Lake Illawarra Floodplain Risk Management Study

LJ1905/R1920v12

Prepared for Lake Illawarra Authority, Wollongong City Council & Shellharbour City Council

January 2012

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Document Control

Version	Status	Date	Author		Reviewer	
1	Preliminary Draft	14/01/2002	Louise Howells / Greg Collings	LCH/ GBC	Neil Lawson	NVL
2	Draft	02/12/2002	Louise Howells / Shangyou Zhang	LCH/ SYZ	Neil Lawson	NVL
3	Final	30/07/2004	Louise Howells / Emma Maratea	LCH/ ERM	Neil Lawson	NVL
4	Revised Final	26/11/2004	Louise Howells / Emma Maratea	LCH/ ERM	Neil Lawson	NVL
5	Revised Final	14/04/2005	Louise Howells	LCH	Neil Lawson	NVL
6	Revised Final	13/06/2005	Louise Howells	LCH	Neil Lawson	NVL
7	Revised Final	07/07/2006	Emma Maratea	ERM	Neil Lawson	NVL
8	Revised Final (Internal)	06/08/2008	Emma Maratea / Tanja Mackenzie	ERM/ TJM	Louise Collier	LCC
9	Draft for Re-Exhibition	May 2010	Emma Maratea	ERM	Louise Collier	LCC
10	Final Draft for Re-Exhibition	April 2011	Emma Maratea	ERM	Louise Collier	LCC
11	Final	November 2011	Jacqui Druce	JGD	Louise Collier	LCC
12	Updated Final	January 2012	Jacqui Druce	JGD	Louise Collier	LCC

Foreword

The State Government's Flood Policy is directed towards providing solutions to existing flood risks in developed areas and ensuring that new development is compatible with the flood risk and does not create additional flooding risks in other areas.

Under the policy, the management of flood liable land is the responsibility of Local Government and in the case of Lake Illawarra, also involves the Lake Illawarra Authority (LIA), as the overarching management body for the Lake. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

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

1. Formation of a Committee	Established by the LIA and includes Council, community group representatives and State agency specialists.
2. Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3. Flood Study	Determines the nature and extent of the floodplain.
4. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
6. Implementation of the Plan	Implementation of actions outlined in the Plan which may include construction works, planning modification or emergency response modifications.

The Lake Illawarra Floodplain Risk Management Study completes the fourth stage of the management process for the Lake Illawarra Floodplain. This study has been prepared for the Lake Illawarra Authority, Wollongong City Council and Shellharbour City Council by Cardno to review flood risks and to examine floodplain management options and to prioritise identified strategies for implementation within a Floodplain Risk Management Plan (a separate document, Cardno, 2012).

Executive Summary

Background and Study Development

The Lake Illawarra Flood Study was completed in 1999 by Lawson and Treloar and published in 2001. This study identified flood levels for the Lake Illawarra Floodplain based on the Lake conditions in 1997. This Floodplain Risk Management Study (FRMS) was commenced as the next stage of the floodplain management process in 2000. Following the commencement of the FRMS large-scale entrance works were completed in 2001 and 2007, resulting in different conditions to those assessed under the flood study. However, the pre-2001 conditions have been adopted as the base case conditions for the purposes of this FRMS. Since the commencement of this study, several additional aspects of floodplain management have been identified and incorporated into the study. These include:

- The assessment of True Hazard to more accurately identify flood risk categories (which are in part based on 100 Year ARI low and high hazard); and
- The assessment of the impact of climate change on flood levels around the Lake foreshore and the implications for floodplain management.

As a result, the development of this FRMS has been a more detailed approach than originally envisaged, as such this document represents the incorporation of progress in floodplain management over the last 10 years.

Study Area

The floodplain of the main body of Lake Illawarra has highly urbanised areas that extends to cover the suburbs of Windang, Oak Flats, Albion Park Rail, Yallah, Koonawarra, Kanahooka, Berkeley, Lake Heights, Kemblawarra and Primbee, on the south coast of NSW. The floodplain lies within both the Wollongong City Council and the Shellharbour City Council local government areas. The Lake is generally open to the sea through an entrance channel that has historically, during times of lower catchment flow, undergone a sediment accretion cycle thereby reducing the conveyance capacity of the channel. This channel has undergone change with the construction of breakwaters on both the southern and northern sides of the entrance over the past 10 years.

The catchment of 23,500 hectares consists of a range of land uses. A number of properties adjacent to the Lake are susceptible to above-floor flooding in the 100 Year Average Recurrence Interval (ARI) and the Extreme Flood/Probable Maximum Flood (PMF) events.

Floodplain Management

Using the merits-based approach advocated in the NSW State Government's *Floodplain Development Manual* (2005), and in consultation with the community, the Lake Illawarra Authority, Shellharbour City and Wollongong City Council's and state agency stakeholders, a number of potential options for the management of flood risk were identified. These options included flood modification measures, property modification measures and emergency response modification measures to reduce flood risk. A limited list of flood modification options were assessed against a range of criteria (technical, economic, environmental and social). These options included:

- Entrance stabilisation,
- Removal of Windang Bridge causeway and replacement with a bridge,
- Culverts through Windang Causeway.

In addition to these options, the Lake Illawarra Authority also requested that an assessment of the cumulative impact of filling portions of the Lake foreshore be undertaken.

As outlined above, during the course of this study, large-scale entrance management works were completed to address a number of issues (including flooding). The assessment of the effects of this 'option' has been included within the report (**Section** 9) for completeness. It should be noted that the floodplain management options presented in this report have been assessed against the condition prior to the construction of the entrance works (referred to as the 'pre-2001 condition').

Assessment of Floodplain Management Options

Hydraulic modelling of the options was undertaken along with an assessment of the economic, social, environmental, land use and planning issues. The assessment found that neither of the options associated with the modification of Windang Bridge or its causeway are feasible on economic grounds (i.e. these options have very low cost-benefit ratios). However, the works for the stabilisation and modification of the entrance channel, which have been constructed in a form varying from that originally proposed and detailed in this report, should partly reduce the flood risk to the area, provided that the channel is maintained.

Property modification and emergency response modification measures considered for the floodplain include:

- Voluntary House Raising (VHR);
- Voluntary House Purchase (VP);
- Amendments to existing planning instruments and preparation of new plans and policies;
- Improvements to flood warning and evacuation procedures, and
- Public awareness and education.

The VHR and VP options were found to provide only marginal benefits and instead it is recommended that habitable floor levels should be set at the flood planning level (FPL) when these and all properties in the floodplain are redeveloped in the future.

A combination of the various types of options can be considered for inclusion in the Floodplain Risk Management Plan.

Climate Change

The Inter-governmental Panel on Climate Change (IPCC) Assessment Report 2007 (Known as 'Climate Change 2007') concludes that climate change and sea level rise are inevitable. The *Floodplain Development Manual* (NSW Government, 2005) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change and sea level rise on flood behaviour.

More recently, the NSW Government released the *NSW Sea Level Rise Policy Statement* (DECCW, 2009) and the *Flood Risk Management Guide – Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010). These documents have been prepared to assist local councils, the development industry and consultants to incorporate the sea level rise planning benchmarks in floodplain risk management planning and flood risk assessments for new development. The information in these documents updates the sea level rise information in the *NSW Floodplain Development Manual* (NSW Government, 2005) and should be read in conjunction with the Manual. These documents also update the sea level rise section of the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (DECC 2007). However, the 2007 guideline provides additional information relating to the management of the impacts of climate change on existing developed areas and on potential changes to flood-producing rainfall events caused by climate change.

In accordance with the advice presented in the documents above, the following tasks have been undertaken within this FRMS to address the issue of climate change:

- Hydraulic modelling of four climate change scenarios (based on IPCC predictions and OEH recommendations);
- Mapping of 100 Year ARI flood extents for the four climate change scenarios;
- An analysis of the properties impacted by flooding under the various climate change scenarios;
- An assessment of the consequences of adopting each of the four scenarios as part of the relevant planning provisions (LEP and DCP) and exploration of different approaches to address this issue; and
- Recommendations for planning provisions to be included in the Floodplain Risk Management Plan.

Floodplain Risk Management Plan

The Floodplain Risk Management Plan (Cardno, 2012) is a summary of the proposed activities derived from this study to manage the flood risk for the Lake Floodplain. The implementation of this plan is the next step of the floodplain management process.

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Glossary

Annual Exceedance Probability (AEP)	Refers to the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. E.g., if a peak flood discharge of 500m³/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500m³/s or larger events occur in any one year.
Annual 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.
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.
Building Area	Building area is the footprint of a building and does not include the garage. Allowable developable area in a lot is to be derived from floor space ratio for the land consistent with zoning.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Concessional Development	As defined in the Wollongong City Development Control Plan (2009) Chapter E13 – Floodplain Management, Appendix A, being development such as additions or alterations to an existing dwelling (20 – 40 m^2) to the habitable floor area; garages or outbuildings (with a maximum floor area of 20m - 40m^2); and redevelopment for the purposes of substantially reducing the extent of flood affectation to an existing building.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 100 Year ARI flood event.
Development	Is defined in Part 4 of the Environmental Planning and Assessment Act, 1979: Infill development: refers to the development if 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. E.g., the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning 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. E.g., as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or

	major extensions to urban services.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Extreme Flood Event	The largest flood that could conceivably occur at a particular location, estimated for Lake Illawarra using a modified approach based on the Probable Maximum Precipitation methodology discussed in the Lake Illawarra Flood Study (Lawson and Treloar, 2001). Generally it is not physically or economically possible to provide complete protection against this event. The extreme event defines the extent of flood prone land, that is, the floodplain. (See also Probable Maximum Flood).
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain that causes it.
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 fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
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 management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. The maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.

Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Possible danger to life and limb; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage 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	The term given to the study of the rainfall and runoff process; in particular, the evaluation of flow parameters such as water level and velocity.
Low hazard	Should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe/culvert and overland stream flow.
Non-concessional development	Any development that is not concessional development (see concessional development).
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.

Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, estimated from probable maximum precipitation (see also Extreme Flood Event). Generally it is not physically or economically possible to provide complete protection against this event.
Probable maximum precipitation (PMP)	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. It is the primary input to the estimation of the probable maximum flood.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
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.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.
Wholesale	The wholesale area relates to the full area of the proposed site(s) or lot(s) for development.

1 Introduction

This Floodplain Risk Management Study for the Lake Illawarra Foreshore has been undertaken by Cardno for the Lake Illawarra Authority on behalf of Wollongong City Council and Shellharbour City Council. The study has been undertaken in accordance with the NSW Government's *Floodplain Development Manual* (2005).

1.1 Background

Lake Illawarra is a shallow coastal lagoon located about eight kilometres south of Wollongong on the undulating coastal plain between the ocean and the cliffs of the Illawarra Escarpment (see **Figure 1.1**). The Lake is an important recreational asset for the Illawarra Region, and also provides an important habitat for wildlife and acts as a valuable commercial and recreational fishing ground.

In the past, flooding of the Lake Illawarra foreshore has caused property damage, restricted property access and has been a general inconvenience to residents and tourists. These flooding issues, combined with considerable development pressure along the Lake foreshore, have prompted the Lake Illawarra Authority, Wollongong and Shellharbour City Councils, through the Lake Illawarra Floodplain Management Committee to prepare a Floodplain Risk Management Plan for the Lake Illawarra foreshore area.

It should be noted that the area addressed by this Floodplain Risk Management Study is limited to the body of Lake Illawarra, areas of the Lake foreshore east of the F6 freeway and the Lake entrance area. The estimation of flood behaviour in the tributary streams was not addressed within the flood study report (Lawson and Treloar, 2001), and consequently, this study is also confined to the Lake foreshore areas.

During the course of this study, both the Stage 1 entrance management works (southern training wall and channel dredging) were completed in 2001 and Stage 2 entrance management works (northern training wall) were completed in 2007. The assessment of these combined works as a flood modification option has been included within the report (**Section** 9) for completeness. It should be noted that the Stage 2 entrance works were undertaken and completed after the completion of the hydraulic modelling for both the Lake Illawarra Flood Study (Lawson and Treloar, 2001) and the floodplain options assessment in this study. Therefore the floodplain management options presented in this report have been assessed against the condition prior to the construction of the entrance works in 2001 (referred to as the 'pre-2001 condition'). An aerial photograph showing the concept for the completed entrance works can be found in **Figure 9.1**.

Since the completion of the entrance works, hydraulic modelling was undertaken to assess potential climate change scenarios (**Section 5.5**). This modelling included the completed entrance works and considered the 100 Year ARI design flood. The results are not significantly different to the results for the "pre-2001" conditions. However, these updated results for the 100 Year ARI are provided in **Section 5.5** and can be used for planning purposes.

1.2 Study Context

This study follows on from the Flood Study (Lawson and Treloar, 2001) and forms stage four of the six stages of the Floodplain Risk Management Process which includes:

1. Formation of a Committee,
2. Data Collection,
3. Flood Study,
4. Floodplain Risk Management Study,
5. Floodplain Risk Management Plan, and
6. Adoption and Implementation of Plan.

As prescribed in the floodplain management process, the Lake Illawarra Floodplain Management Committee was formed in 1997. This committee is chaired by the Lake Illawarra Authority (an independent party established by the NSW Government in 1988 to improve the environment of the Lake Illawarra, its foreshores and related environs).

The Lake Illawarra Authority, under the direction of the two Councils, commissioned the Lake Illawarra Flood Study in 1997. This study was completed by Lawson & Treloar in 1999 and the final version published in 2001. Following completion of the Flood Study, this Floodplain Risk Management Study was commissioned by the Authority in August 2000 and subsequently extended to include a Floodplain Risk Management Plan. Further, in 2007, Cardno Lawson Treloar (now Cardno) was commissioned by the Authority to undertake an assessment of the impacts of climate change on flooding in Lake Illawarra. The findings of this climate change assessment have been incorporated into this Floodplain Risk Management Study.

1.3 Study Objectives

The main objective of this study is the identification and assessment of options and actions that could be implemented to manage the flood risk for the Lake Illawarra foreshore. There are three groups of management measures:

- flood modification measures;
- property modification measures (including climate change planning provisions); and
- emergency response modification measures.

Specific options assessed include those identified and considered appropriate by the Committee.

1.4 Report Outline

This report is presented with the following detail:

- Details and characteristics of the study area (**Section** 2);
- Review of flooding issues and objectives (**Section** 3);
- Details of the community consultation and the existing social concerns regarding flooding (**Section** 4);
- Assessment of flood behaviour including climate change flood modelling (**Section** 5);
- Review of flood planning issues (**Section** 6);
- Details of the magnitude of the existing economic impacts (**Section** 7);
- Identification of suitable strategies (**Section** 8);
- Details of specific options and impacts assessed (**Sections 9 - 12**);
- Overview of potential property modification measures (**Section 13**);
- Overview of potential emergency response modification measures (**Section 14**);
- Economic assessment of options (**Section 15**); and
- Recommendations for the Floodplain Risk Management Plan (**Section 16**).

2 Study Area

2.1 Study Limits

The hydrological investigations for this study covered the whole of the Lake Illawarra catchment. Hydraulic modelling was limited to cover the Lake Illawarra foreshore area, which was defined as the area inundated by floodwaters rising from within the Lake body only. Flood liable areas affected by flows from waterways entering the Lake were not included in the study area.

Figure 2.1 shows a catchment map and the main study area.

2.2 Previous Studies

Several previous studies conducted for Lake Illawarra have been drawn upon in the production of this report including the Lake Illawarra Flood Study (Lawson and Treloar, 2001), the Lake Illawarra Stormwater Management Plan (Forbes Rigby, 2000) and the Lake Illawarra Entrance Improvement Study (Lake Illawarra Authority, 1994). These reports contain important information on the existing flooding and environmental status of the Lake and also the social values of the community. This baseline information has been used in formulating criteria by which to evaluate and rank various floodplain management options.

Brief details of historical flooding can be found in **Section 5.2** and more details are available in the Flood Study (Lawson and Treloar, 2001). **Appendix A** shows a series of photographs from the event of June 1991 as a guide to the type of flooding previously experienced in the area.

2.3 Catchment

Lake Illawarra is a shallow coastal lagoon located on the undulating coastal plain between the ocean and the cliffs of the Illawarra Escarpment. The Lake catchment of approximately 23,500 hectares (excluding the Lake waterway area) is characterised by a low coastal plain, dominated by the western backdrop of the Illawarra Escarpment. The escarpment rises to a height in the catchment of 760m at Mount Murray, but more impressive is the slope of the escarpment, which rises over 400m over a horizontal distance of approximately 3km.

Generally, elevated areas of the catchment closer to the escarpment are rural or forested in character and slope steeply while the lower areas closer to the Lake are flatter and have a mixture of residential, commercial and heavy industrial development. Two major transport links, the F6 freeway and the Illawarra railway line traverse the catchment from north to south. Full details of land use can be found in **Section 2.5**.

2.4 Tributaries, Lake and Foreshore Areas

The Lake body has an area of approximately 35km^2. Tributaries of Lake Illawarra include (anticlockwise from the northern foreshores):

- Minnegang Creek
- Budjong Creek
- Hooka Creek
- Mullet Creek
- Brooks Creek
- Yallah Creek

- Duck Creek
- Wollingurry Creek
- Marshall Mt Creek
- Macquarie Rivulet
- Frazer Creek
- Albion Creek
- Horsley Creek
- Oakey Gully.

Of these watercourses, the Macquarie Rivulet and Mullet Creek catchments contribute some 70% of the total catchment area.

Relative environmental stress levels for some of the creeks within the Lake Illawarra catchment has been investigated by DLWC (now the Office of Environment and Heritage or OEH) in the *Stressed Rivers Assessment Report* (1998), based on channel morphology, riparian vegetation, catchment landuse, proximity of development, barriers to fish passage, water quality and potential/actual acid runoff. The results are presented in **Table 2.1**.

Table 2.1 Stressed Rivers Assessment - Lake Illawarra (after DLWC, 1998)

Catchment	Overall Stress
Macquarie Rivulet	Low
Mullet Creek	Medium
Brooks Creek	Medium
Duck Creek	Medium

The Lake has an average depth of approximately 1.7m with the maximum depth being about 4m. Prior to the completion of entrance works in 2007, the mean water level in the Lake was approximately 0.3m AHD with a small tidal range of 0.03m in the northern regions. The entrance works (southern training wall, completed in 2001, and northern training wall, completed in 2007) have fixed the mouth of the Lake to the north of Windang Island. Since the entrance works were completed, the mean lake level has dropped to approximately 0.13 mAHD with a mean tidal range of 0.07 m across the Lake. The condition of the entrance channel is affected by ocean storms, wave action, floods and tides. The variability in the entrance condition prior to the completion of the entrance works is demonstrated via a series of aerial photographs in **Appendix A**.

The catchment and foreshores of the Lake have been modified through past and current activities such as agriculture, and industrial and urban development, resulting in a decline in water quality in the Lake. Changes to the foreshore have also altered flora and fauna and resulted in the introduction of non-native species. As a guide, changes in the Lake (around the entrance) can also be seen in the sequence of aerial photographs shown in **Appendix A**.

Considerable filling of the Lake foreshore areas has occurred over time to enable development close to the Lake (discussed further in **Section 12** and shown in **Figure 12.1**). Areas of the foreshore on the eastern side of the Lake, such as the Primbee-Windang area, are under some pressure for redevelopment. New development has occurred on the western foreshore in the Shellharbour City Council local government area (LGA), known locally as Macquarie Shores, and further new development is projected for the Kanahooka region on the western side of the Lake in the Wollongong City Council local government area.

Filling of the Lake foreshore involving the placement of some 2 million tonnes of coal wash has also been completed for the subdivision at Yallah adjacent to Macquarie Rivulet (Haywards Bay Development). As part of the works at Yallah, compensatory excavation works involving the removal of some 14,000m^3 of floodplain material have been carried out.

Filling with coal washery discard commenced in August 1994 in the Stage 1 fill area (western half) in accord with Wollongong City Council's development consent. Filling progressed to the balance of the area i.e. Stage 2 fill area in early 1995, also in accord with development consent from Wollongong City Council.

2.5 Existing and Future Land Use

The industrial history of the catchment has included logging, coal mining, and cattle and sheep grazing. In the lower part of the catchment, land that was originally forested has been cleared for agriculture. Hard rock quarries operate in Albion Park Rail, Dunmore and Bass Point. At Dunmore, sand extraction also occurs. Lighter industrial uses such as building industries, servicing and motor vehicle lots are also found within the catchment.

Within the catchment, land use consists of that listed in **Table 2.2,** adapted from WBM Oceanics (2003).

Table 2.2 Catchment Landuse

Land Use	Area (km^2)	% Total Catchment
Total Catchment Area	270	100%
Lake Waterway Area	35	13%
Land Catchment, of which:	235	87%
Urban	54	20% (23% of land area)
Rural	94	35% (40% of land area)
Natural/Forest	87	32% (37% of land area)

At present, there is a consistent pattern of increasing urban areas and decreasing proportion of vegetation from north to south in the catchment.

In addition to the development pressures outlined above in **Section 2.4**, the West Dapto Urban Release Area has the greatest potential change in land use with as many as 20,000 lots to be developed in the next 20 to 30 years. The population of the Shellharbour City Council LGA is also expected to grow at an increasing rate for the next 20 years.

Without appropriate development controls, implemented by both Wollongong City Council and Shellharbour City Council, this increase in urban areas is likely to have an impact on flood risk. Consequently, controls are needed to ensure that the volume of runoff reaching the Lake does not increase and exacerbate flooding.

Without controls, development within the catchment will generally lead to an increase in runoff volume and an increase in the peak discharge either directly to the Lake or to the Lake via the tributary creeks. To ensure flood levels and peak discharges are not exacerbated by future development, a catchment-wide holistic approach to the provision of flood storage and attenuation of flood flows is recommended. Given the potential for maintenance issues, on-site detention on individual residential lots may not have a substantial impact on large-scale floods (i.e. 100 Year ARI and PMF). This is particularly due to the flood mechanism in the Lake being driven by the volume of flow rather than peak discharge. Therefore, regional controls are recommended to mitigate the cumulative impacts on flooding of residential growth in the area. For example regional flood controls include the use of areas such as municipal parks and other large undeveloped lands as detention/retention areas to reduce downstream flooding.

It is recommended that both Councils consider the opportunities for designating land in their respective catchment areas within the strategic planning process to be set aside for regional flood detention/retention systems to mitigate the cumulative impacts of future large scale development in major catchments on flooding the Lake and its floodplain. These may be designed to also off-set associated water quality impacts.

2.6 Soils and Sediments

The catchment geology is generally comprised of Triassic Age Narrabeen Group sandstone and siltstone overlaying Permian Age Illawarra Coal Measures with talus foothill slopes. In the lower regions, residual colluvial soils and clays overlie the lower strata of the Illawarra Coal Measures. Quaternary deposits of alluvium, sands and silts are present on floodplains and in swamps (Forbes Rigby, 2000).

The escarpment in the west falls to approximately 250m where the talus slopes begin. These slopes have a 15-35% grade down to the 100m level, where the residual soils and clays reside at a 5-15% slope. At approximately 4m AHD, recently transported sediments are found on a relatively flat grade (Forbes Rigby, 2000).

There are six main soil landscapes in the area. The descriptions of these landscapes are provided in **Table 2.3**.

Table 2.3 Soil Landscapes

Soil Landscape	Description
Illawarra Escarpment	**Landscape**: Steep to very steep slopes on quaternary talus. Relief 100-500m. Gradients 20-50%. Large landslips are common. Mostly uncleared tall open-forest and closed-forest. **Soils**: Deep colluvial Red Podzolic Soils (Dr5.21) and Brown Podzolic Soils (Db4.21) occur on slopes. Lithosis (Uc5.11) occur when the tallus is recent. **Limitations**: Mass movement and rock fall hazard. Steep slopes and extreme water erosion hazard. Reactive, low wet bearing strength (subsoils), low soil fertility.
Gwynneville	**Landscape**: Undulating to steep hills on Illawarra Coal Measures and Dapto Latite Member on the Coastal Plain. Local relief 10-70m. Slopes 3-25%. Broad to narrow (250-850m) rounded ridges and gently to steeply inclined slopes. Structural benches and occasional rock outcrop. Extensively cleared tall open-forest and open-forest. **Soils:** Shallow (50-100cm) Brown Podzolic Soils 9Db1.11, Db3.11) and Xanthozems (Gn4.34) on upper slopes, Lithosols (Um1.43, Uc1.23) on simple slopes and shallow (<50 cm) Brown Earths (Uf6.3) on midslopes and lower slopes. **Limitations**: Extreme erosion hazard, steep slopes, mass movement hazard, local flooding. Reactive impermeable and low wet bearing strength clay subsoils.
Fairy Meadow	**Landscape**: Alluvial plains, floodplains, valley flats and terraces below the Illawarra Escarpment. Relief <10m. Slopes <5%. Almost completely cleared low open-forest and woodland. **Soils**: Moderately deep (50-100cm) Alluvial Loams (Um5.2) and Siliceous Sands (Uc1.21, Uc5.11) on terraces. Prairie soils (Gn4.31) and Yellow Podzolic Soils (Dy5.41) occur on the drainage plains. **Limitations**: Flood hazard, low wet bearing strength, highly permeable topsoils, high seasonal watertables.

Soil Landscape	Description
Wollongong	**Landscape**: Beaches and coastal foredunes on marine aeolian sands. Beach plains with relief <10m, slopes <3%; foredunes with relief <15m and slope gradients <35%. Spinifex grassland/herbland to closed-scrub on foredunes. **Soils**: deep (>200cm) Calcareous Sands (Uc1.11) on beaches, Siliceous Sands (Uc1.21) on foredunes, localised Humus Podzol/Podzol intergrades (Uc2.21) in low lying areas. **Limitations**: Extreme wind erosion hazard, on-cohesive, highly permeable soils, very low soil fertility, localised flooding and permanently high watertables.
Shellharbour	**Landscape**: Rolling low hills with long sideslopes and broad drainage plans on Budgong sandstone. Relief 30-50m. Slopes <20%. Extensively cleared with stands of tall open-forest and closed-forest. **Soils**: Deep (>150 cm) Prairie soils (Gn3.21) occur on crests and upper slopes. Brown Krasnozems (Gn3.14) occur on midslopes. Red Podzolic soils (Dr4.41) and Prairie Soils (Dy4.11) occur on lower slopes and drainage plains. **Limitations**: Mass movement (localised), shallow soil (localised), water erosion hazard (localised), sodicity, hardsetting, low permeability, low wet bearing strength (subsoil), high shrink-swell (subsoil).
Bombo	**Landscape**: Rolling low hills with benched slopes and sea cliffs with extensive rock platforms on Bumbo Latite. Relief 40-100m. Slope gradients 15-25%. Extensively cleared with stands of closed-forest and tall open-forest. **Soils**: Shallow (<50 cm) Structures Loams (Um6) occur on crests, moderately deep (50-100 cm) Krasnozems (Gn4.11) on upper slopes and benches. Brown Podzolic Soils (Db1.11, Db1.21) and Red Podzolic Soils (Dr2.21) occur on mid and lower slopes. **Limitations**: Rock fall hazard, wave erosion hazard, rocky outcrop, hardsetting, low wet bearing strength.

Acid Sulfate Soils (ASS) also occur in the study area.

2.7 Water Quality

2.7.1 General

Forbes Rigby (2000) outlines that in dry weather water quality in Lake Illawarra usually meets ANZECC (2000) guidelines for the protection of aquatic ecosystems and human recreation. However, in wet weather water quality is often poor. Limited circulation in shallow areas and embayments can also result in poor water quality. Water quality in the Lake and its tributaries is affected by rural runoff, sewer overflows and urban stormwater.

Nutrients and sediments are major concerns in the Lake. Nitrogen concentrations in the Lake (with the exception of ammonia-nitrogen) are generally below ANZECC (2000) trigger levels, but phosphorous concentrations can exceed ANZECC (2000) trigger levels. Chlorophyll-a concentrations have been found to be increasing but are generally below the trigger levels. Dissolved oxygen levels in the Lake are generally good. Faecal coliform concentrations are generally below ANZECC (2000) trigger levels for primary and secondary recreational contact in dry weather, but have been recorded above these levels in wet weather.

The tributaries of Lake Illawarra generally have poor water quality in both wet and dry weather conditions. Nutrients, faecal coliforms, and the concentrations of other parameters periodically exceed recommended trigger levels for both the protection of aquatic ecosystems and for maintaining primary and secondary recreational contact values. Faecal coliform concentrations in Brooks Creek, Budjong Creek and the Macquarie Rivulet can exceed trigger levels during dry weather. The Macquarie Rivulet, Mullet Creek and Duck Creek catchments contribute significant pollutant loads of suspended solids and total nitrogen to Lake Illawarra (Forbes Rigby, 2000).

There are a number of stormwater treatment devices within the catchment such as Gross Pollutant Traps (GPT's), trashracks, sediment ponds and wetlands. These devices assist with the reduction in the loads of constituents delivered to the Lake each year.

Further details can be found in WBM Oceanics (2003).

2.8 Flora and Fauna

Over 700 species of macroscopic flora and fauna have been recorded in the wetlands of the Illawarra Catchments (Chafer, 1997).

Minor deltas have formed where the larger streams enter the Lake, providing suitable environments for the development of alluvial forests, dominated by swamp oak and saltmarsh. The deltas are surrounded with shallow waters and tidal mudflats containing seagrass and macroalgae meadows. These wetlands provide habitat for rare and endangered species of flora and fauna, and are under threat from urban pollution (Chafer, 1997). A number of wetland areas have been gazetted under *State Environmental Planning Policy No 14* (SEPP14).

The largest numbers of fish and fish species reside in the more marine-dominated portions of the Lake where abundant seagrasses grow (discussed further in **Section 10** and shown in **Figure 10.2**). Areas with the most significant amounts of seagrass support the greatest species diversity and therefore it is important to maintain and consider these areas with regard to the impact of any floodplain management options.

Most bushland has been cleared from the coastal plain to make way for development. In some areas, only 8% of native vegetated habitats remain (Chafer, 1997). These remaining areas are home to wide varieties of species and communities, though pressures such as weed invasion and fire may reduce them to sizes that are not able to sustain ecological processes.

Sub-tropical rainforest is the main vegetation community found in the lower areas of the catchment. Eucalypt communities dominate the ridges of the lower slopes of the escarpment, while rainforest dominates the gullies. The benches of the escarpment itself support rainforest at the rear and eucalypts at the front edge. Rich rainforest surrounds gullies formed by watercourses traversing the escarpment (Chafer, 1997).

Further details can be found in WBM Oceanics (2003).

2.9 Recreation

The Lake and its foreshores are currently used for fishing, boating, swimming, and walking. The preservation of these uses forms a significant community-derived value for the catchment according to public consultation associated with the preparation of the Stormwater Management Plan (Forbes Rigby, 2000).

2.10 Entrance Condition and Human Impact

A detailed description of the known flood events to have occurred up to 2003 and the condition of the entrance can be found in **Table 5.2** of this report. Additionally, dates of other key human interventions within the floodplain are listed below:

- 1938 – Wooden bridge constructed across entrance channel.
- During 1960's – Shellharbour Council constructed southern retaining wall across Reddall Reserve. Area previously covered by reeds.
- 1972 – Department of Main Roads constructs new bridge (Windang Bridge) across entrance channel. Work included filling of southern (Back) channel.
- 1988 – 1989 – Shellharbour Council reclaimed areas around the southern approach to Windang Bridge.
- 1999 – 2001 – Lake Illawarra Authority constructs the new southern training wall connecting the beach to Windang Island. Work included minor dredging of the channel, which held the Lake open during the period.
- 2006 - Lake Illawarra Authority commences works associated with the new northern training wall.
- Mid-2007 – The northern entrance training works are completed.

3 Flood Management Issues and Objectives

3.1 Floodplain Issues

A number of issues are pertinent to the Lake Illawarra Floodplain and have been raised either by:

- The Floodplain Management Committee;
- The Community (through the Stormwater Management Plan process);
- The Community and other stakeholders through the public exhibition process; or
- Review of the flood behaviour.

Issues pertinent to the floodplain include:

- Emergency response and management in the event of a major flood;
- Impacts of Climate Change, particularly sea level rise on flooding and inundation of low lying land into the future
- flooding of existing developed areas (residential and commercial) and the economic and social effects (e.g. damage to property, social disruption);
- development pressures on the floodplain and throughout the broader catchment likely to exacerbate flooding;
- interaction between flooding requirements and water quality requirements;
- interaction between flooding and ecological requirements (e.g. requirements of seagrass beds);
- impact of entrance management on flooding; and
- impact of flooding on tourism (particularly Caravan Park areas).

3.2 Floodplain Management Objectives

The objectives of floodplain management for Lake Illawarra are primarily to:

- reduce the risk to life and limb;
- reduce the risk to property and resulting reduction in losses;
- minimise the disruption as a result of flooding;
- ensure compatibility with ecological objectives identified through the Lake Management Process; and
- ensure compatibility with objectives identified through the Stormwater Management Process.

4 Community Consultation

The local community, both flood prone and otherwise, has a key role to play in the development, implementation and success of a management plan. If it is to be accepted and successful, it is essential that clear and concise communications flow between the two Councils and the community so that affected individuals and community groups can 'have their say' and learn of their roles and responsibilities.

4.1 Lake Illawarra Committee

The Lake Illawarra Floodplain Management Committee was formed in 1997. This committee is chaired by the Lake Illawarra Authority on behalf of Wollongong City Council and Shellharbour City Council.

Representatives on the committee include:

- Councillor of Wollongong City Council;
- Councillor of Shellharbour City Council;
- Chair of the Lake Illawarra Authority;
- Technical representative (engineering) from Wollongong City Council;
- Technical representative (engineering) from Shellharbour City Council;
- Technical representative from NSW Office of Environment and Heritage;
- State Emergency Service;
- Convenors of relevant neighbourhood committees; and
- Other community representatives as nominated.

For this Study, the Committee sought to identify a range of appropriate floodplain management measures and assess their effectiveness for managing the floodplain including mitigation of the effects of flooding on existing or proposed development and infrastructure, and to ensure that appropriate Flood Planning Levels and controls were determined for any new development on the floodplain.

In formulating flood management strategies the following issues were considered:

- the existing flood risks;
- stabilisation of the Lake Illawarra entrance area; and
- mitigation works for protection of existing development, including modifications to Windang Bridge.

Several options were identified by the Committee for assessment as part of this Floodplain Risk Management Study to address the issues above, as well as the impact of filling of portions of the Lake Illawarra foreshore associated with possible future development proposals.

4.2 Social Concerns Identified Through the Stormwater Management Plan

The Shellharbour Community Environment Forum was held in October 1998 (Forbes Rigby, 2000). The main concerns drawn from it were:

- Pollution of waterways;
- Flooding;
- Degradation of riparian vegetation;
- Destruction of wetlands;
- Inappropriate development;
- Clearing and weed infestation; and
- Vandalism, off-road vehicle use, and car dumping.

Specific values/objectives identified with regard to flooding include:

- public safety - low risk to humans and property from physical hazards and natural forces; and
- flood proof issues from a pollution perspective.

4.3 Community Meeting

A public meeting, organised by the Lake Illawarra Authority was held on 31 July 2000 from 7:00 - 8:30pm at the Windang Bowling Club and was attended by approximately 45 residents and representatives of various authorities including:

- Lake Illawarra Authority
- Wollongong City Council (both Councillor's and Council personnel)
- Shellharbour City Council (both Councillor's and Council personnel)
- Department of Natural Resources (now OEH).

The purpose of the meeting was to convey the results of the flood study to the community as well as provide an opportunity for the community to voice concerns and identify locations where floodplain management options are required.

At this meeting, the findings of the Flood Study were presented with an opportunity for comments and questions regarding flooding in the area at the end of the formal presentation.

Resident queries and comments at this meeting, relevant to the floodplain management study included:

- Query regarding development at Yallah (see **Sections 2.4 and 2.5** of this report);
- Evacuation required of the Yallah area in the 1984 flood event;
- Griffins Bay - a potential second entrance to the Lake as a flood mitigation option; and
- Extension of Windang bridge on the southern side of the embankment (instead of the causeway).

The option of a second entrance at Griffins Bay was based on community belief that there was a second entrance to the Lake at this location some 60 years ago. A review of aerial photography taken in 1949 (**Appendix A**) indicates that a drain (Tank Trap) was excavated from Griffins Bay to the hind dune area of Perkins Beach. Thus the drain was not a contemporary second natural entrance. However, geomorphological evidence suggests an entrance to the Lake could have existed at the northern end of the Lake, thousands of years ago. If there ever was an entrance at this location it is most likely that it was closed off by coastal processes thousands of years ago.

In terms of floodplain management options that were pursued, the option of a second entrance to the Lake at Griffins Bay was considered but deemed technically not feasible and likely to not produce a suitable economic benefit due to the substantial cost to construct (> $10 million).

The option of the modification of Windang Bridge is outlined in **Sections 10 and 11**.

4.4 Public Exhibition

A draft version of the Floodplain Risk Management Study (and Plan) was publicly exhibited in 2005 for comment. Comments were received and incorporated in the previous revised version.

To allow public review and comment on the additional aspects incorporated into the revised *Floodplain Risk Management Study* (Cardno, 2012) and the draft *Floodplain Risk Management Plan* (such as the climate change assessment and the true hazard assessment), the documents were placed on public exhibition again from 11 July 2011 until 5 August 2011.

Two public information sessions were held on 19 and 20 July 2011, and the Study and Plan were available on the two Councils websites for viewing.

Comments received during the exhibition period have been incorporated into this Final Study.

5 Flood and Climate Change Modelling

5.1 Overview

This chapter provides an overview of the flooding behaviour within the Lake Illawarra Floodplain from various investigations. Flood extents and peak flood levels at various locations are provided based on the modelling undertaken as part of the Lake Illawarra Flood Study (Lawson and Treloar, 2001). This flood information is based on flood modelling for the pre-2001 entrance conditions. In addition to the modelling undertaken as part of the flood study, further modelling was undertaken to assess the flooding risks associated with climate change (sea level rise and changes in rainfall). This additional modelling was based on the entrance conditions in 2008 (after the completion of the Stage 1 and Stage 2 entrance works). The additional modelling only considered the 100 Year ARI flood event.

This chapter also provides a discussion on the impacts associated with coincident flooding and wind generated waves and set-up.

5.2 Overview of Flood Behaviour (Pre–Entrance Works, 2001)

Historically, flooding has occurred in the Lake foreshore areas at a number of locations. The combination of heavy rainfall over the catchment and varying degrees of shoaling in the Lake entrance, have resulted in a range of floods in the Lake. Examples of the impacts and extents of flooding, collated by the Lake Illawarra Authority, are shown in **Appendix A**.

Areas that lie within the floodplain include:

- Kemblawarra;
- Warrawong;
- Lake Heights;
- Berkeley;
- Kanahooka;
- Koonawarra;
- Yallah;
- Albion Park Rail;
- Oak Flats;
- Mount Warrigal;
- Windang; and
- Primbee.

5.2.1 Flooding Mechanism

As outlined in the Flood Study (Lawson and Treloar, 2001), the steep slope of the escarpment has a marked influence on rainfall in the catchment. Onshore winds blowing storms onto the catchment are forced by the escarpment to rise steeply, which in turn cools the air more rapidly thereby increasing the rate of precipitation over the escarpment. This phenomenon, known as orographic rainfall, has historically resulted in higher rainfall intensities over the western parts of the catchment than near the ocean.

Rainfall runoff from the steeper western parts of the catchment flows eastward downslope to quickly reach the much flatter coastal floodplain. Here the flow gathers and slows markedly with resulting increased flood depths. Flood flows in the lower parts of the catchment are complicated by bridge and culvert crossings over the feeder creeks before entering the body of Lake Illawarra.

Floodwaters within the Lake body and its surrounding floodplain are characterised by slow velocities and a near horizontal water surface. Closer to the Lake entrance, the floodwaters accelerate into the entrance channel to pass under the Windang Road Bridge and out to the Tasman Sea. The high velocities in the entrance channel can scour sediment from the entrance channel, widening and deepening the channel as the flood progresses, with the channel width limited by the training walls.

The rate and depth of flooding of the Lake and its foreshores are controlled not only by the rate of catchment runoff but also to a large extent by the size and degree of shoaling of the Lake entrance channel at Windang and the coincident ocean level.

5.3 Design Flood Behaviour: Pre-2001 Conditions

The Lake Illawarra Flood Study (Lawson and Treloar, 2001) identified that foreshore flooding resulting from the design flood events occurs around most of the Lake, but in particular at Primbee, Albion Park Rail, Yallah, Oak Flats and Kanahooka. The flood study considered the 2, 5, 10, 20, 50 and 100 Year ARI events, together with an extreme event (of the order of a Probable Maximum Flood). The estimate of an extreme flood hydrograph could not be made by directly applying the Generalised Short Duration Method (GSDM) of Bulletin 53 (Bureau of Meteorology, 1994), which was the most up to date method available at the time of the assessment. While the Lake Illawarra catchment, with an area of 270 km^2, is within the limits of the Bulletin 53 method with respect to catchment area, the method is limited to storms of duration less than 6 hours. The critical duration for the peak flood level for the 100 Year ARI event, which was estimated at 36 hours, is shown to be considerably longer than the 6 hour limit. The hydrographs obtained by this methodology are at best a coarse estimate of extreme flood event flows. Due consideration of the methodology used to generate the hydrographs should be exercised when quoting the Lake levels estimated using the extreme flow estimates. Further details on the approach utilised can be found in the Flood Study report (Lawson and Treloar, 2001).

The Lawson and Treloar (2001) Flood Study used numerical modelling for hydrology and hydraulics (RAFTS and MIKE11) for the determination of peak Lake levels, discharges and velocities. Flood extent maps were prepared from the model results and available topographic information. The 100 Year ARI and PMF extents, with the pre-2001 entrance conditions, are shown in **Figures 5.1 and 5.2**.

These maps have been prepared based on flood levels derived assuming that the entrance is shoaled with a peak tidal boundary condition of 0.6 mAHD. The flood extents were based on aerial laser survey provided by Shellharbour Council and Wollongong City Council.

It is important to note that the 100 Year ARI extents have been effectively superseded by more recent modelling conducted for the climate change assessment, which is described in **Section 5.5**. However, it should be noted that the modelled flood levels do not differ significantly.

The modelling indicated that critical duration of flooding for the Lake was found to be 36 hours.

Peak flood levels at selected locations are reported in **Table 5.1**.

Table 5.1 Design Flood Levels – Pre-2001 Entrance Works

Ref	Location*	Peak Flood Level (m AHD)						
		100 Year ARI	50 Year ARI	20 Year ARI	10 Year ARI	5 Year ARI	2 Year ARI	Extreme Event (PMF)
1	Griffins Bay	2.30	2.03	1.81	1.57	1.40	1.11	3.24
2	Tallawarra Power Station	2.30	2.03	1.81	1.57	1.40	1.11	3.24
3	Horsley Inlet	2.30	2.03	1.81	1.57	1.40	1.11	3.24
4	Cudgeree Island Channel	2.26	1.99	1.81	1.54	1.40	1.08	3.19
5	Windang Bridge	2.08	1.83	1.63	1.42	1.26	0.99	2.98
6	Entrance Channel	1.98	1.74	1.55	1.35	1.20	0.95	2.84

** Locations illustrated on Figures 5.1 – 5.2.*

The models developed for the Flood Study were used to assess the likely improvements afforded by flood modification options proposed in the latter sections of this report. Further details of model schematisation for the options assessments and the comparisons of the option scenario results with the pre-2001 entrance condition results are outlined under **Sections 9, 10, 11 and 12**.

5.4 Coincident Flooding and Wind Generated Waves and Set-Up

In addition to the mechanism of rainfall-runoff flooding described in this report and in the Flood Study (Lawson and Treloar, 2001), areas of the foreshore can be inundated via the processes of wind set-up, wind-wave action and the associated wave set-up.

However, the effect of wind-waves is location-dependent around the foreshore. For example, only those properties generally immediately adjacent to the Lake foreshore are likely to be affected by wind-waves and the strength of winds from different directions and the length of fetch available (open water distance over which wind-waves are generated). The fetch length will vary around the perimeter of the Lake.

No detailed studies are known to have been completed on the wind-wave climate of the Lake. Consequently, the coincident occurrence of wind generating wave events and a flood event are unknown. A preliminary assessment of the coincidence of flooding and wind events was undertaken to evaluate the likely joint occurrence of the two events based on historical data.

Rainfall and wind data were obtained for those historical events identified in **Table 5.2.** Records of the occurrence of flood events back to 1919 are available, but only events with concurrent data are shown (from 1943). Rainfall daily totals and 9am and 3pm wind data were obtained for the period 1970 - 2003 for the station of Wollongong University (BoM gauge 68188) and from the Sydney Airport anemometer for the period 1939 – 2003 (BoM gauge 66037). Whilst the Sydney Airport gauge is a substantial distance from the site, it is the only gauge with accessible data for the period of interest and is representative of the regional conditions likely to have been observed at the Lake. The events between 1939 and 2003 were considered as part of the analysis.

Some flood events had only a month and year as an identifying feature and as such, consideration of the daily rainfall totals during the course of the month identified the approximate time at which the flood event most likely occurred. The coincident wind during the same period was considered. The findings of the flood study (Lawson and Treloar, 2001) were used to link the reported flood levels to the average recurrence interval for each flood. Where the actual peak flood level was unknown, the minimum level reported was used.

Table 5.2 shows the findings of the assessment and **Figure 5.3** shows the comparison of the larger flood events in graphical format.

Table 5.2 Historical Flood Events - Joint Occurrence with Wind

Date	Entrance State	Date of Rainfall Event	Daily Rainfall Total (mm)	Wind Speed (km/h)	Approximate Wind Direction	Comments
19-May-43	Lake Opened By Council	16-May-43	345.4	24.1	NE	Significant but not very strong winds.
Jan-48	Lake Opened By Council	14-Jan-48	42.7	48.2	S	Fairly strong winds.
1959	Major Flood (>1.5 mAHD) (no date assigned)	19-Feb-59	274.3	46.4	SE	There were three significant rainfall events in 1959 - all had fairly strong winds associated with them.
		21-Jul-59	144	44.6	NE	
		21-Oct-59	171.7	53.6	SE	
Apr-74	Major Flood (>1.5 mAHD)	See Comment	See Comment	See Comment	See Comment	Difficult to tell when event occurred, no significant rainfall recorded. Variable wind direction during April.
Mar-75	Major Flood (1.8m)	11-Mar-75	189	1.8	NW	No high winds correspond with this event.
Mar-77	Major Flood (1.8m)	1-Mar-77	81	22.3	SW	Of note, but not particularly strong winds.
Mar-78	Major Flood (1.6m)	21-Mar-78	136	3.6	NE	This data is the peak rainfall and corresponding wind speed. However, in the two days prior there rainfall in the order of 30-50mm and winds in the order of 40-60km/h (roughly).
Feb-84	Major Flood (1.9m)	22-Feb-84	104.1(see comment) 33.2 (daily total)	22.3	SW	Extended rainfall over the period 18th – 22nd February contributed to the total.
Apr-88	Major Flood (1.5m)	30-Apr-88	194	9.4	SE	No high winds correspond with this event.
Aug-90	Moderate Flood (1.4m)	1-Aug-90	118	22.3	SE	Of note, but not particularly strong winds.
Jun-91	Major Flood (1.8m)	11-Jun-91	202	18.4	SE	Of note, but not particularly strong winds.
May-95	Lake Opened by LIA	18-May-95	144	33.5	S	Of note, but not particularly strong winds.

Date	Entrance State	Date of Rainfall Event	Daily Rainfall Total (mm)	Wind Speed (km/h)	Approximate Wind Direction	Comments
28-Jul-98	Lake Opened by LIA	28-Jul-98	29.6	9.4	NW	No significant rainfall events this month may have opened the Lake for water quality reasons.
Aug-98	Moderate Flood (1.2mAHD)	18-Aug-98	239.6	11.2	SW	No high winds correspond with this event.
15-May-03	Lake Opened by LIA	13-May-03	64.4	1.8	SW	No high winds correspond with this event.

Using a simple fetch calculation (US Army Corps of Engineers, 1984), the threshold wind speed to generate a wave height at various locations around the shoreline of 0.2m has been calculated and is shown in **Table 5.3**.

Table 5.3 Wind Speed Required to Create a 0.2m Wave Height at Lake Shoreline

Wind Direction	Measured longest fetch length (km)	Wind Velocity to Create a wave of 0.2m (km/h)
N	6.5	19.8
NE	9.2	18
E	5.5	19.8
SE	5.2	21.6
S	6.5	19.8
SW	9.2	18
W	5.5	19.8
NW	5.2	21.6
Average	6.6	19.8

An analysis of the 35 year wind data set from Wollongong University was used to evaluate the probability of exceedance for the reported maximum wind speeds associated with each flood event. Preliminary calculations of the wind speed from the known fetch distance and a comparison with the probability of exceedance analysis for the local wind gauge data indicates that a wind speed with a probability of exceedance of between 15 - 20 % is likely to result in a wave height of 0.2 m (i.e. only 20% of the time are the wind speeds of this order or greater). However, it is apparent from **Table 5.3**, that winds of this magnitude can be expected to occur at the same time as a flood event based on historical observations. **Table 5.3** also indicates that the predominant direction for wind during historic flood events is from the south sector (between SE and SW).

However, as outlined above, wind-wave action is likely only to impact on properties on the immediate foreshore. It is unlikely that these properties would be affected by waves generated by moving vehicles (i.e. truck wash), or local afflux from the face of the building fronting the Lake and therefore the addition of these freeboards as well as the wind-wave freeboard is unnecessary. This is discussed further in **Section 6.2**.

5.5 Climate Change Modelling

5.5.1 Purpose of Climate Change Assessment

The Inter-governmental Panel on Climate Change (IPCC) Assessment Report 2007 (Known as ‘Climate Change 2007’) concludes that climate change and sea level rise are inevitable. The *Floodplain Development Manual* (NSW Government, 2005) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change and sea level rise on flood behaviour.

More recently, the NSW Government released the *NSW Sea Level Rise Policy Statement* (DECCW, 2009) and the *Flood Risk Management Guide – Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010). These documents have been prepared to assist local councils, the development industry and consultants to incorporate the sea level rise planning benchmarks in floodplain risk management planning and flood risk assessments for new development. The information in these documents updates the sea level rise information in the *NSW Floodplain Development Manual* (NSW Government, 2005) and should be read in conjunction with the Manual. These documents also update the sea level rise section of the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (DECC 2007). However, the 2007 guideline provides additional information relating to the management of the impacts of climate change on existing developed areas and on potential changes to flood-producing rainfall events caused by climate change.

In accordance with the advice presented in the documents above, the following tasks have been undertaken within this FRMS to address the issue of climate change:

- Hydraulic modelling of four climate change scenarios (based on IPCC predictions and OEH recommendations);
- Mapping of 100 Year ARI flood extents for the four climate change scenarios;
- An analysis of the properties impacted by flooding under the various climate change scenarios;
- An assessment of the consequences of adopting each of the four scenarios as part of the relevant planning provisions (LEP and DCP) and exploration of different approaches to address this issue (outlined in **Section 13.4**); and
- Recommendations for planning provisions to be included in the Floodplain Risk Management Plan (outlined in **Section 13.4.3**).

5.5.2 Climate Change Predictions

The Lake Illawarra climate change assessment was undertaken prior to the release of the *NSW Sea Level Rise Policy* (DECCW, 2009) and at the time of the assessment the *DECC Floodplain Risk Management Guideline* (2007) provided the most recent predictions of sea level rise in NSW and discussed the potential increase in peak rainfall intensities as a result of climate change. The sea level rise predictions provided in the more recent guidelines (DECCW, 2010) do not differ significantly from the DECC (2007) guideline. The comparison of the predictions is provided below in **Table 5.4**.

Table 5.4 Climate Change Scenarios

DECC 2007			DECCW 2010	
Climate Change Scenario	**SLR**	**Rainfall Changes**	**Climate Change Scenario**	**SLR**
Low Level Rise (Low Greenhouse Gas Emissions Scenario)	0.18m	10%	-	-
Medium Level Rise (Low Greenhouse Gas Emissions Scenario)	0.55m	20%	2050	0.4m
High Level Rise (Low Greenhouse Gas Emissions Scenario)	0.91m	30%	2100	0.9m

The medium and high level rise DECC (2007) scenarios were adopted for assessment in this study. However, for the purposes of consistency with current policy and guidelines, the terminology from the DECCW 2010 guidelines has been adopted (i.e. 2050 instead of Medium Level Rise and 2100 instead of High Level Rise). The low level rise scenario has simply been referred to as the 0.18m SLR scenario.

The following four scenarios have been assessed as part of the climate change assessment for Lake Illawarra:

1. **0.18m SLR:** Sea Level Rise of 0.18m, no change in rainfall intensity.
2. **2050 SLR:** Sea Level Rise of 0.55m, no change in rainfall intensity.
3. **2100 SLR:** Sea Level Rise of 0.91m, no change in rainfall intensity.
4. **2050 SLR + 20%:** Sea Level Rise of 0.55m, 20% increase in rainfall intensity.

5.5.3 Climate Change Modelling

Climate change modelling of the four climate change scenarios was undertaken to investigate the potential climate change impacts on flood levels within Lake Illawarra. The modelling was undertaken using a full-process Delft3D model of Lake Illawarra. The model includes catchment flows as well as realistic ocean boundary conditions, for example, tides, waves and storm surge. The model includes sediment transport calculations and morphological change so that the scouring of the entrance during a flood is realistically simulated.

5.5.3.1 Delft3D Model

The Delft3D model for Lake Illawarra was developed during design investigations for the northern training wall undertaken in 2003 and 2004. Since this time there have been significant developments with the Delft3D model, particularly the implementation of the latest generation of sediment transport models. The established Delft3D model of Lake Illawarra has been upgraded to include the TRANMOR-2004 sand transport model which has demonstrated improved simulation of sediment transport and morphological changes in coastal entrances compared to earlier transport models.

Since the completion of the entrance works in mid-2007 and the shift to wetter conditions which have prevailed since mid-2007, the entrance to Lake Illawarra has been in a more open state than in the five years prior. To ensure that the model can simulate the hydrodynamics of the current entrance condition, OEH undertook a data collection exercise in March 2008 to sample flood and ebb tide currents and discharges through the entrance. A full bathymetric survey of Lake Illawarra was also undertaken in March 2008. The Delft3D model has been calibrated to the tidal flow data collected in March 2008 and also to the minor flood and entrance breakout event in May 2003, for which there was already existing data including bathymetry, catchment flows and ocean conditions (Cardno Lawson Treloar, 2004). The model has achieved good calibration for both tidal and flood flow conditions.

5.5.3.2 Boundary Conditions

Catchment flows

Catchment flows have been obtained for the 36 hour, 100 year ARI event from the revised hydrological modelling undertaken in early 2006. For the 20% increase in rainfall scenario, it has been assumed that the runoff volume increases by 20%, although the basic hydrograph form remains the same.

Bathymetry

A variety of data sources have been used to compile the model bathymetry. The recent (2008) hydro-survey provides much of the detail for the model. Available survey and ALS data supplied by Shellharbour and Wollongong Council has been used to define the Lake floodplain. The data compiled in the previous entrance modelling (Cardno Lawson Treloar, 2004) has been used to define the offshore bathymetry.

The critical flood conditions at Lake Illawarra may occur when the entrance is initially closed. For the current modelling scenarios, it has been conservatively assumed that the entrance is initially closed. Based on historical data, the level of the entrance berm when the entrance is closed is typically 1.5m AHD. This berm level has been adopted for the present condition. Under climate change scenarios, it is not unreasonable to assume that, provided there is sufficient sand within the system, the level of the berm may increase in response to a rise in mean sea level (MSL). Therefore, for each sea level rise (SLR) scenario, the berm level has been adjusted according to the increase in MSL.

Initial Lake Level

The initial Lake level has been obtained from 28-day simulations of the Delft3D model with the March 2008 (open) entrance condition to obtain the average water level within the Lake. The initial Lake levels derived from these simulations and then applied to the Delft3D flood simulations are:

- Existing Condition: 0.13m AHD;
- Low-Level Climate Change Scenario: 0.29m AHD;
- Mid-Level Climate Change Scenario: 0.66m AHD; and
- High-Level Climate Change Scenario: 1.00m AHD.

Ocean Boundary Conditions

The methodology adopted for ocean boundary conditions is generally in accordance with the DECCW (2010) *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments*. However, it is important to note that the assessments were completed prior to the release of DECCW (2010) and therefore there are some minor variances in the approach from the recommended methods described in DECCW (2010).

The 20 year ARI ocean storm conditions have been adopted as the downstream boundary condition. The total 20 year ARI storm tide for the present sea-level has been adopted at 1.41m AHD (McInnes et al, 2007). This level has been adjusted by the rise in MSL for each climate change scenarios. The 20 year ARI offshore wave conditions that have were adopted based on long-term wave data from the Botany Bay wave rider buoy are:

- H_s=9.0m
- T_p=13.5s
- Dir=135^o.

The peak ocean storm conditions were conservatively assumed to coincide with the peak catchment inflows into the Lake.

5.5.3.3 Results

Table 5.5 presents peak water levels for the 2001 flood study (MIKE-11 model), the existing condition in the Delft3D model as described above, and the specified climate change scenarios. The agreement between the flood study levels obtained from the MIKE-11 model and the existing case Delft3D scenario is very good. The slightly lower peak level from the Delft3D model is principally due to the rate of entrance opening being more rapid than what was adopted in the previous flood modelling (which did not include dynamic entrance opening).

Table 5.5 100 Year ARI Existing and Climate Change Flood Levels

	100-year ARI Flood Levels (m AHD)					
	Flood Study - 2001 MIKE11 Model	Existing Case Delft3D Model	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Hydrology	36-hour, 100-year ARI	36-hour, 100-year ARI	36-hour, 100-year ARI	36-hour, 100-year ARI	36-hour, 100-year ARI	36-hour, 100-year ARI +20%
Climate Change	Existing	Existing	0.18m SLR	0.55m SLR	0.91m SLR	0.55m SLR
Griffins Bay	2.30	2.24	2.41	2.63	3.04	2.88
Tallawarra Power Station	2.30	2.24	2.41	2.63	3.04	2.88
Horsley Inlet	2.30	2.24	2.41	2.63	3.04	2.88
Cudgeree	2.26	2.24	2.41	2.63	3.04	2.88
Windang Bridge	2.07	2.15	2.35	2.55	3.01	2.77
Entrance Channel	1.99	1.71	1.89	2.25	2.32	2.25

Due to attenuation through the Lake entrance, predicted sea level rise conditions at the ocean interface will not take full effect across the Lake.

The flood extents under the four climate change scenarios are shown separately in **Figures 5.4 to 5.7** and are shown as overlays (including the existing 100 Year ARI extent from the Delft3D model) in **Figure 5.8**.

A comparison of the results from Scenario 2 and 4, show that a 20 percent increase in rainfall generally results in an increase in flood levels of 0.25m for the majority of the Lake's foreshore. This information has been used to inform the selection of a freeboard for planning purposes for the Lake Illawarra floodplain (**Section 6.2**). It is noted that the degree and timeframe for change in flood producing rainfall remains unclear in the scientific literature but there is work currently being undertaken in the current update of ARR (expected to be released in 2012). It is therefore recommended that further consideration of changes to flood producing rainfall events be undertaken following release of the current ARR review or when other policy or specific and widely accepted research becomes available.

6 Flood Planning

6.1 Flood Hazard

Flood hazard can be defined a threat to life and limb and damage caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The *Floodplain Development Manual* (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These factors are:

- Size of Flood;
- Effective Warning Time;
- Flood Readiness;
- Rate of Rise of Floodwaters;
- Depth and Velocity of Floodwaters;
- Duration of Flooding;
- Evacuation Problems;
- Effective Flood Access; and
- Type of Development.

Provisional flood hazard is flood hazard categorisation based on hydraulic principles only (depth and velocity). When provisional flood hazard is considered in conjunction with the above listed factors it provides a comprehensive analysis of the flood hazard, known as the "true hazard".

6.1.1 Provisional Flood Hazard

"Provisional" flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (Appendix L, NSW Government, 2005). The *Floodplain Development Manual* (2005) defines two categories for provisional hazard - High and Low.

The hydraulic model results for the critical duration flood events from the Lake Illawarra Flood Study (Lawson and Treloar, 2001) were processed utilising flood level and velocity to determine provisional hazard. Provisional flood hazards for the 100 year ARI and the PMF events were determined and the extent of hazard is shown in **Figures 6.1 and 6.2** respectively. The provisional hazard is defined accurately only at each of the model cross-sections. Between cross-sections, the hazard has been interpolated using engineering judgement and ground survey (ALS).

6.1.2 True Flood Hazard

Provisional flood hazard categorisation based around initial hydraulic evaluations described above does not consider a range of other factors that influence the "true" flood hazard. Therefore provisional hazard categorisation has been assessed in conjunction with the other factors (which are discussed in detail below) to determine true hazard categories.

The following factors have been assessed using a consensus workshop approach to determine their impact on flood hazard categorisation. An initial workshop was conducted with representatives of the Lake Illawarra Authority, the Department of Natural Resources (now OEH), both Councils and the State Emergency Service in November 2005. A follow up workshop with the same group were held in April 2006. The adopted approach is the outcome of these two workshops.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this Floodplain Risk Management Study, provisional flood hazard has been assessed for both the 100 Year ARI and PMF events which produce the peak water levels in the floodplain. However, it was agreed that the 100 Year ARI storm event was the appropriate event to categorise “true” high hazard for the Lake Illawarra Floodplain.

Effective Warning Time

The effective warning time can also be described as the actual time for people to undertake appropriate actions (such as lift or transport belongings and/or evacuate). This time is generally always less than the total warning time available to emergency agencies. This is because of the time needed to alert people to the imminence of flooding and to have them begin effective property protection and/or evacuation procedures.

Lake Illawarra has a catchment of approximately 23,500 hectares and is characterised by a low coastal plain, dominated by the western backdrop of the Illawarra Escarpment. The large catchment size and predominately flat, low lying characteristics of the lower catchment result in a relatively longer critical duration flood event of 36 hours for the 100 Year ARI flood event in comparison to other floodplains in the region. This represents a significant amount of time before the peak of a flood event.

The SES Division responsible for the Lake Illawarra floodplain does not currently have any predictive capabilities to assist with the evaluation of actual warning time for specific flood events. Therefore, warning time as a true hazard factor is considered generally as not applicable to the Lake Illawarra floodplain and as such does not have an impact on flood hazard categorisation.

Flood Readiness

Flood readiness can greatly influence the time taken by flood-affected residents and visitors to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is generally prompt, efficient and effective. Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The last major flood event in the Lake Illawarra Floodplain was in 1991. The event was approximately a 50 Year ARI flood event. However, the extent of floodwaters during this event was not significantly less than the 100 Year ARI design event (since the difference in flood levels between the events is of the order of 0.5 m). However, due to the time elapsed since the flood event (nearly 20 years) it not considered appropriate to assume that the community is “flood ready”. As such, the flood hazard definition has not been altered to reflect flood readiness.

Rate of Rise of Floodwaters

The rate of rise of floodwaters affects the consequences of a flood. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. Both the catchment and floodplain characteristics affect the rate of rise. Whilst the catchment is relatively steep, the floodplain of Lake Illawarra is fairly flat and the Lake acts as a basin which “fills up” at a fairly constant rate at all locations around the Lake. The average rate of rise for the 100 year ARI event is approximately 0.1m/hour and for the PMF event approximately 0.17m/hour, both of which are considered to be fairly low rates of rise. As such, the rate of rise in Lake Illawarra is not considered to be of an order of magnitude to affect flood hazard definition.

Depth and Velocity of Floodwaters

As outlined in **Section 6.1.1**, provisional hazard mapping is determined from a relationship between velocity and depth. This was carried out at each cross section for maximum depth and velocity couplings for the 100 year ARI and PMF events (**Figures 6.1 and 6.2**). High hazard areas for the majority of the Lake Illawarra floodplain are largely dependent on depth.

Duration of Flooding

The duration of flooding or length of time a community, suburb or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. As Lake Illawarra is a fairly large and flat floodplain, with low rates of rise, the duration of flooding is fairly long. The duration of inundation can be greater than 40 hours for properties along the immediate shoreline of the Lake.

Through the workshop process it was agreed that 24 hours was a reasonable threshold duration of inundation which would identify a property to be classified as high hazard. Generally, greater than 24 hours of flooding in a design event corresponds to a level of approximately 1.3m AHD for the 100 Year ARI event and 1.7m AHD for the PMF event (this varies at the entrance). However, due to the depth constraints on high hazard definition, any areas that are flooded for 24 hours or more are already defined as high hazard under provisional hazard. As such, no additional properties were classified as high hazard due to the duration of flooding.

Evacuation Problems

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because of a number of factors, including:

- The number of people requiring assistance;
- Mobility of people;
- Time of day; and
- Lack of suitable evacuation equipment.

Generally, development types which would pose evacuation problems (such as aged care facilities, hospitals and schools) are not permitted within high risk precincts (as defined by the relevant development control plan). Wollongong Council's DCP (2010) and Shellharbour Council's Floodplain Risk Management DCP (2006) provide full details of land use categories permissible within the floodplain.

Flood warning and the implementation of an evacuation procedure by the State Emergency Service (SES), is widely used throughout NSW to reduce flood damages and the risk to life. Flood warning and evacuation plans are already in place for specific areas within the Lake Illawarra floodplain, primarily the caravan parks on the foreshore, in particular Oaklands, Lake Illawarra Village, The Oasis and South Pacific. The warning systems established for these parks also serve to assist the Councils' and the SES with emergency response activities.

Evacuation problems are an important factor in floodplain management and future planning controls. However, as a true hazard factor it does not affect the hazard categorisation of the floodplain.

Effective Flood Access

The availability of effective access routes from flood prone areas can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions.

The majority of the Lake Illawarra floodplain is dominated by inundation of the foreshore and hence effective flood access is often not impeded significantly. However, the Windang Peninsula is an exception to this. In a 100 Year ARI flood event, the majority of the urban areas on the Peninsula are inundated including major and minor access roads. The inundation of the affected roads impacts not only on flood affected properties but also those which are no directly inundated by flood waters.

The urban areas within the Windang Peninsula that are inundated during a flood are shown on **Figure 6.3**. The areas of inundation and their associated period of inundation during a PMF event are shown. It can be seen on **Figure 6.3** that large portions of the Peninsula are inundated and / or have their access inundated for periods greater than 24 hours during a PMF flood event, including sections of Windang Road. The same information is shown on **Figure 6.4** for the 100 Year ARI event. It can be seen that in a 100 year event, the inundation periods are less than for greater events. However, portions of Windang Road are still inundated for periods up to 18 hours, effectively isolating portions of the Peninsula for this period of time.

The land use zones contained within the Windang Peninsula are shown in **Figure 6.5**. With regards to increased risk due to isolation during a flood event, the risk is primarily contained within zones that permit overnight accommodation. This is due to the slow rate of rise of flood waters. It is likely that any day facilities could be evacuated in a more timely manner. The zones which permit overnight accommodation include R2 (low density residential) and SP3 (tourist).

According to the LEP; dual occupancies, multi-dwelling housing, residential flat buildings, semi-detached dwellings and seniors housing are permissible within Zone R2 (amongst others). Tourist and visitor accommodation is permissible with SP2.

The existing floodplain development matrix in Council's LEP does not limit the density of development within the floodplain, except to identify that residential development is not suitable within high flood risk precincts. The high risk precinct for the Lake Illawarra Floodplain is shown in **Figure 13.1**. It can be seen that this area only affects a small proportion of the residential development on the Windang Peninsula.

The risk as a result of flood isolation increases with the number of people isolated. Therefore, it is recommended that Council consider adopting development controls specific to the residential areas impacted by isolation that limit the number of inhabitants of the area into the future. Further details regarding the recommended development controls and the areas impacted by these controls are provided in **Section 13.2.2**.

Type of Development

The degree of hazard to be managed is also a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and modify management strategies in existing development areas. Both Wollongong and Shellharbour Councils currently have development control policies (DCPs) which consider and manage development within floodplains. The DCPs define prohibited land uses for high, medium and low risk precincts. These flood risk precincts (**Section 13.2**) are defined primarily by true hazard mapping for the Lake.

The following land use categories are prohibited in high risk precincts (high hazard at the 100 Year ARI and riparian zones):

- Essential Community Facilities;
- Critical Utilities;
- Subdivision;
- Residential;
- Commercial and Industrial; and
- Tourist-Related Development.

The following land use categories are prohibited in medium risk precincts (low hazard – to the flood planning level extent – 100 Year ARI + 0.5m):

- Essential Community Facilities; and
- Critical Utilities.

The following land use categories are prohibited in low risk precincts:

- Essential Community Facilities.

A full list of land use categories and land use types are provided in Wollongong Council's DCP (2010) and Shellharbour Council's Floodplain Risk Management DCP (2006).

Through the workshop process it was determined that the hazard category of individual properties would not be altered due to current land use type. However, it is useful to identify any properties which are currently located within the floodplain which may require special consideration in terms of flood impacts such as schools, aged care facilities and community buildings. A preliminary assessment was undertaken to identify these facilities within the floodplain (PMF extent). Properties were identified through a preliminary search of the UBD street directory, the Telstra Yellow Pages and the Local Environment Plan for the two Councils. This search identified a number of schools and other community use buildings located within the floodplain. No nursing homes or child care centres were identified in the floodplain through this process of assessment.

Summary of True Hazard

Due to the nature of flooding in Lake Illawarra many of the factors do not alter the provisional hazard mapping. A summary of the factors which affect flood hazard and the findings of the true hazard assessment are presented in **Table 6.1**.

Table 6.1 Factors Affecting Flood Hazard

Factor	Agreed Criteria
Size of Flood	True high hazard to be determined by 100 Year ARI.
Effective Warning Time	The whole floodplain has a fairly long warning time and therefore, no particular areas would be subject to a higher or lower hazard category on the basis of this factor.
Flood Readiness	Due to the time elapsed since the last major flood event, flood readiness in the Lake Illawarra floodplain is not considered an appropriate factor to alter flood hazard categories.
Rate of Rise of Floodwaters	Rate of rise of flood waters in the Lake Illawarra floodplain is fairly low; as such no additional high hazard category areas have been included due to this factor.

Factor	Agreed Criteria
Depth and Velocity of Floodwaters	Provisional Flood Hazard Mapping (**Figures 6.1 and 6.2**).
Duration of Flooding	All properties which are inundated for 24 hours or more are already classified as high hazard, under provisional categories.
Evacuation Problems	Due to the regulations on permissible development within the floodplain no additional properties were defined as high hazard due to evacuation problems.
Effective Flood Access	Access to Windang Peninsula can be effectively "cut off" during flood events for significant amounts of time. In order to manage the risk associated with this isolation, specific development controls have been developed for this area. See Section 13.2.2.
Type of Development.	This does not affect hazard mapping extents, however this will be incorporated into the development control matrices.

The true hazard assessment undertaken for the Lake Illawarra floodplain identified that it is not necessary to revise the provisional flood hazard mapping for true hazard factors. However, additional development controls were identified for inclusion to address the issue of effective flood access on the Windang Peninsula.

The hazard extents shown in **Figures 6.1 and 6.2** have been utilised to define the flood risk precincts presented in **Section 13.2**. **Section 13.4** outlines how climate change has been incorporated into the flood risk precincts.

It should be noted that High Hazard areas could extend further up the creek systems which flow into Lake Illawarra than shown in **Figures 6.1** and **6.2**, due to catchment flood flows in the creek systems as well as those hazard areas caused by backwater flooding associated with Lake Illawarra. Reference should be made to the respective Floodplain Risk Management Studies of those creek systems for further information.

6.2 Flood Planning Levels

To date, both Wollongong City Council and Shellharbour City Council have adopted the 100 Year ARI flood as the basis for the interim flood planning level for development around the foreshore of the Lake for all land uses with habitable floor levels to be set at the 100 Year ARI + 0.7 m (freeboard).

A similar flood planning level is commonly adopted across NSW as the flood planning level for residential development (Gillespie, 2005). However, the opportunity exists for the variation of the flood planning level on an area basis, on a land-use basis or a combination of area/land use through the adoption of floodplain management 'zones'.

Variation can be made in either the recurrence interval event selected as the 'planning event' or the freeboard adopted.

With respect to the 'planning event' consideration, this is often considered with regard to the design life of a structure, or the lifespan of a person. A commonly adopted design life for a structure may be 50 – 100 years with human lifespan being at the upper end of this range.

Therefore, as outlined in the *Floodplain Development Manual* (NSW Government, 2005), the size of flood and the probability of experiencing the given flood in a period of say 70 years is worthy of consideration in selection of an appropriate recurrence interval. A 100 Year ARI flood has a 50.3% chance of occurring at least once in a period of 70 years and a 15.6% chance of occurring at least twice in the same period. Therefore, the adoption of the

100 Year ARI as the planning flood is considered reasonable for both design life and a human life span and for consistency across NSW and other floodplains within the two local government areas.

The common elements that are generally factored into a freeboard of 0.5 m (Gillespie, 2005) include:

- Uncertainty in flood modelling (0.2 m);
- Local wave action (0.1 m) (wind wave action is site specific);
- Afflux (0.1 m); and
- Climate change – Sea Level Rise (0.1 m).

A freeboard of 0.5m has been proposed for the Lake Illawarra Floodplain based on the following elements:

- Local wave action (0.2m). See **Section 5.4** for details on the derivation of this value;
- Afflux (0.1m);
- Climate change impacts on hydrology (0.25m). This value has been determined by comparing the climate change modelling results for Scenario 2 (2050 SLR and no change in rainfall intensity) and Scenario 4 (2050 SLR and 20% increase in rainfall intensity). The results are provided in **Table 5.5**. The difference between the two sets of results is, on average, 0.25m. This would indicate that the impact of the increased rainfall is approximately 0.25m for the 100 year ARI event.

It should be noted that these elements result in a freeboard of 0.55m, this level of accuracy is not considered appropriate for the purposes of flood planning and therefore a freeboard of 0.5 m is recommended.

No general allowance for uncertainty in flood modelling has been made as information is available on the key uncertainty, being hydrology. Many of the uncertainties have been accounted for in conservative assumptions used in the modelling process.

Sea level rise has not been incorporated into freeboard, but rather into the flood risk precinct mapping (provided in **Figures 13.5 and 13.6**) for planning purposes.

There are some cases where proposed development is recommended to be designed in accordance with the PMF (see **Appendix E** for more details on the types of developments that this applies to). In these cases no freeboard would be applied.

7 Economic Impact of Flooding

7.1 Background

A guide to the nature of flood-related damages can be found in the NSW *Floodplain Development Manual* (2005). Damages can be separated into two categories, the nature and examples of each type are shown in **Table 7.1**.

Table 7.1 Types of Flood Damages (after NSW Government, 2005)

Tangible	**Direct**	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
	Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible		Social - increased levels of insecurity, depression, stress General inconvenience in post-flood stage

To assess the nature of flood damages, all properties in the floodplain require survey and details of the property type. Properties can then be categorised according to their type and assigned a 'stage-damage' relationship that is then used to assess the likely direct tangible damage for each recurrence interval.

Direct tangible damages can be estimated from property information. Indirect tangible and intangible costs are assumed as functions of the direct tangible costs. Details of the actual functions used can be found as a footnote to **Table 7.2**.

7.2 Property and Floor Level Survey

Properties to be surveyed were identified by considering the Extreme Flood/PMF extent (**Figure 5.2**). A total of 1,055 allotments were identified to lie within the floodplain.

A property and floor level survey that covered 808 properties was conducted by the respective Councils in 1999 to aid the damages assessment, 502 in the Wollongong City Council area and 306 in the Shellharbour City Council area. This survey was completed in February 2000. Additional survey was later completed in October 2000 to cover an additional 247 properties which were also identified to lie within the floodplain.

In addition to the residential and commercial areas within the floodplain, there are also a number of Caravan Parks with permanent and temporary sites that were not surveyed. Information on these sites was sought from the managers of the sites by the Lake Illawarra Authority (LIA). The ground levels and floor levels provided were estimated by the LIA or the park managers. These include:

- Oaklands Village (154 permanent demountable homes and 102 permanent caravans);
- Lake Illawarra Village - 309 on-site dwellings;
- South Pacific Park Village - 32 caravans and moveable dwellings; and
- Oasis Resort - 32 permanent dwellings, 11 permanent casuals and 16 tourist cabins.

The damage assessment for the Caravan Parks was undertaken as a separate assessment from the other properties due to the variability in the number of vans within these parks as well as the potential for the vans to be relocated during a flood.

The following property categories were identified:

- Residential;
- Commercial;
- Industrial;
- Caravan; and
- Public (e.g. infrastructure, community buildings etc).

The survey included details of each property within the floodplain (as defined by the flood study). The details of each property included an evaluation of the type of property based on exterior characteristics whilst surveying the floor levels.

Property details acquired include:

- Unit/Street Number, Street Name and Suburb;
- Property type - Comm (C), Indust (I), Resid (R), Public (P), Vacant (V);
- Premises Size (Small, Medium, Large) or Floor Area m^2 (Large C or I);
- $ Value For C or I only (Low ,Medium, High);
- Number of Storeys;
- Do people live on ground floor? (Y or N);
- Property Condition (Poor, Average, Excellent);
- Garden Condition (Poor, Average, Excellent);
- Integrated Survey Grid Coordinates - Easting and Northing;
- Ground Level (m AHD); and
- Floor Level (m AHD).

7.3 Flood Damages

Flood damages can be assessed by a number of means in Australia including the use of programs such as FLDAMAGE or ANUFLOOD. Cardno have developed a program that directly utilises:

- MIKE11 Hydraulic Model result files;
- property survey details; and
- damage curves (a compilation of curves derived from a number of sources).

The outputs of the program are a MapInfo Professional format of the *direct* damage costs. Indirect and intangible costs are difficult to assess without actual data for the floodplain and have therefore been evaluated as functions of the direct costs.

MIKE11 Result Files

The program assigns each property with an interpolated flood level using the nearest MIKE11 cross section. Where cross sections are further than one kilometre away from a property the flood level was assigned individually.

Damage Curves and Preparedness

Based on the property details outlined above, each property was assigned a stage-damage curve. Stage-damage curves indicate the likely cost of damage for a property based on the level of flooding above floor level. Two scenarios are usually considered in the preparation of stage-damage curves:

- the case where the community is 'prepared' for a flood (as a result of flood warnings or general flood awareness); and
- the case where the community is 'unprepared' for a flood (as a result of flash flooding or being unaware that the area floods).

Since the time to flood peak for the Lake Illawarra floodplain is approximately 36 hours, it is possible that the community could be 'prepared' for a flood via flood warning systems and media announcements. Flood awareness in the area is likely to vary greatly, with some residents being extremely aware of the flooding potential of the Lake, whilst others have no prior knowledge of the flood history of the area. Both cases have been considered. It is important to note that the true flood hazard assessment (**Section 6.1**) identified that flood awareness (on flood readiness) is expected to be low.

Stage-damage curves for NSW were reviewed by Cardno for the nearby Allans Creek Floodplain as part of the Floodplain Risk Management Study (2006) for Wollongong City Council. To ensure consistency between the results, a similar approach for this study was advocated involving the adoption of a compilation of curves derived from other studies. Curves were compiled from other studies and adjusted to dollars (in 2000 terms, the time at which the damage assessments were completed) using the 2000 Consumer Price Index (CPI).

The compiled data for NSW classifies properties as follows:

A Residential, Medium Value, Single Storey
B Residential, High Value, Single Storey
C Residential, Medium Value, Two Storey's
D Residential, High Value, Two Storey's
E Commercial, Medium Value, Single Storey
F Commercial, High Value, Single Storey
G Industrial, Medium – High Value, Single Storey
H Large industrial, High Value
I Large industrial, Low Value
J Large Commercial (e.g. Large Shopping Centre)
K Caravan or Relocatable Home.

Note that 'value' is assigned in a subjective manner and generally reflects an assumed correlation between various known parameters (such as property construction type) to the internal value of the contents. This assumption may not hold true for all cases but is likely to be reasonable on average.

The property details outlined above were then linked to these classifications to allow for the damage assessment. Damage curves collated are shown in **Figures 7.1 - 7.4**.

It should be noted that no published data for Caravan damages could be located and an assessment of the likely damage costs was prepared by considering the value of Caravans as at 2000. This was undertaken through a review of new and used Caravan prices and contact with insurers on valuation of Caravans. An assumed damage curve was then developed and adopted.

Advice from the Department of Natural Resources' (now OEH) Specialist Flood Unit indicates that all damage curves adopted from published data should be doubled to account for research on flood damage (Blong, 2000). This advice was received after a substantial portion of the assessments were completed. As such, instead of doubling the damage curve ordinates, the total direct damage component calculated for residential and commercial damages has been doubled for all cases to provide a better guide to the actual damage costs.

7.4 Results

The results of the assessment in terms of costs are presented in **Table 7.2 and Table 7.3.** These results are broken into the damages categories listed in **Table 7.1** for each design flood extent.

From these assessments the average annual damage (AAD) is calculated to be $447,000 for the unprepared community and $198,000 for the prepared community.

The results of the assessment in terms of number of properties affected by above floor flooding are presented in **Table 7.4**. A total of 839 properties (excluding caravans) are affected by flooding up to the Extreme Flood/PMF regardless of preparedness. A breakdown across the two Council areas affected is also provided.

As a guide, **Table 7.5** contains the results of the portion of the assessment for the Caravan Parks (a subset of the results shown in **Table 7.2 and Table 7.3**). The upper limit for the average annual damage (AAD) for the Caravan Parks has been assessed by considering all Caravan Parks fully occupied and completely unprepared. No value for other cases was determined given the variable nature of the potential damage that depends on season and preparedness.

Table 7.2 Results of Flood Damages Assessment - Costs - Unprepared Community

ARI	Tangible						Intangible*	Total Damages
	Residential		Commercial/Industrial		Infrastructure*	Total Tangible Damages		
	Direct	Indirect*	Direct	Indirect*				
Extreme/PMF	27,199,000	8,160,000	1,758,000	879,000	14,479,000	52,475,000	2,624,000	55,099,000
100 Year	3,789,000	1,137,000	108,000	54,000	1,949,000	7,037,000	352,000	7,389,000
50 Year	696,000	209,000	5,000	2,500	351,000	1,263,500	64,000	1,327,500
20 Year	165,000	50,000	-	-	83,000	298,000	15,000	313,000
10 Year	69,000	21,000	-	-	35,000	125,000	7,000	132,000
5 Year	56,000	17,000	-	-	28,000	101,000	6,000	107,000
2 Year	35,000	11,000	-	-	18,000	64,000	4,000	68,000

**Note for all damages assessments: Direct damages have been factored by two to account for advice from OEH– see Section 7.3, Indirect residential ~ 30% direct residential, indirect commercial/industrial ~ 50% direct commercial industrial, infrastructure ~ 50% of total direct residential and commercial/industrial, intangible ~ 5% of Total Tangible Damages. Total damage is the sum of Total Tangible Damage and Intangible Damage.*

Annual Average Damage 'Unprepared' = $447,000

Table 7.3 Results of Flood Damages Assessment - Costs - Prepared Community

ARI	Tangible						Intangible*	Total Damages
	Residential		Commercial/Industrial		Infrastructure*	Total Tangible Damages		
	Direct	Indirect*	Direct	Indirect*				
Extreme/PMF	11,086,000	3,326,000	419,000	210,000	5,753,000	20,794,000	1,040,000	21,834,000
100 Year	1,436,000	431,000	36,000	18,000	736,000	2,657,000	133,000	2,790,000
50 Year	362,000	109,000	4,000	2,000	183,000	660,000	33,000	693,000
20 Year	114,000	35,000	-	-	57,000	206,000	11,000	217,000
10 Year	48,000	15,000	-	-	24,000	87,000	5,000	92,000
5 Year	38,000	12,000	-	-	19,000	69,000	4,000	73,000
2 Year	22,000	7,000	-	-	11,000	40,000	2,000	42,000

Annual Average Damage 'Prepared' = $198,000

Table 7.4 Results of Flood Damages Assessment - Properties Affected by Above-Floor Flooding

ARI	Residential Dwellings Flooded	Commercial/Industrial/ Special Uses Sites Flooded	Total Sites Flooded (WCC)	Total Sites Flooded (SCC)	Total Caravans Flooded	Total
Extreme/PMF	786	53	620	219	645	1484
100 Year	189	6	139	56	459	654
50 Year	53	2	37	18	48	103
20 Year	16	0	10	6	0	16
10 Year	3	0	1	2	0	3
5 Year	2	0	0	2	0	2
2 Year	2	0	0	2	0	2

Table 7.5 Results of Flood Damages Assessment - Unprepared Caravan Parks Fully Occupied

ARI	Tangible						Intangible*	Total Damages
	Residential		Commercial/Industrial		Infrastructure*	Total Tangible Damages		
	Direct	Indirect*	Direct	Indirect*				
Extreme/PMF	6,373,000	1,912,000	-	-	3,187,000	11,472,000	574,000	12,046,000
100 Year	1,405,000	422,000	-	-	703,000	2,530,000	127,000	2,657,000
50 Year	128,000	39,000	-	-	64,000	231,000	12,000	243,000
20 Year	-	-	-	-	-	-	-	-
10 Year	-	-	-	-	-	-	-	-
5 Year	-	-	-	-	-	-	-	-
2 Year	-	-	-	-	-	-	-	-

Upper Limit of Annual Average Damage 'Unprepared' Caravan Parks Alone = $92,000

7.5 Discussion

The average annual damages costs are within a reasonable range as compared to other published average annual damage costs. However, given the limitations with the data supplied with respect to the Caravan Parks the figure may be higher or lower than that reported and this should be considered in any evaluation of options.

8 Identification of Floodplain Management Options

There are a range of flood mitigation measures available to address the issues and objectives defined in **Section 3**. These have been described here in general terms and also with particular reference to the Lake Illawarra foreshore.

8.1 Approaches to Floodplain Management

There are three distinct approaches to reducing flood risk:

- flood modification;
- property modification; and
- emergency response modification.

These are described further in **Table 8.1**.

Table 8.1: Approaches to Floodplain Management

Flood Modification Options	Flood modification options control of floodwaters by the use of structural means such as: ▪ flood mitigation dams and retention/retarding basins, ▪ channel/entrance improvements, ▪ levees and floodways, ▪ catchment treatment, ▪ maintenance of stormwater drains, and ▪ dredging works.
Property Modification Options	Property modification options lessen the extent of the damages by ensuring that all the development is flood compatible. This is generally accomplished through non-structural means such as: ▪ flood proofing (e.g. house raising), ▪ planning and building regulations (zoning), ▪ voluntary purchase, and ▪ land-use changes.
Emergency Response Modification Options	Emergency response modification options Inform the affected parties concerning the nature of flooding so that they can make informed decisions. This can be achieved through: ▪ flood warning and emergency services, and ▪ information and education.

8.2 Flood Modification Options

8.2.1 Dams and Retarding Basins

Flood mitigation dams or retarding basis that have significant flood storage capabilities can significantly reduce the downstream peak flood level. However, they are often extremely expensive and can generally only be justified in economic terms if combined as a water supply, irrigation or power generation dam.

An alternative might be to construct several smaller dams or retarding basins, which perform the same task. These have been employed successfully in many locations throughout the Sydney and Illawarra Region. Generally they are only viable if they can be incorporated as an integral part of a new subdivision.

Although they are an option for any new development upstream to restrict the increase in peak flows caused by urbanisation, there is little scope to use retarding basins along Lake foreshore areas to reduce the flood impact given the vast volumes of runoff entering the Lake from the wider catchment and the lack of suitable sites not already flood liable.

8.2.2 Channel/Entrance Improvement Works

Channel improvement works and construction of flood channels have been used successfully in many locations to reduce flood levels. The activities include realignment and reconstruction of the channel (including dredging) to improve hydraulic efficiency and waterway area.

Some improvement in peak flood levels has been achieved through the Stage 1 and 2 works associated with the stabilisation of the entrance area of the Lake. Further details of the assessment of these works are outlined in **Section** 9.

A further way of increasing hydraulic efficiency is to remove any major hydraulic restrictions. For example, widening the restrictions at bridges may reduce flood levels upstream. The Windang Road Bridge is the only major structure that may have some influence on flood levels.

Further details of the assessment of two approaches to this option are outlined in **Sections 10 and 11**.

8.2.3 Floodways

Artificial floodways are a further way to reduce flood levels by increasing the waterway capacity of the channel either by lowering the overbank area, or by providing a lowered area across a peninsula. Whilst community consultation (**Section 11**) identified that there may be some scope to provide a second entrance at Griffins Bay on the eastern shore of the Lake perhaps operating at a higher level to reduce flood levels for extreme flood events, a preliminary review of this option indicated it was not likely to be technically or economically feasible. This is primarily due to the length of channel that would be required to be constructed, the height of the dune system and the increase of development along the eastern foreshore area adjacent to Griffins Bay. Additionally, the potential for the channel to close off as a result of the net northerly sediment transport along Perkins Beach also makes this option unsupportable.

8.2.4 Levees

Levees have been used in many towns in NSW to lessen flood damages. There may be some opportunity to provide levee protection for some properties on the Lake foreshore.

Dredged material from the Lake or other imported material could be used to form levees at designated locations such as around the Caravan Park areas (eastern foreshores) or along other parts of the eastern shoreline of the Lake to protect foreshore properties.

Levees generally require large amounts of fill and have to protect a considerable number of houses to become cost-effective. Levees may also limit the existing outlook and can detract aesthetically from an area. Consideration should also be given to the implications of levee failure. Levees can introduce new problems with local drainage and this issue requires examination in detail to ensure that flooding from local runoff would not occur after construction. A levee may increase flood levels in either upstream or adjacent foreshore areas depending on the loss of storage or any hydraulic restriction it may impose. The effect of overtopping of the levee should also be addressed unless the design is to the Extreme Flood/PMF level.

No levee banks have been considered in detail as such within this study. However, consideration of ring levees for the Caravan Park areas along the Lake foreshores in the Primbee-Windang area could be the subject of further investigation.

8.2.5 Catchment Treatments

Catchment treatment is the process of modifying the upper catchment to reduce downstream flood peaks. In a rural catchment, afforestation or contour banking may be possible. For an urban catchment planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention basins can be used. As a general concept, catchment treatment should be employed in the future development of the tributaries of Lake Illawarra.

Investigation of this option is not within the scope of this study but is part of studies to be conducted for the individual creeks.

8.2.6 Maintenance of Stormwater Drains

During the course of the exhibition of the Draft Floodplain Risk Management Study (**Section 4.4**), respondents identified that additional maintenance of the stormwater drainage network is required to reduce flood risks during regularly occurring events.

The primary mode of maintenance is the removal of blockages (such as leaf litter, sediments and rubbish) from the system. Quarterly maintenance is expected to address the majority of the risks associated with the potential for blockage, however, there may be circumstances where this is insufficient and therefore 'on-demand' maintenance is also appropriate in response to complaints received by Councils.

8.3 Lake Dredging

Dredging of the Lake is an option to create additional flood storage and therefore potentially reduce peak flood levels. Given the size of the Lake and the volume of inflow, considerable areas of the Lake would need to be dredged in order to facilitate a measurable reduction in flood levels.

Lake dredging could have significant environmental impact (e.g. changes to hydraulic regime, loss of seagrass due to increase in water depth) as well as possibly economic and recreational impact (loss of seagrass results in loss of fish habitat and therefore loss of commercial/recreational opportunities for fishing).

To minimise potential ecological impacts, dredging would need to be limited to depths of 1 - 2 m (this criteria is generally related specifically for the maintenance of seagrass beds). The LIA has previously identified that some 1.2 million m^3 of material could be dredged from shallow bays in the Lake to remove organic rich sediment and improve circulation and boating (**Figure 8.1**). A cursory assessment of the impacts of this proposal indicates that it is likely that this may only result in only a marginal benefit in reducing flood levels.

The Lake volume has been estimated to be 156 million m^3 (further discussed in **Section 12.3** and **Table 12.4**). Thus an increase in volume of 1.2 million m^3 is only of the order of 0.7% of the total Lake volume and is unlikely to make a significant difference with regard to flood impacts for rare and extreme events.

In terms of the ongoing effectiveness of such a proposal, it is likely that siltation of dredged areas (once deeper these areas facilitate sedimentation) will generally reduce any marginal benefits gained.

As such, Lake dredging has not been considered as an option as part of this study. Details of the assessment of the converse action, effects of filling of the Lake are outlined in **Section 12**.

8.4 Property Modification Options

8.4.1 Flood Proofing / House Raising

Flood proofing is the practice of re-designing or retrofitting of buildings to minimise flood damages. Various alternatives are summarised in **Table 8.2**.

Table 8.2 Property Modification Options

Contingent	Permanent
Closure of openings	House Raising
Lifting of contents	Waterproof fittings and materials
Removal of contents	Closure of openings
Controlled flooding	Elevation of high value/high risk contents

Contingent Measures

The contingent measures are dependent upon adequate flood warning and response to be effective. The actual/potential damages ratio (A/P) expresses the reduction in flood damages as a result of contingent measures. Studies in Australia have shown that the A/P ratio is a function of the warning time and the level of preparedness of the community.

As contingent measures are likely to be currently employed during a flood, there is little additional improvement possible using these measures. Public education around Lake Illawarra on an ongoing basis to reinforce the lessons learnt in previous floods will assist in reducing flood damages by this means in future floods.

Permanent Measures

These measures can either be used in isolation or used in conjunction with other options to form a total floodplain management package. House raising is a valid option for dwellings with an existing significant flood exposure. However, the option is not applicable to brick dwellings or slab on ground structures. House raising costs were estimated to be in the range of at least $40,000 to $45,000 making it an option which may be difficult to justify for some properties on a purely economic basis since some properties may not sustain $40,000 worth of damage in a flood.

Waterproofing or closure of openings is probably not practical except perhaps for commercial brick premises. A public awareness campaign to advise residents to raise high value goods would be desirable.

The consideration of watertight barriers (including ancillary components) such as block-work walls constructed around properties has not been included in this assessment due to the expected long-term cumulative impacts of this approach producing a loss of storage within the floodplain.

A detailed assessment of house raising can be found in **Section 13.6**.

8.4.2 Planning and Development Controls

Land zoning, site planning, freeboard and the setting of minimum floor levels are useful devices in the planning and management of future development, whether it be a new development or redevelopment of a site. However, these planning devices are difficult to implement for developed areas with an existing flood problem until sites are redeveloped.

The rezoning of portions of the floodplain or the application of floodplain-specific development controls is the practice of limiting the amount and type of development in the floodplain to minimise the flood risk. Care must be taken when applying land zoning to ensure that it does not exclude acceptable development or sterilise land so that flood-liable land can be used to its maximum potential for the benefit of the community. The degree of flood hazard and type of development as well as the potential flood damages should be taken into consideration when assessing development on flood-liable land. Rezoning and development controls should be considered as a primary flood mitigation measure in order to minimise future flood damages on the Lake foreshore while at the same time maximising the land use potential.

Further details on planning and development controls can be found in **Section 13**.

8.4.3 Voluntary Purchase

Voluntary purchase of flood liable properties has been employed at many locations throughout NSW including Dapto and other parts of the Wollongong LGA. Generally it is most suited to areas where there is a high flood hazard presenting significant risk to life. Such dwellings may sustain regular inundation of which the damages become of the order of the value of the property. Under a Voluntary Purchase Scheme (VPS), Council would purchase identified properties, with the assistance of approved State Government funding, and then return the property area to public open space. It should be noted that voluntary purchase is based on the value of the property assuming flooding were not an issue.

A detailed assessment of properties that would be suitable for voluntary purchase is reported in **Section 13.7**.

8.5 Emergency Response Modification Options

8.5.1 Flood Warning

Flood warning and implementation of an evacuation procedure by the State Emergency Service (SES), is widely used throughout NSW to reduce flood damages and protect lives. Flood warning and evacuation plans are already in place for specific areas within the Lake Illawarra floodplain, primarily the caravan parks on the foreshore, in particular Oaklands, Lake Illawarra Village, The Oasis and South Pacific. The warning systems established for these parks also serve to assist the Councils' and the SES with emergency response activities.

The effectiveness of a flood warning scheme depends upon the following:

- maximum potential warning time before the onset of flooding;
- the warning time provided before the onset of flooding;
- accuracy of the warning;
- awareness of community in responding to a warning; and
- the reduction in flood damages that can be achieved by implementing a flood warning system.

Studies have shown that flood warning systems generally have high benefit/cost ratios, but only if sufficient warning time is provided. The warning time provided is the difference between the maximum potential warning time and the time taken to disseminate the warning to the public. A community willing and able to respond to flood warnings will significantly reduce damages. However, even with a flood warning system, some tangible and intangible flood damages may still occur. There are no detrimental environmental effects with a flood warning system. For Lake Illawarra, given the critical duration of flooding is 36 hours, a warning time of approximately 12 hours is available (given it is likely to take 12 hours for the Lake to rise to a level of concern, another 24 hours will be available before the peak occurs. However, it is important to have warnings issued well prior to the time of the peak to allow people time to evacuate.

The SES also utilises 'Flood Intelligence Cards' for the Lake Illawarra area. It is a recommendation of this study that these flood intelligence cards be updated with the results of the flood study (Lawson and Treloar, 2001) and further modelling described in **Section 5** to ensure the most accurate and up to date information is available in the event of a flood.

Further details on flood warning and other emergency response modification options for Lake Illawarra can be found in **Section 14**.

8.5.2 Entrance Opening Policy

The LIA has a policy to open the Lake's entrance to the ocean (when it is closed) when Lake water levels rise to 0.8 mAHD (i.e. 0.5 m above historical normal Lake level). The water level is measured from the recording station at Cudgeree Bay.

Both Wollongong and Shellharbour City Councils have agreed to the LIA policy. Under closed conditions, when water levels start to rise the LIA monitors weather patterns and arranges for a contractor to have machinery on standby. Before opening, the LIA seeks the approval of relevant government agencies including the two Councils, Department of Primary Industries (Fisheries) and OEH.

8.5.3 Information and Education

Flood awareness campaigns have been proven to significantly reduce the potential flood damages. However, such schemes are difficult to implement in an urban community with a reasonably rapid turnover of residents. Additionally, the perceived value and interest diminishes as the time since the last flood increases. It is recommended that the Committee issue an information brochure to the community at least every two years.

A more detailed review and analysis of information and education could be undertaken since this study only provides a cursory review of the current practices.

Further details on flood warning and other emergency response modification options for Lake Illawarra can be found in **Section 14**.

8.6 Summary of Potential Options

A range of flood mitigation options has been canvassed for the Lake Illawarra foreshore and an assessment made of their viability. This information is summarised in **Table 8.3**.

Table 8.3 Summary of Possible Floodplain Management Measures for Lake Illawarra

Measure	Identifier	Comment
Entrance Stabilisation	Option A	See **Section 9**
Causeway Removal at Windang	Option B	See **Section 10**
Culverts at Windang	Option C	See **Section 11**
Impacts of Foreshore Filling	N/A	See **Section 12**
Land Zoning	N/A	See **Section 13**
Development Controls	N/A	See **Section 13**
Evacuation Plan	N/A	See **Section 14**
Flood Warning	N/A	Updating of Flood Intelligence Cards by SES with Flood Study findings - See **Section 14**
Entrance Opening Policy	N/A	See **Section 8.5.2**
Information and Education	N/A	Flood information brochure to be periodically updated and reissued every two years. See **Section 14.**

9 Option A – Entrance Stabilisation

9.1 Background

Lake Illawarra is connected to the ocean by a 1.7km long entrance channel. Historically the entrance has continually changed under the influence of catchment runoff and coastal processes such as tides, wave action, wind and littoral sediment drift, all of which are known to influence the entrance position and condition.

During the course of this study, large-scale entrance management works were completed to address a number of issues (including flooding). The assessment of the effects of this 'option' has been included within the report for completeness. It should be noted that the floodplain management options presented in this report have been assessed against the condition prior to the construction of the entrance works (referred to as the 'pre-2001 condition').

Table 9.1 reports a historical record of the entrance condition of Lake Illawarra compiled by the Lake Illawarra Authority.

Table 9.1 Historical Record of Lake Illawarra Entrance Condition

Date	Entrance State
1919	Major Flood (> 1.5 mAHD)
1930	Major Flood (> 1.5 mAHD)
29 September 1932	Lake opened by Fishermen
During 1934	Closed
September 1934	Lake Opened by Council
April 1935	Closed
1936	Closed
April – May 1937	Closed
1 July 1937	Lake Opened by Council
November 1942	Closed
19 May 1943	Lake Opened by Council
1943	Major Flood (> 1.5 mAHD)
1944	Closed
1 July 1946	Closed
1947	Closed
January 1948	Lake Opened by Council
22 March 1955	Closed
5 February 1958	Closed
1959	Major Flood (> 1.5 mAHD)
September 1968	Closed
December 1968	Lake Opened by Council
March 1969	Almost Closed
Late 1971	Closed
30 December 1971	Lake Opened by Council
January 1974	Almost Closed
April 1974	Major Flood (> 1.5 mAHD)
March 1975	Major Flood (1.8 mAHD)
March 1977	Major Flood (1.8 mAHD)
March 1978	Major Flood (1.6 mAHD)
February 1984	Major Flood (1.9 mAHD)
April 1988	Major Flood (1.5 mAHD)
August 1990	Moderate Flood (1.4 mAHD)
June 1991	Major Flood (1.8 mAHD)

Date	Entrance State
January – May 1995	Closed
May 1995	Lake Opened by LIA
August 1997 – July 1998	Closed
28 July 1998	Lake Opened by LIA
August 1998	Moderate Flood (1.2 mAHD)
2001	Stage 1 Entrance Works Completed
16 August 2002	Closed
15 May 2003	Lake Opened by LIA

9.1.1 Stage 1 Entrance Works

The LIA constructed Stage 1 Entrance Works (completed in 2001) consisting of a southern training wall that is configured so that it has a lesser tendency to close. Creating a permanently open entrance reduces peak flood levels by providing increased conveyance for catchment runoff to flow to the ocean. An assessment of many of the issues with respect to the hydraulic performance of a stabilised entrance to the Lake was addressed in the *Lake Illawarra Entrance Improvement Study* (Lake Illawarra Authority, 1994).

The following works were completed:

- dredging of the main channel (40 m wide by 2 m deep);
- constructing a new training wall to stabilise the position of the dredged channel to the north side of Windang Island;
- creating a sand dune that extends from the northern end of Warilla Beach to about two thirds of the way towards Windang Island;
- constructing a revetment wall along the edge of Reddall Reserve; and
- creating a swimming area between the revetment wall and the training wall.

9.1.2 Stage 2 Entrance Works

The original options study for entrance improvements (AWACS, 1992) indicated that future periodic dredging of the entrance channel and/or the construction of a northern training wall off Perkins (Windang) Beach might be desirable for the entrance to remain open for longer periods after completion of the southern training wall.

In March 2003 Lawson and Treloar (now Cardno) completed a preliminary investigation into a range of possible northern training walls. The report investigated nine training wall options using the Delft3D Online Sediment morphological model (Lawson and Treloar, 2003a). The options were investigated for performance under the 100 Year ARI flood conditions for flood conveyance and channel scour, and under normal tidal flows, to examine the ability of the channel to be 'self-scouring' under normal conditions. Following submission of this report and review by a panel of stakeholders and experts, one northern training wall option was selected as the preferred option (referred to as Option 9). This option consisted of a training wall approximately 100m to the north of the existing southern training wall, a southern spurwall extension of the existing wall and extensive dredging of the entrance.

The LIA have subsequently implemented Option 9, referred to as the 'Stage 2 works' described above, being the construction of a breakwater off Perkins Beach to reduce shoaling and create an entrance that remains open more frequently. The estimated cost of construction was ~ $4 million. The concept outline if the completed works is shown on **Figure 9.1**.

9.1.3 Flood Analysis Stage 1 and Stage 2 Entrance Works

The flood analysis of this option was undertaken prior to the completion of the Stage 2 works. **Section 5** provides additional model results which incorporate the Stage 2 works.

9.2 Model Assessment

Design flood levels were estimated by including in the MIKE11 model (**Section 5.3**) an entrance condition based on the construction of a southern training wall to stabilise the entrance area and a 40m wide by 4m deep channel connecting the ocean to the Lake body (i.e. 2 m deeper than that constructed). Estimated peak Lake levels with the stabilised entrance channel in place are presented in **Table 9.2** for locations shown in **Figure 5.1**.

Table 9.2 Flood Level Impacts - Entrance Stabilised - Stage 1

Ref	Location	Peak Flood Level (mAHD) Pre-Entrance Works		Peak Flood Level (mAHD)		Peak Flood Level Decrease (m)	
		100 Year ARI	Extreme Event	100 Year ARI	Extreme Event	100 Year ARI	Extreme Event
1	Griffins Bay	2.30	3.24	2.21	3.15	-0.09	-0.09
2	Tallawarra Power Station	2.30	3.24	2.21	3.15	-0.09	-0.09
3	Horsley Inlet	2.30	3.24	2.21	3.15	-0.09	-0.09
4	Cudgeree Island Channel	2.26	3.19	2.15	3.08	-0.11	-0.11
5	Windang Bridge	2.08	2.98	1.83	2.79	-0.25	-0.19
6	Entrance Channel	1.98	2.84	1.71	2.53	-0.27	-0.31

The model results in **Table 9.2** indicate that the Stage 1 entrance stabilisation in its design form could have the effect of reducing peak flood levels with respect to the levels predicted for flooding under the pre-entrance works condition (with a flood entrance). The reduction at the 100 Year ARI level is in the order of 0.09 m in the main body of the Lake whilst a more significant reduction of 0.27 m within the entrance channel.

As outline in **Section 1.**1, since the model assessment was undertaken in 2001, the Stage 1 entrance works have been undertaken. After the completion of the work the channel showed evidence of infilling (due to various influences such as coastal processes, a reduction in low flows into the Lake, and other mitigating circumstances). This has implications for the flood levels reported in **Table 9.2**. Due to the infilling observed since the Stage 1 entrance works were undertaken, it was likely that the design flood levels would be more likely to return to those reported for the pre-entrance works condition. The most recent modelling undertaken to address climate change including Stage 1 and Stage 2 works (**Section 5.5**) supports this assumption with the comparative results shown in **Table 5.4** for the 100 year ARI event.

9.3 Estimated Cost

The final cost of the Stage 1 works was in the order of $5 million. The estimated cost of the Stage 2 entrance work is $4 million.

9.4 Benefit / Cost Analysis

A full benefit cost analysis of both the Stage 1 and Stage 2 works was not undertaken as part of this study.

9.5 Entrance Opening Policy

Under dry weather conditions or sizeable ocean swell conditions the entrance to the Lake has the potential to close. With the completion of the entrance works (Stage 1 and Stage 2) this potential is reduced. Closure could result in increased flood risk to low lying areas until the beach berm is breached. Presently, the Lake Illawarra Authority has a policy to mechanically open the Lake (should it close) when water levels in the Lake reach 0.8 mAHD (being some 500 mm above the historical average Lake level) (**Section 8.5.2**). This policy should continue to be implemented as conditions arise.

10 Option B – Extension of Windang Bridge and Dredging of Back (Southern) Channel

10.1 General

The entrance channel upstream of Windang Bridge consists of two flow paths. The major flowpath lies near the northern shore, which passes to the north of Bevans and Picnic Islands. The other flowpath is near the southern shore and is fed by flow from the channels south of Bevans and Picnic Islands. These flowpaths can be seen in the aerial photograph in **Figure 10.1**.

Downstream of the bridge the northern and southern flowpaths join to the north of Berageree Island to define the entrance channel. A flowpath also exists south of Berageree Island, which separates the island from the causeway. It should be noted that historic Lake surveys show the 'Back Channel' has always been very shallow and covered with dense seagrass growth (**Figure 10.2**).

Prior to the construction of the Windang Bridge, a significant flowpath existed south of the Bevans and Picnic Islands extending down to the south of Berageree Island. This flowpath was first obstructed in 1938 when a timber bridge was constructed. This bridge was replaced in the 1970s along with a causeway from the southern shore to the north of Picnic Island as part of the new bridge construction.

The evolution of this area from 1948 through to 2001 can be seen in aerial photography shown in **Appendix A**. For example, in 1988 the southern foreshore area on both sides of the causeway with shallow water depths was reclaimed and the channel south of Picnic and Berageree Islands was dredged.

10.2 Methodology

The impact of removing the causeway on the existing flood levels was investigated by extending Windang Bridge on its southern approach. Bridge extension widths of 100m and 350m were considered (Options B1 and B2 respectively).

An extension width of 100m corresponds to an alignment of the northern ends of Picnic and Berageree Islands and would provide a free flowing area without any obstruction by Berageree Island (Option B1).

A 350m widening of the bridge would open up a large area west of Berageree Island and would provide the channel south of Picnic Island a direct access to the channel south of Berageree Island (Option B2) as was the case prior to the causeway construction.

10.3 Hydraulic Modelling

The MIKE11 hydraulic model (**Section 5.3**) was modified to represent the two bridge widening options. The Lake bed level for the extended part of the bridge was assumed to be the same as the existing levels in the area. Model runs were carried out for the 100, 20, 5 and 2 Year ARI floods together with the PMF event.

10.3.1 Results

The model results for key locations for the 100 Year ARI flood are presented in **Table 10.1** for locations shown in **Figure 5.1**. Detailed model results for all model cross sections for the 100 year ARI flood are provided in **Appendix B**.

In **Table 10.1**, the flood levels for the pre-entrance works conditions are also provided. The pre-entrance works conditions are defined as those used in the Lake Illawarra Flood Study (Lawson and Treloar, 2001) i.e. pre-2001 conditions.

Table 10.1 Impact of Windang Bridge Widening - 100 Year ARI Flood (Peak Water Levels mAHD)

Ref.	Location	Pre-2001 Entrance Works	Bridge Widening		Peak Flood Level Change (m)	
			100m	350m	100m	350m
1	Griffins Bay	2.30	2.29	2.25	-0.01	-0.05
2	Tallawarra Power Station	2.30	2.29	2.25	-0.01	-0.05
3	Horsley Inlet	2.30	2.29	2.25	-0.01	-0.05
4	Cudgeree Island Channel	2.26	2.24	2.19	-0.02	-0.07
5	Windang Bridge	2.07	2.08	2.09	+0.01	+0.02
6	Entrance Channel	1.99	2.01	2.09	+0.02	+0.10

10.4 Costs

The estimated cost of Option B1 is $3 million and Option B2 is $7.7 million. Details of the cost breakdown for the options can be found in **Appendix D**.

10.5 Benefits

The calculation of the benefit associated with the implementation of the options was undertaken in the same way as that reported in **Section 7**. The use of a comparison of the change in Average Annual Damage (AAD) provides a direct economic assessment of the benefit of the options.

The maximum economic benefit lies with Option B2 (350m removal of causeway) which reduces the annual average damage (AAD) by $34,000 (unprepared case).

The reduction in AAD for Option B1 (100m removal of causeway) is $12,000.

The overall benefit:cost (B:C) ratio is calculated by comparing the potential reduction in AAD with the cost of the option outlined above, for Option B2 the B:C is 0.06 for the unprepared case and 0.03 for the prepared case which is quite low. For option B1, the B:C is 0.06 for the unprepared case and 0.02 for the prepared case.

Due to the nature of the Lake flooding there would be no significant change to flood hazard or extent as a result of either options B1 or B2.

10.6 Discussion

Appendix B shows that the maximum reduction in flood levels is a reduction of 0.18m (in the vicinity of Picnic Island) with a general Lake-wide reduction of 0.05m (see **Table 10.1** for Option B2 for the 100 Year ARI). In general the maximum improvement for the option results in a flood level reduction that is only experienced locally (i.e. in the vicinity of Windang Bridge). Note that in some areas there would be a marginal increase in flood level.

With regard to other possible management options in the area, the results of the modelling show that the 'Back Channel' before the causeway was built had little impact on the flooding behaviour within the Lake. Therefore, to endeavour to re-create/re-establish the 'Back Channel' areas would be of significant cost with little benefit with regard to the reduction of flood levels. It is also likely that there would be little change in the period of inundation of the area as a result of works in this area.

In terms of impacts of these options, there are likely environmental, social impacts both during and post construction. The social aspects are most prominent during construction where there would be impacts such as changes to traffic arrangements and disturbance of recreational fishing activities. The flow-on impact on tourism and the local economy is also an issue that would require consideration. As such, the timing of any works would be better suited to off-peak tourist periods. The works would be large scale and may result in a change to the flushing regime of the Lake that has not been quantified as part of this study. The most significant potential environmental impacts are the likely impacts on Berageree Island and associated SEPP14 wetlands where flood levels will increase in these areas at the 100 Year ARI.

10.7 Recommendations

Due to the limited economic and social benefits associated with this option it is not recommended for implementation.

11 Option C – Culverts through Windang Causeway

11.1 General

This option is similar to Option B (**Section 10**) where a set of box culverts are provided through the causeway to facilitate flow south of Bevans Island through to the entrance channel downstream of Windang Bridge (**Figure 11.1**).

11.2 Methodology

Two sets of culverts were investigated to define a range of possible improvement in the flood levels:

- Option C1 - 20 4.2m x 2.4m box culverts; and
- Option C2 - 40 4.2m x 2.4m box culverts.

11.3 Hydraulic Modelling

The culverts were schematised in the MIKE11 model (**Section 5.3**) to carry flow from south of Bevan and Picnic Islands to south of Beragee Island. An approximate length of 200m was assumed for the culverts. The culvert roughness was assumed to be 0.015 (Manning's n). The model runs were carried out for the 100, 50, 20, 5 and 2 Year ARI floods together with an extreme flood/PMF event.

11.3.1 Results

The model results for key locations for the 100 Year ARI flood are presented in **Table 11.1** for locations shown in **Figure 5.1**. Detailed model results for all model cross sections for the 100 year ARI flood event are provided in **Appendix C**.

Base conditions are assumed to be the same as discussed in **Section 10**.

Table 11.1 Impact of Culverts Through Causeway - 100 Year ARI Flood (Peak Water Levels mAHD)

Ref.	Location	Base Condition	Culverts		Peak Flood Level Change	
			20 Cells	40 Cells	20 Cells	40 Cells
1	Griffins Bay	2.30	2.27	2.26	-0.03	-0.04
2	Tallawarra Power Station	2.30	2.27	2.26	-0.03	-0.04
3	Horsley Inlet	2.30	2.27	2.26	-0.03	-0.04
4	Cudgeree Island Channel	2.26	2.22	2.20	-0.04	-0.06
5	Windang Bridge	2.07	2.07	2.07	0.00	0.00
6	Entrance Channel	1.99	2.06	2.08	+0.07	+0.09

11.4 Costs

The estimated cost of Option C1 is $3.4 million and Option C2 is $5.4 million. Details of the cost breakdown for the options can be found in **Appendix D**.

11.5 Benefits

As for Option B (**Section 10.5**), the calculation of the benefit associated with the implementation of the options was undertaken in the same way as that reported in **Section 7**. The use of a comparison of the change in Average Annual Damage (AAD) provides a direct economic assessment of the benefit of the options.

The maximum economic benefit lies with Option C2 which reduces the annual average damage (AAD) by $32,000 (unprepared case).

The reduction in AAD for Option C1 is $27,000 (unprepared case).

11.6 Discussion

The maximum reduction in flood levels is a reduction of 0.09m (generally a Lake-wide reduction of 0.04m) for Option C1 for the 100 Year ARI (**Appendix C** and **Table 11.1**). An increase in flood levels is also observed near the entrance as a result of this option.

In terms of impacts of these options, there would be likely environmental and social impacts during and post construction. The works are large scale and may result in a change to the flushing regime of the Lake that has not been quantified as part of this study. The most significant potential environmental impacts are the likely impacts on Berageree Island and associated SEPP14 wetlands where flood levels will increase in these areas at the 100 Year ARI.

Social impacts include the loss of a portion of Pelican View Reserve as a result of the construction of the culverts through this area as well as the associated impact on local recreational fishing.

The options would need to consider retaining a natural bed as the base of the culvert since a concrete lined bed is considered inappropriate to meet the requirements of the Department of Primary Industries (Fisheries).

11.7 Recommendations

Due to the limited benefits associated with this option (in either form) considered, it is not recommended for implementation.

12 Impact Assessment of Lake Foreshore Filling

12.1 General

All areas identified by Wollongong City Council and Shellharbour City Council for possible development or redevelopment involving additional filling were considered as part of the impact assessment. This enabled an estimate of the total possible impact on flooding due to filling to be made (also known as the 'cumulative impact'). The areas considered for filling for the assessment are shown on **Figure 12.1**. These areas do not include Public Reserve areas or roads on the foreshores and other areas may also be the subject of applications for development or redevelopment.

In general, these areas are outside major flowpath areas. The highlighted areas in **Figure 12.1** constitute an estimated total of approximately 3.52 million m^3 of fill.

Table 12.1 gives a summary of the fill volumes. Fill volumes have been estimated as the volume needed to fill the designated fill areas to RL 2.80m AHD which is 0.5m above the estimated 100 Year ARI peak Lake level of 2.30m AHD under existing conditions.

Table 12.1 Summary of Fill Volumes

Council Area	Volume (m^3)
Wollongong City	2,396,000
Shellharbour City	1,122,000
Total	**3,518,000**

The total fill volume represents approximately 3% of the total Lake volume at the 100 Year ARI flood level.

12.2 Methodology

The impact of foreshore filling was assessed using the following approach:

- The hydraulic model (MIKE11) developed for the Lake Illawarra Flood Study (Lawson and Treloar, 2001, **Section 5.3**) was adjusted to include the designated fill areas;
- The adjusted model was run for all design ARI flood and Extreme Flood/PMF events for the pre-2001 entrance works condition, and for the 100 Year ARI flood and Extreme Flood/PMF events for the post-Stage 1 entrance works condition (i.e. the conditions evaluated in **Section 9**);
- The impact of foreshore filling was determined by comparing model results for pre and post filling scenarios; and
- Model runs were also undertaken to enable the individual contributions to the incremental flood impact of fill in the Wollongong and Shellharbour local government areas to be ascertained.

No assessment has been made of the impacts of filling on upstream diversions, afflux and changes to the velocities of floodwaters.

12.3 Model Assessment

12.3.1 Results

Model results are presented in **Table 12.2 and Table 12.3.**

Table 12.2 Summary of Model Results - Foreshore Filling

	Peak Water Level (mAHD)					
	Entrance Pre 2001			Entrance Post Stage 1 Works		
Flood Event	Base Case	Future Fill (Total)	Impact (m)	Base Case	Future Fill (Total)	Impact (m)
100 Year ARI	2.30	2.34	0.04	2.21	2.24	0.03
Extreme Event/PMF	3.24	3.28	0.04	3.15	3.20	0.05

Table 12.3 Breakdown of Contributing Impacts by Local Government Area - Foreshore Filling

	Peak Water Level (mAHD)					
	Entrance Pre 2001			Entrance Post Stage 1 Works		
Flood Event	Total Fore shor e	Wollongong Foreshore	Shellharbour Foreshore	Total Foreshore	Wollongong Foreshore	Shellharbour Foreshore
100 Year ARI	2.34	2.33	2.31	2.24	2.24	2.22
Extreme Event/PMF	3.28	3.28	3.25	3.20	3.19	3.16

12.3.2 Sensitivity

The sensitivity of peak flood levels in the Lake to the volume of foreshore filling was also tested. An estimate of the impact on peak flood levels should all areas of the foreshore above the 100 Year ARI flood level (maximum fill) be filled was carried out (e.g. inclusive of public reserves and roads etc). A summary of the reduction of available Lake volume with respect to fill amounts and the impact of the fill on peak flood levels is presented in **Table 12.4**.

Table 12.4 Summary of Lake Volume at 100 Year ARI Level

	Fill (m^3)	**Lake Volume (m^3)**	**Fill as % of Existing Lake Volume**	**% Max Fill wrt Advised fill**	**Maximum Impact on Lake Levels 100 Year ARI Flood (m)**
Existing	-	1.560E+08	0	-	-
Advised Fill*	3,518,000	1.524E+08	2.3%	-	0.03
Max Fill**	11,500,000	1.445E+08	7%	327%	0.09

*Advised fill - the volume of those areas identified within the 100 Year ARI flood extent by both Wollongong City Council and Shellharbour City Council that may be potentially filled as part of residential, commercial or industrial development
** Max fill - the volume of the entire foreshore area that lies within the 100 Year ARI flood extent

The results in **Table 12.4** show that peak flood levels show an impact associated with the filling but are relatively insensitive to the foreshore fill volume. The impact of a volume of nearly 3.3 times the proposed fill volume results in a peak water level rise of about 0.09 m.

12.4 Discussion

The model results summarised in **Table 12.2** indicate that for entrance conditions pre-2001 at the 100 Year ARI level, the greatest likely impact of foreshore filling is 0.04m. The likely impact on an extreme flood event is 0.04 m with the filled area expected to be submerged. Breaking down the cumulative fill impact into components by local government area (**Table 12.3**) reveals that fill in the Wollongong City Council area contributes about 0.03m of the total impact. The Shellharbour City Council fill area contributes 0.01m of the impact.

Slightly smaller levels of impact are predicted with the Stage 1 entrance works as described in **Section 9**. It is interesting to note that the lowering of peak flood levels due to the larger entrance channel is greater than the increase in water level due to foreshore filling. This indicates that a combination of entrance improvements and ultimate foreshore filling would result in lower peak flood levels than under the pre-2001 entrance conditions (only if the entrance channel is maintained at the design cross section area).

12.5 Estimated Costs

Costs of this assessment were not estimated since the option is not specifically a floodplain management option, rather an impact assessment.

12.6 Benefits/Dis-Benefits

A detailed assessment of the impact of foreshore filling (with the entrance condition prior to completion of works in 2001) on property damage has been carried out. The impact of foreshore filling with a modified entrance condition (i.e. with the Stage 1 entrance works) on property damage was not estimated. The following discussion presents the results of the assessment of the impact of foreshore filling with the pre-2001 entrance.

As shown in **Table 12.2**, there will be an increase of approximately 0.04 m in the 100 year ARI flood level for the Lake due to foreshore filling under the existing entrance, which represents a disbenefit with regard to a potential increase in flood damages for properties.

The results of the assessment in terms of costs are presented in **Table 12.5 and Table 12.6**. These results are broken into the damages categories listed in **Table 7.1** for each ARI.

The average annual damage (AAD) is estimated at $470,000 for the unprepared community and $211,000 for the prepared community. In comparison, the AAD values for the existing condition (without foreshore filling) are $447,000 for the unprepared community and $198,000 for the prepared community, as listed in **Table 7.2 and Table 7.3**. The difference is an increase in AAD of $23,000 for the unprepared case. This represents an increase in AAD of approximately 5% as a result of filling. As such, some offset for filling with regard to the impact on AAD will be required should filling proceed.

The results of the assessment in terms of the number of properties affected are presented in **Table 12.7**. A total of 1,492 properties are affected by flooding up to the Extreme Flood/PMF regardless of preparedness, comparing with 1,484 properties for the base condition (without foreshore filling).

12.7 Conclusions

Possible areas on the Lake foreshore which may be developed or redeveloped in the future and may require filling to above currently defined flood levels have been identified by Wollongong City Council and Shellharbour City Council.

The identified development areas constitute an estimated total of 3.52 million cubic metres of required fill. This fill volume equals approximately 3% of the total available flooded volume of the Lake body.

Model results indicate that filling all highlighted areas on the foreshore to the full extent would increase 100 Year ARI flood levels by approximately 0.04m with the pre-2001 entrance. The results also show that the combined impact of foreshore filling and implementation of the entrance option (Stage 1 works) would be to reduce flood levels below existing peak flood levels. This reduction is only as a result of the entrance works.

12.8 Recommendations

Given the potential increase in the number of properties affected (i.e. **Table 7.4** compared to **Table 12.7**) and the increase in the amount of average annual damage, it is not recommended that any further wholesale filling of sites within the area of inundation (defined by the 100 year ARI extent) be undertaken for the purposes of development.

The fill volume calculations were undertaken using the existing 100 Year ARI flooding scenario. However, if the flood levels adopted for planning purposes incorporate sea level rise, as recommended in **Section 13.4.3**, then the filling volume would be increased. This is likely to reinforce the recommendations of additional large scale filling in the floodplain.

Table 12.5 Flood Damages Assessment (Foreshore Filling with Pre-Works 2001 Entrance) – Costs - Unprepared Community*

ARI	Tangible						Intangible*	Total Damages
	Residential		Commercial/Industrial		Infrastructure*	Total Tangible Damages		
	Direct	Indirect*	Direct	Indirect*				
Extreme/PMF	$27,640,000	$8,292,000	$1,714,000	$857,000	$14,677,000	$53,180,000	$2,659,000	$55,839,000
100 Year	$4,295,000	$1,289,000	$128,000	$64,000	$2,212,000	$7,988,000	$400,000	$8,388,000
50 Year	$815,000	$245,000	$14,000	$7,000	$415,000	$1,496,000	$75,000	$1,571,000
20 Year	$200,000	$60,000	-	-	$100,000	$360,000	$18,000	$378,000
10 Year	$70,000	$21,000	-	-	$35,000	$126,000	$7,000	$133,000
5 Year	$57,000	$18,000	-	-	$29,000	$104,000	$6,000	$110,000
2 Year	$36,000	$11,000	--	-	$18,000	$65,000	$4,000	$69,000

* The same methodology used in Table 7.2 has been used for this assessment.

Annual Average Damage 'Unprepared' = $470,000

Table 12.6 Flood Damages Assessment (Foreshore Filling with Pre-Works 2001 Entrance) - Costs - Prepared Community

ARI	Tangible						Intangible*	Total Damages
	Residential		Commercial/Industrial		Infrastructure*	Total Tangible Damages		
	Direct	Indirect*	Direct	Indirect*				
Extreme/PMF	$11,289,000	$3,387,000	$424,000	$212,000	$5,857,000	$21,169,000	$1,059,000	$22,228,000
Extreme/PMF	$1,666,000	$500,000	$41,000	$21,000	$854,000	$3,082,000	$155,000	$3,237,000
100 Year	$428,000	$129,000	$11,000	$6,000	$220,000	$794,000	$40,000	$834,000
50 Year	$137,000	$42,000	-	-	$69,000	$248,000	$13,000	$261,000
20 Year	$50,000	$15,000	-	-	$25,000	$90,000	$5,000	$95,000
10 Year	$38,000	$12,000	-	-	$19,000	$69,000	$4,000	$73,000
5 Year	$23,000	$7,000	-	-	$12,000	$42,000	$3,000	$45,000

Annual Average Damage 'Prepared' = $211,000

Table 12.7 Flood Damages Assessment (Foreshore Filling with Pre-Works 2001 Entrance) - Properties Affected

ARI	Residential Dwellings Flooded	Commercial/Industrial/ Special Uses Sites Flooded	Total sites Flooded (WCC)	Total Sites Flooded (SCC)	Total Caravans Flooded	Total
Extreme/PMF	795	53	627	221	644	1492
100 Year	223	8	157	74	458	689
50 Year	61	3	45	19	48	112
20 Year	17	0	10	7	0	17
10 Year	3	0	1	2	0	3
5 Year	2	0	0	2	0	2
2 Year	2	0	0	2	0	2

13 Property Modification Options

13.1 Overview

A number of property modification options have been considered including:

- Flood Planning Matrices and Development Control Options;
- Rewording Of Section 149 Certificates;
- House Raising Program; and
- Voluntary Purchase Program.

Details of each option and the benefits and impacts are described below.

13.2 Flood Planning Matrices and Development Control Options

13.2.1 Wollongong City Council LGA

In 2010, Wollongong City Council's Development Control Plan (DCP) came into effect. Chapter E13 of the DCP outlines development controls relating to floodplain management. Shellharbour Council adopted the Floodplain Risk Management Development Control Plan (Amendment 1) in April 2006. This DCP is consistent with that of WCC with particular regard to the risk based approach utilising flood risk precincts and a planning matrix for development control purposes. It incorporates a generic matrix in the absence of a catchment specific floodplain risk management plan and allows these to be annexed to the DCP as specific plans are developed and adopted by Council.

Development in the Lake Illawarra floodplain is therefore assessed in a manner consistent with these DCPs. Whilst the DCPs have common elements for the management of flooding with respect to development across the entire LGAs, the DCPs allow for each floodplain within the LGAs to have a separate series of requirements (in the form of a matrix). A planning investigation has been undertaken for Lake Illawarra and described below to allow for the relevant part of the DCPs to be prepared.

13.2.2 Proposed Matrices

Due to the issues associated with Effective Flood Access on the Windang Peninsula (**Section 6.1.2**), two development control matrices have been developed for the Lake Illawarra Floodplain. The first applies to all lands within the floodplain (i.e. PMF extent) except for the Windang Peninsula; the second applies to those lands within the Windang Peninsula as identified on **Figure E1** (in **Appendix E**).

The matrices in **Appendix E** have been developed to be consistent with the WCC Development Control Plan (2010) and Shellharbour Council's Floodplain Risk Management Development Control Plan (2006) and the Shellharbour DCP (2006). The matrices in **Appendix E** are an adaptation of this approach, suitable for the specific flood behaviour of the Lake Illawarra system.

The matrices in **Appendix E** have been prepared to recognise the following issues:

- Emergency services and flood evacuation centres should be prohibited in the floodplain;
- Communications facilities (such as telephone exchanges etc) and electricity substations to be protected and out of the floodplain;

- Need for development applications to be supported by a professionally prepared flood impact assessment. This would require the demonstration of the impacts of flooding on the development and surrounding areas;
- Prohibition or strict controls for any development within all areas associated with high flood hazard;
- Flood proofing of new development, extensions or improvements with appropriate water resistant materials such that flood damage to the structure will be negligible;
- Development can only proceed with consent from Council, on land that is subject to periodic inundation if the development is not likely to:
  - impede the flow of water,
  - aggravate the consequences of flood waters on land having regard to siltation, destruction of vegetation and erosion,
  - increase the level of flood waters in the area, or
  - endanger the safety of persons who occupy the land in the event of a flood.
- Set floor heights for new dwellings and new parts of a dwelling to an acceptable level of flood risk and applicable to specific land uses (floor levels may vary between residential, commercial and industrial development);
- Where substantial development is to occur, raise floor heights of any existing dwellings to an acceptable level of flood risk to match any new parts of the dwelling;
- Ensure adequate freeboard is incorporated into the design of new homes or the raising of any existing dwellings;
- The need for strategic site planning for all sites including:
  - the provision of suitable evacuation (if safe and effective evacuation routes cannot be provided, the proposed land-use is inappropriate),
  - consideration of the topography of the site with regard to the variation of flood hazard and the sites of development (buildings may be better located on higher ground of a site where the impact of flood behaviour and potential damage will be reduced and evacuation can be facilitated),
  - orientation and type of fences (fences can obstruct flood flows, increase levels and possibly hamper evacuation).
- Require appropriate construction supervision and certification for developments in high hazard areas.

Climate change issues have also been incorporated into the proposed DCP matrices (**Appendix E**). These issues are described in more detail in **Section 13.4**.

The matrices in **Appendix E** make reference to 'flood risk precincts'. Both Wollongong City Council and Shellharbour City Council have adopted an approach to defining the floodplain into 'flood risk precincts' for the definition of flood risk. The following definitions for the application of flood risk precincts have been utilised for this study:

High Flood Risk Precinct - is defined as the area within the envelope of land subject to a high hydraulic hazard and floodways in a 100 Year ARI flood event. High hazard is defined in accordance with the *Floodplain Development Manual* (2005). The area that forms the high risk precinct is essentially the 100 Year ARI high hazard area on **Figure 6.1**.

Medium Flood Risk Precinct - is defined as the land between the high risk precinct and the area that lies below the 100 Year ARI level (plus 0.5 metre freeboard), and

Low Flood Risk Precinct - is defined as all other land within the floodplain (i.e. within the extent of the Extreme Flood/Probable Maximum Flood) but not identified as high or medium flood risk precinct. The Extreme Flood/PMF extent is shown in **Figure 5.2**.

Precincts based on the above definitions are shown as a composite in **Figure 13.1**. However, for implementation, the flood risk precincts have been modified based on the outcomes of the climate change assessment in **Section 13.4**. The climate change assessment resulted in modified medium risk precincts. The medium risk precinct for concessional and non-concessional development has been defined as follows:

- Concessional Development: 100 Year ARI flood extent with medium level sea level rise plus 0.5m freeboard.
- All Other Development (Non-concessional development): 100 Year ARI flood extent with high level sea level rise plus 0.5m freeboard.

This modified flood risk precinct mapping is discussed later in this chapter (**Section 13.4.3**) and is shown in **Figures 13.4 and 13.5**.

13.2.3 Implementation of Option

Once the Lake Illawarra Floodplain Risk Management Plan is adopted, it is recommended that the matrices proposed in **Appendix E** be added to the relevant DCPs for the respective Councils. This approach will ensure consistency between the Council areas with regard to planning controls and methodology for development of the Lake foreshore.

13.3 Recommendations for LEP

It is noted that Council's across NSW are currently in the process of preparing new Local Environment Plans in accordance with the directive of the Department of Planning and Infrastructure to conform to the Standard LEP template issued by the Department. Wollongong City Council updated their LEP 2009 in accordance with the Standard LEP template; the LEP 2009 has been in effect since February 2010. At the time of preparation of this study, Shellharbour had not yet updated their LEP in accordance with the template.

In 2007, *Section 117 Direction No. 4.3 - Flood Prone Land* and *Planning Circular PS07-003 New guideline and changes to section 117 direction and EP&A Regulation on flood prone land* were introduced by the then Minister for Planning. This directed Councils to not impose flood-related development controls above the residential flood planning level for residential development on land unless a council provides adequate justification for those controls to the satisfaction of the Director General of the Department of Planning and Infrastructure (i.e. 'exceptional circumstances').

Wollongong City Council sought and was granted exceptional circumstances approval from the then DoP (now DP&I) and DECC (now OEH). The intent of the approval was to allow continued operation of flood-related development controls in the LEP 2009 and DCP above the residential FPL for the purposes of public safety and consistency with safe refuge strategies in flash flood catchments.

Wollongong Council have since incorporated clause 7.3 within Part 7 - Local Provisions - General of the LEP to address the concept of "flood planning area". The clause within the LEP identifies the flood planning area as land at or below the flood planning level.

In reviewing the total hazard of the Lake Illawarra floodplain, it is evident that there are issues associated with public safety and risk to life that requires a statutory basis to manage future risk. Current land use zones enable an increase in the development and population of areas that are now known to become isolated and highly hazardous such as Windang. It is possible for Wollongong Council to review its LEP and utilise mechanisms to strategically manage future development in areas of high risk within its LEP. Such mechanisms include land use zones and local provisions catering specifically high hazard areas such as Windang.

As this is outside the scope of the current Lake Illawarra FRMS&P project, it is recommended that WCC, in consultation with DP&I and other relevant agencies (e.g. OEH & SES), initiate a review of its LEP 2009 to better manage future risk associated with development in the Lake Illawarra floodplain.

Given WCC's approval of exceptional circumstances, it would be prudent for WCC to review the LEP 2009 given the potential isolated nature of Windang has been identified. Reviewing the LEP 2009 and Chapter E13 Floodplain Management of the DCP would also be consistent with objective 7.3(1)(e) of the LEP that states '*the objectives of this clause are as follows……. to limit uses to those compatible with flow conveyance function and flood hazard*'.

It is recommended that Shellharbour Council also include local provisions for flood planning land in their updated LEP when it is prepared. It is also recommended that exceptional circumstances approval be sought in the same manner as WCC to allow for the PMF to be used as a planning level for Lake Illawarra to ensure consistency across the floodplain.

13.4 Climate Change Planning Assessments

13.4.1 Climate Change Property Impact Analysis

Utilising GIS data made available by Wollongong City Council and Shellharbour Council, the property impacts resulting from the various climate change scenarios (**Section 5.5**) were determined in terms of number of cadastral lots and LEP zoning areas affected. The results are provided in tabular form below in **Table 13.1 to Table 13.4**.

Table 13.1 Total Cadastral Lots affected under the 100 Year ARI Flood and Various Climate Change Scenarios

Climate Change Scenario	Number of cadastral lots affected	Average lot size (sq m)	Number of cadastral lots (<2000 sq m)	Increase over current	Average lot size (sq m) (<2000 sq m)
Current (No SLR)	2,621	10,855	2,287	0	754
0.18m SLR	3,155	9,295	2,758	534	744
2050 SLR	3,492	8,637	3,030	871	759
2050 SLR + 20%	3,814	8,182	3,278	1,193	771
2100 SLR	4,007	8,238	3,432	1,386	768

The change reported in **Table 13.1** represents an increase of 120 to 150 % in cadastral lots between the current and the 2100 SLR scenarios.

Table 13.2 Number of 100 year ARI and Climate Change affected cadastral lots with different land use zoning areas by Council area

Affected Zone Types	Number of Affected Lots by LGA				
	Current	0.18m SLR	2050 SLR	2050 SLR + 20%	2100 SLR
Wollongong LGA					
1 - Non-urban Zone	7	7	7	7	7
2A - Low Density Residential Zone	681	946	955	990	1,023
2B - Medium Density	378	420	451	487	495

Affected Zone Types	Number of Affected Lots by LGA				
	Current	0.18m SLR	2050 SLR	2050 SLR + 20%	2100 SLR
Residential Zone					
3A - General Business Zone	0	0	0	2	2
3B - Neigbourhood Business Zone	20	25	25	25	25
3D - Commercial Services Zone	0	0	4	22	22
Shellharbour LGA					
1A - Rural A Zone	9	9	10	10	12
2A - Residential A Zone	520	582	632	672	710
2B1 - Residential B1 Zone	317	386	507	541	583
2B2 - Residential B2 Zone	72	96	128	157	159
2E - Mixed Used Residential E Zone	40	78	111	151	165
3A - Mixed Use Commercial Zone	0	0	1	1	3
4A - Light Industrial Zone	29	33	58	96	132
4A3 - Airport Light Industrial Zone	0	1	1	1	3
5A - Special Uses Zone	20	23	23	23	23
6A - Public Open Space Zone	94	97	102	104	107
7A - Environmental Protection (Wetlands) Zone	4	4	4	4	4
7D - Environmental Protection (Scenic) Zone	6	6	6	6	6
9B - Arterial Roads Reservation Zone	1	1	1	1	1
9C - Local Roads Reservation Zone	2	2	2	2	2
9D - Open Space Reservation Zone	8	8	8	8	8

Table 13.3 Proportion of inundated area under various climate change scenarios

Affected Zone Types	Proportion of All Flood Affected Land (%) at 100 Year ARI in the Lake Illawarra Floodplain by LGA*				
	Current	0.18m SLR	2050 SLR	2050 SLR + 20%	2100 SLR
Wollongong					
1 - Non-urban Zone	4.72	4.54	4.49	4.34	4.12
2A - Low Density Residential Zone	5.12	5.89	5.91	5.81	5.72
2B - Medium Density Residential Zone	2.02	2.24	2.34	2.42	2.34
3A - General Business Zone	0.00	0.00	0.00	0.28	0.27
3B - Neighbourhood Business Zone	0.04	0.06	0.06	0.06	0.05
3D - Commercial Services Zone	0.00	0.00	0.14	0.51	0.44
4A - Light Industrial Zone	0.00	0.00	0.07	0.59	0.48
4B - Heavy Industrial Zone	1.40	1.35	1.34	2.80	2.84
5A - Special Uses Zone	19.18	18.45	18.32	17.68	16.79

Affected Zone Types	Proportion of All Flood Affected Land (%) at 100 Year ARI in the Lake Illawarra Floodplain by LGA*				
	Current	0.18m SLR	2050 SLR	2050 SLR + 20%	2100 SLR
5B - Special Uses (Railway)	0.20	0.19	0.19	0.18	0.17
6A - Public Recreation Zone	10.25	11.04	11.38	11.60	10.97
6B - Private Recreation Zone	17.71	17.32	17.18	16.58	19.37
6C - Tourism Zone	2.01	2.61	2.65	2.49	2.30
7A - Special Environmental Protection Zone	23.09	22.21	21.99	21.22	21.35
7B - Environmental Protection Conservation Zone	11.03	10.61	10.51	10.13	9.63
7C1 - Environmental Protection Rural Residential Zone	2.07	1.99	1.96	1.90	1.81
8A - National Parks, State Conservation Areas and Nature Reserve Zones	0.56	0.93	0.92	0.89	0.84
9B - Reservation Zone (roads)	0.55	0.52	0.50	0.48	0.47
9D - Reservation Zone (open space)	0.05	0.05	0.05	0.04	0.04
	∑ 100%	∑ 100%	∑ 100%	∑ 100%	∑ 100%
Shellharbour					
1A - Rural A Zone	24.16	23.49	23.19	22.50	27.10
2A - Residential A Zone	5.89	6.39	6.33	6.50	6.14
2B1 - Residential B1 Zone	3.42	4.20	5.37	5.46	5.23
2B2 - Residential B2 Zone	1.25	1.64	1.94	2.17	1.98
2E - Mixed Used Residential E Zone	0.61	1.24	1.81	2.35	2.25
3A - Mixed Use Commercial Zone	0.00	0.00	0.32	0.31	0.31
4A - Light Industrial Zone	1.08	1.16	1.58	2.49	3.24
4A3 - Airport Light Industrial Zone	0.00	0.06	0.05	0.05	0.08
5A - Special Uses Zone	46.19	44.91	41.76	40.52	36.80
6A - Public Open Space Zone	10.22	9.95	11.17	11.38	11.17
7A - Environmental Protection (Wetlands) Zone	4.35	4.21	3.92	3.80	3.46
7D - Environmental Protection (Scenic) Zone	2.48	2.40	2.24	2.17	1.97
9B - Arterial Roads Reservation Zone	0.26	0.26	0.24	0.22	0.20
9C - Local Roads Reservation Zone	0.08	0.08	0.07	0.07	0.06
9D - Open Space Reservation Zone	0.01	0.01	0.01	0.01	0.01
	∑ 100%	∑ 100%	∑ 100%	∑ 100%	∑ 100%

** The proportions reported represent the percentage composition by zone of the total flood affected area within the Lake Illawarra floodplain occupied by each LGA. For example under a 0.18m SLR scenario, within the Wollongong LGA, the area (m^2) of flood affected land zoned as 2A Low Density Residential is only 5.89% of the total 100 year ARI flood affected area with the LGA.*

A summary of the key findings of this assessment is provided below:

- Based on the mapping prepared (**Figures 5.4 – 5.7**) and associated information presented in **Table 13.1 to Table 13.4**, there would be an increase in inundation of an additional 1,386 cadastral lots under the 2100 SLR Scenario when compared to the existing 100 Year ARI extent. The majority of these additional lots are zoned as residential (low and medium density).
- Residential properties represent 7.14% and 11.17% of the existing Wollongong and Shellharbour flood affected land within the Lake Illawarra floodplain respectively. Under the 2100 SLR scenario the number of residential properties affected by 100 Year ARI flooding will increase by 459 and 668 in Wollongong and Shellharbour and under the 2100 SLR scenario the proportion of flood affected land that is residential will also increase (8.06% and 15.6% respectively).
- Environmental Protection Zones are currently located in areas which are likely to be flooded by a 100 Year ARI event, and are the dominant land zones affected. This is maintained under all climate change scenarios. However, their proportionate area of inundated land is decreased due to the increase in inundation of other land uses under the various climate change scenarios.
- Within Shellharbour, the inundated Rural 1A Zone area increases under all climate change scenarios. However, it should be recognised that there are only 32 Rural 1A Zone lots within the Shellharbour LGA and the reported proportions are affected by the substantial lot sizes within this zone (i.e. a small number of lots comprise the majority of the flooded area).

13.4.2 Implications for Planning Provisions and Property

The Section 117 Ministerial Direction (PS 07-003, issued 31 January 2007) advised in general terms that only the 100 Year ARI flood extent is to be considered with regards to flood-related development controls (unless in exceptional circumstances, which Wollongong City Council have been granted). The consideration of the climate change assessment was therefore only undertaken by considering the 100 Year ARI flood extent under the four climate change scenarios with respect to potential development controls.

The consequences of adopting the 100 Year ARI flood for each of the four climate change scenarios for planning purposes (i.e. for definition of the medium risk precinct) are discussed below with regard to Wollongong and Shellharbour's relevant DCPs and LEPs. The relevant planning documents are:

- Wollongong LEP 1990 (now superseded by the 2009 version);
- Shellharbour LEP 2000;
- Wollongong City Council's DCP (2010); and
- Floodplain Risk Management Development Control Plan (Shellharbour).

The draft development control matrices for the Lake Illawarra floodplain (outlined in **Section 13.2**) are provided in **Appendix E**. These controls are proposed to be implemented as part of both the Council's DCPs upon adoption of the Floodplain Risk Management Plan. The impacts associated with the climate change scenarios have been discussed with regards to the proposed DCP matrices.

The risk precincts referred to in both Wollongong and Shellharbour's DCPs and referenced in **Appendix E** are defined by the 100 Year ARI true high hazard (High Risk Precinct), FPL extent (Medium Risk Precinct) and the PMF extent (Low Risk Precinct). Climate change modelling and mapping of some of these conditions (i.e. true hazard and PMF under climate change) has not been undertaken for these events and as such the likely planning consequences discussed below are based on the 100 Year ARI results only.

Table 13.4 summarises the increase in lots affected for each of the climate change scenarios for the development types shown in **Appendix E**.

Table 13.4 Increase in Lots Affected by 100 Year ARI Flooding

Type of Development	No. of Lots Affected Existing	Increase in Number of Lots Affected (compared to existing)							
		0.18m SLR		2050 SLR		2050 SLR + 20%		2100	
Residential	2,008	25%	2,508	39%	2,784	49%	2,998	56%	3,135
Commercial & Industrial	50	20%	60	84%	91	241%	178	324%	222
Tourism	44	16%	51	32%	58	50%	66	50%	66
Recreational and Non Urban	268	4%	280	13%	302	18%	315	21%	324
Total (of these land zones)	2,370	22%	2,899	36%	3,235	49%	3,557	57%	3,747

Note: This table only addresses the main land use types that are listed in the draft DCP matrices and it should be noted that there are other lot types in the LEP (such as environmental protection zones and reservation areas). It should also be noted that a large proportion of the floodplain is zoned 'Special Uses' - this has not been included in the planning assessment below.

0.18m SLR Scenario

If it is assumed that the increase in 100 Year ARI extent (**Figure 5.4**) would be similar to the increase in the current high risk precinct extent (**Figure 13.1**), the following comments on adopting the 0.18m SLR scenario for planning purposes can be made:

- For all types of development shown in **Appendix E** (except for *Recreational and Non-Urban* and *Concessional Development*) there would be a moderate increase (16 to 25 percent) in the number of properties that would no longer be developable under the proposed development controls matrices (**Appendix E**) (i.e. their classification would change in the draft DCP matrices from medium to high risk and the land would be considered unsuitable for that use).
- There is only a small increase in the number of *Recreational and Non-Urban* lots that would trigger planning controls.
- Overall, the 0.18m SLR scenario could be adopted for planning purposes without a significant impact on development within the floodplain.

2050 SLR Scenario

If it is assumed that the increase in 100 Year ARI extent (**Figure 5.5**) would be similar to the increase in the current high risk precinct extent (**Figure 13.1**), the following comments on adopting the 2050 SLR scenario for planning purposes can be made:

- There is a significant increase in the number of *Commercial and Industrial* lots (84 percent) that would no longer be developable (i.e. the land would be considered unsuitable for that use). The additional properties are primarily located in Kemblawarra, Lake Illawarra, Albion Park Rail and Oak Flats.
- Approximately two fifths of all developable lots (albeit with floodplain controls) within the floodplain would no longer be developable under the draft development controls matrices (**Appendix E**).

- It should be noted that, whilst the increase in residential lots impacted by 100 Year ARI flooding is only 40 percent, this relates to an increase of 500 lots in the floodplain.

2050 SLR Scenario plus 20% Increased Rainfall

If it is assumed that the increase in 100 Year ARI extent (**Figure 5.7**) would be similar to the increase in the current high risk precinct extent (**Figure 13.1**), the following comments on adopting the 2050 SLR +20% scenario for planning purposes can be made:

- When the implications of the 2050 SLR scenario with and without a 20 percent increase in rainfall are compared, it can be seen that there is a fairly significant impact of adopting a climate change scenario which includes an increase in rainfall.
- The largest number of additional lots affected is in Kemblawarra. The majority of these lots are zoned *Commercial and Industrial*.
- Approximately half of all currently developable lots (albeit with floodplain controls) in the floodplain would no longer be developable under the draft development controls matrices (**Appendix E**).

2100 SLR Scenario

If it is assumed that the increase in 100 Year ARI extent (**Figure 5.6**) would be similar to the increase in the current high risk precinct extent (**Figure 13.1**), the following comments on adopting the 2100 SLR scenario for planning purposes can be made:

- If the 2100 SLR scenario is adopted for planning purposes there may be almost 4,000 properties impacted by stricter flood planning controls than they are currently subject to.
- Approximately 50 percent of residential properties which are currently zoned medium risk precinct are likely to be classified within the high risk precinct and therefore would no longer be developable.
- There is likely to be an increase of more than 300 percent of commercial and industrial lots impacted by high risk precinct planning controls. The majority of these lots are located in Kemblawarra (Wollongong LGA) and Oak Flats (Shellharbour LGA).

The assessment shows that the incorporation of climate change scenarios in the planning and development control process will affect *Commercial and Industrial* zoned properties the most when compared with the existing conditions. However, this assessment also shows that the implications of not adopting some form of climate change condition for planning purposes will result in a large number of properties being impacted by flooding significantly worse than the existing flooding conditions and in the future the properties will not have planning strategies to cope with the flooding conditions under climate change.

The assessment also shows that there will be serious flooding implications under all four climate change scenarios. Further, the 2050 SLR scenario, involving an increase in rainfall, shows that increased rainfall intensities will have a significant impact on flooding in the Lake Illawarra floodplain. However, the assessment also shows that implementing a 2100 SLR scenario immediately would dramatically alter the development controls on thousands of properties, some of which are currently only affected by low risk precinct controls or are not in the floodplain at all. These properties may not feel the implications of climate change for several decades if sea level rise is gradual.

It is also acknowledged that different types of development have different design lives. For example, small scale residential development (i.e. single lot development or alterations and additions) could be considered to have a design life of 50 to 100 years (2060 to 2100) after which the building would be expected to be rebuilt. Whereas a broad scale greenfield/brownfield development may equate to a 100 year or more design life (2100+) for subdivision, buildings and infrastructure (particularly for subdivision and infrastructure). On this basis it may be appropriate to apply different climate change scenarios to the planning provisions for different types of development.

13.4.3 Recommendations for the Floodplain Risk Management Plan

The assessment in **Section 5.5** identifies that not only sea level rise but also increases in rainfall will have a significant impact on flooding behaviour in the Lake Illawarra floodplain (with a coincident 20 year ARI event at the ocean boundary). It is therefore recommended that floodplain planning provisions incorporate both of these components of climate change. Further, the recommended planning provisions for the Lake Illawarra floodplain have been considered with regards to the design life of the proposed development, as follows:

- Recommendations for facilities with a design life of 50 years; and
- Recommendations for facilities with a design life of 100 years.

13.4.3.1 Design Life of 50 Years

Development considered having a design life of 50 years or less includes those developments identified as “Concessional Development” in the Wollongong and Shellharbour Council DCPs.

It is recommended that the planning provisions based on the Medium Level Rise climate change predictions would be the most appropriate for adoption for development considered to have a design life of approximately 50 years (concessional development).

The Flood Risk Precincts that are recommended for adoption for these developments are:

- High Risk Precinct, remains equal to the existing true high hazard extent (similar to **Figure 6.1**);
- Medium Risk Precinct is to be updated to be equal to the 2050 SLR extent (**Figure 5.5**) plus a freeboard of 0.5m (**Section 6.2**); and
- Low Risk Precinct remains equal to the existing PMF extent (**Figure 5.2**).

The compilation of these maps into a single flood risk precinct map is shown in **Figure 13.4**.

In addition, to the revised flood risk precinct mapping, concessional development should adopt a planning level based on the 2050 SLR flood levels.

The adoption of these climate change provisions is not expected to cause unnecessarily conservative controls on development with a relatively short-term timeframe in the floodplain. These planning provisions would apply at least until the next revision of the Lake Illawarra Flood Study or the publication of the IPCC 2013 report. It is recommended that any development that is approved with the short term medium level rise approach be tagged through the Section 149 certificate process (or similar) with an explanation as to the provisions made for climate change.

13.4.3.2 Design Life Greater than 50 years

All development that is not identified as “Concessional Development” in a DCP is considered to have a design life of greater than 50 years.

It is recommended that the planning provisions based on 2100 SLR predictions would be the most appropriate for adoption for development and infrastructure considered to have a design life of greater than 50 years.

The Flood Risk Precincts that are recommended for adoption for these developments are:

- High Risk Precinct, remains equal to the existing true high hazard extent (similar to **Figure 6.1**);
- Medium Risk Precinct is to be updated to be equal to the 2100 SLR extent (**Figure 5.**6) plus a freeboard of 0.5m (**Section 6.2**); and
- Low Risk Precinct remains equal to the existing PMF extent (**Figure 5.2**).

The compilation of these maps into a single flood risk precinct map is shown in **Figure 13.5**.

13.4.3.3 Sea Level Rise Planning Areas

In accordance with the *Draft Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2009) the sea level rise "planning areas" have been mapped. Sea Level Rise Planning Areas have been identified for both Concessional Development and Non-Concessional Development. The Sea Level Rise Planning Areas are provided in **Figures 13.2** and **13.3**.

13.4.3.4 Flood Risk Precincts

As outline previously, the flood risk precincts have been modified based on the outcomes of the climate change assessment. The climate change assessment resulted in modified medium risk precincts. The medium risk precinct for concessional and non-concessional development has been defined as follows:

- Concessional Development: 100 Year ARI flood extent with predicted 2050 sea level rise plus 0.5m freeboard.
- All Other Development (Non-concessional development): 100 Year ARI flood extent with predicted 2100 sea level rise plus 0.5m freeboard.

This modified flood risk precinct mapping is provided in **Figures 13.4** and **13.5**.

13.4.3.5 DCP Matrices

The planning provisions outlined above have been incorporated into the DCP matrices for the Lake Illawarra floodplain provided in **Appendix E**. Further details on the DCP Matrices are provided in **Section 13.2**.

13.5 Section 149 Certificates

Two forms of Section 149 Certificates are issued under the *Environmental Planning and Assessment Act, 1979* for the Lake Illawarra Floodplain for land parcels that fall within the respective Council areas:

- Shellharbour City Council (SCC)
- Wollongong City Council (WCC).

In January 2007, the Department of Planning and Infrastructure issued a new guideline and changes to Section 117 directions and the *Environmental Planning and Assessment (EP&A) Regulation 2000* for flood prone land. This particularly related to residential properties considered to have low flood risk (i.e. the land above the 100 Year ARI flood level, up to the PMF). With regards to Section 149 certificates, the EP&A Regulation was amended such that councils should not include a notation for residential development on Section 149 certificates in 'low flood risk areas' if no flood-related development controls apply on that land. It should be noted that development controls may be applied to some development types (e.g. critical infrastructure) above the 100 Year ARI flood level. However, it should be noted that Wollongong City Council have been granted 'Exceptional Circumstances' under which they can apply the PMF as the planning area.

Wollongong City Council issues Section 149 certificates with information relating to flood risk. Shellharbour City Council also issues Section 149 certificates with information relating to flood risk, but using different wording to that used by WCC.

There are generally two types of certificates issued:

- Section 149(2) Certificates – provide an overview as to whether the land is affected by flooding and any related policies of Council; and
- Section 149(5) Certificates – provide additional details as to flood behaviour/levels/velocities etc as available to Council.

To provide a consistent and up-to-date planning approach, the wording on 149(2) Certificates for properties affected by flooding of Lake Illawarra (specifically the Lake itself, not the tributaries) up to the Extreme Flood/PMF needs to be considered for those properties where development controls are applied.

Section 149(5) certificates could be issued in the future with explicit flood information for all affected properties. An alternative would be the issue of a flood level certificate as a separate document with detailed information on flood levels and possibly flood hazards with appropriate caveats and disclaimers on the accuracy of the information.

The wording of advice on Section 149(2) certificates is one aspect of the flood education process but this education generally only occurs when a property is sold. The following recommendations for certificates have been adapted from guiding information provided in the *Floodplain Development Manual* (NSW Government, 2005).

Overall, the advice should be clear and unambiguous and include:

- required statutory information;
- a note that 'flood-prone' does not necessarily mean the floor areas of dwellings will be inundated, instead it relates to some portion of the site being identified as being flood-prone in a 100 Year ARI flood event and that any development on the land is therefore to adhere to Council's flood-related development controls; and
- adopted flood planning levels for the site as well as reference to the Extreme Flood/PMF, the rare nature of this kind of event and the need for evacuation during rare events.

The wording of the Section 149 certificates is a matter that requires legal advice. However, due to the way in which the flood extents were developed and since only a limited number of ground levels are available for properties, it is recommended that the following words also be included on the certificates issued by both Councils.

"Council does not have sufficient accurate ground level information to indicate the extent of the land that may be affected. This information may be obtained by the applicant/owner through the commission of a Registered Surveyor to determine ground levels on the site and a Chartered Professional Engineer to determine flood extents on the site and flood levels relative to building floor levels".

The process by which the revision of Section 149 certificate wording should be undertaken involves:

- internal review of proposed rewording of certificates by Council;
- legal review of the proposed rewording; and
- adoption of the reworded advice by Council.

13.6 House Raising Program

Voluntary house raising is a possible option that has been given detailed consideration as part of this study.

Issues related with voluntary house raising include:

- the potential for damage to items on a property other than the dwelling raised (such as gardens, sheds and their contents, garages, cars, etc);
- unless a dwelling is raised to above the extreme flood event level, the potential for above floor flooding still remains an issue;
- evacuation will still be required in extreme events if the dwelling is not raised to the extreme flood event level;
- evacuation may be required (e.g. medical emergency during a flood event) even if no above floor flooding occurs. This evacuation is likely to be hampered by floodwaters surrounding a property;
- the complexity of raising double storey dwellings;
- need to ensure the new foundations can withstand flood-related forces, as such house raising is generally only suitable for low hazard areas, however all properties have been considered as part of this assessment regardless of hazard; and
- potential conflict with height restrictions imposed for a specific Zone or locality within the local government area (for properties to be raised a significant level, e.g. greater than 1m). This is likely to be a particular issue for two storey dwellings.

To identify which properties would be suitable for house raising, information on the nature of the construction of each property within the floodplain gathered for the flood damages assessment (outlined in **Section 7**) was utilised for the assessment. This information was used to identify the maximum number of properties in both the WCC and SCC local government areas that may be eligible. Some properties may have been altered since the time of the survey (e.g. house raising may have already occurred or a dwelling may have been reconstructed). However, it has been assumed that the properties are as surveyed for the purposes of this assessment.

Some properties within the floodplain only experience a very minor amount of above-floor flooding (e.g. less than 0.1 m). Nonetheless, all properties that experience above-floor flooding have been included in this assessment.

Each residential property surveyed was assessed for the nature of floor construction – identified as being either slab on ground or piers. Only those properties on piers were assessed as it was considered prohibitive to raise dwellings constructed as slab on ground.

Affected properties that are constructed on piers included a variety of wall construction types including:

- brick;
- brick veneer;
- fibro;

- weatherboard; and
- cladded.

All wall types were included in this assessment, except for brick as this was also considered unlikely and/or prohibitive to raise dwellings constructed as brick. Only single storey dwellings were considered.

A flood level was then assigned to each potential property subject to the 100 Year ARI flood based on the existing flood behaviour as outlined in the flood study report (Lawson and Treloar, 2001). The properties were then sorted based on those with the greatest depth of above-floor flooding and a maximum level was identified for those properties which would need to be raised to have the floor level at a 100 Year ARI +0.5 m freeboard level. Note that the assessment was undertaken prior to the revision of the freeboard associated with the flood planning level (**Section 6.2**) and consequently utilised a 0.5 m freeboard.

Overall, there are 95 properties within the Lake Illawarra floodplain that meet the above criteria. As a guide, the maximum height above ground likely to be required for a property is of the order of 1.04 m to re-establish the current floor level to the flood planning level (i.e. 100 Year ARI + 0.5m). A cost of $40,000 per property raised was assumed.

A breakdown of the numbers of properties and the range of heights they would need to be raised to reach the 100 Year ARI+0.5m level and associated costs are listed in **Table 13.5.**

Table 13.5 Breakdown of Number of Single Storey Properties for House Raising

Depth of Above Floor Flooding	Band of Raising	Approx Number of Eligible Properties	Likely Total Cost for Band
0.30 – 0.54 m	0.80 – 1.04 m	11	$440,000
0.10 – 0.29 m	0.60 – 0.79 m	52	$2,080,000
0.00 – 0.09 m	0.50 – 0.59 m	32	$1,280,000
TOTAL	**-**	95	$3,800,000

Table 13.5 indicates the total cost of a house raising program to ensure all eligible properties are set at the appropriate flood planning level would be at least $3.80 million.

An assessment of the reduction of the average annual damage has been undertaken for the calculation of the cost:benefit ratio of house raising of the total 95 properties. This indicates that the AAD would be reduced to $421,000 from $447,000 for the unprepared case and $184,000 from $198,000 for the prepared case (conservatively assuming the Extreme Event would incur the same amount of damage regardless of the house raising works). The cost:benefit ratio for the unprepared case, for a 50 year planning period and a discount rate of 7% is 0.09 and 0.05 for the prepared case.

These cost:benefit ratios are considered to be too low to substantiate proceeding with this option on an economic basis.

However, considering only those properties that are the most severely affected at the 100 Year ARI event (i.e. those requiring raising of 0.8 m and greater – 11 properties), the AAD would be reduced to $437,000 from $447,000 for the unprepared case and $193,000 from $198,000 for the prepared case. The cost:benefit ratio for the unprepared case is 0.31 and 0.16 for the prepared case.

Whilst having a relatively low cost:benefit ratio (substantially less than 1), the consideration of the raising of these 11 properties, shown in **Figure 13.6** is recommended.

13.7 Voluntary Purchase Program

The option of a Voluntary Purchase program involves the purchase of property by the appropriate Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to a flood compatible use, such as recreation or parkland. This option would free both residents and emergency service personnel and volunteers from the hazard of future floods.

As outlined in **Section 8.4.3**, voluntary purchase is a possible option that has also been given a detailed consideration as part of this study. The procedure by which voluntary purchase could be undertaken could generally include two alternate approaches:

- The owner of land within any zone under the LEP and which is affected by flood hazard may, in writing, request the Council in which their property lies, or a public authority to acquire that land. The owner would thus, relinquish all responsibility of their land to that authority. The economic and social (including psychological) effects of flooding would therefore generally be averted in the future, or
- in the case of properties within the WCC LGA, Clause 5.1 Part 5 of the existing LEP set out a procedure for the identification and acquisition of land and could be applied to land within flood prone area by Council or another public authority. This is considered to be an unfavourable approach as it does not really allow for the process to be 'Voluntary' in the truest sense of the word. As such it is not recommended as an option.

After voluntary purchase, Council would then grant consent for demolition subject to conditions requiring (for example):

- removal of structures, buildings or work which may impact on or be affected by flooding;
- reinstatement of the land or removal of any waste materials or refuse; or
- compliance with any condition imposed by another public authority in granting its consent.

To assist the overall assessment, a preliminary study to identify which properties may be suitable for voluntary purchase was carried out. Information on the nature of the construction of each property within the flood prone areas gathered for the flood damages assessment was utilised for the assessment of the maximum number of properties that may be eligible.

Since the critical duration for the Lake is 36 hours, sufficient time is generally available for flood-affected residents to evacuate. Hence there are limited risk to life issues associated with flooding of Lake Illawarra. The NSW Government Floodplain Management Program provides funding assistance to purchase flood-affected properties under the voluntary purchase scheme for areas generally only where the locality is exposed to high flood risks, such that there is a risk to life.

Consequently, only those properties affected by high hazard flooding have been considered and where limited alternatives are available to mitigate risks (i.e. those properties that are slab on ground and have above floor flooding of greater than 1.0 m at the 100 Year ARI flood). However, no single storey property meets this criterion. One two-storey property meets this criterion but this dwelling does not have living areas on the ground floor and therefore serious flood damage and risk to life issues would not be expected. Consequently, no properties have been identified for voluntary purchase for the floodplain.

14 Emergency Response Modification Options

As a guide, if the community is able to be prepared for a flood, the reduction in flood damages on an annual average basis is over $200,000 per year (the difference between the prepared AAD case of $198,000 and the unprepared AAD case of $447,000, **Section** 7). This substantial benefit of preparation indicates the value of investment in flood warning and evacuation planning for the Lake Illawarra floodplain.

14.1 Flood Warning System

Currently a flood warning system is in place for the Caravan Park areas which has been implemented as part of the conditions of consent for the development by Wollongong City Council. A copy of the Oaklands Village Flood Emergency Evacuation Program, which describes the flood warning process, was made available to assist with the preparation of this report. This program has been reviewed by the SES and Wollongong City Council.

The flood warning system consists of a telemetered system linked to the water level recorders at a number of sites within Lake Illawarra operated by the NSW Department of Finance and Services (NSW Public Works, Manly Hydraulics Laboratory). The system monitors the Lake level every 15 minutes. Both the Oaklands Village and the State Emergency Service are connected by facsimile to the system and are pre-warned of rising Lake levels during heavy rain periods. When the Lake level reaches designated levels the Flood Emergency Evacuation Program is implemented by the Park management. These levels include 0.90 mAHD, 1.2 mAHD and 1.5 mAHD. Under the program in place, the entire park is evacuated by the time the level of the Lake reaches 2.0 mAHD. This system has been in operation since 1993.

The flood warning system in place should continue to be utilised to assist with flood evacuation processes for all areas affected by flooding by the State Emergency Service (SES).

The flood warning system could be upgraded to provide for full public internet access with appropriate interpretation of the data and possibly also an alert email service to major areas and news outlets (such as radio and television broadcasters e.g. WIN) to complement the telephone warning service currently in place and accessible only by OEH and the SES. Real time access for the public is available through the MHL Website to the water level recorders on a retrospective basis as data is downloaded from the water level recorders only on a daily basis. For example, currently the levels can be derived from the following Website links:

- Lake Illawarra Entrance:
  http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=LIE2
- Cudgeree Bay
  http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=CUDG

Wider access to the service and associated education about the availability and use of the service would lessen the burden on the State Emergency Service for door to door alerts for residents. Consideration of the expansion of the system to allow residents to register for an email or SMS to be sent with warnings as required would be an appropriate next step and is recommended to be included as an item for implementation in the Floodplain Risk Management Plan.

14.2 Local Flood Plan Update

14.2.1 Flood Evacuation Plan

It is recommended that a flood evacuation plan, showing flood-free road routes and locations of flood-free evacuation centres be prepared as a priority for the foreshore areas with the greatest numbers of properties at risk, including:

- Primbee;
- Windang; and
- Lake Illawarra (properties that lie immediately on the southern side of Windang Bridge).

This plan should be prepared for incorporation into the Local Plan and should be based on the results of the Flood Study (Lawson and Treloar, 2001) and **Section 5** of this Study. The Plan should be prepared in consultation with the SES, the Department of Family and Community Services and the Local Emergency Management Officers from the two local government areas.

14.2.2 Flood Intelligence Card Update

The SES utilises 'Flood Intelligence Cards' for the Lake Illawarra area. It is a recommendation of this study that these flood intelligence cards be updated with the results of the flood study (Lawson and Treloar, 2001) and further modelling described in **Section 5** to ensure the most accurate and up to date information is available in both the cards and in the Local Flood Plan in the event of a flood.

15 Economic Assessment of Options

A summary of all of the options where an economic evaluation (in the form of a cost:benefit ratio) has been undertaken is provided in **Table 15.1**.

Table 15.1 Options Economic Assessment Summary

Option	Net present value of Damage Reduction (Unprepared Case)	Net present value of Damage Reduction (Prepared Case)	Cost: Benefit Ratio Unprepared	Cost: Benefit Ratio Prepared
B1 (**Section 10**)	$165,609	$55,203	0.06	0.02
B2 (**Section 10**)	$469,225	$193,210	0.06	0.03
C1 (**Section 11**)	$372,620	$151,808	0.11	0.04
C2 (**Section 11**)	$441,624	$165,609	0.08	0.03
House Raising (95 Properties)	$358,819	$193,210	0.09	0.05
House Raising (11 Properties)	$138,007	$69,004	0.31	0.16

Given the low economic benefits identified in **Table 15.1** and the potential environmental impact of the Windang Bridge options (Options B1, B2, C1 and C2, **Sections 10 and 11**), it is not recommended that these options be implemented. Investigation of house raising options for 11 properties indicates that flood awareness of the owners of these properties will translate into significant benefit due to reduction in flood damage rather than raising of the dwellings. Given the nature of flood behaviour of Lake Illawarra, the ability for the community to be prepared for a flood is likely to provide the greatest benefit.

It should be noted that regardless of whether any of the options outlined in **Table 15.1** are implemented, it is important that the Stage 1 entrance stabilisation completed in 2001 be maintained to assist with the reduction of flood levels during flood events. Further works undertaken as Stage 2 in 2007 (**Section 9**) should further assist with this.

16 Recommendations

The purpose of this FRMS is to identify and assess a range of possible measures to manage flood risk in the Lake Illawarra Floodplain.

Table 16.1 provides a summary of all of the measures considered and makes recommendations for inclusion of some of those measures in the Floodplain Risk Management Plan (Cardno, 2012). A total of 16 floodplain risk management options have been recommended for inclusion in the Plan. These options provide a combination of property modification and emergency response options. This will provide a holistic approach to floodplain management within the Lake Illawarra Floodplain.

Table 16.1 Summary of FRMS Recommendations

Floodplain Risk Management Option	Reference Section of FRMS	Assessment Outcomes	Recommended for Inclusion in the FRMP
Option A: Entrance Stabilisation	Section 9	The Stage 1 and Stage 2 works associated with this option are now complete. The Stage 1 works were assessed within this FRMS. The hydraulic modelling found that the Stage 1 works resulted in a reduction in 100 Year ARI flood levels around the Lake foreshore of 0.09m and a reduction of 0.27m at the entrance. Stage 2 works were assessed as part of *Lake Illawarra Entrance Improvement – Proposed Northern Training Wall off Perkins (Windang) Beach* (Lawson and Treloar, 2004).	No. Works already complete.
Option B1: Extension of Windang Bridge by 100m & Dredging of Back Channel	Section 10	Hydraulic modelling showed a reduction in 100 Year ARI flood levels around the Lake foreshore of 0.01m and an increase of 0.02m at the entrance. This option results in a reduction in AAD of $12,000. The benefit-cost ratio for the unprepared case is 0.06. This value does not show a significant economic benefit associated with the option.	No.
Option B2: Extension of Windang Bridge by 350m & Dredging of Back Channel	Section 10	Hydraulic modelling showed a reduction in 100 Year ARI flood levels around the Lake foreshore of 0.05m and an increase of 0.10m at the entrance. This option results in a reduction in AAD of $34,000. The benefit-cost ratio for the unprepared case is 0.06. This value does not show a significant economic benefit associated with the option.	No.
Option C1: 20 Culverts at Windang	Section 11	Hydraulic modelling showed a reduction in 100 Year ARI flood levels around the Lake foreshore of 0.03m and an increase of 0.07m at the entrance. This option results in a reduction in AAD of $27,000. The benefit-cost ratio for the unprepared case is 0.11. This value does not show a significant economic benefit associated with the option.	No.
Option C2: 40 Culverts at Windang	Section 11	Hydraulic modelling showed a reduction in 100 Year ARI flood levels around the Lake foreshore of 0.04m and an increase of 0.09m at the entrance. This option results in a reduction in AAD of $32,000. The benefit-cost ratio for the unprepared case is 0.08. This value does not show a significant economic benefit associated with the option.	No.

Floodplain Risk Management Option	Reference Section of FRMS	Assessment Outcomes	Recommended for Inclusion in the FRMP
Impacts of Foreshore Filling	Section 12	The cumulative impact on flooding of filling all future developable areas in the floodplain would result in up to a 0.05m increase in 100 Year ARI and PMF levels. This relates to an increased in AAD of $23,000 and an increase of 12 properties impacted by flooding in the PMF.	It is recommended that no further wholesale filling of flood affected sites is undertaken, unless supported by a sensitivity analysis indicating that there is no significant impact on flood levels. Also, filling that impacts on active flow areas in the stream networks feeding Lake Illawarra will not be supported.
Development Controls	Section 13	Two DCP matrices have been prepared which are consistent with the format utilised in the Councils' DCPs, which includes controls relevant to the Lake Illawarra Floodplain.	Yes.
Recommendations for LEPs	Section 13	Several recommendations have been made for inclusion in Councils' LEPs. Full details can be found in Section 13. Specifically, it is recommended that WCC review land zonings in the LEP as soon as practical to determine where the cumulative effects of any intensification of use could impact on emergency response given the potential isolation hazard in Windang. It is recommended that the Planning Zone R2 –Low Density Residential be replaced with Planning Zone E4 – Environmental Living in the Windang Peninsula area (within the extents of the Peninsula defined in **Figure 6.5**).	Yes.

Floodplain Risk Management Option	Reference Section of FRMS	Assessment Outcomes	Recommended for Inclusion in the FRMP
Incorporation of Climate Change into Development Controls	Section 13	Concessional Development: ▪ Planning provisions to be based on 2050 sea level rise predictions. ▪ High Risk Precinct, remains equal to the existing true high hazard extent; ▪ Medium Risk Precinct is to be updated to be equal to the 2050 SLR extent plus a freeboard of 0.5m; and ▪ Low Risk Precinct remains equal to the existing PMF extent. Non-Concessional Development: ▪ Planning provisions to be based on 2100 sea level rise predictions. ▪ High Risk Precinct, remains equal to the existing true high hazard extent; ▪ Medium Risk Precinct is to be updated to be equal to the 2100 SLR extent plus a free board of 0.5m; and ▪ Low Risk Precinct remains equal to the existing PMF extent.	Yes
Section 149 Recommendations	Section 13	Recommendations for additional wording to be included on Section 149 Certificates (See Section 13.5).	Yes
House Raising Program (95 Properties)	Section 13	The program would protect 95 eligible properties. The house raising program (if all 95 properties participated) would result in a reduction in AAD of $26,000. This results in a benefit:cost ratio of 0.09. This ratio is considered too low to substantiate proceeding with this option.	No.
House Raising Program (11 Properties)	Section 13	The program would protect the 11 worst affected properties (that are eligible for house raising). The house raising program (if all 11 properties participated) would result in a reduction in AAD of $10,000. This results in a benefit:cost ratio of 0.31. Whilst having a low benefit:cost ratio (substantially less than 1), the consideration of the raising of these 11 properties is recommended.	Yes.
Voluntary Purchase Program	Section 13	No properties have been identified for voluntary purchase for the floodplain.	No.
Flood Warning System	Section 14	It is recommended that the current flood warning system in place at the Caravan Park areas be expanded to be publicly accessible and to allow residents to register for an email or SMS alert.	Yes.
Local Flood Plan Update – Evacuation Plan	Section 14	It is recommended that a flood evacuation plan be prepared based on the results of the Flood Study (**Section 5**) and incorporated into the Local Flood Plan.	Yes.
Local Flood Plan Update – Flood Intelligence Card Update	Section 14	Flood intelligence cards to be updated with the results of the flood study (Lawson and Treloar, 2001) and further modelling described in Section 5 to ensure the most accurate and up to date information is available in both the cards and in the Local Flood Plan in the event of a flood.	Yes.

Floodplain Risk Management Option	Reference Section of FRMS	Assessment Outcomes	Recommended for Inclusion in the FRMP
Entrance Opening Policy	Section 8.5.2	Continued implementation of LIA's entrance opening policy.	Yes.
Information and Education Brochure	Section 8.5.3	It is recommended that Councils update and reissue an information brochure every two years to the community.	Yes.
Information and Education Program	Section 8.5.3	It is recommended that a detailed information and education program be developed for the floodplain.	Yes.
Flood Planning Levels	Sections 5.2, 5.5 and 6.2	1. Adopt the flood levels provided in **Table 16.2** for flood planning purposes. 2. Adoption a freeboard of 0.5m for flood planning purposes.	Yes.
Flood Risk Precincts	Section 13	Adoption the flood risk precincts shown in **Figure 13.4** for concessional development and those shown in **Figure 13.5** for non-concessional development.	Yes.
Catchment-wide regional controls	Section 2.5	It is recommended the two Councils prepare catchment wide regional controls to offset future development impacts in major catchments.	Yes
Strategic Land Use Planning	-	It is recommended that the strategic land use planners of SCC and WCC consider the longer term land use planning on the lake foreshore in line with the NSW Coastal Planning Guideline: Adapting to SLR (DoP, 2010), This may require further assessment of impact of SLR on tidal plains in addition to SLR planning areas.	Yes
Review of the impacts of climate change induced rainfall changes on flooding behaviour in the floodplain.	Section 5.5	It is noted that the degree and timeframe for change in flood producing rainfall remains unclear in the scientific literature but there is work currently being undertaken in the current update of ARR (expected to be released in 2012). It is therefore recommended that further consideration of changes to flood producing rainfall events be undertaken following release of the current ARR review or when other policy or specific and widely accepted research becomes available.	Yes
Maintenance of Stormwater Drains	Section 8.2.6	Councils to regularly maintain the stormwater drainage network within the catchment. To include cleaning of pits to reduce the risk of blockage of the system resulting in surcharging during regularly occurring storm events. This should be undertaken on a quarterly basis and on an as-needed basis when complaints are received.	Yes

Table 16.2 Design Flood Levels to be used for Planning Purposes

	Location*	Peak Flood Level (m AHD)								
		100 Year ARI	100 Year ARI (2050 SLR)	100 Year ARI (2100 SLR)	50 Year ARI	20 Year ARI	10 Year ARI	5 Year ARI	2 Year ARI	Extreme Event (PMF)
	Modelling	Delft3D (2008)	Delft3D (2008)	Delft3D (2008)	MIKE11 (2001)	MIKE11 (2001)	MIKE11 (2001)	MIKE11 (2001)	MIKE11 (2001)	MIKE11 (2001)
1	Griffins Bay	2.24	2.63	3.04	2.03	1.81	1.57	1.40	1.11	3.24
2	Tallawarra Power Station	2.24	2.63	3.04	2.03	1.81	1.57	1.40	1.11	3.24
3	Horsley Inlet	2.24	2.63	3.04	2.03	1.81	1.57	1.40	1.11	3.24
4	Cudgeree Island Channel	2.24	2.64	3.04	1.99	1.81	1.54	1.40	1.08	3.19
5	Windang Bridge	2.15	2.55	3.01	1.83	1.63	1.42	1.26	0.99	2.98
6	Entrance Channel	1.71	2.25	2.32	1.74	1.55	1.35	1.20	0.95	2.84

** Locations illustrated on Figures 5.1 – 5.2.*
** Note: FPL = Design Flood Level + Freeboard (0.5m)*

17 References

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18 Acknowledgements

This study was jointly funded by Wollongong City Council and Shellharbour City Council under the NSW Government Floodplain Management Program and administered by the Lake Illawarra Authority.

This study has been undertaken and report prepared with the assistance of:

- Lake Illawarra Floodplain Management Committee;
- Wollongong City Council;
- Shellharbour City Council;
- Lake Illawarra Authority;
- Office of Environment and Heritage;
- State Emergency Services; and
- The Community of Lake Illawarra.

This study was funded under the State Government's Floodplain Management Program through the Office of Environment and Heritage on a 2:1 (State:Council) ratio.

19 Qualifications

This report has been prepared based on information provided by:

- Wollongong City Council (various GIS layers including LEP, cadastre, 2m-contours, ALS, various environmental planning instruments, plans of management);
- Shellharbour City Council (various GIS layers including LEP, cadastre, 2m-contours, ALS, various environmental planning instruments, plans of management);
- NSW Department of Finance and Services (NSW Public Works) - Property Survey Details for Shellharbour City Council; and
- Wollongong City Council - Property Survey Details for Wollongong City Council.

Figures

FIGURE 1.1
STUDY AREA

Cardno

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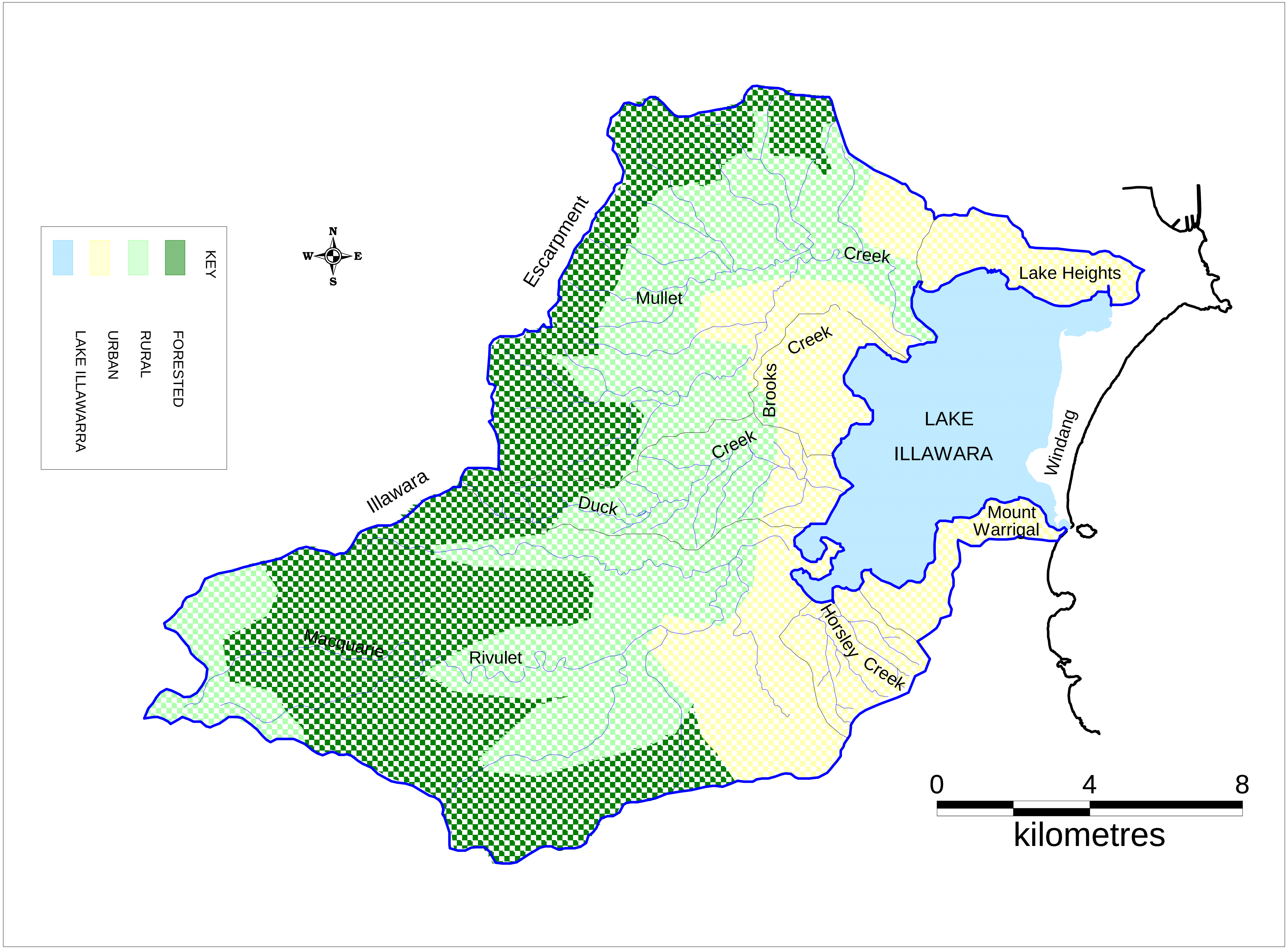

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Management Study

FIGURE 2.1
LAKE ILLAWARRA CATCHMENT

J1905\Figures V12\Figure 2.1 - Catchment.Wor

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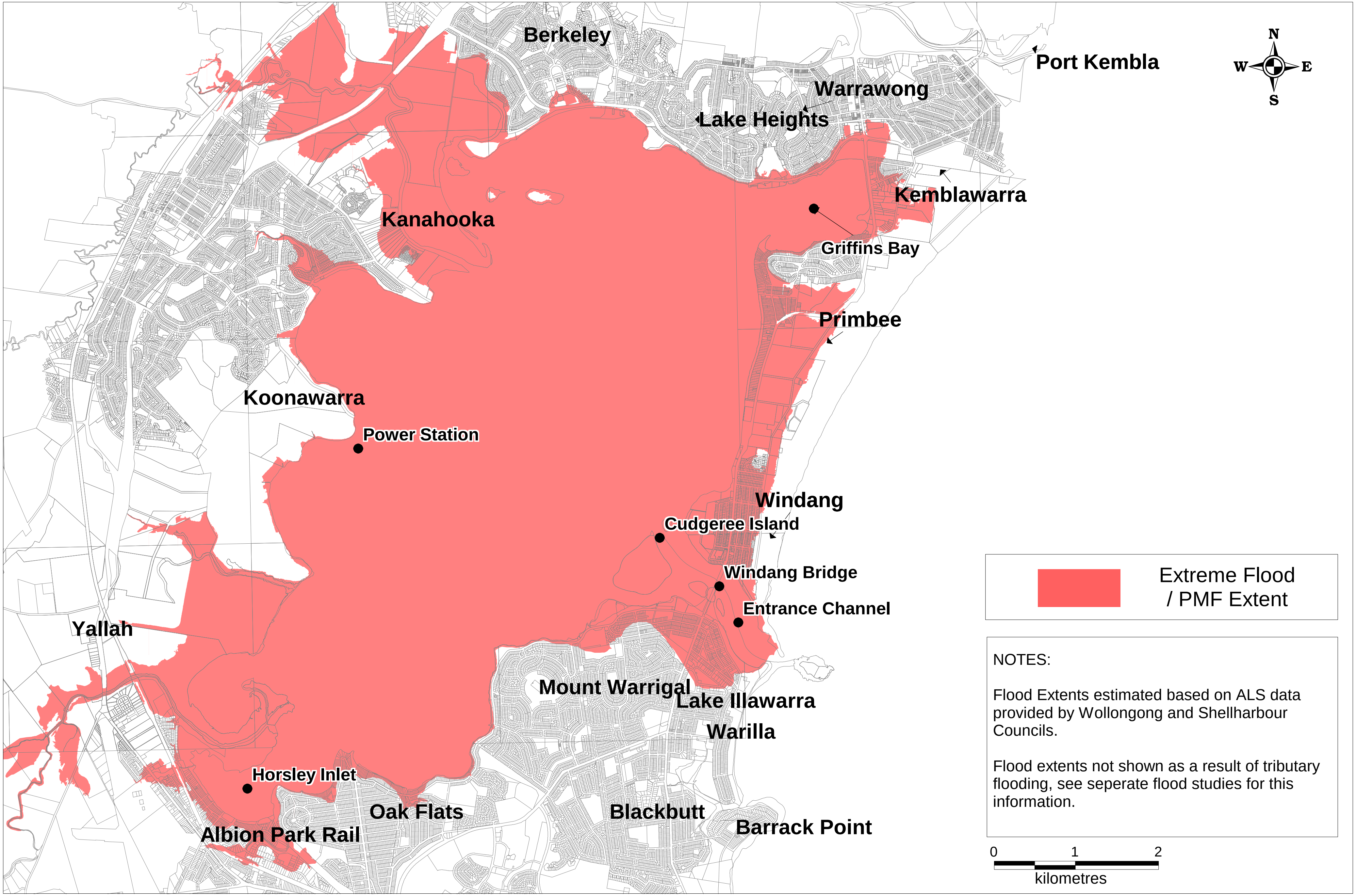
Lake Illawarra Floodplain Risk Management Study

FIGURE 5.1
100 YEAR ARI FLOOD EXTENT

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 5.1 - 1% Extent.Wor



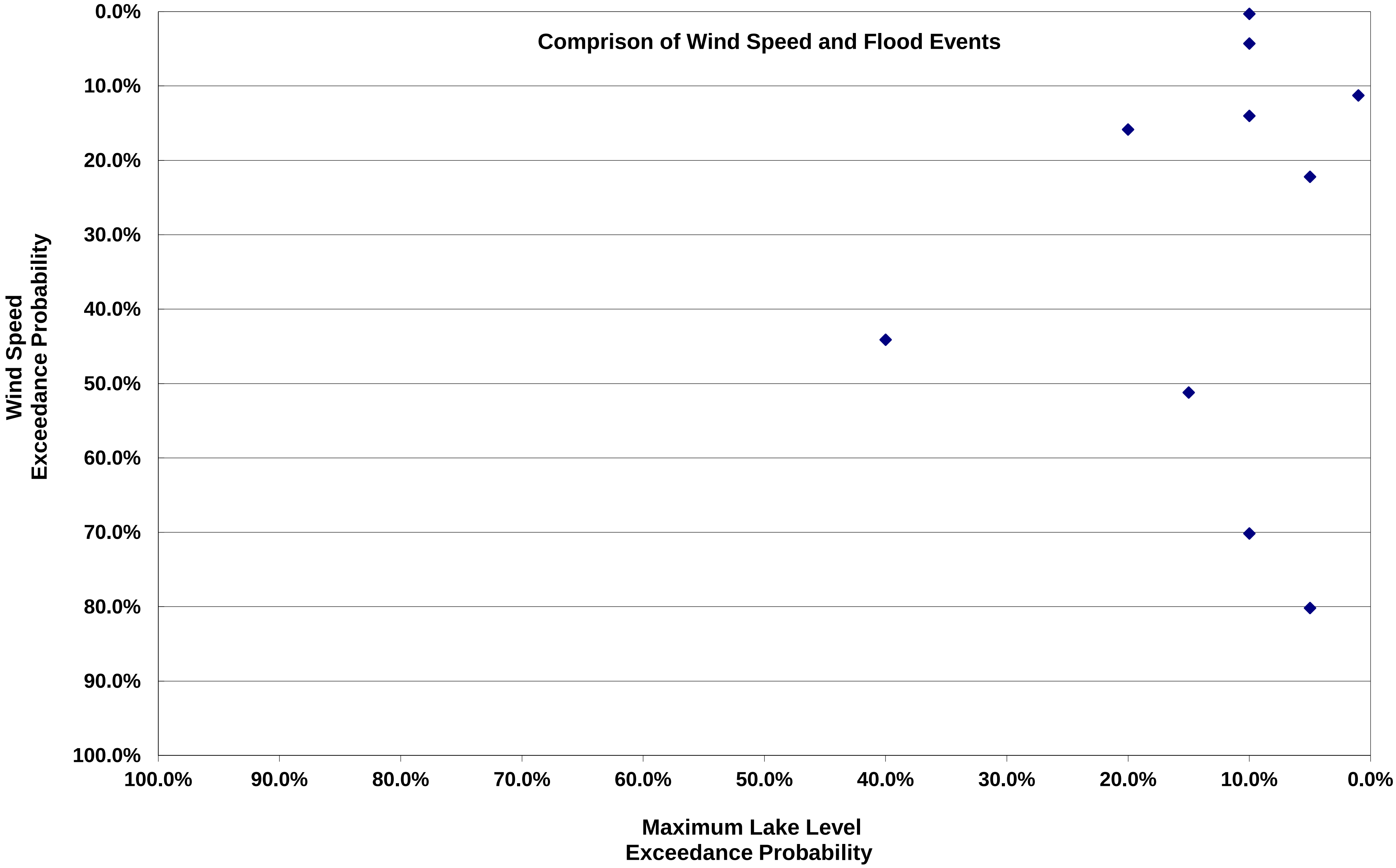
Cardno

J1905/R1920/V12
January 2012

Lake Illawarra Floodplain Risk Management Study

FIGURE 5.2
PROBABLE MAXIMUM FLOOD EXTENT

J1905\Figures V12\Figure 5.2 - PMF Extent.Wor



Comprison of Wind Speed and Flood Events
Wind Speed
Exceedance Probability
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Maximum Lake Level
Exceedance Probability

Cardno

Lake Illawarra Floodplain Risk Management Study

FIGURE 5.4
0.18m SLR 100 YEAR ARI FLOOD EXTENT

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 5.4- 0.18m SLR 100yr.Wor

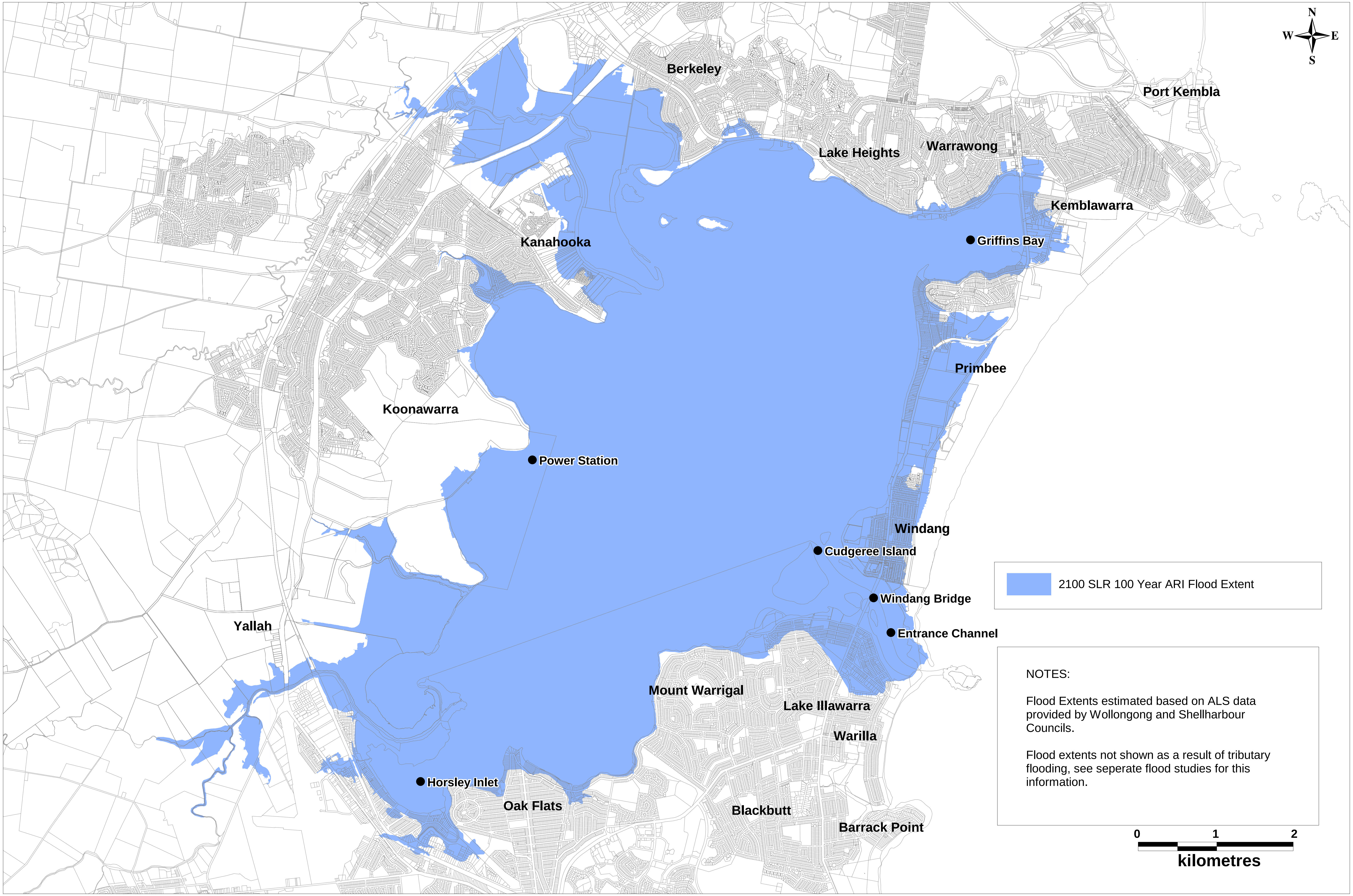
Cardno

J1905/R1920/V12
January 2012

Lake Illawarra Floodplain Risk Management Study

FIGURE 5.5
2050 SLR 100 YEAR ARI FLOOD EXTENT

J1905\Figures V12\Figure 5.5 - MLR 100yr.Wor



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Lake Illawarra Floodplain Risk Management Study

FIGURE 5.6
2100 SLR 100 YEAR ARI FLOOD EXTENT

J1905\Figures V12\Figure 5.6 - 2100 100yr.Wor

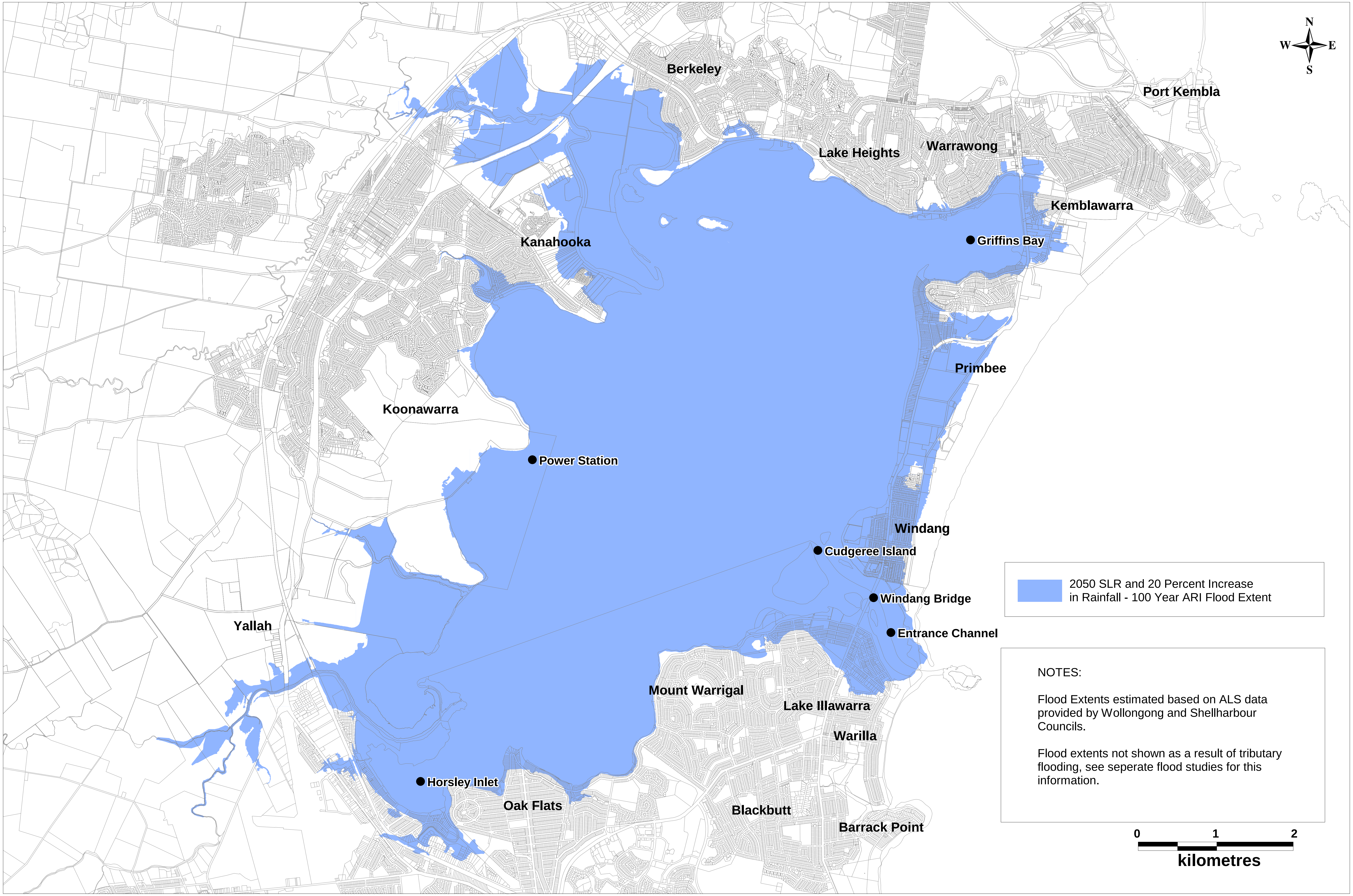

FIGURE 5.7
2050 SLR + 20% RAINFALL 100 YEAR ARI FLOOD EXTENT

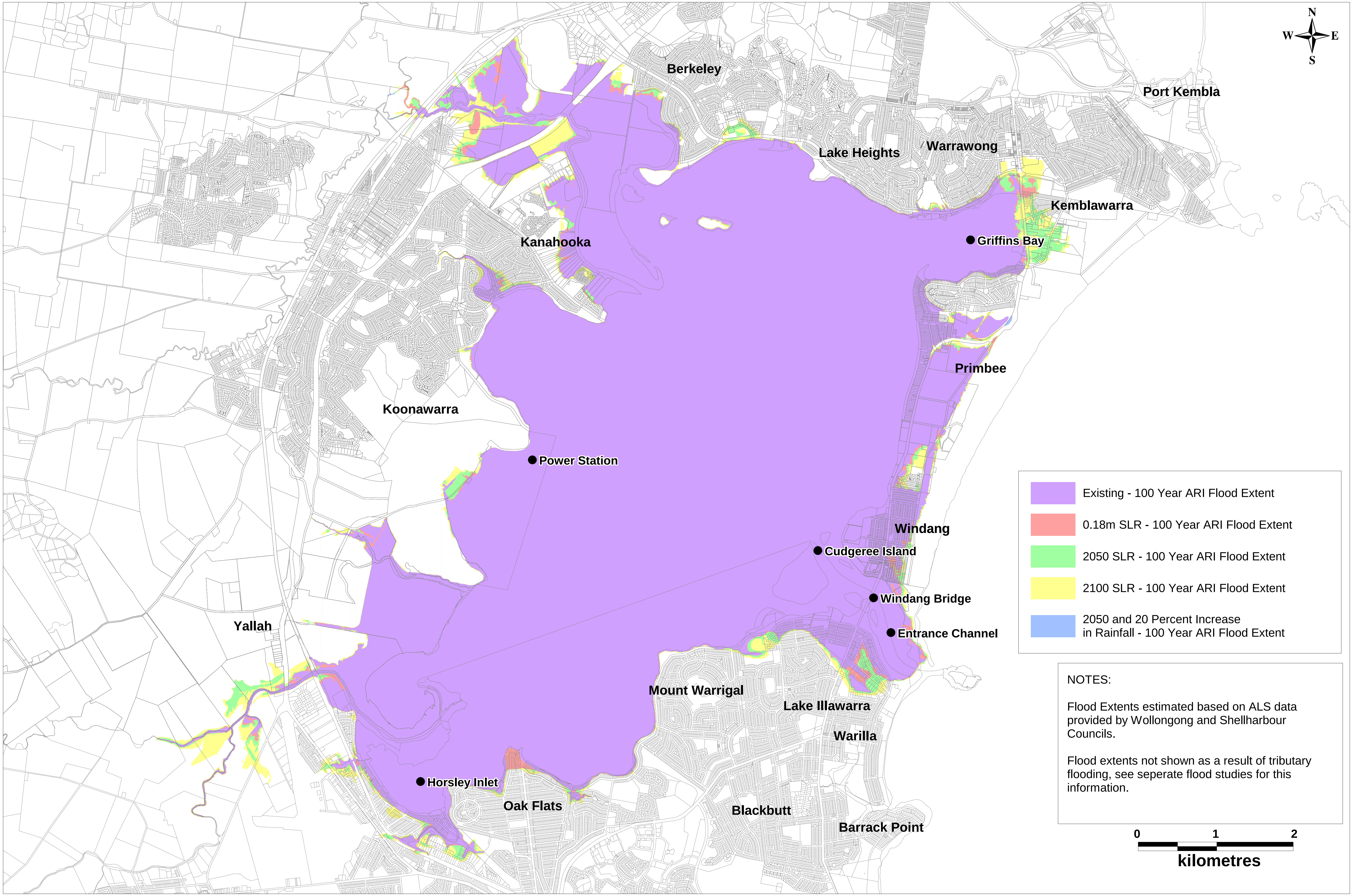

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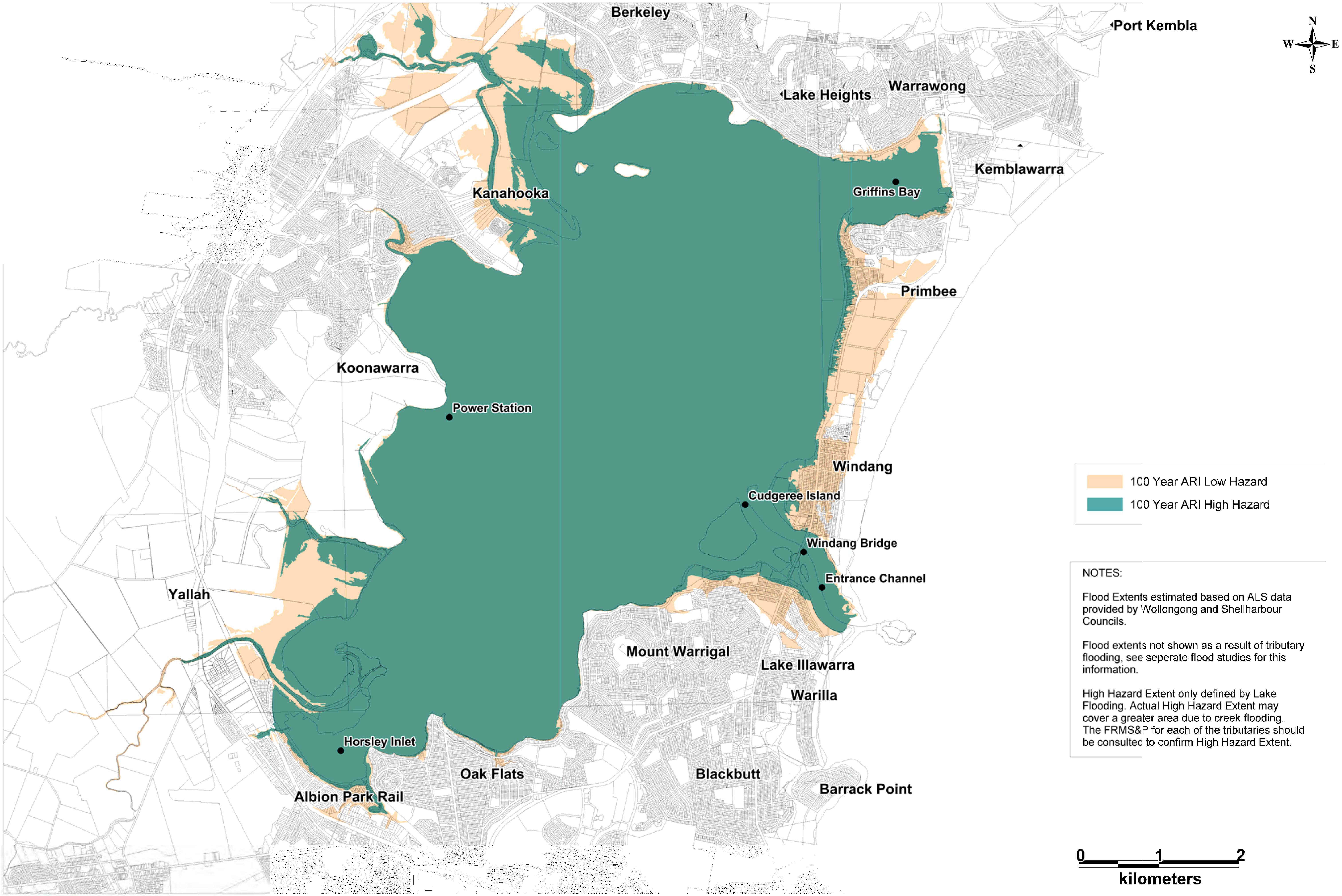
FIGURE 5.8
CLIMATE CHANGE SCENARIOS AND EXISTING
100 YEAR ARI FLOOD EXTENT

J1905\Figures V12\Figure 5.8 - All 100yr.Wor



NOTES:

Flood Extents estimated based on ALS data provided by Wollongong and Shellharbour Councils.

Flood extents not shown as a result of tributary flooding, see seperate flood studies for this information.

High Hazard Extent only defined by Lake Flooding. Actual High Hazard Extent may cover a greater area due to creek flooding. The FRMS&P for each of the tributaries should be consulted to confirm High Hazard Extent.

FIGURE 6.1
100 YEAR ARI PROVISIONAL HAZARD

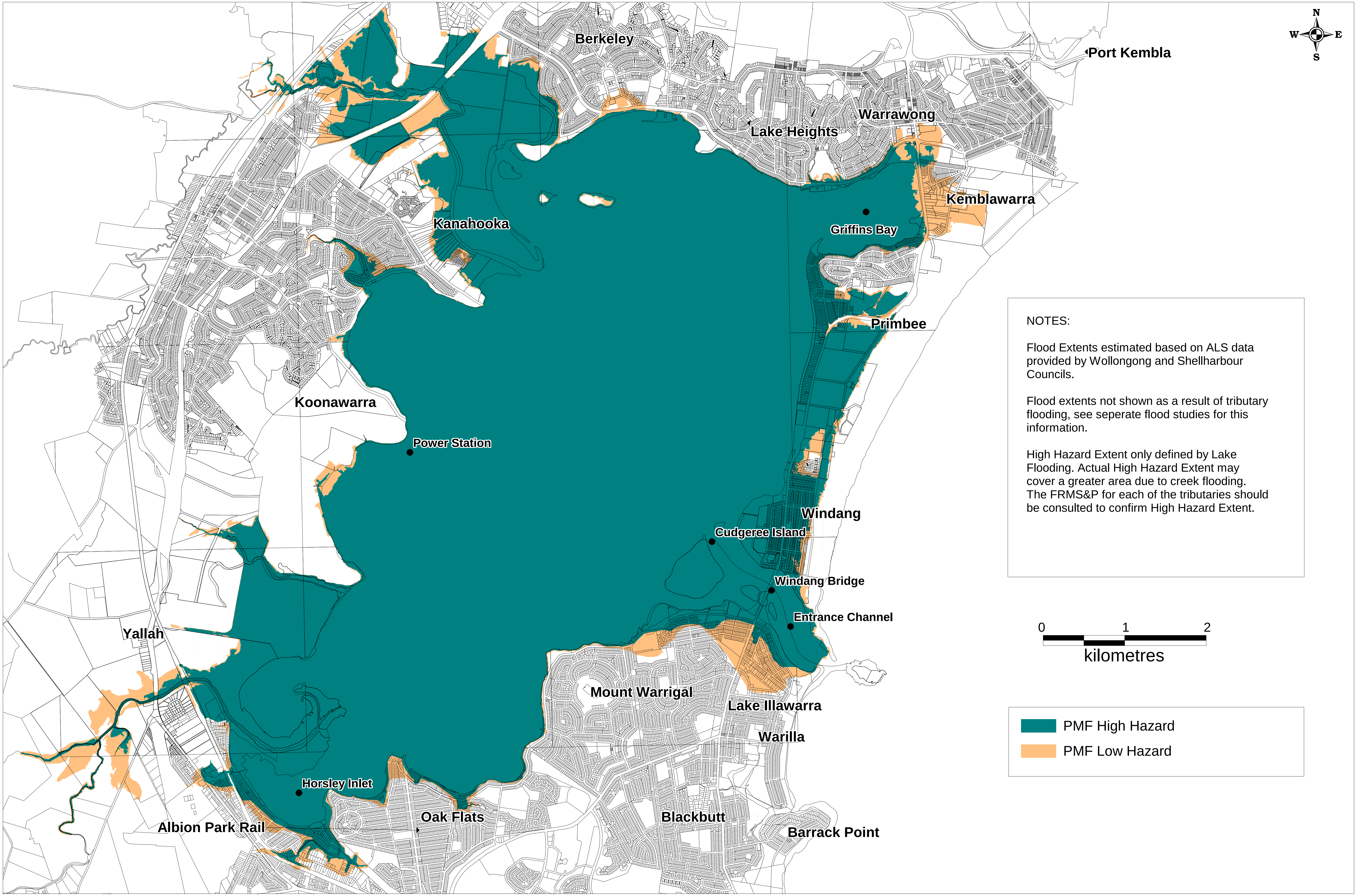


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FIGURE 6.2
PROBABLE MAXIMUM FLOOD PROVISIONAL HAZARD

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 6.2 - PMF Prov Hazard.Wor

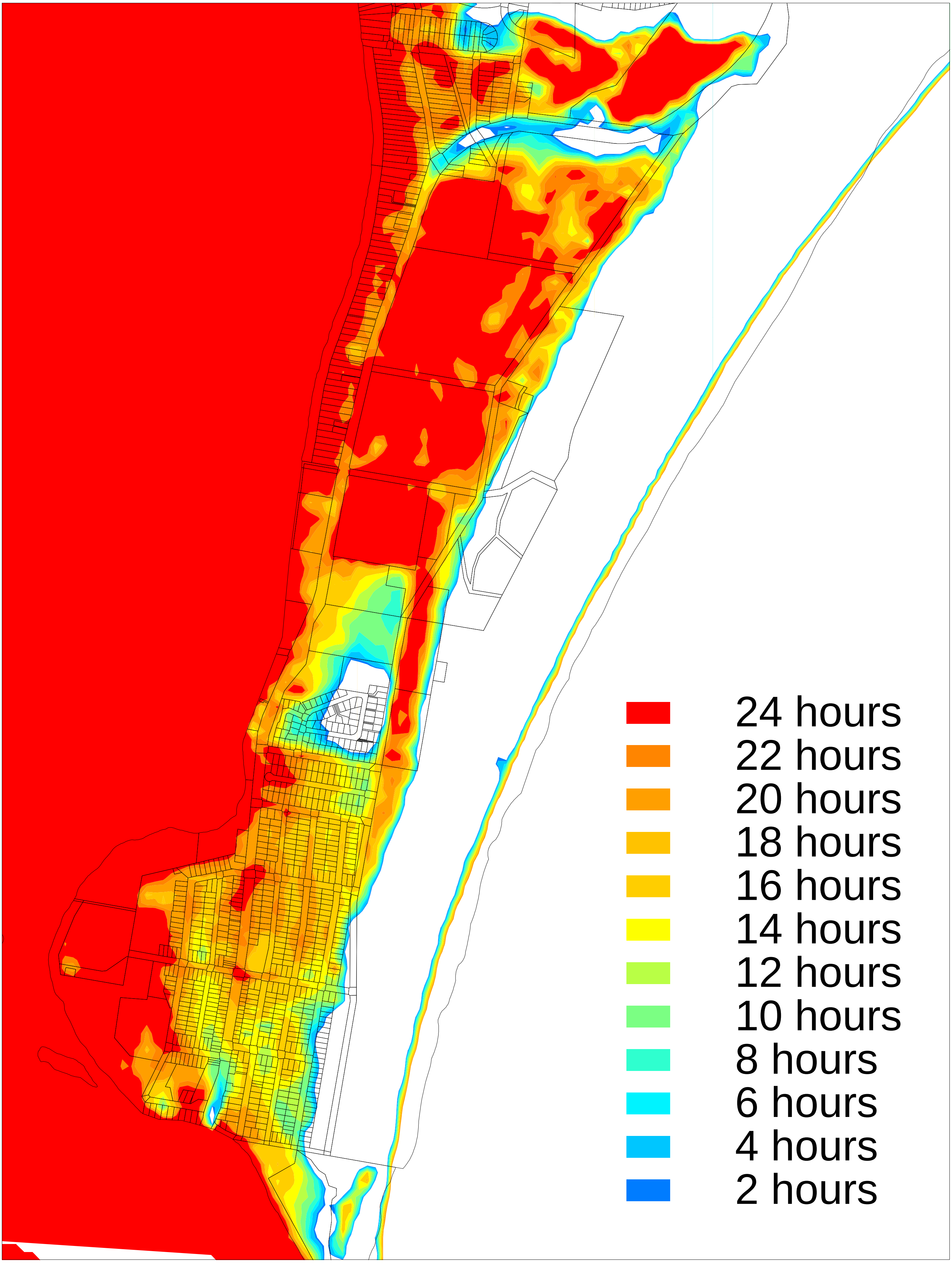

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FIGURE 6.3
PMF INUNDATION PERIODS

Lake Illawarra Floodplain Risk Management Study

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 6.3 PMF Inundation Periods.wor

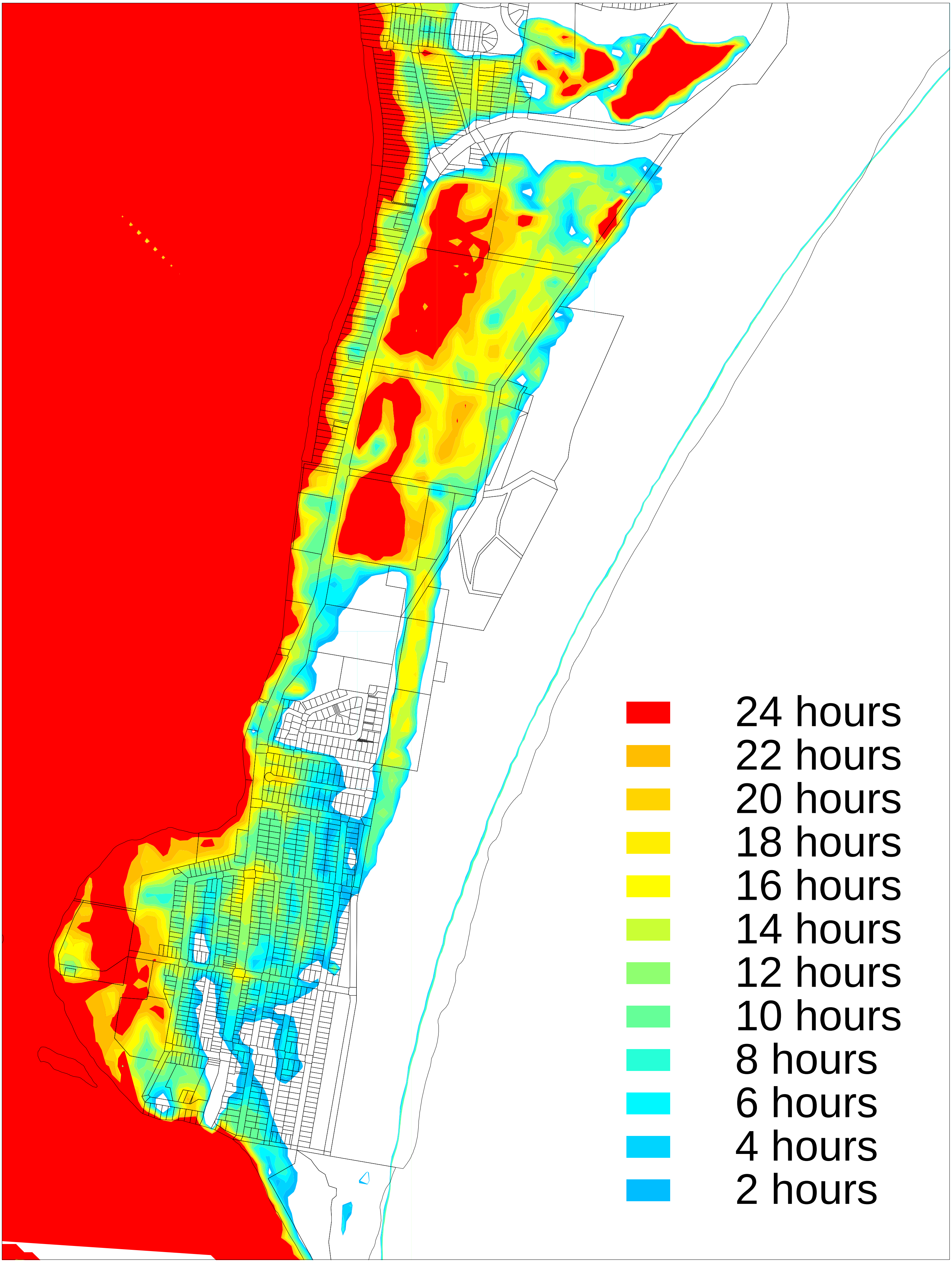

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FIGURE 6.4
100 YEAR ARI INUNDATION PERIODS

Lake Illawarra Floodplain Risk
Management Study

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 6.4 100yr Inundation Periods.wor

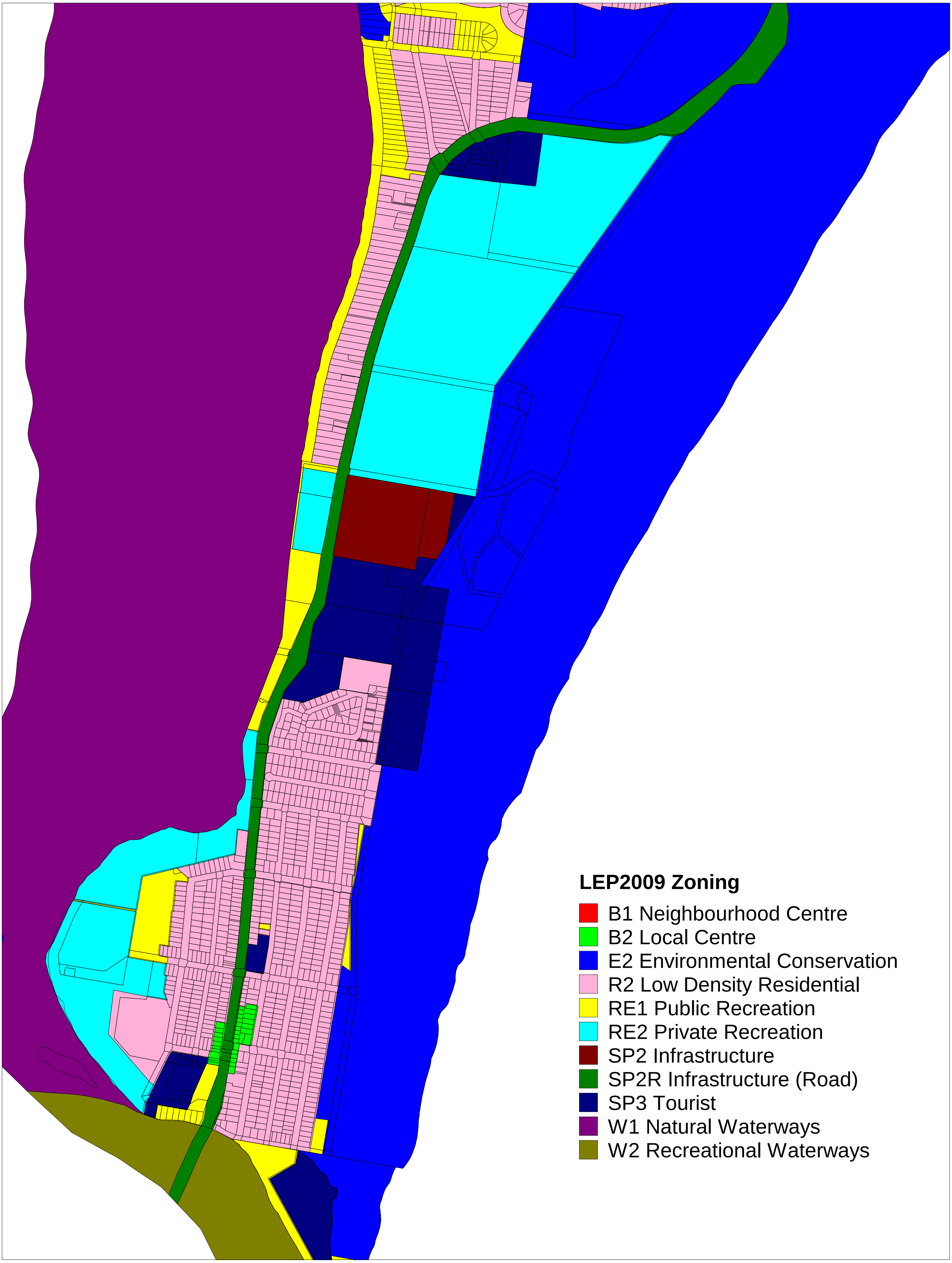


FIGURE 6.5
LAND USE ZONES
WINDANG PENINSULA

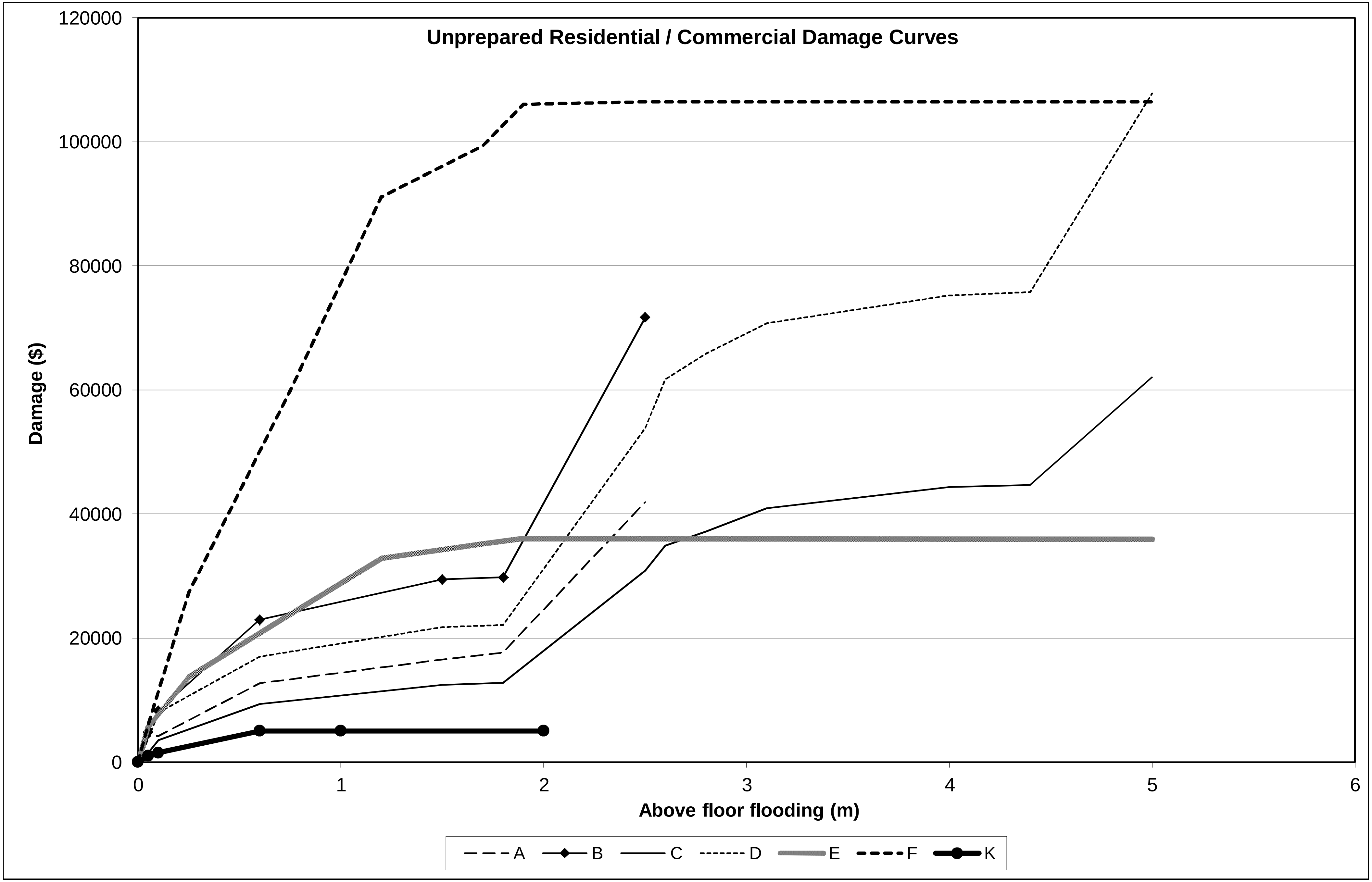
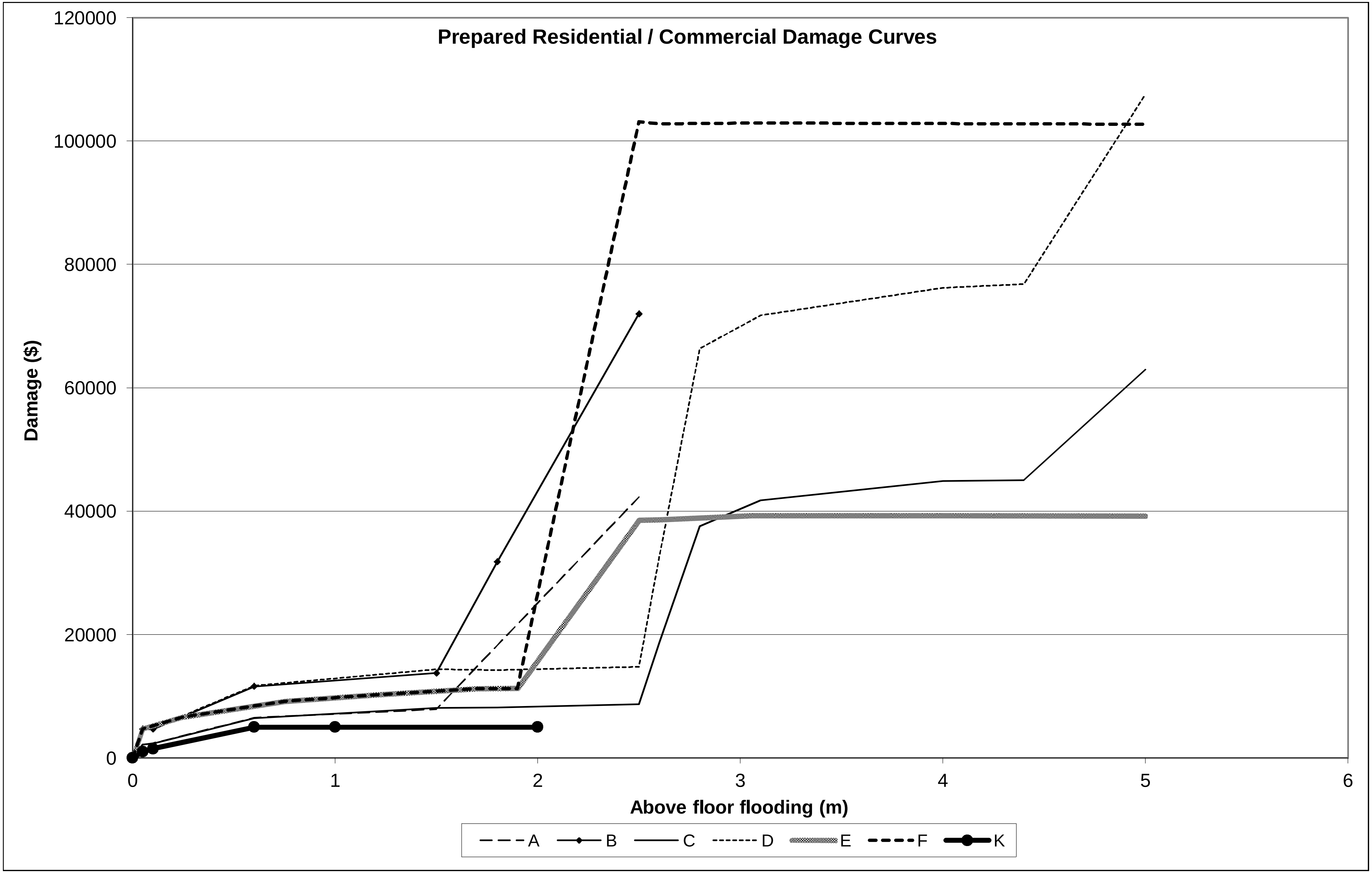


FIGURE 7.1
UNPREPARED RESIDENTIAL/COMMERCIAL DAMAGE CURVES



Prepared Residential / Commercial Damage Curves
Damage ($)
120000
100000
80000
60000
40000
20000
0
0
1
2
3
4
5
6
Above floor flooding (m)
A
B
C
D
E
F
K

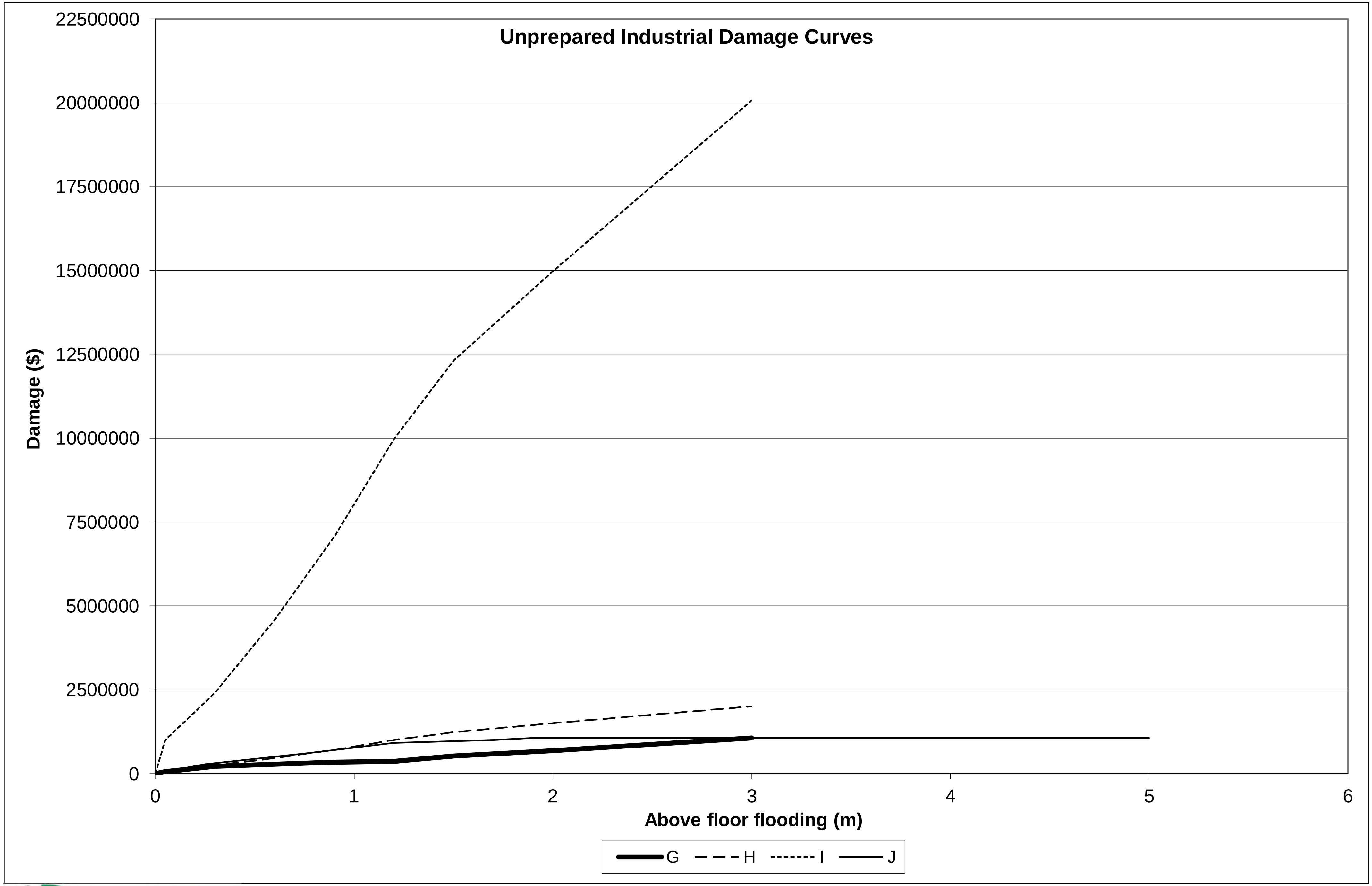


FIGURE 7.3
UNPREPARED INDUSTRIAL DAMAGE CURVES

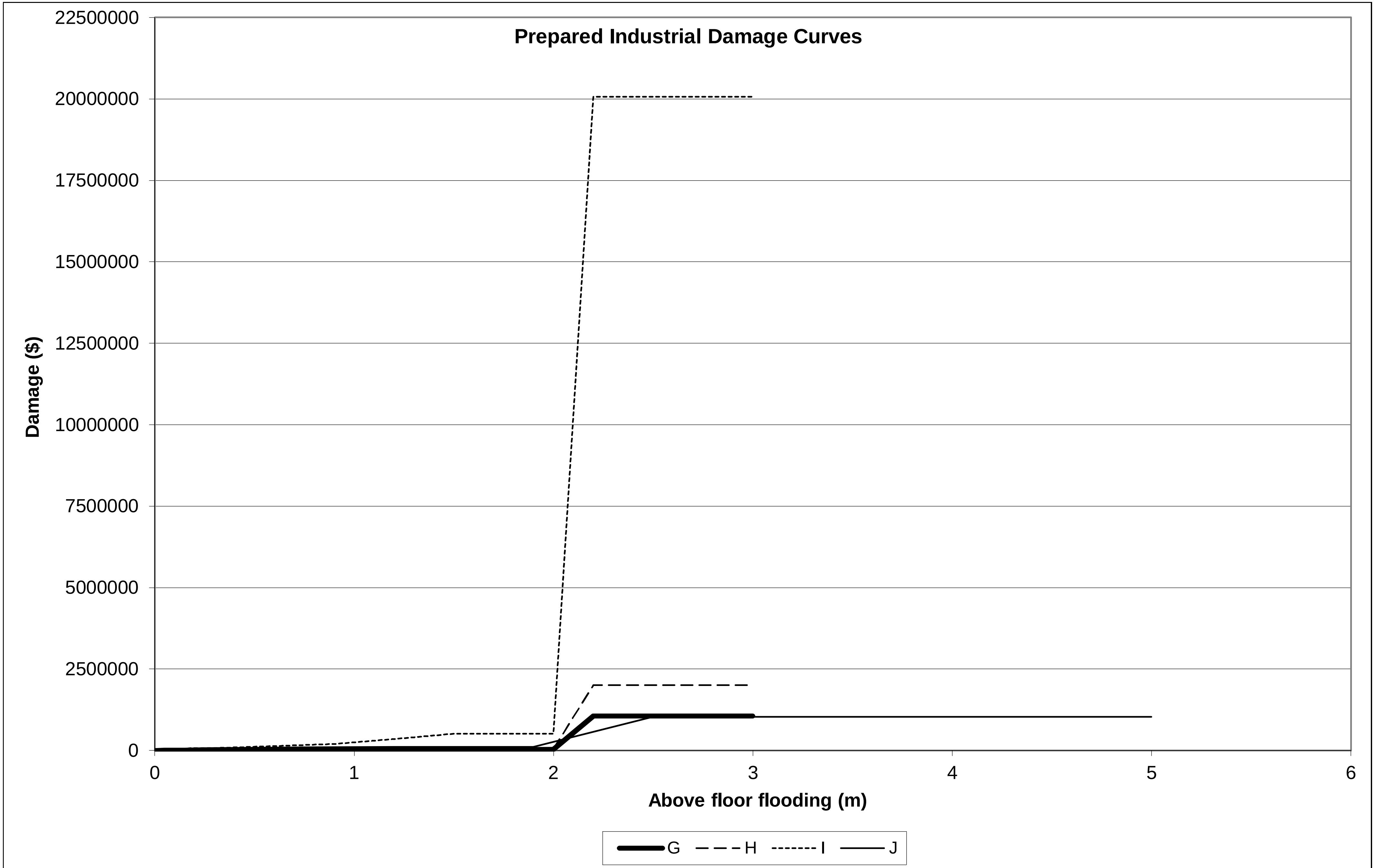


FIGURE 7.4
PREPARED INDUSTRIAL DAMAGE CURVES

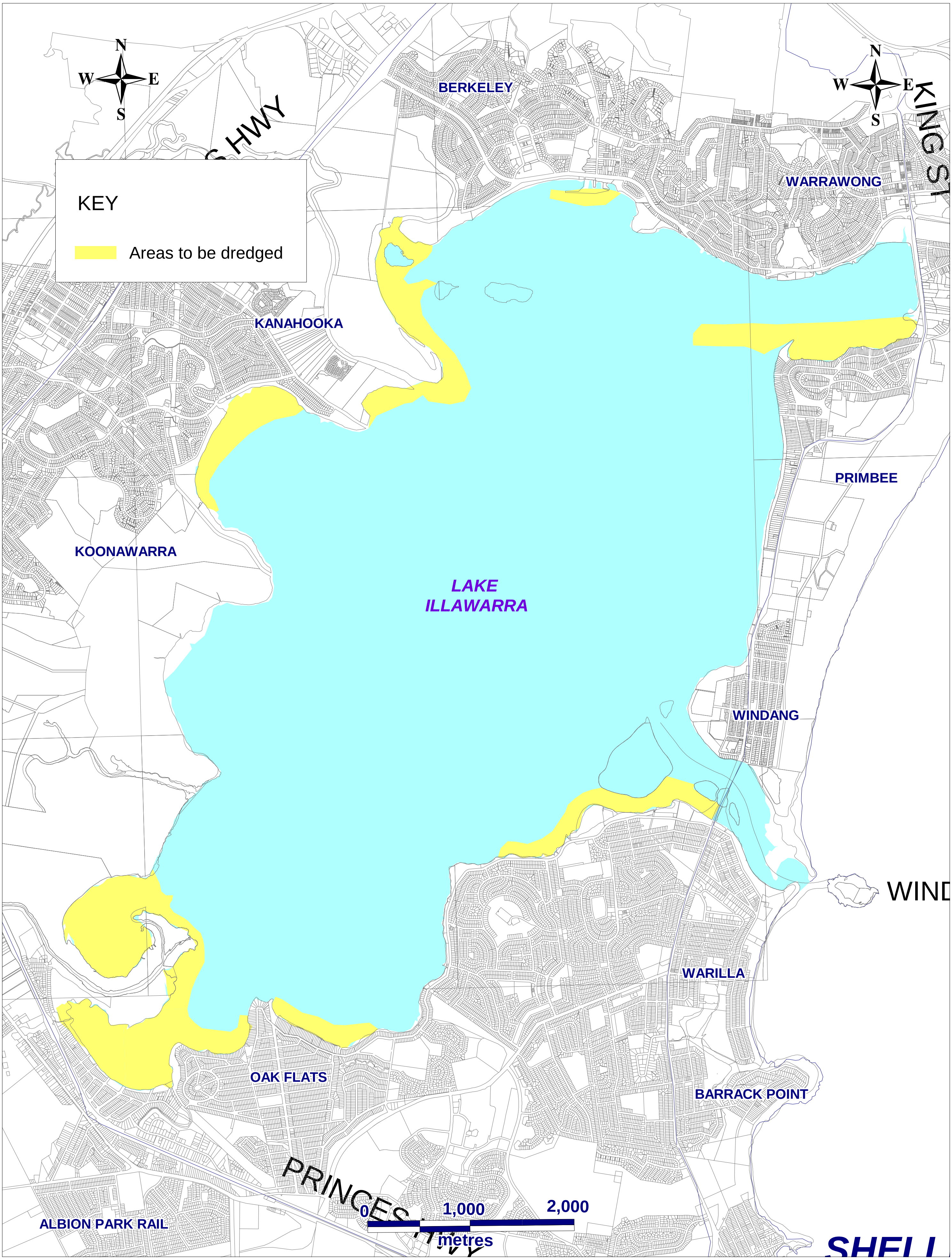


FIGURE 8.1
AREAS PROPOSED TO BE DREDGED

Cardno

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Preliminary designs as at July 2004 (Source: Patterson Britton & Partners)

FIGURE 9.1
STAGE 2 ENTRANCE WORKS

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FIGURE 10.1
SCHEMATIC OF EXTENSION OF WINDANG BRIDGE

J1905/Figures V12/Fig 10.1 - Extension of Bridge.cdr

Source: WBM Oceanic Australia (2003)

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FIGURE 11.1
SCHEMATIC OF CULVERTS UNDER WINDANG BRIDGE
J1905/Figures V12 /Fig 11.1 - Culverts.cdr

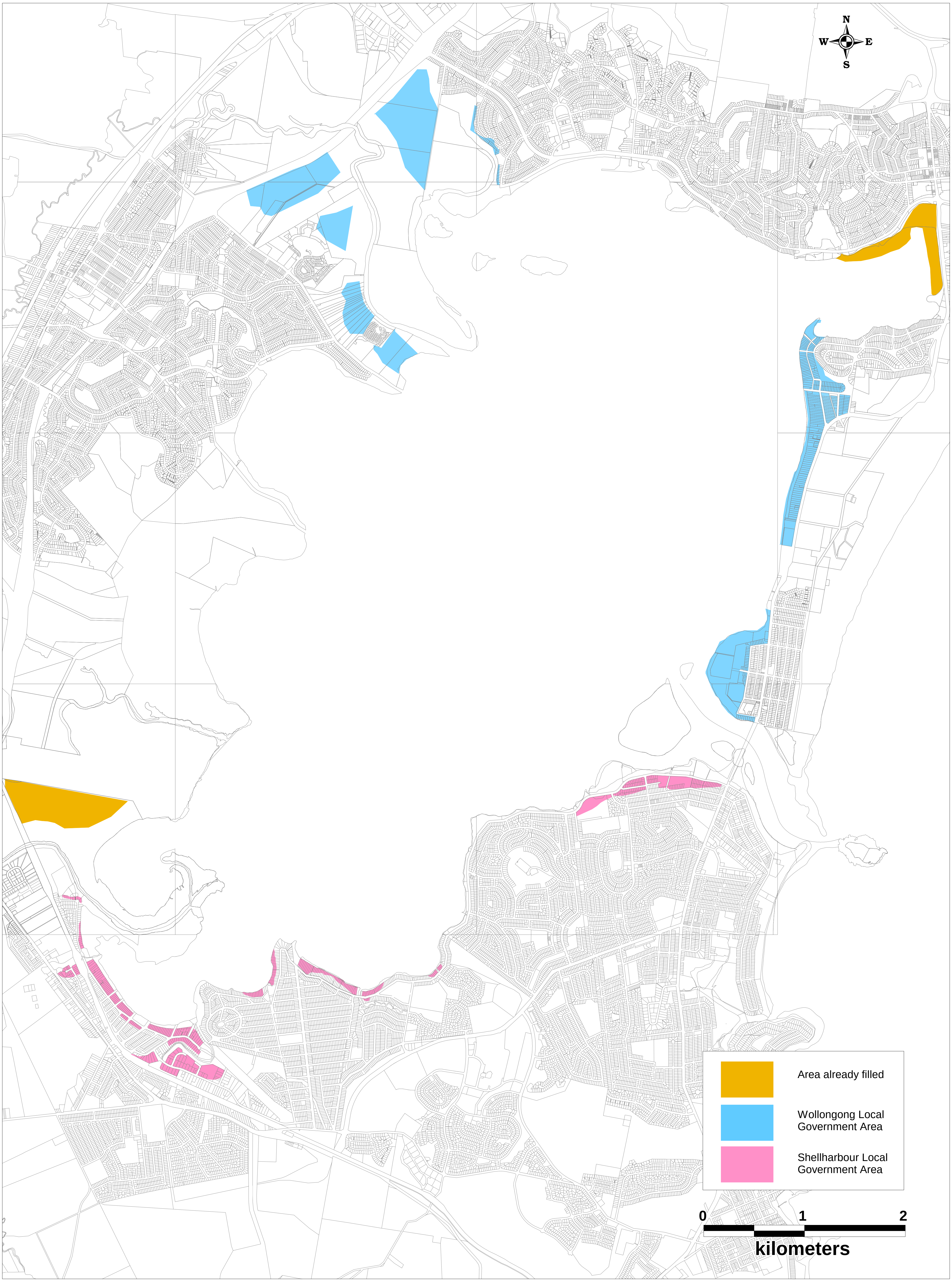

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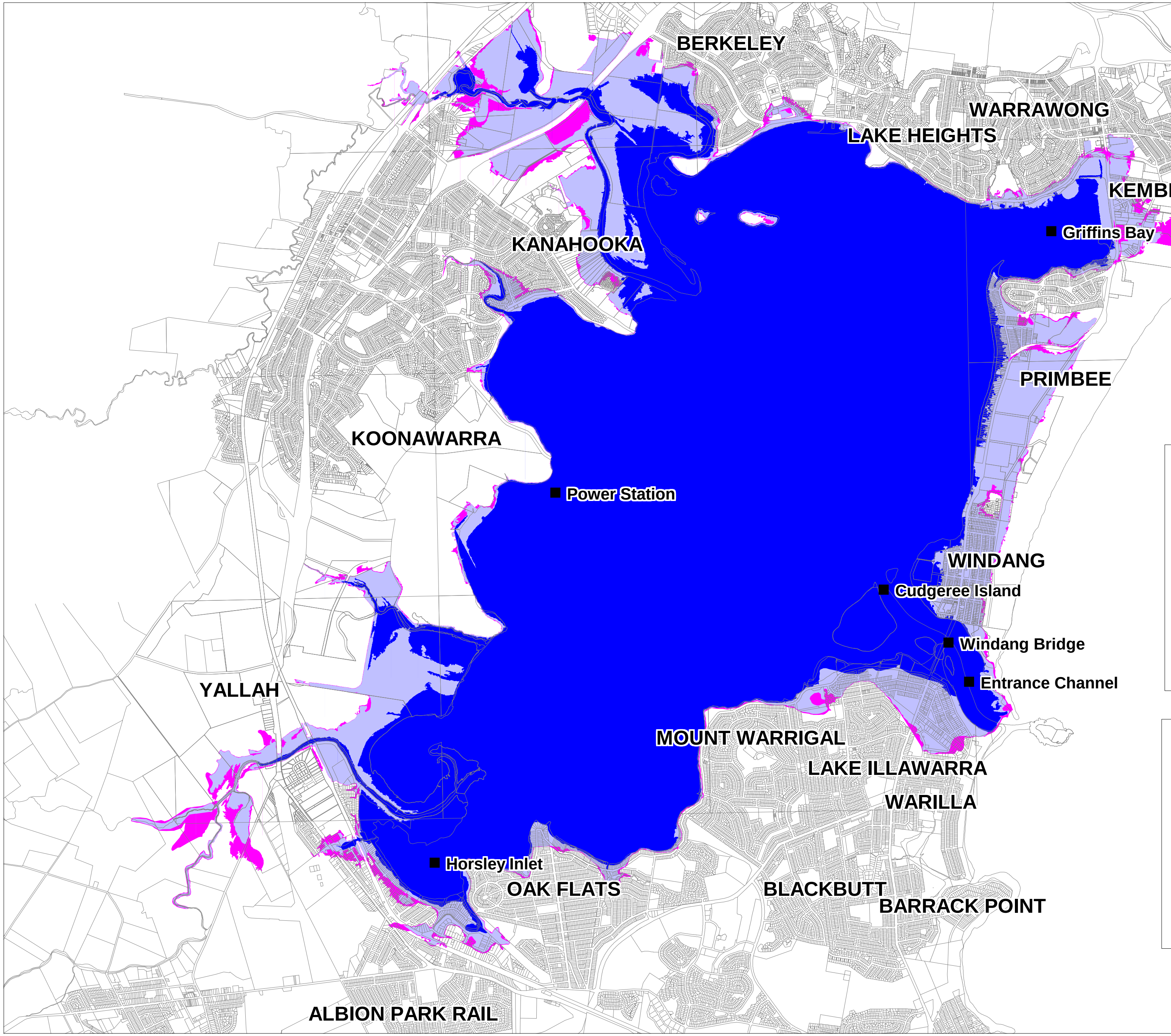
FIGURE 12.1
ACTUAL AND POTENTIAL FILL AREAS



NOTES:

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Flood extents not shown as a result of tributary flooding, see seperate flood studies for this information.

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FIGURE 13.1
FLOOD RISK PRECINCTS

J1905\Figures V12\Figure 13.1 - Flood Risk Precincts.Wor

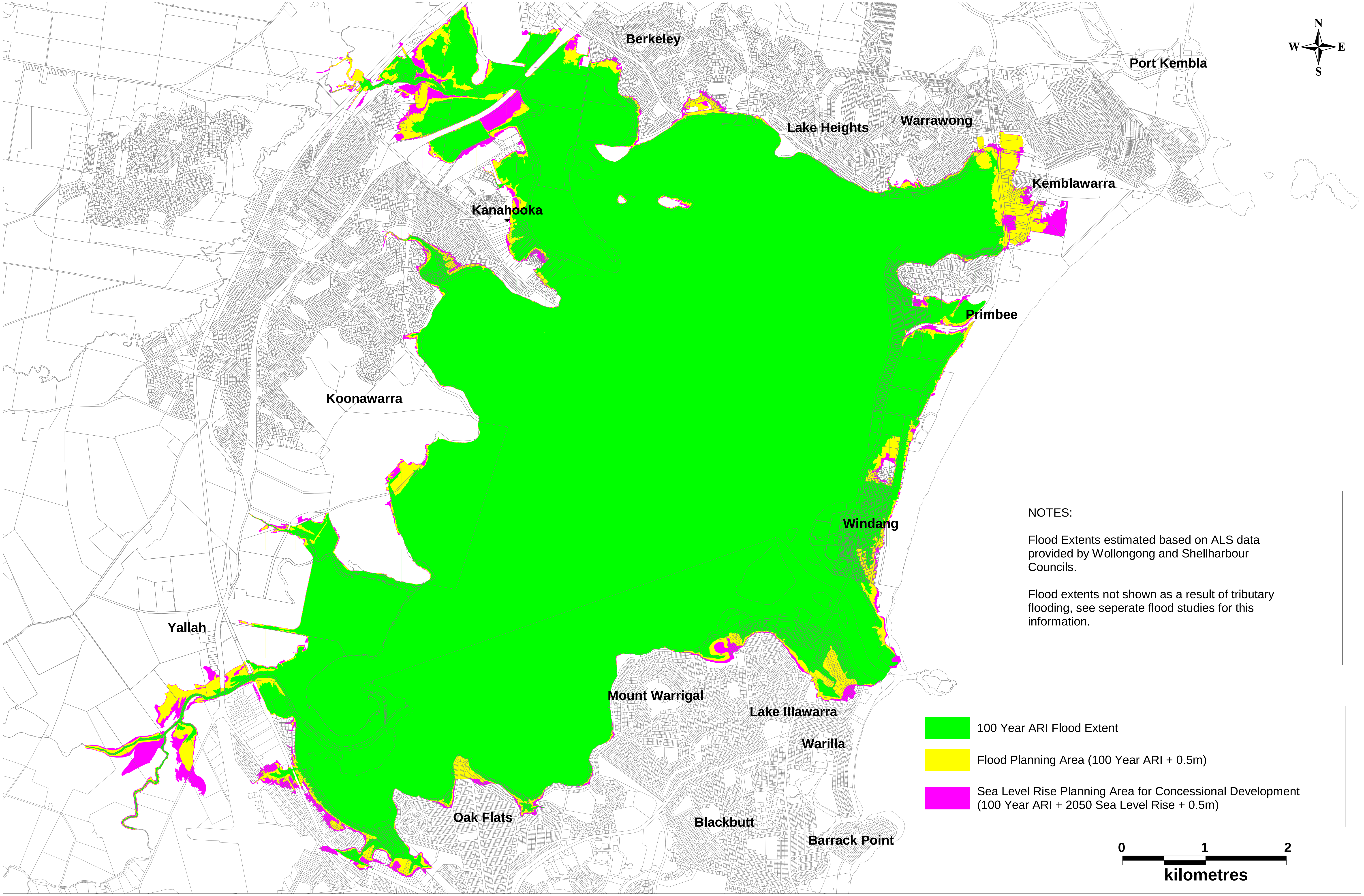

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FIGURE 13.2
SEA LEVEL RISE FLOOD PLANNING AREA - CONCESSIONAL DEVELOPMENT

J1905\Figures V12\Figure 13.2 - SLR Planning Area - Concessional.Wor

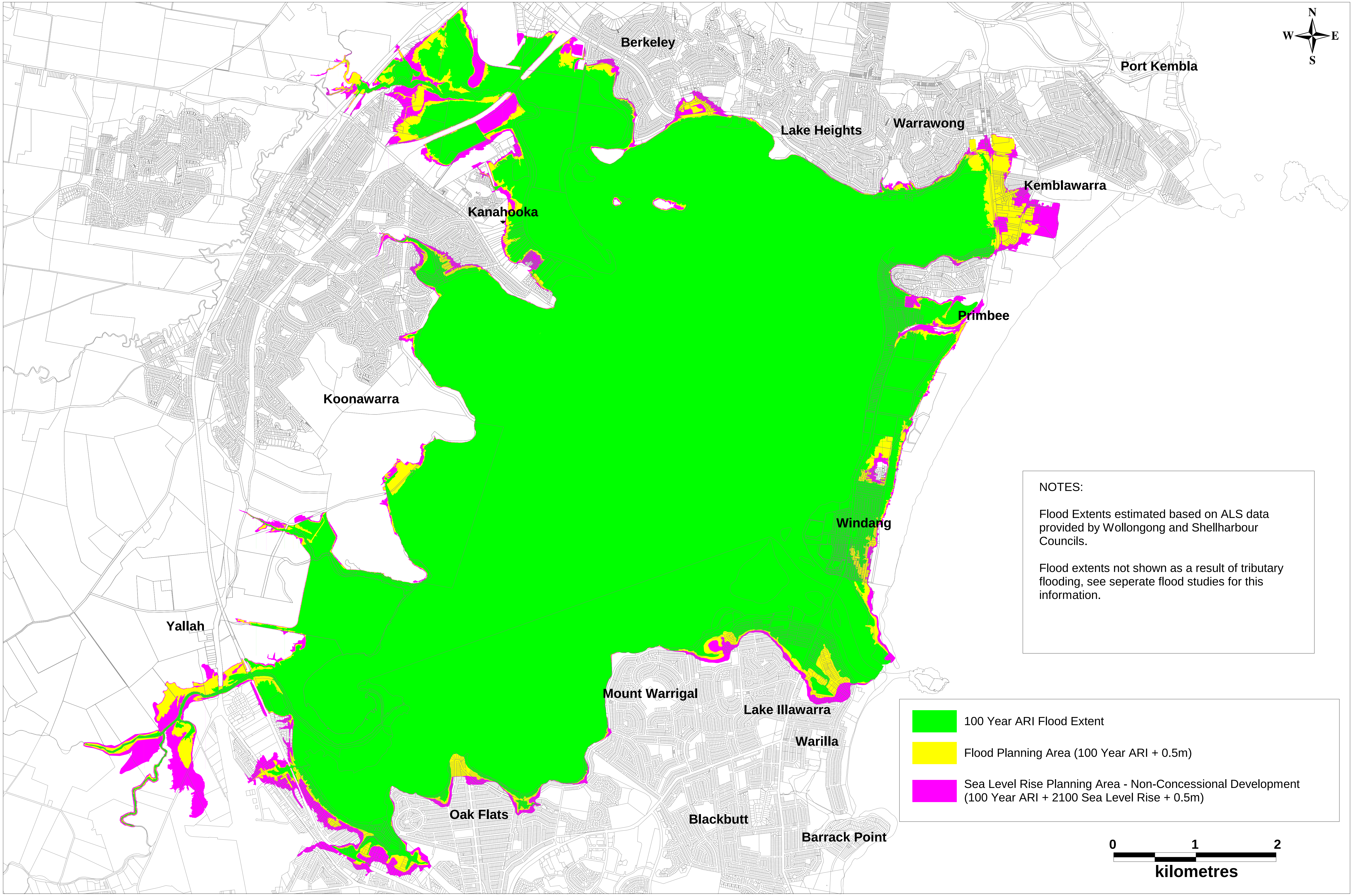

FIGURE 13.3
SEA LEVEL RISE FLOOD PLANNING AREA -
NON-CONCESSIONAL DEVELOPMENT

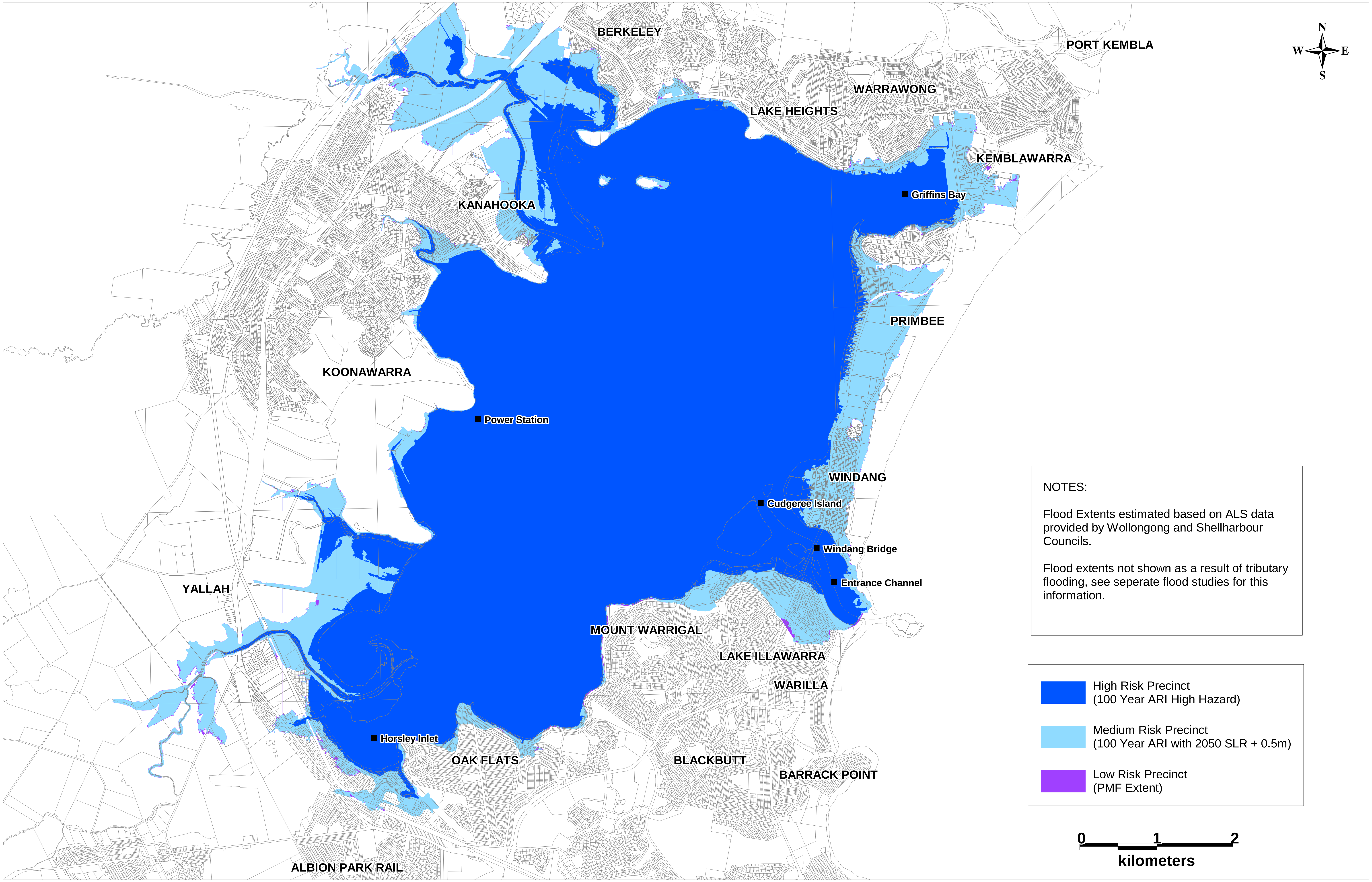

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FIGURE 13.4
FLOOD RISK PRECINCTS
WITH SEA LEVEL RISE - CONCESSIONAL DEVELOPMENT

J1905\Figures V12\Figure 13.4 - Flood Risk Precincts - SLR Concessional.Wor

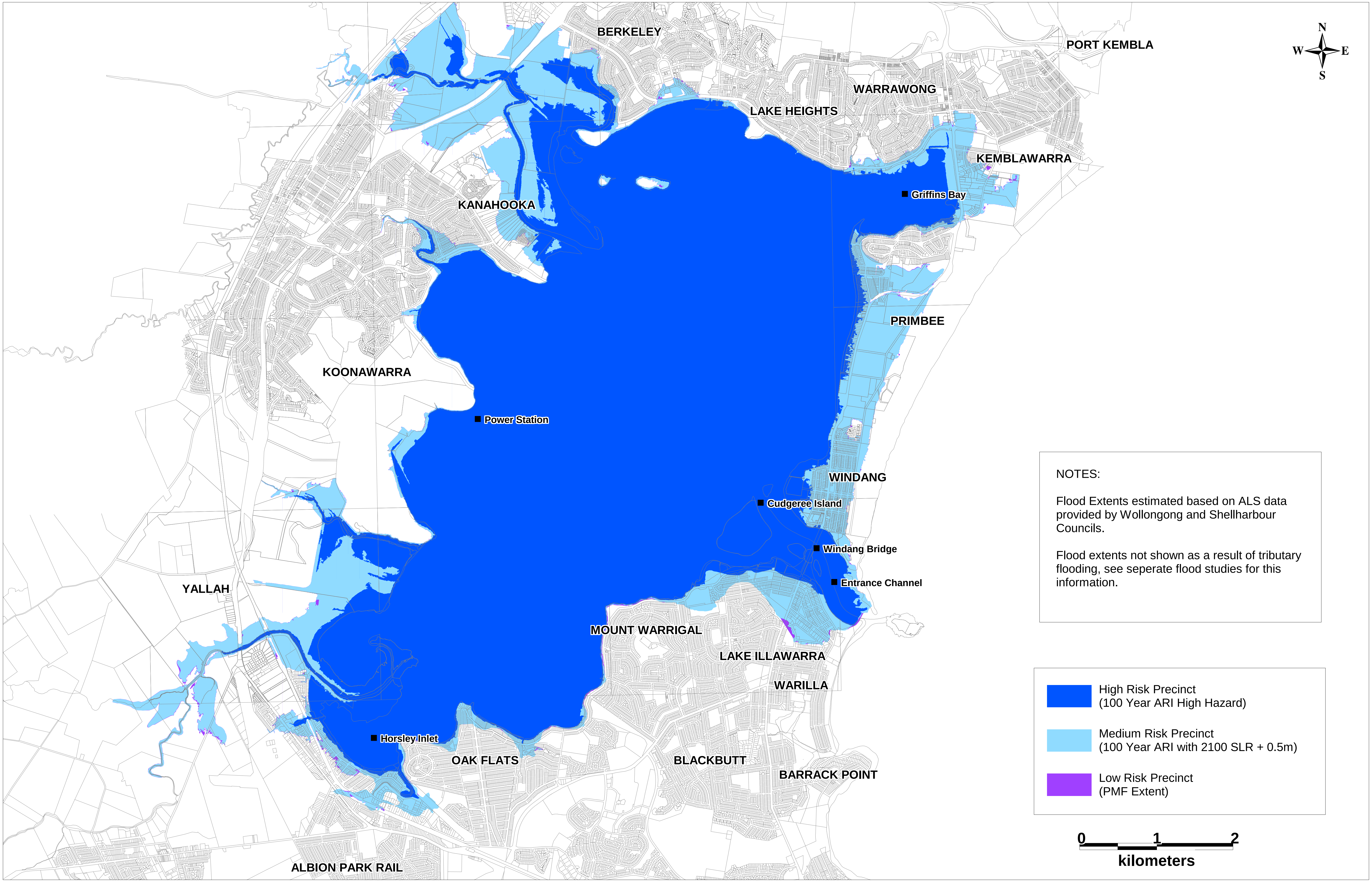

FIGURE 13.5
FLOOD RISK PRECINCTS
WITH SEA LEVEL RISE
- NON-CONCESSIONAL DEVELOPMENT

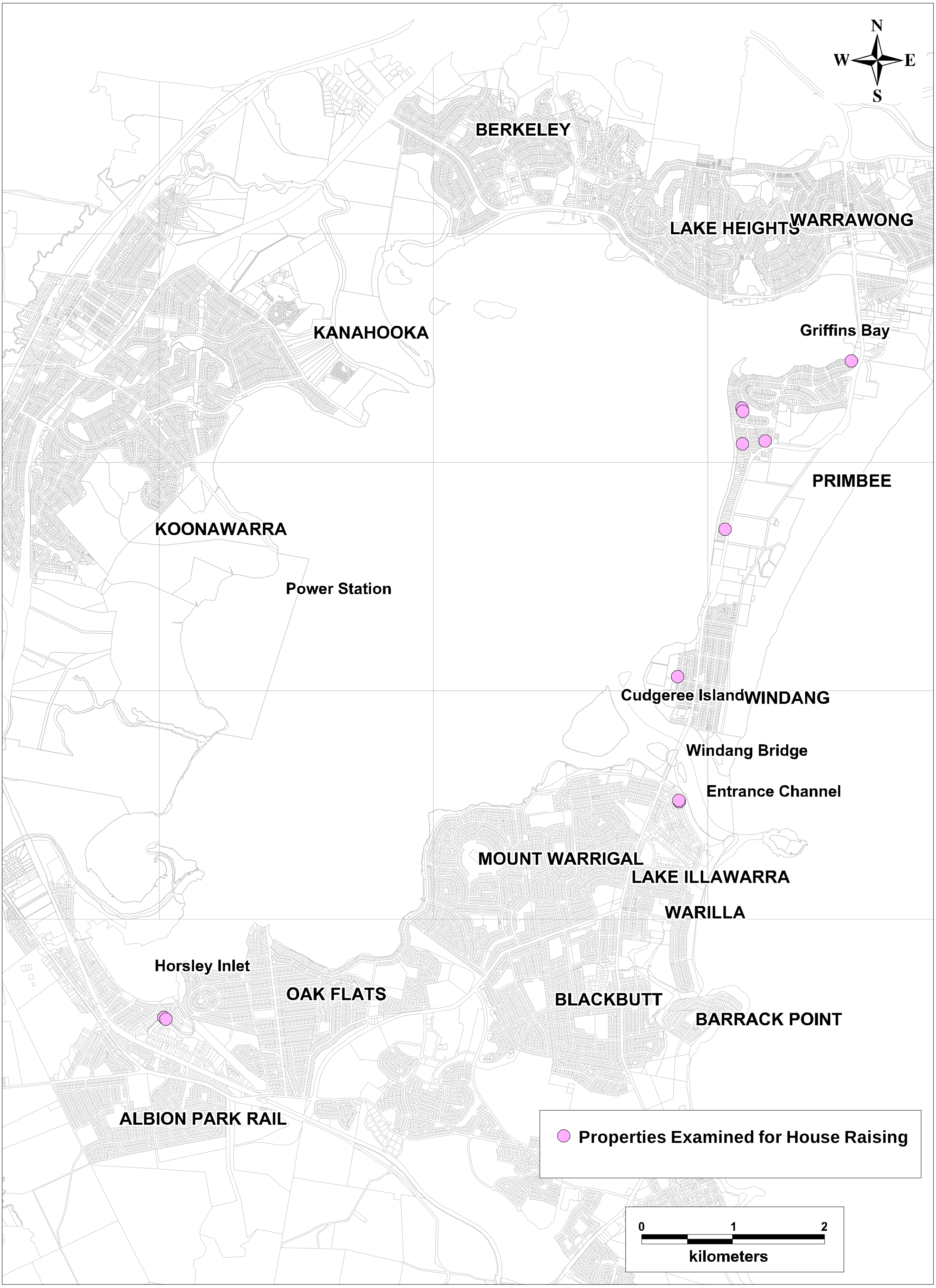

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FIGURE 13.6
PROPERTIES EXAMINED FOR HOUSE RAISING

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure 13.6 - House Raising.Wor

Appendix A

Historical Flood Photographs
Aerial Photographs


Berkeley Staff Gauge - 11/6/91


Griffins Bay reclamation, Corner of Northcliffe Dr & King St - 11/6/91

Berkeley Boat Harbour Fish Co-op - 11/6/91


Berkeley foreshore east of staff gauge - 11/6/91

Windang Rd, Opposite No 118 - 11/6/91

Berkeley Boat Harbour Car Park, West of Co-op - 11/6/91

Windang Rd, Port Kembla Golf Course Opposite No 56 - 11/6/91

Lake Illawarra Yacht Club - 11/6/91

FIGURE A2
HISTORICAL FLOOD PHOTOGRAPHS

Elevated Water Levels Reddall Reserve Foreshore Revetment - 11/6/91

Reclamation along Northcliffe Drive - 11/6/91

Entrance to Lake Illawarra Village Caravan Park - 11/6/91

Lake Illawarra Village Caravan Park, Shellharbour Rd - 11/6/91

Inundation of Windang Rd and Residential Areas - 11/6/91

Inundation of Windang Road - 11/6/91

Inundation of Windang Road - 11/6/91

Inundation of Foreshore Parking Areas, Berkeley Boat Harbour - 11/6/91

Inundation of Windang Road - 11/6/91

Inundation of Foreshore Areas, Windang Primary School - 11/6/91

Inundation of Foreshore Areas, Illawarra Yacht Club - 11/6/91

Inundation of Foreshore Areas, Judboole Parade - 11/6/91

Inundation of Windang Road and Boronia Ave - 11/6/91

Looking at Lake Foreshore East from Windang Bridge - 11/6/91

Looking East to Windang Bridge - 11/6/91

Inundation of Oaklands Village Caravan Park Areas - 11/6/91

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January 2012

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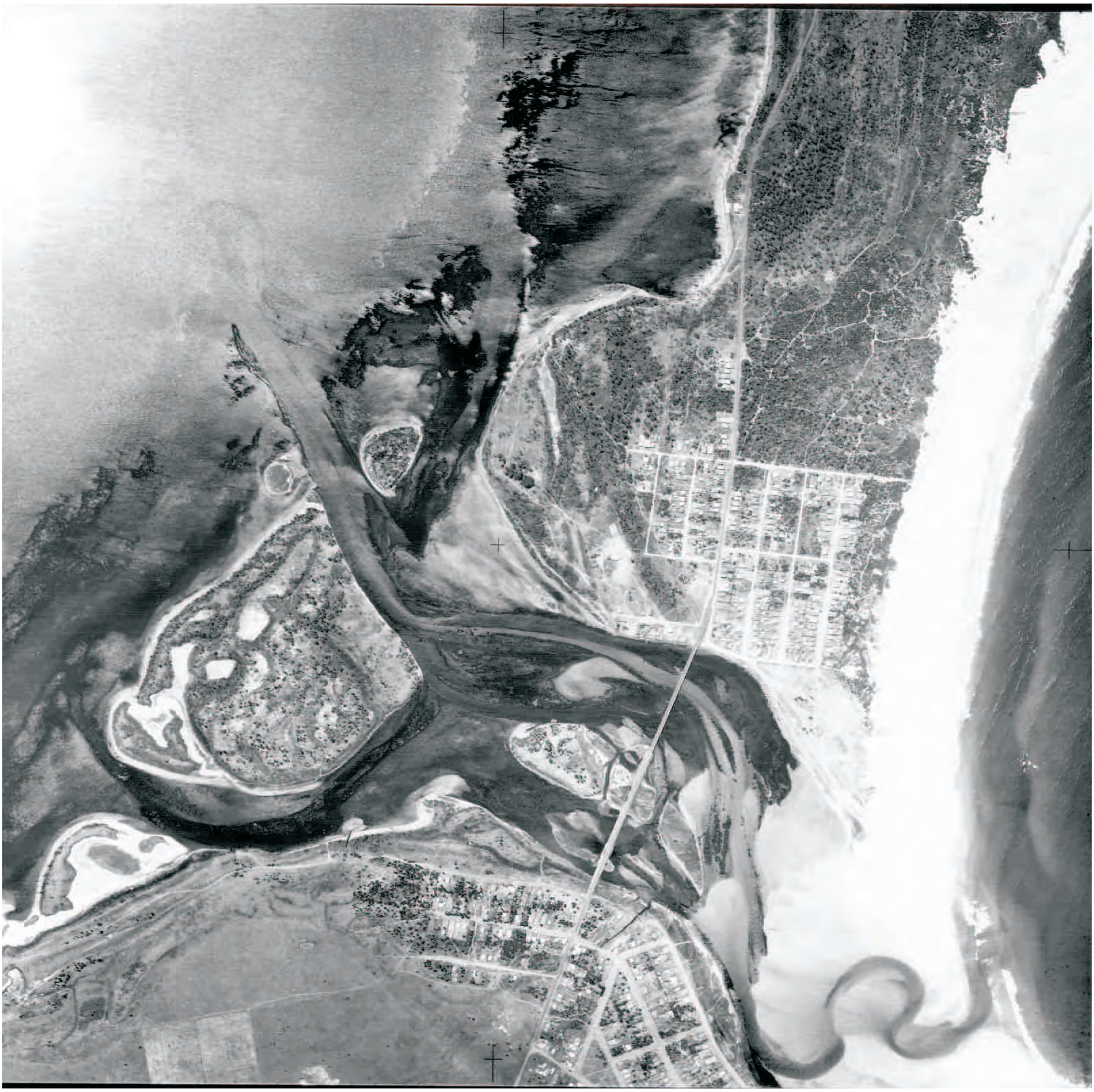
FIGURE A6
HISTORICAL FLOOD PHOTOGRAPHS
J1905/Appendices V12/Appendix A.cdr



23 October 1948

June 1949

4 June 1969

9 March 1988

22 June 2001

Appendix B

Modelling Results for Option B – Modifications to Windang Bridge

OPTION-B

Existing Conditions		Option B1-a, 100 m bridge Widening			Option B2, 350 m bridge Widening		
	Max WL (mAHD)		Max WL	Diff		Max WL	Diff
LAKE-SOUTH 0.00	2.30	LAKE-SOUTH 0.00	2.29	-0.01	LAKE-SOUTH 0.00	2.25	-0.05
LAKE-SOUTH 1500.00	2.30	LAKE-SOUTH 1500.00	2.29	-0.01	LAKE-SOUTH 1500.00	2.25	-0.05
LAKE-SOUTH 2800.00	2.30	LAKE-SOUTH 2800.00	2.29	-0.01	LAKE-SOUTH 2800.00	2.25	-0.05
LAKE-SOUTH 2800.00	2.30	LAKE-SOUTH 2800.00	2.29	-0.01	LAKE-SOUTH 2800.00	2.25	-0.05
LAKE-SOUTH 3800.00	2.30	LAKE-SOUTH 3800.00	2.29	-0.01	LAKE-SOUTH 3800.00	2.24	-0.06
LAKE-SOUTH 3800.00	2.30	LAKE-SOUTH 3800.00	2.29	-0.01	LAKE-SOUTH 3800.00	2.24	-0.06
LAKE-SOUTH 4300.00	2.29	LAKE-SOUTH 4300.00	2.28	-0.01	LAKE-SOUTH 4300.00	2.23	-0.06
LAKE-MIDDLE 0.00	2.30	LAKE-MIDDLE 0.00	2.29	-0.01	LAKE-MIDDLE 0.00	2.25	-0.05
LAKE-MIDDLE 1200.00	2.30	LAKE-MIDDLE 1200.00	2.29	-0.01	LAKE-MIDDLE 1200.00	2.25	-0.05
LAKE-MIDDLE 2200.00	2.30	LAKE-MIDDLE 2200.00	2.29	-0.01	LAKE-MIDDLE 2200.00	2.25	-0.05
LAKE-MIDDLE 2200.00	2.30	LAKE-MIDDLE 2200.00	2.29	-0.01	LAKE-MIDDLE 2200.00	2.25	-0.05
LAKE-MIDDLE 3100.00	2.30	LAKE-MIDDLE 3100.00	2.29	-0.01	LAKE-MIDDLE 3100.00	2.24	-0.06
LAKE-MIDDLE 3100.00	2.30	LAKE-MIDDLE 3100.00	2.29	-0.01	LAKE-MIDDLE 3100.00	2.24	-0.06
LAKE-MIDDLE 3500.00	2.30	LAKE-MIDDLE 3500.00	2.29	-0.01	LAKE-MIDDLE 3500.00	2.24	-0.06
LAKE-MIDDLE 3800.00	2.28	LAKE-MIDDLE 3800.00	2.27	-0.01	LAKE-MIDDLE 3800.00	2.22	-0.06
LAKE-MIDDLE 3920.00	2.26	LAKE-MIDDLE 3920.00	2.24	-0.02	LAKE-MIDDLE 3920.00	2.19	-0.07
LAKE-NORTH 0.00	2.30	LAKE-NORTH 0.00	2.29	-0.01	LAKE-NORTH 0.00	2.25	-0.05
LAKE-NORTH 1000.00	2.30	LAKE-NORTH 1000.00	2.29	-0.01	LAKE-NORTH 1000.00	2.25	-0.05
LAKE-NORTH 1000.00	2.30	LAKE-NORTH 1000.00	2.29	-0.01	LAKE-NORTH 1000.00	2.25	-0.05
LAKE-NORTH 2300.00	2.30	LAKE-NORTH 2300.00	2.29	-0.01	LAKE-NORTH 2300.00	2.25	-0.05
LAKE-NORTH 2300.00	2.30	LAKE-NORTH 2300.00	2.29	-0.01	LAKE-NORTH 2300.00	2.25	-0.05
LAKE-NORTH 3300.00	2.30	LAKE-NORTH 3300.00	2.29	-0.01	LAKE-NORTH 3300.00	2.24	-0.06
GRIFFIN_BAY 1300.00	2.30	GRIFFIN_BAY 1300.00	2.29	-0.01	GRIFFIN_BAY 1300.00	2.25	-0.05
GRIFFIN_BAY 1840.00	2.30	GRIFFIN_BAY 1840.00	2.29	-0.01	GRIFFIN_BAY 1840.00	2.25	-0.05
GRIFFIN_BAY 2500.00	2.30	GRIFFIN_BAY 2500.00	2.29	-0.01	GRIFFIN_BAY 2500.00	2.25	-0.05
GRIFFIN_BAY 2890.00	2.30	GRIFFIN_BAY 2890.00	2.29	-0.01	GRIFFIN_BAY 2890.00	2.25	-0.05
GRIFFIN_BAY 2910.00	0.60	GRIFFIN_BAY 2910.00	0.60	0.00	GRIFFIN_BAY 2910.00	0.60	0.00
GRIFFIN_BAY 3950.00	0.60	GRIFFIN_BAY 3950.00	0.60	0.00	GRIFFIN_BAY 3950.00	0.60	0.00
LAKE-NORTH 3300.00	2.30	LAKE-NORTH 3300.00	2.29	-0.01	LAKE-NORTH 3300.00	2.24	-0.06
LAKE-NORTH 4200.00	2.29	LAKE-NORTH 4200.00	2.27	-0.02	LAKE-NORTH 4200.00	2.23	-0.06
LAKE-NORTH 4320.00	2.27	LAKE-NORTH 4320.00	2.26	-0.01	LAKE-NORTH 4320.00	2.21	-0.06
LAKE-NORTH 4420.00	2.26	LAKE-NORTH 4420.00	2.24	-0.02	LAKE-NORTH 4420.00	2.19	-0.07
BEVANS 0.00	2.29	BEVANS 0.00	2.28	-0.01	BEVANS 0.00	2.23	-0.06
BEVANS 210.00	2.27	BEVANS 210.00	2.26	-0.01	BEVANS 210.00	2.21	-0.06
BEVANS 390.00	2.25	BEVANS 390.00	2.24	-0.01	BEVANS 390.00	2.18	-0.07
BEVANS 610.00	2.23	BEVANS 610.00	2.22	-0.01	BEVANS 610.00	2.16	-0.07
BEVANS 780.00	2.22	BEVANS 780.00	2.21	-0.01	BEVANS 780.00	2.14	-0.08
BEVANS 780.00	2.22	BEVANS 780.00	2.21	-0.01	BEVANS 780.00	2.14	-0.08
BEVANS 880.00	2.22	BEVANS 880.00	2.21	-0.01	BEVANS 880.00	2.14	-0.08
CHANNEL1 0.00	2.26	CHANNEL1 0.00	2.24	-0.02	CHANNEL1 0.00	2.19	-0.07
CHANNEL1 100.00	2.24	CHANNEL1 100.00	2.23	-0.01	CHANNEL1 100.00	2.17	-0.07
CHANNEL1 190.00	2.23	CHANNEL1 190.00	2.21	-0.02	CHANNEL1 190.00	2.15	-0.08
CHANNEL1 290.00	2.22	CHANNEL1 290.00	2.21	-0.01	CHANNEL1 290.00	2.15	-0.07
CHANNEL-N 0.00	2.22	CHANNEL-N 0.00	2.21	-0.01	CHANNEL-N 0.00	2.15	-0.07
CHANNEL-N 130.00	2.22	CHANNEL-N 130.00	2.20	-0.02	CHANNEL-N 130.00	2.14	-0.08
CHANNEL-N 130.00	2.22	CHANNEL-N 130.00	2.20	-0.02	CHANNEL-N 130.00	2.14	-0.08
CHANNEL-N 330.00	2.16	CHANNEL-N 330.00	2.14	-0.02	CHANNEL-N 330.00	2.11	-0.05
CHANNEL-N 330.00	2.16	CHANNEL-N 330.00	2.14	-0.02	CHANNEL-N 330.00	2.11	-0.05
CHANNEL-N 450.00	2.07	CHANNEL-N 450.00	2.08	0.01	CHANNEL-N 450.00	2.09	0.02
CHANNEL-N 450.00	2.07	CHANNEL-N 450.00	2.08	0.01	CHANNEL-N 450.00	2.09	0.02
CHANNEL-N 540.00	2.07	CHANNEL-N 540.00	2.08	0.01	CHANNEL-N 540.00	2.09	0.02
CHANNEL-N 540.00	2.07	CHANNEL-N 540.00	2.08	0.01	CHANNEL-N 540.00	2.09	0.02
CHANNEL-N 640.00	2.07	CHANNEL-N 640.00	2.09	0.02	CHANNEL-N 640.00	2.09	0.02
CHANNEL-S 0.00	2.22	CHANNEL-S 0.00	2.21	-0.01	CHANNEL-S 0.00	2.15	-0.07
CHANNEL-S 130.00	2.22	CHANNEL-S 130.00	2.21	-0.01	CHANNEL-S 130.00	2.14	-0.08
CHANNEL-S 130.00	2.22	CHANNEL-S 130.00	2.21	-0.01	CHANNEL-S 130.00	2.14	-0.08
CHANNEL-S 340.00	2.17	CHANNEL-S 340.00	2.14	-0.03	CHANNEL-S 340.00	2.10	-0.07
CHANNEL-S 340.00	2.17	CHANNEL-S 340.00	2.14	-0.03	CHANNEL-S 340.00	2.10	-0.07
CHANNEL-S 450.00	2.12	CHANNEL-S 450.00	2.13	0.01	CHANNEL-S 450.00	2.10	-0.02

Existing Conditions		Option B1-a, 100 m bridge Widening			Option B2, 350 m bridge Widening		
	Max WL (mAHD)		Max WL	Diff		Max WL	Diff
CHANNEL-S 450.00	2.12	CHANNEL-S 450.00	2.13	0.01	CHANNEL-S 450.00	2.10	-0.02
CHANNEL-S 540.00	2.07	CHANNEL-S 540.00	2.09	0.02	CHANNEL-S 540.00	2.09	0.02
CHANNEL-S 540.00	2.07	CHANNEL-S 540.00	2.09	0.02	CHANNEL-S 540.00	2.09	0.02
CHANNEL-S 590.00	2.07	CHANNEL-S 590.00	2.09	0.02	CHANNEL-S 590.00	2.09	0.02
DES-40 0.00	2.07	DES-40 0.00	2.09	0.02	DES-40 0.00	2.09	0.02
DES-40 140.00	2.05	DES-40 140.00	2.06	0.01	DES-40 140.00	2.09	0.04
DES-40 400.00	1.99	DES-40 400.00	2.01	0.02	DES-40 400.00	2.09	0.10
DES-40 400.00	1.99	DES-40 400.00	2.01	0.02	DES-40 400.00	2.09	0.10
DES-40 800.00	1.48	DES-40 800.00	1.49	0.01	DES-40 800.00	1.56	0.08
DES-40 1600.00	0.60	DES-40 1600.00	0.60	0.00	DES-40 1600.00	0.60	0.00
DES-40 1600.00	0.60	DES-40 1600.00	0.60	0.00	DES-40 1600.00	0.60	0.00
DES-40 2000.00	0.60	DES-40 2000.00	0.60	0.00	DES-40 2000.00	0.60	0.00
PICNIC 0.00	2.22	PICNIC 0.00	2.21	-0.01	PICNIC 0.00	2.14	-0.08
PICNIC 130.00	2.22	PICNIC 130.00	2.20	-0.02	PICNIC 130.00	2.10	-0.12
PICNIC 250.00	2.21	PICNIC 250.00	2.19	-0.02	PICNIC 250.00	2.04	-0.17
PICNIC-CON 0.00	2.21	PICNIC-CON 0.00	2.19	-0.02	PICNIC-CON 0.00	2.04	-0.17
PICNIC-CON 50.00	2.28	PICNIC-CON 50.00	2.28	0.00	PICNIC-CON 50.00	2.10	-0.18
PICNIC-CON 120.00	2.12	PICNIC-CON 120.00	2.13	0.01	PICNIC-CON 120.00	2.10	-0.02
LAKECON1 0.00	2.30	LAKECON1 0.00	2.29	-0.01	LAKECON1 0.00	2.24	-0.06
LAKECON1 10.00	2.30	LAKECON1 10.00	2.29	-0.01	LAKECON1 10.00	2.24	-0.06
LAKECON2 0.00	2.30	LAKECON2 0.00	2.29	-0.01	LAKECON2 0.00	2.24	-0.06
LAKECON2 10.00	2.30	LAKECON2 10.00	2.29	-0.01	LAKECON2 10.00	2.24	-0.06
LAKECON3 0.00	2.30	LAKECON3 0.00	2.29	-0.01	LAKECON3 0.00	2.25	-0.05
LAKECON3 10.00	2.30	LAKECON3 10.00	2.29	-0.01	LAKECON3 10.00	2.25	-0.05
LAKECON4 0.00	2.30	LAKECON4 0.00	2.29	-0.01	LAKECON4 0.00	2.25	-0.05
LAKECON4 10.00	2.30	LAKECON4 10.00	2.29	-0.01	LAKECON4 10.00	2.25	-0.05
BERAGEREE 0.00	2.07	BERAGEREE 0.00	2.09	0.02	BERAGEREE 0.00	2.09	0.02
BERAGEREE 120.00	1.78	BERAGEREE 120.00	1.79	0.01	BERAGEREE 120.00	1.97	0.19
BERAGEREE 180.00	2.03	BERAGEREE 180.00	2.04	0.01	BERAGEREE 180.00	2.07	0.04
BERAGEREE 240.00	1.91	BERAGEREE 240.00	1.93	0.02	BERAGEREE 240.00	1.94	0.03
BERAGEREE 320.00	1.99	BERAGEREE 320.00	2.01	0.02	BERAGEREE 320.00	2.09	0.10
BRCH1-1P 0.00	2.07	BRCH1-1P 0.00	2.09	0.02	BRCH1-1P 0.00	2.09	0.02
BRCH1-1P 20.00	1.00	BRCH1-1P 20.00	1.01	0.01	BRCH1-1P 20.00	1.01	0.01
BRCH1-1P 1580.00	0.60	BRCH1-1P 1580.00	0.60	0.00	BRCH1-1P 1580.00	0.60	0.00
BRCH1-1P 1600.00	0.60	BRCH1-1P 1600.00	0.60	0.00	BRCH1-1P 1600.00	0.60	0.00
NS-CON1 0.00	2.22	NS-CON1 0.00	2.20	-0.02	NS-CON1 0.00	2.14	-0.08
NS-CON1 20.00	2.22	NS-CON1 20.00	2.21	-0.01	NS-CON1 20.00	2.14	-0.08
NS-CON2 0.00	2.16	NS-CON2 0.00	2.14	-0.02	NS-CON2 0.00	2.11	-0.05
NS-CON2 20.00	2.17	NS-CON2 20.00	2.14	-0.03	NS-CON2 20.00	2.10	-0.07
NS-CON3 0.00	2.07	NS-CON3 0.00	2.08	0.01	NS-CON3 0.00	2.09	0.02
NS-CON3 20.00	2.12	NS-CON3 20.00	2.13	0.01	NS-CON3 20.00	2.10	-0.02
NS-CON4 0.00	2.07	NS-CON4 0.00	2.08	0.01	NS-CON4 0.00	2.09	0.02
NS-CON4 20.00	2.07	NS-CON4 20.00	2.09	0.02	NS-CON4 20.00	2.09	0.02
		BRDG-CON1 0.00			BRDG-CON1 0.00	2.10	
		BRDG-CON1 100.00			BRDG-CON1 100.00	2.07	
		BRDG-CON2 0.00			BRDG-CON2 0.00	2.04	
		BRDG-CON2 200.00			BRDG-CON2 200.00	1.94	

Appendix C

Modelling Results for Option C – Culverts under Windang Bridge

OPTION-C

Existing Conditions	Max WL (mAHD)	Option C1, 20 culverts	Max WL	Diff	Option C2, 40 culverts	Max WL	Diff	Diff b/w C1 and C2
LAKE-SOUTH 0.00	2.30	LAKE-SOUTH 0.00	2.27	-0.03	LAKE-SOUTH 0.00	2.26	-0.04	-0.01
LAKE-SOUTH 1500.00	2.30	LAKE-SOUTH 1500.00	2.27	-0.03	LAKE-SOUTH 1500.00	2.26	-0.04	-0.01
LAKE-SOUTH 2800.00	2.30	LAKE-SOUTH 2800.00	2.27	-0.03	LAKE-SOUTH 2800.00	2.26	-0.04	-0.01
LAKE-SOUTH 2800.00	2.30	LAKE-SOUTH 2800.00	2.27	-0.03	LAKE-SOUTH 2800.00	2.26	-0.04	-0.01
LAKE-SOUTH 3800.00	2.30	LAKE-SOUTH 3800.00	2.27	-0.03	LAKE-SOUTH 3800.00	2.26	-0.04	-0.01
LAKE-SOUTH 3800.00	2.30	LAKE-SOUTH 3800.00	2.27	-0.03	LAKE-SOUTH 3800.00	2.26	-0.04	-0.01
LAKE-SOUTH 4300.00	2.29	LAKE-SOUTH 4300.00	2.26	-0.03	LAKE-SOUTH 4300.00	2.25	-0.04	-0.01
LAKE-MIDDLE 0.00	2.30	LAKE-MIDDLE 0.00	2.27	-0.03	LAKE-MIDDLE 0.00	2.26	-0.04	-0.01
LAKE-MIDDLE 1200.00	2.30	LAKE-MIDDLE 1200.00	2.27	-0.03	LAKE-MIDDLE 1200.00	2.26	-0.04	-0.01
LAKE-MIDDLE 2200.00	2.30	LAKE-MIDDLE 2200.00	2.27	-0.03	LAKE-MIDDLE 2200.00	2.26	-0.04	-0.01
LAKE-MIDDLE 2200.00	2.30	LAKE-MIDDLE 2200.00	2.27	-0.03	LAKE-MIDDLE 2200.00	2.26	-0.04	-0.01
LAKE-MIDDLE 3100.00	2.30	LAKE-MIDDLE 3100.00	2.27	-0.03	LAKE-MIDDLE 3100.00	2.26	-0.04	-0.01
LAKE-MIDDLE 3100.00	2.30	LAKE-MIDDLE 3100.00	2.27	-0.03	LAKE-MIDDLE 3100.00	2.26	-0.04	-0.01
LAKE-MIDDLE 3500.00	2.30	LAKE-MIDDLE 3500.00	2.27	-0.03	LAKE-MIDDLE 3500.00	2.25	-0.05	-0.02
LAKE-MIDDLE 3800.00	2.28	LAKE-MIDDLE 3800.00	2.24	-0.04	LAKE-MIDDLE 3800.00	2.23	-0.05	-0.01
LAKE-MIDDLE 3920.00	2.26	LAKE-MIDDLE 3920.00	2.22	-0.04	LAKE-MIDDLE 3920.00	2.20	-0.06	-0.02
LAKE-NORTH 0.00	2.30	LAKE-NORTH 0.00	2.27	-0.03	LAKE-NORTH 0.00	2.26	-0.04	-0.01
LAKE-NORTH 1000.00	2.30	LAKE-NORTH 1000.00	2.27	-0.03	LAKE-NORTH 1000.00	2.26	-0.04	-0.01
LAKE-NORTH 1000.00	2.30	LAKE-NORTH 1000.00	2.27	-0.03	LAKE-NORTH 1000.00	2.26	-0.04	-0.01
LAKE-NORTH 2300.00	2.30	LAKE-NORTH 2300.00	2.27	-0.03	LAKE-NORTH 2300.00	2.26	-0.04	-0.01
LAKE-NORTH 2300.00	2.30	LAKE-NORTH 2300.00	2.27	-0.03	LAKE-NORTH 2300.00	2.26	-0.04	-0.01
LAKE-NORTH 3300.00	2.30	LAKE-NORTH 3300.00	2.27	-0.03	LAKE-NORTH 3300.00	2.26	-0.04	-0.01
GRIFFIN_BAY 1300.00	2.30	GRIFFIN_BAY 1300.00	2.27	-0.03	GRIFFIN_BAY 1300.00	2.26	-0.04	-0.01
GRIFFIN_BAY 1840.00	2.30	GRIFFIN_BAY 1840.00	2.27	-0.03	GRIFFIN_BAY 1840.00	2.26	-0.04	-0.01
GRIFFIN_BAY 2500.00	2.30	GRIFFIN_BAY 2500.00	2.27	-0.03	GRIFFIN_BAY 2500.00	2.26	-0.04	-0.01
GRIFFIN_BAY 2890.00	2.30	GRIFFIN_BAY 2890.00	2.27	-0.03	GRIFFIN_BAY 2890.00	2.26	-0.04	-0.01
GRIFFIN_BAY 2910.00	0.60	GRIFFIN_BAY 2910.00	0.60	0.00	GRIFFIN_BAY 2910.00	0.60	0.00	0.00
GRIFFIN_BAY 3950.00	0.60	GRIFFIN_BAY 3950.00	0.60	0.00	GRIFFIN_BAY 3950.00	0.60	0.00	0.00
LAKE-NORTH 3300.00	2.30	LAKE-NORTH 3300.00	2.27	-0.03	LAKE-NORTH 3300.00	2.26	-0.04	-0.01
LAKE-NORTH 4200.00	2.29	LAKE-NORTH 4200.00	2.25	-0.04	LAKE-NORTH 4200.00	2.24	-0.05	-0.01
LAKE-NORTH 4320.00	2.27	LAKE-NORTH 4320.00	2.23	-0.04	LAKE-NORTH 4320.00	2.22	-0.05	-0.01
LAKE-NORTH 4420.00	2.26	LAKE-NORTH 4420.00	2.22	-0.04	LAKE-NORTH 4420.00	2.20	-0.06	-0.02
BEVANS 0.00	2.29	BEVANS 0.00	2.26	-0.03	BEVANS 0.00	2.25	-0.04	-0.01
BEVANS 210.00	2.27	BEVANS 210.00	2.23	-0.04	BEVANS 210.00	2.22	-0.05	-0.01
BEVANS 390.00	2.25	BEVANS 390.00	2.21	-0.04	BEVANS 390.00	2.19	-0.06	-0.02
BEVANS 610.00	2.23	BEVANS 610.00	2.19	-0.04	BEVANS 610.00	2.17	-0.06	-0.02
BEVANS 780.00	2.22	BEVANS 780.00	2.17	-0.05	BEVANS 780.00	2.15	-0.07	-0.02
BEVANS 780.00	2.22	BEVANS 780.00	2.17	-0.05	BEVANS 780.00	2.15	-0.07	-0.02
BEVANS 880.00	2.22	BEVANS 880.00	2.17	-0.05	BEVANS 880.00	2.15	-0.07	-0.02
CHANNEL1 0.00	2.26	CHANNEL1 0.00	2.22	-0.04	CHANNEL1 0.00	2.20	-0.06	-0.02
CHANNEL1 100.00	2.24	CHANNEL1 100.00	2.20	-0.04	CHANNEL1 100.00	2.18	-0.06	-0.02
CHANNEL1 190.00	2.23	CHANNEL1 190.00	2.18	-0.05	CHANNEL1 190.00	2.17	-0.06	-0.01
CHANNEL1 290.00	2.22	CHANNEL1 290.00	2.18	-0.04	CHANNEL1 290.00	2.16	-0.06	-0.02
CHANNEL-N 0.00	2.22	CHANNEL-N 0.00	2.18	-0.04	CHANNEL-N 0.00	2.16	-0.06	-0.02
CHANNEL-N 130.00	2.22	CHANNEL-N 130.00	2.17	-0.05	CHANNEL-N 130.00	2.15	-0.07	-0.02
CHANNEL-N 130.00	2.22	CHANNEL-N 130.00	2.17	-0.05	CHANNEL-N 130.00	2.15	-0.07	-0.02
CHANNEL-N 330.00	2.16	CHANNEL-N 330.00	2.13	-0.03	CHANNEL-N 330.00	2.12	-0.04	-0.01
CHANNEL-N 330.00	2.16	CHANNEL-N 330.00	2.13	-0.03	CHANNEL-N 330.00	2.12	-0.04	-0.01
CHANNEL-N 450.00	2.07	CHANNEL-N 450.00	2.07	0.00	CHANNEL-N 450.00	2.08	0.01	0.01
CHANNEL-N 450.00	2.07	CHANNEL-N 450.00	2.07	0.00	CHANNEL-N 450.00	2.08	0.01	0.01
CHANNEL-N 540.00	2.07	CHANNEL-N 540.00	2.07	0.00	CHANNEL-N 540.00	2.08	0.01	0.01
CHANNEL-N 540.00	2.07	CHANNEL-N 540.00	2.07	0.00	CHANNEL-N 540.00	2.08	0.01	0.01
CHANNEL-N 640.00	2.07	CHANNEL-N 640.00	2.07	0.00	CHANNEL-N 640.00	2.08	0.01	0.01
CHANNEL-S 0.00	2.22	CHANNEL-S 0.00	2.18	-0.04	CHANNEL-S 0.00	2.16	-0.06	-0.02
CHANNEL-S 130.00	2.22	CHANNEL-S 130.00	2.17	-0.05	CHANNEL-S 130.00	2.15	-0.07	-0.02
CHANNEL-S 130.00	2.22	CHANNEL-S 130.00	2.17	-0.05	CHANNEL-S 130.00	2.15	-0.07	-0.02
CHANNEL-S 340.00	2.17	CHANNEL-S 340.00	2.13	-0.04	CHANNEL-S 340.00	2.12	-0.05	-0.01
CHANNEL-S 340.00	2.17	CHANNEL-S 340.00	2.13	-0.04	CHANNEL-S 340.00	2.12	-0.05	-0.01
CHANNEL-S 450.00	2.12	CHANNEL-S 450.00	2.10	-0.02	CHANNEL-S 450.00	2.10	-0.02	0.00
CHANNEL-S 450.00	2.12	CHANNEL-S 450.00	2.10	-0.02	CHANNEL-S 450.00	2.10	-0.02	0.00
CHANNEL-S 540.00	2.07	CHANNEL-S 540.00	2.07	0.00	CHANNEL-S 540.00	2.08	0.01	0.01
CHANNEL-S 540.00	2.07	CHANNEL-S 540.00	2.07	0.00	CHANNEL-S 540.00	2.08	0.01	0.01
CHANNEL-S 590.00	2.07	CHANNEL-S 590.00	2.07	0.00	CHANNEL-S 590.00	2.08	0.01	0.01
DES-40 0.00	2.07	DES-40 0.00	2.07	0.00	DES-40 0.00	2.08	0.01	0.01
DES-40 140.00	2.05	DES-40 140.00	2.07	0.02	DES-40 140.00	2.08	0.03	0.01

Existing Conditions	
	Max WL (mAHD)
DES-40 400.00	1.99
DES-40 400.00	1.99
DES-40 800.00	1.48
DES-40 1600.00	0.60
DES-40 1600.00	0.60
DES-40 2000.00	0.60
PICNIC 0.00	2.22
PICNIC 130.00	2.22
PICNIC 250.00	2.21
PICNIC-CON 0.00	2.21
PICNIC-CON 50.00	2.28
PICNIC-CON 120.00	2.12
LAKECON1 0.00	2.30
LAKECON1 10.00	2.30
LAKECON2 0.00	2.30
LAKECON2 10.00	2.30
LAKECON3 0.00	2.30
LAKECON3 10.00	2.30
LAKECON4 0.00	2.30
LAKECON4 10.00	2.30
BERAGEREE 0.00	2.07
BERAGEREE 120.00	1.78
BERAGEREE 180.00	2.03
BERAGEREE 240.00	1.91
BERAGEREE 320.00	1.99
BRCH1-1P 0.00	2.07
BRCH1-1P 20.00	1.00
BRCH1-1P 1580.00	0.60
BRCH1-1P 1600.00	0.60
NS-CON1 0.00	2.22
NS-CON1 20.00	2.22
NS-CON2 0.00	2.16
NS-CON2 20.00	2.17
NS-CON3 0.00	2.07
NS-CON3 20.00	2.12
NS-CON4 0.00	2.07
NS-CON4 20.00	2.07

Option C1, 20 culverts		
	Max WL	Diff
DES-40 400.00	2.06	0.07
DES-40 400.00	2.06	0.07
DES-40 800.00	1.53	0.05
DES-40 1600.00	0.60	0.00
DES-40 1600.00	0.60	0.00
DES-40 2000.00	0.60	0.00
PICNIC 0.00	2.17	-0.05
PICNIC 130.00	2.15	-0.07
PICNIC 250.00	2.11	-0.10
PICNIC-CON 0.00	2.11	-0.10
PICNIC-CON 50.00	2.23	-0.05
PICNIC-CON 120.00	2.10	-0.02
LAKECON1 0.00	2.27	-0.03
LAKECON1 10.00	2.27	-0.03
LAKECON2 0.00	2.27	-0.03
LAKECON2 10.00	2.27	-0.03
LAKECON3 0.00	2.27	-0.03
LAKECON3 10.00	2.27	-0.03
LAKECON4 0.00	2.27	-0.03
LAKECON4 10.00	2.27	-0.03
BERAGEREE 0.00	2.07	0.00
BERAGEREE 120.00	1.77	-0.01
BERAGEREE 180.00	2.02	-0.01
BERAGEREE 240.00	1.90	-0.01
BERAGEREE 320.00	2.06	0.07
BRCH1-1P 0.00	2.07	0.00
BRCH1-1P 20.00	1.00	0.00
BRCH1-1P 1580.00	0.60	0.00
BRCH1-1P 1600.00	0.60	0.00
NS-CON1 0.00	2.17	-0.05
NS-CON1 20.00	2.17	-0.05
NS-CON2 0.00	2.13	-0.03
NS-CON2 20.00	2.13	-0.04
NS-CON3 0.00	2.07	0.00
NS-CON3 20.00	2.10	-0.02
NS-CON4 0.00	2.07	0.00
NS-CON4 20.00	2.07	0.00
BRDG-CON2 0.00	2.11	2.11
BRDG-CON2 200.00	1.90	1.90

Option C2, 40 culverts			
	Max WL	Diff	Diff b/w C1 and C2
DES-40 400.00	2.08	0.09	0.02
DES-40 400.00	2.08	0.09	0.02
DES-40 800.00	1.55	0.07	0.02
DES-40 1600.00	0.60	0.00	0.00
DES-40 1600.00	0.60	0.00	0.00
DES-40 2000.00	0.60	0.00	0.00
PICNIC 0.00	2.15	-0.07	-0.02
PICNIC 130.00	2.12	-0.10	-0.03
PICNIC 250.00	2.06	-0.15	-0.05
PICNIC-CON 0.00	2.06	-0.15	-0.05
PICNIC-CON 50.00	2.17	-0.11	-0.06
PICNIC-CON 120.00	2.10	-0.02	0.00
LAKECON1 0.00	2.26	-0.04	-0.01
LAKECON1 10.00	2.26	-0.04	-0.01
LAKECON2 0.00	2.26	-0.04	-0.01
LAKECON2 10.00	2.26	-0.04	-0.01
LAKECON3 0.00	2.26	-0.04	-0.01
LAKECON3 10.00	2.26	-0.04	-0.01
LAKECON4 0.00	2.26	-0.04	-0.01
LAKECON4 10.00	2.26	-0.04	-0.01
BERAGEREE 0.00	2.08	0.01	0.01
BERAGEREE 120.00	1.79	0.01	0.02
BERAGEREE 180.00	2.04	0.01	0.02
BERAGEREE 240.00	1.94	0.03	0.04
BERAGEREE 320.00	2.08	0.09	0.02
BRCH1-1P 0.00	2.08	0.01	0.01
BRCH1-1P 20.00	1.00	0.00	0.00
BRCH1-1P 1580.00	0.60	0.00	0.00
BRCH1-1P 1600.00	0.60	0.00	0.00
NS-CON1 0.00	2.15	-0.07	-0.02
NS-CON1 20.00	2.15	-0.07	-0.02
NS-CON2 0.00	2.12	-0.04	-0.01
NS-CON2 20.00	2.12	-0.05	-0.01
NS-CON3 0.00	2.08	0.01	0.01
NS-CON3 20.00	2.10	-0.02	0.00
NS-CON4 0.00	2.08	0.01	0.01
NS-CON4 20.00	2.08	0.01	0.01
			0.00
			0.00
BRDG-CON2 0.00	2.058	2.06	-0.06
BRDG-CON2 200.00	1.942	1.94	0.04

Appendix D

Details of Option Costing

Preliminary Costing of Floodplain Management Options for Lake Illawarra

OPTION B1 Reduction of Causeway by 100m

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	50,000	1	50,000
2	Survey, Geotech Investigations etc	Item	40,000	1	40,000
3	Detailed Design	Item	60,000	1	60,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	15,000	1	15,000
6	Site Establishment	Item	10,000	1	10,000
7	Erosion and Sediment Control Works	Item	20,000	1	20,000
8	Excavate and dispose of 100m of existing causeway	m3	53	28,000	1,475,600
9	Temporary works	Item	100,000	1	100,000
10	Installation of new bridge piers	Item	300,000	1	300,000
11	Traffic management during construction	Item	30,000	1	30,000
12	Revegetate/Landscape	m2	20	5,000	100,000
13	Dis-establish Site	Item	10,000	1	10,000
14	GST (10%)	Item			224,060
15	Contingency (20%)	Item			492,932
	TOTAL				**2,957,592**
		Say			3,000,000

Note: Costed Using both Rawlinsons 2000 and Cordells Building Cost Guide - Commercial/Industrial, NSW 2000

Preliminary Costing of Floodplain Management Options for Lake Illawarra

OPTION B2 Reduction of Causeway by 350m

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	50,000	1	50,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	100,000	1	100,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	15,000	1	15,000
6	Site Establishment	Item	10,000	1	10,000
7	Erosion and Sediment Control Works	Item	30,000	1	30,000
8	Excavate and dispose of 100m of existing causeway	m3	53	84,000	4,426,800
9	Temporary works	Item	200,000	1	200,000
10	Installation of new bridge piers	Item	500,000	1	500,000
11	Traffic management during construction	Item	40,000	1	40,000
12	Revegetate/Landscape	m2	20	17,500	350,000
13	Dis-establish Site	Item	20,000	1	20,000
14	GST (10%)	Item			582,180
15	Contingency (20%)	Item			1,280,796
	TOTAL				**7,684,776**
		Say			7,700,000

Note: Costed Using both Rawlinsons 2000 and Cordells Building Cost Guide - Commercial/Industrial, NSW 2000

Preliminary Costing of Floodplain Management Options for Lake Illawarra

OPTION C1 Placement of 20 cell culverts through causeway

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	40,000	1	40,000
2	Survey, Geotech Investigations etc	Item	30,000	1	30,000
3	Detailed Design	Item	60,000	1	60,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	15,000	1	15,000
6	Site Establishment	Item	10,000	1	10,000
7	Erosion and Sediment Control Works	Item	10,000	1	10,000
8	Dewatering	Item	100,000	1	100,000
9	Flow diversions/coffer dams	Item	100000	1	100000
10	Traffic Management during construction	Item	10000	1	10000
11	Excavation	m3	80	17,000	1,360,000
12	Temporary works for support	Item	400,000	1	400,000
13	Supply and install box culvert	Item	16,600	20	332,000
14	Supply and place geotextile and rock for bank stabilising	m2	50	1,000	50,000
15	Revegetate/Landscape	m2	20	100	2,000
16	Disestablish Site	Item	10,000	1	10,000
17	GST (10%)	Item			254,700
18	Contingency (20%)	Item			562,740
	TOTAL				**3,376,440**
		Say			3,400,000

Note: Costed Using both Rawlinsons 2000 and Cordells Building Cost Guide - Commercial/Industrial, NSW 2000

Preliminary Costing of Floodplain Management Options for Lake Illawarra

OPTION C2 Placement of 40 cell culverts through causeway

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	40,000	1	40,000
2	Survey, Geotech Investigations etc	Item	30,000	1	30,000
3	Detailed Design	Item	60,000	1	60,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	15,000	1	15,000
6	Site Establishment	Item	10,000	1	10,000
7	Erosion and Sediment Control Works	Item	10,000	1	10,000
8	Dewatering	Item	100,000	1	100,000
9	Flow diversions/coffer dams	Item	100000	1	100000
10	Traffic Management during construction	Item	10000	1	10000
11	Excavation	m3	80	32,000	2,560,000
12	Temporary works for support	Item	400,000	1	400,000
13	Supply and install box culvert	Item	16,600	40	664,000
14	Supply and place geotextile and rock for bank stabilising	m2	50	1,000	50,000
15	Revegetate/Landscape	m2	20	150	3,000
16	Disestablish Site	Item	10,000	1	10,000
17	GST (10%)	Item			407,900
18	Contingency (20%)	Item			899,980
	TOTAL				**5,399,880**
		Say			5,400,000

Note: Costed Using both Rawlinsons 2000 and Cordells Building Cost Guide - Commercial/Industrial, NSW 2000

Appendix E

Proposed DCP Matrix

Planning Consideration	Flood Risk Precincts (FRP's)																							
	Low Flood Risk								Medium Flood Risk								High Flood Risk (and Interim Riverine Corridor)							
	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level	[Unsuitable]	3	[Unsuitable]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	2, 6 or 7	2or5	2	1	2,4,6	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	1	2,4,6
Building Components	[Unsuitable]	2	[Unsuitable]	2	[Not Relevant]	2	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	2	1	2	1	1	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	1	1
Structural Soundness	[Unsuitable]	3	[Unsuitable]	3	[Not Relevant]	3	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	3	2	3	2	2	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	1	1
Flood Affectation	[Unsuitable]	2,3	[Unsuitable]	[Not Relevant]	2,3	2,3	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	2,3	2,3	2,3	2,3	2,3	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	1,3	1,3
Evacuation	[Unsuitable]	2,4	[Unsuitable]	3,4	4	3,4	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	3,4	1,4	3,4	1	1	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	1	1
Management & Design	[Unsuitable]	4,5	[Unsuitable]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Not Relevant]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Not Relevant]	2,3,5	2,3,5	2,3,5	2,3,5	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	[Unsuitable]	2,3,5	2,3,5

Grey	Not Relevant
Dark red	Unsuitable Land Use
Light green	Concessional development to use the 100 Year including Medium Level Sea Level Rise, all other development to use 100 Year including High Level Sea Level Rise.

Floor Level

1	All Floor Levels to be equal to or greater than the 20 year ARI flood plus 0.5m (freeboard) unless justified by site specific assessment.
2	Habitable floor levels to be equal to or greater than the 100 year ARI flood plus 0.5m (freeboard).
3	All Floor Levels to be equal to or greater than the PMF.
4	Floor levels to be as close to design floor level as practical & no lower than existing floor level (alterations or additions only).
5	Floor levels of shops to be as close to the design floor level as practical (i.e. 100 Year ARI + 0.5m). Where it is below the design floor level, more than 30% of the floor area to be above the design floor level or premises to be flood proofed below the design floor level.
6	Garage floor level to be no lower than 300mm above finished adjacent ground.
7	Garage floor level to be no lower than the 100 year ARI flood level minus 300mm or 300mm above finished adjacent ground (whichever is the greater).

Building Components & Method

1	All structures to have flood compatible building components below or at the 100 year ARI flood level plus 0.5m (freeboard).
2	All structures to have flood compatible building components below or at the PMF level.

Structural Soundness

1	IEAust NPER Structural Engineers report to certify that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year ARI flood plus 0.5m (freeboard).
2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year ARI flood plus 0.5m (freeboard).
3	IEAust NPER Structural Engineers report to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a PMF event.

Flood Affectation

1	IEAust NPER Hydraulic Engineers report required to certify that the development will not increase flood affectation elsewhere.
2	The impact of the development on flooding elsewhere to be considered.
3	No wholesale filling of sites around the foreshore of the lake is permitted, unless supported by a sensitivity analysis indicating that there is no significant impact on flood levels. Also, filling that impacts on active flow areas in the stream networks feeding Lake Illawarra will not be supported. However, filling within existing building areas is permitted. Filling of depressions outside of existing building areas may only be permitted subject to it being demonstrated that there is no loss of flood storage across the site for all events up to the PMF.

Evacuation

1	Reliable access for pedestrians required during a 100 year ARI flood.
2	Reliable access for pedestrians and vehicles required during a PMF event.
3	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF, or a minimum of $20m^2$ of the gross floor area of the dwelling to be above the PMF level.
4	The development is to be consistent with any relevant flood evacuation strategy or similar plan.
5	Applicant to demonstrate that evacuation of potential development as a consequence of a subdivision proposal can be undertaken in accord with this Plan.

Management and Design

1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with DCP.
2	Site Emergency Response Flood Plan required (except for single dwelling-houses) where floor levels are below the PMF
3	Applicant to demonstrate that area is available to store goods above the 100 year ARI flood plus 0.5m (freeboard)
4	Applicant to demonstrate that area is available to store goods above the PMF level
5	No external storage of materials below the design floor level which may cause pollution or be hazardous during any flood

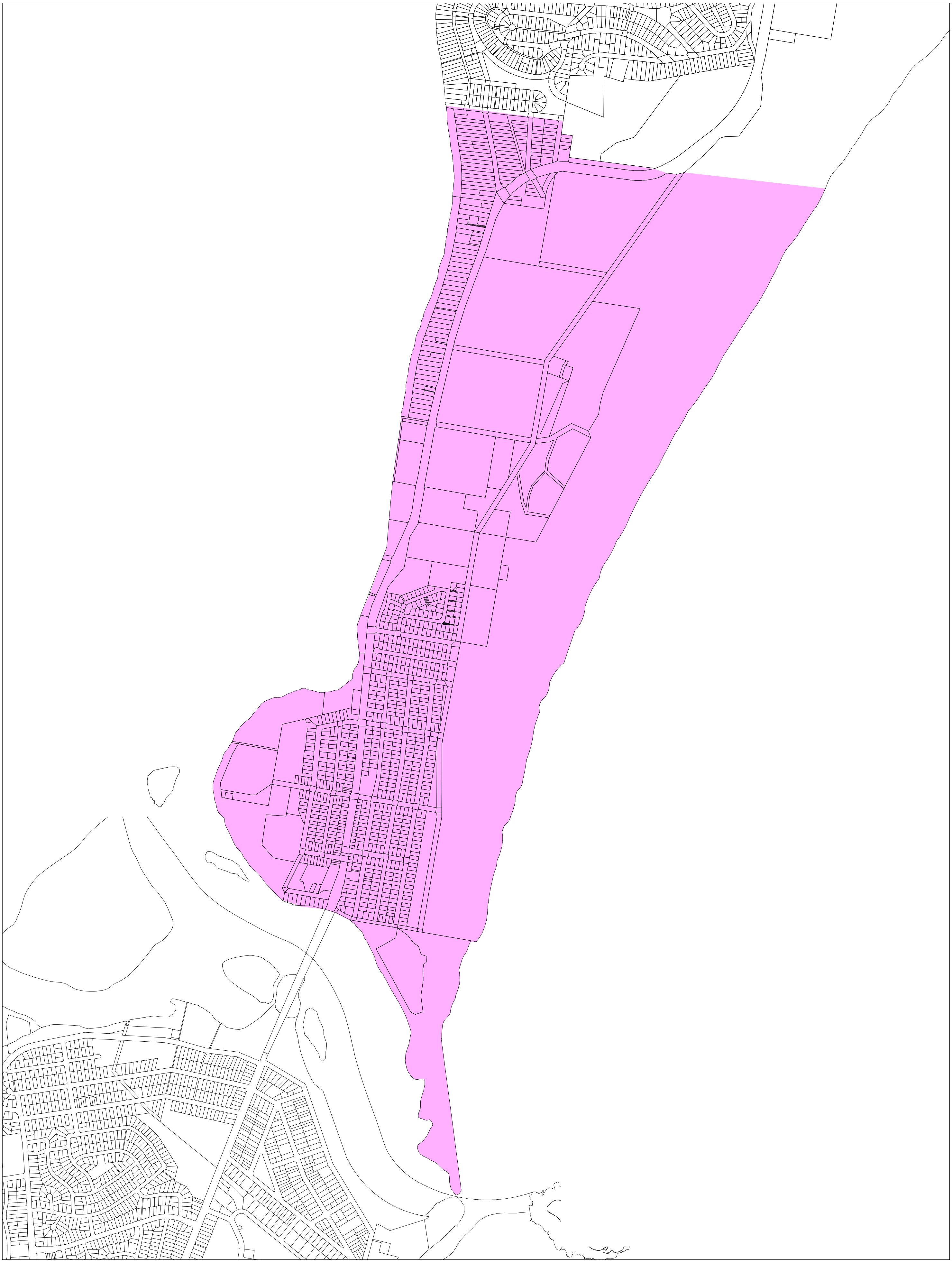
Planning Consideration	Flood Risk Precincts (FRP's): Low Flood Risk								Medium Flood Risk								High Flood Risk (and Interim Riverine Corridor)								Isolation Risk - Applies to the entire Windang Peninsula as shown on Figure E1 - These controls apply in addition to those applied in flood risk precincts.							
	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3										2, 6 or 7	2or5	2	1	2,4,6							1	2,4,6								
Building Components		2		2		2						2	1	2	1	1							1	1								
Structural Soundness		3		3		3						3	2	3	2	2							1	1								
Flood Affectation		2,3			2,3	2,3						2,3	2,3	2,3	2,3	2,3							1,3	1,3								
Evacuation		2,4		3,4	4	3,4						3,4	1,4	3,4	1	1							1	1				3,4	4	3,4		
Management & Design		4,5											2,3,5	2,3,5	2,3,5	2,3,5							2,3,5	2,3,5				1		1		

(grey)	Not Relevant	(dark red)	Unsuitable Land Use	(light green)	Concessional development to use the 100 Year including Medium Level Sea Level Rise, all other development to use 100 Year including High Level Sea Level Rise.

Floor Level

1	All Floor Levels to be equal to or greater than the 20 year ARI flood plus 0.5m (freeboard) unless justified by site specific assessment.
2	Habitable floor levels to be equal to or greater than the 100 year ARI flood plus 0.5m (freeboard).
3	All Floor Levels to be equal to or greater than the PMF.
4	Floor levels to be as close to design floor level as practical & no lower than existing floor level (alterations or additions only).
5	Floor levels of shops to be as close to the design floor level as practical (i.e. 100 Year ARI + 0.5m). Where it is below the design floor level, more than 30% of the floor area to be above the design floor level or premises to be flood proofed below the design floor level.
6	Garage floor level to be no lower than 300mm above finished adjacent ground.
7	Garage floor level to be no lower than the 100 year ARI flood level minus 300mm or 300mm above finished adjacent ground (whichever is the greater).

Building Components & Method	
1	All structures to have flood compatible building components below or at the 100 year ARI flood level plus 0.5m (freeboard).
2	All structures to have flood compatible building components below or at the PMF level.
Structural Soundness	
1	IEAust NPER Structural Engineers report to certify that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year ARI flood plus 0.5m (freeboard).
2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year ARI flood plus 0.5m (freeboard).
3	IEAust NPER Structural Engineers report to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a PMF event.
Flood Affectation	
1	IEAust NPER Hydraulic Engineers report required to certify that the development will not increase flood affectation elsewhere.
2	The impact of the development on flooding elsewhere to be considered.
3	No wholesale filling of sites around the foreshore of the lake is permitted, unless supported by a sensitivity analysis indicating that there is no significant impact on flood levels. Also, filling that impacts on active flow areas in the stream networks feeding Lake Illawarra will not be supported. However, filling within existing building areas is permitted. Filling of depressions outside of existing building areas may only be permitted subject to it being demonstrated that there is no loss of flood storage across the site for all events up to the PMF.
Evacuation	
1	Reliable access for pedestrians required during a 100 year ARI flood.
2	Reliable access for pedestrians and vehicles required during a PMF event.
3	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF, or a minimum of $20m^2$ of the gross floor area of the dwelling to be above the PMF level.
4	The development is to be consistent with any relevant flood evacuation strategy or similar plan.
Management and Design	
1	No increase in development density further than the existing development type (i.e. single dwelling can not become dual occupancy or multi unit).
2	Site Emergency Response Flood Plan required (except for single dwelling-houses) where floor levels are below the PMF
3	Applicant to demonstrate that area is available to store goods above the 100 year ARI flood plus 0.5m (freeboard)
4	Applicant to demonstrate that area is available to store goods above the PMF level
5	No external storage of materials below the design floor level which may cause pollution or be hazardous during any flood
6	No increase in the number of persons staying overnight on site



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Lake Illawarra Floodplain Risk
Management Study

FIGURE E1
WINDANG PENINSULA
DCP MATRIX AREA

J1905/R1920/V12
January 2012

J1905\Figures V12\Figure E1 Windang DCP Matrix Area.wor