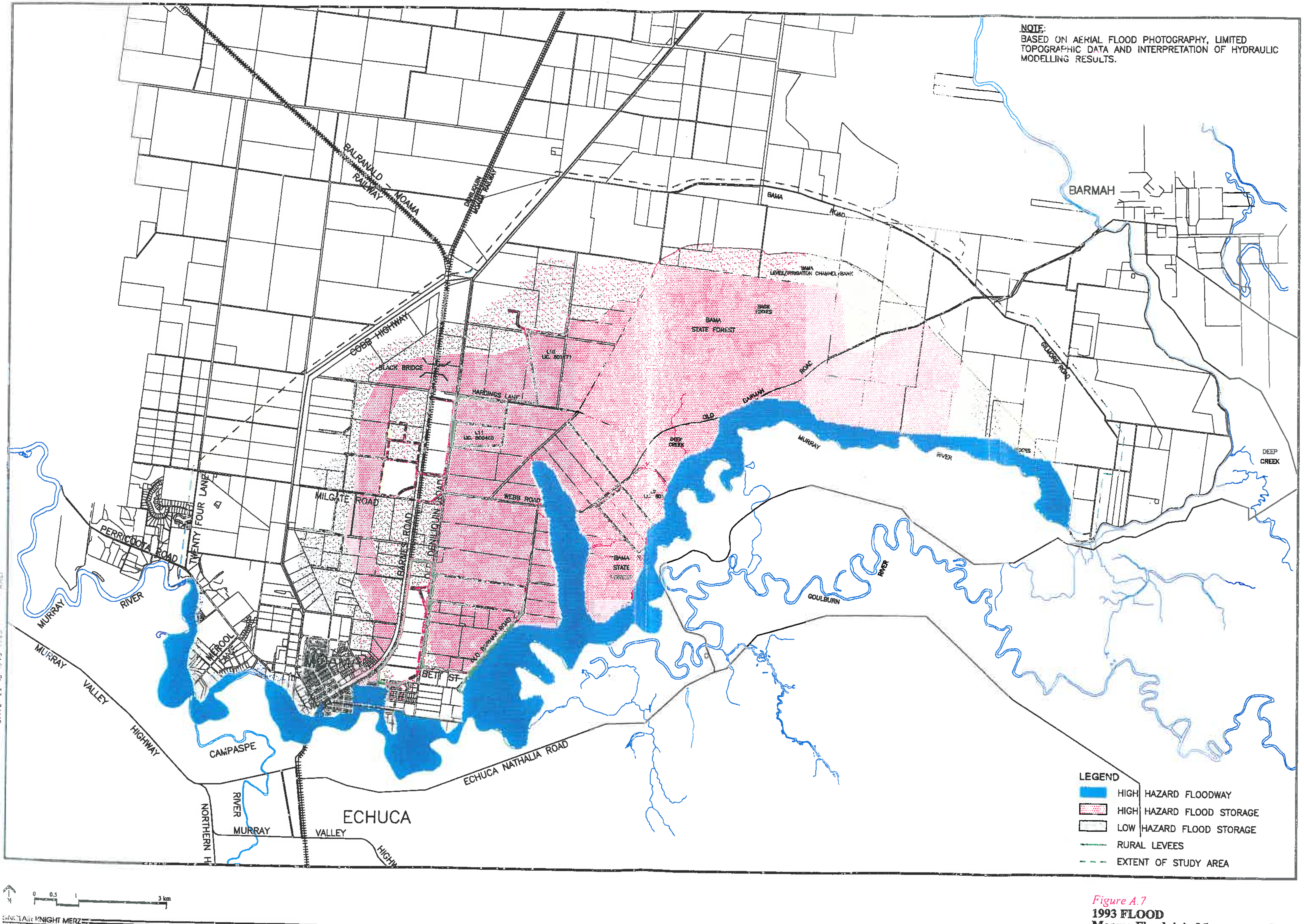

Figure A.7
1993 FLOOD
Moama Floodplain Management Study

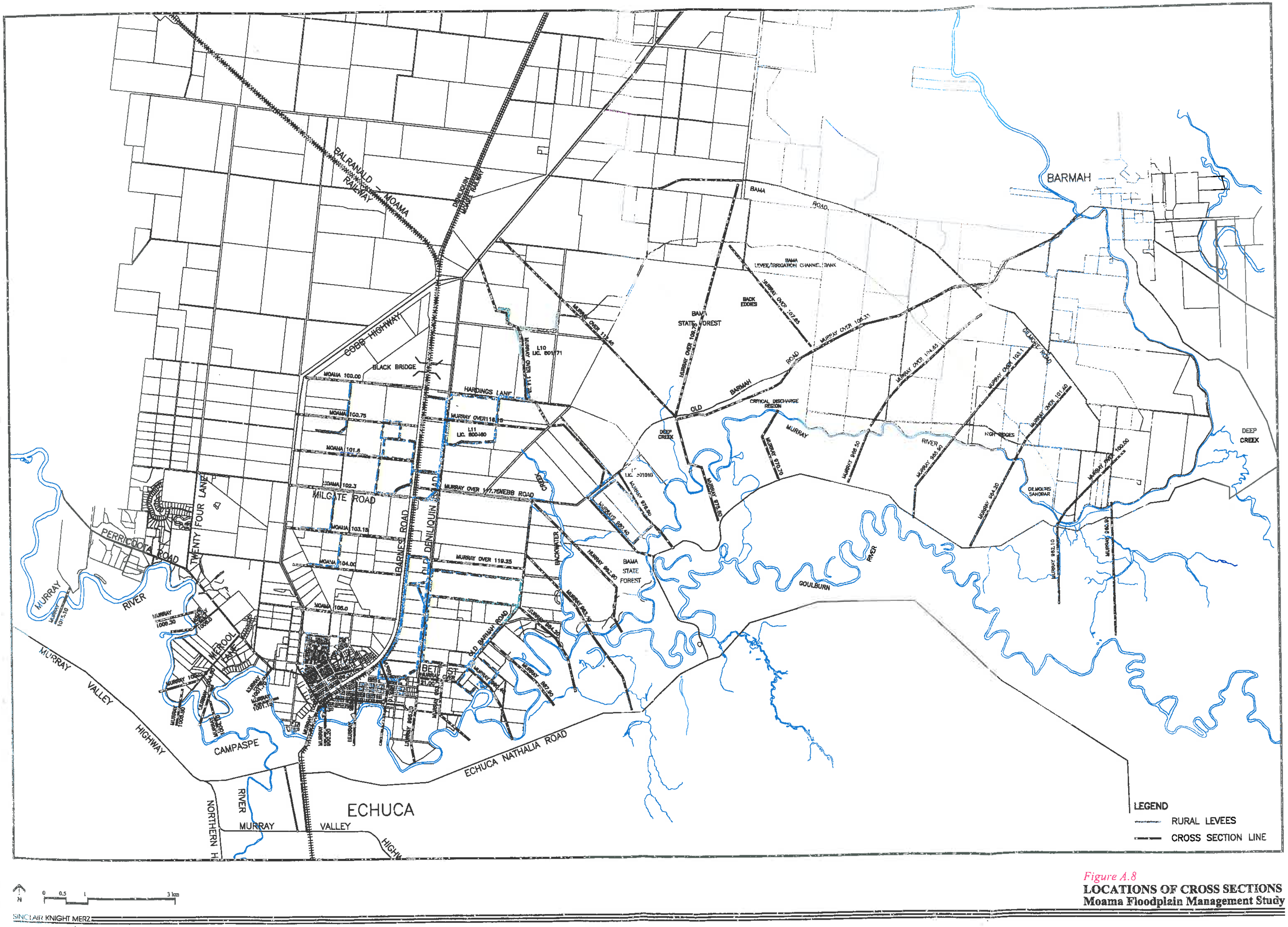

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Figure A.8
LOCATIONS OF CROSS SECTIONS
Moama Floodplain Management Study

Table A. 1: Peak Levels and Flow Velocities for Design Floods

NOTE: See Figure A.8 for cross-section locations.

	Peak Flood Levels (m AHD)							
	Chainage	10 y ARI	20 y ARI	1993 flood	50 y ARI	100 y ARI	200 y ARI	Extreme Flood
Murray	959.90	95.67	96.08	96.17	96.09	96.21	96.34	97.10
River	960.90	95.62	96.01	96.08	96.02	96.14	96.27	97.10
Gilmour >	962.10	95.50	95.84	95.93	95.85	95.99	96.14	97.09
Rd	964.20	95.36	95.69	95.79	95.77	95.92	96.06	97.08
	965.90	95.29	95.64	95.73	95.74	95.89	96.02	97.08
	968.50	95.23	95.60	95.68	95.70	95.86	96.00	97.03
	970.70	95.21	95.58	95.66	95.69	95.85	95.99	97.00
	975.60	95.19	95.57	95.64	95.68	95.83	95.98	96.98
	978.90	95.18	95.55	95.63	95.67	95.83	95.97	96.96
	980.40	95.17	95.55	95.62	95.66	95.82	95.97	96.95
Goulburn >	982.90	95.14	95.53	95.60	95.65	95.81	95.96	96.94
River	983.40	95.14	95.53	95.60	95.65	95.81	95.96	96.94
	984.20	95.12	95.51	95.58	95.63	95.80	95.95	96.94
	987.90	94.97	95.40	95.46	95.55	95.73	95.90	96.94
	990.40	94.84	95.30	95.36	95.48	95.68	95.86	96.94
	993.70	94.73	95.19	95.23	95.40	95.61	95.83	96.94
	995.50	94.68	95.14	95.18	95.36	95.58	95.80	96.92
	997.10	94.56	95.03	95.05	95.28	95.50	95.74	96.90
	998.70	94.46	94.92	94.91	95.21	95.45	95.69	96.89
	999.20	94.43	94.89	94.88	95.19	95.42	95.67	96.88
bridge >	1000.00	94.38	94.83	94.81	95.14	95.37	95.62	96.83
	1000.40	94.37	94.82	94.79	95.13	95.36	95.61	96.83
Echuca >	1001.15	94.34	94.79	94.76	95.11	95.34	95.58	96.81
gauge	1001.70	94.32	94.77	94.73	95.09	95.33	95.57	96.80
	1004.10	94.22	94.66	94.59	95.01	95.24	95.49	96.75
Campaspe>	1004.50	94.21	94.65	94.58	95.00	95.24	95.48	96.75
River	1005.80	94.13	94.58	94.51	94.94	95.18	95.42	96.69
	1006.80	94.06	94.51	94.44	94.88	95.12	95.37	96.65
	1008.00	93.98	94.44	94.37	94.81	95.06	95.31	96.58
	1009.30	93.93	94.40	94.33	94.78	95.02	95.27	96.56
	1015.10	93.70	94.19	94.11	94.58	94.83	95.08	96.38
	1024.40	93.21	93.71	93.64	94.10	94.34	94.58	95.81
	1030.90	92.72	93.22	93.15	93.59	93.84	94.07	95.27
	1050.90	90.71	91.24	91.17	91.59	91.84	92.16	93.78
Murray-	100.00	95.40	95.68	95.79	95.77	95.92	96.05	97.08
Over	101.80	95.36	95.68	95.79	95.77	95.92	96.05	97.08
Bama Forest	103.10	95.29	95.64	95.73	95.73	95.88	96.02	97.06
	104.65	95.22	95.59	95.67	95.70	95.86	96.00	97.03
Old >	106.35	95.21	95.59	95.67	95.69	95.85	95.99	97.01
Barmah Rd	107.65	95.21	95.58	95.66	95.69	95.85	95.99	97.00
	109.75	95.20	95.57	95.65	95.68	95.84	95.98	96.99
	112.45	95.19	95.57	95.64	95.68	95.84	95.98	96.98
	114.75	95.18	95.56	95.63	95.67	95.83	95.97	96.96
	116.15	95.18	95.56	95.63	95.67	95.82	95.96	96.96
Webb Rd >	117.75	95.18	95.56	95.63	95.67	95.82	95.94	96.95
	119.25	95.18	95.56	95.63	95.67	95.82	95.93	96.95
Bett St >	121.00	95.18	95.56	95.63	95.67	95.81	95.92	96.95
	121.40	95.00	95.19	95.23	95.40	95.61	95.84	96.95
	122.40	94.73	95.19	95.23	95.40	95.61	95.83	96.94
Moama	100.00	95.04	95.25	95.37	95.38	95.57	95.80	96.95
(West of	100.75	95.04	95.25	95.37	95.38	95.57	95.80	96.95
Railway)	101.60	95.04	95.25	95.36	95.37	95.57	95.80	96.95
Milgate >	102.30	94.99	95.24	95.36	95.37	95.57	95.80	96.95
Rd	103.15	94.98	95.24	95.36	95.37	95.56	95.80	96.95
	104.00	94.98	95.23	95.35	95.36	95.56	95.80	96.95
	104.85	94.96	95.23	95.35	95.36	95.56	95.80	96.94
	105.00	94.95	95.23	95.35	95.36	95.56	95.80	96.94
Barnes Rd>	106.30	95.00	95.22	95.34	95.36	95.56	95.80	96.93
	106.70	95.00	95.00	95.00	95.21	95.45	95.69	96.89
	107.30	94.46	94.92	94.91	95.21	95.45	95.69	96.89

River	Chainage	Mean velocities (m/s)						
		10 y ARI	20 y ARI	1993 flood	50 y ARI	100 y ARI	200 y ARI	Extreme Flood
Murray River	960.90	0.7228	0.8988	0.7245	0.8988	0.8831	0.8966	0.8956
	962.10	0.6543	0.6755	0.5707	0.6754	0.6616	0.6576	0.6557
	964.20	0.5520	0.5491	0.5942	0.5491	0.5589	0.5463	0.5458
	965.90	0.6127	0.6197	0.5820	0.6197	0.6170	0.6179	0.6150
	968.50	0.4898	0.5774	0.6059	0.5671	0.6039	0.6352	0.6159
	970.70	0.5128	0.5128	0.5296	0.5128	0.5128	0.5128	0.5138
	975.60	0.4358	0.4358	0.4912	0.4358	0.4358	0.4358	0.4368
	978.90	0.3960	0.3984	0.4006	0.3984	0.4023	0.4074	0.3962
	980.40	0.4579	0.4617	0.4715	0.4616	0.4761	0.4914	0.4593
	982.90	0.4045	0.4045	0.4494	0.4045	0.4045	0.4045	0.4061
	983.40	0.2343	0.2353	0.2717	0.2353	0.2374	0.2352	0.2351
	984.20	0.7957	0.7957	0.7137	0.7957	0.7957	0.7957	0.8026
	987.90	0.7179	0.7189	0.7060	0.7189	0.7255	0.7286	0.7202
	990.40	0.7309	0.7309	0.6563	0.7309	0.7309	0.7309	0.7391
	993.70	0.3957	0.4220	0.4601	0.3731	0.3768	0.3790	0.3970
	995.50	0.7123	0.7137	0.7659	0.7137	0.7217	0.7234	0.7124
	997.10	0.6851	0.6856	0.6904	0.6856	0.6923	0.6939	0.6943
	998.70	0.7448	0.7482	0.7906	0.7482	0.7590	0.7605	0.7466
	999.20	0.6828	0.6832	0.6626	0.6832	0.6874	0.6874	0.6795
	1000.00	0.7273	0.7278	0.7424	0.7278	0.7335	0.7347	0.7246
	1000.40	0.5753	0.5756	0.5829	0.5756	0.5785	0.5767	0.5713
	1001.15	0.6044	0.6044	0.5411	0.6044	0.6044	0.6044	0.6027
	1001.70	0.6240	0.6193	0.6764	0.6174	0.6255	0.6261	0.6160
	1004.10	0.7320	0.7452	0.8026	0.7290	0.7348	0.7356	0.7256
	1004.50	0.6840	0.6840	0.6685	0.6840	0.6840	0.6840	0.6853
	1005.80	0.8510	0.8639	0.7936	0.8838	0.8897	0.8950	0.9652
	1006.80	0.8573	0.8618	0.7999	0.8679	0.8687	0.8744	0.9535
	1008.00	0.8317	0.8317	0.8196	0.8353	0.8357	0.8376	0.9142
	1009.30	0.7993	0.7993	0.7941	0.7993	0.7993	0.7993	0.8460
	1015.10	1.1776	1.1776	1.1739	1.1776	1.1776	1.1776	1.1740
	1024.40	0.9798	0.9798	0.9853	0.9798	0.9798	0.9798	0.9760
Murray-Over (Bama Forest & East of Railway)	100.00	0.0082	0.0082	0.0094	0.0082	0.0082	0.0349	0.1812
	101.80	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012	0.1728
	103.10	0.4074	0.5697	0.4072	0.6007	0.5870	0.5182	0.4074
	104.65	0.4190	0.4190	0.4286	0.4190	0.4190	0.4190	0.4192
	106.35	0.1522	0.1730	0.1337	0.1722	0.1808	0.1911	0.1995
	107.65	0.2757	0.2757	0.2757	0.2757	0.2757	0.2757	0.2757
	109.75	0.0966	0.1154	0.0932	0.1110	0.1180	0.1250	0.1326
	112.45	0.1277	0.1620	0.1362	0.1543	0.1659	0.1777	0.1853
	114.75	1.0301	1.1279	1.0731	1.1238	1.1242	1.1507	1.0328
	116.15	0.2658	0.2696	0.2500	0.2716	0.2733	0.2783	0.3285
	117.75	0.0631	0.0697	0.0187	0.0733	0.0782	0.0803	0.1125
	119.25	0.1891	0.1950	0.0555	0.2730	0.2068	0.2759	0.4305
	121.00	0.0373	0.0471	0.0113	0.0498	0.0548	0.1070	0.1128
	121.40	0.2671	0.2671	0.2675	0.2671	0.2671	0.2671	0.2680
	122.40	0.0205	0.0205	0.0206	0.0205	0.0480	0.1036	0.1194
Moama (West of Railway)	100.00	0.0168	0.0277	0.0249	0.0288	0.0305	0.0324	0.0407
	100.75	0.0369	0.0399	0.0298	0.0423	0.0438	0.0472	0.0550
	101.60	0.2265	0.2260	0.2255	0.2200	0.2015	0.2256	0.2035
	102.30	0.0693	0.0819	0.0461	0.0833	0.0861	0.0869	0.0774
	103.15	0.0619	0.0681	0.0354	0.0662	0.0684	0.0657	0.0605
	104.00	0.0853	0.0836	0.0467	0.0668	0.0913	0.0786	0.0566
	104.85	0.1044	0.1012	0.0870	0.0432	0.0444	0.0429	0.1178
	105.00	0.1767	0.2219	0.1312	0.0493	0.0509	0.0496	0.1179
	106.30	0.0236	0.0279	0.0303	0.0303	0.0322	0.0334	0.1218
	106.70	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0399
	107.30	0.0162	0.0162	0.0185	0.0162	0.0162	0.0171	0.0674

Appendix B - Flood Damages

Topographical Information

Figure B.1

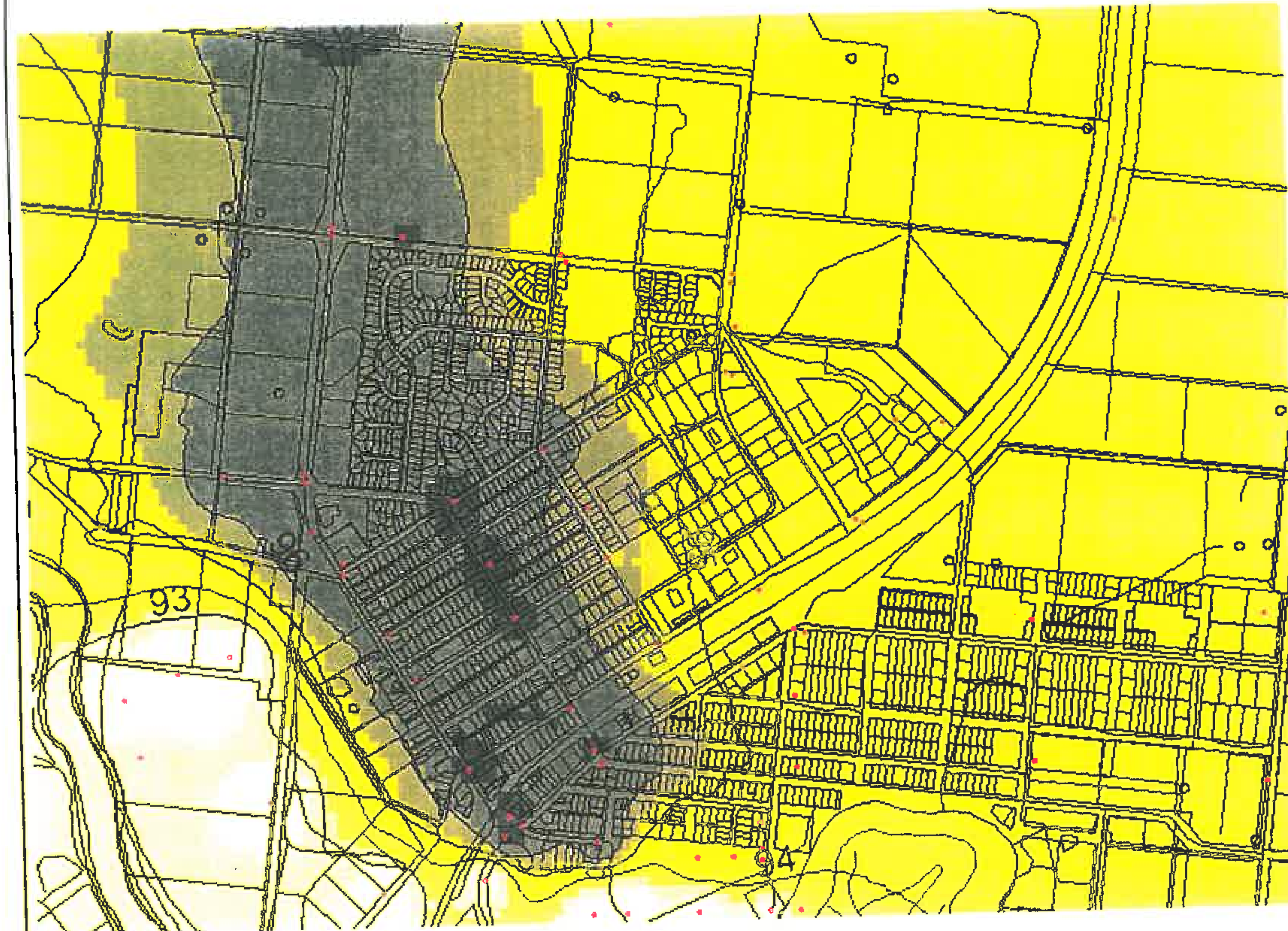
Property Locations

SINCLAIR KNIGHT MERZ

Sinclair Knight Merz Pty Ltd
A.C.N 001 024 095
590 Orrong Road Armadale
Vic. 3143 Australia
Telephone (03) 9248 3100
Facsimile (03) 9248 3364
Job No EN03574

Figure B.2

Interpolated Digital Elevation Model



Legend:

Benchmarks

1m Contours

Cadastre

Elevation

91.10 - 91.80
91.80 - 92.50
92.50 - 93.20
93.20 - 93.90
93.90 - 94.60
94.60 - 95.30
95.30 - 96.00
96.00 - 96.70
96.70 - 97.40

SINCLAIR KNIGHT MERZ

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Existing Conditions

Table B.1 Affected properties

Moama Flood Plain Management Study

No. Affected Properties

Existing Conditions

Affected Properties	Above Floor Flooded						External Flooded						Total Flooded					
	10%	5%	2%	1%	0.50%	Pmf	10%	5%	2%	1%	0.50%	Pmf	10%	5%	2%	1%	0.50%	Pmf
Residential	3	3	94	175	256	875	0	15	132	116	108	194	3	18	226	291	364	1069
Industrial	-	-	55	59	66	77	-	-	4	7	0	0	-	-	59	66	66	77
Commercial	-	-	-	-	-	20	-	-	-	-	-	7	-	-	-	-	-	27
Total	*3*	*3*	*149*	*234*	*322*	*972*	*0*	*15*	*136*	*123*	*108*	*201*	*3*	*18*	*285*	*357*	*430*	*1173*

Table B.2 Potential Damages

Moama Flood Plain Management Study

Estimated Potential Damages ($ million)

Existing Conditions

Potential Damages	Direct Damages						Indirect Damages						Total Damages					
	10%	5%	2%	1%	0.50%	Pmf	10%	5%	2%	1%	0.50%	Pmf	10%	5%	2%	1%	0.50%	Pmf
Residential	0.070	0.090	1.092	2.317	4.112	15.906	0.010	0.014	0.164	0.348	0.617	2.386	0.080	0.104	1.256	2.665	4.728	18.292
Industrial	-	-	0.835	1.485	2.251	4.307	-	-	0.584	1.040	1.576	3.015	-	-	1.419	2.525	3.827	7.323
Commercial	-	-	-	-	-	0.236	-	-	-	-	-	0.130	-	-	-	-	-	0.366
Total	*0.070*	*0.090*	*1.927*	*3.802*	*6.363*	*20.450*	*0.010*	*0.014*	*0.748*	*1.387*	*2.193*	*5.531*	*0.080*	*0.104*	*2.676*	*5.190*	*8.556*	*25.981*

Notes:
1. CPI Index for Internal Damages (Above Floor Flooding) set to 12%
2. Indirect Damages for "Residential" properties set to 15% of Direct Damages
3. Indirect Damages for "Commercial" properties set to 55% of Direct Damages
4. Indirect Damages for "Industrial" properties set to 70% of Direct Damages

Figure B.3
1% Flood
Affected
Properties

Table B.3 Summary Results

Moama Flood Plain Management Study

Summary Table for the Existing Conditions

Property Type	Total No. Affected Properties						Total Damages					
	10%	*5%*	*2%*	*1%*	*0.50%*	*Pmf*	*10%*	*5%*	*2%*	*1%*	*0.50%*	*Pmf*
Residential	3	18	226	291	364	1069	0.080	0.104	1.256	2.665	4.728	18.292
Industrial	-	-	59	66	66	77	-	-	1.419	2.525	3.827	7.323
Commercial	-	-	-	-	-	27	-	-	-	-	-	0.366
Total	*3*	*18*	*285*	*357*	*430*	*1173*	*0.080*	*0.104*	*2.676*	*5.190*	*8.556*	*25.981*

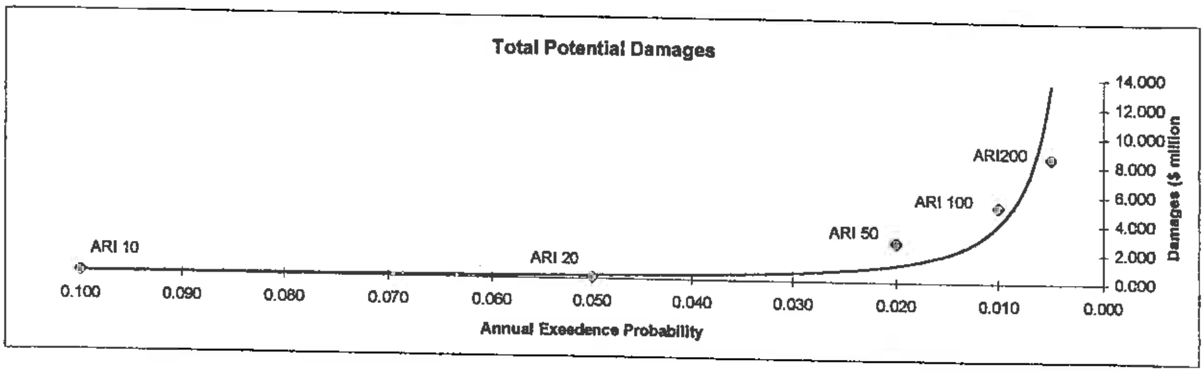
Table B.4 Average Annual Damages

Potential Damages for various Return Period

Existing Conditions

ARI (Years)	AEP	Damages ($ million)	Incremental ($M/year)	Accumulated ($M/year)
5	0.200	0.000	0.0000	0.0000
10	0.100	0.080	0.0040	0.0040
20	0.050	0.104	0.0046	0.0086
50	0.020	2.676	0.0417	0.0503
100	0.010	5.190	0.0393	0.0896
200	0.005	8.556	0.0344	0.1240

Average Annual Damage to AEP 1% estimated to: $0.090 ($M/year)



Levee Option

Table B.5 Affected properties
No. Affected Properties

Mitigation Option

Above Floor Flooded				External Flooded					Total Flooded				
5%	2%	1%	0.50%	10%	5%	2%	1%	0.50%	10%	5%	2%	1%	0.50%
3	13	18	20	0	9	5	2	0	3	12	18	20	20
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*13*	*18*	*20*	*0*	*9*	*5*	*2*	*0*	*3*	*12*	*18*	*20*	*20*

Table B.6 Potential Damages
Estimated Potential Damages ($ million)

Mitigation Option

Direct Damages					Indirect Damages					Total Damages				
10%	5%	2%	1%	0.50%	10%	5%	2%	1%	0.50%	10%	5%	2%	1%	0.50%
0.070	0.086	0.179	0.279	0.375	0.010	0.013	0.027	0.042	0.056	0.080	0.099	0.206	0.321	0.431
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.070	*0.086*	*0.179*	*0.279*	*0.375*	*0.010*	*0.013*	*0.027*	*0.042*	*0.056*	*0.080*	*0.099*	*0.206*	*0.321*	*0.431*

Internal Damages (Above Floor Flooding) set to 12%
ges for "Residential" properties set to 15% of Direct Damages
ges for "Commercial" properties set to 55% of Direct Damages
ges for "Industrial" properties set to 70% of Direct Damages

Figure 8.4

1% Flood Affected Properties with Levee Option

Table B.7 Summary Results

Summary Table for the Mitigation Option

Property Type	Total No. Affected Properties					Total Damages				
	10%	5%	2%	1%	0.50%	*10%*	5%	2%	1%	0.50%
Residential	3	12	18	20	20	0.080	0.099	0.206	0.321	0.431
Industrial	-	-	-	-	-	-	-	-	-	-
Commercial	-	-	-	-	-	-	-	-	-	-
Total	***3***	***12***	***18***	***20***	***20***	***0.080***	***0.099***	***0.206***	***0.321***	***0.431***

Table B.8 Average Annual Damages

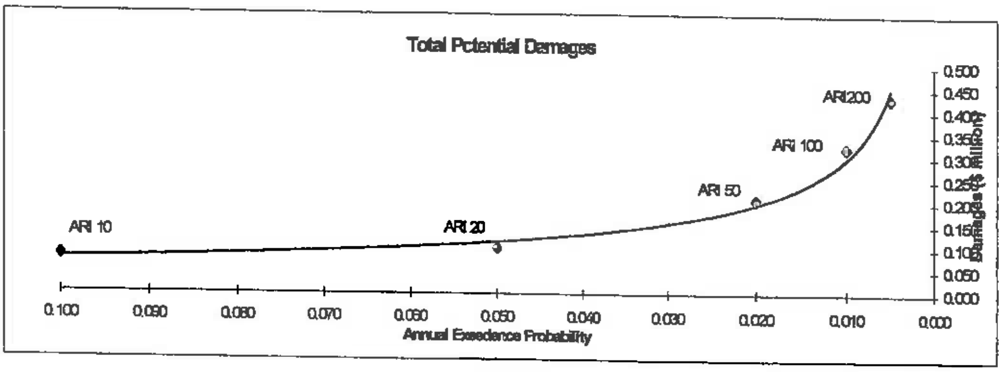
Moama Flood Plain Management Study

Potential Damages for various Return Period

Mitigation Option

ARI (Years)	AEP	Damages ($ million)	Incremental ($M/year)	Accumulated ($M/year)
5	0.200	0.000	0.0000	0.0000
10	0.100	0.080	0.0040	0.0040
20	0.050	0.099	0.0045	0.0085
50	0.020	0.206	0.0046	0.0131
100	0.010	0.321	0.0026	0.0157
200	0.005	0.431	0.0019	0.0176

Average Annual Damage to AEP 1% estimated to: 0.0157 ($M/year)



Appendix C - Cost Estimation

Levee Construction

Earth embankment. Cross-section with 3 m crest and 2.5 : 1 and 3.5 : 1 batters on water and land sides, respectively.

[illegible]	Quantity	Rate	Cost
Site establishment	sum		$5,000
Geotechnical investigation	sum		$3,000
Stripping & spoil stockpile	8 000 m^3	$1.10	$8,800
Placing, carting from within 5 km, compaction	84 000 m^3	$10	$840,000
Top soiling	6,200 m^3	$2.00	$12,400
Site clearance	4.6 ha	$900	$4,140
	Sub-total		$873,340
Contingencies		20%	$174,660
	Total		$1,048,000

Flood Wall

Concrete structure, 0.25 m thick. 50% allowance for footings.

Length (m)	Estimated average height (m)	Rate	Cost
67	2.3	$950	$63,650
25	1.8	$700	$17,500
138	0.8	$300	$41,400
		Sub-total	$122,550
		20% contingency	$24,500
230 m total			$147,050

Railway Culvert

Item	Quantity	Rate	Cost
Establishment / disestablishment	sum		$8,000
Excavation of railway embankment	sum		$2,025
Temporary support of rail track	sum		$8,150
Supply & installation of drainage (11 no. 1800x1500 RC box culverts M270 standard)	9.6 m	$13,650	$131,040
Concrete base for culvert (250mm thick)	56 m³	$1,500	$84,000
Concrete aprons RC	30 m³	$650	$19,500
End structures RC	3 m³	$1,200	$3,600
End structures - other	9.2 m³	$650	$5,980
Backfill to culvert	85 m³	$125	$10,625
Reinstate rail track & ballast	sum		$13,150
Control of rail traffic	sum		$5,000
Sub-total			$291,070
Survey		@ 1%	$2,900
Engineering design / project management		@ 7%	$20,370
Contingencies		@ 20%	$58,200
Total			$372,540

Voluntary Acquisition of Property and Easement Rights

Type / Location of Acquisitions	Valuation
Easements for levee alignment	$ 5,000
Land purchases for levee alignment	$ 59,500
Land purchases in Moama East (floodway, railway to Charter Street)	$ 255,000
Land purchases in other 'B' area (main floodway)	$ 156,500
Total:	$ 476,000

Appendix D - Environmental Planning and Assessment

The environmental impact of the proposed floodplain management option is assessed in terms of Clause 82 of the NSW Environmental Planning and Assessment Regulation 1994.

(a) Any Environmental Impact on a Community

Construction of the preferred option would have short and long term effects on the community. Short-term effects would arise during the construction of the proposed levee. These effects would be primarily related to noise and dust by the construction activities and transport of fill material from off-site.

These impacts could be mitigated by:

- Restricting hours of work to comply with the guidelines of the NSW Environment Protection Authority (EPA) Environmental Noise Control Manual. Accordingly, hours of work should be restricted to 7.00 am to 6.00pm Monday to Friday and 8.00 am to 1.00 pm Saturday with no work permitted on Sunday or Public Holidays. These hours could be varied with the consent of local residents and Murray Shire Council.
- Requiring all plant and equipment to be fitted with approved silencers and maintained to manufacturers' specifications.
- Requiring adequate dust control. Monitors should be established to determine the background dust levels and volumes of dust generated during construction. Dust control could be achieved by:
  - the use of water or other suppressant during construction,
  - requiring loads with potential for dust generation to be covered,
  - requiring vehicle wheels to be cleaned of mud or dust before travelling on public roads.

Longer term impact would arise from the reduction of flood impacts on the community within the area protected by the levee banks. The reduction of flooding frequency and duration is an objective of the activity and would be regarded as a positive impact.

(b) Any Transformation of a Locality.

Moama is the fastest-growing urban centre in NSW west of the Blue Mountains. Adoption of the Floodplain Management Plan by Murray Shire Council and construction of the levee bank would enable Council to manage development within the ecologically sensitive areas of the floodplain in accordance with the Principles of Ecologically Sustainable Development. The locality would not be subject to any transformation, and development within ecologically sensitive areas would be discouraged.

(c) Any Environmental Impact on the Ecosystems of the Locality

The most sensitive and significant ecosystems of the locality are floodplain and related communities. Other important ecosystems are associated with relatively undisturbed vegetation communities on roadside reserves.

The proposed levee bank would be located so as to minimise the extent of clearing required and, accordingly, the impact on ecosystems of the locality. Generally the proposed location would avoid the need for any clearing of floodplain or roadside vegetation. The only exception is the section parallel to, and south of, Simms Street where it would adjoin the Horseshoe Lagoon Centennial Park.

Impacts on the ecosystems could be mitigated by:

- Clear delineation of the limits of disturbance for clearing and access for construction plant and equipment. The clearing limits should be clearly marked in the field prior to commencement of disturbance.
- Avoidance of hollow-bearing trees. The clearing and levee construction should be managed as far as possible to avoid the necessity to clear any hollow-bearing trees. If any hollow-bearing trees are to be cleared, they should be inspected prior to clearing by a suitably qualified ecologist to determine if any fauna are present. If fauna are present, they should be provided with an opportunity to depart prior to clearing. If they do not depart a representative or WIRES or other fauna carer group should be present during clearing to rescue any injured fauna. If any hollows are destroyed by the activity they should be replaced by the erection of artificial nesting / breeding boxes on appropriately sized trees adjacent to cleared area. In addition, hollows may be salvaged from felled trees and attached to nearby suitable trees.
- Location of vehicle and plant parking areas in already cleared areas.
- Avoidance of vehicle refuelling and maintenance except within designated, bunded areas.
- Location of site offices outside ecologically sensitive areas.
- Obligation on the part of the Contractor to develop an acceptable Environmental Management Plan (EMP) for the project construction phase. The EMP should include details of measures to avoid impacts on sensitive ecosystems. It should also include provision for environmental induction of staff and sub-contractors prior to commencement of site works.

(d) Any Reduction of the Aesthetic, Recreational, Scientific or Other Environmental Quality or Value of a Locality.

The study area contains a number of locations which are valuable for aesthetic, recreational, scientific and environmental purposes. The Murray River represents a focus for a variety of recreational pursuits including fishing, swimming, boating and water skiing. There are a number of camping areas and caravan parks in the district which depend on visitors to the Murray for on-going financial viability.

(e) Any Effect on a Locality, Place or Building Having Aesthetic, Anthropological, Architectural, Cultural. Historical, Scientific or Social Significance or other Special Value for Present or Future Generations.

The proposal is substantially restricted to land which is already cleared, and does not involve the demolition of any buildings or structures. It would therefore have no impacts on places or localities or significance. The proposed alignment has been inspected with a qualified sites officer from the Yorta Yorta Local Aboriginal Land Council to check for the presence of scar trees or other items of potential importance for the local aboriginal community. None were identified.

(f) Any Impact on the Habitat of Threatened Species within the Meaning of the Threatened Species Conservation Act 1995

The proposed location of the levee bank would avoid any areas with potential habitat for significant impact on threatened species, their habitat, populations or ecological communities. The proposed levee would be largely located on previously cleared land with no potential as habitat for threatened species. The only section with any potential for impacts on threatened species is the section adjoining the southern side of Moama township.

A number of threatened species of birds, which occupy similar habitat to this section of the study area, have been recorded from the region.

They include:

- *Lophoictinia isura* (Square-tailed kite)
- *Falco hypoleucos* (Grey Falcon)
- *Burhinus magnirostris* (Bush Stone-curlew)
- *Polytelis swainsonii* (Superb Parrot)
- *Lathamus discolor* (Swift Parrot)
- *Ninox connivens* (Barking Owl)
- *Xanthomyza phrygia* (Regent Honeyeater)
- *Grantiella picta* (Painted Honeyeater)

Square-Tailed Kite Habitat range includes all of mainland Australia with the exception of the arid interior where it may occur under good seasonal conditions. It is seldom seen in flocks and constructs bulky loose nets in high trees. It inhabits riverine forests and well-wooded areas near open country. Its diet includes a wide variety of insects and small animals particularly bird nestlings. It is classified as vulnerable under Schedule 2 of the Threatened Species Conservation (TSC) Act 1975.

Grey Falcon Its habitat range includes all of inland mainland Australia, particularly the arid and semi-arid interior. It occupies open scrub and tree lined water courses It nests in the structures of other hawks and corvids and feeds mainly on other bird species. It is classified as vulnerable under Schedule 2 of the TSC Act 1975.

Bush-stone Curlew Its habitat range includes all the Australian mainland with the exception of interior desert areas and coastal NSW. It also occurs in the coastal areas of northern Tasmania. It occupies open woodland, forest edges and along inland watercourses. It is uncommon in the southern parts of its range. Its diet comprises insects, spiders and fruits. It nests in a scrape in the ground. It is classified as endangered under Schedule 1 of the TSC Act 1975.

Superb Parrot Its habitat range is limited to an area of central NSW between the Namoi - Castlereagh River systems in the north and the Lachlan - Murray River systems in the south. Its range is one of the most restricted of any of any Australian parrot. It generally occurs in pairs or small flocks usually not far from water often foraging for seeds sometimes along roadsides. Its diet consists of cultivated grain crops, spilt grain and nectar from flowering eucalypts. It nests very high in tree hollows. It is classified as vulnerable under Schedule 2 of the TSC Act 1975.

Swift Parrot Its habitat range includes all of Tasmania and Victoria, south-east South Australia and the coasts and ranges of eastern NSW and Queensland to the Tropic of Capricorn. It often flies with lorikeets and its diet consists of nectar, berries, fruit, insects and lerp-scale amid the topmost foliage of trees. It nests in tree hollows. It is classified as vulnerable under Schedule 2 of the TSC Act 1975.

Barking Owl Its habitat range extends over most of the eastern States of mainland Australia, the northern parts of the Northern Territory, coastal Western Australia and eastern South Australia. It is absent from Tasmania. It occupies open forest and woodland. Its diet consists of mammals, birds and insects. Pairs and family parties utilise established roosting trees. It nests in tree hollows up to 30 m high. It is classified as vulnerable under Schedule 2 of the TSC Act 1975.

Regent Honeyeater Its habitat range includes the coasts, ranges and slopes of southern and eastern mainland Australia from Spencers Gulf to the Tropic of Capricorn. It is a nomadic species which may suddenly occur wherever suitable food supplies are available. It occupies woodland and open forests and its diet consists of the nectar of eucalypts, angophoras and banksias, insects and native fruits. It nests in tree forks up to 10 m high. It is classified as endangered under Schedule 1 of the TSC Act 1975.

Painted Honeyeater Its habitat range is similar to the Regent Honeyeater although it generally does not occur in coastal areas and its range extends further into the arid and semi-arid areas of Victoria and NSW and into tropical inland Queensland and the Gulf of Carpentaria. It is nomadic and occupies woodland and open forest. Its diet consists of mistletoe berries, nectar and occasionally insects. It constructs net-like nests in tree from 3 to 20 m high. It is classified as vulnerable under Schedule 2 of the TSC Act 1975.

The impact of the proposal on the habitat of any of these species would not be significant. Any impacts would be minimised by the following:

- Clearly delineating clearing areas in the field and prohibiting vehicle access and stockpile siting within uncleared areas.
- Locating the levee bank in previously cleared areas as far as possible.
- Restricting clearing to immature trees without hollows.
- If removal of hollow bearing trees is unavoidable conduct surveys to establish the occupancy status of hollows and only remove trees when the hollows are not occupied.
- If removal of trees with occupied hollows is unavoidable, ensure that a representative of a fauna care group such as WIRES is present during the operation.

(g) Any Endangering of Any Species of Animal, Plant or Other Life Form, Whether Living on Land, in Water or in the Air.

As discussed in (f) above, a number of species of threatened fauna are known to occur in the region in habitat similar to the study area. It is therefore possible that some or all of these species may be present in the study area from time to time. Accordingly, the proposed levee would be located and constructed in accordance with the Precautionary Principle - Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The Principle would be applied by implementing the mitigation measures outlined in (f) above.

Implementation of the Precautionary Principle would ensure that there would not be any endangering of any species of animal or plant or other life form.

(h) Any Long Term Effects on the Environment

The project would reduce the frequency, duration and extent of flooding within the built-up area of Moama located inside the levee bank. This would provide a rational basis for the future development of the Moama urban area. The area which would be protected by the proposed levee has been substantially disturbed over more than 100 years by progressive residential, industrial, recreational and commercial development. The proposed levee would not have any further adverse long-term effects on the environment within this area. The levee would also constrain and focus long-term residential, commercial and industrial development of Moama and therefore reduce the potential for further undesirable flood plain development.

The levee would not have any adverse long term effects on the floodplain within the study area. The floodplain ecosystems are adapted to periodic winter / spring inundation. The proposal would not effect the seasonality of flood events or result in significant changes in flood duration and extent.

The environmental impacts of the construction phase of the project would be limited to the duration of construction. Adequate mitigation measures would be implemented to ensure that construction impacts were limited as far as feasible. The proposed mitigation measures are outlined in (a).(b), (c) and (f).

(I) Any Degradation of the Quality of the Environment

The proposal would not result in any degradation of the existing quality of the environment of the study area. As discussed, construction impacts would be short term and would be mitigated to acceptable levels.

In the longer term, the floodplain management plan would provide the basis for future land-use planning decisions and development approvals by Murray Shire Council which are consist with maintaining the quality of the environment.

These decisions would recognise the environmental and recreational values of the floodplain and undesirable development would be restrained accordingly. They would also recognise the desirability of constraining future residential, commercial and industrial development of Moama to focus on flood-free areas. This would further constrain undesirable development on the floodplain.

(j) Any Risk to the Safety of the Environment

Construction of the proposal would not involve the use of any chemicals or hazardous materials. Servicing and refuelling of vehicles would only be permitted within designated areas. Appropriate dust and erosion control measures would be implemented and the contractor would be required to develop and implement an acceptable environmental management plan. Accordingly, the proposal does not present any risk to the safety of the environment.

(k) Any Reduction in the Range of Beneficial Uses of the Environment

The environment of the study area provides a range of beneficial uses for humans and wildlife. Previous inappropriate development for human uses has reduced the range of beneficial uses for wildlife and also some of the values which are important for human use of the area.

Existing beneficial uses of the environment for humans include recreation and tourism, grazing, agriculture and forestry and residential, commercial and industrial development. The proposal would not prevent continuation of these uses.

The proposal would also ensure that land use and development decisions relating to ecologically sensitive areas on the floodplain and elsewhere would not be inappropriate for the range of wildlife values of the study area.

The range of mitigation measures outlined for the construction phase of the proposal would ensure that the range of beneficial uses of the environment was not compromised during construction.

(l) Any Pollution of the Environment

Pollution of the environment could occur as a result of excess noise, reductions in air quality or pollution of adjoining water courses. As previously outlined, a number of mitigation measures would be implemented during construction to ensure that pollution of the environment did not occur.

The range of measures would include:

- Restrictions on working hours.
- Requirement for mufflers to be fitted to plant and equipment and maintained in accordance with manufacturer's specifications.
- Dust suppression with water or other appropriate measure.
- Removal of dust / dirt from truck wheels prior to travel on public roads.
- Requirement for loads which could generate dust to be covered.
- Requirement for plant / vehicle refuelling to be carried out in designated areas.

Additional measures which would be implemented to establish and maintain sediment control and reduce the likelihood of water pollution include:

- Erection of hay bales around any stormwater inlets which are within the catchment of the works area prior to construction commencing.
- Erection of sediment control fences on downslope side of working areas adjacent to defined watercourses.
- Location of stockpile sites away from watercourses or stormwater drains.
- Regular inspection of the mitigation works to ensure that they are appropriately maintained.
- Inclusion of requirements for pollution control in the environmental induction course for site workers.

In addition, the contractor's environmental management plan would be required to provide full details of location and responsibilities for pollution control and requirements for regular inspection and monitoring.

As a consequence of implementation of these measures there is unlikely to be any risk of measurable pollution of the environment.

(m) Any Problems Associated with the Disposal of Waste

Waste generated by the project would include the following:

- trees and other vegetation cleared during the course of construction,
- domestic waste from site office and crib rooms,
- tyres and oil and greases from plant and machinery maintenance,
- packaging and cardboard / paper wastes from the site office.

It is not anticipated that the proposal would present any problems with disposal of waste. The following measures would be adopted for waste management:

- Inclusion of a waste management action plan in the contractor's EMP.
- Storage of domestic in covered bins approved by Murray Shire Council and disposed to the Council waste collection service.
- Disposal of recyclable materials of to an approved recycler.
- Disposal of oils, greases, tyres and other industrial to approved recyclers or to an industrial collection service.

Trees and waste vegetation material would be disposed of according to the following:

- Where possible the material would be sold to commercial timber interests.
- As much of the remaining timber as possible should be utilised as firewood.
- Any remaining material should be chipped and used as mulch for landscaping of the levee.
- As a last resort any remaining material may be burnt. Any burning would be carried out in accordance with the requirements of Murray Shire Council and the Environment Protection Authority.

(n) *Any Increased Demands on Resources That Are, or Are Likely to Become, in Short Supply*

Construction of the levee would require the consumption of the following resources:

- electricity,
- fuel, oils, greases and other petroleum products,
- paper, cardboard and stationery items,
- fill material for the levee,
- water.

None of these items are currently in short supply nor are they likely to become so in the near future. Fill material would be sourced from an approved existing quarry. There is no shortage of appropriate material in the district.

(o) *Any Cumulative Environmental Effect with Other Existing or Likely Future Activities*

The proposal would affect future development within the study area. Implementation of the proposal would provide Murray Shire Council with the tools to improve land use decision-making and consent for development proposals in accordance with the Principles of Ecologically Sustainable Development. In particular it would:

- Implement the precautionary principle by locating the levee bank mainly within previously cleared land and minimising disturbance to timbered areas. Where disturbance to timbered areas is unavoidable, specific measures are proposed to mitigate potential adverse impacts.
- Conserve biological diversity and preserve ecological integrity. This would be achieved by:
  - implementing the measures outlined for implementation of the precautionary principle;
  - providing Murray Shire Council with the tools to prevent inappropriate development on the floodplain which would adversely affect biological diversity.
- Assist the achievement of inter-generational equity by controlling future development so that the health, diversity and productivity of the existing environment is maintained for future generations.