OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

PUBLIC EXHIBITION

Public Exhibition Draft

March 2019

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Project **Ourimbah Creek Floodplain Risk Management Study and Plan**	**Project Number** **115046**
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LIST OF ACRONYMS

AAD	Annual Average Damages
ABCB	Australian Building Codes Board
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Aerial Reduction Factor
ARI	Average Recurrence Interval
ARR87	Australian Rainfall and Runoff 1987 edition
BCA	Building Code of Australia
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECC	Department of Environment and Climate Change
DEM	Digital Elevation Model
DoP	Department of Planning
DSC	Dam Safety Committee
ERP	Emergency Response Planning
EP&A Act	Environmental Planning and Assessment Act
EY	Exceedances per Year
FDM	Floodplain Development Manual
FIC	Flood Intelligence Card
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
LEP	Local Environmental Plan (GLEP - Gosford, WLEP - Wyong)
LFP	Local Flood Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging or known as ALS (Airborne Laser Scanning)
LLS	Local Land Services
mAHD	meters above Australian Height Datum
MHL	Manly Hydraulics Laboratory
NOW	NSW Office of Water
PMF	Probable Maximum Flood
RAFTS	Hydrologic model
RFS	Rural Fire Service
RMS	Roads and Maritime Services
RMSVMS	RMS Variable Messaging Service
SES	State Emergency Services
SMS	Short Messaging Service
SRA	State Rail Authority
TBPL	Tuggerah Business Park Levee
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood hydraulic computer model
VHS	Voluntary House Raising
VP	Voluntary Purchase
WSUD	Water Sensitive Urban Design
XP-RAFTS	Hydrologic model

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FOREWORD

The NSW State Government's Flood 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 Federal Government may also provide subsidies in some circumstances.

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

1. ***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.

The Ourimbah Creek Floodplain Risk Management Study & Plan (FRMS&P) presented herein constitutes the second and third stages in the NSW Floodplain Risk Management Process for the Ourimbah Creek catchment and follows on from the Flood Study prepared by Catchment Simulation Solutions in October 2013. It updates the previously adopted 2011 Lower Ourimbah Creek FRMP (Paterson Consultants, July 2011) and Bangalow Creek and Cutrock Creek Floodplain Management Plan (Webb McKeown & Associates, March 1997). WMAwater has been engaged by Wyong Shire Council and Gosford City Council (the new Central Coast Council) to prepare this FRMS&P.

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

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TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff (ARR) have produced a set of guidelines for appropriate terminology when referring to the probability of floods. In the past, AEP has generally been used for those events with greater than 10% probability of occurring in any one year, and ARI used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, EY.

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the ARR draft terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the ARR terminology guidelines and uses % AEP for all events the 50% AEP and greater and EY for all events smaller and more frequent than this. The image below provides the relationship between the various terminologies.

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Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
Extreme	0.0005	0.05	2000	2000
	0.0002	0.02	5000	5000
			PMP/ PMPDF	

The blue shaded areas represent the terminology adopted in this report.

BRIEF OUTLINE OF HOW DESIGN FLOOD LEVELS ARE CALCULATED

There are two broad approaches for calculating design events (floods of a known probability of occurrence such as the old 100 year event now termed the 1% AEP). The first is to undertake statistical analysis (termed flood frequency analysis) of a long record of peak flood levels (such as recorded for over 100 years at Windsor and at Maitland). This approach is rarely used (and not possible for the Ourimbah Creek catchment) as there are few places where these accurate long term records exist. The alternative method (termed rainfall runoff modelling) is to use computer models of the catchment which calculate peak flood levels (based on equations of flow) from design rainfall data provided by the BoM. The BoM is able to calculate design rainfall depths across Australia based on an extensive and long term record of historical rainfalls. The accuracy of the computer models are increased by "calibrating" them to historical flood height data using the actual rainfall records from that historical event. The models include detailed definition of the topography derived from laser aerial scanning of the ground (this data has a vertical accuracy of around +/- 150mm and is available at approximately 1m spacings).

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EXECUTIVE SUMMARY

STUDY OBJECTIVE

The main objective of this report is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximate costed recommendations in regards to flood risk mitigation in the catchment.

CATCHMENT DESCRIPTION

The Ourimbah Creek catchment is located on the Central Coast of NSW, approximately 90km north of Sydney. Covering a total area of 160 km^2, the majority of the catchment is contained in the Wyong Shire Local Government Area (LGA), with 8 km² of the catchment contained in the Gosford City LGA to the south. In 2016 the two councils were combined into the Central Coast Council.

Ourimbah Creek generally flows in an easterly direction through state forest and rural properties before passing beneath the Pacific Motorway and Pacific Highway near Palmdale. It continues to flow in a northern and then easterly direction before passing beneath the Main Northern Railway Line and Wyong Road and eventually discharging into Tuggerah Lake at Chittaway Point. The catchment also incorporates a number of significant tributaries that are typically situated east of the Pacific Motorway and Pacific Highway. These include Bangalow Creek, Cut Rock Creek, Chittaway Creek, Dog Trap Gully, Canada Drop Down Creek and Kangy Angy Creek.

The Ourimbah Creek catchment west of the Pacific Motorway is typically characterised by state forest and rural land uses. The catchment area on the eastern side of the Pacific Motorway is significantly more developed and incorporates a range of residential, commercial, industrial and rural land uses. A number of major transportation links also extend across the eastern section of the catchment including the Main Northern Railway, Pacific Highway and Motorway, Wyong Road, Enterprise Drive and Chittaway Road.

FLOODING DOWNSTREAM OF WYONG ROAD

Downstream of Wyong Road the predominant cause of flooding is due to elevated levels in Tuggerah Lakes (as occurred in February 1990 and June 2007). Management measures for this area have previously been investigated in the 2014 Tuggerah Lakes Floodplain Risk Management Study and Plan and have not been considered further in this report.

PAST STUDIES

A number of past studies have looked at flooding in Ourimbah Creek. The latest being the 2013 Ourimbah Creek Flood Study. Possible management measures have also been examined in some of these past studies.

STAKEHOLDER AND COMMUNITY CONSULTATION

Throughout this study there has been consultation with the key stakeholders as well as with the community through the floodplain management committee, newsletters, questionnaires and

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workshops.

EXISTING FLOOD PROBLEM

Flooding has been experienced in the catchment since prior to the 1970's and the more recent February 1990 and June 2007 events typify the nature of the problem. Whilst few urban areas are affected and general less than 10 residential floors inundated (note for the area upstream of Wyong Road and thus not affected by elevated levels in Tuggerah Lakes) the key issues are inconvenience and road access issues. The latter is significant as cars being washed away in floods are one of the main rescue activities undertaken by the SES and in Australia results in the main cause of death in floods. In a 10% AEP event 13 house floors are inundated and in the 1% AEP 34. However in the PMF over 500 houses will be inundated above floor.

Recent developments on the fringe of the floodplain have placed further pressure on the flood problem and in particular at the University of Newcastle, Ourimbah campus where inundation of student vehicles has occurred as well as raising risk to life issues with student access.

PREVIOUS FLOOD MITIGATION MEASURES UNDERTAKEN

The most significant works undertaken by the then Gosford City Council was creek re-alignment and stabilisation in the reach from the Pacific Highway to Teralba Street at Lisarow. Retarding basins were also constructed in the upper catchment to minimise the effects of urbanisation.

Both the former Wyong and Gosford Councils also adopted many property and response modification measures to address the issue.

POSSIBLE FLOODPLAIN MANAGEMENT MEASURES

Management measures can be subdivided into flood modification (changes the nature of flooding), property modification (change to the property) or response modification (changes the response of people) measures as summarised below.

Flood Modification	Property Modification	Response Modification
Levees	Land zoning	Community awareness
Temporary defences	Voluntary purchase	Flood warning
Channel construction	Building & development controls	Evacuation planning
Channel modification	Flood proofing	Evacuation access
Major structure modification	House raising	Flood plan / recovery plan
Drainage network modification	Flood access	
Drainage maintenance		
Retarding basins		

Each possible measure has to be investigated considering the positive and negative social, economic, hydraulic and environmental effects (refer Figure 1 (a to j)). As a result many measures are eliminated.

All flood modification measures investigated in detail are listed below:

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);

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- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3);
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5);
- Option FM6 – Canntree Road Levee (Section 9.2.1.6);
- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7);
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1);
- Option FM9 – Lees Bridge Widening (Section 9.2.5.1);
- Option FM10 – Footts Road Weir Removal (Section 9.2.5.2);
- Option FM11 – Upstream Pacific Motorway Vegetation Management Area (Section 9.2.6.1);
- Option FM12 – Sohier Park Vegetation Management Area (Section 9.2.6.2);
- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1);
- Option FM14 – Combined Channel and Basin (Section 9.2.8).

The following roads have been investigated for flood access improvements:

- Option RM1 – Tuggerah Street at the Pacific Highway (Section 9.3.1.1);
- Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park (Section 9.3.1.2);
- Option RM3 – Coachwood Drive North of Mahogany Close (Section 9.3.1.3);
- Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus (Section 9.3.1.4);
- Option RM5 – Chittaway Road near Burns Road (Section 9.3.1.5);
- Option RM6 – Howes Road, Link Road (Section 9.3.1.6);
- Option RM7 – Orchard Road, Link Road (Section 9.3.1.7);
- Option RM8 – Tall Timbers, Link Road (Section 9.3.1.8);
- Option RM9 – Burns Road Bridge (Section 9.3.1.9);
- Option RM10 – Burns Road Raising and Culvert Upgrades (Section 9.3.1.10);
- Option RM11 – Elmo Street near Footts Road (Section 9.3.1.11);
- Option RM12 – Tapley Road (Section 9.3.1.12);
- Option RM13 – Macdonalds Road near Indigo Place (Section 9.3.1.13);
- Option RM14 – Pacific Highway at Dog Trap Gully (Section 9.3.1.14).

In addition the following other response modification measures have been evaluated:

- Automatic Road Closures and Boom Gates (Option RM15) (Section 9.3.2.1);
- Warning Signs (Option RM16 and RM17) (Section 9.3.2.2);
- Camera Fines (Option RM18) (Section 9.3.2.3);
- Potential Gauges for Flood Warning (Options RM19 and RM20) (Section 9.3.3.2);
- Opportunities for Increasing Available Warning Time (Options RM21 and RM22) (Section 9.3.3.6);
- Opportunities for Reducing Required Warning Time (Options RM23 and RM24) (Section 9.3.3.7);
- Shelter-in-place Feasibility Assessment (Option RM25) (Section 9.3.3.8);
- Flood Emergency Management Planning (Options RM26, RM27, RM28) (Section 9.3.4);
- Create a SES Flood Intelligence Card for Lees Bridge (Option RM29) (Section 9.3.4.3);

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- Emergency Response Plans (Options RM30 and RM31) (Section 9.3.4.4);
- Community Flood Education (Option RM32) (Section 9.3.5).

The following specific property measures have been assessed:

- House Raising (Option PM1) (Section 9.4.1);
- Voluntary Purchase (Option PM2) (Section 9.4.2);
- Land Use Zoning (Option PM3) (Section 9.4.4);
- Changes to Planning Policy (Option PM4) (Section 9.4.7).

In addition Council requested the following specific objectives for flood prone areas, identified as part of the Flood Study to be investigated in this report (these are labelled as Brief Specific Objectives on **Figure 1**a to **Figure 1**j):

1. Cut Rock Creek between Pacific Highway and Teralba Street (Option FM14, see Section 9.2.8);
2. Pluim Park (improved flood access, see Section 9.3.1.1);
3. Tall Timbers Estate (improved flood access, see Section 9.3.1.8);
4. Sohier Park (improved flood access, see Section 9.3.1);
5. Turpentine, Ourimbah and Orchard Roads Kangy Angy (improved flood access, see Section 9.3.1.7);
6. Howes Road (improved flood access, see Section 9.3.1.6);
7. Chittaway Point (house raising, see Section 9.4.1);
8. University of Newcastle Ourimbah Campus. Issues include; access and evacuation (improved flood access, see Section 9.3.1), possible early flood warning system (see Section 9.3.3.3), flooding of lower car parking areas (see Option FM4 and FM5, Section 9.2.1.4 and 9.2.1.5);
9. Burns Road (improved flood access and road closures, see Section 9.3.1 and 9.3.2);
10. Assessment of existing levees (see Section 6.5).

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1. OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT PLAN

1.1. Introduction

The Ourimbah Creek Floodplain Risk Management Plan has been prepared for the Central Coast Council in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 1) and:

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

The Ourimbah Creek catchment is located on the Central Coast of NSW, approximately 90km north of Sydney. Covering a total area of 160 km^2, the majority of the catchment is contained in the Wyong Shire Local Government Area (LGA), with 8 km^2 of the catchment contained in the Gosford City LGA to the south. In 2016 the two councils were combined into the Central Coast Council.

Flooding has been recorded periodically since the 1930's but there are many more recorded instances of flooding in Tuggerah Lakes. It is possible that the incidence of flooding has historically been under reported along Ourimbah Creek and its tributaries. In recent times there have been two significant events, in February 1990 and June 2007. In both these events there was extensive flooding in the Newcastle, Lake Macquarie and Wyong/Gosford regions. Flooding causes significant hardship, including both tangible and intangible damages, to the community and for this reason the Central Coast Council has undertaken a program of studies to address the management of the flood problem in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 1).

1.2. Risk Management Measures Considered

A matrix of possible management measures was prepared and evaluated in this Floodplain Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer Section 9) including flood mitigation dams, additional retarding basins and voluntary purchase of all flood liable buildings. The use of on-site stormwater detention as a flood mitigation measure, as opposed to its use for mitigating the effects of urbanisation was also eliminated.

The full range of measures was evaluated and the outcomes are summarised in Table 1. Table 2 details the matrix scoring system and Table 3 provides the matrix results which ranks the management measures considered.

Community opinion on the full range of options has been canvassed during the public exhibition period. However, it should be noted that these outcomes may change in the future if climate change induced rainfall increases become significant.

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Table 1: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
ON-SITE DETENTION (Section 9.1)	Decrease effects of increased urbanisation.	• On-site detention or retarding basins are suitable measures to mitigate the potential increase in peak flow on downstream reaches as rural areas become urbanised. • Smaller on-site detention can help water quality and local drainage, but has little impact along the main tributaries.
LEVEES AND FILLING (Section 9.2.1)	Prevent or reduce the frequency of flooding of protected areas.	• Levees are suitable on large river systems where they can protect a number of buildings. • May cause local drainage problems and be unacceptable to the community due to restriction of waterfront access and views. • Levees will still be overtopped in major flood events and for this reason flood planning controls will still apply to areas protected by levees. • Specific sites have been investigated.
CHANNEL CONSTRUCTION / FLOODWAYS (Section 9.2.3)	To channel floodwaters away from affected areas and so reduce flood levels.	• The creation of floodways can provide an effective means of diverting floodwaters away from affected areas and thus reducing flood levels. • There are no practical areas where a floodway could be created due to existing development.
CHANNEL MODIFICATIONS (Section 9.2.4)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by straightening of the channel, widening or removal of vegetation along the banks. • However, such measures can often increase flood risk downstream. • These measures are costly to undertake and generally require on going maintenance, have significant environmental impacts, are not an ecologically sustainable measure and are thus rarely used.
REMOVAL OF HYDRAULIC RESTRICTIONS (Section 9.2.5)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by removal of significant hydraulic restrictions such as narrow culverts or low level bridges or even minimising the potential for blockage. • However, such measures can often increase flood risk downstream. • The larger measures (widen culverts or replace a bridge) are generally costly to undertake. Reducing the potential for blockage through regular maintenance is supported. • No location was identified which would provide a significant reduction in above floor inundation

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MEASURE	PURPOSE	COMMENT
		upstream.
DRAINAGE MAINTENANCE (9.2.6)	Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure and may involve removing unwanted vegetation and other debris.	• Is an on going issue for Council. • Is not an environmentally sustainable management measures. • May have significant environmental implications.
FLOOD MITIGATION DAMS, RETARDING BASINS (Section 9.2.7)	Reduce the peak flow from the catchment into Ourimbah Creek and its tributaries by increasing the volume of flood storage in the catchment.	• The size of storages required to make a difference to large creeks such as Ourimbah Creek are very large, making them impractical on environmental, social and economic grounds.
RESPONSE MODIFICATION:		
IMPROVED FLOOD ACCESS (Section 9.3.1)	To ensure safe and reliable access during times of flood.	• There is a significant existing problem and 14 locations were investigated. • Elimination of the flood hazard cannot be eliminated. • Measures have been proposed to reduce the hazard at a number of locations.
ROAD CLOSURES AND NOTIFICATIONS (Section 9.3.2)	To reduce the risk to life of vehicles entering flood waters.	• A number of measures are possible. • Further investigation and liaison with RMS is required to determine the most appropriate and viable measures.
FLOOD WARNING (Section 9.3.3)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	• Relatively short warning time makes it impossible to provide a fail safe warning system. • Any system will provide some additional warning. • Installation of water level gauges is supported.
FLOOD EMERGENCY PLANNING (Section 9.3.4)	Effective planning for emergency response is a vital way of reducing risk to life and property.	• The cost to undertake this measure is small and will provide a high benefit/cost ratio. • A range of measures are provided and supported.
COMMUNITY FLOOD EDUCATION (Section 9.3.5)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	• A cheap and effective method but requires continued effort. • Possible approaches are provided.
PROPERTY MODIFICATION:		
VOLUNTARY HOUSE RAISING	Prevent flooding of existing buildings by raising the floor	• All flood damages will not be prevented and only suitable for non-brick buildings on piers.

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MEASURE	PURPOSE	COMMENT
(Section 9.4.1)	level above the floodwaters.	• Costs approximately $80,000 per house but can vary considerably. • Only suitable for a small number of houses (generally with floor levels first inundated in the 10% AEP (1 in 10 year)) or smaller events and not attractive to all residents. • Should be investigated further for applicable properties.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (Section 9.4.2)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	• High cost per property. • Applicable for isolated, high hazard properties in flood liable areas. • Progress applications for 6 existing properties on Mannings Road. • Investigate scheme for Tall Timbers Estate.
FLOOD PROOFING (Section 9.4.3)	Prevent flooding of existing buildings by sealing all the entry points.	• Generally only suitable for brick, slab on ground buildings. • Less viable for residential buildings but should be considered for non residential buildings of slab on ground construction.
LAND USE ZONING (Section 9.4.4)	Reduce potential hazard and losses from flooding by appropriate land use planning.	• Well-established processes are in place for dealing with land-use in flood hazard areas. • Ourimbah Masterplan must address flooding.
FLOOD PLANNING LEVELS (Section 9.4.5)	Provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.	• Recommended as the 1% AEP + 0.5m freeboard.
FLOOD PLANNING AREA (Section 9.4.6)	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.	• Review undertaken and consistent with best practice.
CHANGES TO PLANNING POLICY (Section 9.4.7)	Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages.	• Council should apply further controls is some areas. • Flood mapping should take into consideration the findings of the Flood Study and this FRMS&P.
MODIFICATION TO THE S10.7 CERTIFICATE (Section 9.4.8)	S10.7 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	• Council should continue to review flood related information on the Section 10.7 Certificate to bring it in line with the findings of the Flood Study and this FRMS&.

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MEASURE	PURPOSE	COMMENT
OTHER MANAGEMENT MEASURES		
FLOOD INSURANCE (Section 9.5)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	• Does not reduce damage, but spreads the cost. • These issues are outside the scope of this present study. • Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.. • Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not available.

1.2.1. Relative Merits of Management Measures

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

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was developed for the Ourimbah Creek area, allowing B/C estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

1.2.2. Management Matrix

The criteria assigned a value in the management matrix are:

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

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- long-term performance given the likely impacts of climate change,
- risk to life.

The colour coded scoring system for the above criteria is provided in Table 2 and largely relates to the impacts in a 1% AEP event. Table 3 indicates the weighting assigned to each measure, however these may be adjusted in the light of community consultations and local conditions.

Table 2: Colour Coded Matrix Scoring System

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

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Table 3: Matrix of Management Measures Investigated in Study

Ref	Option	Section in Study	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 Performance	Risk to Life	Total Score	Rank (Total)	Recommended
FM1	East Chittaway Point Levee	9.2.1.1	3	3	-3	1	-3	-3	0	2	1	3	3	7	29	
FM2	Bangalow Creek Levees	9.2.1.2	3	3	-2	-2	-3	-3	0	1	1	2	2	2	38	
FM3	Mill Street Industrial Area Levee	9.2.1.3	3	2	1	0	-2	-2	0	1	1	2	1	7	29	
FM4	University Lower Carpark Levee	9.2.1.4	3	0	-2	0	-3	-2	0	1	0	2	2	1	41	
FM5	University Lower Carpark Filling	9.2.1.5	3	0	1	0	-3	-1	-1	1	0	3	2	5	35	**Yes**
FM6	Canntree Road Levee	9.2.1.6	3	2	2	-1	-3	-3	0	1	-1	2	2	4	36	
FM7	Existing Levee Survey and Maintenance	9.2.1.7	0	0	3	3	3	3	0	2	3	3	3	23	4	**Yes**
FM8	Baileys Road Diversion Channel	9.2.3.1	1	2	-2	2	-3	-2	-1	0	-2	-1	0	-6	48	
FM9	Lees Bridge Widening	9.2.5.1	1	2	-2	0	-3	-2	0	0	-2	3	0	-3	44	
FM10	Footts Road Weir Removal	9.2.5.2	0	0	1	1	-3	-3	0	0	-1	3	0	-2	42	
FM11	Upstream Pacific Highway Vegetation Management	9.2.6.1	1	1	-2	2	-3	-3	-3	0	-2	-3	0	-12	49	
FM12	Sohier Park Vegetation Management	9.2.6.2	1	1	-2	2	-3	-3	-3	0	-2	-3	0	-12	49	
FM13	Cut Rock Creek Basin	9.2.7.1	1	1	-2	-1	-3	-3	1	0	0	2	0	-4	46	
FM14	Combination of Options FM8 and FM13	9.2.8	2	1	-2	-1	-3	-3	0	0	0	2	0	-4	46	
RM1	Improved access -Tuggerah Street at the Pacific Highway	9.3.1.1	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM2	Improved access -Tuggerah Street and Cutrock Road near Pluim Park	9.3.1.2	0	3	-3	3	-3	-3	0	3	0	3	3	6	31	**Yes**
RM3	Improved access -Coachwood Drive North of Mahogany Close	9.3.1.3	0	3	1	3	-2	-3	0	3	0	3	3	11	25	**Yes**
RM4	Improved access -The Boulevard at the University of Newcastle Ourimbah Campus	9.3.1.4	0	1	-1	1	-3	-3	0	2	0	3	3	3	37	**Yes**
RM5	Improved access -Chittaway Road near Burns Road	9.3.1.5	0	3	-2	2	-3	-3	0	3	0	3	3	6	31	**Yes**
RM6	Improved access -Howes Road, Link Road	9.3.1.6	0	2	-2	3	0	1	0	3	0	3	3	13	24	**Yes**
RM7	Improved access -Orchard Road, Link Road	9.3.1.7	0	3	3	3	0	3	0	3	0	3	3	21	6	**Yes**
RM8	Improved access -Tall Timbers, Link Road	9.3.1.8	-1	3	0	3	-3	1	0	3	-2	3	3	10	26	**Yes**
RM9	Improved access -Burns Road Bridge	9.3.1.9	0	3	-3	3	-3	-3	0	3	0	3	3	6	31	**Yes**
RM10	Improved access -Burns Road Raising and Culvert Upgrades	9.3.1.10	0	3	-2	3	0	1	0	3	0	3	3	14	21	**Yes**
RM11	Improved access -Elmo Street near Footts Road	9.3.1.11	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM12	Improved access -Tapley Road	9.3.1.12	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM13	Improved access -Macdonalds Road near Indigo Place	9.3.1.13	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM14	Improved access -Pacific Highway at Dog Trap Gully	9.3.1.14	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM15	Automatic Road Closures and Boom Gates	9.3.2.1	0	3	3	2	1	1	0	2	1	1	2	16	19	**Yes**
RM16	Automatic Warning Signs and Depth Indicators	9.3.2.2	0	3	2	3	1	1	0	1	1	1	1	14	21	**Yes**
RM17	Early Notification and Road Closures	9.3.2.2	0	3	2	3	2	2	0	3	1	1	1	18	18	**Yes**
RM18	Camera Fines	9.3.2.3	0	3	-2	-1	-2	-1	0	0	-1	1	1	-2	42	**Yes**

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Ref	Option	Section in Study	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 Performance	Risk to Life	Total Score	Rank (Total)	Recommended
RM19	Assessment of Feasibility of Gauge Use	9.3.3.2	0	3	2	3	2	2	0	0	2	1	1	16	19	Yes
RM20	Additional Gauges Recommended for Installation	9.3.3.2	0	3	3	3	2	2	0	3	2	1	0	19	11	Yes
RM21	Increasing Mobile Phone Reception	9.3.3.6	0	3	1	3	1	-2	0	2	2	3	1	14	21	
RM22	Provide Accessible Real-time Flood Information	9.3.3.6	0	3	2	2	2	3	0	1	2	3	1	19	11	
RM23	Flood Warning Messages	9.3.3.7	0	3	3	3	3	3	0	2	2	3	2	24	2	Yes
RM24	Telephone Dial-out System	9.3.3.7	0	3	3	3	3	3	0	3	2	3	2	25	1	Yes
RM25	Shelter-in-place Feasibility Assessment	9.3.3.8	0	3	1	2	0	3	0	0	-2	3	0	10	26	Yes
RM26	Updating of Wyong and Gosford LFPs	9.3.4	0	3	3	3	3	3	0	1	1	3	1	21	6	Yes
RM27	Relocation of Wyong Evacuation Centre	9.3.4.1	0	0	1	3	-3	-2	0	3	1	3	0	6	31	Yes
RM28	Resourcing of Wyong and Gosford SES units	9.3.4	0	0	3	3	3	3	0	3	2	3	0	20	9	Yes
RM29	Create SES Flood Intelligence Card for Lees Bridge	9.3.4.3	0	3	3	3	3	3	0	3	3	3	0	24	2	Yes
RM30	Assist Key Floodplain Exposures to Create Emergency Response Plan	9.3.4.4	0	3	3	1	3	3	0	3	3	2	0	21	6	Yes
RM31	Assist Flood Affected Residents to Create Emergency Response Plan	9.3.4.4	0	3	3	2	3	3	0	2	2	1	1	20	9	Yes
RM32	Prepare Flood Education Program	9.3.5	0	3	3	3	3	3	0	3	3	1	1	23	4	Yes
PM1	House Raising	9.4.1	0	1	-1	2	-1	-2	0	0	1	1	1	2	38	Yes
PM2	Voluntary Purchase	9.4.2	0	1	-3	-1	-3	-3	0	3	-3	3	3	-3	44	Yes
PM3	Land Use Zoning	9.4.4	0	3	-2	-1	1	0	0	0	-2	3	0	2	38	Yes
PM4	Changes to Planning Policy	9.4.7	0	3	-1	0	2	1	0	0	-1	3	3	10	26	Yes

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1.3. Floodplain Risk Management Measures in Plan

The recommended measures are described in Table 4 according to the ranking in Table 3. However a high rank in Table 3 may not necessarily be a high priority measure for implementation as for example, funds may not be available and it will depend upon the ease of implementation (agreement between agencies, responsibility etc.).

Table 4: Recommended Management Measures in Plan

Option	Priority	Responsibility	Costing	Timeframe	Rank (Total)
Telephone Dial-out System	High	Council / SES	Low	Short Term	1
Flood Warning Messages	High	Council / SES	Low	Short Term	2
Create SES Flood Intelligence Card for Lees Bridge	High	SES	Low	Short Term	2
Existing Levee Survey and Maintenance	High	Council	Low	Short Term	4
Prepare Flood Education Program	High	Council / SES	Low	Short Term	4
Improved access -Orchard Road, Link Road	Low	Council / RMS	High	Long Term	6
Updating of Wyong and Gosford LFPs	High	Council	Low	Short Term	6
Assist Key Floodplain Exposures to Create Emergency Response Plan	High	Council / SES	Low	Short Term	6
Resourcing of Wyong and Gosford SES units	High	SES	Low	Short Term	9
Assist Flood Affected Residents to Create Emergency Response Plan	High	Council / SES	Low	Short Term	9
Improved access -Tuggerah Street at the Pacific Highway	Low	Council / RMS	High	Long Term	11
Improved access -Elmo Street near Footts Road	Low	Council / RMS	High	Long Term	11
Improved access -Tapley Road	Low	Council / RMS	High	Long Term	11
Improved access -Macdonalds Road near Indigo Place	Low	Council / RMS	High	Long Term	11
Improved access -Pacific Highway at Dog Trap Gully	Low	Council / RMS	High	Long Term	11
Additional Gauges Recommended for Installation	High	Council	Low	Short Term	11
Early Notification and Road Closures	High	Council / RMS	Low	Short Term	18
Automatic Road Closures and Boom Gates	High	Council / RMS	Medium	Short Term	19
Assessment of Feasibility of Gauge Use	High	Council	Low	Short Term	19
Improved access -Burns Road Raising and Culvert Upgrades	Low	Council / RMS	High	Long Term	21
Automatic Warning Signs and Depth Indicators	High	Council / RMS	Medium	Short Term	21
Improved access -Howes Road, Link Road	Low	Council / RMS	High	Long Term	24
Improved access -Coachwood Drive North of Mahogany Close	Low	Council / RMS	High	Long Term	25
Improved access -Tall Timbers, Link Road	Low	Council / RMS	High	Long Term	26
Shelter-in-place Feasibility Assessment	Medium	Council / SES	Low	Short Term	26
Changes to Planning Policy	High	Council	Low	Short Term	26
Improved access -Tuggerah Street and Cutrock Road near Pluim Park	Low	Council / RMS	High	Long Term	31
Improved access -Chittaway Road near Burns Road	Low	Council / RMS	High	Long Term	31

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Option	Priority	Responsibility	Costing	Timeframe	Rank (Total)
Improved access -Burns Road Bridge	Low	Council / RMS	High	Long Term	31
Relocation of Wyong Evacuation Centre	Medium	Council / SES	Medium	Short Term	31
University Lower Carpark Filling	High	Council /Univ	High	Short Term	35
Improved access -The Boulevard at the University of Newcastle Ourimbah Campus	Medium	Council / RMS	High	Long Term	37
House Raising	Medium	Council / OEH	Medium	Long Term	38
Land Use Zoning	High	Council	Low	Short Term	38
Camera Fines	High	Council	Low	Short Term	42
Voluntary Purchase	Medium	Council / OEH	High	Long Term	44

Notes:

Costing: Low < $40K, Medium $40K to $100K, High > $100K

Timeframe: Short < 2 years, Long > 2 years

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2. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Wyong Shire Council and Gosford City Council (now Central Coast Council). The Study is composed of two phases:

1. The Ourimbah Creek Floodplain Risk Management Study; and
2. The Ourimbah Creek Floodplain Risk Management Plan.

This document details; The Ourimbah Creek Floodplain Risk Management Study; and the Ourimbah Creek Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Flood Study (Reference 2) undertaken by Catchment Simulation Solutions and completed in 2013 which defined the design flood behaviour in the Ourimbah Creek catchment under existing conditions.

2.1. Study Objectives

The main objective of this FRMS&P is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximately costed recommendations in regards to flood risk mitigation in the catchment.

Council requires consideration of a range of management options to effectively manage existing, future and continuing flood risks in the catchment. The outcomes from the Floodplain Risk Management Study and Floodplain Risk Management Plan will also assist the SES in updating the Local Flood Plan for the catchment.

The objectives as outlined in the Brief are more specifically described in Section 2.2 and 2.3 below.

2.2. Floodplain Risk Management Study and Plan Objectives

The objective of the FRMS&P is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. This includes:

- Reduce the flood risk to people and property in the existing community;
- Ensure future development is controlled in a manner consistent with the flood risk (taking into account the potential impacts of climate change);
- Reduce private and public losses due to flooding;
- Protect and where possible enhance the creek and floodplain environment;
- Be consistent with the objectives of, the Government's Flood Prone Land Policy and Gazetted Floodplain Development Manual (2005);
- 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;

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- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans; and to
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

2.3. Brief Specific Objectives

In addition Council requested the following specific objectives for flood prone areas, identified as part of the Flood Study to be investigated in this report (these are labelled as Brief Specific Objectives on Figure 1a to Figure 1j):

1 Cut Rock Creek between Pacific Highway and Teralba Street (Option FM14, see Section 9.2.8);
2 Pluim Park (improved flood access, see Section 9.3.1.1);
3 Tall Timbers Estate (improved flood access, see Section 9.3.1.8);
4 Sohier Park (improved flood access, see Section 9.3.1);
5 Turpentine, Ourimbah and Orchard Roads Kangy Angy (improved flood access, see Section 9.3.1.7);
6 Howes Road (improved flood access, see Section 9.3.1.6);
7 Chittaway Point (house raising, see Section 9.4.1);
8 University of Newcastle Ourimbah Campus. Issues include; access and evacuation (improved flood access, see Section 9.3.1), possible early flood warning system (see Section 9.3.3.3), flooding of lower car parking areas (see Option FM4 and FM5, Section 9.2.1.4 and 9.2.1.5);
9 Burns Road (improved flood access and road closures, see Section 9.3.1 and 9.3.2);
10 Assessment of existing levees (see Section 6.5).

Additionally, recommendations for future planning (see Section 9.4) and emergency response (see Section 9.3) also assist in addressing the above referenced issues.

Whilst Ourimbah Creek exits to Tuggerah Lakes and potentially a mitigation measure for Tuggerah Lakes may affect flooding within Ourimbah Creek, it should be noted that this study does not include the assessment or review of any measures relating to the management of flooding within Tuggerah Lakes. Refer to Section 3.2 which provides a summary of previous floodplain risk management studies that have been undertaken for both Ourimbah Creek and Tuggerah Lakes.

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3. BACKGROUND

The headwaters of the Ourimbah Creek catchment are located within the Great Dividing Range near Kulnura. The creek generally flows in an easterly direction through state forest and rural properties before passing beneath the Pacific Motorway and Pacific Highway near Palmdale. It continues to flow in a northern and then easterly direction before passing beneath the Main Northern Railway Line and Wyong Road and eventually discharging into Tuggerah Lake at Chittaway Point.

The catchment also incorporates a number of significant tributaries that are typically situated east of the Pacific Motorway and Pacific Highway. These have been summarised in the Flood Study (Reference 2), and are reproduced below:

- **Bangalow Creek**, originates in bushland between Tumbi Umbi and Ourimbah. It drains in a westerly and then northerly direction through the township of Ourimbah before joining Ourimbah Creek. Bangalow Creek drains a sub-catchment area of 27 km² to its confluence with Ourimbah Creek.
- **Cut Rock Creek**, which forms part of the larger Bangalow Creek sub-catchment. The creek drains in a northerly direction through Lisarow, beneath the Main Northern Railway Line, Pacific Highway and Teralba Street before joining Bangalow Creek near Ourimbah. The Cut Rock Creek sub-catchment occupies an area of 10 km².
- **Chittaway Creek**, which has its headwaters along Brush Road and drains in a westerly direction through Fountaindale before making its way north beneath Old Chittaway Drive and then west beneath Enterprise Drive and the Main Northern Railway line before entering Bangalow Creek. Chittaway Creek drains a sub-catchment area of 6 km² to Bangalow Creek.
- **Dog Trap Gully**, which originates in bush land west of Ourimbah and drains in a northerly direction before turning east and flowing through the township of Ourimbah, beneath the Pacific Highway and Main Northern Railway and into Bangalow Creek. The Dog Trap Gully sub-catchment occupies an area of 5 km².
- **Canada Drop Down Creek**, which has its headwaters in the State Forest and drains in an easterly direction through Palmdale before joining Ourimbah Creek just upstream of the Pacific Motorway. The Canada Drop Down Creek sub-catchment occupies an area of 22 km².
- **Kangy Angy Creek**, which originates in State Forest / bush land and drains in a south easterly direction though the village of Kangy Angy before flowing east beneath the Pacific Motorway and Pacific Highway and into Ourimbah Creek. The Kangy Angy Creek sub-catchment drains an area of 4 km².

The Ourimbah Creek catchment west of the Pacific Motorway is typically characterised by State Forest and rural land uses. The catchment area on the eastern side of the Pacific Motorway is significantly more developed and incorporates a range of residential, commercial, industrial and rural land uses. A number of major transportation links also extend across the eastern section of the catchment including the Main Northern Railway, Pacific Highway, Wyong Road, Enterprise Drive and Chittaway Road.

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3.1. Summary of Flood Risk and Affectation

Various flooding hotspots and areas of localised risk have been identified by the works undertaken as part of this FRMS&P. The study area can be broadly delineated into four areas or Flood Precincts with individual risk characteristics. These four areas are summarised below with the locations displayed on Figure 1 (a to j):

1. **Ourimbah Creek Downstream of Wyong Road –** Property flood affectation in this area is significant. The majority of over floor flood affectation within the catchment is experienced by properties in this region. During the 1% AEP flood event, of the 450 residential properties that are flooded over floor catchment wide, 416 of these are situated in the area downstream of Wyong Road (see Section 7.1.1). Properties in this area are flooded not only by Ourimbah Creek flows but also elevated water levels in Tuggerah Lake. Examination of the flood hazard in this region indicates that during a 1% AEP flood most properties are situated in areas of H3 Hazard (see Section 6.2 for a description of flood hazard classifications) which means that flood waters are unsafe for vehicles, children and the elderly, however the structural stability of buildings is not an issue. Access roads in this area are typically cut in events smaller than the 20% AEP event and are subject to even higher levels of flood hazard with a H4 classification indicating the flooding conditions are unsafe for all people and vehicles.

2. **Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road –** The Ourimbah Creek floodplain bounded by the Pacific Motorway to the west and Wyong Road to the east is characterised by High Hazard flooding (H5 classification, see Section 6.2) in the 1% AEP event. 12 properties in this area are flooded above floor during the 1% AEP event and numerous properties become isolated in smaller flood events (less than the 20% AEP in many instances) leading to dangerous Low Flood Islands and Low Trapped Perimeter Areas (see Section 6.3).

3. **Ourimbah Creek Floodplain upstream of the Pacific Motorway–** Similar to Ourimbah Creek floodplain downstream of the Pacific Motorway, this region is characterised by High Hazard flooding (H5 and H6 classification, see Section 6.2) during the 1% AEP event. Even during smaller events such as the 20% AEP, flood depths and velocities at properties and on access roads pose an extreme hazard to pedestrians and motorists. Again, due to flooding of access roads by smaller flood events (less than 20% AEP, numerous properties become isolated leading to dangerous Low Flood Islands and Low Trapped Perimeter Areas (see Section 6.3). Seven properties in this area are flooded above floor during the 1% AEP event.

4. **Cut Rock and Bangalow Creeks –** In spite of the large number of residential property situated in this region (~770 total), property flood affectation and flood risk at properties in this region is typically not as high as for the previously described flood hotspots. Approximately 15 residential properties are flooded over floor in the 1% AEP event with flood hazard in the vicinity of properties generally not exceeding the H3 Hazard classification (see Section 6.2).

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However, flooding in Cut Rock and Bangalow Creeks is likely responsible for the highest levels of risk to life in the catchment due to the frequent and hazardous flooding of key access routes. Risk to life for motorist at a number of crossings (see Section 6.4) was noted by various key stakeholders (see Section 4.2) to be particularly high for the following reasons:

- High traffic volumes using these access roads;
- Motorist unfamiliarity with these crossings and the associated risk during times of flood;
- Frequency of flooding (events < 1EY) at numerous locations of these crossings;
- Lack of alternative access routes during flood;
- Insufficient early warning and notification of road closures; and
- Inadequate means of deterring motorists from crossing closed roads.

Improving flood access, early warning and deterring motorists from entering floodwaters at these crossings provides the best means of mitigating flood risk throughout the study area and is a key outcome of the current study.

3.2. Relevant Studies

This study is based on the findings of the 2013 Ourimbah Creek Flood Study (Reference 2). A review and summary of this study is presented in Section 5.

Various other reports salient to the current study have been reviewed with details provided in the following sections. These reports have been considered for this FRMS&P, with reference to these studies found throughout this report.

3.2.1. Previous Studies

Prior to completion of the 2013 Ourimbah Creek Flood Study (Reference 2), various other studies applicable to flooding in the catchment have been undertaken. These studies are listed below and a summary of each study is presented in the Flood Study:

- Paterson Consultants - Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan, July 2011 (Reference 3);
- WMAwater - Tuggerah Lakes Floodplain Risk Management Study – Final Report, November 2014 (Reference 4);
- Webb McKeown & Associates - Upper Ourimbah Creek Flood Study, June 1997 (Reference 5);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Study, May 1997 (Reference 6);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Flood Study, December 1994 (Reference 7);
- Sinclair Knight & Partners - Lower Ourimbah Creek Flood Study – Draft, October 1986 (Reference 8);
- Cameron McNamara Consultants - Cut Rock Creek Valley Floodplain Management Study, June 1982 (Reference 9)

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- WMAwater – Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, December 2014 (Reference 10) (provided as Appendix G);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Plan, March 1997 (Reference 11).

Additionally, a number of smaller Flood Impact Assessments have been undertaken, typically for proposed developments across the catchment. A complete list is presented in the Flood Study (Reference 2).

Of particular interest to the current study is the Paterson Consultants (2011) and Webb McKeown & Associates (1997) Floodplain Management Studies which the current study will supersede. Details of these studies are presented in Sections 3.2.2 and 3.2.3 respectively.

Additionally, the community consultation questionnaire results collected as part of this study (Section 4.1) further highlighted the communities concerns relating to the condition of the entrance to Tuggerah Lakes, and in particular dredging and enlarging the entrance channel for flood mitigation purposes. This was investigated at length as part of the Tuggerah Lakes Floodplain Risk Management Study (WMAwater, 2010) with the findings reiterated in Section 3.2.4.

3.2.2. Paterson Consultants - Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan, July 2011 (Reference 3)

The Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan was prepared for Wyong Shire Council by Paterson Consultants. The report was commissioned to review the draft Ourimbah Creek Floodplain Management Study" (Hyder Consulting Pty Ltd, January, 2001) and then develop a floodplain risk management plan. The study covers the lower 8 kilometres of Ourimbah Creek extending from the Wyong Road crossing of Ourimbah Creek (i.e., Lees Bridge) upstream to the confluence of Ourimbah Creek and Bangalow Creek. Only the section of Ourimbah Creek upstream of Wyong Road was considered as flood levels downstream of Wyong Road are dominated by Tuggerah Lake.

An important outcome of this study was a review of previous flooding investigations across the lower Ourimbah Creek catchment with comment being made that many of the previous studies had various inadequacies including:

- failure to adequately represent the routing of flow through the catchment;
- failure to consider all available historic information in the calibration and verification of models;
- adopting high Mannings 'n' coefficients in the hydraulic model; and/or,
- attempting to represent the complex 2-dimensional movement of floodwaters using simplified 1-dimensional hydraulic models.

The 2013 Ourimbah Creek Flood Study (Reference 2) is noted to have addressed these issues (see Section 5.2.8) through use of a calibrated/verified 2D hydraulic model.

The study then undertook to develop a floodplain risk management plan in accordance with the

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NSW Government flood policy as described by the NSW Floodplain Development Manual. The floodplain management component of the study identified eight issues related to:

- current estimated potential flood damages;
- land use zoning and planning;
- flood warning emergency operations;
- provision for housing for "seniors" and persons with disabilities;
- development of better understanding of flood behaviour;
- voluntary acquisition of flood liable properties;
- public information and education;
- operations and maintenance.

Based on the above, a floodplain risk management plan was derived to address these issues. The Paterson Consultants (2011) Ourimbah Creek Floodplain Risk Management Plan presented in Table 10.1 of the study has been reproduced herein as Table 5.

Table 5: Paterson Consultants (2011) – Floodplain Risk Management Plan

Risk Management Issue	Response	Priority	Duration	Projected Cost
1. Land Use Planning	1. Revise Interim Policy	Immediate	1 month	Council cost only
	2. Develop flooding DCP	High	6 months	Council cost only
2. Transfer of Flood Knowledge	1. Council, through its LEMC, assist SES to condense local flood knowledge in the Local Flood Plan	High	3 months	Council cost only
3. NSW Government State Planning Policy (Housing for Seniors)	Request changes to include flood risk	High	2 months	Council cost only
4. Public Information and Education	1. Ensure flood risk notation on Section 149 Certificates is up to date	High	2 months (and on-going)	Council cost only
	2. Develop site specific flood information brochures	High	6 months	$20,000 plus on-going $4,000 every four years
5. Inspection and maintenance of existing infrastructure	Develop inspection and maintenance procedures	High	On-going	Council cost only
6. Development of Flood Knowledge	1. Update the hydrologic and hydraulic studies	Medium to Low	18 months	$60,000
	2. Obtain high flow measurement	High	On-going	Subject to floods occurring

3.2.3. Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Study, May 1997 (Reference 6)

The Bangalow Creek and Cut Rock Creek Floodplain Management Study was prepared by Webb McKeown & Associates for Wyong Shire Council and Gosford City Council. The study outlines a range of flood mitigation measure that could potentially be implemented to reduce the existing flood problem across the Bangalow, Cut Rock and Chittaway Creek catchments and ensure future development is completed in a manner that recognises the variation in flood hazard across different sections of the floodplain. The following locations were identified as areas where significant flood damages are likely to be incurred:

- Pluim Park / Tall Timbers Estate / Manning Road *(12 buildings inundated in 1% AEP flood)*;
- Donna Close / Janine Close / Narelle Close *(1 building inundated in 1% AEP flood)*;
- Subdivisions east of Tuggerah Street *(1 building inundated in 1% AEP flood)*;
- Brands Place / Lisarow Street (*23 buildings inundated in 1% AEP flood)*;
- Shirley Street *(1 building inundated in 1% AEP flood)*;
- Mill Street Industrial Area *(2 buildings inundated in 1% AEP flood)*;

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- Dog Trap Gully *(1 building inundated in 1% AEP flood)*; and,
- Chittaway Creek *(3 buildings inundated in 1% AEP flood).*

The Bangalow Creek and Cut Rock Creek Floodplain Management Plan was completed in March 1997 (Reference 11) and a copy of the summary is provided as Appendix G.

A review of the Reference 6 study, the Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, was completed in December 2014 (Reference 10). Further details on this addendum are presented in Section 3.2.6 and a cop[yis provided as Appendix G.

3.2.4. WMAwater - Tuggerah Lakes Floodplain Risk Management Study - Final Report, November 2014 (Reference 4)

The current study community consultation process highlighted the community's perception that the condition of the entrance to Tuggerah Lakes should be modified as a flood mitigation measure to reduce flooding in the lower reaches of Ourimbah Creek.

The WMAwater 2014 Study undertook a detailed investigation into various potential mitigation measures relating to the condition of the entrance including:

- Maintenance of the entrance channel (dredging);
- Enlarging the entrance channel; and
- Emergency opening of the entrance during flood.

None of the investigated options were recommended as part of the WMAwater 2014 Study due to a number of factors ranging from significant economic, environmental and social costs through to a lack of positive benefits associated with reductions in peak lake levels and flood affectation. Additionally, it was noted that permanent opening of the entrance could lead to increased flooding in some instances due to elevated ocean levels.

Based on the findings from the WMAwater 2014 Study, modification of the entrance as a flood mitigation measure is not recommended and the current study will not revisit investigating these options.

3.2.5. WMAwater – Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, December 2014 (Reference 10)

This study was undertaken after completion of the 2013 Flood Study and is provided as Appendix G. The Reference 10 study is a desktop review of the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan (Area G2 – Pluim Park/Tall Timbers estate/Mannings Road). It was undertaken to review the previous outcomes in light of the inability of residents of the Tall Timber estate to access the estate during frequent storm events experienced on several occasions in 2011, 2012 and 2013.

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The outcome is reported as an addendum to the 1997 Floodplain Management Plan and is viewed as an interim measure to ascertain whether any short term measures could be implemented to reduce the risk to life. In the long term, it is Council's intention to provide a long term solution.

The main outcomes of the Reference 10 study that are pertinent to the current study are:

1. *The access road from Tuggerah Street to Tall Timbers estate is privately owned. The road level is not considered to be in accordance with current best practice in floodplain management due to its vulnerability to be cut in minor frequent storm events (potentially several times a year). Construction of an upgraded bridge or high level footbridge on privately owned land to improve access and funded by Council does not conform with Council's responsibilities. The responsibility for upgrading the road should rest with the private owners of the access road. Raising of the access road would provide benefit in minor frequent storm events only and may place people at greater risk in another part of the floodplain.*

2. *The proposed access via the railway maintenance track during rare flood events was not formalized at the time of development of the site and the area has since been fenced off to the public. Council has approached Railcorp regarding permission for Council to construct an elevated pedestrian/cycleway alongside the railway line on Railcorp land to provide flood free pedestrian access from the estate.*

   A pedestrian footbridge over the railway line near Ourimbah Street Lisarow has also been considered however Railcorp have safety concerns.

3. *Council does not undertake creek maintenance on privately owned land where there is no easement in place. Council would only consider such works if a life threatening or similar situation arose. Dredging or clearing within the easement will reduce flood levels and the frequency of overtopping of the private access road but the benefit will be very minor unless the capacity of the waterway opening under the access road is significantly increased.*

4. *Council will clear debris or fallen trees which are causing a blockage in main drainage infrastructure or on local roads. Residents wanting debris removed from their property are responsible for the organisation and payment for the works either through Council's household pick up service or a private company. If an area is declared a Natural Disaster area, government funding could be made available for clean up through the appointed Recovery Committee.*

5. *Council has an annual program for road inspection, maintenance and upgrading. Any road works necessary are prioritised within the limits of the funds available. Council does not maintain privately owned access roads e.g. the access road to Tall Timbers estate.*

6. *Gosford City Council, in conjunction with NSW SES, is in the process of preparing additional flood intelligence for the Gosford City Local Flood Plan for Tall Timbers Estate. The NSW SES will undertake a flood safety awareness program for the residents. Gosford City Council has installed a flood warning system. The construction of a safe refuge in the estate for flood events larger than the 1% AEP (sometimes referred to as vertical evacuation or*

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shelter in place) would ensure that residents remain dry in events larger than the 1% AEP. However this measure does not eliminate the risk to life for the entire community.

7. *Voluntary purchase of all houses in Tall Timbers estate is unlikely to receive funding from state or federal government authorities because the house floors are only inundated in events larger than the 1% AEP, consequently this option will have a very low benefit cost ratio.*

8. *Development controls will ensure that any future development are constructed in accordance with best practice but will not reduce the risk to life of the road access.*

3.2.6. Jacobs – Upgrade of Pacific Highway HW10, Ourimbah Street to Parsons Road, Lisarow, Roads and Maritime Services, October 2014 (Reference 12)

This study was not reviewed as part of the 2013 Flood Study. Roads and Maritime Services (RMS) propose to upgrade the Pacific Highway, Ourimbah Street to Parsons Road, Lisarow. A flood impact assessment was prepared as part of the Review of Environmental Factors with the aim of identifying strategies to manage impacts to flooding during construction and operation.

The main features of the Highway Upgrade proposal include:

- Widening to include two additional 3.3 metre wide lanes (one northbound and one southbound);
- Widening of shoulders by up to 2.0 metres, for consistent widths along the length of the proposal;
- Maintaining a 60 kilometres per hour design and posted speed limit;
- A new rail overbridge replacing the existing bridge over the Main Northern Railway Line located to the south of the intersection of the Pacific Highway and Railway Crescent; and
- Intersection upgrades at:
    - Chamberlain Road and Pacific Highway intersection;
    - Rail maintenance access road;
    - Macdonalds Road and Pacific Highway intersection to be relocated around 25 metres to the south to align with Tuggerah Street and new traffic lights installed at the intersection;
    - Railway Crescent and Pacific Highway intersection; and
    - Dora Street and Railway Crescent intersection.

The study determined flood impacts associated with the upgrade for flood levels, flow velocities, flood hazard and flow distributions for the 50%, 20%, 5%, 1% and 0.5% AEP and PMF events. The flood impacts are described below:

- Flood levels are typically not increased by more than 0.01 metres for flood events from the 50% AEP event up to the 1% AEP event, including in flood-sensitive areas such as the Tall Timbers residential estate.
- There are no marked flow velocity impacts or redistribution of flow which increase the flood hazard in the study area. There are flow velocity increases near the upgraded hydraulic structures which can be managed by rock scour protection. Other areas of

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relatively high velocity increases on the floodplain do not result in excessively high absolute velocities and are not expected to worsen the scouring potential of overland flows.

- Flood hazard mapping shows that the extent of high flood hazard areas are not increased in each AEP flood event as a result of the proposal.
- The proposal does not increase the duration of inundation in the study area. Potentially susceptible habitats and vegetation species would not be impacted by longer durations of flooding.

The present study has examined the above mentioned report and note that due to the minimal flood impacts associated with the Highway Upgrade, the Flood Study (Reference 2) flood model is suitable for use for this FRMS&P without amendment.

The present study has also made the following observations relating to the proposed Macdonalds Road exit mentioned above:

- The exit is flooded in the 0.5EY event and potentially more frequent events not modelled as part of the Highway Upgrade study.
- In the 20% AEP flood the exit experiences depths > 0.5 m and velocities of ~1 m/s. This is a flood hazard classification of H3 (see Section 6.2) which means that it is unsafe for all vehicles.
- In the 1% AEP flood the exit experiences depths > 1.8 m and velocities >1.5 m/s, placing flooding of the proposed exit in the H5 flood hazard classification. This poses an extreme risk to motorists.

As part of the present study the RMS has been contacted in relation to this exit ramp to request that the access road be made flood free in the 1% AEP event. A letter addressed to RMS outlining this request is presented in Appendix F.

3.3. Overview of Existing Catchment

3.3.1. Demographic Overview

The Ourimbah Creek catchment consists of many suburbs, including Chittaway Point, Fountaindale, Kangy Angy, Ourimbah, Lisarow, Mount Elliot, Palmdale, Palm Grove, Central Mangrove and Kulnura to the west. Understanding the social characteristics of the area can help in ensuring that the most appropriate flood risk management practices are adopted. The Census data and community consultation questionnaire responses can provide useful information on categories including dwelling and tenure type, languages spoken, age of population and movement of people into and out of the area.

Table 6 summarises the 2011 Census results for sub-areas within the catchment, which gives an indication of demographics, language and property tenure.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer time have a better understanding of local flooding issues than those who have recently moved to the area. Within the last five years 13% of the community

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consultation respondents had moved to the Ourimbah catchment area, with the remaining living in the catchment longer than five years. This means that the majority of the current population would have experienced the significant June 2007 flood event and likely have good awareness of flood risk in the region.

Table 6: 2011 Census Data

Suburb	Population	Population Age (%)		English spoken at home (%)	Tenure (%)	
		0-14 years	>65 years		Owned	Rented
Kangy Angy	316	18	18	95	80	18
Ourimbah, Palm Grove, Palmdale	4,162	22	9	92	74	26
Lisarow	5,038	24	9	93	81	17
Fountaindale	631	16	14	93	92	9
Berkeley Vale	8,486	23	14	94	76	22
Chittaway Point	1,901	19	14	94	73	25
Total / Average	**20,534**	20	13	93	79	19

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them (where possible). Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risk. The 2011 Census data indicates approximately 80% of the catchment own their homes again indicating the general population is likely to have good awareness of flood risk.

The languages spoken by the population are also useful to consider as this can have implications in regard to the provision of flood information to the public and during assisted flood evacuation. Over 90% of people in each of the suburbs within the catchment speak English at home, with a small number of residents speaking another language at home including German, Cantonese, Indonesian, Tongan, Italian, Spanish, Arabic, French, Greek and Malay.

3.3.2. Land Use

The land use zones as identified in Councils' LEPs (Wyong 2013 and Gosford 2014) are available on Council's website.

The land usage varies significantly throughout the catchment within predominately rural (*RU1 – Primary Production and RU3 – Forestry*) and environmental (*E1 – National Parks and Nature Reserves, E2 – Environmental Conservation and E3 – Environmental Management*) uses upstream of the Pacific Motorway.

In the areas surrounding the Pacific Motorway and downstream, land use is a mix of residential (*R1 – General Residential and R2 – Low Density Residential*), business (*B2 – Local Centre and B7 – Business Park*), industrial (*IN1 – General Industrial and IN2 – Light Industrial*) and environmental (*E1, E2 and E3*) uses. The region bounded by Enterprise Drive, Wyong Road and the Main North Line railway is a large business and industrial hub (*B7 and IN1*) that is subject to flooding with a range of flood liability.

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Ourimbah Creek downstream of Enterprise Drive is zoned as a waterway (*W1 – Natural Waterway*) discharging into Tuggerah Lake (*W2 – Recreational Waterway*).

3.4. Available Data for FRMS&P

3.4.1. Data Request

At commencement of the study WMAwater requested all relevant available data from Council. This data included, but was not limited to, the following:

- 2013 Ourimbah Creek Flood Study Report and Data;
    - TUFLOW hydraulic models and results;
    - XP-RAFTS hydrology models and results;
    - All survey data (cross sections, structure survey).
- GIS Data:
    - Aerial photography (2014);
    - Topographic survey data in the form of ALS/LiDAR (2014), Digital Elevation Model (DEM) and contours;
    - Cadastre, layers and names for roads and creeks;
    - Zoning, Council owned land, SEPP 14 or 19 land, vegetation / environmental land uses;
    - Stormwater drainage details including pit and pipe data including dimensions, locations, cross-sections and reduced level heights for inverts etc;
    - General GIS information (roads, watercourses, etc.).
- Prior flood mapping, including flood levels if available;
- Wyong Shire Council DCP 2013;
- Gosford City Council LEP 2014 & DCP 2013;
- Flood Impact Assessment undertaken by RMS for the Pacific Highway Upgrade;
- Any previous flood related studies/reports.

3.4.2. Floor Level Survey and Estimation

The Ourimbah Creek FRMS&P requires building floor levels for all properties contained within the PMF flood extent. Floor level estimates are used to determine flood damage estimates (see Section 7.1). Given the large catchment area and number of flood affected properties, theodolite based survey of all properties was not financially feasible. Details of how building floor levels were estimated are presented below:

- The Bangalow and Cut Rock Creek FRMS Report (Reference 6) contains approximately 147 surveyed property floor levels that were obtained and used in the current study.
- Floor level survey was performed by Cahill & Cameron Surveyors Pty Ltd. for 91 properties contained within the Gosford LGA during December 2015.
- The floor levels of the remaining 1,965 properties within the PMF extent were estimated by use of LiDAR data in combination with visual inspection of floor level heights by WMAwater engineers. Visual inspection was undertaken by two methods:
    - Over 300 properties were visited by WMAwater engineers on a site visit. These properties were those that could not be analysed by available digital imagery and

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were predominately situated in rural locations.

- The remaining properties had floor levels estimated based on analysis of available digital imagery.

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4. STAKEHOLDER CONSULTATION

Consultation is an important element of the floodplain risk management process ultimately facilitating community engagement and acceptance of the overall project. During the Flood Study, community consultation was undertaken to assess the flood experience of the community and gather additional data. Further community consultation has also been undertaken as part of the FRMS&P. This includes a questionnaire, liaison with the key stakeholders and agencies listed in Section 4.2 and meetings with Council. Goals of on-going community consultation are to consult with residents to keep them informed of the progress of the study and to obtain community ideas and feedback on potential mitigation and management measures proposed. Final community consultation proposed is in the form of public exhibition of the Draft reports.

4.1. Questionnaire Distribution

A community newsletter and questionnaire (Appendix B) was distributed to residents situated within the Ourimbah Creek PMF extent during November 2015. The newsletter aimed to inform the community of the Ourimbah Creek FRMS&P and the survey provided the community with an opportunity to highlight their flood affectation and to provide input into this FRMS&P. In particular, the questionnaire was intended to obtain ideas for mitigation works or management plans to reduce flood risk and to determine if the community is interested in voluntary purchase or Voluntary House Raising (VHR) schemes (see Sections 9.4.1 and 9.4.2).

A total of 159 replies (out of 2178 distributed) resulted in a return rate of 7% which is similar to questionnaire return rates of other floodplain risk management studies in the area. A summary of the questionnaire results is presented in Figure 2 with the questionnaire returnee locations displayed in Figure 3.

A total of 48 questionnaire respondents mentioned that they thought Tuggerah Lake should be opened up to the ocean, with or without the use of break walls. 23 respondents suggested that improved maintenance of drains and creeks would improve conveyance and reduce peak flood levels. Approximately 63% of all respondents thought that flooding at a frequency of less than 100 years is acceptable which is generally in line with the aims of this FRMS&P. However, 33% of respondents mentioned that they thought any degree of flooding is never acceptable which would require the engineering of mitigation structures to the PMF. It was also found that a significant number of people were interested in voluntary purchase (37 respondents interested) and Voluntary House Raising (29 respondents interested) schemes.

Generally three topics were the focal point of all returned questionnaires. These were, dredging/opening of the Tuggerah Lakes entrance, creek clearing/maintenance and potential mitigation works. A summary of the key topics discussed in the returned questionnaires is presented below:

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Potential Flood Mitigation Works Identified via Community Consultation

- Opening, dredging or constructing breakwalls to enhance flow conveyance out of Tuggerah Lakes (see Section 3.2.4);
- Levee banks around eastern Chittaway Point, along Bangalow Creek and along the east of Ourimbah Creek to protect Mill Street industrial area (see Section 9.2.1);
- Straightening creek alignments where possible (see Section 9.2.4);
- Removal of weir at Footts Road (see Section 9.2.5);
- Raising Geoffrey Road (see Section 9.3.1);
- Maintenance of drains and creeks, clearing litter, fallen trees and debris regularly (see Section 9.2.6); and
- Construction of retention basins (see Section 9.2.7).

The above listed potential flood mitigation works have been investigated along with those outlined in Section 2.3.

Voluntary Purchase and House Raising Schemes

- Details related to a potential VHR Scheme are presented in Section 9.4.1.
- Details related to a potential voluntary purchase scheme are presented in Section 9.4.2;

Other Flood Ideas

- Installation of flood depth indicators and signage along Ourimbah Creek Road (see Section 9.3.2.2);
- Distribution of instruction booklets for residents – *"What to do in a Flood"* (see Section 9.3.5); and
- Reconsideration of proposed location of Kangy Angy Rail Maintenance Facility (see Section 4.2.7).

Additionally, a number of local residents reported major creek bank erosion on private land. These residents were referred to Local Land Services for advice and assistance (see Section 4.2.4).

4.2. Specific Consultation with Key Stakeholders and Agencies

In addition to the local community the Brief requested consultation with the following key stakeholders and agencies:

- Council Planners;
- The University of Newcastle Ourimbah Campus;
- Tuggerah Lakes Estuary, Coastal and Floodplain Management Committee (subsequently disbanded);
- Gosford Council's Catchments and Coast Committee (subsequently disbanded);
- Office of Environment and Heritage (OEH);
- Local Land Services (LLS);
- Department of Planning (DoP);
- NSW Office of Water (NOW);
- State Emergency Services (SES);

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- Bureau of Meteorology (BoM);
- Manly Hydraulics Lab (MHL);
- Roads and Maritime Services (RMS);
- State Rail Authority (SRA);
- Transport for NSW;
- Ourimbah Residents Association.

These stakeholders and agencies have been contacted for input into this FRMS&P. A summary of responses is provided below where applicable, and the information has been incorporated into this FRMS&P.

Planners from both Wyong and Gosford Councils were contacted for input into the current study. Details are provided in the section below.

4.2.1. Wyong Council Planners

The Ourimbah Masterplan and Land Use Review is currently being undertaken by Wyong Council's planners and consultants. The Masterplan was at final draft stage (Reference 13) at February 2017. The aim of this Masterplan project is to develop a vision to guide investment in the use and development of land and infrastructure over the next 20 years for the region identified in Image 1. This Masterplan is hoped to facilitate both growth and connectedness as Ourimbah is a location where motorway, highway and railway converge, connecting it to regional destinations and national markets. Connectedness is about using this physical infrastructure to link frequently visited locations such as the town centre, train station and University campus.

The Masterplan proposes that the existing creek crossing on Burns Road be replaced by a flood free access bridge that will cross Ourimbah Creek and the Main Northern Railway Line. The Masterplan indicated that the cost of this bridge would be in excess of $20 million (Council liaison with RMS indicates that the cost of this bridge would be approximately $100 million). The proposed bridge would solve many of the risk issues associated with the current Burns Road crossing (see Section 2.3), however due to the significant cost and potential long term implementation plan a number of other solutions to minimise risk at this location have been investigated.

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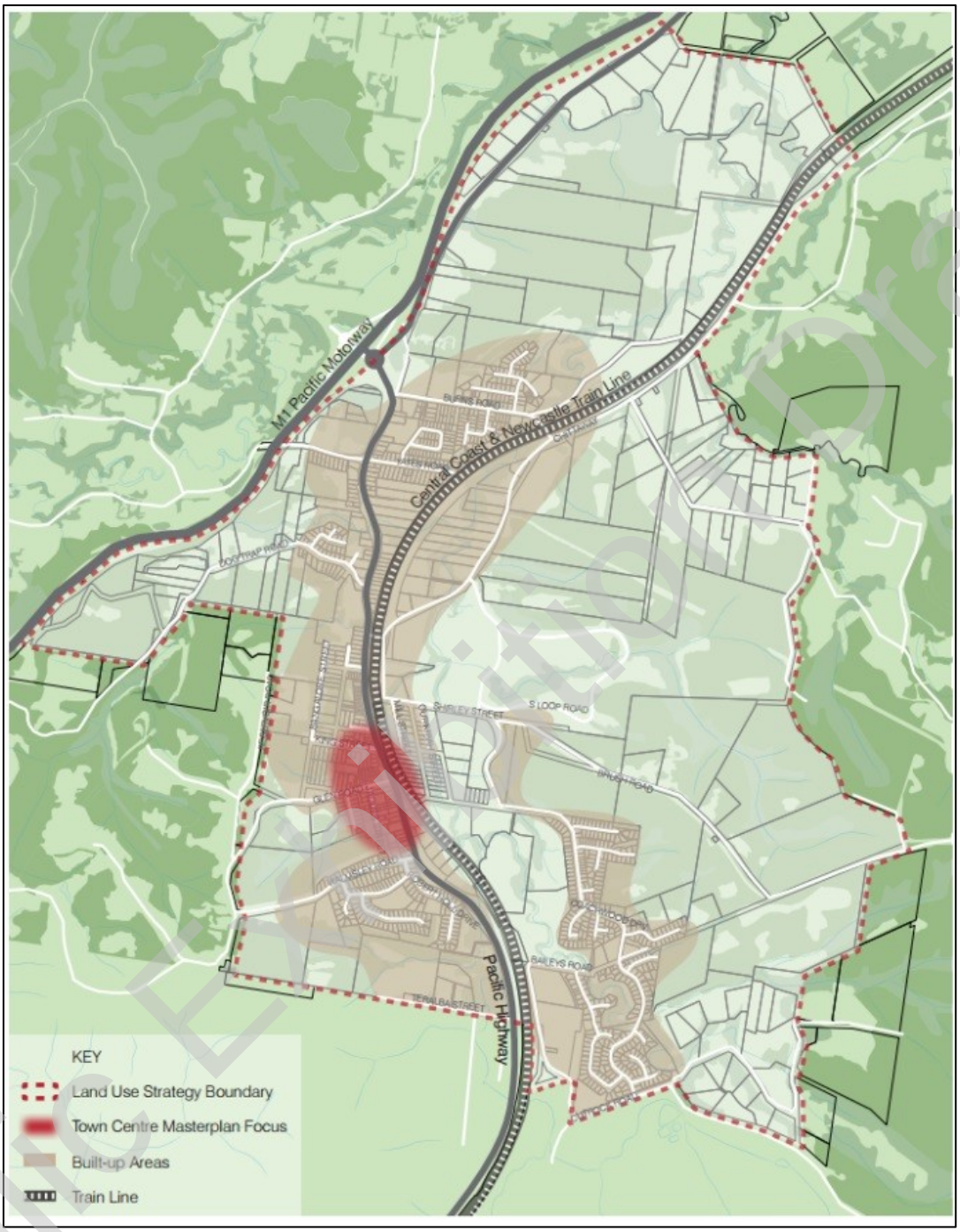
Image 1: Ourimbah Master Plan Study Area



This FRMS&P recommends that the Ourimbah Masterplan carefully considers flood behaviour and affectation determined by the Flood Study and this FRMS&P.

4.2.2. Gosford Council Planners

Gosford Council planners were contacted for input into this FRMS&P. It was noted that various Plan items from the 'Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2' Study (WMAwater 2014, Reference 10) have had applications for funding made to OEH and are currently awaiting funding for implementation. OEH however considered it was premature to fund any of these projects separate from a complete review of the Ourimbah Creek Floodplain Risk Management Study, which is now currently being undertaken. These items

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include:

- Voluntary purchase of 14 properties in Tall Timbers Estate and 6 in Mannings Road, Narara;
- Emergency Pedestrian Access Route - Stage 1 - Tall Timbers to Mannings Road, Narara;
- Emergency Pedestrian Access Route - Stage 2 - Mannings Road to pedestrian overbridge opposite Teralba Street, Narara; and
- Emergency Pedestrian Access Route - Stage 3 - Tall Timbers to McDonalds Road, Narara.

4.2.3. The University of Newcastle

The University of Newcastle Ourimbah Campus is situated on the eastern side of Bangalow Creek and services over 1,000 students on a daily basis. Liaison with University staff indicated that the campus has a number of flood related concerns. The University reportedly closes multiple times per year due to issues associated with flooding and storms. Additionally, flooding of two carparks was noted as a key concern with significant implications for risk to life.

The University enquired about the possibility of an early flood warning system, however as described in Section 9.3.3.3, the available warning time is inadequate for emergency response.

Various potential flood risk mitigation measures have been investigated, namely:

- Improving flood access (Section 9.3.1) – This reduces the risk associated with flooded access roads;
- Option FM4 and FM5 (Section 9.2.1.4 and 9.2.1.5) – Levee or filling to protect the northern lower carpark for events up to the 1% AEP event;
- Installation of a stream gauge on Bangalow Creek (Section 9.3.3.2) – can be used for flood warning, albeit only short warning times are available; and
- Recommendation to prepare a Flood Plan for the University to assist in emergency response (Section 9.3.4.4).

4.2.4. Local Land Services (LLS)

Greater Sydney LLS is responsible for the Ourimbah Creek catchment and have been consulted as part of this study. Specifically, LLS was contacted for assistance in regards to questionnaire respondents (see Section 4.1) who reported erosion and degradation of the creek channel on private land. These residents were referred by WMAwater to LLS and were advised to make a submission to obtain funding for bank stabilisation as per that recommended by LLS.

4.2.5. Manly Hydraulics Lab (MHL)

Manly Hydraulics Laboratory (MHL) has the capability to design, build, operate, and maintain flood warning systems. Flood warning systems provide near real-time information to support the management of flood prone land and infrastructure. Various organisations, including RMS, NSW Police, State Emergency Service (SES), Local Government, and the Bureau of Meteorology use MHL flood warning systems.

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Flood warning systems combine the services of MHL's automated data acquisition systems to collect environmental data; with MHL's automated messaging and alarming service. When high water level or rainfall threshold conditions are encountered, an automated alarm is issued, and notifications are sent to recipients in various formats (email, SMS, web services, and social media integration).

MHL have been contacted to provide a preliminary pricing for installation of a flood warning system by installation of rainfall and stream gauges. Preliminary pricing for each gauge type are:

- Rainfall Gauge - $13,000 installation, plus $2,000/annum maintenance; and
- Stream Gauge - $20,000 installation, plus $2,000/annum maintenance.

Some savings can be made if both a rainfall and stream gauge are installed at the same location, particularly in ongoing maintenance costs.

4.2.6. Roads and Maritime Services (RMS)

RMS was contacted as part of the current study for the following reasons:

1. **Early Warning Notification of Road Closures -** The potential for utilising RMS Variable Messaging System (VMS) or addition of new signage on the Pacific Motorway and Highway at Ourimbah to provide early notification of road closures on Burns Road, Chittaway Road and Shirley Street due to flooding.

2. **Tuggerah Street Upgrade –** RMS are currently upgrading the Pacific Highway between Ourimbah Street and Parsons Road. As part of this upgrade, the existing Tuggerah Street exit is also proposed for upgrading. WMAwater has recommended that the concept design of this exit be revised to provide flood free access to Tuggerah Street for events up to the 1% AEP event.

3. **RMS Stream Gauges –** Council have noted that RMS has installed a stream gauge on Cut Rock Creek (in the Lisarow Swamp) to record base flow for the above mentioned upgrade of the Pacific Highway. WMAwater has sought permission for Council to take over ownership of this gauge.

Two letters addressed to RMS detailing the above are presented in Appendix F.

WMAwater has received two official responses for the above listed questions and are waiting on a third. RMS responses are summarised below:

<u>Early Warning Notification of Road Closures</u>
Liaison with RMS re the Pacific Motorway/Highway VMS, indicated that whilst it is possible to use the VMS for this purpose, it is not recommended as RMS would prioritise RMS warning messages over those of warning of flooded road closures. Accordingly, it could not be guaranteed that notification of flooded roads would be displayed to commuters. In place of the

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VMS, RMS noted that they are open to discussion with Council about the possibility of installing signage within the RMS owned road easements.

Tuggerah Street Upgrade by Cardno

A joint meeting between Council, WMAwater, RMS and Cardno to discuss the feasibility of the RMS raising the proposed Tuggerah Street exit ramp was held in October 2016. A case was made as to why the road should be raised with RMS agreeing to investigate this option. RMS has not provided a response.

RMS Stream Gauge

RMS will allow Council to take over ownership of the RMS stream gauge which could potentially be used as a flood warning gauge (see Section 9.3.3.2).

4.2.7. Transport for NSW

In May 2014 the NSW Government announced the New Intercity Fleet Program to replace the ageing trains carrying intercity customers from Sydney to the Central Coast, Newcastle, the Blue Mountains and the Illawarra. The program includes a purpose built fleet maintenance facility proposed at Kangy Angy to service and maintain the new trains. At the time of this FRMS&P, Transport for NSW was placing on public display 'A Review of Environmental Factors and concept design' (Reference 14) for the proposed facility. A community notification providing further project details is presented in Appendix C.

As part of the development of the maintenance facility, Transport for NSW is developing a concept design for the site in Kangy Angy, which includes a new alternative access road aimed to link Enterprise Drive to Orchard Road, offering flood free access for residents north of the Main North Line railway.

Currently, properties on the northern side of the Main North Line railway have road access via Turpentine Road. This road is frequently flood affected causing property isolation and was a key area of resident concern as identified in the Flood Study (see Section 2.3) and again from liaison with the Ourimbah Residents Association (see Section 4.2.8). The proposed link road will provide flood free access to these properties thus greatly improving local resident access during flood.

The access road would be accessed from Enterprise Drive via a new intersection with Old Chittaway Road. From the intersection with Enterprise Drive, the access road would start to ramp up to a curved viaduct structure over the Main North railway. The access road would be designed in accordance with the requirements of Central Coast Council and, in addition to the proposed traffic lanes would include other elements such as a shared user path, anti-throw screens and appropriate lighting.

The proposed New Intercity Fleet Maintenance Facility review of environmental factors report (June 2016, Reference 14) indicated that a link road is to be constructed that crosses the Main Northern Railway Line which allows access to the region during times of flood. It was noted even with the construction of the link road, properties to the west of the proposed facility on

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Turpentine and Ourimbah Roads could still be isolated during flood as the intersection of Orchard and Ourimbah Roads is flooded by in excess of 2 m during the 20% AEP event. A submission was made to Transport for NSW as part of this FRMS&P requesting that flood access issues be fully considered as part of the proposed rail facility design. Further details are presented in a letter addressed to Transport for NSW contained in Appendix F.

The most recent Facility design plans (June 2016, Reference 14) indicate that a flood access road is proposed which will allow flood access to these isolated properties. The addition of the flood access route will allow flood access to properties to the west of the Facility and is a good outcome for Council and the community. This proposal is supported from a risk management perspective.

The community consultation process highlighted that some local residents are opposed to the Kangy Angy facility (see Section 4.1) due to perceived flood impacts, however the current study makes clear that this facility will not impact on peak flood levels for events up to and including the 1% AEP as the facility is situated outside of the flood extent. However one issue raised by local residents is the increased runoff due to less infiltration as a result of covering the present pervious surface with an impervious surfaces (building roofs and hard stand areas). This issue is addressed below.

Removal of natural vegetation and the sealing of pervious surfaces with hard stand areas or building roofs will increase the volume of runoff into the adjoining creek systems. However the magnitude of the increase is impossible to accurately estimate based on the limited information provided to date. It would depend upon:

- if on-site detention or water re-use storage tanks are provided in the facility;
- if the runoff from buildings exits directly to the creek system or is made to pass through what is known as a Water Sensitive Urban Design feature (WSUD). WSUD features are specifically designed to reduce, as far as possible, the amount of increased runoff from entering the creek system and at the same time ensure water quality is maintained. It is noted that detention basins are proposed as part of the design.

In summary, it is likely that even with the most comprehensive design there will be some increase in runoff into the creek systems. However this will only be noticeable in frequent events which occur several times every year. In large flood events the increase in volume of runoff will make insignificant affect on the peak flow and thus the peak flood levels. This is because the total area of site (not all of which will be impervious surfaces) is only 50 hectares or 0.5 km^2 (or 0.3% of the total catchment area of Ourimbah Creek). These and other water quality, groundwater and flooding issues have been addressed in the New Intercity Fleet Maintenance Facility Project - Submissions Report (Reference 15).

4.2.8. Ourimbah Residents Association

Liaison with the Ourimbah Residents Association indicated that the main issue of concern is the flooding of access roads. It was noted by Ourimbah Residents Association that road access issues, coupled with a significant risk to motorists entering floodwaters, was historically occurring multiple times per year and had resulted in numerous emergency rescue operations

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(twice in 2015 alone) of people attempting to drive through floodwaters.

The following roads were highlighted by Ourimbah Residents Association as key areas of concern. Analysis of these flood affected roads is presented in Section 6.4:

- Burns Road – busy access road from the Pacific Motorway to Gosford, The Entrance and the University;
- Howes Road – leading to the isolation of a number of residential properties;
- Turpentine Road – leading to the isolation of Ourimbah and Orchard Roads including a number of residential properties;
- Chittaway Road – busy access road; and
- Shirley Street – access road.

Many of the above mentioned issues could potentially be addressed by improving flood access which is described in Section 9.3.1.

A number of management options listed below (with respective sections in this Study) were suggested by Ourimbah Residents Association for consideration in the current study:

- Creek clearing and maintenance (see Section 9.2.6);
- Road and culverts works for the above listed locations (see Section 9.3.1);
- Installation of larger / more obvious signage highlighting the flood risk for roads susceptible to flooding for the above listed locations (see Section 9.3.2);
- More robust safety railings on Burns Road crossing;
- Automated signage on the Pacific Motorway and Pacific Highway notifying road closures and flood risk (see Section 9.3.2.2);
- Investigating the feasibility of automated boom gates (see Section 9.3.2.2); and
- Manned diversion of traffic when roads are closed to prevent people driving into floodwaters (see Section 9.3.2.3).

4.3. Public Exhibition of the Draft Ourimbah Creek FRMS in March 2017

Public exhibition of the Preliminary Draft Ourimbah Creek FRMS was undertaken to ensure community support and this included a community workshop at the University of Newcastle Ourimbah Campus in March 2017. Approximately 80 local residents attended and presentations were made by Council Officers and WMAwater. Following this there was a questions and answer session.

Digital copies of the reports were available on the Council website and hard copies were available at Council Offices and the local library.

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5. OURIMBAH CREEK FLOOD STUDY SUMMARY

5.1. Aims and Objectives of the Flood Study

The 2013 Ourimbah Creek Catchment Flood Study was carried out in order to meet the objective of defining the flood behaviour for the 20% AEP, 10%, 2%, 1%, 0.5% AEP events and the PMF in the catchment and to:

- Define flood behaviour in terms of flood levels, depths, velocities, flows and flood extents within the study area;
- Prepare flood extent mapping (for all design events modelled); and to
- Create a modelling system that might be used in the subsequent FRMS&P to test whatever flood mitigation works might be proposed by either the community, OEH, Council or the consultant.

In order to define flood behaviour, the Flood Study developed a hydrologic model (RAFTS), in conjunction with a linked 1D/2D hydraulic model (TUFLOW).

5.2. Flood Study Review

The Flood Study has been reviewed as part of the current study in the following sections. A summary of design results is presented in Section 5.3. Sections 5.4 to 5.6 examine the Flood Study outputs provisional hydraulic categories, preliminary hazard classification and emergency response planning classifications respectively.

5.2.1. Hydrology Overview

The XP-RAFTS software was used to develop a hydrologic computer model of the catchment. XP-RAFTS is a lumped hydrologic software product that is developed by XP Software and is used extensively across Australia for deriving discharge estimates. The following sections provide a summary of how the model was developed, the adopted input parameters and the outcomes of the model calibration and verification.

The review of the Flood Study hydrology indicates that the results and associated hydrologic model are fit for use in the current study.

5.2.2. Sub-Catchment Delineation and Parameters

The catchment was subdivided into 426 sub-catchments based on the alignment of major flow paths and topographic divides. The sub-catchments were delineated with the assistance of the CatchmentSIM software using a 5 metre Digital Elevation Model (DEM). The current study review of the sub-catchment delineation using available ALS/LiDAR data (see Section 3.4.1) indicates that they are suitable for use in the hydrologic model.

XP-RAFTS requires the slope of each sub-catchment for input into the model. The LiDAR data was also used to check individual sub-catchment slopes, with selected model slopes consistent

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with the topography of the catchment.

The Flood Study's selected roughness values for the hydrologic model are within the range of those recommended by the revised ARR guidelines (Project 15: Two Dimensional Modelling in Urban and Rural Floodplains). Selected Mannings 'n' values are considered suitable for use in the hydrologic model.

The modelled percentage impervious was examined and compared to that observed via analysis of available aerial imagery (see Section 3.4.1). Selected imperviousness values are considered suitable for use in the hydrologic model.

5.2.3. Hydrologic Model Calibration/Verification

Hydrologic computer models are developed using parameters that are subject to natural variability. Accordingly, the model has been calibrated using rainfall and stream flow data from historic flood events to ensure the adopted parameters are producing reliable estimates of rainfall-runoff behaviour. Calibration is typically completed by routing recorded rainfall through the hydrologic model with modelled flow hydrographs compared to recorded stream flow records where available. Calibration is completed by adjusting model parameters to achieve the best match possible between recorded and model-generated hydrographs.

The following criteria were employed to select events suitable for the purpose of model calibration and verification:

- A minimum of three significant flood events;
- Floods after 1990 preferred as stream flow and rainfall information are more available;
- Events where flood marks are available are preferred so the same events can be used for both hydrologic and hydraulic model calibration.

Based on these criteria, the following events were selected for model calibration and verification:

- February 1992;
- June 2007; and,
- June 2011.

Analysis of the hydrologic model calibration indicates that a reasonable calibration/verification process has been achieved by matching model flows to observed stream gauge data.

Design flows from the Flood Study were also compared to design flows from previous studies (see Section 3.2.1) undertaken in the catchment as well as to flows determined by the Probabilistic Rational Method (ARR87). It was noted that the design flow results from the various methods are similar which gives further confidence in the Flood Study.

5.2.4. Design Rainfall

Design rainfall was derived using standard procedures outlined in ARR87 for events up to and including the 0.5% AEP. It was noted that the Flood Study assumed that the design rainfall was evenly distributed across the entire catchment. However, analysis of the design rainfall for the

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region indicates that there is a rainfall gradient with higher rainfalls typically occurring towards the upper part of the catchment. The maximum variation in rainfall intensities was approximately 15% but varies depending on location and event duration.

Analysis of the hydrologic model indicates that the applied design rainfall is approximately equal to the catchment average rainfall. This leads to only minor differences in the applied and 'true' design rainfalls with the applied rainfall typically no more that 5% different to the ARR87 design rainfall at a point. This difference in design rainfall does not lead to significant changes in peak flood level (relative to freeboard) with differences of over 0.1 m uncommon during the 1% AEP event which indicates that the employed methodology is acceptable.

In November 2016 the ARR 2016 design rainfall and temporal patterns were released and in any future studies these should be used.

5.2.5. Critical Duration Analysis

The Flood Study confirmed that flooding in the catchment could occur as a result of a variety of different storm durations. The Flood Study determined that a storm duration of six hours typically produced the worst case flooding conditions across most of the catchment. Longer storm durations (up to 48 hours) tend to produce higher flood levels in the downstream reaches of Ourimbah Creek (e.g., around Chittaway Point).

Given that a range of critical durations were evident across the study area, the Flood Study did not nominate a single storm duration but instead developed a design flood envelope for each design flood event. This involved extracting and comparing peak flood levels, depths and velocities at each TUFLOW model grid cell for each simulated duration and the highest depth, level and velocity at each grid cell was subsequently adopted. It is this 'design flood envelope', comprising the worst case depths, velocities and levels at each grid cell that forms the basis for the design event results. Accordingly, it is important to recognise that the following design flood results are a composite of results from a range of different durations. It is also important to note that the peak flood levels, depths and velocities do not necessarily occur at the same time.

However, upon review of the Flood Study it was noted that the 9 hour duration, a typical critical duration for catchments in eastern NSW, had not been incorporated into the peak flood envelope.

The 9 hour duration was found to be critical at a number of locations, predominantly in the upper reaches and tributaries of Ourimbah Creek, and increases in peak flood level of 0.1 m were not uncommon. However, the majority of locations where increases in peak flood level were experienced were in-bank and not affecting residential properties. Accordingly, the impact of not modelling this event is relatively minor and well within Council's freeboard of 0.5 m and therefore the Flood Study results are suitable for use in the current study.

5.2.6. Design Losses

The Flood Study used continuing losses of 4.0 mm/hr, which is significantly higher than those

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recommended in ARR87 (2.5 mm/hr). These losses were determined via hydrologic model calibration and are likely indicative of the predominantly sandy and sandy loam soils in this Ourimbah Catchment. Typically, it is recommended to use design losses as per those recommended in ARR87 unless calibrated rainfall losses are lower. However use of these higher loss values for the 1% AEP 9 hour duration event indicate that the average difference in flow throughout the model is approximately +3% leading to less than 0.1 m difference in peak flood level at the majority of locations. This indicates that the model is generally insensitive to the selected continuing losses.

An initial loss 15 mm has been used in design flood modelling which is within the ARR87 recommended range for the region (10 to 35 mm/hr).

The selected design loss parameters are suitable for use in hydrologic modelling for the current study.

5.2.7. Areal Reduction Factor

Design rainfall information for flood estimation is generally made available in the form of point rainfall intensities. This is true for the design rainfall described in Section 5.2.4. However, most flood estimates are required for catchments that are sufficiently large that design rainfall intensities at a point are not representative of the real average rainfall intensity across the catchment. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and AEP, is called the Areal Reduction Factor (ARF). It allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.

It was noted that no ARF was used in the development of design flows in the Flood Study, which is contrary to the method recommended in ARR87. The Ourimbah Creek catchment is 160 km² at its outlet which would require an ARF of 0.94 (6% reduction in rainfall intensity) for the 48 hour duration event. However, applying an ARF for the entire catchment would also lead to reductions in rainfall for smaller tributaries upstream, which, due to their smaller catchment area would not require an ARF. The Flood Study method of not applying an ARF to the catchment leads to increased flows in the lower reaches of the catchment and increased flood levels of typically less than 0.2 m in the 1% AEP event, however does not lead to under estimation of peak flows in the upper catchments, as would otherwise occur.

It should be noted that the increased flows in the lower catchment associated with not using an ARF would be negated somewhat by the implementation of the 4.0 mm/hr continuing loss noted in Section 5.2.6.

5.2.8. Hydraulic Modelling Review

The hydraulic model TUFLOW converts applied flow (discharge hydrographs generated by a hydrologic model) into flood levels and velocities. TUFLOW is a finite difference grid based 1D/2D hydrodynamic model which uses the St Venant equations in order to route flow according to gravity, momentum and roughness.

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5.2.9. Model Extent and Topography

The Flood Study modelled the catchment using a linked 1D/2D modelling system. Topography was defined using available DEM data (see Section 3.4) with a 4 m grid size adopted for the urbanised areas to the east of the Pacific Motorway where manmade flow obstructions (e.g., roadway embankments, buildings) are more prevalent. A less detailed 8 metre grid size was adopted across the rural areas to the west of the Pacific Motorway. Channels were modelled in 1D with cross sections taken from a mixture of ground survey and the LiDAR data.

5.2.10. Roughness

Various land uses were assigned Mannings 'n' roughness values as part of the Flood Study. The roughness values used in the model are shown in Table 17 of the Flood Study which has been reproduced as Table 7.

Table 7: Flood Study Selected Mannings 'n'

Material Description Mannings 'n'	
Grass	0.035
Grass with isolated trees	0.04
Grass with sparse trees	0.06
Grass with medium density trees	0.08
Dense tree coverage	0.12
Concrete surfaces	0.015
Car Park (with parked cars)	
Depth < 0.3m - water in contact with vehicle tyres only,	Depth < 0.3m = 0.08
Depth > 0.3m - water in contact with vehicle bodies	Depth > 0.3m = 0.50
Roadways	0.02
Waterbodies (e.g. Dams)	0.04
Railway corridor	0.06
Buildings	3
Creek channels	0.030-0.080
Concrete pipes/culverts	0.015

The Flood Study selected roughness values are within the range of those recommended by Chow (1959) and Henderson (1966) as well as the revised ARR guidelines (Project 15: Two Dimensional Modelling in Urban and Rural Floodplains). Selected Mannings 'n' values are considered suitable for use in the hydraulic model.

5.2.11. Hydraulic Model Calibration/Verification

Hydraulic computer models are developed using parameters that are not known with a high degree of certainty and/or are subject to natural variability. This includes catchment roughness as well as blockage of hydraulic structures. Accordingly, the model should be calibrated using flow and flood mark information from historic floods to ensure the adopted parameters are producing reliable estimates of flood behaviour.

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The Flood Study calibrated the hydraulic model by routing flows from historic floods through the hydraulic model. Simulated flood levels were extracted from the model results at locations where recorded flood marks were available. Calibration was completed by iteratively adjusting hydraulic model parameters to achieve the best possible match between recorded flood marks and simulated flood levels.

The following criteria were employed to select events suitable for the purpose of model calibration and verification:

- A minimum of three significant flood events;
- Contemporary floods preferred as the currently available topographic datasets are likely to provide a good reproduction of topographic conditions at the time of the floods; and,
- Events also used for hydrologic model calibration were preferred.

Based on these criteria, the following events were selected for model calibration and verification:

- February 1992;
- June 2007; and
- June 2011.

Analysis of the hydraulic model calibration indicates that a good calibration/verification process has been achieved by matching model peak flood levels to surveyed levels. The average difference between the modelled and observed flood levels was approximately 0.1 m for the three events which indicates an excellent hydraulic model calibration. Accordingly, the Flood Study hydraulic model is considered suitable for use in design flood modelling and the current study.

5.3. Flood Study Design Event Results

The hydraulic model was run for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF, for which a number of maps have been produced displaying the flood affected regions (see mapping included in the Flood Study – Reference 2).

5.3.1. Peak Flows

The Flood Study noted the peak flows for each design event at a number of locations, as shown in Table 8.

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Table 8: Peak Design Discharges for Existing Conditions (from Flood Study - Reference 2)

Table 24 Peak Design Discharges for Existing Conditions

Location		XP-RAFTS ID	Peak Discharge (m^3/s)						
			20%	10%	5%	2%	1%	0.5%	PMP
Ourimbah Creek	Lyrebird Lane	1.28	286	353	441	536	625	825	2,820
	Moores Point Rd	1.36	297	369	470	586	688	937	3,350
	Footes Rd*	1.42	312	369	472	600	709	984	3,580
	Palmdale Rd*	1.47	312	371	471	600	709	990	3,620
	Sydney Newcastle Freeway	1.49	336	393	454	534	610	819	2,860
	Main Northern Railway	1.57	486	583	715	832	972	1,320	5,280
	Wyong Road	1.59	499	599	735	857	1,000	1,340	5,410
	Tuggerah Lake#	1.60	492	593	730	853	998	1,340	5,370
Canada Drop Down Creek	Palmdale Rd	89.13	70.2	84.6	110	133	153	212	8,58
	Ourimbah Ck Confluence	89.17	102	122	148	177	211	297	1,320
Kangy Angy Creek	Old Tuggerah Rd	171.02	8.69	10.3	12.6	14.5	16.7	22.7	79.0
	Pacific Hwy	171.06	20.3	24.1	29.4	33.6	38.9	53.0	187
Chittaway Creek	Enterprise Dr	163.05	25.5	30.4	36.9	43.2	50.2	70.0	224
	Old Chittaway Rd	163.07	26.8	32.1	39.2	46.0	53.9	75.3	246
Bangalow Creek	Coachwood Dr	119.08	28.3	33.7	42.5	51.1	59.6	80.0	245
	Cut Rock Ck confluence	119.10	34.1	40.5	51.1	61.9	73.0	98.2	315
	Shirley St	119.14	75.0	88.6	108	128	153	213	746
	Chittaway Rd	119.18	112	134	164	190	220	305	1,140
	Burns Rd	119.20	112	134	164	191	221	307	1,150
	Ourimbah Ck Confluence	119.23	137	166	229	283	346	494	2280
Cut Rock Creek	Detention Basin Outflow	137.03	4.86	5.65	7.17	8.11	9.62	13.9	44.8
	Tuggerah St	128.03	27.9	32.7	41	50	59.3	79.9	263
	Railway Upstream	128.07	38	44.6	55.2	67.3	79.3	108	368
	Teralba St	128.08	39.3	46.1	57.2	68.8	80.9	111	376
	Railway Downstream	128.11	42.1	49.7	61.4	72.9	85.2	117	402
Dog Trap Gully	Pacific Hwy	153.06	26.7	31.8	40.1	48.1	56.2	75.4	286

NOTE: * The peak discharges for Ourimbah Creek at Palmdale Road are lower than at Footes Road for some AEPs. This is associated with some of the flow being diverted from Ourimbah Creek via the Bangalow Creek flood runner and, therefore, bypassing Palmdale Road.
Reductions in peak discharge are also evident downstream of Wyong Road. This is associated with the very flat channel slope along this section of Ourimbah Creek which serves to attenuate the peak discharge.

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5.3.2. Flood Depths and Levels

Mapping of peak flood depths and levels is included in the Flood Study. The map set includes the following;

- Peak flood depths and levels for the design flood events (PMF, 0.2EY (20% AEP), 10%, 5%, 2%, 1% and 0.5% AEP);
- Provisional Hazard maps;
- Hydraulic Category maps; and
- Emergency Response Planning Maps.

5.4. Provisional Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (FDM, Reference 1) defines flood prone land to fall into one of the following three hydraulic categories:

- Floodway;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant effect on flood flows, velocities or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities.

The Flood Study defined provisional floodways on the qualitative guidelines presented in the FDM. These guidelines and the adopted criteria to achieve these outcomes are presented in Table 30 of the Flood Study which has been reproduced as Table 9.

The Flood Study went to significant effort to verify the suitability of the delineated floodways by additional checks made in accordance with recommendations outlined in the former DECC (now OEH) *"Floodway Definition"* (Department of Environment & Climate Change, 2007) guideline. This involved blocking sections of the delineated floodways and quantifying the impact that this blockage had on peak flood levels as well as the distribution of floodwaters in the vicinity of the blockage during the 1% AEP flood. The classification of Flood Storage and Flood Fringe were also verified, giving confidence to the hydraulic categories identified in the Flood Study. A review of the hydraulic categorisation is presented in Section 6.1.

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Table 9: Flood Study – Qualitative and Quantitative Criteria for Hydraulic Categories (from Flood Study - Reference 2)

Hydraulic Category	Floodplain Development Manual Definition	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	The following criteria were used to provide an initial appraisal of floodway extents. - V x D > 1 m^2/s - D > 0.5 m and - V > 1 m/s Based on this information, floodways were delineated by hand.
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	Areas that are not floodway and where the depth of inundation is greater than 0.3 metres
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	Areas that are not floodway where the depth of inundation is less than 0.3 metres

NOTES: *Hydraulic categories were only applied to areas subject to inundation (i.e., D > 0m)*
**The adopted criteria were developed specifically for the Ourimbah Creek Catchment only and may not be appropriate for any other areas.*

5.5. Provisional Hydraulic Hazard Classification

The Flood Study defined provisional flood hazard categories in accordance with the FDM. Provisional hazards only take account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 1), while true hazard (see Section 6.2) takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, 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.

The Flood Study established high and low provisional hazard areas for the 1% AEP event and the PMF.

The flood study also undertook preliminary true flood hazard by analysing the provisional hazard mapping in conjunction with the Emergency Response Planning Maps (see Section 5.6). The preliminary true hazard categories reflect consideration of the depth and velocity of floodwaters

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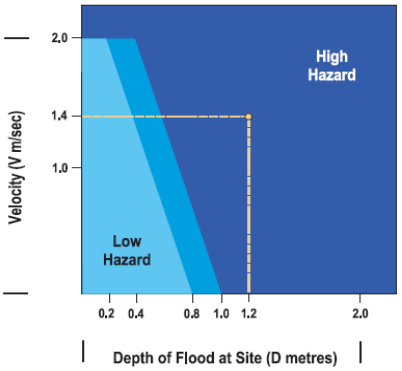
as well as other factors that influence flood hazard, including the potential for isolation and evacuation difficulties.

Diagram 1: Provisional Hydraulic Hazard Categories



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

Extracted from The Floodplain Development Manual (Reference 1)

In general, the provisional hazard categories were retained in the preliminary true hazard mapping. However, the "transitional" provisional flood hazard was changed to a high true flood hazard when subject to the following Emergency Response Planning (ERP) classifications (due to the flood liability of the land in conjunction with potential evacuation difficulties):

- Low Flood Island;
- Low Trapped Perimeter Area; and,
- Overland Refuge area on Low Flood Island or Low Trapped Perimeter Area.

A review of the Flood Study's preliminary true hydraulic hazard is presented in Section 6.2.

5.6. Flood Study Emergency Response Planning Maps

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them (Reference 16). These ERP classifications consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Escape Routes; Trapped Perimeter Areas or Indirectly Affected. The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 10). A flow chart presenting how flood emergency classifications are assigned is presented in Image 2.

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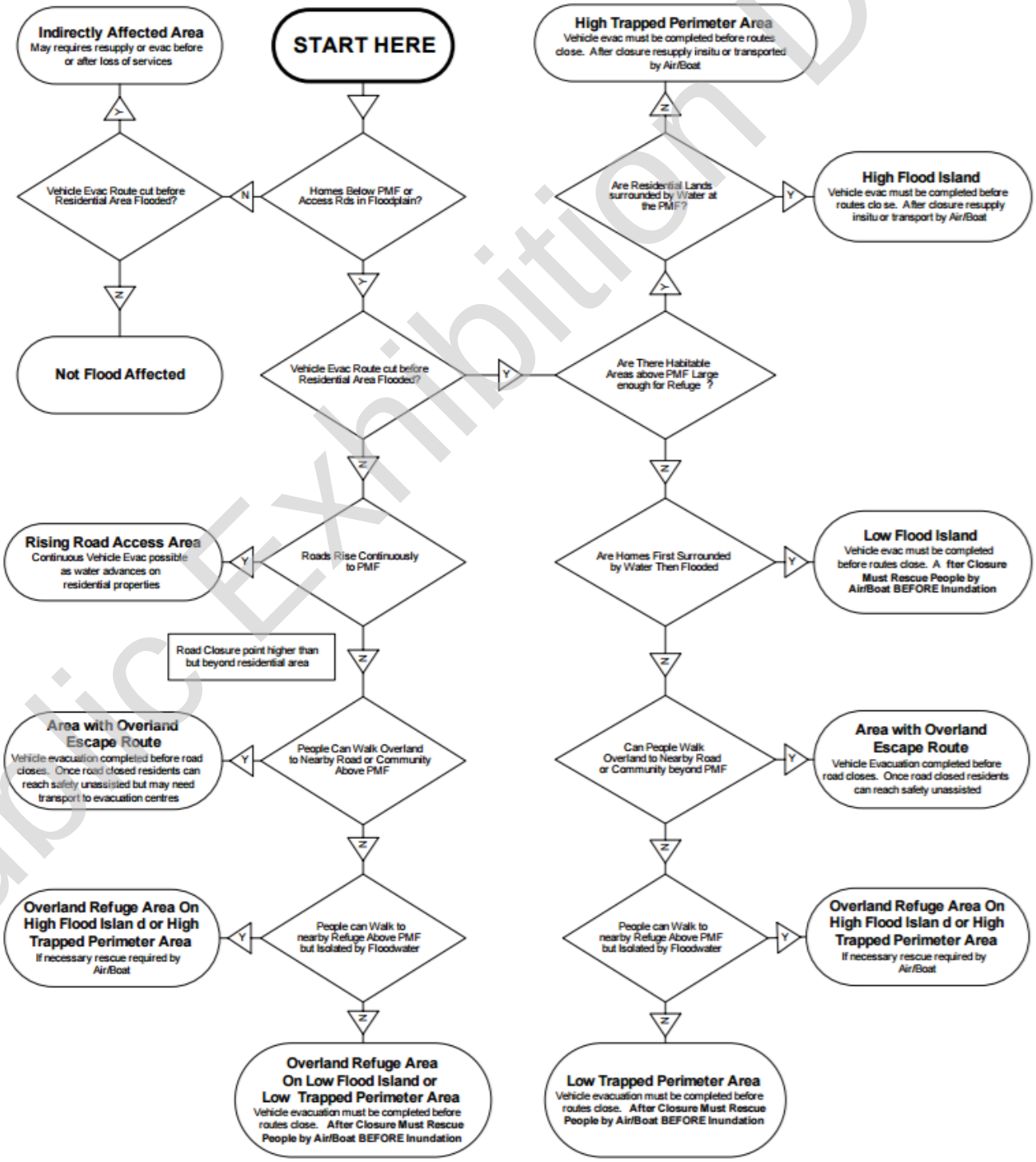
Table 10: Emergency Response Planning Classifications of Communities

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
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

Image 2: Flow Chart for Flood Emergency Reponse Classification (Reference 16)



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The Flood Study classified each allotment within the catchment based upon the flow chart provided in the ERP guideline for both the 1% AEP and PMF. This was completed in an automated fashion using proprietary software based upon consideration of:

- Whether evacuation routes/roadways get "cut off" and the depth of inundation (a 200mm depth threshold was used to define a "cut" road);
- Whether evacuation routes continuously rise out of the floodplain (based upon roadway alignments provided by Gosford and Wyong Council's and a 2m LiDAR-based DEM developed for this study);
- Whether an allotment gets inundated during the nominated design flood and whether evacuation routes are cut or the lot becomes completely surrounded (i.e., isolated) by water before inundation (a lot was considered inundated when there was less than 250 m² of "dry" land area available);
- If evacuation by car was not possible, whether evacuation by walking was possible (an 800 mm depth threshold was used to define when a route could not be traversed by walking).

The Flood Study's ERP mapping has been examined with the findings presented in Section 6.3.

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6. EXISTING FLOOD BEHAVIOUR

6.1. Hydraulic Categorisation

The Flood Study defined the provisional hydraulic categories as per the methods discussed in Section 5.4. The employed methodology and defined hydraulic categories are considered fit for purpose and suitable for use in Council's planning policy. Accordingly, the provisional hydraulic categories are now classified as the true hydraulic categories.

Figures 40 and 41 of the Flood Study present the true hydraulic category mapping for the 1% AEP and PMF events respectively.

6.2. Flood Hazard Classification

The Flood Study mapped the preliminary True Flood Hazard, classifying the floodplain as 'High' or 'Low' hazard. 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 17) provides revised hazard classifications. These add clarity to the description hazard categories and what they mean in practice. This new methodology for determining hazard has been used in this FRMS&P.

The hazard classifications are divided into six categories (Diagram 2) which indicate the restrictions on people, buildings and vehicles:

- H1 - Generally safe for vehicles, people and buildings,
- 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.

Figure 4 and Figure 5 present the hazard classifications based on the H1 – H6 delineations for the 1% AEP and PMF events respectively. Under this classification for a 1% AEP event much of the Ourimbah Creek floodplain is classified as H5 which is considered unsafe for all people and all vehicles with buildings requiring special engineering design and construction, and the creek channel and major runners are considered unconditionally unsafe (H6). Cut Rock Creek flood hazard is typically lower with the H5 and H6 uncommon. Other smaller tributaries experience similar flood hazard classifications as that determined for Cut Rock Creek. No residential homes were identified as situated within areas classed as H6, however numerous homes on the floodplain are surrounded by flood hazard with H5 classification.

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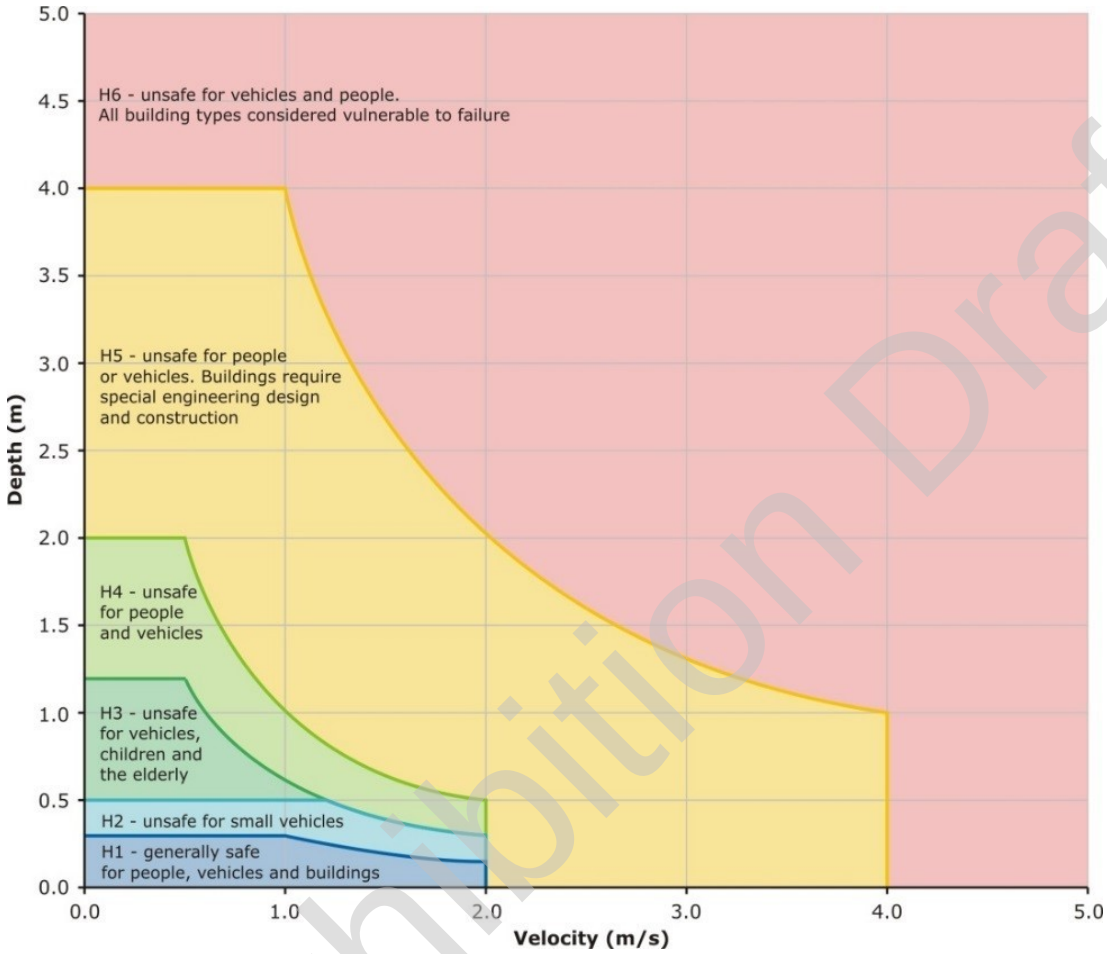
Diagram 2: Hazard Classifications (Reference 17)



6.3. Emergency Response Planning Classifications

The Flood Study defined ERP classifications as per the methods discussed in Section 5.6. The ERP mapping has been reviewed as part of this FRMS&P and was determined to require significant amendments to the classification delineation. Common issues include:

- Lots classified as 'High Trapped Perimeter Area' that are entirely flood affected;
- Lot classifications of 'Low Flood Island' and 'Low Trapped Perimeter Area' appear to be used interchangeable;
- Lots classified as 'Area with Overland Escape Route' are surrounded by lots classified as 'Low Flood Island'; and
- Other less common issues have also been identified.

The current study utilised methodology consistent with that outlined in Reference 16 to reproduce ERP classification maps for the 5% AEP, 1% AEP and PMF events (as per the Reference 16, SES guidelines). These maps are presented in Figure 6 to Figure 8 respectively.

6.4. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning. The Flood Study modelled peak flood depths (black) and velocities (red) within the Ourimbah Creek catchment which are presented in Table 11 at various road crossing. The

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locations of these flooded access roads are presented in Figure 1 (a to j). Cells are shaded in red if a crossing is classified as hazardous for any vehicle (Hazard Class H2, see Section 6.2) during a specific event. Examination of Table 11 highlights the flood liability of access roads throughout the catchment with 15 roads noted as unsafe for smaller vehicles during the 20% AEP event.

This is in agreement with findings from the community/stakeholder consultation (see Section 4) which indicates a large amount of road flood liability and risk associated with motorists attempting these crossing during flood. The roads mentioned below were specifically mentioned as part of the consultation process and a summary of their flood liability is provided below:

- Burns Road –20% AEP Hazard category H5, estimated as first flooded in the 2EY event;
- Howes Road – 20% AEP Hazard category H4, estimated as first flooded in the 2EY event;
- Turpentine Road – 20% AEP Hazard category H4, estimated as first flooded in the 2EY event;
- Chittaway Road – 20% AEP Hazard category H4, estimated as first flooded in the 1EY event; and
- Shirley Street – 20% AEP Hazard category H3, estimated as first flooded in the 0.5EY event.

Research undertaken for the revision of ARR shows that vehicles can become unstable in shallow depths of floodwaters (~0.1 m) if velocities approach 3 m/s. Small cars can float in still water depths of only 0.3 m (Reference 18). In addition, once flooding has subsided, structural damage could make access over a bridge unsafe.

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning, and ensure that evacuation occurs in a timely fashion before conditions deteriorate and hinder the evacuation process, requiring rescue boats and helicopters. Additionally, early warning can allow motorists to better plan their route, make informed choices and thus avoid flood affected areas and road crossings.

Refer to Section 9.3.1 for an assessment of measures to improve flood access.

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Table 11: Flood Depths and Velocities at Creek Crossings

ID	Location* (Figure 1)	Event Depth (m) and Velocity (m/s)						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1	Tapley Road (CRC)	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	1.1 / 0.4	1.2 / 0.4	1.3 / 0.4	2.2 / 0.6
2	The Ridgeway (CRC)	-	-	-	-	-	-	-
3	Orchard Road (CRC trib)	1.1 / 1.3	1.3 / 1.3	1.4 / 1.5	1.5 / 1.4	1.6 / 1.3	1.8 / 1.6	2.9 / 1.7
4	Macdonalds Road (CRC)	0.4 / 2.0	0.5 / 2.3	0.6 / 1.7	0.7 / 1.6	0.8 / 1.4	1.0 / 1.6	1.7 / 8.0
5	Macdonalds Road 2 (CRC)	0.8 / 0.3	0.9 / 0.3	1.0 / 0.4	1.1 / 0.5	1.1 / 0.6	1.2 / 0.6	1.9 / 1.0
6	Fagans Road (BC trib)	-	-	0.1 / 0.4	0.1 / 0.3	0.1 / 0.3	0.2 / 0.3	0.6 / 1.3
7	Coachwood Drive (BC)	-	0.0 / 2.1	0.3 / 2.3	0.4 / 2.3	0.5 / 2.3	0.5 / 2.3	2.1 / 2.3
8	Pryor Road u/s (BC)	-	-	-	-	-	0.3 / 0.3	2.2 / 0.6
9	Pryor Road d/s (BC)	-	-	-	-	-	-	1.0 / 5.7
10	Coachwood Drive (BC trib)	-	-	-	-	0.1 / 0.1	0.1 / 0.4	0.4 / 0.7
11	Shirley Street (BC trib)	-	-	-	0.1 / 1.0	0.1 / 1.1	0.3 / 1.5	2.3 / 2.2
12	Shirley Street 2 (BC trib)	-	-	0.2 / 0.4	0.3 / 0.7	0.3 / 0.7	0.4 / 0.8	1.4 / 3.6
13	The Boulevard u/s (BC)	0.4 / 0.8	0.3 / 0.3	0.4 / 0.3	0.5 / 0.3	0.5 / 0.3	0.7 / 0.4	2.2 / 1.0
14	The Boulevard d/s (BC)	0.2 / 0.5	0.2 / 0.5	0.2 / 0.6	0.2 / 0.6	0.2 / 0.6	0.2 / 0.7	2.2 / 1.3
15	The Boulevard u/s 2 (BC)	0.6 / 0.2	0.7 / 0.2	0.8 / 0.3	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	3.3 / 0.8
16	The Boulevard d/s 2 (BC)	0.6 / 0.3	0.7 / 0.3	0.8 / 0.3	0.9 / 0.4	1.0 / 0.3	1.2 / 0.4	3.3 / 0.7
17	Shirley Street 1 (BC)	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	1.2 / 0.6	1.3 / 0.7	1.4 / 0.9	3.9 / 2.6
18	Shirley Street 2 (BC)	-	-	-	-	-	-	0.9 / 6.7
19	Pacific Highway u/s (DTG)	0.6 / 0.9	1.0 / 0.9	1.1 / 1.0	1.3 / 0.9	1.4 / 0.9	1.6 / 1.5	2.7 / 1.8
20	Pacific Highway d/s (DTG)	0.5 / 2.4	0.6 / 2.5	0.9 / 2.4	1.2 / 2.3	1.4 / 2.1	1.6 / 2.3	2.9 / 2.4
21	Chittaway Road (BC)	0.5 / 1.7	0.5 / 1.7	0.6 / 1.7	0.7 / 1.7	0.8 / 1.7	1.0 / 1.7	3.2 / 1.7
22	Chittaway Road 2 (BC)	0.6 / 1.2	0.7 / 1.3	0.7 / 1.3	0.8 / 1.3	0.9 / 1.3	1.1 / 1.3	3.3 / 1.4
23	Burns Road (BC)	1.9 / 1.5	2.1 / 1.7	2.3 / 1.6	2.5 / 1.6	2.6 / 1.5	2.8 / 1.6	4.9 / 3.3
24	Old Chittaway Road (CC)	0.2 / 1.4	0.3 / 1.6	0.4 / 1.7	0.4 / 1.8	0.5 / 1.8	0.6 / 1.9	2.2 / 1.9
25	Enterprise Drive (CC)	-	-	-	-	-	-	1.2 / 3.4
26	Turpentine Road (CC)	1.5 / 0.4	1.6 / 0.3	1.7 / 0.3	1.8 / 0.4	1.8 / 0.4	2.0 / 0.5	1.6 / 3.1
27	Palmdale Road (OC)	0.1 / 0.4	0.2 / 0.8	0.4 / 1.7	0.8 / 1.7	0.9 / 1.7	1.3 / 1.7	4.7 / 1.7
28	Footts Road (OC)	1.8 / 1.5	2.0 / 1.8	2.2 / 1.7	2.5 / 1.7	2.6 / 1.4	3.0 / 1.7	7.0 / 5.4
29	Palmdale Road (CDDC)	0.2 / 0.7	0.2 / 0.7	0.5 / 1.0	0.6 / 1.3	0.8 / 1.4	0.9 / 1.5	3.9 / 2.1
30	Railway (OC)	-	-	-	-	-	-	0.5 / 6.1
31	Wyong Road (OC)	-	-	-	-	-	-	0.5 / 8.0
32	Tuggerah Street (BC)	1.8 / 0.6	2.0 / 0.6	2.2 / 0.6	2.3 / 0.6	2.5 / 0.5	2.7 / 0.6	3.9 / 2.4
33	Tuggerah Street (BC)	0.3 / 0.4	0.4 / 0.3	0.6 / 0.4	0.8 / 0.4	1.0 / 0.4	1.1 / 0.4	2.3 / 0.6
34	Tuggerah Street 2 (BC)	0.4 / 0.3	0.5 / 0.3	0.7 / 0.4	0.8 / 0.6	1.0 / 0.3	1.1 / 0.7	2.3 / 1.6
35	Woodview Avenue (BC)	0.1 / 0.4	0.2 / 0.5	0.2 / 0.6	0.2 / 0.7	0.2 / 0.4	0.2 / 0.3	1.0 / 2.6
36	Pacific Highway (CRC)	-	-	-	-	-	-	-
37	Nr Cassinia Close Lisarow(CRC)	0.2 / 0.7	0.3 / 0.7	0.3 / 0.7	0.4 / 0.6	0.4 / 0.6	0.4 / 0.6	1.2 / 0.9
38	Nr Ridgeway / Pacific Hgw (CRC)	0.3 / 0.7	0.3 / 0.5	0.4 / 0.5	0.5 / 0.6	0.5 / 0.4	0.6 / 0.6	1.3 / 0.8
39	Teralba St (CRC)	0.6 / 0.1	0.7 / 0.1	0.9 / 2.5	1.0 / 1.6	1.1 / 1.3	1.2 / 1.7	2.5 / 0.1
40	Lisarow St (CRC)	0.3 / 0.6	0.4 / 0.5	0.5 / 0.5	0.5 / 0.6	0.5 / 0.7	0.8 / 0.6	2.3 / 0.8
41	Pacific Hwy (CRC)	-	-	-	-	-	-	0.2 / 1.1

* CRC = Cut Rock Creek, BC = Bangalow Creek, DTG = Dog Trap Gully, CC = Chittaway Creek, OC = Ourimbah Creek, CDDC = Canada Drop Down Creek, trib = tributary of.

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6.5. Existing Levee Assessment

The following levees in the catchment have been identified:

- Tuggerah Business Park Levee (TBPL); and the
- Main Northern Railway Line Levee.

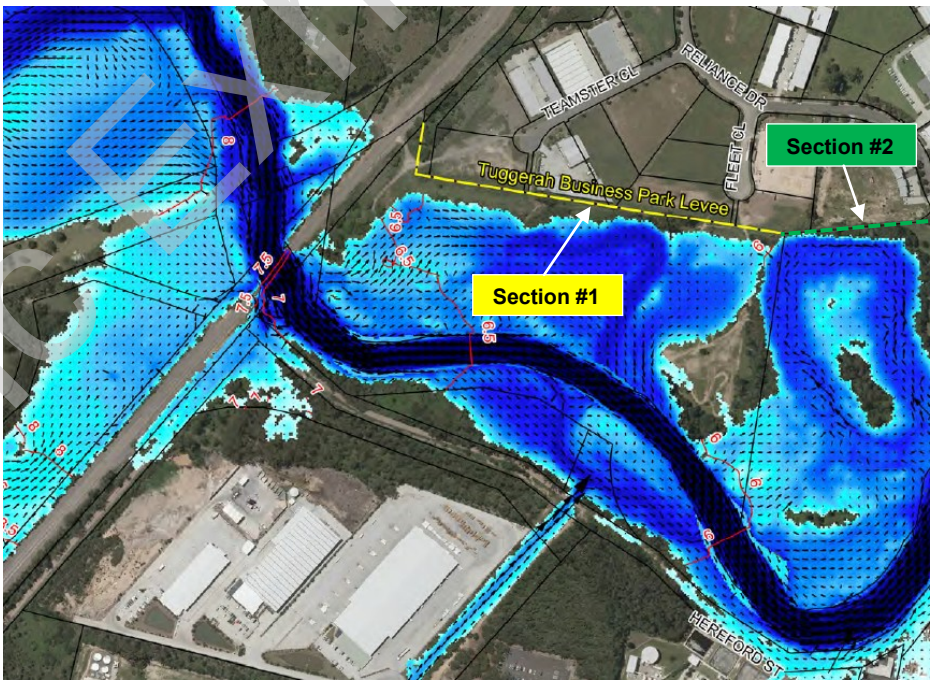
This assessment has been untaken using 2014 LiDAR data (see Section 3.4.1) which has a vertical accuracy of 0.3 m (95% Confidence Interval) and a horizontal accuracy of 0.8 m (95% Confidence Interval). Accordingly, the LiDAR data is only suitable for providing an indicative assessment. Additionally, the structural design of these structures has not been assessed.

Ground survey and a maintenance / geotechnical assessment of these levees is required for a detailed levee assessment and is recommended in Section 9.2.1.7.

6.5.1. Tuggerah Business Park Levee

The TBPL is situated on the northern bank of Ourimbah Creek between the Main North Railway Line and Wyong Road. The levee can be described as being composed of two parts, namely the TBPL East and TBPL West. The TBPL West is situated between the Main North Railway Line near Teamster Close and Reliance Drive near Fleet Close (see Image 3). The TBPL East is situated to the east of the TBPL West and runs parallel to Reliance Drive meeting a drainage channel immediately west of Wyong Road (see Image 4).

Image 3: TBPL West (Reference 2)



The crest level of the TBPL West levee ranges from 7.5 to 6.8 mAHD (from west to east) between the Railway and Fleet Close (Section #1) which is 0.5 to 1.2 m above the level of the 1% AEP. To the east of Fleet Close (Section #2) the levee crest is poorly defined and ranges from 6.5 to 7.5 mAHD (from west to east) which is 0.9 to 1.9 m above the level of the 1% AEP event. This part of the levee is not overtopped until events larger than the 0.5% AEP.

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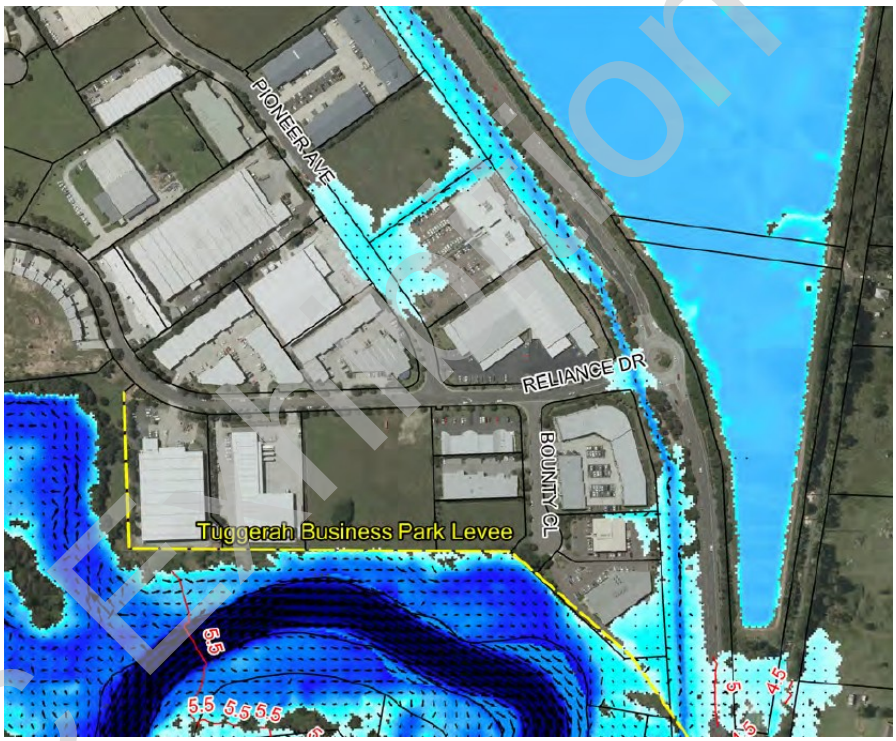
Sections of the TBPL East levee do not appear to be formalised based on analysis of the LiDAR. The crest level of the levee ranges between 6 to 5 mAHD (from west to east), however it may contain lower sections that cannot be identified via analysis of the LiDAR. Ground survey is required to undertaken a more detailed analysis. The Flood Study modelled this levee using a breakline however no information regarding where crest levels were obtained was provided.

1% AEP flood levels bordering the TBPL East levee range from 5.5 to 5.2 mAHD and accordingly there is very little if any freeboard constructed into the design height of this levee. Modelling indicates that the levee is slightly overtopped at its eastern end and that flood waters backwater into the drainage channel bordering Wyong Road. This causes some flooding in the Tuggerah Business Park away from the channel proper (see Image 4).

Image 4: TBPL East (Reference 2)



6.5.2. Main Northern Railway Line Levee

The Main Northern Railway Line levee is located on the western side of the Main Northern Railway line (within the rail corridor), directly west of the Berkeley Vale industrial area (Image 5) and was constructed based on design plan drawn in 1991. The levee is designed to prevent overtopping and subsequent “wash out” of the railway line ballast (Reference 2).

The crest level of the levee ranges from 10.4 to 11.2 mAHD which is at least 0.7 m higher than the 1% AEP flood level. The levee is not overtopped by the 0.5% AEP event, however it is overtopped by the PMF.

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Image 5: Main Northern Railway Line Levee

Image provided from Google Maps

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7. ECONOMIC IMPACTS 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 a non-subjective 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 Table 12.

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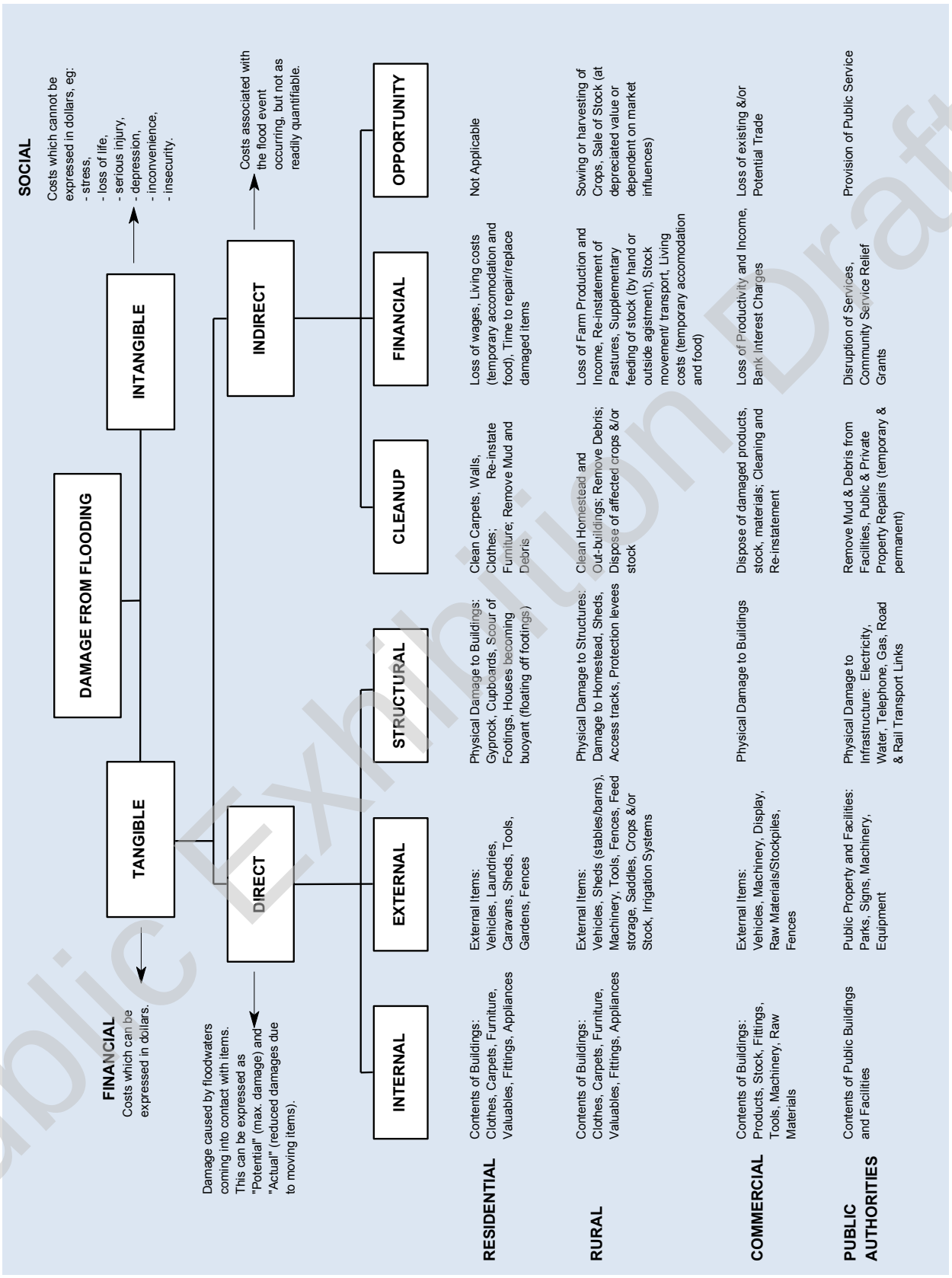
Table 12: Flood Damages Categories



7.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 12). Direct damages are caused by floodwaters wetting goods and possessions

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thereby damaging them and resulting in either costs to replace or repair or in a reduction to 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 damage estimates are also useful when studying the economic effectiveness of proposed mitigation options, however difficulties arise when trying to assess intangible damages such as loss of life. 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, floor level survey and estimates were made (see Section 3.4.2). This was used in conjunction with modelled flood level information from the Flood Study to calculate damages. Damage calculations were carried out for all properties within the PMF extent.

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.

A flood damages assessment had previously been undertaken for areas flood affected by Tuggerah Lakes as part of the Reference 4 study. This included areas of the lower reaches of the Ourimbah Creek catchment typically downstream of Wyong Road (referred to as Management Area TL5 in Reference 4). As a flood damages assessment has already performed for the area downstream of Wyong Road, these damages have not been reassessed in the current study to avoid double counting and overestimating flood damages for the region.

Damages were calculated for residential and commercial\industrial properties, discussed separately below. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should 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.

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7.1.1. 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 930 residential properties. Surveyed and estimated floor level data was obtained by the methods outlined in Section 3.4.2. A summary of the flood damages assessment is provided in Table 13 for the Ourimbah Creek catchment. As previously discussed, the damages downstream of Wyong Road have not been assessed to avoid double counting and overestimating flood damages.

Table 13: Residential Flood Damages for Properties Situated Upstream of Wyong Road

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	35	3	$ 220,000	$ 6,000
10% AEP	67	13	$ 920,000	$ 14,000
5% AEP	104	19	$ 1,522,000	$ 15,000
2% AEP	119	26	$ 2,279,000	$ 19,000
1% AEP	144	34	$ 2,840,000	$ 20,000
0.5% AEP	180	53	$ 4,481,000	$ 25,000
PMF	633	525	$ 47,039,000	$ 74,000
Average Annual Damages (AAD)			**$ 380,000**	**$ 600**

Table 13 indicates a moderate degree of flood liability for more frequent events with 34 properties (4%) flooded above floor level in the 1% AEP event. During the PMF there are an estimated 525 properties (56%) flooded above floor level indicating a high degree of flood risk and associated flood damages. On average, flooding in Ourimbah Creek, upstream of Wyong Road, cost Council and the community $380,000 per annum.

7.1.2. Non-Residential – Commercial and Industrial

Non-residential land uses in the study area are typically situated bordering the Pacific Highway with a large business/industrial hub bounded by Enterprise Drive, Wyong Road and the Main North Line Railway in the lower reaches of the catchment.

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;

- 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 is 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 insufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

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A summary of the flood damages assessment for commercial and industrial properties is provided in Table 14 for the Ourimbah Creek catchment. Table 14 indicates relatively limited flood liability for non-residential properties.

Table 14: Estimated Non-residential Flood Damages for Ourimbah 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	5	3	$ 268,000	$ 53,500
10% AEP	7	3	$ 372,000	$ 53,100
5% AEP	12	3	$ 395,000	$ 32,900
2% AEP	13	4	$ 531,000	$ 40,800
1% AEP	22	6	$ 752,000	$ 34,200
0.5% AEP	44	29	$ 3,252,000	$ 73,900
PMF	170	168	$ 38,429,000	$ 226,100
Average Annual Damages (AAD)			**$ 226,000**	**$ 1,300**

7.1.3. Critical Infrastructure and Vulnerable Facilities

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning 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;
- Drain cleanout and maintenance;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts;
- 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.

There are two electrical sub-stations in the catchment which are described below along with their flood affection.

Ourimbah Zone Sub-station - is situated at 4 Yates Road, Ourimbah. Analysis of the design results indicates that the sub-station is flood free for events up to and including the 0.5% AEP

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event. The substation is flooded by depths of approximately 1 m in the PMF event.

Berkeley Vale Zone Sub-station - is situated at 14 Apprentice Drive, Berkeley Vale. Analysis of the design results indicates that the sub-station is flood free for events up to and including the 0.5% AEP event. The substation is flooded by depths of approximately 2 m in the PMF event.

A sewage treatment plant is situated on Ibis Road off Wyong Road. This area is situated outside of the study area so specific flood liability cannot be described.

On site sewage systems are still present on some of the older residential lots, most notably at Tall Timbers. Inundation of these systems presents a significant health hazard for residents or the SES / Police / RFS who may enter flood waters during the event or as part of the clean up operation. In addition in a very large flood event it is possible that the reticulated sewage system may fail and discharge effluent into floodwaters.

The study area has a number of schools and learning centres which are listed below along with their flood liability.

Table 15: Flood Affected Schools in Ourimbah Creek Catchment

Name	Address	Yard First Flooded	Above floor flooding
Lisarow Public School	17 Macdonalds Rd, Lisarow	20% AEP	PMF
Ourimbah Public School	121 Pacific Hwy, Ourimbah	0.5% AEP	0.5% AEP
Central Coast Rudolf Steiner School	45 Catamaran Rd, Fountaindale	PMF	Not flooded
Chittaway Bay Public School	Chittaway Rd, Chittaway Bay	PMF	PMF
Newcastle University Ourimbah Campus	The Boulevard	20% AEP	PMF

Flooding to schools, and to similar institutions, would have different impacts depending on the time of day and obviously during school hours response would be more critical due to the number of persons on the site. It is important that the schools have effective flood plans implemented (see Section 9.3.4).

In addition to the above there are a number of other private and public properties/facilities that are vulnerable to flooding (e.g child care, aged care centres).

7.2. 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.

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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.

Flood affectation to many of the critical infrastructure and vulnerable facilities (Section 7.1.3) may also result in significant intangible damages. For example, damage to service supply (water, sewage) will affect households as will the temporary closure of schools or child care facilities as repairs are carried out. The flood affectation to these facilities will not necessarily occur at the site of the facility. Thus just because the facility is not directly affected by flooding does not mean that flooding will not have a bearing on the facilities activities and the resulting community. For example, with schools, child care, aged care, universities the main issue is with access to the facility and this may be some distance from the building. With service infrastructure (sewer, water, electricity) the main facility will likely not be directly affected by floodwaters but the supply will be affected by say fallen trees hitting power lines or closure of the sewer system as floodwaters are entering the system in the flooded area. Many of these affectations to the critical infrastructure and vulnerable facilities are variable and will not necessarily occur in all floods or at the same locations. It is only through review of past floods that the true affectation to critical infrastructure and vulnerable facilities can be addressed.

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8. CURRENT PLANNING INSTRUMENTS AND LEGISLATION

8.1. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event. The Standard provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event. Flood hazard areas are identified by the relevant State/Territory or Local Government authority.

The BCA is produced and maintained by the Australian Building Codes Board (ABCB), and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

8.2. State Provisions

8.2.1. EP&A Act 1979

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

8.2.2. Ministerial Direction 4.3

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. The objectives of Direction 4.3 are:

> *(a) 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*
>
> *(b) 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.*

Various clauses within Direction 4.3 provide additional legislation in regards to development on the floodplain. This includes restrictions that do not allow for development in the floodway, flood impacts on adjoining properties, and development intensification within the flood planning area.

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8.2.3. 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, it recognises that a different emphasis is required to address issues particular to a rural floodplain. These issues include:

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data, and
- The environmental values associated with flood dependent ecosystems on a rural floodplain.

8.2.4. Planning Circular PS 07-003

Planning Circular PS 07-003 provides advice on a package of changes concerning flood-related development controls for land above the 1% AEP flood and up to the Probable Maximum Flood (PMF).

Councils can make an application to the DoP for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in the LEP, as per Planning Circular PS 07-003. This can be useful for areas where there are significant increases in flood risk associated with increased flood magnitude above the 1% AEP event. Some Councils, where this is an issue, choose to prohibit sensitive land uses below the PMF.

Both Gosford and Wyong Council LEPs have Floodplain Risk Management Clauses allowing for flood related development controls to be applied up to the level of the PMF. In both LEPs, these

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controls only restrict sensitive development types.

8.2.5. Section 10.7 (formerly Section 149) Planning Certificates

Section 10.7 Planning Certificates are issued in accordance with the EP&A Act 1979. They contain information on how a property may be used and the restrictions on development. A person may request a s10.7 certificate to obtain information about his or her own property but generally a s10.7 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919, requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Most councils' Planning Certificates are issued under Section 10.7 (2) and 10.7 (5) of the EP&A Act 1979. A separate request can be made for a Section 10.7 (2) Certificate which confirms whether complying development may be carried out under the State Environmental Planning Policy 2008 (Exempt and Complying Development). Information to be disclosed on a Section 10.7 (2) Planning Certificate is specified under the Environmental Planning and Assessment Regulation 2000 (Schedule 4) and includes the following where relevant:

-
  - Names of relevant planning controls i.e SEPP's, LEP's, REP's, DCP's;
  - Declared State Significant Developments;
  - Zoning and land uses under the planning control;
  - Critical habitat;
  - Heritage Information;
  - Land reserved for acquisition;
  - Coastal Protection;
  - Mine subsidence;
  - Road widening and road realignment;
  - Council and other public authority policies on hazard risk restrictions (including flooding);
  - Section 94 Contributions Plans.

8.3. Local Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments are 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 control development on flood prone land. Plans and Polices have been discussed below and later have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 9.4.7).

A 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

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NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

Wyong Shire Council's LEP was adopted in 2013, and Gosford City Council in 2014. Both were prepared under the Standard Instrument LEP program.

8.3.1. Central Coast Council Merger – Integration of Flood Controls

The May 2016 merger of Wyong and Gosford Councils will require the integration of Councils' planning polices, including the LEPs and DCPs. Advice on how the integration of these planning policies is best achieved is outside of the scope of the current study. It is recommended that Council engage a specialist planning consultant to prepare advice for integration of the Wyong and Gosford LEP/DCP.

The following sections describe the plans/policies adopted by the respective Councils prior to the amalgamation.

8.3.2. Wyong Shire Council Local Environment Plan 2013 (WLEP 2013)

Clause 7.2 of WLEP 2013 relates to flood planning and states:

7.2 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) will not 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) will not 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.

Clause 7.3 relates to flood risk management and states:

7.3 Floodplain risk management

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

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood.

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) air strips,
(b) air transport facilities,
(c) child care centres,
(d) correctional centres,
(e) educational establishments,
(f) electricity generating works,
(g) emergency services facilities,
(h) group homes,
(i) helipads,
(j) home-based child care,
(k) hospitals,
(l) hostels,
(m) public utility undertakings,
(n) respite day care centres,
(o) (Repealed),
(p) seniors housing,
(q) sewerage systems,
(r) water supply systems.

(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 Plan.

8.3.3. Gosford City Council Local Environment Plan 2014 (GLEP 2014)

Clause 7.2 of GLEP 2014 relates to flood planning and is the same as that presented in Wyong Council's LEP. GLEP2014 also includes the same 7.3 Floodplain Risk Management clause, however it is slightly different, stating:

7.3 Floodplain risk management

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

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood, but does not apply to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood plus 0.5 metre freeboard..

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(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) caravan parks,

(b) correctional facilities,

(c) emergency services facilities,

(d) group homes,

(e) hospitals,

(f) residential care facilities,

(g) tourist and visitor accommodation.

(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.

8.3.4. Wyong Shire Council Development Control Plan 2013

Chapter 3.3 of the Wyong Shire Council DCP deals with floodplain management. The stated objectives are:

- *To minimise the risk to human life and damage to property by controlling development on flood prone land*
- *To apply a performance and merit based approach to all development decisions taking into account ecological, social, engineering safety and environmental considerations to ensure development is appropriate and sustainable*
- *To ensure that the development or use of floodplains waterways and riparian corridors does not adversely impact upon aesthetic, recreational and ecological values*
- *To ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods*
- *To promote flood compatible building design that considers requirements for the development of flood prone land and does not adversely impact on adjoining properties*
- *To establish guidelines for the development of flood prone land that are consistent with the NSW Flood Policy and NSW Floodplain Development Manual (2005) and as updated by the associated Floodplain Risk Management Guides*

The DCP stipulates development controls based on the risk precinct (four precincts defined by flood risk) and land use, provided in a matrix replicated in part below. These consider planning aspects such as minimum floor levels, structural considerations, emergency access and egress requirements, impacts of the development on others, etc.

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Proposed Land use	Precinct 1 FPL to PMF	Precinct 2 Below FPL	Precinct 3 Flood Storage and Flow Paths (up to 10% AEP)	Precinct 4 High Hazard (up to 50% AEP)
1 Single Dwelling Houses		1, 9	2, 5, 7	
2 Agriculture & Recreation		2	2, 5, 7	
3 Sheds / Garages / ancillary Residential		1	2, 5, 7	
4 Commercial and Industrial Uses		2, 6		
5 Medium to High Density Residential				
6 Critical or Sensitive Facilities	3			
7 Land Subdivision	4			
8 Tourist Development				
9 Caravan parks - short-term sites		6	5, 6	
10 Permissible Earthworks		8		

Flood related development controls do not apply

Flood related development controls apply (refer to numbered prescriptive criteria below)

If the proposal is to be pursued further, a performance based assessment is to be provided demonstrating that the proposed development is compatible with the flooding characteristics of the site (refer to Section 3.2 and Appendix C of the DCP).

In addition, the DCP stipulates general requirements for fencing, car parking, fill, on-site sewer management, and storage of hazardous substances. Appendix B of the DCP provides a table of flood compatible materials based on the building component.

8.3.5. Gosford City Council Development Control Plan 2013

Section 6.7.7.6 provides details of the flood targets for the LGA, with the objectives stated as:

- *To reduce private and public losses resulting from floods.*
- *To enable safe access or evacuation of people to the existing public road network during flooding.*
- *To maintain the existing flood regime and flow conveyance capacity.*
- *To avoid significant adverse effects on the floodplain environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of any river bank or watercourse.*
- *To limit land uses to those compatible with flow conveyance function and flood hazard.*

A Flood Control Target Matrix (partially shown below) is provided which stipulates varying controls based on land use. Additional information is also provided for subdivisions, parking and fencing. The chapter also states that:

> *'If the subject land falls within the area of an existing Floodplain Risk Management Plan then the development must comply with specific conditions of the plan.'*

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Table 4 Flood Control Target Matrix

Development	Development Types					
Control Targets	Pools & Spas	Residential Buildings (Rural)	Residential Buildings (Urban)	Group homes, seniors housing, emergency facilities	Commercial, Industrial	Subdivisions (Urban & Rural)
Floor levels	-	B	B	A	B	-
Flood Impacts	C	C	C	C	C	C
Subdivisions	-	-	-	-	-	D
Access & Parking	-	E	-	F	E	E
Fencing	-	G	G	G	G	G

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9. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to manage flood risk and reduce flood damages. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the Ourimbah Creek catchment.

It should be noted that cost estimates have been provided for the various options outlined below. These cost estimates are indicative only and typically only provide an order of magnitude estimate for the comparison of various options.

9.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories;

- **Flood modification measures (denoted as 'Option FM', 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. On site detention is used to mitigate the increase in peak flow from a site resulting from changing the land type from pervious cover to impervious cover. However it is not possible to reduce flood levels in a large river system such as Ourimbah Creek through on site detention.

- **Response modification measures (denoted as 'Option RM', 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 (denoted as 'Option PM', 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.

Table 16 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for the Ourimbah Creek catchment and have not been recommended.

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Table 16: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	Land zoning	Community awareness
Temporary defences	Voluntary purchase	Flood warning
Channel construction	Building & development controls	Evacuation planning
Channel modification	Flood proofing	Evacuation access
Major structure modification	House raising	Flood plan / recovery plan
Drainage network modification	Flood access	
Drainage maintenance		
Retarding basins		

Figure 1 and Figure 9 indicate where localised management measures have been considered in detail and described in the various sections below.

9.2. Flood Modification Measures Considered

All flood modification measures investigated in detail are listed below.

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);
- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3)
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5);
- Option FM6 – Canntree Road Levee (Section 9.2.1.6);
- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7);
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1);
- Option FM9 – Lees Bridge Widening (Section 9.2.5.1);
- Option FM10 – Footts Road Weir Removal (Section 9.2.5.2);
- Option FM11 – Upstream Pacific Motorway Vegetation Management Area (Section 9.2.6.1);
- Option FM12 – Sohier Park Vegetation Management Area (Section 9.2.6.2);
- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1);
- Option FM14 – Combined Channel and Basin (Section 9.2.8).

9.2.1. Levees and Filling

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

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behind the levee.

Localised levees or bunding can be applied around individual properties. Such measures are considered minor property adjustments and are discussed in Section 9.4.3.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within 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 using hydraulic modelling techniques 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, wave action from passing vehicles or watercraft and effects of wind.

OPTIONS CONSIDERED

The community consultation questionnaire (see Section 4.1) indicated that residents were interested in the implementation of levees or filling at various locations in the catchment including:

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);
- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3);
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5)
- Option FM6 – Canntree Road Levee (Section 9.2.1.6).

Details for each of the above listed levees are provided in the following sections. Additionally, the survey and maintenance of existing levees is discussed in:

- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7).

9.2.1.1. Option FM1 – East Chittaway Point Levee

Levees situated adjacent and parallel to Ourimbah Creek at Chittaway Point were investigated on both the southern and northern sides of the Creek. Levees were found to be not suitable for flood mitigation at Chittaway Point for a variety of reasons:

- Flooding in Chittaway Point can be due not only to Ourimbah Creek but elevated levels in Tuggerah Lake. Levees would need to be designed to stop both sources of flooding and would therefore be required to protect from flooding from two directions requiring long ring levees;
- As both sides of floodplain would be denied by the levees, increases in peak flood level upstream and in the channel would be significant and the required design height of the

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levees would need to be approximately 2 m above surrounding ground level. If constructed out of compacted earth the base width of the structure would be between 10m and 20m, thus requiring a considerable amount of space. Though this could be reduced if a concrete wall or similar narrower "wall" type structure was created;

- The total length of both levees would be +10 km, largely constructed on private land;
- Due to the height and length of the levees and the need for acquisition of private land, the cost of construction of the levees would be extremely expensive (estimated to be in the order of +$150 million); and
- Many land holders may not wish to have a levee constructed in their backyard due to the impact on views and a reduction in the amenity provided by Ourimbah Creek.

Due to the significant cost of construction and the impact on resident's views and the amenity of Ourimbah Creek, consideration of Option FM1 has not been investigated further.

9.2.1.2. Option FM2 – Bangalow Creek Levees

Option FM2 examined various levee alignments in Bangalow Creek as recommended by respondents as part of the community questionnaire. No suitable location for implementation of a levee was identified in this area for the following reasons:

- Properties are widely distributed, meaning that any benefit created by a levee only benefits a small number of properties;
- The majority of properties in this area are not flooded over floor until the PMF event which indicates relatively minor flood affectation;
- The wide distribution of properties and low flood affectation indicate that any expensive works, such as a levee (+$2 million) would have a poor Benefit/Cost (B/C) ratio; and
- Leveeing the Bangalow Creek floodplain would lead to significant increases in peak flood levels in surrounding areas which can impact on properties situated outside of the levee.

No suitable location to construct a levee on Bangalow Creek was identified. Accordingly, Option FM2 has not been investigated further.

9.2.1.3. Option FM3 – Mill Street Industrial Area Levee

The community questionnaire indicated that community members were interested in investigating the construction of a ring levee surrounding the Mill Street industrial area. The model results indicate that a levee with an average height of 1 m (inclusive of a 0.5 m freeboard) would provide protection in the 1% AEP event.

Option FM3 was modelled for the 1% AEP event with the peak flood level impacts presented in Figure D 1. The modelled Option FM3 ring levee removes flood affectation for the Mill Street industrial precinct, however causes increased flood levels on the floodplain (up to 0.3m upstream). Minor increases in flood level affect residential properties on Bristowe Close to the south-east. However the majority of the affectation is within the heavily vegetated riparian corridor where there is no development. The levee does not "block" the flow path as much as expected as there is already a significant impediment due to the existing buildings and the long

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axis of the levee is aligned parallel with the flow path.

The other major problem with this levee is access to each property across the levee. A 1.5m high levee requires a 1:6 grade for vehicle access with say a 2m wide crest. Thus 20m extent of land is required for access. This is impossible to achieve for each of the six individual properties. Possible solutions could be to allow only one access point and each property would provide an access easement for the other properties and/or reduce the levee with construction of a solid concrete wall.

The Option FM3 levee provides benefits to industrial properties whilst causing minor increases in flood affectation for residential properties. As the levee only protects non residential properties it is likely that significant owner funding will be required as the state government's program is more focussed on residential mitigation measures. This measure should be presented to the property owners and their support obtained before further investigation of Option FM3 is investigated further.

This levee would become a flood free island protecting the property inside. However this could potentially increase the risk to life if owners decided to stay within the leveed area and either had to be rescued or chose to attempt to evacuate themselves.

9.2.1.4. Option FM4 – University Lower Carpark Levee

As part of the Stakeholder consultation, the University of Newcastle (see Section 4.2.3) noted that the two lower carparks at the Ourimbah Campus are frequently flood affected. The issue of flooding of the southern carpark near Shirley Street could potentially be addressed by raising The Boulevard which could also improve flood access to the University. Further details are presented in Section 9.3.1.4.

To mitigate flooding of the northern carpark a levee could be constructed to protect parked cars and to remove the risk of people trying to rapidly exit the carpark during times of flood. Option FM4 modelled the construction of a levee to protect the northern carpark. A levee with an average embankment height of 2.5 m above surrounding ground level (inclusive of 0.5 m freeboard) and a length of 200 m could be used to achieve flood protection in the 1% AEP event. A significant issue with this option is the width of an earthen levee would exceed 15m. An alternative might be a concrete wall.

Option FM4 was modelled for the 1% AEP event with the peak flood level impacts presented in Figure D 2. The modelled levee alignment protects the carpark and produces no adverse effects on the surrounding floodplain.

An indicative construction cost of the levee is $200,000 (may be more if a concrete wall construction) which would be funded by the University of Newcastle. A smaller design event could be selected to inform the design height of the levee to save on the cost of construction. A levee should only be constructed in conjunction with monitoring of creek levels, using the proposed gauge described in Section 9.3.3.2. Levees do have the potential to increase flood risk if they become overtopped. Failure of a 2.5 m levee would pose a significant risk to life to

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anyone in the carpark at that time. If the design height of the levee is approached, university security should be notified to man the carpark, and the carpark closed, once a threshold is reached. There is also the risk of levee failure before overtopping occurs.

A B/C ratio for this measure and for filling (Section 9.2.1.5) is impossible to accurately estimate as this requires data on the likelihood of cars being left in the car park during a flood as most are removed once the owners become aware of the flood risk. Cars are also insured for damage in floods if comprehensively insured.

A more reasonable approach to reducing flood affectation of the carpark may be to raise the entire carpark. This is discussed in Section 9.2.1.5.

9.2.1.5. Option FM5 – University Lower Carpark Filling

Option FM5 has been examined with the aim of achieving the same objective as Option FM4, i.e. the protection of the lower University carpark. Filling of the carpark, rather than a levee, would remove the risk of levee overtopping failure as well as issues with internal drainage.

Modelling of this option indicates that raising of the carpark will have no impacts on peak flood levels on the surrounding floodplain. The level to which the carpark is raised could again be based on a trade-off between cost of construction and the level of flood protection.

To achieve 1% AEP flood immunity the carpark would need to be raised by 2.5 m (assuming 0.5 m freeboard) which would require approximately 13,000 m³ of fill. The estimated cost of construction is $400,000.

Option FM5 is recommended for further investigation through detailed costing and design as it would reduce the risk to life and damages to vehicles. However whilst the impacts of filling are minimal, filling of the floodplain is generally not supported as approval for this amount of filling may establish a precedent for approvals for other floodplain filling activities. This is one of the reasons why Council has previously rejected applications by the University to fill the land. This issue would need to be resolved initially before further detailed investigation is undertaken.

9.2.1.6. Option FM6 – Canntree Road Levee

Examination of the design results indicates that in events larger than the 1% AEP floodwaters overtop Wyong Road to the north of Lees Bridge, creating a new flow path through the area to the east of Canntree Road. This breakout affects numerous residential properties as well as a proposed development site and is subject to high hazard flows (H5 and H6, see Section 6.2) in the PMF. Areas of these hazard classifications pose a significant risk to life and structures in a large flood event. A levee at this location could potentially prevent floodwater from overflowing Wyong Road and Canntree Road and affecting the land north of Oscar Drive.

The implementation of a levee to stop flow passing through this area has been investigated. The Option FM6 levee was modelled and extends 250 m north from the Wyong/Geoffrey Road roundabout. The levee was designed for the 0.5% AEP event and was required to be on

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average 1.0 m higher than the Wyong Road crest height (1.6 m above surrounding ground level) including 0.75 m freeboard. An indicative cost of construction is $250,000 assuming that the levee does not require works to be undertaken on Wyong Road. The reduction in AAD associated with Option FM6 is $2,000, indicating a B/C ratio of 0.1.

Figure D 3 presents the impact on peak flood levels with implementation of Option FM6 for the 0.5% AEP event. Option FM6 ameliorates 0.5% AEP flood affectation for properties downstream, however leads to significant increases in flood levels (up to 0.2 m) and flood affectation upstream.

The construction of the levee described above does not provide protection from a full range of design events, with floods larger than the 0.5% AEP still posing a risk to properties downstream. To protect these properties up to the level of the PMF, a levee with an embankment 4 m above surrounding ground level would be required. A levee to the PMF would remove the high velocity flows for all events in the area thus significantly reducing risk to life, however would not ameliorate flood affectation due to flooding of the area by Ourimbah Creek flows downstream of Lees Bridge. An indicative cost of construction for a levee designed to not be overtopped in the PMF is $750,000, however there would be no reduction in AAD as downstream properties would still be flooded. The reduction in flood hazard and associated risk to life cannot be monetised.

Due to the increased flood affectation for properties upstream of Wyong Road and the poor B/C ratio, Option FM6 is not recommended and has not been considered further.

There is the potential that land downstream may be developed as a residential subdivision and this levee has been suggested for flood protection. Whilst this may be cost effective for the land developer it raises the question whether a levee should be used for this purpose. In general levees are constructed to mitigating existing flood damages and risk to life but not to support new development in the floodplain. For this reason some councils in NSW have a policy that new developments must meet the pre-levee design flood levels for construction and development approval.

9.2.1.7. Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance

The existing Tuggerah Business Park and Main Northern Railway Line Levees (see Section 6.5.1) require ground survey to identify low points that reduce the protection afforded by the levee. It is recommended that once the low points are identified maintenance to formalise the levee be undertaken as well as development of a levee management plan.

RECOMMENDATIONS

► Undertake detailed costing and design of filling the University of Newcastle Ourimbah Campus lower carpark (Option FM5, see Section 9.2.1.5).

► Undertake ground survey and maintenance works for existing levees within the catchment (Option FM7, Section 9.2.1.7) and development of a levee management plan.

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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.

DISCUSSION

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 ability of a workforce to install. 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.

RECOMMENDATIONS

► In the Ourimbah Creek catchment, demountable defences are not suitable to be used to reduce flood risk and inundation, due to the lack of suitable locations for their placement and insufficient available warning time (see Section 9.3.3).

9.2.3. Channel / Floodway Construction

DESCRIPTION

Channels or floodways can be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration.

DISCUSSION

Locations for potential drainage and diversion channels were investigated as potential mitigation measures. Option FM8 was identified and found to provide some benefit in terms of reduced flood levels.

9.2.3.1. Option FM8 – Baileys Road Diversion Channel

Option FM8 investigated the construction of a 1.5 m deep by 16 m wide diversion channel parallel and to the east of Main Northern Railway Line, aimed at diverting a portion of flow north from Cut Rock Creek before it crosses west through the Pacific Highway towards Lisarow Street. The invert of the diversion channel was modelled at approximately 1.8 m below the creek top of bank.

Option FM8 was modelled for the 1% AEP event with the peak flood level impacts presented in Figure D 4. Option FM8 reduces 1% AEP peak flows through the Lisarow Street area and upstream at the Tall Timbers estate (key areas described in the Brief, see Section 2.3). The reduction in flow leads to a decrease in peak flood level of up to 0.3 m, however widespread increases in peak flood level are experienced downstream of the diversion channel.

An indicative cost of implementation of Option FM8 is $400,000, with the Option providing little

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in terms of reductions to AAD (B/C < 0.1). The concept design modelled the Option FM8 channel in the rail easement, however liaison with Transport for NSW indicated that this is not feasible. The location of Baileys Road does not allow enough room for construction of the channel outside of the rail easement.

For the reasons described above, Option FM8 is not feasible and has not been investigated further.

RECOMMENDATIONS

► No channel construction works are proposed.

9.2.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream.

DISCUSSION

The community consultation questionnaire highlighted a desire by members of the community for the investigation of increasing channel capacity by straightening and widening creek channels throughout the study area. In particular, numerous residents noted various works to modify the conveyance characteristics of the entrance to Tuggerah Lakes. Modification of the entrance has been examined in numerous previous studies and shown to be ineffective in reducing property flood affectation (see Section 3.2.4). Further investigation of this issue is outside the scope of the current study.

Considering the above, the following locations were identified where channel straightening could be implemented to increase conveyance:

- Cut Rock Creek downstream of Burns Road;
- Cut Rock Creek downstream of Teralba Street; and
- Canada Drop Down Creek downstream of Palmdale Road.

These locations were modelled to investigate the impacts of undertaking channel straightening works. It was found that channel modification is unsuitable for reducing flood affectation for a variety of reasons, including:

- Modelled reductions in peak flood levels were minor (< 0.2 m) and did not benefit developed land;
- The benefits associated with localised decreases in flood level were offset by increases in flood levels in areas downstream; and
- The environmental cost of modifying these natural channels is significant and is generally not able to be achieved due to stringent environmental policies.

Due to the reasons described above, channel straightening was found to be not feasible and

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has not been pursued further.

RECOMMENDATIONS

► Channel modification measures were shown to provide little benefit to developed land and led to increased flood affectation in the downstream. 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.

9.2.5. Major Structure Modification

DESCRIPTION

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by widening a bridge or raising the deck level.

DISCUSSION

Specific structures noted by Council and the community have been investigated in the following sections.

The addition and modification of various structures could potentially be implemented to improve flood access. Some preliminary concept designs have been investigated in Section 9.3.1. These structures have generally been designed such that roads can be raised to provide better flood access whilst having minimal impact on design flood levels. Accordingly, the structures investigated as part of the improved flood access roads are not described further in this section as they are not considered as flood modification measures (see Section 9.1).

9.2.5.1. Option FM9 – Lees Bridge Widening

As described in Section 9.2.1.6, events larger than the 1% AEP flood overtop Wyong Road to the north of Lees Bridge creating a new flow path through the area to the east of Canntree Road. This breakout affects residential properties and is categorised as high hazard flow (H5 and H6, see Section 6.2) in the PMF.

In an attempt to reduce the flow passing through this area, Lees Bridge, the existing bridge at the Wyong Road crossing of Ourimbah Creek was investigated. Option FM9 investigated doubling the width of the existing bridge to 160 m by removing the approach embankments. It was thought that by increasing the conveyance capacity of Lees Bridge, upstream flood levels would be lower, leading to less flow breaking out and flowing through the area to the east of Canntree Road.

Figure D 5 presents the impact on peak flood levels with implementation of Option FM9 for the 0.5% AEP event. Option FM9 significantly reduces peak flood levels upstream of Lees Bridge which stops flow from overtopping Wyong and Canntree Roads to the north, thus reducing flood

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risk and affectation in this area. However, downstream of Lees Bridge peak flood levels are increased and a number of previously non flood affected properties become flood affected.

Due to the increased flood affectation for properties downstream of Lees Bridge, Option FM9 is not recommended and has not been considered further.

9.2.5.2. Option FM10 – Footts Road Weir Removal

The community questionnaire (see Section 4.1) noted that the weir at Footts Road was of concern to residents. To investigate the impact that the weir has on peak flood levels, the 20% AEP and 1% AEP flood events were modelled with the weir removed. It was found that removing the weir has no impact peak flood levels for either event. The weir potentially impacts on peak flood levels for events smaller than the 20% AEP, however these events have not been investigated as part of this FRMSP.

No changes to the Footts Road weir are recommended as the structure does not affect peak flood levels from the 20% AEP and larger.

RECOMMENDATIONS

► No modifications of existing major structures were identified as suitable for flood mitigation in the study area. As such, channel 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

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the 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, such as those situated in the Ourimbah Creek catchment, environmental legislation, land ownership and funding limits any opportunities for creek clearing and vegetation management.

DISCUSSION

The community questionnaire (see Section 4.1) highlighted the community's concerns about creek channel maintenance in relation to both structure and creek channel blockage.

Structure Blockage

Blockage of structures throughout the Ourimbah Creek catchment has been mentioned by the community questionnaire respondents. Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively the implementation of trash racks or bollards upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. An indicative cost is

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$5,000 to $20,000 per item.

Creek Channel Maintenance

Clearing of the creek channel to increase flow conveyance was also recommended by the community. This was investigated using the hydraulic model with the channel roughness reduced to simulate channel clearing through vegetation management. The Mannings 'n' values of the creek channel reduced by 0.03 may be achievable through vegetation management. It was found that peak flood levels reduced by up to 0.5 m, however peak flood levels downstream of the Pacific Motorway generally increased by ~0.1 m.

Large scale clearing of the creek channel is not possible, however isolated areas of channel maintenance could be achieved. Two locations were identified where vegetation management could provide significant reductions to upstream peak flood levels:

- Option FM11 - Upstream Pacific Motorway vegetation management area; and
- Option FM12 - Sohier Park vegetation management area.

Details of both of these investigated vegetation management Options are presented in the following sections.

9.2.6.1. Option FM11 – Upstream Pacific Motorway Vegetation Management Area

The Option FM11 area is situated on Ourimbah Creek upstream of the Pacific Motorway and required the maintenance of 20 hectares of densely vegetated land, represented by the red polygon in Image 6.

Image 6: Option FM11 - Modelled Extent of Vegetation Management (Mannings reduced)

Image source: Google Earth

The 10% and 1% AEP events were modelled with the reduced roughness implemented and the results were compared to the design results. It was found that channel clearing and vegetation

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management associated with Option FM11 is not suitable as a mitigation option for the following reasons:

- Increased peak flood levels downstream were found to adversely affect residential properties;
- Areas which experienced significant decreases in peak flood levels were typically still flooded by depths in excess of +2 m, even in the 20% AEP event;
- Little benefit was experienced in terms of reductions in over floor flood liability;
- The environmental cost of clearing a natural channel is significant;
- Clearing of native vegetation is generally not able to be achieved due to environmental policies;
- Vegetation management would need to be ongoing and would have significant long term annual costs (+$25,000 / year);
- OEH noted that this area has an ongoing vegetation regeneration program which is in conflict with clearing vegetation; and
- Much to this land is private property and Council does not have the right to undertake these works.

9.2.6.2. Option FM12 – Sohier Park Vegetation Management Area

Option FM12 modelled the impact of creek clearing and vegetation management of Bangalow Creek near Sohier Park. Option FM12 required the maintenance of 3 hectares of densely vegetated land, represented by the red polygon in Image 7.

Image 7: Option FM12 - Modelled Extent of Vegetation Management (Mannings reduced)

Image source: Google Earth

The 1% AEP event was modelled with the reduced roughness implemented and the results were compared to the design results. It was found that whilst decreases in peak flood level of up to 0.2 m were achieved, no properties benefited from these works. Council also noted that much of this land is private property and Council does not have the right to undertake these works without the negation of land purchase or an easement.

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Due to the issues highlighted above, Option FM12 is not recommended for implementation.

RECOMMENDATIONS

► Large scale clearing of the creek channel for flood mitigation purposes is not recommended due to a lack of significant benefits achieved and due to significant economic and environmental costs.

► Previously Gosford City Council introduced vegetation and silt management schemes throughout its completed flood mitigation works. These should be maintained and expanded where possible. However it is acknowledged that these schemes are costly for Councils to operate and must be continued forever to be effective. These schemes are welcomed by the residents.

9.2.7. Retarding Basins

DESCRIPTION

Retarding basins work by storing and controlled release of runoff after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate 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, 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 (see Section 4.1) requested that retarding basins be examined for various locations in the study area. Retarding basins were typically not found to be suitable for flood mitigation in the catchment for the following reasons:

- Local topography was not suitable for construction of a basin (the majority of locations fell into either of these two categories);
    - If the floodplain is too narrow and steep, a basin's embankment must be excessively high in order to achieve enough volume behind the embankment to attenuate the flood peak; or

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  - If the floodplain is too wide, the basin wall must be excessively long (i.e. the width of the floodplain) to form a basin.
- The basin volume must be large enough such that it can attenuate flows for the upstream catchment. Basins with a large upstream catchment area must be very large to have enough volume to attenuate the flood peak. This can lead to an excessively large area of new flooded land within the basin; and
- The location of a basin should not be such that increased flood levels affect sensitive land uses (i.e. residential properties) within the basin.

Taking the above into account, only one location (Option FM13) was trialled to test suitability for implementation of a basin.

9.2.7.1. Option FM13 – Cut Rock Creek Basin

Option FM13 modelled the implementation of a basin on Cut Rock Creek in the area situated upstream of Cutrock Road. The existing road alignment currently acts as a basin with the road forming a barrier leading to the attenuation of flows that do not over top the road. The Option FM13 basin raises the existing road alignment by 1.5 m on average (including 0.5 m freeboard) over a length of 750 m. The existing culverts under Tuggerah Street (2 x 1.05 m Ø and 1 x 0.9 m Ø) and Cutrock Road (2 x 1.2 m Ø) were not modified.

Option FM13 was modelled for the 1% AEP event with the impact on peak flood levels presented in Figure D 6. Option FM13 reduces 1% AEP peak flood levels by up to 0.1 m downstream of the basin which benefits properties at the Tall Timbers estate and on Lisarow Street (key areas mentioned in the Brief for analysis, see Section 2.3). However, these benefits are minor when considering over floor flood affectation as the majority of properties in these areas are not flooded over floor until events larger than the 0.5% AEP.

An indicative cost of implementation of Option FM13 is estimated to be $4.8 million. The reduction in AAD associated with Option FM13 is $1,000, indicating a B/C ratio of less than 0.1. Due to the low B/C ratio Option FM13 is not recommended, however this basin also serves to improve flood access (see Section 9.3.1) by providing flood free access in the 1% AEP event for areas to the east of Cut Rock and Bangalow Creeks. Raising of this section of road to improve flood access may be beneficial as a risk mitigation method and is examined further in Section 9.3.1.2.

A preliminary concept design for Option FM13 is contained in Appendix E.

RECOMMENDATIONS

► Retarding basins were not found to be suitable for flood mitigation in the study area.

► However, Option FM13 has been considered for further investigation in combination with Option FM8 (see Section 9.2.3.1) to examine if this could achieve improved reductions in peak flood levels downstream. The combined Option FM13 / FM8 is investigated as Option FM14 in Section 9.2.8.

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9.2.8. Option FM14 – Combined Channel and Basin

DESCRIPTION

Various flood mitigation measures were investigated to reduce flood affectation in the Ourimbah Creek catchment. No single flood mitigation works was found to be suitable and accordingly combinations of the previously mentioned Options have been investigated. Option FM14 was investigated as the combination of two options, namely:

- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1); and
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1).

DISCUSSION

Option FM14 aimed to reduce flood affectation of properties at the Tall Timbers estate and for Cut Rock Creek between the Pacific Highway and Teralba Street (key areas mentioned in the Brief for analysis, see Section 2.3). A preliminary concept is provided in Appendix E (Figure E 2).

The reduction in peak flood level associated with modelling of Option FM14 for the 1% AEP event is presented in Figure D 7. Results indicate that the combination of these Options significantly reduces flood levels. However, these benefits are generally minor when considering over floor flood affectation as the majority of properties in these areas are not flooded over floor until events much larger than the 0.5% AEP.

Table 17 presents the benefits that Option FM14 provides in terms of reduced property flood affectation (yard and above floor) and the associated reduction in damages. Property yard inundation is significantly reduced with implementation of this Option with 16 fewer yards inundated during the 1% AEP event, however as noted, reductions in over floor flood liability is limited.

Table 17: Option FM14 – Reduction in Property Flood Affectation and Flood Damages

Event	No. Properties No Longer Flooded	No. of Properties No Longer Flooded Over Floor	Reduction in Damages for Event
20% AEP	2	0	$ 4,000
10% AEP	9	0	$ 24,000
5% AEP	13	0	$ 53,000
2% AEP	11	1	$ 67,000
1% AEP	16	1	$ 208,000
0.5% AEP	24	3	$ 331,000
PMF	-	-	$ 0
Average Annual Damages (AAD) Reduction			**$ 9,000**

The damages assessment was undertaken to determine the B/C ratio for implementation of Option FM14. An indicative cost of implementation of the Option FM14 is estimated to be $5.0 million, with the Option expected to provide a $9,000 reduction in AAD. By estimating the expected damages for the next 50 years assuming implementation of this Option a B/C ratio of 0.1 has been calculated indicating that the option is financially unfeasible.

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Whilst Option FM14 was found to not provide a monetary benefit, it does provide a reduction in risk to life. The Option FM13 embankment would significantly improve flood access (see Section 9.3.1) and implementation of the Option significantly reduces flood levels and velocities in the area surrounding Lisarow Street (a key area mentioned in the Brief for analysis, see Section 2.3). This region is currently flooded during events smaller than the 20% AEP and experiences high hazard flows (H3 and H4 classifications, see Section 6.2) during the 1% AEP flood restricting safe flood access. With implementation of this Option, flood depths outside of the channel proper are less than 0.1 m for events up to and including the 5% AEP flood. Flood hazard is also substantially ameliorated with existing 1% AEP flood hazard classifications reduced to predominantly H1 allowing safe evacuation for both pedestrians and vehicles. The reduction in flood hazard is presented in Image 8.

Image 8: Reduction in 1% AEP Hazard with Implementation of Option FM14

An analysis of flood impacts indicates that as with Option FM8, increases in peak flood level at residential properties are experienced downstream of the diversion channel.

RECOMMENDATIONS

► The increases in peak flood level to properties, coupled with the high cost of construction and low B/C ratio make Option FM14 (combination of Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1) and Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1)) unfeasible.

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9.3. Response Modification Measures Considered

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

Fourteen road crossings have been investigated as indicated in Section 9.3.1 together with the following other response modification measures:

- Automatic Road Closures and Boom Gates (Option RM15) (Section 9.3.2.1);
- Warning Signs (Option RM16 and RM17) (Section 9.3.2.2);
- Camera Fines (Option RM18) (Section 9.3.2.3);
- Potential Gauges for Flood Warning (Options RM19 and RM20) (Section 9.3.3.2);
- Opportunities for Increasing Available Warning Time (Options RM21 and RM22) (Section 9.3.3.6);
- Opportunities for Reducing Required Warning Time (Options RM23 and RM24) (Section 9.3.3.7);
- Shelter-in-place Feasibility Assessment (Option RM25) (Section 9.3.3.8);
- Flood Emergency Management Planning (Options RM26, RM27, RM28) (Section 9.3.4);
- Create a SES Flood Intelligence Card for Lees Bridge (Option RM29) (Section 9.3.4.3);
- Emergency Response Plans (Options RM30 and RM31) (Section 9.3.4.4);
- Community Flood Education (Option RM32) (Section 9.3.5).

9.3.1. Improved Flood Access

DESCRIPTION

As described in Section 3.1 with details provided in Section 6.4 and on Table 11 (locations shown on Figure 1 a to j), flooding of key access roads is a major concern for the study area. Flooded roads pose a significant risk to life and hinder effective emergency response. Improving flood access can significantly improve a community's response to flooding.

DISCUSSION

Improving flood access was considered throughout the catchment but was found to be unsuitable for many areas due to the following reasons:

- Many of the access roads would need to be raised in excess of 2 m over a very long distance to significantly improve flood access. For example, to provide flood free access on Ourimbah Creek Road, the road would need to be raised by 1 to 3 m for over 5 kilometres to achieve flood free access in the 20% AEP event;
- In many locations, large increases in flood levels associated with road raising can affect residential properties. Access roads in and out of Chittaway Point (Geoffrey and Chittaway Roads) as well as Palmdale Road are locations where road raising would lead to significant impacts on peak flood levels. Culvert and bridge design could ameliorate this, however implementation of sufficient structures would greatly increase costs; and
- Road construction and design would be highly expensive.

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The Cut Rock Creek and Bangalow Creek floodplains were found to be most suitable for improvements to flood access roads.

Raising of key access roads could potentially improve flood access and increase the safety and trafficability of access roads to allow safe access and egress for residents to their homes. Access to the University of Newcastle Ourimbah Campus could also be improved. Improvements to flood access roads at key locations could potentially address many of the issues highlighted as part of the key stakeholder engagement and outlined in Section 2.3.

The following roads have been investigated for flood access improvements, with details for each of these locations provided in the ensuing sections:

- Option RM1 – Tuggerah Street at the Pacific Highway (Section 9.3.1.1);
- Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park (Section 9.3.1.2);
- Option RM3 – Coachwood Drive North of Mahogany Close (Section 9.3.1.3);
- Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus (Section 9.3.1.4);
- Option RM5 – Chittaway Road near Burns Road (Section 9.3.1.5);
- Option RM6 – Howes Road, Link Road (Section 9.3.1.6);
- Option RM7 – Orchard Road, Link Road (Section 9.3.1.7);
- Option RM8 – Tall Timbers, Link Road (Section 9.3.1.8);
- Option RM9 – Burns Road Bridge (Section 9.3.1.9);
- Option RM10 – Burns Road Raising and Culvert Upgrades (Section 9.3.1.10);
- Option RM11 – Elmo Street near Footts Road (Section 9.3.1.11);
- Option RM12 – Tapley Road (Section 9.3.1.12);
- Option RM13 – Macdonalds Road near Indigo Place (Section 9.3.1.13);
- Option RM14 – Pacific Highway at Dog Trap Gully (Section 9.3.1.14).

9.3.1.1. Option RM1 – Tuggerah Street at the Pacific Highway

The Macdonalds Road exit of the Pacific Highway experiences significant flood affectation and would benefit from improving flood access (refer Image 9).

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Image 9: Tuggerah Street at the Pacific Highway (Option RM1)

RMS are currently planning for the upgrading of the Pacific Highway between Ourimbah Street (at the north end) and Parsons Road roundabout (at the southern end). The Jacobs (2014) study (Reference 12) indicates that a proposed Highway exit ramp to Tuggerah Street is to replace an existing exit ramp to Macdonalds Road. WMAwater have examined flood affectation of the proposed exit based on the above mentioned report and make the following comments:

- The exit is flooded in the 0.5EY (2 year) event and potentially more frequent events not modelled as part of the study.
- In the 20% AEP flood the exit experiences depths > 0.5 m and velocities of ~1 m/s. This is a flood hazard classification of H3 (see Section 6.2) which means that it is unsafe for all vehicles.
- In the 1% AEP flood the exit experiences depths > 1.8 m and velocities >1.5 m/s, placing flooding of the proposed exit in the H5 flood hazard classification. This poses an extreme risk to motorists.

As discussed in Section 4.2.6, WMAwater has contacted RMS in relation to this exit ramp to request that the access road be made flood free in the 1% AEP event. A letter addressed to RMS outlining this request is presented in Appendix F. The feasibility of RMS raising the proposed exit ramp was also discussed in October 2016 at meeting with engineers from Council, WMAwater, RMS and Cardno. A case was made as to why the road should be raised with RMS agreeing to investigate this option.

Pending a response from RMS, WMAwater have developed a preliminary concept design and costing for improving flood access at this location. The concept design allows for flood free access at this location during a 1% AEP flood event. The concept design details are presented in Appendix E (Figure E 1) and involve road raising and additional culverts. An indicative cost estimate for these works is $1.4 million. As an alternative a flood free footbridge could be provided however this is would involve people being outside during a flood event and this introduces other safety issues.

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9.3.1.2. Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park

Tuggerah Street north of Fagans Road and Cutrock Road west of McGrath Close is currently flooded by H2 hazard flooding in the 20% AEP, making it unsafe for smaller vehicles to use this road during this event. In the 10% AEP event, H3 flood hazard is experienced on these roads making the route unsuitable for vehicles of any kind.

Raising this section of Tuggerah Street has the potential to improve trafficability for urban areas to the east of Cut Rock Creek and to the University. Additionally, Option RM2 (refer Image 10) could potentially provide access to Tall Timbers Estate if implemented with Option RM8 (see Section 9.3.1.8).

Image 10: Tuggerah Street at the Pacific Highway (Option RM2)

WMAwater have developed a preliminary concept design and costing for improving flood access at this location aimed to allow flood free access in the 1% AEP event by incorporating the Option FM13 basin (Section 9.2.7.1) into this design. If a storage basin at this location is not the preferred option, additional culverts could be incorporated into the design such that design flood levels are not significantly affected with raising of this section of Tuggerah Street. These features could be examined in detail should improvements to flood access at this location be found to be feasible. A preliminary concept design is presented in Appendix E and involves road raising and additional culverts. An indicative cost estimate for these works is $4.8 million.

9.3.1.3. Option RM3 – Coachwood Drive North of Mahogany Close

Coachwood Drive to the north of Mahogany Close (refer Image 11) is currently first flooded in the 5% AEP event with the 2% AEP event classified as H3 flooding at this crossing making it unsafe for vehicles of any kind. Raising of this road and the addition of culverts could be implemented to improve flood access.

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Image 11: Coachwood Drive north of Mahogany Close

WMAwater have developed a preliminary concept design and costing for improvements to flood access works aimed to allow flood free access at this location during a 1% AEP flood event. The preliminary concept design details are presented in Appendix E (Figure E 3). An indicative estimate for these works is $900,000.

9.3.1.4. Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus

Shirley Street to the north of Brush Road and The Boulevard to the south of North Loop Road (refer Image 12) is currently first flooded by the 20% AEP event with H2 classification flood hazard experienced indicating a potential risk for smaller vehicles. During events exceeding the 10% AEP, a flood hazard classification of H3 is experienced meaning the vehicle access is unsafe for all vehicles. Raising of this road and the addition of culverts could be implemented to improve flood access at this location.

Image 12: The Boulevard at the University of Newcastle Ourimbah Campus

WMAwater have developed a preliminary concept design and costing for improved flood access works aimed to allow flood free access at this location during a 1% AEP flood event. The

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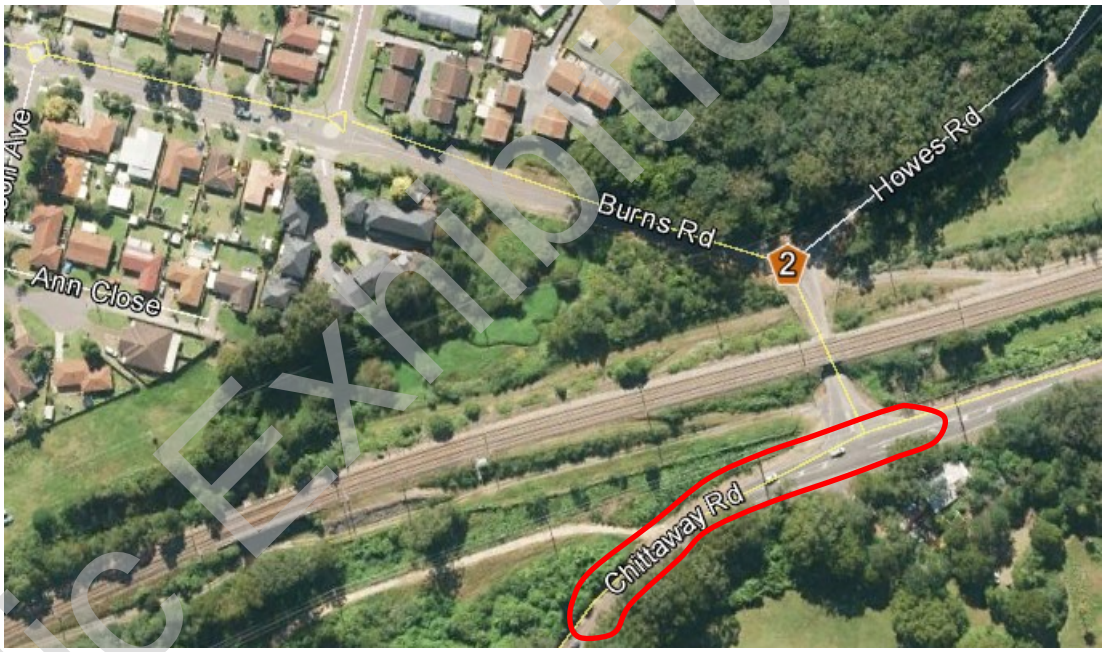
preliminary concept design details are presented in Appendix E (Figure E 4) and involve road raising and additional culverts. An indicative cost estimate for these works is $5 million.

An additional benefit of the described road raising works is the protection afforded for the carpark west of South Loop Road. Implementation of these works would lead to this carpark being flood free during the 1% AEP event.

9.3.1.5. Option RM5 – Chittaway Road near Burns Road

Chittaway Road near its intersection with Burns Road (refer Image 13) is currently first flooded in the 5% AEP event with a H1 flood hazard classification indicating that the road is still trafficable during this event. The 2% AEP event experiences a flood hazard classification of H2 indicating that vehicle access is unsafe for smaller vehicles. The 1% AEP event experiences H3 flood hazard classification. Road raising works at this location could be implemented to improve flood access.

Image 13: Chittaway Road near Burns Road



WMAwater have developed a preliminary concept design and costing for road raising works aimed to allow flood free access at this location during a 1% AEP flood event. The preliminary concept design details are presented in Appendix E (Figure E 5). An indicative cost estimate for these works is $500,000.

9.3.1.6. Option RM6 – Howes Road, Link Road

Stakeholder consultation noted that properties on Howes Road are frequently isolated due to flooding (see Section 4.2.8). Access to Howes Road is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths exceed 1 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable. Howes Road services four properties which are frequently isolated during floods.

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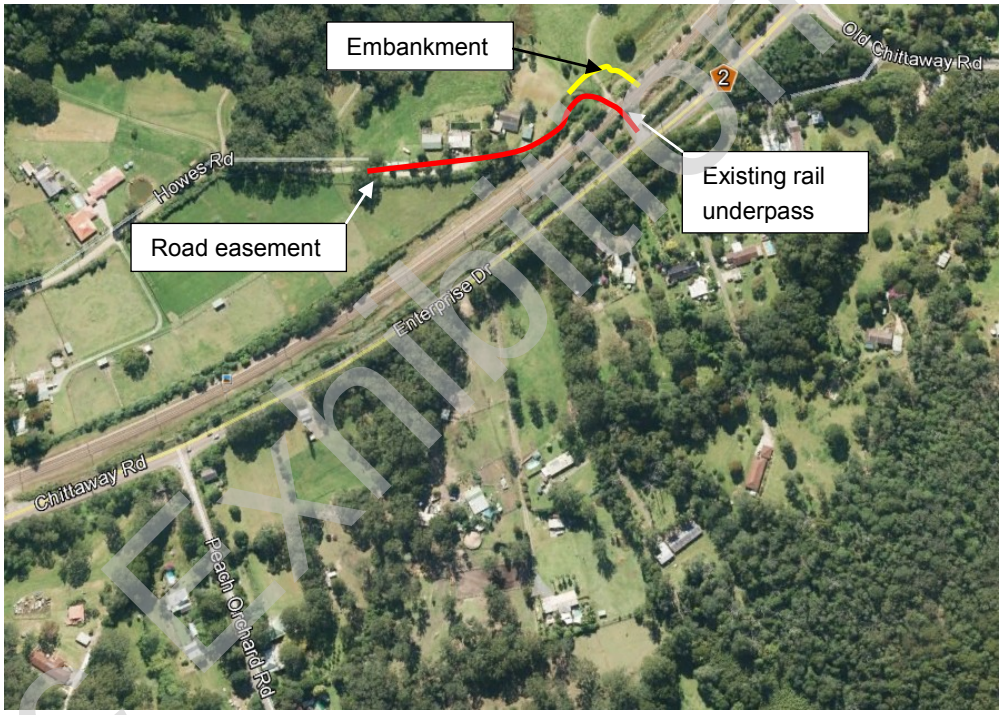
Due to the frequency at which Howes Road becomes flooded, improved flood access is a priority. Providing pedestrian access to these properties during times of flood does not significantly reduce their risk exposure. Emergency vehicle access would not be improved and there are few facilities within walking distance of these properties.

Improved flood access to Howes Road could be achieved by leveeing an existing rail underpass south of Old Chittaway Road to exclude floodwaters, and allowing for a road easement. Discussion with Transport for NSW indicated that allowing access along the rail easement during times of flood is not possible and accordingly negotiation with local residents would be required to provide for a road easement through private land. Image 14 presents the location of the suggested levee embankment and road easement.

Image 14: Howes Road, Link Road



WMAwater have developed a preliminary concept design for levee embankment and road easement works. The preliminary concept design details are presented in Appendix E (Figure E 6). An indicative cost estimate for these works is $500,000. However costs could increase significantly at the design stage after discussions with the relevant land owners (easement or land take costs) and possible geotechnical issues and service relocations.

9.3.1.7. Option RM7 – Orchard Road, Link Road

The stakeholder consultation noted that properties on Orchard, Turpentine and Ourimbah Roads are regularly isolated due to flooding of access roads (see Section 4.2.8). Due to the frequency at which these properties become isolated, improved flood access is a priority.

The proposed New Intercity Fleet Maintenance Facility (see Section 4.2.7) review of environmental factors report (June 2016, Reference 14) indicated that a link road is to be

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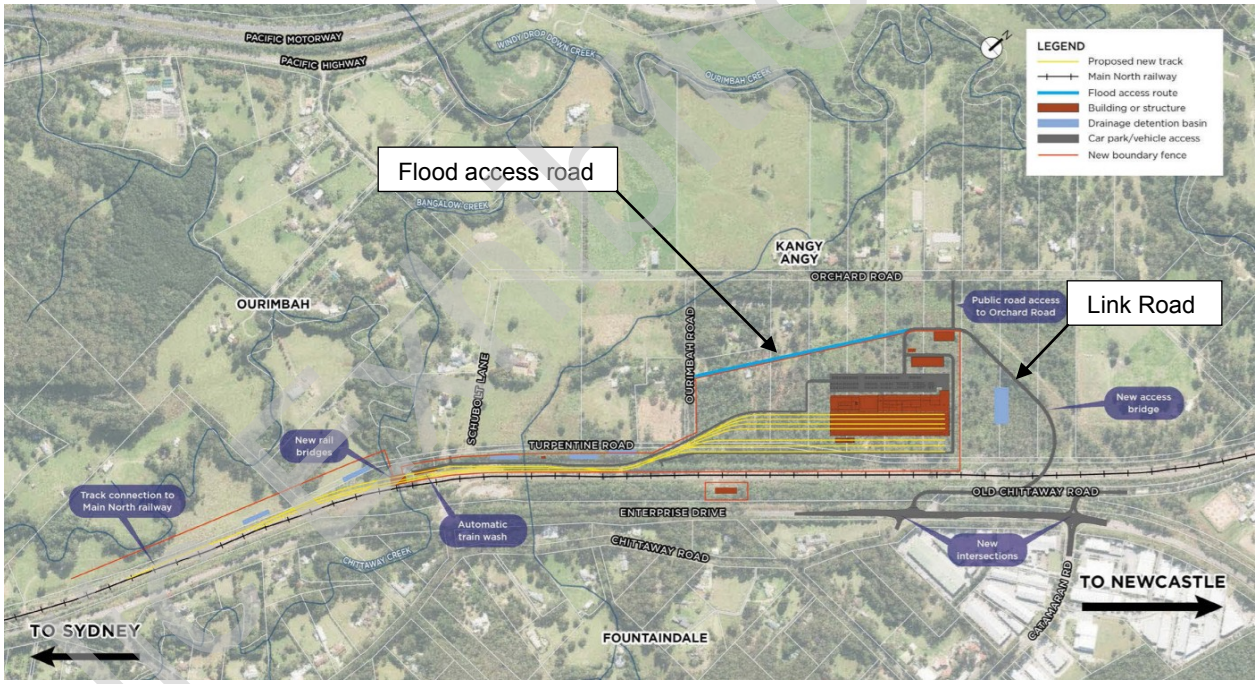
constructed that crosses the Main Northern Railway Line which allows access to the region during times of flood. It was noted even with the construction of the link road, properties to the west of the proposed facility on Turpentine and Ourimbah Roads could still be isolated during floods as the intersection of Orchard and Ourimbah Roads is flooded by in excess of 2 m during the 20% AEP event. A submission was made to Transport for NSW as part of this FRMS&P requesting that flood access issues be fully considered as part of the proposed rail facility design. Further details are presented in a letter addressed to Transport for NSW contained in Appendix F.

The most recent Facility design plans indicate that a flood access road is proposed which will allow flood access to these isolated properties. Image 15 presents the proposed concept design and flood access route. The addition of the flood access route will allow flood access to properties to the west of the Facility which is a critical outcome for Council and the local community. WMAwater support this proposal and Transport for NSW should note the importance of the proposed access road.

Image 15: New Intercity Fleet Maintenance Facility (Reference 14) – Flood Access Road



9.3.1.8. Option RM8 – Tall Timbers, Link Road

A key area of flood risk identified in the Brief (see Section 2.3) is the Tall Timbers Estate. The Tall Timbers access road is frequently flooded in minor storm events (potentially multiple times a year) however the fourteen houses have floors above the 0.5% AEP event. Thus the main issue is the risk to life with using the private access road. The duration of overtopping of the access road will vary considerably depending upon the nature of the rainfall event but could last from less than 1 hour to up to 6 hours, this duration could increase if the culverts beneath the road become blocked by debris. Image 16 displays the potential location of link road between Tuggerah Street and the Tall Timbers Estate.

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Image 16: Tall Timbers Estate and Access Road

The WMAwater 2014 study (Reference 10) found that raising the existing access road was not a suitable method of risk mitigation due to a number of reasons described in the Reference 10 report and summarised in Section 3.2.5. The Reference 10 report found that Voluntary Purchase was the option most suitable for mitigation of flood risk for these properties and Council has applied for funding as part of the Floodplain Risk Management Program.

However, the raising of Tuggerah Street and Cutrock Road near Pluim Park as described in Section 9.3.1.2 may provide an incentive for raising the existing access road to the Tall Timbers Estate due to the possibility of linking the Tall Timbers estate to flood free access even in larger events thus significantly ameliorating flood risk. Should raising of Tuggerah Street be found to be feasible, then raising of the Tall Timbers access road may be preferred to voluntary purchase for mitigation of flood risk at this location.

The cost of raising the Tall Timbers access road was examined in the Reference 10 study and was estimated to cost $1 million for a low level crossing. To further raise the road to above the 1% AEP level the indicative cost of construction is estimated to be $3 million. The Tall Timbers Voluntary Purchase scheme (see Section 9.4.2) which Council have applied for funding from the Floodplain Risk Management Program is estimated to cost $5.6 to $8 million (Reference 10). Accordingly, raising of the Tall Timbers access road may be a more financially competitive method of managing flood risk than the proposed voluntary purchase scheme. However as mentioned previously, numerous other issues associated with raising this road are noted in the Reference 10 study.

9.3.1.9. Option RM9 – Burns Road Bridge

As noted in the Brief and again in the community consultation, the Burns Road crossing of Ourimbah Creek is a particularly high hazard area subject to frequent high risk flooding. Due to

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the nearby placement of the Main Northern Railway Line, road raising cannot be used to increase flood free access at this location.

This location would significantly benefit from the construction of a rail overbridge which would allow access from the northern side of Ourimbah Creek to Chittaway Road by going over the Main Northern Railway Line. Council have discussed this issue with RMS and note that there are two locations where such a bridge may be possible; Burns Road and Yates Road. RMS has advised that a preliminary cost estimate for such a bridge is ~$100 million, and accordingly may not be feasible in the short term. However, funding for this option may be available via a State Government grant or election commitment. RMS may prefer to use Yates Road as the primary location for construction of the rail overbridge.

From a flood mitigation perspective the construction of a bridge to replace the Burns Road crossing of Ourimbah Creek is recommended. However, due to the significant cost and potential long term implementation plan a number of other solutions to minimise risk at this location have been investigated and are described in Section 9.3.2.

9.3.1.10. Option RM10 – Burns Road Raising and Culvert Upgrades

Due to the potential long term timeframe for implementation of Option RM9, Option RM10 has been investigated to assess the feasibility of improving flood access at Burns Road in the short term. Option RM10 (refer Image 17) examines raising Burns Road (between Nellie Road and Howes Road) to the level of Burns Road railway underpass invert (13.3 mAHD) and replacing the existing culverts (2 x 2.6 m x 2.4 m RCBC) with a bridge structure to maximise conveyance.

Image 17: Burns Road Raising and Culvert Upgrades

The implementation of Option RM10 is likely to improve flood access in events much smaller than the 20% AEP, however will provide little benefit in events larger than the 20% AEP event where flow is distributed across the floodplain and flood depths exceed 1 m and velocities exceed 1.5 m/s (H5 Hazard classification). Level of service estimates cannot be made as events smaller than the 20% AEP have not been modelled as part of the current study. Regardless of the size of the bridge structure under Burns Road, Burns Road will still be unpassable during events larger than the 20% AEP.

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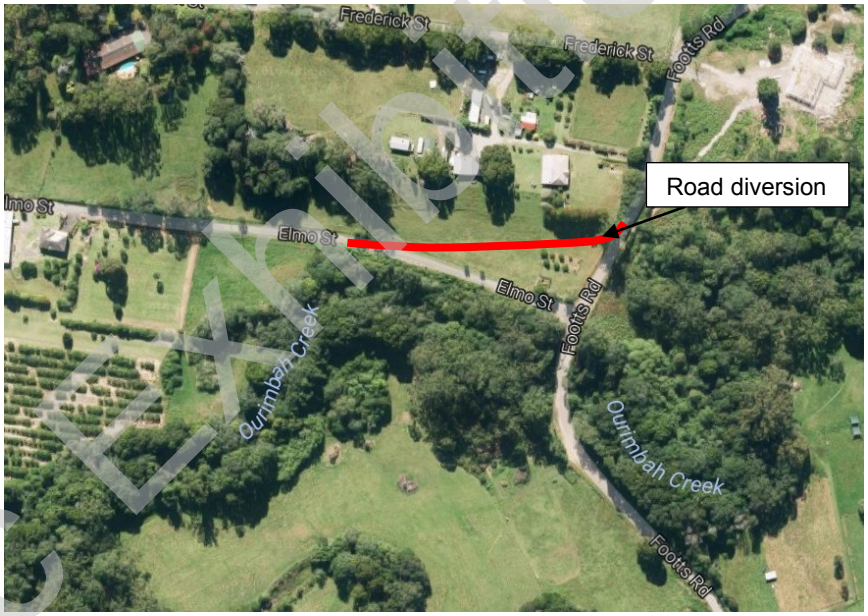
The estimated cost of implementation of Option RM10 is $3 million which is significant, particularly as the Option will be obsolete if Option RM9 is implemented. Accordingly, Option RM10 is not recommended and instead a number of other solutions to minimise risk at this location have been investigated as outlined in Section 9.3.2.

9.3.1.11. Option RM11 – Elmo Street near Footts Road

Elmo Street near Footts Road (refer Image 18) is significantly affected during flood. Access along Elmo Street is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths exceed 2 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable. Due to the frequency at which the road becomes flooded, improved flood access is a priority.

Relocation of approximately 120 m of Elmo Street away from areas frequently flood affected could be implemented to improve flood access at this location.

Image 18: Elmo Street near Footts Road – Road Diversion



The adjusted alignment of Elmo Street would require the road to be diverted onto privately owned land. As part of the detailed design, a land-swap could potentially be negotiated with the adjacent landowner. An indicative cost estimate for these works is $250,000.

9.3.1.12. Option RM12 – Tapley Road

Tapley Road south of The Ridgeway (refer Image 19) is significantly affected during flood. The road provides access for approximately 50 rural properties and is cut about once every two years. Alternative access is available via Maidens Brush Road (unsealed) towards Wyoming.

Access along Tapley Road is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths of 1 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable.

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Due to the frequency at which the road becomes flooded, improved flood access is a priority.

Image 19: Tapley Road – Road Raising and Culvert Upgrades

For implementation of Option RM12 the raising of ~50 m of road and the enlargement of existing culverts is required. An indicative cost estimate for these works is $80,000.

9.3.1.13. Option RM13 – Macdonalds Road near Indigo Place

Macdonalds Road near Indigo Place allows access to Lisarow Public School and several rural properties (refer Image 20). The road is untrafficable in events as small as the 20% AEP. Due to the frequency at which the road becomes flooded, improved flood access is a priority.

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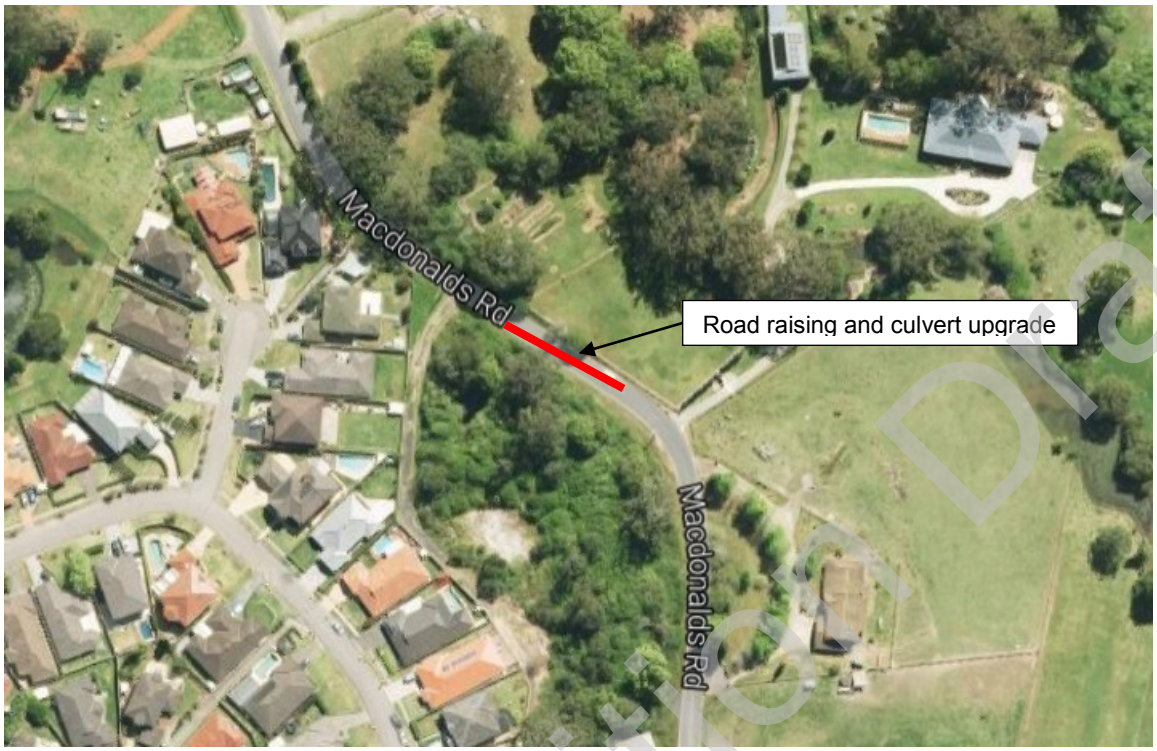
Image 20: Macdonalds Road near Indigo Place – Road Raising and Culvert Upgrades



Option RM13 examines implementation of the raising of ~40 m of road and the enlargement of existing culverts. An indicative cost estimate for these works is $150,000.

9.3.1.14. Option RM14 – Pacific Highway at Dog Trap Gully

The Pacific Highway crossing of Dog Trap Gully (refer Image 19) can be significantly affected during floods with depths of up to 0.6 m experienced in the 20% AEP event. Flooding of this key access road would create major traffic disruption.

Design flood modelling assumed 50% culvert blockage which would affect the frequency and depth of flow over the Pacific Highway. To reduce the amount of blockage, debris control structures should be installed upstream of the structure.

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Image 21: Pacific Highway – Installation of Debris Control Structures

An indicative cost estimate for implementation of Option RM14 is $50,000.

RECOMMENDATIONS

► Investigate the feasibility of improving flood access at various roads (Options RM1 to RM14) and implement when funding becomes available.

► Investigate implementation of Option RM8 (Tall Timbers link road, Section 9.3.1.8) as an alternative to voluntary purchase for Tall Timbers Estate.

9.3.2. Road Closures, Early Notifications and Creek Crossing Deterrents

DESCRIPTION

As noted throughout this report, frequent flooding of access roads is one of the largest contributors to flood risk in the catchment. A list of flooded access roads is presented in Section 3.1, 6.4 and on Figure 1. To mitigate risk associated with motorists using flooded roads, road closures and early notification of these closures, warning signs, depth mark indicators and notification of alternate access routes are recommended.

DISCUSSION

9.3.2.1. Automatic Road Closures and Boom Gates (Option RM15)

Due to the flash flood nature of the Ourimbah Creek catchment (see Section 9.3.3.3), early warning time for road closures are typically not available. Currently, road closures are only implemented by Council and 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 flood risk. In

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response to the limited available warning times, automatic road closures are recommended through either of the following methods:

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 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 (see Section 4.2.5 for gauge installation costs).

2. Prototype 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. It is presumed that the gates can be accessed by emergency vehicles should that be required to rescue people.

Specific roads that are recommended for installation of automatic boom gates are listed below in order of their benefit in the reduction of flood risk:

- Burns Road, Ourimbah (gates near the Nelle Road and Chittaway Road intersections);
- Shirley Street, Ourimbah (gates near the Mill Street and The Boulevard intersections);
- Chittaway Road, Ourimbah (gates near the Brownlee Street and The Boulevard intersections);
- Footts Road Bridge, Ourimbah (gates near the Ourimbah Creek Road and Frederick Street intersections); and
- Tuggerah Street, Lisarow (gates near the Macdonalds Road and Baileys Road intersections).

The appropriate gauges used to provide warning of an impending flood and to inform trigger levels for each of the roads mentioned above are presented below:

- The Burns Road, Shirley Street and Chittaway Road boom gates require the installation of a stream gauge near the University between Shirley Street and Chittaway Road. MHL can assist in the installation and maintenance of this gauge and determination of trigger levels as per that outlined in Section 4.2.5. This stream gauge could also be used by the University to notify of potential flooding of the lower carpark (see Section 9.2.1.4).
- The existing Ourimbah Creek at US Weir gauge (211013) could be used to provide warning and trigger levels for proposed boom gates at the Footts Road crossing; and
- If improved flood access for the Pacific Highway Tuggerah Street exit is not found to be feasible (see Section 4.2.7), thought should be given to installing automatic boom gates and warning signs at the proposed exit. The Council owned gauge at Tall Timbers or the RMS Lisarow wetlands gauges (see Section 9.3.3.2) could be used to provide warning of an impending flood. Alarming these gauges could also be used to notify Council, SES and RMS when roads are cut.

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In addition to the installation of automatic boom gates, flashing warning signs that initiate once a trigger level is exceeded should also be implemented at these locations. To further reduce risk, flood affected roads should not only be closed at the affected creek crossing, but also warning signage be implemented at the turnoff to the affected road. Early notification and warning of closed creek crossings would allow motorists to select another route thus avoiding the creek crossing entirely.

There are possible negative consequences of constructing boom gates (vandalism, failure to obey, provokes frustration if not raised immediately after the event) and these would need to be canvassed prior to implementation.

An assessment of the implementation of Automatic Road Closures and Boom Gates as a flood risk mitigation option is examined in the Management Plan with the reference name Option RM15.

9.3.2.2. Warning Signs (Option RM16 and RM17)

The large number of flood affected roads in the Ourimbah Creek catchment (see Section 6.4) makes closing all roads during times of flood difficult. Additionally, residents who live in areas to which access roads are frequently flood affected may resent road closures, particularly if they are in a large vehicle which is able to cross the flood affected road even once a trigger level has been exceeded (trigger levels would need to be set relatively low to ensure that smaller vehicles could safely pass). Roads which are not key access roads and only service a small local community, may not need to be closed in times of flood as local resident's often understand the flood risk associated with their local road. Instead of road closures, automatic flashing warning signs (triggered by the gauges described in Section 9.3.2.1) and early notification of flooded roads are recommended. Early notification of road closures allow the community to make early informed decisions in regards to route selection during times of flood.

<u>Automatic Warning Signs and Depth Indicators (Option RM16)</u>

Specific locations that are recommended for installation of automatic warning signs and depth indicators are listed below in order of their benefit in the reduction of flood risk:

- Burns Road Ourimbah Creek crossing;
- Turpentine Road at the Main North Railway Line;
- Palmdale Road Ourimbah Creek crossing;
- Pacific Highway near Dalgety Road;
- Geoffrey Road (near Church Road)
- Elmo Street (near Footts Road);
- Chittaway Road (between Aston Wilde Avenue and Oberon Road);
- Chittaway Road (near Lakedge Avenue); and
- Old Chittaway Road (near Enterprise Drive).

Automatic flashing warning signs are estimated to cost approximately $20,000 per location not including the cost of the gauge (see Section 4.2.5 for gauge installation costs), and depth indicators are estimated to cost $5,000 per location.

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An assessment of the implementation of Automatic Warning Signs and Depth Indicators as a flood risk mitigation option is examined in the Management Plan with the reference name Option RM16.

Early Notification of Road Closures (Option RM17)

The early notification of road closures are particularly beneficial as it allows motorist to select another route thus avoiding a flooded creek crossing entirely. Specific locations that are recommended for installation of early notification of road closure signs are listed below:

- Pacific Motorway to the north and south of Pacific Motorway/Highway interchange – used to divert traffic away from Burns Road during times of flood;
- Pacific Highway near Parsons Road (north bound lanes) – used to provide early notification of road closures at Tuggerah Street, Shirley Street, Chittaway Road and Burns Road;
- Pacific Highway north of Burns Road (south bound lanes) – used to provide early notification of road closures at Tuggerah Street, Shirley Street, Chittaway Road and Burns Road.

WMAwater contacted RMS to investigate if the Pacific Motorway/Highways VMS could be used as a means of early notification of road closures. Liaison with RMS indicated that whilst it is possible to use the VMS for this purpose, it is not recommended as RMS would prioritise RMS warning messages over those of flooded road closures. Accordingly, it could not be guaranteed that notification of flooded roads would be displayed to commuters. In place of the VMS, RMS noted that they are open to discussion with Council about the possibility of installing signage within the RMS owned road easements. Additional signage is estimated to cost approximately $25,000 per sign not including the cost of the gauge (see Section 4.2.5 for gauge installation costs).

An assessment of the implementation of the Early Notification of Road Closures as a flood risk mitigation option is examined in the Management Plan with the reference name Option RM17.

9.3.2.3. Camera Fines (Option RM18)

As a further deterrent for motorists that insist on using the Burns Road crossing during times of flood, a flood camera could be installed which photographs vehicles using the crossing when the road is closed. Fines and demerit points may increase the incentive not to use this crossing at times of flood. The Queensland State Government have implemented this strategy with some success in a number of LGAs in Queensland.

A flood camera and associated fines could potentially reduce the number of motorists using Burns Road during times of flood and significantly reduce risk to life. Flood cameras could also be installed at other locations where motorists often ignore road closures.

The implementation of a flood camera is estimated to cost $75,000. Revenue raised by fines could be used to pay for the operational costs of the camera.

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RECOMMENDATIONS

► Implementation of automatic boom gates (RM15) to close identified high risk roads during times of flood (see Section 9.3.2.1).

► Implementation of automatic warning signs (RM16 and RM17) at various identified locations (see Section 9.3.2.2).

► Council/RMS liaise with the aim of implementing early notifications of road closure signage (RM16 and RM17) on the Pacific Motorway and Pacific Highway (see Section 9.3.2.2).

► Council and the SES undertake a feasibility assessment for installing a flood camera (RM8) on Burns Road (see Section 9.3.2.3).

9.3.3. Flood Warning and Emergency Response Strategies

9.3.3.1. General Considerations

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 19). Evacuation should be the primary strategy where the available warning time and resources permit (Reference 19). 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.

9.3.3.2. Potential Gauges for Flood Warning (Options RM19 and RM20)

Various rainfall and stream gauges situated in the catchment have the potential to provide real-time rainfall and river level recordings. These gauges have been described in the Flood Study and are listed below:

- Rainfall Gauges:
    - Kulnura - #561078;
    - Peats Ridge (Waratah Road) - #61351;
    - Lisarow at Fagans Road - #561079;
    - Mardi Dam at Old Maitland Road - #561082; and

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  - Narara - #561085.
- Stream Gauges:
  - Ourimbah Creek at US Weir - #211013;
  - Ourimbah Creek DS of Bangalow Creek - #211015;
  - Ouirmbah Creek at Lees Bridge - #211425;
  - Lisarow at Fagans Road - #242464;
  - Tall Timbers private access road gauge; and
  - Lisarow Swamp RMS gauge for Pacific Highway Upgrade.

Typically real-time rainfall and stream gauge information can be used for flood warning, however as discussed in Section 9.3.3.3, even rainfall gauges cannot be used to provide enough warning time for the safe evacuation of the majority of residents due to the flash flood nature of Ourimbah Creek catchment. However as discussed throughout this report, the frequent flooding of access roads is one of the largest contributors to flood risk in the study area. To minimise the risk associated with motorists entering floodwaters, automatic road closures are recommended using boom gates and telemetry technology. Stream gauges can be used to provide reliable information about the depth of flooding above a road crossing allowing closure of this road.

Each of the stream gauges listed above can be linked to automatic boom gates or warning signs as well as to notify Council, RMS and the SES once a predefined threshold has been exceeded. This would allow these agencies to act and perhaps send personnel to man the flood affected creek crossing or notify RMS so that warning messages could be displayed on the VMS.

For example, the Tall Timbers Estate access road gauge was recommended for installation as part of the Reference 10 study. The gauge was installed in 2014 approximately 20 m upstream of the Tall Timbers Estate access road and continuously records water level and provides automatic warning via telemetry methods to local residents if various thresholds are exceeded. Specifically, warnings are issued when flood levels at the private access road to the Tall Timbers Estate:

- Exceed a height that is 0.25 m below the road crest height;
- Exceed 0.25 m above the road crest height; or
- Are receding.

An assessment of the feasibility of use of these gauges to assist in flood risk management is examined in the Management Plan with the reference name Option RM19.

<u>Additional Gauges Recommended for Installation (Option RM20)</u>

An additional gauge is recommended for installation on Bangalow Creek at the University of Newcastle Ourimbah Campus (The University Gauge). This gauge would be required for triggering the proposed automatic boom gates on Burns Road, Shirley Street and Chittaway Road and could also be used by the University to notify of potential flooding of the lower carpark (see Section 9.2.1.4). An assessment of the installation of a gauge at the University as a flood risk mitigation option is examined in the Management Plan with the reference name Option RM20. It is proposed that the installation and responsibility for maintenance of the gauge would be undertaken by the University.

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9.3.3.3. Evacuation Feasibility Assessment - Available Warning Time

The feasibility of evacuation from each of the Ourimbah Creek Flood Precincts (see Section 3.1) has been evaluated. The first consideration is available warning times.

Available warning times for flooding due to Ourimbah Creek and its tributaries are short due to the small catchment sizes. Accordingly, these catchments are classified as 'flash flood' catchments where the provision of an effective flood warning service is problematic.

Several challenges to an effective flood warning service have been identified for flash flood catchments (References 20 and 21):

- Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models.
- For flash floods, there is little time to develop reliable flood warnings and for effective dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness and readiness.
- A reliance on rainfall triggers increases the frequency of false alarms.
- The use of water level triggers may not allow sufficient time for response.

For these reasons, the BoM traditionally has not issued specific flood predictions for flash flood catchments. But it does provide more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding:

- General weather forecast. This may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours' notice.
- Flood Watch. This is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours' notice that flooding is possible based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.
- Severe Weather Warning. This is issued for synoptic scale events when torrential rain and/or flash flooding (or other hazardous phenomena) are forecast.
- Severe Thunderstorm Warning. This is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation.

NSW SES may issue Local Flood Advices for locations like Ourimbah not covered by BoM Flood Warnings. For example, during intense rainfall events (e.g. June 2016), notification of SES warnings listed above were made on the Wyong and Gosford SES units Facebook page and on the NSW SES Twitter account.

To add further difficulty to understanding and calculating available warning time, the Ourimbah Creek catchment is composed of numerous smaller tributaries (see Section 9.3.4) which significantly impact on warning times. For example the peak flood level recorded at the Ourimbah Creek at US Weir gauge (211013) can often occur after the peak flood level achieved at the Pacific Motorway situated 7 to 8 km downstream. This is due to the addition of flows from Canada Drop Down Creek immediately upstream of this location. A similar situation arises on

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the Ourimbah Creek floodplain between the Pacific Motorway and Wyong Road (see Section 3.1) where peak flood levels are impacted by contributions from Bangalow Creek and thus the flood peak can again occur prior to that recorded at Gauge #211013. Again, predicting the timing of peak flood levels relative to a particular upstream location is difficult due to the contribution of flows from various sources.

Due to the difficulties described above (short flood travel times and poor correlation of timing and flood levels at different locations) using stream gauges (see Section 9.3.3.2) to provide warning of an impending flood event is not suitable. Instead design rainfall has been analysed to investigate if rainfall gauges could be used to provide advanced warning of an impending flood event.

The available warning time for various locations within the study area from the time of peak rainfall for various durations is presented in Table 18. These timings have been extracted from the Flood Study hydrologic model for the 1% AEP event. Other design events of varying AEP were also examined. However differences in the timing of peak flood levels did not vary significantly with the exception of the PMF which was slightly quicker (4 hours to Wyong Road).

Table 18: Available Warning Time to Flood Peak From Recorded Rainfall Above a Threshold

Location	Creek	2 Hour Event (hours)	9 Hour Event (hours)	48 Hour Event (hours)	Estimated Available Warning Time
Stream Gauge (#211013)	Ourimbah	4.9	4.2	11.5	4.5
Pacific Motorway	Ourimbah	5.4	4.0	11.1	4.5
Kangy Angy	Ourimbah	5.1	4.1	11.3	4.6
Wyong Road	Ourimbah	5.9	5.0	12.0	5.4
Tall Timbers Gauge	Cut Rock	2.8	2.1	9.0	2.4
University of Newcastle	Bangalow	2.7	2.1	8.9	2.3
Burns Road	Bangalow	2.7	2.1	9.2	2.3

The warning times presented above are short, particularly in the context of flooded roads which are a key issue of concern in the study area (see Section 6.4). In the majority of cases key access roads would already be flooded when notification of an impending flood event is issued and typically 1 to 2 hours should be removed from the Estimated Available Warning Time (see Table 18) to determine the time available to evacuate before vital roads are flooded and road access is lost.

9.3.3.4. Evacuation Feasibility Assessment - Required Warning Time

There is no formal BoM flood warning for the Ourimbah Creek catchment as the response time is too short. Thus at present residents are made aware of potential flooding through the following methods;

- BoM weather warnings;
- the media (radio, internet, TV);
- own interpretation of the local weather conditions based on historical knowledge;
- SMS texts (for some residents only).

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Any additional warning will improve the potential for residents to further minimise damages and the risk to life. Gosford City Council received a grant from OEH to undertake a Storm and Flood forecasting study for its LGA which is intended to improve and convey warning to customers and the community. Flood warning apps have already been developed in Australia and overseas (UK) to provide information about potential flooding. In Australia these will be developed further by the BoM and / or other authorities and are recommended as an efficient and cost effective means of conveying flood information.

For evacuation to be feasible, the available warning time must exceed the required warning time (see Section 9.3.3.3). The required warning time may be assessed by protocols set out in Reference 22 and since formalised in a *Guide for Using the SES Timeline Evacuation Model Standard Tool*. Calculations for this assessment for the four Flood Precincts described in Section 3.1 and displayed in Figure 1 are set out in Table 19. The time required for the evacuation of all flood affected properties during the PMF was assessed.

Using the NSW SES Timeline Evacuation Model tool suggests that between 5 and 49 hours (see Table 19) would be required to fully evacuate the various Flood Precincts (Section 3.1) in the catchment. This is including standard allowances for warning acceptance, warning lag and traffic safety factors (see Table 19), however this does not include allowances for mobilisation of NSW SES personnel, for the decision to issue an Evacuation Order or for dissemination of the Evacuation Order, which adds to the time required.

The calculations presented in Table 19 are based on a number of assumptions, and the results are very sensitive to the number of doorknocking teams available. The area is serviced by the Wyong and Gosford SES units (see Section 9.3.4). If flooding is threatening in the Ourimbah catchment, it will very likely be threatening in other local catchments as well (for example the Wyong River), and it is unclear how many volunteers would be available for doorknocking in the Ourimbah Creek catchment. Accordingly, it has been assumed that only two teams (eight total for the four Flood Precincts) will be available for door-knocking for each of the Flood Precincts identified in Section 3.1. A method of rapid dissemination (e.g. SMS alerts when water reaches a pre-determined level or rainfall exceeds a predefined threshold) could avoid the need for doorknocking, but experience indicates that personal engagement through doorknocking is a more effective means of persuading people to act and is an appropriate basis for assessing warning delivery time (Reference 22). The SES recommends allowances of one hour for people to accept a warning, another hour for people to prepare to evacuate and another hour (depending on the number of vehicles) for traffic safety. Examination of Table 19 indicates that even assuming a method of rapid dissemination could be employed, to avoid the need for doorknocking (thus removing the Warning Delivery time, see Table 19), required warning times range between 3 and 6 hours to evacuate the various risk precents of the Ourimbah Creek catchment during a PMF event (see Table 19).

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Table 19: Evacuation Timeline Model Calculation for Flood Precincts Defined in Section 3.1

Time required to evacuate	D/S Wyong Rd	Pacific Motorway to Wyong Rd	U/S Pacific Motorway	Cut Rock & Bangalow Creeks	Data source
Number of vehicles					
Residential					
Number of dwellings	1041	62	45	412	WMAwater
Vehicles per dwelling	2	2	2	2	Census
Residential vehicles	2082	124	90	0	Calculated
Commercial					
Number of business premises	6	132	0	29	WMAwater
Vehicles per business	10	10	10	10	Estimate
Commercial vehicles	60	1320	0	290	Calculated
Total vehicles (TV)	2142	1444	90	290	Calculated
Evacuation route					
Number of lanes (various routes)	2	8	1	3	Maps
Evacuation route capacity (RC) (veh/hr)	800	3200	400	1200	SES
Warning Delivery (WD)					
# properties at 5 minutes per home assuming 2 teams	44	8	2	18	SES
Evacuation timing (hrs)					
Warning acceptance factor (WAF)	1	1	1	1	SES
Warning lag factor (WLF)	1	1	1	1	SES
Travel time (TT) =TV/RC	3	0.5	0.2	0.2	Calculated
Traffic safety factor (TSF)	1	1	1	1	SES
Total time required to evacuate (TR) = WAF+WLF+TT+TSF+WD	**49**	**12**	**5**	**22**	**Calculated**
BoM forecast time	0	0	0	0	BOM
Warning Time to Road Access Cut	3	2	2	1	Calculated
Total time available (TA)	**3**	**2**	**2**	**1**	**Calculated**
Time = TA – TR	**-46**	**-10**	**-4**	**-21**	Calculated

9.3.3.5. Available and Required Warning Time - Conclusion

Examination of Table 19 indicates that rainfall is not suitable for providing warning of an impending flood event for any of the Flood Precincts within the catchment as the available warning is less than the time available to evacuate.

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. All of the Flood Precincts described in Section 3.1 have access roads that are cut during events less than the 20% AEP event by flood hazards of H2 classification (see Section 6.2) and greater as described in Section 6.4. A map presenting the Flood Precincts and flooded access roads is presented in Figure 1.

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9.3.3.6. Opportunities for Increasing Available Warning Time (Options RM21 and RM22)

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 19). Frequent false alarms could lead to a situation where warnings are ignored by most of the community.

Opportunities for increasing available warning time are limited for the majority of the catchment, however two options have been considered:

- Option RM21 - in some areas potential benefits to available warning time could be achieved by increasing mobile phone reception. Areas to the west of the Pacific Motorway, particularly along Ourimbah Creek Road, have limited mobile phone coverage. Improvements to telecommunications infrastructure could increase mobile service coverage and potentially allow for the rapid dissemination of SES warnings and evacuation orders; and
- Option RM22 - provide accessible real-time flood information (such as a flood portal) and help residents to interpret this information by providing design flood heights for gauges as well as estimated flood depths at their properties. Additionally, flood level triggers for various gauges could be established which could be set up to issue phone messages or SMS directly to subscribers.

Options RM21 and RM22 have been assessed in the Management Plan. However, again is should be noted that the increases in available warning time associated with these Options would be limited due to the reasons described in Section 9.3.3.3. Additionally, any associated warning messages/evacuation orders could potentially exacerbate risk by increasing the chance of motorists entering flood waters.

9.3.3.7. Opportunities for Reducing Required Warning Time (Options RM23 and RM24)

Opportunities to reduce the required warning time can also be considered. The Flood Warning manual (Reference 23) 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. The preparation of flood warning messages is examined as Option RM23.

An important question is how the people affected by flooding can best be given the appropriate information. The potential for restricted road access (see Section 6.4) and the large number of properties means that door-knocking may be too slow to reach everyone in time. An automated telephone dial-out system could be implemented for residents of the Ourimbah Creek floodplain. The ability of such a system to quickly reach a large number of subscribers is often beneficial for mitigating flood risk. The setup of a telephone dial-out system is examined as Option RM24.

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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.

The preparation of flood warning messages and setup of a telephone dial-out system for the rapid dissemination of flood information as a flood risk mitigation option is examined in the Management Plan with the reference names Option RM23 and RM24.

9.3.3.8. Shelter-in-place Feasibility Assessment (Option RM25)

Shelter-in-place has been investigated as Option RM25 as a possible means of risk mitigation for the study area. As noted in Section 9.3.3.1, the SES has a number of concerns about this approach. Consideration of the safety of sheltering-in-place in the Ourimbah Creek floodplain is investigated in this section. Recommended planning controls to facilitate a shelter-in-place policy are examined in Section 9.4.7. Shelter-in-place is a last resort measure and evacuation should be undertaken at the earliest opportunity when it is safe to do so.

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 on 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 Sections 9.3.3.3 to 9.3.3.5, the evacuation potential of the Ourimbah Creek 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 24) 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 of fatalities occurred not in the home, but outside when people have entered flood waters (38% of women and 43% of men - Reference 25).

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. These characteristics vary greatly between each of the Flood Precincts described in Section 3.1 with a summary for each precinct provided below.

Downstream Wyong Road

For the Flood Precinct downstream of Wyong Road (see Figure 1), the majority of properties are two storey buildings. Additionally, the difference in peak flood level between the PMF and the FPL is relatively minor. Accordingly, the majority of residents have access to habitable floor space above the level of the PMF either within their home or at a neighbours place. Flood

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hazard in the region is typically H3 classification which poses no risk to the structural integrity of buildings. Shelter-in-place is therefore relatively low risk for these properties. A number of issues do exist with the long duration of flooding in Tuggerah Lake and issues with sewerage and effluent release, however the associated risk with these issues are assumed to be less than motorists attempting to crossing flood waters.

Residents of properties in this Flood Precinct are recommended to shelter-in-place during a flood event unless properties have rising road access to above the level of the PMF in which case early evacuation is recommended. Examination of the PMF Emergency Response Classification map (Figure 8) can be used to determine which properties have rising road access.

Ourimbah Creek Floodplain from Upstream of the Pacific Motorway to Wyong Road

For the two Flood Precincts described in Section 3.1, *Ourimbah Creek Upstream of Pacific Highway* and *Ourimbah Creek Floodplain between Pacific Highway and Wyong Road* (see Figure 1) the difference between the FPL and the PMF ranges between 2.5 to 4 m which means that typically even for two storey buildings the second storey habitable floor level is often below the level of the PMF. Additionally, numerous properties are situated in areas of H5 hazard classification in the 1% AEP and H6 classification in the PMF. These hazard classifications can impact on the structural integrity of the building (see Section 6.2) making them potentially unsuitable for shelter-in-place.

Properties that were determined to have an unacceptable level of risk based on the criteria outlined in Section 9.4.2 have been proposed for voluntary purchase. Residents of properties in this region not eligible for voluntary purchase are recommended to shelter-in-place, acknowledging that residual risk is unabated for events approaching the magnitude of the PMF. However this residual risk is significantly less than the risk associated with evacuation due to the increased chance of motorists entering flood waters during events with a much higher probability of occurrence. Properties that have rising road access to above the level of the PMF and to an evacuation centre (see Section 9.3.4) are recommended to evacuate early.

If various improvements to flood access are implemented (see Section 9.3.1), it is recommended that properties with rising road access evacuate early to local SES evacuation centres (see Section 9.3.4). Additionally, in the long term this risk could be reduced through planning constraints implemented through Council's LEP and DCP (see Section 9.4.7).

Cut Rock and Bangalow Creek Floodplains

For the Cut Rock Creek and Bangalow Creek Flood Precinct (see Figure 1) the difference between the FPL and the PMF is typically less than 2 m, however the majority of homes are single storey dwellings which have no habitable floor space above the level of the PMF. Flood hazard in the region is typically H3 classification in the 1% AEP which poses no risk to the structural integrity of buildings, however this increases to H5 classification in the PMF.

Residents of properties in this region are recommended to shelter-in-place as a last resort, acknowledging that residual risk is unabated for events approaching the magnitude of the PMF. However this residual risk is significantly less than the risk associated with evacuation due to the

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increased chance of motorists entering flood waters during events with a much higher probability of occurrence. Properties that have rising road access to above the level of the PMF and to an evacuation centre (see Section 9.3.4) are recommended to evacuate early.

If various improvements to flood access are implemented (see Section 9.3.1), it is recommended that properties with rising road access evacuate early to local SES evacuation centres (see Section 9.3.4). Additionally, in the long term this risk could be reduced through planning constraints implemented through Council's LEP and DCP (see Section 9.4.7).

9.3.3.9. Emergency Response Recommendations

Due to the short available warning times and the various other factors described in the previous sections, the provision of an effective flood warning service for flooding in the Ourimbah Creek 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.

Shelter-in-place is the recommended emergency response for all areas of the catchment unless properties have rising road access to above the level of the PMF in which case early evacuation is recommended. The Wyong Local Flood Plan (LFP - Reference 26 see Section 9.3.4) already recommends shelter-in-place for a number of areas within the catchment. Further investigation of this option would need to be undertaken by the SES as they are the responsible authority for evacuation.

An assessment of the feasibility of a Shelter-in-place policy as a flood risk mitigation option is examined in the Management Plan with the reference name Option RM25.

RECOMMENDATIONS

► Option RM19 (Section 9.3.3.2) – investigate the suitability of existing gauges to be used for flood warning.

► Option RM20 (Section 9.3.3.2) - installation of a stream gauge on Bangalow Creek near the University of Newcastle Ourimbah Campus.

► Option RM23 (Section 9.3.3.7) - prepare a suite of flood warning messages (NSW SES).

► Option RM24 (Section 9.3.3.7) - construct and maintain a telephone dial-out system for the rapid dissemination of flood information and instructions (NSW SES).

► Option RM25 (Section 9.3.3.8) - implement a shelter-in-place strategy (NSW SES).

9.3.4. Flood Emergency Management Planning (Options RM26, RM27, RM28)

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.

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The NSW SES is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by flood planning and NSW SES maintains the Wyong and Gosford Local Flood Plans (References 26 and 27).

Residents living in and proprietors working on the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Wyong Shire Local Flood Plan (Wyong LFP - Reference 26) is a sub-plan of the Wyong Shire Local Emergency Management Plan and the Gosford City Local Flood Plan (Gosford LFP - Reference 27) is a sub-plan of the Gosford City Local Emergency Management Plan. Volumes 1 of the Wyong and Gosford LFPs were endorsed in June 2013 and February 2014 respectively. These LFPs outline responsibilities and procedures for preparing for, responding to and recovering from floods within their respective LGAs. Both LFPs provide information for areas within the Ourimbah catchment, albeit this information is limited. A review of both Flood Plans is presented in the ensuing sections, along with a recommendation to encourage key floodplain exposures to create their own specific Flood Plans.

It is recommended that both the Wyong and Gosford LFPs be updated. This option is examined in the in the Management Plan with the reference name Option RM26. Some recommendations for these updates are presented in Sections 9.3.4.1 and 9.3.4.2. Furthermore, relocation of the Wyong evacuation centre is recommended with the reference name Option RM27.

Additionally it is recommended that the Wyong and Gosford SES units are resourced appropriately so that they can perform a flood rescue function in Flood Precincts *Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road* and *Ourimbah Creek Floodplain Upstream of Pacific Motorway* (see Section 3.1) at short notice. This option is examined in the Management Plan with the reference name Option RM28.

9.3.4.1. Wyong LFP

Clause 3.5 of Volume 1 of the LFP lists two operations centres in the Wyong LGA:

- NSW SES Wyong Operations Centre is located at Levitt Street, Wyong, 2259;
- The Wyong Shire Emergency Operations Centre is located at Arizona Road, Charmhaven;

An extreme flood in the region would inundate access roads (see Section 6.4) from both of these operations centres to the catchment thus hindering SES response. This risk should be noted in the LFP.

Clause 3.8 of the Wyong LFP indicates that the following problem areas in the catchment are monitored during flood:

- Geoffrey Road, Chittaway;
- Burns Road, Ourimbah;
- Ourimbah Creek Road;
- Shirley Street, Ourimbah and the University car park;

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- Turpentine Road, Ourimbah.

Clause 3.18 lists the following relevant evacuation centres:

- Ourimbah Lisarow RSL Club, Pacific Highway, Ourimbah (near Dog Trap Road).

This building is flooded in a PMF event and is not easily accessible during smaller floods due to flooded access roads. Accordingly, it is recommended that the evacuation centre be moved to a location off the floodplain and additional centres should be added to increase accessibility during flood. The following locations could be investigated by the SES for use as evacuations centres:

- Residents in areas downstream of Wyong Road on the southern side of Ourimbah Creek – buildings on Blade Close, including Kimnastix, Sico South Pacific etc.
- Residents on the northern side of Ourimbah Creek – Tuggerah Westfield.
- Residents on the eastern side of Cut Rock and Bangalow Creeks – University of Newcastle Ourimbah Campus, Science buildings.
- Residents Ourimbah Creek upstream of Wyong Road and the western side of Cut Rock and Bangalow Creeks – Central Coast Youth Club.

Relocation of the Wyong evacuation centre from the Lisarow RSL to one of the locations listed above should be considered and has been examined in the Management Plan with the reference name Option RM27.

Annex A describes the 'flood threat' and provides some details for Ourimbah Creek, however additional information based on the current study could be added. In particular the Flood Precincts described in Section 3.1 could be defined in the LFP, similar to that presented in Figure 1. Additionally, design flood maps for the catchment could be included to display flood affectation and extent.

Annex B describes 'the effects of flooding on the community' and notes the following key areas of flood affectation (Wyong LFP, 2013):

- *'Bangalow Creek - The flood liable area of Bangalow Creek affects the car park of the University Campus and some older properties in Shirley Street which have been surrounded by water a number of times in the past';*
- *'University Campus - The University Campus has a flood management procedure adopted since about 2000 and the campus was closed in a minor event in 2003. The risk is that large numbers of students trying to enter or leave the University may try to cross the floodplain along Brush Road to get to the railway station or highway by foot or by car';*
- *'Enterprise Drive - Enterprise Drive, the arterial road into that area, may be extended through the Ourimbah Floodplain in the foreseeable future and would tend to worsen some flood problems around Sohier Park, Ourimbah. However the road designers are aware of that problem and there have been specific allowances made, so the design will include large culverts or bridge structures to minimise the effects from that arterial road connecting from Enterprise Drive through to the Central Coast Hwy south of the Shire boundary';*
- *'Overflow from Ourimbah Creek into Wyong River - In a flood larger than 100 year ARI it*

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is estimated that Ourimbah Creek would commence to overflow near the Railway into the catchment of Tuggerah Creek and Mardi Creek (through the Tuggerah Business Park and Bryant Drive area) then through the Pioneer Dairy area and into Wyong River. If the flood were large enough, Wyong Road might be cut';

- *'Access to Orchard Road Area - The access to the Orchard Rd rural residential area is via a railway underpass at Turpentine Rd off Enterprise Drive. The underpass becomes inundated at an early stage in Ourimbah Creek floods (or less commonly by floods in the local watercourse which is Chittaway Creek). Residents of the area can then get pedestrian and vehicular egress along a transmission easement to railway land and then Chittaway Road to another underpass of the railway at Ourimbah Creek. However this second underpass also gets cut at later stages of Ourimbah Creek floods. The Orchard Rd area is then inaccessible except by crossing the railway which normally is prohibited.'*

In addition to the above the following should be noted in Annex B and addressed during flood events:

- Sohier Park – A number of flooded properties from the 10% AEP event and potential for large numbers of people attending sporting events. The area becomes isolated;
- Howes Road – number of properties frequently isolated;
- Chittaway Point – large number of properties isolated during floods;
- Burns Road – frequently flooded high risk access road;
- Ourimbah Creek Road - frequently flooded high risk access road; and
- Palmdale Road - frequently flooded high risk access road.

Annex E provides a 'template evacuation warning message for Wyong Shire'. This message is not consistent with the recommended evacuation response of shelter-in-place for areas in the Ourimbah Creek catchment. A template for a warning message to provide information on shelter-in-place is recommended.

Annex F describes the 'evacuation arrangements for the Wyong Shire Council area' and notes the following evacuation arrangements for the region described as Sector F:

- *'Ourimbah township is very low-lying and is inundated in moderate to severe flood events. The township will commence inundation when Bangalow Creek (not gauged) breaks its banks. The remaining parts of this sector can experience flash flooding resulting from heavy rainfall in the catchment. Properties along Ourimbah Creek Road can be isolated when rising water levels in the creek flow across the road. The strategy for these areas is for residents to shelter in place'*.

This is in agreement with recommendations in the current study. The same recommendation should be made for other areas of the catchment and described in the four Flood Precincts (see Section 3.1).

It is recommended that NSW SES give consideration to appropriately resourcing the Wyong SES unit so that it is able to respond efficiently to any urgent demands for rescue, particularly for areas on the Ourimbah Creek floodplain upstream of Wyong Road. This will help ensure that any residents that follow the shelter-in-place recommendations made in this report are able to be evacuated if required during a flood event. Any improvements to the Wyong's SES units

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rescue capability should be reflected in the LFP (probably in the relevant annex of Volume 2).

9.3.4.2. Gosford Local Flood Plan (LFP)

Clause 3.6 of Volume 1 of the LFP lists two operations centres in the Gosford LGA:

- The NSW SES Gosford Operations Centre is located at Erina Works Depot, Pateman Road, Erina, NSW, 2250; and
- The Gosford City Emergency Operations Centre is located at Woy Woy Road, Kariong.

An extreme flood in the region would likely flood access roads thus hindering SES response. This risk could be noted in the LFP. No operations centre is situated in the Ourimbah Creek catchment and the SES may wish to consider this due to the large number of people that are flood affected in the region.

Clause 3.15 of the Gosford LFP lists roads that are flooded within the LGA. This list should be updated to include those listed in Table 11.

Clause 3.18 lists the Gosford RSL Club as the relevant evacuation centre. This is the closest recommended evacuation centre to the catchment, which is some distance away and may not be easily accessible during times of flood. Accordingly, the following replacement locations could be investigated by the SES for use as evacuations centres:

- Residents on the eastern side of Cut Rock and Bangalow Creeks – University of Newcastle Ourimbah Campus, Science buildings; and
- Residents of Ourimbah Creek upstream of Wyong Road and the western side of Cut Rock and Bangalow Creeks – Central Coast Youth Club, Niagara Park.

Annex A describes the 'flood threat' however provides no information specific to the Ourimbah Creek catchment. Information relating to flood affectation of Tall Timbers Estate, Mannings Road and the Lisarow Street area should be defined in the LFP. Additionally, design flood maps for the catchment could be included to display flood affectation and extent.

Annex B describes 'the effects of flooding on the community' and notes Macdonalds Road, Lisarow is monitored during flood. In addition to the above the following should be noted in the LFP and addressed during flood:

- Cut Rock Creek between Pacific Highway and Teralba Street;
- Pluim Park;
- Tall Timbers Estate; and
- Mannings Road.

Annex E provides a 'template evacuation warning message for Gosford Shire'. This message is not consistent with the recommended evacuation response of shelter-in-place for areas in the Ourimbah Creek catchment. A template for a warning message to provide information on shelter-in-place is recommended.

The following Annexes are recommended for inclusion in the Gosford LFP:

- Evacuation arrangements for shelter-in-place; and

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- List of schools and other flood risk uses.

9.3.4.3. Create a SES Flood Intelligence Card for Lees Bridge (Option RM29)

The NSW SES could create a Flood Intelligence Card (FIC) for the existing Lees Bridge gauge (#211425, see Section 9.3.3.2) which would provide a list of consequences and actions for a corresponding gauge height. The FIC should be updated using the findings from the Flood Study and observations of historic events.

Creating a FIC for the Lees Bridge gauge is recommended and examined in the Management Plan with the reference name Option RM29.

9.3.4.4. Emergency Response Plans (Options RM30 and RM31)

As well as updating the Wyong and Gosford LFPs, there would be benefit in NSW SES and Council encouraging and helping key floodplain exposures to prepare and update their own flood emergency response plans. The process of preparing plans would in itself be an important part of raising awareness and preparedness, and could be linked to a Business FloodSafe breakfast (see Section 9.3.5). Among the higher priorities for flood plans are:

- Newcastle University Ourimbah Campus;
- Lisarow Public School;
- Ourimbah Public School;
- Chittaway Bay Public School;
- Pluim Park; and
- Bill Sohier Park.

It is recommended that Council and the SES assist the above listed sites to create Emergency Response Plans (Option RM30) as well as work with affected residents to prepare private emergency response plans (Option RM31). These options are assessed in the Management Plan.

SUMMARY

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. NSW SES has the lead role in planning for and responding to floods. There is a need to update the Wyong and Gosford LFPs and create Flood Plans for key floodplain exposures. Best practice teaches that people will respond more effectively when households and businesses are also engaged in planning to respond to floods which can be achieved through community flood education (see Section 9.3.5).

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RECOMMENDATIONS

- ► Option RM26 (Section 9.3.4) - Review and update the Wyong and Gosford LFPs to include information pertinent to the Ourimbah Creek catchment, drawing on flood intelligence from the Flood Study (Reference 2) and this FRMS&P (NSW SES); relocation of the Wyong evacuation centre is recommended with the reference name Option RM27.
- ► Option RM27 (Section 9.3.4) - Relocate the Wyong evacuation centre off the floodplain.
- ► Option RM28 (Section 9.3.4) - Resource the Wyong and Gosford SES units appropriately so that they can perform a flood rescue function in Flood Precincts *Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road* and *Ourimbah Creek Floodplain Upstream of Pacific Motorway* at short notice (NSW SES).
- ► Option RM29 (Section 9.3.4.3) – Create a SES FIC for the existing Lees Bridge gauge.
- ► Option RM30 (Section 9.3.4.4) – Assist key floodplain exposures to create Emergency Response Plans.
- ► Option RM31 (Section 9.3.4.4) – Assist flood affected residents to create Emergency Response Plans.

9.3.5. Community Flood Education (Option RM32)

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 28).

Based on reviews of 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 the 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

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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 20 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 20: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S 10.7 (formerly 149) 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 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.
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	Council already provides an 'emergency information' portal on its website. An additional flood management portal would be of value to describe the floodplain management process and include Flood Studies and Floodplain Risk Management Studies, a history of flooding in the Ourimbah Creek catchment, procedures for how to obtain flood information, answers to frequently asked questions (FAQs), and advice on becoming flood prepared. The portal could also provide links to BoM warnings and NSW Office of Water gauge heights.
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	Ongoing articles in the newspapers will ensure that the flood issues are

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Method	Comment
newspapers	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	Now that a Flood Study has been prepared, and given the experiences of major floods in the recent past, once the Local Flood Plan is finalised, it would be timely to prepare a FloodSafe guide for the Ourimbah Creek catchment describing flood behaviours in historical and design floods, and listing appropriate actions. If major flood mitigation works will be implemented following this FRMS&P, it would be advisable to wait until these are done.
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.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate and visible location at a time that people will be at home. 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.

The actual approaches that are adopted would depend upon Council Officers, advise from the SES and discussions with local community representatives. For example historical flood depth markers are accepted in some communities but not in others. Typical approaches that might be instigated would involve:

- audit the existing SES community flood education strategy;

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- develop; educational messages targeting dangerous behaviours;
- improved signage at high hazard road low-points;
- install flood totem poles with coloured bands to indicate levels reached by previous floods;
- make available additional flood hazard information at a property scale, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans;
- undertake a pilot project involving the distribution of property level flood information in "hard copy" format to a small section of the catchment;
- develop a flood information portal on Council's web-site.

RECOMMENDATIONS

► Engage with the community to prepare an ongoing flood education program, with appropriate methods for program evaluation (NSW SES and Council).

9.4. Property Modification Measures Considered

Property modification measures 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.

The following specific property measures have been assessed:

- House Raising (Option PM1) (Section 9.4.1);
- Voluntary Purchase (Option PM2) (Section 9.4.2);
- Land Use Zoning (Option PM3) (Section 9.4.4);
- Changes to Planning Policy (Option PM4) (Section 9.4.7).

9.4.1. House Raising (Option PM1)

DESCRIPTION

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,

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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.

An indicative cost to raise a house is $80,000 though this 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,
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

House raising as a flood mitigation option in the Ourimbah Creek catchment is likely suitable for the Flood Precincts *Downstream of Wyong Road* and *Cut Rock and Bangalow Creek Floodplains* described in Section 3.1. Both of these precincts have relatively small differences in design level between the 1% AEP and PMF events making it achievable to build floor levels above the level of the PMF and typically do not experience high flood hazard classifications (H5 and H6). Additionally, numerous homes are flooded in frequent flood events such as the 20% AEP which indicates a significant reduction in flood damages could be achieved. Additionally, house raising will help to maximise the number of properties in these Precincts which have habitable floor levels above the level of the PMF and are therefore suitable for shelter-in-place during a PMF event (see Section 9.3.3.8). Areas of the Ourimbah Creek floodplain upstream of Wyong Road are generally not suitable for house raising due to high hazard flows.

The floor level database prepared as part of this study (Section 3.4.2) did not include identification of houses that may be suitable for house raising thus suitable individual houses cannot be identified from the database. However experience in other areas has shown that generally all the houses that could be raised easily have been raised, the remaining ones are either too difficult to raise, have reached the end of their life or the owners do not wish to enter via steps. Many for example have been raised at Chittaway Point. From a B/C perspective the non brick houses that could be raised are nearing the end of their useful life, thus raising them is generally not cost effective due to their expected future short life span.

Experience has shown that many owners of houses that potentially could be raised are not interested for reasons such as:

- they do not want an elevated entry to their house;
- the house is old without modern facilities and will be re-developed in the near future;
- owners will have to live elsewhere during the construction phase (possibly 2 months);
- owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace);
- whilst it is possible to raise most single storey non brick houses many owners consider the inconvenience too much of a burden;

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- flood insurance is now available, for a typical house at Chittaway Point there is an additional premium of approximately $4,000 to include flood insurance;
- all low lying buildings will have experienced above floor inundation over the past 30+ years and this is accepted by the owners as the consequences of living close to a creek or lake.

SUMMARY

It is recommended that a house raising feasibility assessment be undertaken for the two Flood Precincts mentioned above which would include detailed analysis of individual property construction and suitability for raising as well as community consultation with residents to gauge community and personal interest. An assessment of the feasibility of a voluntary house raising scheme as a flood risk mitigation option is examined in the Management Plan with the reference name Option PM1.

RECOMMENDATIONS

► Option PM1 - Undertake a House Raising feasibility assessment for the area downstream of Wyong Road and within the Cut Rock Creek and Bangalow Creek floodplains.

► Appropriate planning and development controls should negate the need for future raising of properties (see Section 9.4.5).

9.4.2. Voluntary Purchase (Option PM2)

DESCRIPTION

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, 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.

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.

Council has a voluntary purchase scheme currently proposed for 14 properties in Tall Timbers Estate, and six on Mannings Road, Lisarow, which is awaiting grant funding. If the improved flood access and link road to the Tall Timbers Estate are found to be not feasible and cannot be implemented (see Section 9.3.1.8) Council should undertake the voluntary purchase of the 14 Tall Timbers Estate properties as previously recommended in Appendix G.

As part of the current study, a review of flood risk identified an additional 12 properties that are

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proposed for voluntary purchase. Properties that are considered fall into the following risk categories:

- Situated in, or are completely surrounded by high hazard areas classified as H5 or H6 (see Section 6.2) in the 1% AEP event; and are
- Situated in PMF ERP areas (see Section 6.3) defined as *Low Flood Island* or *Low Trapped Perimeter Area*; or are
- Situated in, or are completely surrounded by 1% AEP floodway (see Section 6.1).

Properties situated in these areas are subject to an unreasonable degree of risk as the structural stability of these properties could be compromised in the 1% AEP event and residents are isolated with no means of egress. Voluntary purchase is the only means of risk mitigation as no suitable risk mitigation measures were identified.

The locations of these properties are not presented in this report due to privacy issues. WMAwater have provided a Memorandum to Council which identifies these properties.

A B/C analysis to justify a voluntary purchase scheme or reduce the number of additional properties (12) proposed cannot be readily undertaken. The key reason that houses are included in a voluntary purchase scheme is the potential risk to life not the economic worth of the reduction in damages. For example, at Tall Timbers no floors are inundated in the 1% AEP event (and never have been inundated) but the houses are included due to the risk to life issues with crossing the bridge. Economic quantification of the reduction in flood risk would be required to include in a B/C analysis. This reduction in intangible damages is more appropriately assessed qualitatively and cannot be compared to tangible flood damages which are included in a conventional B/C analysis.

An assessment of the feasibility of a voluntary purchase scheme as a flood risk mitigation option is examined in the Management Plan with the reference name Option PM2.

RECOMMENDATIONS

► Council should progress the existing voluntary purchase scheme for the six properties on Mannings Road.

► Council should review how flood risk will be mitigated for properties in Tall Timbers Estate should improvements to flood access roads be found to be feasible. If found to be not feasible and cannot be implemented Council should undertake the voluntary purchase of the 14 Tall Timbers Estate properties as previously recommended in Appendix G.

► All recommended management measures and specific management controls as detailed in Appendix G should be maintained.

► Council should undertake a voluntary purchase feasibility assessment to investigate extending the scheme to include the additional 12 properties identified.

9.4.3. Flood Proofing

DESCRIPTION

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

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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.

DISCUSSION

Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction. As such, flood proofing can be stipulated within Council DCPs as requirements for structures below the FPL.

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.

Both Gosford and Wyong Council's DCPs promote flood proofing principles for development and structures which are below the FPL. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, and maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Whilst it is a requirement of the Floodplain Development Manual (Reference 1) 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 FPL 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.

RECOMMENDATIONS

► Planning controls should allow some flexibility in the type of flood proofing adopted.

► Temporary flood gate options should be included in building design for low risk non-habitable developments.

9.4.4. Land Use Zoning (Option PM3)

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

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are generally governed by a LEP. To make any significant changes to the provisions of a LEP, a planning proposal must be prepared. The Draft Final Ourimbah Masterplan (see Section 4.2.1) is currently investigating the potential for future rezoning in the Ourimbah town centre area.

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 Ourimbah Creek catchment comply with the current NSW standards. No changes to the current land use zoning are recommended from a flood mitigation perspective.

RECOMMENDATIONS

► the Ourimbah Masterplan should carefully consider flood behaviour and affectation determined by the Flood Study and this FRMS&P.

9.4.5. 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) 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 from 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 standard FPL for residential development as defined in the Manual is the 1% AEP event plus 500 mm freeboard. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example, in areas prone only to shallow overland flooding, application of the 500 mm freeboard can be excessive.

Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use

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in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building / development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

According to the 2005 *NSW Government Floodplain Development Manual* (Reference 1) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL (Flood Planning Level) is actually provided given the following factors*:

- uncertainties in estimates of flood levels,
- differences in water level because of "local factors",
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change. This largely relates to rainfall increase as future sea level rise has been relatively accurately determined by the Intergovernmental Panel for Climate Change (IPCC) and should not be included within the 0.5m freeboard. For this study area sea level rise will only affect those areas affected by the Tuggerah Lakes FPA.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). For example, in a future flood 1% AEP event blockage (due to say a car wedged in the creek) may elevate the peak level just upstream. However such an event would be considered as rarer than the 1% AEP as that type of blockage is an exception as it would not always occur in every flood.

There is no scientific reason for assuming a 0.5m allowance for freeboard. In some locations (say Windsor on the Hawkesbury River) it could be argued that a greater freeboard should be applied as the PMF is several metres above the 1% AEP, thus 0.5m represents only a relatively small increase in flood magnitude. At other locations a 0.5m increase above the 1% AEP may approach the PMF level and thus represents a very large increase in flood magnitude. Council could adopt varying freeboards across its LGA however this is likely to be confusing to manage by Council staff and it is difficult, if not impossible, to justify the criteria as to why one area should have a different freeboard to another. For simplicity a 0.5m freeboard is adopted by nearly all Councils in NSW for mainstream flooding. Some Councils adopt a smaller freeboard when the depths of inundation in urban areas, with no defined creeks or channels, are shallow (less than 0.3m).

RECOMMENDATIONS

► The Floodplain Development Manual (2005) recommended FPL of the 1% AEP event plus 0.5 m freeboard is considered appropriate for areas flooded by Ourimbah Creek and its

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tributaries.

9.4.6. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. A FPA map is a required outcome of the FRMS&P.

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 will be 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 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 (Reference 1) (1% AEP plus 0.5 m freeboard) is suitable for areas of mainstream flooding.

RECOMMENDATIONS

► The FPA developed from the Flood Study has been reviewed and is considered consistent with the Floodplain Development Manual FPA approach. Council's current FPA map based on the Flood Study findings does not require revision.

9.4.7. Changes to Planning Policy (Option PM4)

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 9.3.3). 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 9.3.3.8) and flood compatible buildings.

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DISCUSSION

Both Councils address development in flood risk areas in their respective DCPs, and provide matrices which apply 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. Consideration should be given to the following options:

Wyong Council:

- For those areas classed as risk precinct 3 in the DCP, but classified Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - Properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by;
    - demonstrating that rising road and/or pedestrian access through low hazard flooding (H1 and H2) is available to a 'safe haven' at or above the level of the PMF; and
    - If a structure is to be used as the primary 'safe haven', the structure must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the PMF;
  - Issuing annual flood awareness information with the rates notices in these areas to maintain a high level of understanding of the risk, and what it means at that particular property. In particular, promoting sheltering in place and ways to minimise damages during a flood event.
  - The current DCP allows filling of the building footprint, car parking areas and driveways within this precinct, the cumulative impact of which has the potential to change the flood behaviour.

- For those areas classed as risk precinct 4 in the DCP, but classified Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - These areas are required to undertake a performance based assessment, however at present the assessment does not list particular targets for some aspects. For example: *"is compatible with the established flood hazard of the land…",* and *"incorporates appropriate measures to manage risk to life and property from flood."*. Whilst the DCP does advise that Council staff are consulted prior to undertaking the assessment, providing specific criteria within the DCP would ensure future development is appropriate with the flood risk and is not open to interpretation. This might include:
    - Specifying that properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by providing access to a 'safe haven' at or above the level of the PMF;
    - Requiring structures used as the primary 'safe haven' be flood compatible and structurally able to withstand the forces of flooding, and providing prescriptive building design and / or material specification.

- The current precinct mapping is based directly on the outputs from previous flood modelling, and as such, single lots may contain more than one Precinct. Consideration should be given to revising the mapping to ensure lots are only allocated as one precinct (corresponding to the highest flood risk).

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Gosford Council:

- For those areas classified as Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - Properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by;
    - demonstrating that rising road and/or pedestrian access through low hazard flooding (H1 and H2) is available to a 'safe haven' at or above the level of the PMF; and
    - If a structure is to be used as the primary 'safe haven', the structure must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the PMF
  - Issuing annual flood awareness information with the rates notices in these areas to maintain a high level of understanding of the risk, and what it means at that particular property. In particular, promoting sheltering in place and ways to minimise damages during a flood event.

Central Coast Council Merger – Integration of Flood Controls

The recent merger of Wyong and Gosford Councils will require the integration of Councils' planning polices, including the LEPs and DCPs. Advice on how the integration of these planning policies is best achieved is outside of the scope of the current study. It is recommended that Council engage a specialist planning consultant to review the Wyong and Gosford LEP/DCP and to prepare advice for integration of these planning policies.

An assessment of the feasibility of changes to Council's planning policies as a flood risk mitigation option is examined in the Management Plan with the reference name Option PM4.

RECOMMENDATIONS

► Council could 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, potentially taking into consideration the ERP classifications described in Section 6.3.

► Option PM4 - Council should engage a specialist planning consultant to prepare advice/content for the conflation of Councils' LEPs and DCPs.

9.4.8. Modification to the S10.7 Certificate

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:

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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.

Some Councils include detailed flooding information in s.10.7 (5) Planning Certificate 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 could 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.

Council currently provide property-based flooding information on Council's website which is a benefit to the community. More detailed information can be obtained from Council by way of

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purchase of a flood information certificate.

Under the s117 directions Council cannot impose flood related development controls above the residential flood planning level for residential development (such as precincts where Council might seek to impose controls for a PMF refuge for the sake of refuge-in-place). In these instances Council would have to apply to the Minister for exceptional circumstances.

RECOMMENDATIONS

► Council should review the information provided on the s.10.7 certificates in light of the information in the Ourimbah Creek Flood Study and this FRMS&P.

9.5. Flood Insurance

DESCRIPTION

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments.

DISCUSSION

It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not available.

RECOMMENDATIONS

► Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this FRMS&P. This planning must include consideration of the future risk from sea level rise and climate change.

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10. ACKNOWLEDGEMENTS

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