northern beaches council

MANLY LAGOON FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

NORTHERN BEACHES COUNCIL

wma water

October 2018

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

MANLY LAGOON FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

OCTOBER 2018

Project **Manly Lagoon Floodplain Risk Management Study and Plan**	Project Number **115006**
Client **Northern Beaches Council**	Client's Representative **Duncan Howley**
Authors **Ella Harrison** **Fabien Joly** **Catherine Goonan**	**Prepared by**
Date **30 October 2018**	**Verified by**

Revision	Description	Distribution	Date
7	Final	Northern Beaches Council	Oct 18
6	Public Exhibition Final Draft	Northern Beaches Council	Mar 18
5	Public Exhibition Draft for review	Northern Beaches Council	Mar 17
4	Draft Stage 3 Report	Northern Beaches Council	Jul 16
3	Draft Stage 2 Report for review	Northern Beaches Council	Jun 16
2	Final Stage 1 Report	Northern Beaches Council	Mar 16
1	Draft Stage 1 Report issued for review	Northern Beaches Council	Dec 15

Cover photo (left): Manly Lagoon (Courtesy of Office of Environment and Heritage)
(right): Manly Lagoon Reserve Playground - Queenscliff, April 2015 (Courtesy of CNDoz via www.flickr.com/photos/cndoz/17015341977)

MANLY LAGOON FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE OF CONTENTS

PAGE

LIST OF APPENDICES

LIST OF ACRONYMS

AAD	Annual Average Damages
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff 1987 and 2016 editions
B/C	Benefit Cost Ratio
BoM	Bureau of Meteorology
DCP	Development Control Plan
DISPLAN	Disaster Plan
DSC	Dam Safety Committee
ERP	Evacuation Response Planning
EP&A Act	Environmental Planning and Assessment Act
EY	Exceedances per Year
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
OEH	NSW Office of Environment and Heritage
OSD	On Sire Detention
LEP	Local Environmental Plan
LFP	Local Flood Plan
LGA	Local Government Area
mAHD	meters above Australian Height Datum
PMF	Probable Maximum Flood
RCP	Representative Concentration Pathway of greenhouse gas concentration adopted by the Intergovernmental Panel on Climate Change
SES	State Emergency Services
TUFLOW	Hydraulic Computer Model for estimating flood levels

LIST OF TABLES

LIST OF DIAGRAMS

LIST OF FIGURES

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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

1. ***Data Collection***
2. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management Study***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

EXECUTIVE SUMMARY

Background

This report report comprises an overview of the work that has been undertaken by WMAwater on the Manly Lagoon Floodplain Risk Management Study and Plan. It builds on prior stage reports and, in accordance with the Brief, it additionally includes a discussion of:

- hydraulic and hazard categorisation;
- future development scenarios;
- review of climate change;
- flood damages assessment; and
- emergency management.

The Study, which follows on from the Manly Lagoon Flood Study (Reference 1), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy and the Floodplain Development Manual (Reference 2). A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the catchment, over-floor flooding of residential, commercial and industrial properties, road flooding and emergency response during a flood event. A range of measures aimed at managing this flood risk were also assessed for their efficacy across a range of criteria, which allowed certain options to be recommended, forming the basis of the Floodplain Risk Management Plan (FRMP) for the area.

In May 2016, Pittwater, Manly and Warringah Council's merged to form the Northern Beaches Council. As such, Manly Lagoon catchment now falls within one Council Local Government Area. The area which previously fell within Warringah Council's LGA is herein referred to Northern Beaches Central, and that within the previous Manly Council LGA is Northern Beaches South. At present, each separate Council's planning and policy guidance is being retained and therefore remains relevant to the current study.

Existing Flood Environment

The catchment is predominantly urbanised with industrial, commercial and residential development. There are three major commercial centres within the catchment – Warringah Mall, Balgowlah Industrial Estate, and Stockland Balgowlah. The floodplain of the lagoon itself is primarily open space, comprising of golf courses, parks and reserves. Manly Dam is located in the upper catchment, and has a catchment area of approximately 500 hectares comprising predominantly bushland. This accounts for approximately one quarter of the total Manly Lagoon catchment area.

Flooding within the Manly Lagoon catchment can result from either elevated ocean conditions, catchment flooding, or a combination of both, however catchment flood events represent the dominant flooding mechanism in the catchment. Whilst ocean derived flooding will cause

inundation for properties close to the lagoon, the extent and severity of flooding is significantly less than the catchment derived event of corresponding probability.

Floodplain Risk Management Options

The Floodplain Risk Management Study includes an investigation of possible options for the management of flood risk in the study area. These included flood modification works such as the construction of levees and retarding basins, drainage upgrades and channel modifications, as well as planning measures and response modification options. The measures were assessed for their ability to reduce flood risk while also considering their economic, social and environmental impact. A multi-criteria matrix assessment was used to directly compare the options. The options recommended arising from this assessment and hence recommended for evaluation in the FRMP are shown in Table 1. Further details of these options are found in Section 9.

Table 1: Recommended Floodplain Risk Management Options

Option ID	Description	Reference
LV02	Clearview Place Levee	9.2.1.2
MD01	Investigation into Manly Dam Airspace Availability	9.2.8.1
PM03	Flood Proofing	9.4.3
PM04	Land Use Zoning	9.4.4
PM05	Flood Planning Levels	9.4.5
PM06	Flood Planning Area	9.4.6
PM07	Changes to Planning Policy	9.4.7
PM08	S10.7 Certificates	9.4.8
RM01	Emergency Planning	9.3.1
RM02	Flood Warning	9.3.2
RM04	Road Closures, Early Notifications	9.3.4
RM05	Community Education and Awareness	9.3.5

1. INTRODUCTION

1.1. Study Area

The Manly Lagoon catchment is located in the recently formed Northern Beaches Local Government Area (LGA), comprising land within Northern Beaches Central (previously Warringah Council LGA) and Northern Beaches South (previously Manly LGA), as shown in Figure 1. The catchment encompasses an area of approximately 18 km^2, whilst the lagoon itself is relatively small, with a surface area of approximately 0.1 km^2. The lagoon is located in the east of the catchment, with its entrance to the Tasman Sea at Queenscliff Beach. Manly Lagoon is fed primarily by Burnt Bridge Creek, Brookvale Creek and Manly Creek as well as receiving inflows from a large number of stormwater drains. The Manly Creek sub-catchment includes inflows from Manly Dam and Curl Curl Creek.

1.2. The Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 2) the floodplain risk management process is formed of sequential stages as shown in Diagram 1:

Diagram 1: Floodplain Risk Management Process

The Manly Lagoon Catchment Coordinating Committee is acting as the Floodplain Risk Management Committee. As described in the Floodplain Development Manual, the role of the Committee is to assist Council undertaking the floodplain risk management process, and acts as both a focus group and forum during the process.

The Manly Lagoon Flood Study was completed in 2013 by BMT-WBM (Reference 1). The Floodplain Risk Management Study and Plan (FRMS&P) are being undertaken for the catchment in two phases:

Phase I – Floodplain Risk Management Study in which the floodplain management issues confronting the study areas are assessed, management options investigated and recommendations made. Specific objectives for this phase include:

- Identifying innovative solutions to the management of flood hazards within the study area.
- Provide recommendations regarding the trigger level at which reactive mechanical opening of the closed entrance should be undertaken.
- Assess the economic impact of flooding.
- Review and discuss strategies for raising the awareness of flood risk and the level of flood preparedness in the catchment.

Phase II – Floodplain Risk Management Plan which is developed from the floodplain risk management study and details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and ensuring that such plans are informed to a degree by climate change sensitivity.

The Plan consists of prioritised and costed measures for implementation. The Plan is included in Section 10.

2. BACKGROUND

2.1. Manly Lagoon Catchment

2.1.1. Flooding Behaviour

Flooding in the Manly Lagoon catchment is dominated by catchment flooding, although elevated ocean conditions can also cause flooding and contribute to catchment driven events. The entrance conditions have an influence on flood behaviour, with higher entrance berm levels leading to higher peak flood levels. The Lagoon is managed by Council, who undertake mechanical opening of the Lagoon entrance in times of heavy rain at defined trigger levels.

Short duration events (up to 9 hour duration) typically provide for the worst case flooding conditions in Manly Lagoon, with a level of 3.0 mAHD at Pittwater Bridge in the 1% AEP event. The rise in flood waters can be relatively fast. Peak flood levels in Manly Lagoon are recorded less than 30 minutes after the flood peaks at Brookvale and in the Burnt Creek deviation. Four hotspot locations have been identified including Kenneth and Balgowlah Roads, Balgowlah, Manly Lagoon North Bank and Brookvale. Further detail regarding flood behaviour in these locations is provided in Section 5.

2.1.2. Land Use

Figure 2 shows the land use within the Manly Lagoon catchment, as defined in the relevant Local Environment Plans. The catchment is predominantly urbanised with industrial, commercial and residential development. There are three major commercial centres within the catchment – Warringah Mall, Balgowlah Industrial Estate, and Stockland Balgowlah. The floodplain of the lagoon itself is primarily open space, comprising of golf courses, parks and reserves. Manly Dam is located in the upper catchment, and has a catchment area of approximately 500 ha comprising predominantly bushland. This accounts for approximately one quarter of the total Manly Lagoon catchment area.

2.1.3. Manly Lagoon Entrance

The entrance to Manly Lagoon is located at the northern end of Queenscliff beach, bounded to the north by a rocky headland and urban development to the south. There are two low flow pipes, each with 1.8 m diameter, and a concrete channel. Stuart Somerville bridge crosses the Lagoon at Queenscliff beach. The rate of discharge into the ocean from the lagoon is controlled at this point by a rock bar (at approximately 0.2 mAHD) and the bridge abutments.

During a significant flood event, a secondary relief channel is cut through the sand berm at Queenscliff Beach which allows water to discharge directly into the ocean from downstream of the Bridge, rather than via the concrete channel. The opening regime of the relief channel is controlled by Council and based on actual and predicted lagoon water levels, and the observed hydraulic, weather and ocean conditions. The Manly Lagoon Emergency Flood Channel

Protocol (2000) dictates that cutting of the relief channel should begin once water levels in the Lagoon rise above *1.0-1.4 mAHD* as a result of rainfall, and a head difference of 0.6 m exists between the lagoon and the ocean.

The beach berm at the entrance of the Lagoon will naturally build up over time, and breakouts will occur without intervention during high lagoon levels and/or wave processes at the entrance.

2.1.4. Manly Dam

Manly Dam has a storage capacity of approximately 2,000 ML, with the crest of the Dam at 35.84 mAHD. The water level in the Dam is maintained at 34.1 mAHD (1.7 m below the crest). The Dam has a fixed crest continuous spillway approximately 250 m long. The water levels in the Dam are controlled and monitored by Sydney Water and Northern Beaches Council, with Sydney Water primarily releasing water for dam safety control, and Council for flood mitigation. Water in the Dam is also extracted by the two hydraulics laboratories located in Manly Vale for testing of physical models. The water is later released into Manly Creek. Scour valves are used to regulate the water level in the Dam, with a combined discharge capacity of 2.6 m^3/s. Previous investigations estimated that initial water levels in the Dam impact peak design flood levels in the Manly Lagoon catchment by 0.1 m to 0.2 m.

The current operating procedure for the opening and closing of the scour valves are:

- Water level is to be maintained at 34.1 mAHD (1.7 m below crest level);
- At 1.0 m below crest level, Council is notified to open the scour valves operated by Council;
- At 0.5 m below crest level, Sydney Water are notified to open the scour values operated by Sydney Water; and
- At 1.6 m below crest level, Council and Sydney Water are notified to close the scour valves if they have been opened.

2.1.5. Social Characteristics

Information is available from the 2011 census (http://www.abs.gov.au/) to understand the social characteristics of this study area which includes the suburbs of French's Forest, Allambie Heights, Freshwater, North Manly, Manly Vale, Manly, Brookvale, Seaforth, North Balgowlah, Beacon Hills, Balgowlah, Fairlight and Queenscliff. Understanding the social characteristics of the area can help in ensuring that the right floodplain risk management practices are adopted. Table 2 below shows some selected characteristics.

Table 2: 2011 Census data

	NSW	Northern Beaches South	Northern Beaches Central
Population Age:			
0 – 14 years	19.2%	18.9%	20.1%
15 - 64 years	66.1%	67.6%	64.5%
> 65 years	14.7%	13.5%	15.5%
Average people per dwelling	2.6	2.5	2.7
Own/mortgage property	66.6%	61.6%	66.6%
Rent property	30.1%	36.5%	25.9%
Moved into area:			
- within last year	-	20%	14.7%
- within last five years	-	50%	39.7%
No cars at dwelling	10.9%	12.3%	7.9%
Speak only English at home	72.5%	81.9%	80.1%

Based on these statistics the area aligns fairly consistently with the state average. Approximately half the residents have lived in the area for more than 5 years, combined with a high proportion of home owners, suggests there is likely to be some familiarity with flooding amongst the community.

2.1.6. Drainage System and Structures

The Manly Lagoon catchment comprises a substantial pit and pipe network, with pipes ranging in size from 0.3 m diameter to large 10 m by 5 m structures (Burnt Bridge Creek beneath Condamine Street), as shown in Figure 3. In addition, there are three main creek systems which flow into the Lagoon; Burnt Bridge Creek, Manly Creek and Brookvale Creek, and they comprise a mixture of natural channels and culvert sections. There are two bridges, Pittwater Road bridge and Stuart Somerville bridge. Manly Dam is also located within the Lagoon's catchment area.

2.2. Previous Studies

A number of studies have previously been undertaken for the Manly Lagoon catchment, as listed below.

- Manly Lagoon Flood Study, BMT-WBM, 2013 (Reference 1);
- Ryan Place Overland Flood Study, Webb, McKeown & Associates, 2007;
- Brookvale Bus Depot Flood Study, Arup, 2007;
- Bangaroo Street Flood Investigation, Cardno Lawson Treloar, 2006 and
- Manly Lagoon Flood Study, MHL, 1992.

A brief overview of the two flood studies (2013 and 1992) is provided below, with further information regarding the other studies summarised within the 2013 Flood Study report.

2.2.1. Manly Lagoon Flood Study, BMT-WBM, 2013

The primary objective of this Flood Study was to define the flood behaviour under historical, existing and future conditions (incorporating potential impacts of climate change), for the full range of design flood events. The study provided information on flood levels and depths, velocities, flows, hydraulic categories and provisional hazard categories. It also identified the impacts future climate change and potential changes in the catchment and lagoon entrance could have on flood behaviour.

Key findings from the flood study are:

- Longer duration events (6-9 hours) typically provide for the worst case flooding conditions in Manly Lagoon. In the lower reaches of all of the tributary catchments, flood levels are dominated by the Lagoon flooding conditions. The peak water level in the Lagoon extends a significant distance up the tributary channels. In the upper reaches of the tributary catchments, shorter duration events in the order of 2 hours provide the critical flood condition in terms of peak water level;
- The rise of flood water levels can be relatively fast. The potentially rapid inundation has implications for flood warning and emergency response;
- Catchment derived flood events represent the dominant flooding mechanism. The entrance condition has some influence on catchment flood behaviour with higher entrance berm levels providing for higher peak flood levels. The existing entrance management policy provides for manual breakout of the Lagoon entrance at defined trigger levels in preparation for imminent flooding. Irrespective of the successful implementation of a manual entrance breakout, significant flood inundation may be expected during major catchment flood events;
- The worst flood affected areas are typically in the lower parts of the catchment. These areas include the foreshore of the Lagoon around Riverview Parade. Much of the lower floodplain area is however, occupied by park lands/golf courses such that flood risk exposure to existing property is limited. Elsewhere, the Warringah Mall and Balgowlah Industrial Estate are located on the alignments of Brookvale Creek and Burnt Bridge Creek respectively. When drainage system capacities in these areas are exceeded, there is potential for overland flow through these areas;
- Peak design flood water levels are expected to progressively increase as the impacts of climate change manifest. Potential sea level rise will provide for a worsening of existing flood conditions in the Manly Lagoon catchment through higher ocean water levels (tide and storm surge), higher entrance berm and higher water levels in the Lagoon; and
- With potential sea level rise, normal tide levels in the Lagoon will approach and eventually exceed the current trigger levels for manual entrance management of the Lagoon. Future openings would need to be at significantly higher trigger levels to be effective. Low-lying land currently impacted by flooding may also be subject to regular, or permanent, tidal inundation at some time in the future.

2.2.2. Manly Lagoon Flood Study, MHL, 1992

The 1992 Flood Study estimated design flood levels for the PMF, 1% AEP, 5% AEP and 20% AEP flood events. The 1D Mike-11 hydraulic model established for the study was limited to the following areas:

- Manly Lagoon and surrounding parks and golf courses;
- Brookvale Creek down from Warringah Mall;
- Manly Creek down from Manly Dam; and
- Burnt Bridge Creek down from Condamine Street.

The hydraulic model network was defined based on cross-sections at approximately 200 m intervals, and calibrated to the June 1991 rainfall event and tested using the April 1988, March 1975 and May 1974 rainfall events.

This study did not take into account the urban trunk drainage network, and assumed that the entrance would always be mechanically opened at 1.4 mAHD.

2.3. Flood Study Modelling Review and Update

As part of the current study, WMAwater undertook a review of the flood modelling established in the 2013 Flood Study by BMT-WBM. The review established that:

- The model which had been used was a proprietary model developed by BMT-WBM which combines morphological modelling with flood modelling. This model is not available for others to use; and
- The model produced results (flood levels, depths and velocities) in limited locations throughout the study area that were not able to be replicated using the latest commercially available version of TUFLOW (as of August 2015).

Further, BMT-WBM has subsequently advised that the solution scheme used for flood modelling in the Flood Study (pre-2012 version of TUFLOW) could lead to situations in which the capacity of 1D networks could be underestimated (BMT-WBM, 2015).

As such, WMAwater has carried out an assessment of the differences in results produced by existing and revised flood models.

2.3.1. Methodology

The assessment involved the following:

- The flood study TUFLOW model was converted to the most recent TUFLOW version (2013-12 AC);
- All design events and durations were modelled. To achieve this, some alteration of the pipe schematisation and pipe roughness was required in places to improve the stability of the model. These changes were minor, particularly in the context of a 1% AEP event,

however improved the stability of the model runs. Figure 4 shows an example of some of the changes made;

- An approximation of the variable entrance conditions was required as the morphological module was not used; and
- Impact maps were produced which included a comparison of peak water levels as well as peak flow rates in the 1D network elements. These are shown on Figure 5 and Figure 6 respectively.

2.3.2. Results

Figure 7 shows the flood extents for the PMF, 1% and 20% AEP design events. Generally the impact of the updated modelling work is minimal, particularly in regard to residential flood affectation. However in some commercial areas there are some reductions in peak flood levels and flood extent. The key areas where design flood definition has changed are:

- Brookvale, where levels have been reduced between 0.1 m – 0.5 m;
- Manly Vale, where in specific locations there are reductions of up to 0.5 m in peak water levels, although generally the reduction in levels is less; and
- Various other localised areas where some change has occurred. The most notable being those areas adjoining the northern side of the lagoon where flood extents are reduced.

In all instances, the reduction in flood levels in the revised model is a result of an increase in 1D network flow. The model update also resulted in a reduction in the range of critical durations. The Lagoon previously had a nine-hour critical duration, but this is now two-hour. This is again due to the 1D network more effectively delivering flow downstream when using the updated version of TUFLOW.

The areas impacted by the reduced flood levels mainly include commercial property, although there are some limited areas of residential properties affected by the changes.

3. CONSULTATION

3.1. Community Consultation

One of the central objectives of the FRMS is to actively liaise with the community throughout the process, keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consisted of:

- Media release
- Establish a project website;
- Distribution of brochure and questionnaire survey to community;
- Consult with other key stakeholders; and
- Public exhibition period including drop-in sessions.

A copy of the consultation material is provided in Appendix B.

3.1.1. Community Questionnaire

2633 paper questionnaires were mailed out to residents in the Manly Lagoon catchment in April 2016. In addition, an online version of the questionnaire was also made available. 134 paper responses were received (5% return rate) as well as 14 online surveys and two other emails containing historical flood photographs.

Key findings include:

- 90% of responses were from residential properties, of which 82% were owner-occupiers.
- 49% of respondents were concerned about flooding at their property, and 75% were concerned about flooding in their local areas.
- Council is generally thought to be the main source of flood information.
- 25% of respondents had firsthand experience of flooding, with 4% experiencing over-floor inundation in the past.
- Respondents were asked to rank a list of potential mitigation options from high to low preference. The results are presented graphically in Diagram 2 overleaf. There was a strong preference for increasing the conveyance of the creek / lagoon, and undertaking works on the piped network. There is also a strong preference to avoid bridge or road works, levees, and flood education & awareness activities. Other options such as basins, flood warning & evacuation planning, and development controls had mixed responses.

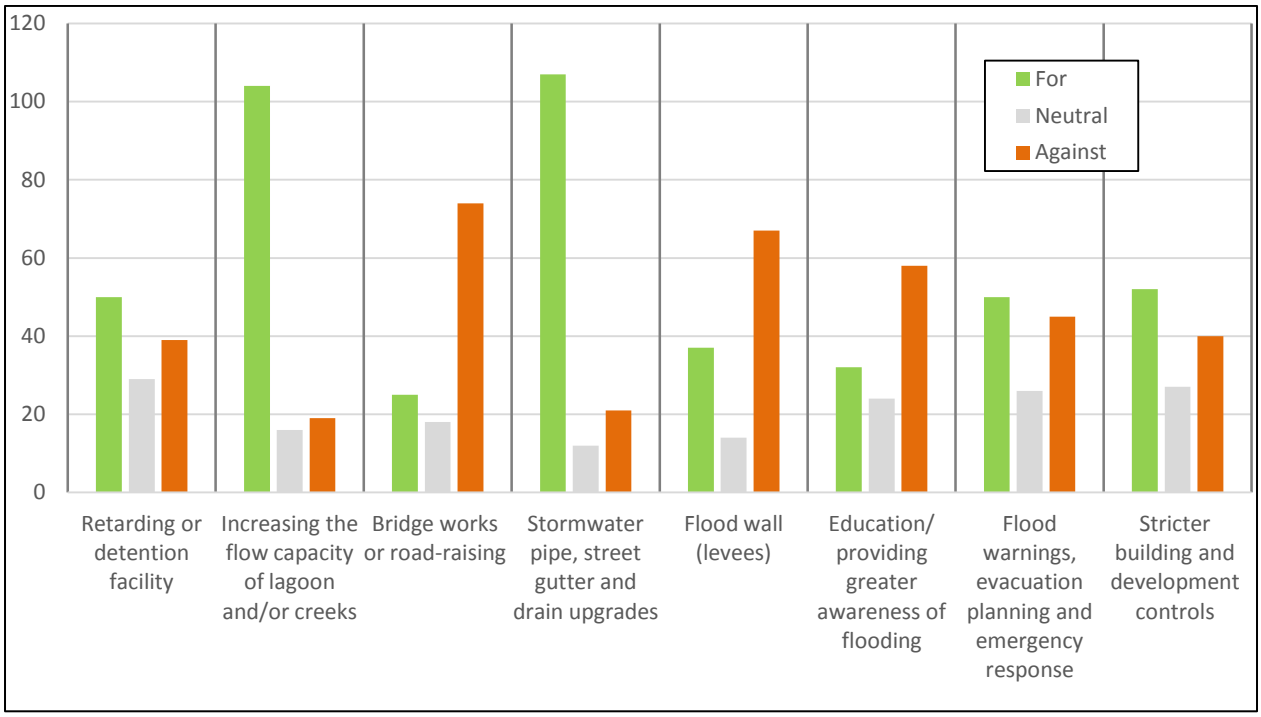

Diagram 2 Summary of community consultation responses to management options

3.1.2. Public Exhibition

Public exhibition of the Draft Manly Lagoon Floodplain Risk Management Study and Plan is required by the Local Government Act (1993, Section 402). This section stipulates that Council must exhibit the draft plan for public comment for a period of at least 28 days, and that submissions must be considered by the Council before the plan is endorsed or amended.

The Draft Manly Lagoon Floodplain Risk Management Study and Plan was endorsed for public exhibition at the Council meeting on 17 April 2018. The exhibition period ran from the 11th June to the 13th July 2018. The report was made available online and as hardcopy at all Council libraries and customer service centres. Two drop-in sessions were hosted on the evenings of the 26th and 28th June 2018 at Dee Why Civic Centre and Manly Town Hall respectively, with around 40 people attending over the 2 days. At the completion of the public exhibition period, the *Have Your Say* website had received 225 visits, and six written submissions had been received. These submissions have been logged in Appendix C, which also notes how each submission has been addressed.

4. FLOODPLAIN MANAGEMENT POLICY

It is important to understand the state legislation that overarches all local planning so as to enable appropriate floodplain risk management measures to be proposed that meet both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

The objectives of this direction are:

- *to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and*
- *to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.*

Clause (3) of Direction 4.3 states:

- *This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.*

Clauses (4)-(9) of Direction 4.3 state:

- *A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).*
- *A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.*
- *A planning proposal must not contain provisions that apply to the flood planning areas which:*
    - *permit development in floodway areas,*
    - *permit development that will result in significant flood impacts to other properties,*
    - *permit a significant increase in the development of that land,*
    - *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*
    - *permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

- *A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).*

- *For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).*

- *A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:*

- *the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or*

- *the provisions of the planning proposal that are inconsistent are of minor significance.*

4.1.1. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both.

4.1.2. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the restrictions on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) planning certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

1) *Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*

2) *Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*

3) *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property.

4.1.3. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 (SEPP) are:

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

- *providing exempt and complying development codes that have State-wide application, and*
- *identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and*
- *identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and*
- *enabling the progressive extension of the types of development in this Policy, and*
- *providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.*

4.1.4. General Housing Code

Part 3 of the SEPP relates to the *"General Housing Code"*.

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.6 of the SEPP, relates to:

Development that is complying development under this code

Clause 3.1 states:

3.1 Land to which code applies

This code applies to development that is specified in clauses 3.2-3.5 on any lot in Zone R1, R2, R3, R4 or RU5 that:

(a) has an area of at least 200 m^2, and

(b) has a width, measured at the building line fronting a primary road, of at least 6 m.

Clause 3.2 of the SEPP states:

3.2 New single storey and two storey dwelling houses

The erection of a new single storey or two storey dwelling house is development specified for this code.

Clauses 3.3-3.5 generally relate to single and two storey dwelling houses and ancillary development.

Division 2 of Part 3 of the SEPP contains:

Development standards for this code

Subdivision 9 contains:

Development standards for particular land

Subdivision 9 contains Clause 3.36C of the SEPP which relates to development standards for the General Housing Code on *"flood control lots"*. A *"flood control lot"* is defined in the SEPP as:

flood control lot *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*

Note. *This information is a prescribed matter for the purpose of a certificate under section 10.7 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a s.10.7 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.36C states:

3.36C Development standards for flood control lots

(1) This clause applies to:

(a) to all development specified for this code that is to be carried out on a flood control lot,

and

(b) in addition to all other development standards specified for this code.

(2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering as not being any of the following:

(a) a flood storage area,

(b) a floodway area,

(c) a flow path,

(d) a high hazard area,

(e) a high risk area.

(3) The development must, to the extent it is within a flood planning area:

(a) have all habitable rooms no lower than the floor levels set by the council for that lot, and

(b) have the part of the development at or below the flood planning level constructed of flood compatible material, and

(c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probably maximum flood level), and

(d) not increase flood affectation elsewhere in the floodplain, and

(e) have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and

(f) have open car parking spaces or carports that are no lower than the 20-year flood level, and

(g) have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3 m during a 1:100 ARI (average recurrent interval) flood event.

(4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:

(a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or

(b) will not increase flood affectation elsewhere in the floodplain.

(5) If a word or expression used in this clause is defined in the Floodplain Development Manual, the word or expression has the same meaning as it has in that Manual unless it is otherwise defined in this clause.

(6) In this clause:

***flood compatible material** means building materials and surface finishes capable of withstanding prolonged immersion in water.*

***Floodplain Development Manual** means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

***flow path** means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

***high hazard area** means a high hazard area identified in the council's flood study or flood risk management study carried out in accordance with the Floodplain Development Manual.*

***high risk area** means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

4.1.5. Summary of State Legislative and Planning Polices

From the above discussion of the General Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, an s.10.7 notification is not applied and, as a result, planning controls relating to flooding do not apply and Exempt Development can be undertaken. This highlights the importance of Council undertaking Flood Studies (such as this FRMS) to ensure appropriate properties are tagged and planning controls applied to reduce the risk and impact of flooding for current and future occupants.

4.2. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding.

The three former Northern Beaches councils all had well developed approaches to flood risk management, however each was different in a number of ways which resulted in different experiences and outcomes for flood affected residents and businesses. Following amalgamation, Council harmonised the way that flooding is managed, including the relevant DCP clauses and design standards that stipulate the requirements for developing on flood prone land.

An LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

Manly Lagoon is covered by two LEPs. Manly (Northern Beaches South) LEP was adopted in 2013 and Warringah (Northern Beaches Central) LEP was adopted in 2011. Both were prepared under the Standard Instrument LEP program.

4.2.1. Manly Local Environment Plan 2013 (MLEP2013)

Clause 6.3 of MLEP 2013 relates to flood planning and states:

6.3 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN: 0 7347 5476 0), published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:
***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

4.2.2. Warringah Local Environment Plan 2011 (WLEP2011)

Clause 6.3 of WLEP 2011 relates to flood planning and states:

6.3 Flood planning

(6) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(7) This clause applies to land at or below the flood planning level.

(8) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(9) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN: 0 7347 5476 0), published in 2005 by the NSW Government, unless it is otherwise defined in this clause.

(10) In this clause:
***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

4.2.3. Manly Development Control Plan 2013

Section 5.4.3 of the Manly DCP 2013 (as amended August 2017) addresses flood prone land. It provides maps of high, medium and low flood risk planning precincts and a matrix of requirements which are varied by flood risk and land use, and includes provisions for flood effects caused by development, drainage infrastructure and creek works, building components and structural soundness, storage of goods, flood emergency response, floor levels, car parking, fencing and pools which are based on the defined risk and land use. For the majority of instances the Flood Planning Level is used as the required level, however in some cases the PMF also needs to be considered (for example, in the case of evacuation or in the provision of essential services or vulnerable development).

The performance criteria that must be met are:

1.1 Performance Criteria

(a) **Site layout and built form**: The site layout and ultimate built form of the proposed development should be compatible with the flood risk. Site analysis and layout should incorporate flood risk as a critical element in site planning.

(b) **Public interest**: The proposed development should not result in increased risk—to human life or damage to property or infrastructure—beyond acceptable limits.

(c) **Private and public cost**: The economic and social costs, which may arise from damage to property from flooding, should not be exacerbated by proposed development.

(d) **Flood effects caused by development activity**: Development should not detrimentally increase the potential flood effects on other development or properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.

(e) **Drainage infrastructure and creek works**: Any proposed works on drainage infrastructure or natural creeks, whether or not carried out as flood modification measures, shall:
   a. Not cause adverse flooding impacts;
   b. Not result in a loss of flood storage;
   c. Increase protection of existing and proposed development; and
   d. Not have a detrimental impact on the environment.

(f) **Building components**: Building components and materials likely to be affected by flood waters should be designed, built and installed so as not to be damaged by those floodwaters.

(g) **Structural soundness**: The proposed development shall be designed and constructed so that it remains structurally sound for its intended life taking into account all the likely flood events during that lifetime.

(h) **Storage of goods**: Goods that are likely to amplify the damages arising from flood events—including but not limited to pollutants and toxic chemicals—shall be stored so as not to find their way into floodwaters.

(i) **Flood emergency response**: Proposed developments should only be permitted where effective warning time and reliable access is available for evacuation from an area potentially affected by floods to an area free of risk from flooding. Such an area may be within the same building where a shelter-in-place option is appropriate and achievable. The emergency response should be consistent with the Flood Emergency Response Planning for Development in Pittwater Policy where it applies to the land. The proposed development should have procedures in place (such as warning systems, signage or evacuation drills) so that people are aware of the need to evacuate and relocate goods and motor vehicles during a flood and are capable of identifying an appropriate evacuation route.

(j) **Floor levels**: All floor levels within a proposed development shall be set at the required prescriptive level with additional consideration for the following:
   a. The passage of flood waters;
   b. The purpose for which that floor area is to be used;
   c. The relationship with the surrounding roadways;
   d. The relationship with the existing building if the proposal is an extension; and
   e. Surrounding built form and streetscape.

(k) **Fencing**: Fencing shall be designed and constructed so that it does not impede and/or direct the flow of floodwaters, add debris to floodwaters or increase flood affectation on surrounding land.

4.2.4. Warringah Development Control Plan 2011

Part E11 of the Warringah Development Control Plan 2011 addresses flood prone land. The clause is identical to the Clause 5.4.3 of the Manly Development Control Plan, 2013 described above.

4.2.5. Summary of Council Policy

Both Warringah and Manly LEPs have been prepared under the Standard Instrument LEP program and include the relevant Flood Planning sections. Further planning control for flood affected properties is provided in the DCPs. Later stages of this study will consider potential changes to the local planning policies which may improve clarity and/or consistency across the Manly Lagoon catchment.

4.2.6. Flood Risk Management Policy

The Flood Risk Management Policy establishes the flood risk management approach within the Northern Beaches Council LGA. It lists Councils objectives for managing flood risk and a range of strategic and operational actions that Council undertakes to identify, manage and respond to flooding.

5. EXISTING FLOOD ENVIRONMENT

5.1. Flood Behaviour Overview

Below provides a summary of the existing flood behaviour in Manly Lagoon catchment as defined in the 2013 Flood Study and subsequent model update undertaken as part of this FRMS&P:

- 2 hour duration events typically provide for the worst case flooding conditions in Manly Lagoon, with a level of 3.0 mAHD at Pittwater Bridge for the 1% AEP event;
- The rise in flood water levels can be relatively fast due to the size of the catchment. Peak flood levels in Manly Lagoon are recorded less than 30 minutes after the flood peaks at Brookvale and in the Burnt Creek deviation;
- Flooding can result from either elevated ocean conditions, catchment flooding, or a combination of both, however catchment flood events represent the dominant flooding mechanism in the catchment. Whilst ocean derived flooding will cause inundation for properties close to the lagoon, the extent and severity of flooding is significantly less than the corresponding catchment derived event;
- The entrance condition has some influence on catchment flood behaviour with higher entrance berm levels providing for higher peak flood levels. The existing entrance management policy provides for manual breakout of the Lagoon entrance at defined trigger levels in preparation for imminent flooding. Irrespective of this, significant flood extents may be expected during a major catchment event; and
- Four hotspot locations have been identified which are the most adversely affected areas in the catchment. These are shown on Figure 8 and are described below.

Location A – Kenneth Road & Balgowlah Road

Due to the low ground levels, the area around Kenneth Road is highly flood affected. The road is inundated in all design events, and peak depths reach 1 m in the 1% AEP event, with velocities of 1.5 m/s. The area is affected by lagoon flooding and overland flooding.

Location B – Balgowlah

Flooding occurs in this area as a result of three different mechanisms – overland flooding, catchment flooding and ocean flooding, and can result in high velocities and depths.

Location C – Manly Lagoon north bank

Manly Lagoon is located at the downstream end of the catchment. In a 1% AEP event the flood levels peak at 2.9 mAHD. Flooding is influenced by two consecutive bridges and the entrance conditions / low flow pipes.

Location D – Brookvale

Clearview Place is a primary flowpath in this area. The high flows and velocities present a significant risk to pedestrians, motorists and property along the street. The street is aligned with

the original creek channel, which was replaced with a pipe. However, the pipe capacity is exceeded in the 1% AEP event, resulting in peak depths of 1.65 m and peak velocities of 1.1 m/s.

Warringah Mall is at the downstream end of an open channel. A culvert under the mall directs water to the lagoon, however, the culvert capacity is exceeded in significant flood events. This results in peak depths of 1.5 m and velocities of 1 m/s in the 1% AEP event.

5.1.1. Design Flood Data

Table 3 provides peak flood levels at key locations (shown on Figure 9) across the catchment for the 10%, 5%, 1% AEP and PMF design events

Table 3: Design Flood Levels at Key Locations

ID	Location	Peak Flood Level (mAHD)			
		10% AEP	5% AEP	1% AEP	PMF
1	Manly Lagoon at Pittwater Bridge	2.55	2.69	2.96	5.75
2	Manly Lagoon at Riverview Parade	2.58	2.72	2.99	5.76
3	Manly Creek upstream the lagoon	3.90	4.18	4.83	6.17
4	Manly Creek at Mermaid Pools	11.31	11.66	12.15	14.96
5	Brookvale Creek downstream M8	5.85	5.91	6.06	6.70
6	Manly Lagoon downstream Kenneth Road	2.56	2.70	2.97	5.75
7	Brookvale Creek at Clearview Place	19.76	20.19	20.79	23.73
8	Brookvale Creek at Warringah Mall	11.30	11.83	12.51	14.59
9	Burnt Bridge Creek between West Street and M8	12.32	12.53	12.87	13.86
10	Burnt Bridge Creek at Hope Street	33.18	33.51	34.30	35.88
11	M8 upstream Balgowlah	10.65	10.96	11.12	12.20

5.2. Hydraulic and Hazard Classification

For the purposes of floodplain risk management in NSW, floodplains can be divided into hydraulic and hazard categories. Details of this process are provided in the NSW Governments Floodplain Development Manual (2005, Appendix L) (Reference 2) and *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 3), as well as briefly described below.

Hydraulic categories describe the flood behaviour by categorising areas depending on their function during the flood event, specifically, whether they transmit large quantities of water (floodway), store a significant volume of water (flood storage) or do not play a significant role in either storing or conveying water (flood fringe). Although the three categories of hydraulic function are described in the Floodplain Development Manual (The Manual) (Reference 2), their definitions are largely qualitative and the manual does not prescribe a method to determine each area. The Manual gives one indication of how to quantitatively differentiate floodway and flood storage, when it states that flood storage areas, when completely filled with solid material, will

not raise peak flood levels by “more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%”.

Hydraulic categories have been defined by considering detailed assessment of flood behaviour, the available topographic information and interpretation of the hydraulic model results and knowledge of the catchment. Figure 10 to Figure 17 show the categorisation for the PMF, 0.1%, 0.5%, 1%, 5%, 10% and 20% AEP catchment design events as well as the 1% AEP catchment with a 5% AEP ocean coincident event.

As with hydraulic categories, hazard classification plays an important role in informing floodplain risk management in an area. Previously, hazard classifications were binary – either Low or High Hazard as described in the Manual. However, in recent years there has been a number of developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 3) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories (Diagram 3) which indicate the restrictions on people, buildings and vehicles:

- H1 - No constraints;
- H2 – Unsafe for small vehicles;
- H3 - Unsafe for all vehicles, children and the elderly;
- H4 - Unsafe for all people and all vehicles;
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

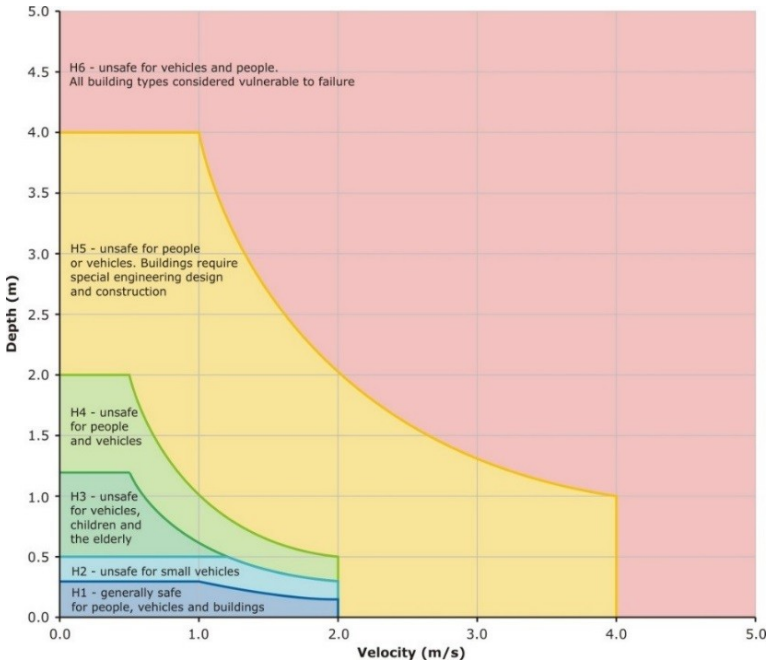

Diagram 3 Hazard Classifications

Hazard categories are often grouped based on consequences. Figure 18 to Figure 25 provide the hazard classification for all the design events, with H1 & H2 and H3 & H4 grouped into two categories due to their similarity in consequences. Under this classification, the most hazardous areas of the floodplain are generally constrained to the non-habitable areas, the parks, reserves, golf courses etc., lying adjacent to the waterways. There are two pockets of residential development, however, which are shown to be in areas unsafe for people and/or vehicles from the 5% AEP event – these are already identified as hot spot locations (Kenneth Road and Riverview Parade).

The Floodplain Development Manual (Reference 2) requires that other factors be considered in determining the "true" hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows. However, to assess the full flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. The classification is a qualitative assessment based on a number of factors as listed in Table 4. A weighting of 1 or 2 would reduce the provisional hazard severity, 3 would have no impact, and 4 or 5 would increase the hazard severity.

Table 4: Hazard Classification

Criteria	Weighting	Comment
Size of flood	3	Whilst some residential areas located in areas unsafe for people / vehicles from the 5% AEP event, the majority of residential areas are located in the lower hazard areas for all events except the PMF.
Flood Awareness of the Community	3	Recent flooding and near-misses has elevated the communities' awareness of flooding. Initiatives such as the Northern Beaches Flood Warning System assist in maintaining this awareness.
Depth and Velocity of Floodwaters	3	Already accounted for in the provisional hazard
Effective Warning and Evacuation Times	5	Fast onset of flooding with little warning time means residents may be caught off guard.
Evacuation Difficulties	3	The majority of properties can be evacuated to nearby high land if required.
Rate of Rise of Floodwaters	4	Flash flooding characteristics increases the likelihood that people may not be aware of the flood risk until access routes are inundated.
Duration of Flooding	2	The catchment is generally subjected to short durations of flooding, and therefore areas are unlikely to be isolated or hazardous for significant durations of time.
Effective Flood Access	3	The majority of the catchment has effective flood access. Those areas without effective flood access are already categorised in the higher risk categories.

Based on the above assessment, the provisional flood hazard categorisations will not be changed and already capture the true hazard satisfactorily.

6. FLOOD EMERGENCY RESPONSE ARRANGEMENTS

Emergency response measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks in an area. Current emergency response arrangements for the Manly Lagoon catchment are discussed below.

6.1. Emergency Response Planning Documentation

The Manly Lagoon catchment is covered by the Northern Beaches Local Emergency Management Plan (EMPLAN) July 2017. The plan covers and details arrangements for the prevention, preparation, response and recovery for emergencies within the area. Major arterial roads within the catchment include:

- Warringah Road;
- Pittwater Road;
- Condamine Street;
- Burnt Bridge Creek deviation;
- Wakehurst Parkway (which is noted to often close due to flooding);
- Sydney Road; and
- Manly Road.

The EMPLAN identifies that the combat agency for flooding is the NSW SES, however there is currently no Local Flood Plan for the area, although this is currently being drafted.

6.2. Northern Beaches Flood Warning System

The Northern Beaches Flood Warning System is a joint venture between Northern Beaches Council (formerly, Pittwater, Warringah and Manly Councils), with support from the Bureau of Meteorology (BoM) and the Office of Environment and Heritage (OEH).
The aim is to provide a basic flash flood warning system to the community, through live publishing of rainfall and water level gauges. As part of the project, additional gauges have been installed across the area. The information is provided on a public website (*http://www.mhl.nsw.gov.au/users/NBFloodWarning/).*

As well as publishing live and historical gauge information the website provides some emergency planning information. Current advice is to watch out for 70mm rainfall in 3 hours and/or 150mm rainfall in 24 hours and states that "*when flash flooding is likely, leave low-lying homes and businesses well before any flooding begins. Evacuation is the best action to take, but only if it is safe to do so".*

The warning system provides a wealth of data, although it is not specifically tied to consequences for properties or specific locations. Without this link, the warning system becomes a data display tool rather than a risk management tool.

Improving the system is not simply a matter of creating these links, or identifying key thresholds. Flood liability in the Manly Lagoon floodplain varies across the catchment and results from various mechanisms. This means that each area of flood liability may have a different metric that needs to be used to set threshold values. Further, given the limited catchment size and its fast response rate, the question remains as to what is to be done in times of flooding for those properties at risk. The current system provides advice that evacuation should occur whenever flash flooding is deemed likely. However, without the link to consequences of heavy rain, very few people are likely to self-evacuate given the system's criteria for them doing so (rainfall depths over specific periods of time). Furthermore, whilst evacuation is generally the preferred option, it may not be achievable and encouraging people to be in a vehicle during a flood is not recommended (discussed further in Section 6.4).

As such, it is recommended that this system is integrated with SES and Council activities such as road closures and evacuations. This would be best achieved through the implementation of a local SES flood plan.

6.3. Flood Emergency Response Classifications

The Floodplain Development Manual (Reference 2) requires flood studies to address the management of continuing flood risk to both existing and future development areas. As continuing flood risk varies across the floodplain so does the type and scale of the emergency response problem and therefore the information necessary for effective Emergency Response Planning (ERP). Classification provides an indication of the vulnerability of the community in flood emergency response and identifies the type and scale of information needed by the SES to assist in ERP.

Criteria for determining flood ERP classifications and an indication of the emergency response required for these classifications are provided in the Floodplain Risk Management Guideline, 2007 (Flood Emergency Response Planning: Classification of Communities). Table 5 summarises the response required for areas of different classification. However, these may vary depending on local flood characteristics and resultant flood behaviour, i.e. in flash flooding or overland flood areas.

Table 5: Response Required for Different Flood ERP Classifications

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

The ERP classifications for regions within the hydraulic model extent have been defined for the 1% AEP and PMF flood events in Figure 26 and Figure 27. The classification has been undertaken on a precinct basis rather than lot-by-lot and is targeted at those areas which may require evacuation or assistance during a flood event. These are described in Table 6 below.

Table 6: ERP Categorisation for Hotspot Locations PMF event

Area (refer Figure 8 for locations)	Emergency Response Planning Categorisation
Hotspot A – Kenneth Rd & Balgowlah Rd	Low Flood Island
Hotspot B - Balgowlah	Low Trapped Perimeter and Low Flood Island
Hotspot C – Manly Lagoon North Bank	Low Flood Island
Hotspot D - Brookvale	Rising Road Access

6.4. Access and Movement during Flood Events

Any flood response measure suggested as part of this study must take into account the availability of flood free access, and the ease with which movement may be accomplished. As part of the current study, a review of the access roads and evacuation arrangements has been undertaken and is discussed in the following sections.

6.4.1. Access Road Flooding

The details of flood affectation of 20 access roads (Table 7) across the catchment area are provided in Table 8 with locations shown on Figure 28.

Table 7: Flood Affected Road Locations

ID	Road Location (refer Figure 28)
1	Pittwater Bridge
2	Intersection Kenneth and Balgowlah Road
3	Intersection Balgowlah Road and Golf Parade
4	M8 at Brookvale Creek
5	Intersection Kenneth and Roseberry Road
6	Pittwater Road at Riverview Parade
7	William Street
8	Intersection Condamine Street and M8
9	M8 at Kitchener Street
10	Kenneth Road next to swimming pool
11	Clearview Place
12	Old Pittwater Road Bridge
13	Cross Street at Warringah Mall
14	Intersection Cross and Green Street
15	M8 at Manly Creek
16	Sloane Crescent
17	Warringah Road
18	Intersection Condamine Street and Balgowlah Road
19	Intersection Burnt Bridge Creek Deviation and Sydney Road
20	Wakehurst Parkway near Warringah Aquatic Centre

Table 8: Inundation of Access Roads

Location	Road Level (mAHD)	First Event Flooded (AEP)	Peak Velocity 1% AEP (m/s)	Rate Of Rise 1% AEP (cm/min)	Time Of Inundation 1% AEP (hour)	Peak Flood Depth (mAHD)			
						20% AEP	5% AEP	2% AEP	1% AEP
1	2.08	20%	0.73	1.32	4.67	0.29	0.58	0.73	0.87
2	2.05	50%	0.72	1.09	5.16	0.41	0.70	0.84	0.97
3	2.05	50%	0.49	1.37	6.43	0.72	1.00	1.15	1.27
4	8.37	50%	1.75	1.89	1.10	0.22	0.36	0.43	0.49
5	6.26	50%	0.23	2.54	1.80	0.50	0.78	0.87	0.94
6	2.00	50%	0.43	1.52	4.33	0.49	0.76	0.91	1.03
7	9.62	50%	0.75	1.63	3.23	0.75	0.88	0.97	1.03
8	10.22	20%	1.39	11.16	0.87	0.22	0.82	0.88	0.87
9	25.60	20%	3.48	2.09	0.40	0.12	0.26	0.37	0.39
10	2.30	50%	0.40	0.92	2.83	0.31	0.41	0.55	0.68
11	17.92	50%	2.26	3.86	0.64	0.27	0.50	0.64	0.79
12	14.18	50%	1.60	5.55	0.37	0.19	0.30	0.38	0.43
13	11.57	2%	1.99	Shallow	Shallow	0.00	0.00	0.14	0.16
14	9.18	50%	0.41	3.71	1.87	0.66	0.94	1.10	1.25
15	5.1	5%	0.40	Shallow	Shallow	0.00	0.05	0.06	0.06
16	7.52	5%	2.83	Shallow	Shallow	0.00	0.05	0.12	0.16
17	*Flood free*								
18	*Flood free*								
19	*Flood free*								
20	*Flood free*								

6.4.2. Evacuation Planning

During a flood which triggers evacuation, locations will need to be identified which are safe and able to accommodate the affected individuals. Details of evacuation centres are not provided in the DISPLAN. Due to the short warning time and relatively short durations of flooding, formal evacuation is unlikely to be possible for most residents. The Emergency Response Classification (see Section 6.3) identified that rising road access routes, or overland escape routes, are available for the majority of the residents, however it did identify two residential and one commercial area of concern – these have been as classed Low Flood Islands. For these properties, there are no flood free access routes and land and building inundation occurs. As formal evacuation is unlikely to be able to occur in time, sheltering in place (remaining in situ) becomes the most likely default scenario.

In order to safely shelter in place, residents would need to be able to promptly access a building which has some floor area above the PMF. A review of the floor level information for residential properties in the areas identified as Low Flood Islands has been undertaken. For the area between Riverview Parade and Pittwater Road (121 properties), there were no public buildings. There are also no private buildings with floor levels above the PMF. Four properties had floor

levels higher than the 1% AEP level (but lower than the PMF), however all four had ground inundation from the 50% AEP event.

For the area on the southern side of the lagoon, around Eurobin Avenue (65 properties), seven properties had floor levels above the 0.1% flood (but less than the PMF). Ground levels for these properties were first inundated from events ranging between the 50% AEP to the 2% AEP. There were another eight properties with floor levels above the 1% AEP level, again with ground levels inundated from events varying between the 50% AEP and 2% AEP event. Sheltering-in-place may be possible for floods up to approximately the 1% AEP level. This does, however, assume that neighbours with raised floor levels would be willing to act as shelters for others in their community, and that access between properties was possible.

The other issue is whether buildings are able to withstand the forces of floodwater, buoyancy and debris in large events, and remain safe for the entire duration of a flood. It is beyond the scope of this study to assess this on a building by building basis. In general however, light-framed weatherboard or timber dwellings sitting on stumps are at greater risk of being removed from their foundations, and brick, two-storey dwellings would generally be preferred as local refuges.

Isolation is another consideration. The tolerability of isolation reduces as the duration of flooding increases. In the modelled 1% AEP event affected residents would generally be isolated for no more than 6 hours. Whilst this is not ideal, and may be uncomfortable for residents, it is a tolerable duration of time to remain in situ.

7. FUTURE FLOOD ENVIRONMENT

The following sections consider changes to the flood environment as a result of future conditions namely, further development in the catchment, and climate change.

7.1. Changes due to Development

The cumulative impact of future development has been assessed by filling all the flood affected area in the catchment to the Flood Planning Level (FPL). The FPL is derived from the concurrence of a 1% AEP catchment scenario with a 5% AEP ocean scenario plus 0.5 m of freeboard.

The impact of future development on peak flood levels is shown in Figure 29. The average increase is slightly above 0.4 m, although this can reach 1 m in Balgowlah and Brookvale. This is primarily a result of overland flow paths through private property being blocked by the fill. The scenario causes slight decreases (0.05 m) around the lagoon.

7.2. Changes due to Climate Variation

Whilst there is general consensus that the climate in the future will be different from current conditions, there is uncertainty in the magnitude, and even the direction, of that change. Climate change has the potential to impact flooding through changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events, and through sea level rise. However, quantifying the effects of climate change on these factors is a difficult task, and includes large uncertainties. As such, using an approach based on a sensitivity analysis of different scenarios, and focusing on the consequences (like that used in the Coastal Zone Management Plan for Collaroy-Narrabeen Beach & Fisherman's Beach, 2014) facilitates an assessment of the potential impacts of climate change despite this uncertainty.

The NSW Government issued a policy statement in 2009 which required Councils to consider a sea level increase of 0.4 m by 2050 and 0.9 m by 2100 (relative to 1990 levels), and a sensitivity analysis of increases in rainfall intensity of +10%, +20% and +30%. Whilst this policy has now been repealed and Councils are required to make their own assessments, the estimates are still widely used in NSW.

For sea level rise, current estimates vary between 0.13 m increases by 2050 for low emissions scenarios, to as high as 0.98 m for high emission scenarios in 2100. The *Floodplain Risk Management Guideline: Practical Consideration of Climate* Change (Reference 4) recommends undertaking a sensitivity analysis which includes 0.18 m, 0.55 m and 0.91 m increases in sea level rise, whilst information provided by CSIRO and Bureau of Meteorology (Climate Change in Australia website) suggests increases ranging from 0.22 m to 0.88 m by 2090 for Eastern Australia. Therefore, the commonly applied estimates of +0.4 m (2050) and +0.9 m (2100) remain reasonable factors to use in sensitivity analyses as they encompass a significant portion of the range in estimates.

Australian Rainfall and Runoff (ARR) recommends using the RCP 4.5 (low emissions) and RCP8.5 (high emissions) for impact assessment, and allowing for a 5% increase in rainfall for every one degree Celsius of increased temperature. Using the methodology prescribed in ARR and the outputs of the Climate Future web tool, the following estimates of rainfall increase for the Manly Lagoon catchment are generated.

Table 9: Climate Change Rainfall Increases

Scenario	2025	2050	2090
RCP4.5	+2.5%	+2.5%	+12%
RCP8.5	+12%	+12%	+20%*

** assuming 3.5°C increase based on the Climate Futures result of >3°C*

Based on this, using the +10% and +20% rainfall increase would sufficiently cover the range of expected changes in rainfall.

As such, six climate change scenarios have been modelled as the basis of the impact assessment, all derived from the 1% AEP design event with a 5% ocean condition, being:

- +0.4 m sea level rise;
- +0.9 m sea level rise;
- +0.4 m sea level rise and +10% rainfall;
- +0.9 m sea level rise and +10% rainfall;
- +0.4 m sea level rise and +20% rainfall;
- +0.9 m sea level rise and +20% rainfall.

The consequences of climate change were assessed based on the impact on estimated flood damages, changes to above-floor property inundation and extent of hazardous (H4, H5) areas.

7.2.1. Impacts on Property Inundation and Flood Damages

The climate change scenarios increased the number of residential properties affected by 22 – 38%, and increased the estimated flood damages by 49 –91%. This is because not only were more properties affected, there was a significant increase in those which experienced above floor inundation (33% - 54%), and hence tangible damages were increased.

Table 10: Impact on Tangible Residential Damages and Above Floor Affectation, 1% AEP event

Scenario*	No. Properties Affected (change from existing)	No. Flooded Above Floor (change from existing)	Approximate Total Damages for Event (% change from existing)
Existing	381	289	$28.5m
+0.4 m sea level rise only	463 (+22%)	384 (+33%)	$42.5m (+49%)
+0.9 m sea level rise only	486 (+28%)	409 (+42%)	$48.2m (+69%)
+0.4 m sea level rise and +10% rainfall	489 (+28%)	404 (+40%)	$46.0m (+61%)
+0.9 m sea level rise and +10% rainfall	507 (+33%)	428 (+48%)	$51.4m (+80%)
+0.4 m sea level rise and +20% rainfall	510 (+34%)	422 (+46%)	$49.5m (+74%)
+0.9 m sea level rise and +20% rainfall	524 (+38%)	445 (+54%)	$54.5m (+91%)

* Scenarios are based on the 1% AEP catchment event with 5% AEP ocean conditions

7.2.2. Impact on Flood Hazard

A comparison of the “worst case” climate change scenario (+0.9 m sea level rise and +20% rainfall increases) with the current 1% AEP hazard classification is shown on Figure 30. This shows that whilst the areas of ‘high hazard’ (H5 & H6) increase, they are predominantly confined to the non-developed areas adjacent to the lagoon and creeks. The extent of residential properties affected by flooding does increase, particularly around Hotspot A on the south side of the lagoon. There is also some increase in affected properties in Hotspot C on the north side. These areas generally lie in hazard category H3 & H4.

8. ECONOMIC IMPACT OF FLOODING

The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also an objective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Diagram 4.

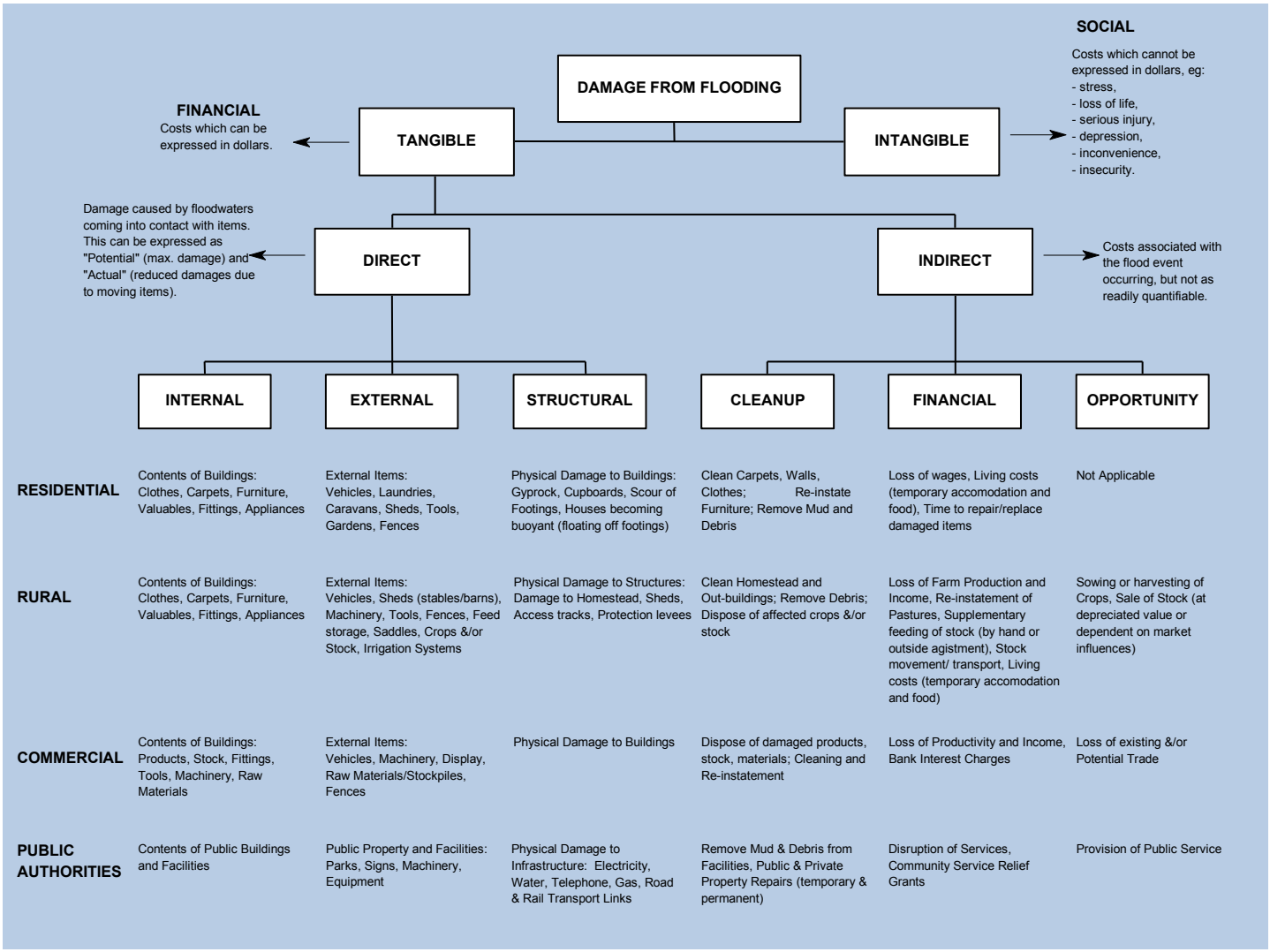

Diagram 4: Flood Damages Categories

8.1. Tangible Flood Damages

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

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development a desktop estimation of floor levels was undertaken using the provided Digital Elevation Model, aerial imagery and Google Street-view. In addition, field survey for the highest risk properties was also obtained. The survey data was used in conjunction with modelled flood level information to calculate damages. Damage calculations were carried out for all properties within the PMF extent, and floor levels were estimated for these properties.

The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

The total estimated damages from both residential and non-residential properties are provided in Table 11. Damages were calculated for residential and commercial/industrial properties separately, as well as for the former Warringah and Manly Council LGAs, as discussed in the following sections.

Table 11: Estimated Total Flood Damages (residential & non-residential) for Manly Lagoon catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20% AEP	125	62	$8,150,000	$65,200
10% AEP	220	133	$15,492,000	$70,418
5% AEP	274	191	$21,947,000	$80,099
2% AEP	337	251	$29,844,000	$88,558
1% AEP	401	310	$36,880,000	$91,970
0.5% AEP	458	356	$43,578,000	$95,148
PMF	868	765	$136,515,000	$157,275
Average Annual Damages (AAD)			$5,102,000	

The flood damages estimates do not include the cost of restoring or maintaining public services and infrastructure. It should also be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements, damages can be under estimated.

8.1.1. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. A flood damages assessment was undertaken for 1457 residential properties. Remote survey using ALS data, street view and site visits was used to estimate the majority of the floor levels in the catchment. 69 high risk properties were surveyed by registered surveyors.

A summary of the flood damages assessment is provided in Table 12 for the Manly Lagoon catchment as a whole. Table 13 presents the results for those properties within Northern Beaches South only and Table 14 for those located within Northern Beaches Central.

Table 12: Estimated Residential Flood Damages for Manly Lagoon catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages*	Average Tangible Damages Per Flood Affected Property*
20% AEP	89	32	$3,303,000	$37,100
10% AEP	164	85	$7,824,000	$47,700
5% AEP	209	135	$12,396,000	$59,300
2% AEP	253	176	$16,934,000	$66,900
1% AEP	304	225	$ 21,749,000	$71,500
0.5% AEP	350	263	$26,167,000	$74,800
PMF	672	582	$87,866,000	$130,800
Average Annual Damages (AAD)			$2,595,000	$3,900

Table 13: Estimated Residential Flood Damages for Manly Lagoon catchment within Northern Beaches South area

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages*	Average Tangible Damages Per Flood Affected Property*	%age of total residential damages
20% AEP	30	14	$1,411,000	$ 47,000	43%
10% AEP	51	22	$2,260,000	$ 44,300	29%
5% AEP	64	38	$3,605,000	$ 56,300	29%
2% AEP	88	55	$5,246,000	$ 59,600	31%
1% AEP	120	85	$8,085,000	$ 67,400	37%
0.5% AEP	151	106	$10,462,000	$ 69,300	40%
PMF	329	299	$ 46,133,000	$ 140,200	53%
Average Annual Damages (AAD)			$929,000	$2,800	36%

Table 14: Estimated Residential Flood Damages for Manly Lagoon catchment within Northern Beaches Central area

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property	%age of total residential damages
20% AEP	59	18	$1,893,000	$32,100	57%
10% AEP	113	63	$5,565,000	$49,200	71%
5% AEP	145	97	$8,792,000	$60,600	71%
2% AEP	165	121	$11,688,000	$70,800	69%
1% AEP	184	140	$13,664,000	$74,300	63%
0.5% AEP	199	157	$15,705,000	$78,900	60%
PMF	343	283	$41,733,000	$121,700	47%
Average Annual Damages (AAD)			$1,666,000	$4,900	64%

8.1.2. Non-Residential – Commercial and Industrial

There are three main pockets of non-residential land use in the catchment, Warringah Mall, Stockland Balgowlah and the Balgowlah Industrial Estate. Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of activity as indicated below;

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed, but when access to it is restored;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to be moved and in other instances there may be no sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

A summary of the flood damages assessment for commercial and industrial properties is provided in Table 15 for the Manly Lagoon catchment. Table 16 presents the results for those properties within Northern Beaches south only and Table 17 for those located within Northern Beaches Central. The non-residential damages account for approximately 40% of the total AAD in the catchment.

Table 15: Estimated Non-residential Flood Damages for Manly Lagoon catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20% AEP	36	30	$4,847,000	$134,600
10% AEP	56	48	$7,668,000	$136,900
5% AEP	65	56	$9,551,000	$146,900
2% AEP	84	75	$12,910,000	$153,700
1% AEP	97	85	$15,131,000	$156,000
0.5% AEP	108	93	$17,411,000	$161,200
PMF	196	183	$48,649,000	$248,200
Average Annual Damages (AAD)			$2,507,000	$12,800

Table 16: Estimated Non-residential Flood Damages for Manly Lagoon catchment within Northern Beaches South area

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property	%age of total non-res damages
20% AEP	10	8	$1,566,000	$156,600	32%
10% AEP	16	15	$2,608,000	$163,000	34%
5% AEP	18	17	$3,083,000	$171,300	32%
2% AEP	25	24	$4,272,000	$170,900	33%
1% AEP	30	29	$5,153,000	$171,800	34%
0.5% AEP	36	34	$6,291,000	$174,700	36%
PMF	62	60	$15,687,000	$253,000	32%
Average Annual Damages (AAD)			$827,000	$13,300	33%

Table 17: Estimated Non-residential Flood Damages for Manly Lagoon catchment within Northern Beaches Central area

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property	%age of total non-res damages
20% AEP	26	22	$3,281,000	$126,200	68%
10% AEP	40	33	$5,060,000	$126,500	66%
5% AEP	47	39	$6,468,000	$137,600	68%
2% AEP	59	51	$8,639,000	$146,400	67%
1% AEP	67	56	$9,978,000	$148,900	66%
0.5% AEP	72	59	$11,120,000	$154,400	64%
PMF	134	123	$32,962,000	$246,000	68%
Average Annual Damages (AAD)			$1,680,000	$12,500	68%

8.2. Public Infrastructure

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; telephone and electricity supply including transmission poles/lines, sub-stations and

underground cables; roads and bridges including traffic lights/signs; and costs to employ the emergency services and assist in post-flood clean up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise:

- Clean-up costs;
- Erosion and siltation;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts, water and sewer infrastructure;
- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

8.3. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items, etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post-flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example, the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. As well as the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up, etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

9. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flood risk and reduce flood damages. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the Manly Lagoon catchment.

9.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 2) separates risk management measures into three broad categories;

- **Flood modification measures (Section 9.2)** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

- **Response modification measures (Section 9.3)** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community, and provision of flood insurance.

- **Property modification measures (Section 9.4)** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

In addition, the following measures were specifically requested to be assessed as part of the Management Study:

- Any possible options to mitigate nuisance flooding at Balgowlah/Kenneth Road, including:
    - Installing a tidal flap/valve on the pipe;
    - Implications of insufficient maintenance or pipe failure;
    - Raising Balgowlah Road and the Manly Senior Citizens carpark;
    - Incorporating in-pipe storage in the upper catchment; and
    - Underground detention (with possible retention for reuse) in Keirle Park.
- Emergency management to consider the impacts of flooding on Manly SES headquarters, Manly Council depot and Quirk Road electrical substation;

- Levee and in-line check valve on stormwater pipes at the Manly Lagoon end of Campbell Parade;
- Allambie Heights drainage augmentations;
- Review options identified in the 1996 Manly Lagoon FRMS and identify any options which could be reinvestigated;
- Assess the impact of lowering the storage level of Manly Dam; and
- Assess the impact of extending the low flow channel under Stuart Somerville bridge by lowering the bed rock level.

Table 18 provides a summary of all the options considered in this study. Details of their assessment are included in the following sections, and their approximate location shown on Figure 31.

Table 18: Manly Lagoon Catchment management options considered

Category	Option	ID	Description	Reference	Recommended
Flood Modification Measures	Levee	LV01	Levee around Riverview Parade area as per 1996 Floodplain Management Study. Levee set to the 1% AEP level without freeboard.	9.2.1.1	No
		LV02	New levee located upstream of Warringah Mall near Clearview Place to prevent mainstream flooding. Levee set to 1% AEP level without freeboard.	9.2.1.2	**Yes**
		LV03	Levee located around properties in hotspot location A (Kenneth Road & Balgowlah Road) as per 1996 Floodplain Management Study. Levee set to 1% AEP level without freeboard.	9.2.1.3	No
		LV04	Levee located along Campbell Parade and along Manly Creek, constructed to the 5% AEP level.	9.2.1.3	No
	Temporary Flood Barriers	TB01	Use of temporary flood barriers to protect small areas or individual properties.	9.2.2	No
	Floodways / diversion channels	DC01	New flow path created south of Pittwater Bridge to recreate the original channel which was piped over in 1952.	9.2.3	No
	Channel modification	CM01	Lowering the creek upstream of Clearview Place by approximately 0.5 m for 20 m.	9.2.4.1	No
		CM02	Lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m.	9.2.4.2	No
		CM03	Rock channel upstream of the twin low-flow pipes is extended upstream of Stuart Somerville Bridge by 60 m.	9.2.4.3	No
		CM04	Lowering the 25 m long bed rock beneath Stuart Somerville Bridge by 0.4 m.	9.2.4.4	No
	Drainage Modification	DM01	Installation of new pipe system (2 x 0.6 m pipes) along Balgowlah Road.	9.2.5.1	No
		DM02	Installation of new pipe system (2 x 0.6 m pipes) along Balgowlah Road.	9.2.5.2	No
		DM03	Installation of flap valve where the pipe at Keirle Park discharges into the lagoon to prevent ingress of waters from the lagoon into the drainage system during smaller events.	9.2.5.3	No
		DM04	New pipe system (2 x 0.6 m pipes) in Balgowlah starting at Pitt Street until Manly West Park	9.2.5.4	No
		DM05	Installing new pipe network (2 x 0.6 m pipes) along Kenneth Road between Rosebery Street and Quirk Road	9.2.5.4	No

Flood Modification Measures		DM06	New pipe system (2 x 0.6 m) along Green Street and William Street to reduce local overland flows.	9.2.5.4	No
		DM07	New 1500 m trunk drainage system through Brookvale (box culvert of 3 m x 1.5 m)	9.2.5.7	No
	Drainage maintenance	DR01	Dredging at Pittwater Bridge to a channel level of -1.5 mAHD	9.2.6.1	No
		DR02	Dredging upstream and downstream of Stuart Somerville Bridge to the rock bar level (0.2 mAHD)	9.2.6.2	No
	Retention basins	RT01	New basin on Manly Creek at Millers and David Thomas Reserve. Spillway 2 m above bottom of basins (total storage volume of 146 000 m^3).	9.2.7.1	No
		RT02	Installing underground detention tank in Keirle Park. (1000 m^3 storage)	9.2.7.2	No
	Dams	MD01	Lowering the initial water level of Manly Dam to the operating level, 34.14 mAHD.	9.2.8.1	**Yes**
		MD02	Lowering initial water level in the Manly Dam by 0.2 m below the crest level to 35.64 mAHD to assess the impact of storing water in the dam.	9.2.8.2	**Yes**
		MD03	Lowering initial water level in the Manly Dam by 0.4 m below the crest level to 35.44 mAHD to assess the impact of storing water in the dam.	9.2.8.3	**Yes**
		MD04	Lowering initial water level in the Manly Dam by 0.8 m below the crest level to 35.04 mAHD to assess the impact of storing water in the dam.	9.2.8.4	**Yes**
Response Modification Measures	Emergency Planning	RM01	Development of Local Flood Plan	9.3.1	**Yes**
	Flood Warning	RM02	Add new stream gauges on each of the three creeks, continuation of Northern Beaches Flash Flooding Warning System	9.3.2	**Yes**
	Improving road access	RM03	Raising Balgowlah Road and the Senior Citizens carpark. The road was raised by 1 m - 1.5 m for approximately 560 m. The carpark was raised by 1.5 m in the west and 1.3 m in the east.	9.3.3	No
	Road Closures	RM04	Add list of affected roads to Local Flood Plan. Flag some for depth indicators	9.3.4	**Yes**
	Community Education and Awareness	RM05	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	9.3.5	**Yes**
Property Modification Measures	Voluntary House Raising	PM01	Assesses raising eligible residential properties to reduce flood damages.	9.4.1	No
	Voluntary House Purchase	PM02	Assesses purchasing eligible residential properties to remove residents from high flood risk areas and reduce floodway obstruction.	9.4.2	No
	Flood Proofing	PM03	Future development of commercial properties within FPA should incorporate flood proofing up to the FPL	9.4.3	**Yes**
	Land Use Zoning	PM04	Changes to land use zoning should consider flood compatibility using outcomes from this report.	9.4.4	**Yes**
	Flood Planning Levels	PM05	Based on the 1% AEP + 0.5m as defined in the 2013 Manly Lagoon Flood Study.	9.4.5	**Yes**
	Flood Planning Area	PM06	As defined in the 2013 Manly Lagoon Flood Study.	9.4.6	**Yes**
	Changes to Planning Policy	PM07	DCP updated with FPL and FPA as discussed above	9.4.7	**Yes**
	S10.7 Certificates	PM08	Provide flooding info on Council's website, include up to date flooding info on future S10.7 (2) and (5) certificates requested	9.4.8	**Yes**

9.2. Flood Modification Measures

9.2.1. Levees and Embankments

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis. Although a levee can keep out flood waters, flooding can occur behind the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event and uncertainties.

OPTIONS CONSIDERED

Four levee options were assessed and are discussed in the following sections. Note that at this stage freeboard has not been included in setting levee design crest levels however this will be a necessary inclusion should any levee options be progressed. Freeboard accounts for uncertainty in modelled flood levels, localised changes in flood level, wind setup, wave action, and settlement and defects in the levee banks.

9.2.1.1. LV01: Levee Option 1 – Riverview Parade

The Riverview Parade residential area is separated by a channel at Lakeside Crescent. Consequently two levees were modelled which aimed to alleviate mainstream flooding in hotspot C (Figure 8). The levee crests are designed to 3.1 mAHD (approximately the 1% AEP level without freeboard). The first is 1200 m long and encloses properties along Palm Avenue and Riverview Parade, while the second levee is 485 m long, and encircles a number of properties between Pittwater Road and Rowe Street.

Figure 32 and Figure 33 show the impact on peak flood levels for the 1% AEP and 5% AEP design events respectively. The two levees displace water during flood events and cause an

increase in flood levels both upstream and downstream of the newly protected areas. In the 1% AEP event a volume of 107,500 m^3 is displaced from within the levee, while in the 5% AEP 77,800 m^3 is displaced. Increases to flood levels of 0.1 m occur upstream of the levee system in the 1% AEP event and peak levels across the entire lagoon downstream of the levee also increase by 0.01 m. With the levees in place 93 houses are no longer flooded in the 1% AEP event, and 84 are no longer flooded in the 5% AEP event. However, one property is newly flooded during the 1% AEP Event.

☒ **LV01 Recommendation**

The levee is not recommended due to the adverse impacts it causes to flood levels upstream and downstream of the protected area.

9.2.1.2. LV02: Levee Option 2 - Clearview Place

A levee at Clearview Place was modelled which aimed to reduce mainstream flooding in hotspot D (Figure 8). The modelled levee is 90 m long and the crest height set to the 1% AEP level (23.1 mAHD). No additional outlet pipes have been modelled at this stage.

The impact on peak flood levels for the 1% AEP and 5% AEP design events is shown in Figure 34 and Figure 35 respectively. In the 1% AEP event there is a reduction in peak levels of up to 0.5 m at Clearview Place, and a reduction in peak flow, as shown in Table 19. However, the levee creates an obstruction to the flow, resulting in higher flood levels upstream of Clearview Place. This results in two new properties being flood affected in the PMF. This could be addressed with further levee design optimisation.

There is an existing culvert starting just downstream of the proposed levee running directly beneath Clearview Place. Table 19 notes the flow rates over the road and through the culvert beneath Clearview Place to compare current flows with those expected with levee construction (taken at approximately No. 8 Clearview Place).

Table 19: Flow at Clearview Place for Existing Condition and LV02 option.

Location	Existing 1% AEP peak flow (m^3/s)	LV02 1% AEP peak flow (m^3/s)
Overland flow path Clearview Place	32.08	10.97
Flow through culvert below Clearview Place	39.26	45.07
Total flow through Clearview Place	**71.34**	**56.04**

More of the previously overland flow is now routed through the existing culvert, which would make the area sensitive to blockage or constricted pipe flow. However, given the significant potential reduction in flood levels this option should be considered further.

☑ **LV02 Recommendation**

This option causes benefits and should be investigated further, however sensitivity of the existing culvert to blockage should not be overlooked.

9.2.1.3. LV03: Levee Option 3 – Kenneth Road

A levee to protect the flooded properties in hotspot location A (Burnt Bridge Creek near Kenneth Street and Balgowlah Road) was originally considered in the 1996 Floodplain Management Study but was dismissed due to the low benefit-cost ratio (estimated at 0.6). The option was reinvestigated as part of the current study.

A similar levee configuration was modelled, with the levee running from Pacific Parade to Cameron Avenue for approximately 790 m at a design height of 2.97 mAHD (approximately the 1% AEP level without freeboard). The design includes flap valves installed on the existing pipe system to prevent ingress of floodwaters from the lagoon.

The impact on peak flood levels for the 1% AEP and 5% AEP design events are shown on Figure 36 and Figure 37 respectively. Whilst the levee protects the residential area from lagoon flooding, the existing pipe system has insufficient capacity to drain the local flows from behind the levee, which reduces the overall benefit. Flood levels are reduced by 0.02 m in the 5% AEP event and 0.22 m in the 1% AEP event.

☒ **LV03 Recommendation**

This option is not recommended as the benefits available are minor and unlikely to justify the significant cost of construction and maintenance. Local drainage may also be an issue.

9.2.1.4. LV04: Levee Option 4 – Campbell Parade

The option models a levee located along Campbell Parade and Manly Creek to protect the small commercial precinct bounded by Campbell Parade, Quirk Road and Lovett Street in hotspot C. The design includes flap valves installed on the existing pipe system.

The levee crest has been set to 2.77 mAHD (5% AEP design height, no freeboard). The levee is 450 m long and the impact on peak water levels shown on Figure 38 and Figure 39. The figures show a reduction of flood levels of approximately 0.1 m in the 5% AEP event and negligible increase in peak flood level. As expected, the levee does not have any impact on flood levels in the 1% AEP event.

A levee on the same alignment but at the height of the 1% AEP event was also modelled, however it did not have any impact on flood damages and hence has not been reported upon.

☒ **LV04 Recommendation**

This option is not recommended as the benefits available are minor and unlikely to justify the significant cost of construction and maintenance.

SUMMARY

Four levee options have been investigated with a range of outcomes. Generally the levees do provide benefits in terms of reductions in flood levels, though these are either too minor to justify the extensive cost of construction, or come at the expense of other residential areas in the form of worsened flood impacts (usually upstream of the levee). The exception is Option LV02, in which the upstream area is largely not developed, and provides significant benefits downstream. Further investigation and optimisation of the levee is recommended to ensure that no properties upstream of the levee are adversely impacted, and to ensure the culvert beneath Clearview Place can be maintained and free of blockage, as it will be the preferred levee outlet.

9.2.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times.

DISCUSSION

The short warning time available in the Manly Lagoon catchment significantly limits the opportunities to deploy temporary flood barriers on a large scale. This type of option is more suitable for riverine flooding in rural towns where there are fewer unprotected properties, and significantly longer warning time, as their deployment requires substantial resources (both man hours and vehicles for transportation of barriers from storage to the site).

SUMMARY

While temporary flood barriers may provide some benefit as a property-level protection measure for those properties located near the Lagoon, they are not recommended for wide scale implementation in this catchment.

☒	**Recommendation** Not recommended as the required warning time to allow for deployment is not generally available in this catchment.

9.2.3. Floodway and Diversion Channels

DESCRIPTION

Floodway or bypass channels redirect a portion of the flood waters away from the main channel. The opportunities for their implementation are limited by topography, availability of land, potential flood level impacts and ecological considerations.

DISCUSSION

In a heavily urbanised and well established catchment like Manly Lagoon, there is little opportunity to create significant diversion channels due to lack of available land and/or high costs associated with land acquisition. However, one option to more formally manage overland flow routes was explored and is described below.

OPTION CONSIDERED

DC01: Diversion Channel Option 01 – Pittwater Bridge

Prior to the 1950s, Manly Creek divided into the North and South channel at what is now Pittwater Road, before merging again downstream of Hinkler Park. As part of the bridge upgrade works undertaken in the mid-1950s, the south channel was disconnected and replaced with a pipe, as shown in the design drawings replicated in Diagram 5.

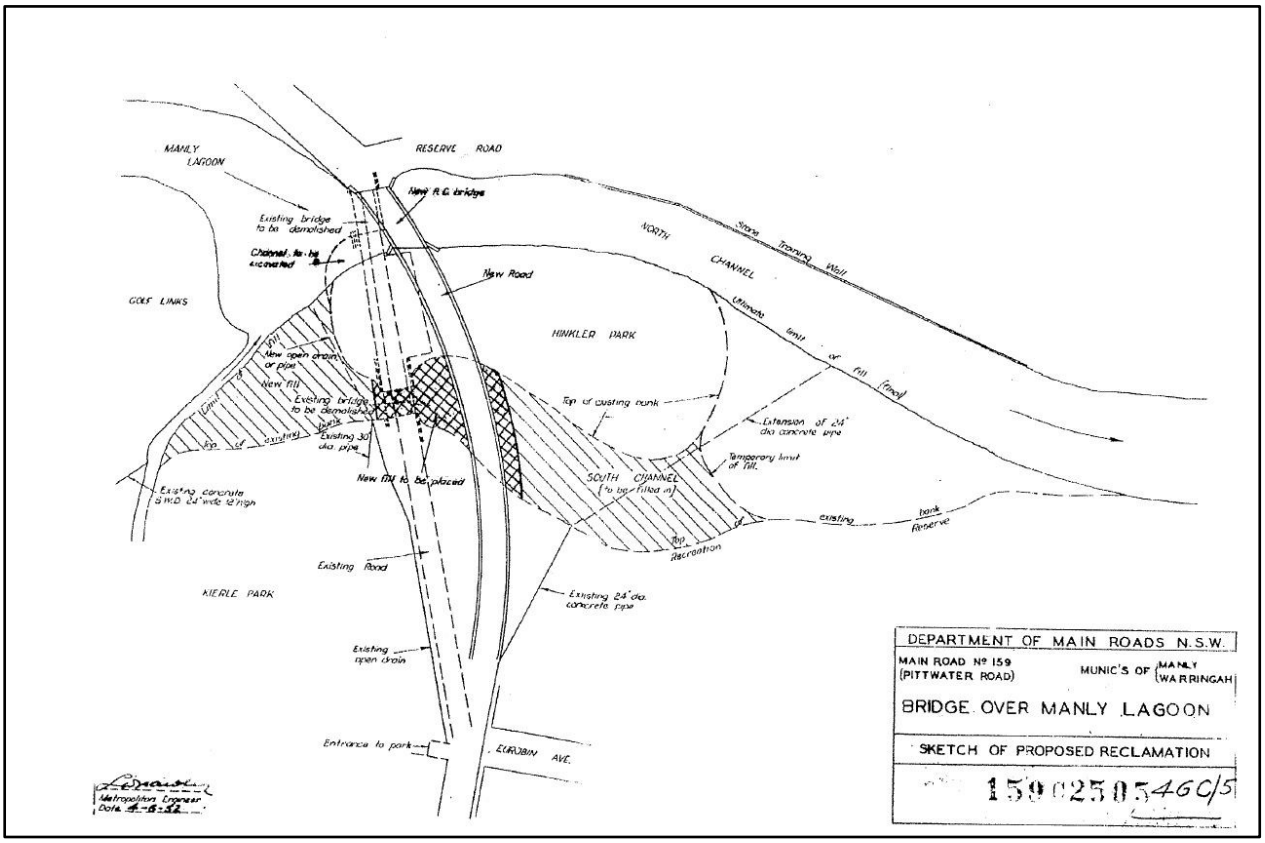

Diagram 5 Proposed Bridge over Manly Lagoon (Dept. Main Roads NSW, 1952)

Option DC01 modelled the reinstatement of the South channel, with the bed level set to -1.5 mAHD, resulting in 4980 m^3 of material being "removed". These works caused a

redistribution of flow, as noted on Figure 40, with more of the flow conveyed through the newly excavated channel and a reduction in the northern peak flow. However, the works did not provide any benefits in terms of flood levels in the 1% AEP event, also shown on Figure 40. The option was also modelled for the 5% AEP event (Figure 41), which showed a localised decrease in peak flood levels upstream of the channel but no widespread flood level impacts.

SUMMARY

This option is likely to have a more significant impact for the smaller, more regular flood events and may also assist with improving the ecology in the lagoon. However, from a flood risk management perspective it is not considered a feasible option due to the negligible impacts on the larger flood events.

☒	**DC01 Recommendation** In a well-established and heavily urbanised catchment like Manly Lagoon, there is no land immediately available to construct a secondary channel, and any such works would involve significant land acquisition costs (assuming the land could be acquired at all) and construction costs.

9.2.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/creek system. This includes a range of measures from straightening, concrete lining and removal/augmentation of structures.

DISCUSSION

The hydraulic capacity of a river channel to discharge floodwater can be increased by widening, deepening or re-aligning the channel, and by clearing the channel banks and bed of obstructions to flow (Reference 2). The effectiveness of channel modifications depends upon the characteristics of the river channel and valley in which it lies.

As a management measure, channel modifications have a number of potential disadvantages, for example:

- they facilitate the transfer of floodwaters downstream and can accentuate downstream flooding problems;
- the potential impacts of such works on channel bed and bank stability both upstream and downstream of the site;
- the high cost of maintenance;
- the destruction of riverine habitat; and
- the visual impact of replacing naturally varying channel sections with a section of more uniform geometry.

OPTIONS CONSIDERED

Four options have been identified and assessed in the Manly Lagoon catchment. Two are related to Brookvale Creek and two are related to the entrance and the Stuart Somerville bridge.

9.2.4.1. CM01: Channel Modification Option 1 - Clearview Place

This option explored lowering the bed of Brookvale Creek upstream of Clearview Place by approximately 0.5 m for a 20 m stretch to help increase the storage volume within the creek itself so as to reduce overland flooding. However, this option had no impact on flood levels in the 1% AEP event due to the magnitude of waters being conveyed in such an event (Figure 42). There is a small impact (-0.01 m) for the 5% AEP event (Figure 43).

9.2.4.2. CM02: Channel Modification Option 2 – Warringah Mall

This option explored lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m and was modelled in the 1% AEP and 5% AEP design events. This showed localised benefits for the land located adjacent to the lowered section (Figure 44 and Figure 45), with peak flood levels reduced by 0.16 m for the 1% AEP and 0.39 m for the 5% AEP event.

9.2.4.3. CM03: Channel Modification Option 3 - Stuart Somerville Bridge

Currently a rock channel is located upstream of twin low flow pipes near the lagoon entrance, which ends downstream of the Stuart Somerville bridge. Option CM03 investigated the impact of extending this lower channel upstream of the bridge, involving the removal of 205 m^3 of material and a finished invert of 0.00 mAHD.

The option results in a marginal reduction in peak flood levels by up to 0.02 m in the 1% AEP event (Figure 46) and 5% AEP event Figure 47.

9.2.4.4. CM04: Channel Modification Option 4 - Stuart Somerville Bridge

This option modelled the impact of lowering the rock bar level below the bridge. Currently this rock bar is set at 0.2 mAHD. This rock bar was lowered by 0.4 m, removing 92 m^3 of material. The result shows a small impact for the 1% AEP event (Figure 48) and 5% AEP event (Figure 49).

SUMMARY

CM01, CM02, CM03 and CM04 Recommendation

☒ Channel modification measures CM01, CM03 and CM04 were shown to provide little benefit to developed land. Additionally, environmental impacts are likely to be significant. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

Option CM02 did show benefits in terms of flood level reduction, however it does not reduce property damages, and construction costs are expected to be significant given the easement constrictions between commercial buildings. This option is therefore not recommended

9.2.5. Drainage Modification

DESCRIPTION

Like channel modification, drainage modification measures are undertaken to improve the conveyance of the existing drainage system, in this case the stormwater pipe network. Measures may include increasing pipe sizes or number of pipes, altering system layouts, or removing potential constrictions.

DISCUSSION

Drainage modification works had strong community support based on the survey data, and 7 options across the Manly Lagoon catchment have been considered and are discussed in the following sections.

9.2.5.1. DM01: Drainage Modification Option 1 – Balgowlah Road

This location was flagged by the community during consultation as a hotspot, and many residents were keen to improve flooding at this location. To address this, the installation of two 0.6m diameter pipes along Balgowlah Road, between Kenneth Road and the Lagoon, were modelled for the 1% AEP and 5% AEP mainstream event. This option however had no impact in either event, due to the small capacities of the pipes relative to the volume of floodwaters. Impacts are shown for the 1% AEP event in Figure 50 and the 5% AEP event in Figure 51.

9.2.5.2. DM02: Drainage Modification Option 2 - Balgowlah Road

This option tests Option DM01 during the 1% AEP local rainfall event with varying tide conditions, rather than during a mainstream flooding event. Two tide cases were modelled: a full lagoon with water level at 1.4 mAHD (Figure 52A) and an empty one where the water level in the lagoon is 0.34 mAHD (Figure 52B). Installation of additional pipes showed a slight benefit during a high tide scenario, with peak flood levels reduced by up to 0.05 m in the golf course. The benefit of the additional pipes was more extensive in the low tide scenario, benefitting the

golf course and some residential properties on Golf Parade, Role Street and Alexander Street near Balgowlah Road, though flood level reductions were still limited to less than 0.05 m.

This option is ineffective for both mainstream and local flooding as the proposed pipe invert level is below the warning level in the lagoon. Balgowlah Road is not sufficiently higher than the Lagoon to allow the pipe outlet to be at an effective elevation (i.e. above the lagoon water level during an event). Hence the pipe would be full (and backwatering) rather than providing any flood relief. Figure 53 shows a long section of Balgowlah Road, running from south to north with Chainage 0 at Kenneth Road.

9.2.5.3. DM03: Drainage Modification Option 3 – Keirle Park

This option explored installing tidal flap valves on the pipes discharging into Manly Lagoon at Keirle Park. Under current conditions water from the Lagoon enters the drainage system and discharges during small events. Flap valves would prevent this from happening whilst still allowing water to discharge when the lagoon levels are lower. This option has been modelled for the 10% AEP event and 20% AEP event, with impacts shown on Figure 54 and Figure 55 respectively. There are no impacts on flood levels in either event.

9.2.5.4. DM04: Drainage Modification Option 4 – Pitt Street

This option simulated the installation of two 0.6 m diameter pipes from Pitt Street to Manly West Park. There is only a very small impact on peak flood levels in the 1% AEP event along the pipe alignment (Figure 56), close to 0.01 m. In the 5% AEP event (Figure 57), peak levels are reduced by up to 0.05 m. Both events show minor localised increases up to 0.05 m at the downstream outlet of the pipe.

9.2.5.5. DM05: Drainage Modification Option 5 – Kenneth Road

This option simulated two 0.6m diameter pipes on Kenneth Road, near the SES headquarters which is located just west of the commercial precinct near Condamine Street, Balgowlah Road and Kenneth Street. The impact in the 1% AEP event is shown on Figure 58 and presents a minor decrease in flood levels around the pipe line of up to 0.05 m. The pipes are more effective in the 5% AEP event, with reductions in flood levels up to 0.1 m as shown on Figure 59, however there is an associated increase in flood levels around the pipe outlet of up to 0.05 m.

9.2.5.6. DM06: Drainage Modification Option 6 – William Street

This mitigation option investigated installing a new twin pipe system along William Street, discharging into Brookvale Creek. These pipes were modelled as 2 × 0.6 m diameter pipes and were assessed for both the 1% AEP and 5% AEP flood event. Impacts from this mitigation option are shown in Figure 60 and Figure 61 for these two events respectively. The 1% AEP event showed local reductions of up to 0.05 m, while the 5% AEP event showed reductions of up to 0.2 m. There are minimal increases in water level as a result of the mitigation option with only a small portion of Brookvale Creek at the point of discharge experiencing an increase of up

to 0.05 m. The peak flow on William Street is 4.43 m^3/s during a 1% AEP event. The pipe system reduces the flow by 1.85 m^3/s.

9.2.5.7. DM07: Drainage Modification Option 7 – Clearview Place to Motorway

This mitigation option investigated installing a new trunk system through Brookvale. These pipes were modelled as a box culvert of 3 m by 2 m and were assessed for both the 1% AEP and 5% AEP flood events. The impacts of this mitigation option are shown in Figure 62 for the 1% AEP event and Figure 63 for the 5% AEP event. Results showed that the proposed system provide local reductions of up to 0.3 m for the 5% AEP event and 0.2 m for the 1% AEP event. Downstream of the pipe outlet there are minimal increases in flood level, however these are limited to the golf course and are within 0.05 m of the current design flood levels. The pipe system reduces the overland flow by 14.34 m^3/s during a 1% AEP event and 9.9 m^3/s during a 5% AEP event.

SUMMARY

☒ **DM01-DM07 Recommendation**

While some drainage modification options had minor benefits on flood levels, the associated costs in the densely urbanised environments would be prohibitive. As such, drainage modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.6. Drainage Maintenance

DESCRIPTION

Ongoing maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. For natural channels, environmental policy can govern how the creek channel is maintained by restricting creek clearing and vegetation management.

Blockage has the potential to considerably increase flood levels in the catchment. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Dredging is a retroactive solution that has been assessed for effectiveness as a flood management strategy below, however is usually a costly exercise with negative environmental impacts and is not likely to be recommended.

DISCUSSION

Structure Blockage

Blockage of structures can be reduced through the establishment of ongoing maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. Regular clearing of leaf litter and other debris from the channel banks will reduce the available material which may block structures. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

Creek Channel Maintenance

Actions such as maintaining appropriate types and density of channel vegetation, and clearing excessive litter and silt may temporarily increase the flow conveyance and reduce flood levels in the vicinity of open channel reaches. However, such work must be undertaken on a regular basis as silt and vegetation will re-accumulate with time. In general, such activities provide some benefit for the smaller, more frequent floods, however, have limited impact on significant events. This type of work is strongly supported by the community during the consultation period.

9.2.6.1. DR01: Dredging Option 1 – Pittwater Bridge

Dredging part of the channel beneath Pittwater Bridge to a bed level of -1.5 mAHD was modelled. The quantity of material removed is approximately 1500 m^3. This had a limited impact on flood levels in the 1% AEP design event (shown on Figure 64) and the 5% AEP event (shown on Figure 65), as the increased cross sectional area was insignificant compared to the overall design flows. Nevertheless, the option does cause some reduction in property affectation in various design flood events. These benefits are reflected in the reduction in AAD (noted in Table 23) which lead to the option having a positive, though relatively low BCR, indicating the option is not considered economically viable.

9.2.6.2. DR02: Dredging Option 2 – Stuart Somerville Bridge

Dredging upstream and downstream of Stuart Somerville bridge to the rock bar level of 0.2 mAHD was modelled in the 1% AEP and 5% AEP design events (Figure 66 and Figure 67). A volume of 2800 m^3 of material was removed for this option. The depth of dredging is directly related to the height of the rock bar, with the eroded entrance already close to the rock bar level. The impact on flood levels was minimal due to the relatively insignificant increase in waterway area compared to the flood volumes, though the option did result in a minor reduction in property damages as noted in Table 23.

SUMMARY

☒	**DR01 and DR02 Recommendation** No creek channel maintenance strategies were identified as suitable for flood mitigation in the study area. As such, channel maintenance was not considered further and the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.7. Retarding Basins

DESCRIPTION

Retarding basins work by storing floodwaters during an event and then controlling the release of the water once the peak has passed. These can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to assist in alleviating existing flood problems.

DISCUSSION

Retarding basins can significantly reduce peak flows and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Large retarding basins can be a safety hazard. Appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

The community questionnaire respondents showed a marginal preference for retarding basins. A review of the catchment identified three potential locations, discussed further in the following sections.

9.2.7.1. RT01: Retention Basin Option 1 – Millers and David Thomas Reserve

This option involves the construction of two new retarding basins at David Thomas and Miller Reserve. They are 1 m deep and have 1 m levees around them. The total volume of storage available in the basins is close to 170,000 m^3. The option was modelled in the 1% AEP and 5% AEP events, with impacts shown in Figure 68 and Figure 69 respectively. Quite widespread reduction in flood levels was seen downstream of the retention basins in both modelled events. Impacts in the 1% AEP event showed reductions up to only 0.1 m, and no properties no longer flooded. Benefits were greater in the 5% AEP event, where widespread reductions of up to 0.2 m were noted and a number of locations no longer flooded.

There were no notable reductions in property damages however, and the cost of construction and maintenance would not be justified by the slight reduction in flood levels.

9.2.7.2. RT02: Retention Basin Option 2 – Keirle Park

This option modelled the construction of an underground water storage facility below Keirle Park. It measures 5 m by 100 m with a height of 2 m. Due to the elevation of the Park the storage 'basin' would be affected by the tide and water level in the Lagoon. Therefore, flap valves have been added to pipes upstream and downstream from the structure. A new twin 0.6 m pipe has been added along Kenneth Road and connected to the structure. This option has been modelled for the 10% AEP event and 20% AEP event, shown in Figure 70 and Figure 71. The retention basin does not reduce the peak flood level in either event, as the capacity is insignificant compared to the volume present during a flood event.

RT01 and RT02 Recommendation

No retarding basins were identified as suitable for flood mitigation in the study area. Moreover the volume of water during a flood makes any flood storage in a basin ineffective. As such, retarding basins were not considered further and the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.8. Dams

DESCRIPTION

Dams are built to control and store large quantities of water. They are built for a variety of purposes, including water supply, irrigation, flood control, environmental control and hydro-electricity. They may be built to solely serve one of these objectives, or multiple purposes.

Dams serve a flood mitigation role by impounding flood waters and releasing them at lower, controlled rates, thereby reducing flood levels downstream of the dam.

DISCUSSION

Manly Dam was originally built for water supply in the 1890's, however since 1939 it has been designated a reserve for public recreation due to its relatively low storage capacity. Water is also extracted from the Dam by Manly Hydraulics Laboratory, and a small portion of the storage capacity is controlled for flood mitigation. Manly Dam is also used for public recreation, including mountain biking trails, bushwalking and a number of water sports such as swimming, water skiing, kayaking and fishing.

As discussed in Section 2.1.4 Manly Dam has a storage capacity of approximately 2,000 ML, with the crest of the Dam at 35.84 mAHD. The water level in the Dam is maintained at 34.1 mAHD (1.7 m below the crest). The water levels in the Dam are controlled and monitored by Sydney Water and Northern Beaches Council, with Sydney Water primarily releasing water for dam safety control, and Council for flood mitigation.

OPTIONS CONSIDERED

Four options have been modelled, based on varying initial water levels in the dam. The flood study, and subsequently the modelling undertaken as part of this study, assumes the dam is at full storage capacity of 35.84 mAHD (crest level). This is 1.7 m above the operating level. Option 1 below investigates using the operating level (34.14) as the initial water level. The subsequent options investigate initial water levels between the operating level and full storage capacity to optimise the available storage.

9.2.8.1. MD01: Manly Dam Option 1 - Operating Level

This option assumes the dam level is at 34.14 mAHD, which is the designated operating level and 1.7 m below the water level adopted for modelling in the Flood Study and other options assessed in this report.

In the 1% and 5% AEP event, seen in Figure 72 and Figure 73, this option provided a widespread reduction in flood levels compared to the design case scenario. The greatest impacts are seen on Manly Creek immediately downstream of the dam before entering the lagoon, with some areas no longer flooded, and others experiencing reductions of more than 0.3 m. Downstream of Condamine Street, the impacts to flood peaks are lower (up to 0.2 m), though widespread.

There is no change to peak flood levels in the upper reaches of Brookvale Creek or Burnt Bridge Creek. Figure 72 and Figure 73 show the impacts for a short duration (2 hour) critical duration as established in Section 2.3.2. This option has also been assessed for 4.5h, 6h, 9h and 12h durations. The results show that the benefits of maintaining the operating level stand for a duration lower than 12h (refer Table 20).

Table 20: Reduction of Peak flood level for the 1% AEP event and different durations at Manly Lagoon

Duration	Impact (m)
2 hour	-0.16
4.5 hour	-0.23
6 hour	-0.23
9 hour	-0.25
12 hour	-0.13

9.2.8.2. MD02: Manly Dam Option 2 - Lowering Initial Water Level by 0.2 m

This option models an initial water level in the dam of 35.64 mAHD, 0.2 m lower than the design case scenario of full storage capacity, and 1.5m above the operating level.

The extent of the impacts mimic those shown in Option 1 and are presented Figure 74 and Figure 75 for the 1% AEP and 5% AEP events respectively, however, flood level reductions are smaller in magnitude. On Manly Creek, there are some small areas of reductions of up to 0.3 m, though most flood levels are reduced by 0.1 m or less. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by at most 0.05 m.

9.2.8.3. MD03: Dam Option 3 - Lowering Initial Water Level by 0.4 m

This option models an initial water level in the dam of 35.44 mAHD, being 0.4 m lower than the design case scenario of full storage capacity, and 1.3 m above the operating level.

The extent of the impacts shown on Figure 76 and Figure 77 again mimic those shown in Option 1. On Manly Creek, there are some small areas of reductions of more than 0.3 m, though most are reduced by 0.2 m or less. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by at most 0.1 m.

9.2.8.4. MD04: Dam Option 4 - Lowering Initial Water Level by 0.8 m

This option models an initial water level in the dam of 35.04 mAHD, being 0.8 m lower than the design case scenario of full storage capacity, and 0.9 m above the operating level.

The same area experiences reduced flood levels, with some land on Manly Creek no longer flooded, and flood levels general reduced by more than 0.3 m as indicated on Figure 78 and Figure 79. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by up to 0.2 m.

SUMMARY

☑ **MD01, MD02, MD03 and MD04 Recommendation**
The above analysis has showed that having a lower water level in the dam is beneficial to the downstream catchment in the event of a storm. Further investigation is recommended to assess methods to increase airspace (either by lowering the operating level or raising the spillway), while meeting requirements of other stakeholders and dam users.

9.2.9. Economic Assessment of Site Specific Measures

The cost effectiveness of management measures in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each measure and this was compared, where appropriate, to the measure's reduction in AAD. Where no significant benefit to AAD was found, the measure's cost effectiveness was assessed qualitatively.

9.2.9.1. Costing

High level cost estimates in have been prepared for each flood mitigation measure assessed in this study. The estimates are suitable for use in the preliminary economic assessment (in Section 9.2.9.3), however it is noted that the rates and quantities on which the costings are based are subject to change over time. For this reason, the preliminary cost estimates (summarised in Table 21) should be reviewed prior to the detailed design phase of any recommended measures to obtain a more accurate costing. A preliminary detailed costing for Option LV02 is available in Appendix D.

Table 21: Costings of Management Measures

Option	Capital	Maintenance per year
DM01 - Twin 0.6 m Diameter pipe along Balgowlah Road Mainstream Event	$ 2,074,000	$ 2,800
DM02 - Twin 0.6 m Diameter pipe along Balgowlah Road Local Event	$ 1,936,000	$ 2,800
DM03 - Flat Valve at Keirle Park	$ 12,000	$ 500
DM04 - Twin 0.6 m Diameter pipe from Pitt Street to Quirk Road	$ 3,313,000	$ 4,800

Option	Capital	Maintenance per year
DM05 - Twin 0.6 m Diameter pipe from Roseberry Street to Quirk Road	$ 1,322,000	$ 1,900
DM06 - Twin 0.6 m Diameter pipe from William Street to Brookvale Creek	$ 2,623,000	$ 3,800
DM07 - Box Culvert from Clearview Place to Brookvale creek	$ 13,841,000	$ 14,400
RT01 - Retention Basin Millers and David Thomas Reserve	$ 35,529,000	$ 10,000
RT02 - Retention Basin Keirle Park	$ 338,000	$ 10,000
DR01 - Dredging Option Pittwater Bridge	$ 357,000	$ 8,900
DR02 - Dredging Option Stuart Somerville Bridge	$ 666,000	$ 16,700
DC01 - New flowpath through Pittwater	$ 2,104,000	$ 10,000
CM01 - Creek lowered at Clearview Place	$ 383,000	$ 9,600
CM02 - Creek lowered upstream Warringah Mall	$ 505,000	$ 12,600
CM03 - Rock Channel extended upstream of Stuart Somerville bridge	$ 218,000	$ -
CM04 - Rock Bar lowered at Stuart Somerville Bridge	$ 93,000	$ -
LV01 - Levee around Riverview Parade	$ 8,173,000	$ 16,900
LV02 - Levee at Clearview Place	$ 485,000	$ 1,000
LV03 - Levee at Balgowlah Road	$ 3,832,000	$ 7,900
LV04 - Levee at Campbell Parade	$ 2,183,000	$ 4,500

Table 21 shows that the retention basin Measure RT01 is the most costly. It is followed by the more localised upgrades, all of which require significant works. It should be noted that all cost estimates are largely approximate due to the uncertainty around possible additional costs arising from construction complications in a densely urbanised area, which may include costs related to easement access and land acquisition. The costs should be used mainly to indicate the relative cost of the measures.

9.2.9.2. Damage Assessment of Measures

The total damage costs were evaluated for all measures and compared against the existing base case, as shown in Table 22. The assessment for the measures was carried out in accordance with OEH guidelines utilising data obtained from the floor level survey and height-damage curves that relate the depth of water above the floor with tangible damages. The damages were evaluated for a range of design events from the 0.5 EY up to the PMF.

Table 22: Average Annual Damage Reduction of Management Measures

Option	AAD	Reduction in AAD due to Measure
DM01 - Twin 0.6 m Diameter pipe along Balgowlah Road Mainstream Event	$5,096,000	-$6,000
DM02 - Twin 0.6 m Diameter pipe along Balgowlah Road Local Event	$5,102,000	-
DM03 - Flat Valve at Keirle Park	$5,102,000	-

DM04 - Twin 0.6 m Diameter pipe from Pitt Street to Quirk Road	$5,100,000	-$2,000
DM05 - Twin 0.6 m Diameter pipe from Roseberry Street to Quirk Road	$5,078,000	-$23,000
DM06 - Twin 0.6 m Diameter pipe from William Street to Brookvale Creek	$5,018,000	-$83,000
DM07 - Box Culvert from Clearview Place to Brookvale creek	$4,971,000	-$131,000
RT01 - Retention Basin Millers and David Thomas Reserve	$4,310,000	-$791,000
RT02 - Retention Basin Keirle Park	$5,102,000	-
DR01 - Dredging Option Pittwater Bridge	$5,074,000	-$28,000
DR02 - Dredging Option Stuart Somerville Bridge	$5,097,000	-$5,000
DC01 - New flowpath through Pittwater	$5,013,000	-$89,000
CM01 - Creek lowered at Clearview Place	$5,089,000	-$12,000
CM02 - Creek lowered upstream Warringah Mall	$5,098,000	-$4,000
CM03 - Rock Channel extended upstream of Stuart Somerville bridge	$5,084,000	-$17,000
CM04 - Rock Bar lowered at Stuart Somerville Bridge	$5,089,000	-$12,000
LV01 - Levee around Riverview Parade	$4,300,000	-$801,000
LV02 - Levee at Clearview Place	$5,060,000	-$41,000
LV03 - Levee at Balgowlah Road	$5,061,000	-$40,000
LV04 - Levee at Campbell Parade	$5,102,000	-

The results show that the large scale levee LV01 and the retention basin RT01 each have the greatest reduction in AAD, with a reduction close to $800,000, approximately 20% of the catchment's AAD.

9.2.9.3. Benefit Cost Ratio of Measures

Following estimation of the measure's cost and AAD, the benefit/cost ratios (B/C) of the measures were calculated. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the total nett present worth (NPW) of costs (including capital and annual maintenance over 50 years) and is used to compare the economic worth of assessed mitigation options. Table 23 lists the reduction in AAD due to the measures, and compares this to the works' respective capital and maintenance costs to produce a B/C. B/C ratio values above 1 indicate that the economic benefit of the measure is greater than its cost.

Table 23: Benefit/Cost Ratio for Management Measures

Measures	AAD	Reduction in AAD	NPW of AAD Reduction*	Capital	Maintenance (Annual)	NPW of Costs*	B/C Ratio
DM01	$5,096,000	-$6,000	-$85,000	$2,074,000	$3,000	$2,113,000	0.04
DM02	$5,102,000	-	-	$1,936,000	$3,000	$1,975,000	
DM03	$5,102,000	-	-	$12,000	$1,000	$19,000	
DM04	$5,100,000	-$2,000	-$25,000	$3,313,000	$5,000	$3,380,000	0.01
DM05	$5,078,000	-$23,000	-$347,000	$1,322,000	$2,000	$1,349,000	0.26
DM06	$5,018,000	-$83,000	-$1,229,000	$2,623,000	$4,000	$2,676,000	0.46

DM07	$4,971,000	-$131,000	-$1,933,000	$13,841,000	$14,000	$14,042,000	0.14
RT01	$4,310,000	-$791,000	-$11,687,000	$35,529,000	$10,000	$35,669,000	0.33
RT02	$5,102,000	-	-	$338,000	$10,000	$478,000	
DR01	$5,074,000	-$28,000	-$409,000	$357,000	$5,000	$482,000	0.85
DR02	$5,097,000	-$5,000	-$68,000	$666,000	$9,000	$899,000	0.08
DC01	$5,013,000	-$89,000	-$1,312,000	$2,104,000	$10,000	$2,244,000	0.58
CM01	$5,089,000	-$12,000	-$183,000	$383,000	$8,000	$517,000	0.35
CM02	$5,098,000	-$4,000	-$57,000	$505,000	$10,000	$682,000	0.08
CM03	$5,084,000	-$17,000	-$258,000	$218,000	-	$218,000	1.18
CM04	$5,089,000	-$12,000	-$185,000	$93,000	-	$93,000	1.62
LV01	$4,300,000	-$801,000	-$11,830,000	$8,173,000	$17,000	$8,409,000	1.41
LV02	$5,060,000	-$41,000	-$607,000	$485,000	$1,000	$499,000	1.22
LV03	$5,061,000	-$40,000	-$594,000	$3,832,000	$8,000	$3,943,000	0.15
LV04	$5,102,000	-	-	$2,183,000	$5,000	$2,246,000	-

* NPW: Net present worth calculated over 50 years at 7%,

Four measures presented in Table 23 have a B/C ratio above 1, indicating they are potentially justifiable on economic grounds alone. The high B/C ratio for options CM03 and CM04 in particular is however a reflection of their low capital cost estimates, rather than their efficacy in reducing flood damages. As described in this section, the high-density urban area means that both the cost of works and the estimate of property damage have large uncertainties. As described, the cost has factored the space constraints into the estimate, but there may be further construction issues that increase the cost. With regards to damages, they may be much higher than have been estimated (and therefore the reduction in damages also larger), but are difficult to estimate in further detail without damage curves specific to the various types of commercial developments.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would be a net contributor to the benefits that could be gained from these management measures. These factors have been considered in the Option Assessment Matrix in Section 9.5.

9.3. Response Modification Measures

Response modification measures aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities, evacuation and planning, and better flood-educated communities.

9.3.1. RM01: Flood Emergency Management Planning

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification. The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW

and is responsible for the control of flood operations. Residents living in and proprietors working on the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Manly Lagoon catchment is not currently covered by a Local Flood Plan. Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations, such as the Flood Study and this FRMS. NSW SES has the lead role in planning for and responding to floods, and should coordinate with Councils on concerns such as road closures and establishing flood-free detours. During community consultation respondents were marginally supportive of flood emergency management planning.

SUMMARY

Collaboration between Council and SES is recommended to draft a Local Flood Plan, a document which would note hotspots as identified in Section 5.1, identify roads affected by inundation and outline flood warning and evacuation protocols, which are described in the subsequent sections.

☑	**RM01: Recommendation** Development of a Local Flood Plan is recommended, based on outcomes of this report and collaboration between Council and the SES.

9.3.2. RM02: Flood Warning and Emergency Response Strategies

DESCRIPTION

Early evacuation is the NSW SES's preferred emergency response for flooding. This reflects the understanding that the safest place to be in a flood is well away from the affected area (Reference 5). Evacuation should be the primary strategy where the available warning time and resources permit (Reference 5). The alternative to evacuating is shelter-in-place which is to shelter in a building within the floodplain.

The SES contends that sheltering in a building that does not have a habitable floor level above the level of the PMF is not low risk and does present a number of concerns:

- floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- structural collapse of the building that is providing the place of shelter (unless the building has been designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- isolation, with possible loss of power, water and sewerage;
- people's unpredictable behaviour (e.g. drowning if they change their mind and attempt to evacuate through flooded roads);
- people's mobility (not being able to reach the highest part of the building);
- people's safety (fire and accident); and
- people's health (pre-existing condition or sudden onset e.g. heart attack).

Accordingly, where sufficient warning time for safe evacuation is available, early evacuation from the floodplain is recommended.

DISCUSSION

As described in Section 6.2, the Manly Lagoon catchment is already covered by the Northern Beaches Flash Flooding Warning System (Reference 6). This system provides live, publicly available data on the rainfall and stream gauges situated in the Northern Beaches area. The current gauges located within the Manly Lagoon catchment are:

- Manly Lagoon at Queenscliff;
- Manly Lagoon at Riverview Parade.

The biggest shortfall with the current flood warning system is the lack of integration with flood risk or consequence, i.e., flooding implications at particular gauge records. Providing some linkages between gauge recordings and key locations such as access roads or predictors of property inundation would greatly improve the system.

9.3.2.1. Opportunities for Increasing Available Warning Time

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast rainfall has an even greater degree of uncertainty associated with estimating flood affectation. Evacuations based on uncertain triggers may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable (Reference 5). There is also the issue that frequent 'false alarms' could lead to a situation where warnings are ignored by most of the community.

Accordingly, no opportunities for increasing available warning time have been identified for the Manly Lagoon catchment.

9.3.2.2. Opportunities for Reducing Required Warning Time

Opportunities to reduce the required warning time can also be considered. The Flood Warning Manual (Reference 7) also makes the point that especially in catchments which have limited warning times, there is value in setting up warning messages before flooding occurs. The NSW SES could draft a series of messages for various scenarios, which would enable more rapid broadcast and dissemination during a flood emergency.

An important question is how the people affected by flooding can best be given the appropriate information. An automated text messaging system could be implemented for residents of the Manly Lagoon floodplain. The ability of such a system to quickly reach a large number of subscribers is often beneficial for mitigating flood risk. However, as mentioned previously, implementation of such a system would still not allow enough time to safely evacuate the floodplain. Instead these warnings could be used to inform residents of flood risk and road closures and request that residents stay in their homes.

9.3.2.3. Shelter-In-Place Feasibility Assessment

Shelter-in-place has been investigated as a possible means of risk mitigation for the study area. As noted in Section 9.3.2.3, the SES has a number of concerns about this approach. Consideration, in broad terms, of the safety of sheltering-in-place in the Manly Lagoon floodplain is investigated in this section.

As mentioned, response modification measures aim to reduce risk to life and property in the event of flooding. This includes provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people living within the floodplain:

- Evacuation: the movement of occupants out of the floodplain before the property and access roads becomes flood affected; and
- Shelter-in-place: the movement of occupants to a building that provides vertical refuge on the site or near the site before their property becomes flood affected.

As described in Section 6.4.2, the evacuation potential of the Manly Lagoon catchment in the event of flooding is limited. Accordingly, it was concluded that safe evacuation is not possible for a large number of properties within the catchment, and in some instances may actually exacerbate risk by increasing the chance of motorists entering flood waters. This conclusion is in accordance with the Australasian Fire and Emergency Service Authorities Council (2013, Reference 5) guideline which states that evacuation is the most effective strategy, provided that evacuation can be safely implemented. Additionally, a review of flood fatalities in Australia has found that the large majority (76%) of fatalities occurred not in the home, but outside when people have entered flood waters (Reference 8). A key issue with shelter-in-place is whether floor levels are sufficiently high to be above the level of the PMF and what hazard classification is experienced at the property for various events.

SUMMARY

Due to the short available warning times and the various factors described in the previous sections, the provision of an effective flood warning service for flooding in the Manly Lagoon catchment is difficult. Issuing evacuation orders in many cases may actually exacerbate risk by requiring people to leave their homes leading to an increased risk of motorists attempting to traverse floodwaters.

RM02: Recommendations

☑

► NSW SES to prepare a Local Flood Plan for the Manly Lagoon catchment in consultation with Council.

► Link existing gauge information as well as outputs from this and other reports with thresholds for road closures.

► Shelter-in-place preferred to evacuation for properties with sufficiently high floor levels.

9.3.3. RM03: Improved Flood Access – Pittwater Road

DESCRIPTION

As described in Section 5.1, flood access is a concern for two residential areas and one commercial area in the Manly Lagoon catchment. Improving flood access in these areas could significantly improve a community's response to flooding, as well as reducing risk to life, burden on SES resources and flood damages.

DISCUSSION

Providing flood free access through road raising is typically only achievable near areas which are sparsely populated and where flood depths are relatively shallow. For the critical areas, roads are flooded by approximately 1 m in the 1% AEP event and are located in heavily urbanised areas. Furthermore, the road raising would need to occur across significant lengths. However, for completeness one road raising scenario was modelled, as discussed below.

This option involved raising Pittwater Road south of Pittwater Bridge to the edge of the floodplain in order to provide flood-free access for the isolated properties in this area. However, the road functions as an important flow path during a mainstream event. This option has been investigated for the 1% and 5% AEP events. Any change to the road elevation would cause negative impacts (Figure 80 and Figure 81). Moreover as per the levee options outlined, the raised road would prevent the water from the local catchment entering the lagoon.

SUMMARY

Due to its cost and negative impacts on flood levels this option is not recommended and no further economic analysis has been undertaken.

RM03: Recommendation

☒

The raising of Pittwater Road south of Pittwater Bridge is not recommended as it provides flood-free access at the cost of increasing flooding for a number of properties and obstruction of the existing flow path.

9.3.4. RM04: Road Closures, Early Notifications and Creek Crossing Deterrents

DESCRIPTION

Due to the issues described in Section 9.3.3, alternatives to raising access roads are considered to mitigate the potential risk of motorists and pedestrians using flooded roads. Options include road closures, warning signs and depth mark indicators. Due to the short warning times within the Manly Lagoon catchment, options to automate these processes are explored wherever possible. Table 24 below lists major roads at risk of overtopping during a range of flood events.

Table 24: Roads at Risk of Overtopping

Road	Location	Depth overtopped (m)		
		2 Yr. ARI	10% AEP	1% AEP
Balgowlah Road	Between Pittwater and Kenneth Road	0.65	0.95	1.4
Sydney Road	Between Maretimo Street and Pickworth Avenue	0.16	0.18	0.22
Pittwater Road	Oliver Street intersection	0.5	0.75	1.2
Condamine Street	Just south of Manly Creek overbridge	-	0.2	0.3
Condamine Street	Between Kenneth Road and Burnt Bridge Creek Deviation	-	0.5	0.9
Kenneth Road	Near Roseberry Street Roundabout	0.32	0.7	1
Balgowlah Road	East of Hill Street	0.3	0.4	0.45
Balgowlah Road	Between Suwarrow Street and Daintrey Street	0.17	0.22	0.25
Pittwater Road	Hope Avenue intersection	0.22	0.25	0.28
Pittwater Road	150m North of Condamine Street	0.26	0.32	0.4
Wakehurst Parkway	300m South of Aquatic Drive	0.1	0.23	0.27
Warringah Road	250m east of Wakehurst Parkway intersection	0.2	0.25	0.28
Burnt Bridge Creek Deviation	At Kitchener Street Overpass	-	0.2	0.35

DISCUSSION

9.3.4.1. Automatic Road Closures and Boom Gates

Currently, road closures are only implemented by Council, SES or RMS once they have been notified of flooding of an access road. This means that the road is flooded well before it is closed thus greatly increasing the risk or pedestrians and motorists attempting to cross floodwaters.

Automated road closures could provide a viable alternative through either:

1. Automated warning signs and boom gates that signal (using telemetry technology) once a trigger level has been reached at a nearby gauge. This would significantly reduce the time taken to close roads by negating the need for Council and SES personnel to

determine the need for, and travel to, the road closure site. Cost per gate including telemetry technology is estimated to be $20,000 not including the cost of the gauge.

2. Flood gates which self-deploy during periods of high flow. The flood gates are locked in the open position at low-lying crossings and are designed to automatically unlock and close road access when floodwaters reach a pre-set depth. In flood situations the gates provide a highly visual barrier to warn motorists and discourage attempts to cross flooded waterways. When water recedes to an acceptable level the flood gate is deactivated by Council officers to allow vehicle access to the crossing. The cost per gate is estimated to be $60,000.

A system which allows a visual check may be required to prevent accidents or injury caused by automated boom gate closure.

9.3.4.2. Automatic Warning Signs and Depth Indicators

In addition or as an alternative to closing flooded roads, warning signs, lights and depth indicators could be used to alert residents of flooded roads (and their potential closure).

Automatic flashing warning signs (triggered by the gauges described in Section 9.3.4.1) and early notification of flooded roads could be used. Automatic flashing warning signs are estimated to cost approximately $20,000 not including the cost of the gauge, and depth indicators are estimated to cost $5,000 per location.

☑ **RM04: Recommendation**
Installation of flood depth indicators, warning signs and road closure gates to be implemented where required as funds become available.

9.3.5. RM05: Community Flood Education

DESCRIPTION
Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension. Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced. (Reference 9).

Based on evidence from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not only consisting of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and flooding; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

DISCUSSION

Table 25 provides a list of methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 25: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S10.7 certificate notifications	Section 10.7 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has the opportunity to provide more detailed information about the land's flood affectation under S10.7(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.

Method	Comment
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. shelter-in-place). Proactive and regular issuance is desirable.
Council website	The Northern Beaches Council currently provides a link to the Northern Beaches Flood Information Network on its website. This site shows the location of rainfall and water level gauges, and notes the key rainfall intensities to watch out for (70 mm in 3 hours or 150 mm in 24 hours).
Community Working Group	Council could initiate a Community Working Group framework to provide a valuable two way conduit between the local residents and Council.
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. NSW SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood issues are not forgotten. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.
NSW SES FloodSafe Guide	Continued distribution of the local FloodSafe guide which should be revised based on the findings of the current study, and again upon implementation of the FRMP.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.

Method	Comment
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate time and visible location. The event would be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out. These materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. A meeting could also encourage property owners to develop self-help networks and particularly people checking on neighbours if a flood is imminent. Longer-term residents with flood experience could be used to help provide other residents with an understanding of previous floods and how to prepare for future flooding.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. Flood marker poles could be installed in frequently visited locations to show the height flood waters reached in previous historic flood events.

Assessment of implementation of a community education program is examined in the Option Assessment Matrix (see Section 9.5)

☑ **RM05: Recommendation**
Engage with community to prepare an ongoing flood education program, with appropriate methods for program evaluation to be undertaken by SES and Council.

9.4. Property Modification Measures Considered

9.4.1. PM01: Voluntary House Raising

DESCRIPTION

Voluntary house raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce flooding particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types, or properties in high hazard areas.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood, particularly in high hazard areas. Ideally floor levels should be raised to be above the level of

the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

The cost of raising a house can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house;
- generally only single storey houses can be raised;
- generally only timber, fibro and other non-masonry construction can be raised;
- generally only pier and non-slab on ground construction can be raised; and
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

SUMMARY

House raising as a flood mitigation option in the Manly Lagoon catchment is not considered an appropriate measure as the houses are generally slab-on-ground construction.

☒ **PM01: Recommendation**

Voluntary house raising is not considered appropriate in this catchment due to the slab-on-ground construction of the majority of properties.

9.4.2. PM02: Voluntary Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, or located within the floodway, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain and reduces the number of people living in high flood risk areas.

DISCUSSION

Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place. Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program as long as a number of complying criteria are met.

Commercial and industrial buildings are not eligible for voluntary purchase, and there are few residential properties located within the various floodways (see Hydraulic Categories in Section 5.2). Furthermore, the cost of acquiring eligible properties in this location would be significant

and prohibitive given current property values. Therefore voluntary purchase is not considered an appropriate measure in the Manly Lagoon catchment.

☒ **PM02: Recommendation**
There are few properties eligible for voluntary purchase within the catchment, and it is likely house prices would be prohibitive. This option is not recommended in the Manly Lagoon catchment.

9.4.3. PM03: Flood Proofing

DESCRIPTION

This measure applies to all future developments undertaken within the flood planning area (as defined in Section 9.4.6), including refurbishment of existing dwellings and construction of new buildings.

Part 3 of the SEPP relates to the *"General Housing Code"*. Section 3.36C (3b) states that "*The development must, to the extent it is within a flood planning area: have the part of the development at or below the flood planning level constructed of flood compatible material."* Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction.

DISCUSSION

Flood proofing is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and other smaller barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

Temporary flood barriers such as sandbagging and floodgates can be a cheaper option for existing properties, and can be useful where there is frequent shallow flooding, although it relies on someone to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

SUMMARY

Whilst it is a requirement of the Floodplain Development Manual (Reference 2) that new residential properties have their flood levels above the 1% AEP event plus a freeboard,

commercial properties are not subject to such a requirement unless stipulated by Council. New commercial buildings can be required to be flood proofed to the Flood Planning Level when constructed which would include consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in the DCP. It is recommended that planning controls allow some flexibility in the type of proofing adopted, and for temporary flood gate options to also be included in building design for low risk non-habitable development.

☑ **PM03: Recommendation**
Future development of commercial properties within the flood planning area should incorporate flood proofing up to the flood planning level.

9.4.4. PM04: Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a Local Environmental Plan (LEP). To make any significant changes to the provisions of a LEP, a planning proposal must be prepared.

DISCUSSION

Zoning can be a powerful tool in reducing flood damages, however, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time. Progressive zoning can be used to encourage long term change in flood resilience. The current land use zones for Manly Lagoon catchment are presented in Figure 2 and comply with the current NSW standards. No changes to the current land use zoning are recommended from a flood mitigation perspective.

SUMMARY

This FRMS&P recommends that in the event that the land use zoning is altered, Council should carefully consider flood behaviour and affectation determined by the Flood Study and this FRMS&P.

☑ **PM04: Recommendation**
Changes to land use zoning in the Northern Beaches LGA should consider flood compatibility using outcomes from this report.

9.4.5. PM05: Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual - Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control

measure for managing future flood risk and is derived form a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- uncertainty in estimating flood levels;
- differences in water level because of local factors; and
- potential changes due to climate change.

The FPL is used in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc.

DISCUSSION

The current approach to define the FPL is to remain consistent with current best practice. Therefore, FPLs should be revised based on the revised modelling (described in Section 2.3.2).

☑	**PM05: Recommendation** FPLs should be revised based on the findings of this study.

9.4.6. PM06: Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA is based on the flood extent formed by the 1% AEP mainstream flooding event plus 500 mm freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may therefore be applied to development which is not flooded in a 1% AEP event. The purpose of extending the FPA past the 1% AEP flood extent is to allow for model uncertainties, any future increases in flood extent due to climate change, as well as allow for differences between flood behaviour during events.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

DISCUSSION

The FPA as defined by the Floodplain Development Manual is suitable for areas of mainstream flooding. The FPA was updated as part of the 2013 Manly Lagoon Flood Study (Reference 1).

PM06: Recommendation

☑ Adoption of FPA based on results of the 2013 Manly Lagoon Flood Study.

9.4.7. PM07: Changes to Planning Policy

DESCRIPTION

Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- guide new development away from high flood risk locations;
- ensure that new development does not increase flood risk elsewhere; and
- develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Examination of existing risk throughout the study area indicates that managing this risk is particularly problematic due to the ineffective warning times available, lack of access routes, and frequent flooding (see Section 9.3.2). However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long term management of these areas and how this can be facilitated by planning tools. For example, high risk areas may need to be rezoned or have more stringent development controls applied to ensure areas of safe refuge onsite for shelter-in-place (Section 9.3.2.3) and flood compatible

DISCUSSION

Council addresses development in flood risk areas in its DCP and provides matrices which applying varying degrees of restrictions to development based on the land use and flood risk. Applying stricter development controls in the hotspot areas has the potential to reduce the long term flood risk.

PM07: Recommendation

☑ Council should consider applying more stringent, and specific, planning and development controls to the areas classified as Low Flood Islands / Low Trapped Perimeter Areas.

Flood Mapping for the DCP should be updated based on the findings of this current study, taking into consideration the FERP classifications described in Section 6.3.

9.4.8. PM08: Modification to S10.7 Planning Certificates

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land. Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

> ***7A Flood related development controls information***
>
> *(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*
>
> *(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*
>
> *(3) Words and expressions in this clause have the same meanings as in the standard instrument set out in the Standard Instrument (Local Environmental Plans) Order 2006.*

Legal reviews of the effectiveness of s.10.7 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (low moderate or high) and also whether flooding applies generally to the area or more specifically to the land which is the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- the type of flooding;
- whether flooding is from major rivers or local overland flooding; and
- the extent of flooding (whether widespread or relatively confined).

It should be noted that the s.10.7 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in a s.10.7(2) Planning Certificate, there is scope within a s.10.7(5) Planning Certificate for providing this additional type of information.

There can be a general perception from the public that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by

adding information in s.10.7(5) Planning Certificates to show the percentage of the property inundated as well as floor levels and other flood related information. In addition, the hazard category could be provided, and also advice regarding climate change increases in flood level.

The compulsory s.10.7(2) Planning Certificate should include, in terms of flood risk:

- whether or not the property is in the FPA;
- any development controls due to the property being within the FPA;
- responsibility for maintenance and compliance for OSD features; and
- highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in s.10.7(5) Planning Certificates as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.10.7(5) Planning Certificates should include:

- flood levels / depths over the property;
- percentage of property which is flood affected;
- the likelihood of flooding;
- floor levels (from Council's floor level survey if available); and
- potential flood hazard.

SUMMARY

As Council information for s.10.7 Planning Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its website.

Data from the hydraulic modelling used in the 2013 Manly Lagoon Flood Study should be incorporated into Council's s.10.7 Planning Certificate database. All residents should be advised by personalised mail from Council if their land is affected. Council should determine the appropriate event for advising residents and ensure that the same criteria are used as in establishing the FPA.

☑ **Recommendations**

Publish up-to-date information on all future s10.7 planning certificates issued based on the 2013 Manly Lagoon Flood Study. It is encouraged that full details are provided in Part(5) as standard practice when a Part(2) is requested.

Provide flooding information on Council's website.

9.5. Option Assessment Matrix

9.5.1. Background

Multi-variate decision matrices are recommended in the Floodplain Development Manual (Reference 2) and therefore it is also a recommendation of this report that multi-variate decision matrices be developed for specific management options, allowing benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- risk to life;
- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- compliance with EP&A Act 1979 (whether the work adversely impacts existing development, involves development in the floodway, or encourages development which increases spending on flood mitigation, infrastructure or services)
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- long term performance;
- environmental and ecological benefits;
- impacts on the SES;
- political and/or administrative issues; and
- long-term performance given the potential impacts of climate change.

The scoring system for the above criteria is provided in Table 26. Tangible costs and damages are also used as the basis of B/C analysis for some measures.

Table 26: Matrix Scoring System

SCORE:	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Compliance with EP&A Act 1979	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental & Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political / administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

The assessment matrix is given in Table 27, with each of the assessed flood modification management options scored against the range of criteria. The 'Community Acceptance' score is based on initial consultation undertaken at the commencement of the Study and feedback received during the public exhibition period. It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

Table 27: Multi-Criteria Matrix Analysis (Flood Modification Measures Assessed)

Type of Option	Option ID	Option	Section in Report	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental/Ecological Benefits	Impact on SES	Political/Admin Issues	Long Term Benefit	Risk to Life	Total Score	Rank
Levee	LV01	1% AEP Levee around Riverview Parade area	9.2.1.1	0	0	-3	-3	1	-3	-2	-2	-3	-2	-3	-20	**22**
	LV02	Levee upstream of Warringah Mall near Clearview Place	9.2.1.2	3	3	2	3	2	2	-1	3	-2	2	3	20	**2**
	LV03	Levee located around Kenneth Road & Balgowlah Road hotspot	9.2.1.3	0	0	-2	-1	-2	-2	-1	0	-2	-1	0	-11	**16**
	LV04	Levee 5% AEP level located along Campbell Parade and along Manly Creek	9.2.1.3	0	1	-1	-1	-2	-2	0	0	-2	-1	0	-8	**6**
Temporary Flood Barriers	TB01	Use of temporary flood barriers to protect small areas or individual properties.	9.2.2	0	0	0	1	1	1	0	-1	-2	-1	0	-1	**3**
Diversion channels	DC01	New flow path created south of Pittwater Bridge to recreate the original channel (piped over in 1952).	9.2.3	0	0	-3	-3	-3	-3	-3	1	-3	1	1	-15	**21**
Channel modification	CM01	Lowering the creek upstream of Clearview Place by approximately 0.5 m for 20 m.	9.2.4.1	0	0	-2	-1	0	-3	-1	0	-2	0	0	-9	**10**
	CM02	Lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m.	9.2.4.2	1	1	-2	-2	0	-3	-1	0	-2	0	0	-8	**6**
	CM03	Rock channel upstream of the twin low-flow pipes is extended upstream of Stuart Somerville Bridge by 60 m.	9.2.4.3	0	0	-2	-1	1	-3	-1	0	-2	0	0	-8	**6**
	CM04	Lowering the 25 m long rock beneath Stuart Somerville Bridge by 0.4 m.	9.2.4.4	0	0	-2	-1	2	-3	-1	0	-2	0	0	-7	**4**
Drainage Modification	DM01	Installing a new pipe system (2 x 0.6 m pipes) along Balgowlah Road	9.2.5.1	0	0	-3	-1	-3	-3	-1	1	-3	0	0	-13	**19**
	DM02	Installing a new pipe system (2 x 0.6 m pipes) along Balgowlah Road, tested for impacts in the 1% AEP local event.	9.2.5.2	1	0	-3	-1	-3	-3	-1	1	-3	0	0	-12	**18**
	DM03	Installing tidal flap valve where the pipe at Keirle Park discharges into the lagoon	9.2.5.3	0	0	-3	-1	-3	-3	-1	1	-3	0	0	-13	**19**
	DM04	New pipe system (2 x 0.6 m pipes) in Balgowlah starting at Pitt Street until Manly West Park	9.2.5.4	1	1	-3	-1	-3	-3	-1	1	-3	0	0	-11	**16**
	DM05	Installing new pipe network (2 x 0.6 m pipes) along Kenneth Road between Rosebery Street and Quirk Road	9.2.5.4	1	2	-3	-1	-3	-3	-1	1	-3	0	0	-10	**13**
	DM06	New pipe system (2 x 0.6 m) along Green Street and William Street to reduce local overland flows.	9.2.5.4	1	2	-3	-1	-3	-3	-1	1	-3	0	0	-10	**13**
	DM07	New 1500 m trunk drainage system through Brookvale (box culvert of 3 m x 1.5 m)	9.2.5.7	2	2	-3	-1	-3	-3	-1	1	-3	0	0	-9	**10**
Drainage maintenance	DR01	Dredging at Pittwater Bridge to a channel level of -1.5 mAHD	9.2.6.1	0	0	-2	2	1	-3	-3	0	-3	0	0	-8	**6**
	DR02	Dredging upstream and downstream of Stuart Somerville Bridge to the rock bar level (0.2 mAHD)	9.2.6.2	1	0	-2	2	-3	-3	-3	1	-3	0	0	-10	**13**
Retention basins	RT01	New basin on Manly Creek at Millers and David Thomas Reserve. Spillway 2 m above bottom of basins (total storage volume of 146 000 m^3).	9.2.7.1	1	0	-2	-1	-3	-3	-1	1	-2	1	0	-9	**10**
	RT02	Installing underground detention tank in Keirle Park. (1000 m^3 storage)	9.2.7.2	0	0	-1	1	-3	-3	-1	0	-1	1	0	-7	**4**
Dams	MD01-MD04	Further investigation into methods of increasing airspace in Manly Dam	9.2.8.1	3	3	2	3	3	2	1	3	3	2	2	27	**1**
	Recommended in Floodplain Risk Management Plan for further investigation															

9.5.2. Results

As shown in the matrix, the flood modification options assessed are largely ineffective in improving flood levels and reducing property damages, with most options scoring zero for these two criteria. Furthermore, a number of options are considered either technically or financially unfeasible. This is due to the heavily urbanised catchment and floodplain, in which any construction works would be especially costly due to space constraints and issues with land acquisition. Given these constraints, the localised reductions in flood levels are generally negligible in comparison with the overwhelming volume of water moving through the area during a flood event.

Options LV02 and MD01-4 were the exceptions, with both these options causing reduction in flood levels and an improvement in property affectation. Response and property modification measures have not been assessed in this matrix.

10. FLOODPLAIN RISK MANAGEMENT PLAN

This section comprises the Floodplain Risk Management Plan (the Plan) and forms a framework identifying aims, objectives, and a guide by which the plan will be implemented. Any recommendations in terms of policy should be reviewed and approved by Councils planners.

10.1. Aims and Objectives

The primary objective of the Floodplain Management Plan is to recommend a range of property, response and flood modifications that address the existing and future flood problems, in accordance with the Floodplain Development Manual (Reference 2). The recommended works and measures presented in the Plan will:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;
- Reduce private and public losses due to flooding;
- Protect and, where possible, enhance the river and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the Floodplain Risk Management Plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community;
- Ensure actions arising out of the Plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the Floodplain Risk Management Plan is fully integrated with the local emergency management plan (Local Flood Plan) and other relevant catchment management plans; and
- Establish a program for implementation and a mechanism for the funding of the plan and should include priorities, staging, funding, responsibilities, constraints, and monitoring.

10.2. Identification of Actions Suitable for Implementation

A number of mitigation options have been investigated as part of this FRMS. Table 28 summarises the measure that have been assessed and are deemed worth to be either implemented immediately, or that warrant further investigation. These options have been included in the Floodplain Risk Management Plan, shown in Table 29.

Table 28: Summary of Recommended Mitigation Measures

Option ID	Description	Reference
LV02	Clearview Place Levee	9.2.1.2
MD01	Investigation into Manly Dam Airspace Availability	9.2.8.1
PM03	Flood Proofing	9.4.3
PM04	Land Use Zoning	9.4.4
PM05	Flood Planning Levels	9.4.5
PM06	Flood Planning Area	9.4.6
PM07	Changes to Planning Policy	9.4.7
PM08	S10.7 Certificates	9.4.8
RM01	Emergency Planning	9.3.1
RM02	Flood Warning	9.3.2
RM04	Road Closures, Early Notifications	9.3.4
RM05	Community Education and Awareness	9.3.5

Table 29: Floodplain Risk Management Plan

Option ID	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
FLOOD MODIFICATION MEASURES									
LV02	Clearview Place Levee	New levee located upstream of Warringah Mall near Clearview Place to prevent mainstream flooding. Levee set to 22.3 mAHD	Reduced peak flood levels and extent through the waterway downstream (east) of the Princes Highway.	Blockage through the culvert beneath Clearview Place must be prevented as it now conveys a greater flow.	Council would be responsible for construction and maintenance.	OEH Funding available for feasibility, detailed design and construction	$458,000	1.22	Low
MD01	Investigation into Manly Dam Airspace Availability	Further investigation into optimising the airspace in Manly Dam whilst satisfying all stakeholders is recommended	Additional storage during storms, reduction in downstream flood levels.	Balancing the interests of dam users and stakeholders.	Council, in consultation with all dam users and stakeholders.	OEH Funding available for feasibility, detailed design and construction	Unknown	N/A	High
PROPERTY MODIFICATION MEASURES									
PM03	Flood Proofing	Future development of commercial properties within FPA should incorporate flood proofing up to the FPL	Reduction in damages during flood events for commercial properties	None	To be included in Council's DCP and applied to future commercial development controls.	Not required	Minimal - Council Work Hours	N/A	High
PM04	Land Use Zoning	Changes to land use zoning should consider flood compatibility using outcomes from this report	Ensures future development is compatible with the flood risk	Any changes to land zoning require a Planning Proposal	Council - and to be clearly communicated to residents as required	No funding available	Minimal - Council Work Hours	N/A	High
PM05	Flood Planning Levels	Update FPL based on the 1% AEP + 0.5m as defined in the 2013 Manly Lagoon Flood Study	Better clarification for setting required floor levels of proposed development within the Flood Planning Area	None - FPL is already set at 1% + 0.5 m	Council - and to be clearly communicated to residents as required	No funding available	Minimal - Council Work Hours	N/A	High
PM06	Flood Planning Area	As defined in the 2013 Manly Lagoon Flood Study	The FPA map will provide clarification for setting flood planning levels for proposed development	None - FPL is already set at 1% + 0.5 m	Council - and to be clearly communicated to residents as required	No funding available	Minimal - Council Work Hours	N/A	High
PM07	Changes to Planning Policy	DCP updated with FPL and FPA as discussed above	Better clarification for setting required floor levels of proposed development within the FPA	None	Council - and to be clearly communicated to residents	No funding available	Minimal - Council Work Hours	N/A	High
PM08	S10.7 Certificates	Provide flooding information on Council's website, include up to date flooding information on future s10.7 (2) and (5) certificates requested	Additional details provided on s10.7 (5) can improve flood risk awareness in the community.	None	Council - and to be clearly communicated to residents	No funding available	Minimal - Council Work Hours	N/A	High
RESPONSE MODIFICATION MEASURES									
RM01	Emergency Planning	Development of Local Flood Plan	The local flood plan gives catchment specific information to the SES for use during a flood event	None	SES and Council	OEH Funding Available under 'Projects to improve flood warning'	Minimal	N/A	High
RM02	Flood Warning	Add new stream gauges on each of the three creeks, continuation of Northern Beaches Flash Flooding Warning	Up to date weather and storm information for residents, provided by BoM and SES	None	SES and Council	OEH Funding Available under 'Projects to improve flood warning'	N/A	N/A	Low
RM04	Road Closures, Early Notifications	Add list of affected roads to Local Flood Plan, install depth indicators where noted.	Improved flood awareness for motorists and pedestrians.	Minimal ongoing maintenance of depth markers, flood posts and gates required	SES and Council	OEH Funding Available under 'Projects to improve flood warning'	Up to $100,000	N/A	Medium
RM05	Community Education and Awareness	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	Improved community awareness of flooding and greater appreciation of the flood risk for residents and business owners	Information may be ignored or forgotten by residents	SES and Council	OEH Funding Available under 'Projects to improve flood warning'	Minimal	N/A	Medium

11. REFERENCES

1 Former Warringah Council and Manly Council
Manly Lagoon Flood Study
BMT-WBM, 2013

2. NSW Government
Floodplain Development Manual
2005

3. Attorney General's Department
Managing the Floodplain: a guide to best practice in flood risk management in Australia
Commonwealth of Australia, 2013

Department of Environment and Climate Change
4. **Floodplain Risk Management Guideline: Practical Consideration of Climate Change**
State of New South Wales, 2007

AFAC
5. **Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events**
Australasian Fire and Emergency Service Authorities Council, April 2013

Former Pittwater Council, Warringah Council, Manly Council, Dept. Public Works Manly Hydraulics Laboratory
6. **Flash Flood Warning System for Sydney's Northern Beaches**
2013

Attorney General's Department
7. **Flood Warning – Australian Emergency Manuals Series, Manual 21**
Commonwealth of Australia, 2009

Haynes, K et al.
8. **'Shelter-in-place' versus evacuation in flash floods**
2009

Keys, C.
9. **'A combat agency and its hazard: a New South Wales State Emergency Service perspective on the management of flooding', *Australian Journal of Emergency Management*, 17(2), 14-18, 50-55**
2002

Appendix A

GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and

	typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain.

	continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage

Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- $ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- $ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- $ major overland flow paths through developed areas outside of defined drainage reserves; and/or
- $ the potential to affect a number of buildings along the major flow path.

mathematical/computer models

The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach

The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures

Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge

The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Manly Lagoon Floodplain Risk Management Study and Plan

Local Resident / Business Owner Survey | April 2016

Community consultation is an important component of the Floodplain Risk Management Study and Plan process. The local knowledge of residents and business operators, and their personal experiences of flooding are an important source of information. We are particularly interested in your views on how flooding should be managed in your local area.

WMAwater, on behalf of Warringah and Manly Councils, is preparing a Floodplain Risk Management Study and Plan of the Manly Lagoon catchment which is located across both the Warringah and Manly Local Government Areas.

The Floodplain Risk Management Study aims to help Councils make informed flood risk management for the future.

Please return the survey and any photographs you have of historical flood events to Council by 6 May 2016 via the reply paid envelope.
Alternatively, please complete the survey online, via the following link:
https://www.surveymonkey.com/r/manlylagoonsurvey

WARRINGAH COUNCIL | MANLY COUNCIL | SURF CITY MANLY AUSTRALIA® SURF CITY AUSTRALIA® | NSW GOVERNMENT Office of Environment & Heritage | wma water

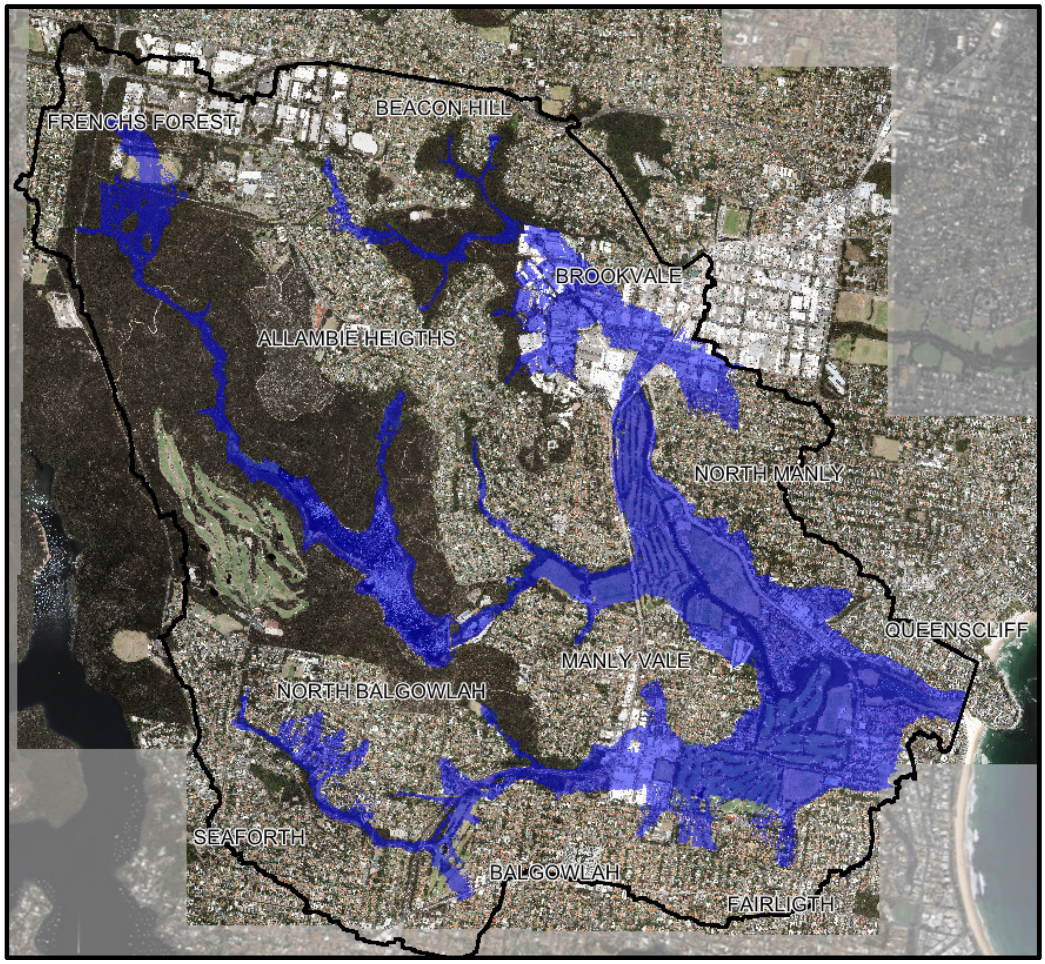

Figure: The Study Area

Responses to the questionnaires will be collated and will help drive the selection of floodplain management options in the Manly Lagoon catchment. These options will be investigated and assessed within the Floodplain Risk Management Study and Plan, and the draft reports will be open to comment through a public exhibition period.

If you have any queries or would like any further information, please don't hesitate to contact us at the below addresses.

This project is supported by the NSW Government's Floodplain Risk Management Program.

WMA Water	Warringah Council	Manly Council
Ella Harrison P: 02 9299 2855 E: harrison@wmawater.com.au wmawater.com.au	**Duncan Howley** P: 02 9942 2381 E: duncan.howley@warringah.nsw.gov.au warringah.nsw.gov.au	**Patrick Stuart** P: 02 9976 1606 E: records@manly.nsw.gov.au manly.nsw.gov.au

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

Manly Lagoon Floodplain Risk Management Study and Plan - Survey

Q1. Could you please provide us with the following details, to locate specifically where your comments and responses relate to? This information will not be shared without your consent. Alternatively the survey can be filled in anonymously.

Name: _____
Address: _____
_____
Daytime Ph: _____
Email: _____

Q2. Do you give permission for someone from WMAwater or Council to contact you to discuss some of the information you have provided us? ☐ Yes ☐ No

Q3. How many people regularly live on this property? _____

How many residents are in the following age groups:
0 – 4 years: _____ 5 – 14 years: _____ 16 – 64 years: _____ 65+ years: _____

Q4. Is your property: (please tick one)

☐ Residential (Owner-Occupied) ☐ Residential (Tenant-Occupied)

☐ Business (Owner-Occupied) ☐ Business (Tenant-Occupied)

☐ Other (please specify) _____

What type of structure is your property/business? (please tick one)

☐ Detached House ☐ Apartment/Flat ☐ Attached/Semi-attached House (e.g. Duplex)

☐ Townhouse/Unit ☐ Industrial ☐ Commercial

☐ Other (please specify) _____

Q5. Are you concerned about flooding on your property? ☐ Yes ☐ No

In your local area? ☐ Yes ☐ No

Have you looked for information regarding flooding on your property or in your local area?

☐ From Council (website, customer service centre or other)

☐ Viewed a Property Planning (Section 149) Certificate

☐ Information from a real estate agent, previous owners, neighbour etc.

☐ Emergency Services

☐ Other (please specify): _____

Manly Lagoon Floodplain Risk Management Study and Plan - Survey

Q6. How long have you lived or worked at this address? _____ years _____ months
If you have experienced any flood events, please specify below.

Date of Event	____/_____/____	____/_____/____	____/_____/____
What level did the floodwater reach?	Above your floor ☐ Within your yard/land ☐ Within others' property ☐ Over roads/paths ☐	Above your floor ☐ Within your land/yard ☐ Within others' property ☐ Over roads/paths ☐	Above your floor ☐ Within your yard/land ☐ Within others' property ☐ Over roads/paths ☐

Q7. As a member of the local community, you may have your own ideas about how to reduce flood risks. Which of the following do you prefer (1 = most preferred, 5 = least preferred). Please note, that whilst the following management options have been used in other locations, some may not be suitable or cost-effective for the Manly Lagoon catchment.

Proposed Option	Preference
Retarding or detention facility (these temporarily hold water and reduce flooding) Suggested location/other comments:	1 2 3 4 5
Increasing the flow capacity of lagoon and/or creeks (eg. dredging, clearing, removing structures) Suggested location/other comments:	1 2 3 4 5
Bridge works or road-raising Suggested location/other comments:	1 2 3 4 5
Stormwater pipe, street gutter and drain upgrades Suggested location/other comments:	1 2 3 4 5
Flood walls (levees) Suggested location/other comments:	1 2 3 4 5
Education / providing greater awareness of flooding Suggested location/other comments:	1 2 3 4 5
Flood warnings, evacuation planning and emergency response Suggested location/other comments:	1 2 3 4 5
Stricter building and development Controls Suggested location/other comments:	1 2 3 4 5

Q8. If you have any further comments that relate to the Manly Lagoon Floodplain Risk Management Study and Plan, please provide them in the space below (or attach additional pages if necessary).

_____

_____

_____

_____

_____

Thank you for providing the above information

Appendix C

Submission ID	Topic	Submission – Key Points	Response
1	LV02: Levee Option 2 – Clearview Place	Consider converting part of the culvert near Clearview Place to an open channel.	No corridor of public land has been retained above the Clearview Place culvert. The culvert runs directly through the centre of the road alignment. Converting this culvert to an open waterway is not considered feasible due to: • The culvert is a known significant roost for a number of threatened microbat species, conversion of the culvert to an open waterway would remove this important habitat. • The culvert runs under the centre of Clearview Place and an open creek line could not be accommodated in the road reserve. • The culvert is under pressure, an open waterway would have less capacity, promote surcharge and increase flood levels in Clearview Place and downstream. • An open creek line in the centre of a road reserve would pose an unacceptable safety risk to vehicles and pedestrians. • This would be a prohibitively expensive exercise, with minimal water quality or flooding justification.
2	MD01-04: Dam Options 1-4 – Lowering Initial Water Level	Consider impact of lowering initial water level in Manly Reservoir on waterbird sanctuary at western end of the reservoir and aquatic habitat in Manly Creek upstream.	Refer to submission #20 - It is noted also that the investigation into Manly Dam operating water levels will consider environmental factors and impacts.
3	Re Protection of remnant bushland adjacent to Manly Creek	Bushland areas of Crown land in the upper reaches of Manly Creek should be zoned E2 (Environmental Conservation) for environmental and flood mitigation purposes.	Council has commenced the Local Environmental Plan Review process together with the Greater Sydney Commission and Department of Planning and Environment in order to implement the Actions of the North District Plan. This requires Council to review the suitability of LEP and DCP controls, including land use zones, to inform a new consolidated Local Environmental Plan. The community will be provided with an opportunity to have their say through this process.

Submission ID	Topic	Submission – Key Points	Response
4	Re Conversion of open culverts to more natural waterways	Concrete culverts that drain into Manly Lagoon could be enhanced with instream features and vegetation to reduce peak flow as well as improve landscape amenity.	Refer to Submission 1.
5	Driveways	New developments can result in a considerable increase in hard surface areas, including driveways. The cumulative impact of a torrent of runoff flowing into gutters and drains can contribute to flooding. Site specific attention to the design and gradient of hard surfaces may be helpful.	New developments are required to implement on-site detention to replicate pre-developed flows and offset increases in impermeable surfaces.
6	Water Sensitive Urban Design	Water Sensitive Urban Design Policy	While the goals of WSUD and flood risk management are not incompatible, this FRMS is designed to investigate options to reduce flood risk in large events (1% AEP event), while WSUD is typically limited to improving the management of local drainage and stormwater in relatively small (frequent) events.

Submission ID	Topic	Submission – Key Points	Response
7	General	Support for the Draft Study and Plan, and acknowledgement of challenges in making floodplain risk management decisions.	Noted
8	Option LV02	Support for LV02 (Levee at Clearview Pl), noting peak flood level benefits are limited to the retail and commercial areas of Brookvale.	Noted. Peak flood level impacts in the 1% AEP event are not shown to extend downstream of Warringah Golf Course, thereby limiting the benefits to commercial and retail areas of Brookvale
9	Options MD02,03,04	Manly Dam operations need to balance competing objectives and end users, including safety of downstream properties, operations of Hydraulic Labs, wetland environment and recreational use of the lagoon.	Refer to submission response #20.

Submission ID	Topic	Submission – Key Points	Response
10	Levees	Levees in urban areas can be challenging due to access to easements, space constraints, visual amenity, and upstream flood impacts.	There are several challenges associated with levees in urban areas, and the listed concerns are valid. Option LV02 is recommended to be investigated further for installation at the rear of commercial/industrial properties on Clearview Place, in the upper reaches of the catchment. The levee would back onto bushland and have minimal impact on visual amenity of local residents. The flood level impact is presented on Figure 34 and shows that peak flood level increases are limited to undeveloped land and would not adversely impact other properties. Downstream properties are significantly benefited as peak flood levels are reduced. Construction challenges will be addressed during the detailed design stage. It is noted that further investigation would be required prior to any option progressing.
11	Flood Response Planning	Support for emergency response planning measures as a high priority.	Noted. Option RM01, development of a Local Flood Plan is listed as a high priority in the Floodplain Risk Management Plan
12	Flood Proofing	Flood related development controls must be strictly enforced to ensure new developments adhere to minimum floor level requirements and do not cause flood impacts to neighbouring properties.	Refer to Northern Beaches DCP and DA assessment process.
13	Flood Response Planning	Properties at risk of flooding should be identified by Council.	The FRMS has developed a Flood Planning Area map, which is used to identify properties within the 1% AEP extent plus 500 mm freeboard. Information regarding flood risk is provided to property owners via the Section 10.7 Certificates.

Submission ID	Topic	Submission – Key Points	Response
14	Community Education	Property owners should be made aware of their flood risk and how to prepare their property for a flood.	Noted. Option RM05, Community Flood education, provides several ways in which community flood awareness and preparedness can be improved. These are recommended for implementation in the Floodplain Risk Management Plan.
15	Community Education	Improvement in flood information networks and information is a priority.	Noted
16	Community Participation	The affected community should be involved in the planning process more extensively than just making submissions.	Within the Floodplain Risk Management Process, the community is represented on the Floodplain Management Committee, and is asked for input at the start of the project (via a survey), and towards the end of the project via the Public Exhibition period.
17	Flood Response Planning	The flood planning process should consider new developments, such as District Park, Lagoon Park, Hinkler Island, Aiken Reserve, Keile Park and others.	In theory, new development should be planned in built so as not to make current risk any worse, and preferably better. If the LEP / DCP and generally planning process is working, the new development isn't an issue. For this reason, Council's policies on Land Use Planning and the DCP are reviewed as part of the FRMS. Furthermore, FRMS studies are updated periodically to ensure the modelled catchment conditions reflect the most up to date development and other changes within the catchment.
18	Dredging	The water quality and pollution of Manly Lagoon has significantly worsened over the last thirty years. Support for dredging options that would likely improve the water quality.	Council completed a large dredging project in 2010-11 at Manly Lagoon, for the primary purpose of improving the aesthetics of the lagoon. Future dredging projects will need to be well justified with a strong flood or water quality benefit. The FRMS has determined that dredging options have minimal impact on flood behaviour and property damages and have not been recommended for implementation as part of the FRMP. The water quality benefits of dredging can be explored separately to the FRMS process.

Submission ID	Topic	Submission – Key Points	Response
19	Levee	The eastern end of Campbell Parade (outside NBSC Mackellar Girls Campus) is subject to flooding during heavy rains and high tides, affecting parked cars, traffic, school buses, access to school and businesses and Passmore Reserve.	A levee and one-way flap valves at the end of Campbell Parade have been investigated in the Floodplain Risk Management Study. The levee can only protect against very minor flooding at the end of Campbell Parade and does not justify the likely significant costs of design and construction. Flood depth markers for Campbell Parade to warn of potential flooding and the hazard of existing flooding can be investigated further for implementation.
20	Dam Airspace	The impact of releases from Manly Dam on flood behaviour has been seen to be significant, and this submission supports increasing airspace to better control outflows during heavy rain events. Competing interests are acknowledged, especially keeping water levels high for water skiing amenity.	The Floodplain Risk Management Plan has recommended undertaking an investigation into the optimisation of airspace in Manly Dam. Additional airspace in the dam would provide storage during storms and help reduce downstream flood levels. It will be challenging to balance the interests of dam users and stakeholders, which is why a further study has been recommended.
21	Levee	Support for Option LV02: Levee at Clearview Place. Interest in receiving further details when available.	Support for Option LV02, the Levee at Clearview Place is noted. The project is assessed at a fairly high level as part of this study, and more details would likely become available during the detailed design process.

Submission ID	Topic	Submission – Key Points	Response
22	Dredging	Support for dredging options, noting additional benefits of improving water quality in Manly Creek by clearing blockage and allowing better flow/drainage.	Support for Option DR01 and DC01 is noted. These options have not been recommended in the Floodplain Risk Management Plan as they do not have a material impact on flood risk or property affectation. However, Council has noted the potential benefits in terms of water quality and community amenity and will consider these further separately to this study.
23	Dredging	Support for dredging and suggestion for increasing extent of dredging higher up Manly Creek towards Nolan Reserve. Dredging may be compatible with plan to rehabilitate the banks of Manly Creek.	Aspects of dredging related to water quality and bank rehabilitation are outside the scope of this report.

Appendix D

Table D1: Cost Estimate - Option LV02						
Item No.	**Description of work**	**Quantity**	**Unit**	**Rate**	**Cost**	
1. General Construction Costs						
1.1	Site establishment, security fencing, facilities and disestablishment					
1.2	Provision of sediment and erosion control					
1.3	Construction setout and survey					
1.4	Work as executed survey and documentation					
1.5	Geotechnical supervision, testing and certification					
	SUBTOTAL (Assumed as 15% of works cost)				**$**	**42,180**
2. Demolition and Clearing						
2.1	Clearing and grubbing	500	sq. m	12	$	5,800
2.2	Strip topsoil and stockpile for re-use (assuming 150mm depth)	75	cu. m	29	$	2,175
2.3	Dispose of excess topsoil (nominal 10% allowance)	8	cu. m	70	$	522
	SUBTOTAL				**$**	**7,911**
3. Excavation and earthworks						
3.1	Removal of top soil and vegetation (100 mm)	50	cu. m	84	$	4,189
3.2	Fill in embankment (could be supplied from spillway excavation if suitable)	550	cu. m	376	$	206,745
3.3	Fuel	550	l/m³	5	$	2,954
3.4	Compaction of new material	550	cu. m	43	$	23,628
3.5	Allowance for removal of unsuitable material (10%)	55	cu. m	11	$	591
3.6	Top soil seeding	500	cu. m	32	$	16,110
3.7	Top soil placement	500	cu. m	32	$	16,110
	SUBTOTAL				**$**	**272,701**
	CONSTRUCTION SUBTOTAL				**$**	**323,377**
4. Contingencies						
4.1	50% construction cost				**$**	**161,688**
	CONSTRUCTION TOTAL, exc. GST				**$**	**485,065**
	GST				$	48,507
	CONSTRUCTION TOTAL, inc. GST				**$**	**533,572**
	CONSTRUCTION TOTAL, rounded				**$**	**533,600**