LOWER MACLEAY
FLOODPLAIN MANAGEMENT STUDY

FEBRUARY, 1997

WEBB, McKEOWN & ASSOCIATES PTY. LTD.
CONSULTING ENGINEERS
KEMPSEY SHIRE COUNCIL

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FLOODPLAIN MANAGEMENT STUDY

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FOREWORD

The State Government’s Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1. *Flood Study*  
   - determine the nature and extent of the flood problem.

2. *Floodplain Management Study*  
   - evaluates management options for the floodplain in respect of both existing and proposed development.

3. *Floodplain Management Plan*  
   - involves formal adoption by Council of a plan of management for the floodplain.

4. *Implementation of the Plan*  
   - construction of flood mitigation works to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

A flood study was previously completed for the Macleay River. This was based on technology and data available at that time. This present study has reviewed the flood study using currently available data and up-to-date technology. This has ensured that it is a suitable tool for examining options in the floodplain management study which forms the main part of this report.
1. INTRODUCTION

The Macleay catchment covers some 11,500 km² (Figure 1). The main tributaries including the Aspley, Muddy and Chandler Rivers rise in the Great Dividing Range and flow across the New England Tableland before falling into rugged gorge country. The Macleay itself emerges from the gorges some 35 km upstream of Kempsey. Below Kempsey the river meanders through a wide expanse of low lying floodplain (Figure 2), which is subject to frequent and persistent flooding.

While the Macleay River is the dominant watercourse on the floodplain, significant tributaries are Christmas and Clybucca Creeks to the north and the Belmore River and Kinchela Creek to the south. The Macleay enters the ocean through a trained entrance at South West Rocks which was first breached during the flood of 1893. Previously the river entrance was at Grassy Head. The old channel between Grassy Head and South West Rocks has now become a complex backwater.

There are no dominant topographical features on the floodplain. The highest points east of Kempsey are the rocky headlands at Grassy Head, Smoky Cape, Hat Head and Crescent Head. These are linked by relatively high sand dunes which more or less confine the floodplain but are subject to breakouts during large floods.

The highest points in the floodplain itself are the levees adjoining the major watercourses. These levees were produced naturally but have been selectively raised as part of flood mitigation works over the past forty years.

Settlement on the floodplain consists of numerous farms and several small villages. The farms were originally principally used for dairying, but most have now moved to beef production. The major floodplain village, Smithtown, still supports an operating dairy factory while the village of Jerseyville is a centre of the local fishing industry. Other villages are Gladstone and Kinchela while parts of Frederickton are also flood liable.

During major events, floodwaters drain to the ocean via a number of routes in addition to the river entrance itself. Significant outflows occur at Korogoro Creek, Ryans Cut, Killick Creek and South West Rocks Creek. Water can also flow either into or from the Hastings catchment to the south via Connection Creek. In the major flood of 1949, other breakouts were reported at various points between Crescent Head and Grassy Head.

Significant flood mitigation works, including levees, drains and control structures, have been constructed over the last 30 years in an attempt to reduce the flooding problem. Though most of these works have fulfilled their design intentions some have not met with universal approval due to unforeseen adverse effects.

The report which follows examines the floodplain in its present state and presents options to improve the future performance of the area during and after flooding and in non flood periods. The report includes a review of the present mitigation scheme and an assessment of modifications.
or additions which might make it more effective or reduce adverse impacts. Many of the options presented were put forward at a series of public meetings, which produced a wide range of suggestions to reduce flood impacts in the valley or remedy perceived shortcomings of present works or practices.

The study was conducted by Webb, McKeown & Associates under the auspices of the Macleay Floodplain Management Committee which was responsible for identifying potential mitigation measures.

The lower Macleay in general has been the subject of a number of previous flooding investigations and several studies are presently looking at specific areas of the floodplain. Chapter 2 summarises the reports of relevance.

The previous Flood Study of the lower Macleay was published in 1989 and used technology which has now been superseded. Accordingly the first task of the present study was to update the Flood Study work and review its findings. Chapter 3 discusses this aspect. Flood behaviour was determined using two computer based models which between them converted rainfalls (which are comparatively well documented) to flood levels. The models were calibrated and checked against historical records then used to determine "design flood" conditions with known probabilities of being exceeded in any given year.

The results from the review were used to help define the present flood problem in Chapter 4. This chapter also contains comment on post flood drainage and the major environmental problems associated with this.

Chapter 5 discusses potential mitigation options applicable to the rural villages and provides some economic detail on the construction of levees.

Chapter 6 covers mitigation and restoration options suggested for the rural areas. These options were largely generated from a series of area workshops and present views from a wide spectrum of interests.

Finally, Chapter 7 draws the various strands together to produce a series of recommendations which form the basis for improved flood and post flood performance in the floodplain. These recommendations were formulated from discussion within the Floodplain Management Committee.
2. PREVIOUS STUDIES

A number of previous studies have looked at flooding of the Lower Macleay and these have provided useful background information and data. The following reports were of particular relevance:

- Kempsey - Evaluation of Options for Flood Protection, April 1985 (Reference 1)
  
  This was prepared prior to the Flood Study (Reference 2). A mathematical model known as the CELLS model was set up and calibrated for the Macleay River between Aldavilla and Smithtown. The model was used to investigate four flood protection options for Kempsey.

- Macleay River Flood Study, April 1989 (Reference 2)
  
  This produced levels throughout the lower Macleay for floods of 5%, 2%, 1% AEP and an extreme event using the CELLS model. The study area consisted of the river and associated floodplains from Aldavilla to the ocean entrance near South West Rocks. Other ocean outlets were included in the modelling.

- Review of Kinchela Creek and Belmore River Floodway Capacities, November 1993 (Reference 3)
  
  During the Kinchela Creek Flood Channel investigation (References 4 & 5) it was discovered that the capacities of the Kinchela Floodways were less than had been understood. This prompted a review of the capacities of the three major floodways in the area: the Belmore Floodway and the Kinchela Eastern and Western Floodways.

  The study used a RUBICON model which was adapted from the CELLS model used in Reference 2.

- Kinchela Creek Flood Channel (Stages 1 & 2), July and October 1994 (References 4 & 5)
  
  This study investigated a proposal to construct a flood channel between the Eastern Floodway on Kinchela Creek and the headwaters of Korogoro Creek. The study was carried out in two stages.

  The Stage 1 report concluded that the proposal was hydraulically feasible, but that substantial engineering works would be required.

  The Stage 2 report concluded that the proposal was economically viable and worthy of further investigation. This report also looked at the possibility of opening the Belmore and Kinchela Floodways later than at present. It was found that this could be viable with some compensatory levee raising.
Hat Head Levee - Hydraulic Review, October 1994 (Reference 6)

This study produced 1% design flood levels and an indication of flood levels during an extreme event. The study was commissioned as a result of an investigation of the structural security of the levee (Reference 7).

A Supplementary report was issued in May 1996. This report revised the flood levels using the model developed in the Floodplain Management Study.
3. FLOOD STUDY REVIEW

3.1 General

The Macleay River Flood Study (Reference 2) established flood conditions (levels and velocities) with a given probability of occurring in any year and thus enabled identification of development at risk from flooding. The Flood Study produced "design" floods of 1%, 2% and 5% Annual Exceedance Probability (AEP) and an extreme event which approximated the Probable Maximum Flood (PMF).

Since the study was published there have been technological advances in the mathematical modelling of hydraulic behaviour. Because of this a new hydraulic model was used for this Floodplain Management Study. This necessitated a review of the Flood Study results.

3.2 Hydrologic Modelling

3.2.1 Choice of Model

The first phase in the modelling exercise was to convert rainfall data into estimates of streamflow. The model chosen had to be able to accept rainfall data that varied from place to place across the catchment as well as variability over time. The model also had to produce flows at nominated points within the catchment for input to the hydraulic model.

The Watershed Bounded Network Model (WBNM) (Reference 9) was used in the original Flood Study and is still considered to be state of the art. The same model was therefore used in the present study. For the sake of completeness the following two sections provide basic information on the use of WBNM. They repeat information given in the Flood Study. Figure 3 shows the adopted model layout.

3.2.2 Model Calibration

The Department of Land & Water Conservation (DLWC) gauging station at Turners Flat, upstream of Kempsey, was used as the principal reference point for model fitting. Four floods were used for calibration and the best fits to the observed flow hydrographs were obtained by using the following parameters.

---

1 Annual Exceedance Probability is the probability of a given flood being equalled or exceeded in any given year.
### 3.2.3 Model Design Parameters

Design rainfalls were entered into the adopted model to produce inflow hydrographs to the hydraulic model. The first step was to determine the duration of rainfall which produced the highest peak flow in the river for a flood of given AEP. This is called the critical duration, and was determined by running the model with 1% rainfalls for a series of durations. The critical duration was found to be 48 hours.

The design parameters for WBNM, based on the results of the calibrations, were adopted as:

- $C = 1.22$
- Initial Loss = 0mm
- Continuing Loss = 2mm/h

Rainfall depths were allocated to the sub-catchments in the model using isohyetal patterns drawn from the design rainfall depths. These isohyets are presented in Reference 2.

### 3.2.4 Model Refinement

As part of the present study the WBNM sub-catchment layout was refined for the catchment downstream of Aldavilla, see Figure 3. This area corresponds to the general extent of the hydraulic model.

The refined model was used to produce 28 separate inflow hydrographs for the hydraulic model. These hydrographs were provided on all significant tributaries entering the study area and at several locations on the floodplain.

The design rainfall depths for this redefined area were derived from the design 48 hour isohyetal patterns used in the Flood Study.
3.3 Hydraulic Modelling

3.3.1 Introduction

The studies carried out in the 1980’s used a computer based model known as CELLS. This model is now obsolete, and a model representing current technology was developed for the Flood Study review and subsequent Floodplain Management Study. This model had to be capable of replicating historical flood performance, as well as accommodating the detailed changes required for flood mitigation options and providing a good approximation for evaluating post flood drainage performance.

The model chosen for the task was HD-System RUBICON (Reference 10). This is a fully dynamic, pseudo two-dimensional computer based model which represents the river and floodplain as a series of branches joined together by nodes.

3.3.2 The RUBICON Model

HD-system RUBICON was developed by Haskoning BV and Delft Engineering Software in the Netherlands. It can be used for studying a wide range of hydraulic engineering problems, such as:

- flood wave propagation through channels, rivers, floodplains and reservoirs,
- tidal flow in rivers and estuaries,
- determining the effects of structures in channel systems,
- sediment movement in rivers and estuaries,
- optimum design and operation of irrigation and drainage systems,
- entrance breakout through an erodible beach berm,
- wave propagation in hydropower systems,
- wave propagation resulting from dam failures,
- hydraulic parameters in water quality studies.

Modelling is based on the full de Saint-Venant equations solved with a highly accurate and efficient modification of Preissmann’s implicit finite difference scheme. It is very flexible in specifying external and internal boundary conditions. The user can select from a number of system elements to simulate complex flow over floodplains or define structures at any point of the channel system, such as weirs, gates, culverts, siphons, spillways, sluices, storm surge barriers, levees, etc.

Limitations are the accurate simulation of super-critical channel flow and two-dimensional flow situations where the convective momentum terms play a significant role. Neither of these situations is of importance in the Lower Macleay.
The following model elements are available:

- branches,
- nodes,
- gridpoints,
- cross-sections,
- structures,
- lateral flows.

**Branches** are used as schematised elements for:

- rivers,
- channels,
- estuaries,
- ocean entrances,
- connections between floodplain cells,
- closed conduits.

At the branch limits, **nodes** are included to provide for:

- free branch ends,
- branch connections,
- floodplain cells.

A single node can connect any number of branches. A boundary condition can be applied at a free branch as a function of:

- height,
- flow,
- critical outflow,
- or any user defined parameter.

**Gridpoints** are located along branches and have an associated **Cross-Section** which defines the topography. **Structures** can be defined at any place along a branch and basically provide a relationship between the discharge and upstream/downstream water levels. The definitions of structures are quite flexible and include culverts, free overflow structures, submerged structures, underflow structures or local loss structures. It is also possible to simulate complex gate opening/closing structures or pumps.

**Culverts** are modelled using the approach adopted by Boyd (Reference 11). Culverts are checked for outlet and inlet control and the lesser flow is adopted. **Weirs** are represented by a set of parameters for a formula and are generally represented as a series of horizontal steps with appropriate discharge coefficients.

**Inflows** are generally input at the upstream nodes as a flow versus time function. However **Lateral inflows** can also be included as a flow versus time function at any location along a branch. The downstream boundaries are a height versus time function representing the varying ocean level.
3.3.3 The Macleay Model

As previously stated, the Lower Macleay floodplain was modelled in the 1980's using the CELLS computer package. A CELLS model was initially set up covering the Macleay River between Aldavilla and Smithtown to investigate flood protection options for Kempsey (Reference 1). The model was then extended for the Flood Study (Reference 2) to include the river and associated floodplains from Aldavilla to the ocean near South West Rocks. Other ocean outlets were also included.

In the early 1990's a RUBICON model was developed for a number of studies in the Belmore/Kinchela area (References 3 to 6). Initially, the RUBICON model was adapted from the CELLS model used in the Flood Study. It was then further refined with each subsequent study.

The model layout adopted for the present study is shown on Figure 4. It consists of 186 branches and 120 nodes. There are more than 800 components (cross-sections, "weirs", storage areas and structures) representing the topography of the river channels and floodplain. The model covers the main river from Aldavilla to the ocean and all of the floodplain below Kempsey. The southern limit of the floodplain has been set at Crescent Head Road.

Much of the topographic information was transferred from the old CELLS model but this was complemented at various locations by more recent survey taken either specifically for this study or for other studies over the past few years. In particular, new survey covering Killick Creek, Christmas Creek and Spencers Creek was included in the model.

New survey was also obtained for some 2km of the left bank of the Macleay upstream of Jerseyville. The survey used here for the Flood Study had been taken along the road rather than the bank, which was subsequently found to be higher.

Numerous structures (floodgates, bridges, headworks) were included in the model which were not previously considered. These include:
- bridge under the Pacific Highway at Christmas Creek,
- headworks on Christmas Creek,
- floodgate on Killick Creek,
- bridges and culverts on Clybucca Creek,
- floodgate on Clybucca Creek,
- numerous culverts draining into the Macleay River, Belmore River and Kinchela Creek.

Connections to the ocean were included at the entrance, South West Rocks Creek, Rowes Cut, Korogoro Creek, Ryans Cut and Killick Creek. The Crescent Head Road at Connection Creek was modelled as a weir which allowed flow to the south.
The floodways on the Belmore River and Kinchela Creek were modelled by a special routine which simulated the opening and closing of the gates at set levels at Kempsey Traffic Bridge, or elsewhere if required.

The model is able to cover the full range of flood events from small, in bank freshes up to an extreme event approximating the PMF. It can also give a first approximation to post flood drainage behaviour.

It should be noted that the present study does not require precise modelling of Kempsey as there is already a Floodplain Management Study of the town. Because of this, the model has not been finely tuned in the Kempsey area. The level of precision is sufficient to provide satisfactory results in the study area but not sufficient to provide definitive answers in Kempsey itself.

3.3.4 Calibration

The May 1963 flood was used to calibrate the model which was then verified against the August 1949 and May 1980 floods. Rainfall, ocean tide and recorded flood level data for these events were taken from the previous studies.

WBNM was used to convert historical rainfall into inflow hydrographs for RUBICON. Manning's "n" and weir coefficients were then adjusted within acceptable ranges to match the recorded flood height data.

During the initial stages of calibration it was found that the modelled levels consistently plotted below recorded flood levels for both the 1963 and 1980 floods in the reach between approximately Seven Oaks Bend and Longreach Island. An investigation into the sources and datums of the observed levels revealed that they were based on Public Works gauge zeroes which had since been revised. The differences in the gauge zeroes at some key gauges are given in Table 1.

Table 1: Comparison of Gauge Zeroes

<table>
<thead>
<tr>
<th>Gauge Location</th>
<th>Old GS (m AHD)</th>
<th>New GS (m AHD)</th>
<th>Difference (m)</th>
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</thead>
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<tr>
<td>Frederickton</td>
<td>-0.536</td>
<td>-0.536</td>
<td>0</td>
</tr>
<tr>
<td>McCuddens (d/s Seven Oaks Bend)</td>
<td>+0.092</td>
<td>-0.040</td>
<td>-0.132</td>
</tr>
<tr>
<td>Gladstone Bridge</td>
<td>-0.353</td>
<td>-0.548</td>
<td>-0.195</td>
</tr>
<tr>
<td>Kinchela</td>
<td>-0.070</td>
<td>-0.410</td>
<td>-0.340</td>
</tr>
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</table>

In the light of this information, reported flood levels at these locations were adjusted downwards by the appropriate amount. Levels at points between those in the table were adjusted by a proportional amount. The modelled results, together with recorded data are shown on Figures 5 and 6. A reasonable fit was achieved.
The 1949 verification (Figure 7) was obtained by allowing substantial breakouts to the ocean, as was reported at the time. Two extra breakouts were modelled to the north of the main entrance while the breakouts at Rowes Cut, Ryans Cut and Killick Creek were widened compared to the present conditions. The major floodways and control structures were also removed from the model as they were constructed after 1949. The levees along the banks of the river and main tributaries were not removed because no information was available to allow any adjustments to be made. This helps explain why the modelled 1949 results are high between Smithtown and Frederickton.

The adopted Manning's 'n' values were 0.030 to 0.035 in the main channel of the Macleay River, 0.035 in the Be!more River and 0.035 in Kinchela Creek. Manning's 'n' in overbank areas was generally 0.040.

3.4 Design Floods

The 5%, 2%, 1% AEP and extreme events were required for the present study. In addition to design flow hydrographs, suitable ocean level hydrographs were required.

Since the Flood Study was published the DLWC has carried out further investigations on design ocean conditions and this has led to a revision of design levels. Table 2 shows the maximum levels used in the Flood Study and those now adopted as downstream boundary conditions in the hydraulic model.

### Table 2: Design Ocean Levels

<table>
<thead>
<tr>
<th>Event</th>
<th>Max. Ocean Level (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood Study</td>
</tr>
<tr>
<td>Extreme</td>
<td>2.6</td>
</tr>
<tr>
<td>1%</td>
<td>2.6</td>
</tr>
<tr>
<td>2%</td>
<td>2.4</td>
</tr>
<tr>
<td>5%</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Peak height profiles along the Macleay River for the design floods are shown on Figure 8. This figure presents an envelope of peak levels as derived by RUBICON. The river does not peak everywhere at the same time. Tidal influences are more dominant near the entrance and progressively phase out upstream.

Table 3 compares design flood levels derived for the 1989 Flood Study and levels adopted in the present study at various locations along the main river. The Table shows that, despite the lower peak ocean levels, design levels in the present study are generally higher than the Flood Study downstream of Smithtown. Above Smithtown design levels from the present study are less than
Those in the Flood Study. The maximum difference in design flood levels between the two studies is of the order of 0.4 m.

These differences are not unreasonable given the different models used and are within the generally accepted tolerance of flood modelling. It should also be noted that because the models represent the river and floodplain in different ways the levels being compared are not necessarily at exactly the same points.

Table 3: Comparison of Design Flood Levels (mAHD)

<table>
<thead>
<tr>
<th></th>
<th>Ocean Entrance</th>
<th>Jerseyville</th>
<th>Kinchela Junction</th>
<th>Belmore Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% Present Study</td>
<td>2.30</td>
<td>3.55</td>
<td>4.16</td>
<td>4.78</td>
</tr>
<tr>
<td>Flood Study*</td>
<td>2.6</td>
<td>3.7</td>
<td>4.15</td>
<td>5.15</td>
</tr>
<tr>
<td>2% Present Study</td>
<td>2.20</td>
<td>3.32</td>
<td>3.94</td>
<td>4.67</td>
</tr>
<tr>
<td>Flood Study*</td>
<td>2.4</td>
<td>3.3</td>
<td>3.9</td>
<td>5.0</td>
</tr>
<tr>
<td>5% Present Study</td>
<td>2.05</td>
<td>2.65</td>
<td>3.51</td>
<td>4.52</td>
</tr>
<tr>
<td>Flood Study*</td>
<td>2.2</td>
<td>2.5</td>
<td>3.65</td>
<td>4.75</td>
</tr>
</tbody>
</table>

Note: * interpreted from Figure 32 (Reference 2).
4. PRESENT SITUATION

4.1 Village Areas

Five rural villages are located fully or partly on the floodplain. Table 4 indicates that the 1% flood would cover the floors of approximately 280 houses in these villages with perhaps as many properties again having water over the ground. The greatest depth above floor level would be 2.3 m.

Table 4: Properties Flooded in a 1% Event

<table>
<thead>
<tr>
<th>Village</th>
<th>Houses Flooded Above Floor</th>
<th>Properties Flooded Above Ground (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frederickton</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Smithtown</td>
<td>127</td>
<td>257</td>
</tr>
<tr>
<td>Gladstone</td>
<td>101</td>
<td>155</td>
</tr>
<tr>
<td>Kinchela</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>Jerseyville</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>TOTAL</td>
<td>278</td>
<td>492</td>
</tr>
</tbody>
</table>

(1) Available survey may not identify all above ground flooding.

In an extreme flood, at least 500 houses might be inundated above floor level.

Appendix A presents the methodology adopted for assessing flood damages in the village areas. A summary of the estimated damages for the villages is presented in Table 5. This table only assesses the Average Annual Damage for floods up to 1% AEP as this is the damage that will be prevented by any mitigation works (see Chapter 5). Both direct and indirect damages are included but not intangibles.

Table 5: Average Annual Damages for Villages

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1% AEP</td>
<td>2% AEP</td>
</tr>
<tr>
<td>Frederickton</td>
<td>547,000</td>
<td>502,500</td>
</tr>
<tr>
<td>Smithtown</td>
<td>2,108,100</td>
<td>1,745,900</td>
</tr>
<tr>
<td>Gladstone</td>
<td>1,699,400</td>
<td>1,463,300</td>
</tr>
<tr>
<td>Kinchela</td>
<td>181,300</td>
<td>80,100</td>
</tr>
<tr>
<td>Jerseyville</td>
<td>238,300</td>
<td>183,500</td>
</tr>
</tbody>
</table>

Note: 1. This is the theoretical damage for the 1980 flood calculated on the same basis as the other events. The flood is taken to have a 20% AEP.
2. Average annual damage in this table excludes the effect of floods larger than 1% AEP.
4.2 Rural Flood Mitigation Scheme

The floods of 1949 and 1950 led to intensive interest in flood mitigation in the lower Macleay. A series of investigations in the 1950's led to the adoption of a floodplain wide flood mitigation scheme which had the objective of controlling major flooding at Kempsey and minor flooding throughout the remainder of the floodplain.

Flood mitigation in the Macleay and other valleys was considered to be a priority need and there was widespread public support at the time. There was not the same appreciation as there is now of the potential environmental impacts of flood mitigation works, or the latent problems with acid sulfate soil occurrence and how it could be affected by over drainage. There was also no appreciation of the relationship between drainage and pasture species change in the back swamp areas.

The aim of the scheme below Kempsey was to control the passage of an "in bank" flood, which was defined as 2550 m$^3$/s at Frederickton. This was equivalent to a gauge height of 5.18 m (17 ft)\(^2\) at Kempsey Traffic Bridge (KTB). Under natural conditions this flood would have broken the banks at several points. The scheme aimed to prevent this by raising the natural levees where necessary and providing flow relief through temporary storage off the Belmore River and Kinchela Creek. The scheme also incorporated a number of barrages (known locally as "headworks") to prevent backwater flooding in minor floods up the major tributaries.

The design of the scheme accepted that floods greater than 5.18 m at KTB could not be controlled on the floodplain. These floods would overtop the levee system and cause widespread inundation of farmland and the back swamps.

Another component of the scheme was the provision of an extensive drainage network throughout the floodplain. The network was intended to limit flood damages by facilitating the rapid removal of floodwaters, thus allowing farms to return to production quickly. All drains feeding into the main river or its tributaries were fitted with non-return gates to prevent floodwaters entering the floodplain through the drainage outlets. Some drainage was also directed to ocean outfall works at Korogoro Creek, Ryans Cut and Killick Creek.

Almost all of this planned scheme was constructed in stages from the late 1950's to the mid 1970's. The major flood mitigation (as distinct from drainage) components of the scheme and their approximate dates of construction are listed in Table 6.

---

2 The Kempsey Traffic Bridge gauge is the reference point for flooding in the valley. Many members of the floodplain community still relate to imperial measurements on the gauge and these are given here at key points. The gauge zero is 0.525 m above AHD, hence a gauge reading of 5.18 m is equivalent to 5.71 m AHD.
Table 6: Major Flood Mitigation Structures

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Killick Creek</td>
<td>headworks</td>
<td>pre 1958</td>
</tr>
<tr>
<td>Kempsey to Frederickton</td>
<td>levees</td>
<td>pre 1960</td>
</tr>
<tr>
<td>Christmas Creek</td>
<td>headworks</td>
<td>1963</td>
</tr>
<tr>
<td>Clybucca</td>
<td>headworks</td>
<td>1966</td>
</tr>
<tr>
<td>Korogoro Creek</td>
<td>headworks &amp; control levee</td>
<td>1968</td>
</tr>
<tr>
<td>Kinchela Creek</td>
<td>floodways &amp; headworks</td>
<td></td>
</tr>
<tr>
<td>Ryans Cut</td>
<td>headworks</td>
<td>1973</td>
</tr>
<tr>
<td>Belmore River</td>
<td>floodway &amp; headworks</td>
<td></td>
</tr>
<tr>
<td>Macleay</td>
<td>levees</td>
<td>1976, 1978</td>
</tr>
</tbody>
</table>

The flood mitigation scheme is operated by controlling the opening of the floodway gates on the Belmore River and Kinchela Creek. The Belmore Floodway was designed to remove flow from the main river and thus lower levels in the river. This was considered a more attractive option than additional levee raising along the Macleay. The Kinchela Floodways were designed to prevent overtopping of the natural and artificial levee system along Kinchela Creek.

The operation of the system has been the subject of close scrutiny over the past few years and in the most recent flood (February 1996) a new procedure was trialed. This procedure may form the basis of permanent changes to operations as a result of this study and other work. However, it is appropriate at this stage to document the operational procedure which has been in place up to the beginning of 1996.

The procedure has been determined by a combination of theoretical considerations and practical imperatives. The theoretical considerations concluded that the Kinchela floodways should be opened for any flood which would exceed a level of 4.12 m (13'6") at Kempsey. It was also considered, for the sake of equity, that once the Kinchela floodways were opened, the Belmore floodway should also be opened. The practical aspect was that the gates had to be opened by Council staff on the site. Once floodwaters rose over the local roads (at about equivalent to 4.1 m at Kempsey) it would be difficult and potentially dangerous for staff to remain in the area.

The operation of the gates was thus controlled by staff on the spot who would open the Kinchela floodways once water commenced to lap the road. They would then drive to Belmore and open that floodway and then evacuate the area. Once the flood had subsided they would return to close the gates and prevent further flow into the back swamp storage areas.

Farmers in the Belmore/Kinchela area have expressed concerns that the scheme unfairly disadvantages them to the benefit of other areas. This has led to a series of studies into the
operation of the scheme and possible alternative procedures (References 3 to 5). The principal findings of these reports are incorporated into the discussion of rural options in Chapter 6.

4.3 Floodplain Drainage

4.3.1 Description

When the flood mitigation scheme was being evolved one of the chief concerns was the amount of time floodwaters remained on farmland after the passage of the flood wave. It was considered that an essential part of any successful flood mitigation scheme would allow the rapid removal of ponded water.

The adopted scheme included a series of major drains linking the back swamps to either the main river, one of the major tributaries or the ocean. These drains were fitted with gates where they passed under the levees to prevent water entering the swamps from downstream. It was intended that individual farmers or Drainage Unions would construct branch drains to the trunk lines to further facilitate the removal of water.

The drains have worked very well in their intended purpose, however, they have introduced a number of unforeseen problems which have adversely impacted on both the ecology and economic viability of the lower Macleay. The impacts are discussed briefly below.

4.3.2 Impact on Pastures

The drainage has lowered the water table and reduced the area and persistence of natural wetlands on the floodplain. This has led to a gradual change in the composition of the swamp pastures from a dominance of water tolerant types to species more adapted to well drained grasslands. This has increased the grazing season in normal years but has decreased the drought reserve and nutritive value of the swamp pastures. The new pasture species are much less tolerant of flooding than the former species with the result that they are often killed by inundation and are then slow to recover adequate productivity. Consequently, swamp areas that once provided a large measure of drought relief - and thus allowed farmers substantial flexibility in managing their properties - are now affected at the same time as adjoining paddocks.

In flood times the introduced grasses die when inundated then rot and seriously reduce the dissolved oxygen levels in the ponded water. This low (or zero) dissolved oxygen water has a major impact on fish when drained into the main river and its tributaries (see Section 4.3.4).

4.3.3 Acid Sulfate Soils

The condition now known as acid sulfate potential derives from the presence of iron pyrites in water saturated marine sediments which underlie the lower Macleay (and most other coastal)
Lower Macleay Floodplain Management Study

floodplain alluvial soils. The Department of Land and Water Conservation has prepared a series of acid sulfate soil maps covering the lower Macleay floodplain. Figure 9 shows a composite summary derived from these maps with an overlay consisting of the main drains from the lower Macleay flood mitigation scheme.

When exposed to air the iron pyrites within the acid sulfate soils oxidise in a complex process to produce sulphuric acid. The resulting acidity may cause a significant fall in soil and drain water pH levels and increase the solubility of iron, aluminium and other heavy metals.

Marine organisms are known to be particularly sensitive to low pH levels and the accompanying higher concentration of metal ions. These conditions may also be toxic to some plants, but adapted wetland plant species seem to be relatively tolerant.

During extended dry periods, or in situations where the water table has been artificially lowered, pyrite oxidation may occur with the release of acid into the groundwater of the back swamps. In some instances this acidity appears to slowly migrate upwards and become deposited in the surface layers of soil. During these periods, low pH levels (below 4) can often be detected in free standing water in the drains. It has also been proposed that dissolved iron in the acid water may oxidise further causing additional oxygen depletion in the acid water.

When rain begins to fall prior to flooding, resident acid water may be pushed out of the back swamps into the main drainage and river tributary system. It has been suggested that "plugs" of de-oxygenated acid water may occur at certain locations trapping marine organisms and causing fish kills.

Although a number of surveys have been conducted during dry periods that have identified acid sulfate conditions, notably at Seven Oaks, Clybucca and also in some drains (notably Thurgoods) in the Belmore/Kinchella area, the quantitative effects of acid sulfate on the environment before and after flooding have not been determined.

If acid sulfate causes damage to marine life, this is more likely to occur just before flooding rather than after. When large volumes of neutral (pH 7) floodwaters mix with acid water the acidity is moderated. Dilution by tenfold causes the pH to rise by 1 unit; dilution by one thousand increases the pH by three units.

The advancing floodwaters might be expected to dilute and flush out any free standing acid water. As the floodwaters recede there may be some drainage from the groundwater, but this would not seem to be sufficient to create acid conditions. The clays giving rise to acidity commonly have very low hydraulic conductivities (only about 1-4 mm per day) and would be unable to supply sufficient flow to acidify the receding floodwaters. It is also doubtful whether there would be sufficient dissolved iron under these conditions to deplete oxygen levels in the water to any significant extent.
However, controversy continues on the contribution of sulfate acidity to damaging environmental episodes such as fish kills.

The relative importance of acid sulfate compared with other phenomena such as water deoxygenation from decaying organic matter will only be determined by continuous monitoring of pH, dissolved oxygen, temperature, and perhaps dissolved iron levels over an extended period including prolonged dry weather and floods at a number of critical locations.

4.3.4 Impact on Aquatic Ecology and Fisheries

There are significant commercial and recreational fishing activities, and oyster farming, within the lower Macleay. Approximately ten commercial fishermen regularly work in the Macleay, targeting fish such as mullet using mesh nets and mud crabs using traps. Outside the estuary, trawlers catch fish and prawns, many of which are ecologically linked to the estuary. Commercial fishing is closed in the Belmore River and upstream of Kempsey, in the Macleay. There is some evidence of a decline in fisheries catch in the Macleay, and this is linked by some researchers to the effects of flood mitigation works. Further work needs to be done to assess this.

Oysters are cultured in the lower Macleay, principally around Shark Island and the Macleay Arm, and in Clybucca Creek and Andersons Inlet. Culturing involves the collection of spat (oyster larvae) and their growth to an edible size. The various stages of oyster farming are carried out in different parts of the estuary. According to local oyster farmers, flooding and acid sulfate soils have had significant effects on oyster production and there have been reports of heavy mortalities of oysters in Clybucca Creek and Andersons Inlet following heavy rain. The extent to which these two waterways may be "high-risk" areas warrants further investigation.

Recreational fishing is widespread through the lower Macleay, with fish being sought in similar areas to those fished by commercial fishermen. According to NSW Fisheries, the Macleay supports a large population of Australian bass, a significant recreational species.

Significant factors affecting aquatic ecology and fisheries in the lower Macleay have been identified as the distribution and availability of habitat, salinity, obstacles to the movement of aquatic organisms within and beyond the estuary and water quality. One of the major challenges for management is to distinguish natural phenomena from the effects of human activities and, where the latter is the case, to place these effects within an appropriate context.

Although there have been several studies already in the area, there is an urgent need to gather some basic quantitative information to:

- assist in the prediction of whether and to what extent altering flood mitigation could benefit aquatic ecology and fisheries, and
- determine more precisely the nature and magnitude of fish kills. The basic requirements for further quantitative research should include sampling at appropriate spatial scales.
and, where necessary, over time. In general, it is also crucial that replicate samples be taken to assist in quality assurance and facilitate statistical analysis of data, evaluate the potential for restoring estuarine and freshwater wetlands throughout the valley.

There is clear evidence that the drainage works have impacted on fish health. Fish kills are part of the process of nature and can be remembered occurring on the Belmore River many decades ago. However, there is general consensus that the number of kills has increased significantly since the drainage works were constructed. There is also concern among elements of the fishing community that kills are only the spectacular tip of the iceberg and that more significant damage may be occurring due to declining health and diversity of estuarine life. This concern spreads also to the oyster industry which mainly operates in the lower Clybucca area.

While these concerns have been held for some time substantive, quantitative data on water quality has only recently started to be collected and to date this has only been done in relation to fish kills.

In the Belmore Kinchela area, information available on fish kills comes from a paper published in 1980 on monitoring done by NSW Fisheries and Council reports on fish kills in March 1995 and January and February 1996. Several water samples were collected after the fish kills in early 1996. The samples indicated that lack of dissolved oxygen was the major factor in the kills. At this stage it is unclear whether the lack of oxygen was due to rotting vegetation or to high acidity which may have caused deoxygenation due to the precipitation of iron.

Another feature of the drainage works which has been blamed for exacerbating kills is as follows. In pre-works days poor quality water would enter the top of the tributaries and make its way downstream towards the main river. The fish would swim ahead of the "slug" of poor water and escape into the main river where the toxicity of the water would be diluted. The drainage works have introduced a series of inputs along the length of the tributaries, under the natural levee banks. It is now possible for poor quality water to enter the tributary through one of these points and cut the fish off from escape to the main river.

4.3.5 Wildlife Habitat

The floodplain wetlands of the North Coast are a significant feature of the Australian environment for waterfowl. The area is considered one of the three major drought refuges on the continent. The wetlands have been impacted by human development since last century: first by clearing and grazing and more lately by flood mitigation and drainage works. The latter have had several effects.

Firstly, the construction of levees and control gates has reduced the frequency of inundation of the wetlands. This has reduced the amount of water available and also the variability of water levels. The latter is an important element in producing nutrients to encourage plant growth and thus maintain the food cycle.
Secondly, the construction of drains has reduced the amount of time the wetlands are full and has also increased the risk that they will dry out in times of drought. This particularly affects the breeding of many water birds as they require an extended period (in excess of four months) of good water supply in order to successfully produce and raise a family.

A third concern is the possible impact on wildlife and wildlife habitat of increased acidity due to the activation of potential acid sulfate soils (PASS). No definitive studies have been carried out on this subject and it can only remain a matter for conjecture. While no obvious signs of affection to wildlife habitat in the floodplain as a whole have been observed (other than the long term scald areas) the potential for gradual impacts cannot be dismissed. Monitoring of water quality parameters during flood and non-flood periods in key areas of the floodplain may assist in defining this problem.

Reference 12 contains a summary of the situation as it was in the late 70's with references to earlier studies which add some more detail. It would seem that little has changed in the intervening years. The report identified that the remaining wetlands of significance were those at Upper Belmore and Swanpool.

4.3.6 State Wetland Management Policy

In early 1996 the Department of Land and Water Conservation issued a policy statement for the management of wetlands (Reference 13). The policy is relevant to the present study because any changes to the post flood drainage arrangements will impact on the remnant floodplain wetlands.

Among other objectives of the policy the following are particularly relevant:

- to encourage the management of wetlands so as to halt and where possible reverse:
  - loss of wetland vegetation,
  - declining water quality,
  - declining natural productivity,
  - declining natural flood mitigation,

- to encourage projects and activities which will restore the quality of the State's wetlands.

4.3.7 Yarrahapinni

The Yarrahapinni Wetlands Reserve Trust is in the process of restoring estuarine conditions to a former estuarine wetland at Yarrahapinni which was converted to freshwater conditions as part of the flood mitigation works. This project will provide invaluable information on the restoration process and its effects. It should be closely monitored to determine lessons for the rest of the lower Macleay and the wider region.
5. VILLAGE MITIGATION OPTIONS

5.1 Levees

Levees usually take the form of earth embankments, partly because of cost and partly for aesthetic reasons. Where there is insufficient space for an earthen levee, concrete walls are utilised.

Levees generally function well for floods up to the design level but once they are overtopped the resulting damage can be serious, as was dramatically demonstrated at Nyngan in 1990. This is because the water level inside the levee can rise very quickly after overtopping and can be accompanied by high velocities. Also people tend to develop a false sense of security when living behind a levee and normally consider themselves safe from all floods. It is generally not possible for economic and aesthetic reasons to build a levee which will exclude all floods up to the PMF.

When a levee is constructed it is important to dispose of, or store harmlessly, the runoff which occurs inside the levee after the river rises. As levees are built at low lying points, there can often be a considerable catchment area behind the works. The internal water can be disposed of by utilising flap gate type floodgates; by running it in pressure pipes from higher areas; by providing storage ponds which will not themselves cause flooding; or by pumping. Pumps have the disadvantage that they would be used very infrequently and may not operate properly on the rare occasions they are required. Maintenance costs can also be high.

There is an extensive system of levees throughout the rural sections of the Macleay Floodplain and a small levee at Smithtown. The construction of further levees around the villages to protect them from flooding up to the 1% event was examined.

A typical section of earth levee would have a 3 m top width and 1:4 side slopes (see Figure 11). The top height would be 0.5 m above the 1% flood level to provide a freeboard to allow for local hydraulic conditions, wave action and computational uncertainties. The embankment would be constructed of compacted sound earth with no organic matter. Following construction it would be turfed or hydro mulched.

Conceptual levee alignments for the villages are shown on Figure 10. No attempt has been made at this stage to define an exact alignment for each levee. This would be done at the design stage when detailed survey and identification of local constraints were available.

The RUBICON model was used to examine the potential impact of the levees on general flood behaviour. It was found that the impacts were minimal as the leveed areas did not block any significant flow paths and the amount of floodplain storage excised was negligible. A more detailed examination of hydraulic impacts in the immediate area could be incorporated in the detailed design of the levees.
5.1.1 Costs

The required levee heights were determined along the length of each of the five conceptual alignments. This information is summarised in Table 7.

Table 7: Levee Heights and Lengths

<table>
<thead>
<tr>
<th>Village</th>
<th>Design Crest Level (m AHD)</th>
<th>Levee Length at Given Height (m)</th>
<th>Total Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Frederickton</td>
<td>7.5</td>
<td>-</td>
<td>80</td>
</tr>
<tr>
<td>Smithtown</td>
<td>5.5</td>
<td>460</td>
<td>600</td>
</tr>
<tr>
<td>Gladstone</td>
<td>6.5</td>
<td>400</td>
<td>690</td>
</tr>
<tr>
<td>Kinchela</td>
<td>5.0</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Jerseyville</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Based on the typical section shown in Figure 11, a rate for total levee cost per metre length as a function of height was obtained. The breakdown of the rate is presented in Table 8.

Table 8: Levee Unit Cost Rate

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity (per m length)</th>
<th>Unit</th>
<th>Rate ($</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear and Grub Base</td>
<td>8h + 3</td>
<td>m²</td>
<td>1.00</td>
<td>8h + 3</td>
</tr>
<tr>
<td>Strip and Stockpile Topsoil</td>
<td>8h + 3</td>
<td>m²</td>
<td>1.20</td>
<td>9.6h + 3.6</td>
</tr>
<tr>
<td>Excavation</td>
<td>1.5</td>
<td>m³</td>
<td>4.00</td>
<td>6</td>
</tr>
<tr>
<td>Supply of Fill</td>
<td>3h + 4h²</td>
<td>m³</td>
<td>8.00</td>
<td>24h + 32h²</td>
</tr>
<tr>
<td>Spread and compact fill in</td>
<td>3h + 4h²</td>
<td>m³</td>
<td>10.00</td>
<td>30h + 40h²</td>
</tr>
<tr>
<td>250mm layers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trim Batters</td>
<td>8h + 0.5</td>
<td>m²</td>
<td>1.20</td>
<td>9.6h + 0.6</td>
</tr>
<tr>
<td>Spread Topsoil</td>
<td>8h + 3</td>
<td>m²</td>
<td>2.00</td>
<td>16h + 6</td>
</tr>
<tr>
<td>Supply and Lay Turf</td>
<td>8h + 3</td>
<td>m²</td>
<td>3.50</td>
<td>28h + 10.5</td>
</tr>
</tbody>
</table>

Total Levee Cost per m length as a function of height = 72h² + 125.2h + 29.7

Note: (1) As a function of levee height (h). (2) Taken from Reference 5.
The levee construction cost estimates were calculated from the information in Tables 7 and 8 and are shown in Table 9.

Table 9: Levee Construction Cost Estimates

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frederickton:</strong></td>
<td></td>
</tr>
<tr>
<td>Levee Cost</td>
<td>810,000</td>
</tr>
<tr>
<td>Internal Drainage</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$910,000</td>
</tr>
<tr>
<td><strong>Smithtown:</strong></td>
<td></td>
</tr>
<tr>
<td>Levee Cost</td>
<td>1,380,000</td>
</tr>
<tr>
<td>Internal Drainage</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Restore Damage to Yards</td>
<td>500,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3,380,000</td>
</tr>
<tr>
<td><strong>Gladstone:</strong></td>
<td></td>
</tr>
<tr>
<td>Levee Cost</td>
<td>2,100,000</td>
</tr>
<tr>
<td>Internal Drainage</td>
<td>800,000</td>
</tr>
<tr>
<td>Restore Damage to Yards</td>
<td>200,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3,100,000</td>
</tr>
<tr>
<td><strong>Kinchela:</strong></td>
<td></td>
</tr>
<tr>
<td>Levee Cost</td>
<td>690,000</td>
</tr>
<tr>
<td>Roadworks</td>
<td>120,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$810,000</td>
</tr>
<tr>
<td><strong>Jerseyville:</strong></td>
<td></td>
</tr>
<tr>
<td>Levee Cost</td>
<td>810,000</td>
</tr>
<tr>
<td>Internal Drainage</td>
<td>200,000</td>
</tr>
<tr>
<td>Roadworks (including new wharf access)</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$1,010,000</td>
</tr>
</tbody>
</table>

5.1.2 Benefit/Cost Analysis

The benefit gained from constructing the levees is the potential savings due to the reduction in flood damages to properties protected by the levees (see Table 5). A discount rate of 7% and project life of 25 years was adopted to convert these damages to Net Present Worth (see Appendix A).

The results of the analysis are shown in Table 10. The table only considers benefits derived from preventing tangible damages. Adding intangibles would increase the B/C ratio.
### Table 10: Levee Benefit/Cost Analysis

<table>
<thead>
<tr>
<th>Village</th>
<th>AAD for all properties (Table 5) ($)</th>
<th>Construction Cost (Table 9) ($)</th>
<th>Benefit/Cost Ratio</th>
<th>Sensitivity Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frederickton</td>
<td>74,730</td>
<td>910,000</td>
<td>0.96</td>
<td>1.29</td>
</tr>
<tr>
<td>Smithtown</td>
<td>353,290</td>
<td>3,380,000</td>
<td>1.23</td>
<td>1.65</td>
</tr>
<tr>
<td>Gladstone</td>
<td>325,500</td>
<td>3,100,000</td>
<td>1.23</td>
<td>1.68</td>
</tr>
<tr>
<td>Kinchela</td>
<td>6,220</td>
<td>810,000</td>
<td>0.09</td>
<td>0.12</td>
</tr>
<tr>
<td>Jerseyville</td>
<td>26,420</td>
<td>1,010,000</td>
<td>0.31</td>
<td>0.41</td>
</tr>
</tbody>
</table>

where:  
- $\text{AAD} = \text{Average Annual Damages (\$)}$  
- $i = \text{Discount Rate (\%)}$  
- $n = \text{Project Life (years)}$

#### 5.2 Improve Access

In a large flood all the villages, except Frederickton, are cut off from large towns with food and medical facilities. If upgraded access could be provided this would allow more time for evacuation. The only village for which this might be a practical option is Jerseyville.

#### 5.3 Flood Proofing of Buildings

This mainly involves installation of special doors and seals to prevent the entry of floodwaters when the water outside the building is above floor level. The technique can be effective with industrial and commercial brick premises.

There are problems with applying the principle to houses because of the high cost and need for continuing maintenance. It is dependent on adequate flood warning time (to ensure all openings are sealed) in order to be effective.

Two storey residences might be subject to a form of flood proofing involving limited use of the ground floor. In some cases single storey residences could be flood proofed by raising fences and sealing gates (or ramping over) to protect the individual allotments.
5.4 House Raising

Houses can be raised above flood level and placed on piers. The procedure is easier with weatherboard or fibro construction but is now been successfully applied to brick buildings.

5.5 Zoning and Minimum Floor Levels

In newly developing areas future flood damages can be limited by zoning land to flood compatible uses. Residential development may be zoned in marginally flood liable land with floor level controls. Residential development may also be zoned in flood liable land which has been protected by structural measures (e.g. levees) together with floor level controls.

Floor level controls allow infill development or redevelopment under existing zonings, but control the development to restrict flood damage potential. This should be an integral part of the Floodplain Management Plan which is to be prepared in the next phase of the floodplain management process.

5.6 Voluntary Purchase

Where houses are identified as being in a particularly hazardous area the most viable and cost effective option may be to make a standing offer to buy the property at market valuation whenever the owner so desires, providing that funds are available at that time.

This approach was adopted for certain properties at Kempsey but is probably not appropriate in the lower Macleay as flood velocities are much lower.

5.7 Flood Warning and Emergency Services

Flood damages can be significantly reduced if sufficient warning is given to allow occupiers to raise expensive items or to remove them (especially vehicles) from the floodplain. One of the greatest social traumas of flooding is often the loss of memorabilia, items which can usually be saved relatively easily if there is adequate warning and public education.

Risk to life and limb can also be significantly reduced if enough time is available to evacuate people before the situation becomes dangerous. This applies not only to the residents but also to the rescue workers such as the SES and Police.

This strategy has merit in the case of the Macleay floodplain as the large catchment area allows a long warning time.
5.8 Public Information and Education

It may be possible to reduce flood damages, trauma and risk to personnel by conducting a public education program although the effectiveness of this approach has yet to be shown in practice. A large percentage of the population will not attend meetings or read brochures. Even those who do read the information find difficulty in assimilating the information if they have no first hand experience.

Given the increasing need for Councils and Government Authorities to make sure that information is disseminated effectively to the public, it is desirable that a formalised public education program should be part of the Floodplain Management Plan for the Macleay Floodplain. Such a program should be regularly reinforced and should be targeted to achieve maximum audience penetration. One way to achieve this would be to focus on children by encouraging local schools to include in their studies a component on flooding and living with floods. Organising competitions around the theme of flood awareness and safety could also be effective.
6. RURAL MITIGATION OPTIONS

6.1 Area Considerations

A series of public meetings were held to determine the concerns and suggestions of people in various parts of the floodplain regarding operation and management of the flood mitigation scheme, during both flood and non-flood periods. While there were many points in common it was also apparent that the different areas had different concerns and priorities. The issues raised in each area are summarised below.

6.1.1 Belmore/Kinchela

- flood warning,
- effects of levees and headworks on drainage times after local flooding,
- unnatural flooding and water dumping,
- poor control of flood gates,
- over drainage,
- management of the water table,
- salt water intrusion in Upper Belmore,
- sell and lease back of land,
- realignment of land boundaries,
- stress and trauma,
- water entering from Hastings via Connection Creek,
- effect of flood damages on employment opportunities,
- post flood problems,
- "Giant Fish Trap" effect,
- grass species,
- greater consultation,
- tidal intrusion due to operation of headworks.

6.1.2 Seven Oaks

- over drainage,
- raising the water table,
- acid sulfate soils,
- grass species,
- getting rid of floodwaters,
- existing drains too deep,
- sell and lease back of land,
- realignment of boundaries,
- salinity upstream of Clybucca headworks,
- threat of litigation if works are modified,
• SEPP14 threat if farmland reverts to wetland pasture.

6.1.3 Remainder

• bank erosion in lower Clybucca,
• dredging of main river,
• affect of aluminium on oysters,
• concern if the present scheme is changed,
• any changes to drains on a case by case basis,
• inadequate protection at Rainbow Reach,
• low points in Flood Mitigation Scheme levees.

6.2 Assessment of Options

The range of concerns expressed by floodplain users is clearly wide. Many of the suggestions, while perhaps beneficial to some interests, could be detrimental to others. The following sections address all the options suggested and provide a brief summary of the perceived advantages and disadvantages of each, covering both the views of the proponent and of those that may have some concerns.

It must be recognised that most of these suggestions have been offered as a component of an overall approach and are not intended to be stand alone solutions. Some of the options are alternatives to other proposals. The choice between alternative options should be made taking into account local conditions and the wishes of all the stakeholders.

The following discussion is presented in the light of understanding and technology available at the time of this report. Future developments may open up new possibilities or render some of the proposed responses inadequate or redundant. For this reason the analysis of this report should be subjected to continuing review and upgrading. The Floodplain Management Plan must be considered a living document which can adapt to changed understanding, knowledge and perceptions.

For ease of discussion the options have been grouped together by kind rather than by area or any other criteria. The first group are those which envisage changes to the flood mitigation structures; this is followed by options to alter the operation of the scheme; discussion of drainage and water quality issues; legal (including land tenure) and finally issues which do not conveniently fit under any other heading.
6.3 Structural Measures

6.3.1 Modifications to Clybucca Headworks

Option i) leave as is,
Option ii) that the headworks structure on Clybucca Creek be removed in order to permit tidal movement upstream thereby increasing the size of the estuary,
Option iii) that the Clybucca Headworks or its operation be modified so that the excessive reduction in upstream water level during very low tides is reduced,
Option iv) that the operation or maintenance of the Clybucca Headworks be modified to prevent saline intrusion upstream of the gates,
Option v) provide a fishway to bypass the headworks.

Clearly the proposals are not compatible, but they do highlight the point that the Clybucca Headworks (and other flood mitigation works which restrict the free movement of estuarine waters and affect the associated habitat) are the focus of considerable thought and concern. The following segments set out the advantages and disadvantages of implementing each alternative.

Option i) - (leave as is)

Advantages
• prevent saline intrusion upstream of the headworks and allows use of the in stream water by the farmers adjoining the creeks and channels.

Disadvantages
• largely prevent the use of the water body upstream of the headworks for the estuarine fishery. However, the potential area available upstream of the works is relatively limited,
• fish that do manage to move upstream of the headworks may become trapped and unable to avoid poor water quality, namely high acidity and/or low dissolved oxygen,
• lowers water levels and enhances the potential for acid sulfate release upstream of the headworks during periods with very low tides and with low freshwater runoff volumes.

Option ii) - (that the headworks structure on Clybucca Creek be removed in order to permit tidal movement upstream thereby increasing the size of the estuary)
Advantages
- allow free movement of estuarine flora and fauna upstream of the existing headworks structure,
- allow the establishment and maintenance of freshwater fish assemblages that have linkages with the estuary (e.g. Australian bass, freshwater eels and freshwater herring),
- increase the level of the water table upstream thereby reducing the incidence of acid sulfate occurrences,
- reduce the severity of low DO occurrences in the lower estuary,
- enhance the viability of oyster culture in some parts of the lower Clybucca downstream of the headworks.

Disadvantages
- reduce or eliminate the viability of farming in some parts of the Clybucca upstream of the headworks,
- allow the ingress of floodwaters from downstream in low level floods and freshes,
- by increasing the salinity of the surface waters in the drains introduce constraints on stock watering and irrigation.

Option iii) - (that the Clybucca Headworks or its operation be modified)

The primary purpose of modifying the headworks or its operation would be to exclude spring tides and prevent over drainage during the associated low tides. Keeping the gates closed during such tides would be one way of achieving this. During non flood periods when there were neap tides the gates could be kept open most of the time.

Advantages
- reduce the incidence of acid sulfate drainage upstream of the headworks and thereby improve water quality,
- increase the water table upstream and improve farm productivity.

Disadvantages
- possible reduction in post flood drainage efficiency of the headworks depending on how they are modified,
- greater cost in the maintenance and operation of the headworks.

Option iv) - (that the operation or maintenance of the Clybucca Headworks be modified to prevent saline intrusion upstream of the gates)

At the present time the gates occasionally stick open allowing saline water to penetrate upstream and adversely affect landowners. The proposal involves closer monitoring and/or maintenance of the gates.
Lower Macleay Floodplain Management Study

Advantages

- eliminate the incidence of high salinity upstream of the headworks thereby improving water quality for stock watering and irrigation.

Disadvantages

- increased capital and maintenance costs.

Option v) - (provide fishway)

Advantages

- provide upstream passage for fish and invertebrates without adversely affecting landowners.

Disadvantages

- the proposal has been subjected to a preliminary examination in conjunction with this study and it would appear to be either very difficult or impractical to implement,
- there is a danger that if more fish do in fact establish themselves upstream of the headworks, there will be larger fish kills when poor quality water occurs.

Overall Assessment

Option i), the "do nothing" option, would limit the efforts currently being made to address the acid sulfate problem in the area. Water quality problems and excessive lowering of the water table would continue.

Option ii) would involve a significant change in the ecosystem, to a cohesive habitat extended fishery, but would adversely affect the farming utility of the area upstream of the headworks. Before such a move could be contemplated a full EIS/Public Consultation program would be needed to evaluate the benefits and disbenefits. Apart from gathering information on current utilisation of the area by aquatic organisms, close observation of the impending Yarrahapinni restoration could provide data for evaluation and would appear to be prudent before proceeding further.

Option iii) does not appear to have any disbenefits other than the capital cost and ongoing maintenance cost. An evaluation of the benefits and any alternatives to achieving the same aim would be required to answer the economic benefits question.

Option iv) may only involve a change in maintenance procedures or increased monitoring. Automatic water sampling upstream of the headworks could be used to achieve early warning of high salinity levels. The costs of implementation do not appear to be high and the benefits could be significant.
Option v), if successful, would have advantages for all stakeholders. Further investigation (e.g. by literature review) would be an appropriate way to approach this issue.

Outcome

The Committee considered all of the options and selected a compromise between Options iii) and iv). Refer to Recommendation 5 in Chapter 7.

6.3.2 Raise Levees in Belmore/Kinchela Area

A proposal is presently being studied to open the Belmore and Kinchela floodways later in the rising stage of a flood and to close them earlier on the falling stage. This would mean that the floodway gates would not be open at all for some freshes and would be open for less time during all floods. Consequently less water would enter the storage basins. For the proposal to work some of the levees along both the Belmore River and Kinchela Creek would need to be raised.

Option i) leave as is,
Option ii) selectively raise levees along the Belmore River and Kinchela Creek as part of a scheme to allow less frequent operation of the floodways.

Option ii) is the subject of a separate study which has shown potential economic benefits from the option. The study is now entering the phase of detailed environmental assessment.

While no final operational parameters have yet been set, indications are that the Belmore floodway may not be opened until 4.57 m (15') on the KTB gauge while the Kinchela floodways could remain closed until 4.88 m (16').

Option i) - (leave as is)

Advantages
• no changes to the present balance between flood mitigation, farming and fisheries,
• no cost.

Disadvantages
• affected landowners consider that the present arrangement is inequitable,
• land is arguably flooded more frequently than is necessary to maintain the objectives of the flood mitigation scheme.
Option ii) - (raise levees (in conjunction with less frequent operation of the floodways))

Advantages
- less disruption to farms,
- more equitable distribution of flood problems,
- economic benefits,
- possible increased employment.

Disadvantages
- less main river flooding to swamp areas,
- concerns on environmental impacts (subject of separate study),
- does not change frequency of flooding from local catchments,
- because the frequency of flooding is reduced this may lower the water table further which could exacerbate acid sulfate soil problems,
- there will be a decrease in the deposition of flood borne soil in the floodplain and possibly an increase in sedimentation in the main channels.

Overall Assessment

The proposed levee raising and changed operations have been shown to provide economic benefits to the local landholders and would also reduce their concerns that they are being disadvantaged by the present scheme for the benefit of others.

Other parties have expressed concern regarding the impact on wetland areas and water quality.

The proposal is about to enter the environmental investigation phase which will incorporate comprehensive involvement of all interested parties. This will provide a good test as to whether the diverse interests in the valley can work together to achieve solutions which are to the common benefit.

Outcome

The issue of levee raising (Option ii)) is about to be addressed in a REF. Refer to Recommendation 6 in Chapter 7.
6.3.3 Block Connection Creek

Floodwaters can travel in either direction between the Macleay and Hastings floodplains by crossing the Crescent Head Road at Connection Creek.

Option i) leave as is,
Option ii) block the connection by raising the road or building a parallel levee and providing flood gates,
Option iii) build a diversion bank to divert water towards Killick Creek.

Option i) - (leave as is)

Advantages
• from the viewpoint of the Macleay farmers allows drainage to the Hastings if that river is lower than the Macleay.

Disadvantages
• allows drainage the other way when the Hastings is higher.

Option ii) - (block the connection)

Advantages
• protects the Macleay from Hastings floods.

Disadvantages
• prevents drainage of Macleay floods to the Hastings,
• cost,
• unknown environmental impacts.

Option iii) - (diversion bank to Killick Creek)

This would not involve a total blockage like option ii). It would involve re-direction of the Hastings floodwaters by building a diversion bank either north or south of the Crescent Head road. Flows would thereby be “diverted” rather than “blocked” reducing the adverse effect on Hastings’ landowners.

Advantages
• would direct the Hastings floodwaters towards the Killick Creek headworks and reduce flows into the Upper Belmore.

Disadvantages
• in large Macleay floods could hinder flow towards the Hastings thereby delaying drainage times in the Upper Belmore,
the extra flows could have adverse impacts on flood levels and duration of flooding at Crescent Head.

**Overall Assessment**

Clearly equity (and legal) considerations would require any blockage to apply both ways, i.e., it would not be possible to install gates to drain the Macleay to the Hastings but prevent drainage the other way.

While blocking the connection (or building a diversion bank) may be beneficial in some floods, it would be a disbenefit in others and the overall effect is likely to be neutral.

**Outcome**

The Committee resolved to adopt Option i) "leave as is". Refer to Recommendation 7 in Chapter 7.

**6.3.4 Levee Protection at Rainbow Beach**

The left bank of the river along Rainbow Reach is low lying and the lowest points are subject to inundation in high tides. This section was not included in the original flood mitigation proposals, but some rock protection has been provided, a small levee constructed and flap gates installed on drain outlets.

Local landholders are concerned that proposed works elsewhere will worsen their position. They have indicated that they are prepared to accept works elsewhere provided they do not receive a reduced level of protection.

Because flooding in the area is heavily influenced by both tidal conditions and river flows, defining the appropriate level of protection is not a simple task. A satisfactory combination would appear to be a flood reaching 4.88 m at KTB (the approximate opening height for the Kinchela floodways under the proposal mentioned in Section 6.3.1) and a tide reaching 2 m on the tide board (approximately 1 m AHD).

The hydraulic model was run to simulate these inputs under present operating procedures. The resultant flood levels at Rainbow Reach ranged from 1.19 m AHD to 1.37 m AHD. These levels are at about the height of the existing levee/high bank. There are some low points which would overflow and there is generally little freeboard, especially in the section east of Rainbow Reach Road. The flood levels could be expected to be raised marginally under the proposed gate operations now being considered.

In order to provide a better level of protection for this area the levee would need to be raised in low sections over a length of some 2000 m.
Option i) leave as is.
Option ii) raise the levee along the left bank to provide better protection compatible with that experienced in the remainder of the floodplain.

Option i) - (leave as is)

Advantages
• no direct public costs,
• no change to existing topography/frequency of flooding.

Disadvantages
• reasonably frequent flooding,
• perception by local farmers that they are being unfairly treated,
• may cause opposition to other changes proposed to the existing Flood Mitigation Scheme.

Option ii) - (raise the levee)

Advantages
• greater productivity,
• promotes perception of fairness in sharing the flood burden.

Disadvantages
• cost,
• possible minor changes to flood behaviour locally.

Overall Assessment

It would appear that some works are required in order to achieve a flood mitigation scheme which has wide based community support and which is perceived to provide equitable treatment to all affected parties.

Outcome

Option ii) should be considered by the Committee. Possible outcome at Recommendation 8 in Chapter 7.
6.3.5 Bank Erosion

The identified bank erosion problems of concern are within the lower Macleay River system.

Option i) evaluate the extent of the problem and prepare a management plan.

Advantages
- no serious attack can be mounted on the problem until the details provided by a Management Plan are available,
- a plan is the necessary first step towards any solution.

Disadvantages
- could involve high costs,
- likely to involve long term capital and maintenance costs.

Overall Assessment

Preparation of a Management Plan is a necessary first step towards understanding and treating the problem. Such a plan should encompass the main river and all major tributaries on the floodplain.

Outcome

The Committee resolved that a Management Plan should be prepared. Refer to Recommendation 9 in Chapter 7.

6.3.6 Dredging

Option i) dredge the river in order to lower flood levels.

Advantages
- small lowering of flood levels.

Disadvantages
- high environmental impact,
- prohibitive costs to provide any real benefit,
- problems with disposal of spoil,
- need to repeat on a regular basis.
Overall Assessment

Dredging is not a cost effective flood mitigation measure and serious environmental problems could be encountered in disposing of the spoil. Modelling has shown that to have any real impact on flood levels the bed would need to be lowered by between 0.5 m and 1.0 m over a significant length. This would cost between $50M and $100M and would need to be regularly repeated.

Outcome

The Committee resolved that dredging was not a practical option. Refer Recommendation 10 in Chapter 7.

6.3.7 Flood Channels

Five possible alignments for flood channels were considered as shown on Figure 10. These were modelled for a repeat of the May 1980 flood and for a flood having 80% of the 1980 flows (the "8080" flood). This approximates the "in bank" discharge (Section 4.2) used in the design of the flood mitigation scheme.

Table 11 indicates the physical features represented in the option runs. Table 12 presents the impacts of the options at various points in the floodplain.

**Table 11: Flood Channel Options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Kinchela</th>
<th>Belmore</th>
<th>Clybucca</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100m wide channel to Korogoro Creek, raise levees</td>
<td>as is</td>
<td>as is</td>
</tr>
<tr>
<td>2</td>
<td>as for 1</td>
<td>100m wide channel to ocean, raise levees</td>
<td>as is</td>
</tr>
<tr>
<td>3</td>
<td>as for 1</td>
<td>100m wide channel to head of Kinchela channel, raise levees</td>
<td>as is</td>
</tr>
<tr>
<td>4</td>
<td>as is</td>
<td>as is</td>
<td>channel along natural depression from Seven Oaks Bend</td>
</tr>
<tr>
<td>5</td>
<td>as is</td>
<td>as is</td>
<td>100m wide channel from Frederickton</td>
</tr>
</tbody>
</table>
Table 12: Impacts of Flood Channel Options (m)

<table>
<thead>
<tr>
<th>Location</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
<th>Option 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frederickton</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
<td>-0.02</td>
<td>-0.12</td>
</tr>
<tr>
<td>Belmore Junction</td>
<td>0.02</td>
<td>0.11</td>
<td>0.05</td>
<td>-0.04</td>
<td>-0.10</td>
</tr>
<tr>
<td>Kinchela Junction</td>
<td>0.04</td>
<td>0.08</td>
<td>0.03</td>
<td>-0.02</td>
<td>-0.06</td>
</tr>
<tr>
<td>Jerseyville</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.00</td>
<td>-0.02</td>
</tr>
<tr>
<td>Clybucca Ck d/s hw</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Belmore R. at Floodway</td>
<td>0.02</td>
<td>0.81</td>
<td>-0.97</td>
<td>-0.04</td>
<td>-0.10</td>
</tr>
<tr>
<td>Belmore Swamp</td>
<td>-0.10</td>
<td>-0.89</td>
<td>-0.89</td>
<td>-0.11</td>
<td>-0.14</td>
</tr>
<tr>
<td>West Kinchela</td>
<td>-0.22</td>
<td>-0.20</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.07</td>
</tr>
<tr>
<td>Kinchela Creek</td>
<td>0.27</td>
<td>0.31</td>
<td>0.03</td>
<td>-0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>Kinchela Swamp (N)</td>
<td>-0.42</td>
<td>-0.42</td>
<td>1.05</td>
<td>-0.29</td>
<td>-0.33</td>
</tr>
<tr>
<td>Kinchela Swamp (S)</td>
<td>-0.80</td>
<td>-0.80</td>
<td>-0.20</td>
<td>-0.30</td>
<td>-0.34</td>
</tr>
<tr>
<td>Korogoro Creek</td>
<td>0.89</td>
<td>0.90</td>
<td>0.56</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

As an extension of Option 4, additional runs were carried out to examine the interaction of a flood channel from Seven Oaks Bend with the present floodways on the Belmore River and Kinchela Creek. The Seven Oaks Flood Channel would take a peak flow of about 90m³/s and would marginally reduce flood levels in the main river. This in turn would allow some small adjustment to the present operating levels of the Belmore and Kinchela floodways.

Overall Assessment

The model results show that none of the floodways would have a significant impact on flood levels throughout the floodplain. There is still the possibility that some of the proposals might be beneficial in localised areas. Any such prospect would need to be subjected to detailed environmental and economic assessments as is presently being carried out for proposals in the Belmore/Kinchela area.

Outcome

The Committee resolved that the floodways were not beneficial overall but may be worthy of consideration in local areas. Refer to Recommendation 11 in Chapter 7.

6.3.8 Flood Mounds

When overbank flooding in the rural areas is predicted, farmers have to move cattle quickly over long distances to find flood refuges. Some areas do not have safe refuges within practicable
distances of the flood bound farms. This problem causes added costs and stress in organising transport and agistment.

Option i) construct flood mounds at strategic locations on the floodplain to provide refuge for cattle where natural safe refuges are unavailable.

Advantages
- less cost and stress in preparing for floods,
- potentially less flood damages from stock losses,
- less disruption to other road users.

Disadvantages
- initial cost in setting up mounds (and ongoing maintenance costs),
- possible localised adverse effects on flood behaviour due to loss of flood storage or disruption of flow paths,
- availability of suitable sites and fill material to develop the mounds.

Overall Assessment

Flood mounds have clear advantages during floods in significantly reducing one of the major flood preparation stresses on farmers. Benefits to road trafficability from reduced stock movement could bring advantages to other road users such as emergency services.

The mounds would occupy only a small percentage of the floodplain and there should be little difficulty in locating them such that hydraulic and visual impacts are minimised.

Outcome

The Committee resolved that financial assistance should be sought from Government for the construction of flood mounds in appropriate areas. Further investigation is required to determine suitable sites. See Recommendation 12.

6.3.9 Additional Gates on Drains

Two drains in the Upper Belmore are not fitted with flood gates and the landowners claim post flood drainage is delayed when the headworks flood gates are opened too soon after a flood.

Option i) install flood gates.

Advantages
- allows present operation of headworks to continue.
Disadvantages

- may cause over drainage,
- cost.

A second option is presented in Section 6.4.4, which also contains the overall assessment and outcome.

6.3.10 Low Points in Flood Mitigation Scheme Levees

A number of submissions have commented on low points in the present main river levee system between Frederickton and Jerseyville. These low points allow local flooding of some properties in floods below the design "bank full" event. The proposed levee works at Rainbow Reach are addressed under Section 6.3.4.

Option i) survey the existing levees to identify low points and fill these to design grade in consultation with local landholders.

Advantages

- eliminate damage and disruption in small floods,
- restore equity of flood affectation.

Disadvantages

- very slight rise in main river areas.

Overall Assessment

This work should be considered necessary maintenance of the existing system. It will reduce damages and, perhaps more importantly, reestablish the principal of equity under the flood mitigation scheme.

Outcome

Council will carry out the necessary survey and establish a program to fill the low points. Refer Recommendation 13 in Chapter 7.
6.4 Changes to Operations

6.4.1 Warning

Landowners on the Belmore River and Kinchela Creek believe that they are not given adequate warning when Council proposes to open the floodways. Options include holding discussions with the local SES regarding local flood warnings, and improved communications with Council.

Option i) upgrade flood warnings and communication.

Advantages
- increase landholder acceptance of floodway operations,
- allow preparation for flooding - moving cattle, etc.

Disadvantages
- extra work for SES and Council.

Overall Assessment

These are reasonable suggestions which should be followed up. It is understood that Council is now attempting to upgrade its communications with the affected landholders.

Outcome

The Committee accepted that Council should upgrade the warnings for this area. Refer to Recommendation 14 in Chapter 7.

6.4.2 Gate Operations

This refers to proposals to amend the operations of the Belmore and Kinchela floodways in order to cause less flooding in the overbank storage areas. The proposed changes have been studied elsewhere and would require some upgrading of levees along the two streams to be fully effective. Section 6.3.2 provides a brief overview of the advantages and disadvantages of the option. As stated there, a detailed environmental assessment is about to begin.

Outcome

The Committee resolved that current gate operations (based on the February 1996 trials) should be maintained for the present. Refer Recommendation 15 in Chapter 7.
6.4.3 No Change to Present Flood Mitigation Scheme

A strong view has been expressed in some quarters that the present flood mitigation scheme is operating satisfactorily and that any proposed changes will be opposed.

Option i) that the present scheme and its operation be left as it is.

Advantages
- everyone is used to the present situation and knows how to respond,
- no additional adverse impacts due to any proposed changes,
- no public controversy over changes.

Disadvantages
- the present scheme was designed in the 1950's and has never been reassessed. In the light of 40 years' experience and extra knowledge a re-appraisal is well overdue,
- some members of the community already feel strongly that change is necessary,
- the present scheme has several demonstrated or alleged drawbacks especially with respect to fisheries, acid sulfate soils and pasture composition,
- opportunities for enhanced habitat value whilst maintaining flood protection are lost.

Overall Assessment

Any proposal in the valley will impact on the wider community; it will benefit some and possibly disbenefit others. Doing nothing at all will also raise concerns in some quarters - it will also represent a lost opportunity.

There is a need to examine the present scheme to see where it can be improved. There is then a need for the community to fairly examine the proposals and accept change where that can be shown to have an overall benefit.

Outcome

The Committee accepted that the scheme needed re-examination. Refer to Recommendation 16 in Chapter 7.
6.4.4 Operation of Headworks

This is the second option to alleviate the problem discussed in Section 6.3.9.

Option ii) modify the operation of the Belmore River headworks by opening the gates later after a flood. This will ensure that the river upstream of the gates is drawn down further before opening and hence upstream drainage would be improved.

Advantages
- no structural changes,
- no cost.

Disadvantages
- will delay the post flood movement of fish,
- will require more flexibility and possible dispute between conflicting priorities.

Overall Assessment

It appears that this area is not gaining the intended benefit from the flood mitigation works. It is not clear at this stage which of the two options is the more viable and both should be examined further.

Outcome

Council will check the suitability of fitting flood gates to the two drains and also the funding implications. At the same time the possibility of altering the headworks operation will be reviewed. Refer Recommendation 18 in Chapter 7.

6.5 Drainage

An integral part of the original flood mitigation scheme was the provision of drainage to facilitate rapid removal of floodwaters from the flood storage areas. There is general agreement that at least some of the drainage works have caused unanticipated problems and that remedial measures are necessary. Some of the problems that have been identified include drains being too deep in some locations and over drainage caused by deep drains and other factors in some areas.

The following sections consider the options which have been put forward. It is not possible to fully separate the drainage options into independent modules. Sections 6.5.1 to 6.5.5 cover individual elements more or less in isolation while Section 6.5.6 provides an overall assessment of the whole issue.
6.5.1 Raise Water Table

Many drains have been excavated to too low a level and have unnecessarily lowered the water table. This has two major impacts: it has led to the activation of potential acid sulfate soils with resulting deterioration of water quality; water loving natural pastures have been replaced with less water tolerant introduced species.

Option i) leave as is,
Option ii) modify floodgates so that inflow and outflow can be more readily regulated,
Option iii) construct weirs (perhaps temporary) across drains,
Option iv) fill in drains that have no demonstrable function,
Option v) introduce modified management practices.

Option i) - (leave as is)

Advantages

• no cost,
• no risk of works causing further unanticipated problems.

Disadvantages

• the present system is almost universally acknowledged as having problems,
• pastures are less productive both after floods and during droughts,
• aquatic ecology, including fisheries, is affected by poor water quality especially after freshes.

Option ii) - (modify floodgates)

This would see the one-way gates at the downstream ends of the major drains being opened at appropriate times to allow water from the main streams back into the drains. This has already been done informally in some areas.

Advantages

• prevent excessive lowering of the water table,
• provide more water to some farmlands.

Disadvantages

• can allow saline water into drains thus reducing the productivity of the farmlands,
• raises the question of responsibility for the operation of the system and ensuring the gates are closed when a flood is predicted.
Option iii) - (construct weirs)

A number of weirs could be placed across existing drainage channels to raise the water table upstream. The weirs could be permanent, or temporary (removable) structures such as drop boards to allow full channel flow during initial flood drainage.

**Advantages**
- prevent over drainage and excessive lowering of the water table,
- proper operation before floods is less critical than Option ii).

**Disadvantages**
- could inhibit post flood drainage, but could be designed to suit both (i.e. drop boards),
- could lead to landowner conflicts.

Option iv) - (fill in non-functional drains)

This would involve drains that have no real benefit for landowners in facilitating after flood drainage.

**Advantages**
- prevent over drainage and excessive lowering of the water table.

**Disadvantages**
- could lead to landholder conflicts if there is disagreement on the functionality of a particular drain.

Option v) - (modified management practices)

This option in fact implies a combination of all of the above suggestions, managed in a sensible way to optimise the outcomes. It is likely that such outcomes would lead to a generally “wetter” environment which would benefit the ecology (both fish and birds) and improve the “drought fodder” situation on the farms. It should also reduce the incidence of acid water and low dissolved oxygen occurrences. Close co-operation between a number of landowners would be required.

**Advantages**
- beneficial to all concerned: improved pastures, water quality and wetlands.

**Disadvantages**
- may be time consuming for farmers,
- will require education and follow up,
- possible conflict (and legal action) if there are disagreements as to what constitutes sound practice in a given situation,
6.5.2 Rebuild Drains (and make them shallower)

This option argues that many of the existing drains are too deep. They should be filled in and replaced with wider, shallower drains which would have the same effectiveness in removal of floodwaters but would not draw the water table down excessively. Installation of low weirs would tend to have a similar effect.

Option i) make existing drains shallower.

Advantages
- will maintain higher water table levels with the attendant advantages of improved pastures and water quality,
- reduce over drainage,
- improve water quality within the drain,
- greater vegetative growth could have ecological advantages and could provide useful fodder especially in drought times,
- no conflict over operation.

Disadvantages
- cost - it will probably be necessary to modify most flood gate structures, either by raising the structures, or it may be possible to leave a deeper section of drain immediately upstream of the gates compatible with the existing drain invert level,
- greater vegetative growth could require more drain maintenance.

6.5.3 Rapid then Slow

Option i) modify the headworks or flood gate structures to maintain drainage times for floodwaters whilst preventing over drainage of the water table.

Advantages
- provides the best of both worlds.

Disadvantages
- cost,
- responsibility and liability for operation,
- practicality has not yet been demonstrated locally.
6.5.4 Prevent “Fish Trap”

Two types of “fish trap” occur during and after flooding. The first relates particularly to the Belmore River and Kinchela Creek where it appears that fish are being trapped and killed by poor quality water after small flood events. The apparent mechanism is that low DO water and/or low pH water escapes from drains near the downstream ends of the tributaries thus preventing fish from escaping into the main river. The fish are then trapped between this water and a slug of poor quality water travelling down the tributaries.

The second type occurs when turbid water in the main river keeps fish in the tributaries. When the floodways are opened fish are washed onto the floodplain where they are stranded and die.

Option i) change the operation of the floodways,
Option ii) control the timing of the opening of downstream flood gates,
Option iii) construct a flood channel to the ocean at Korogoro Creek.

Option i) - (this is discussed in Section 6.3.2 - the following discussion relates particularly to fish kills)

Advantages
• will reduce the frequency of fish being dumped on the floodplain.

Disadvantages
• when the gates do operate the number of fish “sucked in” may be greater because the level of water in the creeks would be higher,
• will not eliminate the problem of fish being trapped between areas of poor quality water within the main creeks.

Option ii) - (control timing of opening downstream flood gates)

It is proposed that water draining from the swamps be initially released from the head of the tributaries before the flood gates along the tributaries are opened. In this way it may be possible for the fish to move out to the main river ahead of the advancing poor quality water thereby not becoming “trapped”. Modification of both the operation and the actual gate structures themselves would be required.

Advantages
• will avoid the early release of poor quality water at the downstream end of the creeks which can trap the fish.
Disadvantages
- cost involved in modifying all the floodgate structures,
- may delay drainage of downstream areas,
- will introduce controversy over the operation in each particular incident,
- will require water quality monitoring to determine when upstream slug has passed and the downstream gates can be opened.

Option III) - (flood channel to the ocean)

A flood channel is one of the options being examined for the Belmore Kinchela area; a REF will soon commence to develop the options further. It is likely that one of the benefits of a flood channel would be a reduction in fish kills via the “Fish Trap” effect.

6.5.5 Examine Drains Case by Case

This proposal suggests that no overall changes to the scheme are necessary, but that individual drainage systems need to be re-assessed on their merits. Care would need to be taken that all affected stakeholders are properly consulted with regard to the changes being proposed. A co-operative effort is envisaged by means of Landcare groups or similar with appropriate technical advice supplied to enable groups to make informed decisions.

Option i) reassess individual drainage schemes on their own merits.

Advantages
- will ensure that only those proposals which are demonstrably beneficial will be allowed,
- will allow detailed study and discussion of individual proposals.

Disadvantages
- no allowance for the cumulative or interactive effects of individual components,
- possible legal difficulties for individuals (see Section 6.7.3),
- time consuming.

6.5.6 Overall Assessment of Drainage

As stated in Section 6.5.1, there is widespread agreement that the present drainage component of the flood mitigation scheme is in need of an overhaul. There is clear evidence of over drainage which has led to the activation of acid sulfate soils, deterioration in water quality and adverse changes in pasture type.

Most of the drainage options presented above have merit but none is without its drawbacks. Of particular concern is that most will require an increased commitment to operation of the scheme.
during floods from Council and probably landowners. This will not only increase the pressure on people during and after floods but will also open the way for conflict within the community.

In the end, changes should be considered on a case by case basis, but this consideration should be within the framework of a general floodplain wide policy and with the knowledge of the potential interactions of the individual initiatives. There also needs to be clarity on the legal position of people who take initiatives (see Section 6.7.3).

Outcome

The Management Plan, the next phase of this study, will include proposals to improve drainage practices. Refer to Recommendations 19 and 20 in Chapter 7.

6.6 Water Quality

One of the greatest concerns expressed throughout the floodplain was the poor quality water emanating from drains on the recession of a flood. Much of the discussion in the preceding Section (6.5) derives from this. This section discusses how the changes suggested in Section 6.5 would impact on the major water quality issues.

6.6.1 Grass Species

The over draining of land has led to a change in grass species from natural, water loving strains such as water buffalo to introduced species with lower water tolerance in lower areas away from the natural levees. The new species have reduced the pasture value of the floodplain land, particularly with regard to drought resistance.

Because the new species are less water tolerant, they die when submerged for a few days and then begin to rot. This process removes dissolved oxygen from the water. Samples taken after the February 1996 fish kills show extremely low DO levels (as well as other potentially toxic decay compounds) and suggest that this was the major cause of the kills.

Reducing over draining will enable rehabilitation of the swamp areas and encourage the original grasses to return. This will both increase the value of the pasture and also improve the oxygen content of drainage water.

6.6.2 Acid Sulfate Soils

The drainage work constructed over the years has lowered the water table particularly in the back swamps. This has increased the area of exposure of potential acid sulfate soils. The opening up of drains through the alluvial levees has also facilitated the discharge of acid water into the tributary system where previously it might have been contained in the back swamps.
The mechanism for the upward movement of sulfate acidity from the subsoils of the back swamps is not well understood, but may be related to constant evaporation from the soil surface with upward capillary movement from below. Raising the water table is likely to reverse this process at least to some extent.

Redesigning the drainage system to broader and shallower drains is likely to reduce discharges of very acidic water (below pH 4). Careful management with partial reflooding of acid scald areas may result in reclamation. Experiments are presently being carried out at Seven Oaks on scald rehabilitation. Although it is perhaps too early to be definitive, the early results are promising.

### 6.6.3 Aluminium

Oyster farmers on the lower Clybucca Creek expressed particular concern about levels of dissolved aluminium. As well as affecting oysters, aluminium is considered to be the primary cause of injury and death in fish. Aluminium and other toxic metals (particularly iron) are dissolved in water where high acidity occurs. Thus, raising the water table and preventing potential acid sulfate soils from being exposed to oxygen (and thereby preventing the formation of sulphuric acid) will directly reduce the incidence of dissolved aluminium.

### 6.6.4 Data Collection

While there is a reasonable body of evidence to support the discussion on water quality problems, there are no systematic or long term records to provide detailed scientific data. It would seem especially important if major changes are proposed to the mitigation scheme or the drainage system, that proper monitoring be introduced to record the impacts of these changes. This would allow more informed activities elsewhere and also provide input to help adjust changes to achieve optimum performance.

Plans are presently in hand to test various management practices with the potential to impact beneficially on acid sulfate effects. Some tests have already commenced but unfortunately no systematic, quantitative baseline data have been collected. These tests will therefore, have to be judged on a qualitative basis.

If further proposed tests are to be exploited to their full potential then baseline data collection should begin without delay. The collection of water quality data should be co-ordinated with the collection of quantitative data on water levels (Section 6.8.4).

### Outcome

The Committee recommended systematic water quality data collection. Refer to Recommendation 21 in Chapter 7.
6.7 Legal/Legislative

6.7.1 Sell/Lease Back of Rural Land

This proposal involves the Government purchasing low lying land from the existing landowners and then ensuring that it is managed in such a way as to maximise the ecological values. The land could still be used for farming, but only on a sustainable basis. The land would be leased back for farming, but the Government as the owner of the land, would require farming practices compatible with maximising ecological values.

Option i) the Government would purchase low lying land and lease it out ensuring that future management was achieving environmental benefits. This would clearly change the use of the land for farming, e.g. the emphasis would be on wetland drought fodder rather than dryland farming.

Advantages
- land managed to enhance/restore environmental values,
- water quality and other problems addressed.

Disadvantages
- opposition to sales,
- economic viability of managers - need for subsidy?
- funding of purchases.

Overall Assessment

Land use in the lower Macleay has been changing with economic circumstances. Dairy farming has been declining except in competitive, high productivity areas, and marginal land has been given over to beef cattle production. However, land prices remain at relatively high levels encouraged to some extent by rural residential demand.

Some farmers believe that land in the more difficult areas may have been over drained. This has caused colonisation with less productive grass species, or weeds such as smart weed, and a decline in profitability. Return to better water table management may improve the productivity of marginal farms, but many may never return to viability on a stand alone basis.

It is unlikely that the economic conditions for farming will ever return to former levels and this begs the question as to whether some marginal land might be better returned to wetlands as wildlife habitat. There should be a local review of the economics of farm performance over the past 10 to 15 years with some projections of economic return to the community under three scenarios:

i) Existing management practices.
ii) Improved management practices with farmer co-operation on modified drainage/better water table maintenance.

iii) Ecological management with some areas returned to wetland.

Depending on the outcomes of such a review, there could be community support for sell and lease back of the land in some areas.

Outcome

The Committee resolved that finance be considered by Government for sale and lease back to a willing seller. Refer to Recommendation 23 in Chapter 7.

6.7.2 Realign Boundaries

In the past most farms had several different types of land: swamp, levee and up river properties. This enabled the owners to carry on efficiently through all seasons.

Nowadays the holdings are smaller and much of this flexibility has gone.

Option i) to restructure the floodplain holdings so that each owner has both high and swamp land and therefore can manage his property more efficiently.

Advantages
- more efficient operation of farms,
- possible increased employment opportunities,
- higher property values.

Disadvantages
- difficult to resolve equity,
- significant costs in realigning infrastructure (fences, roads, etc.) to suit new boundaries.

Overall Assessment

This is a proposal which has merit in theory. However, the practicabilities of implementing it seem immense. For a start it would require the enthusiastic goodwill of all affected owners and even then it would be very difficult to arrive at solutions which pleased everyone. To work effectively, any implementation would need to be on a voluntary basis, and would be piecemeal rather than affecting whole areas.
Outcome

The Committee resolved that realignment of boundaries should be an available option for Government in local areas. Refer to Recommendation 24 in Chapter 7.

6.7.3 Legal Position on Change

It is difficult to propose any change that might find universal acceptance. There are a large number of stakeholder groups in the lower Macleay that have firmly held views on the causes of environmental problems and on the appropriate methods of correction. It is by no means certain that broad agreement on any course of action could be obtained from all the affected groups. In fact there is no guarantee that all landholders within an affected area would support proposed changes.

Although in the past quasi autonomous government organisations, such as the Drainage Unions or Landcare groups, had a general indemnity from damages actions, it is not certain that they would have sufficient protection in today's legal environment.

Indeed the present position is that the threat of injunction or expensive legal proceedings is usually sufficient to ensure complete inaction on any proposal that might change the status quo.

It will be necessary to explore with Government the steps that might be taken to protect sensible remedial work from the threat of injunction or litigation, and to indemnify the members of any community organisation that are prepared to authorise projects and/or carry out the work

Option i) put the problem before the Government,
Option ii) make insurance or potential compensation available,
Option iii) carry out a careful technical evaluation before proceeding.

Option i) - (Government)

Advantages
• rights and responsibilities enshrined in legislation.

Disadvantages
• difficult to gain priority on the political agenda,
• still open to interpretation of the court.

Option ii) - (Insurance)

Advantages
• will cover any major financial disaster.
Disadvantages
- continuing cost,
- may encourage claims.

Option iii) - (Technical Evaluation)

Advantages
- will address and hopefully eliminate any unsound proposals,
- will give a legal defence.

Disadvantages
- technical correctness does not ensure legal victory,
- most of these issues are a matter of opinion and there will probably always be an "expert" who will say that you got it wrong.

Overall Assessment

The legal question is a major impediment to making alterations to the present system. It can frustrate good ideas and frighten people from trying new initiatives. Unfortunately, there seems to be little that can be done to overcome the problem. The best solution would be for some party (DLWC, Council, Drainage Unions, Landcare) to claim or obtain indemnity, perhaps under provisions similar to those incorporated in Section 733 of the Local Government Act.

Outcome

Council, with active assistance from all interested parties, should approach Government. Refer to Recommendation 25 in Chapter 7.

6.7.4 SEPP14

Some farmers are concerned that they might be subject to SEPP14 wetlands classification if they re-flood land or otherwise modify the drainage to rehabilitate acid sulfate conditions. The state wetlands policy recognises that controlled grazing can be a legitimate use for wetlands. However, the policy is new and its precise application to areas such as the Macleay is presently untested. The Department of Urban Affairs and Planning (DUAP) issued a statement in December 1995 (Circular No. B10) stating that the rehabilitation of "severe acid sulfate scalds" would not lead to the declaration of a SEPP14 wetland. This statement may need to be extended to include rehabilitation of degraded lands to restore wetland pasture species and thereby limit acid runoff from ASS areas.

It may be appropriate for landholders to seek an undertaking from the Government/Local Government that reclamation of the land will not give rise to any unreasonable restriction on its use.
for agriculture or other purposes that would have been available on any other ordinary rural land in the district.

Option i) that formal application be made to the Government to ensure that if farmers do restore wetland areas on their land, they will be able to manage their farms in the same way as other farmers in the district.

Advantages

- one of the uncertainties in the decision making process will be removed,
- strong disincentive for farmers to co-operate in improving the environment unless this problem is overcome.

Disadvantages

- if agreement not achieved, subjects farmers to a potentially lengthy and costly EIS process.

Outcome

An application already made to Government has resulted in some clarification of the situation (DUAP Circular B10). A further application may have to be made to fully clarify the situation.

6.8 Other Issues

6.8.1 Consultation

Concerns were raised that there had been insufficient consultation in the past between Council and potentially affected members of the floodplain community. In some ways the floodplain management process has been a first step towards correcting this problem, but there is a need for continuing consultation, both on general issues and on specific proposals.

The process could be expanded to incorporate the diverse interests of the valley and thus enable the wider community to appreciate the problems that others face on the floodplain. If carried out successfully, this could lead to a much greater acceptance of any proposed changes to the flood mitigation system and of the continuing need to operate the system in the best interests of the floodplain community as a whole.

A critical component of the consultation process is that all proposals for change are presented in a concise and understandable manner and that all predicted impacts are stated explicitly with any underlying assumptions explained. Moreover, all possible outcomes (based on knowledge of the system at the time) of changes should be considered to provide stakeholders with an understanding of the consequences of action and inaction.
6.8.2 Employment Opportunities

Farmers in the Belmore/Kinchela area are of the view that if the frequency of flooding could be reduced in their area to a level similar to that experienced elsewhere in the floodplain, this would enable them to operate their farms more efficiently and thus employ more staff. The particular problems of this area are being looked at in more depth in a separate and more detailed study as referred to elsewhere.

Outcome

The Committee resolved that employment opportunities shall be considered in evaluating options. Refer to Recommendation 26 in Chapter 7.

6.8.3 Stress and Trauma

Stress is a recognized consequence of flooding. It can affect both an individual's health and their personal relationships within the community. A major concern causing stress for farmers is the potential loss of income which can last for up to a year after a flood. While the drama of a natural disaster (in this case flooding) cannot be removed, its consequences can be lessened if people are prepared in advance and have adequate warning to secure personal belongings and valuables. For farmers it also relates to personal safety and the safety of their stock which can become isolated and drown during a flood.

Mitigating the effects of stress evolves around increased flood awareness, better flood warning and appropriate support from Government agencies after a flood to help people get back on their feet. The particular costs of stress are difficult to quantify but are implicitly included in "intangible damages" from flooding, and thus form part of the evaluation of benefits and costs from proposed floodplain management measures.

Outcome

The Committee resolved that the prevention of stress and trauma should be considered in evaluating options. Refer to Recommendation 26 in Chapter 7.

6.8.4 Water Level Gauges

At present the floodplain is served by a fairly comprehensive network of manually read water level gauges which was installed in the early days of the Macleay County Council. It would be wise to review this network to ensure that all relevant gauges are in good repair and that readers are appointed and trained.
Kempsey Shire Council has recently installed automatic, telemetry gauges on the main river at Kempsey Traffic Bridge, Belmore Junction, Kinchela Junction and Jerseyville. This network has provided very useful information on the last few minor floods. It should be complimented by two more gauges, one in the vicinity of Seven Oaks Bend and one at the downstream end of Rainbow Reach. A gauge approximately midway between Jerseyville and Kinchela would also be useful but is not a high priority. The extra gauges would not only provide additional useful information in their own right but would ensure that the network provided adequate data even if one of the recorders malfunctioned.

Further useful information could also be obtained from gauging selected drains to establish their performance during flood recessions and dry periods. The gauges should be semi portable so that they could be moved to different sites after a few years if required. This exercise should be closely co-ordinated with the collection of water quality data (Section 6.6.4).

Outcome

The Committee resolved that more telemetry gauges should be installed. Refer to Recommendation 22 in Chapter 7.

6.8.5 Stock Movement During Floods

At present the Rural Lands Protection Act provides that stock cannot be moved on public roads unless a walking stock permit has been obtained and suitable stock signs are displayed.

It is proposed that the Government be approached to amend the Act to allow movement of stock in emergencies (flood or fire) without a permit. General area wide warning signs would be displayed by the Council in place of signs being required by each individual farmer.

Option i) to amend the Rural Lands Protection Act to allow movement of stock in emergencies providing general warning signs are displayed.

Advantages

• the initiative would reduce delays in commencing stock movement,
• general signs provided by Council would provide adequate warning without imposing significant costs/delays on farmers.

Disadvantages

• possible increased confusion to road users due to less specific road signage.

Overall Assessment

Given the practical requirement to move cattle as soon as possible after a warning has been issued, and the general awareness of flooding in the rural community, the possible disadvantage
is more perceived than real. Amendments to the Act would give Council direct control over stock movements and would allow quicker reaction to a pending emergency.

Outcome

The Committee resolved that Government be approached to amend the Rural Lands Protection Act. Refer Recommendation 28 in Chapter 7.

6.8.6 Raising/Realignment of the Pacific Highway

The Pacific Highway can affect flood behaviour in the area between Frederickton and Clybucca. Residents are concerned that previous work on raising the Highway has had adverse impacts on local flooding.

Option i) that the concerns of local residents regarding the impacts of previous works be addressed by the RTA in the context of any proposed future work on the Highway.

Advantages
• would provide the opportunity to resolve the perception of past mistakes,
• any corrective works can be combined with other planned works.

Disadvantages
• may be a delay in addressing the matter although further work in this area is believed to be imminent.

Overall Assessment

The proposal is probably the quickest way to investigate and remedy any adverse impacts from previous works. It would also lead to a continuing awareness of the need to assess any future works.

Outcome

Council to request the RTA to consult with both Council and local residents to resolve any outstanding flooding or drainage problems as part of any future works on the floodplain. Refer Recommendation 29 in Chapter 7.
6.8.7 The Greenhouse Effect

The Greenhouse Effect results from the presence of gases in the atmosphere which allow the sun's rays to penetrate to the earth but reduce the amount of energy radiated back. It is this trapping of the reflected heat which has enabled life to exist on earth.

Recently, there has been concern that increasing amounts of greenhouse gases resulting from human activity may be raising the average surface temperature of the earth. This in turn may affect the climate and sea level. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

Climatic Change

It has been suggested that one possible consequence of the Greenhouse Effect would be an increase in rainfall. Recent advice from the Bureau of Meteorology indicates that the possible mechanisms are far from clear, and there is no indication that the changes would in fact increase design rainfalls for major storms. Even if an increase in rainfall (total annual rainfall) does occur, the impact design rainfalls may not be adverse. Hence the Bureau has no intention at present of revising design rainfalls to take account of the Greenhouse Effect.

It has also been suggested that the Cyclone Belt may move further south. The possible impacts of this on design rainfalls cannot be ascertained at this time as little is known about the mechanisms that determine the movement of cyclones under existing conditions.

Sea Level Change

Another possible consequence of an increase in the earth's average surface temperature could be a rise in sea level. Assessing any impact is complicated by other long term influences on mean sea level changes. Latest estimates of possible impacts seem to average around a possible rise of 0.2 m by the year 2050. This is within freeboard allowance adopted in Council's present policy.

Conclusions

It is recommended that the impact of the Greenhouse Effect on design flood levels in the Lower Macleay should be monitored as more information becomes available.

Given the present state of knowledge it is not possible to quantify any potential impacts on flood levels from the Greenhouse effect. The best that can be done is to consider it as one factor in setting freeboard allowances under the Floodplain Management Plan. Refer Recommendation 30 in Chapter 7.
7. RECOMMENDATIONS

7.1 Village Mitigation Options

1. Council proceed with concept designs of levees at Frederickton, Smithtown and Gladstone with a view to confirming the economics and social and environmental impacts of the proposals.
2. Further consideration be given to levee protection or flood free access from Jerseyville.
3. Minimum floor levels at each village to be set in the Floodplain Management Plan.
4. A comprehensive public education program, including local schools, be devised and implemented on a regular basis.

7.2 Structural Options

5. Small and progressive modifications be made to the Clybucca Creek headworks operations to control the water table and improve water quality (pH, Al, salinity, DO) upstream of the gates. The process to be monitored upstream and downstream of the gates in close co-operation with Seven Oaks Drainage Union projects involving ponding and water table management.
6. Raising of levees on the Belmore River and Kinchela Creek, together with modifications to the operation of the floodways, to be addressed in a Review of Environmental Factors (REF).
7. No works to be carried out on Connection Creek to alter flood flows to or from the Hastings River or Killick Creek.
8. The low points in the levee and bank on the left bank at Rainbow Reach to be filled in to produce a consistent level of protection. This work might be considered as part of the Belmore/Kinchela REF.
9. The extent of bank erosion problems throughout the floodplain be determined and a Management Plan prepared. The already identified problems on Clybucca Creek would be included in this Plan.
10. Dredging is not a practical flood mitigation option from the perspective of either economics or environmental impact and therefore should not be pursued further.
11. None of the flood channels investigated would have a significant impact on flooding throughout the floodplain. Channels should still be considered in localised areas in conjunction with detailed economic and environmental assessment.
12. Council to seek advice from DLWC on likely availability of 2:1 funding for flood mounds in areas where there is no natural high ground and no evacuation routes are available for moving cattle into high land. Other sources of funding are also to be investigated. Council to be requested to waive the development application fee for mounds and to identify sources of material. The Floodplain Management Plan should identify suitable areas for construction of mounds.
13. Council is to survey to low points along both banks between Frederickton and Jerseyville to identify low points in the levee scheme with a view to filling these to design grade in consultation with local landholders.

7.3 Changes to Operations Options

14. Council should continue its efforts to upgrade communications with the floodplain community to enable more effective dissemination of flood warning advice.
15. The current operation (February 1996) of the Belmore and Kinchela floodways should be retained until the proposed REF is resolved.
16. The problem of inadequate post flood drainage in the upper Belmore due to operation of the headworks should be resolved.
17. The present flood mitigation scheme has been in operation for several decades. There is a need to re-examine the scheme in the light of its performance and present day standards.
18. Council is to check the suitability of fitting flood gates to the two ungated drains in Upper Belmore, and examine the possibility of changing the operation of the Belmore headworks to improve post flood drainage.

7.4 Drainage Modification Options

19. The Floodplain Management Plan will include proposals to modify management practices to raise the water table where necessary. The proposals will be based on an investigation of needs in various areas and may include, but will not be limited to, the options set out in Section 6.5.
20. Moves to improve the quality of drainage water should reduce the problem of fish becoming trapped and killed in the Belmore River and Kinchela Creek and no other measures are proposed at this time.

7.5 Water Quality/Data Collection Options

21. Council should purchase a series of water quality data loggers. These would initially be installed on the Belmore, including the monitoring of apparent saltwater intrusion through the Killick Creek headworks. Once the Belmore investigation is completed the instrumentation could be transferred to other areas as required. They would be used to obtain data for both flood and non-flood conditions. Additional sources of funding for purchase and operation should be considered. As funds become available more should be purchased and installed. Data are to be provided on request to other bodies. The objectives of the data collection are to be clearly specified.
22. Two additional telemetry sensors should be installed on the Macleay at Seven Oaks Bend and Rainbow Reach. Consideration should also be given to installing a gauge in the vicinity of Summer Island and some sensors in selected drains.
7.6 Legal/Legislative Options

23. The Government should consider buying and leasing back land in local areas where there is a willing seller. Rate relief could also be considered to encourage changed management practices.

24. Realigning boundaries to provide a better mix of land types could be considered in local areas where there is a general willingness to participate.

25. Council, in association with relevant Government Departments and peak industry bodies, should approach Government to seek an indemnity provision for individuals, groups or agencies against claims for flood damages resulting from modifications to existing flood control, drainage works or practices. The indemnity would apply where the modifications were designed to reduce the environmental and agricultural productivity impacts of over drainage and/or lowered water tables so long as flood protection is not compromised. It is suggested that the indemnity could follow similar principles to those incorporated in Section 733 of the Local Government Act.

26. Potential employment opportunities and relief of stress and trauma should be considered in evaluating changes to the flood mitigation scheme.

27. Council, in conjunction with the Floodplain Management Steering Committee, should investigate management methods for Acid Sulfate Soil issues including introduction of a DCP or LEP or amendment to existing floodplain management policies.

28. The Rural Lands Protection Act be amended to make provision for the movement of stock in time of flood or fire without the need to obtain a moving stock permit or stock signs, subject to local authority approved signs being in place.

29. Council to request the RTA to consult with both Council and local residents to resolve any outstanding flooding or drainage problems as part of any future works on the floodplain. This particularly applies in relation to any proposed upgrading works on the Pacific Highway.

30. The impact of the Greenhouse Effect on design flood levels in the lower Macleay should be monitored as more information becomes available.

If these recommendations are to come to fruition there is a need for close co-operation between all interested parties.
8. REFERENCES

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    December 1980.
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The NSW Wetlands Management Policy
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FIGURE 8
DESIGN FLOOD PROFILES
APPENDIX A: URBAN FLOOD DAMAGES

A1. INTRODUCTION TO FLOOD DAMAGE ASSESSMENT

Damages due to flooding fall into two broad classes: "Tangible" and "Intangible". Tangible damages are those which can be estimated in dollar terms while Intangible damages refer to such things as increased feelings of insecurity, mental stress and associated health problems, inconvenience and social dislocation. The latter are clearly very difficult to quantify in any meaningful way. Sometimes they are given an economic cost by applying a factor to the Tangible damages.

Because of this problem, estimates of flood damages concentrate on the tangible aspects, which are further divided into Direct and Indirect damages. Direct damages are caused by physical contact with floodwaters while indirect damages are principally the costs incurred in the aftermath of the flood event. These include such things as clean up costs, loss of wages, cost of temporary accommodation, etc.

A number of damage assessments have been carried out after flooding in NSW in the past few years. The more relevant of these to the Macleay River floodplain are the Western Sydney Floods in August 1986 (Reference A1), the Nyngan Flood in April 1990 (Reference A2) and the Inverell Flood in February 1991 (Reference A3).

The general approach of all the studies is to quantify direct damages in terms of an average value per unit (house, shop, factory) for a given depth of flooding over the floor. Indirect damages are estimated either as a percentage of direct damages or as so much per property regardless of depth. The different classifications of flood damaged property are described separately in the following sections.

The present study did not set out to provide a detailed inventory of potential flood damages along the lower Macleay River. Rather, the objective was to identify damages that could be prevented by implementing the mitigation options discussed in Chapter 5. For this reason some potentially large damages such as might occur in an extreme flood have not been quantified.

A2. TANGIBLE DAMAGES

A2.1 Residential

It is almost impossible to anticipate the flood damages which might occur in any individual house, however, because large numbers of houses tend to be flooded, it is possible to provide a fair estimate of average damages. When these averages are applied over a large number of houses, the total damages estimate should be reasonably accurate.
Direct residential damages are subdivided into four categories.

- **Internal Damages**
  
  This category covers damages to the contents of the houses, such as carpets, furniture, appliances, etc. The damages will vary considerably with the depth of floodwaters over the floor. At Nyngan the average flood damages was $9400 and the average depth 0.75m.

  Reference A2 adopted the following relationship:

  \[
  D = 0.06 + 1.42H - 0.61H^2 \quad \text{for} \ H < 1.0m \\
  D = 0.75 + 0.12H \quad \text{for} \ H \geq 1.0m
  \]

  where,

  \( H \) = height above floor

  \( D \) = damage ($)

  \( D_2 \) = damage ($) for \( H = 2m \)

  Suitable values for \( D_2 \) are $13 000 for small houses and $16 000 for medium sized houses.

- **Structural Damages**

  These relate to the actual structure of the building and are a function of both depth and velocity. Structural damages at Nyngan and Inverell were estimated at approximately $5000 per house, but at both locations high velocities were involved. On the Macleay River there are unlikely to be high velocity flows. Structural damages have been assumed to be $3000 for flooding 0.5m above floor level for a medium sized house in reasonable condition.

- **External Damages**

  This covers items outside the house. It includes garden sheds and contents, gardens, fences, etc., but the major component of the damages relates to motor vehicles. External damages are therefore very sensitive to the amount of warning time and the availability of flood free access. At Nyngan external damages amounted to $4500 per house, because the final flooding of the town came quickly and there was nowhere to evacuate vehicles. In the 1986 Sydney floods, average external damages were $2150 and at Inverell $2500.

  A damages figure similar to that at Inverell ($2500) seems appropriate.
Indirect Damages

Indirect residential damages can vary significantly. One significant factor is the time which elapses before people can return to their houses. In the Sydney floods of 1986, indirect damages were calculated as 5% of direct damages, but did not include cleanup costs. The costs for Nyngan were $7700 per property and were $2400 for Inverell. The Nyngan costs reflect the fact that residents were evacuated for several weeks. The Inverell costs seem more appropriate to the Macleay Floodplain. An allowance of $2500 per flooded house was made.

A2.2 Commercial/Industrial

Damages to commercial and industrial buildings are much more difficult to quantify for two reasons:

- the damages to a given property vary much more than with houses, as they are heavily influenced by the type of business being carried out and the amount of stock carried,
- industrial enterprises in particular, cannot simply be averaged out. Where large factories or warehouses are involved (in particular the Smithtown dairy factory), the only way to get a good estimate of potential damages is to do a site specific survey of the enterprise.

In the absence of definitive information on commercial properties these were treated as residential.

The Smithtown dairy factory was excluded from the analysis because of difficulties in estimating potential flood damage.

A2.3 Public Assets

Damage to public property can contribute a significant proportion to total flood costs. Important items include roads, parks, car parks, water and sewerage, electricity, telephone and gas.

In the Inverell flood of February 1991, direct costs to the local Council accounted for $1M out of total direct damages of $10.5M.

Table A1 summarises the Inverell Council costs.
Table A1: Inverell Flood of February 1991 - Damages to Council Assets

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($000)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parks and Gardens</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Buildings (including amenities block)</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Car Parks</td>
<td>244</td>
<td>(200,000 on one)</td>
</tr>
<tr>
<td>Roads (in the Town)</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>Suspension Foot Bridge</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>

One point that emerges from the table is that single items, such as a severely damaged car park or a destroyed bridge, can significantly affect the total bill.

On the Macleay River high flow velocities as occurred in the Inverell Flood of February 1991 are unlikely. Damages to Public Assets were excluded from the analysis.

A2.4 Intangible Damages

Intangible damages are those flood damages which by their nature are extremely difficult if not impossible to quantify in monetary terms. Generally these damages are indirect and occur following a flood.

Intangible damages can be categorised as follows:

- Residential

Post flood damage surveys have linked flooding to stress, ill-health and trauma in the residents. For example the loss of memorabilia, pets, insurance papers, etc., may cause stress, and as a consequence, ill-health. In addition flooding may affect personal relationships by contributing to marriage breakdowns or leading to stress in domestic/work situations. Residents may worry each time heavy rain occurs and there is a threat of flooding. This may be reflected in increased sickness or depression requiring psychiatric help. These effects may therefore induce a lowering in the quality of life of the flood victims.

Flood victims may also suffer injuries during the flood or during the clean-up process. Whilst the direct costs of such injuries may be accounted for in the flood damages survey, the physiological effects or discomfort may last for a long time.
The most extreme consequence due to flooding is death and unfortunately this is not a rare occurrence. The literature provides many examples of deaths in Australia of local residents and rescue workers as a result of flooding.

- **Commercial/Industrial**

Whilst a large number of businesses carry insurance for loss of trade during the period of the flood, and until the clean-up is complete, they may still suffer a financial loss. For example business confidence from clients may be reduced permanently or clients may take their business elsewhere during the flood/-clean-up period and may never revert to the original supplier.

- **Services**

The loss of services to customers, e.g., transport disruption, loss of education, loss of power, etc., will occur and these are generally not taken account of within the tangible damage category.

- **Environmental**

Environmental damage may occur as a result of flooding; for example flora and fauna may be lost. However the riverine environment is a natural system and it is difficult to quantify the effects of flooding. Some flora and fauna can in fact benefit from flooding. The breeding cycle for some avifauna is typically triggered by flooding. The loss of man-made structures which have a "heritage" or non-replaceable value are real costs which cannot be quantified.

No attempt has been made to quantify intangible damages in this study. When considering benefit/cost figures which may be marginal in terms of economic worth, the likelihood of additional intangible damages which could be prevented by the works should be taken into account by implying a higher real value to the benefits figure.

**A2.5 Average Annual Damages**

While the total likely damages figure in a given flood is useful to get a "feel" for the magnitude of the flood problem, it is of little value for economic evaluation. When considering the economic effectiveness of a proposed mitigation option the key question is the total damages prevented over the life of the option. This is a function not only of high damages which occur in large floods but also of lesser but more frequent damages which occur in small floods.

The standard way of expressing flood damages is in terms of average annual damages. These are calculated by multiplying the damages that can occur in a given flood by the probability of the flood occurring in a given year. They are then summed across the range of floods. By this means
the smaller floods which occur more frequently are given a greater weighting than the rare catastrophic floods.

A2.6 Benefit/Cost Analysis

The economic viability of flood mitigation works can be assessed in terms of the costs of the works and the potential flood damages costs which could be saved as a result of the works. The latter are derived in terms of Annual Average Damages while the costs can be estimated from concept designs.

Before the costs can be compared with the savings due to the reduction in flood damages, the two numbers have to be expressed in common terms. The most effective way to do this is to convert the Average Annual Damages to a Net Present Worth (NPW) which can be compared directly with the present costs. To calculate the NPW the life of the works and an estimated rate of return on investment need to be set. The economic lives of the levees and roadworks have been taken as 25 years and the representative rate of return as 7% which is in accordance with NSW Treasury guidelines.

The ratio of the NPW of benefits (average annual damages prevented) to costs is the Benefit/Cost ratio (B/C ratio). The relevant figures are included in the discussions of options in Chapter 5.

The benefits calculated in this report are for Tangible Damages only. This means that to assess the full benefits of the works one needs to take into account the potential Intangible Damages prevented. In conventional economic theory, a B/C ratio of 1.0 is required to achieve a worthwhile project. With flood mitigation projects this is only rarely achieved with Tangible Damages alone. In effect, if the B/C ratio for Tangible Damages is at least 0.3 to 0.4, implicit consideration of intangibles could be sufficient to justify a project. In addition, given the difficulties in calculating flood damages and benefits, B/C ratios are more useful in determining which is the better of a number of alternatives rather than whether a project is economically viable in an absolute sense. Social and environmental factors also need to be taken into account in finally determining which of various competing projects should proceed.

A3. REFERENCES

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APPENDIX B: MODELLING OF SEVEN OAKS DRAINAGE

B1. INTRODUCTION

A number of issues were raised in the public meetings which related specifically to the drainage of the Seven Oaks area. These included the impact of the Clybucca headworks on upstream water levels and the potential impacts of placing weirs across the main Seven Oaks drain.

In order to determine the possible consequences of these proposals, a hydraulic model was developed to simulate both post flood drainage of the Seven Oaks area and tidal influences.

B2. THE MODEL

A separate RUBICON model was used to simulate the Seven Oaks area. The model layout is shown on Figure B1. The model incorporates the major man-made drains and significant natural depressions upstream of the Clybucca headworks.

Topographic information for the model was obtained from construction plans for the man-made channels and survey specifically carried out for this study by Blyth Hadlow & Associates.

B3. RESULTS

The model showed very effectively the impact of the headworks on upstream water levels under tidal conditions. Figure B2 shows modelled levels upstream and downstream of the gates. The downstream levels represent an idealised tide ranging from +0.4 mAHD to -0.4 mAHD. The upstream level reduces below the mid range (0 mAHD) after five cycles and would continue to reduce (although more slowly) until there was an input of water from upstream.

The effect would be even more marked during larger tidal variations such as those experienced around Christmas each year.

Figure B3 shows the impact of inserting a weir in the Seven Oaks Drain at Yerbury's bridge. The weir crest was assumed to be at 0.0 mAHD. The graph shows the recession from a flood or fresh and indicates that the weir would significantly raise the upstream water level. The downstream level would fluctuate slightly more because of the lost storage upstream of the weir to allow damping.