LAKE MACQUARIE CITY COUNCIL

LAKE MACQUARIE WATERWAY FLOOD RISK MANAGEMENT STUDY and PLAN

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Project Lake Macquarie Waterway Flood Risk Management Study and Plan	Project Number **29076**
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AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
BOM	Bureau of Meteorology
CFERP	Community Flood Emergency Response Plan
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	Department of Environment, Climate Change and Water (now OEH)
FPL	Flood Planning Level
GIS	Geographic Information System
HWC	Hunter Water Corporation
IFD	Intensity, Frequency and Duration of Rainfall
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
LIDAR	Light Detecting and Ranging (ALS and LIDAR refer to exactly the same process of obtaining survey)
m	metre
m^3/s	cubic metres per second
NASA	US National Aeronautical and Space Administration
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SES	State Emergency Service
SQID	Stormwater Quality Improvement Device
SWW	Severe Weather Warning
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
WBNM	Watershed Bounded Network Model (hydrologic computer model)
WSUD	Water Sensitive Urban Design
WTP	Water Treatment Plant
1D	One dimensional hydraulic computer model
2D	Two dimensional hydraulic computer model

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1. FOREWORD

The State Government's Flood Prone Land 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 flood management process in NSW has recently been up-dated to incorporate consideration of the effects of climate change, and particularly the effects of sea level rise, on mean water levels and on flood levels.

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/foreshore Risk Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.

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

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.

This Lake Macquarie Waterway Flood Risk Management Study and Plan constitutes a review of the second and third stage of the management process, namely the August 2000 Lake Macquarie Floodplain Management Study and the July 2001 Lake Macquarie Floodplain Management Plan. This review has been prepared by consultant WMAwater for Lake Macquarie City Council and was undertaken following a review of the 1998 Lake Macquarie Flood Study, to include the June 2007 long weekend storm/flood event and incorporation of the implications of climate change. The results of this Waterway Flood Risk Management Study and Plan Review will provide the basis for the future management of flood liable foreshores areas surrounding the Lake Macquarie waterway. The study concentrates on those areas of the foreshore within the boundaries of Lake Macquarie City Council, with no investigation of land within the Wyong local government area.

2. LAKE MACQUARIE WATERWAY FLOOD RISK MANAGEMENT PLAN

2.1. Introduction

The Lake Macquarie Waterway Flood Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (April 2005) and the August 2010 Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessment and:

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

The Lake Macquarie waterway (the lake itself) has a catchment area of approximately 700 square kilometres to the Pacific Ocean. Of this approximately 110 square kilometres (16%) is the area of the lake. The lake is approximately 22 kilometres in length and up to 8 kilometres wide, with a perimeter of 170 kilometres.

The lake is surrounded by bushland, parkland, and residential developments that value its scenic quality as well as its commercial and recreational value. The entrance to the Pacific Ocean is by the narrow and shallow 4 kilometre long Swansea Channel. The lake level is normally at 0.10 mAHD and tidal fluctuations are generally only ±0.05m. Elevated ocean levels (high tides and storm surge) as well as intense rainfall over the catchment cause the lake level to rise.

The highest recorded lake water level is 1.25 mAHD in 1949 (at Marks Point), with 1.05 mAHD reached in the June 2007 long weekend storm/flood event and 1.00 mAHD in February 1990. The June 2007 long weekend storm/flood event, and the February 1990 flood event were of the order of a 30 year Average Recurrence Interval (ARI) design event.

Flooding causes significant hardship (tangible and intangible damages) to the community, and the impacts will increase as sea levels rise, and for this reason Lake Macquarie City Council has undertaken a program of studies to address the management of flood risks.

The present review was initiated by Lake Macquarie City Council to reassess flood risk management options and incorporate the NSW Government's sea level rise benchmarks, based on predictions by the Intergovernmental Panel on Climate Change (IPCC) and the CSIRO Technical Review for Australia, and also the potential increase in rainfall intensities due to climate change, and evaluate suitable adaptation measures.

2.2. Risk Management Measures Considered

A matrix of possible management measures was prepared and evaluated in this Waterway Flood Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer Section 6.2) including:

- Flood mitigation dams and retarding basins: - on the basis of high cost, large footprint, and environmental impact,
- Modifying the existing Swansea entrance channel or constructing a new entrance at another location: - on the basis of high cost, may exacerbate flooding, and environmental impact,
- Catchment treatment, to increase soil infiltration and storage of rainfall in the catchment: on the basis of minimal reduction in flood levels,
- Voluntary purchase of flood affected buildings, as it is uneconomic and has a high social impact.

The full range of measures was evaluated in Section 6 and the outcomes are summarised in Table 1. Community opinion on the full range of options was canvassed during the public exhibition period in October and November 2011. However it should be noted that these outcomes may change in time if community expectations change and/or as an outcome of the proposed local area adaptation plans. The final options documented in the Lake Macquarie Waterway Flood Risk Management Plan reflect the current community input.

Table 1: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
FLOOD MITIGATION DAMS, RETARDING BASINS, ON-SITE DETENTION (See 6.2.1)	Reduce the peak flow from the catchment into the lake by increasing the volume of flood storage in the catchment.	Not considered further as these measures have negligible impact on lake flooding. The size of storages required to make a difference to lake floods are very large, making them impractical on environmental, social and economic grounds. Smaller on-site detention can help water quality and local drainage, but has little impact on lake flooding.
ENLARGE OR DUPLICATE THE ENTRANCE (See 6.2.2)	Increase the flow rates and volumes of exchange between the ocean and the lake.	Not considered further as it will exacerbate the peak height of most lake floods due to increased penetration into the lake of ocean tides, storm surge and wave set up. May make tidal inundation from sea level rise worse by increasing tidal range in the lake.
MANAGEMENT OF THE ENTRANCE (See 6.2.2)	Ensure changes in Swansea channel due to sea level rise, dredging, silting up, or erosion do not exacerbate flooding.	Currently dredging is undertaken to maintain a navigable channel and has minimal or no effect on normal lake levels or flood levels. Channel condition and function is monitored regularly. Management of the entrance by constructing barriers or locks will not be a viable means of reducing flooding or preventing sea level rise in the lake.
CATCHMENT TREATMENTS (See 6.2.3)	Reduce volume of runoff from catchment by maximising water retention and absorption, and minimising impervious surfaces such as roofs and roads.	These measures can be effective in small catchments, to protect local creeks, and to improve water quality, but are not effective in larger catchments or in reducing lake flood levels.
EARTHEN OR CONCRETE LEVEE BANKS, FLOODGATES,	Prevent or reduce the frequency of flooding of protected areas. Prevent or	Relatively expensive for larger structures but may be economically feasible for smaller structures on the lake. May cause local drainage problems and social problems

AND PUMPS PREVENTING FLOODING AND PERMANENT INUNDATION (See 6.3.1)	delay permanent inundation from rising sea levels.	due to restriction of waterfront access and views. No specific sites have been investigated or identified at this time. In some cases this may be the only option to prevent inundation from sea level rise.
WORKS TO MINIMISE LOCAL DRAINAGE PROBLEMS (See 6.3.2)	To reduce the incidence of local runoff ponding in yards and streets.	Flooding in this manner does not usually enter buildings but it occurs frequently and causes significant inconvenience. In low-lying areas with little or no fall to drainage basins (the lake) there is no easy or cheap solution. Flap-gates on drains can reduce local flooding from high tides. A community based approach should be introduced to monitor, identify and (possibly) resolve some problem areas.
REDUCE THE IMPACTS OF WAVE RUNUP (See 6.3.3)	To prevent wave run up increasing flood levels and flood damage in foreshore areas.	The wave runup effect is site specific and varies significantly around the lake depending on local aspect and weather conditions. Seawalls, other foreshore structures and/or vegetation can protect against waves, but may not be effective in times of flood (see levees 6.3.1), and can shift the problem to neighbouring properties. Properties should be set back from the shoreline where possible.
PROPERTY MODIFICATION:		
HOUSE RAISING (See 6.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	All flood damages will not be prevented. Only suitable for non-brick buildings on piers. The cost is approximately $60,000 per house, but can vary considerably and is unlikely to be cost effective. Only suitable for a small number of buildings and not attractive to all residents. Nevertheless it should be investigated further as, along with levees, house raising is one of the only measures to mitigate increased flood levels from sea level rise, although it is not appropriate in areas where the land beneath buildings becomes permanently or frequently inundated. Council should consider whether "slab on ground" construction is appropriate if there is the possibility that the house may require raising in the future.
FLOOD PROOFING (See 6.4.1)	Prevent flooding of existing buildings by sealing all the entry points.	Generally only suitable for brick, slab on ground buildings. Less viable for residential buildings but should be considered for non residential buildings of slab on ground construction.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (See 6.2.4)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	High cost per property. Applicable for isolated, high hazard properties in flood liable areas. None have been identified in the study.
MODIFICATION TO THE S149 CERTIFICATE (See6.4.4)	S149 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	Council should review flood and permanent inundation related information on the Section 149 Certificate to bring it in line with the findings of this Flood Risk Management Plan. Council should make property information on flooding accessible on the internet.
STRATEGIC PLANNING ISSUES (See 6.4.2 & 6.4.3)	Reduce potential hazard and losses from flooding, tidal inundation, and permanent	Well-established processes are in place for dealing with land-use in flood hazard areas. However, permanent inundation and changes in flood hazard over time, as a

	inundation by appropriate land use planning.	result of rising lake levels, are new issues and will require new responses. Land use planning will have to consider the possibility that some foreshore areas may become unfit for habitation due to permanent inundation, loss of infrastructure and services, increased flood hazard, and loss of access. Protection measures (levees, filling etc), planned retreat, additional conditions on development, and changes in zoning are possible planning responses. Retreat and adaptation of foreshore ecosystems (saltmarsh, wetlands etc.) needs to be included in future land use planning. Local adaptation plans should be developed, in close consultation with affected communities, to consider these issues as they affect each area.
PROVISION AND MAINTENANCE OF INFRASTRUCTURE AND SERVICES (See 6.4.5)	Ensuring infrastructure and services can be provided and maintained for the life of a development.	A risk and adaptation assessment to be undertaken for each service in each foreshore area as part of local adaptation plans for foreshore management areas. Asset life and access to services will have to be determined when assessing individual developments. Facilities such as foreshore parkland may not be replaced if inundated or damaged, but provision may be made to allow retreat and relocation.
MINIMISE THE RISK OF ELECTROCUTION (See 6.4.6)	Design new electrical work, retro-fit existing electrical work, and educate residents, to prevent live wires going underwater in floods.	New circuits in habitable dwellings are installed at or above the 100 year ARI flood level plus 0.5m freeboard. A risk and adaptation assessment to be undertaken to look at ways to encourage residents to retro-fit existing properties, with circuit breakers, for example identify and upgrade public facilities. Use education and awareness campaigns to alert residents to the danger and suggest solutions.
RESPONSE MODIFICATION:		
FLOOD WARNING (See 6.5.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	System currently in place but it is based largely on regional catchment data. A more specific Lake Macquarie system that includes the effect of elevated ocean levels, wave runup and sea level rise could provide greater accuracy. The cost to improve the system is unknown but it is likely to be small and will provide a high benefit/cost ratio.
FLOOD EMERGENCY MANAGEMENT (See 6.5.2	To ensure that evacuation can be undertaken in a safe and efficient manner.	The SES Flood Plan and Lake Macquarie Local Flood Plan should be updated to include more local Community Flood Emergency Response Plans for vulnerable communities. Currently, only Dora Creek has such a plan. The cost to improve the Plan is unknown but it is likely to be small and will provide a high benefit/cost ratio.
PUBLIC INFORMATION AND RAISING FLOOD AWARENESS (See 6.5.3)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	A cheap and effective method but requires continued effort.
OTHER MANAGEMENT MEASURES		
PLANNING REGULATIONS FOR TOURIST/CARAVAN PARKS (See 6.6.1)	To ensure that tourist and caravan park development is compatible with the flood hazard and temporary residents have an adequate	Review Council's policy on affected caravan parks located on or adjacent to the lake foreshore. Develop flood awareness program for temporary residents of caravan parks and other tourist accommodation in flood hazard areas.

	level of flood awareness.	
MINE SUBSIDENCE (See 6.6.2)	The Mines Subsidence Board has indicated that parts of Lake Macquarie waterway are within, or may become within, a mine subsidence area.	Current practice is to manage mining to prevent longwall extraction beneath foreshore areas. The extent of these management areas needs to be reviewed with the relevant State agencies to make allowance for sea level rise. If already mined areas are likely to experience continued subsidence, further detail is required to define the likely extent and magnitude of mine subsidence and an appropriate allowance, over and above the 0.5m freeboard, should be included in the flood development assessment process.
FLOOD INSURANCE (See 6.6.3)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	Does not reduce damage, but spreads the cost. Insurance against catchment (rainfall-induced) flooding is commercially available at a price, and governments are currently considering universal or subsidised schemes. Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise (ocean-induced) is not available.

2.3. Foreshore Risk Management Measures in Plan

The recommended measures are described below (in no particular order within each priority group). The measures will be further refined and assessed by development of detailed local area adaptation plans for each foreshore management area.

<u>**HIGH Priority**</u>

1. **Undertake a detailed assessment (Local Area Adaptation Plans) for each foreshore management area, in consultation with each affected community, of the implications and adaptation measures available to plan for and mitigate the effects of sea level rise (flooding and tidal inundation).**
    - **Cost:** moderate
    - **Responsibility:** Lake Macquarie City Council
    - **Timeframe:** begin 2012 and aim to complete priority areas by the year 2015

2. **Undertake a detailed review of the provision and maintenance of services and infrastructure in the foreshore areas in the year 2050 and 2100.**
    - **Cost:** moderate
    - **Responsibility:** Lake Macquarie City Council and other service providers
    - **Timeframe:** by the year 2015 and/or in conjunction with development of plans in 1 above

3. **Establish criteria to define when land becomes "unsuitable" for current or proposed future use due to permanent inundation.**
    - **Cost:** moderate
    - **Responsibility:** Lake Macquarie City Council
    - **Timeframe:** by the year 2013 and/or in conjunction with development of local area adaptation plans in 1 above

4. **Review the wording on the Section 149 certificates, development restriction certificates and flood control lot certificates to incorporate revised flood planning levels and new permanent inundation planning level.**
   - **Cost:** low
   - **Responsibility:** Lake Macquarie City Council
   - **Timeframe:** by the year 2012

5. **Review strategic land use planning to accommodate adaptation to changed flooding and inundation due to sea level rise. The review should include suitable development densities and types, possible need for retreat areas, future protection and adaptation of foreshore ecosystems, foreshore access and recreation, foreshore community facilities, and land required for infrastructure and protection works.**
   - **Cost:** moderate
   - **Responsibility:** Lake Macquarie City Council and NSW Government
   - **Timeframe:** by the year 2013

6. **Develop or adopt financial models to prepare for future costs of possible protection works, infrastructure up-grades, relocations, and other adaptation options**
   - **Cost:** moderate
   - **Responsibility:** Lake Macquarie City Council and other service providers
   - **Timeframe:** by the year 2014

<u>MEDIUM Priority</u>

1. **Undertake a review of the suitability of slab on ground construction in the foreshore areas and whether other forms of building construction can be undertaken that would reduce flood hazard and/or allow future adaptation such as house raising.**
   - **Cost:** low - moderate
   - **Responsibility:** Lake Macquarie City Council and NSW Government
   - **Timeframe:** by the year 2014

2. **Undertake a review of the flood warning system and if necessary update.**
   - **Cost:** low - moderate
   - **Responsibility:** Lake Macquarie City Council and the Bureau of Meteorology
   - **Timeframe:** by the year 2013

3. **Review Council's policy "Caravan Parks on Flood Prone Lands Surrounding Lake Macquarie Waterway (2005)" for caravan and cabin parks in the foreshore area.**
   - **Cost:** low
   - **Responsibility:** Lake Macquarie City Council and caravan park owners
   - **Timeframe:** by the year 2012

LOW Priority

1. **Assess the possible implications of mine subsidence in the area for flood related development controls.**
   - **Cost:** low
   - **Responsibility:** Lake Macquarie City Council and Mines Subsidence Board
   - **Timeframe:** by the year 2013

2. **Inform the SES of the outcomes of this Plan and the possible implications for flood evacuation. If necessary the SES should update their Flood Plan.**
   - **Cost:** low
   - **Responsibility:** Lake Macquarie City Council and SES
   - **Timeframe:** by the year 2013

3. **Evaluate whether a house raising scheme or similar will be supported by the community and is a practical adaptation measure for sea level rise and if so establish such a scheme.**
   - **Cost:** low to evaluate. Approximately $60,000 to raise a non brick house, but highly variable
   - **Responsibility:** Lake Macquarie City Council and local community
   - **Timeframe:** ongoing

4. **Ensure that ongoing local drainage problems are monitored and addressed, in accordance with Council's ability to fund such works.**
   - **Cost:** moderate
   - **Responsibility:** Lake Macquarie City Council and local residents
   - **Timeframe:** ongoing

5. **Monitor any changes to the sedimentation and erosion regime in the Swansea channel.**
   - **Cost:** no cost to Council – NSW Maritime conduct quarterly bathymetric surveys of the main channel
   - **Responsibility:** Lake Macquarie City Council and NSW Government
   - **Timeframe:** ongoing

3. INTRODUCTION

3.1. Background

Lake Macquarie is a saline tidal lake with a permanently open entrance in the Hunter Region of New South Wales, 95 kilometres north of Sydney and 20 kilometres south of Newcastle (Figure 1). The main features of the lake are provided in Table 2.

Table 2: Main Features of Lake Macquarie Waterway

Total Catchment Area	700 km^2
Area of Lake	110 km^2 (16% of the total catchment area)
Length of Lake	22 km in a north-south direction
Width of Lake	varying from 2 km to 8 km in an east-west direction
Perimeter Length	170 kilometres
Average Water Depth	8 to 9 metres
Maximum Water Depth	11 metres (near Pulbah Island)
Contributing Catchments	Dora Creek (230 km^2) Cockle Creek (111 km^2) Stoney Creek (36 km^2) Each of the other contributing catchments has a catchment area of less than 30 km^2.

The Lake Macquarie waterway is the largest coastal lake in eastern Australia and is surrounded by extensive residential, commercial and industrial developments. The lake is a valuable natural resource for the region, providing commercial and recreational usage, as well as being of high scenic value. The outlet of the Lake Macquarie waterway to the Pacific Ocean is by the narrow and shallow entrance channel at Swansea (Swansea Channel). Today it has a permanently open entrance which has been extensively modified by man made structures (filling of the northern embankment, dredging and construction of sea walls).

The water level in the lake is typically at 0.1 mAHD but can rise to 0.4 mAHD following a period of high ocean levels. Australian Height Datum (AHD) is the common national plane approximating to mean sea level. Under normal circumstances, the ocean tide (±0.5 m) has little impact (±0.05 m) on the water level in the lake. Intense rainfall over the catchment combined with elevated ocean levels can raise the water level in less than 24 hours causing significant flooding of the foreshore areas and hardship to the community.

For the purposes of this investigation, the study area was subdivided into seven foreshore management areas as shown on Table 3 and on Figure 2. These areas are defined as generally land below the 4 mAHD contour and are shown on Figures 3 to 10.

Table 3: Foreshore Management Areas

Figure	Suburbs	Area	Total Surveyed Buildings	Surveyed Residential Buildings	Surveyed Commercial Buildings	Surveyed Industrial Buildings
3	Boolaroo, Edgeworth, Glendale, Speers Point, Teralba	Cockle Creek	240	233	3	4
4	Croudace Bay, Eleebana, Valentine, Warners Bay	Warners Bay	267	261	6	0
5	Belmont, Belmont South, Marks Point	Marks Point - Belmont	905	897	8	0
6	Blacksmiths, Pelican, Swansea	Swansea – Pelican - Blacksmiths	2087	2030	56	1
7 and 10	Balcolyn, Bonnells Bay, Brightwaters, Dora Creek, Mirrabooka, Morisset, Morisset Park, Nords Wharf, Silverwater, Sunshine, Windermere Park, Wyee Point	Dora Creek	707	704	3	0
8	Arcadia Vale, Balmoral, Buttaba, Carey Bay, Coal Point, Fishing Point, Kilaben Bay, Rathmines, Wangi Wangi	Carey Bay – Arcadia Vale	228	227	1	0
9	Blackalls Park, Bolton Point, Booragul, Fassifern, Fennell Bay, Marmong Point, Toronto	Toronto - Fassifern	365	347	5	13
	Total		**4799**	**4699**	**82**	**18**

Note: The above table is based on the database of surveyed floor levels of buildings, mostly on lots below 2 mAHD, provided by Lake Macquarie City Council. It is likely that buildings on lots above 2 mAHD and below 4 mAHD are not included. The surveyed buildings represent less than half the total building stock in the study area.

Table 3 indicates that the majority of residential, commercial and industrial buildings that are likely to be affected by flooding are on the eastern shore (Figures 5 and 6) and near Dora Creek (Figure 7).

3.2. Objectives

Lake Macquarie City Council engaged WMAwater (formerly Webb, McKeown & Associates) to review the 2000 Lake Macquarie Floodplain Risk Management Study and 2001 Plan (References 1 and 2) in light of the NSW Government's benchmarks for sea level rise as well as guidelines for rainfall intensity increases (Flood Risk Management Guide - Reference 3 and Floodplain Risk Management Guideline – Practical Consideration of Climate Change – Reference 4).

The objectives of the Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts, together with opportunities to enhance the foreshore environments. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and as a result of climate change (sea level rise). This review combines and updates the previous Lake Macquarie Floodplain Risk Management Study (2000 – Reference 1) and Plan (2001 – Reference 2) into one document.

A glossary of flood related terminology is provided in Appendix A.

3.3. Floodplain Risk Management Process

As described in the 2005 NSW Government's Floodplain Development Manual (Reference 5), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: *Flood Study.*
Stage 2: *Floodplain/Foreshore Risk Management Study.*
Stage 3: *Floodplain/Foreshore Risk Management Plan.*
Stage 4: *Implementation of the Plan*.

The 2012 Lake Macquarie Waterway Flood Study (Reference 6) undertook a review of the first stage of the management process, namely the 1998 Lake Macquarie Flood Study Part 1 and Part 2 (References 7 and 8), to include the June 2007 long weekend flood event and incorporate the implications of climate change.

This document provides a review of the August 2000 Lake Macquarie Floodplain Risk Management Study and July 2001 Plan (References 1 and 2) which constitutes the second and third stages in the process. It has been termed a "waterway" management study rather than a "floodplain" management study as the former term is more widely understood to represent the areas subject to flooding around the Lake Macquarie waterway.

3.4. History of Flooding

Historical records (dating back to 1927) show that periodically the level of the lake has risen in response to heavy rainfall over the catchment and/or elevated ocean levels. This has resulted in the flooding of land and occasionally of building floors. The dates and approximate peak lake levels of all known significant floods since 1926 are shown in Table 4.

Table 4: Flood Events

Date (in order of severity)	Approximate Peak Lake Level (mAHD)
18 June 1949	1.25
Easter 1946	1.20
11 June 1930	1.10
9 June 2007	1.05
2 May 1964	1.00
4 February 1990	1.00
1953	0.90
1926/27	0.80
25 February 1981	0.80
May 1974	0.80
4 March 1977	0.70

Notes: Data obtained from the 1998 Lake Macquarie Waterway Flood Study - Reference 7.
Levels may be an average of several recorded heights.
It is likely that several floods prior to 1970 may not have been recorded.

The records show that the highest recorded flood level was 1.25 mAHD in 1949 (observed at Marks Point) with the most recent major floods occurring in June 2007 (1.05 mAHD) and in February 1990 (1.00 mAHD). Accurate recording of lake levels has only been available since installation of the NSW State Government operated gauges at Marks Point and Belmont in 1986.

3.5. Causes of Flooding

Flooding of the foreshore areas of Lake Macquarie may occur as a result of a combination of factors including:

- an elevated ocean level due to an ocean storm surge, wave setup at the entrance and/or a high astronomic tide,
- rainfall over the lake and the catchments (Dora Creek, North Creek, South Creek etc.) entering Lake Macquarie,
- wind wave action causing wind setup and runup on the foreshore within the lake,
- a permanent rise in ocean and lake levels due to climate change.

Flood levels on the Lake Macquarie foreshore are affected by runoff from the surrounding catchments into the lake as well as inflows from the Pacific Ocean due to elevated ocean levels. Elevated ocean levels occur due to a combination of tides (the high tide varies from approximately 0.5 m to 1.1 mAHD during the year) and what are known as ocean anomalies. The main components of ocean anomalies (difference between the predicted and the recorded tide) are storm surge and wave setup at the entrance to the Lake Macquarie waterway. Together these components can raise ocean levels by up to 1 m.

3.6. Flood Planning Levels

3.6.1. Year 2011 Design Flood Levels

One of the key considerations in modelling coastal systems is the probability of occurrence of a combined ocean and rainfall event and the relative magnitude of both. It is considered to be overly conservative to assume a 100 year ARI (1% AEP) ocean event will occur concurrently with a 100 year ARI (1% AEP) rainfall event, however there are no data available to accurately define a suitable approach.

As part of the updating of the flood study (2012 Lake Macquarie Waterway Flood Study - Reference 6) ocean anomalies were investigated and two runoff/ocean design scenarios were adopted. A design ocean event in conjunction with a similar or smaller magnitude rainfall event (termed an ocean dominated event) and a design rainfall event in conjunction with a similar or smaller magnitude ocean event (termed a rainfall dominated event).

A summary of the adopted design scenarios is provided in Table 5.

Table 5: Design Event Scenarios

OCEAN DOMINATED		DESIGN EVENT (ARI)	RAINFALL DOMINATED	
Peak Design Ocean Level + Wave Setup (m AHD)	Co incident Design Rainfall Event (ARI)		Co incident Design Ocean Event (ARI)	Co incident Design Ocean Level + Wave Setup (m AHD)
2.18	100 year	PMF	100 year	1.70
1.80	100 year	500 year	100 year	1.70
1.75	100 year	200 year	100 year	1.70
1.70	20 year	100 year	20 year	1.63
1.67	20 year	50 year	20 year	1.63
1.63	20 year	20 year	20 year	1.63
1.41	10 year	10 year	10 year	1.41
1.38	5 year	5 year	5 year	1.38
1.30	2 year	2 year	2 year	1.30

The following conditions were adopted for the design year 2011 flood analysis:

- 0.1 mAHD initial (average normal) water level in the Lake Macquarie waterway,
- 48 hour critical rainfall storm duration inflows (for all design events except the PMF) in conjunction with the respective ocean tides as shown in Table 5,
- design ocean levels based on the design levels in Fort Denison/Sydney Harbour plus a wave setup component,
- all design tides assume the "shape" of the tidal hydrograph of the May 21st to 27th 1974 event (approximately 160 hours with the peak at 110 hours) as recorded at Fort Denison in Sydney Harbour. This tidal hydrograph approximates the 100 year ARI design ocean event,
- the peak ocean level was coincided with the peak rainfall burst in the 48 hour duration rainfall event.

An envelope approach was adopted which assumed the maximum of an ocean dominated event and a rainfall dominated event. The results indicated that downstream of the bridge the ocean dominated event produces the higher level but upstream the rainfall dominated event produces the higher level. The adopted design flood levels for the lake are provided in Table 6 together with a comparison with those adopted previously.

The main reason that the levels have changed (notably in the PMF) is because of different assumptions regarding the peak ocean levels and the joint co-incidence of ocean and rainfall events. Changes to the 100 year, 50 year and 20 year ARI levels range from increases of 0.1 m to 0.3 m but in the PMF a reduction of 0.2 m. Re-modelling of design events will always produce minor changes to flood levels due to the different approaches and models employed.

Table 6: Summary of Flood Levels on the Lake Macquarie Foreshore

Event (ARI)	Still Water Level on the Lake Macquarie foreshore (excludes wave runup in the lake)			Still Water Level downstream of Swansea Bridge		
	Year 2011 OLD (mAHD)	Year 2011 NEW (mAHD)	Year 2011 Difference (m)	Year 2011 OLD (mAHD)	Year 2011 NEW (mAHD)	Year 2011 Difference (m)
PMF/extreme	2.63	2.45	-0.18	2.01	2.06	+0.05
500 year	n/c	1.87		n/c	1.69	
200 year	n/c	1.69		n/c	1.64	
100 year	1.38	1.50	+0.12	1.67	1.57	-0.10
50 year	1.24	1.38	+0.14	1.64	1.54	-0.10
20 year	0.97	1.23	+0.26	1.49	1.50	+0.01
10 year	n/c	0.94		n/c	1.27	
5 year	n/c	0.82		n/c	1.24	
2 year	n/c	0.65		n/c	1.15	

Notes: n/c = not calculated previously
Underlined levels have been derived by interpolation from model results rather than actual modelling

In addition to flooding due to runoff/ocean levels there is another form of flooding resulting from waves running up the foreshore (wave runup). This is where waves (caused by wind acting on the water surface of the lake) break and "runup" the foreshore. Part 2 of the 1998 Lake Macquarie Flood Study (Reference 8) investigated the effects of wave runup at 48 locations. The results indicate that wave runup may increase the still water design lake levels by up to 1m (average of 0.3m) for the 100 year ARI event.

Table 7 provides a summary of key flood related levels for the Lake Macquarie waterway (upstream of the Swansea Bridge).

Table 7: Lake Macquarie Waterway Levels Relating to Sea Level Rise

Level	Measure	Basis of Calculation	Planning & Development Conditions	Property Certificate
0.10 mAHD	Year 2011 lake mean still water level	Approx 30 years lake tide gauge average (Flood Study – Reference 6)		
< =1.00 mAHD	Below Year 2100 lake mean still water level	Hazard to land use, infrastructure, buildings, and services from progressive rise in permanent lake levels to Year 2100	High hazard permanent lake inundation area and high hazard lake flood area (flood fringe)	Properties shown as "Progressive inundation – sea level rise" (or similar) on 149(2) Certificate
1.00 mAHD	Year 2100 lake mean still water level	Year 2011 lake level + 0.9 m sea level rise		
1.23 mAHD	Year 2011 20 ARI year flood	Flood Study – Reference 6		
< =1.50 mAHD	Below Year 2011 100 year ARI flood	Assessment of depth/velocity of Year 2100 100 year ARI flood and other hazard factors	High hazard lake foreshore area (flood fringe)	
1.50 mAHD	Year 2011 100 year ARI flood	Flood Study – Reference 6		
1.61 mAHD	Year 2050 20 year ARI flood level	Flood Study – Reference 6	Flood planning level for non-habitable buildings with Year 2050 asset life	
1.50 mAHD – 2.32 mAHD	Between high hazard flood level and Year 2100 100 year ARI flood level		Low hazard lake foreshore area (flood fringe)	
1.86 mAHD	Year 2050 100 year ARI flood level	Flood Study – Reference 6 – includes 0.4 m sea level rise		
2.10 mAHD	Year 2100 20 year ARI flood level	Flood Study – Reference 6 – includes 0.9 m sea level rise	Flood planning level for non-habitable buildings with Year 2100 asset life	
2.32 mAHD	Year 2100 100 year ARI flood level	Flood Study – Reference 6 – includes 0.9 m sea level rise		

Level	Measure	Basis of Calculation	Planning & Development Conditions	Property Certificate
2.36 mAHD	Year 2050 Flood Planning Level	Year 2050 100 year ARI flood level + 0.5 m freeboard	Flood planning level for habitable buildings with Year 2050 asset life	
2.45 mAHD	Year 2011 PMF	Flood Study – Reference 6		
2.81 mAHD	Year 2050 PMF	Flood Study – Reference 6 – includes 0.4 m sea level rise		
2.82 mAHD	Year 2100 Flood Planning Level	Year 2100 100 year ARI flood level + 0.5 m freeboard	Flood planning level for habitable buildings with Year 2100 asset life	
<=3.00 mAHD	Year 2100 Flood Planning Level "rounded up"	Year 2100 100 year ARI flood level + 0.5 m freeboard "rounded up" to allow for plus-or-minus 0.15 m margin in aerial survey	Nominated as "flood control lot" for purposes of Exempt and Complying Development Codes SEPP	Properties shown as "Lake flooding" (or similar) on 149(2) Certificate
3.27 mAHD	Year 2100 PMF	Flood Study – Reference 6– includes 0.9 m sea level rise	Flood planning level for "sensitive development" such as hospitals, aged-care facilities	

3.6.2. Year 2050 and Year 2100 Design Flood Levels

Design flood levels for the year 2050 and year 2100 have been modelled in the current 2012 Lake Macquarie Waterway Flood Study (Reference 6) and are provided in Tables 6 and 7. The criteria for establishing these are:

- The NSW Government's benchmarks in the 2010 Flood Risk Management Guide (Reference 3) for sea level rise by the year 2050 (+0.4 m) and the year 2100 (+0.9 m) were adopted and included in the hydraulic modelling undertaken in the 2012 Lake Macquarie Waterway Flood Study (Reference 6).
- The 2012 Lake Macquarie Waterway Flood Study (Reference 6) undertook an assessment of a 10%, 20% and 30% potential climate change increase in design rainfall intensities. However no increase in rainfall intensity has been included at this time as there is no certainty that such an increase will occur. The Bureau of Meteorology is undertaking on-going research in this field and once definitive advice is provided this should be considered with a view to amending the year 2050 and year 2100 design flood levels (either upwards or downwards). The results from the 2012 Lake Macquarie Waterway Flood Study (Reference 6) indicate that a 10% increase would raise the 100 year ARI flood levels by 0.12 m.
- Climate change may also increase the ocean storm surge and wave setup components incorporated in establishing the design ocean levels adopted in the 2012 Lake Macquarie Waterway Flood Study (Reference 6). These issues have also been investigated in that study and conclude that ocean storm surge, wave setup and associated factors may increase design flood levels in Lake Macquarie by 0.15 m. This potential increase in design flood levels has not been included in estimation of the year 2050 or year 2100 design flood level estimation as there is no certainty that such an increase will occur.
- Wind setup on Lake Macquarie (the effect of wind pushing water into a bay) may raise water levels in a local area and was investigated in the 2012 Lake Macquarie Waterway Flood Study (Reference 6). Wind setup has been estimated to raise local water levels by less than 0.1 m. The effect of climate change on wind setup may potentially increase this by 0.05 m. Wind setup has not been included in establishing design flood levels for year 2011, year 2050 or year 2100 conditions as it is a local condition, of relatively small magnitude and will affect (if it occurs during the design event) only a small percentage of the foreshore area.
- Wave runup (waves break and runup the foreshore reaching a higher level than the static water level) was investigated in the 2012 Lake Macquarie Waterway Flood Study (Reference 6). For 47 of the 48 sites investigated the maximum wave runup level (coincident with the 100 year ARI event) above the static water level is 0.5 m or less. Wave runup is a very localised effect that is highly influenced by the local topography and will likely not

extend beyond 50 m from the foreshore. It can be relatively easily mitigated by a formal structure (mound or wall) or vegetation (mangroves or trees). There are no reported occurrences of wave runup causing damage to property or risk to life in the February 1990 or June 2007 events.

- The 0.5 m freeboard above the 100 year ARI design flood level that is used to establish the minimum floor level of a residential building caters for uncertainty in design flood estimation, wind and wave action and local hydraulic effects. The effect of sea level rise cannot be included within this freeboard as it has been established with a reasonable degree of certainty that it will occur (2010 Flood Risk Management Guide - Reference 3).
- An overriding consideration in establishing the year 2050 and year 2100 design flood levels is that the assumed sea level rise has not yet occurred, thus there is some additional freeboard allowance in the years leading up to the year 2050 and 2100 should a large flood event occur prior to these dates.

3.6.3. 0.5 m Freeboard

A freeboard allowance above the design standard (generally the 100 year ARI flood level) is to provide reasonable certainty that other hydraulic effects do not compromise the adopted standard. There is no technical reason that a 0.5 m freeboard and not some other value (lower or higher) is applicable for Lake Macquarie. A review of the hydraulic effects included in the freeboard indicates:

- Uncertainties in design flood levels: Whilst there is always uncertainty in design flood estimation the magnitude of any error for the Lake Macquarie waterway is relatively small compared to river systems (say a maximum of ±0.3 m) due to the small height difference between a PMF and say a 20 year ARI event (on river systems there is a much greater range),
- the effect of local hydraulics (say flow between buildings raising levels) is not a factor at Lake Macquarie due to the relatively slow rate of rise of the floodwaters,
- wave action (causing wave runup) will generally be 0.5 m or less and there is no evidence that it has actually occurred. In the majority of the foreshore areas the existing and proposed developments are outside the potential 50 m impact zone of wave runup,
- Climate change: Sea level rise has been considered separately (not within the freeboard) as it has been established with a reasonable degree of certainty that it will occur as stated in the 2010 Flood Risk Management Guide (Reference 3). Other possible climate change effects are assumed to be included within the freeboard as there is no certainty that they will occur and possibly some may reduce flood levels (decrease in rainfall intensities may occur),
- the very large area of the lake (110 km^2) means that future development in the catchment or filling of the floodplain will produce no significant increase in the design flood levels and this component can effectively be ignored for the Lake Macquarie waterway.

On the basis of the above assessment a freeboard of 0.5 m is reasonable.

3.7. Council's Flood Policy

3.7.1. Flood Policy

Lake Macquarie City Council has had a development control policy for flood liable land for over 30 years. It has varied over those years in response to more information becoming available and as a reflection of NSW Government policy.

The policy as documented in the Council report of 6 April 1998 states:

- *habitable rooms to be a minimum 500 mm above the 1:100 year flood levels for still water conditions,*
- *non-habitable rooms to be at or above the 1:20 year flood level,*
- *commercial rooms to be a minimum 500 mm above the 1:100 year flood level,*
- *boat sheds to be constructed at the approved filling level if applicable, otherwise at the natural surface level,*
- *floors of industrial buildings to be constructed at or above the 1:100 year flood level,*

At particular locations, Council requires the applicant to provide a report from an appropriate Consulting Engineer, showing:

- *1:100 year flood levels allowing for the effects of wind/wave action, at the site of the proposed development,*
- *that the proposed development is capable of withstanding the effects of the wind/wave action associated with a 1:100 year flood.*

In 2008 Council applied new flood planning levels to these development criteria, to incorporate the predicted effects of sea level rise in Lake Macquarie up to the year 2100.

3.7.2. Related Issues

- The State Emergency Services has prepared (April 1996) a comprehensive Local Flood Plan (a sub-plan of the Local Disaster Plan).
- Council's Sea Level Rise Policy and interim development assessment procedure has been applied to new developments since 2008 with no significant objection from developers or legal challenges.
- Council's Section 149 Certificate advises landowners if Council has a policy to restrict development by reason of the likelihood of flooding, sea level rise or tidal inundation. Since mid-2009 this notice is placed on all foreshore lots where any part of the land is below the 3 mAHD contour.
- Council is not aware of any quantitative flood damage data or complaints with respect to wind/wave activity. It is also not aware of any quantitative flood damage data as a result of the February 1990 or June 2007 events.

- Council will provide (for a fee) a “Development Restrictions Certificate - Flooding/Tidal Inundation/Climate Change” for a property. This certificate provides flood information including Council’s flood planning level requirements, a survey of the existing buildings and grounds and whether existing buildings comply with Council’s present floor height policies.
- Council will provide (for a fee) a Flood Control Land Certificate advising whether complying development may be undertaken under the Exempt and Complying Development Codes State Environmental Planning Policy.

In the past Council has issued Flood Awareness leaflets. Currently definitive flood information is only provided to landowners via the “Development Restrictions Certificate”.

3.8. Previous Studies

3.8.1. Lake Macquarie Waterway Flood Study 2012 (Reference 6)

The 2012 Lake Macquarie Waterway Flood Study (Reference 6) provides the most up to date information on design flood behaviour. This report was undertaken to update the previous Lake Macquarie Flood Studies (References 7 and 8) undertaken in 1998.

The main reasons for updating the hydraulic modelling approach are as follows:

- use of a two dimensional (2D) hydraulic model,
- availability of detailed bathymetric data to better describe the bed of the Swansea channel rather than the cross sections used previously,
- availability of Airborne Laser Scanning (ALS) survey that provides a very accurate definition of the foreshore topography,
- a more detailed appraisal of design ocean level conditions,
- incorporation of predicted climate changes and sea level rises,
- incorporation of data for the June 2007 long weekend storm/flood event in the calibration process, and
- incorporation of an “envelope” approach based on the maximum of an ocean dominated event and a rainfall dominated event.

The adopted approach was to establish a TUFLOW 2D hydraulic model based on the available bathymetric and ALS survey with inflows from a WBNM hydrologic model. A calibration/verification was undertaken to the February 1990 and the June 2007 long weekend storm/flood events. The model was then used for design flood estimation with sensitivity analysis undertaken to determine the impacts of various model parameters.

An envelope approach of the ocean and rainfall dominated scenarios was adopted as summarised in Section 3.5.

Climate Change

Global climate change is predicted to raise sea levels and possibly change local rainfall intensities. The NSW Government has introduced a set of benchmarks for the assessment of raised sea levels and guidelines for increases in design rainfall intensities (Flood Risk Management Guide - Reference 3 and Floodplain Risk Management Guideline –Practical Consideration of Climate Change – Reference 4). As a result, the following climate change scenarios were analysed for the 5 year, 20 year and 100 year ARI events (results can be interpolated for intermediate events).

- **Rainfall Induced flooding**: increase in design rainfall of 10%, 20% and 30%,
- **Increase in mean sea levels**: increase in sea level of 0.4 m and 0.9 m. *All sea level rise scenarios assume that the initial water level in the lake rises by a similar amount to the sea level rise, thus for a 0.4 m sea level rise the initial water level increases from 0.1 m to 0.5 m AHD,*
- **Rainfall Induced flooding with increase in mean sea levels** : combination of increase in design rainfall (10%, 20% and 30%) and increase in sea level (0.4 m and 0.9 m),
- **Ocean Induced flooding:** increase in sea level of 0.4 m and 0.9 m.

A summary of the results are:

- The effect of rainfall increase varies depending upon the size of the event. At the 5 year ARI level a 10% rainfall increase approximates a 0.05 m increase in peak water level while at the 100 year ARI level the increase approximates a 0.12 m increase.
- The effect of a sea level rise varies depending upon the size of the event. At the 5 year ARI level a 0.4 m sea level rise approximates a 0.40 m increase in peak water level while at the 100 year ARI level the increase approximates a 0.35 m increase.
- Results for a combined sea level and rainfall increase for the rainfall dominated scenario generally reflects the addition of the rainfall and sea level increases.
- Results for the 5 year, 20 year and 100 year ARI events ocean dominated scenarios indicates that flood levels will increase by a similar magnitude to the sea level increase.

This report does not consider the effects of flooding due to a tsunami.

3.8.2. Lake Macquarie Floodplain Risk Management Study and Plan - 2000 (References 1 and 2)

The 2000 Lake Macquarie Floodplain Risk Management Study and 2001 Plan (References 1 and 2) provided an assessment of management measures to mitigate risk associated with the flood planning levels predicted in the 1998 Lake Macquarie Flood Study (References 7 and 8). In summary the outcomes were:

- flood mitigation dams, retarding basins, river improvement works and floodways were considered not viable (largely on environmental, economic and practical grounds),

- no suitable sites for levees that would be supported by the residents were found,
- local flooding causes inconvenience but does not reach floors levels. There are no viable economic solutions but the problem should be monitored,
- catchment treatment should be encouraged but would not reduce flood levels,
- the wave runup effect is not well understood and should be monitored. Proposed developments should not exacerbate the potential problems,
- house raising is only suitable for a small number of buildings but should be implemented where appropriate,
- flood proofing is not viable for residential buildings but is appropriate for commercial buildings,
- improvements to flood related development controls were suggested,
- no buildings were identified as suitable for voluntary purchase,
- rezoning to remove existing flood liable buildings was considered unlikely to be socially acceptable or sufficiently attractive to developers,
- improvements to the flood warning, evacuation planning and flood awareness procedures were supported,
- development measures (climate change, further development and filling of the floodplain) were addressed.

3.8.3. Lake Macquarie Adaptive Response of Estuarine Shores to Sea Level Rise – 2010 (Reference 9)

The objective of this report was to gain an appreciation of how the foreshores of the Lake Macquarie waterway might respond to rising sea levels Ten case study locations were examined in terms of sediment/rock material, vegetation, back beach form and profile. The study also examined wind and wave set up. The outcome was to develop a methodology to investigate foreshore changes to sea level rise that can be re-applied at other sites.

The study established a hydrodynamic model to investigate shoreline erosion and recession. The model simulated the effect of larger storms on the foreshore profile and was able to look at seabed forces generated by storm waves at each location. The model results indicate the factors affecting the shoreline response around the Lake Macquarie waterway are:

- wave climate and near shore depth,
- vegetation,
- sediment type, and
- sediment sources and sinks.

The study concluded that it was likely that the existing Lake Macquarie shoreline would shift as a result of sea level rise and shoreline erosion. The extent of the inundation is dependant on the topography, while the extent of erosion is dependant largely on the sediment type and wave energy. Mapping potential risk from erosion is site specific and as such was not incorporated into this plan.

4. STUDY AREA

4.1. Land Use

The majority of the lake perimeter is within the Lake Macquarie local government area (LGA), with approximately 15% within the Wyong local Government area. The Wyong LGA includes the land to the south around Point Wolstoncroft. Some key features of the Lake Macquarie LGA (www.lakemac.com.au) are:

- it is one of the fastest growing cities in the Hunter, and one of the largest cities in New South Wales,
- Lake Macquarie's population is fast approaching 200,000,
- Lake Macquarie is the Hunter region's largest city, accounting for 37% of the Lower Hunter population,
- Lake Macquarie is the fourth most populous city in NSW, and the eighth most populous city in Australia,
- The population of Lake Macquarie is expected to grow by 60,000 to 70,000 people over the next 25 years, which will create a demand for 36,500 new dwellings,
- The percentage of population aged 55+ will increase from 29% to 39% of the total population over the next 20 years.

However, whilst the LGA has experienced steady growth in recent times it is unlikely that the pressure for increased housing densities or new subdivisions in the next (say) 50 years will require the rezoning of any vacant land currently inundated in the Probable Maximum Flood envelope. This is because there is a large amount of available land in the LGA outside this envelope, though in many parts others issues may inhibit development. Higher density development within the envelope has the potential to increase flood damages and risk to life unless the flood problem is adequately addressed.

The land use (within the Lake Macquarie LGA) in the foreshore areas surrounding the lake (assumed as land below 4 mAHD) comprises the full range of planning zones listed in Lake Macquarie Local Environmental Plan 2004 namely:

- Rural (1),
- Residential (2.1 and 2.2),
- Business (3),
- Industrial (4),
- Infrastructure (5),
- Open Space (6),
- Environmental Protection (7),
- National Park (8),
- Natural Resources (9), and
- Investigation (10).

A summary of the number of properties within the above land use zones and having some part of their property below 4 mAHD is shown on Table 8.

Table 8: Land Use for Lake Macquarie Waterway Foreshore Properties (below 4 mAHD)

Suburb	No. Prop	Zone 1.1	Zone 1.2	Zone 2.1	Zone 2.2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Arcadia Vale	112	0	0	104	0	0	0	0	8	0	0	0	0
Argenton	37	0	0	0	25	2	2	2	5	1	0	0	0
Balcolyn	195	0	0	181	0	0	0	0	5	9	0	0	0
Balmoral	86	0	0	79	0	0	0	0	2	5	0	0	0
Barnsley	94	0	0	3	0	0	4	0	31	55	0	0	1
Belmont	646	0	0	216	207	158	0	6	46	13	0	0	0
Belmont North	1	0	0	0	0	0	0	0	0	1	0	0	0
Belmont South	423	0	0	408	0	0	0	1	9	5	0	0	0
Blackalls Park	366	0	32	245	29	0	0	4	21	34	0	1	0
Blacksmiths	769	0	0	296	408	20	0	0	24	21	0	0	0
Bolton Point	93	0	0	85	0	0	0	0	6	1	1	0	0
Bonnells Bay	411	0	0	339	50	4	0	0	10	5	2	0	1
Boolaroo	207	0	0	175	1	0	23	0	8	0	0	0	0
Booragul	108	0	0	98	0	0	0	0	9	1	0	0	0
Brightwaters	242	0	0	229	0	0	0	0	1	12	0	0	0
Buttaba	91	0	0	85	0	0	0	0	3	3	0	0	0
Cameron Park	1	0	0	0	0	0	0	0	1	0	0	0	0
Cams Wharf	18	0	1	0	0	0	0	0	9	8	0	0	0
Cardiff	2	0	0	0	0	0	0	1	0	1	0	0	0
Carey Bay	109	0	0	97	6	0	0	0	6	0	0	0	0
Caves Beach	137	0	0	118	0	0	14	0	3	2	0	0	0
Coal Point	349	0	0	342	0	0	0	0	6	1	0	0	0
Cooranbong	304	27	46	147	2	0	3	5	4	66	0	0	4
Crangan Bay	0	0	0	0	0	0	0	0	0	0	0	0	0
Croudace Bay	81	0	0	76	0	0	0	1	4	0	0	0	0
Dora Creek	781	7	20	642	0	13	3	3	15	78	0	0	0
Edgeworth	449	0	0	329	27	19	27	1	42	4	0	0	0
Eleebana	135	0	18	101	0	0	0	2	8	5	0	0	1
Eraring	60	0	25	0	0	0	1	0	1	33	0	0	0
Fassifern	172	0	0	105	34	3	0	6	18	0	0	2	4
Fennell Bay	134	0	0	86	39	0	0	1	7	0	0	0	1
Fishing Point	180	0	0	177	0	0	0	0	3	0	0	0	0
Glendale	73	0	0	3	51	7	4	0	7	1	0	0	0
Kilaben Bay	173	0	5	160	0	0	0	0	5	3	0	0	0
Lake Macquarie	5	0	0	0	0	0	0	2	0	2	0	1	0
Little Pelican	1	0	0	0	0	0	0	0	0	1	0	0	0
Mandalong	11	6	0	0	0	0	0	0	0	4	0	1	0
Marks Point	594	0	0	333	215	8	0	3	25	10	0	0	0
Marmong Point	85	0	0	73	0	6	0	0	5	1	0	0	0
Martinsville	5	0	1	0	0	0	0	0	0	4	0	0	0
Mirrabooka	41	0	0	37	0	0	0	0	2	1	0	1	0
Morisset	145	19	23	41	0	0	5	2	2	50	0	0	3
Morisset Park	128	0	0	92	0	0	0	0	17	19	0	0	0
Murrays Beach	14	0	0	0	0	0	0	0	9	0	0	0	5
Myuna Bay	6	0	0	0	0	0	0	0	1	5	0	0	0
Nords Wharf	124	0	0	111	0	0	0	0	9	4	0	0	0
Pelican	374	0	0	360	0	0	0	0	8	6	0	0	0
Pinny Beach	1	0	0	0	0	0	0	0	0	0	0	0	1
Rathmines	103	0	0	75	2	2	0	1	10	13	0	0	0
Silverwater	75	0	0	71	0	0	0	0	0	4	0	0	0
Speers Point	195	0	0	82	87	11	5	0	10	0	0	0	0
Sunshine	117	0	0	111	0	0	0	0	5	1	0	0	0
Swansea	1678	0	0	766	760	86	0	7	40	19	0	0	0
Swansea Heads	30	0	0	8	0	0	0	0	0	22	0	0	0
Teralba	202	2	4	18	104	22	7	6	20	17	0	2	0

Suburb	No. Prop	Zone 1.1	Zone 1.2	Zone 2.1	Zone 2.2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Toronto	656	2	0	313	95	47	80	10	73	34	0	1	1
Valentine	211	0	0	176	22	3	0	0	7	3	0	0	0
Wangi Wangi	132	0	0	87	6	22	1	0	12	1	2	1	0
Warners Bay	492	0	2	165	218	53	18	2	8	26	0	0	0
Windermere Park	99	0	0	94	0	0	0	0	3	2	0	0	0
Woodrising	10	0	0	5	0	2	0	0	1	1	0	0	1
Wyee	43	3	17	0	0	0	0	0	3	8	0	11	1
Wyee Point	178	0	8	66	0	0	0	0	18	59	0	0	27
Yarrawonga Park	29	0	0	27	0	0	0	0	2	0	0	0	0
Total	12823	66	202	8037	2388	488	197	66	617	685	5	21	51

Note: Some land was not assigned a zoning

The majority of use (based on the number of properties and not land area) is (2.1) Residential (63%) and (2.2) Residential (19%). However based on land area the non-urban zones cover the larger land area. The main features of the lake foreshore are:

- The land rises relatively steeply around the majority of the western perimeter and parts of the eastern perimeter. As a result flooding is largely confined to a narrow band fronting the lake. In many places it does not extend beyond the lot immediately fronting the lake. This is particularly true for the western side apart from the mouth of Dora Creek and at Fennell Bay and Marmong Point. The exception is also the areas around the channel, where the land is relatively low lying and flat;
- For a (large) part of the lakes perimeter, public land (6(a) Public Recreation or 7 Environmental Protection) separates the lake from the residential (or other) use,
- The main areas affected by flooding in the past (1949, 1990 and 2007) are the suburbs of Swansea, Belmont South and Marks Point, near the Swansea Channel entrance, and Dora Creek. These areas have low relief and any overbank flooding affects a large number of occupied properties,
- Lake Macquarie waterway is the focal point of the LGA and is a significant commercial, environmental, recreational and scenic asset,
- There are few vacant residential, commercial or industrial properties surrounding the lake foreshore. The majority of future activities will be the re-development or extension of existing land use activities. In recent years there has been a small amount of subdivision for residential dual occupancies and other higher density usage in the foreshore areas,
- Some boatsheds have been converted to habitable rooms. Council has not granted approval for these conversions,
- There are few non-residential or public usage buildings around the foreshore. The main ones are commercial developments (shops) in Swansea and Blacksmiths and several industrial developments at Toronto,
- There are a number of tourist facilities on the foreshore including 15 caravan parks, several marinas (Marks Point, Toronto, Marmong Point, Pelican, Wyee Point), motels, private jetties and parks.

4.2. Building Floors

Lake Macquarie City Council provided a database of all buildings with surveyed floor levels located on the foreshores of Lake Macquarie on land below (approximately) 4.0 mAHD (Table 9).

Table 9: Buildings Located on the Foreshores of Lake Macquarie Waterway (below 4 mAHD)

Suburb	Total Surveyed Buildings	Residential Surveyed Building	Commercial Surveyed Building	Industrial Surveyed Building	Lowest Floor Level (m AHD)	Lowest Ground Level (m AHD)	% Surveyed Properties with Maximum Ground Level < 2m AHD#
Arcadia Vale	12	12	0	0	0.7	0.6	0%
Balcolyn	25	25	0	0	1.3	0.4	56%
Balmoral	4	4	0	0	1.7	0.6	50%
Belmont	264	260	4	0	1.1	0.0	65%
Belmont South	237	234	3	0	0.9	0.5	93%
Blackalls Park	156	156	0	0	1.1	0.2	68%
Blacksmiths	494	479	15	0	1.2	0.2	82%
Bolton Point	2	2	0	0	1.7	1.2	0%
Bonnells Bay	71	71	0	0	1.0	0.2	35%
Boolaroo	85	83	0	2	1.2	0.7	74%
Booragul	11	11	0	0	2.2	1.2	0%
Brightwaters	60	60	0	0	1.2	0.1	37%
Buttaba	26	26	0	0	0.7	0.1	35%
Carey Bay	33	33	0	0	1.3	0.1	36%
Caves Beach	3	3	0	0	2.1	1.4	33%
Coal Point	52	52	0	0	0.7	0.0	0%
Cooranbong	3	3	0	0	2.7	0.0	33%
Croudace Bay	20	20	0	0	1.3	0.5	85%
Dora Creek	409	406	3	0	1.2	0.0	86%
Edgeworth	128	126	1	1	2.1	0.2	23%
Eleebana	28	28	0	0	1.1	0.1	4%
Fassifern	66	66	0	0	1.1	0.1	70%
Fennell Bay	20	20	0	0	1.0	0.1	10%
Fishing Point	28	28	0	0	0.9	0.1	0%
Glendale	11	11	0	0	2.5	0.4	0%
Kilaben Bay	64	64	0	0	1.4	0.2	22%
Marks Point	404	403	1	0	0.6	0.2	82%
Marmong Point	30	29	1	0	1.1	0.4	90%
Mirrabooka	9	9	0	0	1.7	1.2	0%
Morisset	2	2	0	0	3.9	0.6	0%
Morisset Park	9	9	0	0	1.2	0.0	0%
Nords Wharf	33	33	0	0	1.0	0.2	6%
Pelican	314	313	1	0	0.9	0.0	74%
Rathmines	2	2	0	0	1.4	1.0	0%
Silverwater	26	26	0	0	1.2	0.1	46%
Speers Point	7	5	1	1	1.3	0.7	71%
Sunshine	26	26	0	0	0.7	0.2	27%
Swansea	1276	1235	40	1	0.8	0.0	93%
Teralba	9	8	1	0	1.7	0.0	89%
Toronto	80	63	4	13	0.5	0.1	29%
Valentine	79	78	1	0	1.2	0.0	41%
Wangi Wangi	7	6	1	0	1.7	0.9	0%
Warners Bay	140	135	5	0	1.2	0.7	65%
Windermere Park	25	25	0	0	1.2	0.3	24%
Wyee Point	9	9	0	0	1.5	0.3	44%
TOTAL	**4799**	**4699**	**82**	**18**			

surveyed floor level data are not available above 2 mAHD

Most of the properties were surveyed prior to 2000 if they were on land below 2 mAHD (the old Flood Planning Level) and some new developments have been surveyed since then. Therefore, most buildings with floors above 2 mAHD and on land below 4 mAHD, have not been surveyed. That is, the surveyed buildings comprise about 50% of the total stock below the 4 mAHD contour but more than 90% of buildings in the area below 2 mAHD.

The data in Table 9 indicate:

- 98% of all surveyed buildings on the foreshore of Lake Macquarie are residential,
- the suburbs with the majority of buildings (80%) are Belmont (6%), Belmont South (5%), Blackalls Park (3%), Blacksmiths (10%), Dora Creek (9%), Edgeworth (3%), Marks Point (8%), Pelican (7%), Swansea (27%), Warners Bay (3%),
- the suburbs of Balcolyn, Belmont, Belmont South, Blackalls Park, Blacksmiths, Boolaroo, Croudace Bay, Dora Creek, Fassifern, Marks Point, Marmong Point, Pelican, Speers Point, Swansea, Teralba, Warners Bay have over 50% of the properties with buildings below 4 mAHD on land where the entire property is below 2 mAHD, thus in a large flood there is little “dry” land on the property.

4.3. The Entrance Channel

Water levels in the Lake Macquarie waterway are dependent on ocean levels but are controlled by the entrance channel (Swansea Channel) which connects the Lake Macquarie waterway to the ocean. The channel is approximately 4 kilometres long and is characterised by numerous shoals and scoured deeper areas. The entrance at Blacksmiths Point is approximately 350 m wide (between the breakwaters). As the volume of the Lake Macquarie waterway is so large, less than one percent is exchanged in each tidal cycle. A brief summary of the history of the channel is provided in Table 10.

Table 10: History of the Swansea Channel

Year	Event
1878	Construction of the Swansea breakwaters commence
1884	Construction of the 1st Swansea Bridge
1887	Construction of the Swansea breakwater is completed
1939 to 1996	Dredging works begin in 1939 and continue in order to improve the navigability of the channel
1980 to 2001	Salts Bay foreshore is stabilised after a long period of recession
1996 to 2008	Dredging removes 210,000m^3 from the upper reaches of the Swansea Channel

The channel has been extensively altered by human activities notably:

- ocean entrance training works (late 1800s) which removed the shoals at the entrance, producing an increased tidal range in the lake,
- construction of the 1st Swansea bridge in 1884 and reclamation of the northern approach (late 1800s) producing a significant hydraulic restriction at this point,

- construction of the 2nd Swansea bridge in 1909,
- in the 1950s various dredging and reclamation activities were undertaken in the vicinity of Elizabeth and Pelican Islands near Marks Point,
- construction of the 3rd Swansea bridge in 1955,
- construction of the 4th Swansea bridge in 1980 (a duplicate bridge structure was constructed),
- more recently in 2006, stabilisation works involving placing ballast around the piers was undertaken,
- dredging of the ocean entrance channel around 1981 and more recently.

The channel has responded to natural and man-made effects through changes in the pattern of erosion and sedimentation. These are natural phenomena which will always occur, but the pattern and rate and change is affected by human modifications such as breakwalls, dredging, and seawalls.

Changes to the entrances to coastal lakes such as Lake Macquarie can disrupt the natural estuarine processes and consequently cause ecological changes in the lake. Solving one problem with man-made works tends to impact upon other areas. Management of the estuary and lake environs must therefore consider the broader implications of any works and their inter-relationships.

4.4. Regional Development Strategy

The Lower Hunter Regional Strategy, released by the NSW Department of Planning in October 2006, is a strategy that guides planning in the five local government areas of Lake Macquarie, Newcastle, Port Stephens, Maitland, and Cessnock for the period 2006 to 2031 and is reviewed every 5 years. A summary of this strategy is provided in Table 11.

Table 11: Lower Hunter Regional Strategy

Area	Additional People	New Homes	New Jobs	Regional Centres	
Lower Hunter	160,000	115,000	66,000	6 major regional centres, 1 regional city	
Lake Macquarie	60,000	36,000	12,200	3 major regional centres, 6 main town centres, 2 renewal corridors	
Dwelling Capacity Projections					
Area	**Centres and Corridors**	**Urban Infill**	**Total Infill**	**New Release**	**Total Dwellings**
Lake Macquarie	14,000	7,000	21,000	15,000	36,000
Total for the Lower Hunter	32,000	16,000	48,000	69,200	117,200
Lake Macquarie as a % of the Lower Hunter	44%	44%	44%	22%	31%

The strategy highlights the risk of flooding and states that "*Future urban development will not be located in areas of high risk from natural hazards, including sea level rise, coastal recession, rising water table and flooding".*

Despite this statement, the pressure to accommodate an additional 115,000 new dwellings by the year 2031 may mean that areas at future risk of flooding are considered for continued development. Any proposals in these areas must carefully consider the impacts of future flooding.

4.5. Environmental Summary

The 1997 Lake Macquarie Estuary Management Plan (Reference 10) described the environmental qualities of the Lake Macquarie waterway in detail. The values of the Lake Macquarie waterway identified in the 1997 Lake Macquarie Estuary Management Plan included:

- foreshore and waterway recreational activities;
- tourism;
- commercial and recreational fish stocks;
- biodiversity, including estuarine habitats such as wetlands and seagrass beds; and
- major industrial and commercial operations.

The major recommendations and actions of the 1997 Lake Macquarie Estuary Management Plan (Reference 10) were to:

- Establish suitable management structures, including the Office of the Lake Macquarie and Catchment Coordinator, and the Lake Macquarie Coastal and Estuary Management Committee.
- Manage navigation issues in the entrance channel, including studies to establish the optimum 'stable' channel configuration, and a series of dredging and channel modification programs to improve the navigation channel.
- Manage sedimentation and navigation issues in the lake, including a program to remove 'black ooze' in some locations.
- Reduce entrance channel foreshore erosion, particularly works to stabilise the foreshore at Salts Bay, Coon Island, Pelican, and Black Neds Bay.
- Improve water quality, with catchment management measures and stormwater controls, including the construction of wetlands and SQIDs on creeks and drainage lines.
- Protect ecology, by improving water quality and protecting ecosystems such as seagrass beds, mangroves, and saltmarsh.
- Maintain fisheries, through healthy ecosystems and by removing commercial fishing from the lake.
- Foreshore management by encouraging protection of natural foreshores, and controlling construction of foreshore infrastructure such as seawalls, boat ramps, and jetties.

4.6. Community Consultation

4.6.1. Stakeholder Consultation Plan

Council engaged consultants Molino Stewart Pty Ltd to help prepare and implement a stakeholder consultation plan associated with the public exhibition of the draft *Lake Macquarie Waterway Flood* Study and *Lake Macquarie Waterway Flood Risk Management Study and* Plan in October and November 2011. A copy of their report is provided as Appendix D.

4.6.2. Outline of Plan

The draft *Lake Macquarie Waterway Flood* Study and *Lake Macquarie Waterway Flood Risk Management Study and* Plan were placed on public exhibition from 13 October to 28 November 2011, and members of the public were invited to make submissions. Copies of the reports were available from Council libraries, the Customer Service Centre and from Council's website, along with an electronic survey and feedback form.

Owners of all foreshore properties below 3 mAHD (approximately 7700 property owners) were direct-mailed information about the studies, with an invitation to attend one of six information sessions and workshops held at Morisset, Toronto, Boolaroo, Charlestown, Belmont and Swansea in November 2011.

More than 370 people attended the workshops. The evaluation surveys showed that, on average, more than 80% of participants were satisfied or highly satisfied with all elements of the workshops. The lowest rating was given to the 'quality of information', almost certainly reflecting the dissatisfaction of those participants who didn't accept the science of climate change and sea level rise. Workshop participants filled in a survey covering their attitudes to major issues, and their level of agreement with the proposed flood risk management options. As well, their comments during small-group discussions were recorded and collated, and other comments were collected on a message board.

Other elements of the consultation included:

- Feedback from the Lake Macquarie Floodplain Management Committee, Lake Macquarie Community Advisory Group, Lake Macquarie Developers Forum, and Lake Macquarie City Council,
- Direct mail and requests to make submissions to more than 60 business chambers, development industry groups, infrastructure providers, community environment groups, and NSW government agencies.

4.6.3. Summary of Responses

The summary of the responses to the workshop and on-line surveys (345 received) is contained in the report by Molino Stewart in Appendix D. The Molino Stewart report also includes a précis of the issues raised in small-group workshop discussions and via the message board.

Written submissions were received from 22 residents and stakeholder organisations. A summary of the submissions and Council's response is provided in Table 12 and discussed in the following sections.

TECHNICAL CORRECTIONS AND SUGGESTIONS

A few submissions pointed out errors or inconsistencies in the text or in the assumptions made in the flood modelling.

Council response

Response to submissions suggesting technical improvements and corrections are listed in the table below, and some detailed responses have been sent individually. Several changes have been made to the draft reports in response to these submissions.

MANAGEMENT OPTIONS

There were several suggestions supporting or opposing various management options proposed in the *Draft Flood Risk Management Study and Plan* (such as seawalls, dredging etc.).

Council response

These suggestions will be considered, along with the outcome of the community survey and community workshops, when Council approves its recommendations for action after the *Study and Plan* are adopted. Some suggestions, such as widening or deepening Swansea Channel, have already been rejected by the report as they do not reduce the effects of flooding in the lake, and may actually make it worse.

Table 12: Summary of Submissions of – Draft Lake Macquarie Waterway Flood Study and Flood Risk Management Study and Plan

Name/organisation	Key points of submission	Response to submission
Resident 1	Questions the science behind sea temperature increase and sea level rise. Proposes alternative analysis based on own (unpublished) research.	Covered in summary response (see above)
Resident 1	Queries calculation of 1.0 metre lake rise as sea level rises, and the calculation of 1:100 flood level.	Misreading of the report – no change required
Resident 1	Comments on generation of tsunamis and response of oceans to low pressure systems	Tsunami not included in Flood Study – separate study underway by NSW Government.
Resident 2	Waste of time and money. Will Council compensate for a drop in property value?	Covered in summary response (see above)
Resident 3	Questions the science of sea level rise	Covered in summary response (see above)
Resident 4	Need plain-English summary of Study and Plan to make them more accessible. Recommends adaptable buildings and innovative design to make buildings more flood proof eg. floating homes, waterproof cupboards. Change regulations to encourage innovative design.	Will be considered when implementing management recommendations and developing Local Area Adaptation Plans.
Resident 5	Supports seawall to protect properties in her area, but recognises problems with foreshore access for sailors. Doesn't support use of rock gabions for seawall construction.	Will be considered when implementing management recommendations and developing Local Area Adaptation Plans.
Resident 6	Supports recommended management options. Options will vary from place to place – no "one-size-fits-all" solution. Asks for regular review of science and education of the public. Some properties may have to be sacrificed.	Will be considered when implementing management recommendations and developing Local Area Adaptation Plans.
Resident 7	Request photos be changed in Figure 12 of the Flood Study	Report amended

Name/organisation	Key points of submission	Response to submission
Resident 8	Streets in his area not shown on map in Study.	Report amended
Resident 9	Queries accuracy of projections and objects to notification on Section 149 Certificates on the basis of faulty projections. Expresses concern that insurance premiums may rise if properties are tagged as flood affected, and blames this for recent premium rise of 40%.	Covered in summary response (see above)
Resident 10	Requests specific study on flooding in Cold Tea Creek and Belmont Lagoon as it has capacity to cut the Pacific Highway.	Is included in current study. More detail will be provided when Local Area Adaptation Plan is developed.
Resident 11	Raises several suggestions and issues: use rainwater tanks for stormwater detention to reduce flooding; widen the channel to allow flood water to escape; no evidence of sea level rise; objects to affect of Section 149 notification on property values. Concern over tsunami.	Covered in summary response (see above). Tsunami not included in Flood Study – separate study underway by NSW Government.
Resident 12	Detailed comments on text and analytical aspects of the reports – too many to detail.	Some changes and corrections made to report. Individual response sent.
ADW Johnson Pty Ltd.	Queries several of the flood modelling assumptions and sea level rise assumptions. Queries the use of language such as "will" in reference to future scenarios. Submission based on information in the Summary document, not on the full Study.	Submission based on "Summary" document – issues are covered in the full Study and Plan.
Northrop Engineers	Questions choice of 100 year ARI rainfall with 20 year ARI ocean level – too conservative. Check accuracy of reference to levels in earlier Study.	Basis for the choice of various parameters explained in an Individual response. No change to the Study.
Resident 13	Proposes better stormwater management in Black Neds Bay, and dredging in Black Neds Bay and Swansea Channel. Objects to Section 149 notifications at the proposed levels.	Covered in summary response (see above). Specific measures for Black Neds Bay will be considered in more detail when Local Area Adaptation Plan is developed.

Name/organisation	Key points of submission	Response to submission
Resident 14	Questions the science of sea level rise, and attaches several letters and newspaper stories in support. Because science is wrong, then other measures incorporating sea level rise are unnecessary.	Covered in summary response (see above)
Belmont Chamber of Commerce	Asking if land will be rezoned as a result of the Study and Plan, and if owners will be compensated for loss of value.	Covered in summary response (see above). Individual response sent to answer some specific questions asked in the submission.
Gosford City Council	Discrepancy between management options, with options (eg. house-raising) seeming to be favoured in some parts of the report, and dismissed in late sections. No costing of management options.	Will be considered in more detail, including costing, when Local Area Adaptation Plans are developed.
Resident 15	Questions the science of sea level rise. Suggests better management of stormwater in catchments would reduce lake flooding.	Covered in summary response (see above)
Resident 16	Questions the science behind sea level rise and provides own analysis.	Covered in summary response (see above)
Resident 17	Questions the science of global warming and sea level rise.	Covered in summary response (see above)
Hunter Water Corporation	Concerned with effect of possible changes in development intensity on service costs to affected areas. If new development areas are needed or 'development rights' are transferred, there is no guarantee that services can be provided to new areas. Requested access to Flood Study data to assist in their vulnerability mapping for HWC assets.	Individual response. No changes in urban planning patterns or densities without consultation with HWC and other service providers. No problem with access to Flood Study data and analysis.

PROPERTY PLANNING

Several submissions raised concerns about notifications on Section 149 property certificates, effects on property values, future insurance costs, and compensation for potential future changes in property value.

Council Response

- Council is obliged by law to indicate on Section 149 property certificates any special development restrictions that are attached to properties. Since 2009, all flood-exposed properties located below the 3 metre AHD topographic contour have had a notation indicating that they may be affected by sea level rise and lake flooding. As a result of the current study we are proposing to restrict the notification of sea level rise effects to properties below the 1 metre AHD topographic contour, so fewer properties will carry this notification. The lake flooding notification will remain on properties below the 3 metre AHD topographic contour.
- Council cannot predict the likely effects on property values of a notation on Section 149 property certificates. However, there has been no overall market effect since the Section 149 notification was added, in 2009, to all properties below the 3 metre AHD topographic contour. The effects, if any, are likely to be small compared to other market factors such as interest rates, demand for waterfront properties, and economic climate.
- There is not expected to be any change in the cost or availability of flood insurance for properties as a result of the *Lake Macquarie Waterway Flood Risk Management Study and Plan*. This is because there are no additional properties identified as affected by flood or sea level rise. In general, the availability of flood insurance can be greater in localities, such as Lake Macquarie City, where Councils have well-developed flood risk management plans, and impose restrictions such as floor height requirements on new buildings in flood-affected areas. However, some insurance companies may charge differential premiums based on their assessment of flood risk on an individual property. It is up to the companies if they use the Section 149 property certificate for this (some do, some don't), and several companies now offer a "universal" flood cover irrespective of property location. Council is planning to negotiate with insurance retailers in 2012 to gain better recognition of the reduction in risk from flooding as a result of the *Lake Macquarie Waterway Flood Risk Management Study and Plan.*
- If there is a change in property values in flood-affected areas as assessed by the Valuer-General, there will be a related change in Council rates payable on these properties. There is currently no avenue for compensation if there is a reduction in the Valuer-General's assessment of the value of a property.

THE SCIENCE OF SEA LEVEL RISE

A number of submissions questioned the science behind the adopted sea level rise predictions that underpin the *Lake Macquarie Waterway Flood Study* and *Lake Macquarie Waterway Flood Risk Management Study and Plan*.

Council response

The feedback was considered, but there will be no change to this aspect of the reports. Some of the reasons for maintaining these predicted levels of sea level rise are:

- The background reports are based on peer-reviewed scientific studies that have been incorporated into scientific reviews such as those prepared by the Intergovernmental Panel on Climate Change (IPCC), US National Aeronautical and Space Administration (NASA), Bureau of Meteorology (BOM), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).
- Both NSW State Government Policy Statement (2009) and Lake Macquarie City Council Policy (2008) require Council to include consideration of sea level rise when planning for new developments. The NSW State Government *Sea Level Rise Policy Statement (2009)* requires Council to use benchmarks of 0.4 metres of sea level rise by 2050, and 0.9 metres of sea level rise by 2100. These are the levels that have been adopted in the *Lake Macquarie Waterway Flood Study.* The basis for these levels is set out in *Technical note: Derivation of the NSW Government's sea level rise planning benchmarks* (2009).
- None of the feedback presented information from peer-reviewed scientific publications that would require any change to the predicted levels.
- As new and better scientific information is published, the flood and permanent inundation levels in the *Lake Macquarie Flood Study* will be reviewed and up-dated as required, within the legal framework set by the NSW Government.

4.6.4. Conclusions

From all responses received from the workshops, community surveys, and written submissions in relation to the draft *Lake Macquarie Waterway Flood* Study and *Lake Macquarie Waterway Flood Risk Management Study and* Plan, the following general conclusions have been made by Molino Stewart Pty Ltd (see Appendix D for full report):

- Residents would like to be included in decisions relating to management of flooding and sea level rise.
- Economic considerations such as the protection of the value of private property and the provision of compensation where property usability or value is negatively impacted are very important to potentially flood-affected residents.
- Residents want local-scale flood modification measures such as drains, levees and sea walls to be used by Council to manage flood risk, but were not supportive of 'big' projects such as dams and entrance barriers.
- Response modification measures (eg. community education and improved warning systems) and property modification measures are also favoured to manage flood risk and sea level rise impacts.
- A relatively high proportion of residents are sceptical about climate change and the resultant sea level projections.
- Many residents are concerned about the possible impact of sea level projections on their property values.
- Residents want Council to provide more and clearer information to them about flooding, climate change and sea level rise, and keep them up-to-date with the latest information.

5. EXISTING FLOOD ENVIRONMENT

5.1. Flood Behaviour

Flooding on the Lake Macquarie foreshore may occur as a result of a combination of factors including:

- an elevated ocean level due to an ocean storm surge, wave setup at the entrance, a high astronomic tide and or an increase in mean sea levels,
- rainfall over the lake and the tributaries entering the Lake Macquarie waterway,
- wind wave action causing wind setup and runup on the foreshore within the lake, and/or
- permanent and tidal inundation as a result of rising sea and lake levels.

One of the key considerations in modelling coastal systems is the probability of occurrence of a combined ocean and rainfall event and the relative magnitude of both. It is considered to be overly conservative to assume a 100 year ARI ocean event will occur concurrently with a 100 year ARI rainfall event, however there are no data available to accurately define a suitable approach. For this reason, two scenarios were analysed: a **Rainfall Dominated** scenario which assumes the design rainfall over the catchment in conjunction with a design ocean event of equal or smaller magnitude and an **Ocean Dominated** scenario which assumes the design ocean event in conjunction with the design rainfall of equal or smaller magnitude.

Further details of this approach are provided in the 2012 Lake Macquarie Waterway Flood Study (Reference 6).

5.2. Hydraulic Classification

The 2005 NSW Government's Floodplain Development Manual (Reference 5) defines three hydraulic categories which could be applied to areas of the foreshore, namely floodway, flood storage or flood fringe.

Floodways are *"those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels"*. For the Lake Macquarie waterway the only floodway areas are the Swansea Channel and the channels of the creeks (Dora, Cockle, North, South, Stony and Marmong) entering the lake, and three floodways for over-bank flows in Dora Creek, identified in the Dora Creek Floodplain Management Plan.

Flood storage areas are "*those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.*".

Flood fringe is *"the remaining area of flood prone land after floodway and flood storage areas have been defined"*.

There is no precise definition of flood storage and flood fringe or accepted approach to differentiate between the two areas. For this study, it was assumed that all the land on the perimeter of the lake is flood fringe. It is not referred to as flood storage as this implies that the filling of this land will have some significant impact on flood levels by reducing the temporary floodplain storage capacity. This is not the case at Lake Macquarie given the magnitude of the lake (Table 2). Land beyond the perimeter of the lake and within the floodplains of the tributary creeks (Dora, Cockle, North, South, Stony and Marmong Creeks) may be flood storage or floodway when considering flow along those creeks (i.e as part of a separate study).

5.3. Flood Hazard Classification

The 2005 NSW Government's Floodplain Development Manual (Reference 5) determines the *provisional flood hazard* categorisation of an area based on the combination of the depth and velocity of floodwaters on the land. As the flood fringe areas surrounding the lake have effectively nil velocity the provisional hazard categories were derived based solely upon the depth of inundation.

If the depth is > 0.8m then the provisional hazard is HIGH, if the depth is < 0.8m then the provisional hazard is LOW. The boundary of the provisional High and Low hazard classification will change according to the magnitude of the flood.

However, to assess the full flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. As with provisional (hydraulic) hazard, land is classified as either *low* or *high* hazard for a range of flood events.

An additional consideration is now required for areas that become permanently inundated as a result of sea level rise. While there is not a catastrophic event, it presents a high hazard to property and infrastructure over time. The classification is a qualitative assessment based on a number of factors as listed in Table 13.

Table 13: Hazard Classification

Criteria	Weight (1)	Comment
Size of the Flood	High	Up to a (say) 5 year ARI event the damages are confined to isolated properties. In larger floods the damages are increased significantly inundating large parts of Belmont, Swansea, Marks Point and Blacksmiths.
Flood Awareness of the Community	High	Whilst residents are aware that the lake level rises during a flood (and have recently experienced the June 2007 event) the resulting extent of inundation in (say) a 100 year ARI event will be much greater than what is expected by the majority of the community.
Depth and Velocity of Floodwaters	Low	Shallow depths (generally less than 0.5 m) and very low velocity.
Effective Warning and Evacuation Times	Medium	Probably only 6 to 12 hours. There is only a very small likelihood that residents would be caught completely unaware but they are unlikely to have the foresight to react appropriately to the situation.
Evacuation Difficulties	Medium to High	For the majority of residents evacuation should be relatively easy as there is nearby high ground for vehicles and the majority of goods can be saved by raising them (say) 1 m off the ground within the building. However, the number of buildings/people requiring assistance will severely extend the services of the rescue services (SES, Police, etc.) with the main areas on the eastern shore. At Swansea the hazard is significantly increased due to the distance (> 1 km) to high ground.
Rate of Rise of Floodwaters	Low	The rate of rise of floodwaters in lake systems is slow compared to river systems. The maximum rate was approximately 100 mm/h in June 2007 and for the 100 year ARI event. Whilst the rate of rise is slow this must be considered within the context that only a small rise is needed to inundate a large number of buildings.
Duration of Flooding	High	The duration of inundation is much longer than on a river system. The lake may be near its peak for over 12 hours. However, this extended duration is unlikely to add significantly to the damages but will increase the risk to life (more crossings) and will add considerably to the level of inconvenience and the recovery time. Permanent inundation due to sea level rise is of indefinite duration.
Effective Flood Access	Low to Medium	The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained. Boats can effectively be used to ferry residents to high ground. In events up to the 100 year ARI event four wheel drive access is possible. In larger events with greater depths (above 0.5 m) other forms of transport will be required. The main problem will be congestion due to the number of vehicles.
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action, Sewage overflows	Low	The impact of this factor will vary between events and even within a flood event as the wind direction changes. It will have its greatest impact within (say) 50 m of the shoreline. The impact of debris is unlikely to be a factor except in the most extreme cases where major floating objects (boats broken from their moorings, timber and debris picked up from upstream floodplains) come into contact with buildings or residents. Erosion or sedimentation during a flood event is also unlikely to be a significant factor except in areas of high wind/wave activity, along the entrance channel (high velocities). Wind set up may raise water levels by up to 0.2 m (1998 Lake Macquarie Flood Study - Reference 8).
Provision of Services	Medium	In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Permanent inundation from sea level rise may lead to permanent loss of services.

Note: (1) Relative weighting in assessing the hazard.

Based on the above assessment, the flood hazard at Lake Macquarie waterway would be increased to HIGH for properties in the flood fringe area at or below the current (year 2011) 100 year ARI flood level of 1.5 mAHD, where water depths in a year 2100 100 year ARI flood (2.32 mAHD) will exceed 0.8 m.

To manage the long term hazard from permanent inundation as sea levels rise, a new High Lake Hazard or similar category is suggested, as management responses to deal with the hazards from permanent inundation will be somewhat different from those used to deal with flooding.

The remaining flood fringe area, between the year 2011 100 year ARI level (1.5 mAHD) and the year 2100 100 year ARI level (2.32 mAHD) is considered low hazard due to the low water velocity and flood depths below 0.8 m.

These general hazard classifications will have to be reviewed against specific local conditions, and may increase in areas where the general depth of floodwaters exceeds 1 m, there are high flow velocities, and/or there is a risk of isolation and difficulties for evacuation. This may include some properties within Dora Creek and Swansea, for example.

In floods greater than the 100 year ARI the hazard will increase as the depth increases. For the majority of areas, the flood level will increase gradually, and as such, residents will be able to evacuate to higher ground. In a PMF event the main areas of high hazard are the same as for the 100 year ARI event and there are no significant areas that would “suddenly” become high hazard in the PMF as opposed to a gradual increase as the flood level rises.

5.4. Flood Risk and the Social Impacts of Flooding

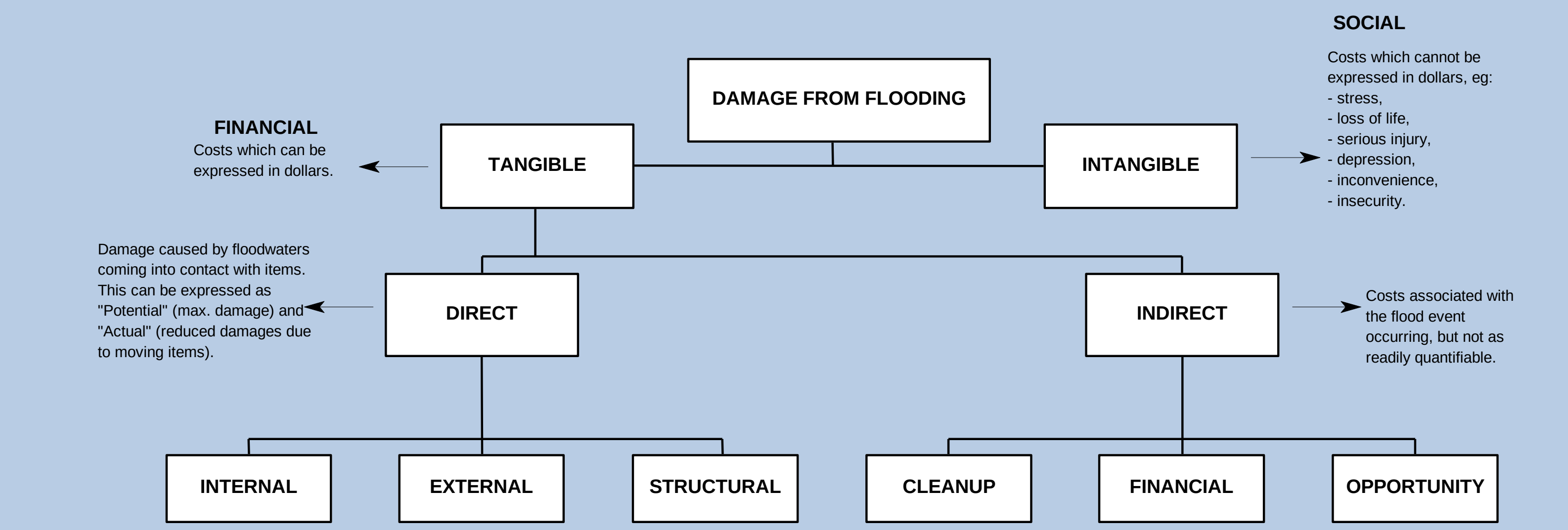
The costs of flood damages (a summary of the types of flood damages is shown on Table 14) and the extent of the disruption to the community depend upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damages,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the lake foreshore, failure of services (sewerage), flood borne debris, sedimentation and wind/wave runup, and
- the types of asset and infrastructure affected.

In order to quantify the effect of inundation on the existing development along the foreshore, a floor level database was provided by Lake Macquarie City Council for use in this study (further details are provided in Appendix C). This database was originally developed over 10 years ago but only some, not all, new developments on flood-prone land have been added since then by Council.

The original survey targeted properties on land below 2 mAHD, so floor level data for buildings on properties on land above 2 mAHD is not complete. The database also included some 100 non residential properties (out of over 4800). For un-surveyed properties above 2 mAHD floor levels are assumed to be at or near ground level, as most construction is slab-on-ground.

Table 14: Flood Damages Categories (excluding damage and losses from permanent inundation)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

As the focus of this Waterway Risk Management Study and Plan is on residential properties, given the relatively small number of non-residential properties identified and the fact that many are on the foreshore as part of their function (eg. boat hire) a full re-survey of these properties was not justified and existing information considered appropriate for this plan.

Flood damages can be defined as being “tangible” or intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value.

5.4.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories, direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or a reduction in their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood including the cost of temporary accommodation, loss of wages by employees etc.

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

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. For the calculation of AAD at Lake Macquarie waterway it was assumed that there are no flood damages in the 1 year ARI event.

A flood damages assessment was undertaken for existing development in the Lake Macquarie waterway community and is summarised on Figure 11 and Tables 15, 16 and 17. It should be noted that a significant contribution to the average annual damages is the houses inundated in the 5 year ARI and smaller events. Also it is likely that some building floors will not have been identified in the database or have been re-developed since the time of the survey.

Table 15: Summary of Surveyed Building Floors Flooded (from Table 9)

Base									
Flood Level (mAHD)	0.65	0.82	0.94	1.23	1.38	1.50	1.69	1.87	2.45
Area	2 year	5 year	10 year	20 year	50 year	100 year	200 year	500 year	PMF
Cockle Creek	0	0	0	2	8	12	17	33	99
Warners Bay	0	0	0	7	12	22	51	99	219
Marks Point - Belmont	1	4	13	71	154	234	402	552	833
Swansea – Pelican -Blacksmiths	0	5	11	89	221	430	809	1099	1732
Dora Creek	0	1	1	26	50	84	165	258	528
Carey Bay – Arcadia Vale	0	4	5	15	30	45	66	94	182
Toronto - Fassifern	1	1	1	15	32	48	83	140	242
Total	2	15	31	225	507	875	1593	2275	3835
+0.4m Sea Level Rise									
Flood Level (mAHD)	1.04	1.21	1.32	1.61	1.74	1.86	2.05	2.23	2.81
Area	2 year	5 year	10 year	20 year	50 year	100 year	200 year	500 year	PMF
Cockle Creek	0	2	6	13	18	33	42	68	147
Warners Bay	0	6	9	36	63	93	148	186	243
Marks Point - Belmont	23	67	118	329	438	543	689	770	879
Swansea – Pelican -Blacksmiths	36	100	171	755	996	1204	1472	1691	2031
Dora Creek	6	24	40	134	193	255	349	458	603
Carey Bay – Arcadia Vale	6	14	23	59	77	94	127	155	205
Toronto - Fassifern	3	12	23	68	96	137	186	213	279
Total	74	225	390	1394	1881	2359	3013	3541	4387
+0.9m Sea Level Rise									
Flood Level (mAHD)	1.54	1.71	1.81	2.10	2.20	2.32	2.51	2.69	3.27
Area	2 year	5 year	10 year	20 year	50 year	100 year	200 year	500 year	PMF
Cockle Creek	12	18	25	45	68	83	110	132	186
Warners Bay	25	54	79	158	181	207	225	236	262
Marks Point - Belmont	266	411	501	716	764	796	851	873	890
Swansea – Pelican -Blacksmiths	711	1129	1316	1794	1893	1965	2010	2039	2071
Dora Creek	101	170	236	373	445	483	542	577	656
Carey Bay – Arcadia Vale	51	72	88	131	152	173	187	199	218
Toronto - Fassifern	55	87	119	193	208	229	251	271	321
Total	1221	1941	2364	3410	3711	3936	4176	4327	4604

Table 16: Summary of Increase in Surveyed Building Floors Flooded

	Existing	Sea Level Rise 0.4 m			Sea Level Rise 0.9 m		
ARI	Buildings Inundated	Buildings Inundated	Increase	Increase (%)	Buildings Inundated	Increase	Increase (%)
2 year	2	74	72	3600%	1221	1219	60950%
5 year	15	225	210	1400%	1941	1926	12840%
10 year	31	390	359	1158%	2364	2333	7526%
20 year	225	1394	1169	520%	3410	3185	1416%
50 year	507	1881	1374	271%	3711	3204	632%
100 year	875	2359	1484	170%	3936	3061	350%
200 year	1593	3013	1420	89%	4176	2583	162%
500 year	2275	3541	1266	56%	4327	2052	90%
PMF	3835	4387	552	14%	4604	769	20%

The damages were calculated with use of a number of height/damage curves (that is, curves which relate the depth of water above the floor with tangible damages) which were developed based on guidelines provided by DECCW (now Office of Environment and Heritage).

Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

For the Lake Macquarie waterway assessment, internal damages were allocated a maximum value of $60,000 occurring at a depth of 2 m above the building floor level (and linearly proportioned between the depths of 0 to 2 m). Structural and indirect damages were grouped together and given a maximum value of $20,000 assumed to occur at 1.5 m depth above the building floor level and linearly proportioned for the depths below this. External damages were allocated a maximum of $1,000 occurring at 0.5 m above the property ground level and linearly proportioned for depths below this.

This estimate does not include the cost of restoring or maintaining services and infrastructure.

Table 17: Summary of Tangible Flood Damages (based on Table 15)

Foreshore Management Area	2Y	5Y	10Y	20Y	50Y	100Y	200Y	500Y	PMF
Existing									
Cockle Creek	$0	$0	$1,000	$29,000	$135,000	$255,000	$503,000	$911,000	$3,749,000
Warners Bay	$0	$0	$0	$72,000	$222,000	$465,000	$1,174,000	$2,467,000	$9,854,000
Marks Point - Belmont	$7,000	$47,000	$218,000	$1,535,000	$3,385,000	$5,787,000	$11,384,000	$18,390,000	$44,716,000
Swansea – Pelican - Blacksmiths	$2,000	$47,000	$172,000	$1,664,000	$4,149,000	$8,491,000	$20,233,000	$34,647,000	$88,239,000
Dora Creek	$1,000	$20,000	$33,000	$440,000	$1,081,000	$1,948,000	$4,393,000	$7,854,000	$24,674,000
Carey Bay – Arcadia Vale	$0	$55,000	$106,000	$373,000	$689,000	$1,127,000	$2,060,000	$3,262,000	$8,749,000
Toronto - Fassifern	$18,000	$36,000	$52,000	$299,000	$678,000	$1,175,000	$2,361,000	$4,157,000	$12,070,000
Total	$28,000	$205,000	$582,000	$4,412,000	$10,339,000	$19,248,000	$42,108,000	$71,688,000	$192,051,000
+ 0.4m sea level rise									
Cockle Creek	$3,000	$23,000	$77,000	$384,000	$579,000	$886,000	$1,497,000	$2,281,000	$6,721,000
Warners Bay	$1,000	$53,000	$145,000	$808,000	$1,460,000	$2,371,000	$4,405,000	$6,716,000	$14,044,000
Marks Point - Belmont	$459,000	$1,371,000	$2,443,000	$8,724,000	$13,107,000	$17,992,000	$26,808,000	$35,159,000	$56,838,000
Swansea – Pelican - Blacksmiths	$691,000	$1,854,000	$3,236,000	$16,666,000	$26,152,000	$36,448,000	$54,479,000	$71,443,000	$121,176,000
Dora Creek	$91,000	$376,000	$761,000	$3,220,000	$5,201,000	$7,660,000	$12,382,000	$17,676,000	$34,655,000
Carey Bay – Arcadia Vale	$160,000	$343,000	$525,000	$1,651,000	$2,366,000	$3,202,000	$4,748,000	$6,421,000	$12,125,000
Toronto - Fassifern	$84,000	$258,000	$471,000	$1,818,000	$2,758,000	$4,048,000	$6,545,000	$8,979,000	$16,519,000
Total	$1,489,000	$4,278,000	$7,658,000	$33,271,000	$51,623,000	$72,607,000	$110,864,000	$148,675,000	$262,078,000
+ 0.9m sea level rise									
Cockle Creek	$296,000	$536,000	$724,000	$1,674,000	$2,164,000	$2,867,000	$4,230,000	$5,684,000	$10,636,000
Warners Bay	$559,000	$1,277,000	$1,938,000	$5,057,000	$6,404,000	$8,086,000	$10,670,000	$12,779,000	$18,000,000
Marks Point - Belmont	$6,686,000	$12,065,000	$15,807,000	$29,307,000	$34,103,000	$39,434,000	$47,151,000	$53,305,000	$68,694,000
Swansea – Pelican - Blacksmiths	$14,754,000	$28,477,000	$36,976,000	$70,492,000	$80,922,000	$91,854,000	$107,801,000	$119,437,000	$151,928,000
Dora Creek	$2,329,000	$4,696,000	$6,568,000	$13,798,000	$16,933,000	$20,683,000	$26,536,000	$31,559,000	$45,323,000
Carey Bay – Arcadia Vale	$1,296,000	$2,190,000	$2,839,000	$5,205,000	$6,190,000	$7,442,000	$9,355,000	$11,061,000	$15,527,000
Toronto - Fassifern	$1,375,000	$2,516,000	$3,450,000	$7,259,000	$8,656,000	$10,329,000	$12,912,000	$15,165,000	$21,713,000
Total	$27,295,000	$51,757,000	$68,302,000	$132,792,000	$155,372,000	$180,695,000	$218,655,000	$248,990,000	$331,821,000

* Tangible damages includes external damages which may occur with or without house floor inundation

Based on the above, the average annual damages for the foreshore management areas are shown on Table 18.

Table 18: Annual Average Damages

Foreshore Management Area	Existing Year 2011	+0.4m sea level rise year 2050	+0.9m sea level rise year 2100
Cockle Creek	$14,000	$64,000	$454,000
Warners Bay	$30,000	$150,000	$1,108,000
Marks Point - Belmont	$338,000	$1,639,000	$8,814,000
Swansea - Pelican - Backsmiths	$491,000	$2,871,000	$20,379,000
Dora Creek	$122,000	$587,000	$3,638,000
Carey Bay – Arcadia Vale	$81,000	$355,000	$1,637,000
Toronto - Fassifern	$85,000	$342,000	$1,965,000
Total	**$1,161,000**	**$6,008,000**	**$37,995,000**

Tangible damages will also occur as a result of permanent inundation as a result of sea and lake level rises. There is no current damage but, as land and, even some structures, are affected by rising lake levels by the year 2050 and beyond, there will be a financial cost through loss of land use and damage to buildings and infrastructure. The Lake Macquarie Environmental Security Assessment report prepared for Lake Macquarie City Council in 2010 (Reference 11) estimated the total losses in land value from permanent inundation to the year 2100 at $528 million, although this would not start to be realised until after 2050.

Figure 12 provides a graph of the design flood levels taking into account sea level rise and increases in rainfall intensities for the Lake Macquarie waterway and Swansea Channel. Figure 13 indicates the number of building footprints affected in the various design events (the footprints were obtained from aerial photography and predominantly represent residential, commercial and industrial buildings but may include other structures such as sheds or garages). Figure 14 indicates the areal extent of inundation in the various design events and within each planning zone. Figure 15 indicates the number of properties affected in the various design events and within each planning zone. Figure 16 indicates the number of properties according to the percentage of land inundated within the property for the various design events.

5.4.2. Intangible Flood Damages

The intangible damages associated with flooding are inherently more difficult to estimate. In addition to the direct and indirect damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that the consideration of intangible damages is included when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur on the foreshores of the Lake Macquarie waterway is discussed below.

Isolation

Isolation (the ability to freely exit and enter your house) during flood events will become a significant factor for local residents in areas such as Dora Creek and to a lesser extent at Swansea. There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood (as happened in June 2007). However, isolation is of significant concern if a medical emergency arises during a flood.

Population Demographics

Analysis of the 2006 Census data indicates that there are some particular features of the population demographics of the community on the foreshores of Lake Macquarie waterway that would contribute to additional intangible damages, particularly community resilience.

These include age and income population characteristics. The population in some of the suburbs most vulnerable to floods and inundation from sea level rise and storms attributable to the impact of climate change are significantly older than the Lake Macquarie City average. For example, while the median age of the population of Lake Macquarie is 40 years old, the median age of the population of Swansea is 48 years old, in Belmont it is 46, and in Dora Creek it is 44 years old. The median age of people in New South Wales is 37 years.

Furthermore, the percentage of the population over 65 years old in Swansea is 28.4%, in Belmont 28.1%, and in Dora Creek it is 21%, compared to the Lake Macquarie median of 16.8% (the NSW median is 13.8%). Older populations and low incomes are linked, as many older retirees are no longer earning incomes.

While some households in some vulnerable communities enjoy high incomes, many people living in vulnerable foreshore communities are living on incomes that are significantly lower than the Lake Macquarie average. For example, median household weekly income in Swansea is $570/week, in Belmont it is $587/week and in Dora Creek it is $810/week, compared to the Lake Macquarie average of $922/week (the NSW median is $1036/week).

Unemployment levels in these communities are generally higher than the Lake Macquarie median, with unemployment level in Swansea being 13.3%, in Belmont 8%, and Dora Creek 8.87%, compared to the Lake Macquarie median of 6.7% (the NSW median is 5.8%).

These age, income and unemployment statistics indicate the possibility of lower resilience of these vulnerable foreshore communities to adapt to change, therefore requiring local adaptation plans that acknowledge and respond to specific local challenges. Well-developed emergency preparedness, response and recovery programs are also required.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.,) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. To some extent, this does not appear to be a significant issue at Lake Macquarie waterway as a number of residents experienced both the February 1990 and June 2007 events and this issue has not become apparent in post flood surveys. The increasing hazard due to climate changes and rising sea levels is likely to add to community and individual stress, as it makes future events even more difficult to predict, and planning for the future even more uncertain.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. At Lake Macquarie waterway the absence of high velocities as well as high flood depths (say > 1 m) means that the risk is smaller than in other flood liable communities. However the risk is increased due to the duration of inundation and the length of some evacuation routes (Dora Creek and Swansea).

5.5. Flood Awareness and Flood Warning

The flood awareness of the community and the available flood warning time are important factors in reducing the likely flood damages. Based on experience in other areas and discussions with local residents and others it is likely that the flood awareness of the community is medium to low. A contributing factor is that about 1% of the LGA’s population will be temporary (holiday makers or possibly weekenders), although this percentage will be higher in foreshore areas which are popular with visitors and tourists. However the available flood warning time is high for the following reasons:

- The lake rises relatively slowly (say on average less than 100 mm per hour),
- The Bureau of Meteorology operates a flood warning system based upon regional rainfall and river gauges,
- The residents will be aware of the water actually rising across their yards (unless at night) and heavy rain in their neighbourhood, and
- Residents are generally aware that as the lake rises it will inundate the surrounding foreshore areas. Residents who have been in the area for a few years will have experienced minor rises in the water level (and possibly even the February 1990 and June 2007 events) and will be aware that larger events may occur causing more severe inundation.

The extent or success of damage mitigation measures employed by the residents during the February 1990 or June 2007 events is unknown. However the relatively shallow depth of above floor inundation means that it is easy to “lift” (portable) items above the water level. However carpets and fixed items (such as kitchen and cupboards) cannot generally be saved.

5.6. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include:

- recreational/tourist facilities,
- water and sewerage supply,
- gas supply,

- telephone supply,
- electricity supply including transmission poles/lines, sub-stations and underground cables,
- roads and bridges including traffic lights/signs, and
- costs to employ the emergency services and assist in cleaning up.

Damages to the public sector can contribute a significant proportion of the total flood costs. There are no accurate estimates of the amount of damages to the public sector in previous floods.

Fixed infrastructure such as roads and sewer are particularly vulnerable to permanent and tidal inundation as sea and lake levels rise. Infrastructure in low-lying areas close to the lake foreshore can expect to experience increased corrosion, rising groundwater levels, and more frequent tidal inundation. This will increase maintenance and service costs, and may lead to long-term failure of some assets unless they are re-designed or relocated. The future risk, and cost, to infrastructure needs to be investigated in more detail as local Area Adaptation Plans are prepared for vulnerable foreshore communities.

5.7. Impacts of Flooding on Commercial and Industrial Activities

Commercial and industrial activities will also be adversely affected by flooding and vulnerable to permanent and tidal inundation as sea and lake levels rise. The magnitude of the damages will likely be less than for the residential community as there are much fewer buildings susceptible to flooding (Table 9). A rigorous study of these activities has not been undertaken but it is also likely that as re-development occurs (many commercial premises have a much shorter lifespan than houses) measures to mitigate the impacts of flooding and climate change can be incorporated into the building design. This issue would need to be examined on a case by case basis.

5.8. Environmental Impacts of Flooding

Flooding is a natural phenomenon that has been a critical element in the formation of the present topography. Thus erosion, sedimentation and other results from flooding should be viewed as part of the natural ecosystem. It is only when these effects impact on man-made elements that they are of concern, and similarly, when development impacts or exacerbates these processes.

However, as natural areas become permanently inundated by rising sea and lake levels, and tidal and flood regimes change, ecosystems will be affected by the changes to hydrology. Foreshore ecosystems such as mangroves, saltmarsh, and wetlands may be inundated, or suffer from changes in salinity, groundwater, and tidal inundation. The Lake Macquarie Wetlands Climate Change Assessment study for Lake Macquarie City Council in 2010 (Reference 12) showed that a 0.9 m increase in lake level would inundate 680 ha (28%) of foreshore wetlands, but up to 90% of some types such as saltmarsh and swamp-oak forest.

Assessment of the environmental impact of property protection and flood modification measures needs to consider changes in baseline environmental conditions caused by sea level rise, such as permanent inundation of tidal saltmarsh. For example, protection works such as berms or sea walls could affect ecosystems such as saltmarsh, and/or block off possible areas for ecosystem retreat. Filling and changes to local drainage patterns could also affect ecosystems dependent on a particular hydraulic pattern of wetting and drying.

Strategic planning for areas affected by permanent inundation and increased flooding must include consideration of ecosystem adaptation and retreat, particularly for tidal saltmarsh, and foreshore and coastal wetlands. The future protection and conservation of ecosystems dependent on lake water levels should be included in the development of Area Adaptation Plans that are recommended as part of this study and plan.

5.9. Flood Emergency Response Classification

To assist in the planning and implementation of response strategies, the SES in conjunction with DECCW (now OEH) has developed guidelines to classify communities according to the impact that flooding has upon them. Flood affected communities are considered to be those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue.

Based on the guidelines, communities are classified as either, Flood Islands, Road Access Areas, Overland Access Areas, Trapped Perimeter Areas or Indirectly Affected Areas (refer Table 19). From this classification an indication of the emergency response required can be determined.

Table 19: Emergency Response Classification of Communities

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Areas with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

The guideline was applied for the community and for all foreshore management areas of Lake Macquarie waterway the community was classified as Low Flood Island based on the following criteria:

- there are homes and access roads below the PMF,
- vehicle evacuation routes are cut before homes are inundated,
- there are no habitable areas for refuge (except the homes themselves),

- the homes are first surrounded by floodwaters and then inundated, and
- thus vehicle evacuation must be completed before the route is closed.

In summary, a local flood action plan should be prepared for each foreshore management area and communicated with the community. Due to the extensive area and number of people requiring the services of the SES, the main focus for many residents will be on self-help during a flood.

5.10. Implications of Climate Change and Sea Level Rise

5.10.1. Background

Climate change is predicted to cause an increase in sea level and possibly changes to design rainfall intensities. The likely impacts of a rise in sea-level include:

- an increase in the intensity and frequency of storm surges;
- increased foreshore erosion and inundation of low lying coastal lands;
- further loss of important coastal wetland ecosystems; and
- damage to and destruction of human assets and settlements.

In developed areas such as Lake Macquarie waterway, changes in the climate, such as an increase in storm activity, together with a rise in sea level are likely to influence future building design, standards and performance as well as energy and water demand and in particular coastal/estuary planning.

Given that the Lake Macquarie waterway has a wide foreshore, future development and redevelopment of foreshore areas will need to factor how future sea-level rise will impact on the developments. Nearly 4000 residential and commercial properties will be at least partially affected by a 0.9m rise in sea levels (Figure 15), affecting their future use and development. By area, it is public land that is most affected (Figure 14), covering Council reserves, Crown land, and National Parks. Rising sea and lake levels will affect construction and reconstruction of foreshore structures, such as seawalls, fixed jetties and boat ramps, and public foreshore access in the future. Mitigation and adaptation options to address the potential impacts of climate change, particularly for coastal communities, will become increasingly more expensive and problematic.

The 2005 Floodplain Development Manual (Reference 5) and 2010 Flood Risk Management Guide (Reference 3) requires that Flood Studies and Risk Management Studies consider the impacts of sea level rise and climate change on flood behaviour.

5.10.2. Key Developments

Since completion of the Lake Macquarie Flood Study reports (References 5 and 6) in 1998, current best practice for considering the impacts of climate change (sea level rise and rainfall increase) have been evolving rapidly. Key developments in the last three years are summarised in Section 7of the 2012 Lake Macquarie Waterway Flood Study (Reference 6).

5.10.3. How will Climate Change Affect Water Levels in the Lake Macquarie Waterway?

Climate change has the potential to alter the water level in both non-flood and flood times.

During Non Flood Times

The main impacts in non-flood times will be:

- The “normal” water level in the Lake Macquarie waterway will rise from the current 0.1 mAHD average lake water level. The predicted increase in lake levels is the same as the expected sea level rise (by 0.4 m in 2050 to 0.5 mAHD and by 0.9 m in 2100 to 1.0 mAHD), as determined by the NSW State Government’s 2010 Flood Risk Management Guide (Reference 3).
- Through-out the year, a series of elevated ocean levels (combination of high astronomic tides and/or storm surges) over a few days will “pump up” water levels in the Lake Macquarie waterway. This “highest non-flood lake water level in a year” is estimated to be 0.5 mAHD and will rise by an equivalent amount to the climate change sea level rise. Thus each year lake water levels of 0.9 mAHD (+0.4m sea level rise) and of 1.4 mAHD (+0.9m sea level rise) will occur as a result of elevated ocean levels.
- It is possible that the tidal range and seasonal variation in water level within the lake (i.e change in tidal prism) may change in response to rainfall or temperature changes but the extent is unknown at this time.

The increase in the “normal” water level in the Lake Macquarie waterway in “non-flood” times may result in increased maintenance costs and/or modifications costs for existing developments and infrastructure due to more frequent inundation in non-flood times. For example, low lying roads will be more frequently inundated. Inflows of water from the Lake Macquarie waterway to sewer surcharge vents in backyards may also occur more frequently. The increased cost for residents and Lake Macquarie City Council to maintain the existing developments and infrastructure is unknown. A separate study is required to quantify the effect in non flood times but it is likely that at some time in the future the existing services in particularly low lying areas (say a road) will become unable to be maintained and it will have to be relocated or re-built. This may affect service standards to existing developments.

The increase in water levels during non-flood times may also see some areas of land that are currently dry become flooded most of the time. This will affect the current use of that land and strategic planning is necessary to reduce the economic impact resulting from this flooding.

Any change in the “normal” water level regime will impact on the ecology of the Lake Macquarie waterway. The implications of this are largely outside the scope of this Waterway Risk Management Study and Plan.

During Flood Times

There are several broad ways in which climate change and sea level rise will affect water levels in the Lake Macquarie waterway during floods, namely:

- *The increase in ocean level* will raise the "normal" water level in Lake Macquarie Waterway as well as the assumed ocean level adopted for design flood analysis in the 2012 Lake Macquarie Waterway Flood Study (Reference 6). In this study an ocean dominated and rainfall dominated design flood scenario were examined. For each of these design scenarios the adopted ocean levels will rise due to climate change. The results are provided in Table 20.
- *The increase in peak rainfall intensity and storm volume* will increase design flood levels in the Lake Macquarie waterway. The sensitivity of the lake flood levels to increased rainfall was investigated and the results are provided in Table 20.
- *A change in entrance conditions along the Swansea Channel* has been investigated in the 2010 Tidal Prism Modelling of Lake Macquarie study (Reference 13). The effects of any change are relatively small and have not been considered further at this stage.
- *A change in wind activity* on the Lake Macquarie waterway will change the "wave runup" flood level around the foreshores. At this time the impact of this effect is unknown. The 2012 Lake Macquarie Waterway Flood Study (Reference 6) indicated that the impact would be an increase in runup level of the order of 0.1 m.

Table 20 and Figure 12 provide a summary of the design flood levels in the Lake Macquarie waterway due to sea level rise and rainfall intensity increases.

Table 20: Summary of Design Lake Levels

	Peak Lake Level (mAHD)					
		Sea Level Rise		Rainfall Increase		
Event (ARI)	**Existing**	**+ 0.4m**	**+ 0.9m**	**10%**	**20%**	**30%**
2 year	0.65	1.04	1.54	0.71	0.77	0.83
5 year	0.82	1.21	1.71	0.88	0.94	1.00
10 year	0.94	1.32	1.81	1.03	1.11	1.19
20 year	1.23	1.61	2.10	1.32	1.40	1.49
50 year	1.38	1.74	2.20	1.50	1.61	1.72
100 year	1.50	1.86	2.32	1.62	1.73	1.84
200 year	1.69	2.05	2.51	1.81	1.92	2.03
500 year	1.87	2.23	2.69	1.99	2.10	2.21
PMF	2.45	2.81	3.27	2.57	2.68	2.79

Note: Underlined levels have been derived by interpolation from model results rather than actual modelling

Land Inundated by Design Scenarios

Flood extent mapping for the following design scenarios is provided in Appendix B.

- Existing 100 year ARI lake level = 1.5 mAHD,
- Year 2050 100 year ARI lake level = 1.86 mAHD (assumes +0.4 m sea level rise only),
- Year 2100 100 year ARI lake level = 2.32 mAHD (assumes +0.9 m sea level rise only),
- Year 2100 "normal" lake water level = 1.0 mAHD.

Table 21 provides a tabulation of the number of properties affected in the design scenarios.

Table 21: Properties Affected – Flood Design Scenarios

Event and Peak Level (m AHD)	No. of Properties Affected	No Building footprints Affected
Year 2011 2yr ARI - 0.65	2224	216
Year 2011 5yr ARI-0.82	3251	669
Year 2011 10yr ARI-0.94	4024	1187
Year 2100 Lake Level-1.00	4450	1562
Year 2011 20yr ARI-1.23	5973	3057
Year 2011 50yr ARI-1.38	6747	3967
Year 2011 100yr ARI-1.5	7331	4661
Year 2011 200yr ARI-1.69	8192	5595
Year 2050 100yr ARI -1.86 (+0.4m SLR)	8750	6282
Year 2011 500yr ARI-1.87	8776	6300
Year 2100 100yr ARI -2.32 (+0.9m SLR)	9709	7245
Year 2011 PMF-2.45	9932	7475
Year 2100 100yr ARI (+ 0.5m freeboard)-2.82	10608	8054

Are the Implications of Climate Change Significant?
A rise in the “normal” lake water level, annual peak lake water level and the design flood levels will have a significant effect.

5.10.4. Implications of Future Development

Due to the limited availability and relatively small scale of residential zoned land in the contributing catchments, the hydrologic impacts (increased runoff) of increased building construction will have no significant impact on the flood regime (increased runoff or rate of runoff). Council’s Development Control Plan requires that new developments do not increase stormwater run-off into lake catchments, although the controls only apply to the smaller, more frequent rainfall events (less than 20 year ARI).

Future filling of the foreshore (for roads or building pads) will reduce the available temporary floodplain storage capacity. However, given the large foreshore surrounding the lake, the area of the lake (110 km^2), and the likely scale of the filling, it is considered that filling of the foreshore will have no significant impact on flood levels. All filling proposals must still be considered in terms of their potential impact on local drainage, effects on foreshore processes, and overland flow paths in the foreshore areas.

6. RISK MANAGEMENT MEASURES

6.1. General

The 2005 NSW Government's Floodplain Development Manual (Reference 3) separates risk management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees. At Lake Macquarie waterway this would also include any works that modify the entrance to the Pacific Ocean (Swansea Channel).

Property modification measures modify land use and development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), strategic planning (such as land use zoning), building regulations (such as flood-related development controls), or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

6.1.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows). It is a standard method for using the time value of money to appraise long-term projects of the reduction in flood damages (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. Due to the limited number of options available this matrix was not rigorously used for each option. It is a recommendation of this report that multi-variate decision matrices be developed for specific foreshore management areas, allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts. The matrix below is designed to set out a general scheme to illustrate how a local matrix might be developed.

6.1.2. Management Matrix

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events,
- number of properties benefited by measure,
- technical feasibility (design considerations, construction constraints, long-term performance),
- community acceptance and social impacts,
- economic merits (capital and recurring costs versus reduction in flood damages),
- financial feasibility to fund the measure,
- environmental and ecological benefits,
- impacts on the State Emergency Services,
- political and/or administrative issues,
- long-term performance given the likely impacts of climate change and ocean/sea level rises, and
- risk to life.

The scoring system for the above criteria is provided in Table 22 and largely relates to the impacts in a 100 year ARI event. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions.

Table 22: Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	**>100mm increase**	**50 to 100mm increase**	**<50mm increase**	**no change**	**<50mm decrease**	**50 to 100mm decrease**	**>100mm decrease**
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straightforward	straightforward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

6.2. Measures Not Considered Further

It was apparent that after a preliminary matrix assessment that a number of risk management measures were not worthy of further consideration. These are summarised in Table 23.

Table 23: Risk Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	**Social Effect**	**Environ-mental Impact**	**Cost to Implement**	**Benefit/ Cost Ratio**
FLOOD MODIFICATION MEASURES:					
Flood Mitigation Dams, etc.	Yes but minimal	Nil	Very High	Very High	Low
Change the existing entrance or construct another entrance	No	Very High	Very High	Very High	Low
Catchment Treatment	Minimal	Nil	Low	Low	Nil
PROPERTY MODIFICATION MEASURES:					
Voluntary Purchase of all Buildings Inundated in the PMF	Nil	High	Nil	High per building	Probably Low
RESPONSE MODIFICATION MEASURES:					
Nil					

6.2.1. Flood Mitigation Dams, Retarding Basins, On-Site Detention

Large flood mitigation dams within the catchment are not viable on economic, social and environmental grounds. Construction of retarding basins (say up to 50 000 m^3) and the use of on-site stormwater detention or retention systems are increasingly being used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments (say up to 5 km^2) or to mitigate the effects of increased runoff caused by development. However, these structures would have negligible impact upon lake levels.

6.2.2. Change the Existing Entrance or Construct another Entrance

Enlarging the Swansea Channel entrance will not reduce flooding, sea level rise, or tidal inundation. In fact, by allowing easier access to the lake for oceanic tides, storm surge, and wave setup, it will increase flood peaks, tidal inundation, and ocean-induced lake water level rise. It would also be expensive to construct and maintain. Constructing another opening from the ocean to Lake Macquarie to the north of the existing entrance would have all the same problems and, like the channel-deepening, it would be counter-productive. There would be a high social (loss of land), environmental (loss of flora and fauna, impact on lake ecosystem, impact on coastal processes at the existing and new outlets) and economic costs (excavation and bridging costs), making these measure impractical. Measures such as a “Thames” style barrage to prevent elevated ocean levels from entering the lake are unlikely to be successful for all storms, as many events that produce elevated ocean levels (storm surge) also produce intense rainfall causing flooding. Thus a barrier would keep flood waters in as well as keeping storm surge out, providing little net benefit in Lake Macquarie waterway. Such engineered barriers are also very expensive to construct and maintain, and may have significant environmental impacts. Such barriers will have no effect on long-term sea level and lake level rise.

6.2.3. Catchment Treatment

Catchment treatment modifies the runoff characteristics of the catchment to reduce inflows to the lake. For an urban catchment, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention (now called Water Sensitive Urban Design or WSUD). For a rural catchment, this involves limiting deforestation or contour ploughing of hill slopes. These measures can reduce the volumes of storm water run-off in relatively small, frequent events, typically up to about 5 year ARI events. They have little effect in larger, less frequent events, above say a 20 ARI event. These measures can be effective on small catchments but have a negligible impact on large catchments such as Lake Macquarie waterway.

As a general concept, catchment treatment techniques and WSUD should be encouraged (eg. on-site detention, limit on-site imperviousness for developments, controls on rural land use) along with water quality and other environmental controls as these approaches provide significant local drainage and non-flooding benefits. However as a management measure to reduce flood levels on the foreshore of the Lake Macquarie waterway they are ineffectual and are not supported for this purpose.

6.2.4. Voluntary Purchase of Buildings

Voluntary purchase of the buildings inundated above floor level in the 100 year ARI flood (over 800 at say $500 000+ per building) cannot be economically or socially justified. Generally, Government funding is only available for voluntary purchase of buildings that are frequently flooded in a high hazard area. Even purchasing the approximately 50 buildings inundated above floor level in the February 1990 and June 2007 events would cost approximately over $25 million. Voluntary purchase may also introduce a number of social problems (residents are unwilling to sell, or are unable to find alternative accommodation with similar attributes) which can be difficult to resolve. Results from previous public consultation programs indicated little support for this measure.

In some flood liable areas individual buildings may be suitable for voluntary purchase due to their particular circumstances (isolation, high hazard, regularly flooded). In the foreshore areas surrounding the lake, no individual building has been identified as being suitable for voluntary purchase.

However, this option may be more practical when considering land and buildings affected by permanent inundation. Protection measures for these properties may be expensive to build and maintain, and may have a high environmental impact, making voluntary purchase or other forms of compensation more attractive. Such purchases are not considered necessary at this stage, and are not likely to be required for many years, but should be included in planning for future management of sea level rise in vulnerable areas.

6.3. Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:

- dams (not considered further – see 6.2.1),
- retarding basins (not considered further – see 6.2.1)
- entrance modifications (not considered further – see 6.2.2),
- levees, flood gates, pumps,
- local drainage issues,
- assessment of wind wave runup.

Discussion on each of these measures is provided in the following sections.

6.3.1. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the foreshore from flooding or inundation from the lake up to a certain design event. They are commonly used on large river systems (eg. Hunter and Macleay Rivers) but can also be found on small creeks in urban areas. They are used less frequently on coastal estuaries, but there are flood levees to mitigate lake flooding at, for example, North Entrance on Tuggerah Lakes in Wyong Council LGA.

Flood gates allow local runoff to be drained from an area (say an area protected by a levee) when the external level is low, but when the river or lake is elevated, the gates prevent floodwaters from the river entering the area (they are commonly installed on drainage systems within a levee area).

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates. Unless designed for the PMF, levees will be overtopped. Under overtopping conditions the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that the levee has "solved" the flood problem (as happened with Hurricane Katrina in New Orleans, USA).

DISCUSSION

There are no levee systems on the foreshores of the Lake Macquarie waterway. On Tuggerah Lakes (south of Lake Macquarie waterway) there is a levee with associated flood gates at The Entrance North, with Wilfred Barrett Drive acting as the levee bank. Photographs from the February 1990 and June 2007 floods indicate that in both events there was considerable flooding within the levee area. It is unclear whether this was due to the local catchment runoff being unable to drain away successfully to the lake or inflow from malfunctioning flap gates from the lake. Certainly Wilfred Barrett Drive (the levee) was not overtopped. Some of the key issues regarding levees are summarised in Table 24.

Levees have been considered for areas around the foreshore however there are no obvious areas (inability to tie into high ground, likely to have a low cost benefit ratio due to the length of structure required) where a levee similar to The Entrance North could be constructed. At Swansea it is likely that access/visual amenity and cost will be significant issues. At Marks Point - Belmont these issues together with ensuring the upstream catchment does not cause flooding from within the protected areas are the major issues. In summary there are no foreshore management areas where a levee could be built that would not introduce some adverse impact, however from an engineering perspective these can all be overcome. The main concerns are social and to a lesser extent environmental issues.

Whilst at first glance levees may appear a viable means of protection of existing developments from the effects of sea level rise the above concerns with levees still apply. Once it is realised that levees may be the only solution to protect existing developments from sea level rise there may be a greater acceptance by the community.

Pumps have been suggested as a means of addressing the “internal drainage” problem but are not widely used in levee type situations in NSW. Some of the drawbacks of employing pumps are:

- high capital cost. In many instances two sets of pumps are installed in case one set is being repaired or maintained when the flood occurs,
- high maintenance cost. The pumps have to be regularly maintained and tested by trained personnel,
- relatively high risk of failure. Experience in other areas has shown that as the pumps are used only infrequently there is a relatively high risk of failure due to:
    - inadequate maintenance of the pumps causing seals or valves to deteriorate,
    - power cuts caused by the storm,
    - failure of the device which activates the pumps.

The pumps are only required to operate for a short time (several hours) possibly once or twice a year. If they fail to start or fail during the event there is practically no likelihood that service personnel will be able to restart them prior to the peak level being reached. An alternative to pumps is to install additional flap gated culverts and these can be more cost effective though also can fail (mainly due to vandalism or vegetation “jamming” the mouth open).

Table 24: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
"Environmentally Sensitive Measure"	A well-designed vegetated earthen embankment set back far enough from the foreshore to retain beaches and foreshore access, and that does not interrupt local drainage, can have minimal environmental impact. However, in many locations it is hard to meet all these criteria, and it will become increasingly difficult as lake levels rise and permanently inundate foreshore areas.
Protects a large number of buildings.	A levee system could protect a large number of buildings from being inundated up to the 100 year ARI or even larger flood event. At Lake Macquarie waterway it is possible to protect to the PMF (2.8 mAHD in year 2050) as this event is only 1.3 m greater than the year 2011 100 year ARI. At many other locations this is not possible due to the large height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure (of say flood gates) will generally be small (say less than $10 000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy living on the foreshores of Lake Macquarie waterway because of the visual attraction of the water and a (say) 2.0 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependant on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the landtake and associated costs (possible services re-location and access) which add considerably to the cost. For these reasons no detailed costings have been undertaken at this stage. It is likely that levees will cost several million dollars depending upon their size and location but may be the only viable mitigation measure to protect against sea level rise.
Low to medium benefit cost ratio	Whilst the levee system may protect a large number of buildings from being inundated in a (say) 100 year event it is likely to have a low to medium benefit cost ratio as there are few buildings floors inundated (and so being able to be protected) in the more frequent floods (less than a 10 year ARI event). However with sea level rise the benefit cost ratio will increase and it may become economically viable.
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the lake itself. At present local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure. This is a particular problem in areas on creek mouths and deltas, such as Dora Creek, Cockle Creek, South Creek, Stony Creek, North Creek, and LT Creek as floodwaters from the catchment may get behind the foreshore levee.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the water.	Access to the water for boating and other activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points.

SUMMARY

A review of the flood liable areas surrounding Lake Macquarie waterway indicates that there are no areas where a levee system, similar to that at The Entrance North on Tuggerah Lakes could be constructed to protect existing buildings. The levee system at The Entrance North would appear to not have worked successfully in the February 1990 or June 2007 event due to issues with internal drainage.

This measure is one of the only means of protecting existing buildings from sea level rise and therefore must be considered further. From an engineering perspective it is possible to construct levees at say Swansea and Marks Point, however in the first instance community acceptance must be obtained, land availability assessed, and environmental and social impacts considered. It is likely that such levee systems will have much higher benefit cost ratios in areas that will be permanently inundated by sea level rise (lake level rises from 0.1 mAHD to 1.0 mAHD).

6.3.2. Local Drainage Issues

DESCRIPTION

Local stormwater flooding is probably the flooding mechanism which is most widely identified by the community as being of concern, the only exception being where the residents actually experienced the February 1990 or the June 2007 floods. Local flooding occurs in nearly all suburbs on the foreshores due to the relatively flat grades. Many residents consider that local flooding is a significant issue (possibly many view this as a greater issue than the more infrequent flooding of Lake Macquarie waterway) and report this to Council.

DISCUSSION

Local flooding results from rainfall over the local catchment being unable to quickly drain away. Generally it only occurs after several hours of rain and will not cause above floor inundation. In the past there has been extensive ponding (areas such as Swansea or Marks Point) but this has been significantly reduced with installation of kerb and guttering in the streets adjoining the lake. Ponding in yards still occurs and may take several days to drain away. It is likely to be associated with high water table conditions and is exacerbated when in high tides occur simultaneously or if the drainage system is restricted by debris, silt or vegetation. This still occurs to some extent around Chapman oval in Swansea.

Upgrading the sub-surface system to improve yard to road drainage would improve the situation in the short term but is unlikely to solve the longer term problem with sea level rise and would not be cost effective (on the basis of a reduction in tangible damages). Flap gates on culverts can prevent back flow from the lake but apart from at Swansea this is unlikely to be an issue. At Swansea on the northern side facing the Swansea Channel their application might be more beneficial and should be investigated further.

Debris (litter, vegetation) in the piped system is not considered to be a major contributing factor according to Council officers. Installation of agricultural drains in the yards would assist in reducing the incidence of local flooding. As the benefits of the works are largely intangible (reduction in inconvenience) it is difficult to justify these works on economic grounds.

SUMMARY

Local flooding is a significant issue for many residents but preliminary investigation indicates that there is no viable economic solution. One approach would be to more closely identify the worst affected areas and provide a newsletter suggesting how residents could minimise the impacts of nuisance flooding. If residents are willing to participate, this could be combined with assistance from Landcare groups to control exotic vegetation in the watercourses. A community based approach with input from Lake Macquarie City Council, is likely to be the most successful, with Council using the level and credibility of community information to inform its maintenance priorities for drainage works. This should be accompanied by a public education program to explain the difference between local and lake flooding and how the public can be involved in reducing the local flooding problem.

6.3.3. Assessment of Wave Runup

DESCRIPTION

The actual flood level at a site depends upon a combination of the still water level and the effect of local wind/wave action (wave runup).

DISCUSSION

The wave runup effect at Lake Macquarie depends upon a number of interrelated factors summarised in Table 25.

Table 25: Factors Influencing Wave Runup Effects

General Factors	Comment
Maximum Fetch across Lake Macquarie	The length of open water used to determine the wind wave condition (varies from 1.5 km to 9 km).
Direction of Maximum Fetch	Design wind data vary depending upon the direction (by up to 20%).
Approximate Offshore Water Depth	Can vary from 1 m to 5 m. This influences the breaking of the waves.
Local Factors	**Comment**
Offshore Beach Profile	The slope of the lake bed can vary significantly.
Foreshore Beach Profile	The slope and vegetation type influence the extent of wave activity.
Embankment or Seawall	Many locations have stone or earthen embankments. The height, slope and location of these structures relative to the shoreline and buildings influences the breaking waves.
Location of Nearest Building	Some buildings are located on the shoreline whilst others are over 50 m away.

The 1998 Lake Macquarie Flood Study Part 2 – Foreshore Flooding report (Reference 8) uses a "Guideline" method to combine wind setup and catchment runoff water levels to determine the 100 year ARI (and the 20 year ARI) design runup levels at the 48 locations around the foreshore of Lake Macquarie. The guideline method for the 100 year ARI event was to adopt the highest of either:

- the 100 year ARI design lake level (taken as 1.38 mAHD) with an approximate 1 year ARI wind velocity,
- the 100 year ARI wind velocity with an approximate 1 year ARI design lake level of 0.4 mAHD.

The results showed that there were no locations where the second scenario (the higher wave runup condition) produced the highest runup levels and only one location (Site 4, Bolton Point) where the difference was less than 0.3 m and at that location there was no development likely to be affected.

The results from the 1998 Lake Macquarie Flood Study Part 2 – Foreshore Flooding report (Reference 8) for the nominated 48 sites around the lake indicate (for the 100 year ARI event) that the maximum increase is 1.0 m, the minimum is 0.1 m and the average is 0.3 m, as summarised in Table 26. The similar values for the 1 year ARI design lake level scenario is also provided in Table 26.

Table 26: Wave Runup Effects – 100 year ARI Event and 1 year ARI Event

% of Sites with Runup Level below	Runup Level above 100 year ARI (m)	Runup Level above 1 year ARI (m)
10%	0.2	0.4
20%	0.2	0.6
30%	0.2	0.6
40%	0.2	0.6
50%	0.3	0.7
60%	0.3	0.7
70%	0.4	0.8
80%	0.5	0.9
90%	0.5	1.2
100%	1.0	1.4

The key points regarding the use of wave runup data are summarised below:

- Wave runup effects produce an increase in the design flood level (Table 26) and also require that the structural integrity of any proposed structure be more closely examined.
- Council has adopted a 0.5 m freeboard (for setting floor levels of residential buildings) above the 100 year ARI flood level. A significant component of this freeboard allowance is to cater for the effects of wave runup.
- 90% of the 48 sites analysed have a wave runup effect of 0.52 m or less which is approximately within the 0.5 m freeboard allowance.
- Of the remaining 10%, at four out of the five sites the level only applies as there is an existing building on the foreshore. The remaining site is at Marmong Point where the level is attributable to the particular beach profile.
- Wave runup effects will generally only occur over a small percentage of the lake foreshore in a given event (in the prevailing wind direction).

- The effects will vary in time and space as a result of changing foreshore profiles. This may occur naturally (sedimentation, erosion, vegetation growth) or as a result of human activities (construction).
- New buildings located close to the foreshore will experience the greatest wave runup impact (increased design flood level and increased potential for structural damage). Further away the impacts reduce significantly. The zone of influence of the wave runup effect varies considerably depending upon the topography of the area. In a relatively flat area (Swansea) the impact may be over 200 m whilst in a steeply rising foreshore area the impact may be 10 m or less.
- Of the factors influencing wave runup (Table 25) only three, foreshore beach profile, embankment or seawall and location of nearest building, can possibly be modified to reduce the impact. The likely adverse social impact, the high cost and likely low benefit cost ratio makes any modification measure impractical.

Further discussion on wave runup and the likely impacts of climate change on wave runup are provided in Section 8 of the 2012 Lake Macquarie Waterway Flood Study (Reference 6).

SUMMARY

Council already includes consideration of wave impacts in their development approval process for foreshore properties. The considerations include: setbacks to remove properties from the wave impact zone; technical assessment of foundation stability; and wave-resistant foundation design. Council also considers foreshore stabilisation works in areas of high impact and/or foreshore erosion, using cobble beaches, sloping rock walls, and vegetated back-shore areas to help dissipate wave energy and prevent erosion.

This action is considered adequate at this time. Further monitoring will ensure that it is accurately quantified and if necessary Council's procedure should be modified as new information becomes available. The approval process should be modified to ensure that any proposed development on the foreshore does not exacerbate the situation for surrounding properties and is considered within the proposed Adaptation Plans.

6.4. Property Modification Measures

6.4.1. House Raising and Flood Proofing

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors. However it has limited application as it is not suitable for all building types. Also, it is more common in areas where there is a greater depth of flooding than on the Lake Macquarie foreshore and raising the houses allows creation of an underfloor garage or non-habitable area (though it is essential that this underfloor area and its contents will not incur flood damages, as if it is infilled this may negate the benefits of house raising). House raising and flood proofing are not suitable options for properties that are affected by permanent inundation as, while the building may be above lake flood levels, the land and infrastructure will be affected by the rising waters.

DISCUSSION

House raising is suitable for most non-brick single storey houses on piers and is particularly relevant to those situated in low hazard areas on the foreshore. The benefit of house raising is that it eliminates flooding to the height of the floor and consequently reduces the flood damages. It should be noted that larger floods than the design flood (used to establish the minimum floor level) will inundate the house floor (although this is unlikely to be an issue for the Lake Macquarie waterway). It also provides a “safe refuge” during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency, or larger floods than the design flood occurs.

Funding is available for house raising in NSW and has been widely undertaken in rural areas (Macleay River floodplain) and urban areas (Fairfield and Liverpool). An indicative cost to raise a house is $60,000 though this can vary considerably depending on the specific details of the house. Home raising was the traditional method of eliminating tangible flood damages but is less prevalent today in NSW as:

- the majority of suitable buildings have already been raised,
- the houses that can be raised are nearing the end of their useful life,
- house styles and requirements (ensuites, cabling, air conditioning) means that the timber piered homes are less attractive than in the past,
- most households indicate that they would prefer to use the funding to construct a new house,
- re-building rather than renovations are becoming more cost effective. In many suburbs in Sydney 30 year old brick homes are being demolished as the cost per m^2 to renovate is up to twice the per m^2 cost of re-building. Thus if 50% of the house is to be renovated it is cheaper to re-build.

The house raising potential at Lake Macquarie waterway cannot be accurately assessed due to the lack of detail in the floor level database. However it is acknowledged that there will be a lot (>100 houses) that could be raised (though many may be impractical or the owners are unwilling). Subsidised house raising has been available in Lake Macquarie for more than 30 years, but only about 20 owners have used the scheme, and none since 2001. This option is unattractive to home owners, and subsidies from the NSW Government are difficult to obtain.

An alternative to house raising for buildings that are not compatible, is flood proofing or sealing off the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Also there are issues of compliance and maintenance. Based upon our experience we do not consider flood proofing a viable measure for existing houses on the foreshores of the Lake Macquarie waterway. However flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Guidelines are provided in a booklet *“Reducing Vulnerability to Flood Damage”* prepared in 2006 for the Hawkesbury-Nepean Floodplain Management Steering Committee (Reference 15).

A house raising/re-building subsidy scheme has been considered whereby the home owner can put the payment towards the cost of a replacement house constructed in a flood-compatible way rather than raising the existing building. Such a scheme has been promoted in other flood prone communities in NSW where there are large numbers of houses that could be raised but many owners wish to re build and/or consider it more cost effective. This scheme would provide a financial incentive to undertake house raising or re-building works and would be available to all house owners whose house is flood liable. However such a scheme is not expected to receive funding from the federal or State Government's flood mitigation program and thus is unlikely to be affordable.

Slab-on-ground construction is probably the current most common method of housing construction. A significant issue with this mode of construction is that the building floor is generally not much higher than the ground level, thus there is a risk with overland flow or shallow depths of flooding that some above-floor flooding will occur. House raising has been undertaken for slab on ground houses in the past (Fairfield) and should be investigated further in order to protect existing buildings from sea level rise. Slab-on-ground construction is much harder to adapt if sea level rise or other climate changes require a more radical or speedier response than currently predicted.

Subsidies for house raising implies that Council and the NSW Government will be maintaining the existing services and infrastructure for the life of the building, including provision for sea level rise. This situation needs to be reviewed before approval is given to ensure that these services can actually be provided for the life of the asset.

House raising can also be a means by which a new house can be built at the existing FPL but is constructed in such a manner that it can be raised in the future as climate change impacts occur. This type of modular/adaptive housing construction is not common in NSW but is employed in the USA where the habitable floor may be several metres above the ground. A concern with this approach is that the surrounding ground in the property may remain saturated due to rising water tables and will also become more frequently inundated. Also of concern is the increase in maintenance required to ensure the condition of the roads remains acceptable and evacuation routes are maintained. These issues will need to be addressed if this type of housing construction is permitted.

As limited funding for house raising is available from the NSW Government, future dwellings in areas subject to sea level rise should incorporate adaptable design elements to enable them to be more easily raised in the future.

SUMMARY

For the majority of currently flood affected buildings around Lake Macquarie waterway house raising and flood proofing are not viable means of flood protection. However if advertised and favourable responses are obtained from the owners a house raising subsidy scheme could be further investigated (subject to ensuring that Lake Macquarie City Council and the NSW Government will be maintaining the existing services for the life of the building and including sea level rise).

In addition a house re-building subsidy scheme should be initiated in order to provide an incentive to all house owners whose house floor is flood liable.

Council should also consider whether slab-on-ground construction is an appropriate form of house construction in areas that will be subject to a climate change induced sea level rise. An alternative is to require houses that can have service connections adjusted, their floors easily raised in the future, or be re-located if the risk becomes too great.

6.4.2. Strategic Planning Issues

DESCRIPTION

The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases, it is possible to develop flood prone lands without resulting in undue risk to life and property.

The strategic assessment of flood risk (as part of the present study) can prevent new development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels. Development control planning includes both zoning and development controls.

With sea level rise the continued habitation or re-development of an area may become increasingly difficult to sustain, as the risk increases, and the maintenance of services and infrastructure becomes increasingly expensive. There are several flood liable areas in NSW where past floods have caused relocation to higher ground (Terara village to Nowra on the Shoalhaven River following the 1860 and 1970 floods) or the gradual decline of an area with limited potential for re-development (Horseshoe Bend at Maitland following the February 1955 flood).

The two issues of continued habitation or approval for re-development must be considered in light of future elevated flood levels and the “normal” lake level due to sea level rise.

DISCUSSION

Flood extent mapping (Appendix B) has been undertaken as part of this study, based on the best available information (airborne laser scanning and accurate to ±0.15 m) and should be used by Council to identify properties subject to flood related development controls and as a result of sea level rise.

It may be that some existing developed areas cannot be protected by adaptation (house raising) or defence (levees) mechanisms. For these areas Council and the community will need to establish some form of retreat or re-development strategy. While such measures will not be necessary for many years, planning should start now to allow sufficient time to develop suitable adaptation plans, funding models, and market mechanisms to make the transition as easy and equitable as possible.

Each of these areas must be examined in detail as it may be that some form of "land swap" or similar can be achieved (as has being envisaged following the January 2011 floods in south east Queensland). For example, current developable land is turned into open space or some other use that will not be as affected by sea level rise. Alternatively some form of insurance fund or similar might be established to "pay out" affected land owners. The details of such a scheme have not been evaluated. A retreat policy needs careful consideration and significant public consultation before it can be implemented.

Many residential properties have land at or below 1 mAHD and during non-flood times this land is not inundated as the "normal" water level is around 0.1 mAHD with a maximum annual water level of around 0.5 mAHD. However during flood times such as the June 2007 long weekend event, where the water level reached approximately 1.1 mAHD, floodwaters can remain above 0.8 mAHD for over 24 hours.

With sea level rise the "normal" water level in Lake Macquarie waterway will rise by a similar amount to the ocean. This means that low lying land will be more frequently inundated by tides and at times of elevated ocean levels (storm surge, for example). With a 0.9 m sea level rise all land below 1 mAHD (approximately the existing 15 year ARI flood level) will be permanently inundated. It is predicted that this level will be the "normal" water level in Lake Macquarie waterway by approximately the year 2100. Consideration needs to be given to planning for when the land becomes unsuitable for habitation due to frequent inundation.

Filling

Filling of the foreshore is generally not considered an acceptable means of permitting future development as it "destroys" the ecology of the area, disrupts the lake foreshore processes, and affects local drainage. On riverine floodplains filling can raise flood levels by eliminating temporary floodplain storage and, in some cases, reduce the hydraulic conveyance. At Lake Macquarie waterway the hydraulic effect on flood levels will be negligible given the size of lake storage in the existing foreshore and the likely quantity of fill. If the ecological issues can be overcome this will provide a means of permitting future re-development at higher levels at the subdivision scale.

Filling close to the shoreline is more problematic, as it will have a greater environmental impact, and will be affected by rising lake levels. Even if the land surface is raised, rising groundwater levels, foreshore recession, and increasing difficulty with drainage means filling close to the lake shoreline may not be a suitable or effective solution.

Managed filling could also be adopted for infill development as long as care is taken to ensure local drainage issues are not exacerbated and services (roads, sewer, water) can be accommodated. Possibly a staged approach can be undertaken where the new buildings and garages are constructed on elevated pads and in time the remainder of the property and the roads are raised. This piece-meal approach can lead to disharmony within the community when there are some filled and some non-filled properties.

The advantage of this approach is that it allows existing land owners to remain on their property and still enjoy the qualities of the area without construction of levees.

Planned Retreat

Permanent inundation, increased flooding, and foreshore recession as a result of rising lake levels may make some land unsuitable for future development or re-development.

However there is uncertainty regarding the predicted sea level rise or its timeframe. Thus it may be possible to permit development in these areas with the proviso that if the sea level rise eventuates then the development must retreat according to a planned retreat strategy. This strategy could be based on a suite of conditions, or thresholds including groundwater levels, inundation in non-flood times, continued provision of services and infrastructure, or availability of access allowing residents to stay until site conditions are considered unsuitable. While such measures will not be necessary for many years, planning should start now to allow sufficient time to develop suitable adaptation plans, funding models, and market mechanisms to make the transition as easy and equitable as possible.

Limit the Extent of Development

Future residential development in low lying areas could be restricted to the "lowest residential" zoning. Thus any development that will increase the present residential density would not be permitted. Thus dual occupancy, sub division or increasing the site coverage (increasing the size of the building) would not be permitted. In affected areas already zoned for medium density residential or urban centres, this could mean "back-zoning" to a lower development density, which may have legal and financial ramifications for Council. Legislative and financial options for Council and property owners to help deal with these situations should be raised with the NSW and federal Governments, as the problem will occur in all coastal LGAs. There is also the possibility of establishing "transferable development rights" or similar schemes to encourage voluntary changes to inappropriate property zonings. These controls could be further refined through local Area Adaptation Plans.

Ensuring Adequate Evacuation

For many of the existing flood liable areas (Dora Creek and Swansea), even if house raising, construction of a levee or filling was undertaken, and the services issues resolved, there is still no safe access to high ground in flood. Whilst in a medical emergency a helicopter or flood boat could access the area many residents will attempt to cross the floodwaters (collect children, leave house, obtain food). This represents a burden on the SES to "rescue" residents and a risk to life to the residents who cross floodwaters unprepared.

At present many locations do not have adequate flood access and this will be exacerbated with sea level rise. The lack of adequate access may mean that some areas should not be further developed.

SUMMARY

Strategic planning is the main approach for reducing flood damages to future developments and in particular to adapt to the implications of the sea level rise benchmarks.

No detailed assessment of each foreshore area has been undertaken or the necessary public consultation to determine which strategy should be employed, through local area adaptation plans, for example. It is recommended that this process be undertaken (it may take several years) to develop an appropriate approach for each foreshore management area.

This study has nominated seven foreshore management areas, however these could be further sub-divided into smaller areas if required. The three areas likely to experience the greatest impact from sea level rise are Marks Point-Belmont, Swansea-Pelican-Blacksmiths and Dora Creek. In some areas there are fewer properties likely to be affected (Cockle Creek and Warners Bay) and the adaptation issues may introduce less significant challenges. Based on feedback from the proposed community consultation program Council will need to initiate a program to examine each area.

6.4.3. Rezoning

The 2010 NSW Coastal Planning Guideline: Adapting to Sea Level Rise (Reference 14) sets out principles for strategic and statutory land use planning in coastal areas. Principle 3 of the Guideline is to “avoid intensifying use in coastal risk areas…” and Principle 4 is to “consider options to reduce land use intensity in coastal risk areas where feasible”. While it seems “common sense” to prevent additional development in vulnerable areas this could, in effect, ‘freeze’ new development in all flood affected foreshore areas. This is contrary to the aim of the NSW Government’s 2005 Floodplain Development Manual (Reference 5) which seeks to allow new development in flood affected areas, provided the risk is adequately assessed and managed.

In general, it is likely to increase the risk to persons and property, if more buildings, infrastructure and people are located in flood hazard areas, particularly high hazard areas and areas vulnerable to permanent inundation. So, land in the lake flood hazard areas should not be re-zoned if it increases development intensity. Individual developments that increase development intensity within current zonings, should be assessed against the increased risk to persons and property as a result of the development to ensure there is no increase in risk.

In some specific circumstances, rezoning of flood liable land for higher density development could encourage people to purchase and demolish existing flood liable property and redevelop the area in accordance with Council’s design floor level policy. This strategy is difficult to implement, as generally the surrounding residents, who are not flood affected, consider that the quality of the area would be adversely affected by the increased building density. Furthermore the high cost to purchase the existing land and building is unlikely to make this measure financially attractive to developers. Additional concerns are the cost to provide and maintain on going services (particularly with sea level rise) as well as the likely lack of adequate flood access. Such proposals should be considered against, at least, the criteria of “no increase in risk compared to current risk” for the life of the development.

The wholesale rezoning of all flood liable lands is not appropriate, but this measure could be used on a local scale as a means of removing or improving flood liable buildings.

6.4.4. Modification to the s149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased and thus detail in Part 5 may not be made known to the purchaser unless it is specifically requested. Under Part 2 Council is required to advise if it is aware of the flood risk as it is of any other known risk (bush fire, land slip etc.).

The current wording shown on Section 149(2) and 149(5) certificates provides only limited details of the extent of flood and sea level rise effects.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). It is noted that Council has for many years issued a Flood Advisory Letter which has been well received. New technology allows the possibility of this information being available through an on-line property inquiry.

It should be noted that the Section 149 certificate only relates to the subject land and not any building on the property. This can be confusing or misleading to some.

The information provided under Part 2 of the certificate is determined by the legislation and unless specifically included by the Council provides no indication of the extent of inundation. Under Part 5 there is scope for providing this additional type of information. Residents in many areas have suggested that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information onto Part 5 to show the percentage of the property inundated as well as floor levels and other flood related information.

In addition the hazard category could be provided and also advice regarding climate change increases in flood level.

Flood related development controls (such as stipulation of a minimum floor level at say the 100 year ARI plus a freeboard of 0.5 m – termed the Flood Planning Level or FPL) are the most constructive measure for reducing flood damages to new residential dwellings. Developments more vulnerable to flooding (hospitals, electricity sub stations, “seniors” housing) must consider rarer events greater than the 100 year ARI when determining their FPL. With predicted sea level rise the FPL is increased to account for climate change for the life of the development. However, the FPL does not address the full range of issues when considering flood and permanent inundation risk such as access and failure of essential services.

The 0.5 m freeboard should still be included in the FPL and, as recommended in the 2010 Flood Risk Management Guide (Reference 3), it should not be assumed that the freeboard can take full account of climate change. According to the 2005 Floodplain Development Manual (Reference 5) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL is actually provided given the following factors*:

- uncertainties in estimates of flood levels,
- differences in water level because of "local factors",
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). Whilst climate change is included as one of the above factors there is no advice as to what the contribution for each factor should be. The 2010 Flood Risk Management Guide (Reference 3) states "*Freeboard should not be used to allow for sea level rise impacts, instead these should be quantified and applied separately*..". The 0.5 m freeboard allowance allows for uncertainties, thus, if the best advice is that sea levels will rise by 0.9 m by the year 2100, the FPL should be calculated to include this rise in the modelled flood heights. The climate change component in the 0.5 m freeboard allowance accounts for any uncertainty in estimation of the 0.9 m sea levels rise, and other climate change factors that are more difficult to predict such as changes in rainfall intensities and storm frequencies.

Whilst raising the floor levels will ensure that the floors are not flooded in the design event (with sea level rise) there is still the issue of whether adequate services (sewer, roads) can be provided and that the private land will be suitable for habitation (i.e not permanently or regularly inundated so as to make the land unsuitable).

SUMMARY

It is recommended that Council consider revising the flood related information on the Section 149 Certificate, particularly to include notification about areas likely to be permanently inundated by the "normal" lake level in the year 2100. There is an option for separate notifications for flooding, and for permanent inundation as a result of predicted sea level rise.

As Council information for 149 Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

6.4.5. Provision of Public Services

DESCRIPTION

The ability of public services (sewer pipes, pumps and treatment plants; water pipes and pumps; electricity; gas; roads; traffic facilities; cycleways; footpaths and bridges; recreational and sporting facilities; stormwater drains; stormwater pits and treatment devices) to accommodate increased water levels due to climate change is unknown. Probably the most critical (if failure during a flood occurs) is provision of sewerage. This loss of service affects both flood liable and non-flood liable properties if they are connected to a pump station that fails.

As lake levels rise some services will be affected by permanent inundation, increased tidal inundation, and rising water tables. This is likely to increase maintenance costs (roads and other services such as drainage, sewer, water, gas and electricity), as assets are affected by salt water corrosion and saturation, and access for maintenance becomes more difficult and expensive. Local stormwater drainage infrastructure will become less effective, and may have to be redesigned and replaced.

This will add to the maintenance budget of Lake Macquarie City Council, Roads and Maritime NSW, and the supply authorities such as Hunter Water Corporation and may mean that, for example, the road standard will be reduced to a lesser standard in order to maintain a level of service. A reduction in service levels may have ongoing ramifications for public safety and amenity.

DISCUSSION

When the predicted sea level rise benchmarks are considered with regard to the existing service levels, such as sewer outlets and manhole levels, significant works and costs are required to maintain the service at working condition.

Council and supply authorities need to undertake reviews of the impact of sea level rise on the maintenance of the services provided.

Lake Macquarie City Council is responsible for provision of stormwater drainage facilities around the foreshore and Council's Stormwater Asset Risk Management Plan identifies more frequent flooding due to climate change effects, such as increasing lake levels, as a high risk. The Stormwater Asset Risk Management Plan recommends this risk be treated by identifying areas where more frequent flooding is likely to occur, where it will have greatest community impact, and prioritising drainage infrastructure upgrade works in these areas. Implementing the detailed review of infrastructure in each foreshore management area, as recommended by this plan, will therefore make a key contribution to addressing critical flood risks within the City.

Table 27 summarises the approximate number of stormwater assets located within each of the hazard zones identified by this plan.

Table 27: Council Stormwater Assets within Hazard Zones

Hazard Zone	Approximate number of stormwater pipes	Approximate number of stormwater pits, pollutant traps, detention basins and outlet structures
Low Flood Hazard Zone (below 2.32m AHD)	2270	2680
High Flood Hazard Zone (below 1.5m AHD)	1480	1650
High Lake Hazard Zone (below 1.0m AHD)	840	820

Of the stormwater assets listed in Table 27, those within the High Lake Hazard Zone present the greatest concern with respect to ongoing serviceability, maintenance and replacement costs. Most of these stormwater assets are not designed for saltwater environments, and may fail earlier than planned. These early failures are likely to be among the most noteworthy impacts of rising lake levels on Council's existing stormwater assets.

In most cases, protecting existing low-lying stormwater assets from salt-water incursion is not likely to be a feasible management strategy. 'Retreating' or abandoning stormwater assets from the High Lake Hazard Zone, may be the preferred management option in some locations. Identifying these locations requires detailed risk-cost-benefit assessment for the whole asset life cycle on a location-specific basis. This work should be included in the detailed adaptation assessments for each foreshore management area. Accommodating salt-water incursion would involve installing saline-resistant replacements for each affected asset. This would impose significant additional costs on Council between now and 2100. For example, if all stormwater assets below 1.0m AHD are replaced early, the cost to Council is likely to exceed $25 million.

If Council is unable to secure sufficient funds to accommodate (via early replacement and upgrade) saline incursion, or to abandon low-lying stormwater assets, flood impacts on private property could increase.

For new stormwater assets, accepting the impacts of saline incursion would be an imprudent management strategy. Accommodating these impacts for new assets may be possible in many locations. To ensure assets created as part of future development are fit for purpose, and can be maintained at reasonable costs, Council should update the technical guidelines that support its development controls. The updated guidelines should require stormwater infrastructure design below 2.82 mAHD to consider increased outlet levels (lake levels). The updated guidelines should also require new stormwater assets below 1.0 mAHD to be constructed with salt-resistant materials. However, in some locations, it will not be technically feasible to accommodate the impacts of saline incursion. At these locations, installation of new stormwater assets will need to be avoided. The work required to identify locations to avoid new stormwater assets should be included in detailed adaptation assessments for each foreshore management area.

The ability for recreation and open space areas to accommodate increased water levels due to climate change will vary throughout the Lake Macquarie LGA. The most critical issues include:

- How to continue to provide connectivity within Council's open space network?
- How to ensure the community still has use of and access to sufficient high quality recreation, open space and community facilities?

Rising lake levels will significantly affect access to foreshore areas and the use of these sites for formal/informal recreation, and threaten the linkages between open space areas, particularly via formalised shared pathways. There will be substantial cost implications for Council to continue to provide waterfront areas for the community to enjoy. These costs could be in the form of acquisition of additional open space, or engineering solutions such as the construction of over-water walkways.

Lake levels will also impact upon Council's formal recreation and open space facilities such as sportsgrounds and lake facilities. In some instances there may not be the opportunity for engineering solutions or to purchase additional open space. Alternatively, significant funds will be needed to upgrade/expand nearby facilities.

Future planning and land acquisition for open space and new community facilities should consider the implications of sea level change and avoid development in high risk areas.

A study by the Department of Planning in 2008 showed that in the Lake Macquarie LGA about 20 kilometres of roads are in areas below 1.0 mAHD. These roads will already be subject to frequent flooding, and the maintenance of the sub-grade and surface will be difficult due to high groundwater, poor drainage, and frequent inundation. This will gradually get worse as lake levels rise, and eventually the roads may become unserviceable and/or permanently inundated.

There are about 170 kilometres of road in the flood area between 1.0 mAHD and 3.0 mAHD. Maintenance costs on these roads are likely to increase with rising water and flood levels. While raising roads is possible, the costs are significant, and there are practical issues with drainage (adjoining properties usually drain to the road, so raising the road can interrupt local drainage) and the effect of rising water levels on groundwater levels and the road foundation.

Hunter Water Corporation, who is responsible for installing, operating, and maintaining water and sewerage services in Lake Macquarie has prepared the "Climate Change Adaptation Plan - Hunter Water's Plan to adapt to an uncertain climate". The plan recognises the effect that sea level rise will have on Hunter Water's assets, and their ability to maintain services up to the year 2050, and rates the risk from sea level rise as High to Extreme for key aspects of their operation. Their Plan sets out a table of actions that includes:

- incorporate predicted sea level rises when designing and constructing new infrastructure,
- liaise with Council regarding any proposed foreshore protection works,
- map key water and wastewater assets vulnerable to climate change impacts, including sea level rise,
- develop guidelines for network servicing strategies to include consideration of sea level rise,

- update condition assessment of critical assets, including mains, to include considerations of sea level rise and other climate change impacts.

Consistent with standard planning practices, Hunter Water considers the future environmental vulnerabilities on both:

- Existing assets, through routine condition assessment programs and reliability/maintenance strategies, which identify both the operational performance of the asset and the future asset vulnerability. These investigations guide the future management of the asset, with potential environmental adaptation incorporated into traditional rehabilitation, replacement or upgrade strategies. This management practice is currently being implemented on existing sewer mains and wastewater pump stations on the lake foreshore, with successful environmental and service solutions being undertaken.
- Future assets, through regional master planning and growth related upgrade strategies, which consider future environmental vulnerabilities on the long term operation of an upgraded or new asset or facility.

The provision of public services is essential for the continued habitation of flood liable areas. For some (water, electricity, gas) they can be relatively easily modified for sea level rise, others (sewer, stormwater drainage systems, roads) are more difficult but can be achieved. Failure of the sewerage system can occur during floods for many reasons including:

- loss of electricity supply (power outage or damage to power lines caused by storm damage),
- failure at the pumping station,
- the pumps are turned off as the water level rises above toilets or sewer vents.

The loss of supply of a sewerage system represents a potential life threatening hazard to human life as raw sewage will enter the flood waters which residents will be wading around in. In addition residents who do not have a functioning sewage system should be evacuated from their homes. This would also include those houses that are not flooded but experience a failure of the sewerage system for several days. This will place considerable additional burden on the SES.

The most difficult service to adapt to rising water levels is the provision of roads. Whilst infrequent flooding will cause only minor damage it is the frequent inundation of the road base by elevated “normal” lake levels that will incur significantly increased maintenance costs. This can obviously be addressed by filling and raising of the road but again at significant cost and disruption to the community (driveway access and local drainage issues).

SUMMARY

Future refinement of the planning practices for public service infrastructure will continue to benefit from integrated development and assessment, conducted by relevant service providers in collaboration with Council, of the impacts of elevated lake water levels and other climate change impacts. This will allow service providers to develop appropriate solutions, in consultation with relevant local communities, as part of local area adaptation plans for each foreshore management area.

Following the adoption of this Flood Study and Flood Risk Management Plan, Council needs to work with other key infrastructure providers to ensure they integrate the Study findings and Management Plan recommendations in their climate change adaptation planning. Other infrastructure providers will have to develop local planning and maintenance assessments for areas vulnerable to sea level rise and increased flooding, for consideration when local area plans are developed by Council and the community.

6.4.6. Minimise the Risk of Electrocution

DESCRIPTION

Minimising the chance of electrocution by turning of the electricity supply during a flood should be 'standard practice' for residents and commercial owners during floods. The risk of electrocution can also be reduced by installing electrical circuits above, at least, the flood planning level (100 year ARI flood level + 0.5 m freeboard).

DISCUSSION

There is always the risk of electrocution in times of flood and whilst this has occurred elsewhere there is no record of injury or loss of life due to electrocution on the foreshores of Lake Macquarie waterway in the February 1990 or the June 2007 long weekend events. In order to reduce the risk of electrocution a flood education program should be undertaken in vulnerable communities, especially with older housing stock.

SUMMARY

There is a risk of electrocution during flooding and from an increase in lake water levels due to sea level rise on the foreshores of Lake Macquarie waterway which needs to be addressed. At a minimum flood education programs should encompass this issue, and there may be role for specific programs targeted at tradesmen, for example, to encourage safer installations.

All new developments and re-developments should have requirements to locate unsealed electrical circuits at least 0.5 m above the 100 year ARI flood level. Ways to encourage retro-fitting of older buildings should be investigated, which could range from requiring circuit breakers as a condition for any re-development approvals, offering incentives to encourage owners to up-grade, to considering mandatory retro-fitting requirements. A minimum aim should be to have all properties in flood hazard areas to, at least, be fitted with a circuit breaker.

6.5. Response Modification Measures

6.5.1. Flood Warning

DESCRIPTION

It may be necessary for a number of residents to evacuate their homes during or following a major flood, such as the February 1990 and June 2007 events, though it is understood that many residents stayed in their homes (possibly moved goods and themselves to an upper floor or onto tables or such like).

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators,
- the flood awareness of the community responding to a warning.

For smaller catchments a Severe Weather Warning (SWW) is provided by the Bureau of Meteorology (BOM) but this is not specific to a particular catchment.

DISCUSSION

The BOM is responsible for flood warnings on major river systems such as Lake Macquarie waterway and the Hunter River. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods).

Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BOM (refer flood awareness in Section 6.5.3).

Flooding on Lake Macquarie waterway differs from flooding on the tributary creeks or on major river systems. Firstly, the rate of rise of the lake is relatively slow providing more warning time. Secondly, the magnitude of the rise is also relatively small (only 1.4 m in a 100 year ARI event) with the level responding more to the volume of runoff and ocean conditions rather than the magnitude of the peak inflows.

As the lake rises relatively slowly residents are unlikely to be “caught completely unaware” and should have some time to prevent damages to easily moved items such as televisions, rugs, clothing and cars as long as they are in the building at the time or nearby. As the depth of floodwaters is shallow (generally less than 0.5 m) it is also easy to raise goods above the water. Intangible damages such as the loss of memorabilia, important papers and pets should also be much reduced.

The 2012 Lake Macquarie Waterway Flood Study (Reference 6) examined a range of rainfall durations (24 to 72 hour) to determine the design storm duration which produces the highest lake level and concluded that the 48 hour duration was critical, although the 36 hour duration was only slightly lower. However, it is misleading to consider that the duration of the design rainfall event is necessarily related to the available warning time. A much shorter duration storm (36 hours) may produce a peak very similar (but slightly smaller) than the adopted design duration. The peak level in the lake in a 48 hour 100 year ARI event occurs approximately 38 hours after the start of the storm. For the first 6 hours there is little runoff from the catchments and the lake barely rises. Thereafter the lake rises at a relatively constant rate of approximately 70 mm per hour.

During a large lake flood, residents may be isolated for up to approximately 18 hours.

The 2012 Lake Macquarie Waterway Flood Study (Reference 6) indicated that the peak lake level was sensitive to the ocean level, thus the warning time is affected by the state of the ocean (high tide, storm surge, wave setup).

SUMMARY

The BOM already has a flood warning system for Lake Macquarie waterway and, for the first time, a specific Lake Macquarie flood warning was issued for the June 2007 event. However, it seems the BOM warning was based on regional data, and they do not have a specific model or local data-collection to predict flood behaviour for the Lake Macquarie waterway. A review of the system is currently being undertaken to ensure that it will work successfully in all future events.

The greatest improvement in the accuracy of any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event with particular emphasis on the adequacy and accuracy of the flood warning system. This post flood assessment has been undertaken for the June 2007 event by the BOM.

Improving the flood warning system is relatively inexpensive and is likely to have a high benefit/cost ratio. It has no apparent adverse environmental or social impacts. The new information and predictive modelling from the 2012 Lake Macquarie Waterway Flood Study (Reference 6) should be provided to the BOM and other agencies to assist with their flood prediction and warning system.

6.5.2. Flood Emergency Management

DESCRIPTION

As mentioned above, it may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the lead agency under the Displan, the SES. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- there can be confusion about 'ordering' evacuations, with rumours and well-meaning advice taking precedence over official directions which can only come from the lead agency, the SES
- they are hazardous for both rescuers and the evacuees,

- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers, and
- people (residents and visitors) do not appreciate the dangers of crossing floodwaters.

For this reason, the preparation of a Community Flood Emergency Response Plan (CFERP) helps to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, what to do/not to do during floods etc. It is the role of the SES to develop a CFERP for vulnerable communities. Dora Creek is the only community in Lake Macquarie with a local CFERP currently in place.

DISCUSSION

The SES has the skills and experience to undertake the necessary evacuations.

SUMMARY

The SES should ensure that the Local Flood Plan for all settlements surrounding Lake Macquarie waterway is up to date and includes feedback from the June 2007 event and the recommendations of this plan. This might include floor level and ground level details provided in this report and the 2012 Lake Macquarie Waterway Flood Study (Reference 6). In addition, input from the local community (e.g Council, RFS, and community representatives) through a Community Flood Emergency Response Plan (CFERP)) is required to ensure that workable actions for the community are incorporated. Priority should be given to the implementation of this Plan once completed, which will involve ongoing community education and awareness.

6.5.3. Public Information and Raising Flood Awareness

DESCRIPTION

The success of any flood warning system and the evacuation process depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed and educated? How aware is the community to the threat from sea level rise?

Flood Preparedness: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs (of less importance with digital photography) and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. To some extent many of the above issues for Lake Macquarie waterway have already been addressed by the community as a result of the June 2007 long weekend and February 1990 floods. However, Lake Macquarie residents have not experienced a 100 year ARI flood so have no experience of such a severe event (approximately 0.5 m higher than the February 1990 and June 2007 events).

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the June 2007 long weekend flood, which caused significant damage, the community generally has a medium level of awareness at this time (it will decline as the time since the last flood increases and maybe increase as a result of community flood or climate change awareness programs).

- *History of residence*. Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. It would appear that the majority of the residents have lived in the area for several years and are therefore familiar with flooding. Also it is very likely that new residents will be aware from advice at the time of their property purchase (Section 149 certificate) or from neighbours after they move in. It is very unlikely that a new resident buying a house along the foreshore of the Lake Macquarie waterway will not be aware of the potential of flooding, many will also be aware of the potential of sea level rise affecting their property in the future.

- *Whether an effective public awareness program has been implemented.* It is understood that no large scale awareness program has been implemented in the past for the foreshore areas, although in the last few years there have been many articles in the national and local press regarding the effects of sea level rise. Some have specifically mentioned Lake Macquarie foreshore as being an area of potential affectation.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness, diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (larger than the June 2007 long weekend event) will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 100 year ARI (or sometimes termed a 1% AEP event) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred. A similar analogy is after "tossing" a coin say 5 times and coming up with "heads" each time, the chance of "heads" on the next throw is still 50:50.

Some NSW Councils (Rockdale, Pittwater, Maitland) have initiated catchment-wide flood awareness strategies (for residential and commercial). For Lake Macquarie waterway only a residential strategy is required as there are few significant commercial areas in flood hazard areas. Lake Macquarie City Council and the SES websites also provide excellent information on flood awareness and other flood related and climate change information.

SUMMARY

Based on feedback it would appear that the majority of residents around the foreshores of Lake Macquarie waterway have a medium level of flood awareness and preparedness. However this may not be the case for the "holiday" visitors.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures as well as advice provided on the Council's and SES's websites. These need to be updated on regular basis.

Table 28 provide examples of various flood awareness methods that can be used.

Table 28: Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of ongoing implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding on the foreshores of Lake Macquarie waterway (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Displays at caravan parks or similar	This is an inexpensive way of informing the tourist/holiday maker community and may be combined with related displays.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible (as occurred successfully after the June 2007 long weekend event).
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database and post flood data collection program	A database would provide information on (say) which houses require evacuation, which public structures will be affected (eg. telephone or power cuts). This database should be reviewed after each flood event. It is already being developed as part of this present study. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as blockage of drains or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

6.6. Other Management Measures

6.6.1. Planning Regulations for Tourist/Caravan Parks

DESCRIPTION

There are approximately 15 tourist/caravan parks on the foreshores of Lake Macquarie waterway although many are not affected by flooding. The number of cabins/sites on the foreshore is unknown. Those most susceptible to inundation are provided in Table 29 (as at 2005).

Table 29: Tourist Parks on the Lake Macquarie Foreshore likely to be susceptible to Flooding

Caravan Park	Suburb	Ownership
Swansea Gardens Tourist Park	Swansea	Council
Belmont Pines Tourist Park	Belmont South	Council
Wangi Point Tourist Park	Wangi Wangi	Council
Blacksmiths Beach Tourist Park	Blacksmiths	Council

These parks within the foreshore present their own unique problems, namely:

- there is generally poor access with a single entrance/exit which may be controlled by gates,
- a poor (or no) site map is generally available to show the internal road system or the types of vans,
- fixed annexes on caravans or cabins which may contain high cost equipment such as freezers or stoves,
- there may be poor internal lighting which may fail during a flood,
- there is probably no comprehensive flood emergency plan or it has not been tested recently,
- there may be a problem in communicating to the residents due to the lack of or failure of the public address system or telephone network,
- short term residents will have little flood awareness of the flood risk or damage minimisation measures,
- a number of cabins or vans may be vacant thus increasing the workload and possible risk to life of the “rescuers” in removing vans or raising goods in cabins,
- there is the risk that vans may float and crash into each other or obstruct exit routes,
- caravans and many cabins have little structural integrity and thus can easily be damaged or completely destroyed by floodwaters. As caravans and cabins are relatively high value items they represent a significant financial loss to the owner, although they can be insured, and
- the internal fittings (cupboards, fridges, beds) are usually non-removable and quickly damaged by floodwaters.

DISCUSSION

In theory caravans can be easily moved to high ground in a flood. However, in practice experience has shown that this is unlikely to occur for a number of reasons including owner not present, limited time, caravan cannot readily be moved etc.

Lake Macquarie waterway has a much slower rate of rise than a river system. For many of the of parks, while there is nearby high ground where caravans and residents can be moved, there has been no assessment or specific identification of potential evacuation areas. Also, as the cabins and caravans are all (say) 0.5 m above the natural surface they are unlikely to be flooded above floor in events smaller than a year 2011 50 year ARI event (assuming the ground level is 0.8 mAHD or above).

Shoalhaven City Council has special provisions for caravan parks on the floodplain which include:

- rapid knock down annexes,
- quick release ties on the vans to prevent them floating away,
- an effective evacuation strategy documented in a Flood Action Plan,
- restrictions on the type of vans, eg. vans that cannot be towed not permitted in certain areas, no rigid annexes, and
- specific inclusion of caravan parks in the SES Local Flood Plan.

Similar provisions could be applied to flood affected caravan parks in Lake Macquarie.

SUMMARY

Cabins and caravan parks on the foreshore can be exposed to significant flood risk even though the risk is reduced because there is usually some warning time, there is nearby high ground, and the frequency of above-floor flooding is low. However the June 2007 long weekend event has shown that a much shorter duration of rainfall (< 24 hours) than previously assumed can produce flooding, thus the available warning time can be insufficient to enact a safe evacuation. In the June 2007 event the issue was further compounded by the flood occurring on a long weekend when many are going on holiday and thus not as prepared as they normally might be. As well, evacuation is made more difficult in storm conditions by high winds, fallen trees, and road closures.

This issue has been addressed in Council's 2005 Policy for Caravan Parks (Reference 16) and Performance Criteria and Development Standards are documented. This Policy is currently programmed to be reviewed by Council and should be updated in case the nature of the park has been upgraded and also to include the implications of sea level rise.

6.6.2. Mine Subsidence

The Mine Subsidence Board has indicated that parts of Lake Macquarie waterway are within a mine subsidence area. The magnitude of subsidence could be between 0.1 m and 0.6 m. Further detail is required to define the likely extent and magnitude of mine subsidence and an appropriate allowance, over and above the 0.5 m freeboard, should be included in the flood development assessment process. Mine subsidence may also influence which areas will be exposed to permanent inundation from sea level rises.

6.6.3. Flood Insurance

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments. It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance and how insurance companies evaluate the risk (is it based on the house floor being inundated or the ground within the property?). These issues are outside the scope of this present study and are currently being re-assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

Insurance companies will not cover damage from storm surge, but the Flood Study shows that it is rainfall events in the catchment that cause severe lake floods, with ocean induced lake levels significantly lower than rainfall induced levels.

Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this Lake Macquarie Flood Study and Risk Management Study and Plan. This planning must include consideration on the future risk from sea level rise and climate change.

7. ACKNOWLEDGMENTS

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- Lake Macquarie City Council,
- NSW Office of Environment and Heritage,
- Ministry for Police and Emergency Services Department of Attorney General and Justice,
- Council's Floodplain Management Committee,
- Residents surrounding the foreshores of the Lake Macquarie waterway.

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Figures

Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of

	connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to

	the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople

	begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to "water level". Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Appendix C

APPENDIX C: INFORMATION ON REPRESENTATION OF PROPERTY AND FLOOR LEVEL DATA

The property and floor level data that have been used in this study and represented on the various figures and tables in this report was provided by Lake Macquarie City Council in April 2011. The following lists some of the details and assumptions in the application of this information.

- The data are current as at April 2011,
- The building footprint database was provided as a shape file (GIS) and only shows the outline of the building. There is no link from the footprint to a street address and in places the footprint may cross property boundaries. The footprint predominantly represents a residential, commercial or industrial building, however sheds or garages may have also be included. It is also possible that some footprints have been missed out.
- In places the zone boundaries do not align with the Lot boundary (this situation generally only occurs for Lots that are not zoned for residential, commercial or industrial use). In the representations made in this report the zone assigned to a Lot is the zone boundary that aligns with the Lot boundary.
- Properties are defined as all Lots with the same Property Number.
- For ease of application, in the majority of the figures and tables a horizontal water surface was assumed within the lake and in the Swansea Channel. This is not strictly correct as there is a gradient within the Swansea Channel.
- A 5m by 5m ground grid, created from the ALS survey, was used to define the ground surface.
- It is noted that the building footprint shape file indicates that there may be many building floors not contained within the floor level database.
- The extent of the foreshore area was defined by the 4 mAHD ground contour.
- The ALS has a vertical accuracy of approximately +/- 0.2m.

Appendix D