PENRITH CITY COUNCIL

College, Orth and Werrington Creeks Catchment
Floodplain Risk Management Plan

Final Report

October 2021

Catchment Simulation Solutions

College, Orth and Werrington Creeks Catchment Floodplain Risk Management Plan

Final Report

Client	Client Representative
Penrith City Council	Elias Ishak

REVISION / REVIEW HISTORY

Revision #	Description	Prepared by	Reviewed by
1	Preliminary draft report for Council review	D. Tetley	C. Ryan
2	Draft report for public exhibition	D. Tetley	R. Ryan
3	Final report	D. Tetley	R. Ryan

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Note: Adopted by Penrith City Council in its Ordinary Meeting on 21 February 2022

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Acknowledgement
Penrith City Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning Industry and Environment.

The preparation of the plan was steered by Penrith City Council Floodplain Risk Management Committee whose members include councillors, council staff, community representatives and representatives from state agencies and adjacent councils. The plan is the culmination of many months of investigation, analysis and flood modelling, which has been supported by valuable contributions from representatives of the Floodplain Risk Management Committee, community of Penrith and Penrith City Council.

It has been prepared by incorporating contributions from individuals from the local community and key stakeholders. Contributions from members of the Floodplain Risk Management Committee have been essential to the formation of management strategies that have been considered as part of the Plan and are greatly appreciated. The collegial manner in which input has been provided to the project from representatives from the Penrith City Council has been critical to its success.

Disclaimer

EXECUTIVE SUMMARY

The College, Orth and Werrington Creeks catchment is located in the Penrith City Council Local Government Area and occupies a total area of 12 km^2. The extent of the catchment is shown on **Figure 1** and includes parts of the suburbs of Orchard Hills, Caddens, Kingswood, Cambridge Park, Werrington and Werrington County.

The catchment is significantly urbanised with a mix of residential and commercial properties, as well as a small area of industrial properties. There are a number of important facilities within the catchment including the Nepean Hospital, Western Sydney University, TAFE NSW Nepean and Kingswood campuses and Cobham Youth Justice Centre. The catchment is also traversed by the Great Western Highway and the Western Railway Line that cuts across the catchment in an east to west direction.

The urbanised sections of the catchment are typically drained by a stormwater system that conveys runoff into College and Orth Creeks which, in turn, drain into Werrington Creek. During periods of heavy rainfall across the catchment, there is potential for the capacity of the stormwater system to be exceeded. In these circumstances, the excess water travels overland, potentially leading to inundation of roadways and properties. There is also potential for water to overtop the banks of the various creeks and inundate the adjoining floodplain.

The 'College, Orth and Werrington Creeks Catchment Floodplain Risk Management Study' (Catchment Simulation Solutions, 2021) involved a detailed assessment of the flood risk across the catchment. This included quantifying the risk that floodwaters pose to people, buildings, vehicles and other properties within the catchment, as well as the potential economic impact of flooding.

The Study also evaluated a range of options that could be potentially implemented to better manage the flood risk. This included structural options such as stormwater upgrades as well as non-structural options such as modifications to planning documents.

The outcomes of the Floodplain Risk Management Study serve as the basis for the recommendations documented in this Floodplain Risk Management Plan. A summary of all options that are recommended for implementation or further investigation as part of the Plan to better manage the existing and potential future flood risk are summarised in **Table 1**. The recommended options are also shown on **Figure 2**. Further information on each option including costs and implementation responsibility is also provided in **Table 1**. **Table 1** also included the multi-criteria assessment (MCA) ranking for each flood modification option so the implementation priorities can be understood.

It is recommended that flood modification options FM1, FM3, FM4 and FM5 are targeted for implementation in the medium term. The capital cost to implement these options is predicted to be about $2.3 million. However, implementation of these options is predicted to reduce the total flood damage costs across the catchment by about $2.7 million over the next 50 years.

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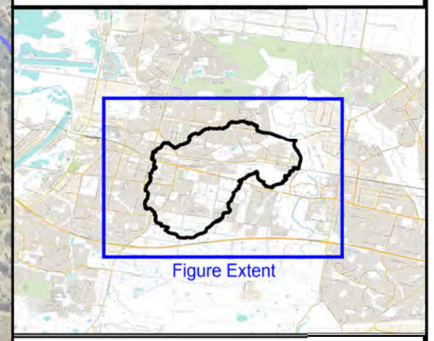
College, Orth and Werrington Creek Catchment Flood Risk Management Study and Plan



LEGEND

College, Orth and Werrington Creeks Catchment

Watercourse

Railway

Notes:

Aerial photograph date: 2019

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Figure 1: College, Orth and Werrington Creeks Catchment

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Sydney, NSW 2000

File Name: Figure 1 College, Orth and Werrington Creeks Catchment.wor

Response Modification Options

RM1 - Community Education Strategy
High Priority

RM2 - Make property level flood information available
Medium Priority

RM3 - Local flood plan updates to accommodate response planning
High Priority

RM4 - Home flood plans
High Priority

RM5 - Business flood plans
High Priority

RM6 - Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas
Medium Priority

RM10 - Local Flood Plan Updates to Accommodate Recovery Planning
High Priority

Property Modification Options

PM1 - Changes to LEP
High Priority

PM2 - Changes to DCP
High Priority

PM3 - Update Section 10.7 Certificates
High Priority

Flood Modification Options

FM3 - Lincoln Drive Park Basin Augmentation
Medium Priority

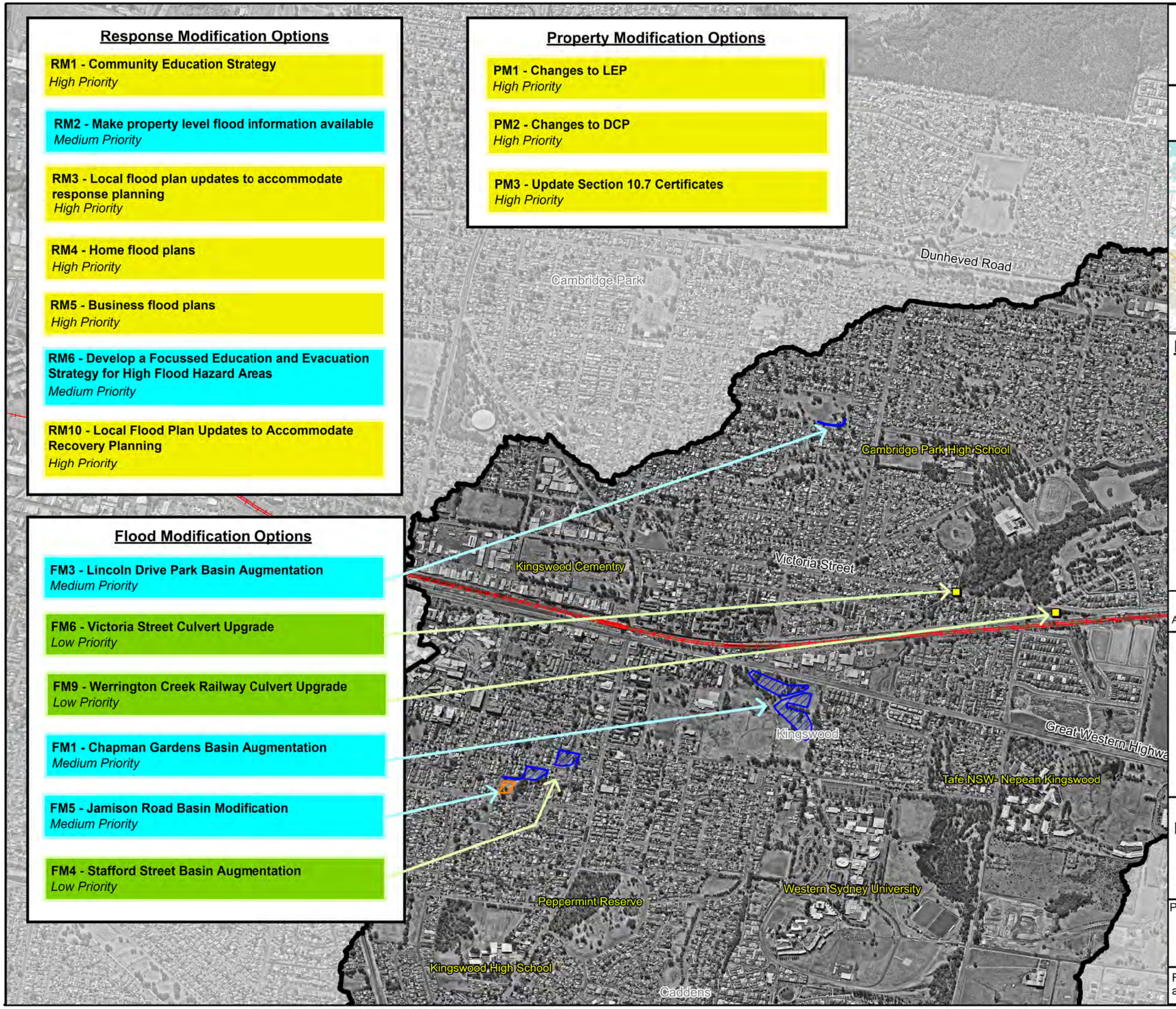
FM6 - Victoria Street Culvert Upgrade
Low Priority

FM9 - Werrington Creek Railway Culvert Upgrade
Low Priority

FM1 - Chapman Gardens Basin Augmentation
Medium Priority

FM5 - Jamison Road Basin Modification
Medium Priority

FM4 - Stafford Street Basin Augmentation
Low Priority



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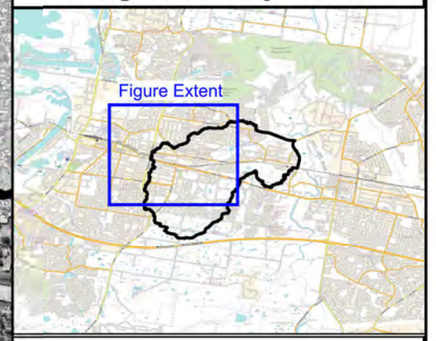
College, Orth and Werrington Creek Catchment Flood Risk Management Study and Plan



LEGEND

- High Priority Option
- Medium Priority Option
- Low Priority Option

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Aerial photograph date: 2019

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Figure 2: Floodplain Risk Management Plan for College, Orth and Werrington Creeks Catchment

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Sydney, NSW 2000

File Name: Figure 2 FRMP for College, Orth and Werrington Creeks Catchment.wor

Flood modification options FM6 and FM9 are recommended for implementation as longer term options. This will add a further $3.4 million to the overall implementation cost of the Plan however, would provide significant improvements to emergency response and additional evacuation opportunities along the major east-west transportation links of the Great Western Highway and Victoria Street. This is considered essential to support the ongoing urban expansion within and adjacent to the catchment and help ensure the existing flood risk is not increased because of the expected population increase in the area.

Despite the significant capital outlay that would be required to implement the Plan, the reduced frequency and severity of flooding would provide a range of non-monetary benefits to the local community. This would include less frequent and less deep inundation of local roads (including the major east-west transportation links of the Great Western Highway and Victoria Street) and less disruption, inconvenience and anxiety associated with frequent inundation.

Implementation of the flood modification options will reduce the frequency and depth of inundation but will not eliminate the potential for inundation completely. Therefore, it will be necessary to also implement the remaining non-structural (i.e., planning and emergency response) options to help ensure the continuing and future flood risk is also managed. This would largely draw upon Penrith City Council and SES resources and this time commitment is estimated to require an additional $280,000.

Table 1 Recommended Floodplain Risk Management Options

#	Option Description	Report Section	Estimated Cost	Implementation Responsibility	MCA Rank	Priority
Flood Modification Options						
FM1	Chapman Gardens Basin	3.2	$1.14 million	Penrith City Council	4	High
FM3	Lincoln Drive Basin	3.3	$0.05 million	Penrith City Council	=5	Medium
FM4	Stafford Street Basins	3.4	$0.52 million	Penrith City Council	=5	Medium
FM5	Jamison Road Basin Augmentation	3.5	$0.58 million	Penrith City Council	2	High
FM6	Victoria Street Culvert Upgrade	3.6	$2.11 million	Penrith City Council	=9	Low
FM9	Werrington Creek Railway Culvert Upgrade #2	3.7	$1.33 million	Penrith City Council and Transport for NSW	=9	Low
Property Modification Options						
PM1	Changes to LEP	4.1	$20k	Penrith City Council	-	High
PM2	Changes to DCP	4.2	$40k	Penrith City Council	-	High
PM3	Update Section 10.7 Certificates	4.3	$8k	Penrith City Council	-	High
Response Modification Options						
RM1	Community education strategy	5.1	$30k up front and $10k bi-annually.	SES and Penrith City Council	-	High
RM2	Make property level flood information available	5.2	$20k for required IT infrastructure. $30k for compiling required datasets and website interface.	Penrith City Council	-	High (mapping updates) & Medium (for online mapping portal)
RM3 + RM10	Local Flood Plan updates to accommodate response and recovery planning	5.3 & 5.6	$50k	SES	-	High
RM4	Home flood plans	5.4	Residents and business owner's time. Plus, approximately $15k for Council and SES time	Individual home and business owners with assistance from SES and Council	-	High
RM5	Business flood plans				-	High
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	5.5	$50k	SES and Penrith City Council	-	Medium

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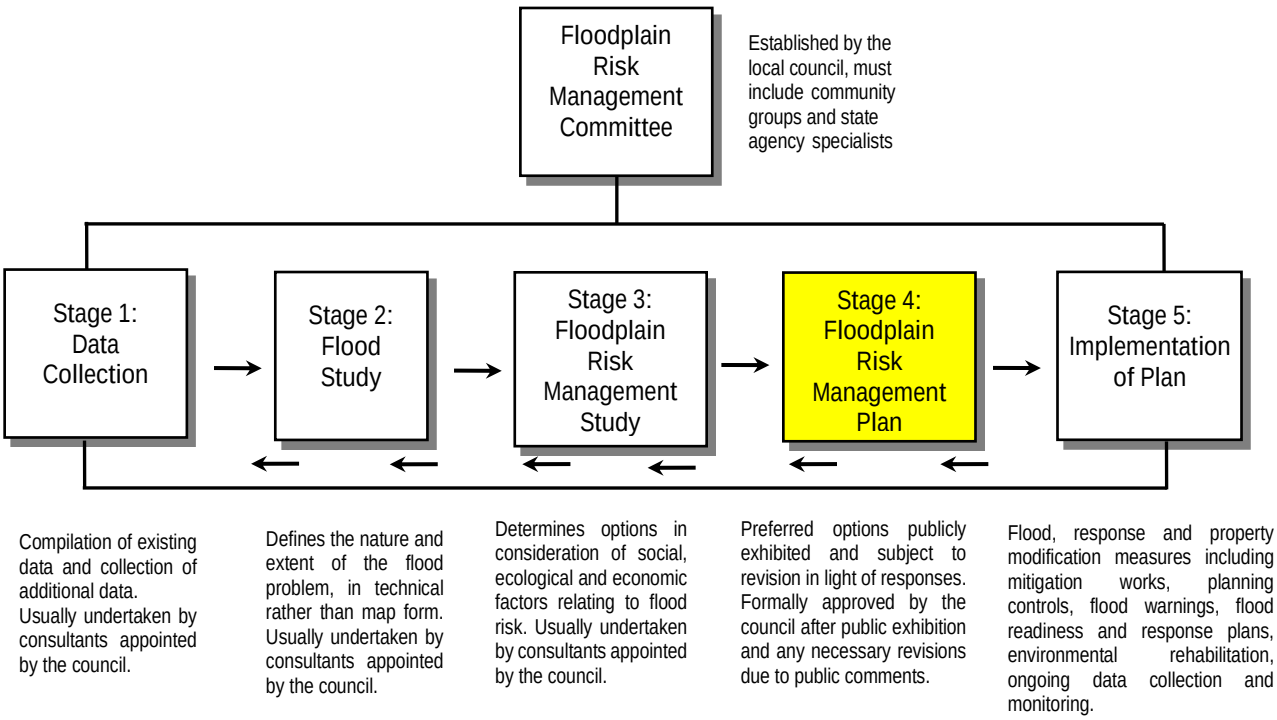
1 OVERVIEW

1.1 The Floodplain Risk Management Process

The '*College, Orth & Werrington Creeks Catchment Floodplain Risk Management Plan*' has been prepared in accordance with the requirements of the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005).* The '*Floodplain Development Manual*' (2005) guides the implementation of the State Government's *Flood Policy*. The *Flood Policy* is directed towards providing management and mitigation measures to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005)*.

Under the Policy, the management of flood liable land remains the responsibility of Local Government. However, the State Government provides specialist technical advice to assist Local Government in its floodplain management responsibilities and subsidies to councils to complete the floodplain management process including implementation of flood mitigation works, if feasible, to alleviate existing problems.

The Policy provides for technical and financial support by the State Government through the floodplain risk management process which is outlined below.



The Floodplain Risk Management Plan represents Stage 4 of the Floodplain Risk Management process. The Plan provides a targeted list of options that can be implemented by Council and others to manage flood risk in the College, Orth & Werrington Creeks catchment, based on the outcomes of the broader Floodplain Risk Management Study.

1.2 Risk Management Approach

The primary goal of the Floodplain Risk Management Plan is to provide a consolidated list of measures that can be implemented moving forward to better manage the existing and potential future flood risk. In this regard, it is first necessary to quantify the existing flood risk and identify locations within the catchment where this risk is considered to be unacceptable. A comprehensive assessment of the flood risk was completed as part of the Floodplain Risk Management Study and a summary of the outcomes of this assessment is provided in Chapter 2 of this report.

The options that are recommended for flood risk management have been grouped into one of three distinct categories, which are detailed below:

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across flood liable areas. Each flood modification option is prefixed with an "FM" identifier and the recommended flood modification options are presented in Chapter 3.
- **Property Modification Options**: refers to modifications to planning controls or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Each property modification option is prefixed with an "PM" identifier and the recommended property modification options are presented in Chapter 4.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Each response modification option is prefixed with an "RM" identifier and the recommended response modification options are presented in Chapter 5.

A suggested implementation strategy for the Plan is also provided in Chapter 6. It outlines implementation priorities for each of the recommended options along with responsibilities and estimated costs. The implementation strategy is only for this catchment area. However, these projects will need to compete with other recommended flood mitigation projects throughout the LGA for funding.

2 THE EXISTING FLOOD RISK

2.1 Catchment Description

The College, Orth & Werrington Creeks catchment is located in the Penrith City Council (PCC) Local Government Area and occupies a total area of 1200 hectares (i.e. 12 km^2).

The headwaters of the catchment are located in Orchard Hills, just to the north of the M4 Motorway. College Creek drains in a northerly direction through this area where the land use transitions from rural to higher density residential, including the new Cadddens and Caddens Hill subdivisions. College Creek continues to drain north through the Western Sydney University Kingswood campus and passes under the Great Western Highway where it is joined by Orth Creek. Werrington Creek commences at the junction of College and Orth Creeks and continues to drain in a north-easterly direction and into South Creek. Very little of the Orth Creek channel remains. Much of the original creek channel was replaced by a subsurface stormwater system to facilitate urban expansion across the Kingswood area.

The catchment is traversed by several major transportation links including the Great Western Highway, Western Railway Line, Victoria Street, Bringelly Road, Werrington Road and Dunheved Road. The railway embankment forms a significant barrier to flow being elevated at least 3 metres above the floodplain of Werrington Creek.

There are also several important facilities within the catchment including the Western Sydney University Penrith campuses (Werrington North, Werrington South and Kingswood), TAFE NSW Nepean and Kingswood campuses and the Nepean Hospital.

2.2 The Existing Flood Risk

2.2.1 Flood Hazard

Computer flood modelling of the College, Orth & Werrington Creeks catchment was completed as part of the 'College, Orth & Werrington Creeks Catchment Floodplain Risk Management Study' (Catchment Simulation Solutions, 2021). This involved simulating a range of hypothetical "design" floods that included the 1% AEP event (also referred to as the 1 in 100 year flood) and the probable maximum flood (PMF), which is the largest flood that could occur.

The predicted water depths and velocities from each design flood simulation were used to map flood hazard categories. As shown in **Plate 1** and described in **Table 2**, the hazard categories assess the potential vulnerability of people (including children and the elderly), cars and structures based upon the depth and velocity of floodwaters at a particular location.

The flood hazard mapping for the 1% AEP flood is provided in **Figure 3** and the flood hazard mapping for the PMF is provided in **Figure 4**.

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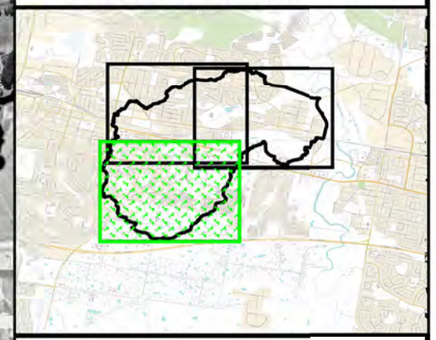
College, Orth and Werrington Creek Catchment Flood Risk Management Study and Plan



LEGEND

Hazard Categories

- H1 - Generally Safe
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles. Buildings require special design
- H6 - Unsafe for people and vehicles.All buildings vulnerable to failure

Notes:

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Scale 1:9,000 (at A3)

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Figure 3.1: Flood Hazard for the 1% AEP Flood

Prepared By:

Catchment Simulation Solutions
Suite 10.01, 70 Philip St
Sydney, NSW 2000

File Name: Figure 3 Flood Hazard for the 1%AEP Flood.wor

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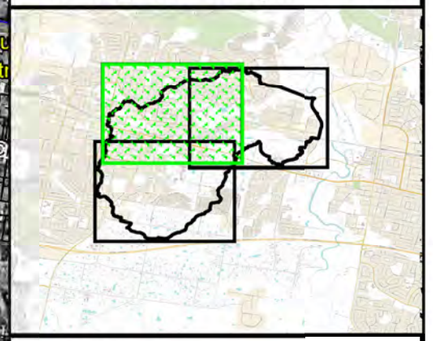

LEGEND

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Notes:

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Figure 3.2: Flood Hazard for the 1% AEP Flood

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File Name: Figure 3 Flood Hazard for the 1%AEP Flood.wor

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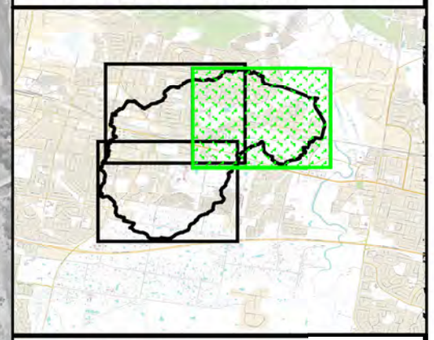

LEGEND

Hazard Categories

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Notes:

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Scale 1:9,000 (at A3)

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Km

Figure 3.3: Flood Hazard for the 1% AEP Flood

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File Name: Figure 3 Flood Hazard for the 1%AEP Flood.wor

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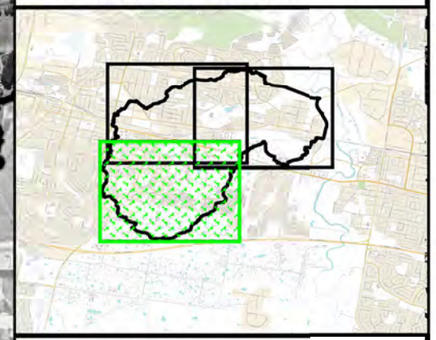

LEGEND

Hazard Categories

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Notes:

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Scale 1:9,000 (at A3)

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Figure 4.1: Flood Hazard for the PMF

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File Name: Figure 4 Flood Hazard for the PMF.wor

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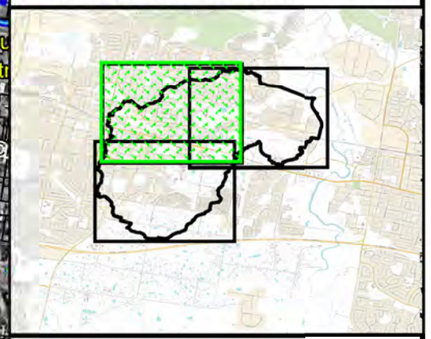

LEGEND

Hazard Categories

- H1 - Generally Safe
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- H3 - Unsafe for vehicles, children and elderly
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Notes:

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Scale 1:9,000 (at A3)

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Figure 4.2: Flood Hazard for the PMF

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File Name: Figure 4 Flood Hazard for the PMF.wor

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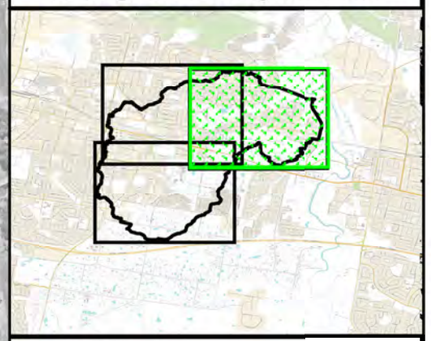

LEGEND

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Notes:

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Figure 4.3: Flood Hazard for the PMF

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Sydney, NSW 2000

File Name: Figure 4 Flood Hazard for the PMF.wor

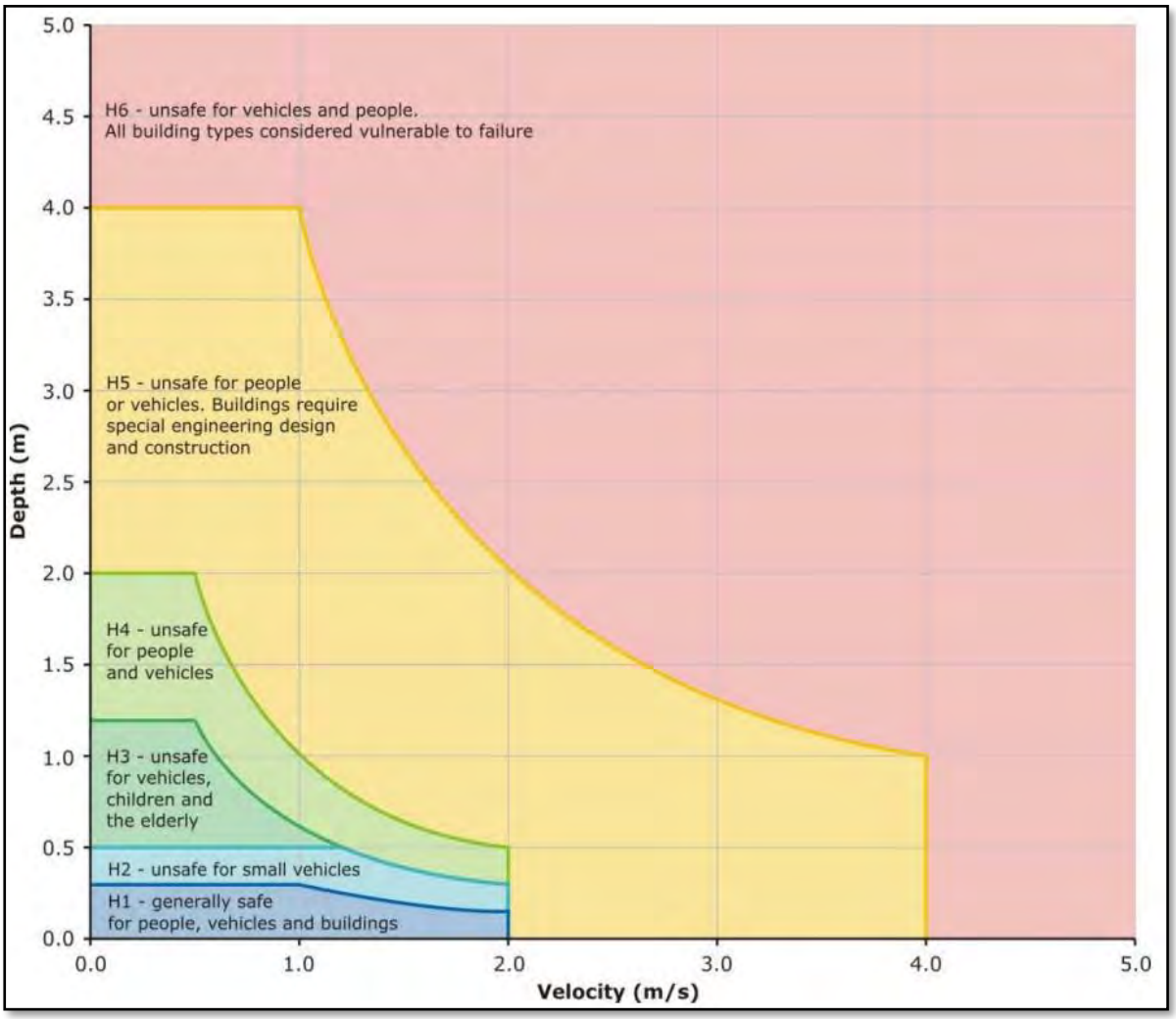

Plate 1 Flood Hazard Vulnerability Curves (Geoscience Australia, 2019)

Table 2 Description of Adopted Flood Hazard Categories (Geoscience Australia, 2019)

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings. Relatively benign flood conditions. No vulnerability constraints
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Figure 3 shows that during the 1% AEP flood, higher hazard areas (i.e., H3 and above) are generally contained to defined watercourses. However, there are some areas of the catchment exposed to overland flooding (notably across Kingswood) where H3 hazard areas are prevalent along with localised areas of H4 hazard. Accordingly, during a 1% AEP flood, some sections of the catchment would not be safe for vehicles or people, regardless of their physical ability.

Figure 4 shows that there is a notable increase in flood during the PMF. More specifically, a significant proportion of the floodplain would be exposed to H5 hazard conditions with isolated areas exposed to H6. Therefore, there is potential for structural damage to buildings and other infrastructure during the PMF. Of note are properties located in the following areas that would be impacted by H5 flood hazard:

- Jamison Road to Bringelly Road at Kingswood.
- Great Western Highway to Victoria Street at Kingswood.
- Railway Street and Walker Street at Werrington.

2.2.2 Economic Impact

The results of the design flood simulations were also used to prepare flood damage cost estimates so that the potential economic impact of flooding could be understood. The flood damage assessment is intended to estimate flood damage costs across the catchment for existing conditions across the full range of design floods for residential, commercial and industrial properties as well as infrastructure. This includes damage associated with above floor inundation as well as damage to properties even when above floor flooding is not predicted.

The flood damage estimates were prepared for each potentially flood liable property in the catchment by comparing the design flood level estimates with the floor levels for each property to determine an above floor flooding depth for each design flood. The above floor flooding depths were then combined with flood damages curves (relationships that describe the typical damage cost relative to the depth of above floor flooding) to provide a flood damage estimate for each property for each design flood.

As part of the damage cost calculations, the number of properties subject to above floor inundation during each design flood was calculated (this includes both above floor flood damage and damage from yard flooding or external damage). This information is summarised in **Table 3**. The number of properties subject to flood damage (i.e., when only the yards of properties are flooded) are also listed in **Table 3**. External damage included damage to items such as fences, sheds and garages.

Table 3 shows that during the 1% AEP flood, one hundred and eighty-nine (189) residential properties are predicted to suffer external flood damage, and an additional sixty-nine (69) properties are predicted to experience above floor inundation. During the PMF, five hundred and fifty (550) residential properties are predicted to incur external flood damage, with a further eight hundred and fifty-four (854) residential properties inundated above floor level.

Table 3 Number of Properties Subject to Above Floor Inundation and Property Damage

Flood Event	Residential		Commercial and Industrial		Total Number	
	External Damage Only	Above Floor Inundation	External Damage Only	Above Floor Inundation	External Damage Only	Above Floor Inundation
0.5EY	10	0	1	1	6	1
20% AEP	24	5	3	3	27	8
10% AEP	69	12	9	9	78	21
5% AEP	121	21	17	17	138	38
2% AEP	144	45	21	21	165	66
1% AEP	189	69	29	29	218	98
0.5% AEP	215	81	33	33	248	114
0.2% AEP	240	101	38	38	278	139
PMF	550	854	74	74	624	928

The damage estimates for each design flood for existing conditions are summarised in **Table 4**. It indicates that if a 1% AEP flood were to occur, nearly $9 million worth of damage could be expected. Nearly 80% of these damage costs would be incurred across residential properties. **Table 4** also shows that the flood damage cost would increase to nearly $100 million if a PMF was to occur.

Table 4 Summary of Flood Damages for Existing Conditions

Flood Event	**Flood Damage Costs** ($ millions)			Incremental Contribution to Average Annual Damage
	Residential	Commercial and Industrial	Total Damages	
0.5EY	0.03	0.05	**0.08**	$11,274
20% AEP	0.51	0.08	**0.60**	$100,534
10% AEP	1.57	0.40	**1.97**	$128,214
5% AEP	2.86	0.97	**3.83**	$144,899
2% AEP	4.62	1.39	**6.01**	$147,571
1% AEP	6.99	1.96	**8.95**	$74,790
0.5% AEP	8.19	2.27	**10.47**	$48,532
0.2% AEP	10.31	2.94	**13.25**	$35,571
PMF	83.90	12.33	**96.23**	$109,428
			TOTAL AAD	**$800,812**

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD takes into consideration the frequency of a particular flood occurring and the damage incurred during that event to estimate the average damage that is likely to occur each year, on average. The AAD for the College, Orth and Werrington Creeks

catchment was estimated to be just over **$800,000**. Accordingly, if the "status quo" was maintained and no flood management options are undertaken, residents and business owners within the catchment as well as infrastructure providers, such as Penrith City Council, would likely be subjected to cumulative flood damage costs of around $800,000 per annum (on average).

It should be noted that all damage costs are estimates only. Actual damage costs during future floods may vary depending on the magnitude of the flood and the types of properties impacted.

2.3 The Potential Future Flood Risk

2.3.1 Future Catchment Development

The College, Orth & Werrington Creeks catchment is already significantly developed. However, there are parts of the catchment that are currently undeveloped and have the potential to be developed in the future. Furthermore, there are some areas where there is potential for intensification of development (e.g., single dwellings being replaced by townhouse developments).

This future development has the potential to alter existing flood behaviour which may impact on the existing flood risk across the catchment. Therefore, additional analysis was undertaken as part of the Floodplain Risk Management Study to quantify the potential impacts that future development may have on the flood risk in the study area.

The analysis showed that during the 1% AEP flood, the additional runoff under future catchment conditions has the potential to increase existing flood levels across large proportion of the catchment. However, across most areas, the magnitude of the flood level increases is not predicted to exceed 0.1 metres. The most notable exceptions are on the southern side of the railway line at the Werrington Creek culvert crossing as well as near the Werrington train station. At these locations, flood level increases of between 0.1 and 0.2 metres are anticipated. Accordingly, future catchment development does have the potential to increase the existing flood risk across these already problematic areas.

2.3.2 Climate Change

An assessment of the potential impact that climate change may have on the existing flood risk was also completed as part of the Floodplain Risk Management Study. This involved assessing the impacts that a 9% increase and a 23% increase in existing 1% AEP rainfall would have on existing flood levels as per guidance provided in 'Australian Rainfall and Runoff' (Ball et al, 2019).

A 9% increase in rainfall is predicted to increase 1% AEP flood levels by at least 0.05 metres along most watercourses and overland flow paths. The 23% increase in rainfall is predicted to increase existing 1% AEP flood levels by more than 0.1 metres at most locations.

The most significant increases in flood levels are predicted to occur on the southern side of the railway embankment. This includes flood level increases of between 0.2 and 0.5 metres

along Werrington Ck at Kingswood (near George Street) and 0.1 to 0.2 metre increases across Railway St at Werrington.

Accordingly, the outcomes of the assessment show that increases in rainfall associated with climate change have the potential to produce a notable increase in the severity of flooding across the catchment.

2.4 Summary of Flooding "Trouble Spots"

The following areas within the College, Orth and Werrington Creeks catchment are likely to experience significant property damage, risk to life and evacuation difficulties during floods:

- Jamison Road to Bringelly Road, Kingswood: This area is predicted to experience extensive inundation during floods as frequent as the 20% AEP event. H3 hazard is predicted across multiple properties in the 1% AEP flood while H5 hazard is common during the PMF.
- Cox Avenue to Orth Street, Kingswood: The railway embankment results in notable ponding depths in Cox Avenue during most of the simulated design floods. A notable overland flow path also extends through multiple properties on the southern side of the railway. H3 hazard is predicted across multiple industrial and residential properties during the 1% AEP flood while H4 hazard is common during the PMF.
- Chapman Gardens to Victoria Street, Kingswood: H4 hazard is predicted across some sections of the Great Western Highway and localised areas of H5 hazard are predicted south of the railway line (although they are commonly contained to open space). During the PMF, H5 hazard is predicted across multiple commercial and residential properties between the Great Western Highway and Victoria Street.
- Victoria Street to Heath Street, Kingswood: H2 and H3 hazard is predicted across a significant number is residential properties during the 1% AEP flood. During the PMF, the hazard is predicted to increase to H4 and H5 across several properties as well as a significant length of Joseph Street.
- Sandringham Avenue & Lincoln Drive Park to Herbert Street, Cambridge Park. H3 and H4 hazard is predicted across some Cambridge Street properties and H5 hazard is predicted long Campton Avenue during the 1% AEP flood. During the PMF, a continuous stretch of H5 hazard is predicted to extend from Lincoln Drive to Herbert Street.
- William Street, Cambridge Park: The full width of William Street is predicted to be inundated during the 1% AEP flood between Neeta Avenue and Herbert Street, including some areas exposed to H5 hazard. H5 hazard with localised sections of H6 hazard are predicted along William Street during the PMF.
- Rugby Street to William Street, Cambridge Park. An overland flow path extends through multiple residential properties. Up to H3 hazard is predicted during the 1% AEP flood while small areas of H5 hazard are predicted during the PMF.
- Orleton Place to Francis Street, Werrington County: Comprises an extensive overland flow path impacting on multiple properties as well as a significant length of Glencoe Avenue. H3 hazard is predicted along a number of roadways and through several properties during the 1% AEP flood and H4 and H5 hazard is predicted across similar areas during the PMF.

- Edward Close to Dunkley Place, Werrington. Extensive ponding is predicted at low points in Gibson Avenue and Dunkley Place (both locations are trapped low points). H3 hazard is predicted across a number of adjoining residential properties during the 1% AEP flood while the ponding depths are significant enough during the PMF to H4 hazard (i.e., unsafe for vehicles and people).
- Railway Street and Walker Street, Werrington. The railway embankment is predicted to generate significant water depths on the southern side of the railway. H3 with localised areas of H4 are predicted during the 1% AEP flood. During the PMF, H5 hazard is predicted to extend across numerous residential properties.

3 Flood Modification Options

3.1 Overview

3.1.1 Flood Modification Options Considered

The outcomes of the existing flood risk assessment were used to develop an initial list of forty-nine (49) flood modification options that could be potentially implemented to better manage the existing flood risk in the College, Orth and Werrington Creek catchment. The list of options that were initially considered included:

- Detention basins.
- Culvert and bridge upgrades.
- Stormwater upgrades.
- Creek and channel modifications.
- Topographic modifications.
- Levee modifications.

It was not feasible to undertake a detailed assessment of all forty-nine (49) flood modification options as part of the Study. Therefore, a qualitative assessment of each potential option was completed to assess the potential feasibility of each option and to determine which measures showed merit for further detailed assessment. The full list of options that were initially considered are provided in the Study and the final list of flood modification options that were selected for detailed assessment are provided in **Table 5** and are denoted FM1 to FM20.

3.1.2 Detailed Option Assessment Approach

The "shortlist" of flood modification options identified in **Table 5** were subsequently assessed in detail as part of the Study to determine which would likely be feasible and move forward for inclusion in the Plan. Each option was assessed against a range of criteria, as detailed below:

- Hydraulic Factors: Each option was included in an updated version of the computer flood model and was used to re-simulate flood behaviour with the option in place. This allowed the hydraulic benefits (i.e., reductions in flood levels) afforded by each option across difference parts of the catchment to be quantified.
- Financial Feasibility: Concept design plans were prepared for each option which allowed preliminary implementation cost estimates to be prepared. The results from the computer model simulations were also used to prepare updated flood damage cost estimates for each option. This allowed the 'benefits' of each option to be quantified (in terms of a reduction in flood damage costs) and compared to the implementation cost of each option (refer **Table 5**). This allowed a monetary benefit to cost ratio (BCR) to be prepared for each option. A BCR of more than 1 indicates the economic benefits are predicted to outweigh the implementation cost while a BCR of less than 1 indicates that there will still be a financial benefit, but it will not be sufficient to cover the implementation cost. The BCR for each option is also summarised in **Table 5**.

Table 5 Summary of Economic Outcomes for Flood Modification Options

Flood Modification Option		Description of Option	Economic Impact			Multi Criteria Assessment Ranking
			Cost of proposed work ($ millions)	Reduction in Flood Damage Costs ($ millions)	Benefit Cost Ratio	
FM1	Chapman Gardens basin	Provide additional flood storage volume in existing Chapmans Gardens basin at Kingswood by elevating basin wall plus excavation to provide additional storage depth	$1.14	$0.25	0.2	4
FM2	Great Western Highway basin	Construct new detention basin in existing open space between the Great Western Highway and Railway Line at Kingswood	$0.80	$0.00	Less than 0.1	10
FM3	Lincoln Drive Park basin	Elevate the existing embankment in Lincoln Drive Park to create a larger detention area	$0.05	$0.03	0.6	=5
FM4	Stafford Street Basins	Create two new detention basins in existing open space on either side of Stafford Street at Kingswood	$0.52	$0.38	0.7	=5
FM5	Jamison Road basin modifications	Lower existing basin invert to provide additional storage volume and provide new 525mm diameter low flow pipe	$0.58	$2.47	4.3	2
FM6	Victoria Street culvert upgrade	Replace the existing 5 x 3.35m wide x 1.8m high box culverts with 6 x 3.6m wide x 2.1m high box culverts and elevate road surface by 200mm	$2.11	$0.01	Less than 0.1	=9
FM7	Great Western Highway culvert upgrade	Provide a new 3.2m wide x 2.1m high box culvert from the outlet of the Chapman Gardens basin, along the Great Western Highway and into College Creek just upstream of the Orth and Werrington Creeks confluence	$2.45	$0.08	Less than 0.1	12
FM8	Werrington Creek railway culvert upgrade #1	Replace the existing 4 x 2.25m diameter culverts under the railway line with 3 x 3m wide x 1.8m high box culverts	$1.12	$0.02	Less than 0.1	=7
FM9	Werrington Creek railway culvert upgrade #2	Installation of an additional 1.5 metre diameter culvert that would extend from upstream of the railway line near French Street subdivision to northern Victoria Street. 2 new 3m wide x 0.9m high box culverts would also be installed under Victoria Street	$1.33	$0.01	Less than 0.1	=9
FM10	Werrington Railway	Installation of a new 0.9 metre diameter culvert through the railway (starting near the northern extent of	$0.85	$0.10	0.1	=9

Flood Modification Option		Description of Option	Economic Impact			Multi Criteria Assessment Ranking
			Cost of proposed work ($ millions)	Reduction in Flood Damage Costs ($ millions)	Benefit Cost Ratio	
	Station culvert upgrade	Landers Street) and extending into the Parkes Avenue Sporting Complex				
FM11	Dunkley Place stormwater upgrades	Installation of additional stormwater pits and pipes in Chrisan Close, Gibson Avenue and Dunkley Place at Werrington	$1.29	$0.23	0.2	=6
FM12	Orleton Place to Francis Street stormwater upgrades	Installation of additional stormwater pits and pipes between Orleton Place to Francis Street including Rugby Street and Glencoe Avenue at Werrington County	$1.51	$0.18	Less than 0.1	=6
FM13	Rugby Street to Neeta Avenue stormwater upgrades	Installation of additional stormwater pits and pipes between Rugby Street and Neeta Avenue at Cambridge Park (including Wembley Avenue and Twickenham Avenue)	$0.84	$0.02	Less than 0.1	=9
FM14	Victoria Street to Joseph Street stormwater upgrades	Installation of additional stormwater pits and pipes between Victoria Street and area of open space south of Joseph Street at Kingswood	$0.78	$0.23	0.3	=7
FM16	Stapley Street to Bringelly Road stormwater upgrades	Duplication of existing stormwater system between the existing Jamison Road detention basin (south of Stafford Street) and First Street	$3.59	$0.13	Less than 0.1	11
FM17	College Creek and Orth Creek channel enlargement	Enlarging existing College Creek and Orth Creek channels by around 20 metres north of Great Western Highway at Kingswood	$0.31	$0.02	Less than 0.1	8
FM18	Great Western Highway Median Modification	Remove a section of median strip at low point in Great Western Highway near College Creek culvert at Kingswood	$0.06	$0.02	0.3	6
FM19	Combined option #1	FM1: Chapman Garden Basin plus FM4: Stafford Street Basins plus FM5: Jamison Road Basin	$2.24	$2.74	1.2	1
FM20	Combined option #2	FM1: Chapman Garden Basin plus FM4: Stafford Street Basins plus FM5: Jamison Road Basin plus FM6: Victoria Street Culvert Upgrade plus FM9: Werrington Creek Railway Culvert Upgrade #2	$5.68	$2.77	0.5	3

- Change in Above Floor Flooding: The results from the updated flood modelling were also used to quantifying the change in the number of buildings subject to above floor inundation with each option in place during each design flood.
- Emergency Response Impacts: This assessment focussed on the ability of each option to result in less frequent and deep inundation of roads which would provide improved opportunities for vehicular evacuation.
- Technical Feasibility: An assessment of any technical impediments was completed for each measure to determine if there would be any "showstoppers" that may render the option impractical.

The outcomes of the options evaluation were subsequently used to inform a multi criteria assessment (MCA). The MCA assigns an overall "score" to each option that reflects the full range of evaluation criteria (including tangible and intangible evaluation criteria). The score reflects how well each option performs relative to other options allowing the options to be ranked which provides valuable insight into implementation priorities as part of the Floodplain Risk Management Plan. The MCA rankings are also listed in **Table 5**.

Based on the outcomes of the MCA, the following options were selected to move forward into the Plan:

- FM1 – Chapman Gardens Basin.
- FM3 – Lincoln Drive Basin.
- FM4 – Stafford Street Basin.
- FM5 – Jamison Road Basin.
- FM6 – Victoria Street Culvert Upgrade
- FM9 – Werrington Creek Railway Culvert Upgrade #2

A summary of key assessment outcomes for each recommended option are provided in the following sections.

3.2 FM1 – Chapman Gardens Basin

Description: Provide additional flood storage volume in existing Chapmans Gardens basin at Kingswood by elevating basin wall plus excavation to provide additional storage depth

Priority: Medium

Estimated Cost: $1.1 million

Implementation Responsibility: Penrith City Council

NOTE: FM1 should be implemented prior to FM5 to ensure no adverse impacts across downstream properties

FM1 involves upgrading the existing Chapmans Garden basin to provide greater attenuation of flows during floods in the catchment. This involves lowering the elevation of the existing

basin by an average of approximately 1 meter and elevating the existing basin wall by about 0.6 metres to provide additional storage capacity of around 15,000 m^3 (cubic meters).

It is expected that the basin modifications would cost around $1.1 million to implement.

FM1 is predicted to afford the following benefits:

- Flood damages costs would be reduced by around $250,000 over the next 50 years.
- One (1) fewer property would be exposed to above floor flooding in a 5% AEP flood and five (5) fewer properties would be exposed to above floor flooding during the 1% AEP flood. A summary of the change in number of properties impacted by above floor flooding during each design flood is provided in **Table 6**.
- The flood immunity of the Great Western Highway will be improved (currently access is cut in 5% AEP flood, but this will improve to a 2% AEP flood). Furthermore, access along Victoria Street will also be improved (currently cut in a 10% AEP flood which will improve to a 5% AEP flood). As these are the main east-west evacuation routes in the catchment, the emergency response benefits of FM1 are significant.
- Seven (7) fewer properties are predicted be subject to inundation during a 5% AEP flood and five (5) fewer properties would be subject to inundation during a 1% AEP flood. A summary of the change in number of properties impacted by below floor and yard flooding during each design flood is provided in **Table 7**.
- FM1 will offset the flood level increases that are predicted if FM5 is implemented.

The Great Western Highway is operated by Transport for NSW (TfNSW). Due to the benefits that the option affords this road, it is suggested that TfNSW be included in future discussions regarding this option.

Table 6 Change in Number of Properties Subject to Above Floor Flooding for Each Recommended Flood Modification Option

Flood Modification Option	Change in Number of Properties with Above Floor Inundation*			
	20% AEP	5% AEP	1% AEP	PMF
Detention Basin Upgrades				
FM1 - Chapman Gardens basin	0	-1	-5	0
FM3 - Lincoln Drive Park basin	0	0	0	-1
FM4 – Stafford Street Basins	0	0	-2	0
FM5 - Jamison Road basin modifications	-3	-6	-6	-1
Culvert Upgrades				
FM6 - Victoria Street culvert upgrade	0	0	0	-1
FM9 - Werrington Creek railway culvert upgrade #2	0	0	0	-2

NOTE: * A negative value indicates the option is predicted to reduce the number of properties subject to above floor flooding and a positive value indicates the option is predicted to increase the number of properties subject to above floor flooding.

Table 7 Change in Number of Properties Subject to Below Floor (i.e., Yard) Flooding for Each Recommended Flood Modification Option

Flood Modification Option	Change in Number of Properties Subject to Below Floor Inundation*			
	20% AEP	5% AEP	1% AEP	PMF
Detention Basin Upgrades				
FM1 - Chapman Gardens basin	0	-7	-5	0
FM3 - Lincoln Drive Park basin	0	-2	-2	0
FM4 – Stafford Street Basins	-3	-4	-2	0
FM5 - Jamison Road basin modifications	-10	-20	-11	-3
Culvert Upgrades				
FM6 - Victoria Street culvert upgrade	0	-1	0	0
FM9 - Werrington Creek railway culvert upgrade #2	0	0	0	-1

NOTE: * A negative value indicates the option is predicted to reduce the number of properties subject to below floor flooding and a positive value indicates the option is predicted to increase the number of properties subject to below floor flooding.

FM1 provides beneficial emergency response benefits for the Great Western Highway and Victoria Street as well as providing flood level reductions across several properties located between the Great Western Highway and Victoria Street. Importantly, FM1 is also predicted to offset the adverse flood impacts that are predicted if FM5 was implemented in isolation. Therefore, it is critical that FM1 is implemented before FM5. It is also recommended that FM5 be considered with FM1 as part of future detailed hydraulic and concept design assessments to confirm FM1 is able to suitably mitigate the additional flow that is directed into Chapman Gardens with FM5 in place.

The following tasks are recommended to progress this option further:

1) Penrith City Council to initiate discussions with TfNSW to provide an overview of benefits that FM1 affords the Great Western Highway and determine any constraints within and adjacent to the road corridor that may impact on the option. These discussions could also be used as an opportunity to determine if TfNSW is planning other road works in the area that could enhance the performance of FM1 (such as the median modifications discussed as part of FM17 in the Study).
2) Undertake a survey of existing services and other assets (e.g., stormwater, sewer) in the vicinity of the proposed work. This should focus on the north-eastern corner of Chapman Gardens to confirm the vertical and lateral extent of potential excavation activities.
3) Based on any constraints identified above, undertake a concept design investigation to confirm the optimal basin configuration. This should explore alternate embankment heights, spillway arrangements, stormwater upgrades and outlet modifications. The assessment should consider all potential floods (noting that small flood level increases were predicted to extend onto Cosgrove Crescent during the PMF). The assessment

should also consider the performance of the basin upgrade in isolation as well as in combination with FM5 and FM4. In this regard, a combined concept design investigation incorporating FM1, FM4 and FM5 may be the most efficient approach for this stage of work.

4) Prepare detailed construction plans for the preferred concept design option. Prepare a detailed final cost estimate and seek funding to implement this option.

3.3 FM3 – Lincoln Drive Basin

Description: Elevate existing basin wall by around 0.5 metres to provide additional flood storage capacity.

Priority: Medium

Estimated Cost: $50,000

Implementation Responsibility: Penrith City Council

FM3 involves elevating the embankment of an existing detention basin located on the northern side of Lincoln Drive at Cambridge Park to create a larger, formal detention basin. This will involve elevating the existing embankment by around 0.5 metres.

It is expected that the basin modifications would cost about $50,000 to implement.

FM3 is predicted to afford the following benefits:

- Flood level reductions of up to 0.3 metres are predicted across Cambridge Street properties during the 1% AEP flood.
- Flood damages costs would be reduced by around $30,000 over the next 50 years.
- One (1) fewer property would be exposed to above floor flooding during the PMF (refer **Table 6**).
- The flood level reductions are sufficient to ensure that Lincoln Drive would remain trafficable during floods up to and including the 1% AEP flood (this road is currently cut in a 5% AEP flood).
- Two (2) fewer properties would be subject to inundation during a 5% AEP flood and a 1% AEP flood (refer **Table 7**).

The following tasks are recommended to progress this option further:

1) Undertake a concept design investigation that investigates alternate embankment height and basin outlet configurations (including a spillway to cater for PMF) to confirm optimal basin arrangement.
2) Prepare revised cost estimate for preferred concept design option so economic feasibility of option can be confirmed. Also, complete consultation with local property owners that would be benefited by the option to confirm community support.
3) Prepare detailed construction plans for the preferred concept design option. Prepare a detailed final cost estimate and seek funding to implement this option.

3.4 FM4 – Stafford Street Basin

Description: Create two new detention basins in existing open space on either side of Stafford Street at Kingswood

Priority: Medium

Estimated Cost: $520,000

Implementation Responsibility: Penrith City Council

FM4 would take advantage of existing open space on either side of Stafford Street to construct two new detention basins. This will require lowering the existing ground surface by between 0.1 and 0.5 metres for the southern basin and lowering the ground surface of the northern basin by between 0.2 and 1.1 metres. The embankments of both basins would be in the order of 1 metre high. This will afford around 5,000 m^3 of additional flood storage volume in total.

It is expected that the implementation of FM4 would cost about $520,000.

FM4 is predicted to afford the following benefits:

- Flood level reductions of more than 0.1 metres are predicted across multiple properties between Stafford Street and Chapman Gardens during the 20% AEP, 5% AEP and 1% AEP floods.
- Flood damages costs would be reduced by just under $400,000 over the next 50 years.
- Two (2) fewer properties would be exposed to above floor flooding during a 1%AEP flood (refer **Table 6**).
- Three (3) fewer properties would be subject to inundation during a 20% AEP flood, four (4) fewer properties would be inundated in a 5% AEP flood and two (2) fewer properties would be subject to inundation during a 1% AEP flood (refer **Table 7**).
- The broader social benefits of this option are notable with less frequent above floor flooding and less frequent inundation of yards, garages and sheds not only reducing the financial impacts of flooding but also reducing mental stress and anguish associated with frequent flooding.
- Reduce waters depths across multiple roadways which will lower the flood hazard should any cars attempt to drive through floodwater.

Overall, FM4 is predicted to afford flood level reductions across a significant high risk area of the catchment located between Stafford Street and Chapman Gardens. The hydraulic assessment completed as part of the Study show that flood level increases were predicted across some private properties that adjoin the basin. Therefore, further refinement of the basin design is required to ensure private properties are not adversely impacted during any flood.

The following tasks are recommended to progress this option further:

1) Council to undertake discussions with local community to gauge level of community support for this option. This would include discussing the current flood exposure of the

local area and how this option would benefit the same area. It is likely that this consultation can be completed in conjunction with FM5 given the close proximity of both options.

2) If the above discussions yield a positive outcome, concept design options should be explored that takes account of any issues or concerns that are raised by the local community. This should aim to maximise the hydraulic benefits across downstream properties while avoiding adverse flood impacts across private property (as discussed above, the concept design explored as part of the Study resulted in flood level increases extending marginally into some properties). It is recommended to undertake a hydraulic assessment that considers the performance of FM4 in isolation as well as in combination with FM5 and FM1.
3) Prepare detailed construction plans for the preferred concept design option. Prepare a detailed final cost estimate and seek funding to implement this option.

3.5 FM5 – Jamison Road Basin

Description: Lower existing basin invert to provide additional storage volume and provide new 525mm diameter low flow pipe

Priority: Medium

Estimated Cost: $580,000

Implementation Responsibility: Penrith City Council

NOTE: FM1 should be implemented prior to FM5 to ensure no adverse impacts across downstream properties

FM5 will involve lowering the bottom of an existing detention basin located on the northern side of Jamison Road at Kingswood to provide around 4,000m^3 of additional storage volume. Install a new 0.525 metre diameter low flow pipe from the existing surcharge pit on the southern side of the basin and extend down to the existing triple 1.5 metre diameter outlet pipes. One of these existing basin outlet pipes will be blocked to "free up" capacity in the downstream pipe system and take better advantage of the additional storage volume that will be provided.

It is expected that the implementation of FM5 would cost about $580,000.

FM5 is predicted to afford the following benefits:

- Flood damages costs would be reduced by nearly $2.5 million over the next 50 years. This yields a preliminary benefit to cost ratio of more than 4.
- Flood level reductions of up to 0.3 metres are predicted across multiple properties between Stapley Street and Hargrave Street during the 20% AEP, 5% AEP and 1% AEP floods.
- Three (3) fewer properties would be exposed to above floor flooding during the 20% AEP flood, six (6) fewer properties would be exposed to above floor flooding in the 5% AEP and 1% AEP floods, and one (1) fewer property would be exposed to above floor flooding during the PMF (refer **Table 6**).

- Ten (10) fewer properties would be subject to inundation during a 20% AEP flood, twenty (20) fewer properties would be inundated in a 5% AEP flood, eleven (11) fewer properties would be subject to inundation during a 1% AEP flood and two (2) fewer properties would be inundated during a PMF (refer **Table 7**).
- Like FM4, the broader social benefits of FM5 are notable with less frequent above floor flooding and less frequent inundation of yards, garages and sheds not only reducing the financial impacts of flooding but also reducing mental stress and anguish associated with frequent flooding.
- FM5 is predicted to afford some notable emergency response benefits. More specifically, Jamison Road (a major east-west transportation link in the catchment) is currently cut in a 20% AEP flood which is predicted to improve to a 5% AEP flood with FM5 in place.

Overall, FM5 is the best performing option in terms of economic return (i.e., highest benefit to cost ratio). It also provides the greatest reduction in above floor flooding as well as number of properties where flooding would be completely eliminated.

However, implementation of FM5 in isolation is predicted to direct additional water through the stormwater system towards Chapman Gardens. This is predicted to result in additional flow spilling from the Chapman Gardens basin, across the Great Western Highway and adjoining car yards. Flood level increases are also predicted along Werrington Creek as far downstream as Lake Werrington. Therefore, it is important that FM1 is implemented before FM5 to ensure adverse flood impacts are avoided.

The following tasks are recommended to progress this option further:

1) Undertake a survey of services and other assets (e.g., sewer) in the vicinity of the proposed work to confirm potential basin excavation depths or potential need for relocation of services or assets.
2) Undertake a concept design investigation that aims to optimise basin volume and stormwater modifications. It is recommended that hydraulic assessment consider the performance of FM5 in isolation to confirm if adverse flood impacts are still predicted across downstream properties. If adverse flood impacts are still predicted, the assessment should consider FM5 in combination with FM1 and or FM4 to offset the flood impacts.
3) Once a preferred concept design option is prepared, undertake consultation with the local community.
4) Prepare detailed construction plans for the preferred concept design option. Prepare a detailed final cost estimate and seek funding to implement this option.

3.6 FM6 – Victoria Street Culvert Upgrade

Description: Replace the existing 5 x 3.35m wide x 1.8m high box culverts with 6 x 3.6m wide x 2.1m high box culverts and elevate road surface by 200mm

Priority: Low

Estimated Cost: $2.1 million

Implementation Responsibility: Penrith City Council

FM6 would involve upgrading the existing Victoria Street culvert crossing to provide additional flow carrying capacity. This would involve replacing the existing 5 x 3.35m wide x 1.8m high box culverts with 6 x 3.6m wide x 2.1m high box culverts. This option would also include elevating the roadway surface by 0.2 metres to accommodate the higher culverts which would also assist in reducing the frequency of road overtopping.

It is expected that FM6 would cost about $2.1 million to implement. Therefore, the capital outlay required to implement this option is significant.

FM6 is predicted to afford the following benefits:

- Improvements to emergency response are arguably the biggest benefits afforded by this option (given the importance of this road as a major evacuation route for the existing population and potentially expanded future population). More specifically, the existing road is cut during a 5% AEP flood and this option would ensure it remains trafficable during a 1% AEP flood.
- Flood level reduction of up to 0.1 metres are predicted during the 5% AEP and 1% AEP floods along the Werrington Creek channel upstream of Victoria Street.
- One (1) fewer property is predicted to be exposed to above floor flooding during the PMF (refer **Table 6**).
- One (1) fewer property would be subject to inundation during a 5% AEP flood (refer **Table 7**).

Given the importance of Victoria Street for evacuation purposes, the improved immunity that this option provides is significant from an evacuation and emergency response perspective. In addition, there is potential for further subdivision and development of land between the railway line and Werrington Creek in the future. Therefore, there will likely be a higher reliance on this road in the future which adds further importance and value to this option in providing improved evacuation opportunities for the future population in this area.

Due to the high capital cost and the fact that this option aims to benefit the future urban expansion of the catchment area located north of the railway line, it is recommended that FM6 is implemented as a lower priority and longer-term option. It is also recommended that all future FM6 investigations also consider FM9 (discussed in the next section) as both options (or variations of both options) will be required to ensure the emergency response benefits along the full length of Victoria Street are full realised.

Consultation with SES is also recommended to confirm current emergency response limitations in the area and the long-term emergency response goals to support the future population growth in the area (targeting no net increase in required resources from the SES). These discussions can serve as the basis for refining the design of the road and drainage upgrades for FM6 as well as FM9.

3.7 FM9 – Werrington Creek Railway Culvert Upgrade #2

Description: Installation of an additional 1.5 metre diameter culvert that would extend from upstream of the railway line near the French Street subdivision to Victoria Street. Two new 3m wide x 0.9m high box culverts would also be installed under Victoria Street.

Priority: Low

Estimated Cost: $1.3 million

Implementation Responsibility: Penrith City Council and Transport for NSW

FM9 would involve the installation of an additional 1.5 metre diameter culvert that would extend from upstream of the railway line near the French Street subdivision to Victoria Street. The existing culvert would also be extended to create a more hydraulically efficient system. The dual 1.5m diameter culverts would feed into two new 3m wide x 0.9m high box culverts under Victoria Street that would discharge into an existing open channel on the northern side of the road. The box culverts would aim to direct additional flow below Victoria Street thereby reducing the frequency of roadway overtopping.

It is expected that FM9 would cost about $1.3 million to implement.

FM9 is predicted to afford the following benefits:

- The section of Victoria Street that is benefited by this option is currently inundated during floods as frequent as a 10% AEP event and is cut by floodwaters in the 0.2% AEP flood. With FM9 in place, evacuation will only be cut during the PMF.
- Flood level reductions of between 0.2 and 0.35 metres are predicted on the southern side of the railway line during floods up to and including the 1% AEP event.
- Two (2) fewer properties is predicted to be exposed to above floor flooding during the PMF (refer **Table 6**).
- One (1) fewer property would be subject to inundation during a PMF (refer **Table 7**).

As noted in Section 3.6, it is anticipated that Victoria Street will service a larger population as new development progresses in the area north of the railway line. Therefore, the reliance of the community on this roadway to serve as an evacuation route will grow in the future. Therefore, any improvements to the level of service afforded by Victoria Street during floods is a significant advantage moving forward and this option will serve as an important piece of supporting infrastructure with FM6 to achieve this.

This option extends across land and infrastructure that is owned and operated by a range of agencies including Penrith City Council and Transport for NSW. Therefore, consultation and coordination with each of these agencies will be required should this option be further explored in the future. In addition, consultation with the SES will be required to confirm the current and potential future emergency response impacts.

It is recommended that FM9 is targeted as a longer-term option in combination with FM6.

3.8 Other Options

Other options investigated as part of the Floodplain Risk Management Study were also found to afford some notable reductions in flood levels and extents. Council and asset owners (e.g., TfNSW) should consider these options for implementation as part of their ongoing works programs, asset replacement, road upgrades etc. These options include:

- FM7 – Great Western Highway Culvert Upgrades.
- FM10 – Werrington Railway Station Culvert Upgrade.
- FM11 – Dunkley Place Stormwater Upgrades.
- FM12 – Orleton Place to Francis Street Stormwater Upgrades.
- FM13 – Victoria Street to Joseph Street Stormwater Upgrades.
- FM17 – Great Western Highway Median Modifications.

Further information of each of these options is provided in the Floodplain Risk Management Study.

4 PROPERTY MODIFICATION OPTIONS

4.1 PM1 – Updates to Local Environmental Plan

Description: Updates to Local Environmental Plan (specific details are provided below)

Priority: High

Estimated Cost: $20,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

A comprehensive review of Penrith City Council's Local Environmental Plan (LEP) 2010 was completed and the outcomes of this review are documented in the Floodplain Risk Management Study. Based upon this review, it is recommended that any future updates of the LEP consider the following changes to better manage the flood risk across the full range of potential floods:

- Make the flood planning area map publicly available in a logical and easy to find location. It is recommended that these are provided as a separate document to the gazetted Penrith LEP 2010 maps so they can be updated as frequently as required when updated flood study and floodplain risk management study information becomes available.
- The existing Clause 7.2 of Penrith LEP 2010 currently states "This clause applies to land at or below the flood planning level", with the flood planning level defined as "the level of the 1:100 ARI flood event plus 0.5 metres freeboard". The current definition of the flood planning event and freeboard does not allow flexibility in defining the flood planning level throughout the different catchments in the LGA, should this design flood and freeboard not be appropriate. A potential option for providing more flexibility in the description of the flood planning level is:
  - ***flood planning level*** *means the level of a 1:100 ARI (average recurrence interval) flood event plus 0.5 metres freeboard or other design flood or freeboard as determined by an adopted floodplain risk management plan by the Council, prepared in accordance with the NSW Government's Floodplain Development Manual.*
- More flexibility can be incorporated into Clause 7.2 by redefining how land subject to this clause is selected. Currently, the clause employs the following wording:
  (a) land at or below the flood planning level,
  (b) land identified as "Flood planning land" on the Clause Application Map.

  Suggested changes to the wording in the existing clause to provide more flexibility are provided below:

  (a) land at or below the flood planning level,

  or

  (a) land at or below the flood planning level, and
  (b) land identified as "Flood planning area" on the flood planning area map.

- Include an additional "Floodplain Risk Management" clause in the LEP (i.e., Clause 7.3) which would relate to the areas between the flood planning area and the edge of the floodplain (i.e., PMF extent).

The process of updating an LEP can be time consuming as it requires extensive review and exhibition periods. However, discussions with Council planners indicate that there are plans to update the LEP soon. As a result, it is recommended that the LEP updates be pursued as a short term, high priority option.

As a starting point, it is recommended that Council planners consolidate the LEP update recommendations from all recent floodplain risk management studies and plans within the LGA. This will form the basis for preparing a planning proposal which will then be forwarded onto DPIE for review and begin the various exhibition and review processes that will culminate in the preparation of an updated LEP.

4.2 PM2 – Updates to Development Control Plan

Description: Updates to Development Control Plan (specific details are provided below)

Priority: High

Estimated Cost: $40,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

A review of the Penrith Development Control Plan (DCP) 2014 was completed and a detailed discussion on the outcomes of this review are documented in the Floodplain Risk Management Study. Based upon this review, it is recommended that any future updates of the DCP consider the following changes to better manage the flood risk across the full range of potential floods:

- Clear prescriptive controls with defined thresholds for acceptable planning and development applicants. This can be most efficiently achieved through provision of a flood planning matrix.
- Clearly defined flood planning level, including the defined flood event and freeboard, for the various development categories, such as residential, commercial, industrial, vulnerable and critical infrastructure.
- Consideration of the full range of design flood events, up to and including the PMF, for strategic planning purposes, and for vulnerable developments and critical infrastructure.
- Provide updated H1-H6 flood hazard mapping from this study and other recently adopted floodplain risk management plans in the LGA and consideration of the use of flood planning constraint categories (FPCC) mapping.
- Clear controls for change of use and concessional development in flood prone areas.
- Clear controls for filling in the floodplain, based on catchment wide analysis.
- Minimising the potential for increased flood risk via increased density as a result of redevelopment of a site located in the floodplain. This could be potentially achieved by

including a control prohibiting more intensive land uses within the PMF extent or, as a minimum, within the FPA.

- The DCP does not currently include considerations for flood mitigation works. Flood mitigation works may have a flood planning level that is higher or lower than the proposed residential flood planning level and should be determined via a merits-based assessment. The full range of design flood events should be used when assessing the potential failure of the flood mitigation works.

In addition, it is recommended that the following additional modifications are made to the DCP to address the significant flood hazard during the PMF that is predicted across a number of properties located near the railway line at Kingswood and Werrington:

- Include an elevated mezzanine level or second storey as part of any new development. This is intended to allow for vertical evacuation if safe evacuation from the dwelling cannot be completed.
- A requirement that all bedrooms be located on the second storey for residential dwellings. This is intended to ensure that residents would remain safe should a PMF occur at night when they are asleep.
- Inclusion of a balcony on the second level to allow emergency boat rescue in emergencies (e.g., medical emergency) or should the area be isolated for an extended period.
- Engineering report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF plus freeboard.

Discussions with Council planners indicate that there are plans to update the DCP in the near future. Therefore, it is recommended that the DCP updates are commenced as a high priority option.

It is suggested that Council consolidates the DCP recommendation contained in this Study and Plan along with other recent floodplain risk management studies and plans within the LGA. This will serve as a starting point for updating the DCP. Although the DCP must also undergo review and exhibition periods, these are not as exhaustive as the LEP (typically DCP amendments must be exhibited for a minimum of 28 days).

4.3 PM3 – Updates to Section 10.7 Certificates

Description: Update Section 10.7 certificate to reference updated design flood information generated as part of the current study.

Priority: High

Estimated Cost: $8,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

It is recommended that Council update Section 10.7 certificates to reference the updated design flood information generated as part of the current study. This will help to ensure the

most up-to-date information is available and used for properties located within the College, Orth and Werrington Creeks catchment.

This needs to be implemented with the other changes identified in the preceding sections of this report regarding the updating of the LEP and DCP flood mapping information to include all flood constraints up to and including the PMF.

5 Response Modification Options

5.1 RM1 – Community Education Strategy

Description: Develop local FloodSafe documents and educational messages targeting dangerous behaviours during a flood

Priority: High

Estimated Cost: $30,000 up front. Follow up required to maintain awareness and would cost approximately $10,000 bi-annually.

Implementation Responsibility: SES with assistance from Penrith City Council

An effective community education program is often the most effective emergency response planning strategy as it allows individuals to become more self-sufficient and less reliant on emergency services.

It is recommended that the preparation of the FloodSafe documents for the local area to provide general education information will be further considered by SES. The documents could be developed to be generic enough to indicate how residents can plan for floods even if their property is not flood prone, what to do during a flood, such as evacuation routes and centres, and what options are available to residents and business owners to assist with post-flood recovery.

It is also recommended that the SES consider a range of messaging that can be disseminated to the community via media agencies (both print and online). Samples of potential messages are provided in the Floodplain Risk Management Study that target dangerous behaviour (i.e., warning against driving, walking or playing in floodwaters) and overland flooding (i.e., advising flooding can occur away from creeks and rivers).

The above education recommendations are intended to be generic enough to allow application across overland flooding areas in the broader LGA. In addition, to these more general education activities, it is recommended that targeted education be completed for particularly high-risk sections of the catchment. This is discussed further in Section 5.5.

5.2 RM2 – Make Property Level Flood Information Available

Description: Develop a standardised approach for presenting flooding information across all catchments and work towards incorporating available flood information into an online flood portal

Priority: High (presentation of flood information) and Medium (online flood portal)

Estimated Cost: Approximately $20k for required IT infrastructure. Approximately $30k for compiling required datasets and website interface.

Implementation Responsibility: Penrith City Council

A starting point for improving people's readiness for floods is to help them better understand how they could be directly affected by floods. Knowing how their house or business could be directly affected by floods is more likely to cut through the scepticism that can grow when communities are not flooded for some years.

Penrith City Council currently makes a range of flood information available on its website. However, there is a lack of consistency in how flood information across different catchments is presented. If Council would like to continue to use the website and PDF mapping as their preferred approach for providing flood information to the community, they could consider arranging for future studies to provide mapping at a consistent scale (e.g., 1:5,000) and provide standard mapping outputs in a consistent colour scheme. In the short term, Council could consider using their internal GIS resources to prepare a standardised set of maps based on the GIS outputs that have been produced as part of each study.

However, over the medium to long term, there would be value in collating the available spatial flood outputs that are generated as part of flood studies and floodplain risk management studies and incorporating this information on an online mapping webpage. This would help to ensure that:

- All available flood information is provided on a single webpage.
- Results are presented in a consistent manner regardless of who completed the study.
- There are no scaling issues as the community can use the interface to zoom in and out, as required.

There is also potential to include other flood information and links such as Bureau of Meteorology warnings, live information on nearby rain gauges, and the latest advice from relevant organisations such as the SES and TfNSW. Therefore, if well maintained, a website can serve as a central repository for a range of contemporary flood information.

The mapping page could include design flood depths, flood levels and flood hazard. This would assist with providing owners or purchasers of property in the catchment with the flood information related to flood constraints. Together with the planning controls recommended for the DCP, this flood data would assist the property development process in the LGA.

Discussions with Council indicate that consolidating of all flood data and development of an online mapping page are currently under consideration. It is recommended that Council continue with the development of this online mapping taking on board the recommendations provided above.

5.3 RM3 – Local Flood Plan Updates to Accommodate Response Planning

Description: Update Penrith Local Flood Plan (LFP) to align with new SES LFP template and to incorporate the review findings documented in the Floodplain Risk Management Study

Priority: High

Estimated Cost: Approximately $40k when combined with FM10

Implementation Responsibility: SES

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) was reviewed, and the outcomes of this review are summarised in the Floodplain Risk Management Study. This review identified areas of the LFP requiring revision, especially to Volume 2, which needs to be updated to include information from recently completed flood studies and floodplain risk management studies along with actual floods.

The LFP does not include any consideration of the College, Orth & Werrington Creeks catchment or local overland flooding in the Penrith LGA, so it is currently not representing the full range of flood risks throughout the LGA.

Flood intelligence generated as part of the current study that could be incorporated into the LFP includes:

- Design flood extents, depths, velocities, hazard and warning times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and
- Evacuation constraints in design floods up to PMF.

It is recommended that SES will further consider the suggested updates to the LFP based upon the recommendations documented in this study as well as other recently adopted floodplain risk management plans for other catchments in the LGA.

5.4 RM4 and RM5 - Flood Emergency Response Plans

Description: Promote the preparation of Home and Business Emergency Flood Plans. Council and SES could assist preparation of the plans by 'prefilling' some of the required information.

Priority: High

Estimated Cost: Home and business owners' time, Council and SES time

Implementation Responsibility: Individual home and business owners with assistance from SES and Council

It is unlikely that many residential, commercial or industrial properties within the flood prone areas have formal flood emergency response plans. Accordingly, the preparation of home and business flood plans is encouraged as a way of making the broader community more "flood aware" and allowing the community to be more proactive during future floods and less reliant on emergency services. The plan should set out protocols to be followed by the household or business before, during and after a flood to help minimise damages and the potential for risk to life at the property level. The Flood Plans in this catchment should clearly highlight the roads vulnerable to flooding in the area (e.g., Great Western Highway, Victoria Street, Jamison Road) and the need to stay off flooded roads.

The SES has developed an online Home Emergency Plan website that can guide homeowners through the development of the plan:
http://www.seshomeemergencyplan.com.au/index.php

The SES has also developed a Business FloodSafe Toolkit to assist with the preparation of Business FloodSafe plans. These can be completed either online or as a hardcopy (see http://www.floodsafe.com.au/what-floodsafe-means-for-you/business).

A SES Business Breakfast could also be hosted to promote the development of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process.

As the response strategy for most properties will be very similar, the SES with assistance from Council, could potentially "pre-fill" much of the information necessary which will improve the chances of a successful implementation of this option across the catchment.

It is difficult to mandate the preparation of the flood plans in the first instance and then ensure flood plans are reviewed and updated. It is suggested that Penrith City Council could send out reminders (e.g., as part of rates notices) regularly (suggested every 2 years) to encourage existing owners and renters to prepare plans in the first instance and remind them to update the plans regularly. Regular notifications such as this would also assist in ensuring that plans are prepared if the property changes hands.

5.5 RM6 – Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas

Description: SES, with the assistance of Penrith City Council, to arrange targeted education activities to highlight nature and extent of flood risk. SES to consider setting up communication groups with high-risk sections of the community to assist in providing additional advice before and during a flood and promote more efficient evacuation processes.

Priority: High

Estimated Cost: Approximately $50,000 (within SES's and Penrith City Council's Operational Budget)

Implementation Responsibility: SES with assistance from Penrith City Council

A number of residential properties located between Jamison Road and Victoria Street at Kingswood and adjacent to the railway line at Werrington are predicted to be exposed to at least H5 external hazard, or H4 hazard inside of buildings (or both) during the PMF. These properties are likely to be unsafe during a PMF and evacuation is considered to be the best risk reduction measure for these properties during large floods.

However, the large number of buildings potentially impacted by unacceptably high hazard during the PMF coupled with short warning times means that emergency services may be unable to assist residents with evacuation. Although, residents could "self-evacuate", this is not encouraged as attempting to evacuate too late may expose people to an even higher flood hazard than if they were to remain in their homes. Therefore, it is considered that the safest option is to continue to rely on the SES to facilitate safe evacuation from high-risk areas.

However, due to the minimal warning times, residents in high-risk areas will need to be ready to promptly act on an evacuation order issued by the SES. Therefore, it is important that residents in the high flood hazard areas are aware of their potential flood exposure and are ready to evacuate on short notice.

As outlined in Section 5.2, a starting point for improving people's readiness for floods is to help them better understand how they could be directly affected by floods. Although the general education strategies summarised in Section 5.1 are also relevant to this area, a more targeted education strategy is considered necessary to assist the community in better understanding the unique severity of flooding that could be experienced in the area during the PMF. This will likely require one-on-one interaction with households from SES (with potential support from Council staff) to present the available information, answer questions and assist in the preparation of flood emergency response plans.

To assist in flood preparedness efforts, it is recommended that households in the high-risk area prepare emergency kits. The emergency kits include items that will be important during a flood should services be disrupted (e.g., torches, batteries) along with a list of essential items

that will need to be included should evacuation be required (e.g., medications, drinking water, baby supplies). The emergency kit will assist in expediting evacuation efforts.

Given the limited amount of advanced warning time, it is recommended that the SES explore opportunities to establish a "communication group" for the local high-risk area (e.g., SMS, Facebook group, Viber group, WhatsApp group). This would allow for rapid communication between the SES and households and would assist in promoting more efficient evacuation efforts.

There may also be benefits in exploring an automated alert system. Although a formal flood warning system is unlikely to be viable for the catchment, the installation of a sub-daily (i.e., "tipping bucket" type) rainfall gauge in the upper catchment may assist in providing additional guidance on when evacuation may be required. The gauge could be set up with a telemetry system with predefined rainfall triggers that could send an automated message (via the Facebook or WhatsApp groups discussed above), phone call and or text message to potentially vulnerable properties.

Overall, it is recommended that:

- SES (with assistance from Council) initiate a focussed education strategy for the high-risk areas within Kingswood and Werrington so these households can fully understand their level of flood exposure during very rare floods.
- Households should be encouraged to prepare emergency kits and complete checks of this kit on an annual basis.
- Households should be encouraged to prepare flood emergency response plan. As the response strategy for most properties will be very similar, the SES with assistance from Council can "pre-fill" much of the information necessary.
- SES to consider setting up communication groups with high-risk sections of the community to assist in providing additional advice before and during a flood and promote more efficient evacuation processes.
- Council and the Bureau of Meteorology could explore the potential for installing a rainfall gauge that could serve to issue automated flood warnings based on rainfall depth triggers.

5.6 RM10 – Local Flood Plan Updates to Accommodate Recovery Planning

Description: Local Flood Plan to reflect additional flood recovery responsibilities for various agencies

Priority: High

Estimated Cost: Approximately $40k when combined with FM3

Implementation Responsibility: SES (although providers of essential facilities and services including Council, Sydney Water, DPIE would be called upon to assist with the post flood recovery efforts)

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) sets out the responsibilities of various agencies in post-flood recovery. Recovery, as outlined in the LFP, largely rests with the SES with assistance from other agencies, as required.

It is suggested that additional, specific items could be included in the LFP to further assist emergency services and the community to expedite post-flood recovery, including:

- Council and Sydney Water to ensure vital facilities such as water and sewer are restored and operational.
- Council to aid in removing waste and debris as part of clean-up activities.
- Appropriate agencies to ensure vital utilities such as communication, power and gas are restored and operational.
- Appropriate agencies to offer welfare assistance and counselling services; and
- Council (with potential support from DPIE) to record post-flood information to assist in future updates and calibration of flood models and flood studies.

5.7 Other Options

Some roadway upgrade options were explored and yielded some notable emergency response improvements. However, they also produced adverse flood impacts across some properties. Furthermore, some of the flood modification options that are recommended for investigation and potential implementation afford similar emergency response benefits without adverse flood impacts. Therefore, the flood modification options are recommended in preference to the roadway upgrades. Nevertheless, opportunities for elevating major roadways such as the Great Western Highway and Victoria Street could be explored to supplement the flood modification options if roadway modifications are proposed in the future.

A flood warning system is unlikely to yield sufficient additional warning time flood to be of significant value to the local community. Nevertheless, there may be benefits in installing additional sub-daily rainfall gauges as part of a broader warning system in addition to providing a potential trigger system for the implementation of RM6.

6 IMPLEMENTATION, MONITORING AND REVIEW

6.1 Implementation Plan

The recommended options have been prioritised according to how easily each option could be implemented and the anticipated benefits afforded by each option (i.e., options that are relatively straight forward to implement and have a significant benefit have been assigned a high priority).

However, it should be noted that the Plan and the suggested implementation priorities presented in this report can be considered draft in nature. Ultimately, implementation of the plan is the responsibility of Council and emergency services. These agencies will need to make decisions on how to coordinate and prioritise the various recommendations in the Plan. Factors that may influence the implementation and prioritisation of the recommendations may include:

- How effective the options are at reducing the flood risk.
- What resources are required to implement the option.
- What resources are available to implement the option.
- What constraints might need to be addressed to implement the option (and whether any constraints might prevent implementation all together)

A suggested implementation plan for the flood modification options, property modification options and response modification options is provided in **Table 8**, **Table 9** and **Table 10** respectively. The tables summarise the implementation priorities, responsibilities, and estimated costs.

6.2 Costs and Funding

The total capital cost to implement the Plan is expected to be about $5.7 million. In addition to the capital costs, some options will incur ongoing maintenance costs. As noted in **Table 8**, many of the options will require an investment in time from various agencies including Penrith City Council and the State Emergency Service in addition to monetary contributions.

Funding for implementation of the plan could be potentially obtained from the following sources:

- NSW State Government's Floodplain Management Grants (through DPIE)
- Penrith City Council's capital and operating budgets
- Section 7.11 (formally Section 94) contributions
- Commonwealth Government's Natural Disaster Resilience Program
- Volunteer labour from community groups

It is expected that most of the recommended options will be eligible for funding through the NSW State Government's Floodplain Management Grants on a 2:1 basis (State Government : Council). This can include additional investigations, design activities as well as construction.

However, funding under this program cannot be guaranteed as funding must be distributed to competing projects across the state. Furthermore, the NSW Government's Floodplain Management Grants are primarily available to manage risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties. It should also be noted that ongoing costs (e.g., maintenance) will generally be the responsibility of Council.

6.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually reviewed and updated over time to ensure that it evolves with the catchment and takes advantage of any improvements in flood knowledge, such as new flood studies, historic floods or information on climate change.

As a minimum, it is recommended that the Plan be revisited after 5 years.

Table 8 Implementation Plan for Flood Modification Options

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
FM1	Chapman Gardens basin	Providing additional flood storage volume in existing Chapmans Gardens basin at Kingswood by elevating basin wall plus excavation to provide additional storage depth	1) Council to initiate discussions with TfNSW to provide an overview of benefits that FM1 affords the Great Western Highway and determine any constraints within and adjacent to the road corridor that may impact on the option. These discussions could also be used as an opportunity to determine if TfNSW is planning other road works in the area that could enhance the performance of FM1. 2) Complete a survey of services and other assets in the vicinity of the proposed work. 3) Based on any constraints identified above, undertake a concept design investigation to confirm the optimal basin configuration. This should explore alternate embankment heights, spillway arrangements, stormwater upgrades and outlet modifications. The assessment should consider all potential. The assessment should also consider the performance of the basin upgrade in isolation as well as in combination with FM5 and FM4. In this regard, a combined concept design investigation incorporating FM1, FM4 and FM5 may be the most efficient approach for this stage of work. 4) Detailed construction plans can then be prepared, final cost estimates can be prepared, funding can be sought, and the option can be potentially implemented.	$1.14 million	Penrith City Council	4	High

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
FM3	Lincoln Drive basin	Elevate the existing embankment in Lincoln Drive Park to create a larger detention area	1) Complete a concept design investigation that investigates alternate embankment height and basin outlet configurations (including a spillway to cater for PMF) to confirm optimal basin arrangement. 2) Prepare revised cost estimate for preferred option so economic feasibility of option can be confirmed. 3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought.	$0.05 million	Penrith City Council	=5	Medium
FM4	Stafford Street basin	Create two new detention basins in existing open space on either side of Stafford Street at Kingswood	1) Council to undertake discussions local community to gauge level of community support for this option. This would include discussing the current flood exposure of the local area and how this option would benefit the same area. It is likely that this consultation can be completed in conjunction with FM5, given the close proximity of each option. 2) If the above discussions yield a positive outcome, concept design options should be explored that takes account of any issues or concerns that are raised by the local community. This should aim to maximise the hydraulic benefits across downstream properties while avoiding adverse flood impacts across private property (as discussed above, the concept design	$0.52 million	Penrith City Council	=5	Medium

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
			explored as part of the Study resulted in flood level increases extending marginally into some properties). It is recommended that hydraulic assessment consider the performance FM4 in isolation as well as in combination with FM5 and FM1. 3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought and the option can move towards implementation.				
FM5	Jamison Road basin	Lower existing basin invert to provide additional storage volume and provide new 525mm diameter low flow pipe	1) Complete a survey of services and other assets in the vicinity of the proposed work to confirm potential basin excavation depths or potential need for relocation of services or assets. 2) Undertake a concept design investigation that aims to optimise basin volume and stormwater modifications. It is recommended that hydraulic assessment consider the performance of FM5 in isolation to confirm if adverse flood impacts are still predicted across downstream properties. If adverse flood impacts are still predicted, the assessment should consider FM5 in combination with FM1 or FM4 to offset the flood impacts. 3) Once a preferred concept design option is prepared, undertake consultation with the local community.	$0.58 million	Penrith City Council	2	High

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
			4) Detailed construction plans should then be prepared for the preferred concept design option while taking into account any feedback that is received from the local community. This should include preparation of a detailed cost estimate so that funding for the option can be sought and the option can move towards implementation.				
FM6	Victoria Street culvert upgrade	Replace the existing 5 x 3.35m wide x 1.8m high box culverts with 6 x 3.6m wide x 2.1m high box culverts and elevate road surface by 200mm	1) Undertake consultation with SES to confirm current emergency response limitations for Victoria Street and identify likely future emergency response requirements. 2) Refine scope of required culvert and road upgrades for FM6 and FM9 to meet emergency response requirements and explore opportunities for hydraulic improvements upstream and downstream of Victoria Street. 3) Work towards preparation of design plans to support future urban expansion for the area	$2.11 million	Penrith City Council	=9	Low
FM9	Werrington Creek railway culvert upgrade #2	Installation of an additional 1.5 metre diameter culvert that would extend from upstream of the railway line near French Street subdivision to Victoria Street. Two new 3m wide x 0.9m high box culverts would also be installed under Victoria Street		$1.33 million	Penrith City Council and Transport for NSW	=9	Low

Table 9 Implementation Plan for Property Modification Options

Property Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
PM1	Changes to LEP	1. Council planners to consolidate the LEP update recommendations from all recent floodplain risk management studies and plans (including this Plan) within the LGA. 2. Council to prepare planning proposal and undertake various exhibition and review processes to prepare updated LEP.	$20k	Penrith City Council	High
PM2	Changes to DCP	1. Council to consolidate the DCP recommendation contained in this Plan along with other recent floodplain risk management studies and plans within the LGA. 2. Council to prepare draft DCP and complete exhibition processes to prepare updated DCP.	$40k	Penrith City Council	High
PM3	Update Section 10.7 Certificates	1. Council to update Section 10.7 certificates to reference the updated design flood information generated as part of the Floodplain Risk Management Study.	$8k	Penrith City Council	High

Table 10 Implementation Plan for Response Modification Options

Response Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
RM1	Community education strategy	1. SES to prepare FloodSafe documents for the local area to provide general flood education information (focussing on overland flooding). 2. SES to develop a range of messaging that can be disseminated to the community via media agencies (both print and online).	$30k up front and $10k bi-annually.	SES and Penrith City Council	High
RM2	Make property level flood information available	1. Council to consider arranging for future studies to provide flood mapping at a consistent scale and provide standard mapping outputs in a consistent colour scheme. 2. Council to consider using their internal GIS resources to prepare a standardised set of maps based on the GIS outputs that have been produced as part of each study. 3. Council to collate the available spatial flood outputs that are generated as part of flood studies and floodplain risk management studies and incorporate information on an online mapping webpage to serve as a central repository for flood information.	$20k for required IT infrastructure. $30k for compiling required datasets and website interface.	Penrith City Council	High (mapping updates) & Medium (for online mapping portal)
RM3 + RM10	Local Flood Plan updates to accommodate response and recovery planning	1. SES to update LFP to include information from recently completed flood studies and floodplain risk management studies and actual floods. 2. SES to include additional, specific items in the LFP to further assist emergency services and the community to expedite post-flood recovery.	$50k	SES	High

Response Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
RM4	Home flood plans	1. Council and SES could assist in 'prefilling' some of the required information for the preparation of the Home and Business Emergency Flood Plans.	Residents and business owner's time. Plus, approximately $15k for Council and SES time	Individual home and business owners with assistance from SES and Council	High
RM5	Business flood plans				High
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	1. SES to conduct one-on-one meetings with high risk households and businesses (with potential support from Council staff) to present the available flood information, answer questions and assist in the preparation of flood emergency response plans. 2. SES to explore opportunities to establish a 'communication group' for the local high-risk area to allow for rapid communication between the SES and households and assist in promoting more efficient evacuation efforts. 1. SES to explore an automated alert system where a sub-daily rainfall gauge could be set up with a telemetry system with predefined rainfall triggers that could send an automated message, phone call and or text message to potentially vulnerable properties.	$50k	SES and Penrith City Council	Medium

7 REFERENCES

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8 GLOSSARY

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. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
average recurrence interval (ARI)	the long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
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.
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).
effective warning time	The time available after receiving advice of an impending flood and before 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, or local overland flooding associated with major drainage before entering a watercourse, or coastal inundation resulting from super-elevated sea levels or waves overtopping coastline defences excluding tsunami.
flood awareness	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 and 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 PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls.

flood planning levels (FPLs)	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.
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	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
flood readiness	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 flow, or a significant increase in flood levels.
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.

hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (*2005*).
historical flood	a flood which has actually occurred.
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 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	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. 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; or - water depths generally in excess of 0.3m (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; or - major overland flowpaths through developed areas outside of defined drainage reserves; or - the potential to affect a number of buildings along the major flow path.
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.

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 or evacuation of some houses. Main traffic routes may be covered. major flooding: Appreciable urban areas are flooded or extensive rural areas are flooded. Properties, villages and towns can be isolated.
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 annual exceedance probability*).
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 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.

sub-daily rainfall gauge	Also referred to as a 'pluviometer' or 'tipping bucket' gauge. Automated rainfall gauge that reports rainfall at small time increments
TUFLOW	is a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.
velocity	the speed or rate of motion (*distance per unit of time, e.g., metres per second*) in a specific direction at which the flood waters are moving.
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.