Attachment 1 to Item 10.3.1.

Draft Hawkesbury Floodplain Risk Management Study and Plan 2025 – Report

Date of meeting: 23 July 2024
Location: Council Chambers
Time: 6:30pm

Hawkesbury City Council

Hawkesbury Floodplain Risk Management Study and Plan 2025

DRAFT FOR PUBLIC EXHIBITION

wma water

Level 2, 160 Clarence Street
Sydney, NSW, 2000

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

HAWKESBURY FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN -2025

DRAFT REPORT

JULY 2024

Project Hawkesbury Floodplain Risk Management Study and Plan -2025	**Project Number** 123027
Client Hawkesbury City Council	**Client's Representative** C.Haron
Project Manager M. Babister	

Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Stage 1 Report Draft	HCC	M.Retallick J.Fraser	M. Retallick		JUL 23
1	Draft FRMS and P	HCC	M.Retallick M.Babister			JUNE 24
2	Draft FRMS and P for Public Exhibition	HCC	M.Retallick M.Babister			JULY 24

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

APPENDICES:

LIST OF PHOTOGRAPHS

LIST OF DIAGRAMS

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DCCEEW	Department of Climate change, energy and the environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	metres above Australian Height Datum
OEH	Office of Environment and Heritage (now DCCEEW)
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore the term Exceedances per Year (EY) is recommended. 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.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

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	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

FOREWORD

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

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

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

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management***
   - 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 Review Hawkesbury Nepean Floodplain Risk Management Study and Plan constitutes the second stage of the management process. This study has been prepared by WMAwater for Hawkesbury City Council and provides the basis for the future management of flood prone lands affected by the Hawkesbury River in the Hawkesbury Local Government Area.

Funding for this study was provided by Hawkesbury City Council and the Department of Climate Change, Energy and the Environment and Water. This document does not necessarily represent the opinions of the NSW Government or the Department of Climate Change, Energy and the Environment and Water.

EXECUTIVE SUMMARY

STUDY AREA

The Hawkesbury-Nepean catchment covers some 22,000km^2, extending as far south as Bowral and Goulburn, and as far west as Lithgow. The study area (refer to Figure 1) includes the Hawkesbury River and surrounding tributaries located within the Hawkesbury Local Government Area. The area extends from Yarramundi in the south to Wisemans Ferry in the north, containing major population centres of Windsor and Richmond. The study area extends from Agnes Banks to Wisemans Ferry, having a river distance of approximately 83 km, and a floodplain area of approximately 220km^2 subject to inundation in the Probable Maximum Flood.

FLOOD MODEL

A detailed flood study was undertaken by the NSW government for the Hawkesbury-Nepean Valley in 2024 to define the existing flood behaviour at a regional scale. This study forms the basis for the current floodplain risk management study and plan. The limits of mapping of the Hawkesbury-Nepean Valley Flood Study (2024) are shown in Figure 3.

The TUFLOW hydraulic model for the catchment was developed by Rhelm and Catchment Simulation Solutions (CSS) as part of the Hawkesbury-Nepean River Flood Study (Reference 18). The model has a grid resolution of 15m and was calibrated and validated against historical events, including in the March and July 2022 events. The results of the flood study are reproduced in this management study.

EXISTING FLOOD BEHAVIOUR

Peak flood levels for the 20%, 10%, 5%, 2%, 1%, 0.5% AEP, 1 in 1000, 1 in 2000, 1 in 5000 AEP and Probable Maximum Flood (PMF) design events are presented in Figure 4 to Figure 23 and in the table below at Key Locations.

The majority of flood levels are only slightly changed from the 2019 Regional Flood Study. There is no significant change in the 10% to 0.5% AEP and no change in the 1% AEP (>30mm). The detailed TUFLOW model shows significant increases in flood levels in extreme events compared to previous studies. This is caused by bend losses in extreme events in the tightest bends. This has resulted in the PMF increasing by 3.9m at Windsor, 5.8m at Sackville and 4.9m at Wisemans Ferry.

FLOOD DAMAGES

A flood damages assessment was undertaken for the LGA, the outcomes of which are summarised in Table 2. A total of 4766 residential and non-residential properties within the floodplain are flooded above floor level in a 1% AEP event and 19080 properties are flooded above floor level in a PMF event in the Hawkesbury LGA.

Table 1: Design Flood Levels at Key Locations (as per Figure 1) from the 2024 Flood Study

ID	Location		Peak Flood Levels (mAHD)								
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	1 in 1000 AEP	1 in 2000 AEP	1 in 5000 AEP	PMF
1	Yarramundi	13.24	15.71	17.1	17.56	18.09	19.12	21.64	23.03	24.52	30.58
2	North Richmond	12.47	14.73	15.91	16.48	17.51	18.68	21.41	22.88	24.41	30.56
3	Freemans Reach	11.57	12.95	13.94	15.97	17.37	18.55	21.33	22.82	24.37	30.55
4	Windsor Bridge	9.71	11.7	13.78	15.94	17.35	18.53	21.32	22.81	24.36	30.55
5	McGraths Hill	-	-	-	15.93	17.34	18.53	21.32	22.81	24.36	30.55
6	South Creek at Hawkesbury Valley Way	9.75	11.66	13.77	15.93	17.34	18.53	21.32	22.81	24.36	30.55
7	South Creek at Richmond Road	9.82	11.67	13.77	15.93	17.34	18.53	21.32	22.81	24.36	30.55
8	Sackville Ferry	5.45	7.92	10.16	12.48	13.89	15.42	18.68	20.75	22.54	29.37
9	Lower Portland	4	5.82	7.57	9.78	10.98	12.86	17	18.7	20.27	26.63
10	Leets Vale	2.72	3.97	5.2	6.76	7.81	9.38	13.02	14.49	15.82	21.23
11	Wisemans Ferry	2.2	3.12	4.21	5.4	6.39	7.87	11.35	12.72	14	18.89

"-" Is not flooded

Table 2: Estimated flood damages

Event (AEP)	Properties Affected	Properties Above Floor	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20%	110	85	$21,631,774	$196,652
10%	756	660	$133,737,634	$176,902
5%	1,552	1,224	$294,075,698	$189,482
2%	3,619	2,818	$920,102,849	$254,242
1%	5,388	4,766	$1,985,984,728	$368,594
0.5%	7,211	6,263	$2,920,302,887	$404,979
0.2%	10,551	9,360	$4,413,264,517	$418,279
0.1%	13,300	12,070	$5,780,240,946	$434,605
PMF	19,173	19,080	$10,343,023,203	$539,458
Average Annual Damages (AAD)			**$90,868,080**	

FLOODPLAIN RISK MANAGEMENT STUDY

This Floodplain Risk Management Study process under the direction of the Floodplain Risk Management Committee has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multi-criteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on the SES.

These measures have been grouped into the following general categories:

- **Flood modification measures** modify the physical behaviour of a flood (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees.

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

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

As part of the study a review of progress on the recommendations of the 2012 Floodplain Risk Management Plan was undertaken. The achievements against the plan are detailed in Section 8. In 2012 Council recognised that the flood problem in the in the Hawkesbury-Nepean was too big for Council to manage without state assistance and that large scale mitigation would need to examined by the NSW state government with the rising of Warragamba Dam for flood mitigation providing an opportunity to significantly reduce flood risk in the order of 3.5m at Windsor. This would reduce flood levels for most dwellings by nearly one and half stories and on average decrease the flood risk for most properties by a factor of four. In 2023, the NSW Government announced after the Environmental Impact Statement for the raising of Warragamba Dam had been on public display, that the NSW Government would not be proceeding with the raising of Warragamba Dam and the government would look at alternative mitigation strategies. The floodplain management committee recognised that this would mean that Council would need to dramatically change its approach to floodplain management as no other options exist that will lower flood levels by metres and that the Currency Creek Bypass option should be considered further.

As part of the current study a number of structural mitigation options were modelled in the flood model to assess their impact on flood behaviour. These included Pitt Town Levee, McGraths Hill levee, South Windsor Levee, Wilberforce Levee and Currency Creek Bypass.

FLOODPLAIN RISK MANAGEMENT PLAN

The Floodplain Management Study has undertaken a review of the full range of management measures with the outcomes providing the basis for the Floodplain Management Plan. An assessment of the relative merits of the measures has been undertaken. Table 3 summarises the recommended options for inclusion in the floodplain risk management plan.

Table 3: Floodplain Risk Management Plan – DRAFT

	Option ID	Option Name	Description	Benefits	Concerns	Funding	Responsibility	Cost or B/C Ratio	Overall Rank*
Flood Modification	FM 1	McGrath Hill Levee	A ring levee around McGraths Hill. Protection to a 2% AEP level.	Protection of flood prone properties	• Provide a false sense of security, • Would not protect any approved habitable areas, • Have a small impact on surrounding properties that while small the total intangible damages are large, and • Would protect illegal enclosed downstairs areas (McGraths Hill)	May be eligible for NSW Government funding	State Government/ Council	High cost and low B/C	
	FM 2	Pitt Town Levee	A levee protecting Pitt Town to a 2% AEP level. The levee would be on average 5m high.					High cost and low B/C	
	FM 3	South Windsor Levee	Levee to improve access. At a 2% AEP level.					High cost and low B/C	
	FM 4	Wilberforce Levee	A levee around low lying areas of Wilberforce.					<0.1	
	FM 5	Survey of levees	A number of minor levee banks that assist with managing small floods and are associated with drainage works levee banks have been built within the Hawkesbury-Nepean Valley. These would be surveyed for extent and level	Understanding of flood protection and inclusion in future modelling	N/A	May be eligible for NSW Government funding	Council	$200,000	
	FM 6	Currency Creek Bypass	Bypass channel through the saddle between Freemans Reach and Currency Creek which would short circuit approximately 21 km of river.	Widescale reduction in flood levels	Some increases in flood levels downstream of Sackville	May be eligible for NSW Government funding	State Government	<0.05	
Property Modification	PM 1	Voluntary Purchase	Voluntary purchase (VP) involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain.	Generally, the land is returned to open space and hydraulic capacity increased.	Mainly implemented over a long period for residential areas. Vacant lots may be sold by Council. Economic cost and social impacts can be high	May be eligible for NSW Government funding	Council	Minimal for feasibility	
	PM 2	Flood Planning Levels	Adopt Flood Planning Levels at the 0.5% AEP plus 0.5m developed in the FRMS&P.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels	May be considered more onerous for developers.	Council	Council	In House	

				depending on the type of development.					
	PM 3	Revise LEP and develop DCP	Continue to apply existing LEP. Consider recommendations for improvements as part of this FRMS&P. Improvements include: consistent terminology, update to use FPCC categories, develop DCP and include 5.22 in LEP	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In House	
	PM 4	Provision of flood information to residents via Section 10.7 Planning Certificates	In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Council to provide further detail from current FRMS&P results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	Council	In House	
	PM 5	House Raising	House raising has been widely used throughout NSW to eliminate inundation from habitable floors.	This approach provides more flexibility in planning, funding and implementation than voluntary purchase. A total of 81 properties were identified as being flooded in frequent events (10% AEP). A feasibility study is recommended.	Its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10% AEP event or less).	May be eligible for NSW Government funding	Council	Minimal for feasibility	
	PM 6	Flood Proofing	Continue to encourage flood proofing and flood compatible materials.	This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.	More vulnerable uses may use building in the future and this would need to be managed.	Council	Council	In House	
Response Modification	RM 1	Flood Warning	The following options are recommended: • Update of the Local Flood Plan to reflect flood levels from the current study •Cameras on bridge approaches to also be made available on disaster dashboard	Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.	Flood warning is critical to ensuring safe evacuation in large events.	May be eligible for NSW Government funding/ SES	Council/SES	<$50k Ongoing maintenance	

	RM 2	Flood Awareness and Preparedness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council	Council in collaboration with other response agencies and community organisations.	Annual Budget to be determined and allocated.	
	RM 3	Evacuation Planning	• The NSW SES Local Flood Plan was prepared in 2020 and schedule for review in 2025. This should be updated to include the new flood mapping contained in this report. • Any major future events within this time should be incorporated into flood intelligence and evacuation planning.	Better evacuation planning and awareness of flood risk.		Council/ TfNSW/SES	Council/SES	In House	

1. INTRODUCTION

1.1. Study Area

The Hawkesbury-Nepean catchment covers some 22,000km^2, extending as far south as Bowral and Goulburn, and as far west as Lithgow. The study area (refer to Figure 1) includes the Hawkesbury River and surrounding tributaries located within the Hawkesbury Local Government Area. The area extends from Yarramundi in the south to Wisemans Ferry in the north, containing major population centres of Windsor and Richmond. The study area extends from Agnes Banks to Wisemans Ferry, having a river distance of approximately 83 km, and a floodplain area of approximately 220km^2 subject to inundation in the Probable Maximum Flood.

The total catchment area upstream of Windsor is ~12800km^2, including 9000km^2 upstream of Warragamba Dam, 670km^2 upstream the Grose River tributary and 1800km^2 from the Nepean River to Warragamba Junction. Downstream of Windsor, South Creek and the Colo River join the Hawkesbury River, with catchment areas of 580km^2 and 4600km^2 respectively. Downstream of the Colo River Junction are the Macdonald River (1850km^2) and Webbs Creek (350km2) tributaries. The timing of inflows from the Colo River, Macdonald River and Webbs Creek can have significant impact on the flood levels at downstream locations.

A detailed flood study was undertaken by the NSW government for the Hawkesbury-Nepean Valley in 2024 to define the existing flood behaviour at a regional scale. This study forms the basis for the current floodplain risk management study and plan. The limits of mapping of the Hawkesbury Nepean Valley Flood Study (2024) are shown in Figure 3.

1.2. Objectives

WMAwater was engaged by Hawkesbury City Council (HCC) to develop a floodplain risk management study and plan for the Hawkesbury River within its LGA. The previous management plan was published in 2012. The current study and plan takes into consideration:

- an up-to-date understanding of the full range of flood behaviour and consequences in the study area.
- changes in modelling techniques
- changes in available information
- the implementation of best practice flood management practices and latest standards.
- NSW government decision to not proceed with the raising of Warragamba Dam for flood mitigation.

The objectives of the present Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts. It also seeks to ensure future development is controlled in a manner consistent with the flood hazard and risk at

this time, and in the future as a result of predicted climate change.

Key drivers for undertaking the present study and plan include:

- The need for an updated understanding of flood risk and flood behaviour, incorporating the recently adopted updated national flood guidelines (ARR, 2016/9).
- The need for an updated decision-making process for land use planning and development controls.
- The need for development and appraisal of floodplain management measures appropriate to the location and acceptable to the local community economically, socially and environmentally.
- provide a better understanding of the:
    - variation in flood behaviour, flood function, flood hazard and flood risk in the study area based on the outputs of the regional 2D modelling study in the Hawkesbury-Nepean River (Rhelm/CSS 2024)
    - impacts and cost from a range of modelled flood events on the existing and future community
    - impacts of development and climate change on flood risk
    - emergency response situation and limitations
    - effectiveness of current management measures at local level within the Hawkesbury LGA considering its interface with the regional flood risk management measures proposed by the state government; and
- facilitate information sharing on flood risk across government and with the community.

2. BACKGROUND

2.1. Catchment Description

The study area consists of the portion of the Hawkesbury-Nepean River contained within the Hawkesbury City Council area (Figure 1). The Hawkesbury-Nepean Valley consists of a sequence of floodplains interspersed with incised sandstone gorges. The catchment covers some 22,000 square kilometres, stretching from Goulburn and Lithgow upstream of Warragamba Dam, and downstream to Broken Bay. The Valley consists of several key floodplains, the furthest upstream is at the town of Wallacia. Downstream of this, the Nepean River joins the Warragamba River to discharge into another floodplain at Penrith and Emu Plains.

The floodplain becomes constricted at Castlereagh although this is not a gorge on the same scale as others in the valley. The major Richmond-Windsor floodplain is located below Yarramundi. The river then enters the lower Hawkesbury River below Wilberforce and a series of incised sandstone gorges that extend around 100 kilometres from Sackville to the ocean at Broken Bay. Due to its history the river has two names: the Nepean River upstream of the junction of the Grose River at Yarramundi, and the Hawkesbury River downstream to the coast.

Dyarubbin, also known as the Hawkesbury River, is a culturally rich and historically significant waterway. For at least 50,000 years, the Darug and Darkinjung people have called Dyarubbin home. Early colonists recorded the Hawkesbury's Aboriginal name in the 1790s, but they Anglicised it, writing is as "Deerubbin".

Residential development within the LGA generally consists of small settlements. Major centres exist at Windsor and Richmond. Small settlements include North Richmond, Wilberforce, McGraths Hill, and Pitt Town.

2.2. Flood History

Windsor has Australia's longest flood record. This record, along with oral history from Aboriginal people, and geomorphological and geological clues in the landscape all point to a long history of floods in the Hawkesbury-Nepean system. The historical flood record suggests the Hawkesbury-Nepean system is subject to multidecadal flood cycles, where there are long periods of frequent and large floods, followed with similar periods of infrequent and small floods.

The largest known modern flood at Windsor occurred in 1867, which peaked at 19.7m AHD. While a detailed summary of Windsor's flood-record is available in the Hawkesbury-Nepean Regional Flood Study (Reference 17). Table 4 contains a summary of the 10 largest events at Windsor.

In July 2022, a 13.93m AHD flood was recorded at Windsor. This is the 11th largest event recorded at Windsor.

Table 4: Summary of the ten largest historical floods at Windsor

Year	Level (m AHD)
1867	19.68
1864	15.05
1961*	14.95
1809	14.7
1964*	14.57
1900	14.5
1978*	14.46
1817	14.4
1870	14.14
1816	14.1

*Events which occurred after the completion of the Warragamba Dam construction

2.3. Previous Studies

Hawkesbury Floodplain Risk Management Study and Plan (2012)

This report was commissioned by Hawkesbury City Council and completed by Bewsher Consulting. This study documents the flood risk in the Hawkesbury, including the flood risk to property and life. The key outcome was the Floodplain Risk Management Plan, explaining and establishing priority for seven components to manage flood risk in the area. This included Community Flood Education and Resilience, Emergency Management, a Feasibility Study for a Levee at McGraths Hill, and Voluntary House Raising. Other options are discussed in detail in the report. This is the most recent study undertaken for the study area. The current study will supersede this.

Resilient Valley, Resilient Communities: Hawkesbury–Nepean Valley Flood Risk Management Strategy (INSW, 2017)

This is a comprehensive framework for the NSW Government, local councils, businesses and community to work together to reduce and manage the flood risk in the Hawkesbury-Nepean Valley. The Strategy identifies the scale of flood risk in the Valley and provides short and long-term options for flood risk mitigation. There is no simple or single solution to reducing the flood risk, with the Strategy outlining suggested actions to deliver nine key outcomes. These outcomes were:

1. Coordinated flood risk management across the Valley now and in the future.
2. Reduced flood risk in the Valley by raising Warragamba Dam wall.
3. Strategic and integrated land use and road planning.
4. Accessible contemporary flood risk information.
5. An aware, prepared and responsive community.
6. Improved weather and flood predictions.
7. Best practice emergency response and recovery.

8. Adequate local roads for evacuation.
9. Ongoing monitoring and evaluation, reporting and improvement of the Flood Strategy.

Taskforce Options Assessment Report (INSW, 2019)

This report details the investigations undertaken by the Hawkesbury-Nepean Valley Flood Management Taskforce from its establishment in 2014 up to 2016, when its recommendations were adopted in the Resilient Valley, Resilient Communities: Hawkesbury-Nepean Valley Flood Risk Management Strategy. The purpose of the Taskforce Options Report was to inform the Warragamba Dam Raising environmental impact assessment, and to provide details of the options assessments which were undertaken in the development of the Flood Risk Management Strategy. The report summarises all infrastructure and non-infrastructure options considered by the Taskforce, explaining the reasons for supporting/not supporting each of the options. This includes the engineering, environmental and economic assessment of shortlisted infrastructure options, and for non-infrastructure options, how they contribute to the prevention, preparation, response and recovery aspects of the flood risk management cycle.

Hawkesbury-Nepean Valley Regional Flood Study (WMAwater, 2019)

The Hawkesbury-Nepean Regional Flood Study was developed in 2019 to provide contemporary flood risk information for the valley. The study describes the existing flood behaviour of the Hawkesbury-Nepean Valley from Bents Basin to Brooklyn Bridge, adopting best-practice modelling methodology to do so. The modelling framework developed as part of the study models 20,000 events to represent the observed flood behaviour in the valley. The model allows for assessment of evacuation options.

Hawkesbury-Nepean River Flood Study (NSW Reconstruction Authority, 2024)

This study is an update on the 2019 Regional Flood Study, using a calibrated two-dimensional TUFLOW model and one-dimensional Rubicon model to define flood behaviour in the Hawkesbury-Nepean Valley. The Monte-Carlo modelling framework developed for the 2019 Regional Flood Study was updated, running 20,000 events through the Rubicon model to represent the observed flood behaviour in the valley. A subset of events were selected for each AEP quantile, and run through the TUFLOW model to generate a flood surface. This study forms the existing flood information presented. The TUFLOW model developed as part of the study has been used for the options assessment in the current study.

2.4. Environmental Summary

The study area, from Yarramundi and Agnes Banks to Wisemans Ferry, has been subject to agriculture, clearing and urbanisation. This is particularly true for the key population centres of Richmond and Windsor.

Several areas of environmental significance exist within the LGA including wetlands at Pitt Town

Lagoon and Longneck Lagoon. Under the Biodiversity Conservation Act 2016 No 63 (BC Act), these are examples of "*endangered ecological communities Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and Southeast Corner Bioregions*". Further, some wetlands north of Agnes Banks are listed under the State Environmental Policy (Coastal Management) 2018. According to the Hawkesbury-Nepean State of the Catchments 2010 report, wetlands in the catchment were rated "Very Poor". This includes Pitt Town Lagoon and Longneck Lagoon identified above.

There are other key ecological communities within the study area, such as the Agnes Banks Woodland, which is listed as a Critically Endangered Ecological Community under the BC Act. Hawkesbury Council also contains land listed under the *National Parks and Wildlife Act 1974* including Windsor Downs Nature Reserve, Pitt Town Nature Reserve, and Cattai National Park. Acid sulphate soils are found within the study area, including in the Richmond-Windsor floodplain. Local streambank erosion was identified as an issue between "The Breakaway" upstream of Windsor Bridge downstream to Sackville Ferry (Worley Parsons, 2012). These environmental issues will be considered in the development of mitigation measures and their assessment.

2.5. Demographic Overview

Understanding the social characteristics of the study area can help in shaping the methods used for community engagement and in ensuring appropriate risk management practices are adopted. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. According to The Flood Preparedness Manual (Reference 10), it is also possible, using population census data and other information held by councils and state agencies, to identify the potential number and location of people in an area (or the proportion of the community's population) with special needs or requiring additional support during floods.

The Flood Preparedness Manual (Reference 10) identifies that, in general, people who belong to the following groups may be considered especially susceptible to the hazard floods pose:

- **The elderly**, especially those living alone and/or frail, who are often unable to respond quickly or without assistance;
- **Those with low incomes**, including the unemployed and others on pensions, who may lack resources which would give them independence of decision making and action;
- **Single-parent families, large families or families with very young children**: these may be characterised by low adult / child ratios making evacuation difficult;
- **Those lacking access to a motor vehicle** may need additional assistance to evacuate;
- **Newcomers** (i.e. those residents in their communities for only short periods), who are unlikely to appreciate the flood threat and may have difficulty understanding advice about flooding. They may need special attention in terms of threat education and communication of warnings and other information;
- **Members of Culturally and Linguistically Diverse communities**, who need special consideration with respect to the development of preparedness strategies as well as

warnings and communications during flood events. Special attention may also be needed if actions which become necessary during floods offend cultural sensitivities;

- **The ill** or **infirm** who need special consideration with respect to mobility, special needs, medications, support and 'management' to ensure they continue to receive appropriate care and information; and
- **Those whose homes are isolated by floods**, requiring early evacuation, or if evacuation orders are ignored, may need medical evacuation resupply of essential items, or emergency rescue.

The following information has been extracted from the 2021 Census for the Hawkesbury LGA.

Hawkesbury Demographic Overview

Population: 67,207
No. of Private Dwellings: 25,473
No. of lone person households: 5,019
Property Tenure:

- 73.0% owned (either outright or with a mortgage)
- 24.0% rented

Language

- 88.4 % of people speak only English at home

No. persons over the age of 75: 4,774
Elderly people may be unable to respond as quickly to flood emergencies without requiring some assistance.

No. single parent families: 2,903
Single parent families can mean a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Statistics from https://www.abs.gov.au/census/find-census-data/quickstats/2021/LGA13800

2.6. Legislation and Policies

2.6.1. Land Use

Hawkesbury Local Environmental Plan 2012 makes local environment planning provisions for the Hawkesbury Council area. The land use zoning for the study area is presented in Figure 2. The catchment is mixed use with areas of general residential, general industrial, recreation and other non-developed uses in flood affected areas. The majority of flood affected land is zoned residential, industrial or primary production.

2.6.2. Floodplain Management Policy

It is important to understand the state legislation that overarches all local planning so as to enable appropriate floodplain risk management measures to be proposed that meet both state and local

statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

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

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

Objectives

The objectives of this direction are:

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

Clause (3) of Direction 4.3 states:

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

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

- *A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).*
- *A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.*
- *A planning proposal must not contain provisions that apply to the flood planning areas which:*
    - *permit development in floodway areas,*
    - *permit development that will result in significant flood impacts to other properties,*
    - *permit a significant increase in the development of that land,*
    - *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*

- *permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

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

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

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

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

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

2.6.2.1. NSW Flood Prone Land Policy

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

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

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

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

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

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

2.6.2.2. Section 733 – Local Government Act 1993

Section 733 of the Local Government Act relates to Exemption from liability – flood liable land, land subject to risk of bush fire and land in coastal zone. It states:

(1) A Council does not incur any liability in respect of:

(a) any advice furnished in good faith by the council relating to the likelihood of any land being flooded or the nature or extent of any such flooding, or

(b) anything done or omitted to be done in good faith by the council in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.

And;

(3) Without limiting subsections (1), (2) and (2A), those subsections apply to:

(a) the preparation or making of an environmental planning instrument, including a planning proposal for the proposed environmental planning instrument, or a development control plan, or the granting or refusal of consent to a development application, or the determination of an application for complying development certificate, under the Environmental Planning and Assessment Act 1979, and

(b) the preparation or making of a coastal zone management plan, or the giving of an order, under the Coastal Protection Act 1979, and

(c) the imposition of any condition in relation to an application referred to in paragraph (a), and

(d) advice furnished in a certificate under section 149 of the Environmental Planning and Assessment Act 1979, and

(e) the carrying out of flood mitigation works, and

(f) the carrying out of coastal management works, and

(f1) the carrying out of bush fire hazard reduction works, and

(f2) anything done or omitted to be done regarding beach erosion or shoreline recession on Crown land, land within a reserve as defined in Part 5 of the Crown Lands Act 1989 or land owned or controlled by a council or a public authority, and

(f3) the failure to upgrade flood mitigation works or coastal management works in a response to projected or actual impacts of climate change, and

(f4) the failure to undertake action to enforce the removal of illegal or unauthorised structures that results in erosion of a beach or land adjacent to a beach, and

(f5) the provision of information relating to climate change or sea level rise, and

(f6) anything done or omitted to be done regarding the negligent placement or maintenance by a landowner of temporary coastal protection works, and

(g) any other thing done or omitted to be done in the exercise of a council's functions under this or any other Act.

(4) Without limiting any other circumstances in which a council may have acted in good faith, a council is, unless the contrary is proved, taken to have acted in good faith for the purposes of this section if the advice was furnished, or the thing was done or omitted to be done, substantially in accordance with the principles contained in the relevant manual most recently notified under subsection (5) at that time.

2.6.2.3. Section 10.7 Planning Certificates

In accordance with Section 10.7 (formerly Section 149) of the EP&A Act, Councils can issue planning certificates which describe planning and development matters relating to a piece of land. The two planning certificates are available under the EP&A Act are Section 10.7 (2) and 10.7 (5) planning certificates. Obtaining a Section 10.7 certificate is required under the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 when land is bought or sold.

Specifically, Section 10.7 of the EP&A Act states:

> *(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a **planning certificate**) with respect to any land within the area of the council.*
>
> *(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).*
>
> *(3) (Repealed)*
>
> *(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.*
>
> *(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.*
>
> *(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.*
>
> *(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.*

2.6.2.4. Schedule 4 Planning Certificates

Schedule 4 Planning certificates of the Environmental Planning and Assessment Regulation (EP&A Regulation), 2000, sets out which matters are to be included in a planning certificate under Section 10.7 (2) of the EP&A Act and includes but is not limited to information such as planning instruments that apply to development, zoning and land use under relevant Local

Environmental Plans (LEPs) and State Environmental Planning Policy (SEPP) and complying development.

Specific to flood related development controls information, Schedule 4, 7A of the EP&A regulation states:

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

Section 10.7 (2) and 10.7 (5) certificates are more detailed certificates and includes all information specified in Schedule 4 and any additional information Council may choose to provide. Types of flood related information that could be provided in a Section 10.7 (2) and 10.7 (5) planning certificate include design flood depths, percentage of the lot flood affected or evacuation information (note that this is not an exhaustive list).

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

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

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

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

- *providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.*

2.6.2.6. General Housing Code

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.3 of the SEPP, relates to ***Requirements for complying development under this code***. Clauses 3.1 (1) states:

3.1 Development that is complying development under this code

(1) The following development is complying development under this code –

a. the erection of new 1 or 2 storey dwelling house and any attached development,
b. the alteration of, or an addition to, a 1 or 2 storey dwelling house (including any addition that results in a 2 storey dwelling house) and any attached development,
c. the erection of detached development and the alteration of, or an addition to, any detached development.

and

(3) Lot requirements

Complying development specified for this code may only be carried out on a lot that meets the following requirements –

a. the lot must be in Zone R1, R2, R3, R4 or RU5,
b. the area of the lost must not be less than 200m^2,
c. the width of the lot must be at least 6m measured at the building line,
d. there must only be 1 dwelling house on the lot at the completion of the development,
e. the lot must have lawful access to a public road at the completion of the development,
f. if the development is on a battle-axe lot – the lot must be at least 12m by 12m (not including the access laneway) and must have an access laneway that is at least 3m wide.
g. If the development is on a corner lot – the width of the primary road boundary of the lot must be at least 6m..

Division 2 of Part 3 of the SEPP "***General standards relating to land type***" contains Clause 3.5 *"Complying development on flood control lots"*

A *"flood control lot"* is defined in the SEPP as:

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

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

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

Clause 3.5 states

3.5 Complying development on flood control lots

(1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following –
(a) a flood storage area,
(b) a floodway area,
(c) a flow path,
(d) a high hazard area,
(e) a high risk area.

(2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards –
(a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,
(b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,
(c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris, and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),
(d) the development must not result in increased flooding elsewhere in the floodplain,
(e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,
(f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,
(g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

(3) The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Policy.

(5) In this clause -

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

flood planning level *means –*
(a) the flood planning level adopted by a local environmental plan applying to the lot, or
(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

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

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

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

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

Note 1. ***Council, flood control lot, habitable room*** *and* ***professional engineer*** *are defined in clause 1.5*
Note 2. A section 10.7 certificate from a Council will state whether or not a lot is a flood control lot.

2.6.2.7. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*, which applies to development that is specified in clauses 3A.2–3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5. Section 3A.38 contains "Complying development on flood control lots". The standards contained in this section are the same as those in Clause 3.5 provided in Section 2.6.2.7, with the exception of Clause 2 (c) which states:

> *2 (c) any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level)*

2.6.2.8. Low Rise Housing Diversity Code

Part 3B of the SEPP contains the "Low Rise Housing Code", applying to the development in clause 3B.1 on lots in Zones RU5, Zone R1, Zone R2 or Zone R3. Section 3B.5 contains "Complying development on flood control lots". The standards contained in this section are the same as those in Clause 3.5 provided in Section 2.6.2.7, with the exception of Clause 3A which states:

> *3A) Without limiting subclause (3), a joint report must--*
> *(a) include a signature made by each professional engineer by whom the report is prepared, and*
> *(b) where conclusions of the report are based on data, surveys or other material--include the name and author of the document on which the conclusions are based.*

2.6.2.9. Greenfield Housing Code

Part 3C of the SEPP contains the “Low Rise Housing Code”, applying to the development in the Housing Code or the Transitional Housing Code on lots in Greenfield Housing Code Area. Section 3C.6 contains “Complying development on flood control lots”. The standards contained in this section are the same as those in Clause 3.5 provided in Section 2.6.2.7.

2.6.2.10. Commercial and industrial (new buildings and additions) code

Part 5A of the SEPP contains the “Commercial and industrial (new buildings and additions) code”, applying to the development in clause 5A.2 on lots in Zone B1, B2, B3, B4, B5, B6, B7, B8, IN1, IN2, IN3, IN4 or SP3. Section 5A.30 contains “Complying development on flood control lots”. The standards contained in this section are the same as those in Clause 3.5 provided in Section 2.6.2.7.

2.6.2.11. Summary of State Legislative and Planning Polices

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

2.6.2.12. Flood Prone Land Package

On the 14th July 2021, the Department of Planning and Environment (DPE) implemented updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation consideration in land use planning.

The changes include:

- A revised Ministerial Direction 4.1 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979,
- a revised planning circular on flooding
- a new guideline: Considering Flooding in Land Use Planning
- Revised Local Environmental Plan flood clauses,
- Amendments to Schedule 2, Section 9 of the Environmental Planning and Assessment Regulation 2001,
- State Environmental Planning Policy Amendment (Flood Planning) 2021.

The key changes and implications are outlined below:

- Amendments to Schedule 2 of EP&A Regulation including changes to Clause 9(1), Clause 9(2). These amendments now require councils to note on Section 10.7 certificates if any

flood related development controls apply to the land relating to either the Flood Planning Area, hazardous materials / industry, sensitive, vulnerable or critical uses.

- The Ministerial Direction 4.1 has been amended to remove the requirement for councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (currently included in Clause 7 of Direction 4.3).
- Two proposed LEP clauses relating to the Flood Planning Area, and Special Flood Consideration.
    - The Flood Planning Area clause allows council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools.
    - The clause relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.

2.6.3. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Policies have been discussed below (see 2.6.3.1 and Section 2.6.3.2).

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 Development Planning Controls (DCPs). LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Hawkesbury Council's LEP was gazetted in August 2012 and was prepared under the Standard Instrument LEP program.

2.6.3.1. Hawkesbury Local Environment Plan 2012 (LEP2012)

Clause 5.21 of LEP 2012 relates to flood planning and states:

5.21 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 flood function and behaviour on the land, taking into account projected changes as a result of climate change,

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,

(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

***Considering Flooding in Land Use Planning Guideline** means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.*

***flood planning area** has the same meaning as it has in the Floodplain Development Manual.*

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

2.6.3.2. Hawkesbury City Council Flood Policy 2020 and Schedule of Flood Related Development Controls.

The Flood Policy ("the Policy") addresses the requirements of Clause 5.21 in the LEP2012, setting out the development controls for all Development Applications within the Flood Planning Area of Hawkesbury City Council. The Policy is to be used in conjunction with a Schedule of Development Controls ("the Schedule"). The controls are defined for Flood Hazard Categories, and take into consideration "*flood function (floodway, flood storage or flood fringe) the vulnerability of land use types, likely evacuation constraints and measures that can be implemented to minimise risk to life and flood damages.".* The Flood Policy was adopted in 27th October 2020 and amended in 29

June 2021.

The Policy defines the Flood Planning Area as *the land below the 1:100 ARI flood event.*

For the purpose of defining development controls in the Schedule, the hazard categories range from H1 (i.e., Generally safe for vehicles, people and buildings) to H6 (i.e., Unsafe for vehicles and people. All building types considered vulnerable to failure).

Flood controls depend on whether the proposal is:

- new development, or
- is for the purposes of additions, alteration, intensification, rebuilding or redevelopment of an existing use, and
- if an existing use, whether or not it is within a compatible or incompatible Hazard Category.

According to the Policy "Hawkesbury City Council supports and encourages the need for regional flood mitigation measures in the Hawkesbury-Nepean Valley to be investigated and implemented by the Commonwealth and NSW State Governments and other relevant Authorities" noting that the flood problem in the Hawkesbury-Nepean Valley is too large for one organisation to take the burden of fixing by itself.

The controls are outlined in "the Schedule" adopted dated 2021. Permissible land uses (eg critical uses, single residential, multi residential and commercial etc) by hazard category are documented in Table 2 of the Schedule. It has controls related to emergency management, cut and fill and floor levels.

The Schedule also outlines the documents to be supplied with a Development Application, which include documentation outlining access to Regional Flood Evacuation Routes.

3. AVAILABLE DATA

3.1. Flood Model

The TUFLOW hydraulic model for the catchment was developed by Rhelm and Catchment Simulation Solutions (CSS) as part of the Hawkesbury-Nepean River Flood Study (Reference 18). The model has a grid resolution of 15m and was calibrated and validated against historical events, including in the March and July 2022 events. The verification for the 2022 events is documented in the Hawkesbury-Nepean River March and July 2022 Floods Review (Reference 9) and detailed in Reference 18. This model was used for mapping and options assessment for the current study (Figure 3).

The design surface for flood planning is calculated by running 'representative events' through the TUFLOW model. These events are determined through a Monte-Carlo framework run by WMAwater, which involves running 20,000 events through a calibrated one-dimensional Rubicon model to generate an equivalent record of 200,000 years. The representative events create the critical flood level in various areas. The following events were representative for the Hawkesbury LGA (Table 5) and have been used in the modelling presented in this report. More detail on the representative events can be found in Reference 18.

Model runs were undertaken to validate the results provided. These were largely reproduced with minor inconsistencies in the order of a few millimetres occurring due to different GPU cards being used. These differences are minor and unlikely to affect the results.

Table 5: Representative Events in the Hawkesbury LGA

Design Event	Representative events within Hawkesbury LGA
20% AEP	BD03301, BD02406, BD08555, BD04234
10% AEP	BD02615
5% AEP	RD00245, RD08304, RD06766, RD04971, RD03529, BD07572
2% AEP	RD05471, RD08941
1% AEP	RD02523, RD01158, RD03816
0.5% AEP	RD00558, RD09247
0.2% AEP	RD00723, RD03880, RD06478
1 in 1000 AEP	RD02664, RD03510, RD05981
1 in 2000 AEP	RD00180, RD00937, RD08763
1 in 5000 AEP	RD01374, RD04070, RD09388
PMF	PMF to Sackville

3.2. Buildings Points

A GIS layer representing points for buildings as per 2018 was provided by NSW Reconstruction Authority for the Hawkesbury-Nepean LGA in order to undertake the average annual damages. Additional points were sourced for the Penrith, Blacktown and Hills District LGA in order to undertake a relative damages assessment for the options which cause impacts outside the

Hawkesbury LGA.

The points represented residential, commercial, industrial, public buildings and caravans. Multi storey buildings were represented by one point per dwelling within the dwelling, including those above the ground floor. Approved subdivisions at the time of the data set creation were represented by multiple points placed within the street. Table 6 and Table 7 summarises the properties.

Table 6: Summary of building points in Hawkesbury Nepean LGA

Type	Number of
Residential	19,599
Commercial, industrial and public	2,970
Caravans	637

Table 7: Number of points by LGA

LGA	Total number of points
Hawkesbury	23,206
Penrith	18,935
Blacktown	10,871
The Hills	1,711
TOTAL ALL LGAs	**54,723**

3.3. Site Visit

WMAwater conducted a site visit of the catchment in October 2022. The tasking during the site visit comprised:

- Photographs of selected structures in the catchments including culvert sizes and bridges.
- General photographs capturing catchment characteristics.

4. COMMUNITY CONSULTATION

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

- The Council's Floodplain Management Sub-Committee,
- Hawkesbury City Council's website, and
- Public meetings.

Community engagement was undertaken between 4 September 2023 to 2 October 2023, which included a questionnaire which asked participants to rank potential mitigation options from most to least favourable. General trends noted were that levees were the least favourable of all proposed options. Improved flow paths (for example Drainage into Chain of Ponds, McKenzie's Creek and South Creek from development) and raising the dam wall were suggested options for investigation.

4.1. Hawkesbury Floodplain Risk Management Advisory Committee

The Floodplain Management Committee oversees and assists with the floodplain risk management process being carried out within the Council LGA. The committee is comprised of representatives from various stakeholder groups and includes:

- Council management
- Local Emergency Management Officer and other council officers
- DCCEEW Group representative
- NSW Reconstruction Authority and other state agencies as required and
- local residents and community representatives

A number of mitigation options were workshopped with the committee, which formed the basis for the options assessment and draft management study. Outcomes of the committee meetings include support for investigating further (refer to Section 8.3 for detail):

- Currency Creek bypass
- Wilberforce Levee

Overall, the committee endorsed improvements to evacuation routes and flood mitigation capacity in Warragamba dam. In particular the following options were identified for investigation and further discussion:

- Currency Creek bypass
- Wilberforce Levee
- High level bridge to West Portland Road
- Raising Springwood Road
- Floodways, flood drainage and flood gates
- Assessment of flood evacuation routes

4.2. Public Exhibition

Following approval by the Council and Floodplain Management Committee, this Draft Floodplain Risk Management Study and Plan will be placed on public exhibition. This is the opportunity for the community to examine the report and the study outcomes and make any comments or suggestions.

To be completed after exhibition

5. EXISTING FLOOD BEHAVIOUR

5.1. Design Flood Behaviour

Peak flood levels for the 20%, 10%, 5%, 2%, 1%, 0.5% AEP, 1 in 1000, 1 in 2000, 1 in 5000 AEP and Probable Maximum Flood (PMF) design events are presented in Figure 4 to Figure 23 and Table 8 at Key Locations.

The majority of flood levels are only slightly changed from the 2019 Regional Flood Study. There is no significant change in the 10% to 0.5% AEP and no change in the 1% AEP (>30mm). The detailed TUFLOW model shows significant increases in flood levels in extreme events compared to previous studies. This is caused by bend losses in extreme events in the tightest bends. This has resulted in the PMF increasing by 3.9m at Windsor, 5.8m at Sackville and 4.9m at Wisemans Ferry.

5.1.1. Windsor Area

The floodplain at Windsor is the most severely affected by flooding on the Hawkesbury-Nepean River. In a 1 in 10 AEP event, flood levels at Windsor Bridge are 11.7 m AHD. By this level, a number of properties are isolated on low flood islands after access roads are cut.

In the 1 in 100 AEP event, the flood level at Windsor Bridge is 17.35 mAHD and the flood extent increases substantially from the 1 in 10 AEP event. In the 1 in 100 AEP event, the suburb of McGraths Hill is completely submerged, and while some areas of Windsor, South Windsor and Pitt Town are above the 1 in 100 AEP extent, they are isolated as flood islands. Windsor Road is inundated as far as Vineyard Railway Station (about six kilometres from Windsor Bridge). Macquarie Street is overtopped near Windsor Railway Station and again at the low point near Bligh Park.

Depths around the Richmond Lowlands floodplain and through Freemans Reach in a 1 in 100 AEP generally exceed eight metres at the peak of the flood. Depths along Rickabys Creek and South Creek on the Windsor floodplain exceed 10 metres (noting this is from backwater flooding). In general, on the Windsor floodplain, the depths in the 1 in 100 AEP event exceed two metres with large areas more than 8m deep. Flood depths in South Creek reach 14m.

In the PMF event, flood levels reach 30.55 mAHD at Windsor Bridge, inundating virtually all of the flood islands including Windsor and Richmond. Backwater flooding up South and Eastern Creeks inundates part of suburbs as far south as St Marys, including Marsden Park, Shanes Park, Llandilo, Vineyard, Riverstone and Schofields.

5.1.2. Downstream of Sackville

Downstream of Sackville, the river meanders away from the floodplain and into the gorge country of the Lower Hawkesbury River. The 1 in 10 AEP event has a level of 3.12 m AHD at Wisemans Ferry, while the 1 in 100 AEP event has a level of 6.39 m AHD. At Wisemans Ferry, overbank flow occurs in events as frequent as the 1 in 5 AEP event. In the 1 in 10 AEP event, overbank depths of up to 2 metres occur, and in the 1 in 100 AEP event, overbank depths at Wisemans Ferry reach six metres. The PMF event reaches a level of 18.89 m AHD, 11.53 metres above the 1 in 100 AEP event. Due in part to the topography and the smaller difference in flood levels between frequent and rare events, the change in flood extent from the 1 in 100 AEP to the PMF event is relatively small. However, roads are often cut in frequent events and evacuation of isolated communities can be an issue.

Table 8: Design flood levels at key locations

ID	Location	Peak Flood Levels (mAHD)									
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	1 in 1000 AEP	1 in 2000 AEP	1 in 5000 AEP	PMF
1	Yarramundi	13.24	15.71	17.1	17.56	18.09	19.12	21.64	23.03	24.52	30.58
2	North Richmond	12.47	14.73	15.91	16.48	17.51	18.68	21.41	22.88	24.41	30.56
3	Freemans Reach	11.57	12.95	13.94	15.97	17.37	18.55	21.33	22.82	24.37	30.55
4	Windsor Bridge	9.71	11.7	13.78	15.94	17.35	18.53	21.32	22.81	24.36	30.55
5	McGraths Hill	-	-	-	15.93	17.34	18.53	21.32	22.81	24.36	30.55
6	South Creek at Hawkesbury Valley Way	9.75	11.66	13.77	15.93	17.34	18.53	21.32	22.81	24.36	30.55
7	South Creek at Richmond Road	9.82	11.67	13.77	15.93	17.34	18.53	21.32	22.81	24.36	30.55
8	Sackville Ferry	5.45	7.92	10.16	12.48	13.89	15.42	18.68	20.75	22.54	29.37
9	Lower Portland	4	5.82	7.57	9.78	10.98	12.86	17	18.7	20.27	26.63
10	Leets Vale	2.72	3.97	5.2	6.76	7.81	9.38	13.02	14.49	15.82	21.23
11	Wisemans Ferry	2.2	3.12	4.21	5.4	6.39	7.87	11.35	12.72	14	18.89

(- means the key location is not flooded. Flooding may occur nearby)

5.2. Hydraulic and Hazard Classification

5.2.1. Hazard Classification

Hazard classification plays an important role in informing floodplain risk management. It reflects the likely impact of flooding on development and people, providing a measure of potential risk to life and property damage, from a flood event. Hydraulic hazard is typically determined by considering the depth and velocity of floodwaters. In recent years, there have been a number of developments in the classification of hazards. Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth, velocity and velocity depth product.

Hydraulic hazard categories have been determined for the study area in accordance with the NSW Flood Risk Management Manual (Reference 11) and its accompanying guideline FB03 – Flood Hazard (Reference 12).

The accompanying guideline FB03 (Reference 12) contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 1.

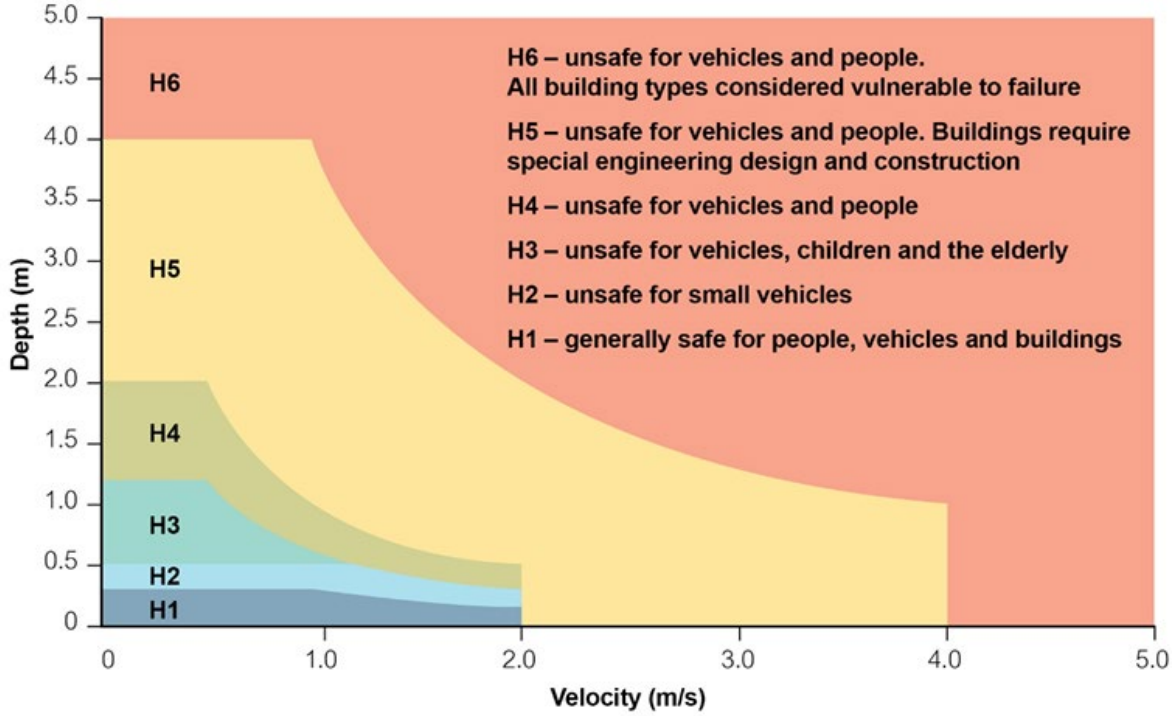


Diagram 1: General flood hazard vulnerability curves

This classification provides a more detailed distinction of the practical vulnerabilities of hazard categories, identifying the following 6 classes of hazard:

- H1 – No constraints, 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 all people and all vehicles. All building types considered vulnerable to failure.

It should be noted that these classifications are based on the physical flood behaviour in design flood events and do not account for other hazards that may exist (such as, road surface failure) or the variability in real storm events.

Figure 24 to Figure 35 present the hydraulic hazard categorisations for the 20%, 5%, 1%, 0.5%, 0.2% AEP and PMF events based on the results from the 2024 Flood Study. Overall the majority of the floodplain is subject to H5 (Unsafe for all people and all vehicles. Buildings require special engineering design and construction) or H6 (Unsafe for all people and all vehicles. All building types considered vulnerable to failure). The edges of the floodplain are subject to lower hazard (H1 to H4) but as the events become rarer the extent of H1 to H4 shrinks. Much of the areas classified as H5 and H6 are driven by the depth rather than the velocity.

5.2.2. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the Floodplain Risk Management process to assist in the assessment of the suitability of future types of land use and development, and the formulation of floodplain risk management plans.

Hydraulic categorisation involves mapping the floodplain to indicate which areas are most important for the conveyance of floodwaters, and the temporary storage of floodwaters. The Flood Risk Management Manual (Reference 11) defines land inundated in a particular event as falling into one of the three hydraulic categories listed in Table 9 based on their function during a flood event. The flood function of an area may change with the magnitude of the event, the most extreme example being areas which are flood free during a smaller more frequent flood event, forming part of a floodway in larger less frequent events. Typically, development within floodway or flood storage areas would be likely to cause water to flow into other areas redistributing the flood risk, unless the development is carefully designed to avoid these impacts. Understanding these categories can inform land use planning strategies for the appropriate management of flood risk.

Table 9: Hydraulic Categorisation Definitions

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels. • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which my adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• 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, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• Remaining area of land affected by flooding after floodway and flood storage areas have been defined; • Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

There are no discrete criteria or parameters which explicitly break down the floodplain into the three categories of flood function that would be suitable for all catchments. Different approaches and techniques are used in practice and by different authorities, based on the specific features of the catchment in question. These approaches aim to validate the areas of the floodplain falling into each hydraulic category, rather than defining them.

The hydraulic categories are remapped from the 2024 Flood Study which used a combination of indicator techniques. A large area of the floodplain is categorised as floodway. Storage areas exist around Rickabys Creek, South Creek, Killarney Chain of Ponds, Roberts Creek, Currency Creek and Greens Creek. Between a 0.5% and 0.2% AEP a floodway develops at Currency Creek overflow.

6. CONSEQUENCES OF FLOODING ON THE COMMUNITY

Flooding affects the Hawkesbury community much worse than in most locations in NSW due to the extreme flood range. This range means that houses are not just at risk of flooding but are flooded to a sufficient depth that total replacement is required and entire suburbs need to be evacuated. In most coastal rivers the PMF event would typically be a couple of metres above the 1% AEP event. At Windsor the PMF is 13m above the 1% AEP. For these reasons the risk to life in the Hawkesbury Nepean is higher than anywhere else in NSW. This flood range means that recovery from a major flood will take much longer than in most other locations and many homes and businesses that aren't flooded will still be significantly affected by damaged infrastructure that takes a significant time to repair.

6.1. Hawkesbury-Nepean Flood Evacuation Modelling

Due to the extreme risk to life in the Hawkesbury-Nepean there have been extensive studies on the evacuation for the last 20 years. As part of the Hawkesbury-Nepean Valley Flood Risk Management Strategy a detailed agent-based Flood Evacuation Model (FEM) was setup by the data61 business unit of CSIRO. This agent-based model is the most complex flood evacuation model setup in Australia. This model simulates the evacuation of each individual household in the valley.

The FEM simulates the NSW SES evacuation timeline and arrangements under a range of assumptions. It provides the NSW Government with a repeatable process to quantify existing and ongoing risk associated with the cumulative impact of growth and climate change on road evacuation capacity in the valley.

The purposes of the FEM are to:

- understand road network evacuation performance under a range of flood events,
- identify regional road capacity constraints including when/where roads are cut due to flooding,
- assess the risk to life for various locations due to the vehicular capacity of the road evacuation network,
- assess how potential upgrades to improve the evacuation capacity of the road network reduce the risk to life,
- inform government on the ability of the existing and future road network to accommodate emergency evacuations under various land use, flood mitigation and road network infrastructure scenarios.

The model represents the SES flood evacuation strategy and human response to evacuation orders. The model also allows for traffic queuing and re-routing as links become cut and used fine-scale sub sectors. The model uses an ensemble of 87 events drawn from the 20,000 Monte Carlo events used in the Hawkesbury-Nepean Flood stud (2019). The model uses a range of fast and slow rising events that nominally exceed the 2%, 1%, 0.5%, 0.2%, 1 in 1000, 1 in 2000, 1 in 5000 AEP flood levels at Windsor.

This model allows different evacuation triggers and strategies to be assessed along with the increase in congestion from population growth and the benefits of road upgrades. The key metric from each design event is the number of vehicles which are trapped and unable to exit the floodplain and which sub sector they left from. In smaller floods vehicles could be trapped in low flood islands and in events where very small numbers of cars are trapped it is likely that they are just short of high ground and therefore likely to have a short walk out. When large numbers of vehicles are trapped a reasonable percentage will perish if not rescued.

A key outcome from setting up the model is that the SES can provide very granular evacuation advice to individual streets and suburbs. As detailed modelling and information is available from the SES, a limited set of key information is produced within this report.

6.2. Road Overtopping and Length of Inundation

A number of low level crossings and roads exist within the catchment. Due to the extent and depth of flooding, these roads can be cut for periods of time, severing communities and restricting access to emergency services. The FEM model considers evacuation in large flood events but even frequent events have a large impact on the community when low level bridges and Ferrys are cut.

Table 10 lists the low level crossings and their typical period of closure in a 1% AEP event.

Table 10: Low level crossings and their typical period of closure in a 1% AEP event

Location	Closure Level	1% AEP flood level	Typical Time of Closure in a 1% AEP event (hr)
Yarramundi Bridge	5.61 m AHD	18#	185#
North Richmond Bridge	7.82 m AHD	17.46	155
Windsor Bridge	9.00 m AHD	17.35	140
Sackville Ferry	1.60 m AHD	13.89	185
Lower Portland Ferry	3.0 – 3.5 * m AHD		200
Webbs Creek Ferry	3.0 – 3.5 * m AHD		200
Wisemans Ferry	3.0 – 3.5 * m AHD		200

Closure levels are approximate as ferries can be closed depending on conditions. Bridges can be closed based on debris, expected peak and flood behaviour.

*Based on Windsor Gauge as per SES flood plan

#Come from different representative events. The event that produces the peak level doesn't produce the peak inundation time.

Table 11 provides a list of low points on evacuation routes that are inundated during the 1% AEP design flood event. Ground elevation at these low points were derived from the ALS. This table

provides an indication of what design event these roads are likely to be first cut. Evacuation towards Parramatta on Windsor Road is effectively cut for McGraths Hill at 13.5 mAHD and slightly later for Windsor when the link between Jim Anderson Bridge and Windsor Road is cut.

The length of time in a 1% AEP event till a low point in the road is cut and how long it can be expected to be cut is presented in Table 12. The Monte Carlo modelling shows that while these are typical times the durations can vary by 24 hrs longer or shorter than this. Road access is assumed to be cut at the low point when flood depths on the road exceed 10 mm. For example, access to McGraths Hill will stay inundated for 75 hours.

Table 11: Design Flood Levels at Low Points in Roads

ID	Road Name	Level of low point in road (mAHD)	Flood levels for 1% AEP at low points (mAHD)
1	Windsor Rd	13.5	17.34
2	Richmond Rd	14.2	17.34
3	Pitt Town Rd	15.9	17.27
4	South Creek	17.3[1]	17.34
5	Londonderry Rd	18.2	-
6	Castlereagh Rd	20.2	-
7	Sackville Rd	4.3	13.91[2]
8	Putty Rd	9.6	13.18[2]

[1]This is the level of the Jim Anderson Bridge but access to lower level near Windsor.

[2]This is based on a nearby water level gauge.

Table 12: Inundation Times of Road Low Points During Typical 1% AEP flood event

ID	Evacuation Routes	Location of low point	Level of low point in road (mAHD)	Typical total time of inundation (hr)
1	Windsor Rd	Near McGarths Hill	13.5	75
2	Richmond Rd	Near South Creek Bridge	14.6	67
3	Pitt Town Dural Rd	On Pitt Town Dural Rd	15.9	41
4	South Creek	Jim Anderson Bridge	17.3	Not flooded
5	Londonderry Rd	Between College St and Cameron St	18.2	Not flooded
6	Castlereagh Rd	On The Driftway	20.2	Not flooded
7	Sackville Rd	Near W Portland Rd	4.3	150[1]
8	Putty Rd	Near Roberts Creek	9.6	66[1]

[1]This is based on a nearby water level gauge.

Diagram 2 shows graphically when the roads are first cut compared to the Windsor water level gauges in a typical 1% AEP event. They also include the defined levels for Major, Moderate and Minor flooding at Windsor Gauge in the SES Flood Emergency Sub Plan.

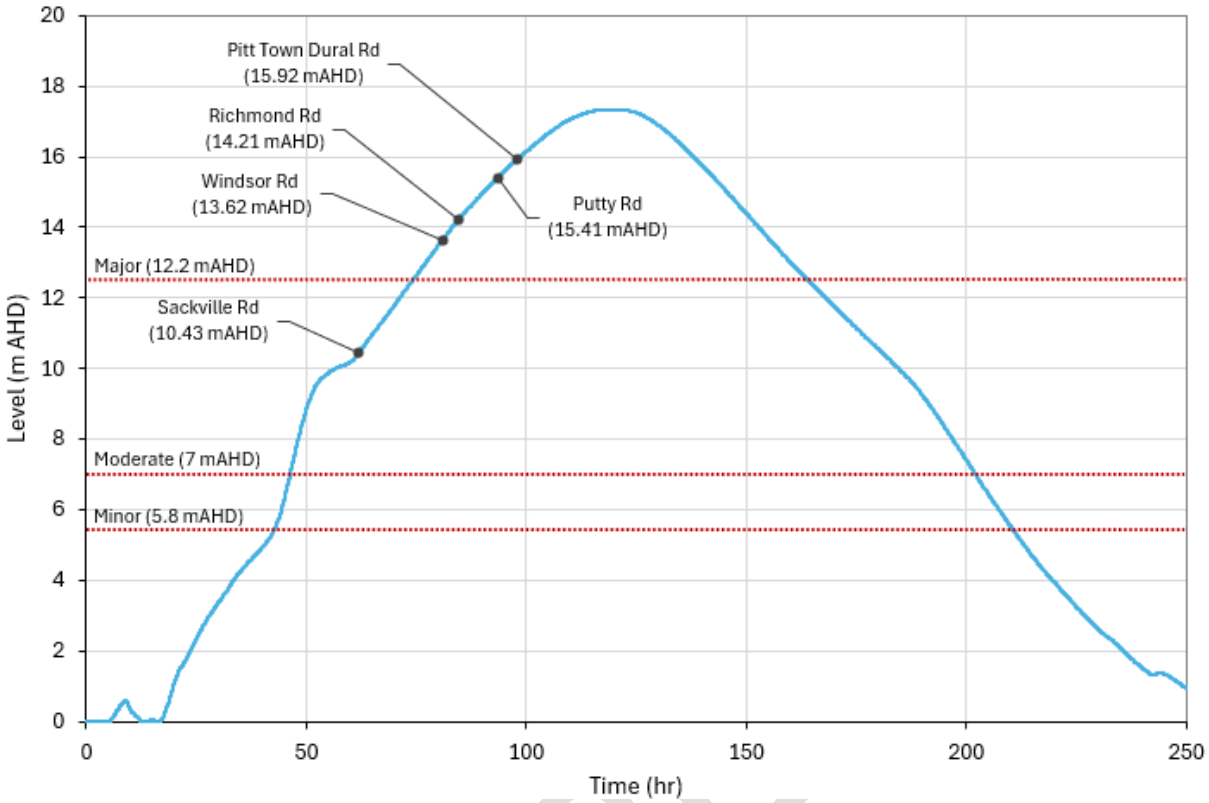


Diagram 2: 1% AEP Hydrograph including evacuation routes and corresponding inundation levels at the Hawkesbury Windsor Gauge (#212426)

6.3. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include recreational/tourist facilities, water and sewerage supply, telephone and electricity supply (including transmission poles/lines, sub-stations and underground cables), roads and bridges (including traffic lights/signs), and costs to employ the emergency services and assist in post-flood clean up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise:

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

Flooding of public infrastructure can have a lingering effect on residents that may not have been directly affected by the event.

6.4. Economic Impact of Flooding

The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also provide 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 Diagram 3.

The assessment of flood damages not only quantifies potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding, as shown in Appendix A.

The building floor level data set was developed by analysing the ALS data and building footprints available. The height of the roof compared to the ground level was used to determine if the building was one or two storey or elevated. This was then used to determine the likely floor level. Additional buildings in areas of new development were added to the building points layer.

Table 13: Summary of building points in Hawkesbury Nepean LGA

Type	Number of
Residential	19,599

Commercial, industrial and public	2,970
Caravans	637

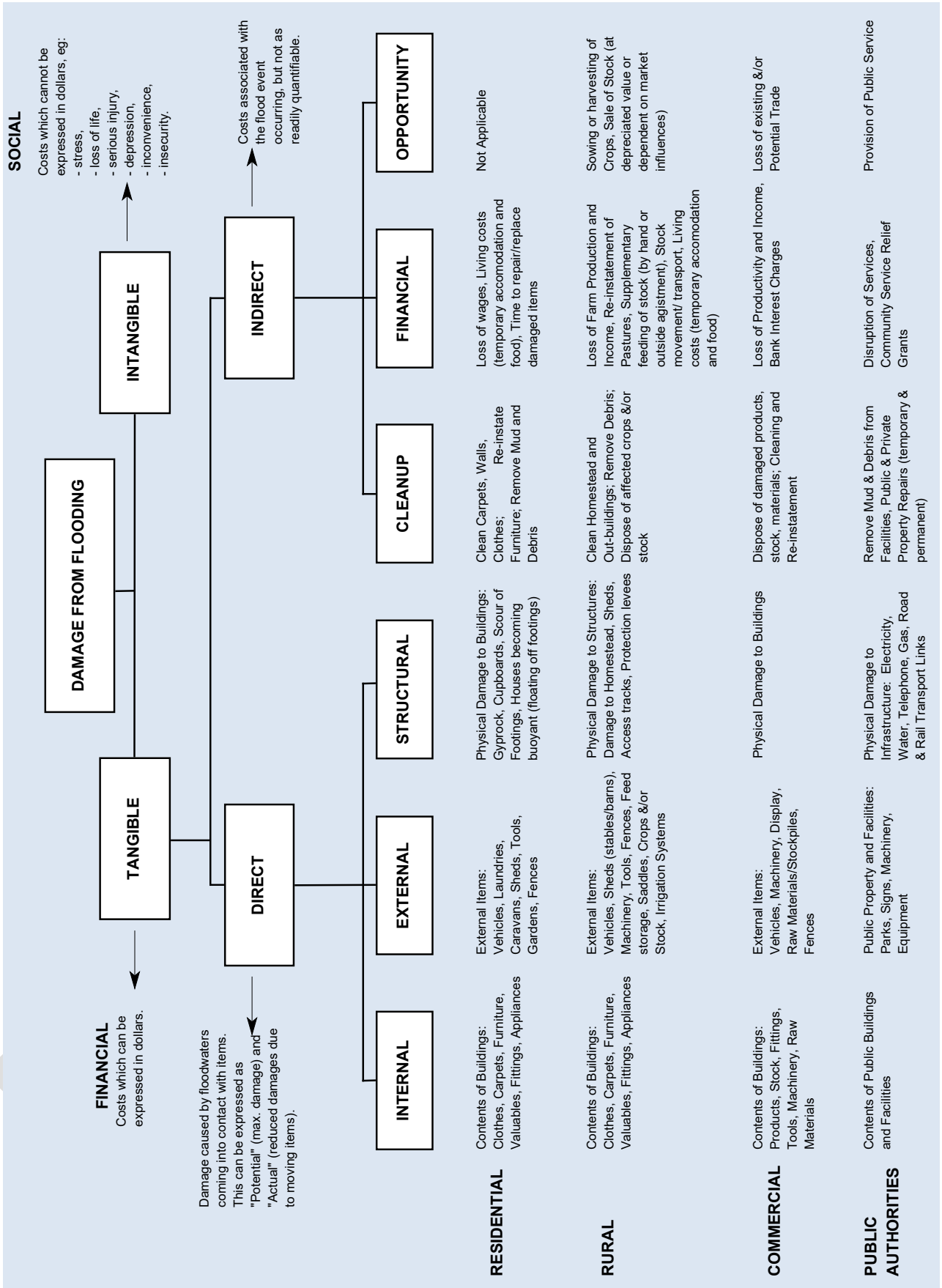


Diagram 3: Flood damages categories (including damage and losses from permanent inundation)

6.4.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (see Diagram 3). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction 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, property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision-making process.

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

To quantify the damages caused by inundation for existing development, a floor level estimate was developed. This was used in conjunction with modelled flood level information to calculate flood damages. Floor levels were estimated using building outlines and LiDAR estimates of the ground and roof levels. Based on the maximum distance between the roof and ground it was determined in the building was single storey, raised single storey or two storey. An average storey height and roof slope were used to estimate the floor level. A more detailed flood level survey is recommended for future studies.

A flood damages assessment was undertaken for existing development in accordance with the Flood Risk Development Manual (Reference 11). 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.

6.4.2. Residential Properties

6.4.2.1. Direct Internal Damages

Internal damages were assumed follow the relationship with depth of inundation adopted in the DCCEEW damages spreadsheet for houses. This varies for houses on slab/low set, high set houses and two storey houses. The caravan parks were analysed in the residential category. Damages curves for caravan parks were assumed to be a maximum of $100,000. In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages has not been included in the analysis.

6.4.2.2. Direct Structural Damages

Structural damages were assumed follow the relationship adopted in DCCEEW damages spreadsheet. This varies for houses on slab/low set, high set houses and two storey houses. In floods rarer than the 1% AEP event, there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages has not been included in the analysis.

6.4.2.3. Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to $13,860 for houses. This assumes that the majority of vehicles and items are moved by residents.

6.4.2.4. Indirect Damages

Indirect damages such as clean-up costs were assumed to be $8,274 for residential properties. Costs related to additional accommodation and loss of rent were assumed to be $1,365. These costs are incurred in the damages calculations once flooding above floor depth is greater than 10mm.

6.4.3. Non-residential Properties Damages

6.4.3.1. Direct Damages

There is no formal guidance on damage curves for non-residential properties in the Flood Risk Development Manual (Reference 11) damages spreadsheet.

Non-residential properties were categorised into, industrial properties, and commercial properties. Commercial properties were categorised into low, medium and high.

Industrial properties were assumed to have the same damage curves as the medium commercial properties.

6.4.3.2. Indirect Damages

As damage curves for residential properties include both indirect and direct damages, damage curves assumed for caravan parks also include indirect and direct damages.

6.4.4. Summary of Damages

Damages calculated for the study area are provided in Table 14. A total of 4766 residential and non-residential properties within the floodplain are flooded above floor level in a 1% AEP event and 19080 properties are flooded above floor level in a PMF event in the Hawkesbury LGA. This flood damage estimates do not include the cost of restoring or maintaining public services and infrastructure. They also do not consider damages to any basements or cellars, hence where properties have basements, damages can be underestimated.

Table 14: Estimated flood damages

Event (AEP)	Properties Affected	Properties Above Floor	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20%	110	85	$21,631,774	$196,652
10%	756	660	$133,737,634	$176,902
5%	1,552	1,224	$294,075,698	$189,482
2%	3,619	2,818	$920,102,849	$254,242
1%	5,388	4,766	$1,985,984,728	$368,594
0.5%	7,211	6,263	$2,920,302,887	$404,979
0.2%	10,551	9,360	$4,413,264,517	$418,279
0.1%	13,300	12,070	$5,780,240,946	$434,605
PMF	19,173	19,080	$10,343,023,203	$539,458
Average Annual Damages (AAD)			**$90,868,080**	

Table 15 provides a summary of number of properties first affected by each event. A property was considered affected once it incurs damages according to the damage curves. Non-residential properties, adopted damage curves assumed that no damages were incurred when flood level was below the floor level. Therefore, the number of non-residential properties first affected above ground and above floor are the same for each event. In general, there is a significant increase in houses flooded in the 2% AEP event compared to more frequent events.

Table 15: Number of properties first affected each event

Event (AEP)	Residential		Non-residential	
	First affected above ground	First affected above floor	First affected above ground	First affected above floor
Not Flooded	0	93	0	0
20%	59	36	50	50
10%	489	420	157	157

5%	640	411	156	156
2%	1,676	1,220	391	391
1%	1,305	1,530	465	465
0.5%	1,526	1,223	296	296
0.2%	2,940	3,095	400	400
0.1%	2,443	3,214	306	306
PMF	5,280	5,117	593	593

7. INFORMATION TO INFORM DECISIONS ON ACTIVITIES IN THE FLOODPLAIN AND MANAGING FLOOD RISK

7.1. Flood Emergency Response Classification

Flooding can result in obstruction of evacuation routes and the subsequent isolation of areas of the floodplain. The Flood Emergency Response Classification (FERC) provides a basis for understanding the varying nature, seriousness, and scale of these issues, with a particular emphasis on isolation, across the floodplain. The FERC for the study area was developed in accordance with the NSW Flood Risk Management Manual (Reference 11) and its accompanying guideline, EM01 – Support for Emergency Management Planning (Reference 13). The methodology (refer to Diagram 4) was applied for events to the PMF design event, and the classification results are presented in Figure 46 and Figure 47. This information will be provided to the NSW State Emergency Services (NSW SES) upon completion of this project.

It is important to note that the FERC classification has been prepared based on existing development within the study area. It does not consider the classification that may pertain to new development on currently vacant land.

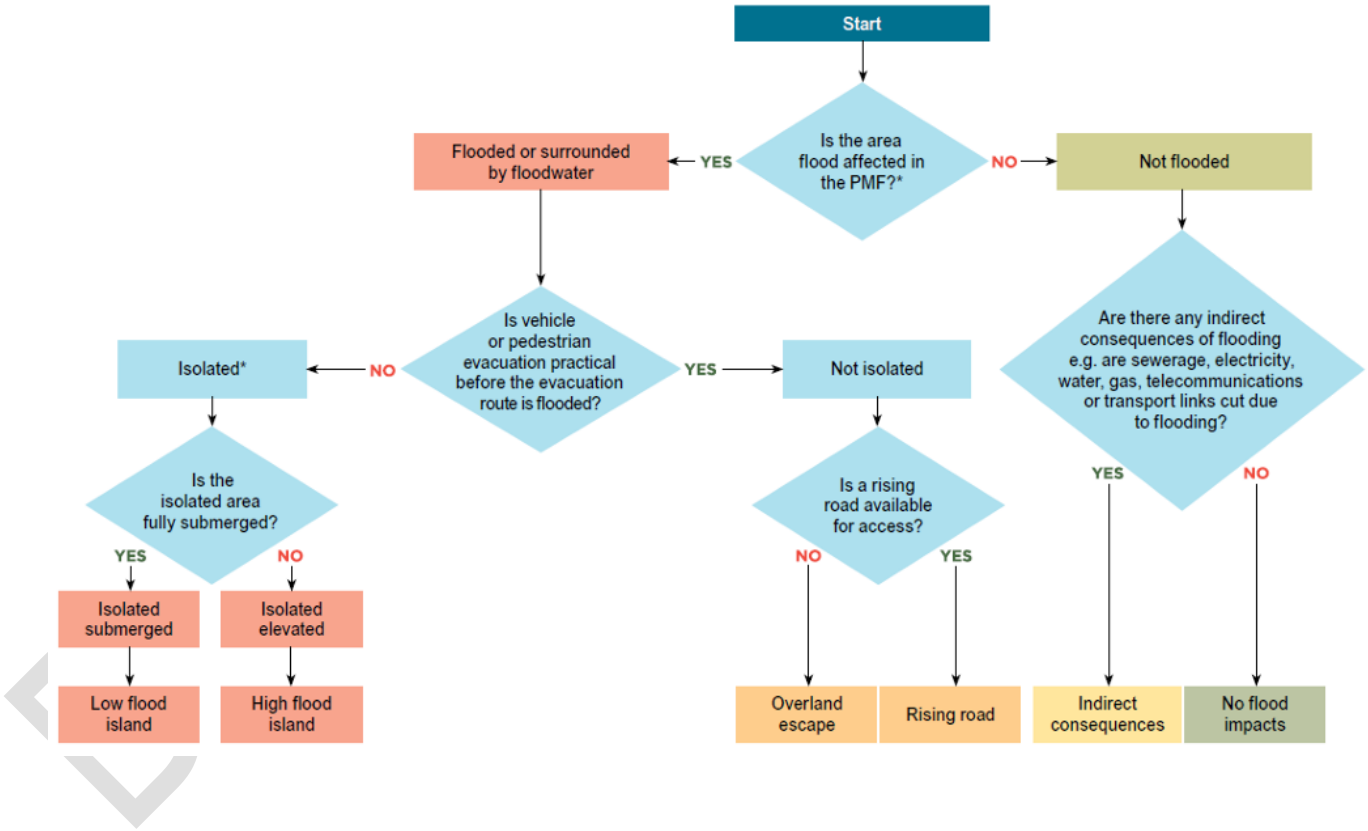


Diagram 4: Flow Chart for Determining Flood Emergency Response Classifications (Reference 25)

The classifications used are described below, taken directly from the Floodplain Risk Management Guideline (EM01).

- **High Flood Island.** The flood island has land higher than the limit of flooding for the event being considered. During a flood these high islands are isolated from other areas of the community by floodwater, terrain, development, or infrastructure. However, there is an opportunity for people to retreat to higher ground within the island, and therefore, the direct risk to life is reduced. The area may require resupply by boat or air if not evacuated before the road is cut. If it is not possible to provide adequate support (such as community and medical facilities) during the period of isolation, evacuation will have to take place before isolation occurs. Isolation without these services is more likely to result in fatal decisions to cross floodwaters.
- **Low Flood Island.** The flood island is lower than the limit of flooding for the event being considered. During a flood event the area initially becomes isolated by floodwater, terrain, development or infrastructure. If floodwater continues to rise after it is isolated, the land on the island will eventually be completely inundated by floodwaters. Evacuation of the community will be required prior to evacuation routes being closed as people left stranded on the island may drown.
- **Areas with Rising Road Access.** Areas where access roads rise steadily uphill and away from the rising floodwaters. The community will not be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes, for example, people living in 2-storey homes may initially decide to stay but reconsider after water surrounds them. These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.
- **Area with Overland Escape Route.** Areas where escape from rising floodwater is possible by traversing overland to higher ground. The area may also have access roads to flood-free land that cross lower-lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater after roads are cut is possible but involves traversing overland to higher ground. Anyone not able to walk out before access roads are cut must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.
- Not Flooded and Indirect Consequences. These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

The majority of the floodplain between Windsor, Agnes Bank, Richmond, McGraths Hill is considered low flood island (Figure 46). The area between Agnes Bank and Yarramundi is High trapped Perimeter. Much of the lower reaches of the river (Figure 47) are rising road access, overland escape route with patches of low trapped perimeter or high trapped perimeter.

7.2. Flood Planning Constraint Classifications

Guideline 7-5 of the Australian Disaster Resilience Handbook Collection (Reference 20) recommends using Flood Planning Constraint Categories (FPCCs) to better inform land use planning activities. These categories condense the wealth of flood information produced in a flood study and classify the floodplain into areas with similar degrees of constraint. These FPCCs can be used in high level assessments of land use planning to inform and support decisions for strategic planning.

For detailed land use planning activities, it is recommended that the flood behaviour across the range of flood events be considered, depending on the level of constraint.

The Flood Risk Management Manual and its supporting guideline, Understanding and Managing Flood Risk (FB01) recommends the use of four constraint categories. It is recommended that isolation potential also be considered for the high constraint category. This could include areas classified as 'Submerged' (FIS) or 'Elevated' (FIE) (Refer Section 7.1). In the study area, the isolation potential is relatively high.

The constraints defined by AIDR Handbook Collection - Guideline 7-5: Flood Information to Support Land-use Planning have been adapted to suit the study area and are outlined in Table 16. The associated FPCC map can be found on Figure 48 and Figure 49. The map shows that there are limited areas of FPCC 2 (2a, 2b and 2e). Although some areas of FPCC 2C and 2D exist in locations where evacuation is important. The majority of the floodplain is FPCC 1 (1a+1b).

Table 16: Flood Planning Constraint Categories for the Study Area

	Constraints[1]	Implications	Considerations
FPCC 1	Floodway and flood storage areas in the DFE event.	Any development is likely to affect flood behaviour in the 0.5% AEP event and cause impacts elsewhere.	Majority of developments and uses have adverse impacts on flood behaviour or are vulnerable. Consider limiting uses and developments to those that are compatible with flood function and hazard.
	H6 hazard in the DFE event	Hazardous conditions considered unsafe for vehicles and people, all types of buildings considered vulnerable to structural failure.	
FPCC 2	Floodway in the 0.2% AEP event	People and buildings in these areas may be affected by dangerous floodwaters in rarer events.	Many uses and developments will be more vulnerable in these areas. Consider limiting new uses to those compatible with flood function and hazard (including rarer flood flows) or consider treatments to reduce the hazard (such as filling).
	H5 flood hazard in the 1% AEP event	Hazardous conditions considered unsafe for vehicles and people, and all buildings vulnerable to structural damage.	

	Constraints[1]	Implications	Considerations
	H6 flood hazard in the 0.2% AEP event	Hazardous conditions develop in rare events which may have implications for the development and its occupants.	Consider the need for additional development control conditions to reduce the effect of flooding on the development and its occupants.
	Areas of FPCC 3 surrounded by FPCC 2 or FPCC 1	Hazardous conditions arise due to isolation (see below)	
FPCC 3	Within the FPA (0.5% AEP + 0.5m)	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings is unlikely.	Standard land use and development controls aimed at reducing damage and the exposure of the development to flooding are likely to be suitable. Consider additional conditions for critical utilities, vulnerable facilities and key community infrastructure.
	Note: Areas classified as FPCC 3 that are surrounded by FPCC2 and/or FPCC1 have been reclassified as FPCC2.	Even if elevated, hazard may arise from the area being isolated and cut off by deep or fast flowing water. Without a safe evacuation route, risk to life exists even if the building itself is not threatened. Such areas are reclassified as FPCC2 (see above)	See FPCC 2
FPCC 4	Within the PMF extent	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event.	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.
	Note: Areas classified as FPCC 4 that are surrounded by FPCC2 and/or FPCC1 have been reclassified as FPCC2.	Even if elevated, hazard may arise from the area being isolated and cut off by deep or fast flowing water. Without a safe evacuation route, risk to life exists even if the building itself is not threatened. Such areas are reclassified as FPCC2 (see above)	See FPCC 2

[1]Constraints applied in this FRMS&P to determine FPCCs. Based on the constraints defined in Reference 20 with adjustments to the DFE and FPL to be 0.5% AEP and the 0.5% AEP plus 0.5m respectively. Refer to Section 8.4.4.1 for discussion.

7.3. Climate Change

There is clear evidence that increases in global temperatures has led to an increase in the intensity of rare rainfall, and that extreme flooding globally has increased over the 20th century (Reference 14). Global warming has been observed for several decades and has been linked to changes in

key parts of the hydrologic cycle including changes in rainfall behaviour, rainfall intensity, soil moisture and runoff (Reference 21). Climate change can alter flood behaviour in the catchment by changing:

- Probability of long duration rainfall intensities;
- Storm type and frequency;
- Rainfall spatial and temporal patterns; and
- Antecedent conditions.

The interaction of these characteristics makes predicting the impact of climate change on flood behaviour complex.

7.3.1. Rainfall Depth and Frequency

The interaction of a warming climate and rainfall is complex. A warmer climate leads to an increase in the potential moisture-holding capacity of the atmosphere which is one of the key factors in the depth of precipitation in rarer rainfall events, however on large catchments long duration rainfall events are also dependant on sources and transport of moist air. Statistically significant increases in rainfall intensity have been detected in Australia for short duration rainfall events and are likely to become more evident towards the end of the 21st century (Reference 15). Changes in long duration events are expected to be smaller and harder to detect, but projections analysed by Reference 22 showed that an increase in daily precipitation intensity is likely under climate change. It is worth noting that a warming climate can lead to decreases in annual rainfall along with increases in flood producing rainfall.

7.3.2. Storm Type and Frequency

Nearly all the rarer flood events on the Hawkesbury-Nepean catchment are caused by East Coast Lows. Research suggests that East Coast Lows will become slightly less frequent but the larger flood producing East Coast Lows will become more intense.

7.3.3. Spatial and Temporal Rainfall Behaviour

The influence of warmer climate on the spatial and temporal aspects of rainfall is not as well understood as the likely changes in rainfall intensity. Work by Abbs et al. (Reference 23) suggests that increases will be more pronounced in areas with strong orographic enhancement which could lead to larger increases in upper reaches of the catchment. Work by Wasco and Sharma (Reference 24) analysing historical storms found that, regardless of the climate region or season, temperature increases are associated with rainfall patterns becoming less uniform, with the larger fractions increasing in rainfall intensity and the lower fractions decreasing.

7.3.4. Antecedent Conditions

Changes to rainfall and evaporation as a result of climate change will impact on the antecedent conditions prior to an event. It is likely that evaporation will increase (Reference 21) by 2030 and 2070 by approximately 2%. Increased evaporation in combination with decreased rainfall could

result in decreases in annual runoff, and hence drier antecedent conditions. This drying will slightly reduce the impact of increased rainfall on flood levels however historically many of the larger flood events have occurred in particularly wet years and been preceded by smaller events. Therefore, changes to antecedent conditions will be negligible.

7.3.5. Assessment of Climate Change Impacts

The 2023 Flood Risk Management Manual (Reference 11) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change (sea level rise and rainfall increase) on flood behaviour.

There are limited climate change results in the 2024 Flood Study. Appendix G of Technical Volume 11 provides flood surface profile and flood levels at key locations, but flood maps have not been provided.

The climate change assessment in the 2024 Flood Study was conducted according to ARR 2019 interim advice, which assumes 5% increase in rainfall per 1ºC increase in mean temperature based on the IPCC 5th Assessment Report (AR5) (2014). These temperature projections were however superseded by the IPCC 6th Assessment Report (AR6) (2023).

The NSW Department of Planning and Environment published Flood risk management guideline FB01 “Understanding and managing flood risk” in 2023. Guideline FB01 considers 7% increase in rainfall intensity and volume per 1ºC increase in mean temperature based on the CSIRO’s Climate Futures Tool.

The draft of the new climate change guidelines which are an update to the current ARR 2019 climate change chapter have been released for consultation. Based on the draft guideline, for rainfall duration longer than 24 hour there will be 8% increase in rainfall per 1ºC increase in mean temperature. It also increases initial and continuing losses which will slightly reduce the net rainfall increase. It is therefore expected that the change in rainfall based on the new guideline will be within the same range proposed in the NSW guideline FB01.

The ARR 2019 used significantly lower temperature increases based on IPCC5 than those in the NSW guideline FB01 and the draft ARR climate change guideline. Consequently, this resulted in a correspondingly lower projected increase in rainfall. For example, the ARR 2019 climate change guideline predicts 9.5% increase in rainfall due to 1.862ºC increase in mean temperature by 2090 based on the RCP 4.5 scenario (see Figure 1). The forecast is slightly less than the 10.5% rise in rainfall by year 2030 recommended by the draft climate change guideline under the Shared Socioeconomic Pathway (SSP) 2-4.5 scenario which is equivalent to RCP4.5. Moreover, the draft guideline projects a 23% increase in rainfall by 2090 under the SSP2-4.5 scenario, which is substantially higher—over twice the rate—than the increase proposed by the ARR interim advice.

For this reason, the current draft ARR guidelines has been used to reflect the most up to date science on temperature and rainfall scaling.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	0.869 (4.3%)	0.783 (3.9%)	0.983 (4.9%)
2040	1.057 (5.3%)	1.014 (5.1%)	1.349 (6.8%)
2050	1.272 (6.4%)	1.236 (6.2%)	1.773 (9.0%)
2060	1.488 (7.5%)	1.458 (7.4%)	2.237 (11.5%)
2070	1.676 (8.5%)	1.691 (8.6%)	2.722 (14.2%)
2080	1.810 (9.2%)	1.944 (9.9%)	3.209 (16.9%)
2090	1.862 (9.5%)	2.227 (11.5%)	3.679 (19.7%)

Diagram 5: ARR 2019 Climate change Guide – current (From ARR Data Hub)

Table 2. IPCC Sixth Assessment Report (AR6) global mean surface temperature projections (ΔT) for four socio-economic pathways relative to 1961-1990. The 90% uncertainty interval is provided in parentheses†.

Climate Scenario	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Current and near-term (2021-2040) (°C)	1.3 (0.9-1.8)	1.3 (0.9-1.9)	1.3 (1.0-1.9)	1.4 (1.0-2.0)
Medium-term (2041-2060) (°C)	1.6 (1.1-2.3)	1.8 (1.3-2.6)	2.0 (1.5-2.9)	2.3 (1.6-3.2)
Long-term (2081-2100) (°C)	1.7 (1.1-2.6)	2.7 (1.9-3.8)	3.6 (2.7-5.0)	4.5 (3.2-6.3)

† Projections obtained from the IPCC atlas https://interactive-atlas.ipcc.ch/ (Iturbide et al. 2021; Gutiérrez et al. 2021)

Diagram 6: ARR 2019 Climate Change Guide – New

In order to understand how climate change will affect the catchment the Climate Change Calculator (ccc.wmawater.com.au) was used. The tool provides an understanding of the change in risk. Calculations were undertaken to Windsor. Diagram 7 shows how the 3 day 1 % AEP catchment average rainfall to Windsor will change under the various climate change pathways. This is the average rainfall on the catchment with more intense rainfall falling on the upper reaches of the Nepean, Wingecarribee and Grose Rivers. With lower rainfall on the flatter terrain such as South Creek. This Diagram 7 shows that by 2090 rainfall will increase by 14% for the lowest emission scenario (SSP1) to 41% for the highest emission scenario (SSP5).

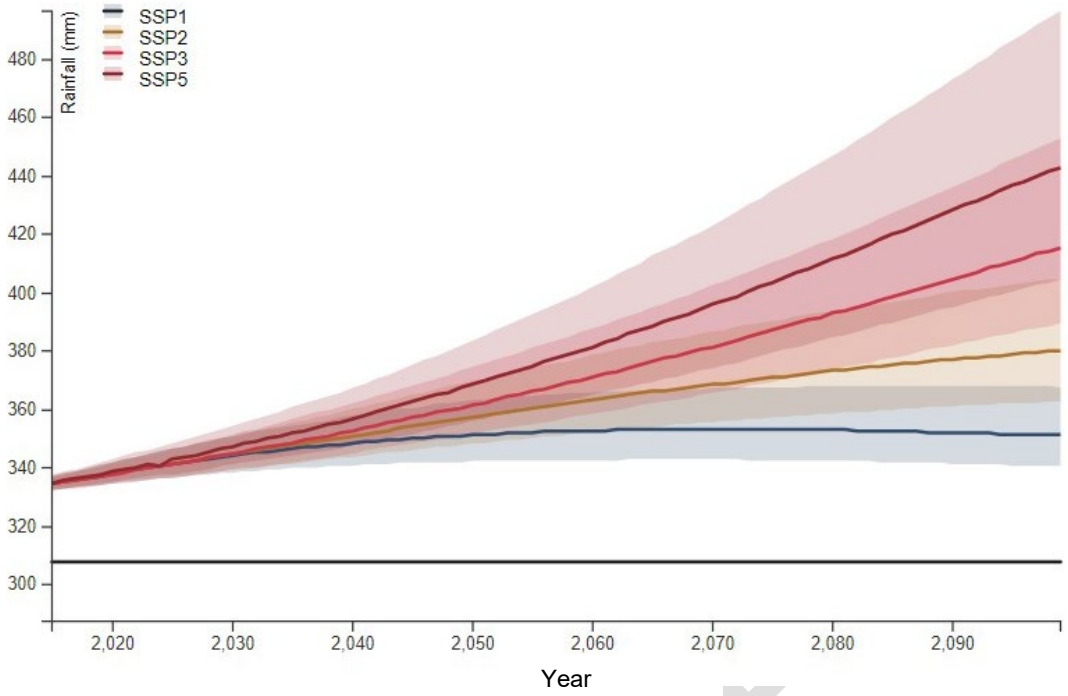


Diagram 7: Change in Catchment Avaerage Rainfall to Windsor under Climate Change – 1% AEP

Table 17 shows the probability of a 1% (1 in 100) AEP based on past climate under current and various future dates for each emissions scenario. Under SSP3 which has the developed world making limited movement to a low carbon economy, the current 1% AEP flood will be 4 times more likely to occur with a probability of 1 in 24.8 AEP. In contrast Table 18 shows the historical design standard you would need to adopt to achieve the 1% AEP (1 in 100 AEP) in the future. To achieve 1% AEP design standard in 2090 under SSP3 you would need to adopt a historic design standard of 1 in 580 AEP. Warming to date means that the historical 1% AEP event is nearly twice as likely with an AEP of 1 in 57.2.

Table 17: A historical 1 in 100 AEP event (BOM 2016 IFD) is equivalent to a 1 in X AEP event in the future

	SSP1	SSP2	SSP3	SSP5
2024	57.2	57.2	57.2	57.2
2030	54.1	53.6	53.5	51.7
2060	47.7	41.2	37.2	32.6
2090	48.1	34.4	24.8	19.3
Mean over 70 year period	49.3	42	36.3	31.1

Table 18: A future 1 in 100 AEP event is equivalent to a 1 in X AEP historical event (BOM 2016 IFD):

	SSP1	SSP2	SSP3	SSP5
2024	181	181	181	181
2030	193	195	196	204
2060	226	273	315	380

2090	223	351	580	887
Mean over 70 year period	205	241	284	336

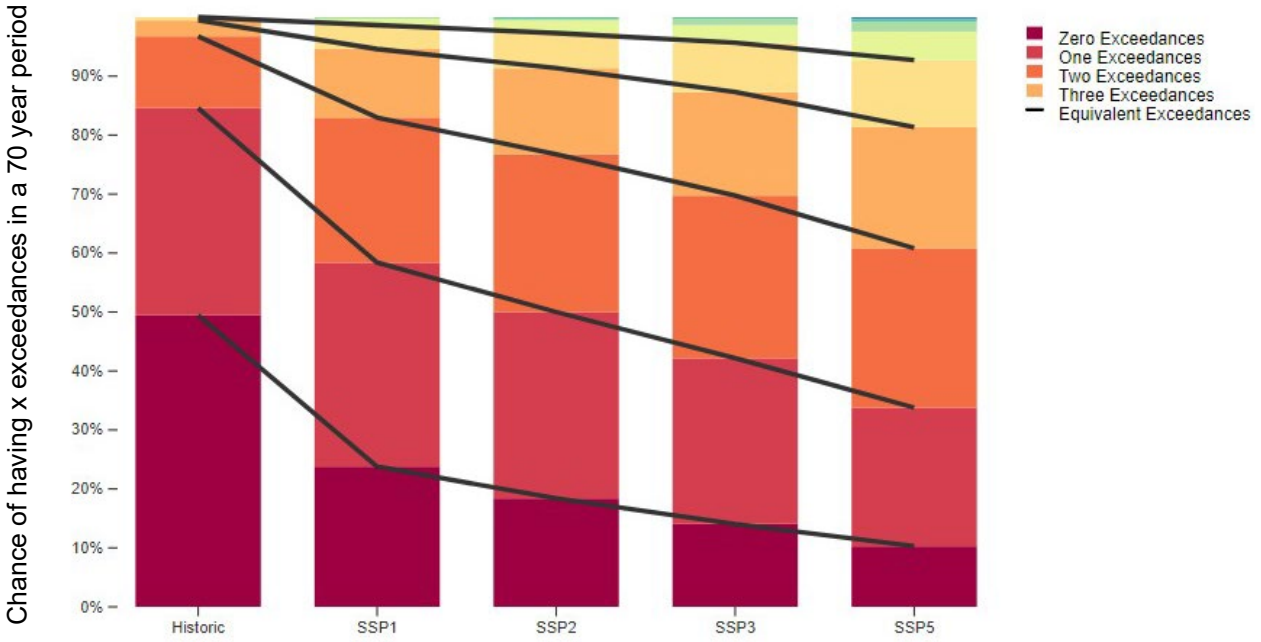


Diagram 8: Expected Exceedances over 70 year period – Windsor

Diagram 6 shows the number of exceedances over a 70 year period from 2024 to 2093 of the historical 1% AEP design level under various scenarios. One of the reasons the 1% AEP design standard has been used throughout most of the western world is that under a fixed climate and a 70 year life there is approximately a 50% chance of not experiencing a 1% AEP flood. The 50% chance of experiencing one or more floods is made up of a 33% chance of experiencing one and 13% chance of experiencing two and a 4% chance of experiencing three or more. This is shown in the first column. With climate change there is a significant increase in the number of events people will experience. Under SSP3 a chance of no 1% AEP flood over a 70 year period is less than 15%.

Diagram 9 shows how flood levels are likely to increase with climate change. The blue lines represent historic climate flood levels such as the 1% AEP. Following the blue line to the left indicates how the probability of the current 1% AEP will change in time with climate change. Following the vertical line of a probability will show how a certain probability event will increase with climate change. The 1% AEP level (17.3 mAHD in historical climate) will exceed 20m under some climate scenarios. The PMF will also change with climate change however this has not been explicitly modelled. The current PMF has been shifted for climate change.

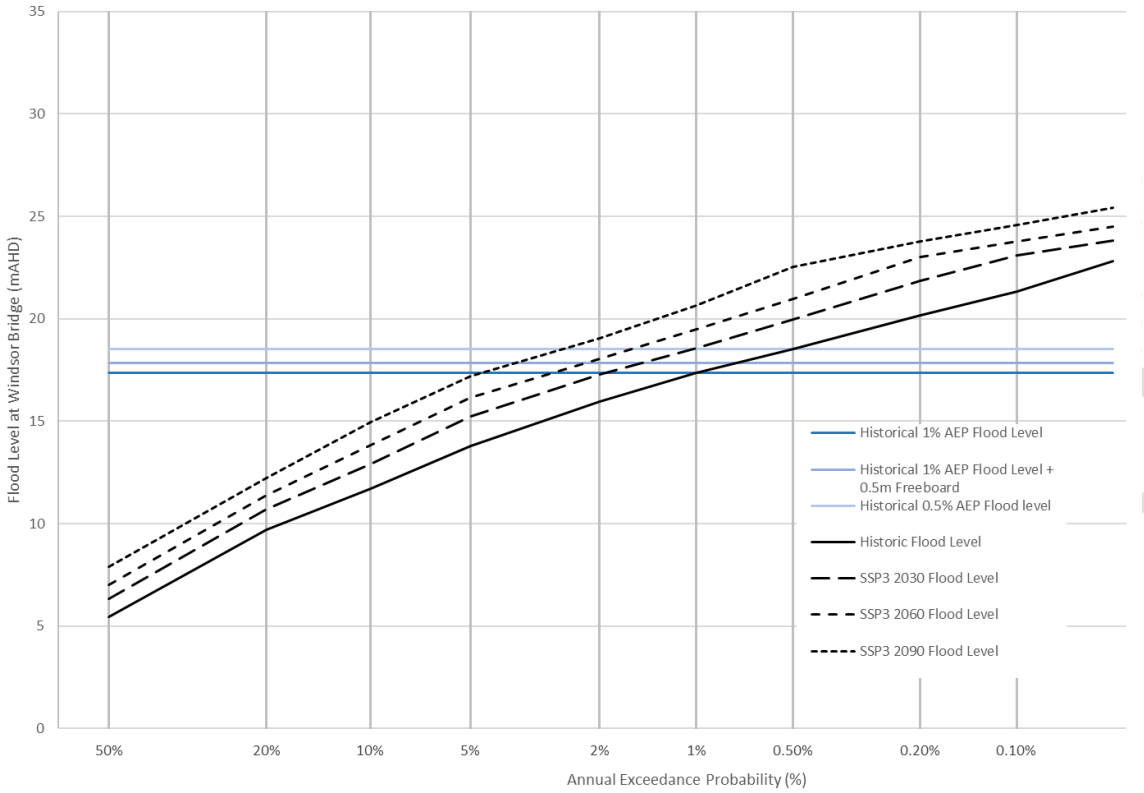


Diagram 9: Change in flood levels with climate change

Diagram 10 shows how the damages for each design event will shift will climate change scenario. Table 19 presents the AAD in todays dollars for 2030, 2060 and 2090 planning scenarios for the different SSPs. It also presents the difference between using the historic data (Historic) and when you adjust that data by the warming that has already occurred (2024). Over the range of climate futures Climate change will result in a 86% to 325% increase in the AAD.

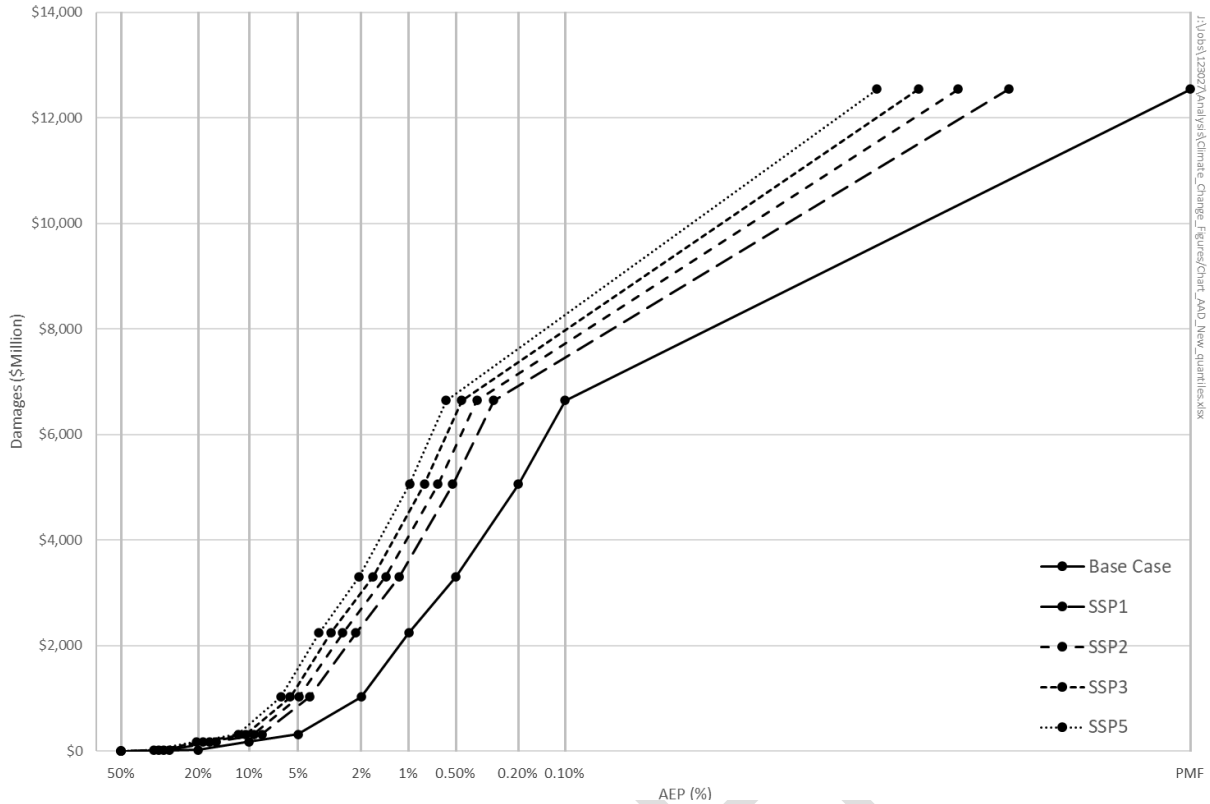


Diagram 10: Change in Damages with Climate Change

Table 19: Change in Average Annual Damages under Climate Change

	SSP1	SSP2	SSP3	SSP5
Historic	$106 Million	$106 Million	$106 Million	$106 Million
2024	$167 Million	$167 Million	$167 Million	$167 Million
2030	$175 Million	$176 Million	$177 Million	$182 Million
2060	$197 Million	$225 Million	$246 Million	$275 Million
2090	$197 Million	$266 Million	$357 Million	$448 Million
Mean over 70 years (2024-2093)	$192 Million	$221 Million	$251 Million	$288 Million

8. OPTIONS ASSESSMENT

8.1. Overview

The NSW Government Flood Risk Management Manual (Reference 11) separates risk management measures into three broad categories:

Flood modification measures modify the physical behaviour of a flood (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees.

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

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

Table 20 provides a summary of the floodplain risk management measures that could be considered for the Hawkesbury LGA.

Table 20: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Flood mitigation dams	Land zoning	Community awareness/preparedness
Retarding basins	Voluntary purchase	Flood warning
Bypass floodways	Building & development controls	Evacuation planning
Channel modifications	House raising	Evacuation access
Levees	Flood proofing	Flood plan / recovery plan
Temporary Flood Barriers	Flood access	Flood insurance

8.1.1. Relative Merits of Management Measures

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

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using

the classical benefit/cost approach.

8.2. Previously considered options

The previous 2012 floodplain risk management plan (Reference 26) was developed in a very different environment to today's understanding of flood risk. While our understanding of historical flood risk in the floodplain has not changed the current and future risk has changed dramatically. In 2012 Council recognised that the flood problem in the in the Hawkesbury-Nepean was too big for Council to manage without state assistance and that large scale mitigation would need to examined by the NSW state government with the rising of Warragamba Dam for flood mitigation providing an opportunity to significantly reduce flood risk in the order of 3.5m at Windsor. This would reduce flood levels for most dwellings by nearly one and half stories and on average decrease the flood risk for most properties by a factor of four. While Council, SES, Infrastructure NSW and Transport for NSW implemented many of the recommendations of the 2012 study, Council chose not to implement the town planning controls.

Today's understanding of current and future flood risk is very different. In the 2016/2019 edition of Australian Rainfall and Runoff (ARR, Reference 2) provided the ability to calculate the impact of climate change on flood levels. These impacts are dramatic and the new draft advice that will be formalised this year shows that current flood risk has increased significantly.

In 2023, the NSW Government announced after the Environmental Impact Statement for the raising of Warragamba Dam had been on public display, that the NSW Government would not be proceeding with the raising of Warragamba Dam and the government would look at alternative mitigation strategies. The combination of the dam raising and climate change would still have resulted in a lowering of the overall flood risk. The floodplain management committee recognised that this would mean that Council would need to dramatically change its approach to floodplain management as no other options exist that will lower flood levels by metres and that the Currency Creek Bypass option should be considered further.

The 2012 floodplain risk management plan (Reference 26) has achieved many important outcomes including:

- Delivery of the Hawkesbury Nepean flood strategy (NSW government)
- Updated high resolution mapping and modelling (Infrastructure NSW)
- A detailed flood evacuation model (SES, Infrastructure NSW)
- Many education and awareness initiatives including 150 year commemoration of the 1867 flood (Council and state government)
- Updated evacuation planning and signposting (SES, Infrastructure NSW)

Table 21 lists the items from the 2012 floodplain risk management plan (Reference 26) and the actions to date.

Table 21: Hawkesbury Floodplain Risk Management Plan (Reference 26) Summary and Status

ITEM	AGENCY	ACTIONS TO DATE
1. Community Flood Education and Resilience		
(a) *Review and evaluate Regional Public Awareness Program.*	Hawkesbury City Council, State Emergency Services	(a) Awareness program for Hawkesbury Nepean Valley recently/currently undertaken by iNSW and SES in conjunction with HCC as a partner, as part of the actions of the Hawkesbury Nepean Flood Strategy – Resilient Valley/Resilient Communities.
(b) *Issue flood certificates on regular basis.*	Hawkesbury City Council, State Emergency Services	(b) Council has two types of flood certificates; a simple one and a more detailed one which provides information such as hazard to assist with determining which developments controls are applicable under Flood Policy – data based on 2012 Study.
(c) *Prepare suburb-specific FloodSafe guides.*	Hawkesbury City Council, State Emergency Services	(c) Awareness program for Hawkesbury Nepean Valley recently/currently undertaken by iNSW and SES in conjunction with HCC as a partner, as part of the actions of the Hawkesbury Nepean Flood Strategy – Resilient Valley/Resilient Communities.
(d) *Prepare flood tolerant housing poster and brochure.*	Hawkesbury City Council, State Emergency Services	(d) Awareness program for Hawkesbury Nepean Valley recently/currently undertaken by iNSW and SES in conjunction with HCC as a partner, as part of the actions of the Hawkesbury Nepean Flood Strategy – Resilient Valley/Resilient Communities.
(e) *Enhance flood information on Council's web-site.*	Hawkesbury City Council, State Emergency Services	(e) Awareness program for Hawkesbury Nepean Valley recently/currently undertaken by iNSW and SES in conjunction with HCC as a partner, as part of the actions of the Hawkesbury Nepean Flood Strategy – Resilient Valley/Resilient Communities. Establishment of Emergency Dashboard on Council's website, which provides information and links to information and resources in relation to natural disasters and relevant agencies such as SES, Police and RFS.
(f) *Commission book and video production on Hawkesbury flooding and vital community responses.*	Hawkesbury City Council, State Emergency Services	(f) Council led flood exhibition at Hawkesbury Museum in 2017.
(g) *150 year commemoration of 1867 flood.*	Hawkesbury City Council, State Emergency Services	(g) 150 year commemoration carried out in 2017.
(h) *Install flood icons/markers at key locations.*	Hawkesbury City Council, State Emergency Services	(h) Have applied for a grant to carry out this recommendation a couple of times, however been unsuccessful due to NSW Government strategy and work across the Hawkesbury-Nepean Valley.
(i) *Continue to host Business FloodSafe breakfasts.*	Hawkesbury City Council, State Emergency Services	(i) Nil
2. Emergency Management		
(a) Implement dual outbound lanes on Jim Anderson Bridge during flood emergencies.	State Emergency Services, Transport for NSW	(a) As part of delivering HNV Flood Strategy, Transport for NSW is undertaking investigations for road improvements (Road Resilience Program). This work includes investigations to improve flood immunity of evacuation routes through drainage works, road shoulder upgrades or the raising of low points.
(b) Enhance emergency management assessment tools. Develop best traffic modelling to better assess implications of various evacuation scenarios. Integrate with flood modelling.	State Emergency Services	(b) TfNSW and SES development of a Flood Evacuation Model for the Hawkesbury-Nepean Valley.
(c) Promote construction of community refuges within major new buildings on flood islands to service the existing communities.	Hawkesbury City Council, State	(c) WestInvest funded project to provide community centre at North Richmond for use during natural disasters
(d) Continue to prepare and maintain flood emergency management plans for special uses and utilities.	Private Sector, Hawkesbury City Council, State Emergency Services, State	(d) New SES Hawkesbury-Nepean SubPlan released in 2020. Hawkesbury-Nepean flood emergency sub plan | NSW Government iNSW & SES, in collaboration with councils, recently released flood emergency management plan template to all caravan parks for use. Council's adopted Local Approvals Policy – Caravan Parks requires flood evacuation plans for Approvals to Operate.

ITEM	AGENCY	ACTIONS TO DATE
(e) Use caravan park emergency management plan template to raise awareness and increase preparedness.	Private Sector, Hawkesbury City Council, State Emergency Services, State	(e) iNSW & SES, in collaboration with councils, recently released flood emergency management plan template to all caravan parks for use. Council's adopted Local Approvals Policy – Caravan Parks requires flood evacuation plans for Approvals to Operate.
(f) Review and update Hawkesbury-Nepean Flood Emergency Sub Plan and NSW State Flood Sub Plan	State Emergency Services, Bureau of Meteorology, State	(f) New SES Hawkesbury-Nepean SubPlan released in 2020. Hawkesbury-Nepean flood emergency sub plan | NSW Government
(g) Provide additional evacuation capacity possibly through a new crossing of South Creek at Eighth Ave, Llandilo.	Hawkesbury City Council, Transport for NSW, State	(g) As part of delivering HNV Flood Strategy, Transport for NSW is undertaking investigations for road improvements (Road Resilience Program). This work includes investigations to improve flood immunity of evacuation routes through drainage works, road shoulder upgrades or the raising of low points.
(h) Identify local evacuation route upgrades and revise FRMP.	Hawkesbury City Council, State Emergency Services	(h) As part of delivering HNV Flood Strategy, Transport for NSW is undertaking investigations for road improvements (Road Resilience Program). This work includes investigations to improve flood immunity of evacuation routes through drainage works, road shoulder upgrades or the raising of low points.
(i) Investigate lane duplication options, east of Jim Anderson Bridge.	Hawkesbury City Council, State Emergency Services	(i) Nil.
3. Future Development – Flood risk advice to consent authorities		
(a) Provide advice to Council and State Government concerning severity of flood evacuation risks as per Tables 4 and 5.	Hawkesbury City Council, State	(a) Nil.
4. Town Planning		This section was not adopted by Council at that time. However, a number of changes to legislation and state policy have happened:
(a) Advise DPI of principal planning recommendations of this Plan.	Hawkesbury City Council, State	(a) Nil
(b) Amend flood risk provisions of Council's existing DCP.	Hawkesbury City Council, State	(b) Council adopted Flood Policy in 2020 which was based on a risk approach. Council adopted a Local Approvals Policy for caravan parks (July 2023) to manage the impacts of floods on caravan parks. (i)
(c) Amend LEP in Accordance with Volume 3.	Hawkesbury City Council, State	(c) LEP Standard Instrument dictates the wording of clauses in LEP. New flood clauses for LEPs were introduced 5.21 (mandatory) and 5.22 (optional). Council chose not to include Clause 5.22 until the Review of Hawkesbury FRMS&P has been completed.
(d) Prepare maps to guide application of Codes SEPP.	Hawkesbury City Council, State	(d) Nil.
(e) Revise S149 notifications in accordance with Volume 3.	Hawkesbury City Council, State	(e) Notifications to be included on planning certificate in relation to flooding were changed with the introduction of State Governments Flood Package. Now includes advice for development controls for certain development on land between the flood planning area and the PMF – relates to Clause 5.22 of the Standard Instrument.
(f) Lodge application for 'exceptional circumstances' with DPI & OEH.	Hawkesbury City Council, State	(f) No longer required. Removed as part of the changes introduced by the State Government's Flood Package. Flood planning levels/areas are now determined as part of the floodplain management process.
5. VHR and Redevelopment		
(a) Survey all houses inundated in 20 year ARI events.	Hawkesbury City Council	Have applied for a grant to carry out this recommendation twice, however have been unsuccessful due to NSW Government Strategy and work across the Hawkesbury-Nepean Valley
(b) Assess eligibility for voluntary house raising (VHR) redevelopment and possibly for voluntary house purchase (VP).	Hawkesbury City Council	

ITEM	AGENCY	ACTIONS TO DATE
(c) *Report back to Council. Revise FRMP if required.*	Hawkesbury City Council	
6. McGraths Hill		
(a) Feasibility study of 50 year levee including consultation.	Hawkesbury City Council	No further investigation following release of the Hawkesbury-Nepean Valley Strategy - Resilient Valley, Resilient Communities Recommendations of the Flood Inquiry.
(b) Assess community attitudes to levee and refuge mound.	Hawkesbury City Council	
(c) *Report back to Council. Revise FRMP if required.*	Hawkesbury City Council	
7. Updating Flood Behaviour Data in the Valley		INSW flood study 2019 has provided more contemporary flood data for the Hawkesbury Nepean Valley. INSW is currently undertaking 2D modelling and updating flood data from that carried out in 2019. This newer data is expected to be exhibited from June 2024.
(a) *Utilise latest 2D flood modelling and latest topographical data.*	Hawkesbury City Council, Other Councils, State	
(b) *Extend along main tributaries.*	Hawkesbury City Council, Other Councils, State	
(c) *Include revised IFD rainfall.*	Hawkesbury City Council, Other Councils, State	
(d) *Include for revised climate change influences.*	Hawkesbury City Council, Other Councils, State	
(e) *Update data for smaller more frequent flood events.*	Hawkesbury City Council, Other Councils, State	

8.3. Flood Modification Measures

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale.

8.3.1. Flood Mitigation Dams and Retarding Basin

DESCRIPTION

Dams have been used in rural areas of NSW to reduce peak flows downstream. However, typically their main purpose is for water supply. Dams are rarely used as a flood mitigation measure on account of the:

- high cost of construction,
- high environmental damage caused by the construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low benefit cost ratio, and
- lack of suitable sites, as a considerable volume of water needs to be impounded by the dam in order to significantly reduce flood levels downstream.

Retarding basins, also known as detention basins, are small-scale flood mitigation dams commonly used in urban catchments for the same reasons. A retarding basin provides temporary storage for floodwaters, and works by capturing floodwaters during an event, to be released at a lower flow rate once the peak of the flood has passed. Retarding basins can be an effective means of reducing peak flood levels, however depending on the outlet design and operation, may increase the duration of flooding by prolonging the release of stored floodwaters. There are a number of challenges associated with retarding basins including availability of land, appropriate topography, risk of overtopping and ongoing maintenance. Based on the catchment and taking into account the above factors, retarding basins were not considered further.

DISCUSSION

While there are a number of challenges with flood mitigation dams they have the potential to significantly reduce downstream flood levels. The raising of Warragamba dam by approximately 14m was previously considered by the State Government with an EIS published in 2021. The benefits of the flood mitigation dam included:

- Reduced 1% AEP peak flood level by 3-4m.
- Significantly reduced average annual damages
- Increased flood warning time allowing for increased time to evacuate

While the raising of Warragamba Dam for flood mitigation purposes is no longer being pursued, it is recognised by the Floodplain Management Committee as the only floodplain mitigation measure

available to provide widespread protection to the valley. The reductions in flood levels achieved by a floodplain mitigation dam are used as a benchmark for other mitigation measures.

SUMMARY AND RECOMMENDATION

While the raising of Warragamba Dam for flood mitigation purposes is no longer being pursued, it is recognised by the Floodplain Management Committee as the only floodplain mitigation measure available to provide widespread protection to the valley.

8.3.2. Levees, Floodgates and Pumps

DESCRIPTION

Levees are built as means of eliminating the inundation of floors and yards during a flood event (up to the design height of the levee together with a freeboard allowance of typically 0.5m). Levees can be successfully employed on large river systems where they protect a large number of properties. They often comprise earthen embankments but can also be constructed as concrete walls or other similar structures.

Unless designed for the PMF, levees will be overtopped. Under overtopping conditions, the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that a levee has “solved” the flood problem (as happened with Nyngan, NSW in 1990 and Hurricane Katrina in New Orleans, USA).

In the event of levee failure, properties impacted are likely to experience relatively short to no warning time of the failure, resulting in high velocities and high inundation depths in a relatively short period of time and therefore a high provisional hazard. It should be noted that overtopping of a levee is not considered failure of the levee, as the levee may have been designed to overtop in some events. A large number of houses are not built to withstand the hydrostatic pressure that would be present following failure of the levee and ponding of floodwater.

Flood gates or rubber flap valves allow local runoff to be drained from an area (say an area protected by a levee) when the external level is low, but when the river is elevated, the gates prevent floodwaters from the river entering the area.

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates.

DISCUSSION

Some of the key issues regarding levees are summarised in Table 22.

Table 22: Key Features of Levee Systems

ISSUE	COMMENT

ADVANTAGES:	
"Environmentally Sensitive Measure"	A well-designed vegetated earthen embankment set back far enough from the creek and that does not interrupt local drainage, can have minimal environmental impact. However, in many locations it is hard to meet all these criteria. Levees cannot have large trees planted on them because if the trees fall over in a storm it may affect the structural integrity of the levee.
Protects a large number of buildings	Whilst this is generally the case due to the relatively scattered nature of the flood liable properties it is impossible to construct a new levee that would protect a large number of buildings.
Low maintenance cost	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure will generally be small (for example less than $5,000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents	Residents enjoy living near the creek system because of the visual attraction of the water or bush and a high embankment could significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the purchase of land and associated costs (possible services re-location and access) which add considerably to the cost.
Low to medium benefit cost ratio	Whilst the levee system may protect a several buildings from being inundated in a given event, for example the 1% AEP event, it is likely to have a low to medium benefit cost ratio as there are few buildings floors inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP event).
Local runoff from within the "protected area" or upstream may cause inundation	The ponding of local runoff from within the protected area may produce levels similar to that from the creek itself. At present local runoff already causes problems in several low lying areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure.
May create a false sense of security	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005). A regularly used quote regarding levees is that there are only two types of levees. Those that have failed or those that will fail in the future.
Relaxation of flood related planning controls	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access	A levee will provide restricted access to the area and/or the bush or riverine areas. This can be addressed by (expensive) re-design of entry points.

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

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

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

Whilst flood gates and pumps have been used successfully at a number of locations throughout NSW over many years, they require ongoing maintenance to ensure their continued success. Vandalism, corrosion, damage or vegetation growth can all result in failure at critical times. Some form of ongoing maintenance program is therefore required. Ensuring the power supply for pumps remains operable during times of flood can also be problematic. Within NSW floodgates are being replaced with automatic operating smart gates.

Levees, floodgates and pumps were considered in the preliminary options assessment:

- McGraths Hill
- Wilberforce
- South Windsor
- Pitt Town

The Windsor-McGraths Hill Macro Levee was investigated. The Macro Levee was 9km long and crossed several creeks. The levee would be 10-14m high in some locations. It is not considered further due to practicalities in construction and Floodplain Committee feedback.

Generally, there is a practical limit to levee height. Also the base width also increases with height. Providing a higher levee to provide greater protection means tying into high ground becomes difficult. Above a certain level the length of the levee will increase substantially. Levees provide the greatest benefit when greater than 80% flood affected properties are inside the levee so the number of properties that benefit is much larger than the small number who are impacted. As discussed in Section 7 climate change rainfall increases will result in higher flood levels reducing the levee of protection provided by a levee.

OPTIONS CONSIDERED

McGraths Hill Levee (FM1)

A ring levee around McGraths Hill was been proposed in the 1997 study (Reference 27) and has also been considered more recently by INSW (Reference 29). Figure 52 shows the extent of the levee. Due to the low nature of McGraths Hill it is very difficult to build a levee above the 2% AEP level. Even at the 2% AEP level the levee will have a very high embankment particularly in the north east corner. Figure 52 shows a cross section of the levee. Nearly all of the housing in McGraths Hill has the primary habitable approved floor level at 16mAHD (which is approximately the current 2% AEP level). Many houses were constructed as two storeys to achieve this and many of the lower stories are no longer flood compatible. The option protects 381 properties from above floor flooding and 632 from above ground flooding in a 2% AEP. The impacts outside the levee caused by this option are in the order of 0.005m in a 2% AEP event (Figure 53). Three properties are that were not previously flooded are flooded above floor level.

Benefits of the McGraths Hill Levee:

- A levee would provide slightly more time for the lower properties in McGraths hill to evacuate
- Protect garages and downstairs flood compatible levels of many of the two storey properties

Disadvantages of the McGraths Hill Levee:

- Provide a false sense of security,
- Would not protect any approved habitable areas,
- Have a small impact on surrounding properties that while small the total intangible damages are large, and
- Would protect illegal enclosed downstairs areas.

Pitt Town Levee (FM 2)

A levee protecting Pitt Town to a 2% AEP level was modelled (Figure 55 to Figure 57). The levee would be on average 5m high. When this option was first identified in the 1997 Study (Reference 27) it was considered reasonably viable however the new development will mean a large amount of acquisition. The option provides protection in a 2% AEP event to approximately 103 houses. The option provides protection to mainly older houses, many of which were built before current planning standards. Figure 56 shows the impacts of the levee on flood levels in a 2% AEP event with widespread increases of 0.0027m. Four houses are newly flooded above floor level by the option.

South Windsor Levee (FM 3)

This option was originally proposed to keep access to Windsor open for longer by cutting off the overflow at George Street. This overflow connects the Rickabys Creek backwater area to the South Creek backwater area. Until flood waters reach approximately 16mAHD at Windsor there is 100mm of gradient between these two storage areas. The original proposal was to protect the road with a levee (Figure 58). The levee was modelled at a 1% AEP level. The option protects 468 properties from above floor floodings and 500 from above ground flooding. Five properties are newly flooded above floor level by the option.

Impacts for the levee case compared to the existing case in a 1% AEP event are presented in Figure 59. However, the levee maintains the difference in water level for longer, raising levels slightly in the Rickabys Creek area. Access improvements might be better achieved by raising the road and installing a series of box culverts rather than a levee.

Wilberforce Levee (FM 4)

A levee around Wilberforce has been previously suggested (Reference 27). Figure 61 shows the extent of the levee. A levee was modelled at the 2% AEP level. A total of 25 properties are protected from above floor level flooding and 52 from above ground flooding. A small number of properties are flood free in events less than a 2% AEP due to the levee. This levee cuts off a smaller area of the floodplain and therefore results in lower impacts (Figure 62 and Figure 70). The practical limit for construction height of the levee is the 2% AEP level. The levee would be quite high in the southern corner. The impacts outside the levee caused by this option are in the order of 0.001m. The option reduces AAD by approximately $129,000 (Table 21). The impacts in the surrounding LGAs are minor will minimal change in AAD (Table 22). While this is the most viable of the levee options the benefit cost ratio is likely to be less than 0.1 as construction costs (not including easements or property acquisitions) would be in the order of $1 Million. It would have partially split the town causing social disbenefits.

Table 23: Average Annual Damages change – Wilberforce Levee – Hawkesbury LGA

Event	Existing Damages	Change in Damages
PMF	$9,587,875	$0
0.1%	$5,851,793	$0
0.2%	$12,550,865	$0
0.5%	$13,872,268	$0
1%	$16,424,880	$0
2%	$20,781,895	-$27,067
5%	$11,711,042	-$97,173
10%	$8,343,693	-$5,644
20%	$3,367,934	$0
Change in AAD	$102,492,245	-$129,913

Table 24: Change in Average Annual Damages – Wilberforce Levee - By LGA

LGA	Change in AAD with Wilberforce Levee
Hawkesbury	-$129,913
Penrith	-$201
The Hills	-$1,332
Blacktown	$932
TOTAL Change in AAD	-$130,514

Survey of Existing Levees (FM 5)

A number of minor levee banks that assist with managing small floods and are associated with

drainage works have been built within the Hawkesbury-Nepean Valley. These levees are on privately owned land, have suffered damage in recent events and the status of the levees is unknown. It is recommended that a detailed survey of the levees is undertaken and that a maintenance program be developed .

SUMMARY AND RECOMMENDATIONS

Of the levee options investigated Wilberforce levee produced the lowest impacts as it was on the edge of the floodplain. The options produced very minor impacts in a 2% AEP that were widespread. Overall, the reduction in AAD compared to the cost of the option found that it was unviable. Pitt Town, South Windsor and McGraths Hill levees are not recommended for further consideration. A detailed survey of the existing levee banks is recommended.

8.3.3. Channel Modifications

DESCRIPTION

Channel works include any measure that increases the hydraulic efficiency of the main channel or immediate overbank areas. In this way, flood levels are reduced by either increasing the waterway area or increasing the velocity of flow. Measures include:

- vegetation or other forms of clearing,
- channel widening,
- dredging,
- concrete lining,
- creek shortening,
- removal, raising or upgrading of hydraulic structures (bridges, roads).

All the above measures have been employed at various times on different river systems in NSW. However, apart from local areas, these measures are now generally not considered to be environmentally and economically sustainable. In addition, they may introduce additional problems such as bank erosion, sedimentation, issues with land ownership and permission, increases in flood levels downstream, and these measures require an on-going maintenance regime.

DISCUSSION

The 1997 study (Reference 27) identified that a bypass channel through the saddle between Wilberforce/Ebenezer and Currency Creek which would short circuit approximately 21 km of river (FM 6). This ridge acts as an overflow path between the Hawkesbury River and Currency Creek in a 20% AEP event (Figure 72). The flood level differential between the two locations is approximately 4m in a 1% AEP event. There is ample head to drive flows down a cutting with a fuse plug spillway. The option was fine tuned with a series of fuse plugs to limit operation to events rarer than 5% AEP and to hold levels near this range for as long as possible.

The option does involve significant evacuation and widening of the channel. Approximately 8.7

Million m^3 of Hawkesbury Sandstone (Approximately 3 Million m^3) and soil material would need to be excavated. The channel was modelled as a large trapezoidal channel with 1 in 1.4 sides (Figure 71). The INSW 2019 option would require two bridges over Sackville Road and Argent Road, and minor roadwork at Stannix Park Road which have not been included in the TUFLOW modelling as they will have limited impact on flood levels.

While it would lower levels in a 1% AEP event by 1 m at Windsor, it would raise levels in Currency Creek and the Hawkesbury-Nepean River below Sackville. Table 25 and Figure 72 to Figure 79 shows the change in flood levels at key locations. The 1% AEP flood level with Currency Creek in place is reduced by approximately 1m at McGraths Hill compared to existing levels. Flood levels between Sackville and Wisemans Ferry are increased by 0.6m.

This is the only option that provides wide scale flood reductions in the major population centres. While the flood level impacts are significant they are lower than those provided by a flood mitigation dam. The bypass option decreases upstream flood levels but increases downstream levels.

Table 25: Currency Creek Bypass Change in Flood Level

ID	Location	Existing 1% AEP (mAHD)	Change in flood level with Currency Creek Bypass(m)
1	Yarramundi	18.09	-0.21
2	North Richmond	17.51	-0.71
3	Freemans Reach	17.37	-0.98
4	Windsor Bridge	17.35	-1
5	McGraths Hill	17.34	-1.01
6	South Creek at Hawkesbury Valley Way	17.34	-1.01
7	South Creek at Richmond Road	17.34	-1
8	Sackville Ferry	13.89	0.61
9	Lower Portland	10.98	0.69
10	Leets Vale	7.81	0.6
11	Wisemans Ferry	6.39	0.58

Flood levels are reduced by Currency Creek Bypass at 5500 properties in a 1% AEP with 1234 no longer flooded above floor level (Table 26). However, Currency Creek Bypass increases flood levels at 549 properties with 19 newly flooded above floor level.

Table 26: Properties subject to increase and decrease in flooding – Currency Creek Bypass

Event	Increase in Level*	Decrease in Level*	No Longer flooded Above Floor Level	No Longer flooded Above Ground Level	Newly Flooded Above Floor Level	Newly Flooded Above Ground Level
20%	43	234	0	1	0	0
10%	8	967	1	4	0	0
5%	374	1624	10	19	6	8
2%	584	3854	888	1015	33	34
1%	549	5503	1234	1034	19	26
0.5%	586	7403	1387	1702	22	20
0.2%	656	10761	1984	2127	28	26
0.1%	688	13337	1878	1856	9	14
PMF	803	18370	45	22	0	0

*Any change in level greater than 0.001m. Typical impact assessments use 0.010m as a minimum cut off

The reduction in average annual damages was calculated (Table 27). As the impact stretches beyond the Hawkesbury LGA boundaries the average annual damages change outside the LGA was also calculated (Table 28). Flood levels and damages are reduced from a 5% AEP through to the PMF. Overall the option reduces AAD by $21.5 million in the Hawkesbury LGA. The decrease in average annual damages in the Penrith and Blacktown LGA are reduced while the Hills Shire slightly increases (Table 28). The total valley wide change in Average annual damages is a decrease in the order of $25 Million. The average annual damage reduction is significantly less than that in Reference 29. The estimated cost in the 2019 Taskforce Report (Reference 29) based on 2015 costs was $753 Million ($957 Million in 2024 adjusted for CPI, although construction costs have increased more). This includes construction costs, land acquisition costs, maintenance costs (including deposited sediment removal and reinstating fuse plugs). It is unclear if this number includes the cost of the two bridges. This would make the benefit cost ratio less than 0.05.

A detailed assessment of the environmental impacts for Currency Creek Bypass was undertaken in Reference 28. The additional flow into Currency Creek would result in geomorphic changes to the channel. The channel would cross agricultural land and native vegetation including 3 threatened communities:

- Cumberland Plain Woodland
- River-flat Eucalypt Forest
- Shale Sandstone Transition Forest

Threatened flora recorded within and directly adjacent to the Currency Creek Bypass include (Reference 28):

- Pultenaea parviflora (TSC Act Endangered and EPBC Act Vulnerable) and
- Dillwynia tenuifolia (TSC Act Status Vulnerable)

A number of issues would need to be resolved if the option were constructed including:

- Where to store such a large volume of material once removed out of the floodplain
- Potential geotechnical issues
- Potential mitigation measures for those with increased flood risk
- Detailed survey to confirm importance of habitat in the bypass footprint for threatened species
- Detailed Aboriginal Archaeological assessment
- Investigation of biodiversity offsets
- Benefits of the option under climate change
- Who would be responsible for fuseplug maintenance

Table 27: Average Annual Damages – Option Currency Creek Bypass – Hawkesbury LGA

Event	Existing Damages	Change in Damages
PMF	$9,587,875	-$555,443
0.1%	$5,851,793	-$1,068,755
0.2%	$12,550,865	-$3,058,718
1%	$13,872,268	-$4,647,958
1%	$16,424,880	-$6,212,049
2%	$20,781,895	-$5,883,559
5%	$11,711,042	-$41,954
10%	$8,343,693	-$58,320
20%	$3,367,934	-$28,363
AAD	$102,492,245	-$21,555,119

Table 28: Change in Average Annual Damages – Option Currency Creek - By LGA

LGA	Change in AAD with Currency Creek Bypass
Hawkesbury	-$21,555,119
Penrith	-$1,263,471
The Hills	$16,903
Blacktown	-$2,485,399
TOTAL Change in AAD	-$25,287,086

SUMMARY AND RECOMMENDATION

Currency Creek Bypass provides wide spread reductions in flood levels across design events. However, flood levels are increased downstream of Sackville. The option is not recommended for further consideration.

8.3.4. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging which

are deployed before the onset of flooding. They are usually on a larger scale than simply sand bagging at the entrance to a house, but include blocking flood waters from entering through driveways and gaps in existing flood defence levee structures.

DISCUSSION

The effectiveness of these measures relies on a sufficient warning time and the ability of a workforce to install them. They are therefore often used as a means to assist in current mitigation measures rather than the sole protection measure. It is important that temporary barriers are not used without planning and investigation as they can raise flood levels in other locations. Temporary barriers can be effective for closing gaps in a levee if a flood occurs during construction. Temporary barriers should only be used when they do not restrict or block a flow path or reduce flood storage. Temporary flood barriers could be used to keep low points on roads open longer.

SUMMARY AND RECOMMENDATIONS

Temporary flood barriers could be used to keep roads open longer.

8.4. Property Modification Measures

8.4.1. Flood Access

DESCRIPTION

One of the main ways of improving evacuation is to ensure that there are adequate evacuation routes available and appropriate warnings as to when the routes will become impassable.

DISCUSSION

Maintaining appropriate access to or from affected areas during times of flooding is important to ensure that:

- people have the chance to evacuate themselves and valuables/belongings before becoming inundated or trapped by rising floodwaters,
- emergency services (NSW SES, ambulance, police, etc.) are not restricted or exposed to unnecessary hazards in carrying out their duties, and
- areas are not isolated for extended periods of time, preventing people from going about their normal routines or business or restricting access to essential services.

There are a number of issues to be considered in raising roads including:

- the relatively high cost,
- the level they should be raised to,
- how much benefit is provided,
- whether the raising of the road causes an unacceptable hydraulic impact, and
- the entire evacuation route needs to be raised to a minimum serviceability level from the affected area to high ground.

The 2012 Floodplain Risk Management Study recommended:

- Traffic modelling to improve evacuation planning and integrated into flood modelling
- Dual outbound lanes on Jim Anderson Bridge during flood events
- Additional evacuation capacity through a new crossing of South Creek at Eight Ave, Llandilo.
- Identification of local evacuation route upgrades
- Investigate dual lane options for Jim Anderson Bridge

As part of the delivering HNV Flood Strategy, TfNSW is undertaking investigations for road improvements (Road resilience Program). This includes improvements to flood immunity of evacuation routes through drainage routes, road shoulder upgrades and raising of low points. This is coupled with evacuation modelling by the SES. Councils flood committee supported the assessment of flood evacuation route upgrades.

A number of local evacuation routes were suggested by the community including:

- A high level bridge to West Portland Road (North Sackville)
- Raising Springwood Road

These are supported as they will build resilience, subject to them being designed in accordance with standard practice (which will ensure minimal impacts). As shown in Section 8.3 small structural works in the floodplain can have far stretching impacts.

The Pitt Town Bypass aims to reduce traffic through the town centre, improve safety for road users and enhance flood resilience for local residents. The Pitt Town Bypass is currently planning for construction. The Bypass crosses an overflow path from Pitt Town lagoon to Long neck lagoon that activates in 5% AEP events. Crossings in this area should be carefully designed to result in minimal impact in the regional flood events not just local events. The Pitt Town levee modelling discussed in Section 8.3 does not consider the Pitt Town bypass, which is also not included in the 2024 Flood Study.

Transport for NSW is currently undertaking concept design for a higher level bridge for North Richmond. Due to the extent of impacts of a bridge and associated road network, the final bridge will be cut in major flood events (at a 5% AEP level). However, the higher level access will remain open longer than the current bridge (flooded in a 20%AEP) during flood events. Diagram 11 visually represents the old and new Richmond Bridges.

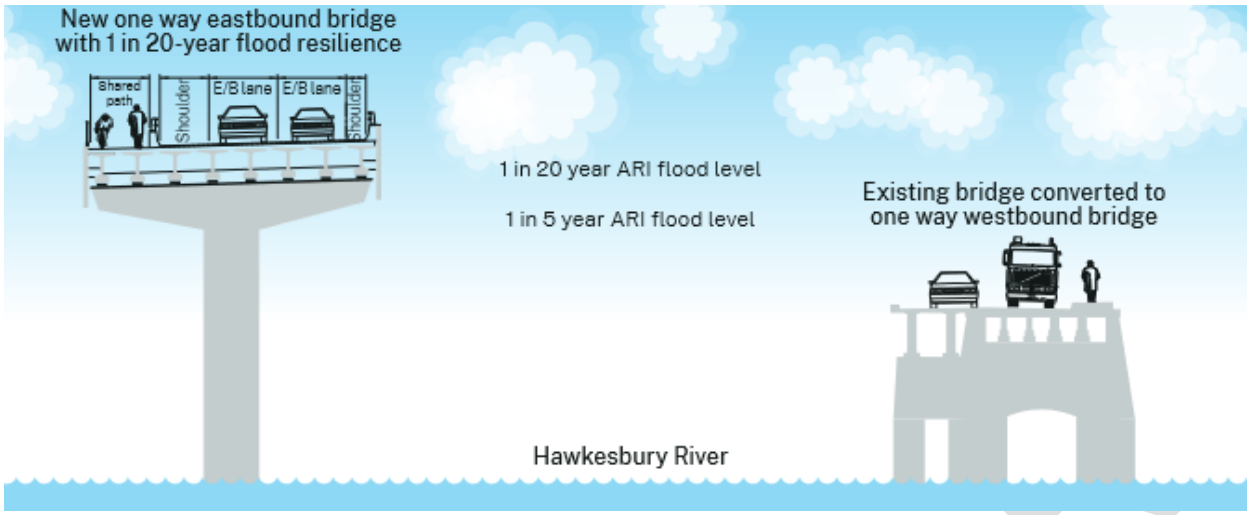


Diagram 11: New Richmond Bridge (Source: TfNSW)

Ferries are located at Sackville, Webbs creek and Wisemans Ferry and provide a vital transport link for the inhabitants of the lower valley. It is recommended that the latest flood study information is provided to the Ferry Operators to assist with their planning for an event, planning of ferry moorings and assist in a quicker recovery post event. The two-dimensional model will allow the identification of lower velocity areas suitable for moorings.

SUMMARY AND RECOMMENDATIONS

Improvement of evacuation routes are supported subject to them being design to the appropriate design standard such that the flooding impacts are minimal.

8.4.2. Land Use Zoning

DESCRIPTION

Suitable and correct zoning of flood liable land is a key aspect in managing flood prone areas. It ensures development only occurs in suitable locations compatible with flood risk and hazard. As recognised in the Flood Risk Management Manual (Reference 11) land use planning cannot be undertaken effectively without a good understanding of the flood risks and the associated consequences.

DISCUSSION

The LEP zones land uses in the HCC LGA comply with the current NSW standards. 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 become degenerative. Progressive zoning can be used to encourage long term increase in flood resilience.

SUMMARY AND RECOMMENDATIONS

No changes to Councils land use zoning are recommended.

8.4.3. Voluntary Purchase (PM1)

DESCRIPTION

Voluntary purchase (VP) involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally, the land is returned to open space. The following eligibility criteria must be met to allow funding under the VP Scheme:

1. *Only councils are eligible to apply for funding under the program. It is not open directly to individuals.*
2. *VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property.*
3. *Subsidised funding is generally only available for residential properties and not commercial and industrial properties.*
4. *Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government.*
5. *The individual properties within a scheme should be identified within an FRMP developed in accordance with the Floodplain Development Manual (2005) and adopted by the council.*
6. *Funding under the program is only available for properties identified in a VP scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the VP scheme is eligible for funding.*
7. *Under limited circumstances, VP can be considered for funding prior to completion of an FRMP. However appropriate investigations and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include scoping the VP scheme.*
8. *Properties being considered for VP should be located:*
    a. *Within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them. However, a house in a location that is classed as high hazard on the basis of depth or provisional hazard alone would not be automatically eligible for VP. Hazard categorisation should be based on the true hazard assessment and consider a range of other factors that influence flood hazard as detailed in the Floodplain Development Manual (2005).*
    b. *Within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function.*
    c. *Within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected. Eligibility will be considered as part of the detailed investigation and design for the works project. Funding the purchase of the property would be considered as part of the total works package which could include preconstruction activities.*

9. *Unless it is being purchased to facilitate a mitigation work, vacant land is not generally eligible for funding as it does not achieve the main aim of VP. Development controls should be used to limit the potential development of vacant land so that this is consistent with the flood function and flood hazard at the location.*
10. *Two or multi-storey properties may be eligible for funding despite the upper floors not being directly affected by over-floor flooding. Residents retreating to the upper floors and their potential rescuers may still face significant risk to life and the building may not be designed to be structurally sound for the potential range of flood conditions. An additional hazard assessment needs to be undertaken to confirm eligibility of multi-storey properties.*

DISCUSSION

Voluntary purchase is mainly implemented over a long period for residential areas in high hazard areas. Voluntary purchase is a means of removing isolated or remaining buildings, thus freeing both residents and potential rescuers from the danger and cost of future floods. It also helps to restore the hydraulic capacity of the floodplain (storage volume and waterway area).

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

It is not uncommon for the uptake of voluntary purchase properties to slow down once most of the owner-occupied housing stock has been purchased. This can create fragmented neighbourhoods where it is common for the remaining housing to be dominated by rental properties and visually unappealing businesses. The voluntary purchase zoning can encourage rental investors to hold on to properties.

Land swap schemes can also help accelerate the clearance of the floodway, such as that undertaken in Grantham, Lockyer Valley, Queensland following the January 2011 floods. Through such a scheme, people who own land within the floodway would be offered deeds for another parcel of land outside of the floodway in return for their current property, which is returned to Council for demolition and clearance.

Voluntary purchase should be considered for properties in high to extreme hazard (H5 and H6) areas. Properties in hazard category H4 may be considered where the peak flood depths are large enough to make house raising unrealistic or where they are in a particularly dangerous location. Within the study area there are 2413 properties which have high to extreme hazards in the 1% AEP event. However, an estimated 1700 are likely eligible under the criteria though some might be essential for farming or historic buildings. The cost of such a program is likely to be cost

prohibitive at current property prices. However removing the highest risk properties (eg affected in events more frequent that a 5% AEP and not properties relating to agriculture) would remove in the order of 20% of the damages and would be a much lower number of properties. Properties on low flood islands with difficult evacuations should be prioritised.

SUMMARY AND RECOMMENDATIONS

A total of 2413 properties are affected by high to extreme hazards during the 1% AEP flood event. However, a lower number are likely eligible under the criteria. A detailed assessment of their viability should be undertaken. Investigation into only including the properties subject to the highest hazard in frequent events.

8.4.4. Building and Development Controls

These measures include managing flood risk for future development through development controls.

8.4.4.1. Flood Planning Levels (PM2)

DESCRIPTION

Flood Planning Levels (FPLs) are an important development control in floodplain risk management. Through planning controls Council has requirements for all new development to set finished floor levels above a given flood level. The Floodplain Risk Management Manual (Reference 25) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is a useful mitigation measure for future flood risk and is derived from a combination of flood level results from a flood event of specific probability, usually the 1% AEP, and freeboard of usually 0.5m. FPLs do not apply to existing development, but through development controls which are enforced on generally all new development.

DISCUSSION

Stipulating FPLs for all new development is one of the most effective measures in reducing flood damages to new properties without preventing development in a flood prone area entirely. Defining the appropriate FPL 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 and development in flood prone areas and of implementing management measures.

Developments more vulnerable to flooding such as hospitals, electricity sub stations, and housing for the elderly or less physically mobile, should consider rarer events than the 1% AEP when determining their FPL. However, the FPL does not address the full range of issues when considering flood and permanent inundation risk such as access and failure of essential services.

According to the Floodplain Risk Management Manual (Reference 25) the purpose of freeboard is to give reasonable certainty that the reduced flood risk exposure implied by selection of a particular flood as the basis of a FPL is actually provided, given the following factors:

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

Freeboard of 0.5m should be included in the FPL. Initially freeboard included an allowance for climate change. However it is now widely accepted that it is not enough to account for climate change particularly in the Hawkesbury LGA. In a real flood, some of the factors described above may reduce the flood level (local factors) or not apply at all (no wave action). There is no advice as to what the contribution for each factor should be.

FPLs are generally required to be defined or applied for the following broad land uses:

- community services (schools, halls),
- critical services (hospitals, police stations, Council offices),
- residential (single and multi-unit),
- rural areas,
- commercial/industrial,
- recreational facilities,
- caravan parks,
- additions/extensions to existing structures, and
- public utilities (electricity, sewer, water, phone, etc).

Typically, in coastal locations a 0.5m freeboard raises the 1% AEP to a 0.5% AEP level. At Windsor the freeboard would need to be 1.2m. With climate change 2030 1% AEP flood levels are already close to the historic 0.5% AEP. Given the extreme flood range, consideration should be given to using a flood planning level greater than the 1% AEP. The extreme flood range or the climate change risk are enough in isolation to recommend a higher flood planning level than the 1% AEP.

HCC current planning documents set the FPL to the 1% AEP level without freeboard. It is recommended that Council adopt the 0.5 % AEP (1 in 200 AEP) plus 0.5 freeboard for the flood planning level. The resultant flood planning area from regional floods is shown on Figure 50 and Figure 51. Therefore, it is recommended that Councils planning documents be updated to reflect this. Consideration should be given to the inclusion of climate change in planning levels. Council should consider making the FPA and other flood information and extents available on its website.

The 2024 Flood Study includes regional flooding and does not include local catchment flooding, which may produce higher flood levels in the upper reaches of tributaries. Council is currently undertaking the Redbank Creek, Colo River, Green Creek, Webbs Creek and Macdonald River flood studies. The Flood planning levels from these studies should also be considered.

UPDATED FLOOD PLANNING LEVEL

A freeboard of 0.5m is recommended for the study area. The Flood Planning Area (FPA) is defined as the extent of the FPL (the 0.5% AEP (1 in 200 AEP) event plus a freeboard). Figure 50 and Figure 51 shows the proposed Flood Planning Area.

SUMMARY AND RECOMMENDATIONS

It is recommended that Council update its flood planning area and flood planning levels based on the current study and tributary studies it is currently undertaking. Consideration should be given to the inclusion of climate change. Council should consider making the FPL and flood depths available on its website.

8.4.4.2. Revise LEP and Develop DCP (PM3)

DESCRIPTION

Updated and relevant planning controls, outlined in several of the preceding sections, are important in flood risk management. Appropriate planning restrictions can significantly reduce flood damages, by ensuring that development is compatible with flood risk. 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 to ensure development in flood prone areas is suitably designed, for example with raised floor levels. They can also be used to develop appropriate evacuation and disaster management plans to reduce flood risks to the existing population.

DISCUSSION

The primary objective of the NSW Government's Flood Policy is "to reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding, utilising ecologically positive methods wherever possible".

Appropriate development controls involve consideration of the social, economic, environmental and risk to life of consequences associated with the occurrence and management of floods. This involves trading off various benefits of reducing the impacts of flooding on development, against the costs of restricting land use in flood prone areas and of implementing appropriate management measures.

The outcomes of this study should feed into Councils planning documents in respect to flood related development controls or, alternatively, the existing documents can simply refer to this study and plan. Council has updated its LEP to the NSW standard instrument to include Clause 5.21. Council has not adopted Clause 5.22 special flood considerations.

The Flood Prone Land Package included a second optional clause 'Special Flood Consideration' which provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.
(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,
(c) to avoid adverse or cumulative impacts on flood behaviour,
(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,
(e) to avoid adverse effects of hazardous development on the environment during flood events.
(2) This clause applies to—
(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and
(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood,
may—
(i) cause a particular risk to life, and
(ii) require the evacuation of people or other safety considerations.

The LEP currently does not include the 5.22 Special Flood Considerations clause. Changes to the NSW Government planning framework in relation to flooding allows Council the opportunity to include a second clause within their LEPs which applies to land between the FPA and the PMF extent and considers sensitive and hazardous uses in addition to those uses which may have evacuation constraints. This inclusion empowers Council to apply controls that ensure the developers of such facilities appropriately consider and plan for the full range of flood risk at the site, so as to reduce potential property damages and minimise the risk to life in future flood events.

Given the extreme flood range and evacuation challenges there is a clear case for Council to apply Clause 5.22. This would allow Council to make future development more resilient and allow the community to recover faster. Examples include encouraging new development and knockdown/rebuilds to construct two storey houses if below the 0.5% AEP. This would also require a map of the area to which this clause applies to be available in Council's DCP.

Section 2.6.3 provides a summary of the current LEP and planning documents for HCC. A review of these documents, and some changes are recommended as detailed below. Typically development controls are based on the 1% AEP. Due to the extreme flood range in the Hawkesbury-Nepean the 0.5% AEP is recommended. Flood maps are produced by the study for a full range of AEPS so Council can be aware of the full range of flood risk for the sites.

The flood constraint category mapping aims to consolidate all the mapping outputs to assist planners. Council is currently using the outputs of the FPCC mapping (Figure 48 and Figure 49) to determine areas where development should be constrained and areas where less restrictions are required in order to update their planning documents. The AIDR guide provides example planning constraints for the various FPCC categories. For example FPCC1 – Development is discretionary provided it doesn't adversely affect flood function. Intensification of existing and new key community, utility and vulnerable, residential and commercial uses may be prohibited.

CHANGES or CONSIDERATIONS FOR COUNCILS PLANNING DOCUMENTS

- Update terminology – the current planning documents use Average Recurrence Interval. Current best practice is to use Annual Exceedance Probability.
- Section 7.2 discusses the Flood Planning Constraint Categories developed as part of this study which provide a contemporary means of dividing the floodplain into subregions with common flood risk characteristics, for the appropriate application of development controls. Council is currently updating its DCP to reflect FPCC.
- Care should be taken when specifying numerous specific development types that all types of possible development is covered or that there is a general catch all category.
- Encourage flood proofing but noting its limited range of benefits
- Encourage multistorey dwellings and commercial units
- Develop a DCP

Note: Recommendations regarding changes to flood related development plans and policies are intended to express the objective of the control, however the phrasing of specific controls is ultimately Council's decision.

It is essential that Development Application officers review the applicability of all, flood, stormwater and localised runoff controls, to properties, in order to reduce the cumulative effects of flooding in the catchment.

In addition, the recommendations made in this report pertain specifically to the management of regional flood risk in the study area, and the applicability and suitability of such controls for use in other parts of the LGA for local tributary flooding is to be confirmed prior to making any changes to the LEP or other planning documents.

SUMMARY

As part of the Floodplain Management Study, Council's Local Environment Plan and planning documents have been reviewed. Council and the community should consider changes to its LEP as discussed. Council to develop a DCP.

8.4.4.3. Provision of Flood Information to Residents via Section 10.7 Planning Certificates (PM4)

DESCRIPTION

Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the 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.

Schedule 2 of the Environmental Planning and Assessment Regulations 2021 gives requirements for inclusion on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. In particular

Schedule 2, Clause 9 refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls. Recent changes to the flood prone land package (refer Section 2.6.2.12) now require notifications to be placed on land between the FPA and the probable maximum flood (PMF) and is subject to flood-related development controls.

DISCUSSION

HCC currently provided Section 10.7 certificates. It is recommended that the high-resolution flood information included in this study and local catchment studies undertaken by Council is used by Council to improve community flood awareness, by providing information to residents via Section 10.7 Planning Certificates. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 5) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA and if flood related development controls apply, (10.7(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7 (2) and (5));
- Percentages of lots affected by the FPA(s) if not 100%, (10.7 (2) and (5));
- Likelihood of flooding and mechanism (10.7 (2) and (5));
- Flood hazard (10.7 (2) and (5));
- Hydraulic categorisation (e.g. floodway) (10.7 (2) and (5));
- Evacuation routes/ constraints (10.7(2) and (5)); and
- Associated Mapping for the above items (10.7 (2) and (5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding helps prepare residents for evacuation, and improves the ability of residents to recover following an event. Improved flood risk awareness may also reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated.

Land owners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5) Planning Certificates. Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to S10.7 Planning Certificates.

SUMMARY AND RECOMMENDATIONS

Section 10.7(2) and (5) Planning Certificate notations regarding flooding should be continued to provide information on all mechanisms of flood risk at the site. A greater level of detail can be provided via Section 10.7(5) certificates using outputs from this Study and Council's other Floodplain Risk Management Studies.

8.4.5. House Raising (PM5)

DESCRIPTION

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. This approach provides more flexibility in planning, funding and implementation than voluntary purchase. However, its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10% AEP event or less).

1. *Only councils are eligible to apply for funding under the program. It is not open directly to individuals. Requests from home owners to raise houses for hardship reasons are not eligible for funding.*
2. *Subsidised funding is generally only available for residential properties and not commercial and industrial properties.*
3. *Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government. Properties built after this date should have been constructed in accordance with the principles in the manual.*
4. *The individual properties in a scheme should be identified[3] in an FRMP developed in accordance with the Floodplain Development Manual (2005) and adopted by the council.*
5. *Funding under the program is generally only available for properties identified in a VHR scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the VHR scheme is eligible for funding.*
6. *Under limited circumstances, VHR can be considered for funding prior to completion of an FRMP. However scoping, prioritisation and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include scoping the VHR scheme and addressing the issues outlined in Section 3 above.*
7. *Properties which are benefiting substantially from other floodplain mitigation measures – such as houses already protected by a levee or those that will be – will not be funded for VHR.*
8. *VHR should generally return a positive new benefit in damage reduction relative to its cost (benefit–cost ratio[4] greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial social and community benefits or VHR is compensatory work for the adverse impacts of other mitigation works.*
9. *The scheme should involve raising residential properties above a minimum design level, generally the council's flood planning level (FPL) and comply with the council's relevant development control requirements.*

DISCUSSION

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. A number of techniques may be used. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. However, it does not reduce the external hazard, evacuation issues or yard/garage damages.

The Floodplain Management Program Grant Funding of this measure generally only cover the basic costs of raising the structure. The subsidy is usually offered on a relative basis depending on the severity of the problem and potential damages. Residents will most likely have to contribute their own funds to make up any difference and to facilitate the associated works or modifications.

Photo 1: Examples of House Raising

The 2012 floodplain risk management study recommended house raising be investigated for properties flooded in a 20% AEP. This action has not been implemented but warrants further reconsideration since the government is no longer pursuing catchment wide mitigation options.

In a 10% AEP event, 81 residential properties are flooded above floor level and subject to low hazard. A review of these houses for pre 1986 construction and already 2 storey construction indicates that less than 50 would likely qualify following a detailed assessment. A detailed survey of floor levels of properties is recommended along with a detailed Voluntary House raising study. The cost of basic house raising is typically in the order of $80-120,000 per house. It is recommended that Council develop a prioritised list of houses for raising.

While only a small number of the flood prone properties in the Hawkesbury-Nepean are suitable for house raising, it is a good strategy to as it many of the very low lying properties are of an older style construction which is suitable for raising and have some of the highest flood risk. It may be worth while looking at the higher AEP given the number of flood prone houses. An indication of the property's eligibility for house raising could be recorded on the Section 10.7 Certificate to ensure future potential purchasers are made aware of their options.

SUMMARY AND RECOMMENDATIONS

A total of 81 properties were identified as being flooded in frequent events (10% AEP) and subject to low hazard. Properties flooded frequently contribute a significant portion of the average annual flood damages. It is recommended that:

- Council undertake floor level survey of properties
- Council investigates a house raising program and prioritise houses should funding become available.
- The feasibility study should investigate which properties are suitable for raising.

8.4.6. Flood Proofing (PM6)

DESCRIPTION

An alternative to house raising for buildings that are not compatible or not economically viable, is

flood proofing or sealing off the entry points to the building. This measure can be used for all building use types and it is possible to retrofit an existing building. Flood proofing requires sealing of doors and possibly windows (new frame, seal and door); sealing and re-routing of ventilation gaps in brick work; sealing of all under floor entrances and checking of brickwork to ensure there are no gaps or weaknesses in mortar.

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building but techniques are used to reduce damages while dry proofing aims to totally exclude flood waters from entering a building.

DISCUSSION

Flood proofing is rarely used in NSW for residential buildings and is more suited to commercial premises with only one or two entrances and where maintenance operation procedures can be better enforced. Flood proofing is typically used for commercial buildings and can include raising of easily damaged/high cost items such as commercial stock, equipment and/or machinery.

There have been considerable advances in the principles and approaches to flood proofing properties, both in the retrofitting and construction phases. Two guidelines of particular note are:

- *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas* (2006), Hawkesbury-Nepean Valley Floodplain Management Steering Committee
- *Flood Resilient Building Guidance for Queensland Homes* (2019), State of Queensland (Queensland Reconstruction Authority)

Brisbane City Council have also recently piloted the Flood Resilient Homes Program to increase the uptake of flood proofing for high risk (50% AEP) properties, which is now being rolled out across the LGA (see https://www.citysmart.com.au/floodwise/ for further information).

Dry flood proofing requires the sealing of doors and possibly windows; sealing and re-routing of ventilation gaps in brickwork; sealing of all underfloor entrances and checking of brickwork to ensure that there are no gaps in the mortar. It is generally only suitable for brick buildings with concrete floors. Dry flood proofing is best incorporated into a structure at the construction phase. Alternatively, temporary dry flood proofing can be achieved by flood gates which fit over doors (Photo 2), windows and vents. These are installed by the property occupant before the onset of flooding. These can be more effective than sandbags if correctly installed.

Dry flood proofing should not be used in areas where flooding is deep as hydrostatic pressure of the floodwaters may cause structural issues. This method should only be applied in areas where flood depths are less than 0.5m although some sources suggest that dry flood proofing could be applied in areas with flooding up to 1m depending on the structure of the building. Dry proofing is also not ideal in areas with fast flowing water. Dry proofing is not considered viable for residential properties in the study area due to flood depths and velocities.

Photo 2: Dry proofing on doors of residential property

Wet flood proofing assumes water will enter the property and is designed to minimise damages and/or reduce recovery times. Electrical outlets are raised above flood levels to reduce risk of electrocution. The choice of materials used in construction can reduce flood damages, for example timber composites are likely to swell. New buildings are designed to allow a property to drain and provide adequate ventilation for drying.

It is a general condition of the Floodplain Risk Mitigation Manual (Reference 25) that floor levels of new residential properties are above the 1% AEP event plus freeboard. Commercial properties are not subject to such requirements unless stipulated by Councils. New commercial buildings can be required to be flood proofed to the Flood Planning Level when constructed. Council would make these requirements through the DCP and planning controls. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing, and temporary flood gate options. New developments or extensions could be required to use flood proofing.

Flood proofing will not reduce flood hazard and in fact the hazard may be increased if the measure results in occupants remain in their premises and a larger flood eventuates. Due to the flood range in the Hawkesbury-Nepean this option only provides benefit in a narrow range.

SUMMARY

Flood proofing is a good solution for reducing flood risk to commercial and industrial properties. Flood proofing for residential dwellings is considered less appropriate as there can still be risk to life if people remain in the building; raising floor levels above flood levels is considered to be safer. However, as existing houses cannot be raised, flood proofing is useful for existing properties.

Grant funding is not usually available for flood proofing. This option is generally less expensive than house raising. Although Council cannot be responsible for flood proofing existing properties,

they can enforce flood proofing for any new development within flood prone areas through planning controls. Furthermore, Council can, through a flood awareness campaign targeted at both commercial and residential property owners, make available information on flood proofing existing buildings such as temporary flood barriers. Due to the flood range in the Hawkesbury-Nepean this option only provides benefit in a narrow range.

RECOMMENDATION
Promote flood proofing for commercial properties in catchment, and residential properties below the habitable floor level.

8.5. Response Modification Measures

8.5.1. Flood Warning (RM1)

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

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

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

Flood warning systems are based on stations that automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided by the BoM (who provide flood forecasts) to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods). Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BoM.

The NSW government in collaboration with the BoM have invested significant heavily in improving flood warning on the Hawkesbury-Nepean. A new flood forecasting system has been developed specifically for the Hawkesbury-Nepean which will eventually be rolled out for all of Australia. This system considers all of the BoM forecast products to produce the best possible lead time as well as producing public forecasts this system is used to help the SES mobilise and plan for possible events.

The NSW SES has recently updated the Local Flood Plan (June 2020). Due to the changes in design flood estimates as a result of the 2024 Flood Study it is recommended that the plan is updated in the near term to reflect updated peak flood levels particularly the estimate for the PMF. Due to infrequency of flooding the Local Flood Plan has had limited real life testing events. However, the Monte Carlo modelling (Reference 17) and evacuation modelling (Reference 19) allows the full range of events likely to be experienced to be planned for. Joint planning exercises are held between SES, BoM, Water NSW and other agencies.

The NSW SES monitors local gauges in times of flood and maintain a database of flood intelligence records to assist in providing the community with the best possible flood warnings. Flood Warnings detail observed and expected levels at Windsor, Sackville, Lower Portland, Wisemans Ferry, Macdonald River, Colo River. An example warning is shown below. The SES issues detailed flood warnings with evacuation notifications identifying specific house numbers to evacuate. Flood evacuation signs are posted along evacuation routes.

As part of the work by SES, INSW and TfNSW the deck levels and closure levels of the main bridges are known. A number of bridge cameras were installed by the Live Traffic NSW project by Transport for NSW (TfNSW) in conjunction with HCC:

- Cattai Rd, Cattai Creek Bridge
- Sackville Ferry
- Wisemans Ferry
- Webbs Creek
- Yarramundi Bridge
- The bridge at North Richmond
- Lower Portland Ferry

It is recommended that cameras are also made available on Councils Disaster Dashboard. Consideration should be given to installing additional cameras at low points eg. Colo or Pitt Town.

SUMMARY AND RECOMMENDATIONS

The following options are recommended:

- Cameras on bridge approaches to also be made available on disaster dashboard
- Update of the Local Flood Plan to reflect flood levels from the 2024 Flood Study

Example flood watch April 2024 event (from Hawkesbury SES Facebook)

Flood Watch and Act - Prepare to evacuate advise has been issued for:
RICHMOND LOWLANDS AND CORNWALLIS
Kurrajong Road
The back of Francis Street
The back of Dight Street
Percival Street and Rickabys Creek.
Bensons Lane
Cornwallis Road
Cornwells Lane
Cupritts Lane
Gow Lane
Ingolds Lane
Old Kurrajong Road
Onus Lane
Percival Street
Powells Lane
Ridges Lane
Triangle Lane
PITT TOWN NORTH
Properties along Hall St including Percy's Place Caravan Park
CATTAI
Riverside Caravan Park
GRONOS POINT
Properties along Gronos Farm Road and Manns Road.
SACKVILLE
Properties near the intersection of Sackville Road and Tizzana Road.
SACKVILLE NORTH
Following properties:
951 Sackville Ferry Road (Anderson Farm)
All dwellings in 968 Sackville Ferry Road (Ulinbawn Water Ski Park)
All dwellings in 952 Sackville Ferry Road
942 to 968 Sackville Ferry Road
CUMBERLAND REACH
450 to 480 Laws Farm Road
560 to 600 and 501 Laws Farm Road
LOWER PORTLAND (EAST OF THE HAWKESBURY RIVER
Properties in the following streets:
496 to 608 River Road
531 to 659 River Road
760 to 918 River Road
733 to 901 River Road
991 to 1427 and 988 to 1426 River Road
Newill's Caravan Park
Riveria Ski Gardens

8.5.2. Flood Awareness and Preparedness (RM2)

DESCRIPTION

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

- *Flood Awareness*: How aware is the community to the threat of flooding? Have they been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat? Do they (or the NSW SES) have damage minimisation strategies (such as sand bags, raising of possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the evacuees to evacuate households to minimise damages and the potential risk to life? How will the evacuation be implemented, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river/creek systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have survived previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

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

- *Frequency and impact of previous floods.*
- *History of residence*.
- *Whether an effective public awareness program has been implemented.*

Prior to 2021 there had not been a large flood on the Hawkesbury-Nepean since August 1990 and many new and long term residents had forgotten about floods. With the flood of 2021 and two floods in 2022 the community is a lot more aware of flooding. However there is also a level of complacency as these three floods have a probability of 1 in 10, 1 in 15 and 1 in 20 AEP yet much of the media and social media treated them as very rare once in a lifetime style events. Larger floods will require the evacuation of whole suburbs. While the Hawkesbury LGA residents are much more aware of flooding than they were prior to 2021 many residents still underestimate the extent and level floods can get to. The other significant event was the 150 year commemoration of 1867 flood (in 2017) which at 19.7m was 5.8m higher (or two storeys) than the July 2022 (which was the highest of the recent floods). Continued education of residents of the chance of these rare events occurring again is recommended.

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

A major hurdle is often convincing residents that major floods will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP event (or sometimes termed a 100 year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred (a 1 in 20 chance each year).

There have been various awareness campaigns by SES and INSW (now NSW Reconstruction Authority) to improved flood awareness. There is a wealth of fact sheets and resources available on the SES website for the Hawkesbury Nepean including fact sheets, evacuation routes, getting ready and interactive videos. Some information is available in multiple languages. Regular awareness campaigns are recommended to continue to ensure that the level of flood awareness in the Hawkesbury LGA stays high.

SUMMARY

The community is significantly more flood aware than they were prior to the recent floods. There is also some misconception on the probability of these events. An awareness program around these aspects and the frequency of flooding in the catchment is recommended to continue.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures, additional flood markers, flood history reminders on significant anniversaries of major events, as well as advice provided on the Council's and SES's websites. These need to be updated on a regular basis. A specific fact sheet should be produced for each catchment relating specifically to the local issues.

Table 29 provides examples of various flood awareness methods that can be used.

Table 29: Flood awareness methods

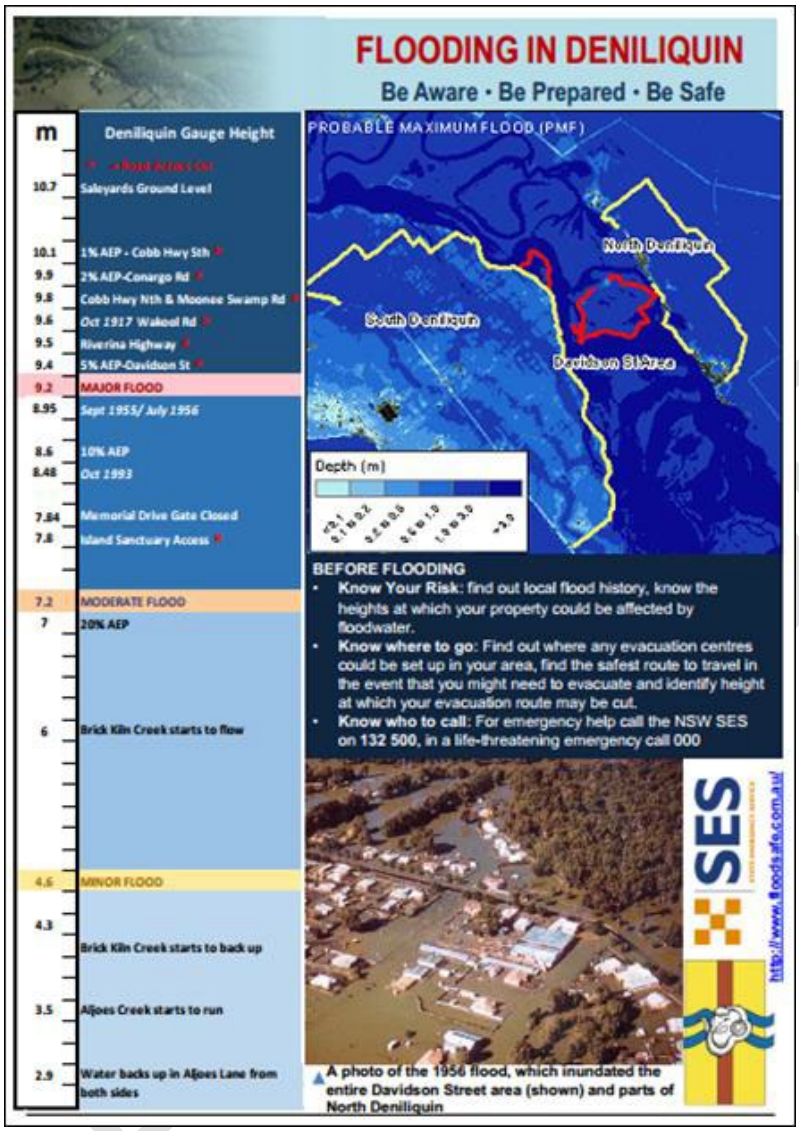
Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or bi-annually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood planning levels or any other relevant information. These should also be handed out as part of rental property information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various

	authorities and can be combined with water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Local Fairs	This is an inexpensive way of informing the community and may be combined with related displays. Include photographs, newspaper articles and information on development controls and standards, flood evacuation and readiness procedures.
Historical Flood Markers or Depth Indicators on Roads	Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of the potential hazards. Particularly appropriate near local waterways and low points which become flow paths during large events.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Floods	Collection of data from floods that occur in the future will assist in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Notification of Section 10.7 Planning Certificate Details	Floodplain property owners were indirectly informed that they were potentially flood affected as part of the public consultation program and floor level survey. Future residential property owners are advised during the property searches at the time of purchase by details provided on the Section 10.7
Web-based tools	Online presentations, activities, gauge data, GIS information on Council website.
Updates on Council website	Council already provide regular updates on the current flood situation on the home page of their website. The website also provides information on flood preparedness, response and recovery.
NSW SES flood awareness programs	The NSW SES are undertaking a flood awareness program in the catchment including, leaflets and flyers, and stalls at local events.

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

Below is an example of a fridge magnet produced to educate residents on what a specific gauge

height means.



RECOMMENDATION

- Develop a flood awareness program.
- It is recommended that a community flood awareness campaign be undertaken with the updated flood mapping

8.5.3. Evacuation Planning (RM3)

DESCRIPTION

It may be necessary for some residents to evacuate their homes in a flood. This would be undertaken under the direction of the SES who are the lead agency under the Displan. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents.

DISCUSSION

The main problems with all flood evacuations are:

- They must be carried out quickly and efficiently,
- They are hazardous for both the rescuers and the evacuees,
- Residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers and increasing the risk to the rescuers,
- The number of people to be evacuated,
- The mobility or special requirements to evacuate residents, and
- Evacuation routes may be cut some distance from the residential areas and people do not appreciate the danger.

A number of residents will be required to be evacuated in a flood event. The NSW SES has the skills and experience to undertake the necessary evacuations. Any flood awareness programs should target the need for evacuation.

Access to properties can be cut for some time and residents will try to drive through floodwaters to return home or undertake regular tasks. The NSW SES advice is never to drive through floodwaters but recent past events in Queensland, NSW and Victoria in 2011 demonstrated that many people do not adhere to this advice. Cars can float in as little as 0.3m depth of water and consequently a number of lives have been lost and the lives of rescuers put at risk in rescuing stranded motorists. Warning signs advising motorists of the risk of driving through floodwaters are posted throughout the LGA.

There are 9 designated flood evacuation routes in the Hawkesbury LGA which include easy to follow flood evacuation signs posted along evacuation routes. There are detailed triggers within the SES flood plan that apply to sectors and subsectors. These form parts of the flood warnings issued.

Appendix A contains information on when properties are first flooded that can be used by the SES for evacuation planning.

The time at which key roads are cut is important for evacuation planning. **Error! Reference source not found.** and **Error! Reference source not found.** shows the total time the catchment is under water during a 1% AEP flood event. Inundation times in low lying areas such as south of McGraths Hill are up to 215 hrs in the 1% AEP event. North west of Bligh Park, duration of inundation varies from 20 – 40 hours. Diagram 2 depicts the time at which emergency access road is cut in a 1% AEP event relative to the Windsor flood level gauge in a typical 1% AEP event.

SUMMARY AND RECOMMENDATIONS

- The NSW SES Local Flood Plan was prepared in 2020 and schedule for review in 2025. This should be updated to include the new flood mapping.
- Any major future events within this time should be incorporated into flood intelligence and evacuation planning.

9. MULTI-CRITERIA ANALYSIS

The Flood Risk Development Manual (Reference 11) recommends the use of multi-criteria assessment matrices (MCMA) when assessing flood risk mitigation measures. A MCMA provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a cost-benefit analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCMA will not give a definitive 'right' answer. Rather, it provides a tool to debate the relative merits of each option.

9.1. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criteria: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in several criteria and should not be considered further. The scoring system is provided in Table 30 and the outcomes of the assessment shown in Table 31. Discussion of the results is provided in Section 9.3.

9.2. Results

The results of the multi-criteria assessment are provided in Table 27, with each of the assessed management measures scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis, which stakeholders can then use to make a decision.

For the same reason, the total score given to each option, is only an indicator to be used for general comparison. Options with positive scores indicate that the benefits of the option outweigh negative aspects. These options have been recommended for inclusion in the Floodplain Risk Management Plan.

9.3. Discussion of Results

The multi-criteria matrix assessment results, presented in Table 31, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Majority of flood modification measures, that is, structural options, do not score well in terms of economic merits. Reasons for this include:
    - To reduce property damages, structural options need to effectively reduce flood risk in rare events. To do this, structural options need to be substantial in size, i.e. levee height or basin storage capacity – leading to high capital costs, land purchase requirements, and ongoing maintenance costs.
- Flood Proofing received a rank of 7, as it delivers benefits across a range of criteria including economics, reduction in flood risk, property affectation, as well as playing a small role in community flood awareness;
- Adoption of the Flood Planning Level, and Revise LEP and DCP are the some of the most cost effective methods to reduce property damages in the study area, and have additional benefits relating to improvements to community flood awareness. These options are rank 4.
- Flood Warning, flood awareness and preparedness and evacuation planning scored the highest. Due to their low cost for huge benefit, no barriers to implementation and has the benefit of saving lives
- Response Modification Measures and Property Modification Measures tend to score more highly than Flood Modification measures, as they can be implemented for a relatively low cost, lead to the reduction of property damage and improvement in community resilience in the long term, and do not incur negative environmental impacts;

To be updated with options feedback in the public exhibition.

Table 30: Multi-criteria Matrix Assessment - Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	*Ability to stage proposed works*			Works cannot be staged	NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Emergency Access	*Flood depths and duration changes for critical transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities[1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to acess but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruptioin or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
	Community and stakeholder support[2]	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.
[2] Community and stakeholder support scores will be completed following Public Exhibition

Table 31: Multi-criteria Matrix Assessment Results

	Economic			Social								Environmental		Other Aspects			
Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities[1]	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support[2]	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	**Total Score**	**Overall Rank**
McGraths Hill Levee	-3	-2	-1	-3	0	0	3	0	-1	0		-1	0	-3	1	-10	24
Pitt Town Levee	-3	-2	-1	-1	0	0	3	0	-1	0		-1	0	-3	1	-8	23
South Windsor Levee	-3	1	-1	3	1	2	3	0	0	1		-1	0	-3	1	4	9
Wilberforce Levee	-2	1	-1	1	0	0	3	0	0	0		-1	-2	-3	1	-3	22
Survey of Levees	0	0	0	0	0	0	0	0	0	0		0	0	0	1	1	12
Currency Creek	-2	-3	2	3	2	2	3	2	1	1		-3	-2	-3	1	4	9
Voluntary Purchase	1	1	1	1	0	0	3	0	0	0		0	-1	-3	0	3	11
Flood Planning Levels	2	2	0	2	0	0	3	0	1	0		0	0	0	0	10	4
Revise LEP and DCPs	2	2	0	2	0	0	3	0	1	0		0	0	0	0	10	4
Provision of flood information to residents via Section 10.7 Planning Certificates	2	2	0	2	0	0	3	0	1	0		0	0	0	0	10	4
House Raising	1	1	2	0	0	0	3	0	1	0		0	0	-3	1	6	8
Flood Proofing	-1	1	0	0	0	1	2	0	0	0		0	0	3	1	7	7
Flood Warning	3	2	0	3	0	0	3	0	3	0		0	0	3	2	19	1
Flood Awareness and Preparedness	3	2	0	3	0	0	3	0	3	0		0	0	3	2	19	1
Evacuation Planning	3	2	0	3	0	0	3	0	3	0		0	0	3	2	19	1

10. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

The Floodplain Management Study has undertaken a review of the full range of management measures with the outcomes providing the basis for the Floodplain Management Plan. An assessment of the relative merits of the measures has been undertaken taking into account:

- 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 SES;
- political and/or administrative issues;
- long-term performance given the possible impacts of climate change;
- risk to life.

Table 30 lists the mitigation measures that have been recommended by the Floodplain Risk Management Study for implementation and describes the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 8 of the Study.

The Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual.

Table 32: Floodplain Risk Management Plan

	Option ID	Option Name	Description	Benefits	Concerns	Funding	Responsibility	Cost or B/C Ratio	Overall Rank*	Priority	Reference
Flood Modification	FM 1	McGrath Hill Levee	A ring levee around McGraths Hill. Protection to a 2% AEP level.	Protection of flood prone properties	• Provide a false sense of security, • Would not protect any approved habitable areas, • Have a small impact on surrounding properties that while small the total intangible damages are large, and • Would protect illegal enclosed downstairs areas (McGraths Hill)	May be eligible for NSW Government funding	State Government/ Council	High cost and low B/C		Low	8.3.2
	FM 2	Pitt Town Levee	A levee protecting Pitt Town to a 2% AEP level. The levee would be on average 5m high.					High cost and low B/C		Low	
	FM 3	South Windsor Levee	Levee to improve access. At a 2% AEP level.					High cost and low B/C		Low	
	FM 4	Wilberforce Levee	A levee around low lying areas of Wilberforce.					<0.1		Low	
	FM 5	Survey of levees	A number of minor levee banks that assist with managing small floods and are associated with drainage works levee banks have been built within the Hawkesbury-Nepean Valley. These would be surveyed for extent and level	Understanding of flood protection and inclusion in future modelling	N/A	May be eligible for NSW Government funding	Council	$200,000		Medium	
	FM 6	Currency Creek Bypass	Bypass channel through the saddle between Freemans Reach and Currency Creek which would short circuit approximately 21 km of river.	Widescale reduction in flood levels	Some increases in flood levels downstream of Sackville	May be eligible for NSW Government funding	State Government	<0.05		Low	8.3.3
Property Modification	PM 1	Voluntary Purchase	Voluntary purchase (VP) involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain.	Generally, the land is returned to open space and hydraulic capacity increased.	Mainly implemented over a long period for residential areas. Vacant lots may be sold by Council. Economic cost and social impacts can be high	May be eligible for NSW Government funding	Council	Minimal for feasibility		Medium	8.4.3
	PM 2	Flood Planning Levels	Adopt Flood Planning Levels at the 0.5% AEP plus 0.5m developed in the FRMS&P.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to	May be considered more onerous for developers.	Council	Council	In House		High	8.4.4.1

				minimum floor levels or flood proofing levels depending on the type of development.							
	PM 3	Revise LEP and develop DCP	Continue to apply existing LEP. Consider recommendations for improvements as part of this FRMS&P. Improvements include: consistent terminology, update to use FPCC categories, develop DCP and include 5.22 in LEP	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In House		High	8.4.4.2
	PM 4	Provision of flood information to residents via Section 10.7 Planning Certificates	In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Council to provide further detail from current FRMS&P results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	Council	In House		High	8.4.4.3
	PM 5	House Raising	House raising has been widely used throughout NSW to eliminate inundation from habitable floors.	This approach provides more flexibility in planning, funding and implementation than voluntary purchase. A total of 81 properties were identified as being flooded in frequent events (10% AEP). A feasibility study is recommended.	Its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10% AEP event or less).	May be eligible for NSW Government funding	Council	Minimal for feasibility		Low	8.4.5
	PM 6	Flood Proofing	Continue to encourage flood proofing and flood compatible materials.	This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.	More vulnerable uses may use building in the future and this would need to be managed.	Council	Council	In House		High	8.4.6

Response Modification	RM 1	Flood Warning	The following options are recommended: • Update of the Local Flood Plan to reflect flood levels from the current study •Cameras on bridge approaches to also be made available on disaster dashboard	Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.	Flood warning is critical to ensuring safe evacuation in large events.	May be eligible for NSW Government funding/ SES	Council/SES	<$50k Ongoing maintenance		High	8.5.1
	RM 2	Flood Awareness and Preparedness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council	Council in collaboration with other response agencies and community organisations.	Annual Budget to be determined and allocated.		High	8.5.2
	RM 3	Evacuation Planning	• The NSW SES Local Flood Plan was prepared in 2020 and schedule for review in 2025. This should be updated to include the new flood mapping contained in this report. • Any major future events within this time should be incorporated into flood intelligence and evacuation planning.	Better evacuation planning and awareness of flood risk.		Council/ TfNSW/SES	Council/SES	In House		High	8.5.3

11. ACKNOWLEDGEMENTS

This study was carried out by WMAwater and funded by Hawkesbury City Council and the NSW State Government. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Hawkesbury City Council
- DCCEEW
- Council's Floodplain Committee
- Residents of Hawkesbury City Council LGA

12. REFERENCES

1. Pilgrim DH (Editor in Chief)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Institution of Engineers, Australia, 1987.

2. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)
Australian Rainfall and Runoff: A Guide to Flood Estimation
Commonwealth of Australia, Australia, 2019

3. Babister, M., Trim, A., Testoni, I. & Retallick, M
The Australian Rainfall & Runoff Datahub
37th Hydrology and Water Resources Symposium Queenstown NZ, 2016

4. Babister, M & Barton C (Editors)
Australian Rainfall and Runoff Revision Project 15: Two Dimensional Modelling in Urban and Rural Floodplains- Stage 1&2 Report P15/S1/009
Engineers Australia, 2012

5. NSW Government
Floodplain Development Manual: The management of flood liable land
April 2005

6. Commonwealth of Australia
Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia
AIDR 2017

7. Worley Parsons
Hawkesbury River Pre-dredging Investigations between Windsor and Sackville Ferry
Hawkesbury City Council, 2012

8. NSW Government
Hawkesbury-Nepean State of the Catchments 2010 report
2010

9. Infrastructure NSW
Hawkesbury-Nepean River March and July 2022 Floods Review: Hydrology, Riverbank Erosion, and Flood Mitigation Scenarios
February 2023

10. (AIDR) Australian Institute for Disaster Resilience
Australian disaster resilience guideline Manual 20 Flood Preparedness
2009

11. NSW Government

Flood Risk Management Manual
2023

12. NSW Government
Flood Risk Management Guideline FB03 – Flood Hazard
2023

13. NSW Government
Flood Risk Management Guideline EM01 – Support for Emergency Management Planning
2023

14. Trenberth KE
Changes in precipitation with climate change.
Climate Research 47:123-138, 2011

15. Westra S, Evans J, Mehrotra R, Sharma A,
A conditional disaggregation algorithm for generating fine time-scale rainfall data in a warmer climate,
Journal of Hydrology, 479, 86-99, 2013

16. Wasco C and Sharma A
Steeper temporal distribution of rain intensity at higher temperatures within Australian storms,
Nature Geoscience Letter, 8 June 2015

17. WMAwater
Hawkesbury-Nepean Valley Regional Flood Study
Jan 2019

18. NSW Reconstruction Authority.
Draft Hawkesbury-Nepean River Flood Study.
2024.

19. INSW
Hawkesbury-Nepean Valley Flood evacuation modelling to inform flood risk management planning
May 2023

20. AIDR
Australian Disaster Resilience Handbook Collection-Guideline 7-5: Flood Information to Support Land-use Planning
2017

21. Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds
Climate Change and Water. Technical Paper VI.
Geneva, Switzerland: Intergovernmental Panel on Climate Change.
Available at : http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers_climate_change_and_water.htm
2008.

22. CSIRO
Climate change in Australia, Technical report
2007

23. Abbs, D., and T. Rafter
Impact of climate variability and climate change on rainfall extremes in western Sydney and surrounding areas: Component 4 – dynamical downscaling,
Report to the Sydney Metro Catchment Management Authority and partners, CSIRO Climate Adaptation Flagship, Melbourne, Victoria. 2009

24. Wasco C and Sharma A
Steeper temporal distribution of rain intensity at higher temperatures within Australian storms,
Nature Geoscience Letter, 8 June 2015

25. DCCEEW
Draft update to the Climate Change Considerations chapter in Australian Rainfall and Runoff: A Guide to Flood Estimation
2024

26. Bewsher Consulting
Hawkesbury Floodplain Risk Management Study and Plan
2012

27. Webb, McKeown & Associates
Hawkesbury Nepean Flood Management Strategy: Engineering Studies to Modify Flood Behaviour, Final Report,
Prepared for Hawkesbury Nepean Flood Management Advisory Committee, September 1997.

28. BMT WBM
Project 1.4 Impact Assessment of Infrastructure Flood Mitigation Options - Final Report, prepared for Infrastructure NSW, November 2015

29. INSW
Taskforce Options Assessment Report
2019

Figures

Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

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

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

	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: - the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or - water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or - major overland flow paths through developed areas outside of defined drainage reserves; and/or - the potential to affect a number of buildings along the major flow path.

mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B. EMERGENCY RESPONSE INFORMATION