PENRITH CITY COUNCIL

Little Creek Catchment
Floodplain Risk Management Study

Final Report

Volume 1 of 2: Report Text & Appendices

October 2021

Catchment Simulation Solutions

Little Creek Catchment

Floodplain Risk Management Study

Final Report

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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 study 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 study 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 Study 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.

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1 INTRODUCTION

1.1 Background

The Little Creek catchment is located within the Penrith City Council Local Government Area and includes the suburbs of Oxley Park, Colyton, St Marys and North St Marys. The catchment covers a total area of approximately 465 hectares and is shown on **Figure 1**.

The area is highly urbanised with a mix of residential (primarily concentrated south of the railway line) as well as commercial and industrial properties (primarily concentrated north of the railway line). The upstream (i.e., southern) section of Little Creek has been primarily replaced by a subsurface stormwater drainage system. This stormwater system conveys runoff in a north-westerly direction, beneath the western railway line and into the remaining open channel section of Little Creek which, in turn, drains into South 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 "open" section of the creek network and inundate the adjoining floodplain.

The catchment has a history of flooding, with severe flooding having been experienced in August 1986 and October 1987. The most recent significant flood in the catchment occurred in March 2014. A selection of photographs from past floods in the catchment are provided in **Appendix K**.

In recognition of the potential for flooding to occur, Penrith City Council completed the *'Little Creek Catchment Overland Flow Flood Study'* (WMAwater) in 2017. The flood study defines the nature and extent of the existing overland and mainstream flood problem across the Little Creek catchment. It provides information on design flood discharges, levels, depths and velocities, as well as hydraulic and flood hazard categories for a range of design floods.

The flood study predicted inundation of over 300 properties at the peak of the 1% AEP flood and more than 800 properties at the peak of the probable maximum flood (PMF). A number of roadways were also predicted to be inundated including major transportation links such as the Great Western Highway.

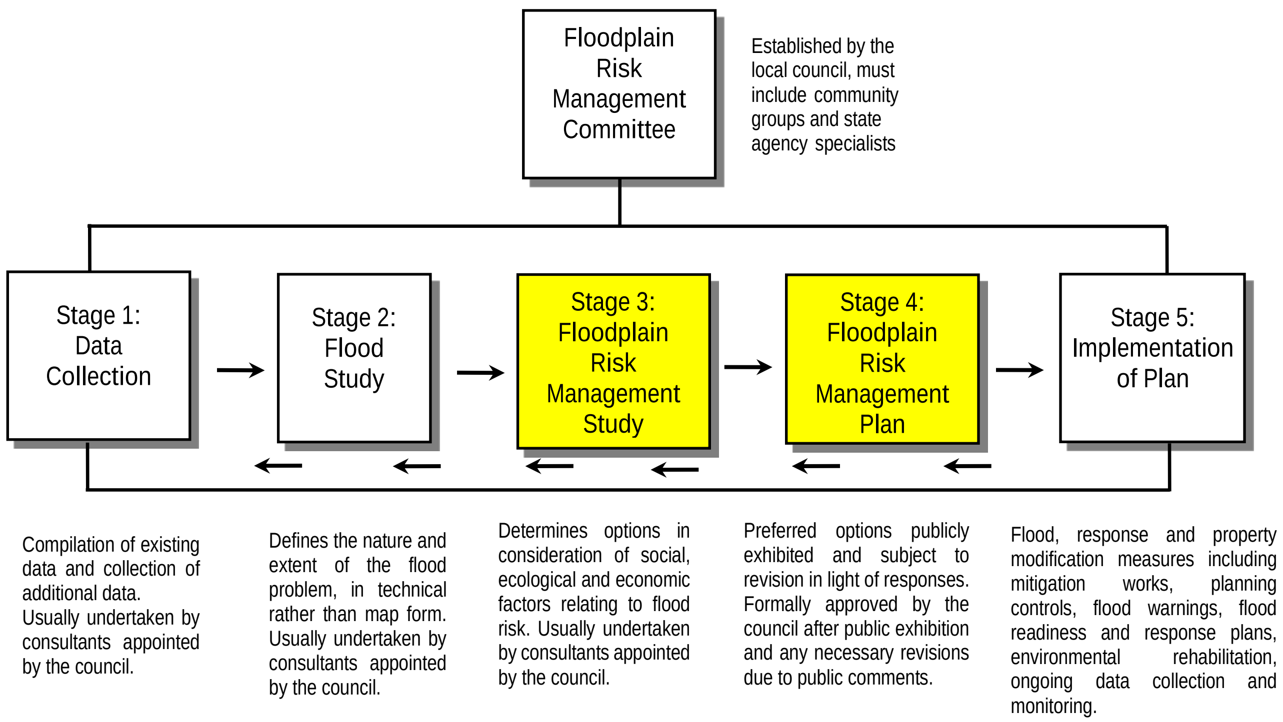
Penrith City Council subsequently engaged Catchment Simulation Solutions to prepare a Floodplain Risk Management Study and Plan for the Little Creek catchment. The overall goal of the Floodplain Risk Management Study and Plan is to evaluate a range of potential flood risk reduction options culminating in a preferred set of options that can be implemented to best manage the flood risk across the Litte Creek catchment.

1.2 The Floodplain Risk Management Process

The *'Little Creek Floodplain Risk Management Study and Plan'* has been prepared in accordance with the requirements of the NSW Government's *'Floodplain Development Manual' (NSW Government, 2005).* The *'Floodplain Development Manual'* 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.



Stages 1 and 2 of this process were completed as part of the *'Little Creek Catchment Overland Flow Flood Study'* (WMAwater, 2017). The current study represents stages 3 and 4 of the floodplain risk management process and will build upon the work that was previously completed as part of the 2017 Flood Study. This will include reviewing the previous study to ensure it provides the best possible representation of the existing flooding problem in the catchment. It will also identify, assess and compare various options for managing the flood risk across the catchment, culminating in the preparation of the Little Creek Catchment Floodplain Risk Management Study. The Floodplain Risk Management Plan draws on the outcomes of the Study and provides a preferred set of options that will outline how to best manage the existing, future and continuing flood risk across the Little Creek catchment.

It is noted that there is also potential for the lower parts of the catchment to be subject to inundation as a result of floodwaters "backing up" along the Little Creek channel from South Creek. Although the impact of South Creek flooding across the lower sections of the catchment was considered as part of the study, flooding and the management of the flood risk across the broader South Creek catchment is addressed in a separate report titled *'South Creek Floodplain Risk Management Study and Plan'* (Advisian, 2020).

South Creek and the downstream extent of Little Creek can also be impacted by flooding from the Regional Hawkesbury Nepean River during a Probable Maximum Flood (PMF) event. In general, flooding from the Hawkesbury Nepean would only impact on areas north of the railway line and would be supplemented with flood warnings that would allow property owners to take appropriate actions to reduce the potential for flood damages and undertake evacuation. Assessment of this flooding mechanism has not been specifically addressed as part of the current study, which is focussed on short duration, local catchment flooding.

1.3 Report Structure

The following report forms the Little Creek Catchment Floodplain Risk Management Study and Plan. It has been divided into the following sections:

- Chapter 1 – Introduction: Provides an overview of the study including background information, main goals of the study and the floodplain risk management process along with information on the report structure.
- Chapter 2 - Catchment Information: Provides general information on the catchment including available flooding information, potential constraints, key facilities and the makeup of the local community.
- Chapter 3 – Consultation: Summarises the consultation that was completed with key stakeholders and the community and the outcomes of this consultation.
- Chapter 4 – The Existing Flood Risk: Describes the current impact of flooding on the community for a range of different floods. This includes an assessment of the impact of flooding on key facilities, the potential cost of flooding as well as the potential for floodwater to damage buildings or pose a danger to personal safety.
- Chapter 5 – Land Use Planning Information: Provides a review of current national, state and local legislations, policies and guidelines that affect the development of flood prone land within the catchment.
- Chapter 6 – Exiting Emergency Management Information: Provides an overview of emergency management measures that are currently implemented across the catchment to assist in managing the flood risk. Opportunities to improve these existing protocols are also contained in this section.

- Chapter 7 – Options for Managing the Flood Risk: Provides an overview of potential options to manage the flood risk, and the options assessment approach undertaken in this study.
- Chapters 8 to 10: Discusses the merits of a range of flood, property and response modification measures that could be potentially implemented to manage the existing, future and continuing flood risk across the catchment.
- Chapter 11: Summarises which flood risk management options are recommended for inclusion in the Floodplain Risk Management Plan for the Little Creek catchment.

The Floodplain Risk Management Study report comprises two volumes:

- Volume 1 (this document): contains the report text and appendices; and
- Volume 2: contains all figures and maps that supplement the Volume 1 report.

2 CATCHMENT INFORMATION

2.1 Overview

The following chapter provides a summary of relevant information for the Little Creek catchment. This includes a description of the catchment, the makeup of the local community, critical and vulnerable facilities as well as an overview of previous flooding investigations.

2.2 Catchment Description

The Little Creek catchment is located in the Penrith City Council (PCC) Local Government Area and occupies a total area of approximately 465 hectares (i.e. 4.65 km^2). The extent of the catchment is shown on **Figure 1** and includes parts of the suburbs of Oxley Park, Colyton, St Marys and North St Marys.

The entire catchment upstream of Kurrajong Road is drained by a constructed stormwater system. The stormwater system conveys runoff into the Little Creek channel which surfaces to the north of Kurrajong Road (near its intersection with Plasser Crescent) and conveys runoff into South Creek. There is no formal drainage easement along the full length of Little Creek.

The catchment is traversed by several important transportation links including the Great Western Highway and the Western Railway Line which both run across the catchment in an east to west direction. St Marys train station is located within the lower portion of the catchment. The embankments of the Great Western Highway and the Western Railway Line form a notable overland flow impediment with the Western Railway Line, in particular, being elevated more than 6 metres above the adjoining terrain.

As shown in **Figure 2**, the catchment is generally quite flat, with the headwaters of the catchment located at elevations around 60 mAHD, falling at a grade of about 1.5% to the Great Western Highway. From the Great Western Highway down to South Creek, the catchment "levels out" to slopes of around 0.5%. The junction of Little Creek and South Creek is located at an elevation of around 20 mAHD.

2.3 Land Uses

2.3.1 Existing Land Use

Figure 3 shows the existing land zoning information for the catchment based upon information contained in the Penrith Local Environmental Plan (LEP) 2010. **Table 1** also summarises the different land use zonings across the catchment and the area occupied by each. It confirms that the catchment is heavily urbanised with residential and industrial land uses covering 88% of the catchment.

As shown in **Figure 3**, the area located south of the Western Railway Line primarily comprises of residential land use. However, there are scattered areas of open space (some of which serve as flood detention basins). This includes one basin within the playing fields of Colyton

High School, and another two interconnected basins located between the Great Western Highway and the Oxley Park Public School.

Table 1 Summary of Catchment Land Use based on Penrith City Council LEP 2010

Land Use Zoning		Area (ha)	Percentage of Catchment
Residential	R2	140.03	30%
	R3	89.17	19%
	R4	3.88	1%
Industrial	IN1	174.23	37%
Business and Mixed Use	B1	1.09	less than 1%
	B4	2.82	1%
Environmental	E2	10.19	2%
Recreation	RE1	27.48	6%
	RE2	0.63	less than 1%
Special Activities	SP1	2.48	1%
	SP2	13.12	3%
	TOTAL	465	100%

The catchment area located to the north of the Western Railway Line primarily comprises of industrial land uses. This includes the Dunheved Industrial Area which is located at the downstream end of the catchment.

2.3.2 Potential Future Development

As discussed, the Little Creek catchment is highly urbanised with little opportunity for significant future urban expansion. There is no land currently identified as “greenfield space” that would be available for new development.

Most of the recent development in the Little Creek catchment is via infill type development, such as the construction of granny flats. There is also evidence of low-density residential dwellings being knocked down and replaced by medium density residential developments, such as duplexes or townhouses.

There are, however, some major developments planned for the Little Creek catchment by agencies other than Council, including state and federal governments. The most significant one of these is the north-south rail link from the new Western Sydney airport, and the construction of a freight terminal associated with this rail line. Both of these are planned to be located within the Little Creek catchment. Further details of these works are anticipated to be released by the state and federal governments.

An assessment of the potential impacts of future development in the catchment is provided in Section 4.4.

2.3.3 Critical and Vulnerable Facilities

The catchment also includes a number of land uses that may be particularly vulnerable to the impacts of flooding (i.e., vulnerable facilities) as well as facilities that may play an important emergency response role during floods (i.e., critical facilities). The location of vulnerable and critical facilities are shown in **Figure 4**. These facilities are also summarised in **Table 2**.

Table 2 Critical and Vulnerable Facilities

	Facility		Address
Critical Facilities	Fire Stations	St Marys Fire Brigade	194 Great Western Highway, St Marys
	Police Stations	There are no police stations located within the catchment (local police station is located on King Street at St Marys)	
	State Emergency Service	There are no SES buildings located within the catchment (local SES unit is located at Fowler St, Claremont Meadows)	
	Ambulance Stations	There are no ambulance stations located within the catchment	
	Electricity	St Marys Zone Substation	95 Bennett Toad, St Marys
		Former Distribution Substation	3a Anne Street, St Marys.
	Water and Sewer	Sewer pump station	76A Lee Holm Road, St Marys
	Hospitals	There are no hospitals located within the catchment	
Vulnerable Facilities	Aged Care	There are no aged care facilities located within the catchment	
	Pre-Schools and Child Care	Busy Bee Long Day Child Care Centre	146 Glossop Street, St Marys
		Young Explorers Early Learning Centre	143 Adelaide Street, St Marys
		Evergreen Early Education Centre	68 Sydney Street, St Marys
		St Marys Blinky Bills Preschool	263 Great Western Highway, St Marys
		First Memories Early Learning Centre	54 Ball Street, Colyton
		Five Senses Childcare	14 Bennett Road, Colyton
		Keymer Child Care Centre	27-29 Bentley Road, Colyton
		Ridge-Ee-Didge Child Care Centre	17 Woodland Ave, Oxley Park
	Primary Schools	Oxley Park Public School	114-130 Adelaide Street, St Marys
		Bennett Road Public School	100-114 Bennett Road, Colyton
	High Schools	Colyton High School	37-53 Carpenter Street, Colyton
	Churches	St Demetrios' Greek Orthodox Church	47 Hobart Street, St Marys
		St Marys District Baptist Church	253 Great Western Highway, St Marys
		St Marys Samoan Seventh Day Adventist	253 Great Western Highway, St Marys
		St Marys Presbyterian Church	14 Marsden Road, St Marys
		Colyton Church	100/114 Bennet Toad, Colyton

2.4 Local Environment

2.4.1 Landscape

The Little Creek catchment includes an area of land mapped as "Scenic and Landscape Value" in Council's LEP. This is the area along and immediately north of the railway line, from St Marys train station (in the west of the catchment) along the rail corridor to Melbourne Street and the riparian areas along Ropes Creek (in the east of the catchment). This land is primarily zoned as SP2 (Infrastructure) and IN1 (General Industrial). The extent of this area is shown in **Figure 5**.

Council's LEP states the objectives for land identified as "Scenic and Landscape Value" is to identify and protect areas that have particular scenic value either from major roads, identified heritage items or other public places, and to ensure development in these areas is located and designed to minimise its visual impact.

The potential for implementation of structural mitigation measures in these areas will have to take into account the visual impact the option may have on the area identified as having a particular scenic value.

2.4.2 Aboriginal Heritage

Two Aboriginal heritage sites were identified as falling within the Little Creek catchment as part of a search completed on the Aboriginal Heritage Information Management System. The location of the sites is shown on **Figure 5** and these include:

- Open Camp Site
- Potential Archaeological Deposit

The declaration of an Aboriginal Place does not change the status of or affect ownership rights for the land. However, a declared Aboriginal Place must not be modified, harmed or desecrated without an Aboriginal Heritage Impact Permit issued under the NSW NPW Act 1974. Accordingly, any potential mitigation options in the vicinity of an Aboriginal Heritage location would be subject to these same restrictions.

2.4.3 Local Heritage Sites

There are a number of heritage items listed in the Environmental Planning Instrument (EPI) of the Council LEP. **Table 3** provides a summary of all heritage items listed in the Penrith City Council LEP 2010 that are located within the Little Creek catchment. The location of each heritage item in also shown in **Figure 5**. As shown in **Figure 5**, most of the heritage items are located within the St Marys area.

Table 3 Summary of Heritage Sites Listed by Penrith LEP 2010

ID	LEP Heritage Item Number	Description
1	*282*	St Marys Railway Station
2	*303*	St Marys Cemetery
3	*304*	Milestone – Great Western Highway
4	*862*	Milestone – Great Western Highway

Schedule 5 of the Penrith LEP 2010 aims to conserve the environmental heritage of Penrith. This includes conserving the heritage significance of heritage items and heritage conservation areas, including associated fabric, settings and views; conserving archaeological sites and conserving Aboriginal objects and Aboriginal places of heritage significance. The clause lists a number of heads of consideration for when consent is or is not required for a development that may impact on a heritage item. The potential for implementation of structural mitigation options in areas with heritage listing will need to consider the effect of the proposed measure on the heritage significance of the item or area.

2.4.4 NSW State Heritage Sites

There is one site within the Little Creek catchment that is listed under the NSW Heritage Act 1977. This is the St Marys railway station, and its location is shown by the green triangle in **Figure 5**.

2.5 Demographics

Understanding the characteristics of the population living and working within the catchment is an important component of developing and assessing potential flood risk management options. For example, the availability of internet, the primary language spoken at home and the availability of a motor vehicle can have a strong bearing on the feasibility of different education, flood warning and evacuation strategies.

In this regard, the Australian Bureau of Statistics (ABS) provides a range of information for the areas of Colyton-Oxley Park, and St Marys-North St Marys that was collected as part the 2016 census. A summary of pertinent information extracted from the ABS website (http://www.abs.gov.au/) is provided in **Table 4**. **Table 4** also includes averages for each statistic for the state of NSW.

The information presented in **Table 4** shows that:

- Approximately 28,000 people reside in the suburbs included in this study. However, the Little Creek catchment does not cover the full extent of each suburb. Based on the proportion of the suburbs falling within the catchment extent, it is estimated that the population contained within the catchment is about 12,800. However, information provided by Council (refer Section 2.3.2) suggests that this population is likely to increase in the future as a result of “infill” developments such as granny flats and single dwellings being replaced by high density developments such as townhouses.
- Approximately one third (i.e., 33%) of the population would be considered more vulnerable to the impacts of flooding (i.e., people under the age of 15 or over the age of 65). The median age of residents within the area is 34.
- The majority of households speak English at home. However, more than a quarter of the population have said they speak a language other than English at home. This includes Arabic, Tagalog (i.e., Filipino), Hindi and Samoan.
- Approximately 64% of the dwellings are owner occupied in the Colyton and Oxley Park suburbs and 33% are rented. The number of rental properties is much larger in St Marys and North St Marys with 50% of dwellings rented and 45 % owner-occupied. The

proportion of renters across the catchment is, therefore, higher than the state average (32%) indicating there is potential for greater "turn over" of residents in the catchment and less potential flood exposure and awareness.

Table 4 Summary of Catchment Demographics

Statistic			Colyton & Oxley Park	St Marys & North St Marys	NSW
Population Statistics		Total population	11,591	16,072	7,480,228
Population Statistics	Age	Median Age	34	34	38
Population Statistics	Age	Less than 15 years of age	2425	3321	18.5%
Population Statistics	Age	Greater than 65 years of age	1450	2168	16.3%
Population Statistics		Proportion of population that volunteers	10%	10%	18.1%
Population Statistics	Education	Year 12 or equivalent	51%	49%	53.9%
Population Statistics	Education	Year 10 or equivalent	18%	17%	26.2%
Population Statistics	Education	Did not Complete Year 10	13%	13%	11.1%
Dwelli	Motor Vehicle	Dwellings with no vehicles	7%	12%	9.2%
Dwelli	Motor Vehicle	Dwellings with ≥ 1 vehicle	89%	82%	87.1%
Dwelling Statistics		Average persons per dwelling	2.9	2.6	2.6
Dwelling Statistics	The language spoken at home	Speaks English only	67%	66%	68.5%
Dwelling Statistics	The language spoken at home	Other	Arabic 3.9%	Tagalog 2.3%	Mandarin 3.2%
Dwelling Statistics	The language spoken at home	Other	Hindi 2.2%	Arabic 2.2%	Arabic 2.7%
Dwelling Statistics	The language spoken at home	Other	Tagalog 1.8%	Samoan 1.7%	Cantonese 1.9%
Dwelling Statistics		Proportion of renters	33%	50%	32%
Dwelling Statistics	Dwelling Type	Separate house	84%	65%	66%
Dwelling Statistics	Dwelling Type	Semi-detached, row or terrace house, townhouse	15%	20%	12%
Dwelling Statistics	Dwelling Type	Flat, unit or apartment:	1%	15%	20%
Dwelling Statistics	Dwelling Type	Other dwelling (cabin, caravan):	0%	0%	1%
Income		Median total household income ($/weekly)	$1,370	$1,171	$1486
Income		Median Rent ($/weekly)	$350	$340	$380
Internet Statistics		No Internet connection	18%	23%	15%
Internet Statistics		Access to Internet connection	80%	73%	83%
Internet Statistics		Not Stated	3%	4%	3%

- 80% of households have an internet connection in the Colyton and Oxley Park suburbs while 73% of households have internet access in St Marys and North St Marys. This is much lower than the state average of 83%.
- The average household within the catchment has 2 or more people, and at least one motor vehicle. However, there are around 10% of properties with no access to a motor vehicle.
- The median household income for all suburbs within the catchment is less than the state average.

Overall, the demographic information indicates that:

- A significant proportion (i.e., approximately one third) of the population would be more susceptible to the impact of flooding;
- A lower proportion of the local community has access to online recourses which can impact on the effectiveness of some flood education and flood warning services; and
- if a large flood occurred that resulted in significant financial losses, there would be less potential for the local community to financially recover.

2.6 Past Studies

A summary of previous flood investigations relevant to the Little Creek catchment is provided below. They are listed in chronological order to demonstrate how the understanding of flooding and the management of flood risk across the catchment has evolved.

2.6.1 Drainage Investigation – Little Creek, Colyton, City Engineers Report (1987)

This report was prepared by Penrith City Council staff after the significant flood that occurred in October 1987. The report focusses on the Colyton and Oxley Park area and details the damage caused by floodwaters during the event and also discusses the reasons for the significant flooding that was experienced. It also provides a background on the historical development in the area and the associated construction of the stormwater drainage system.

The report notes that most of the urban development in the Little Creek catchment occurred during the 1950's and 1960's. In the areas south of the Western Railway line, this development was facilitated by replacing the creek system with a piped stormwater system. The stormwater drainage system was designed and constructed to carry a 1 in 5 year ARI design storm, as per Council's engineering standards at the time.

The report goes on to say that once this stormwater system was constructed, property owners erected fences and other obstructions along the overland flowpath. Council endeavoured to acquire a formal easement along the stormwater pipe system in an effort to reduce the overland flow impediments, but at the time of writing, only 6 of the 22 properties affected were amenable to the concept. It is understood that formal easements along this drainage corridor have not been established.

The report details flooding issues at various locations throughout the catchment, and the significant impact that blockage of inlet structures had on flooding characteristics. The report highlights the significant debris that had to be removed from pipes after the flood, such as fridges and wooden doors.

The report then goes on to recommend mitigation options that could potentially be implemented to assist in reducing the nature and extent of flooding in the catchment. However, the report acknowledges that implementation of any of the suggested options may not solve the entire problem at each and every location. The mitigation options suggested as part of the report fall under one of two themes – increasing the minimum stormwater design standard and upgrading the existing system to this standard or providing a formal overland flowpath for storm events greater than the pipe capacity.

The potential options presented in the report include:

1. Restore the overland flowpath by removing paling and steel fences and other minor obstructions and replacing them with "open" pool type fencing;
2. Upgrading stormwater pit inlet capacities to maximise utilisation of the existing pipe system;
3. Complete upgrading of the major drainage lines between the Great Western Highway and Western Railway line;
4. Acquisition of land to provide formal "escape routes" for excess stormwater flows;
5. Diversion of part of excess flow to Ropes Creek;
6. Construction of detention basins to reduce the discharges from the catchment and increase the effective capacity of the existing pipe system; and
7. Provision of an overland flow path from Kent Place, Colyton.

The report also states that the concrete cover over the pit on Hobart Street was in the process of being removed, with appropriate fencing around the pit to be erected. This pit now comprises a large, grated inlet.

The report strongly reiterates that the flooding issues experienced in the Colyton-Oxley Park areas are not unique to this specific catchment, with similar issues in other parts of the LGA, particularly in older areas, where roads and stormwater drainage were designed and constructed to a lesser standard.

The report recommends that Council make funds available to restore overland flowpaths (i.e., Option 1 discussed above). The report also recommends that a further report be submitted to Council following a total review of drainage problems in the whole LGA, to enable a priority programme to be adopted.

2.6.2 Drainage Investigation – Little Creek, Colyton, Sinclair Knight and Partners (1988).

Sinclair Knight & Partners (1988) were engaged by Penrith City Council to undertake a review of the flooding that occurred in the Little Creek catchment in August 1986 and October 1987 and to undertake a feasibility assessment of potential flood mitigation options. This report follows on from the Council report discussed above.

The goals of the investigation included:

- Assess the capacity of the existing drainage system;
- Assess flooding patterns and their causes;
- Review Councils proposals for flood mitigation;
- Identify and analyse any additional alternative flood mitigation measures and
- Evaluate alternative flood mitigation solutions and provide financial analyses.

The report defined flood behaviour for the 1 in 5 year Average Recurrence Interval (ARI) and the 1 in 100 year ARI event using a flood model that was developed using the ILSAX software. This assessment indicated that some sections of the stormwater pipe network had a capacity of no greater than the 5 year ARI flood, and no sections of the stormwater pipe network had a sufficient capacity to convey the 1 in 100 year ARI flood. Inlet capacity was also found to be a limiting factor, with several pits throughout the system expected to surcharge.

The report examined a number of potential flood mitigation options, using the 1 in 100 year ARI for design purposes. As outlined in the previous section, Council had originally suggested seven (7) potential mitigation options which were refined into five (5) mitigation options for detailed assessment. The options investigated included:

1. Development of a channel and overland flowpath system in the Kent street and Carpenter Street areas as well as additional culverts under the Great Western Highway and Bennett Road. The report also recommends an additional culvert between Brisbane Street and Thompson Avenue to convey the 1 in 5 year ARI flow.
2. Variation of Option 1 incorporating some additional piping of overland flows along Carpenter Street.
3. Variation of Option 2 incorporating a new detention basin north of the Great Western Highway.
4. Upgrading parts of the stormwater pipe network and constructing one detention basin at Colyton High School, one detention basin north of the Great Western Highway and one detention basin at the end of Kent Place.
5. Variation of Option 4 to include upgraded pipes across various parts of the catchment and an additional detention basin north of the Great Western Highway.

The report ultimately recommended Option 5 for implementation as the highest priority. It is understood that this option has since been implemented. The report also suggested modification to fence types located throughout the catchment as a shorter-term goal (as per the recommendation in the Council report).

2.6.3 Little Creek Catchment Overland Flow Flood Study (2017)

The *'Little Creek Catchment Overland Flow Flood Study'* was prepared by WMAwater for Penrith City Council in June 2017. The study was commissioned to define flood behaviour across the Little Creek Catchment for topographic and development conditions at that time.

The flood study was the first-time that flood behaviour had been formally defined across the whole of the Little Creek catchment. That is, previous flood investigations focussed on localised sections of the catchment only.

The study included the development of two computer models to simulate flood behaviour across the catchment:

- A DRAINS model which was used to define hydrologic (i.e., rainfall-runoff processes) across the catchment; and,
- A TUFLOW model which was used to define hydraulic processes (i.e., movement of floodwater) across the catchment.

No stream gauges are located within the catchment. Therefore, the DRAINS model could not be formally calibrated. However, the flow hydrographs generated by the DRAINS model were applied to the TUFLOW model and a joint calibration was completed using historic rainfall and flood mark information for the March 2014 flood. The model was also validated using historic information for the October 1987 and April 1988 floods. Overall, the models were found to provide a reasonable reproduction of these past floods.

The calibrated models were used to simulate nine (9) design storms events. This included the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and the probable maximum flood (PMF). The 2-hour storm duration was adopted as the critical duration for all design simulations. Hydrology was defined based on the 1987 version of 'Australian Rainfall & Runoff – A Guideline to Flood Estimation' (Engineers Australia).

The outputs from the design flood simulation were used to prepare design flood extent, depth and velocity mapping, provisional hydraulic hazard mapping and provisional hydraulic categorisation mapping. The preliminary flood planning area and preliminary flood emergency response classifications were also mapped.

The study found that the railway embankment has one of the biggest influences on flood behaviour in the catchment. The study also states that flow behaviour is distinctly different upstream and downstream of the railway corridor. Upstream of the railway line, there are no sections of open channel and the existing stormwater network was found to have a very small capacity (generally between a 50% AEP and 20% AEP capacity only) with numerous overland flow paths through private property. Downstream of the railway line, Little Creek is primarily an open channel that rarely overtops. In areas away from the main drainage line, overland flows were found to generally follow the road network.

The study makes mention of the two (2) detention areas in the catchment – one within the playing fields of Colyton High School, and one immediately upstream of Oxley Park Public School (this actually comprises two separate detention areas separated by an internal control embankment). Both detention areas become active during the 50% design storm event. The following additional insights were also provided:

- Colyton High School Basin: Has sufficient capacity to store water up to the PMF.
- Oxley Park basin: Flow starts to discharge from the basin and through the Oxley Park Public School via an informal spillway during the 5% AEP design storm event. Owing to the flat and broad nature of the spillway area, a small increase in basin stage can result in a significant increase in flows through the school.

The study also provides a detailed discussion on seven flooding "hot spots" (i.e., areas identified as significantly flood affected). The report then provided suggestions on potential flood mitigation options for each of the hot spots. A summary of the flooding hot spots that were identified in the study along with the suggested mitigation measures is provided in **Table 5**. It should be noted that none of the suggested mitigation options were explored in detailed as part of the flood study. However, the suggested options serve as a valuable starting point for identifying potential flood mitigation options that can be examined as part of the current study.

Overall, this study and the models produced as part of this study are considered to provide the best description of flood behaviour across the Little Creek catchment. However, since the flood study was prepared, revised topographic datasets have become available and some additional development has occurred. As a result, it was considered necessary to review the flood models to ensure they still provided a reliable description of contemporary flood behaviour across the catchment. The outcomes of this model review are summarised in Section 4.2.1.

Table 5 Summary of Potential Mitigation Measures for the Little Creek Catchment (WMAwater, 2017)

Hot Spot		Potential Mitigation Option
1	Hobart Street Low Point	Increase railway line cross drainage capacity
2	Plasser Crescent to Kurrajong Road	Modify open channel near Kurrajong Road
3	Canberra Street Low Point	Increase inlet capacity to stormwater network
4	Oxley Park Detention Basins	Alter outlet capacity and spillway crest from basins
5	Shane Street Low Point	Upgrade stormwater pipe capacity in upstream catchment, as a minimum, to satisfy Councils current DCP requirements design objective (currently 5% AEP)
6	Great Western Highway Low Point (east)	a) Increase pipe and overland flow capacity across the Great Western Highway into the Oxley Park Detention Basins b) Detention storage from Bennett Road to Great Western Highway c) Upgrade stormwater pipe capacity in upstream catchment, as a minimum, to satisfy Councils current DCP requirements design objective (currently 5% AEP)
7	Great Western Highway Low Point (west)	

2.6.4 Updated South Creek Flood Study (2015)

The *"Updated South Creek Flood Study"* was prepared by WorleyParsons Services Pty Ltd on behalf of Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils. The study area extends from Bringelly Road in the south to the Richmond Road Bridge crossing in the north. The total study area is about 240 km^2 and lies within the Hawkesbury, Penrith, Blacktown, Liverpool and Fairfield Local Government Areas. The total catchment of South Creek, to its confluence with the Hawkesbury River near Windsor, is 414km^2.

The objective of the study was to update the existing hydrologic and hydraulic models that were previously developed for the catchment as part of the *"Flood Study Report, South*

Creek" (DWR, 1990) and provide contemporary tools for the assessment of flood conditions across the South Creek catchment. The results of the study define the flood behaviour across the South Creek catchment for a range of design floods and provide more reliable estimates of flood planning levels for each local government area.

The XP-RAFTS model of the South Creek catchment developed for the 1990 Flood Study was updated from the 1991 version of the software (Version 2.56) to a later version of XP-RAFTS (Version 6.52). Subcatchment delineation and parameters were reviewed and refined based on contemporary topographic and catchment conditions. The XP-RAFTS model represented the Little Creek catchment using a single subcatchment node. Accordingly, the model does not provide a particularly detailed description of rainfall-runoff processes across the Little Creek catchment.

A 2D hydraulic model of the South Creek system was developed using the RMA-2 software package to replace the previous 1D MIKE-11 and HEC-2 hydraulic models that were developed as part of the 1990 Flood Study. The model is based on a Digital Terrain Model (DTM) developed from ALS data that was gathered for the entire South Creek floodplain between 2002 and 2006. The RMA-2 model does not explicitly represent Little Creek.

The XP-RAFTS and RMA-2 models were used to simulate a range of design floods, including the 0.2%, 0.5%, 1%, 2% and 5% AEP events and the Probable Maximum Flood. The report documents the findings from the modelling investigations, including details on flows, flood levels, flood depths, flow velocities, and provisional hydraulic and hazard categories for current catchment and floodplain conditions. RMA-2 model outputs were provided as part of the current study in waterRIDE outputs. Accordingly, a range of spatial and temporal flood information could be extracted for each design event. However, the quantum of information available for the Little Creek catchment is limited to the area surrounding the South Creek and Little Creek confluence.

The results of the study indicate that the lower sections of the Little Creek catchment can be impacted by South Creek flooding. However, the majority of the Little Creek catchment (most notably the areas located upstream of Glossop Street) are not predicted to be subject to inundation from South Creek even during the PMF.

2.6.5 South Creek Floodplain Risk Management Study and Plan (2020)

This report was prepared by Advisian on behalf of Penrith City Council. The study area extends from Elizabeth Drive in the south to the Richmond Road Bridge crossing in the north, with a total catchment area of approximately 240 km^2.

The study estimates the potential flood damage in the South Creek study area would be:

- 162 properties would be inundated above floor level during a 1% AEP flood.
- 245 properties would be inundated above floor level during a 0.5% AEP flood.
- 2,639 properties would be inundated above floor level during a PMF (residential properties make up for 90% of properties that are inundated above floor level in the PMF).
- The Average Annual Flood Damage cost for the study area was calculated as $985,000.

The suburbs most vulnerable to flooding were found to be St Marys, Werrington, St Clair, Llandilo, Berkshire Park and Oxley Park. For each of these areas, there was a significant "jump" in the number of flood affected properties between the 0.5% AEP flood and the PMF.

Floodwaters from South Creek can start to "back up" Little Creek and extend across the downstream parts of the catchment during the 0.2% AEP flood. The extent of flooding from South Creek is shown in **Appendix I** as **Figure I1**.

A total of 38 structural and non-structural options were initially identified to assist in better managing the flood risk across the study area. The list of options was subsequently refined based on consideration of the expected hydraulic impact, cost of construction, social impacts, and environmental impacts. Nine (9) flood modification measures and two (2) property modification measures were ultimately selected for detailed assessment following the preliminary options assessment.

Based on the outcomes of the assessment of each option (which considered flood impacts, economic impacts, social and environmental impacts), the following measures were recommended as part of the Floodplain Risk Management Plan for South Creek:

- FM1 – Measure F-1A – "low cut" option for excavation downstream, of the western railway crossing of Ropes Creek.
- FM2 – Measure F-7B – upgrade to St Marys Levee plus installation of a flap gate.
- FM3 - Earthen levee at Oxley Park.
- Emergency response management measures.
- Updates to the flood related development controls within the Penrith DCP 2014.

2.6.6 Hawkesbury-Nepean Valley Regional Flood Study 2019.

The *'Hawkesbury-Nepean Valley Regional Flood Study'* was prepared by WMAwater for Infrastructure NSW. The objective of the project was to provide an updated description of flood behaviour across the Hawkesbury-Nepean Valley, which is considered one of the most exposed floodplains in Australia.

The study built upon the 1996 Nepean River Flood Study and included an updated flood frequency analysis. Hydrology was also defined using a RORB hydrologic model that was calibrated and validated using rainfall and stream flow information for 7 historic floods, which included the 1988 and 1990 floods.

The quasi 2-dimensional RUBICON hydraulic model that was developed for the 1996 Flood Study was used and updated as part of the study to define flood hydraulics. The model extended as far upstream as Camden; however accurate modelling begins downstream of Bents Basin. The RUBICON model was calibrated and verified using historic information for 10 flood events.

A Monte Carlo modelling framework was used to define design flood hydrology as part of the study. This Monte Carlo approach was implemented in an attempt to better represent the observed variability in actual flood events. Variables that were randomly sampled as part of this assessment included rainfall intensity and frequency, spatial pattern of rainfall, temporal pattern of rainfall, initial loss, pre-burst rainfall, dam drawdown, relative timing of tributary inflows and tides. This approach is very computationally intensive and is not often completed as part of most flood studies. However, given the high potential flood risk, this more comprehensive approach was considered necessary.

The study provides updated flood levels, extents, depths, provisional hazard and hydraulic categories for the 1 in 5, 1 in 10, 1 in 20, 1 in 50, 1 in 100, 1 in 200, 1 in 200, 1 in 500, 1 in 1000, 1 in 2000, 1 in 5000 AEP floods as well the PMF. The updated results generated as part of the study compared well with the 1996 Flood Study at Warragamba and Windsor but was found to be lower around Penrith.

The study also generated information on the rate of rise, time to rise, rate of fall, time to fall, time above critical levels and travel time for key locations on the floodplain to assist in assessment of risk to life and inform emergency response. Climate change induced rainfall intensity increases, and sea level rise sensitivity analysis was also undertaken.

The report acknowledges that this was a “regional” study and suggests more detailed studies should be completed if a more precise description of flood behaviour is required across local subcatchments. However, the study shows that Little Creek can be impacted by floodwaters backing up from the Hawkesbury River via South Creek in the PMF. The extent of backwater flooding from the Hawkesbury River in the PMF is shown in **Appendix I** as **Figure I2**.

3 CONSULTATION

3.1 Community Consultation

3.1.1 Overview

Penrith City Council recognises that the community plays an important part in the development of the floodplain risk management study and plan for the Little Creek catchment. As a result, consultation was completed with the community as well as key stakeholders at multiple stages through the floodplain risk management process.

Consultation was initially completed as part of the *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017). This was supplemented with additional consultation as part of the current study to obtain additional information that may not have been reported during the flood study or may have come to light since the flood study was prepared. A summary of the outcomes of all consultation that was completed is provided below.

3.1.2 Flood Study (2017)

Community consultation was undertaken during the early stages of the flood study to obtain local information on historical flood events, as well as during the public exhibition of the draft flood study report. There was a range of feedback received during the community consultation phases of the flood study, with approximately 25% of the respondents observing an overland flow path near their property and nearly 20% of respondents having experienced flooding in their properties. The information received was incorporated into the flood study where possible.

3.1.3 Floodplain Risk Management Study (current study)

Consultation with the community was also completed at two stages throughout the current project. The initial community consultation was undertaken during the beginning of the project with the intention of informing the community of Councils undertaking of the floodplain risk management study and plan. This phase of community consultation also intended to seek information from the community that may assist in the development of the risk management plan for Little Creek.

An information sheet and questionnaire were distributed to 3,400 households and businesses during the initial stage of the project. The information sheet informed people of the overall process involved in preparing a floodplain risk management study and plan for the Little Creek catchment as well as the major objectives of the project. A copy of the information sheet is included in **Appendix A**.

The questionnaire asked targeted questions about potential floodplain risk management options that could be implemented in the Little Creek catchment to help manage flooding. The questionnaire also asked questions on emergency management procedures and flood related planning controls, such as how people would respond during future floods and what key development and planning controls should be the focus of council's floodplain risk management objectives. A copy of the questionnaire is included in **Appendix A**.

A total of 236 questionnaire responses were received and a summary of all questionnaire responses is provided in **Appendix A Tables A1** to **A4**. This equates to a 7% response rate, which is lower than response rates for other similar studies (which are most commonly around 10%). This may indicate a lower level of interest in flooding for the community located within this catchment.

A summary of the key outcomes of the questionnaire responses are provided below.

About the Property

Questions 1 to 3 of the questionnaire related to the type of development and the duration of occupation at that property. The responses to this question showed that:

- Around 94% of the respondents indicated they are a resident or own the property. Less than 2% of the respondents indicated they rent the property.
- Almost 5% of the respondents owned a business within the catchment.
- Almost half of the respondents indicated they have resided in the area for more than 20 years, with another 31% indicating they have resided in the area between 5 and 20 years.
- Approximately 20% of the respondents have been in the area less than 5 years.

These responses to these questions indicate that there is a high degree of home ownership with long term tenancy in this catchment, which can be of benefit when planning community awareness and education opportunities in the future.

Flood Awareness

Question 4 aimed to gain an understanding of the level of flood awareness of people in the catchment. The spatial distribution of responses to this question are shown in **Figure A1** in **Appendix A**. The PMF extent is also provided on **Figure A1**. The responses to question 4 indicate that:

- The majority of respondents (113 out of 236) were not sure if their property could be flooded or not.
- Of those respondents who identified their property as being flood liable, 23 out of 44 respondents correctly identified their property as being located within the PMF extent. The remaining 21 respondents are located outside of the PMF extent and would not be considered flood liable.
- Of those responses that identified their property as not being flood liable, 55 out of 75 respondents were correct with their property being located outside of the PMF. The remaining 20 properties are located within the PMF extent and would be considered flood liable.

The fact that a significant number of respondents did not know whether their property could be flooded or incorrectly identified their property as “flood free” or “flood liable” indicates a relatively low level of flood awareness in this catchment. This is not unusual for overland flooding catchments where the majority of properties are located away from a defined watercourse.

Development Controls & Communication

Questions 5 to 7 & 11 focussed on development controls and communications options. The responses to these questions indicate that:

- The community believes that options should target reducing the flood risk across residential properties as a priority.
- The community supported prohibiting all new development on potentially flood liable land (however, controls on small additions were not supported).
- For communication options, the majority of respondents (more than 50%) supported notifying all potentially flood affected properties on a regular basis (refer **Plate 1**). Providing no notifications was poorly supported (less than 2%).
- Updates on Council's website followed by the articles in the local newspaper were the communication modes most responses suggested for reporting project updates and obtaining feedback from the community regarding potential options.

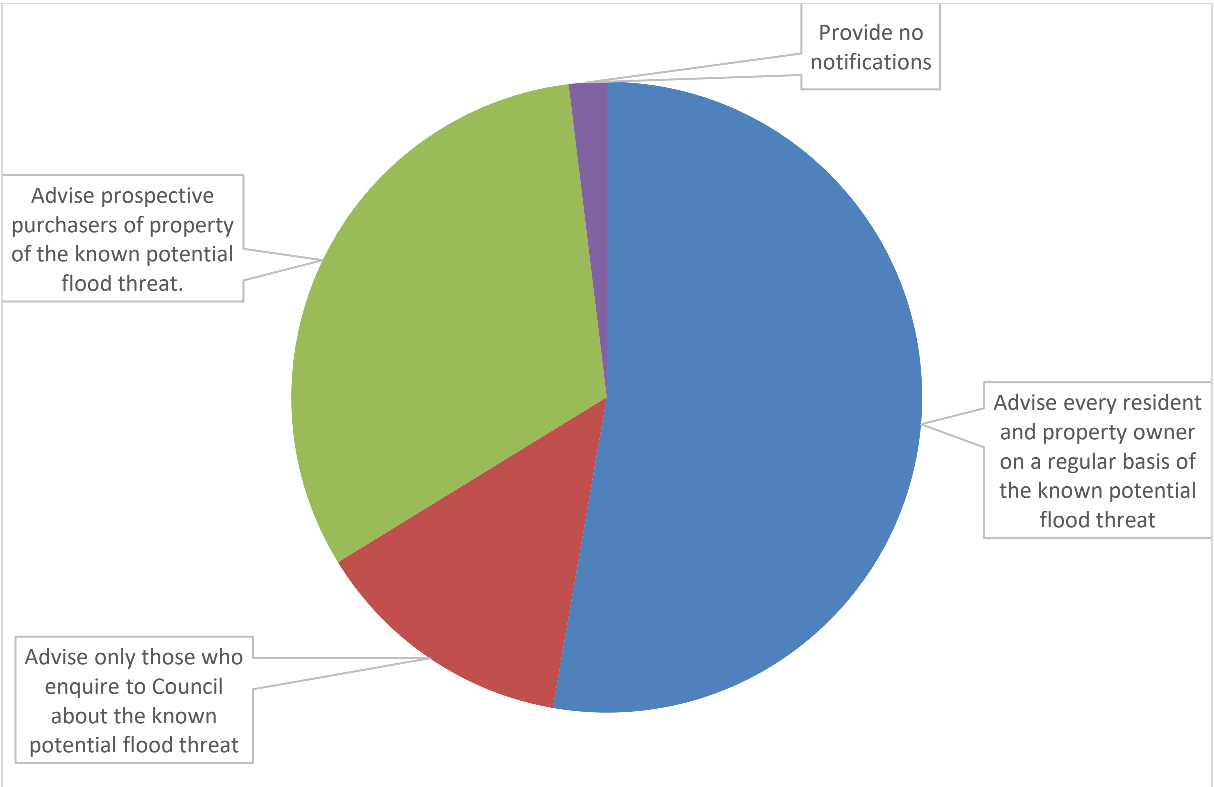


Plate 1 What notifications should Council give about flood affectation of properties

Flood Response

In terms of flood response (questions 8 to 10), the questionnaire responses indicate that (also refer to **Plate 2**):

- Most households (58%) would evacuate early to an evacuation centre during a future flood.
- Around 25% did not have a plan and did not know how they would response during a future flood.
- For those intending to evacuate, safety of their family was the overriding concern.

- The primary reason for not evacuating (i.e., staying home) was concerns for the security of their property if they were to evacuate.

The spatial distribution of responses that reported that they would evacuate versus stay home is provided in **Figure A2**.

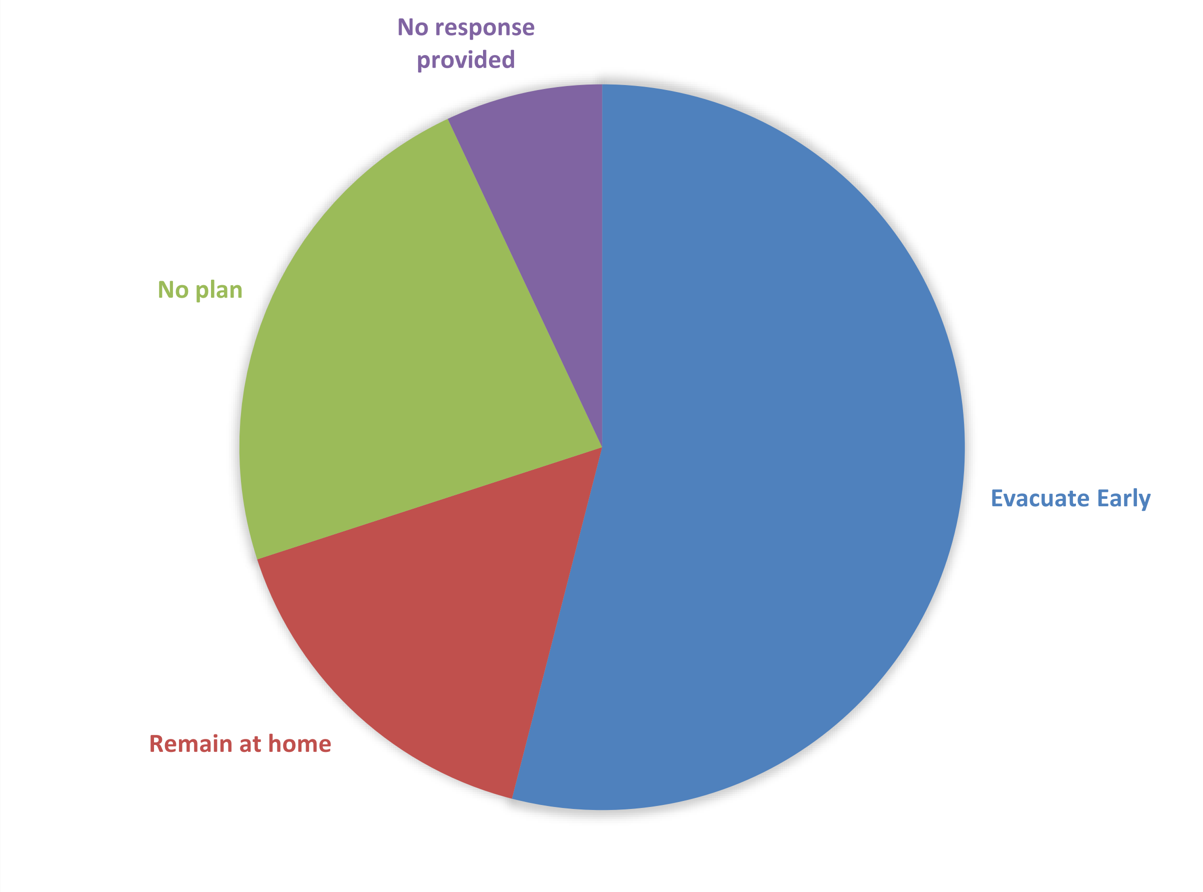


Plate 2 How the community would respond to a future flood in the Little Creek Catchment

Potential Flood Risk Management Measures

In terms of options for better managing the flood risk (question 12), most of the suggested options were supported by the community. **Plate 3** represents the responses that were received to the potential floodplain risk management measures for the Little Creek catchment.

3.1.4 Public Exhibition

The draft 'Little Creek Catchment Floodplain Risk Management Study' was placed on Public Exhibition from the 29 July 2021 until 26 August 2021. A copy of the draft report was made available for review on Council's www.yoursaypenrith.com.au website during the public exhibition period. There was a total of 148 visits to the Your Say webpage and 245 document downloads. The most popular downloads were:

- Fact sheet: 116 downloads
- Floodplain Risk Management Study & Plan Summary Report: 48 downloads

It was also noted that there were 28 downloads of the Flood Study (2017) report

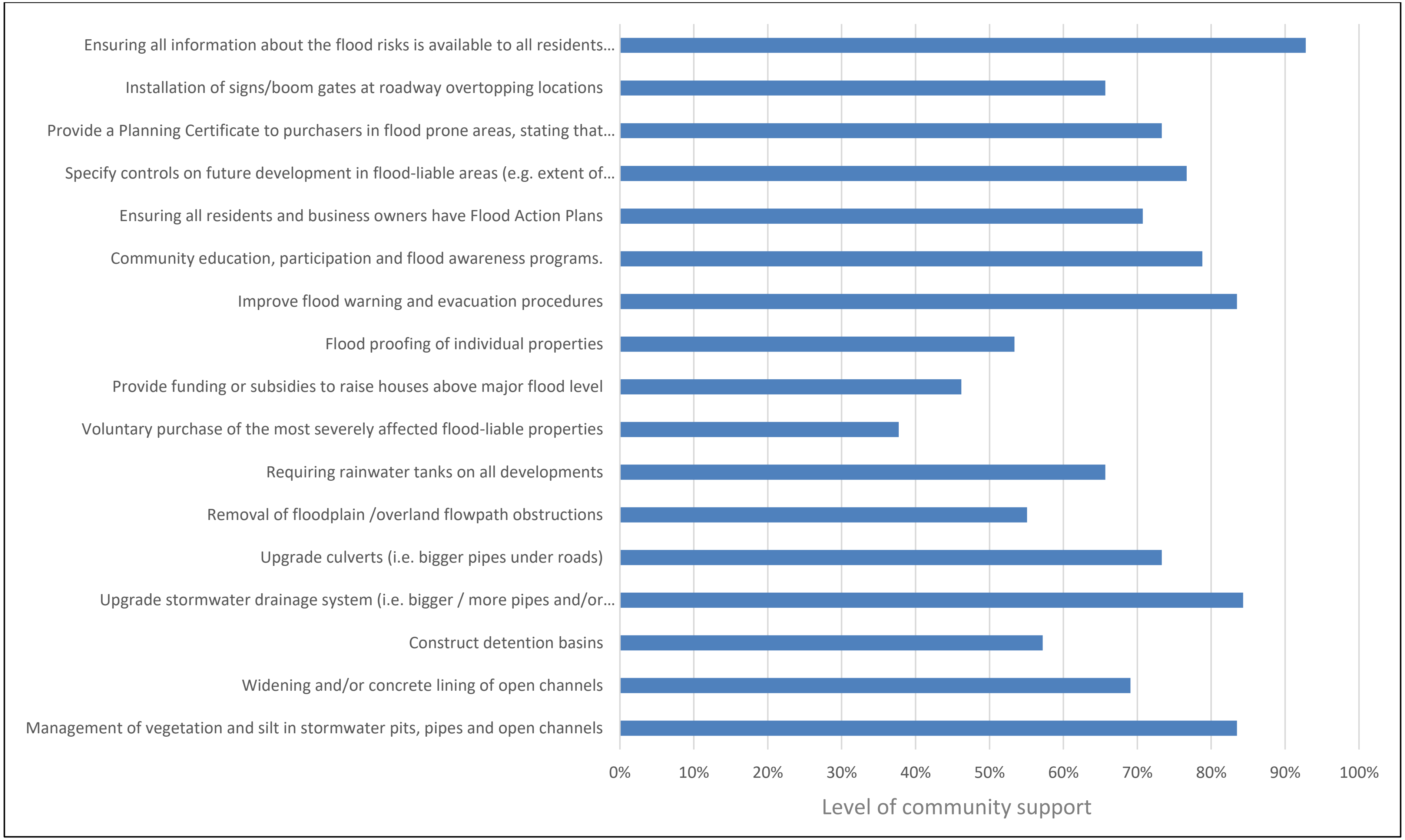


Plate 3 Response to Potential Floodplain Risk management measures for the Little Creek Catchment

It was intended to hold a community workshop during the public exhibition to allow the community to ask questions and raise any concerns directly with Council and Catchment Simulation Solutions staff. Unfortunately, the Covid-19 lock down prevented the in-person workshop. Therefore, an online meeting was arranged on the 17 August between 6pm and 8pm. The online meeting included a PowerPoint presentation which provided an overview of the study. Following the presentation, an opportunity for the community to ask questions/raise concerns was provided. A total of five (5) people attended the online meeting.

A total of eight (8) submissions were also received during the public exhibition period (although three individual submissions were provided by the same applicant). The submissions as well as the comments that were raised during the online meeting generally related to the issues summarised in **Table 6**. **Table 6** also summarises the responses that were provided for each of the major concerns identified.

Table 6 Summary of Public Exhibition Comments and Responses

Comment	Response
The flood planning area/results are not supported by the community's experiences	A storm event of a 1% AEP magnitude has not occurred across the catchment in recent history. As such, residents are unlikely to have experienced larger events that are relevant to flood planning. In addition, the flood planning area incorporates a freeboard to act as a factor of safety for variables that are not known with certainty (e.g., blockage of stormwater pits) which can expand the flood planning area beyond even the 1% AEP flood extent.
Flood mapping is unclear/ambiguous	Low resolution versions of the figures/mapping were provided on Council's website as part of the public exhibition to provide the community with the best opportunity to download and view these figures (the full resolution versions are more than 400MB in size and would have been prohibitively large for many people). High resolution versions of each flood maps are available and specific versions of these maps can be provided on request.
Concerns regarding the potential impacts that the study may have on development potential, insurance premiums and property values.	Property prices are influenced by a range of market factors and there "…remains scant evidence for a sustained decrease in the value (or in growth rate) of houses with a flood risk" (Yeo et al, 2015). That is, other market factors tend to dictate property values. Individual insurance companies typically identify flood prone land and assess risk through their own flood studies, analysis, and flood mapping exercises. In any case, the current study is not significantly different to the 2017 flood study. Therefore, insurance premiums are unlikely to increase because of this specific study.
Concerns that Council plans to rezone land based upon the Study and Plan	The recommended planning changes are intended to update the identification of properties where there is a potential risk of inundation. This will allow any future development across potentially flood affected areas to be completed in a way that minimises the potential for damage to property by floodwaters. There are no plans to re-zone any land within the Little Creek catchment as a result of the study.

Overall, no modifications to the draft 'Little Creek Catchment Floodplain Risk Management Study' were required to address the submissions received.

3.2 Key Stakeholder Consultation

Targeted consultation was also completed with key stakeholders as part of the project. This included:

- Penrith City Council Engineers;
- Penrith City Council Planners;
- Penrith City Council Development Assessment;
- Penrith City Council Floodplain Risk Management Committee;
- Department of Planning, Industry & Environment (DPIE);
- State Emergency Service;
- Sydney Water;
- Bureau of Meteorology;
- Greater Sydney Local Land Services;
- Water NSW;
- Transport for NSW
- Infrastructure NSW;
- Endeavour Energy;
- Penrith Valley Chamber of Commerce; and
- Deerubbin Local Aboriginal Land Council

Letters or emails were distributed to each of the above agencies during the initial stages of the project advertising the commencement of the project and seeking feedback on particular issues that each agency would like investigated as part of the study. Key outcomes of the stakeholder consultation are provided below.

3.2.1 Council Engineers

The Development Engineers noted the following flood related issues in the Little Creek catchment that require review or consideration during the floodplain risk management study:

- Flood planning areas applicable to overland flooding, and appropriate freeboards. The relationship between freeboards applied within a flood planning area of mainstream flooding, and freeboards applied within the flood panning area of overland flow flooding need to be carefully considered. The 0.5m freeboard applied to a mainstream flood level is not always practical or suitable to be applied to overland flow flooding.
- There have been a number of development applications for more vulnerable developments, such as boarding houses, in areas immediately adjacent to, or just inside the flood planning area. Council needs clearer and more definitive flood related development controls for these types of developments, particularly where evacuation during flood events is already an issue.
- The current types of development in this catchment – particularly infill via knock down and rebuild, have the potential to redirect surface water flows and there are minimal current planning controls. Council require all overland flowpaths to be clearly mapped,

and areas required for surface water conveyance, and surface water storage to be identified. Suitable planning controls that would enshrine these flowpaths so that they are considered for all types of development should also be developed so council can implement them into the current suite of flood related planning controls.

- Appropriate development controls for both overland and mainstream flooding are required, with a clear and concise definition of each flooding type and mapping (or the like) that indicates where these controls apply.
- Appropriate development controls are required for applicable development and land use types that are located on land between the flood prone land extent and the flood planning area.

3.2.2 Council Planners

Council's Planner noted the following flood related issues in the Little Creek catchment:

- The State Government has indicated the proposed "north south rail" link from the new Sydney airport to the south west of this area is likely to extend into this catchment. A freight terminal is also proposed within this catchment.
- There is currently a lot of infill type developments being undertaken in the Little Creek catchment. From a planning perspective, if overland flowpaths are not clearly defined, this infill development could be occurring in locations where overland flowpaths occur, therefore, potentially redirecting overland flows onto neighboring properties.
- Hawkesbury-Nepean Valley Regional Flood study (2019) indicated this area could be impacted by flooding from the Hawkesbury Nepean River. This will need to be taken into consideration during this study.
- Council have undertaken two floodplain risk management studies recently that both provide a review and recommendations for flood related development controls. Council will consider all recommendations that come from all the different floodplain risk management studies. Therefore, there was no need for the recommendations included as part of the previous studies to be considered and or influence any planning recommendations arising from the current study.
- Council is intending to update the LEP and the DCP in the near future, so planning recommendations from the FRMS&P will be taken into consideration during that process as well.

3.2.3 Department of Planning, Industry and Environment (DPIE)

A representative from the Department's Environment, Energy and Science Group provides advice to Council in considering the best practice floodplain management principles and the Department's guidelines during the development of the study.

3.2.4 State Emergency Service (SES)

A representative from that State Emergency Service (SES) raised a number of issues for consideration during this study. The SES Hazard Planning Unit also provided information on the history of Requests for Assistance received during the period 2014 – 2017. The information shows that:

- Evacuation along flood prone roads is an issue in this catchment. SES are currently updating their evacuation planning though this catchment based on sectors.

- SES have provided formal comments to Council on recent planning proposals where evacuation in or around flood prone roads is an area of concern. The increasing densities in these areas, where the site itself may not be flood prone, but the access roads become inundated during a flood event, are a concern to the SES.
- Glossop Street is an important evacuation route.

3.2.5 Sydney Water

Sydney Water have indicated they have one sewer pump station within the catchment. It is located just off Lee Holm Drive, St Mary's.

3.2.6 Infrastructure NSW

Infrastructure NSW have undertaken the Hawkesbury Nepean Valley Regional Flood Study (2019). At this point in time, Infrastructure NSW have indicated they do not have any additional information related to flooding that would assist this floodplain risk management study.

3.2.7 Endeavour Energy

Endeavour Energy have indicated there are 2 significant assets in the study area which are shown in **Figure 4** and include:

- St Marys Zone Substation located at 95 Bennett Toad, St Marys
- Former Distribution Substation located at 3a Anne Street, St Marys.

Endeavour Energy's former distribution substation site at 3A Anne Street St Marys no longer has any 'in-service' electricity infrastructure. The site has been identified as surplus to future network requirements.

Endeavour Energy have indicated that the St Marys Substation is not expected to be significantly directly affected in a flood event, maintaining road access to the site is the primary focus of flood mitigation for this asset. Maintaining road access to the site that allows for electricity supply to be maintained for a longer period and quicker restoration of supply is regarded by Endeavour Energy as being a significant factor in mitigating the risks to the electricity distribution network.

Endeavor Energy have a 'Flood Response Plan' for all of their assets that is based on a substation prioritisation ranking, comprised of flood risk and damage potential to focus the flood response efforts toward areas and resources in order of highest importance. It includes details of the flood levels giving an indication of accessibility prior to floods closing roads, rather than the heights at which electricity mains and substation are inundated. However, a review of Endeavor Energy assets within the Little Creek catchment indicates that they are located clear of the floodplain. Therefore, inclusion of these assets within the Flood Response Plan is not considered necessary.

Endeavor Energy have also indicated there are technical specifications for design, construction and commissioning based on a risk assessment framework. Flooding and flood impacts are included in this risk assessment framework. The design principles for the location of electricity infrastructure are based on the 1% AEP flood level, with the framework, recognising that floods up to the Probable Maximum Flood (PMF) may occur and the asset may experience flood damage.

4 THE EXISTING FLOOD RISK

4.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is first important to understand the nature and extent of the existing flood risk. This is typically achieved through the preparation of a flood study, which provides information on key flood characteristics (including flood depths, levels, velocities, flood hazard and hydraulic categories) for a range of floods up to and including the probable maximum flood. Penrith City Council commissioned the 'Little Creek Catchment Overland Flow Flood Study' (WMAwater, 2017) to fulfil this requirement. An overview of the outcomes of the flood study are provided in Section 2.6.3.

Further information on the flood study and the associated outputs that were used to describe the existing flood risk are provided in the following sections. It also describes the nature and extent of the potential future flood risk by quantifying the potential impacts that climate change as well as future catchment development may have on flood behaviour.

4.2 Existing Flood Behaviour

4.2.1 Overview

The *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017) was undertaken on behalf of Penrith City Council to define design flood behaviour across the Little Creek catchment for a range of design floods.

The 2017 flood study used DRAINS to simulate the hydrological characteristics of the catchment, and TUFLOW to define the hydraulic processes across the study area. The 0.5 EY, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design flood events were simulated and mapped. Preliminary flood hazard and hydraulic category maps were also prepared. The study also identified "flooding hot-spots" and preliminary flood mitigation options.

The DRAINS and TUFLOW models were reviewed as part of the current study and were found to have been developed in accordance with modern best practice. As a result, the outcomes generated by the model are considered to provide a reliable description of existing flood behaviour at the time the study was completed.

However, since the flood study was completed in 2017, there have been some localised changes in catchment conditions that may impact on flood behaviour (increase in development density, e.g., new townhouse style developments). Therefore, it was considered necessary to update the TUFLOW model to include these new developments to ensure it provided the best possible representation of contemporary flood behaviour.

In addition, a revised flood estimation guideline was released after publication of the flood study. The guideline is referred to as *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Ball et al, 2019) and aims to provide improved estimates of flood behaviour. Accordingly, it was considered prudent to apply the updated flood estimation procedures across the Little Creek catchment.

Further discussion on the model updates that were completed, and the outcomes of the revised design flood simulations are presented in the following sections.

4.2.2 Flood Model Updates

The flood study hydraulic model utilised a range of datasets to represent the variation in topography in the TUFLOW model. However, LiDAR that was collected in 2011 served as the primary topographic input for the model.

However, since the completion of the flood study additional development has occurred that was not represented in the flood study model. This includes redevelopment in some areas of the catchment (e.g., low density residential buildings being replaced by townhouses).

To ensure the TUFLOW model provided the best possible representation of contemporary catchment conditions, a revised digital elevation model (DEM) was developed based upon LiDAR that was collected in 2019. Material updates were also completed to reflect changes in hydraulic roughness across the catchment. A comparison between the DEM used in this study and the DEM used in the 2017 flood study is indicated in **Plate 4**.

Plate 4 shows terrain differences across most of the catchment. However, the differences are most commonly no greater than ±0.1 metres. The most significant terrain differences (i.e., greater than 0.5 metres) are predicted near Lee Holm Road. A review of this area indicates that the elevation changes are related to material stockpiles that have been modified across the site over time (i.e., the stockpiles are continuously modified, so these differences are to be expected). In all instances, the more significant changes in terrain elevations are associated with new development and can be explained.

4.2.3 Australian Rainfall & Runoff 2019

Flood Behaviour across the Penrith City Council LGA for the past three decades has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia). This included the '*Little Creek Overland Flow Flood Study'* (WMA Water, 2017).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016). This guideline was further refined and released in 2019 (herein referred to as ARR2019). The 2019 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Geoscience Australia, 2019) is considered to reflect modern best practice for flood estimation.

As outlined in the previous section, several updates were completed to the TUFLOW model as part of the study to ensure it reflected contemporary catchment conditions. Therefore, it was necessary to rerun the TUFLOW model to re-define existing flood behaviour across the catchment. As the model already needed to be re-run it was considered worthwhile applying the revised ARR2019 procedures to ensure the flood estimation techniques reflected modern best practice. Accordingly, the results that are presented in the following sections reflect the updated ARR2019 procedures. Further details on how the ARR2019 assessment was completed as part of the study is provided in **Appendix J**.

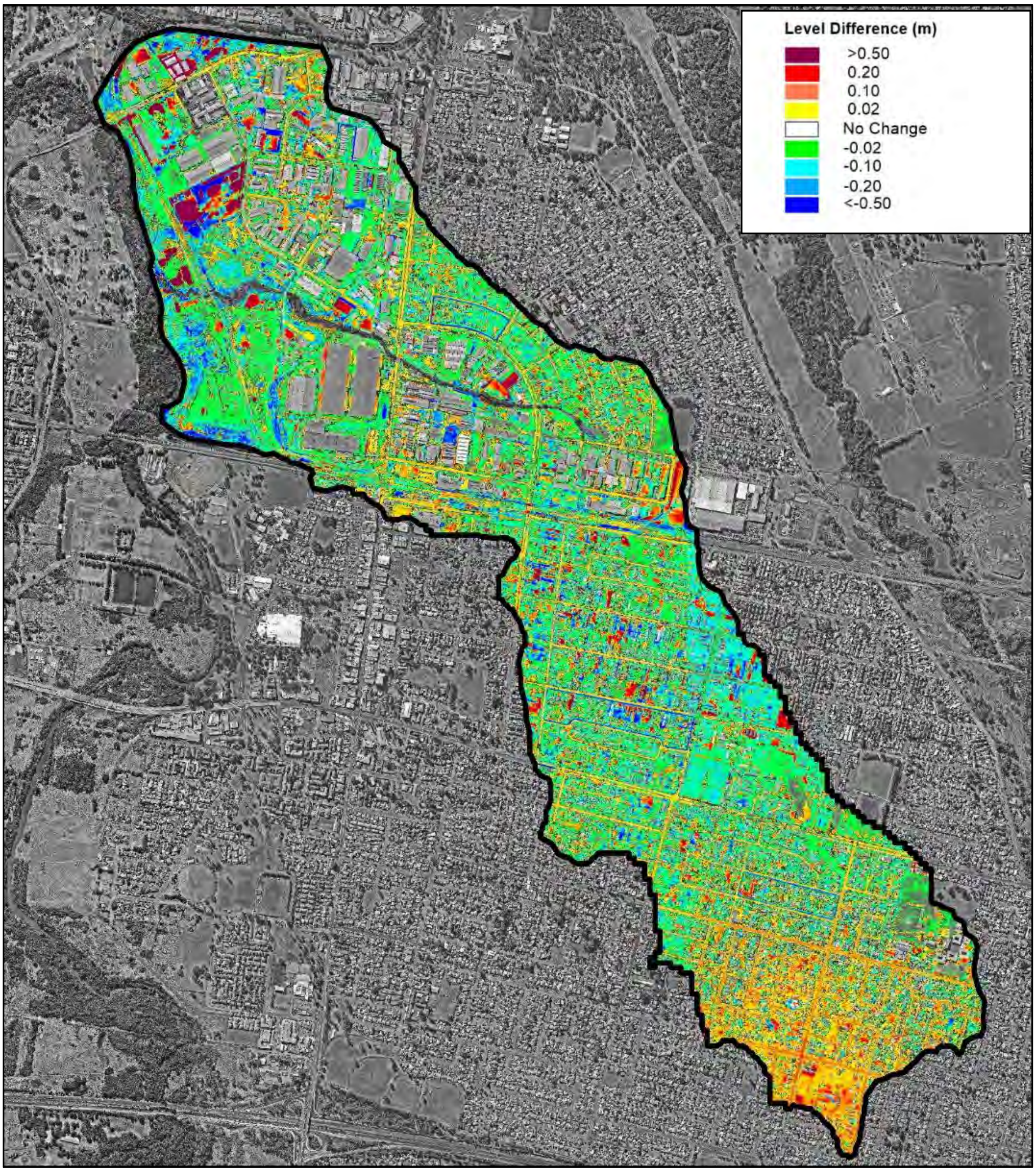


Plate 4 Difference between 2019 DEM used in this study and DEM used in the 2017 flood study.

4.2.4 Design Rainfall Depths

Design rainfall depths for the Little Creek catchment are provided in **Table 7**. The results from the revised ARR2019 flood modelling indicates that rainfall over a 15 minute to 60 minute period typically produced the worst case flooding across the study area (highlighted in blue in **Table 7**).

Table 7 Design Rainfall Depths (ARR2019)

DURATION	Average Rainfall Depth (mm)								
	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMP
10 min	13.8	17.4	20.8	24.2	28.8	32.3	35	39.5	N/A
15 min	17.2	21.7	26	30.3	36	40.5	43.8	49.5	N/A
20 min	19.7	24.9	29.8	34.7	41.2	46.3	50.1	56.7	N/A
25 mins	21.6	27.2	32.6	37.9	45.1	50.6	54.9	62.2	N/A
30 min	23.2	29.1	34.9	40.5	48.2	54.2	58.8	66.6	230
45 min	26.7	33.3	39.8	46.2	54.9	61.8	67.2	76.2	291
1 hour	29.3	36.3	43.3	50.2	59.7	67.3	73.2	82.9	339
1.5 hour	33.2	40.8	48.5	56.2	66.9	75.5	82.1	93.0	387
2 hours	36.3	44.3	52.6	61	72.8	82.2	89.3	101	432
3 hours	41.5	50.3	59.7	69.2	82.7	93.6	101	115	485
4.5 hours	47.9	57.9	68.7	79.9	95.6	108	117	132	N/A
6 hours	53.3	64.7	76.8	89.5	107	122	131	148	605
9 hours	62.8	76.7	91.3	107	128	145	156	176	N/A
12 hours	70.8	87.1	104	122	147	166	179	202	N/A
24 hours	94.7	120	145	171	206	233	252	286	N/A
48 hours	123	160	196	233	279	315	360	416	N/A
72 hours	138	182	225	268	320	360	404	462	N/A

NOTE: N/A indicates a design rainfall is not available for the nominated storm duration

A comparison between ARR2019 rainfall depths used for the current study and ARR1987 rainfall depths used in the 2017 flood study are provided in **Table 8**. The ARR2019 design rainfall estimates take advantage of an additional 30 years of historic rainfall information and therefore, should provide improved design rainfall estimates. The comparison shows that the ARR2019 rainfall depths are generally higher than the ARR1987 depths for storm durations less than 60 minutes. For storm durations greater than 60 minutes, the ARR1987 rainfall depths are most commonly higher. However, the average difference between the ARR1987 and ARR2019 rainfall depths is only less than minus 1% overall.

4.2.5 Design Discharges

The DRAINS model was used to simulate rainfall-runoff processes for the design 0.5 EY, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP floods based upon ARR2019 hydrology. The PMF was also simulated. The hydrographs from the DRAINS model were subsequently applied to the TUFLOW model to simulate the passage of water across the catchment during each design flood.

Table 8 Comparison between ARR1987 and ARR2019 rainfall depths

Duration (min)	Rainfall Depth (mm)					
	20% AEP		5% AEP		1% AEP	
	ARR1987	ARR2019	ARR1987	ARR2019	ARR1987	ARR2019
10	16.12	17.40	21.17	24.20	27.81	32.30
15	20.18	21.70	26.44	30.30	34.70	40.50
20	23.41	24.90	30.65	34.70	40.19	46.30
25	26.12	27.20	34.18	37.90	44.82	50.60
30	28.47	29.10	37.25	40.50	48.85	54.20
45	34.13	33.30	44.67	46.20	58.58	61.80
60	38.56	36.30	50.46	50.20	66.15	67.30
90	45.43	40.80	59.41	56.20	77.85	75.50
120	50.84	44.30	66.43	61.00	86.96	82.20
180	59.40	50.30	77.45	69.20	101.22	93.60
270	69.31	57.90	90.18	79.90	117.66	108.00
360	77.33	64.70	100.54	89.50	131.10	122.00
540	90.34	76.70	117.54	107.00	153.42	145.00
720	100.93	87.10	131.69	122.00	172.29	166.00
1080	117.94	105.00	155.09	149.00	204.24	203.00
1440	131.45	120.00	174.33	171.00	231.19	233.00
1800	142.63	132.00	190.69	190.00	254.56	258.00
2160	152.09	143.00	204.82	206.00	275.05	280.00
2880	167.21	160.00	227.82	233.00	308.95	315.00

In addition, to maintain consistency with the Flood Study, the use of the Horton (ILSAX) hydrologic model (as opposed to the initial-continuing loss hydrologic model) was maintained. The Horton (ILSAX) method is accepted in the ARR2019 guidelines and discussed in Book 5, Chapter 3" (DRAINS Help Manual, 2019).

Peak discharges were extracted from the results of the TUFLOW modelling at select locations across the catchment and are presented in **Table 9**. Also included in **Table 9** are the corresponding peak design discharges from the 2017 flood study for comparison purposes.

Peak discharges were also extracted at a more comprehensive set of locations (as shown in **Plate 5**) for each design flood and are provided in **Table 10**.

Table 9 Comparison between ARR1987 and ARR2019 design discharges

Location	Peak Discharge (m³/s)					
	20% AEP		5% AEP		1% AEP	
	2017 FS	2020 FRMS	2017 FS	2020 FRMS	2017 FS	2020 FRMS
Carpenter Street	4.67	4.26	6.49	6.22	8.40	8.45
Great Western Highway	8.26	8.01	9.96	9.22	15.1	15.5
Sydney Street	9.13	9.6	13.9	14.5	16.6	16.9
Hobart Street	10.7	10.5	13.6	13.7	15.6	15.8
Glossop Street	12.5	12.3	16.0	16.0	18.9	19.4
Forrester Road	17.3	16.8	24.4	24.3	32.1	33.0
Lee Holm Road	2.79	2.27	3.76	3.63	4.24	3.95

Plate 5 Design Flood Discharge Reporting Locations

Table 10 Peak Design Discharges (m^3/s) at Key Locations

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
2	Patricia Street	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
5	Colyton High School Basin	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
7	Shane St	1.4	2.7	3.3	4.0	6.1	5.9	6.8	8.2	45.9
8	Bennet Rd	3.8	5.3	6.3	6.7	10.3	9.9	10.9	12.7	56.3
11	Great Western Hwy 1	5.1	6.5	7.2	7.5	10.6	11.5	13.8	16.6	70.7
12	Oxley Park Basin	3.0	4.0	6.3	6.8	9.7	11.5	13.2	17.6	90.4
14	Oxley Park Public School	2.5	3.5	4.4	5.2	6.2	9.8	12.5	17.2	96.4
15	Adelaide St	2.6	3.6	4.5	5.3	6.3	10.2	12.6	17.8	100.7
16	Canberra St	3.9	7.2	8.2	9.6	12.3	13.3	13.8	19.4	118.7
24	Brisbane St	4.5	7.6	9.1	10.2	14.6	14.4	15.2	18.5	107.5
25	Thompsons Ave	6.6	9.9	11.6	12.8	16.3	16.4	17.1	19.9	106.3
26	Kenny Ave	7.0	9.9	12.1	13.1	17.4	17.7	18.4	20.5	109.0
27	Hobart St	8.0	12.4	15.5	17.4	20.5	21.2	22.4	24.5	115.3
28	Plasser Cres	8.1	10.5	12.3	13.7	15.8	16.0	16.5	17.1	77.3
29	Kurrajong Rd	8.1	10.5	12.3	13.9	16.3	16.4	17.2	18.3	85.1
30	Glossop St	9.0	12.5	14.0	15.9	18.4	19.4	20.9	22.7	103.7
31	Forrester Rd	8.8	12.0	16.2	19.2	25.9	27.6	30.5	33.2	100.4
32	93 Lee Holm Rd	10.0	15.2	19.8	23.3	29.2	29.6	32.6	36.8	105.7
33	South Creek confluence	10.0	15.2	19.8	23.3	29.2	29.6	32.6	36.8	105.7

4.2.6 Floodwater Depths, Levels and Velocities

Peak floodwater depths, levels and velocities were extracted from the results of the revised modelling for each design flood and are presented in Volume 2:

- Flood depths: **Figures 6** to **14**.
- Flood levels: **Figures 15** to **23**.
- Flow velocities: **Figures 24** to **32**.

Peak flood levels, depths and velocities were also extracted at key locations throughout the catchment and are presented in **Table 11**, **Table 12** and **Table 13** respectively. The location where the results were extracted is shown in **Plate 6**.

It should be noted that the primary objective of the study is to define the nature and extent of the flooding problem across the catchment. Therefore, there is a need to distinguish between areas of significant inundation depths and those areas subject to negligible inundation. In this regard, the design flood results were filtered using the following criteria before inclusion in the flood mapping:

- Water depths less than 0.15 metres were removed; and
- Isolated "puddles" were also removed if they were less than 100m^2.

During the preparation of the flood mapping it was recognised that the lower parts of the Little Creek catchment can be impacted by flooding from South Creek as well as "backwater" flooding from the Hawkesbury-Nepean River system. Flooding from these watercourses was not considered as part of the current study as it has previously been quantified as part of the *'South Creek Floodplain Risk Management Study'* (Advision, 2020) and *'Hawkesbury-Nepean Valley Regional Flood Study'* (WMAwater, 2019). However, to ensure the flood risk is not understated across the lower catchment, inundation extents from these previous studies are provided in **Appendix I** where they extend into the Little Creek catchment. For more detailed information on flooding in the South Creek and Hawkesbury-Nepean catchment, please refer to the above studies.

The results presented in **Figures 6** to **32** shows that:

- The railway line is a significant impediment to flow, with the figures indicating that water ponds on Hobart Street in floods as frequent as the 0.5EY event. This ponding is primarily a result of water needing to "pond" to a significant depth to fully activate the main inlet located on the northern side of Hobart Street (i.e., the stormwater pit capacity is the primary reason for significantly ponding depths during frequent floods).
- Upstream of the railway, flood behaviour across the Little Creek catchment is typically characterised by overland flow along roadways and through properties in events as frequent as the 20% AEP design flood. Overland flows along roadways are estimated to occur in events as frequent as the 0.5EY event in a number of locations.
- For the catchment area located downstream of the railway line, inundation depths are generally shallow across much of the area (i.e., less than 0.3 metres). However, more significant depths are predicted along and immediately adjacent to designated

waterways primarily between Kurrajong Road and Forrester Road and between Forrester Road and the downstream extents of the catchment.

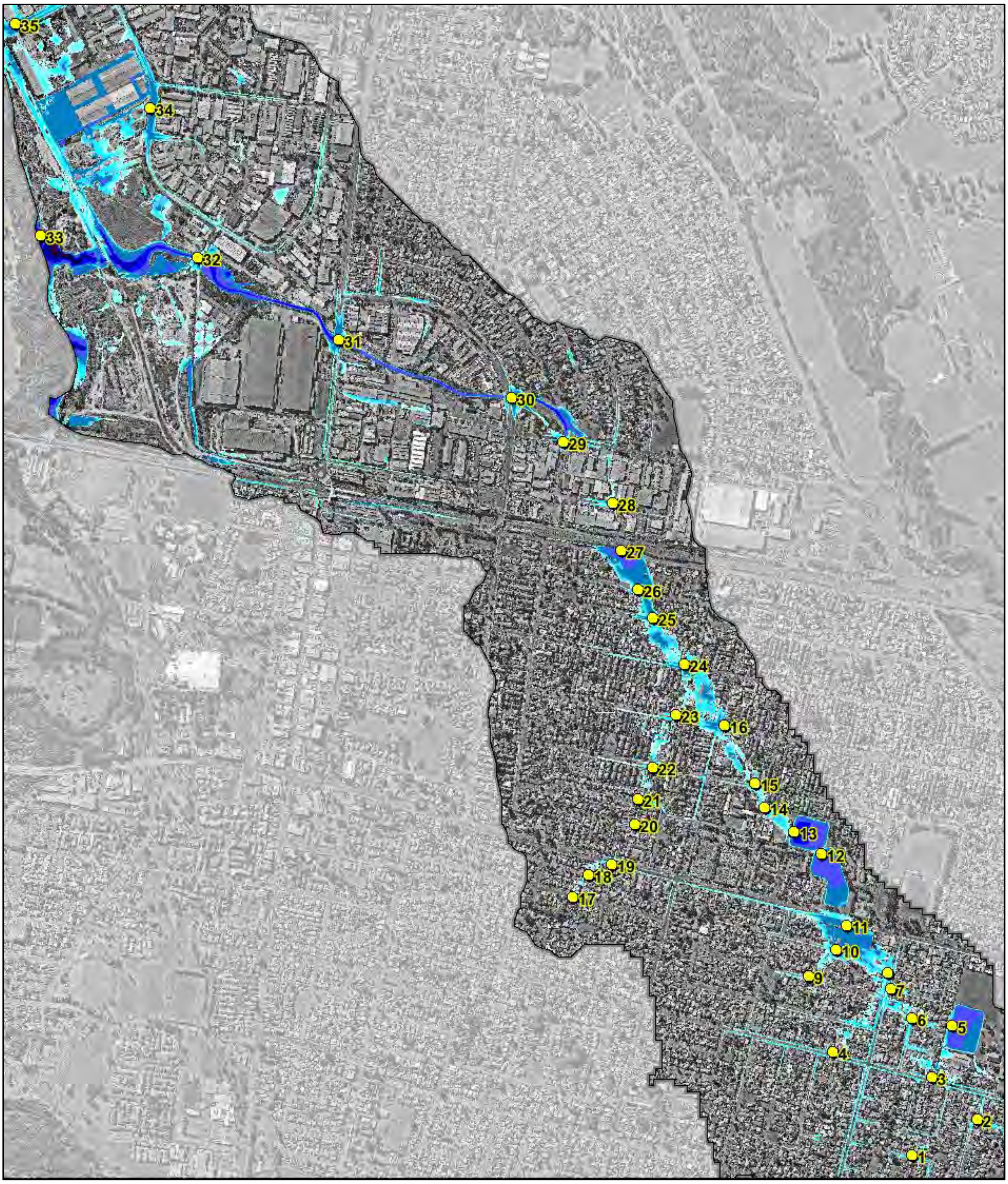


Plate 6 Design Flood Results Reporting Locations

Table 11 Peak Design Flood Levels (mAHD) at Key Locations

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
1	Bentley Road	49.81	50.02	50.06	50.10	50.13	50.15	50.15	50.17	50.21
2	Patricia Street	48.15	48.31	48.34	48.38	48.43	48.45	48.47	48.50	48.61
3	Carpenter St 1	46.33	46.42	46.44	46.48	46.51	46.53	46.55	46.57	46.73
4	Carpenter St 2	47.16	47.20	47.21	47.22	47.23	47.23	47.23	47.24	47.29
5	Colyton High School Basin	45.51	45.64	45.78	45.94	46.14	46.25	46.28	46.32	46.61
6	Kent Pl	45.12	45.25	45.28	45.32	45.38	45.42	45.44	45.48	45.94
7	Shane St	44.38	44.50	44.54	44.60	44.67	44.70	44.72	44.76	45.26
8	Bennet Rd	44.16	44.39	44.45	44.52	44.58	44.61	44.63	44.67	45.14
9	Brooker St	45.23	45.26	45.27	45.28	45.29	45.30	45.31	45.33	45.44
10	Ball Street	43.99	44.02	44.03	44.12	44.28	44.35	44.39	44.45	44.86
11	Great Western Hwy 1	43.69	43.83	43.97	44.12	44.28	44.35	44.38	44.43	44.79
12	Oxley Park Basin 1	41.79	41.87	41.92	41.94	42.01	42.07	42.12	42.19	42.77
13	Oxley Park Basin 2	40.46	40.86	41.24	41.53	41.74	41.76	41.81	41.88	42.36
14	Oxley Park Public School	40.49	40.54	40.57	40.59	40.72	40.76	40.87	41.00	41.96
15	Adelaide St	39.67	39.79	39.83	39.89	40.00	40.04	40.14	40.25	41.30
16	Canberra St	38.77	38.83	38.86	38.89	38.93	38.95	38.96	39.00	40.95
17	Morris St	55.42	55.44	55.46	55.48	55.49	55.49	55.49	55.50	55.54
18	Jacka St	53.27	53.38	53.43	53.46	53.49	53.50	53.51	53.53	53.62
19	Great Western Hwy 2	52.07	52.30	52.52	52.62	52.68	52.71	52.72	52.74	52.82

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
20	Cutler Ave	47.47	47.57	47.63	47.66	47.67	47.71	47.74	47.76	47.87
21	Edmondson Ave	45.39	45.43	45.45	45.47	45.49	45.49	45.50	45.51	45.61
22	Adelaide St 2	42.69	42.72	42.74	42.76	42.77	42.77	42.77	42.78	42.83
23	Canberra St 2	39.28	39.50	39.54	39.56	39.60	39.62	39.63	39.65	40.94
24	Brisbane St	37.63	37.72	37.77	37.85	37.91	37.94	37.97	38.02	40.90
25	Thompsons Ave	36.38	36.48	36.53	36.60	36.66	36.71	36.75	36.81	40.88
26	Kenny Ave	36.06	36.12	36.16	36.21	36.25	36.29	36.43	36.69	40.87
27	Hobart St	34.93	35.14	35.40	35.61	36.02	36.25	36.43	36.69	40.87
28	Plasser Cres	34.64	34.80	34.90	34.95	34.99	35.00	35.03	35.06	36.55
29	Kurrajong Rd	32.15	32.58	32.62	32.65	32.70	32.74	32.76	32.80	33.43
30	Glossop St	31.15	31.19	31.30	31.52	31.71	31.79	31.82	31.87	32.51
31	Forrester Rd	27.90	27.96	28.03	28.13	28.30	28.37	28.45	28.58	29.48
32	93 Lee Holm Rd	24.25	24.46	24.58	24.63	24.69	24.71	24.73	24.75	25.00
33	South Creek confluence	22.60	22.60	22.60	22.60	22.60	22.60	22.60	22.60	22.60
34	Lee Holm Rd	22.81	22.90	22.93	23.00	23.07	23.10	23.13	23.18	23.62
35	Christie St	22.11	22.11	22.11	22.12	22.13	22.13	22.14	22.15	22.41

Table 12 Peak Design Flood Depths (metres) at Key Locations

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
1	Bentley Road	0.32	0.53	0.57	0.61	0.64	0.65	0.66	0.68	0.72
2	Patricia Street	0.41	0.56	0.59	0.64	0.69	0.71	0.73	0.76	0.87
3	Carpenter St 1	0.19	0.28	0.30	0.34	0.37	0.39	0.41	0.43	0.59
4	Carpenter St 2	0.26	0.29	0.31	0.32	0.32	0.32	0.33	0.34	0.39
5	Colyton High School Basin	0.72	0.85	0.99	1.16	1.36	1.47	1.50	1.53	1.82
6	Kent Pl	0.37	0.50	0.53	0.57	0.63	0.67	0.69	0.73	1.19
7	Shane St	0.30	0.42	0.46	0.52	0.59	0.62	0.65	0.69	1.18
8	Bennet Rd	0.05	0.26	0.32	0.39	0.45	0.48	0.50	0.54	1.01
9	Brooker St	0.27	0.30	0.31	0.32	0.33	0.34	0.35	0.37	0.49
10	Ball Street	0.29	0.33	0.34	0.43	0.59	0.66	0.70	0.75	1.16
11	Great Western Hwy 1	0.25	0.38	0.52	0.67	0.83	0.90	0.94	0.99	1.34
12	Oxley Park Basin 1	1.35	1.42	1.47	1.49	1.56	1.62	1.67	1.74	2.32
13	Oxley Park Basin 2	1.16	1.55	1.94	2.23	2.44	2.46	2.51	2.57	3.06
14	Oxley Park Public School	0.26	0.31	0.33	0.36	0.49	0.53	0.63	0.77	1.73
15	Adelaide St	0.11	0.16	0.19	0.24	0.35	0.40	0.49	0.61	1.65
16	Canberra St	0.46	0.52	0.55	0.58	0.62	0.64	0.65	0.69	2.64
17	Morris St	0.35	0.37	0.39	0.41	0.42	0.41	0.42	0.43	0.47
18	Jacka St	0.34	0.44	0.49	0.52	0.55	0.56	0.57	0.59	0.68
19	Great Western Hwy 2	0.02	0.20	0.42	0.52	0.58	0.61	0.62	0.64	0.72

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
20	Cutler Ave	0.05	0.15	0.21	0.23	0.25	0.28	0.31	0.34	0.44
21	Edmondson Ave	0.51	0.56	0.58	0.60	0.61	0.62	0.62	0.63	0.73
22	Adelaide St 2	0.40	0.43	0.45	0.47	0.48	0.48	0.48	0.49	0.54
23	Canberra St 2	0.03	0.25	0.29	0.32	0.36	0.37	0.38	0.40	1.69
24	Brisbane St	0.33	0.41	0.47	0.54	0.61	0.64	0.67	0.71	3.60
25	Thompsons Ave	0.49	0.58	0.64	0.71	0.77	0.82	0.86	0.92	4.98
26	Kenny Ave	0.50	0.56	0.61	0.65	0.70	0.73	0.88	1.14	5.32
27	Hobart St	0.45	0.65	0.91	1.12	1.54	1.76	1.94	2.20	6.38
28	Plasser Cres	0.29	0.44	0.54	0.59	0.63	0.65	0.67	0.71	2.19
29	Kurrajong Rd	0.00	0.42	0.46	0.49	0.55	0.58	0.60	0.64	1.27
30	Glossop St	0.13	0.16	0.28	0.50	0.68	0.77	0.80	0.85	1.49
31	Forrester Rd	0.16	0.23	0.30	0.40	0.56	0.63	0.72	0.84	1.74
32	93 Lee Holm Rd	0.07	0.28	0.40	0.45	0.52	0.54	0.55	0.58	0.82
33	South Creek confluence	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.40
34	Lee Holm Rd	0.52	0.60	0.64	0.71	0.77	0.81	0.84	0.88	1.32
35	Christie St	0.91	0.91	0.92	0.92	0.93	0.94	0.94	0.95	1.22

Table 13 Peak Design Flow Velocities (m/s) at Key Locations

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
1	Bentley Road	0.33	0.51	0.52	0.53	0.54	0.54	0.54	0.55	0.54
2	Patricia Street	0.31	0.41	0.44	0.46	0.48	0.46	0.53	0.51	0.57
3	Carpenter St 1	0.95	0.95	0.94	0.95	0.94	0.92	0.92	1.02	1.24
4	Carpenter St 2	0.54	0.59	0.61	0.63	0.66	0.65	0.67	0.73	0.96
5	Colyton High School Basin	0.03	0.04	0.04	0.04	0.04	0.05	0.06	0.08	0.21
6	Kent Pl	0.64	0.72	0.69	0.70	0.75	0.70	0.70	0.70	0.67
7	Shane St	0.13	0.14	0.16	0.18	0.20	0.17	0.18	0.19	0.32
8	Bennet Rd	0.11	0.38	0.44	0.52	0.70	0.77	0.85	0.97	1.37
9	Brooker St	0.31	0.38	0.42	0.44	0.44	0.43	0.43	0.43	0.67
10	Ball Street	0.21	0.25	0.28	0.32	0.32	0.32	0.33	0.34	0.41
11	Great Western Hwy 1	0.03	0.06	0.10	0.13	0.18	0.23	0.26	0.31	0.75
12	Oxley Park Basin 1	0.23	0.19	0.19	0.20	0.21	0.21	0.25	0.30	0.75
13	Oxley Park Basin 2	0.19	0.20	0.20	0.20	0.20	0.24	0.28	0.34	0.71
14	Oxley Park Public School	0.25	0.26	0.30	0.34	0.38	0.52	0.52	0.68	1.38
15	Adelaide St	0.26	0.33	0.32	0.34	0.31	0.35	0.46	0.60	1.16
16	Canberra St	0.25	0.25	0.28	0.29	0.32	0.29	0.31	0.36	1.23
17	Morris St	0.26	0.27	0.29	0.30	0.32	0.31	0.32	0.34	0.39
18	Jacka St	0.22	0.26	0.26	0.29	0.33	0.33	0.30	0.29	0.32
19	Great Western Hwy 2	0.17	0.20	0.25	0.28	0.30	0.27	0.27	0.29	0.39

#	Location	0.5EY	20% AEP	10% AEP	5% AEP	2% AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
20	Cutler Ave	0.27	0.59	0.93	0.99	1.09	1.28	1.44	1.57	1.75
21	Edmondson Ave	0.31	0.37	0.40	0.42	0.44	0.43	0.44	0.44	0.45
22	Adelaide St 2	0.22	0.38	0.51	0.55	0.60	0.61	0.62	0.65	0.76
23	Canberra St 2	0.19	0.70	0.84	0.93	1.08	1.13	1.18	1.22	1.55
24	Brisbane St	0.47	0.56	0.63	0.68	0.77	0.80	0.84	0.90	1.53
25	Thompsons Ave	0.63	0.70	0.73	0.76	0.76	0.76	0.77	0.79	0.99
26	Kenny Ave	0.62	0.69	0.74	0.86	0.95	0.99	1.04	1.11	1.24
27	Hobart St	0.41	0.58	0.62	0.63	0.50	0.48	0.46	0.47	0.37
28	Plasser Cres	0.10	0.16	0.17	0.16	0.18	0.18	0.19	0.22	1.12
29	Kurrajong Rd	0.12	0.14	0.17	0.21	0.23	0.18	0.19	0.21	0.65
30	Glossop St	0.65	0.62	0.64	0.67	0.65	0.67	0.69	0.69	0.89
31	Forrester Rd	0.38	0.49	0.77	0.93	1.16	1.23	1.32	1.43	2.41
32	93 Lee Holm Rd	0.24	1.04	1.13	1.20	1.31	1.38	1.45	1.56	2.26
33	South Creek confluence	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.22
34	Lee Holm Rd	0.10	0.15	0.17	0.19	0.21	0.22	0.24	0.26	0.31
35	Christie St	0.01	0.02	0.02	0.03	0.04	0.08	0.13	0.14	0.20

- During the 10% AEP design flood event (refer **Figure 8**), floodwater depths are estimated to exceed 0.3 metres on several roadways, including:
  - Patricia Street, Colyton.
  - Thompson Avenue, St Marys.
  - Kenny Avenue, St Marys.
  - Intersection of Canberra Street and Sydney Street, St Marys.
  - Plasser Crescent and the intersection of Kurrajong Road and Plasser Crescent, St Marys.

  The depth in Hobart Street (immediately upstream of the railway line) is estimated to exceed 0.7 metres and in Lee Holm Drive flood water depths are estimated to exceed 0.6 metres during the 10% AEP design flood event. The floodwater depths on Christie Street, St Marys are expected to exceed 0.8 metres.
- During the 1% AEP design flood event (refer **Figure 11**), floodwater depths are estimated to exceed 0.5 metres on several roadways, including:
  - Patricia Street, Colyton.
  - Bentley Road Colyton.
  - Bent Street, St Marys.
  - Intersection of Shane street and Bennett Road Colyton.
  - Thompson Avenue, St Marys.
  - Kenny Avenue, St Marys.
  - Intersection of Canberra Street and Sydney Street, St Marys.
  - Plasser Crescent and the intersection of Kurrajong Road and Plasser Crescent, St Marys.

  The depths in Hobart Street and Forrester Road are estimated to exceed 0.7 metres. In Lee Holm Drive, flood water depths are estimated to exceed 0.9 metres, with the floodwater depths on Christie Street, St Marys estimated to exceed 1.0 metres. Water depths on the Great Western Highway are predicted to exceed 0.8 metres between Whitcroft Place and Woodland Avenue.
- During the PMF (refer **Figure 14**), overland water depths are predicted to exceed 1 metre at a number of locations, including:
  - Kent Place, Colyton.
  - Patricia Street, Colyton.
  - Bentley Road Colyton.
  - Shane street, Colyton.
  - Bennett Road, Colyton.
  - Bent Street, St Marys.
  - Adelaide Street, St Marys.
  - Canberra Street, St Marys.
  - the intersection of Kurrajong Road and Plasser Crescent, St Marys.

- Of a major concern are the floodwater depths in Hobart Street (immediately upstream of the railway line), which are predicted to exceed 6 metres in the PMF. Significant water depths are also predicted within the following streets during the PMF:
    - 5 metres in Kenny Avenue.
    - 4.9 metres in Thompson Avenue.
    - 3.5 metres in Brisbane Street.
    - 2.5 metres at the intersection between Sydney Street and Canberra Street.
    - Greater than 2 metres in Plasser Crescent.
    - 1.2 metres on the Great Western Highway between Whitcroft Place and Woodland Avenue.

Impacts of Revised Flood Modelling

Flood level difference mapping was prepared to quantify the differences between the revised flood modelling results and the results produced as part of the 2017 flood study. The flood level difference mapping is provided in **Plate 7**, **Plate 8** and **Plate 9** for the 5% AEP and 1% AEP floods as well as the PMF.

The flood level difference mapping shows localised increases and decreases in flood levels relative to the 2017 flood study. Across roads and shallow overland flow paths, the revised flood levels are generally higher (primarily associated with the higher rainfall depths for shorter storms under ARR2019). In volume sensitive areas, such as detention basins, the revised flood levels are typically lower than the 2017 flood study. This is associated with the critical ARR2019 storm durations being shorter relative to the ARR1987 design storms which results in less runoff volume. Some notable differences are also observed across the industrial areas in the lower parts of the catchment, which are driven by the development changes in this area that have occurred since the 2017 flood study was completed.

Overall, the revised flood modelling results are considered to provide an improved description of contemporary flood behaviour across the Little Creek catchment that is based on the most recent topographic information and hydrologic procedures.

4.2.7 Inundated Properties

The number of properties inundated during each design flood was also determined. This information is summarised in **Table 14** (there are 2,716 properties contained within the study area). The information presented in **Table 14** indicates that 12% of properties located within the catchment will be at least partly inundated to a depth of at least 0.15 metres at the peak of the 1% AEP flood. This is predicted to increase to nearly 30% during the PMF. Accordingly, major flooding has the potential to impact a significant number of properties within the catchment.

4.2.8 Flood Hazard Categories

Flood hazard defines the potential impact that flooding will have on development and people across different sections of the floodplain. More specifically, it describes the potential for floodwaters to cause damage to property or loss of life (AIDR, 2014).

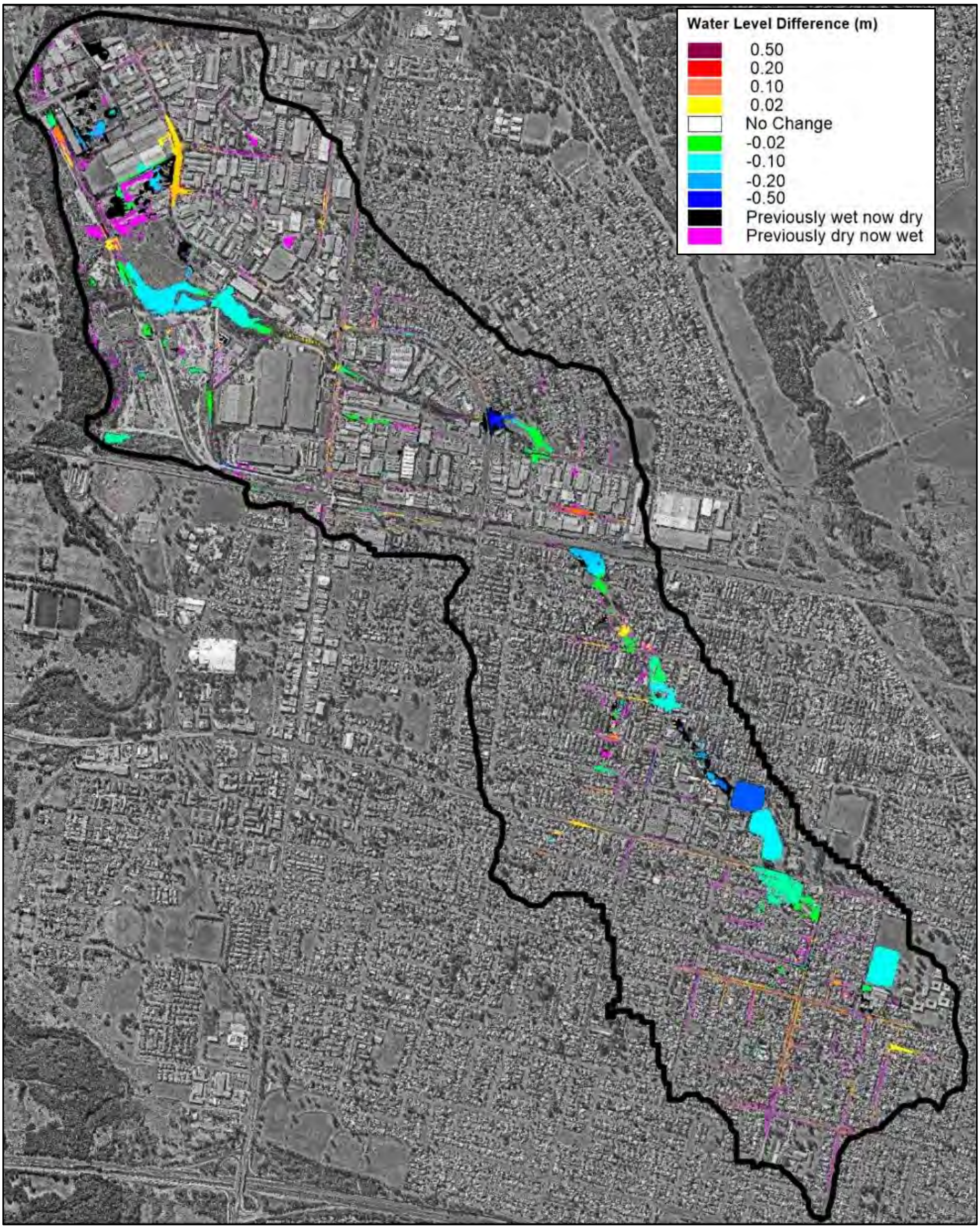


Plate 7 Flood level differences between current study and 2017 flood study for the 5% AEP design flood

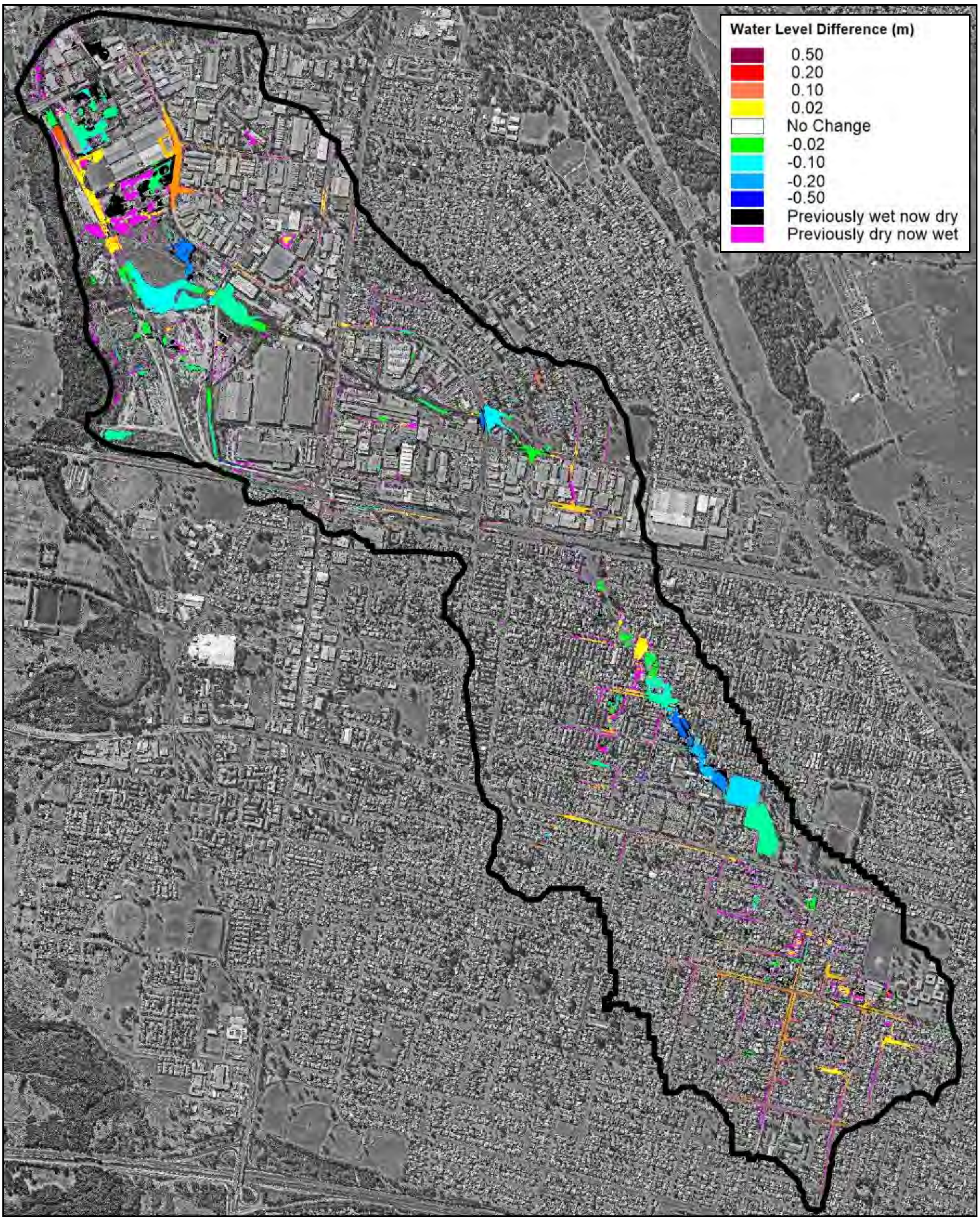


Plate 8 Flood level differences between current study and 2017 flood study for the 1% AEP design flood

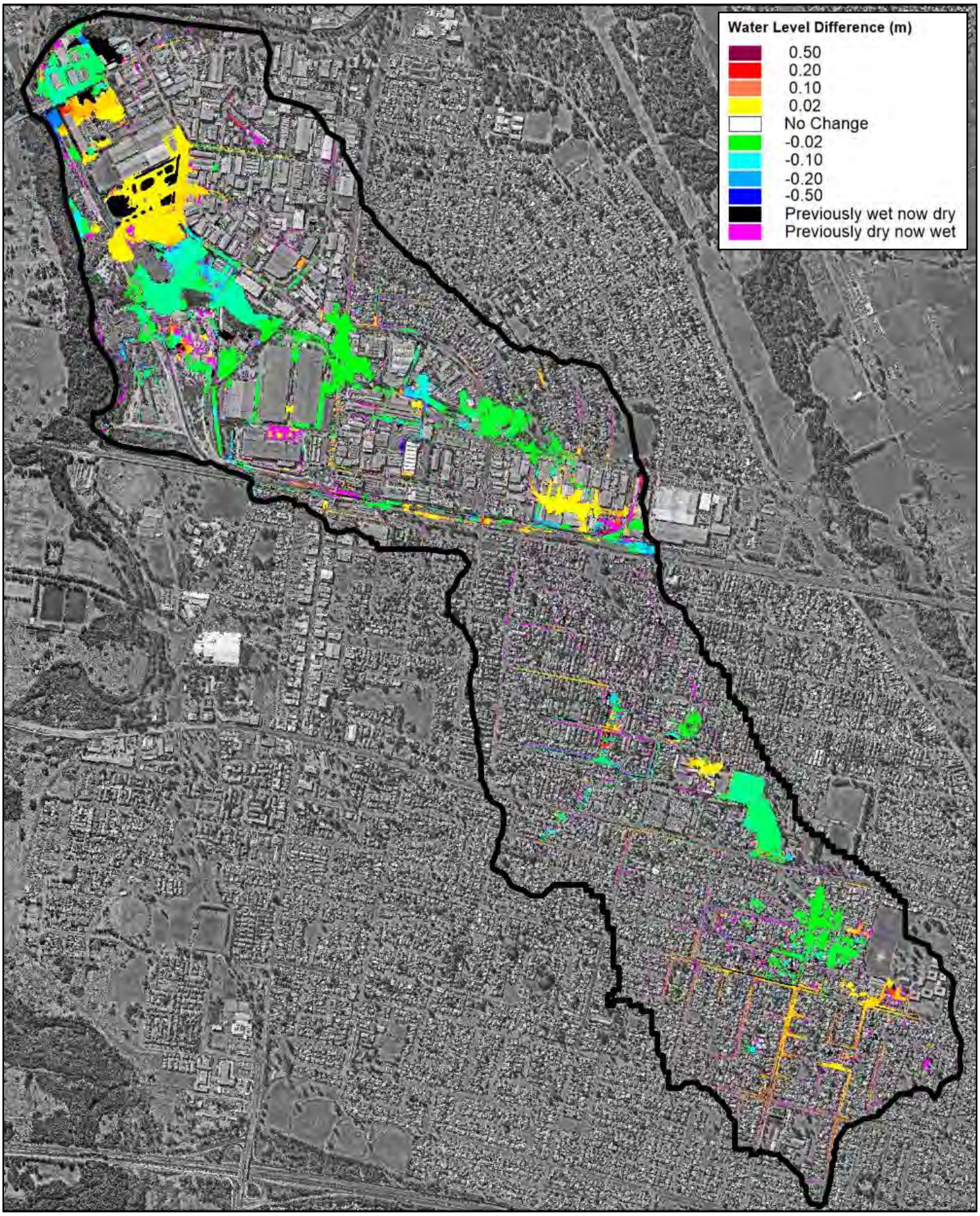


Plate 9 Flood level differences between current study and 2017 flood study for the PMF

Table 14 Number of Inundated Properties

Event	Number of Inundated Properties	Percentage of Total Number of Properties
0.5EY	92	3%
20% AEP	157	6%
10% AEP	193	7%
5% AEP	231	9%
2% AEP	290	11%
1% AEP	313	12%
0.5% AEP	331	12%
0.2% AEP	385	14%
PMF	762	28%

Since the preparation of the flood study, revised flood hazard categories were published in Chapter 7 of Book 6 of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Geoscience Australia, 2019). The hazard curves from this document are reproduced in **Plate 10** and are also described in **Table 15**. As shown in **Plate 10**, the hazard curves assess the potential vulnerability of people (for differing physical abilities), cars and structures based upon the depth and velocity of floodwaters at a particular location. Accordingly, this guideline is considered to provide a good representation of the variety of potential flood hazards that could be experienced in the Little Creek catchment. The resulting hazard maps for the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP as well as the PMF are shown in **Figures 33** to **37** inclusive.

The mapping indicates that the high hazard areas typically coincide with the defined waterway in the areas downstream of the railway line. In the areas upstream of the railway line, the hazard category mapping reflects the overland flow path associated with the general alignment of the historical creek line that has now been developed over.

During the 5% AEP design flood event, Hobart Street is estimated to experience flood hazards up to H3 immediately upstream of the railway line, with small sections of Kenny Avenue, Thompson Avenue, Brisbane Street and Canberra Street also expected to experience flood hazards up to H3. The open space area immediately upstream of the Great Western Highway is estimated to experience flood hazards up to H3, which extends out into some of the residential properties fronting the Great Western Highway. H2 hazard would also extend across the Great Western Highway indicating it would not be safe for vehicles.

Very few habitable areas are predicted to be exposed to a significant flood hazard during events up to and including the 1% AEP event. Nevertheless, several roadways (including the Great Western Highway) are predicted to be unsafe for vehicles at the peak of the 1% AEP design flood event. Sections of Hobart Street are estimated to experience flood hazards up to H4 immediately upstream of the railway line. Sections of Kenny Avenue, Thompson Avenue, Brisbane Street and Canberra Street also expected to experience flood hazards up to H3. The extent of areas impacted by the H3 hazard increase from the 5% AEP design flood event along each roadway.

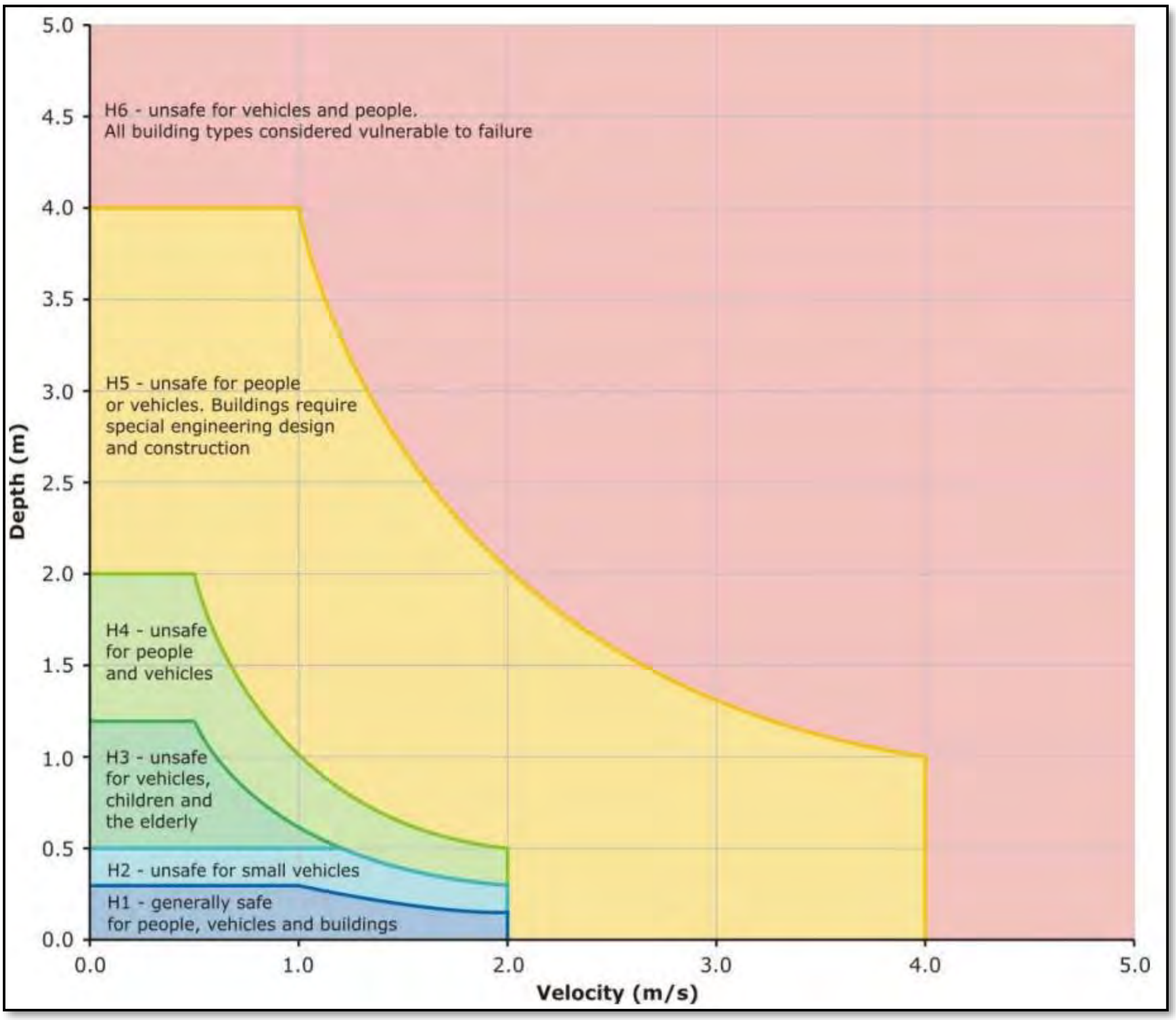


Plate 10 Flood Hazard Vulnerability Curves (Geoscience Australia, 2019)

Table 15 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.

The hazard gradually increases across the catchment between the 1% AEP and 0.2% AEP and the 0.5% AEP design flood events. The flood hazard across most of the catchment does not exceed H4 during these flood events. However, there is a noticeable "jump" in flood hazard between the 0.2% AEP flood and PMF (refer **Figures 36** and **37**). More specifically, during the PMF, a large area of the floodplain upstream of the railway line is predicted to be exposed to H5 and H6 hazard conditions. Therefore, there is potential for structural damage to buildings and other infrastructure during the PMF. Of particular note are properties located in the following H5 areas:

- Hobart Street between Sydney Street and Australia Street.
- Kenny Avenue between Sydney Street and Australia Street.
- Thompson Avenue between Sydney Street and Australia Street.
- Brisbane Street between Sydney Street and Australia Street.
- Canberra Street between Perth Street and Australia Street.
- West side of Lee Holm Drive.
- Christie Street between Lee Holm Drive and the bridge over South Creek.

4.2.9 Hydraulic Categories

Hydraulic categories highlight areas that should be retained for the conveyance and storage of floodwaters (failure to do so will likely have an adverse impact on existing flood behaviour). They also provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour.

Criteria for defining hydraulic categories across the Little Creek catchment were previously established as part of the *'Little Creek Catchment Overland Flow Flood Study'*. However, as the TUFLOW model was updated to reflect contemporary catchment conditions and revised ARR2019 procedures were also applied, it was necessary to update the hydraulic category mapping to reflect the updated modelling results. The criteria used to define these hydraulic categories was the same criteria that was applied for the 2017 flood study, which are summarised in **Table 16**. The flood study included various analyses to confirm the suitability of these criteria (e.g., encroachment analysis to confirm floodway extents). Therefore, these criteria were considered appropriate for application as part of the current study.

The resulting hydraulic category maps for the 5 %, 1%, 0.5%, 0.2% AEP floods as well as the PMF are shown in **Figures 38** to **42**.

North of the railway line, the hydraulic category maps show that floodways are typically contained in close proximity to the main watercourse during events up to and including the 1% AEP. The industrial area around Anne Street and Lee Holm Drive are also predicted to function as floodways. During the PMF a number of additional roadways would likely function as floodways including parts of Forrester Road, Kurrajong Road, Plasser Crescent and a long section of Lee Holm Road.

Table 16 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Qualitative Description	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	• V x D greater than 0.25 m^2/s AND peak velocity greater than 0.25m/s • OR peak velocity greater than 1.0m/s.
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	• Not floodway and depth greater than or equal to 0.20 m
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows or flood levels.	• Not floodway and depth less than 0.20 m

NOTES: V = Velocity, D = Depth
Hydraulic categories were only applied to areas subject to inundation (i.e., depth greater than 0.15m)
**The adopted criteria were developed specifically for the Little Creek catchment only and may not be appropriate for any other areas.*

South of the railway line, the floodway area is generally aligned with the main trunk stormwater pipe alignment. It also extends through the stormwater detention basins immediately adjacent to the Great Western Highway and along several roadways. However, a number of additional roadways would likely function as floodways at the peak of the PMF including parts of Thompson Avenue, Brisbane Street, Canberra Street, Parkin Road and Sydney Street. This floodway area encompasses a number of existing residential buildings, most notably between Adelaide Street and Hobart Street.

4.2.10 Flood Emergency Response Precincts

In an effort to understand the potential emergency response requirements across different sections of the floodplain, flood emergency response precinct (ERP) classifications were prepared in accordance with the floodplain risk management and SES requirements (AEMI, 2014) following the flow chart shown in **Plate 11** (NSW Government, 2007). The ERP classifications can be used to provide an indication of areas which may be inundated or isolated during floods. This information, in turn, can be used to quantify the type of emergency response that may be required across different sections of the floodplain during future floods. This information can be useful in emergency response planning.

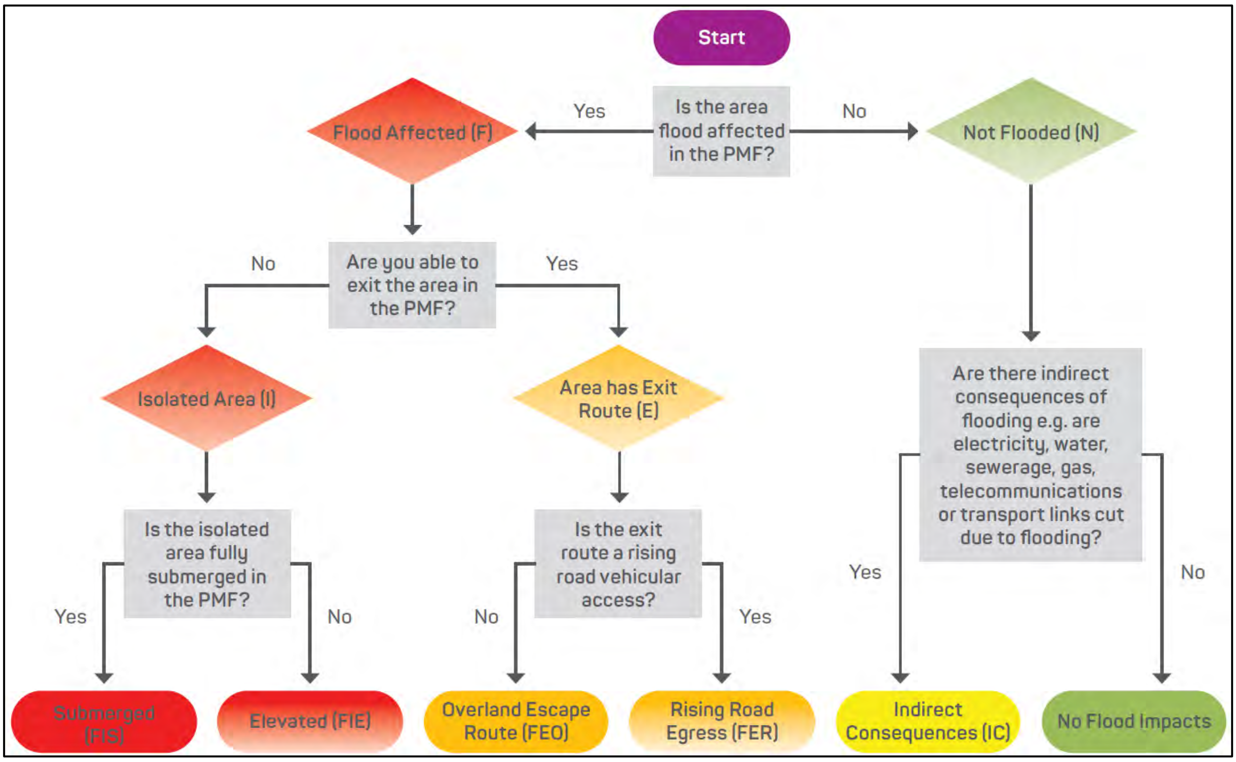


Plate 11 Flow Chart for Determining Flood Emergency Response Classifications (AEMI, 2014).

NOTE: FIS – Flooded, Isolated and Fully Submerged in Design Flood
FIE – Flooded, Isolated with an Area Elevated Above PMF
FEO – Flooded, Exit Route via Overland Escape (vehicular access cut but evacuation on foot may be possible)
FER – Flooded, Exit Route via Rising Road (evacuation routes grade up and away from floodwaters)
IC – Not Flooded, Indirect Consequences (e.g., access cut)

Each lot within the Little Creek catchment was classified based upon the ERP flow chart for the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP floods as well as the PMF. This was completed using the TUFLOW model results, digital elevation model and a road network GIS layer in conjunction with proprietary software that considered the following factors:

- Whether evacuation routes get "cut off" by the depth of inundation (a 0.2 m depth threshold was used to define a "cut" road).
- Whether evacuation routes continuously rise out of the floodplain. This criterion is applied to the nearest cross street or road, assuming it is located outside of the PMF extent (i.e., floodplain).
- Whether properties become flooded. A property is considered "flooded" if more than 5% of the property is inundated by floodwaters. When a property is inundated by less than 5% of the total property area, it was considered to be "elevated".
- Indirect consequences are identified when the property is located completely outside of the flood extent. However, it is impacted by other external factors, such as roadways being cut by water which would prevent access.

The resulting ERP classifications for the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP flood, as well as the PMF, are provided in **Figures 43** to **47** inclusive. A range of other datasets were also generated as part of the classification process to assist Council and the SES. This includes roadway overtopping locations, which are discussed in more detail in **Section 4.3.1**.

Figure 44 shows that during the 1% AEP flood the most common ERP classification is "Flooded with Exit Route Rising Road", which indicates that evacuation routes grade up and out of the floodwaters. The most vulnerable classification is "flood isolated submerged" (i.e. low flood islands), which indicates that the properties are isolated before being inundated. There are a number of "flood isolated submerged" areas scattered through the catchment with the number gradually increasing as the severity of the flood increases. However, the majority of these lots tend to be areas of open space (e.g., adjacent to Hobart Street). There are also a number of areas designated as "flood isolated submerged" which indicates that evacuation routes are likely to be cut during floods, thereby isolating lots even though the lots themselves are not completely inundated. This includes properties fronting Kent Place, Carpenter Street Brooker Street, Ball Street and Adelaide Street.

Figure 45 shows that during the 0.5% AEP flood, the number of properties classified as "flooded isolated elevated" increases relative to the 1% AEP design flood particularly in the industrial areas around Lee Holm Road. The number of "indirectly affected properties" also significantly increases, particularly around the Bennett Road and Carpenter Street area. There are also a significant number of properties classified as "Flooded with Exit Route Rising Road" throughout all areas of the catchment.

Figure 46 shows that during the 0.2% AEP flood, the ERP classification of properties is very similar to that during the 0.5% AEP flood. However, there is less warning time available before roads are cut (this is discussed further in Section 4.3.1). There are also a number of additional properties classified as "flooded isolated submerged" in the downstream areas of the catchment and immediately upstream of the railway line.

Figure 47 shows that during the PMF, there is a large increase in the number of properties classified as "flooded isolated submerged". Many properties have gone from being indirectly affected in the more frequent design flood events, to classified as "flooded isolated elevated" during the PMF. Accordingly, many properties in the catchment may be subject to relatively minor flood-related impacts during more frequent events but could be exposed to a significant risk during larger floods with very limited warning time available.

4.2.11 Flood Detention Basins

The Little Creek catchment includes three formal detention basins. The detention basins attenuate downstream flows during storm events by temporarily storing runoff from the upstream catchment.

Peak design stages within each basin were extracted for each design storm and are provided in **Table 17**. **Table 17** also lists the basin walls elevations (i.e., the level that water would need to reach before overtopping the basin and "spilling" downstream). If a basin is predicted to overtop during a particular event, the corresponding cell in **Table 17** is highlighted in blue.

Table 17 Peak Design Water Levels in Flood Detention Basins

Basin	Basin Wall Elevation (mAHD)	Peak Water Level (m AHD)								
		0.5EY	20% AEP	10% AEP	5%AEP	2%AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
Colyton High School	46.12	45.51	45.64	45.78	45.94	46.14	46.25	46.28	46.32	46.61
Oxley Park (south basin)	41.68	41.79	41.87	41.92	41.94	42.01	42.07	42.12	42.19	42.78
Oxley Park (north basin)	41.64	40.46	40.86	41.24	41.53	41.74	41.76	41.81	41.88	42.35

Peak flow velocities across the basin walls were also extracted. The velocities were extracted to gain an understanding of whether there was potential for scour and failure of the basin walls during large floods in the catchment. This information is presented in **Table 18**. It is noted that all basins comprise grassed embankments with no formal spillways. Information provided in the 'Queensland Urban Drainage Manual' (IPWEA, 2018) suggests that even well vegetated areas are liable to erode once the velocity exceeds 3 m/s. Therefore, overtopping velocities of more than 3 m/s are considered to pose a scour risk and are highlighted in **Table 18**.

The information presented in **Table 17** shows that both the Colyton High School and northern Oxley Park basins have sufficient capacity to contain floodwater during floods up to and including the 5% AEP. However, during the 2% AEP flood, both basins are predicted to overtop. The southern Oxley Park is predicted to overtop during each of the simulated design floods. However, as this basin is located in series with the northern Oxley Park basin, the overall Oxley Park basin system provides sufficient capacity to cater for floods up to and including the 5% AEP flood.

Table 18 shows that peak flow velocities from the Colyton Park basin are not predicted to exceed 0.7m/s during any of the simulated design floods. Therefore, there is minimal potential for scour of the basin wall. Whereas the southern Oxley Park basin is predicted to be exposed to velocities that exceed 3m/s during events equal to and greater than the 0.5% AEP flood and the northern Oxley Park basin is predicted to be exposed to velocities of more than 3.5m/s during the PMF. Therefore, there is potential for scour and failure of the Oxley park basin system during particularly large floods in the catchment. The proximity of the Oxley Park public school to the Oxley Park basin system is a concern should failure of either basin occur, particularly given the school is already subject to H5 hazard during the PMF.

Table 18 Peak Overtopping Velocities for Flood Detention Basins

Basin	Peak Flow Velocity (m/s)								
	0.5EY	20% AEP	10% AEP	5%AEP	2%AEP	1%AEP	0.5% AEP	0.2% AEP	PMF
Colyton High School					0.1	0.3	0.4	0.4	0.7
Oxley Park (south basin)	1.0	1.6	1.9	2.0	2.4	2.8	3.2	3.6	4.2
Oxley Park (north basin)					1.0	1.2	1.4	1.8	3.6

4.2.12 Summary

Flooding across the catchment can be delineated into two main areas (i.e. upstream and downstream of the railway line). The results of the design flood modelling show that flooding across the two areas can be characterised as follows:

- Upstream (i.e., south) of the railway line:
    - Flooding generally occurs as a result of the limited capacity of the underground stormwater piped drainage network. This results in surcharging flows occurring along roadways and through private properties. There are very few formal overland flow routes or easements that these overland flows are conveyed in.
    - Flooding can occur as a result of a variety of different storm durations. However, a storm duration of less than 60 minutes typically produces the worst-case flood conditions across most of the catchment. This is true also for the area located downstream of the railway.
    - Several properties are predicted to be inundated in floods as frequent as the 0.5EY design flood event. However, more extensive inundation is generally restricted to events greater than then 20% AEP flood.
    - Hazardous flooding conditions are predicted through some areas of "open space" during floods as frequent as the 5% AEP event. However, the residential areas are generally not exposed to hazards conditions that exceed H4 during floods up to and including the 0.2% AEP flood. Nevertheless, a significant number of residential properties are predicted to be exposed to H5 and H6 flooding during the PMF event.
- Downstream (i.e., north) of the railway line:
    - Floodwaters are generally contained within the main channel or along roadways for all events up to and including the 0.5% AEP. During the PMF event, water is predicted to overtop the railway line and spills out into a number of properties immediately downstream of the railway line.
    - Higher hazard areas are typically contained within the creek channel and roadways for events up to and including the 0.5 % AEP event. During the PMF event, the industrial properties immediately downstream of the railway line are exposed to more hazardous flooding conditions.

Further detailed discussion on the impact of flooding on transportation routes, vulnerable and critical infrastructure and the cost of flooding within the catchment is provided below.

4.3 Impacts of Flooding on the Community

4.3.1 Transportation Links

There are several major roadways within the Little Creek catchment which may be required for evacuation or emergency services access during floods. It is important to understand the impacts of flooding on these roads so that appropriate emergency response planning can occur.

An assessment of the location where roadways are first predicted to be overtopped was completed as part of the Flood Emergency Response Precinct classifications discussed in **Section 4.2.10**. The roadway overtopping locations are shown as yellow dots in **Figures 43** to **47**. The numbering on the yellow dots relates to the information presented in the Table included in **Appendix C** and includes:

- The amount of time from the initial onset of rainfall until access is cut.
- The amount of time the roadway would be cut.
- The peak water depth.
- The peak flow velocity.

This information is provided for the 0.5EY, 20% AEP, 10% AEP, 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design flood events.

The total number of road segments cut was also calculated and is presented in **Table 19.**

Table 19 Number of Roads Where Access Would be Cut During Each Design Flood

Design Flood	Number of Roads Cut
0.5EY	23
20% AEP	33
10% AEP	43
5% AEP	43
1%AEP	56
0.5% AEP	57
0.2% AEP	59
PMF	67

In addition to the detailed inundation information presented in **Appendix C** for each road in the catchment, road inundation depths for heavily trafficked roads in the Little Creek catchment were also extracted. The location where major roads are predicted to be cut by floodwaters is shown in **Plate 12** and the associated floodwater depths at each location during each design flood are presented in **Table 20**.

The information presented in **Appendix C** indicates that access would be cut along several roadways in events as frequent as the 0.5EY flood. The roadways most susceptible to inundation include:

- Hobart Street;
- Bennett Road;
- Carpenter Street;
- Great Western Highway;
- Sydney Street;
- Brooker Street;
- Glossop Street; and
- Lee Holm Road.

Of particular note is the Great Western Highway which is the most significant vehicular transportation link in the catchment. The results of the design simulation indicate that the west bound travel lanes can be cut in as little as 15 minutes after the initial onset of rainfall and may remain closed for 2 or more hours. Inundation depths of over 0.3 metres are predicted in floods as frequent as the 20% AEP flood while during the 5% AEP flood more than 0.5 metres of water is predicted across the southern half of the highway.

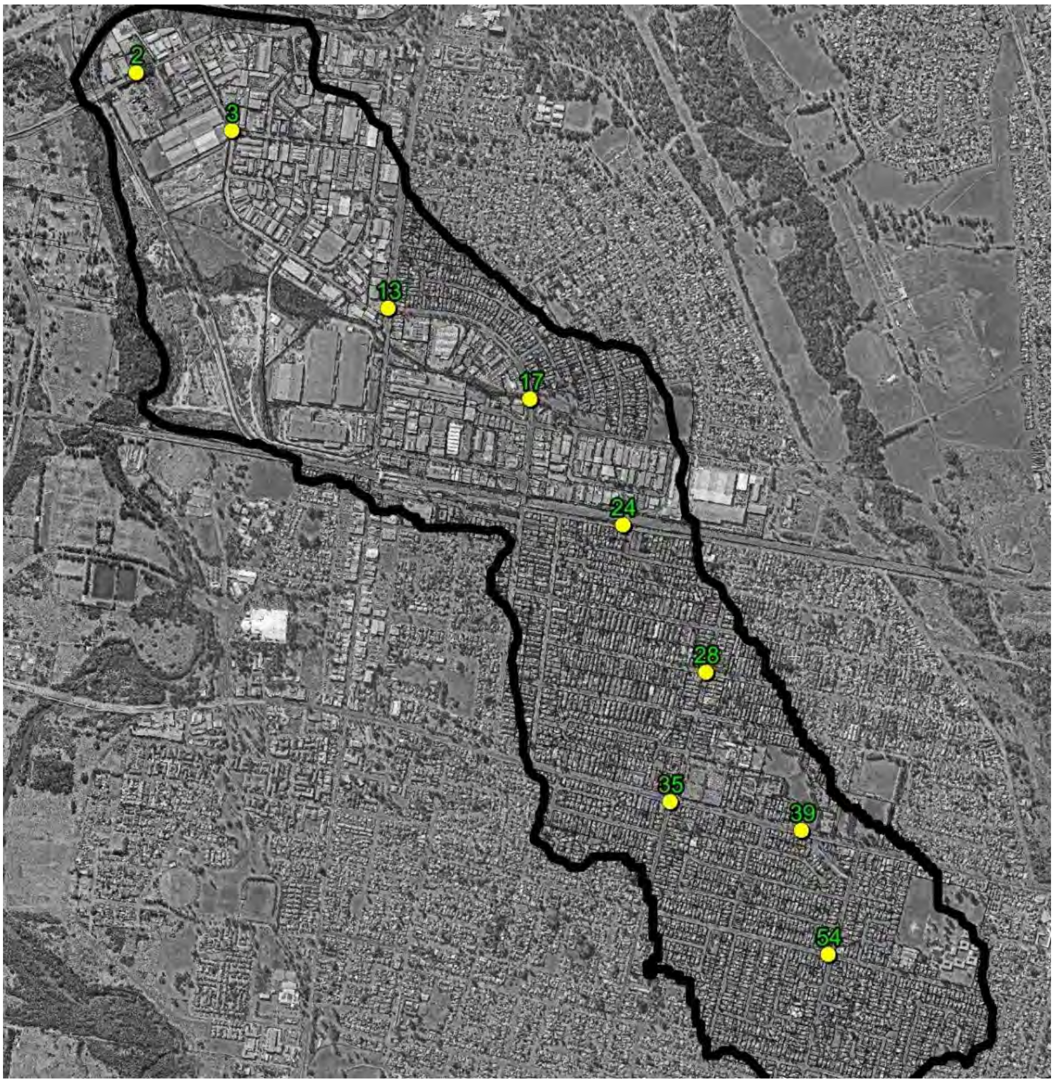


Plate 12 Location of over topping on main road locations in Little Creek catchment

Table 20 Peak depths at road overtopping locations for main roads in Little Creek catchment

Road Overtopping ID*	Road Name	Flood Peak Depth (metres)				
		20% AEP	5% AEP	1% AEP	0.50%	PMF
2	Christie Street	0.34	0.35	0.36	0.37	0.66
3	Lee Holm Drive	0.22	0.32	0.42	0.44	0.93
13	Forrester Road	0.13	0.18	0.21	0.22	0.73
17	Glossop Street	-	-	0.18	0.21	0.89
24	Hobart Street	0.48	0.95	1.60	1.77	6.22
28	Sydney Street	0.36	0.42	0.48	0.49	2.49
35	Marsden Street	0.08	0.11	0.15	0.17	0.22
39	Great Western Highway	-	0.10	0.33	0.37	0.70
54	Carpenter Street	0.09	0.11	0.13	0.14	0.22

*Numbering maintained as per **Appendix C**. Refer to **Figures 43** to **47** for a full outline of all road over toping locations

Glossop Street, which serves as the main north-south transportation link in the catchment is also predicted to be subject to inundation depths of more than 0.2 metres during the 20% AEP flood. However, the road is not predicted to be cut until the 5% AEP flood.

Table 20 also highlights the significant depths of inundation that are predicted in Hobart Street. Peak water depths are predicted to exceed 1.5 metres in the 1% AEP flood and depths of more than 6 metres are predicted at the peak of the PMF.

It should be noted that when reviewing the road inundation information, the inundation times are based on the critical design floods. That is, the storm duration that produced the highest peak flood levels. However, no two rainfall events or floods are the same. Therefore, there is potential for extended periods of rainfall (i.e., longer than the critical duration for the catchment) to inundate roads for longer periods. Similarly, shorter rainfall "bursts" may cut the roads sooner even if they do not generate the maximum inundation depths. Therefore, the road inundation times and depths should be taken as indicative rather than precise. However, the reported road inundation information is based on an "envelope" of multiple storm durations reflecting the shortest amount of time taken to cut a road and the longest amount of time the road remains cut so likely to be indicative of a worst-case scenario.

It should always be remembered that under no circumstances should vehicles attempt to drive through floodwaters regardless of the floodwater depth or the type of vehicle they are driving (SES, 2021).

4.3.2 Vulnerable and Critical Infrastructure

The Little Creek catchment is home to a range of property types and infrastructure. This includes facilities where the occupants may be particularly vulnerable during floods, such as schools. In addition, some facilities will play important roles for emergency response and evacuation purposes during future floods. Therefore, it is important to understand the potential vulnerability of these facilities during a range of floods.

A summary of vulnerable and critical facilities located within the catchment was provided in **Section 2.3.3** and the location of each facility is shown on **Figure 4**. The location of the critical and vulnerable facilities is also shown as hatching on the various flood maps (i.e., **Figures 6** to **29**).

The flood modelling results were interrogated to extract the following information in the vicinity of each facility during each design flood:

- Evacuation
  - Whether access to or from the property is cut;
  - The amount of time before access if cut relative to the initial onset of rainfall; and
  - How long access to and from the facility would be cut;
- Facility impacts
  - Amount of time before inundation of the property commences;
  - Amount of time the property would remain submerged;
  - Above floor flooding depth;
  - Maximum water depth;
  - Maximum flow velocity; and
  - Maximum flood hazard.

This information is provided in **Appendix D** for the 5% AEP, 1% AEP floods as well as the PMF.

The information presented in **Appendix D** shows that many critical and vulnerable facilities are subject to at least partial inundation during events as frequent as the 5% AEP flood. However, in most cases, the depth and velocity of floodwater is unlikely to be sufficient to pose a hazard to people with no properties impacted by flood hazard greater than H3 during the 1% AEP design flood event.

During the PMF, a large number of critical and vulnerable facilities would be exposed to hazard conditions greater than H3 upstream of the railway line. Downstream of the railway, the higher flood hazard areas are most commonly contained within the formalised drainage channel and away from habitable areas.

It should be noted that the reported hazard values refer to the hazard external to the buildings. It is likely that a more tolerable hazard will be experienced within the buildings. As an example, most buildings are not predicted to experience above floor flooding during floods up to and including the 1% AEP flood. Therefore, it is likely to be much safer to stay inside the facilities than try to evacuate by driving through floodwaters provided the building is not damaged during the flood event.

4.3.3 The Cost of Flooding

To assist in quantifying the current financial impacts of flooding on the community, a flood damage assessment was also completed. 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 (e.g., damage to garden sheds, fences etc). A detailed description of the approach used to establish the flood damage cost estimates is provided in **Appendix B**.

Property Database

A property database was developed as part of the study to enable damage calculations to be prepared across residential, commercial and industrial properties. The database was developed in GIS and included floor levels for all habitable buildings located within the PMF extent. For residential dwellings, the lowest habitable floor level was estimated, with the lowest operational or functioning floor level of commercial and industrial properties estimated.

Floor levels were estimated using a "drive by" survey technique. This was completed using Google Street View and was supplemented with site visits where buildings were not visible in Street View. The floor level was estimated by counting the number of steps between the ground level of the property and the front door. The number of steps were then multiplied by the step riser height (170mm height for brick steps and variable height for concrete steps) which was then combined with the LiDAR DEM to provide the floor level estimate. A total of 839 properties were incorporated in the property database with approximately 100 of these properties visited in the field.

The property database also included characteristics of each building such as property type (i.e., residential, commercial or industrial), number of building floor levels, building floor area, number of storeys, building material types and the value of the contents for commercial and industrial properties (low, medium, high).

The property database also estimated the density of development per residential lot. The range of density of development include:

- single dwelling only per lot with an average building size of 150m^2.
- medium density with up to three buildings per lot. Generally, multi storey and a total average building size of 600m^2.
- high density with four or more buildings per lot with multi storey buildings and a total average building size of 720m^2.

Damage Calculations

As outlined in **Appendix B**, 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.

The flood damage calculations account for the following types of damage that can be readily accounted for in monetary terms:

- Direct damage costs which are costs associated with water coming into direct contact with buildings and contents; and

- Indirect damage costs which are costs incurred outside of the specific inundation event, such as clean-up costs and loss of trade (for commercial and industrial properties).

Costs that cannot be readily accounted for in monetary terms (e.g., emotional stress) were not included in the damage calculations.

As part of the damage cost calculations, the number of properties subject to above floor inundation during each design flood was calculated. This information is summarised in **Table 21**. The number of properties subject to property damage (even if above floor flooding is not predicted) are also listed in **Table 21**. This includes damage to external items such as fences, sheds and garages. The frequency of above floor flooding (i.e., the design event at which above floor flooding was first predicted to occur) was also mapped and is shown in **Figures 48.**

Table 21 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	8	0	2	2	10	2
20% AEP	21	0	3	3	24	3
10% AEP	34	1	3	3	37	4
5% AEP	49	6	4	4	53	10
2% AEP	78	16	13	13	91	29
1% AEP	83	24	13	13	96	37
0.5% AEP	99	28	13	13	112	41
0.2% AEP	106	45	18	18	124	63
PMF	112	307	76	76	188	383

Table 21 shows that commercial and industrial properties are impacted in flood events as frequent as the 0.5EY design flood event with two (2) properties predicted to incur over floor flooding. Eight (8) residential properties are predicted to be impacted by external damage in the 0.5EY design flood event, whilst above floor inundation is not predicted to occur across any residential property until the 10% AEP flood, where one (1) residential property is predicted to be impacted. During the 1% AEP event, eighty-three (83) residential properties are predicted to suffer external flood damage, with an additional twenty-four (24) are predicted to experience above floor inundation. During the PMF, over hundred and twelve (112) residential properties are predicted to incur external flood damage, with a further three hundred and seven (307) residential properties inundated above floor level. Thirteen (13) commercial and industrial properties are expected to be inundated during a 1% AEP design flood event, with seventy-six (76) predicted to incur damage during the PMF event.

The damage estimates for each design flood are summarised in **Table 22** for existing conditions and are estimated in 2019 dollars. It indicates that if a 1% AEP flood was to occur, nearly $3.5 million worth of damage could be expected. Two thirds of these damages would be incurred across residential properties. **Table 22** also shows that the flood damage cost would increase to more than $50 million if a PMF was to occur.

Table 22 Summary of Flood Damages for Existing Conditions

Flood Event	Flood Damages ($ millions)			Incremental Contribution to Average Annual Damage
	Residential	Commercial and Industrial	Total Damages	
0.5EY	0.06	0.01	**0.07**	$9,819
20% AEP	0.20	0.02	**0.22**	$42,551
10% AEP	0.37	0.07	**0.44**	$32,956
5% AEP	0.73	0.12	**0.85**	$32,397
2% AEP	1.83	0.88	**2.71**	$53,424
1% AEP	2.48	0.97	**3.45**	$30,797
0.5% AEP	3.02	1.06	**4.08**	$18,840
0.2% AEP	4.13	1.36	**5.49**	$14,364
PMF	37.58	13.35	**50.93**	$56,397
			TOTAL AAD	**$291,545**

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 Little Creek catchment was estimated to be just under **$292,000**. Accordingly, if the "status quo" was maintained, residents and business owners within the catchment as well as infrastructure providers, such as Council, would likely be subject to cumulative flood damage costs of around $292,000 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.

4.4 Impacts of Future Catchment Development

The Little Creek catchment does not include large greenfield areas that have the potential to be developed in the future. However, there are some isolated, undeveloped lots that do have future development potential. The remaining residential areas within the catchment also have the potential to be further developed in the future based upon current land use zonings defined in the Penrith LEP 2010 (e.g., granny flats).

This future development has the potential to alter existing flood behaviour which may impact on the existing flood risk across the catchment. Accordingly, additional simulations were completed to quantify the potential impacts that future development may have on the flood risk in the study area.

Those areas that are already developed but are likely to be redeveloped in the future were identified. This was completed by reviewing land use zoning information relative to contemporary aerial imagery. This review determined that redevelopment was already occurring across some R3 and R4 zoned areas but there was potential for that redevelopment to continue in other areas. Similarly, there was potential for further "granny flat" type development across R2 zoned areas. To provide a conservative assessment of the potential impacts of this potential development, it was assumed that all R2, R3 and R4 areas would be developed to the full extent possible under the current zoning. The impervious proportions that were adopted are summarised in **Table 23**. The extent of the land that was identified as having the potential for future urban development is shown in **Figure 50**.

Table 23 Adopted land use information for future development assessment

Land Use Zone	% of Catchment	Zone Description	Impervious Percentage	
			Current	Adopted Future
R1	10	General residential	65	70
R2	40	Low density residential	52	65
R3	17	Medium density residential	62	85
R4	2.4	High density residential	71	95
IN1	3.7	Industrial development in greenfield sites	5	95

This information was used to calculate weighted average impervious and pervious values for each land use that were used as the basis for updating the models. The updated model was used to re-simulate the 5% AEP, 1% AEP, 0.5% AEP and 0.2% AEP design storm events and the PMF under potential future catchment development conditions.

Flood level difference mapping was also prepared to quantify the impact that future catchment development is predicted to have on "existing" design flood levels across the catchment. The difference mapping is presented in **Appendix E**.

The difference mapping indicates that during the 5% AEP flood, future development is predicted to generate increases in flood levels along the main creek line downstream of the railway line and the overland flowpath upstream of the catchment. These increases are generally less than 0.05 metres. However upstream of the major culverts, such as Glossop Street and the Great Western Highway these increases are more substantial (i.e. 0.1 to 0.2 metres).

During the 1% AEP, 0.5% AEP and 0.2% AEP floods, flood level increases are predicted to be around 0.05 metres along the main creek line downstream of the railway line as well as the overland flowpath upstream of the railway line. However, on Hobart Street immediately upstream of the railway line, flood levels are predicted to increase by more than 0.1 metres over a significant number of residential properties. Accordingly, future catchment development does have the potential to increase the existing flood risk across the catchment and is anticipated to increase flood risk in areas that are already experiencing frequent flooding problems.

It is to be noted that these increases in development do not include any allowance for onsite development controls associated with water management, such as onsite detention. Such controls may influence the potential impacts of future development, particularly of the more frequent flood events. The aim of the analysis undertaken in this study is to provide a general indication of the potential flood impacts should the development in the catchment continue to increase densities. Council does have an existing onsite detention policy that provides the necessary controls for managing stormwater runoff from future developments. Therefore, the impacts indicated above are not anticipated to occur.

It is noted that some filling may be completed as part of future development in the catchment to elevate habitable buildings above the 1% AEP flood in accordance with Council's LEP and DCP. This also has the potential to impacts on existing flood behaviour. However, as the location and extent of any future filling is not known with any certainty, the impacts of future filling were not assessed. However, any filling in floodway and flood storage areas should be avoided.

As noted in Section 2.3.2, the north-south rail link from the new Western Sydney airport will pass through the western section of the Little Creek catchment. A freight terminal associated with this rail line is also proposed. Specific details of this development were not available at the time the future catchment assessment was completed. Therefore, a specific assessment of their impact could be undertaken. In general, the facilities will be located on elevated land adjacent to Little Creek. As a result, it is unlikely that the facilities will impact on existing flood behaviour. Nevertheless, careful design of any creek crossings and or earthworks will need to be completed to ensure nearby properties are not adversely impacted.

Overall, the results of the future catchment simulations show that future catchment development with no onsite detention is predicted to cause increases in existing flood levels along the main channel of Little Creek downstream of the railway line and in the overland flow paths upstream of the railway line. Although the magnitude of the flood level increases typically does not exceed 0.1 metres with some localised areas with increases up to 0.2 metres, it is predicted to result in more significant flood level increases in residential areas. Accordingly, any further increases in flood levels in this catchment is undesirable and indicates efforts will need to be made to ensure runoff from future catchment development is managed to ensure adverse flood impacts are suitably mitigated.

4.5 Impacts of Climate Change

Climate change refers to a significant and lasting change in weather patterns arising from both natural and human induced processes. The NSW Office of Environment and Heritage's *'Practical Consideration of Climate Change'* states that climate change is expected to have adverse impacts on rainfall intensities in the future.

Although there is considerable uncertainty associated with the impact that climate change may have on rainfall, it was considered important to provide an assessment of the potential impact that climate change induced rainfall intensity increases may have on the current flood risk across the study area. In this regard, the results of the 0.5% AEP and 0.2% AEP flood were compared to the results from the 1% AEP flood to gain an appreciation of the impacts of the rainfall intensity increases. The 0.5% AEP rainfall reflects a 9% increase relative to current 1% AEP rainfall intensities, while the 0.2% AEP rainfall reflects a 23% increase relative to current 1% AEP rainfall intensities. Based on information contained on the Australian Rainfall & Runoff Data Hub, this roughly equates to the RCP4.5 2090 projection (9.5% increase in rainfall) and a little higher than the RCP8.5 2090 projection (19.7% increase in rainfall).

Flood level difference mapping was prepared to quantify the impacts that a 9% and 23% increase in rainfall would have on current 1% AEP flood level estimates. The difference mapping was prepared by subtracting the peak 1% AEP flood levels from the 0.5% and 0.2% AEP flood levels. The difference mapping is presented in **Plate 13** and **Plate 14.**

Plate 13 and **Plate 14** show that rainfall intensity increases will increase current 1% AEP flood level estimates across most of the catchment. A 9% increase in rainfall is predicted to increase 1% AEP flood levels by between 0.05 to 0.10 metres along the main alignment of Little Creek. Immediately upstream of the railway line, increases in Hobart Street are expected to rise to 0.2 metres.

The 23% increase in rainfall is predicted to increase existing 1% AEP flood levels by between 0.1 and 0.2 metres at most locations along Little Creek. There are greater localised impacts upstream of some of the larger culverts, including upstream of Glossop Street, upstream of the railway line along Hobart Street, and at the intersection of Sydney Street and Brisbane Street.

Accordingly, the outcomes of the climate change assessment show that increases in rainfall associated with potential future climate change impacts have the potential to produce a notable increase in the severity of flooding across the catchment and the associated flood damage costs that could be incurred across the catchment.

4.6 Summary of Existing Flood Risk and Flooding "Trouble Spots"

The information presented in this section indicates that based on the flood information developed as part of this study, there are a number of areas that have the potential to experience significant property damage, risk to life or evacuation difficulties during floods within the catchment. These areas include:

- Hobart Street, between Sydney Street and Australia Street – this area presents the most significant flood risk in the catchment, particularly during larger floods such as the PMF where H6 hazard conditions are predicted.
- Carpenter Street between Hewitt Street and Schultz Street.
- Bennett Street between Bentley Street and the Great Western Highway.
- Kent Place.
- Sykes Place.
- Brooker Street between Bennett Road and Day Street.
- Great Western Highway between Bennett Street and Marsden Road.

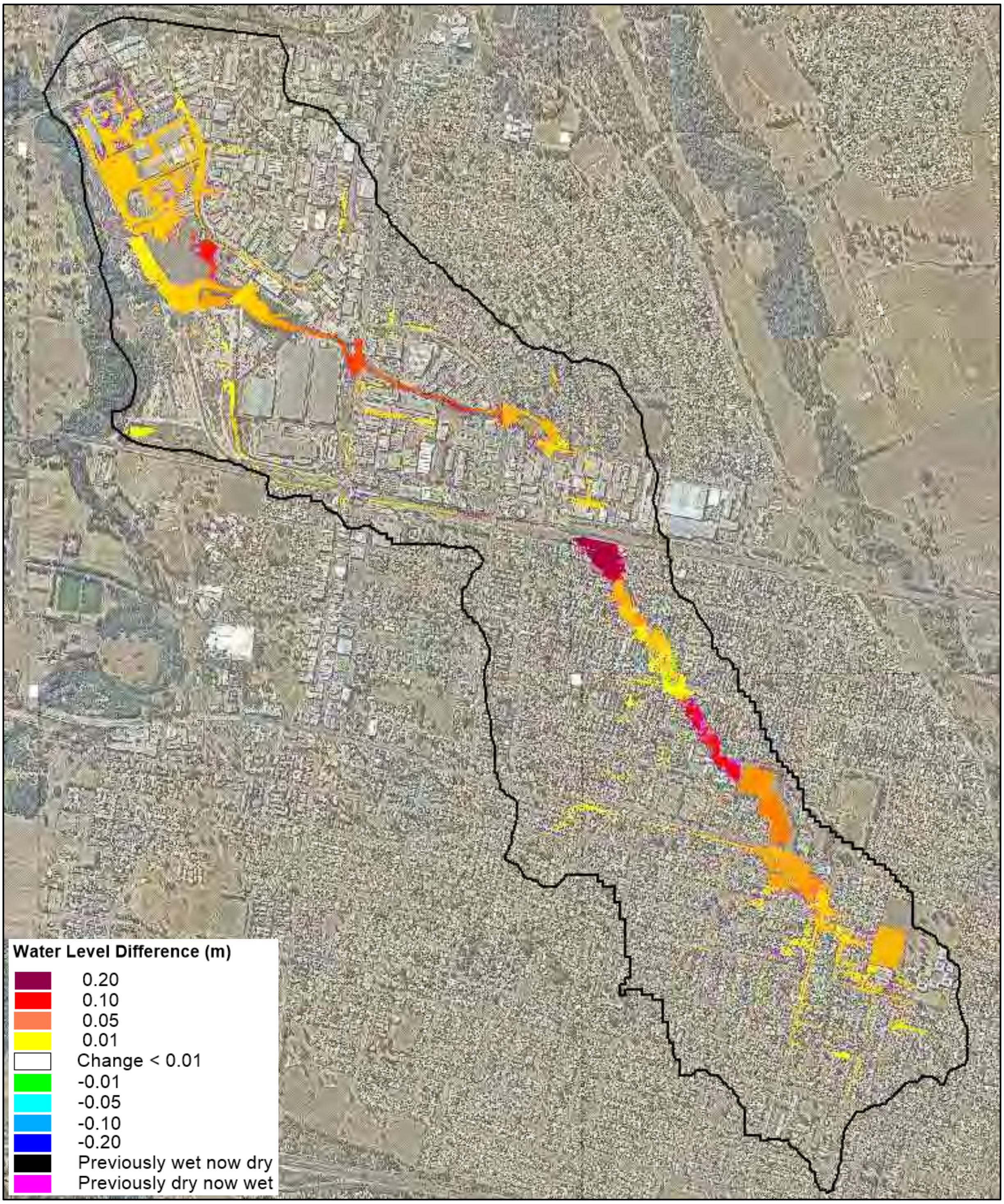


Plate 13 Flood level difference map for 9% increase in 1%AEP rainfall intensity

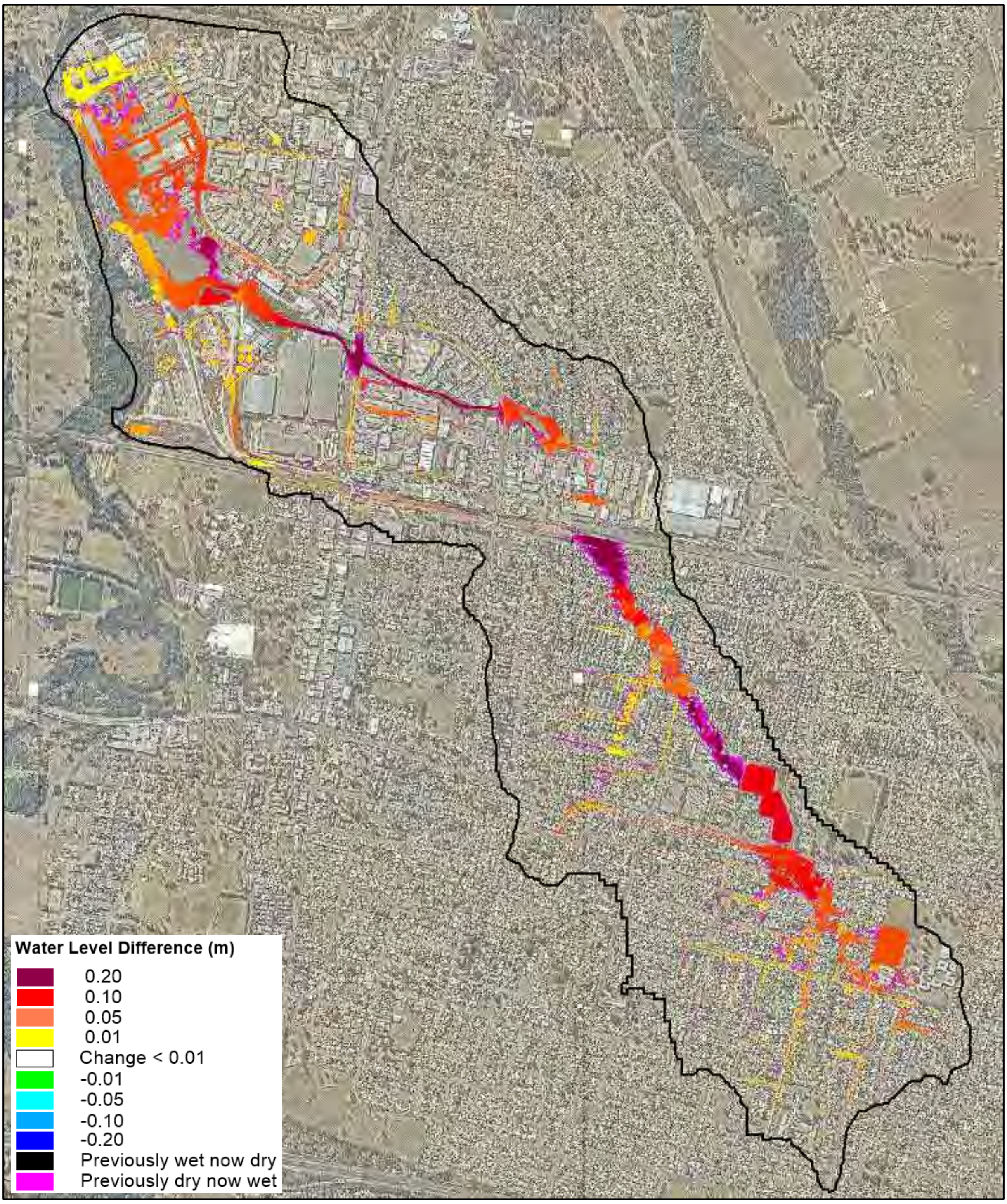


Plate 14 Flood level difference map for 23% increase in 1%AEP rainfall intensity

- Oxley Park Public School.
- Adelaide Street between Bayton Street and Sydney Street.
- Sydney Street between Adelaide Street and Brisbane Street.
- Canberra Street between Perth Street and Australia Street.
- Brisbane Street between Sydney Street and Australia Street.
- Plasser Crescent.

- Kurrajong Road between the two ends of Plasser Crescent.
- Glossop Street between Kurrajong Road and Debrincat Avenue.
- Forrester Road between Harris Street and Glossop Street.
- Lee Holm Road.
- Christie Street, between Lee Holm Road and the South Creek bridge crossing.

5 Land Use Planning Information

5.1 Overview

Appropriate land use planning is one of the most effective measures available to floodplain managers, especially to control future risk but also to reduce existing flood risks as redevelopment occurs. The following sections discuss existing planning legislation and policies that affect the development of land within the Penrith City Council Local Government Area. Where appropriate, recommendations for ways in which Council's planning documents could be modified to better manage the existing and future flood risk are provided.

5.2 NSW State Planning Provisions

5.2.1 Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) provides the over-arching legislative framework for planning and development in NSW. It creates the mechanism for development assessment and protection of the environment from adverse impacts arising from development. The EP&A Act 1979 outlines the level of assessment required under State, regional and local planning legislation and identifies the responsible assessing authority.

Section 9.1 Directions – Direction No. 4.3 (Flood Prone Land)

NSW flood related planning requirements for local councils are set out in Ministerial Direction No. 4.3 Flood Prone Land, issued in 2007 under the then Section 117 (now Section 9.1) of the EP&A Act 1979. It requires councils to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy as set out in the *Floodplain Development Manual* (NSW Government, 2005). It requires provisions in a Local Environmental Plan on flood prone land to be commensurate with the flood hazard of that land. In particular, a planning proposal must not contain provisions that:

- Permit development in floodway areas;
- Permit development that will result in significant flood impacts to other properties;
- Permit a significant increase in the development of that land;
- Are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or
- Permit development to be carried out without development consent except for the purposes of agriculture, roads or exempt development.

The Direction also requires that councils must not impose flood related development controls above the residential flood planning level (FPL, typically the 1% AEP flood plus 0.5m freeboard) for residential development on land, unless a relevant planning authority provides 'adequate justification' for those controls to the satisfaction of the Director-General.

The question as to whether flood behaviour in the Little Creek catchment warrants the imposition of flood related development controls above the residential flood planning level is considered in Section 5.2.4.

At the time of preparing this report (May 2020), DPIE was undertaking a review of the Direction related to Flood Prone Land. This is discussed further in Section 5.2.4.

Guideline on Development Controls on Low Flood Risk Areas, 2007

The '*Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual'* stipulates that *"unless there are exceptional circumstances, councils should adopt the 100-year flood as the flood planning level (FPL) for residential development"* and that "*unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land … that is above the residential FPL*".

The Guideline states that councils should not include a notation for residential development on Section 10.7 certificates for land above the residential flood planning level if no flood related development controls apply to the land. However, the Guideline does include the reminder that councils can include *'such other relevant factors affecting the land that the council may be aware of'* under Section 10.7(5) of the *EP&A Act 1979* indicating variations to this are possible.

In proposing a case for exceptional circumstances, a council would need to demonstrate that a different Flood Planning Level was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Justification for exceptional circumstances would need to be agreed by relevant State Government departments prior to exhibition of a draft local environmental plan or a draft development control plan that proposes to introduce flood related development controls on residential development above the default FPL.

At the time of preparing this report, the Guideline was under review by the NSW State Government. The information presented by the NSW State Government on the proposed updates to the Flood Prone Land Policy indicate that exceptional circumstances will not be required in future if development controls are applied to properties between the FPA and PMF, as long as appropriate floodplain risk management processes have been undertaken to support the need for these development controls.

5.2.2 Environmental Planning and Assessment Regulation 2000

The *Environmental Planning and Assessment Regulation 2000* supports the implementation of the *Environmental Planning and Assessment Act 1979 (*EP&A Act 1979). It provides a number of key provisions for the state-based planning legislation, including planning instruments and development control plans, planning proposals, planning certificates and requirements for environmental assessment under Part 5 of the EP&A Act 1979.

Planning certificates are a means of disclosing information about a parcel of land by providing information on how the land may be used and the restrictions on development of that land. Two types of information are provided in planning certificates: information under Section 10.7(2) and information under Section 10.7(5) of the EP&A Act 1979. The information that can be included on a Section 10.7(2) certificate is prescribed by the *Environmental Planning and Assessment Regulation 2000 (Schedule 4).*

A planning certificate under Section 10.7(2) discloses matters relating to the land, including whether the land is affected by a policy that restricts the development of land. Those policies can be based on identified hazard risks (*Environmental Planning and Assessment Regulation 2000*, Clause 279 and Schedule 4 Clause 7), and whether development on the land is subject to flood-related development controls (EP&A Regulation, Schedule 4 Clause 7A). A lot that is a 'flood control lot' under the Codes SEPP is a prescribed matter for the purpose of a certificate under Section 10.7(2). If no flood-related development controls apply to the land (such as for residential development in areas above the flood planning level), information describing the flood affectation of the land would not be indicated under Section 10.7(2).

A planning certificate may also include information under Section 10.7(5). This allows a council to provide advice on other relevant matters affecting land. This can include past, current or future issues that are considered relevant to that parcel of land.

Inclusion of a planning certificate containing information prescribed under Section 10.7(2) is a mandatory part of the property conveyancing process in NSW. The conveyancing process does not mandate the inclusion of information under Section 10.7(5) but any purchaser may request such information be provided, often pending payment of a fee to the issuing council. Some councils choose to issue the Section 10.7(5) certificate concurrently with the Section 10.7(2) certificate.

5.2.3 State Environmental Planning Policies

SEPP (Housing for Seniors or People with a Disability) 2004

State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 aims to encourage the provision of housing (including residential care facilities) that will increase the supply of residences that meet the needs of seniors or people with a disability. This is achieved by setting aside local planning controls that would prevent such development.

Clause 4(6) and Schedule 1 indicate that the policy does not apply to land identified in another environmental planning instrument (such as Penrith LEP 2010) as being, amongst other descriptors, a floodway or high flooding hazard area.

SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent. *SEPP (Infrastructure) 2007* overrules local planning provisions, including Penrith LEP 2010. *SEPP (Infrastructure) 2007* allows Council to undertake stormwater and flood mitigation work without development consent and the Transport for NSW to undertake certain roadworks without development consent.

SEPP (Exempt and Complying Development Codes) 2008

State Environmental Planning Policy (Exempt and Complying Development Codes) 2008, defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria.

Clause 1.5 of this 'Codes' SEPP defines a 'flood control lot' as:

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

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

These development controls may apply through a LEP or DCP. Exempt development is not permitted on flood control lots, but some complying development is permitted.

Part 3 of the 'Codes' SEPP relates to the *General Housing Code*, which applies to land zoned R1, R3, R4 or RU5.

Clause 3.1 to 3.6 relates to development that is considered as complying development under the 'Codes' SEPP, with Clause 3.5 related to complying development on flood control lots. Clause 3.5 states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a:

- flood storage area,
- floodway area,
- flow path,
- high hazard area, or
- high-risk area.

The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed), flood affectation, access, and car parking (see **Plate 15**).

In addition, Clause 1.18(1)(c) of the Codes SEPP indicates that complying development must meet the relevant provisions of the Building Code of Australia.

In order to facilitate the process of applying for complying development, the following maps have been prepared as part of the study:

- land where Council is confident a Complying Development Certificate (CDC) could be issued, that is, where the land in a flood control lot is not a flood storage area, floodway area, flow path, high hazard area or high-risk area. A map was prepared to identify these areas (refer to **Figure 51**) based upon the following assumptions:
  - Areas that are a floodway or flood storage during the 1% AEP flood; and
  - Areas exposed to a high flood hazard during the 1% AEP flood (for this study, high hazard is considered inclusive of H4–H6 categories)
- Areas that function as a major flow path in the 1% AEP flood (a peak velocity depth product of greater than $0.4m^2/s$ was used for this purpose - this is the dynamic value of the velocity depth product produced in the modelling).

- A "high risk" area was defined as an area that becomes isolated early in a flood and then becomes inundated (flooded, isolated, submerged emergency response classification).

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

Plate 15 Extract from 'Codes' SEPP 2008 Clause 3.5(2) (note: version dated 22 December 2017)

5.2.4 NSW Floodplain Development Manual

Flood Prone Land Policy and Floodplain Development Manual, 2005

The overarching policy context for floodplain management in NSW is provided by the NSW Flood Prone Land Policy, contained within the '*Floodplain Development Manual'* (NSW Government, 2005). The Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods, using ecologically positive methods wherever possible. The Manual promotes a merit approach for development decisions in the floodplain, considering social, economic, ecological and flooding considerations. The primary responsibility for management of flood risk rests with local councils. The Manual assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

At the time of preparing this report, the NSW Floodplain Development Manual was under review by DPIE EES Group.

5.3 Local Provisions

5.3.1 Penrith Local Environmental Plan 2010

Penrith LEP 2010 outlines the zoning of land, permissible development within each land use zone and any special provisions that apply to land within the LGA.

Flood planning is addressed in Clause 7.2 of Penrith LEP 2010. The appropriateness of the Penrith LEP 2010 for managing flood risk in the Little Creek catchment is considered in the following sections.

Flood Planning Level

Flood planning levels (FPLs) and the flood planning area (FPA) are important tools in the management of flood risk. The flood planning area is used to define the area where flood-related development controls apply over development. For those areas contained within the flood planning area, the flood planning levels are frequently used to establish the elevation of key components of a development, such as minimum floor levels.

The flood planning level is typically derived by adding a freeboard to a specific design flood. This specified design flood is frequently referred to as the "planning" flood. The freeboard is intended to account for any uncertainties in the derivation of the planning flood level. Flood planning levels, as well as the freeboard component itself, can be specified for different land uses or types of development (residential, commercial or industrial, based on the vulnerability of the development to flooding) and for different flooding sources (riverine or local overland flooding).

Flood planning levels and the flood planning area can be used to assist in managing the existing and future flood risk by setting design levels for flood mitigation works and identifying the land where flood related development controls apply.

The NSW Government's 'Floodplain Development Manual' 2005 states that in NSW the flood planning level for standard residential development is generally based upon the 1% AEP design flood plus a freeboard, typically 0.5 metres. The Penrith City Council LEP 2010 defines the flood planning level (FPL) across the Penrith City Council LGA as "the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard". This wording is taken from the standard LEP template for NSW and effectively applies a "one size fits all" approach for defining the flood planning level across the LGA.

A flood planning area map was prepared based on the current FPL definition provided in the LEP and is included in **Figure 52**. However, it was noted that application of a 0.5 metre freeboard to the 1% AEP flood level in the upper catchment often resulted in a planning level that was higher than the PMF (i.e., the largest flood that could occur). In such instances, the FPA was "clipped" to the PMF extent to ensure areas located outside of the floodplain were not include in the FPA.

The suitability of the current flood planning level defined in the LEP 2010 was evaluated and the outcomes of this evaluation is summarised in **Appendix F**. This included an assessment of the suitability of the planning flood (i.e., 1% AEP flood) and freeboard (i.e., 0.5 metres).

The assessment determined that adoption of the 1% AEP flood for defining flood planning levels for the catchment is appropriate for most locations and development types.

However, the assessment also determined that there was potential to adopt a freeboard of 0.3 metres in some areas subject to overland flooding while a 0.5 metre freeboard would be required in most areas subject to "mainstream" flooding. The only major exception is the area located upstream of the railway line (e.g., Brisbane Street to Hobart Street), where a higher freeboard could be considered desirable to account for uncertainty at this location. The higher uncertainty across this area is associated with the significant impact that blockage of the main railway culvert and inlet can have on 1% AEP flood levels when combined with the significant railway embankment height. However, as outlines in **Appendix F**, a more practical means of accounting for this uncertainty may be adopting the 0.5% AEP event as the planning flood for the Brisbane Street to Hobart Street area and retaining the standard 0.5 metre freeboard.

Furthermore, as noted in Section 9.2.1, there are some properties located between Adelaide Street and Hobart Street that fall outside of the 'standard' flood planning area (i.e., based on 1% AEP flood + 0.5 metres freeboard) that would be exposed to a H4 internal hazard during the PMF. Accordingly, for these properties, the standard FPL and FPA definition provided in the Penrith LEP may not be sufficient to adequately manage the full range of potential flood risk. Adoption of the 0.5% AEP event as the planning flood (as detailed in the previous paragraph) would overcome some of this limitation by incorporating additional properties in the Hobart Street area within the FPA while also elevating required floor levels and, thereby, reducing the internal flood hazard during the PMF. However, inclusion of additional properties above and beyond this revised flood planning level would still be necessary to ensure all H4 PMF properties are captured within the FPA.

The recommended FPA based on using the 0.5% AEP flood as the planning flood in the Hobart Street area along with properties exposed to a H4 or higher internal hazard in the PMF is also included on **Figure 52**.

The practicalities of varying the standard planning flood and freeboard are discussed in the following sections.

Wording of clause 7.2 of Penrith Local Environmental Plan 2010

As outlined above, Clause 7.2 of Penrith Local Environmental Plan 2010 stipulates a flood planning level that includes a 1% AEP design flood level and a 0.5 m freeboard. Explicitly defining both the planning flood event and the freeboard in the clause does not allow flexibility in the determination of the flood planning level. Therefore, the FPL definition provided in the LEP 2010 provides little scope to increase (or decrease) the standard 0.5metre freeboard or change the planning flood from the 1% AEP event.

This clause is consistent with the DPIE's LEP Model clause 7.3 Flood Planning. "Model clauses" are also referred to as "local provisions" and have been settled by the NSW Governments Parliamentary Counsel's Office. However, they are a non-mandatory and non-compulsory clause issued with the NSW Standard Instrument for a LEP. Minor alterations of the model clause can be made to suit local conditions with appropriate justification.

It is therefore recommended that Clause 7.2 of Penrith LEP 2010 be updated so that all land where flood related controls apply based on the recommended flood planning area would be appropriately notated. Currently, Clause 7.2 of Penrith LEP 2010 currently states that "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" (noting the 1:100 ARI flood event is equivalent to the 1% AEP flood event).

Potential updates to the wording of this clause include to provide flexibility in the selection of a flood planning level and flood planning area include:

i) "This clause applies to land at or below the flood planning level".
Where the flood planning level is defined as the level of the 1% AEP (annual exceedance probability) flood event plus 0.5 metres freeboard or another 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. or:

ii) This clause applies to:
   a) land that is shown as flood planning area, as defined on the flood planning area map, and
   b) other land at or below the flood planning level.
   Where the flood planning area has been defined in an adopted floodplain risk management plan and is publicly available.

Further information on how the flood planning area mapping may be presented is provided below.

Flood planning area mapping and Penrith Local Environmental Plan 2010

The current flood planning area or flood planning level map related to the Penrith Local Environmental Plan 2010 is not available as a single, easy to find source. It is recommended that Council make the flood planning area map related to flood related development controls publicly available in an easy to find and easy to understand location. This could be as a single mapping layer available on the council or the NSW ePlanning portal website or within the development control plan.

It is noted that the flood planning area maps were previously incorporated as part of the Penrith LEP 2010 gazetted maps, however, were separated from this map set circa 2015. It is recommended to continue to provide the flood planning area map as a separate document to the Penrith LEP 2010 maps. Excluding the flood planning area map from the formal and gazetted LEP mapping enables the information associated with the flood planning map to be updated as frequently as needed (i.e., as new flood studies and floodplain risk management studies are adopted) and without the requirement of a Planning proposal. Planning proposals can be expensive and timely, often taking more than twelve (12) months to complete. If the maps are incorporated within the development control plan, there is still legislative process to be followed under Part 3, Division 3.6 of the *Environmental Planning and Assessment Act 1979* and Part 3 of the *Environmental Planning and Assessment Regulation 2000* with a minimum 28 public exhibition period.

Overall, it is suggested that Council's website may be the most versatile location to host the FPA map as it would be much easier to amend and update as new flood information becomes available relative to inclusion in the LEP or DCP.

As noted in the previous sections, consideration should be given to adopting the 0.5% AEP flood as the planning flood within high-risk sections of the catchment (primarily the Hobart Street area). The inclusion of different planning floods across different parts of the catchment (and different parts of the LGA) may make it difficult for the broader community to interpret and understand what planning flood is applicable to a specific property. One potential way to overcome this is to assign each "flood control lot" in the FPA map a colour code corresponding to the planning flood that is applicable at that location. In most cases this will be the 1% AEP flood and may be identified as a blue lot (for example) on the FPA map, while higher risk lots adjacent to Hobart Street may be identified as a green lot (for example) in the FPA map to show that the 0.5% AEP flood is applicable in that area. The colour coding would need to be supported by an appropriate legend to ensure there is no confusion regarding what planning flood applies to each lot.

Floods greater than the planning flood event

Council could also consider introducing a LEP clause related to "floodplain risk management" with the objectives of:

- Better managing the land between the flood planning area and the limit of the floodplain (i.e., PMF extent).
- Protect critical and vulnerable developments.
- Consider evacuation and emergency response requirements across the entire floodplain as part of the development planning and approval processes, making them legally enforceable during a flood event.

Suggested wording for this clause is included in Section 9.2.2.

It is also to be noted that DPIE are currently in the process of working to update advice and guidance to NSW councils on flood planning as part of the *Flood Prone Land Package*. The update of this guidance includes revised Local Environmental Plan flood clauses, and a new guideline on *Considering Flooding in Land Use Planning (2020).* The update to the LEP clause includes a clause similar to that proposed for "floodplain risk management", which is referred to as the "*Special Flood Considerations*". The new clause applies to land between the flood planning area up to the level of the probable maximum flood with specific considerations for sensitive, vulnerable and critical uses, hazardous industry or hazardous material storage establishments and any other land uses requiring controls in relation to risk to life considerations. At the time of writing, DPIE had just completed public exhibition of the updated *Flood Prone Land Package* documents.

Compatibility of existing land use with flood hazard

Figure 3 shows the current land use zonings incorporated in Penrith LEP 2010 for the catchment. An assessment of the compatibility of the existing land use zoning with the national flood hazard categories was undertaken. The results of this assessment for the 1% AEP and the PMF design floods are presented on **Figures 53** and **54** respectively and a summary is also presented in **Table 24.**

Of most interest in reviewing the information presented in **Table 24** and **Figures 53** and **54** is land zoned for habitable development within flood hazard H6 as the depth and velocity of floodwater in these areas is likely to be sufficient to cause structural failure of buildings regardless of their design. Of interest also, are H5 areas where there is still potential for structural damage to buildings and H4 where all vehicles and people would be exposed to a significant flood risk.

Table 24 Compatibility of Current Land Use Zones with National Flood Hazard Categories During the 1% AEP and PMF design flood events

LEP Zone	Area (ha)	Hazard Category													
		PMF							1%AEP						
		No Hazard	H1	H2	H3	H4	H5	H6	No Hazard	H1	H2	H3	H4	H5	H6
B1 (Neighbourhood Centre)	1.05	89%	1%	3%	8%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
B4 (Mixed Use)	2.8	95%	3%	1%	0%	0%	0%	0%	96%	3%	0%	0%	0%	0%	0%
E2 (Environmental Conservation)	10.5	68%	7%	5%	6%	5%	6%	4%	71%	6%	4%	6%	4%	6%	4%
IN1 (General Industrial)	175.1	69%	8%	6%	9%	4%	3%	1%	87%	5%	3%	4%	1%	1%	0%
R2 (Low Density Residential)	140.5	85%	6%	4%	3%	2%	1%	0%	93%	4%	2%	1%	0%	0%	0%
R3 (Medium Density Residential)	90.1	74%	4%	2%	4%	4%	9%	2%	93%	4%	2%	1%	0%	0%	0%
R4 (High Density Residential)	3.9	99%	1%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
RE1 (Public Recreation)	26.9	63%	6%	4%	5%	5%	12%	4%	77%	4%	3%	9%	5%	2%	0%
RE2 (Private Recreation)	0.65	17%	3%	11%	67%	2%	0%	0%	20%	2%	11%	66%	2%	0%	0%
SP1 (Special Activities)	2.5	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
SP2 (Infrastructure)	13.6	59%	17%	9%	6%	6%	3%	0%	89%	6%	3%	2%	0%	0%	0%

The results indicate that the current zoning is broadly compatible with the flood hazard during the 1% AEP flood, with no residential “R2” and “R3”, commercial “B1” and “B4” being exposed to a H4-H6 hazard during the 1% AEP flood. There is a small section of the area zoned industrial “IN1” that is exposed to H4 and a very small amount exposed to H5 flood hazard during the 1% AEP design flood event.

Higher hazard areas are also scattered across the upper catchment including the Oxley Park and Cloyton High School detention basins as well as isolated areas between Brisbane Street and Hobart Street. However, the high hazard is generally contained in non-habitable areas (most commonly zoned RE1: public recreation).

Greater areas are predicted to be exposed to a H4, H5 or H6 hazard during the PMF. H4 and H5 flood hazard conditions extend from the Oxley Park detention basin located immediately upstream of Oxley Park Public School, and continues all the way north to Hobart Street, a distance over one (1) kilometre. H6 flood hazard extends from Brisbane Street to Hobart Street. Some of this area is zoned “RE1” (Public Recreation), however, there are also residential properties zoned “R3” (Medium Density Residential) that fall within the H6 flood hazard areas. The summary included in **Table 24** indicates that 15% of the land zoned “R3” (Medium Density Residential) would fall within the H4, H5 or H6 categories.

During the PMF design flood event, the industrial developments in the downstream parts of the catchment around Plasser Crescent and Kurrajong Road experience H4 and H5 flood hazards. There is also one industrial lot on Lee Holm Drive that is impacted by H4 hazard flooding across almost the entire lot.

There does not appear to be any critical or vulnerable development located within H4, H5 or H6 hazard areas during the 1% AEP flood. During the PMF, a considerable section of the north-eastern part of the Oxley Park Public School grounds are impacted by H5 flood hazards. In addition, the Evergreen Early Education Centre on Sydney Street is impacted by H3, H4 and H5 flood hazards during the PMF design flood event. Incorporating sensitive/vulnerable developments in H4 to H6 hazard areas (despite the PMF being a rare flood) is undesirable given the vulnerable nature of the occupants.

Based on the assessment presented, the LEP zoning appears to be appropriate to the flood hazard for this study area during floods up to and including the 1% AEP flood. That is, there is no obvious need for modification to the current LEP zones with regard to the existing flood hazards across most of the catchment, based on the 1% AEP flood.

There is a notable increase in flood hazard during the PMF. Although it would be desirable to remove habitable development from these high hazard areas, application of the PMF (i.e., a very rare flood) for flood planning purposes would generally not be consistent with the merit approach documented in the ‘Floodplain Development Manual’ (2005) (unnecessary sterilisation of high value of land). However, as there are some properties exposed to H6 hazard, any buildings in these areas are likely to suffer structural damage or failure. Although it would be desirable to remove these high-risk properties (e.g., through a voluntary purchase program), the very high cost makes this impractical (further discussion on the advantages and disadvantages of voluntary purchase are in Section 9.3.1).

In the short term, intensification of development within these H4-H6 hazard areas (and the broader flood liable areas within the catchment) should be discouraged to ensure the existing flood risk is not increased in the future. In addition, locating critical or vulnerable facilities within the high hazard areas should be avoided.

Need for 'Exceptional Circumstances'.

An assessment was completed to determine if and where 'exceptional circumstances' may be appropriate for flood related development controls on residential development on land outside of the proposed FPA. Exceptional circumstances may be triggered when there is an unacceptably high flood risk above and beyond the FPA.

A review of the design flood level results showed that the peak 0.2% AEP flood levels were always less than 0.5 metres higher than the peak 1% AEP flood level at all locations, including the Brisbane Street to Hobart Street area. Therefore, there would be no areas of unacceptable flood risk outside of the FPA during floods up to and including the 0.2% AEP event (as the FPA would fully "contain" the extent of inundation during floods up to and including the 0.2% AEP flood). Therefore, the assessment focussed on the probable maximum flood (PMF). This was completed by determining if there were any H6 hazard areas during the PMF in areas located beyond the FPA. It is acknowledged the NSW State Government is currently reviewing the need for 'exceptional circumstance' as part of the "*Flood Prone Land Package*" that is currently on public exhibition. Once the NSW Government formally releases the guideline "*Considering Flooding in Land Use Planning (2020)"* the requirement to apply for 'exceptional circumstance' may change from the current process.

Plate 16 shows the extent of PMF H6 areas (red) superimposed on the flood planning area for the catchment (blue). It indicates that all areas exposed to a PMF H6 hazard would fall within the FPA. Therefore, there does not appear to be a need for controls beyond the FPA in the Little Creek catchment when considering the hazard external to buildings.

However, as noted in Section 9.2.1, there is likely to be some buildings located outside of the FPA, that may be exposed to a H4 internal flood hazard, which is unsafe for people. Therefore, it is still considered desirable to apply more stringent controls across the H6 hazard areas to better manage the higher flood hazard during extreme floods (e.g., a second storey where occupants could seek refuge). This would require application of controls above the flood planning level and would trigger the need for exceptional circumstances. However, this may not be required with the release of the revised flood planning documents discussed above.

Flood Planning Constraints Categories

Australian Disaster Resilience Handbook 7 *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017) identifies the essential role of land-use planning in limiting the growth in flood risk associated with new land uses and development in the floodplain. Guideline 7-5, *Flood Information to Support Land Use Planning*, sets out a method for translating products from flood studies into Flood Planning Constraint Categories (FPCCs) to better inform land-use planning activities.

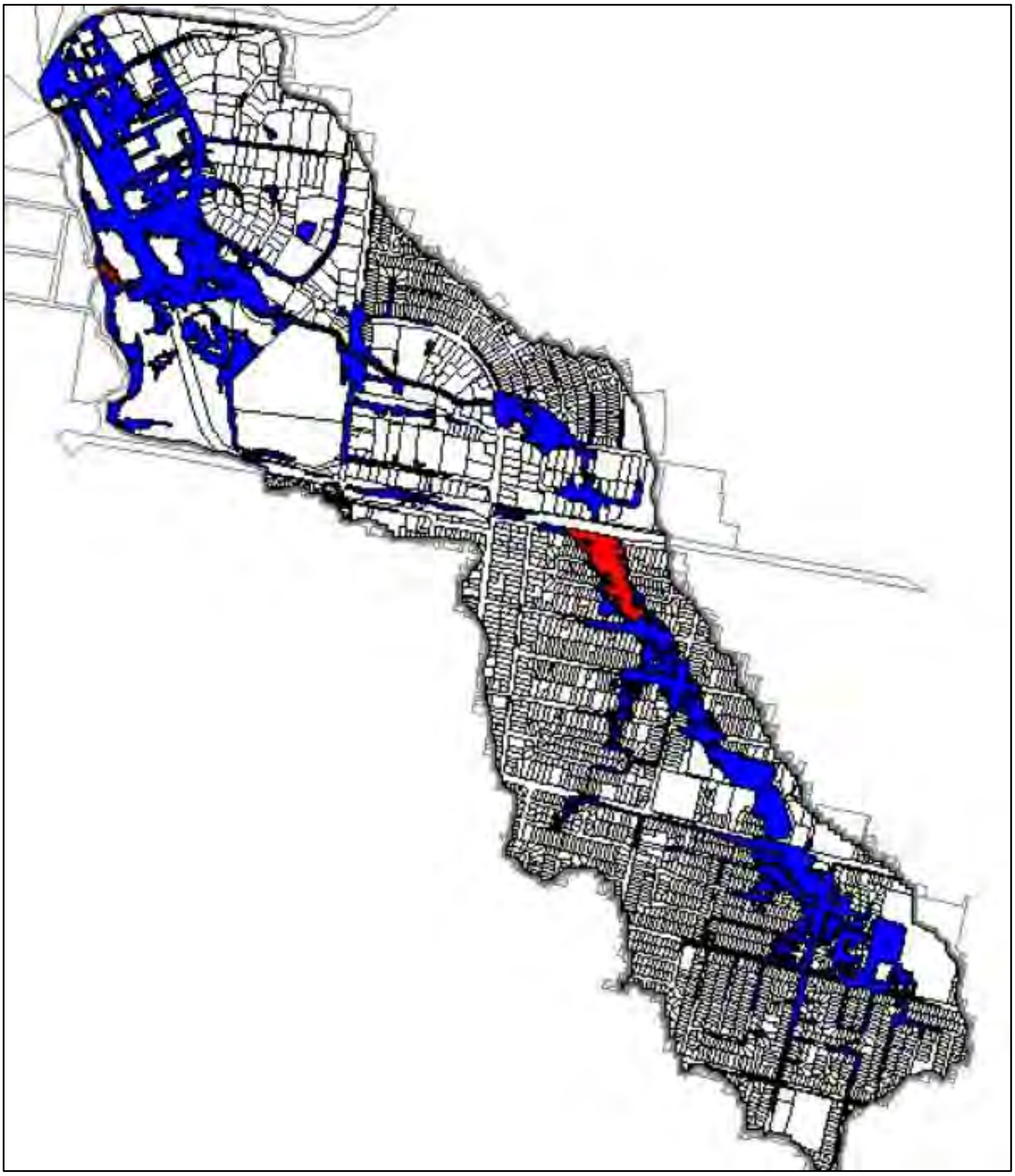


Plate 16 PMF H6 hazard (red) superimposed on the FPA (blue)

This guideline delineates flood liable land into one of four major "constraint" categories (with several subcategories) based upon key flooding considerations such as flood hazard, flood function and emergency response. The resulting categories can serve to inform land use planning activities. The guideline notes that the categorisation is intended to support precinct scale decisions where flow paths and flood extents can be readily defined and was not developed to support change of land use or development at the lot scale.

The Flood Planning Constraint Categories Guidelines are set out in **Table 25**.

Table 25 Flood Planning Constraint Categories (AIDR, 2017)

FPCC	Description	Discussion
1a	Flow conveyance and storage areas in the DFE	Majority of development and uses vulnerable to failure or likely to have adverse flood impacts. Most development in these areas should be limited and any development must be designed to maintain the current flood function.
1b	H6 hazard in the DFE	
2a	Flow conveyance in events larger than the DFE	Many uses in these areas will be vulnerable to high flood hazard during large floods or have the potential to be isolated leading to evacuation difficulties. Vulnerable land uses not suitable for these areas and new development should be limited to those compatible with higher hazard conditions (i.e., special development conditions should be applied).
2b	Flood hazard H5 in the DFE	
2c	Emergency response—isolated and submerged areas	
2d	Emergency response—isolated but elevated areas	
2e	Flood hazard H6 in floods larger than the DFE	
3	Outside FPCC2 — generally below the DFE and the freeboard	Compatible with most development types subject to appropriate development controls being applied to reduce potential for flood damage. Generally, not suitable for vulnerable land uses.
4	Outside FPCC3, but within the probable maximum or extreme flood	Compatible with most development types. Vulnerable facilities may still require development controls

A FPCC of category "1" implies a more flood constrained section of land relative to FPCC category "2", and so on.

Flood Planning Constraints Categories have been mapped and are included in **Figure 55.** This mapping has been prepared based on a range of mapping produced as part of the current study. This includes flood hazard, hydraulic categories, emergency response classifications and the flood planning area.

Areas indicated as Flood Planning Constraint Category (FPCC) 1 and 2 will require careful consideration for future planning and development. Any future development in the catchment needs to be compatible with the flood risks represented in this study and FPCC. Categories 1 and 2 indicate that any type of critical or vulnerable development would not be suitable to be located in these areas (and ideally located outside of Category 4). Strategic planning activities such as rezoning to greater residential or commercial or industrial densities or subdivision should also be limited in FPCC Category 1 and 2 areas due to the significant flood hazard (and therefore risk to life and structural damage to buildings) and potential for development to adversely impact on existing flood behaviour.

5.3.2 Penrith Development Control Plan 2014

The Penrith Development Control Plan 2014 (Penrith DCP 2014) applies to all land zoned for residential and business uses within the Penrith LGA, including the Little Creek catchment. Section 3.5 of Part C of the DCP refers to Flood Planning and includes a lengthy background discussion as well as listing a number of flood planning objectives.

The flood related development controls listed in Part C of the DCP are wide-ranging and extensive. However, this study presents a good opportunity to review and potentially update and consolidate these controls to current best practice, in conjunction with a number of other floodplain risk management studies and plans that have recently been completed across the LGA.

General comments are provided below, with more specific comments listed, where required.

General Comments

i. The current requirements for a flood study are considered onerous as it is required for all development applications on land that is identified as fully or partially flood affected. One of the outcomes of this floodplain risk management plan will be to clearly identify where development in the Little Creek floodplain will be acceptable without the need for a site specific flood study, and under what circumstances a site specific flood study will be required. (This issue is discussed further in **Point xii** below).

ii. The DCP should include clear description of required controls, where feasible. A matrix-based format may be suitable in this regard whereby the specific floor level, car parking, emergency response, structural requirements and flood impact allowances are defined for each land use and flood risk precincts. Subjective words such as "unacceptable" and "unreasonable" should be avoided in development controls. If an applicant wants to vary these prescriptive controls, then the DCP could include a list of "heads of consideration" for the items that would be considered under a "Merits Based Assessment". A merits-based assessment or performance criteria could include matters such as floor levels, structural soundness and flood compatible building materials, flood affectation, emergency management and environmental impacts up to the flood planning level.

ii. The defined flood planning event is not identified in the opening section of the current controls, which leaves it open to interpretation. It is recommended to use the 1% AEP design flood event as the defined flood event for residential, commercial and industrial development and the PMF should be considered for critical infrastructure and vulnerable uses (e.g., childcare centres, education facilities, emergency services facilities, health service facilities, residential care facilities and seniors housing).

iii. Planning proposals for substantial or significant planning or development applications, such as subdivision and rezoning, should consider the full range of design flood events up to and including the PMF. In addition, all strategic planning activities should consider the full range of design flood events up to and including the PMF.

iv. It may be beneficial to define a list of development types and the category they would be treated as for flood related development controls. For example, schools, childcare centres and aged care facilities would be considered as vulnerable developments, emergency services and telecommunication infrastructure would be considered as critical infrastructure. There are a range of residential zoning types within this catchment, from low to medium to high density. Therefore, the potential to apply different flood development controls based on the expected residential density of development should also be considered (noting the compatibility of the current land use zones with the predicted flood hazard is documented in Section5.3.1).

v. Adherence to the "Construction of Buildings in Flood Hazard Areas" (ABCB, 2012) could be listed in the initial stages of the controls. This would assist in streamlining many development controls, such as structural soundness of buildings up to the planning level for the defined flood event.

vi. Reference should always be made to the flood planning level, not just a design flood level.

vii. Updates are required to the hazard classifications referenced so they are consistent with recently completed flood studies and floodplain risk management plans in the LGA as well as future studies and plans. This includes the terminology used in Chapter 7 of Book 6 of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Geoscience Australia, 2019) (as documented in Section 4.2.8), which is considered current best practice. This would enable land that is impacted by either mainstream riverine or overland flooding to be appropriately categorised and appropriate controls assigned based on the risk to vehicles, people and structures.

viii. It is also recommended that flood planning constraint categories (FPCC) are used to clearly define and distinguish the areas where the different types or categories of flood related development controls apply. The FPCC takes into account a range of information including those floods more infrequent than the 1% AEP design flood level, as well as emergency management considerations. FPCC mapping is provided in **Figure 55**.

ix. Development controls associated with the change of use of a building should clearly state what minimum standards are acceptable for flood impacts or resultant flood risk. These controls and associated thresholds could be based on the FPCC or the hazard category the site is located within.

x. Any redevelopment on a lot that is located within the floodplain should not result in an increased flood risk to existing communities or to the new development or an increased reliance on emergency services during times of flood.

xi. Where redevelopment is to occur in flood storage areas where rezoning to a "less dense or lower intensity" land use is not possible, the footprint of the building should not increase from the existing development. This will help minimise the cumulative impacts of developments in the flood storage areas of the catchment.

xii. Controls associated with the filling of land should be based on a catchment wide analysis completed in the floodplain risk management study for each catchment. In this regard, the hydraulic category mapping prepared as part of the current study has identified areas that could be filled without impacting on existing flood behaviour (i.e., flood fringe areas in **Figure 39**). If a development is proposed outside of the flood fringe (e.g., within flood storage areas), the controls should clearly state the allowable impact on properties external to the development site and, preferably, include a requirement that any filling is countered with compensatory cut to prevent loss of flood storage in the floodplain.

xiii. Current DCP controls state that the allowable flood impact of filling of an individual development should not exceed 0.1 metres. It does not state what the planning flood event is. It is recommended that the 0.1 metres be revised to something smaller. In its current form, an allowance of 0.1 metres per development could lead to significant cumulative impacts across the whole catchment, counteracting the purpose of the freeboard in the flood planning level. The 'South Creek Floodplain Risk Management Study' (Advisian, 2020) recommends a threshold increase of no more than 0.02m for impacts outside of the development site. This is considered to be a reasonable threshold as it is "small" but still within the computational limits of most modern flood modelling software.

xiv. 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 risk assessment framework. The full range of design flood events should be used when assessing the potential failure of the flood mitigation works.

5.3.3 Review of Other Floodplain Risk Management Plans

A number of floodplain risk management plans have been adopted by council in the past twelve (12) months, with flood related planning control recommendations yet to be implemented into Councils planning controls. As such, a review was made of these adopted floodplain risk management plans to establish consistencies between the recommendations to planning controls in the Little Creek study area and other parts of the LGA.

South Creek Floodplain Risk Management Study

The 'South Creek Floodplain Risk Management Study' was adopted by Council on 27 April 2020. The study focusses on "mainstream" flooding along South Creek and several of its major tributaries. This did not include Little Creek.

The Study outlines a number of planning modification recommendations, including:

- Update true flood hazard mapping and hydraulic category mapping in the DCP.
- Use Flood Planning Constraints Category Mapping (FPCC) in DCP once FPCC mapping is available across the whole LGA,
- Amend development controls regarding:
  - Extensions to existing developments to permit no increase to the population at risk,
  - Consider location, proposed use and evacuation in the change of use controls,
  - Consider evacuation in rural development.
- Revise the DCP regarding assessment of impact including:
  - Reduce criteria for maximum allowable increase in peak flood levels,
  - Remove control for velocity and flow distribution and replace with a hazard control,
  - Update control for additional flood storage where it can be shown there is no offsite impact,
  - Require assessment of impact criteria in regard to all development (not just existing buildings or potential development sites),
  - Specify that controls must be met for the 1% AEP flood, however, Council may request additional events to be assessed at their discretion.
- Additions to the DCP including:
  - Additional controls for critical facilities (e.g. schools, hospitals, aged care facilities etc.),
  - Require consideration of evacuation from the proposed development as well as the effect of new development on evacuation from existing areas,
  - Requirement for a Flood Impact Assessment commensurate to development size, type and flood risk,
  - Need to include consideration of climate change.

- Revise the format of the DCP to set out different development types and flood risk into a matrix approach.

St Marys Byrnes Creek Catchment Floodplain Risk Management Study and Plan

The 'St Marys Byrnes Creek Catchment Floodplain Risk Management Study and Plan' was adopted by Penrith Council on 23 March 2020. The catchment is located to the west of the Little Creek catchment.

The Study outlines a number of planning modification recommendations, including:

- Improvements to planning and development controls for future development in flood prone areas. This includes dividing the floodplain into six (6) categories, including:
  - Inner floodplain (Hazard category 1),
  - Inner floodplain (Hazard category 2),
  - Intermediate floodplain,
  - Outer floodplain,
  - High hazard floodway, and
  - Low hazard floodway or flood fringe.
- Update wording in Penrith LEP 2010 to include consideration of evacuation or emergency response issues.
- Inclusion of a new floodplain risk management clause that would apply to land identified as "Outer Floodplain" (land between the FPA and the extent of the PMF).

Penrith CBD Floodplain Risk Management Study and Plan

The 'Penrith CBD Floodplain Risk Management Study and Plan' was completed on 23 March 2020. The study area focusses on the Penrith CBD which is located approximately 7km west of the Little Creek catchment and is subject to both mainstream and overland flooding.

The Study outlines several planning modification recommendations, including:

- Council to undertake a comprehensive review of the DCP (PDCP 2014),
- DCP to include a comprehensive set of flood maps (including flood planning area maps),
- DCP to include flood risk zoning addressing mainstream and overland flood risks,
- DCP to use controls reliant on the adoption of multiple FPLs in the LEP,
- Consider amending the LEP to include provision for variable FPLs, and
- Consider applying for "exceptional circumstances" to ensure variable FPL is consistent with the 2007 NSW Government Flood Planning Circular (PS 07 003).

5.3.4 Dunheved Business Park Revitalisation Strategy

The Dunheved Business Park is located within the northern section of the Little Creek catchment. It is divided into Northern, Southern and Eastern Precincts, as outlined in **Plate 17.** The Dunheved Business Park Revitalisation Strategy (The Strategy) was developed in 2014 and proposes a range of infrastructure and public domain improvements. The Strategy defines a future vision for the Dunheved Business Park, listing objectives with a supporting framework of actions and investigations to achieve them. It has been defined as aspirational in approach, as it will take many years to achieve and require partnerships with all levels of government.

Plate 17 - Dunheved Business Park

A primary issue raised in The Strategy is the vulnerability of the stormwater drainage network to flooding, and failures of the drainage network during intense or prolonged rain. The Strategy states that as the stormwater drainage network was constructed in the 1940's, the limitations of the current system are self-explanatory. These limitations are reinforced based on the flood modelling completed as part of the current study.

The Strategy identifies that a major drainage upgrade of the northern and southern precincts would be desirable, however it would require significant funding.

6 Existing Flood Emergency Management Information

6.1 Overview

It is generally not economical to provide "structural" flood risk management mitigation options that eliminate flood risk for all events up to and including the PMF. Therefore, emergency management measures such as evacuation planning and community education are typically employed to manage continuous and residual flood risk during both frequent as well as very rare floods.

The following chapter outlines current flood emergency management strategies for the Little Creek catchment. Where appropriate, it also makes suggestions on ways in which these current emergency management strategies could be improved.

These suggestions and comments are based on engineering judgment and not on emergency management expertise. As such, it is up to SES, the agency responsible for flood emergency management in NSW, to review these suggestions and apply them as they see fit, into their planning and response strategies for the Little Creek catchment.

6.2 Current Local Flood Plan

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) sets out procedures to follow before, during and after a flood including who is responsible for each of these activities within the Penrith LGA (including the Little Creek catchment).

The Penrith City LFP is a sub-plan of the *Hawkesbury Nepean Flood Plan 2015* and the *Penrith Local Emergency Management Plan September 2015*. Both documents are administered by the NSW State Emergency Service (SES).

The *Penrith City LFP 2012* is prepared in accordance with the standard NSW SES flood plan template and was last reviewed in April 2012.

Part 1 of the LFP includes the introduction to the local flood plan, including details about organisational responsibilities and supporting services for managing flooding risks. It currently says relatively little about flooding risks from local overland flow.

Part 2 is in need of an update to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. An annex to the flood plan could be provided, that details the flood risks in the Little Creek catchment (e.g., PMF hazard between Brisbane Street and Hobart Street) as well as other catchments subject to overland flooding where flood study data are available, and include specific details such as the location of vulnerable facilities, roads subject to flooding and the vulnerability of properties to above floor flooding.

Part 3 of the LFP describes response arrangements. The section does not include any considerations of flood emergency management response as a result of local overland flooding. Therefore, more specific and localised information should be included for the Little Creek catchment based on information from this report. Part 3 also refers to evacuation, however, no evacuation centres are listed. It is recommended this section is updated to include this information should those impacted by overland or mainstream flooding in this catchment (and the wider LGA) require evacuation.

A summary of pertinent components of the LFP for update for the Little Creek catchment are provided in **Table 26**.

Table 26 Comments on Current Penrith City Local Flood Plan

Section	Description	Comment
Part 1 – Introduction		
1.1	Purpose	Local overland flooding needs to be included in the purposes of the Penrith City Flood Plan. Currently the flood plan lists flood risk from the Nepean River only.
1.1	Purpose	It is anticipated that local overland flooding risks included from this floodplain risk management study and plan will not comprise reference to "Level 1"and "Level 2" flood risk thresholds for emergency management. Therefore, appropriate thresholds for categorising the flood risk, such as minor, moderate and major, should be included.
1.2	Authority	References in this section should be reviewed to ensure they remain current and correct. This is especially important for the links to the Hawkesbury Nepean Flood Plan 2015 as it is updated.
1.3	Area coved by the Plan	References to the population of Penrith City and SES planning districts should be reviewed to ensure they remain current and correct.
1.4	Description of flooding and its Effects	It is recommended an Annex describing the nature and effects of flooding in the Little Creek catchment is included.
1.5	Responsibilities	The names and responsibilities of the NSW Government Agencies and other groups in this section should be reviewed to ensure they remain current and correct.
Part 2 – Preparedness		
2.3	Development of flood Intelligence	Flood intelligence for the Little Creek catchment should be included based on the information in this report as well as the 2017 Flood Study. Catchment specific information could be included in the form of an Annex, and include information such as: • Characteristics of flooding (Section 0 of this report) for the full range of design storm events, up to and including the PMF. • Flood history (Section 1.3, 1.4 and 6.2 and **Figures 5, 15, 16, 17** of the 'Little Creek Catchment Flood Study' 2017). • Available gauges in the vicinity of the catchment that could be used to support flood intelligence (**Table 1** and

Section	Description	Comment
		Figure 6 of the 'Little Creek Catchment Flood Study' 2017). • Location of vulnerable facilities (**Appendix D** and **Figure 4** of this report) • Roads subject to flooding (Section 4.3.1 and **Appendix C** of this report) • Vulnerability of properties to above floor flooding i.e. when each floor level is anticipated to be impacted by over floor flooding (**Figure 48** of this report). • Flood emergency response planning classifications, as indicated on **Figures 43 – 47** of this report. • Maps of potential flooding should be included in the Local Flood Plan. From this report, the following maps are available: - **Figures 6** to **14** show floodwater depths; - **Figures 15** to **23** show flood levels; - **Figures 24** to **32** show flow velocities. - **Figures 33** to **37** show flood hazard
Part 3 – Response Arrangements		
3.1 – 3.28		Each section of Part 3 will need a review and update to include consideration of local overland flooding within the Penrith LGA. Specific areas for consideration are listed below.
3.1	Control Arrangements	Include Little Creek catchment in the list of potential flooding mechanisms and associated flood risk categorisation and thresholds (low, medium, high or the like).
3.2	Start of Response Operations	This section will need updating to include considerations of when "response operations" will begin for local overland flooding issues in the Little Creek catchment, noting the likely limited warning time available. Currently, the Penrith LFP uses flood warning or flood watch information for the Nepean River only. As stated above, gauges in the vicinity of the catchment that could be used for flood intelligence are included in **Table 2** and **Figure 6** of the 'Little Creek Catchment Flood Study' 2017.
3.3	Designation of Start Time	This section will need updating to include considerations of when "start time" will begin for local overland flooding issues in the Little Creek catchment.
3.6	Operational Management	This section will need updating to include considerations of local overland flooding issues in the catchment.
3.10	Providing Information	It is anticipated that there would be minimal opportunity to provide adequate flood warning for the catchment based on the "flashy" nature of the flooding. Therefore, warning products such as severe weather warnings or flood watches could be used as the basis for designing appropriate flood template messaging. Currently the Little Creek catchment is located within the Bureau of Meteorology "Flood Watch" Area 57, which covers the Hawkesbury and lower Nepean Rivers.

Section	Description	Comment
		There may be opportunity to provide more localised information based on local rainfall. Looks at opportunities to incorporate a local flood warning system that caters for the “flashy” flooding nature of this and other overland flooding catchments. This could include provision of a website or similar and would eliminate the need for the community to “phone in” to the SES during a flood event. The website could include local and current information, such as - Local rainfall - River heights of South Creek and Nepean River to provide some local context to potential flooding - Road conditions - Closure of roads - Advice on how private property owners could protect their residential, commercial or industrial property.
3.10	Providing Information	Recommend the list of media outlets for warning dissemination be reviewed to ensure they remain current and correct.
3.12 and 3.13	Road and Traffic Control	There are a number of roads that are affected by flooding in the Little Creek catchment. Council, the SES, TfNSW and NSW Police have the authority to close roads as a part of the flood management planning process. Council may act as an agent for the TfNSW and close relevant roads as well as closing and re-opening council owned roads. Details of what agency is responsible for closing what roads should be included in this section.
3.17	Affected communities	Include details of flood evacuation centres
Part 4 - Recovery		
Part 4.1 to 4.3		It is recommended Part 4 is updated to include recovery considerations as a result of local overland flooding in the Little Creek catchment.

6.3 Emergency Services’ Capability

The Penrith SES unit has their local headquarters based in 27 Fowler Street, Claremont Meadows and would be the emergency services unit most likely to offer support to the community during floods in the Little Creek catchment.

However, given the size of the at-risk communities in the LGA, and the speed with which flash flooding can occur, adverse consequences are likely to occur across the Little Creek catchment before emergency services personnel can be deployed. As a result, it will be critical that the at-risk communities are able to cope with flooding without reliance on the emergency services. In the short term, this will require development of meaningful flood awareness information and community education campaigns to be designed for the local community and undertaken on a regular basis, possibly annually or bi-annually, coupled with the implementation of appropriate development controls over the medium to long term.

6.4 Response Strategy

6.4.1 Response and Evacuation Strategy theory

A major point of contention in contemporary flood emergency management planning relates to the advantages and disadvantages of evacuation compared to seeking safe refuge in place.

The Australian Fire and Emergency Services Authorities Council (AFAC) (2013) '*Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events'* is considered to represent best practice on this issue. It recognises that the safest place to be in a flood is well away from the affected area. Provided that evacuation can be safely implemented, this is the most effective strategy. <u>Properly planned and executed evacuation is the most effective strategy in terms of a reliable public safety outcome</u>.

However, AFAC recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may be safer than trying to escape by entering the floodwater.

Nevertheless, AFAC argues that remaining in buildings likely to be affected by flooding is not low risk and should never be a default strategy for pre-incident planning: 'where the available warning time and resources permit, evacuation should be the primary response strategy'. The risks of a 'safe refuge in place' strategy include:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level).
- Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris during the PMF).
- Isolation, with no known basis for determining a tolerable duration of isolation.
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment).
- People's immobility (not being able to reach the highest part of the building).
- The difficulty of servicing medical emergencies (pre-existing condition or sudden onset of medical emergency e.g., heart attack) during a flood; and
- The difficulty of servicing other hazards (e.g., fire) during a flood.

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater (Opper et al., 2011). Pre-incident planning therefore needs to include a realistic assessment of evacuation timelines (both time available and time required for evacuation), including assessment of resources available. Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the issuing of warnings and the movement of people at risk.

6.4.2 Little Creek Response and Evacuation Practice

The Penrith Local Flood Plan 2012 does not include consideration of flood emergency management response as a result of overland flooding. Therefore, comment cannot be made on the appropriateness or otherwise of the emergency management and evacuation practices in the Little Creek catchment. As discussed, it is likely that flooding will be occurring, and parts of the catchment will be isolated prior to the effective mobilisation of the emergency services. Therefore, the delivery of timely evacuation warnings and orders is unlikely to be achievable in the Little Creek catchment. While evacuation is the primary and preferred strategy of the NSW SES, the Penrith Local Flood Plan 2012 contains no details on how this may be enacted for overland flooding scenarios and it may not be the most appropriate flood emergency response strategy for the Little Creek catchment.

The national hazard mapping (refer **Figures 33 – 37**) indicates the maximum hazard during the 1% AEP flood is most often H1–H3, which is not unsafe for adults or likely to result in damage to buildings. However, more extensive areas would be exposed to a hazard classification of at least H5 and even H6 hazard during the PMF event which would be unsafe for people and buildings may be susceptible to failure if they are not specifically designed to withstand the forces of the floodwaters. Those properties that would be at least partly exposed to H5 or H6 hazard during the flood are shown in **Plate 18**.

It is estimated that more than 100 buildings located in the catchment would be exposed to above floor flooding depths greater than 1.2 metres in the PMF, which is considered unsafe for adults. These properties are shown in **Plate 19** and are primarily located between Adelaide Street and Hobart Street (i.e., south of the railway).

Early evacuation is considered essential for any of the properties identified in **Plate 18** and **Plate 19**. A particular focus should be placed on the properties identified in **Plate 19** as the significant above floor flooding depths will mean that it will be highly hazardous within these properties as well as outside of the properties.

In addition to the properties identified in **Plate 18** and **Plate 19**, early evacuation is also recommended for people whose prior medical condition means any isolation from medical help is unsafe.

Further discussion on potential evacuation strategies for these properties are provided in Section 10.2.5.

If the NSW SES wishes to maintain evacuation as the preferred strategy for the catchment, then significant work needs to be undertaken to ensure that evacuation can be successfully achieved. This includes at a minimum:

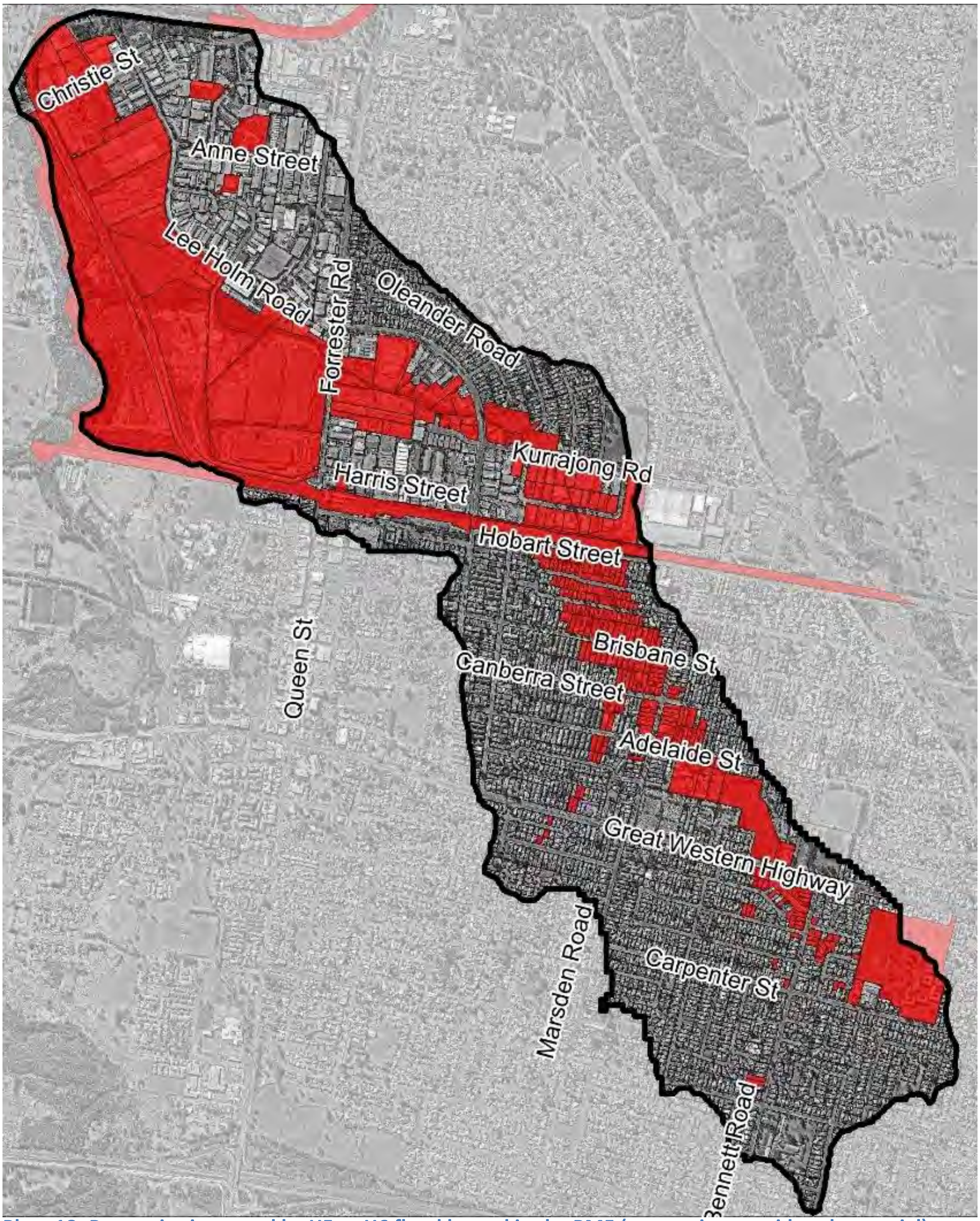


Plate 18- Properties impacted by H5 or H6 flood hazard in the PMF (evacuation considered essential).

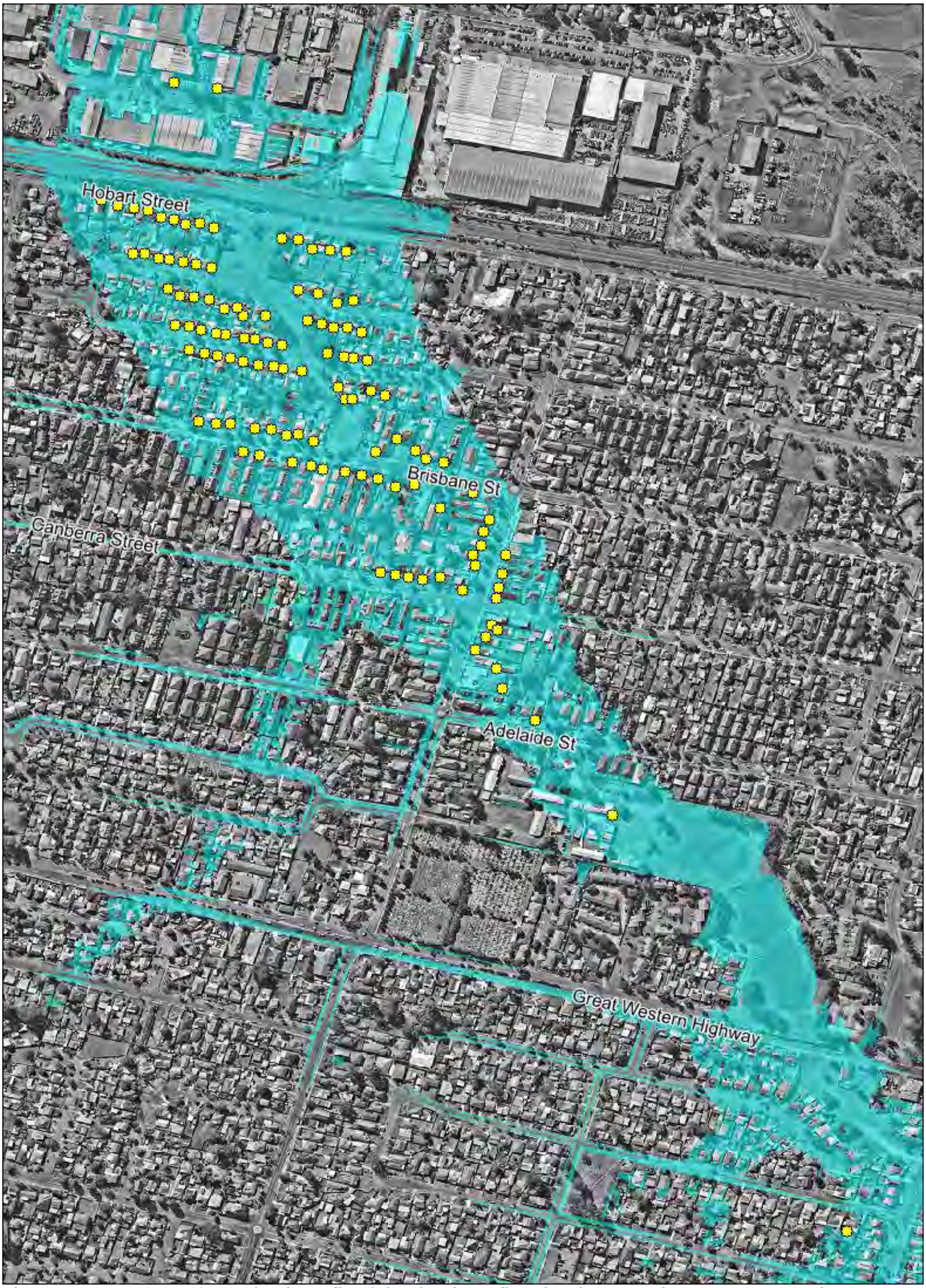


Plate 19- Properties estimated to have flood depths above floor level greater than 1.2 meters in the PMF (evacuation considered essential).

- The identification of appropriate evacuation centres. With different areas of the catchment potentially isolated from each other, several evacuation centres may be required to prevent evacuees from entering floodwaters in an attempt to reach the evacuation centre. There are a number of potential evacuation centres located within or adjacent to the catchment such as:
    - Colyton Neighbourhood Centre, (located at 2760/30 Jensen Street, Colyton).
    - Ridge Park Hall (17-23 Woodland Avenue, Oxley Park).
    - St Marys Community Centre (Mamre Road, near the Great Western Highway, St Marys).
    - There are also a number of schools or other community buildings throughout and adjacent to the Little Creek catchment that could also be used (i.e., the above are suggestions only).
- Evacuation centres would need to be suitably sized and stocked with supplies to cater for evacuees. However, given the relatively small population at risk and the short duration of flooding, the requirements for space and supplies at evacuation centres should not be extensive. It is also likely that a significant proportion of the population at risk will evacuate to private residences such as family and friends, further reducing the potential requirements of local evacuation centres.

7 OPTIONS FOR MANAGING THE FLOOD RISK

7.1 General

As outlined in Chapter 4, a number of properties across the Little Creek catchment are predicted to be exposed to a significant flood risk or significant financial impacts during floods. Accordingly, the following chapters outline options that could be implemented to better manage the flood risk.

7.2 Potential Options for Managing the Flooding Risk

7.2.1 Types of Options

Options for managing the flood risk can be broadly grouped into one of the following categories:

- **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. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk. However, they can also be designed to mitigate potential increases in flood risk associated with future catchment development.
- **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. Modifications to individual properties is typically used to manage existing flood risk while planning measures (e.g., development controls) are employed to manage future flood risk.
- **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. Response modification measures are the key measures employed to manage the continuing flood risk particularly for very large floods such as the PMF.

7.3 Options Considered as Part of Current Study

An initial list of potential flood risk management options was prepared for consideration by Council. The risk management measures were developed based upon consideration of the following factors:

- Location of high flood risk or high flood damage properties;
- Preliminary mitigation measures identified in the *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017);
- Council recommendations; and,
- Feedback provided by the community.

The list of options that were identified are summarised in **Table 27** (flood modification options), **Table 28** (property modification options) and **Table 29** (response modification options).

Table 27 Preliminary List of Flood Modification Options Considered for Managing the Flood Risk

Potential Flood Modification Options	Description of Option
Detention Basins	
Colyton High School Basin modifications	Provide additional storage capacity in *Colyton High School Basin* to reduce discharges downstream of the basin by elevating existing basin embankment. Modifications to existing outlet (low flow outlet and spillway) to take full advantage of basin storage capacity and more safely convey discharges in excess of basin capacity through downstream properties.
Great Western Highway above ground Detention Basin	Construct a new above ground detention basin in existing open space immediately south of the Great Western Highway to reduce downstream discharges and reduce frequency of highway overtopping.
Great Western Highway below ground Detention tank	Construct a new below ground detention tank in existing open space immediately south of the Great Western Highway to reduce downstream discharges and reduce frequency of highway overtopping.
Oxley Park Basin modifications	Provide additional capacity in Oxley Park detention basins to reduce discharges downstream of the basin by elevating existing basin embankment. Modifications to existing outlet (low flow outlet and spillway) to allow flows in excess of basin capacity to be more safely discharge into adjoining Oxley Park Public School.
Brisbane Street Detention Basin	Construct a new detention basin in existing open space immediately north of Brisbane Street to reduce overland flows and existing inundation depths south of the railway. May also require regrading of Brisbane Street to direct overland flow into new basin.
Hobart Street Detention Basin	Construct a new detention basin in existing open space immediately south of Hobart Street to reduce frequency and depth of inundation south of the railway.
Culvert and Bridge Modifications	
Great Western Highway culvert upgrade	Upgrade of the existing culvert to reduce frequency and depth of roadway overtopping at Great Western Highway.
Railway and Hobart Street culvert upgrade	Upgrade of the culvert draining runoff beneath the railway line along with the main inlet structure in Hobart Street to prevent ponding on southern side of railway
Glossop Street culvert upgrade	Upgrade of the existing Little Creek culvert to reduce frequency and depth of roadway overtopping at Glossop Street.
Forrester Road culvert upgrade	Upgrade of the existing Little Creek culvert to reduce frequency and depth of roadway overtopping at Forrester Road.
Stormwater Modification	
Kent Place to Bennet Road stormwater upgrades	Stormwater pit and pipe upgrades between Kent Place and Bennet Road to reduce frequency and depth of overland flooding.
Bennet Road to Great Western Highway stormwater upgrades	Stormwater pit and pipe upgrades between Bennet Road and Great Western Highway to reduce frequency and depth of overland flooding.
Canberra Street to Sydney Street stormwater upgrades	Stormwater pit and pipe upgrades in vicinity of Canberra Street and Sydney Street to reduce frequency and depth of overland flooding.

Potential Flood Modification Options	Description of Option
Great Western Highway to Canberra Street stormwater upgrades	Stormwater pit and pipe upgrades along secondary flow path located between Great Western Highway and Canberra Street to reduce frequency and depth of overland flooding.
Brisbane Street to Hobart Street stormwater upgrades	Stormwater pit and pipe upgrades between Brisbane Street and Hobart Street (including Thompson Avenue and Kenny Avenue) to reduce frequency and depth of overland flooding.
Plasser Crescent stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding at the low point in Plasser Crescent.
Kurrajong Road stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding near the intersection of Kurrajong Road and Plasser Crescent.
Glossop Street stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding at the low point in Glossop Street (near Little Creek culvert crossing).
Forrester Road stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding at the low point of Forrester Road (near Little Creek culvert crossing).
Lee Holm Drive stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding at the low point of Lee Holm Drive.
Stormwater flood gates	Additional of floodgates to help prevent water backing up the stormwater system in areas located downstream of Forrester Road.
Stormwater maintenance plan	Develop a stormwater maintenance plan that targets problematic areas where blockage significantly compounds existing flooding problems.
Channel Modification	
Bennet Road Swale	Construction of an overland flow swale between Bennet Road and the Great Western Highway to contain overland flows to existing open space.
Oxley Park Public School Overland flow path	Construction of an overland flow path between Oxley Park basin and Adelaide Street to safely convey overland flow through school.
Vegetation removal and maintenance	Removal and maintenance of dense vegetation within Little Creek channel to improve flow carrying capacity of the channel.
Lee Holm Drive Swale	Construction of an overland flow path between Lee Holm Drive and Little Creek to reduce ponding depths in Lee Holm Drive and inundation of adjoining properties.
Levee Modifications	
Industrial levee	Construction of a levee to protect industrial properties adjoining Christie Street from South Creek flooding.
Miscellaneous Modifications	
Great Western Highway Median Modification	Remove part sections of Great Western Highway median strip to reduce ponding depths on southern side of road and allow water to discharge downstream more readily.
Open fencing	Replace existing “solid” fencing in overland flow-path areas with open fencing.

Table 28 Preliminary List of Property Modification Options Considered for Managing the Flood Risk

Potential Property Modification Options	Description of Option
Planning Modifications	
Updates to LEP	Update Council LEP to reflect the detailed review completed as part of the current study. This will target development located beyond the FPA but within the PMF, such as critical and vulnerable developments, large scale infrastructure, subdivision and rezoning. This review is to take the NSW Governments "*Flood Prone Land Package*" that is currently on public exhibition into consideration.
Updates to DCP	Update Council DCP to reflect the detailed review completed as part of the current study.
Updates to Section 10.7 certificates	Update Council Section 10.7 certificates to include updated floodprone land information generated as part of the current study.
Property Modifications	
Voluntary purchase of select properties	Voluntary purchase of select properties in high hazard, floodway areas as per eligibility requirements in NSW Government Guidelines.
Flood proofing of select properties	Flood proofing of select residential properties subject to frequent above floor inundation in low hazard areas
Voluntary raising of select residential properties	Voluntary raising of select houses subject to frequent above floor inundation in low hazard areas as per eligibility requirements in NSW Government Guidelines.
Flood barriers	Installation of temporary flood barriers to afford protection from flooding for commercial or industrial properties.

Table 29 Preliminary List of Response Modification Options Considered for Managing the Flood Risk

Potential Response Modification Options	Description of Option
Education	
Community education activities	Various community education activities to increase flood awareness and allow residents to be more self-sufficient during future floods.
Make property level flood information available	Increase the availability and access to the most contemporary property level flood information for all residents and businesses within the LGA to increase flood awareness.
Flood Plans	
Preparation of residential flood plans	Preparation of flood plans by residential property occupiers to identify actions to be taken before, during and after a flood.
Preparation of business flood plans	Preparation of flood plans by business owners to identify actions to be taken before, during and after a flood.
Local flood plan updates	Update NSW SES local flood plan to take advantage of updated flood information generated as part of the current study.
Evacuation Route Upgrades	
Great Western Highway upgrade	Upgrade to Great Western Highway (between Bennet Road and Day Street) to improve level of service
Glossop Street upgrade	Upgrade to Glossop Street to improve level of service
Lee Holm Road upgrade	Upgrade to Lee Holm Road to improve level of service

Potential Response Modification Options	Description of Option
Miscellaneous	
Flood warning system	Development of a flood warning system (and associated recommendations for supporting infrastructure, such as stream gauges) for the catchment to provide additional evacuation time
Focussed Education and Evacuation Strategy	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas
Safe refuge in place strategy	Develop a strategy to allow for safe refuge in place for existing properties at suitable locations within the catchment. At the same time, identify areas where refuge in place is not safe and, therefore, where evacuation is considered essential.

7.4 Qualitative Assessment of Options

7.4.1 Raw Assessment

It was not considered feasible to undertake a detailed assessment of all twenty-nine (29) flood modification options, seven (7) property modification options and ten (10) response modification options. Therefore, a qualitative assessment of each potential option was completed to provide an initial assessment of the potential feasibility of each option and to determine which measures showed merit for further detailed assessment. The evaluation criteria that was employed to complete this assessment is summarised in **Table 30.**

In general, where an option had a beneficial impact against the evaluation criteria, it was assigned a positive score (either +1 or +2). Where an option had negligible impact, it was assigned a score of 0. And where there was a perceived negative impact, a negative value was assigned (either -1 or -2).

Each potential option was "scored" against each of the evaluation criteria using the following approach:

- <u>Impact on Flood Behaviour</u>: detailed modelling of each individual option was not possible. Therefore, the qualitative assessment utilised outcomes from detailed assessments of similar options in other floodplain risk management studies.
- <u>Technical feasibility</u>: Any potential technical "hurdles" were assessed based on the proximity of each option to other infrastructure or obstructions that would hinder implementation.
- <u>Environmental Impacts</u>: The "footprint" of each option was reviewed relative to environmental constraint mapping to determine if there was potential for adverse impacts (in which case a negative score was assigned). If an option has the potential to offer environmental benefits, this was noted by a positive score.
- <u>Economic Benefit</u>: was established by estimating the likely change in flood damage costs. This assessment drew from the outcomes of the assessment of other similar option in other floodplain risk management studies as well as the likely number of properties that would experience flood level reductions.

Table 30 Adopted Evaluation Criteria and Scoring System for Qualitative Assessment of Flood Risk Management Options

Score:	**Impact on flood behaviour**	**Technical Feasibility**	**Environmental Impacts**	**Economic Benefit**	**Cost**	**Impacts on Emergency Response**	**Community Support**
-2	Anticipated to result in significant increase in flood levels or extents	Anticipated to involve significant technical challenges	Significant negative environmental impact	Significant increase in flood damage cost or increase in flood risk	More than $1 million	Significant adverse impact on emergency services response	Majority of community opposed
-1	Anticipated to result in minor increase on flood levels or extents	Anticipated to involve moderate technical challenges	Small negative environmental impact	Minor increase in flood damage cost or increase in flood risk	More than $500k	Small adverse impact on emergency services response	Some community opposed
0	Anticipated to have a negligible impact on flood levels or extents	Anticipated to involve minor technical challenges	Negligible environmental impacts	No change in damages	More than $100k	Negligible impact on emergency services response	Neutral
1	Anticipated to result in a minor decrease in flood levels or extents (impacts 1-5 lots)	Anticipated to involve negligible technical challenges	Small opportunity for environmental enhancement	Minor reduction in flood damage cost or reduction in flood risk	More than $50k	Small improvement to emergency services response	Some community support
2	Anticipated to result in a significant decrease in flood levels or extents (impacts 5 or more lots)	Anticipated to involve no technical challenges	Significant opportunity for environmental enhancement	Major reduction in flood damage cost or reduction in flood risk	Less than $50k	Significant improvement to emergency services response	Majority of community support

- Cost: A "ballpark" cost was estimated for each option based on detailed cost estimates prepared for similar options in other floodplain risk management studies. This included potential land acquisition costs if required.
- Impact on Emergency Response: Assessment of this criterion considered how an option might alter the evacuation requirements, such as length of time or depth of floodwaters across inundated roads, and opportunities for alternate evacuation routes.
- Community Support: The information received during the first stage of the community consultation was used to provide an understanding of the level support for each potential floodplain risk management option.

The outcomes of the initial assessment of each option are presented in **Table H1** in **Appendix H**.

It should be reinforced that this assessment was relative in nature and was only used to prepare a shortlist of options to be assessed in detail as part of the detailed flood risk management options investigations.

7.4.2 Weighted Assessment

It was noted each of the evaluation criteria listed in **Table 30** would not always be considered equal and that higher weightings should be given to some of the evaluation criteria relative to others. Therefore, "weightings" were developed for each of the evaluation criteria to reflect the relative important of each criterion in best managing the flood risk.

The weightings that were developed and applied to each evaluation criteria are represented in **Table 31.** As shown in **Table 31**, the hydraulic performance on flood behaviour was assigned the highest weighting. This was followed by community support, technical feasibility and then economic benefits, cost, environmental impacts, and emergency response impacts. Although emergency response and environmental impacts were assigned a lower weighting, they are both important elements of the assessment process and support the triple bottom line evaluation and management of residual risk.

Table 31 Weightings applied to Scoring Criteria for Assessment of Potential Floodplain Risk Management Options

Scoring Criteria	Weighting
Impact on Flood Behaviour	25%
Technical Feasibility	15%
Environmental Impacts	10%
Economic Benefit	10%
Cost	10%
Impacts on Emergency Response	10%
Community support	20%

Each of the weightings in **Table 31** were applied to the "raw" scores for each option (refer **Table H1** in **Appendix H**) to develop weighted scores for each evaluation criteria. The weighted scores are provided in in **Table H2** in **Appendix H.**

7.4.3 Ranking of Options

The weighted and non-weighted scores for each option were summed to provide an overall score for each option. This served as the basis for ranking each flood modification, property modified and response modification options. The rankings assigned to each option are presented in **Table H3** in **Appendix H** (higher overall scores were assigned a higher ranking relative to lower overall scores).

The rankings provided in **Table H3** in **Appendix H** show that the top ten rankings and bottom ten rankings are similar regardless of whether the weighted of raw scores are used. However, the inclusion of the weightings does have an impact on the order of the ranking.

The raw scores also provide a large number of equal total scores making it difficult to differentiate between some of the options. The weighted scores provide a better basis for ranking of the options and, specifically, which should be carried forward for detailed assessment, which is discussed below.

7.5 Options to be Assessed in Detail

As outlined in the previous sections, a qualitative assessment of each potential option was completed to provide an initial appraisal of the likely feasibility of each option and which options should be assessed in detail. The outcomes of this assessment are presented in **Appendix H**.

As discussed, both "raw" and "weighted" scores were calculated for each option. It was determined that the weighted scores provide a better means of distinguishing between the options and it is the weighted score that formed the basis for determining which option was carried forward for detailed assessment. A summary of the options recommended for detailed analysis are presented in **Table 32** for flood modification options, **Table 33** for property modification options and **Table 34** for response modification options.

The outcomes of the detailed evaluation of each option is presented in Chapter 8 (flood modification options), Chapter 9 (property modification options) and Chapter 10 (response modification options.

Table 32 Flood Modification Options Recommended for Detailed Assessment

Option ID	Flood Modification Option	Description of Option
FM1	Great Western Highway culvert upgrade	Upgrade of the existing culvert to reduce frequency and depth of roadway overtopping at Great Western Highway.
FM2	Railway and Hobart Street culvert upgrade	Upgrade of the culvert draining runoff beneath the railway line along with the main inlet structure in Hobart Street to reduce ponding on southern side of railway
FM3	Glossop Street culvert upgrade	Upgrade of the existing culvert to reduce frequency and depth of Glossop Street overtopping.
FM4	Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	Stormwater pit and pipe upgrades in vicinity of Canberra Street, Sydney Street and Brisbane Street to reduce frequency and depth of overland flooding.
FM5	Glossop Street stormwater upgrades	Stormwater pit and pipe upgrades at low point in Glossop Street to reduce frequency and depth of roadway flooding.
FM6	Lee Holm Drive stormwater upgrades	Stormwater pit and pipe upgrades to prevent frequency and depth of ponding at the low point of Lee Holm Drive.
FM7	Colyton High School Basin Augmentation	Explore opportunities to provide additional storage capacity in existing detention basin and provide dedicated spillway to allow for safe discharge of flows when basin capacity is exceeded
FM8	Oxley Park Basin Augmentation	Explore opportunities to provide additional storage capacity in existing detention basins, revise outlet configuration and provide dedicated spillway to allow for safe discharge of flows through Oxley Park Public School
FM9	Great Western Highway Median Modification	Remove part sections of Great Western Highway median strip to reduce ponding depths on southern side of road and allow water to discharge downstream more readily.
FM10	Combined option #1	Considered the combination of mitigation options FM1, FM2, FM4 and FM8

Table 33 Property Modification Options Recommended for Detailed Assessment

Option ID	Property Modification Option	Description of Option
PM1	Updates to LEP	Update Council LEP to reflect the detailed review completed as part of the current study. This will target development located beyond the FPA but within the PMF, such as critical and vulnerable developments, large scale infrastructure, subdivision and rezoning.
PM2	Updates to DCP	Update Council DCP to reflect the detailed review completed as part of the current study.
PM3	Updates to Section 10.7 certificates	Update Council Section 10.7 certificates to include updated flood prone land information generated as part of the current study.
PM4	Voluntary purchase of select properties	Voluntary purchase of select properties in high hazard, floodway areas as per eligibility requirements in NSW Government Guidelines.

Option ID	Property Modification Option	Description of Option
PM5	Voluntary House raising of select properties	Voluntary house raising of select properties as per eligibility requirements in NSW Government Guidelines.

Table 34 Response Modification Options Recommended for Detailed Assessment

Option ID	Response Modification Option	Description of Option
RM1	Community education activities	Various community education activities to increase flood awareness and allow residents to be more self-sufficient during future floods.
RM2	Make property level flood information available	Increase the availability and access to the most contemporary property level flood information for all residents and businesses within the LGA to increase flood awareness.
RM3	Local flood plan updates	Update Penrith local flood plan 2017 to take advantage of updated flood information generated as part of the current study.
RM4	Preparation of residential flood plans	Preparation of flood plans by residential property occupiers to identify actions to be taken BEFORE, during and after a flood.
RM5	Preparation of business flood plans	Preparation of flood plans by business owners to identify actions to be taken before, during and after a flood.
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	Develop a strategy to educate the community and establish evacuation protocols for areas exposed to H5 and H6 hazard in the PMF (i.e., Adelaide Street to Hobart Street area).
RM7	Flash flood warning system	Development of a flood warning system (and associated recommendations for supporting infrastructure, such as rain gauges) for the catchment to provide additional evacuation time.
RM8	Great Western Highway upgrade	Upgrade to Great Western Highway (between Bennet Road and Day Street) to improve level of service.
RM9	Glossop Street upgrade	Upgrade to Glossop Street to improve level of service.

8 Flood Modification Options

8.1 Introduction

Flood modification options are measures that aim to modify existing flood behaviour by changing the extent, depth and velocity of floodwater across developed areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk.

Flood modification options considered as part of the study included:

- Culvert and Drainage Upgrades:
  - FM1 – Great Western Highway Culvert Upgrade: Section 8.3.1;
  - FM2 – Railway and Hobart Street Culvert Upgrade: Section 8.3.2;
  - FM3 – Glossop Street Culvert Upgrade: Section 8.3.3;
  - FM4 – Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrade: Section 8.3.4;
  - FM5 – Glossop Street Stormwater Upgrade: Section 8.3.5; and
  - FM6 – Lee Holm Drive Stormwater Upgrade: Section 8.3.6.
- Detention Basin Upgrades:
  - FM7 – Colyton High School Basin Augmentation: Section 8.4.1;and
  - FM8 – Oxley Park Basin Augmentation: Section 8.4.2.
- Topographic Modifications:
  - FM9 – Great Western Highway Median Modification: Section 8.5.1.
- Combined Option:
  - FM10 – FM1 + FM2 + FM4 + FM8: Section 8.6.18.5.1.

Further discussion on how each option was assessed is provided below. The outcomes of the assessment of each option are provided in subsequent sections.

8.2 Assessment Approach

8.2.1 Hydraulic Factors

Each of the measures under consideration will likely alter the distribution of floodwaters. Although this aims to reduce the extent and depth of inundation across populated areas, it may divert floodwaters elsewhere, thereby increasing the flooding risk across other areas. Therefore, it is important that the potential flood impacts associated with implementing each option is understood.

The hydraulic benefits of each flood modification option were assessed by including a representation of each option in the hydraulic model and using the updated model to re-simulate each design flood. The hydraulic benefits were then quantified by preparing flood level difference mapping for each option for the 20% AEP, 5% AEP, 1% AEP floods as well as the PMF (the flood level difference mapping shows the magnitude and extent of changes to existing flood levels and the expected flood extents if the option was implemented). The difference mapping is included under the detailed discussion on each option.

Flood level differences were also extracted at a number of locations across the catchment for the 5% AEP and 1% AEP floods and are summarised in **Table 35** and **Table 36**. The locations where the flood level differences were extracted is also provided in **Plate 20**.

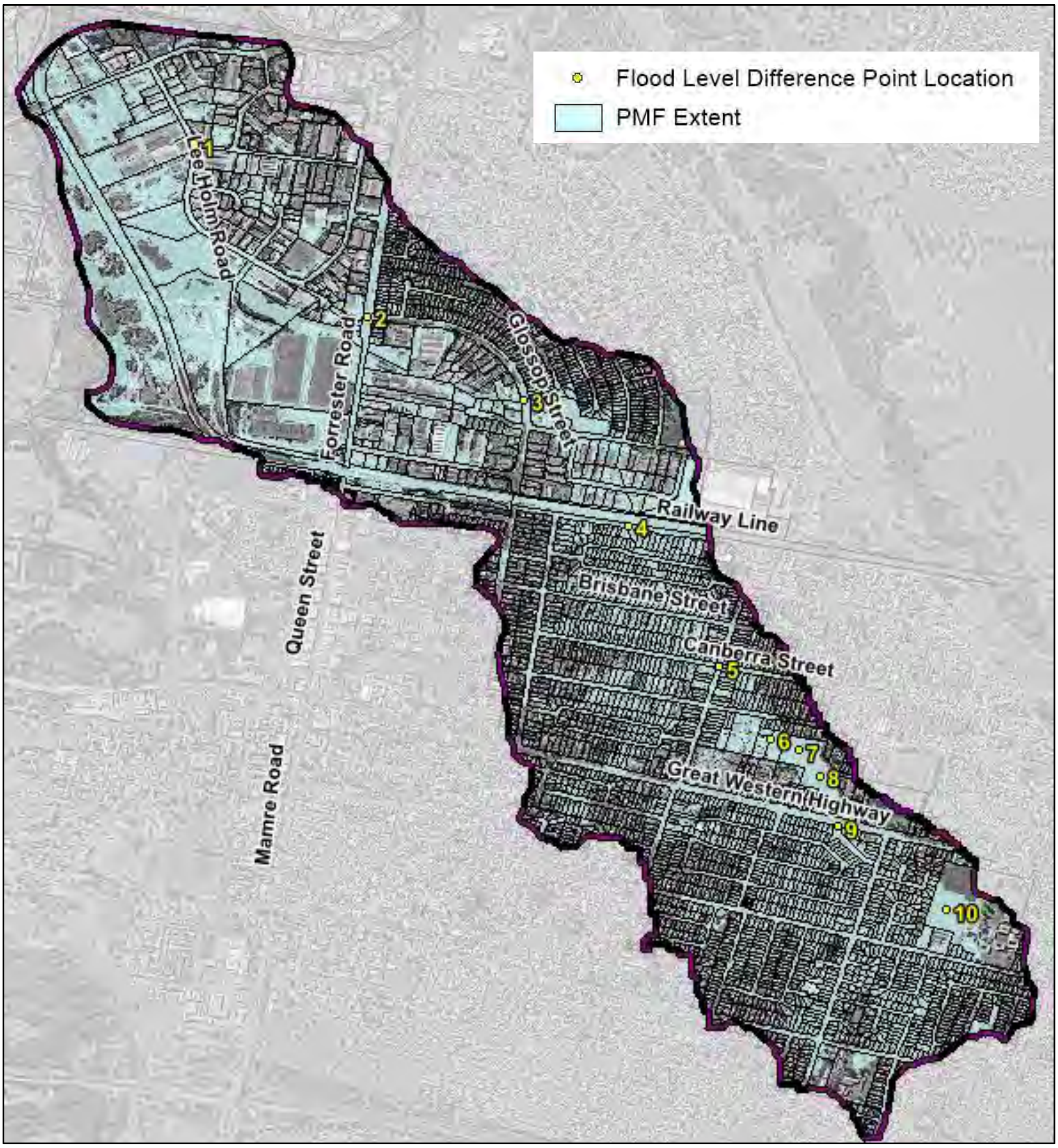


Plate 20 – Locations where flood level differences were extracted

Table 35 Flood level differences for 5% AEP flood with flood modification options in place

Location (refer Plate 4)	Flood Level Differences (m)									
	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	-	-	-	-	-	-	-	-	-	-
4	0.00	-0.29	0.00	-0.15	0.00	0.00	0.00	-0.01	0.00	-0.47
5	0.00	0.00	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	-0.07
6	-	-	-	-	-	-	-	-	-	-
7	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.12	0.00	-0.12
8	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	-0.02
9	-0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.07
10	0.00	0.00	0.00	0.00	0.00	0.00	-0.21	0.00	0.00	0.00

Table 36 Flood level differences for 1% AEP flood with flood modification options in place

Location (refer Plate 4)	Flood Level Differences (m)									
	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.05	-	0.01	-	0.00	0.00	0.00	0.00	0.06
4	0.00	-0.21	0.00	-0.11	0.00	0.00	0.00	-0.03	0.00	-0.36
5	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	-0.04
6	0.05	0.00	0.00	0.00	0.00	0.00	0.00	-0.09	0.04	-0.07
7	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.11
8	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.03	-0.01
9	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.09	-0.06
10	0.00	0.00	0.00	0.00	0.00	0.00	-0.38	0.00	0.00	0.00

It was noted that options that reduce flood levels in one area often increased flood levels elsewhere in the catchment. Any option that results in flood level increases across private property is unlikely to secure state government support and funding. Therefore, each option was refined as part of the hydraulic assessment process to maximise hydraulic benefits while ensuring that adverse flood impacts were minimised. This often meant that the hydraulic benefits provided by an option needed to be reduced to ensure adverse flood impacts were reduced across private property.

8.2.2 Financial Feasibility

A preliminary economic assessment was completed to assist in determining the financial viability of each measure. The assessment was completed by estimating the 'costs' and 'benefits' that could be expected if the options were implemented. This enabled a benefit cost ratio (BCR) to be prepared for each option. The BCR provides the following economic insights:

- BCR greater than 1: The economic benefits (i.e., reduction in flood damage costs) are predicted to be greater than the cost to implement the option.
- BCR between 1 and 0: There is still an economic benefit (i.e., reduction in flood damage costs). However, the cost of implementing the option is greater than the economic benefit.
- BCR equal to 0: There is no economic benefit (i.e., no reduction in flood damage costs) associated with implementing the option.
- BCR is negative: Implementing the option is predicted to generate a negative economic impact (i.e., increase flood damage costs).

From a flooding perspective, economic 'benefits' were quantified as the reduction in flood damage costs if the option is implemented. This was estimated by preparing damage estimates for each design flood event with the option in place and using this information to prepare a revised average annual damage (AAD) estimate. In order for a BCR to be estimated, it is necessary to modify the 'base' AAD estimates (which reflect the average damage that is likely to be incurred in a single year) to a total damage that could be expected to occur over the life of each flood modification option. Accordingly, the AAD estimates were accumulated over a 50-year period and then discounted to a present-day value by applying a discount rate of 7%.

Cost estimates have also been prepared for each option based on initial concept designs. The concept design plans are provided in Volume 2 and the cost estimates are included in **Appendix G**. The cost estimates were prepared using the best available information. However, precise cost estimates can only be prepared following detailed investigations and once detailed design plans have been prepared. Therefore, the costs presented in this report should be considered an estimate only. Nevertheless, they are considered suitable for providing an appraisal of the financial viability of each option.

A summary of the costs to implement each option and the reduction in flood damage costs that could be expected with each option in place is provided in **Table 37**. Further information on the economic performance of each option (including implementation costs and predicted reductions in flood damages) is included as part of the discussion on each option.

In instances where no obvious hydraulic improvement was provided by the option or the option was demonstrating increases in flood levels or extents across private property, an economic assessment was not always completed for the following reasons:

- The lack of positive hydraulic impacts indicates the option is not worth pursuing and would likely yield a poor economic outcome.
- It is highly unlikely the option would be eligible for state government funding (due to adverse flood impacts across private property).

Table 37 Economic Assessment for Flood Modification Options

Flood Modification Option	Present Value of Costs and Damages ($ Millions)		Benefit-Cost Ratio
	Cost Estimate	Reduction in Damage with Option in Place	
Culvert and Drainage Upgrades			
FM1 - Great Western Highway culvert upgrade	0.62	0.35	0.6
FM2 – Railway and Hobart Street culvert upgrade	1.03	0.93	0.9
FM3 - Glossop Street culvert upgrade	0.74	0.01	Less than 0.1
FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	1.29	0.82	0.6
FM5 - Glossop Street stormwater upgrades	0.77	0.00	0
FM6 - Lee Holm Drive stormwater upgrades	Not calculated	Not calculated	Not calculated
Basin upgrades			
FM7 - Colyton High School Basin Augmentation	1.38	1.25	0.9
FM8 - Oxley Park Basin Augmentation	0.53	0.56	0.8
Topographic modifications			
FM9 - Great Western Highway Median Modification	Not calculated	Not calculated	Not calculated
Combined Option			
FM10 – FM1, FM2, FM4 and FM8	3.88	2.55	0.7

8.2.3 Change in Number of Buildings Inundated Above Floor Level

An assessment of the change in the number of buildings subject to above floor inundation during each design flood was also completed for each option. This was completed by comparing peak design flood levels from the revised simulations with each mitigation measure in place against building floor levels in the property database to determine the number of buildings with above floor flooding. This number was then compared against the number of buildings with above floor flooding for the "existing" scenario to determine the change in above floor flooding.

The outcomes of this assessment are summarised in **Table 38**. A negative value indicates a reduction in above floor flooding and a positive value indicates an increase in above floor flooding.

8.2.4 Emergency Response Impacts

Emergency response is arguably one of the most important measures for managing the continuing flood risk across any catchment, particularly during very large floods where flood modification options may not be as effective. Therefore, the potential for each option to impact on current emergency response processes was considered as part of the assessment of each option.

Table 38 Change in Number of Properties Subject to Above Floor Flooding for Each Flood Modification Option for Design Catchment Conditions

Flood Modification Option	Change in Number of Properties with Above Floor Inundation*			
	20% AEP	5% AEP	1% AEP	PMF
Culvert and Drainage Upgrades				
FM1 - Great Western Highway culvert upgrade	0	-3	-2	0
FM2 – Railway and Hobart Street culvert upgrade	0	-1	-2	-1
FM3 - Glossop Street culvert upgrade	0	0	0	0
FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	0	-1	-2	0
FM5 - Glossop Street stormwater upgrades	0	0	0	0
FM6 - Lee Holm Drive stormwater upgrades	Not calculated	Not calculated	Not calculated	Not calculated
Basin upgrades				
FM7 - Colyton High School Basin Augmentation	0	0	0	-11
FM8 - Oxley Park Basin Augmentation	0	0	-1	2
Topographic modifications				
FM9 - Great Western Highway Median Modification	0	0	-3	0
Combined Option				
FM10 – FM1 + FM2 + FM4 + FM8	0	-3	-6	-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.

Due to the "flashy" nature of flooding in the Little Creek catchment, there may be little opportunity for emergency services to be mobilised to facilitate evacuation. Therefore, a focus was placed on identifying options that would result in less frequent and deep inundation of roads and, therefore, would provide improved opportunities for vehicular evacuation.

Table 39 summarises the outcomes of this assessment and documents the design flood where access would first be cut along major roads in the catchment. A road was defined as "cut" if the flood hazard exceeded "H1" across at all lanes of the road.

If the severity of the design flood increases (i.e., gets rarer) after implementation of an option it indicates an improved emergency response outcome (these are shown in green text in **Table 39**). However, if the severity of the flood that causes a road to be cut becomes less severe it indicates a negative emergency response outcome (these are shown in red text in **Table 39**).

Table 39 Change in Roadway Inundation for Each Flood Modification Options

Options	Design Flood that Road is First Cut#										
	Bennet Road	GWH - west bound	GWH - east bound	Adelaide Street	Sydney Street	Brisbane Street	Hobart Street	Kurrajong Road	Glossop Street	Forrester Road	Lee Holm Drive
Existing	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
Culvert and Drainage Upgrades											
FM1 - Great Western Highway culvert upgrade	5%AEP	2%AEP	0.5%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
FM2 – Railway and Hobart Street culvert upgrade	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	5%AEP	10%AEP	0.5EY
FM3 - Glossop Street culvert upgrade	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	0.2%AEP	10%AEP	0.5EY
FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	5%AEP	5%AEP	1%AEP	2%AEP	10%AEP	20%AEP	0.5EY	0.2%AEP	2%AEP	20%AEP	0.5EY
FM5 - Glossop Street stormwater upgrades	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
FM6 - Lee Holm Drive stormwater upgrades	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
Basin upgrades											
FM7 - Colyton High School Basin Augmentation	5%AEP	5%AEP	1%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
FM8 - Oxley Park Basin Augmentation	5%AEP	5%AEP	1%AEP	1%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
Topographic modifications											
FM9 - Great Western Highway Median Modification	5%AEP	5%AEP	0.5%AEP	2%AEP	0.5EY	0.5EY	0.5EY	0.5%AEP	2%AEP	10%AEP	0.5EY
Combined Option											
FM10 – FM1 + FM2 + FM4 + FM8	2%AEP	2%AEP	0.5%AEP	1%AEP	10%AEP	20%AEP	20%AEP	0.2%AEP	5%AEP	20%AEP	0.5EY

NOTE: # Green text indicates an improvement in the frequency of the roadway being cut (i.e. road is cut less often). Red text indicates the road is cut more frequently.

8.2.5 Technical Feasibility

If a structural measure is proposed, it needs to be physically possible to construct the measure considering the option itself as well as any local constraints (services, environmental, heritage etc). Therefore, 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.

8.3 Drainage Upgrades

8.3.1 FM1 - Great Western Highway Culvert Upgrade

As shown in **Figures 7** to **14**, notable inundation is predicted on the southern side of the Great Western Highway. The inundation primarily occurs as a result of the elevated roadway in combination with a lack of sub-surface drainage capacity. This produces two flooding problems in the area:

- The east bound travel lanes of the Great Western Highway are predicted to be cut during floods as frequent as the 0.5EY flood. This can result in significant traffic impacts and the frequency of the road overtopping increases the potential for drivers to be tempted to drive through floodwaters.
- Several residential properties located south of the highway are also predicted to be inundated. This includes three (3) properties where above floor flooding is predicted in the 5% AEP flood, an additional three (3) properties where above floor flooding is predicted during the 2% AEP flood and a further three (3) properties where above floor flooding is predicted during the 1% AEP flood.

Option FM1 attempts to reduce the severity of flooding across the highway as well as to the south of the highway by upgrading the existing culvert that runs beneath the highway. As shown in **Figure 57**, this would involve replacing the existing triple 1.5 metre diameter culverts with three 1.5m wide by 1.8m high box culverts.

A larger box culvert size (5m wide x 1.8m high) was trialled to provide greater flood level reductions south of the highway. But this was determined to generate adverse flood impacts downstream of the Oxley Park detention basins during all simulated design floods. Therefore, a more modest increase in culvert size was ultimately selected.

A cost estimate for FM1 was prepared and is enclosed in **Appendix G**. It shows that FM1 is expected to cost in the order of $600,000 to implement.

The hydraulic model that was used to define design conditions was updated to include a representation of the culvert upgrade. The updated TUFLOW model was then used to re simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 21**.

Plate 21 shows that at the peak of the 20% AEP flood, small flood level reductions (i.e., 0.02 metres) are predicted across multiple properties on the southern side of the Great Western Highway. No increases in flood level are predicted at any location during the 20% AEP flood.

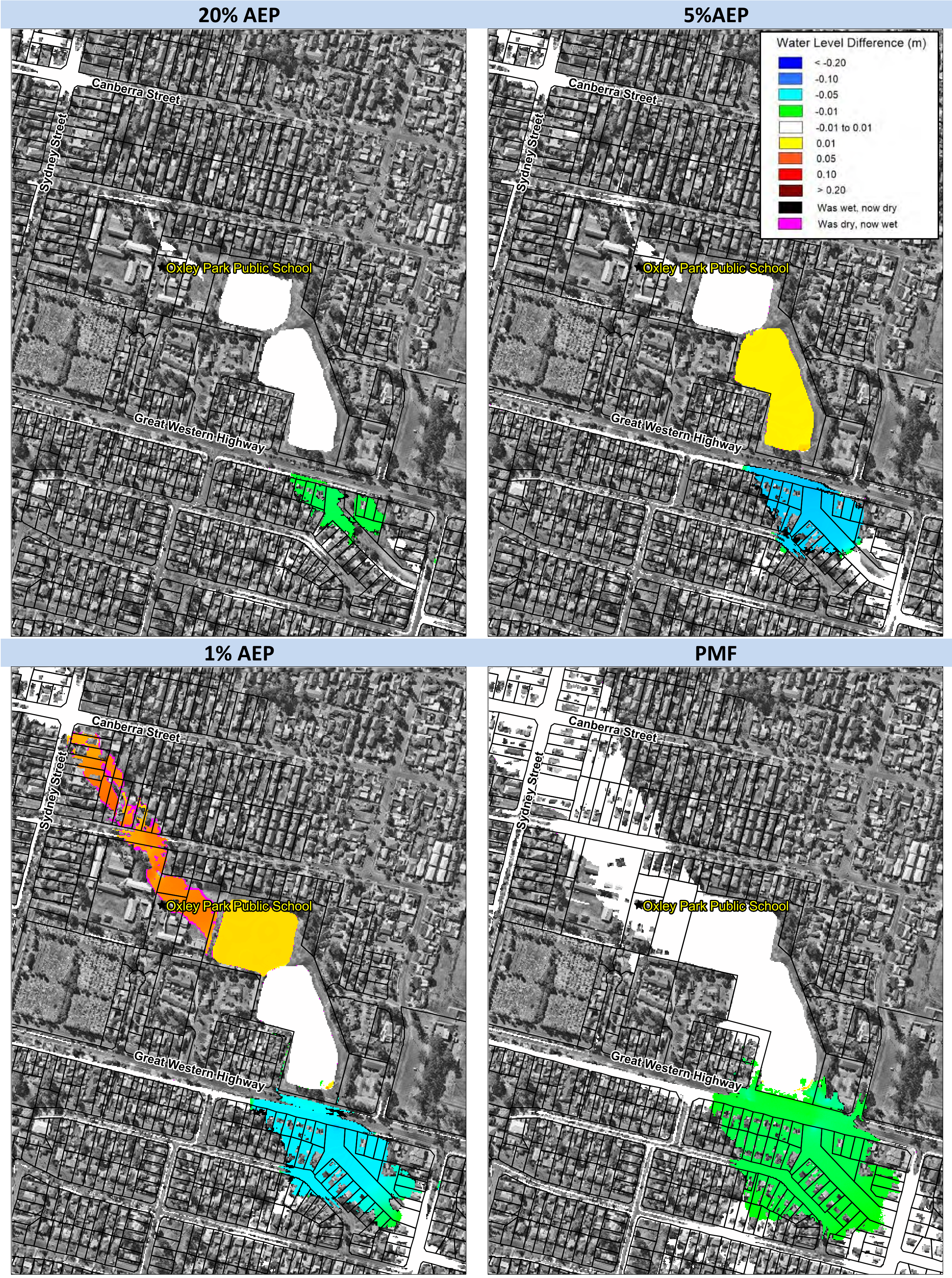


Plate 21 Flood Level Difference Maps for FM1

During the 5% AEP flood, reductions in flood levels of about 0.08 metres can be expected to the south of the Great Western Highway. Up to 14 properties in this area are predicted to experience flood level reductions. The flood level reductions are predicted to result in three (3) fewer properties being exposed to above floor flooding in the 5% AEP flood. Therefore, if this option was implemented, above floor flooding across properties to the south of the Great Western Highway would not commence until the 2% AEP flood.

During the 1% AEP flood, flood level reductions of around 0.05 metres are predicted south of the highway. The flood level reductions are predicted to result in two (2) fewer properties in this area being exposed to above floor flooding during the 1% AEP flood. Therefore, FM1 is predicted to afford notable hydraulic benefits for properties located south of the Great Western Highway.

Only small flood level reductions (0.03 metres) are predicted on the southern side of the highway during the PMF. This is associated with the additional capacity afforded by the upgraded culvert being relatively small when compare to total flow approaching the highway during the PMF.

However, implementation of FM1 is predicted to direct additional water downstream of the highway. During the 20% AEP and 5% AEP floods, the additional water is detained within the Oxley Park detention basins and does not impact on private property. However, during the 1% AEP flood, the detention basins do not have sufficient capacity to detain the additional flows, resulting in flood level increases (typically about 0.05 metres) extending across multiple properties located between the Oxley Park basins and the Sydney Street and Canberra Street intersection.

A revised flood damages assessment was completed with the updated TUFLOW model results. The outcomes of the revised damage assessment indicate that this option is predicted to reduce existing flood damages by around $350,000 over the next 50 years. This affords a preliminary benefit cost ratio of 0.6. This means that the costs to implement this option exceed the benefits.

The Great Western Highway serves as the major east-west transportation link in the catchment and, therefore, forms an important evacuation route. The outcomes of the existing flood assessment determined that all wester-bound travel lanes would be cut by floodwaters during a 5% AEP flood. However, the flood level reductions provided by FM1 would ensure that at least 1 west-bound lane of traffic would remain open during floods up to the 2% AEP flood. Therefore, FM1 would provide a notable emergency response benefit.

There are several services located in proximity to the existing culverts. Survey and potential relocation of some of these services would likely be required should the option proceed. The services include:

- Telstra;
- NBN;
- Sydney Water sewer and water mains.

The Great Western Highway is operated by Transport for NSW (TfNSW). Therefore, coordination with TfNSW would be required for this option to proceed.

The management of traffic during construction will be an important consideration given the highly trafficked nature of the roadway. Although suitable planning should allow the traffic impacts to be minimised during construction, it is unlikely that the impacts can be completely mitigated.

The adverse impacts that are predicted across properties during the 1% AEP flood make FM1 difficult to support in isolation. However, it does afford benefits to several properties located south of the Great Western Highway during a range of floods. Therefore, this option could still be considered as part of a combined option providing the downstream flood impacts are suitably mitigated. The analysis of this combined option is provided in Section 8.6.1.

8.3.2 FM2 – Railway and Hobart Street Culvert Upgrade

One of the area's most significantly impacted by flooding within the Little Creek catchment is located to the south of the railway line in Hobart Street. The rail embankment, which is in the order of 6 meters higher than Hobart Street, serves as a significant barrier to flow and the only way for water to pass though the railway line is via a culvert system (refer **Plate 22**). Water depths of 0.5 metres are predicted in Hobart Street during the 20% AEP flood, increasing to more than 1.5 metres in the 1% AEP flood and more than 6 metres of water is predicted during the PMF. Therefore, it is evident that the existing drainage system does not have sufficient capacity to convey flows through the railway line during large floods in the catchment.

Plate 22 View looking north showing Hobart Street in foreground, stormwater inlet pit and elevated railway embankment

A review of the existing flood modelling outputs suggests that the existing culvert system is not flowing full during more frequent floods, such as the 20% AEP event. Therefore, as a minimum, improving the stormwater inlet capacity in Hobart Street may assist in reducing inundation depths during more frequent floods. This may be as simple as lowering the elevation of the existing pit shown in **Plate 22** so that water does not need to pond to the same depths to fully activate this inlet. However, further analysis determined that during larger floods (such as the 1% AEP flood), the culvert system is flowing full. Therefore, increasing the stormwater inlet capacity alone will not provide a significant benefit during large floods.

Therefore, FM2 would involve upgrading the existing pipe and culverts system in the Hobart Street and railway area in addition to increasing the inlet capacity. As shown in **Figure 58**, the upgrades would include:

- Regrading the area around the main inlet pit to direct water off the road and upgrade of the pit to provide additional inlet capacity.
- Replacing the four existing 1.2 metre diameter pipes beneath Hobart Street with four 1.35m diameter pipes.
- Replacing the existing 6.3m x 3.3m trapezoidal pit on the northern side of Hobart Street with a larger 7m x 3.5m rectangular pit.
- Replacing the existing 2.44m diameter pipe with a 2.7m wide x 2.1 m high box culvert.
- Replacing the existing trapezoidal culvert beneath the railway with a 2.7m wide x 2.1 m high box culvert.

Larger box culverts were explored but were determined to significantly impact on Glossop Street which is an important evacuation route. As a result, the option shown in **Figure 58** was determined to provide the best overall compromise between flood level reductions in Hobart Street area while minimising adverse flood impacts across Glossop Street. Notwithstanding, an assessment of a much larger box culvert was completed, and the outcomes of this assessment are presented in the following section of this report.

A cost estimate was prepared for FM2 and is included in **Appendix G**. This indicates that FM2 would likely cost just over $1 million to implement.

The hydraulic model was updated to include a representation of the drainage upgrade. The updated TUFLOW model was then used to re simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 23**.

Plate 23 show that implementation of FM2 is predicted to provide some significant flood level reductions across Hobart Street during each design flood. More specifically, reductions of 0.1 metres are predicted during the 20% AEP flood, reductions of nearly 0.3 metres are predicted during the 5% AEP and reductions of around 0.2 metres are predicted during the 1% AEP flood.

Only small flood level reductions (0.02 metres) are predicted during the PMF as the larger culvert becomes overwhelmed during this much larger flood. However, the flood level reductions are predicted to extend across a large area between Plasser Crescent and Adelaide Street.

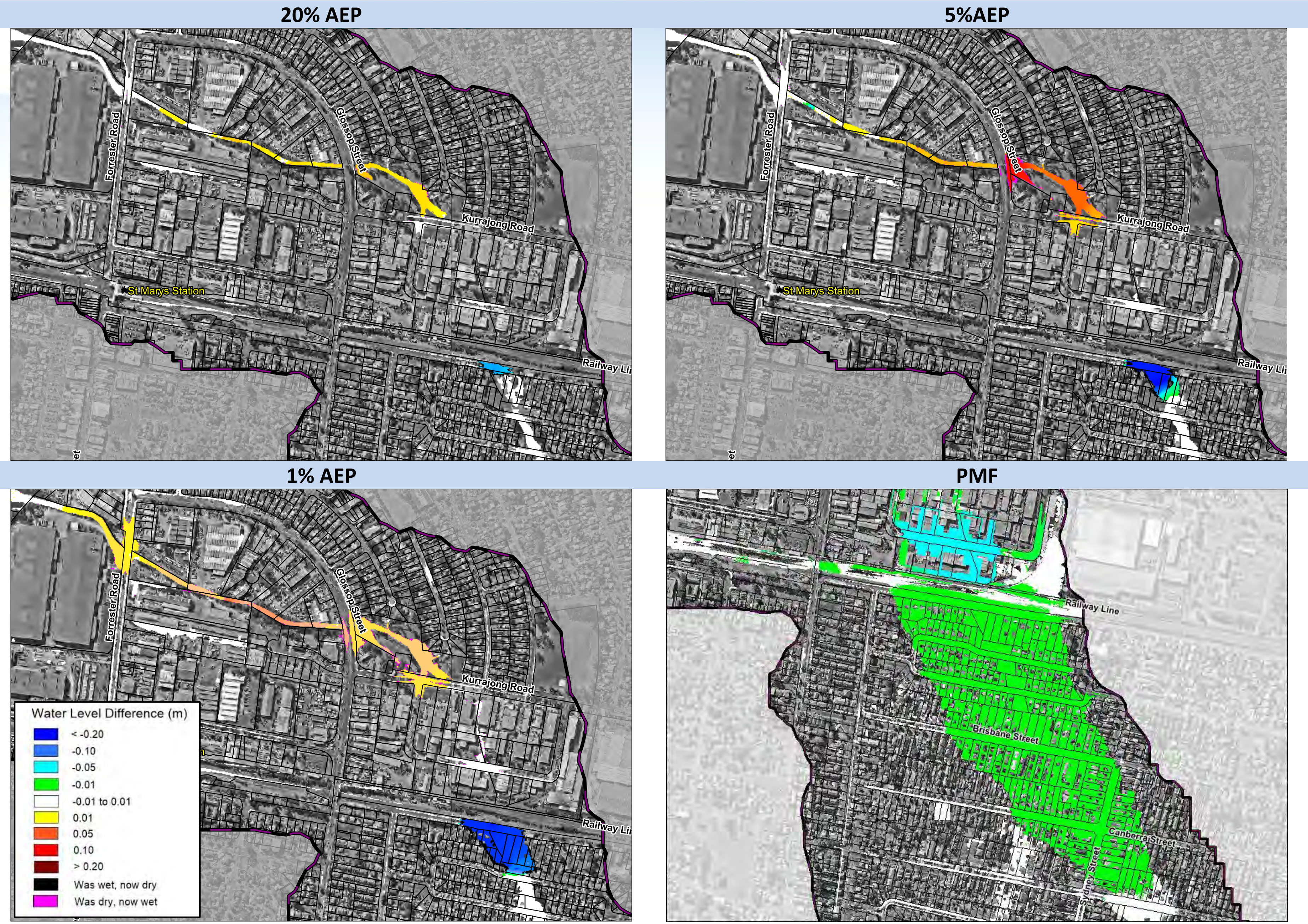


Plate 23 Flood Level Difference Maps for FM2

Plate 23 shows that FM2 is predicted to generate flood level increase across some areas located north of the railway line. Most of the flood level increases are contained to the Little Creek channel or open space. However, the flood level increases are predicted to impact on one property fronting Glossop Street and the rear of one property in Cedar Street. Flood level increases are also expected to extend across Kurrajong Road, Glossop Street and Forrester Road. Additional measures may need to be implemented with FM2 to ensure impacts across private properties and local roads are minimised (e.g., deflector levees or stormwater upgrades).

A revised flood damages assessment was completed with the updated TUFLOW model results. The outcomes of the revised damage assessment indicate that this option is predicted to reduce existing flood damages by $930,000 over the next 50 years. This affords a preliminary benefit cost ratio of just below 1. This indicates that the reduction in flood damage costs are roughly equal to the cost to implement this option (although it needs to be recognised that the cost estimates are preliminary in nature).

The reduction in flood levels is predicted to result in one (1) fewer property with above floor flooding in the 5% AEP event, two (2) fewer properties with above floor flooding in the 1% AEP event and one (1) fewer property with above floor flooding in the PMF.

Although FM2 is predicted to reduce flood levels in Hobart Street, the reductions are not sufficient to provide a significant emergency response improvement (i.e., access is still predicted to be cut during the 0.5EY flood). This appears to be associated with water needing to pond in Hobart Street to “fully charge” the stormwater inlets and culvert system. However, there may be opportunities to explore inclusion of a modified pit arrangement and/or detention area on the southern side of Hobart Street (as discussed in the next section) to reduce ponding depths further during more frequent rainfall events.

Furthermore, **Table 40** shows that FM2 is predicted to result in Glossop Street (the main north-south transportation link in the catchment) being cut more frequently (the south bound lanes are currently cut during a 2% AEP flood, but that reduces to a 5% AEP flood with FM2 in place). Therefore, it will likely be necessary to provide some additional remedial mitigation measures (e.g., a small barrier on the eastern side of Glossop St to hold additional water in creek channel or open space) or combine FM2 with another option such as FM3.

The culvert upgrades extend through the existing railway embankment. Therefore, Sydney Trains will need to be engaged in further feasibility discussions if this option is pursued further. It is unlikely that the railway line can be distributed during the implementation process to ensure continuation of train services during construction which will add to the complexity of implementation of this option. Traffic in Hobart Street will also likely be disrupted during construction.

Overall, FM2 affords some significant benefits across one of the most significant impacted areas within the Little Creek catchment. It is also predicted to provide a benefit cost ratio near 1. Although some flood level increases are predicted across isolated properties and roads, it is likely that these could be offset by implementation of additional local measure or by considering this option as part of a combined option. In either case, this option is considered suitable for further investigations and potential implementation.

Larger Culvert Option

In addition to the culvert upgrade option summarised above, a larger culvert option was also investigated. The additional investigations focused on determining the culvert arrangement that would be necessary to eliminate inundation on Hobart Street during floods up to and including the 1% AEP flood and whether this culvert arrangement would also reduce the flood hazard on Hobart Street to more tolerable levels in the PMF.

These investigations determined that the main limitation associated with any culvert upgrade in the area is the ability to get water from the Hobart Street road surface into the culvert (i.e., you would typically need a small build-up of water in Hobart Street to drive enough water into even very large pits and "fully charge" a large culvert). The only effective way of directing sufficient water into a large culvert was to extend the larger culvert across Hobart Street to a small detention area with a large pit on the southern side of the street that would still allow for some ponding (this will help drive additional flow into the culvert) but would ensure this additional water is contained to open space. You can see this detention area in the 1% AEP depth map shown in **Plate 24**.

With this inlet arrangement, a double 3.3mW x 1.2mH box culvert would be required to remove inundation from Hobart Street during the 1% AEP flood (with the exception of some ponding within the gutter) (refer **Plate 25**).

Flood level difference mapping was prepared for the 1% AEP flood as well as the PMF with the large culvert arrangement in place. This difference mapping is provided in **Plate 25** and **Plate 26** respectively.

Plate 25 shows during the 1% AEP flood, notable reductions in flood levels and inundation extents are anticipated in the Hobart Street area. More specifically, flood level reductions of more than 1.4 metres are anticipated in Hobart Street. However, the benefits are generally restricted to the area contained between Kenny Avenue and Hobart Street.

Plate 26 shows that during the PMF, flood level reductions are predicted to extend across a much larger geographic area extending from Hobart Street south to Adelaide Street. However, the magnitude of the flood level reductions across this area generally do not exceed 0.2 metres. As a result, water depths in Hobart Street are still predicted to approach 6 metres during the PMF. This would not be sufficient to reduce the existing flood hazard in the Hobart Street area (i.e., H5 and H6 hazard would still be common).

Furthermore, it was determined that the larger culvert would need to extend a considerable distance downstream to ensure that properties and roadways between the railway line and Lee Holm Drive were not adversely impacted (a distance of more than 1.7 km). The cost of the culverts alone (i.e., multiple tens of millions of dollars) would be sufficient to render the option impractical.

Therefore, the smaller culvert upgrade option documented in Section 8.3.2 is likely to provide the most practical outcome. Notwithstanding opportunities to further optimise the culvert size could be explored as part of the detailed feasibility assessment for the option that will follow the floodplain risk management study and plan.

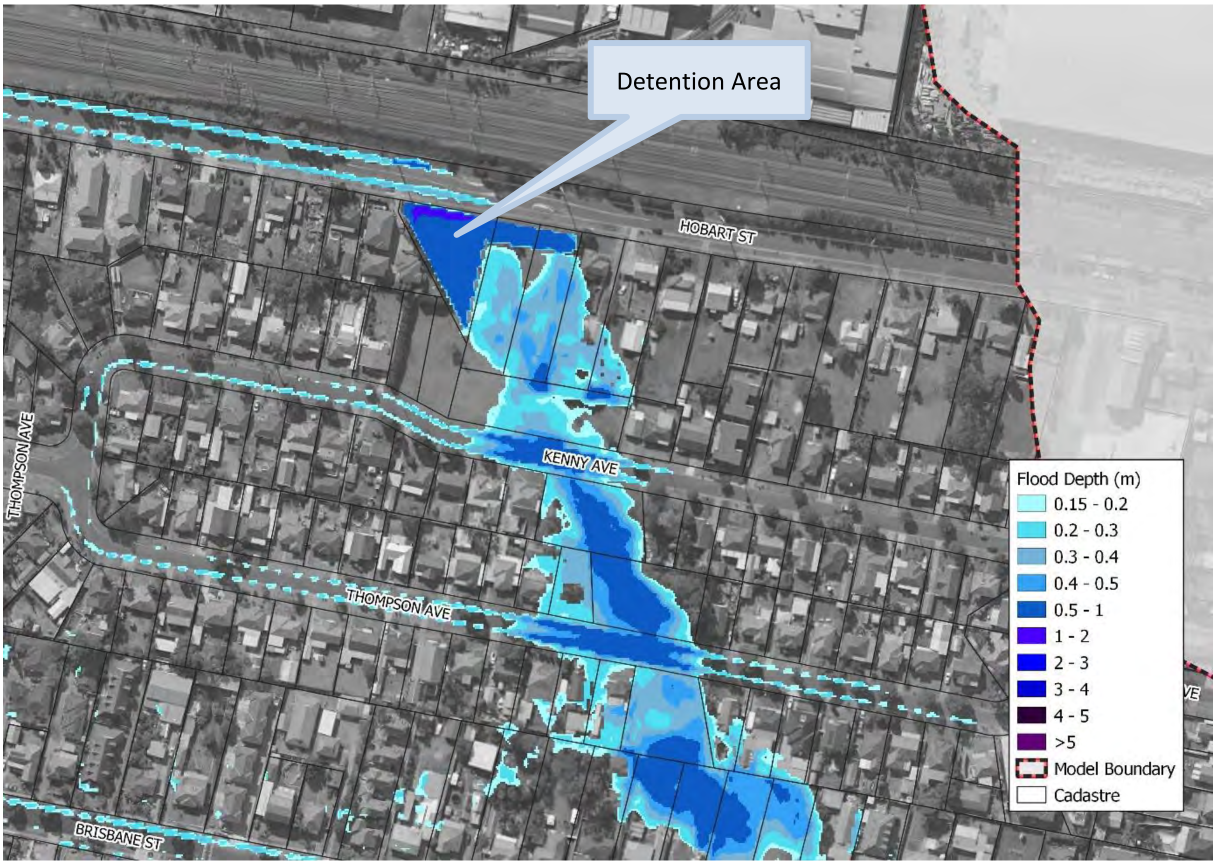


Plate 24 Predicted 1% AEP water depths with larger Hobart Street and Railway culvert upgrade including detention area on southern side of Hobart Street

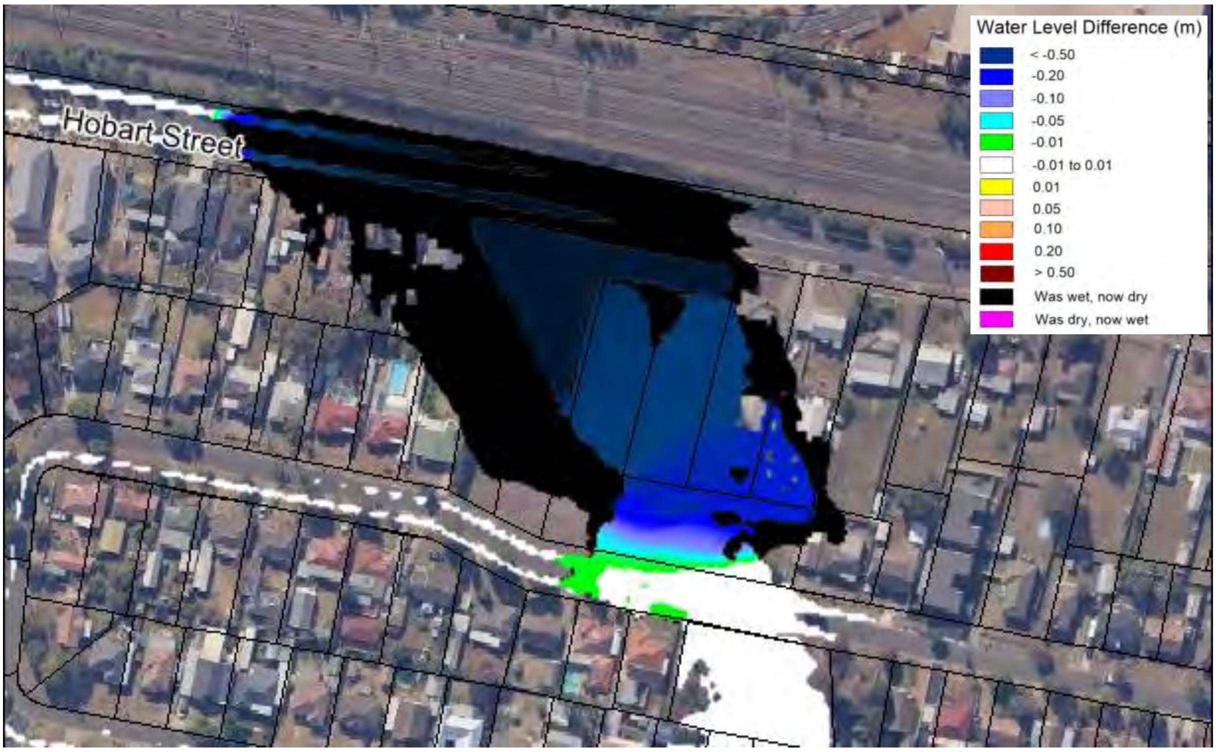


Plate 25 1% AEP Flood Level Difference Map for Larger FM2 Culvert Upgrade

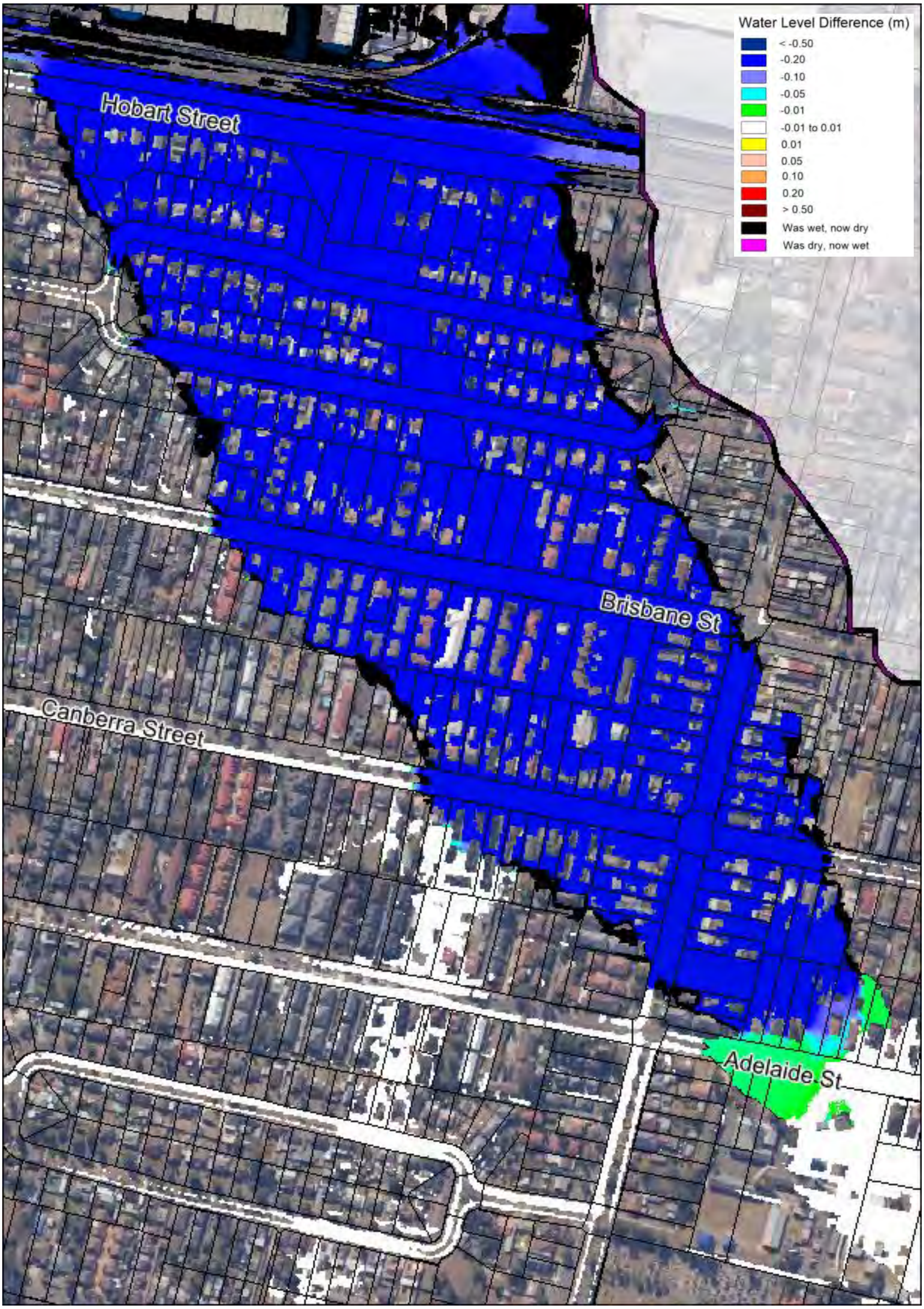


Plate 26 PMF Flood Level Difference Map for Larger FM2 Culvert Upgrade

8.3.3 FM3 - Glossop Street Culvert Upgrade

Glossop Street provides the main north-south transportation link in the Little Creek catchment. Accordingly, it serves as one of the primary evacuation routes in the catchment. The results of the design flood modelling indicate that the eastern travel lanes in Glossop Street would likely be cut during events equal to and greater than the 5% AEP flood. The "build up" of floodwater on the eastern side of Glossop Street also results in inundation of some adjoining properties.

As shown in **Figure 59**, FM3 would involve upgrading the culvert that drains Little Creek beneath Glossop Street. The upgrade would involve replacing the existing 5 cell 1.5m wide by 0.9m high box culvert with four 4.2m wide by 1.2 high box culverts. This culvert size was determined to be the largest culvert size that could be accommodated in the available space. Notwithstanding, the elevation of Glossop Street would need to be elevated by around 0.3 metres to accommodate the higher culverts.

A cost estimate was prepared for FM3 and is included in **Appendix G**. This indicates that FM3 would likely cost about $740,000 to implement.

The hydraulic model was updated to include a representation of FM3. The updated TUFLOW model was then used to re simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 27**.

Plate 27 shows that the culvert upgrade is predicted to reduce flood levels on the eastern side of Glossop Street by around 0.4 metres during the 20% AEP, 5% AEP and 1% AEP floods. This is predicted to largely eliminate inundation of Glossop Street during the 5% AEP flood affording some notable emergency response benefits. However, only very small flood level reductions are afforded during the PMF as even the larger culvert is overwhelmed.

The flood level reductions extend primarily across areas of open space. As a result, this option is not predicted to reduce the number of properties exposed to above floor flooding.

Furthermore, **Plate 27** shows the additional conveyance provided by the larger culvert is predicted to direct additional floodwater into Little Creek downstream of Glossop Street. The associated flood level increases are generally contained to the Little Creek channel, but small flood level increases are predicted to extend onto private property near Lee Holm Drive in the 1% AEP flood. Flood level increases of up to 0.05 metres are also predicted across Forrester Road. Therefore, there is potential for localised impacts to emergency responses in this area.

A number of services extend along Glossop Street in the vicinity of the existing culvert and would likely need to be relocated as part of the construction works. This includes:

- Jemena gas;
- NBN;
- Endeavour Energy; and
- Sydney Water sewer;

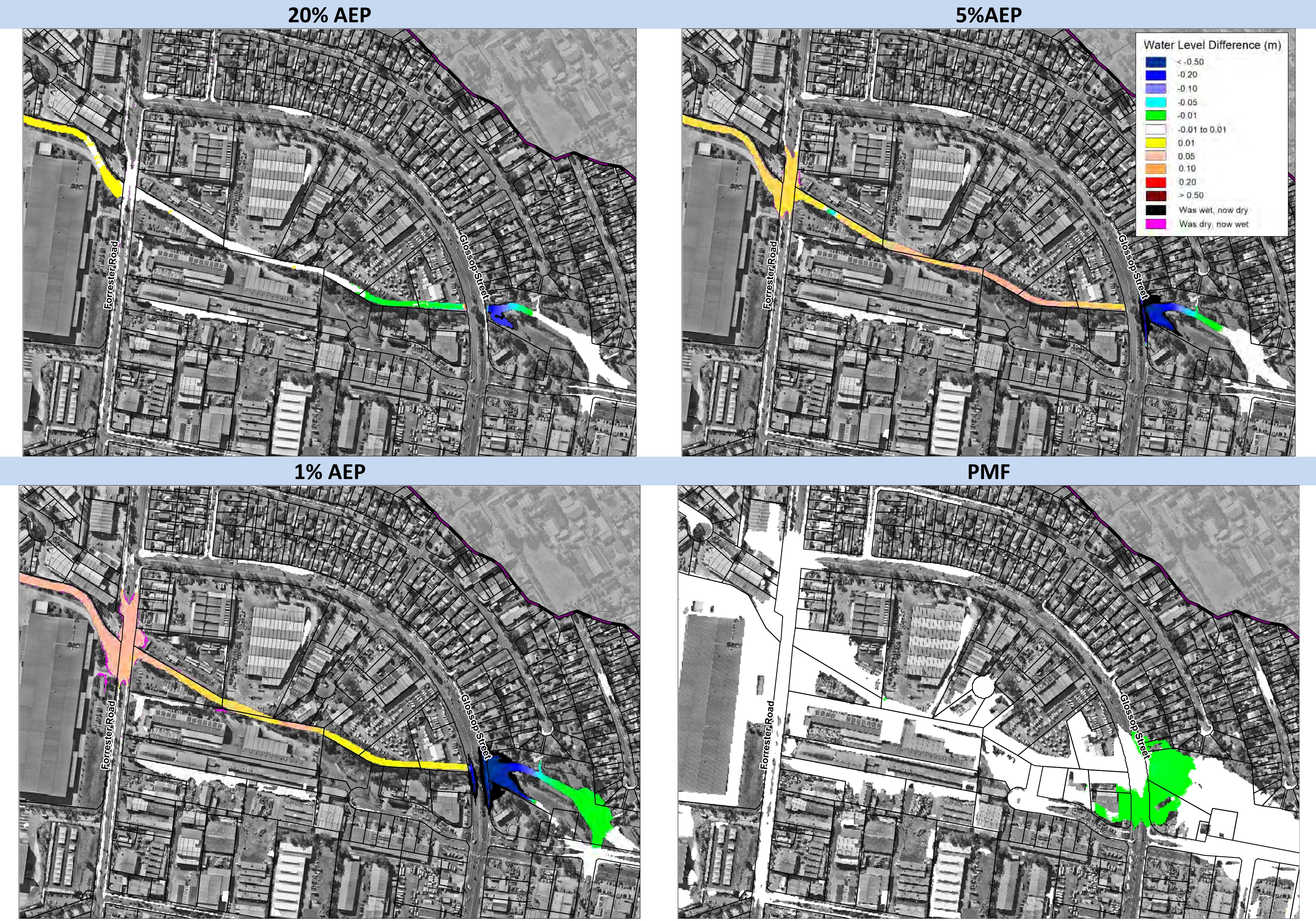


Plate 27 Flood Level Difference Maps for FM3

The results of a revised flood damage assessment show that implementation of FM3 is predicted to reduce existing flood damages by around $10,000 over the next 50 years. This yields a preliminary benefit cost ratio of less than 0.1.

Overall, FM3 is predicted to afford emergency response benefits for Glossop Street (i.e., less frequent inundation and lower depths of inundation). Furthermore, it provides a better hydraulic outcome relative to FM5 (see Section 8.3.5) indicating it is preferred option for reducing the depth and frequency of flooding at the low point in Glossop Street. However, there are predicted to be minimal hydraulic benefits across private properties. As a result, the benefit cost ratio for this option is low (i.e., less than 0.1). However, this option should be considered if asset or roadway upgrades be planned in the future.

8.3.4 FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades

The area of the Little Creek catchment contained between Oxley Park Public School and Brisbane Street does not provide a formalised flow path or areas of open space to contain overland flow. As a result, overland flooding is predicted to extend through multiple private properties during floods as frequent as the 0.5EY event.

FM4 would involve upgrading and expanding the stormwater system in the vicinity of Canberra Street, Sydney Street and Brisbane Street. This would aim to capture and direct a greater proportion of flow below ground, thereby reducing overland flow depths and extents. The extent of the upgrades explored as part of this option are shown in **Figure 60**.

As shown in **Figure 60**, this option would retain much of the existing stormwater system in the area but would supplement this with new drainage lines as well as localised upgrades to the stormwater pit and pipe system. A cost estimate for FM4 was prepared and indicates that it is likely to cost in the order of $1.3 million to implement. Therefore, it is one of the more expensive options investigated as part of the study.

The hydraulic model was updated to include a representation of the stormwater upgrades. The updated TUFLOW model was then used to re-simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in Plate 28.

Plate 28 shows that the stormwater upgrades are predicted to generate flood level reductions during the 20% AEP and 5% AEP floods across a large area extending from the intersection of Canberra and Sydney Streets downstream to Hobart Street. Flood level reductions of at least 0.15 metres are predicted during the 20% AEP flood across most areas. Reductions of between 0.05 and 0.1 metres are also common during the 5% AEP flood with flood level reductions increasing to around 0.15 metres around Hobart Street. Although the stormwater upgrades do not cover the area between Thompson Avenue and Hobart Street, it is evident that the stormwater upgrades more efficiently capture and direct water into the existing stormwater system in this downstream area. However, this additional water is predicted to surcharge in Hobart Street during the 20% AEP flood resulting in a very small (0.01 m) increase in flood level at this location.

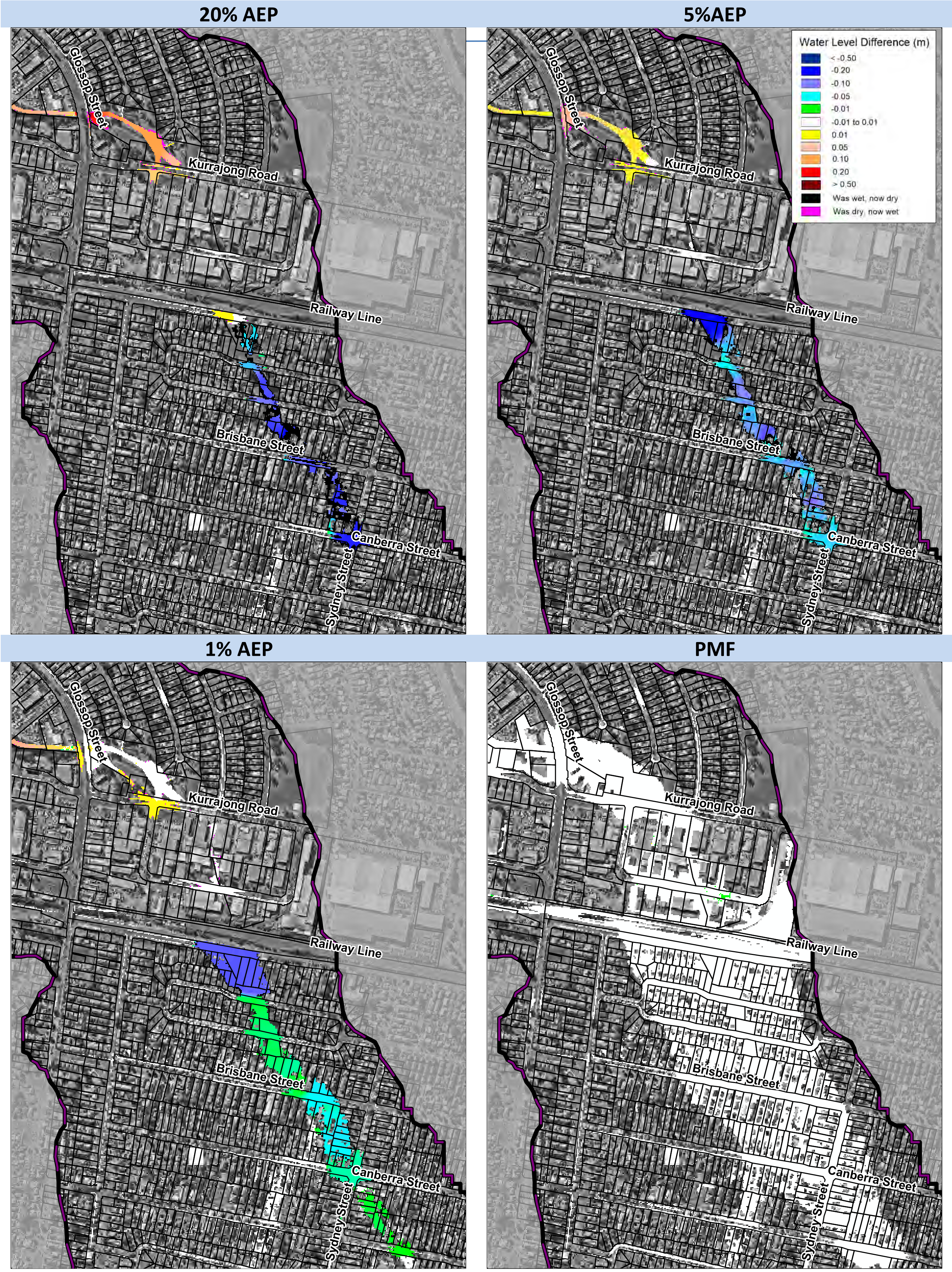


Plate 28 Flood Level Difference Maps for FM4

Plate 28 also shows flood level reductions during the 1% AEP flood extending across a similar area. However, during the 1% AEP flood, the flood level reductions are predicted to extend further upstream to Adelaide Street. Therefore, the stormwater upgrades also serve to more efficiently drain the existing stormwater system upstream of the Canberra and Sydney Streets intersection. The predicted flood level reductions during the 1% AEP flood are more modest relative to the 20% AEP and 5% AEP floods, with reductions most commonly being no greater than 0.05 metres. However, reductions around Hobart Street are predicted to exceed 0.1 metres. Negligible reductions are predicted during the PMF.

Plate 28 also show that FM4 is predicted to direct additional flow north of the railway line and into the Little Creek channel. Although the associated flood level increases are largely contained to the Little Creek channel and do not extend across private property, both Glossop Street and Forrester Road are predicted to experience flood level increases of up to 0.05 metres. Although this is not predicted to alter the frequency that Glossop Street is cut by floodwaters, it is predicted to result in Forrester Road being cut in a 20% AEP flood (it is currently cut in a 10% AEP flood).

However, this is somewhat offset by the reduced flood levels and extents across areas located south of the railway line. More specifically, Sydney Street and Brisbane Street are currently predicted to be a cut in a 0.5EY event. But with the stormwater upgrades this is predicted to increase to a 10% AEP and 20% AEP floods respectively. So overall, there is a net emergency response benefit.

The results of a revised flood damage assessment show that implementation of FM4 is predicted to reduce existing flood damages by more than $800,000 over the next 50 years. This yields a preliminary benefit cost ratio of about 0.6. Therefore, the reduction in flood damage costs is not sufficient to cover the implementation costs. However, it should be recognised that the initial design and cost estimates are preliminary in nature and further refinement of the design could assist in improving the economic outcomes.

The current design concept involves installing the new stormwater pits and pipes primarily within road reserves, thereby, avoiding the need to disturb local properties. However, this does increase the potential for conflicts with existing utilities, which will likely need to be relocated (these relocations are a significant component of the calculated implementation costs). Existing utilities located near components of this option include:

- Jemena gas line;
- NBN;
- Telstra telecommunications;
- Optus telecommunications;
- Endeavour energy; and
- Sydney Water sewer and water mains.

Accordingly, the number of services is significant. Although an allowance for relocation of the services was included in the cost estimate, the need, feasibility and cost for relocation of these services can only be determined following a detailed survey. Therefore, if this option is pursued further, it is recommended that detailed survey of services is completed to allow the cost estimate to be refined and confirm the financial viability of this option.

Overall, FM4 is predicted to afford flood level reductions across a large proportion of the catchment including significant reductions in levels and extents during more frequent floods. This includes existing residential properties that are predicted to be subject to frequent overland flooding as well as adjoining roads. The main negatives associated with this option are the significant cost (which provides a BCR of less than 1) as well as some small flood level increases across Glossop Street and Forrester Road. It is recommended that this option is investigated further to refine the design and associated implementation costs. If these further investigations yield a positive outcome, FM4 may be considered suitable for implementation either as part of the NSW Government's floodplain management program or Council's capital works program.

8.3.5 FM5 - Glossop Street stormwater upgrades

As discussed in Section 8.3.3, Glossop Street is the main north-south transportation link in the Little Creek catchment. As a result, it serves as an important asset from an emergency response perspective during floods. In addition, some properties adjoining the "sag point" in Glossop Street are impacted by flooding during floods as frequent at the 5% AEP event.

FM5 would involve upgrading and expanding the existing stormwater system at the low point in Glossop Street (i.e., at the location where Little Creek passes beneath Glossop Street). This would aim to more efficiently drain local runoff from the low point in the road into the Little Creek channel). The extent of the upgrades explored as part of this option are shown in **Figure 61**.

Larger pipe sizes were also explored as part of the assessment, but this was determined to direct additional water from the eastern side of Glossop Street into the Little Creek channel on the western side of Glossop Street. During smaller floods (e.g., 5% AEP event), this was sufficient to elevate water levels in the Little Creek channel and result in some additional inundation on the western side of Glossop Street. Therefore, the pipe sizes shown in **Figure 61** were determined to provide the best compromise between reducing flood levels on the eastern side of Glossop Street while minimising impacts on the western side of Glossop Street.

The hydraulic model was updated to include the stormwater upgrades. The updated TUFLOW model was then used to re-simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 29**.

As shown in **Plate 29**, the stormwater upgrades are predicted to generate flood level reductions at the low point in Glossop Street in the 20%, 5% and 1% AEP floods. However, the magnitude of the reductions is predicted to be less than 0.1 metres. A flood level reduction of this magnitude is not sufficient to eliminate inundation of the western travel lanes during the 1% AEP flood (i.e., no meaningful emergency response impacts). There are also no significant reductions in flood level during the PMF.

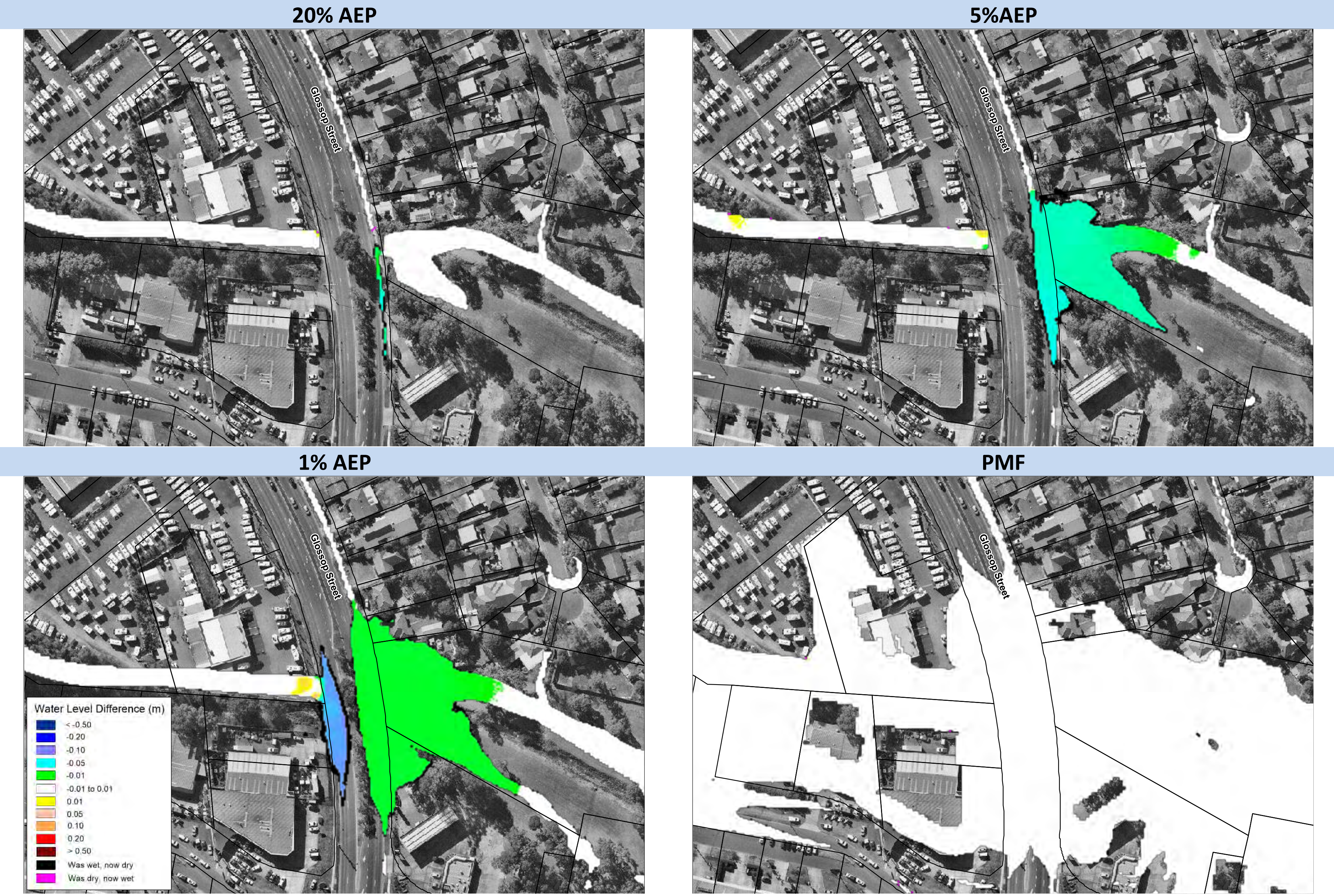


Plate 29 Flood Level Difference Maps for FM5

A cost estimate for FM5 was prepared and indicates that it is likely to cost just under $800,000 to implement. The cost estimate is included in **Appendix G**.

The results of a revised flood damage assessment showed that implementation of FM5 is not predicted to provide a reduction in existing flood damages (associated with the small flood level reductions being largely contained to the road and open space). Therefore, the BCR of this option is 0.

Overall, FM5 is only predicted to afford small reductions in flood levels and minimal emergency response and economic benefits. This poor performance is largely associated with the inundation in the area being driven by the lack of Glossop Street culvert capacity (i.e., the relatively limited amount of additional capacity provided by the stormwater upgrades is not sufficient to make up for the culvert shortfall). Therefore, it appears that FM3 would be the preferred option to implement to reduce the flood risk at this location. Nevertheless, installation of the stormwater upgrades is predicted to afford some hydraulic benefits with no significant adverse flood impacts elsewhere. As a result, Council could consider upgrading the local stormwater system in this area if asset replacement or road upgrades are proposed in the future.

8.3.6 FM6 - Lee Holm Drive stormwater upgrades

Lee Holm Drive services a number of industrial properties across the western parts of the Little Creek catchment. The design flood modelling shows that inundation of the low point in Lee Holm Drive (located near the intersection of Anne Street) would be cut during floods as frequent as the 0.5EY event.

As shown in **Figure 62**, FM6 would amplify the existing stormwater system running from near the Lee Holm Drive and Anne Street intersection in an easterly direction and directly into the Little Creek channel. This would include new and additional stormwater pipes and new stormwater pits. It was determined that upgrading the existing stormwater pits would not provide any significant improvements in the performance of this option (i.e., the pipe system is the limiting factors rather than pit inlet capacity).

The hydraulic model was updated to include the stormwater upgrades. The updated TUFLOW model was then used to re-simulate a range of design floods. Floodwater difference maps were prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 30**.

The difference mapping shows that FM6 is only predicted to produce small and localised reductions in flood level in Warrior Place. Elsewhere, the flood level reductions are predicted to be zero (with the exception of the 20% AEP flood where 0.02 metre reductions are predicted across one industrial property). This lack of benefit indicates that the potential for water to drain from this area is inhibited by its proximity to South Creek. More specifically, elevated water levels in South Creek “back up” along the lower reaches of Little Creek and prevent the downstream stormwater system from draining. As a result, any form of stormwater upgrades in this area is unlikely to afford any significant hydraulic benefit while there are elevated water levels in South Creek or the receiving Little Creek. As a result of this outcome, an economic assessment of this option was not completed.

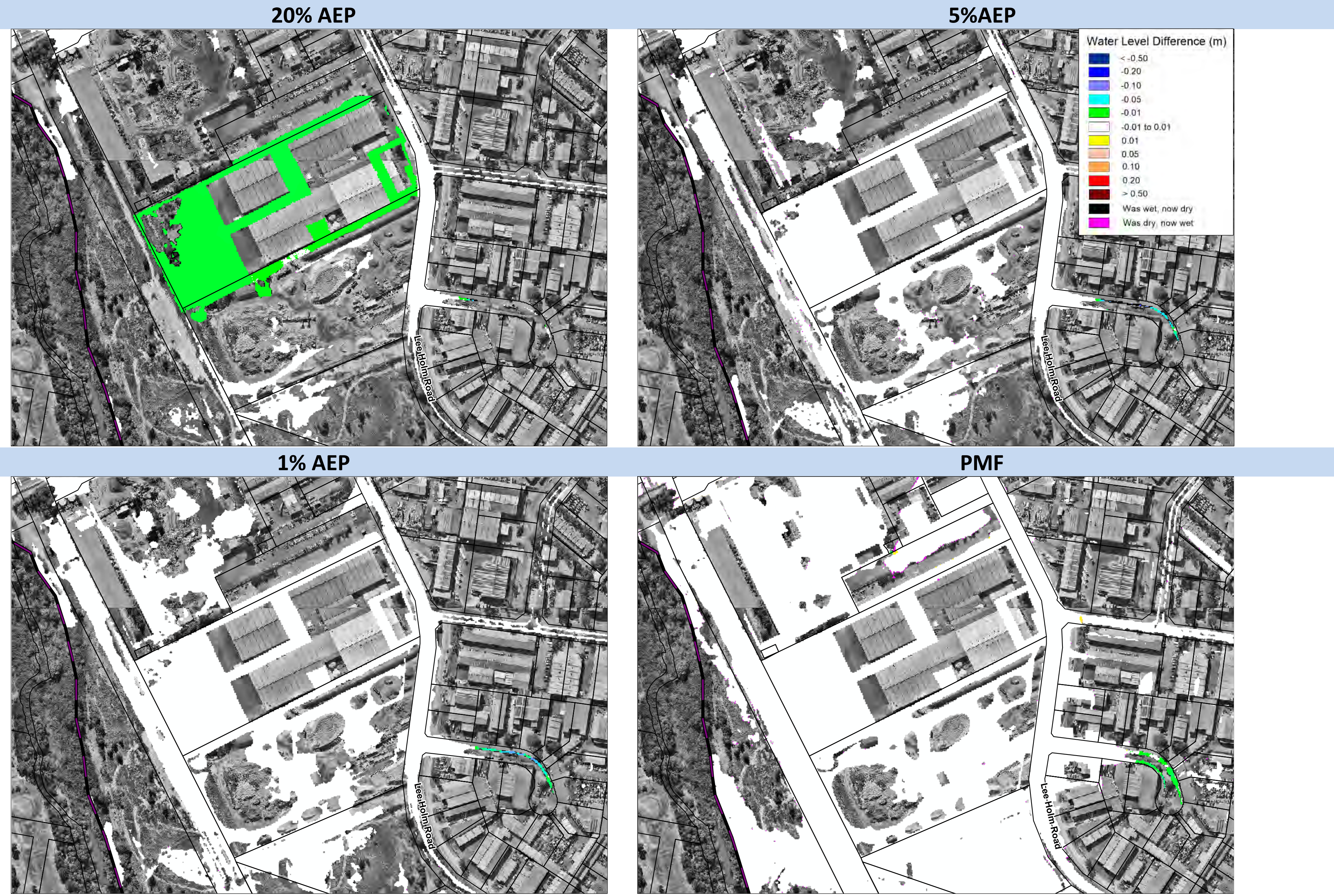


Plate 30 Flood Level Difference Maps for FM6

To further assess the impact that South Creek levels are predicted to have on the performance of this option, additional sensitivity simulations were completed for the 20% AEP and 5% AEP events assuming that there was not flood in South Creek. The difference mapping from these simulations is provided in **Plate 31**.

Plate 31 shows some notable reductions in flood levels in Lee Holm Drive as well as adjoining industrial properties. More specifically flood level reductions of around 0.1 metres are anticipated in Lee Holm Drive and reductions of more than 0.2 metres are predicted in the industrial properties during both the 20% AEP and 5% AEP floods. Therefore, the performance of the stormwater system is strongly correlated to the prevailing South Creek and Little Creek water levels.

Despite the poor economic outcome, it is evident that the stormwater upgrades will afford hydraulic improvements when the stormwater system is able to freely drain. In addition, the upgrades are not predicted to result in any adverse flood impacts. Therefore, there is still merit in considering this upgrade option as part of Council's future asset replacement program for the area.

8.4 Detention Basin Upgrades

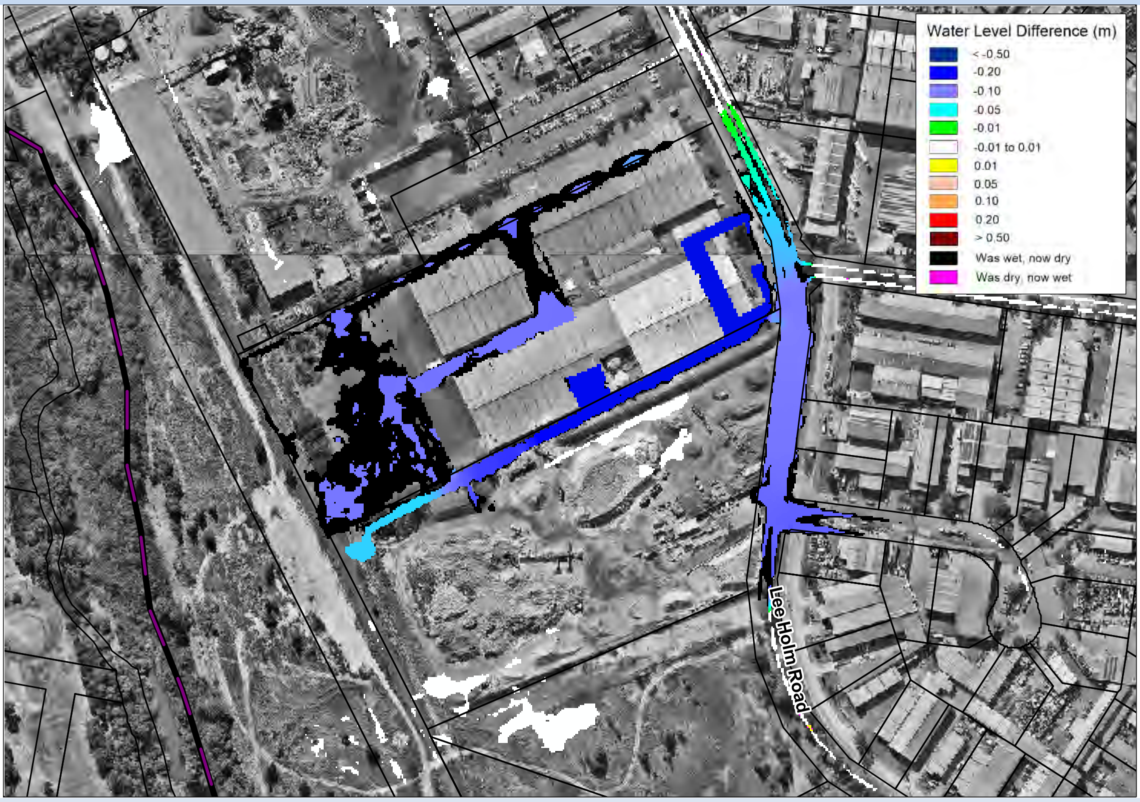
8.4.1 FM7 - Colyton High School Basin Augmentation

The Colyton High School detention basin is located within the south-western corner of the Colyton High School. It is a "dry" detention basin and serves as sporting fields during non-flood conditions. The results of the design flood modelling showed that the detention basin would capture a significant amount of water from the upstream catchment during floods up to and including the 0.2% AEP flood. However, during the PMF, the basin is predicted to overtop resulting in floodwaters spilling through a number of residential properties in Kent Place and Shane Street in an uncontrolled manner (i.e., there is no formal spillway to discharge flow in a controlled manner).

FM7 looked at options to better manage the discharge of flows from the basin during large floods such as the PMF. Unfortunately, the area downstream of the basin is "built out" so there are no opportunities to safely concentrate flows from the basin across a spillway. Therefore, expanding the existing basin storage was explored as a means of reducing the potential for overtopping of the basin during large floods while also providing an opportunity for reducing flood levels across the downstream areas during more frequent floods.

The extent of the topographic modifications associated with the potential basin expansion are shown in **Figure 63**. As shown in **Figure 63**, the option would look to expand the existing basin to the north-west. This would require excavation of around 22,000 m^3 of material to provide a second, lowered sports field at RL45.45m AHD. This elevation was selected as it would remain dry during frequent rainfall events (i.e., less than the 20% AEP) to ensure the functionality of the existing sport fields are not significant impacted but would be "activated" during larger floods. Modifications to the basin outlet pipes was also included to "hold back" additional flow in the basin to reduce downstream water levels. Different outlet pipe sizes were explored as part of the FM7 analysis, but the overall results were determined to be relatively insensitive to changes in pipe size.

20% AEP



5%AEP

Plate 31 **Flood Level Difference Maps for FM6 with lower South Creek water level**

A representation of FM7 was included in the hydraulic model and the updated model was used to re-simulate each design flood. Flood level difference mapping was prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 32**.

Plate 32 show that during the 20% AEP, 5% AEP and 1% AEP floods, the additional storage volume is predicted to produce some notable reductions in flood levels within the Colyton High School basin. However, the additional storage and basin outlet pipe modifications are not sufficient to produce significant reductions in water levels across areas located downstream of the basin (i.e., the reductions are predicted to be less than 0.01 metres across most areas although reductions of 0.03 metres are predicted in the Oxley Park Detention basin during the 20% AEP floods). This outcome is most likely associated with much of the upper catchment bypassing the basin. That is, the basin only collects runoff from a relatively small portion of the upper catchment. Therefore, the net reduction in downstream flows afforded by the basin modifications is relatively small during these more frequent events.

However, during the PMF, the basin modifications are predicted to provide flood level reductions across a significant area of the catchment stretching from the high school downstream to Brisbane Street. The flood level reductions are most commonly around 0.05 metres with the largest decrease being 0.10 metres within the Oxley Park Public School.

Despite the extensive flood level reductions, the additional storage provided in the basin is not predicted to prevent overtopping of the basin during the PMF. However, the flood level reductions are sufficient to reduce the extent of H3 and H4 across a number of Kent Place and Shane Street properties. Therefore, the basin upgrade still affords some benefits to these properties during the PMF. However, it does not eliminate H4 completely across this area (there is still a flood risk for people in the area during the PMF).

The cost estimate included in **Appendix G** indicates that the basin upgrade would cost over $1.3 million to implement.

A revised flood damage assessment was completed based upon the modelling results with the basin upgrade in place. The results of the assessment show that implementation of FM7 is predicted to reduce existing flood damages by more than $1.2 million over the next 50 years yielding a benefit cost ratio of 0.9. Therefore, the potential financial benefits associated with FM7 appear to be significant even if they are not quite sufficient to fully cover the implementation costs. However, this outcome is dominated by the reduction in damages that are afforded in the PMF. During more frequent floods, the damage reductions are predicted to be small. As a result, it may be difficult to justify significant expenditure on this option when the benefits are only likely to be experienced during very rare floods.

Furthermore, the additional inundation across the Colyton High School would likely reduce the level of service afforded by the sports fields (i.e., they would be flooded more frequently). It would also expose a greater proportion of the high school to inundation although the newly introduced depths are less than the current basin.

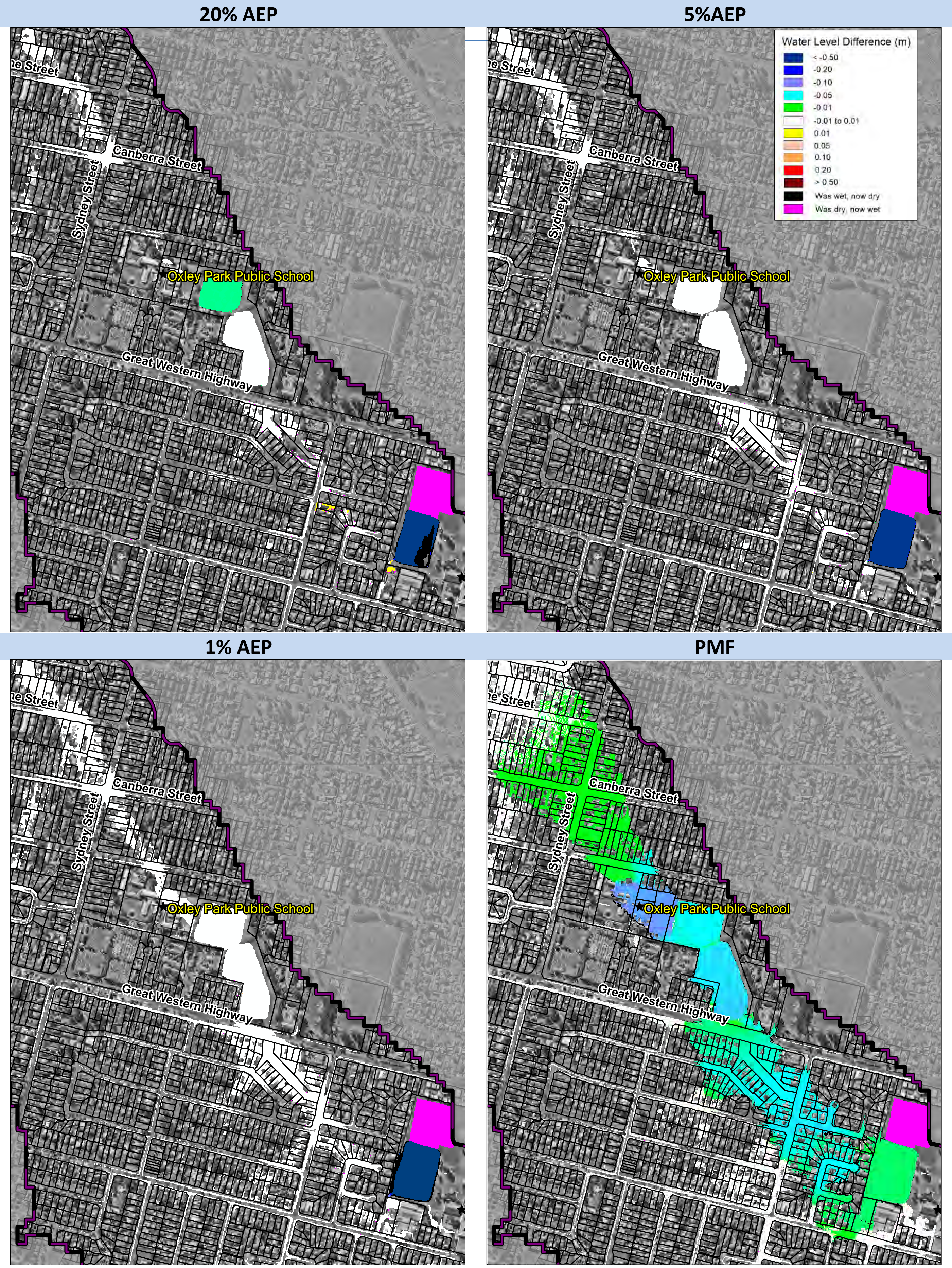


Plate 32 Flood Level Difference Maps for FM7

Although FM7 is predicted to provide some financial benefits, it is considered that other options provide better overall value for money, particularly during more frequent floods. Therefore, it is recommended that other options be pursued in preference to FM7.

8.4.2 FM8 - Oxley Park Basin Augmentation

The Oxley Part Detention Basins comprise two detention basins that are located between the Great Western Highway and Oxley Park Public School. The basins are designed to attenuate flows from the upstream catchment thereby reducing downstream water levels. However, the basins only have sufficient capacity for smaller floods with larger floods overtopping the downstream most basin and discharging through Oxley Park Public School. Furthermore, the basins do not include formal spillways resulting in an uncontrolled release of water. During the PMF, H5 hazard is predicted across parts of the public school as a result of the basins overtopping. Furthermore, as noted in Section 4.2.11, velocities of more than 3.5 m/s are predicted across the downstream basin wall during the PMF which may be sufficient to promote scour and potential failure of the basin wall which would further increase the flood risk across the school as well as downstream properties.

FM8 investigated the potential benefits associated with providing additional storage capacity within the existing basins by elevating the downstream basin wall, reducing the elevation of the bottom of the basins and including an additional basin wall within the southern basin. A formal spillway was also incorporated in the downstream most basin to direct any overtopping water into the car park area of the school rather than the classrooms. This flow path will be further reinforced by completing minor regrading within the public school to help ensure overflows are directed away from the classrooms.

The extent of the modifications that were ultimately selected for FM8 are shown in **Figure 64**. However, a range of alternate options were considered but were not found to be feasible including:

- Elevating the existing “central” basin wall. This was determined to generate significant increases in existing water levels across multiple properties in Whitcroft Place in the PMF.
- Including a levee along Whitcroft Place to protect the properties impacted during the PMF with the central basin wall modifications described above. However, this was predicted to impede runoff draining from Whitcroft Place into basins also resulting in flood level increases.
- Increasing the height of the downstream boundary wall further to increase storage volume. However, this resulted in flood level increases across some Noela Place properties.
- Reducing the size of the norther basin outlet pipe. Although this freed up capacity in the pipe system downstream of Adelaide Street, it resulted in additional overland flow through the Oxley Park Public School.

A representation of FM8 was included in the hydraulic model and the updated model was used to re-simulate each design flood. Flood level difference mapping was prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 33**.

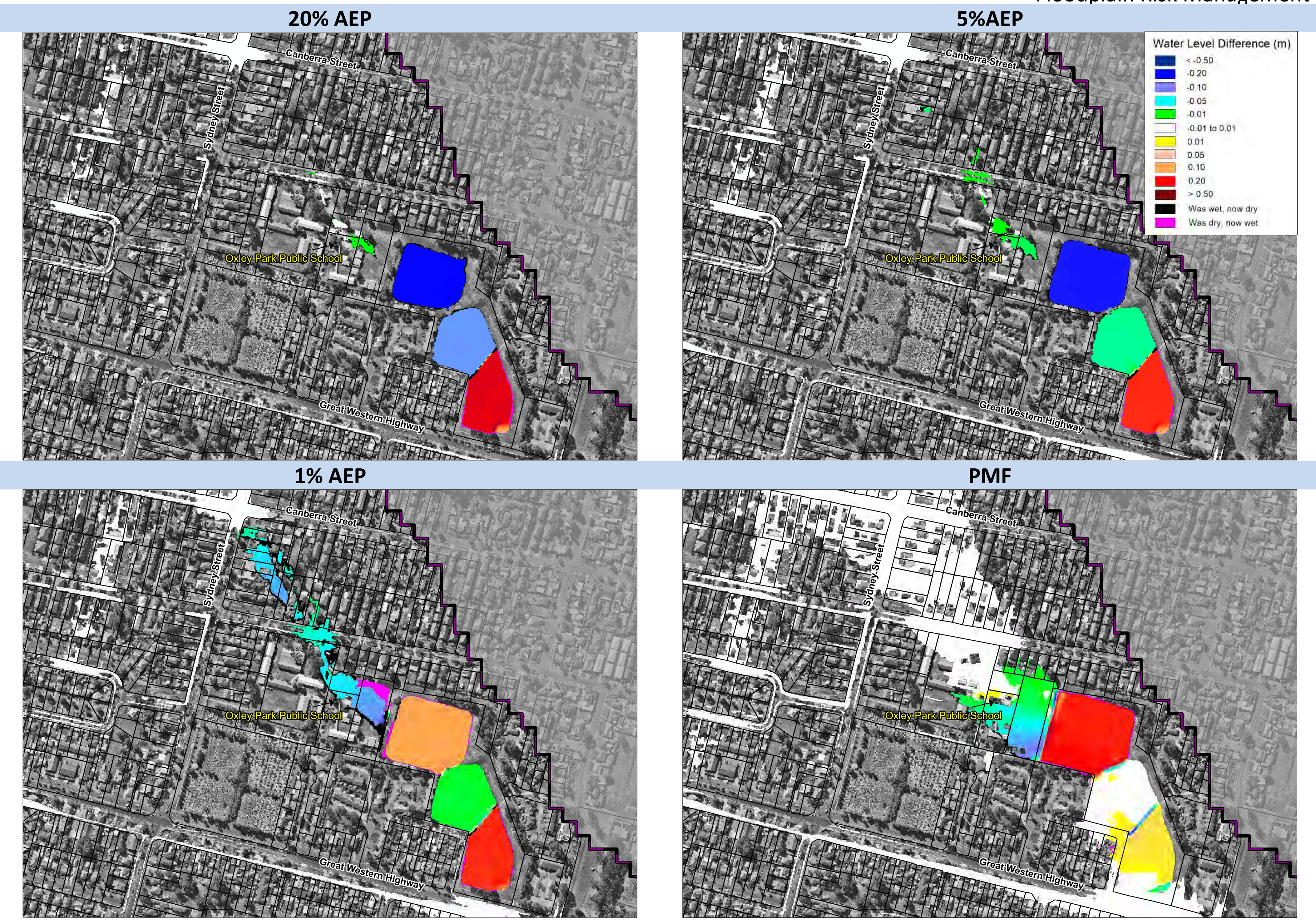


Plate 33 Flood Level Difference Maps for FM8

The difference mapping shows that FM8 will produce flood level reductions during each simulated design floods. The reductions during the 20% AEP and 5% AEP floods are modest due to the existing basins already having sufficient capacity to cater for these smaller floods. The most significant flood level reductions are predicted during the 1% AEP flood where reductions of more than 0.1 metres are predicted across some Adelaide Street properties as well as the Oxley Park Public School. During the PMF, the flood level reductions are predicted to be around 0.05 metres.

FM8 is predicted to produce increases in existing flood levels in some areas. The most notable increases in flood levels are contained within the basins themselves. However, during the PMF, small flood level increases (0.01 m) are predicted to extend into one (1) private property adjoining Whitcroft Place. This is predicted to result in two (2) additional properties being exposed to above floor flooding during the PMF. These increases are undesirable regardless of the rarity of the PMF and indicates that further refinement of the design concept will be required if the option proceeds further. This may include reducing the magnitude of the southernmost basin wall increases or providing some additional storage volume in the southern basin (e.g., by reducing the invert elevation of the basin slightly).

It is expected that FM8 will cost about $900,000 to implement (refer cost estimates in **Appendix G**).

A sewer main does extend across the "footprint" of the proposed works. However, as most of the required earthworks are above or in close proximity to the existing ground surface, it is unlikely that this sewer line would be impacted. However, this would need to be confirmed as part of future investigations.

A revised flood damage assessment with FM8 in place indicates that implementation of this option will likely reduce flood damage costs by nearly $800,000 over the 50 years. This yields a preliminary benefit cost ratio of 0.8. This demonstrates that the reduction in flood damage costs is not quite sufficient to offset the implementation costs (but not far off).

A review of flood hazard mapping shows that the H5 hazard that was prevalent around some Oxley Park Public School buildings is also reduced with FM8 in place (refer **Plate 34**). Therefore, the potential for structural failure of the school buildings during a PMF is reduced. Notwithstanding, if these buildings were not specifically designed to withstand the depth and velocity of water during a PMF, there is still potential for failure so evacuation should be planned as a priority regardless of whether this option is implemented or not.

Due to the proximity of the basin to Oxley Park Public School as well as downstream residential properties, there is a risk that failure of the basin could lead to loss of life or significant damage and financial impacts. As a result, the basin would likely need to be "declared" under the NSW Government's Dams Safety program. This would initially involve a dam break study to establish a basin failure consequence category and then regular inspections of the basin to ensure integrity is maintained over its design life. It is expected that this would add around $300,000 to the overall cost of the basin over a 50-year period, which is accounted for in the cost estimate. Depending on the outcome of the consequence assessment, it may prompt changes to the basin design which could also impact on the implementation cost (this has not been directly accounted for in the cost estimate but could be accommodated in the contingency).

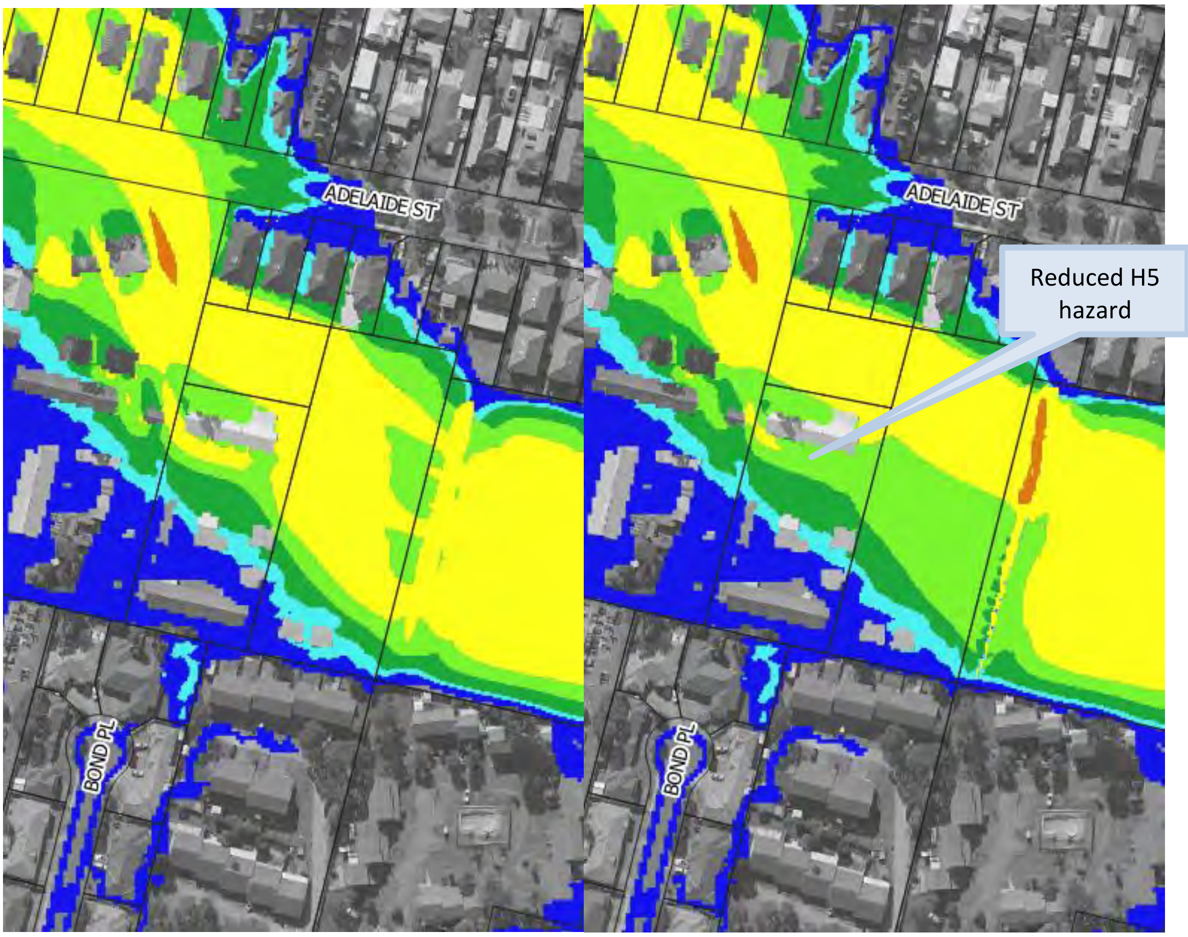


Plate 34 Comparison between PMF flood hazard for existing conditions (left) and with FM8 in place (right)

Overall, FM8 is predicted to afford some beneficial flood level reductions during each simulated design flood. More importantly, the option is predicted to reduce the PMF flood hazard across habitable sections of the Oxley Park Public School such that the potential for structural failure of the school buildings is reduced. FM8 also comprises one of the lowest implementation costs and the highest benefit cost ratios of the options investigated as part of the study. Therefore, there is merit in investigating this option further. These further investigations will need to evaluate opportunities to mitigate the predicted flood level increases across private properties during the PMF.

8.5 Topographic modifications

8.5.1 FM9 - Great Western Highway Median Modification

As discussed in Section 8.3.1, the Great Western Highway is the main east-west transportation link and the most heavily trafficked road in the Little Creek catchment. Inundation of the road is predicted during even frequent floods. Not only does this cause significant disruption to traffic along this important road, it increases the potential for people to attempt to drive through floodwaters. Although flood deaths have been steadily declining since the 1960s, motor vehicle related deaths in floodwaters are rising (Haynes et al, 2016).

As shown in **Plate 33**, the Great Western Highway travel lanes are separated by a median strip. The median strip is elevated above the road surface and also incorporates a garden bed that further elevates the median. As a result, the median strip serves a significant barrier to flow and exacerbates "ponding" depths on the southern side of the highway (and the vegetation planted along the median strip also serves to impede flow).

Plate 35 View looking north showing elevated median strip along Great Western Highway

FM9 would involve removing a section of the median to reduce ponding depths and allow water to more freely discharge in a northerly direction towards the Oxley Park basins. This would be further assisted by lowering the gutter on the northern side of the highway and completing some regrading to promote the movement of water from the highway into the basins. These works may also assist in reducing the extent and depth of inundation across existing residential properties located south of the highway. The extent of the proposed changes is shown in **Figure 65**.

A representation of FM9 was included in the hydraulic model and the updated model was used to re-simulate each design flood. Flood level difference mapping was prepared for the 20% AEP, 5% AEP and 1% AEP floods as well as the PMF and are provided in **Plate 36**.

The difference mapping shows that the median modifications have the desired effect across the highway as well as south of the highway during most of the design floods. More specifically, flood levels across the highway and across properties south of the highway are predicted to reduce by nearly 0.1 metres during the 1% AEP flood and PMF. More modest reductions of around 0.02 metres are predicted during the 5% AEP flood. Negligible reductions are predicted during the 20% AEP flood as water is not predicted to build up sufficiently on the southern side of the highway to activate the new median flow path.

The flood level reductions are sufficient to result in three (3) fewer properties being subject to above floor flooding during the 1% AEP flood. No changes in above floor flooding is predicted during the other design floods.

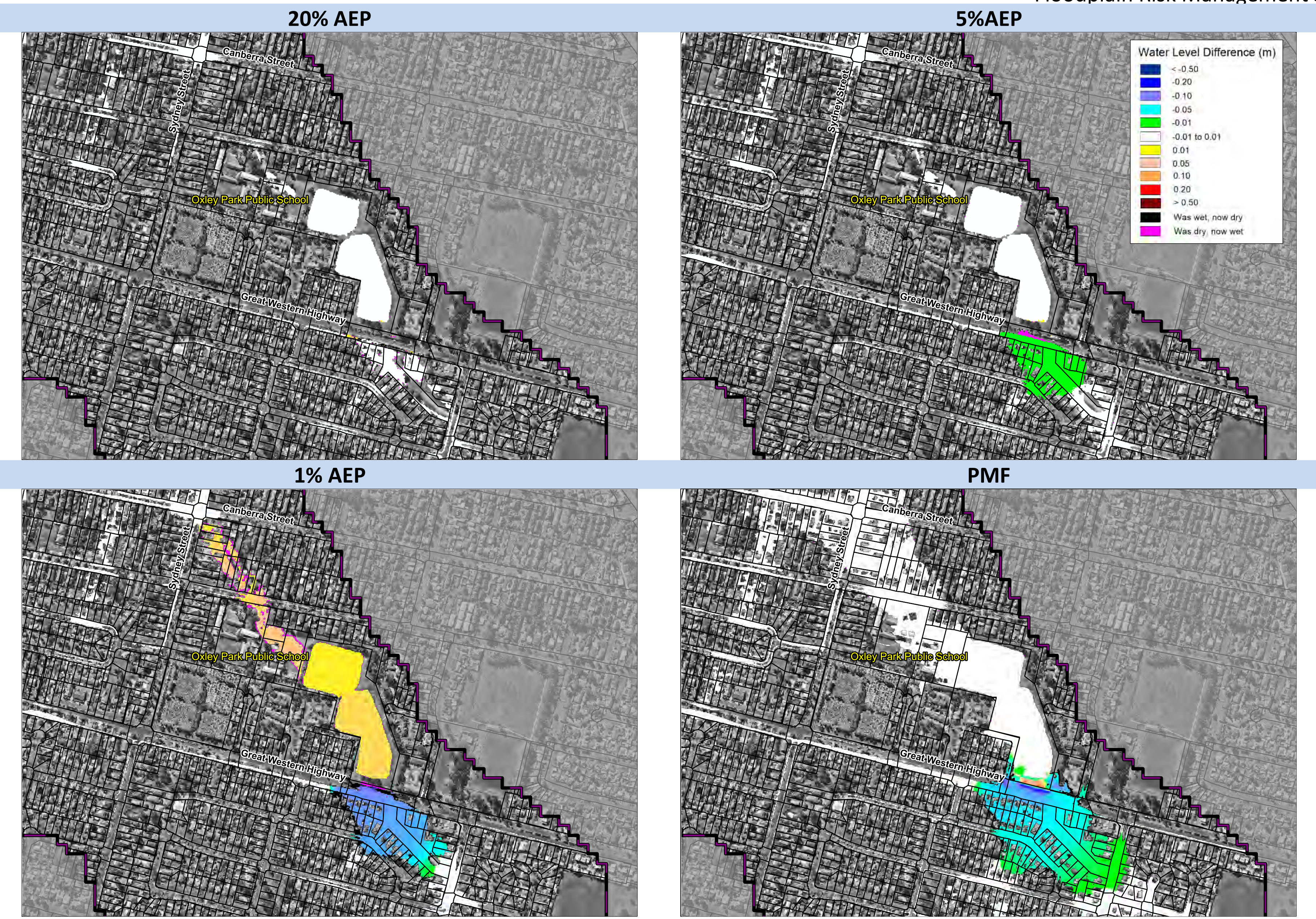


Plate 36 Flood Level Difference Maps for FM9

It is noted that the reductions are not sufficient to prevent inundation of the roadway (as water must still "build up" on the southern side of the road to push through the median located at the crown of the road). However, the earthworks between the highway and the southern side of the Oxley Park basins will allow water to more freely drain from the northern half of the highway. This is predicted to afford an emergency response improvement with the northern half of the road predicted to remain open during the 1% AEP flood (it is currently cut during the 1% AEP flood). Therefore, even if the southern half of the roadway may be cut as frequently as it currently is, the improvements across the northern side of the highway provide additional opportunity for "counter flow" traffic (i.e., opening up one or more lanes on the northern side of the highway for west-bound traffic should the southern lanes be cut).

The primary disadvantage of FM9 is the additional water that is directed north during the 1% AEP flood. This additional flow is predicted to generate flood level increases across a significant area contained between the Oxley Park basins and Sydney Street and Canberra Street intersection. This includes multiple residential properties as well as the Oxley Park Public School. A such, it is difficult to lend support to this option in its current form due to the adverse flood impacts.

A cost estimate for FM9 was prepared and indicates that it is likely to cost about $200,000 to implement. The cost estimate is included in **Appendix G**.

The results of a revised flood damage assessment show that implementation of FM9 is predicted to reduce existing flood damages by nearly $800,000 over the next 50 years. This yields a preliminary benefit cost ratio of 4. Therefore, there is a strong financial incentive for implementing this option.

The Great Western Highway is operated by TfNSW. Therefore, coordination with TfNSW would be required for this option to proceed further.

Like FM1, the viability of this option could be improved if it was combined with another option that would assist in reducing the adverse flood impacts across downstream properties (such as FM8). However, it is considered that FM1 is preferable to FM9 if a combined option is explored for the following reasons:

- FM1 affords benefits across a similar area of the catchment to FM9. However, the magnitude of the flood level reductions afforded by FM1 are more significant during smaller floods.
- FM1 directs water beneath the highway rather than across the highway. Therefore, there are greater emergency response benefits as there is less water travelling across the road surface.

FM9 is predicted to afford flood level reductions across the Great Western Highway as well as properties to the south of the highway. However, the adverse flood impacts that are predicted downstream of the highway make this option difficult to support in isolation. This option could be considered as part of a combined option; however, it is suggested that FM1 would provide a better overall outcome for the highway and adjoining properties. Notwithstanding, it may still be possible to consider FM9 in combination with FM1 (as well as other options) or instead of FM1 if FM1 is not determined to be viable. In any case, it is recommended that this option is “left on the table” for consideration as part of any future road upgrades.

8.6 Combined Option

The preceding sections summarised the outcomes of the assessment of nine individual flood modifications options. Several of the individual options demonstrated notable hydraulic and economic benefits if they were to be implemented in isolation. Some other options also demonstrated significant hydraulic benefits across some areas while adversely impacting on flood behaviour elsewhere. Therefore, an assessment of a combined option was completed to determine if the performance of the individual options could be enhanced while at the same time offsetting the adverse flood impacts that were predicted across some properties. The outcomes of the combined option assessment are summarised below.

8.6.1 FM10: Combined Option 1

The combined option assessment included the following individual options which all demonstrated a positive hydraulic outcome across parts of the catchment:

- FM1: Great Western Highway Culvert Upgrade;
- FM2: Railway and Hobart Street Culvert Upgrade;
- FM4: Canberra Street, Sydney Street and Brisbane Street stormwater upgrades; and
- FM8: Oxley Park Basin Upgrade.

Based on the individual cost estimates that were prepared, implementation of the combined option is likely to cost in the order of $3.9 million.

The TUFLOW hydraulic model was updated to include a representation of the combined option and the updated TUFLOW model was used to re-simulate each design flood with the combined option in place. Peak flood level difference mapping for the 20% AEP, 5% AEP and 1% AEP events along with the PMF were also prepared and are presented in **Plate 37**.

The difference mapping shows that FM10 is predicted to produce notable reductions in flood levels across a significant proportion of the Little Creek catchment. More specifically, flood level reductions are predicted to extend from Bennet Street to Hobart Street. During the 1% AEP event, flood level reductions of at least 0.1 metres are predicted across most of this area with reductions of up to 0.5 metres in Hobart Street during the 5% AEP flood.

Although flood level increases are predicted they are fully contained to the Oxley Park Detention basins in all events except the PMF where a 0.01 metre increase is predicted across one (1) property in Whitcroft Place. Therefore, FM10 largely achieves the objective of mitigating the flood level increases that were predicted when FM1 was implemented in isolation.

A revised flood damage assessment with FM8 in place indicates that implementation of this option will likely reduce flood damage costs by $2.6 million over the 50 years. This yields a preliminary benefit cost ratio of 0.7. Therefore, the reduction in damage costs is nearly sufficient to offset the implementation cost. Further refinement of the designs (particularly FM4 which is the costliest component) may provide opportunities to refine and reduce the cost estimates particularly if some components are completed together (e.g., FM2 and FM4).

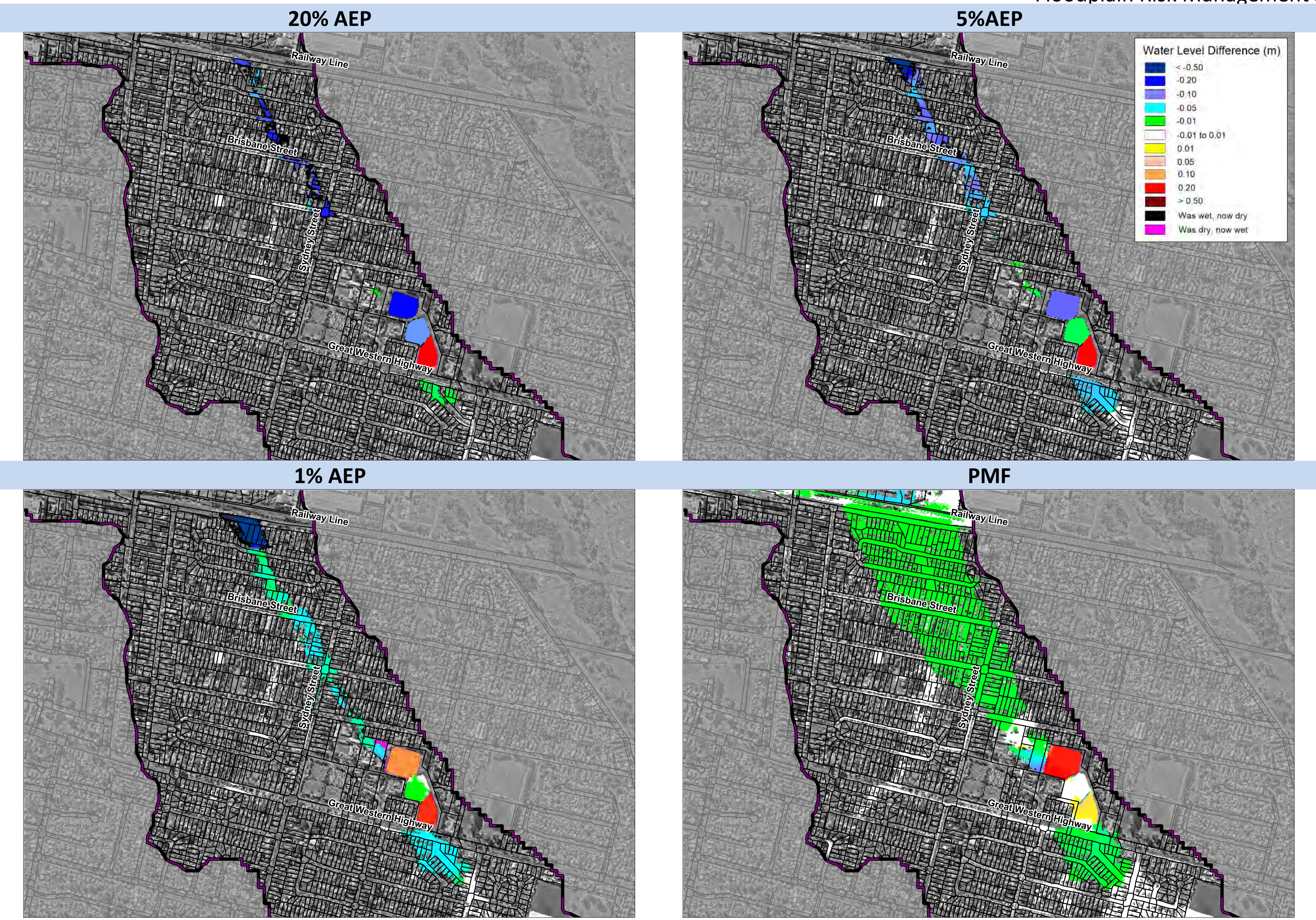


Plate 37 Flood Level Difference Maps for FM10

The number of properties exposed to above floor flooding is predicted to reduce by two (2) during the PMF, three (3) during the 5% AEP flood and by six (6) during the 1% AEP flood. Therefore, as expected, FM10 is predicted to provide the greatest reductions in above floor flooding of all options considered.

FM10 is predicted to reduce the extent and depth of inundation across multiple roads in the catchment, thereby providing significant emergency response improvements as well as reducing the frequency and danger of people potentially driving through floodwaters. As shown in **Table 39**, every major street between Bennet Road and Kurrajong Road inclusive would see less frequent inundation (including the Great Western Highway which is now predicted to remain open up until the 2% AEP flood rather than being cut in a 5% AEP flood). However, it is noted that Glossop Street and Forrester Road would see more frequent inundation. Therefore, as for FM2, some additional measures might need to be included to offset these impacts such as a small barrier on the eastern side of Glossop St to hold additional water in the creek channel and open space.

Overall, implementation of FM1, FM2, FM4 and FM8 together is predicted to provide significant reductions in flood levels, above floor flooding and flood damages along with notable emergency response improvements. Although implementation of any of the individual measures is predicted to improve the current flooding situation, implementing FM1, FM2, FM4 and FM8 together will provide a much more expansive improvement and a better overall outcome for residents in the Little Creek catchment.

8.7 Multi Criteria Assessment

The options evaluation presented in the preceding sections focussed primarily on criteria that can be readily quantified such as economic and hydraulic performance. However, it is acknowledged that each option can also have impacts on important but less tangible aspects such as community support and environmental impacts. Therefore, to enable the relative advantages and disadvantages of each to be more fully understood, a multi-criteria assessment (MCA) was completed. The assessment criteria that were used for the MCA is summarised in **Table 40**.

Like the qualitative assessment of options that was presented in Section 7.4.2, different weightings were assigned to each of the criteria reflecting the relative important of each criterion in best managing the flood risk. The weighting assigned to each criterion is summarised in **Table 40**.

The scoring system that was used to evaluate each criterion is also provided in **Table 40**. In general, the best performing option was assigned a score of plus two (+2). The worst performing options or those options that demonstrated significant negative impacts were assigned a score of negative two (-2). Those options that demonstrated no significant positive or negative impacts were assigned a score of zero (0).

The raw scores that were determined for each option are provided in **Table 41**. The weighted score and the overall ranking of each option based on the weighted score are provided in **Table 42**.

Table 40 Multi-Criteria Assessment Scoring and Weighting Criteria

Criteria	Score	Weight
Flood Impacts		
Hydraulic Impacts	Flood level reductions of more than 0.2 metres = +2 Flood level reductions of less than 0.2 metres = +1 No significant change in flood levels = 0 Flood level increases of less than 0.2 metres = -1 Flood level increases of more than 0.2 metres = -2	x5
Reduction in Above Floor Flooding	Significant reduction in above floor flooding = +2 Small reduction in above floor flooding = +1 No change in above floor flooding = 0 Small increase in above floor flooding = -1 Significant increase in above floor flooding = -2	x4
Economic Impacts		
Cost	Less than $0.25 million = +2 Between $0.25 and $0.5 million = +1 Between $0.5 and $1 million = 0 Between $1 and $2.5 million = -1 Greater than $2.5 million = -2	x4
Reduction in Flood Damages	Greater than $2.5 million = +2 Between $1 and $2.5 million = +1 Between $0.5 and $1 million = 0 Between $0.25 and $0.5 million = -1 Less than $0.25 million = -2	x4
Social Impacts		
Impact on Community (e.g., disruption during construction, impacts to visual amenity)	Significant positive impact = +2 Small positive impact = +1 Neutral = 0 Small negative impact = -1 Significant negative impact = -2	x3
Other Impacts		
Emergency Response Impacts	Significant positive impact = +2 Small positive impact = +1 Neutral = 0 Small negative impact = -1 Significant negative impact = -2	x4
Ecological and Environmental Impacts	Significant positive impact = +2 Small positive impact = +1 Neutral = 0 Small negative impact = -1 Significant negative impact = -2	x3

Table 41 Raw Multi-Criteria Assessment Scores

Criteria	FM1 Great Western Highway Culvert Upgrade	FM2 Railway and Hobart Street culvert upgrade	FM3 Glossop Street culvert upgrade	FM4 Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	FM5 Glossop Street stormwater upgrades	FM6 Lee Holm Drive stormwater upgrades	FM7 Colyton High School Basin Augmentation	FM8 Oxley Park Basin Augmentation	FM9 Great Western Highway Median Modification	FM10 FM1 + FM2 + FM4 + FM8
Flood Impacts										
Hydraulic Impacts	+1	+2	+1	+2	+1	0	0	+2	+1	+2
Reduction in Above Floor Flooding	+2	+1	0	+1	0	0	+1	+1	0	+2
Economic Impacts										
Cost	0	-1	0	-1	0	-1	0	0	+2	-2
Reduction in Flood Damages	-1	+1	-2	+1	-2	-2	+1	0	0	+2
Social Impacts										
Impact on Community	-2	-1	-2	-1	-1	-1	0	0	-1	-2
Other Impacts										
Emergency Response Impacts	+2	+1	+2	+1	0	0	-1	+1	+1	+2
Ecological and Environmental Impacts	0	0	0	0	0	0	0	+1	-1	0

Table 42 Weighted Multi-Criteria Assessment Scores and Ranking of Options

Criteria	Weight	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10
		Great Western Highway Culvert Upgrade	Railway and Hobart Street culvert upgrade	Glossop Street culvert upgrade	Canberra Street, Sydney Street and Brisbane Street stormwater	Glossop Street stormwater upgrades	Lee Holm Drive stormwater upgrades	Colyton High School Basin Augmentation	Oxley Park Basin Augmentation	Great Western Highway Median Modification	FM1 + FM2 + FM4 + FM8
Flood Impacts											
Hydraulic Impacts	x5	5	10	5	10	5	0	0	10	5	10
Reduction in Above Floor Flooding	x4	8	4	0	4	0	0	4	4	0	8
Economic Impacts											
Cost	x4	0	-4	0	-4	0	-4	0	0	8	-8
Reduction in Flood Damages	x4	-4	4	-8	4	-8	-8	4	0	0	8
Social Impacts											
Impact on Community	x3	-6	-3	-6	-3	-3	-3	0	0	-3	-6
Other Impacts											
Emergency Response Impacts	x4	8	4	8	4	0	0	-4	4	4	8
Ecological and Environmental Impacts	x3	0	0	0	0	0	0	0	3	-3	0
TOTAL SCORE		11	15	-1	15	-6	-15	4	21	11	20
RANK		4	=3	7	=3	8	9	6	1	5	2

8.8 Recommendations

Based on the assessment presented in this chapter, the flood modification options included in **Table 43** are recommended for implementation.

Table 43 Flood Modification Options Recommended for Implementation

Priority	Option		Comments
1	FM8	Oxley Park Basin Augmentation	This option affords notable reductions in flood levels and flood hazard across the Oxley Park public school as well as a number of downstream residential properties. It provides one of the highest benefit cost ratios (0.8) and was ranked #1 in the multi-criteria assessment. However, further refinement of the basin design is needed to ensure no properties are impacted by flood level increases during the PMF.
2	FM2	Railway Hobart Street Culvert Upgrade	This option provides the highest flood level reductions across one of the most significantly flood-affected areas of the catchment (i.e., Hobart Street). It provides a benefit cost ratio of just below 1 and was ranked equal second in the multi-criteria assessment.
3	FM4	Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades	This option provides flood level reductions across the highest number of properties of all options considered. The hydraulic effectiveness further improves when combined with FM2. It provides a benefit cost ratio of 0.6 and was ranked the third overall option in the multi-criteria assessment. It is recommended that more detailed investigations are completed to confirm service locations as the need for service relocation was a significant contributor to the overall cost and the need to relocate these services is likely to have an impact on the financial viability of this option.
4	FM1	Great Western Highway Culvert upgrade	If FM8 is determined to be viable as part of future investigations, consideration could then be given to implement FM1. This option provides the most significant reduction in above floor flooding but is predicted to generate flood level increases downstream of the Oxley Park basins. Therefore, it is important that the Oxley Park basin augmentation is completed first to ensure no properties are impacted by flood level increases because of the highway culvert upgrade.

As discussed in Section 8.6.1, implementing each of the options in **Table 43** together is predicted to afford notable benefits and this combined option (FM10) was ranked the number 2 option overall as part of the multi-criteria assessment. Therefore, this combined option should be goal for best managing the flood risk in the catchment in the medium to long term. However, as this will require significant capital investment which may not be available to Council as a single lump sum it is suggested that Council, subject to the outcomes of further detailed feasibility assessments, progressively implement each option in the "priority order" listed in **Table 43** (i.e., FM8 first and FM1 last).

Other options were 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:

- FM3: Glossop Street culvert upgrade.
- FM5: Glossop Street stormwater upgrades.
- FM6: Lee Holm Drive stormwater upgrades.
- FM9: Great Western Highway median modifications.

9 Property Modification Options

9.1 Introduction

Property modification options refer to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties are typically used to manage existing flood risk while planning measures are employed to manage future flood risk.

Property modification options considered as part of the study included:

- Planning Modifications:
  - PM1 – Changes to Penrith City Council LEP: Section 9.2.2;
  - PM2 – Changes to Penrith City Council DCP: Section 9.2.3; and
  - PM3 – Update Section 10.7 Certificate Information: Section 9.2.4.
- Property Modifications:
  - PM4 – Voluntary House Purchase: Section 9.3.1; and
  - PM5 – Voluntary House Raising or Flood Proofing: Section 9.3.2.

Further discussion on each of the above options is provided in the following sections.

9.2 Planning Modifications

9.2.1 Adequacy of Existing Planning Documents in Addressing the Full Range of Flood Risks

Appropriate planning controls are one of the most effective methods available to reduce the flood risk as redevelopment occurs in the future. A review of Council's LEP and DCP was completed as part of the study and the outcomes of this review are provided in Chapter 5 of this document. A summary of recommended updates to the LEP and DCP are also provided in this chapter in Section 9.2.2 and Section 9.2.3.

However, Council's existing LEP and flood-related planning controls are focussed on the "planning flood" (i.e., 1% AEP event). It needs to be acknowledged that there is potential for much larger floods to occur and this may still result in an unacceptably high flood risk despite the application of planning controls (and potential implementation of flood modifications options documented in Chapter 8). This is relevant to the Hobart Street area of the catchment where there is a notable increase in flood hazard in events larger than the 1% AEP flood.

Therefore, to determine whether the existing LEP and DCP will suitably consider the flood risk across the full range of potential floods in the future, additional investigations were completed. This aimed to determine if an unacceptably high flood risk/hazard may persist in the Little Creek catchment assuming the current development controls only are maintained and determine if additional controls may assist in reducing this flood risk to more acceptable levels.

The additional investigations involved the following work and assumptions:

- The floor level of all buildings located within the flood planning areas (FPA) would be elevated to the flood planning level. This was intended to reflect future redevelopment of all properties located within the flood planning area based on floor levels being elevated 0.5 metres above the 1% AEP flood in accordance with the existing LEP and DCP.
- The floor level of all buildings located outside of the FPA were assumed to be maintained at current levels (this is again consistent with the LEP and DCP which does not currently apply development controls beyond the FPA).

The peak PMF level at each property was then compared against the “future” floor levels calculated above. This allowed an above floor flooding depth to be calculated for each property during the PMF, assuming all properties are re-developed in accordance with the DCP 2014. A focus was placed on identifying properties where the above floor flooding depth was predicted to exceed 1.2 metres as this depth of water would produce H4 hazard inside of the building (i.e., unsafe for all people). Therefore, this check aimed to determine if unacceptably high hazard will exist within buildings during the PMF if they were built in accordance with the current DCP and people choose not to evacuate or were unable to evacuate. This also assumes that future dwellings would only comprise a single story (i.e., there is no second storey to evacuate up to).

The outcome of this assessment is presented in **Plate 38**. It shows:

- Buildings where the above floor flooding depth during the PMF is predicted to be less than 1.2 metres (i.e., less than H4 hazard) as black points
- Buildings where the above floor flooding depth during the PMF is predicted to exceed 1.2 meters (i.e., H4 hazard or higher shown as yellow points) and, therefore, where it would be unsafe inside the building.

This determined that more than 100 buildings would likely be exposed to internal flood hazard of at least H4 and would not be safe for any person. If only single level dwellings were provided for these properties, above floor flooding depths of more than 4 metres could be expected for some properties. It is also evident that some properties located outside of the FPA would likely experience H4 internal hazard during the PMF.

Therefore, application of Council’s current minimum floor level requirement (1% AEP flood level +0.5 metres freeboard for properties located within the FPA) would not reduce the flood hazard inside of some buildings to tolerable levels during the PMF. As noted in Section 5.3.1, it is suggested that the 0.5% AEP flood could be adopted as the planning flood in the Hobart Street area. Application of the higher 0.5% AEP event as the planning flood would serve to reduce the flood risk relative to adoption of the 1% AEP flood. However, as the 0.5% AEP flood is no greater than 0.2 metres higher than the 1% AEP flood, application of this higher planning flood level would also not be sufficient to reduce the flood risk to an acceptable level.

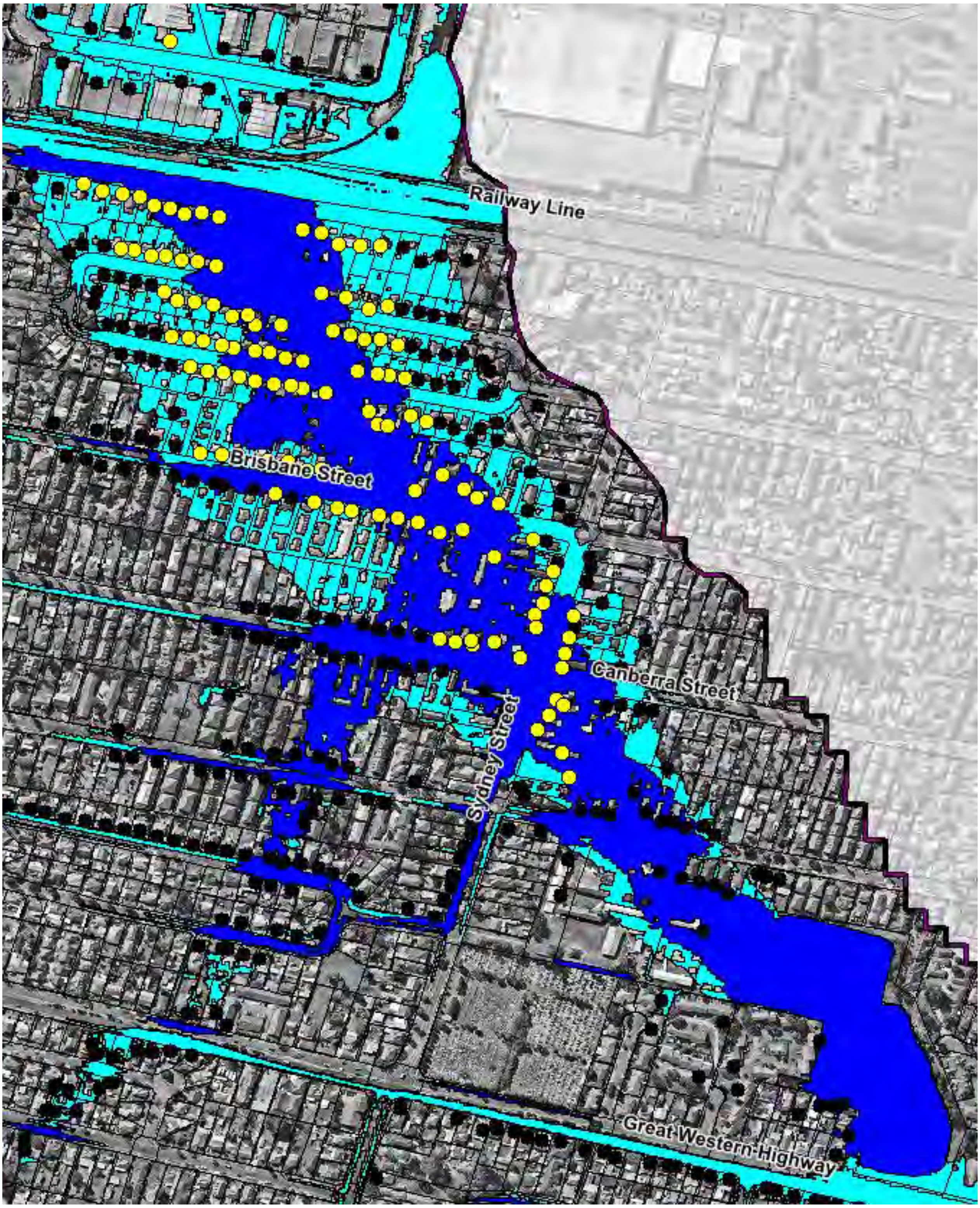


Plate 38 Buildings with internal flood hazard ≥H4 in the PMF (yellow). The PMF extent is show in aqua and the flood planning area is shown in dark blue.

This could be potentially improved upon by including the following additional development requirements when redeveloping buildings identified in yellow in **Plate 38**.

- Include structure controls beyond the FPA up to the limit of the PMF.

- Include an elevated mezzanine level or second storey in structurally sound buildings as part of any new development. Although evacuation is always the preferred response strategy, providing a mezzanine level or second storey as part of any new development will allow future occupants to "evacuate vertically" to a higher elevation if traditional evacuation cannot be safely completed or completed in a timely manner (particularly if the flood occurs at night when people are asleep).
- A requirement that all bedrooms be located on the second storey of residential dwellings. This is intended to improve the safety to residents 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.

It is noted that inclusion of a "standard" second storey (i.e., 2.4 metres above the ground floor) may still result in flood hazard conditions of at least H4 on the second level. Therefore, care will need to be exercised to ensure that the mezzanine level or second storey is sufficiently elevated to reduce the flood hazard during the PMF while taking into consideration any building height limits. However, to confirm whether provision of a mezzanine level or second storey in isolation would be sufficient to reduce the risk to life, the investigations were expanded to determine whether there was potential for structural damage or failure of buildings during the PMF. As noted in Section 4.2.8, a flood hazard category of H5 indicates that there is potential for structural damage or failure of buildings if they are not specifically designed to withstand the forces of floodwaters during the PMF. A flood hazard of H6 indicates that all building types are considered vulnerable to failure.

The outcomes of this assessment are shown in **Plate 39**. Orange points indicate that the building is predicted to be at least partly exposed to H5 hazard during the PMF, while pink points indicate the parts of the building that are predicted to be exposed to at least H6 hazard.

A structural assessment of all buildings identified in **Plate 39** was beyond the scope of this study. However, implementing development controls to reduce the flood hazard during the PMF to tolerable levels for all H6 properties identified in **Plate 39** may not be feasible from an economic perspective. As the structural integrity of these buildings cannot be guaranteed, early evacuation is currently the best flood risk reduction option for these properties. This is discussed further in Section 10.2.5.

Consideration could be given to including these properties in a voluntary house purchase program. However, this is unlikely to be economically viable due to the high capital cost. Further discussion on the advantages and disadvantages of voluntary house purchase is provided in Section 9.3.1.

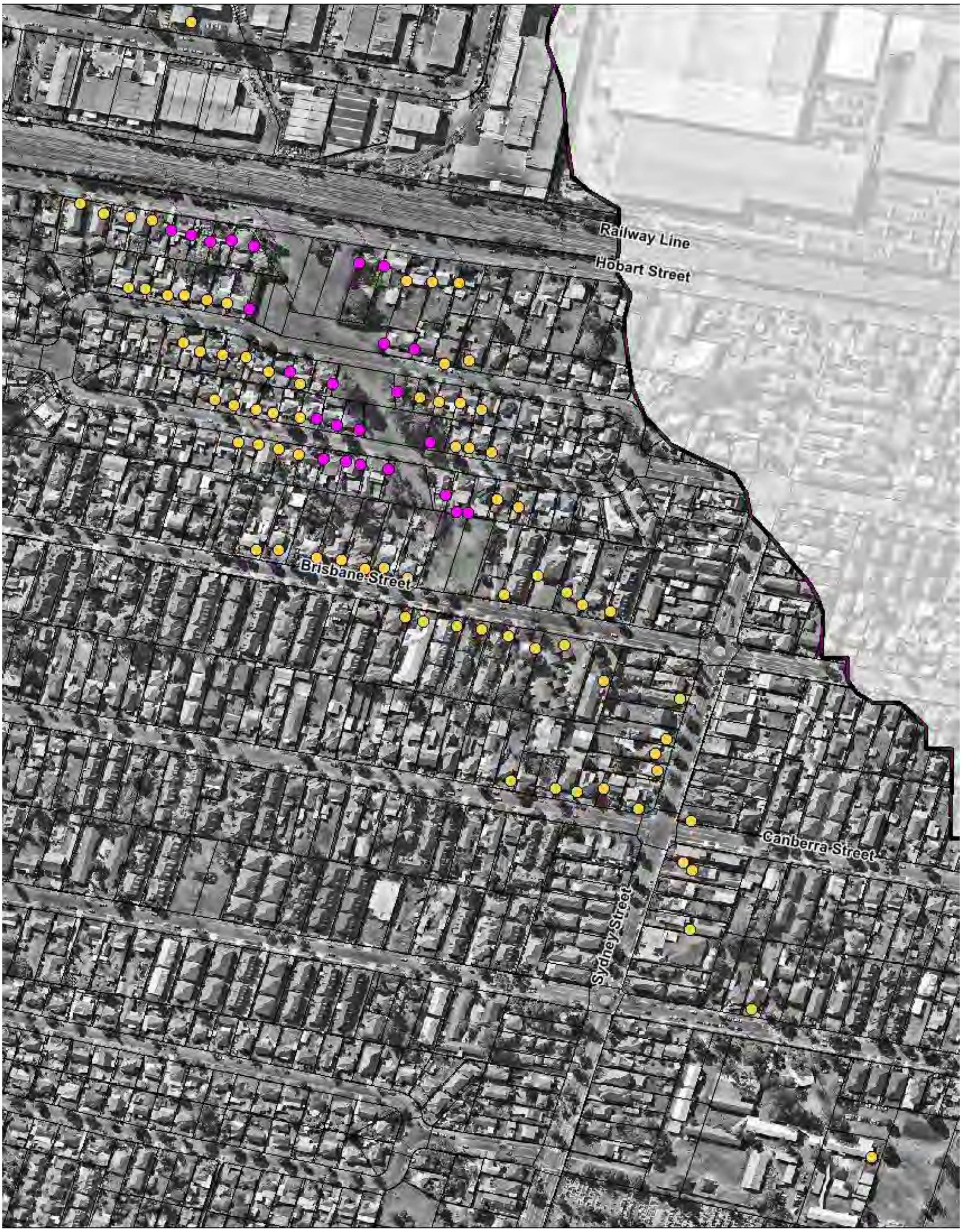


Plate 39 Buildings exposed to H5 (orange points) and H6 (magenta points) hazard during the PMF.

For the balance of properties and buildings exposed to H5 hazard (i.e., orange properties in **Plate 39**), it is possible that the buildings could remain structurally stable if they were specifically designed to withstand the dynamic and hydrostatic forces of floodwaters during the PMF. Therefore, it is recommended that additional development requirements are placed on <u>all properties</u> identified in **Plate 39** to ensure they are designed to remain structurally stable during floods up to and including the PMF. This could include updating the DCP to include the following additional requirement for buildings identified in **Plate 39**:

- Engineering report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF plus freeboard.

9.2.2 PM1 - Changes to Penrith City Council LEP

A review of the Penrith City Council LEP (2010) was completed, and the outcomes of this review are summarised in Section 5.3.1. As discussed in Section 5.3.1, it is recommended that any future updates of the LEP consider the following changes:

- Include properties in Brisbane Street to Hobart Street that are currently located outside the flood planning area but are exposed to greater than H4 hazard in the PMF within the flood planning area.
- Make the flood planning area map related to flood related development controls publicly available in an easy to find and easy to understand 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 freeboard not be appropriate (e.g., Hobart Street area where a higher freeboard or larger planning flood may be desirable). 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). Suggested wording for this clause is provided in **Plate 40** (this is taken directly from the standard instrument LEP template).

Clause XXX Floodplain Risk Management

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

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

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

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

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

(a) childcare centres or facilities,
(b) correctional centres,
(c) education facilities,
(d) emergency services facilities,
(e) group homes,
(f) health service facilities,
(g) residential care facilities, and
(h) seniors housing.

(4) In this clause—

flood planning area means the area of land at or below the flood planning level.

flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus a freeboard or as defined in adopted floodplain risk management plan.

probable maximum flood has the same meaning as it has in the NSW Government's *Floodplain Development Manual (*ISBN 0 7347 5476 0*)* published by the NSW Government in 2005.

Plate 40 Potential Floodplain Risk Management Clause

9.2.3 PM2 - Changes to Penrith City Council Development Control Plan

A review of the relevant Penrith DCP 2014 was completed and a detailed discussion on the outcomes of this review are documented in **Section 5.3.2**. As discussed, it is recommended that any future updates of this DCP consider the following changes:

- Clear prescriptive controls with defined thresholds for acceptable planning and development applicants.
- 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.
- 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 between Adelaide Street and Hobart Street at St Marys (refer to discussion in Section 9.2.1 for further detail):

- Include an elevated mezzanine level or second storey as part of any new development. This is intended to allow for vertical evacuation in the event that 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.

9.2.4 PM3 - Update Section 10.7 Certificate Information

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 Little Creek catchment.

This needs to be implemented in addition to 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.

9.3 Modification Options for Individual Properties

9.3.1 PM4 - Voluntary House Purchase

Voluntary house purchase (VHP) refers to the voluntary purchase of an existing property on a high-risk area of the floodplain. The purchased property is typically demolished, and the land is rezoned so that it can be retained as open space or an equivalent land use that is more compatible with the flood risk.

Due to the high capital costs associated with this option, VHP is typically only considered appropriate in high hazard, floodway areas where there is extreme risk to life and other flood risk reduction strategies are impractical or uneconomic. Moreover, NSW Government funding is only available for VHP for properties that were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted (Office of Environment and Heritage, 2013a).

The computer flood modelling outputs were interrogated with existing building footprints to identify houses that may be eligible for VHP. More specifically, buildings that fell within high hazard or floodway at the peak of the 1% AEP flood were initially considered as being potentially eligible for VHP.

The ARR2019 hazard categories have been adopted as part of the current study (refer Section 4.2.8) to identify properties in 'high hazard' area. In this regard, it was assumed that the H1, H2 and H3 categories would fall under the "Low" hazard category in the NSW Government's 'Floodplain Development Manual (2005)' and the national H4, H5 and H6 categories would fall under the 'high' hazard category in the Manual.

The extent of the area identified as high hazard floodway is shown in **Plate 41**. It shows that there are "pockets" of high hazard floodway across the upper sections of the catchment.

However, they are contained to roadways and detention basins and do not extend across areas with residential buildings. Similarly, the areas of high hazard floodway across the downstream sections of the catchment are fully contained to the Little Creek channel.

Although no properties were identified as falling within a high hazard floodway during the 1% AEP flood, it is noted that multiple properties between Adelaide Street and Hobart Street are exposed to H5 and H6 hazard during the PMF (i.e., high hazard). As outlined in Section 9.2.1, although additional development controls could be potentially incorporated in the DCP to ensure the structural stability of buildings exposed to H5 hazard, properties exposed to H6 hazard do have a high potential for structural damage or failure. Furthermore, no form of flood modification option or planning modification option is likely to reduce this flood hazard to H5 or below. As no other option is likely to reduce the flood risk during the PMF to acceptable levels, the impacted properties may be considered for inclusion in a VHP scheme.

A total of 25 properties were identified as being potentially eligible for voluntary purchase. The cost to purchase all identified properties is estimated to be just over $17 million based on the current median house and unit prices for St Marys ($650,000 and $460,000 respectively). Therefore, the capital cost of a voluntary house purchase scheme would be very high and it is difficult to see how it could be funded.

It is noted that VHP had a relatively low level of community support (i.e., less than 40% of the community supported VHP). As VHP is voluntary, there is no guarantee that individual property owners will agree to having their property purchased, which can reduce the effectiveness and certainty of VHP.

Overall, the very high cost of implementing a VHP is difficult to justify when the benefits are only realised during the PMF. Therefore, it is suggested that funding would be better directed to the flood modification options discussed in Chapter 8 which afford benefits across the full range of flood sizes.

Plate 41 1% AEP high hazard floodway areas (yellow)

9.3.2 PM5 - Voluntary House Raising

Voluntary house raising (VHR) is a well-established method of reducing the frequency, depth and duration of above floor inundation. VHR can be a suitable measure for reducing the flood damage for individual dwellings or can be used as a compensatory measure where other flood mitigation works are predicted to adversely impact on flood behaviour across individual dwellings. An example of house raising is provided in **Plate 42**.

Plate 42 Examples of houses before (top image), during (middle image) and after (bottom image) house raising (photos courtesy of Fairfield City Council)

VHR is best suited to single-storey, timber or clad walled houses with a pier and beam foundation in areas of low flood hazard where structural mitigation works are impractical or uneconomic. It should also be noted that Government funding is only available for VHR for residential properties that were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted (Office of Environment and Heritage, 2013b).

The computer flood modelling outputs were interrogated in conjunction with building footprints to identify houses that may be eligible for VHR. Specifically, houses that met the following requirements were pursued in accordance with criteria defined by Office of Environment and Heritage (2013b):

- Subject to frequent above floor inundation. In this regard, properties that were predicted to be inundated above floor level during events equal to or more frequent than the 5% AEP flood; and,
- Low flood hazard area at the peak of the 1% AEP event.

The extent of the low hazard areas is shown in **Plate 43**.

The outcomes of this assessment revealed that six (6) buildings are located in areas of the floodplain that satisfy the above criteria (refer **Plate 43**). However, four (4) of these buildings are constructed of brick on a concrete slab, so would not be suitable for house raising. As a result, there are two (2) properties within the Little Creek catchment that are considered to be suitable or eligible for voluntary house raising.

It is noted that one of these properties fronting the Great Western Highway would be completely surrounded by floodwater in the 1% AEP design flood event and would be considered as H3 flood hazard. This indicates that there is likely to be an appreciable hazard for any children or elderly residents or guests at this property should they choose to evacuate at the peak of the 1% AEP flood. Further examination of the flood hazards at this property reveal that it is also predicted to be surrounded by floodwaters in the 5% AEP design flood event and would also be considered a H3 hazard. The consistent hazard at this property is primarily a result of the Great Western Highway which results in water ponding to a relatively consistent level on the southern side of the roadway during most floods. Although raising this property would likely reduce flood damage costs, the consistent H3 hazard raises questions regarding whether raising this property would actually reduce the risk to life.

It is suggested that other flood modification options discussed in Chapter 8 be explored to determine if they can reduce the flood hazard on the southern side of the highway to less than H3 which may improve the viability of voluntary raising of these. However, if the flood modification options are able to reduce the flood levels sufficiently, it may also reduce the frequency of above floor flooding and remove the need to house raising of this property as well as the other two properties not eligible for raising that adjoin the Great Western Highway. For example, implementation of FM1 would eliminate above floor inundation for each of the Great Western Highway properties during all events up to and including the 5% AEP flood.

Overall, voluntary house raising is not recommended. However, it could be revisited if the flood modification options discussed in Chapter 8 are determined not to be feasible.

Plate 43 1% AEP low hazard areas (aqua) and properties potentially eligible for voluntary raising (yellow) or voluntary flood proofing.

Flood Proofing

Those houses located within low hazard areas that are not suitable for house raising could be considered for voluntary house proofing (e.g., yellow properties in **Plate 43**). Two types of flood proofing are available:

- 'dry' flood proofing, which aims to prevent the ingress of water into houses; and
- 'wet' flood proofing, which permits water to enter houses but reduces the damage to the structure of the house through the use of flood resilient materials.

'Dry' flood proofing aims to reduce inundation damages by completely preventing the ingress of water. In this regard, 'dry' flood proofing affords several benefits over 'wet' flood proofing as it avoids the potential for damage to building contents, reduces the clean-up efforts after an event and significantly reduces the stress associated with frequent above floor inundation.

'Wet' flood proofing is the cheapest and most straight forward flood proofing option to implement and therefore, tends to be the most common. A typical wet flood proofing cost of $60,000 would flood proof a typical residential building up to one (1) metre above ground level. However, flood proofing would generally not be eligible for full funding as part of the NSW Government's Floodplain Risk Management program. Therefore, at least part of the implementation would need to be covered by the property owner which reduces the likelihood of implementation. Furthermore, wet flood proofing will not remove the potential for ingress of floodwaters. Therefore, there is still potential for damage to contents if they are not stored sufficient high nor does it remove the mental anguish associated with flooding.

As a result of these limitations, voluntary flood proofing is not recommended for implementation in front of the flood modification option discussed in Chapter 8. Nevertheless, it could be considered if none of the other options are determined to be viable.

9.4 Recommendations

Based on the assessment presented in this chapter, the property and planning modification options included in **Table 44** are recommended for implementation.

Table 44 Property Modification Options Recommended for Implementation

Option		Comments and Recommendations
PM1	Changes to LEP	• Make the flood planning area map related to flood related development controls publicly available in an easy to find and easy to understand location. • Update Clause 7.2 to better cater for all land impacted by flood related development controls. • Include an additional "Floodplain Risk Management" clause for areas between the flood planning area and the limit of the floodplain
PM2	Changes to DCP	• Amend Penrith DCP 2014 considering the detailed review presented in Section 5.3.2 of this report and other adopted floodplain risk management plans. • Incorporate additional controls in DCP for high flood risk properties contained between Adelaide Street and Hobart Street at St Marys to ensure structural integrity of buildings during the PMF
PM3	Update Section 10.7 Certificates	• Update Section 10.7 certificate to reference updated design flood information generated as part of the current study

10 Response Modification Options

10.1 Introduction

It is generally not economically feasible to treat all flood risk up to and including the PMF through flood modification and property modification measures. Therefore, response modification measures are implemented to manage the residual flood risk by improving the way in which emergency services and the public respond before, during and after floods. Response modification measures are often the simplest and most cost-effective measures that can be implemented and, therefore, form a critical component of the flood risk management strategy for the Little Creek catchment.

Response modifications options considered as part of the study include:

- Options to improve emergency response planning (i.e., planning before a flood):
  - RM1 – Community education strategy: Section 10.2.1.
  - RM2 – Make property level flood information available: Section 10.2.2.
  - RM3 – Local flood plan updates: Section 10.2.3.
  - RM4 and RM5 – Flood emergency response plans: Section 10.2.4.
  - RM6 – Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas: Section 10.2.5.
- Options to improve emergency response during a flood:
  - RM7 – Flash flood warning system: Section 10.3.1.
  - RM8 – Upgrade of Great Western Highway: Section 10.3.2.
  - RM9 – Upgrade of Glossop Street: Section 10.3.3.
- Options to assist in post-flood recovery:
  - RM10 - Local Flood Plan Updated to Accommodate Recovery Planning: Section 10.4.1.

Further discussion on each response modification option that could be potentially implemented is provided below.

10.2 Options to Improve Emergency Response Planning

Effective planning for emergency response is a vital way of reducing risks to life and property, particularly for infrequent floods that are not managed through flood or property modification measures. Potential opportunities for improvements to existing emergency response planning are discussed below.

10.2.1 RM1 - Community Education Strategy

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.

Although the population contained within the Little Creek catchment is not particularly large, it is unlikely that the local SES unit has sufficient resources to assist all "at risk" properties within this catchment as well as adjoining catchments, particularly during very rare floods (e.g., the PMF). The main emergency response issue in this catchment is the vulnerability of the Great Western Highway to inundation relatively quickly, as it is the main east to west road in this area. Therefore, there is an increased risk of people driving though floodwaters at this location during all flood events. The other location of concern is Hobart Street, between Sydney Street and Australia Street. The SES are aware of the flooding problems at both of these locations. However, even if SES resources can be deployed, the "flashy" nature of flooding within the catchment may mean that roads will already be cut by the time the SES arrive or have time to close off inundated roads. This emphasises the importance of the at-risk communities being equipped to respond appropriately to flooding without reliance on the emergency services.

A community survey conducted for this floodplain risk management study indicated nearly 60% of respondents planned to evacuate to an evacuation centre during future floods. This is a positive outcome as other studies completed by the authors indicate evacuation would often be completed by less than 30% of impacted properties. However, about 25% of respondents had no plan and were unsure of how they would respond during a future flood. Therefore, there is still a need to educate the community so they can better understand the flood risk as well as their level of exposure which will assist in promoting appropriate planning such as the preparation of flood emergency response plans as discussed in Section 10.2.3.

Flood education programs are primarily the responsibility of the NSW SES, with Councils supporting the SES. Key challenges of such programs include the need to maintain community flood awareness and readiness, especially in the absence of major floods that serve as a natural reminder of the risk. In addition, the dynamics of communities can lead to people with no prior knowledge or experience of flooding moving into a flood prone area.

From the flood hazard assessments and the outcomes of the community questionnaire, a number of key messages need to be disseminated to the community in the Little Creek catchment as part of future education activities:

- "Never drive, ride, walk or play in floodwaters." The need to continue broadcasting this message is suggested by the knowledge that motorists in Australia continue to lose their lives when attempting to cross floodwaters, particularly given the susceptibility of the Great Western Highway and Glossop Street (i.e., the major roadways in the catchment) being subject to relatively frequent inundation. Messages could also provide technical information to dissuade drivers from crossing or driving through flooded roads, such as the depths at which cars float. Messages could also target the motivations for crossing water, such as by encouraging childcare centres and schools to advise parents during storms or floods that their children are safe.
- "One day a bigger, faster flood will happen than what anyone has ever seen. Council has modelled what these floods might be like. Learn whether your house or access to your business could be flooded in an extreme flood. Identify whether it's safe for you to stay or whether you need to evacuate before flooding. Plan ahead to keep your family and staff safe". A message such as this is important to encourage evacuation knowing that the hazard during particularly large floods may be sufficient to result in failure of some

residential buildings, particularly around Hobart Street where evacuation is considered to be essential.

- "Flooding can occur away from rivers and creeks". This message aims to reinforce that overland flooding is a risk away from defined watercourses.
- "The safest place to be in a flood is away from the floodwaters. Therefore, early evacuation is recommended for flood prone properties." As the duration of local catchment flooding is relatively short, messaging such as "Wait a few hours rather than go out in the rain" may assist in discouraging driving through floodwaters.

As discussed, the primary flood "hot spot" is concentrated around Hobart Street. Further discussion on potential targeted education strategies for this area is provided in Section 10.2.5

It is also suggested that the SES could prepare Floodsafe documents for the local area to provide general flood education information. 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.

10.2.2 RM2 - Make Property Level Flood Information Available

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, than more generic advice.

The provision of additional flood information was listed as one of the most preferred flood risk mitigation strategies by the community as part of a questionnaire distributed for the current study (refer Section 3.1.3). Therefore, there appears to be a willingness for the community to improve their understanding of the flood risk by becoming more informed.

Council currently makes the following information available to the public on its website (in PDF format):

- Flood study, floodplain risk management study and floodplain risk management plan reports and appendices;
- 1% AEP floodwater level map;
- Flood planning area map; and,
- Full set of flood maps are also provided as a separate downloaded.

Therefore, Council already makes a considerable amount of flood information available on its website. However, there are some limitations with the current arrangement:

- The complete PDF map set often comprises a very large file size. This can reduce the potential for the general public to access all available maps, particularly if trying to gain access from a mobile device.
- The mapping is generally not consistent between studies. This can mean that standard mapping outputs such as depths and velocities are presented with different colour schemes and ranges for each catchment which can prove confusing or difficult to interpret for the public.

- The mapping is generally not to a consistent scale. In particular, some studies provide results at the catchment scale only making it very difficult to identify results at the property level.

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 current study.

However, over the medium to long term, there would be value in taking advantage of the more detailed spatial outputs that are produced as part of flood studies and floodplain risk management studies by collating and incorporating this information on an online mapping webpage. This would help to ensure that results are presented in a consistent manner regardless of who completed the study, would ensure all available flood information is provided on a single webpage and would overcome 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 BoM warnings, live information on nearby rain gauges, and the latest advice from relevant organisations such as NSW SES and TfNSW. Therefore, if well maintained, a website can serve as a central repository for a range of contemporary flood information.

It is suggested that this mapping page could include design flood depths, flood levels and flood hazard, in addition to information describing when and where access to individual properties will be cut during a flood. This would also assist with providing proponents or purchasers of property in the catchment with the full suite of flood information related to flood constrains that council is aware of for each property in this catchment.

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.

In addition to resources required to complete the development of the mapping website, additional Council resources and training may also be necessary to answer inquiries about what this information means and how it could be used to assist in the preparation of property-level flood response plans (discussed in Section 10.2.4).

A "Frequently Asked Questions" (FAQ) may also need to be developed and updated to accompany any upscaling of flood information availability. For example, people are often concerned about the perceived impact of flood information on property values and insurance premiums. Potential answers have been developed by Floodplain Management Australia and the Insurance Council of Australia could be used as a starting point for preparation of a specific FAQ sheet.

10.2.3 RM3 - Local Flood Plan Updates to Accommodate Response Planning

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) was reviewed as part of the current study and the outcomes of this review are summarised in **Table 26**. 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 and actual floods. The LFP does not include any consideration of the Little Creek 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.

As the SES is the agency responsible for flood emergency management, it is recommended that they undertake 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.

10.2.4 RM4 and RM5 - Flood Emergency Response Plans

This floodplain risk management study has estimated that less than 40 properties are predicted to be impacted by over floor flooding in a 1% AEP event. However, this number drastically increases to nearly 400 properties being impacted by above floor flooding in a PMF event.

There are relatively few isolated areas during the 1% AEP flood. Therefore, evacuation during more frequent floods can most commonly occur by people walking from their property to higher ground. However, there are a number of "flood islands" that form during the PMF, in addition to a number of roads that would be cut by floodwaters making evacuation a more difficult prospect.

Accordingly, the flood risks are considered largely manageable during floods up to and including 1% AEP event but increase significantly during the PMF event. The size of the PMF, the number of impacted properties and the flashy nature of flooding demonstrates that the SES would not be able to provide sufficient assistance during a PMF for all properties.

As such, the preparation of residential and business flood plans are a highly valuable option and are discussed in further detail below.

Home Flood Plan Preparation (RM3)

It is unlikely that many private dwellings within the flood prone areas have formal flood emergency response plans given the lack of recent flood events. Accordingly, the preparation of home 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 follow by the household before, during and after a flood to help mitigate damages and the potential for risk to life at the property level. The Home Flood Plans in this catchment should clearly highlight the roads vulnerable to flooding in the area (e.g., Great Western Highway) and the need to stay off flooded roads.

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

With the vulnerability of some of the roads through the study area to flooding, it is anticipated that there will be a significant number of people who will be indirectly impacted by flooding. As such, the preparation of the SES Home Flood Plan could be extended to the wider community to focus on the likely disruption to the road network expected during flood times and the need to travel on roads. This could include information on alternate evacuation routes to help reduce the occurrence of people driving through floodwaters.

Implementation of this option will require innovative approaches to persuade residents to plan ahead for floods. As discussed, in Section 10.2.1, this could be potentially promoted in higher risk areas, such as Hobart Street, via SES door knocking or meet the street type events.

Business Flood Plan Preparation (RM4)

The predicted flooding impacts across the Little Creek catchment are not restricted to residential areas with a number of commercial and industrial properties directly and indirectly impacted by flooding. As such, businesses across flood liable sections of the catchment would also benefit from preparing and maintaining flood plans. The plans set out protocols to follow by the business before, during and after a flood to help mitigate damages and the potential for risk to life at the property level. A well implemented flood plan will also help with the recovery process and ensure businesses will be "back on their feet" sooner rather than later which will assist in minimising the potential for longer term financial impacts.

As for private home flood plans, Council should be able to provide significant information describing the flood risk at the property scale based on the outputs from this study including the potential frequency and depth of inundation as well which roadways will be cut and the likely duration of any isolation (e.g., Lee Holm Drive).

The SES has 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 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.

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

A number of residential properties located between Adelaide Street and Hobart Street at St Marys are predicted to be exposed to at least H5 external hazard or H4 hazard inside of buildings during the PMF. Those properties are shown on **Plate 43** and include 116 buildings that would be at least partly exposed to H5 or H6 hazard (red points) and 118 buildings that would be subject to above floor flooding depths that exceed 1.2 metres (yellow points) during the PMF (including 99 properties that would be exposed to both above floor flooding depths of more than 1.2 m and H5 or H6 hazard). Therefore, all properties shown on **Plate 43** 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 actually expose people of 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 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 10.2.2, 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 10.2.1 are also relevant to this area, a more targeted education strategy is considered necessary to assist the community in better understanding the unique extremity 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 (i.e., evacuation) plans.

A "meet the street" event could also have value where the flood risk could be explained with the assistance of flood maps and animations produced as part of the current study. This may also assist in establishing a greater sense of community and begin "planting the seeds" for establishing communication groups across the higher risk sections of the catchment, to assist in promoting more coordinated evacuation efforts.

The area in **Plate 43** is somewhat unique in that the flood hazard during events up to and including 0.2% AEP across most residential properties does not exceed H3. Furthermore, above floor flooding of most properties in the area only occurs in floods larger than the 0.2% AEP flood. Therefore, although evacuation is always the preferred emergency response strategy, if evacuation was not completed, it is unlikely to result in unacceptable hazard conditions during floods up to and including the 0.2% AEP flood. Therefore, any evacuation strategy for the area needs to strike a balance between too frequent evacuation (i.e., evacuation every time it rains is unlikely to be sustained over the long term) but ensuring evacuation is completed in very rare floods.

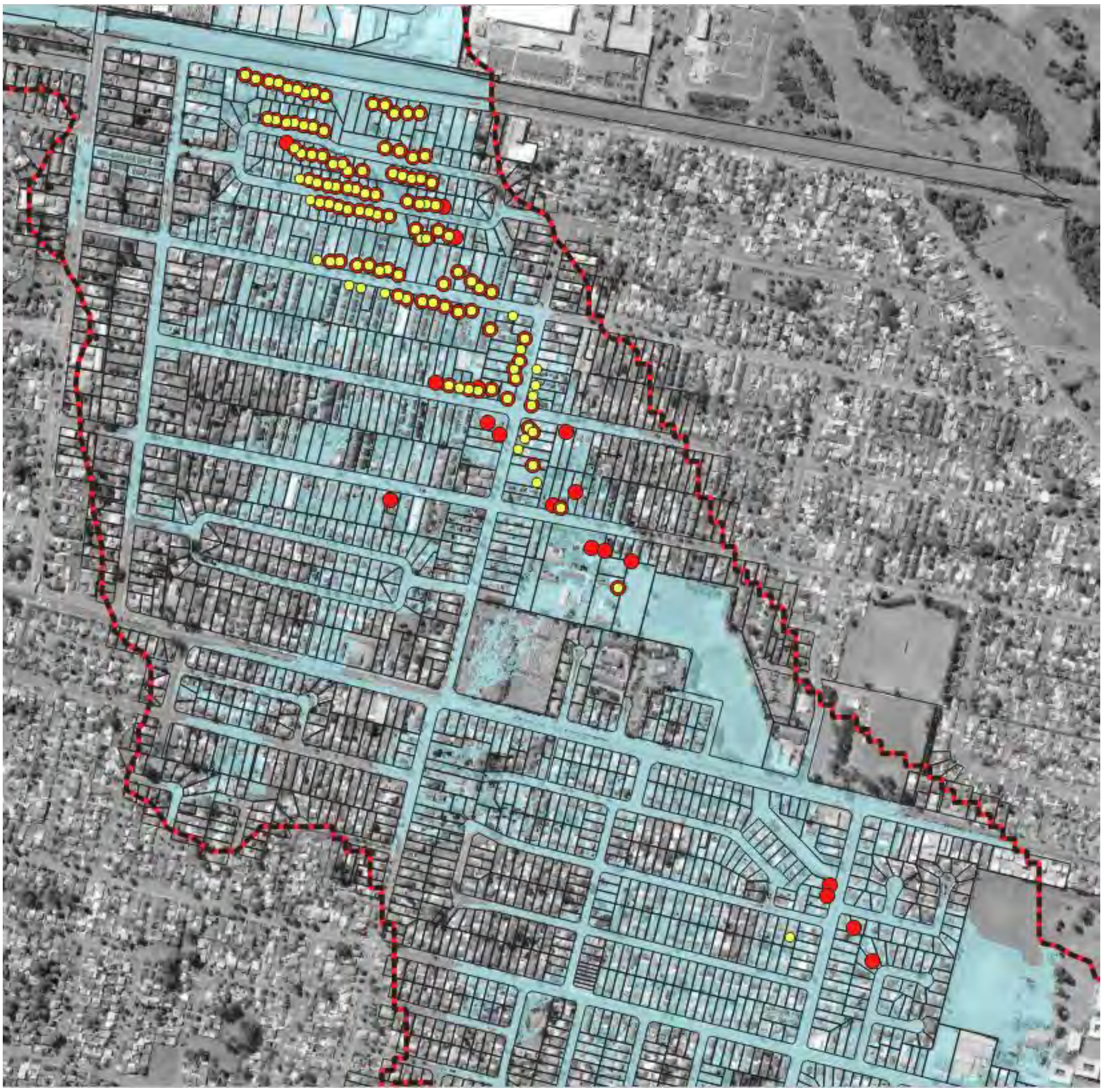


Plate 44 Buildings exposed to H5 or H6 hazard (red) or high hazard internal flooding (yellow) in PMF where evacuation is considered essential

As discussed, there is likely to be minimal advanced warning time during large floods in the Little Creek catchment. Therefore, having an emergency kit pre-prepared and ready for use is the first step in the process. The emergency kit should include (SES, 2020):

- Portable radio with spare batteries
- Power bank with USB cables
- Torch with spare batteries
- First aid kit (with supplies necessary for your household)
- Candles and waterproof matches
- Important papers including emergency contact numbers
- Copy of Home Emergency Flood Plan; and
- Waterproof bag for valuables.

When preparing to evacuate from a property, the following additional items should be included in the emergency kit (SES, 2020):

- A good supply of required medications
- Any special requirements and supplies for babies, the disabled, infirm or elderly
- Appropriate clothing and footwear; and
- Fresh food and drinking water.

The emergency kit should be checked on a regular basis to confirm batteries and electrical devices are charged and working and to restock any perishable items (e.g., rubber gloves). At a minimum, checks should be completed yearly.

The SES would be responsible for leading evacuation efforts. However, the short warning times may make it difficult for the SES to mobilise resources and undertake safe evacuation in a timely manner using a traditional "door knock" approach. Therefore, there may be advantages in the SES looking at expanding its repertoire to taking advantage of modern communication techniques. The goal of this would be to promote more efficient and timely communication and evacuation. In this regard, the SES could look at setting up a communication group for the local high risk area (e.g., SMS, Facebook group, Viber, WhatsApp group) that would allow rapid communication between the SES and households and would assist in promoting more efficient evacuation efforts. These communication channels could be used to:

- Re-iterate severe weather and thunderstorm warnings (refer to Section 10.3.1 for further information of these warnings). This would provide initial advice of the potential for a flood and recommend that households ensure their emergency kits are in order.
- Advise that evacuation will likely be necessary in the immediate future. This would likely be issued during the initial phases of a severe rainfall event (and may be enhanced by the installation of a rainfall gauge in the upper catchment, as discussed in Section 10.3.1). This would request that households be ready for imminent evacuation.
- Advise that evacuation will be necessary and ask that residents move to their front door ready for evacuation and await further instructions from SES staff.

By providing this additional "lead up" information, it will assist the high risk areas in staying informed of an impending flood and it will help to ensure that households are ready to evacuate as soon as the SES initiates the evacuation order.

Fortunately, all roads in the high risk areas are "rising road" evacuation routes, meaning that the roads rise up and away from deeper water. Therefore, evacuees should be able to walk to higher ground without needing to move through areas of deeper water.

If a significant rainfall event were to occur at night, the effectiveness of a system that relies on households making observations can be limited. This can be due to either a lack of sunlight making observations more difficult or people being asleep when the flood occurs. Therefore, there would be benefits in exploring an automated alert system. Although a formal flood warning system is unlikely to be viable for the catchment as a whole (refer discussion in Section 10.3.1), 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 setup with a telemetry system with predefined rainfall triggers (e.g., once rainfall approaches or exceeds the 0.2% AEP rainfall depths documented in **Table 7**), it could send an automated message (via the Facebook or WhatsApp groups discussed above) or phone call or text message to potentially vulnerable properties.

Overall, it is recommended that:

- SES (with assistance from Council) initiate a focussed education strategy for the Adelaide to Hobart Street area in the short term 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 a flood emergency response plan. As the response strategy for most properties will be very similar, the SES or 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 BoM could explore the potential for installing a rainfall gauge that could serve to issue automated flood warnings based on rainfall depth triggers.

10.3 Options to Improve Emergency Response During a Flood

10.3.1 RM7 - Flash Flood Warning System

This option considered the implementation of a flash or local flood warning system throughout the Little Creek catchment. The goal of such a system is to provide sufficient advanced warning of an impending flood that would allow residents and business owners to safely evacuate before floodwaters arrive and take action to reduce the potential impacts of flooding on their property (e.g., elevate stock and belongings to higher ground).

Penrith City Council does not currently operate a flash flood warning system for any of its local catchment (including the Little Creek catchment). Therefore, the only warnings that people in the Little Creek catchment are likely to receive in relation to flooding would be issued by the Bureau of Meteorology and could be either:

- <u>A severe weather warning for flash flooding</u> – this will provide 6 to 24 hours' notice but is unlikely to be more specific than being for "western Sydney" and a general time frame of when it may occur.
- <u>A severe thunderstorm warning</u> – this could be more location specific but probably not better than at an LGA level and will be issued between 30 and 60 minutes before the event.

Neither of these warnings can provide an indication of the intensity of rainfall and the magnitude of flooding likely to occur. Observation of Bureau of Meteorology Radar images will give some indication as to the location and intensity of imminent and actual rainfall and may provide up to 30 minutes of warning. Observation of actual rainfall and runoff will give a better indication of the likelihood of flooding however, by this time there may be limited time to respond appropriately.

A water level gauge could be installed in the high risk Hobart Street area. This could be setup to allow for an automated alarm to sound once threshold water levels in Hobart Street are reached. However, if the trigger is reliant on water beginning to "pond" in Hobart Street, it is unlikely to afford any significant advanced warning of a flood and, therefore, minimal additional opportunity to evacuate.

Placing a rainfall gauge at the upstream parts of the Little Creek catchment to facilitate broadcasting a warning would provide less than 60 minutes warning to downstream catchment areas (noting that the most "at risk" areas are located within the middle and upper areas of the catchment). In some of the larger flood events, roads are cut in less than 30 minutes which would not be sufficient time for people to organise themselves and their household to evacuate, particularly if they were asleep at the time. Accordingly, a flash flood warning system is not recommended for implementation as it is unlikely to yield sufficient additional warning time to allow residents to respond to any warnings that are issued.

Nevertheless, installation of additional sub-daily rainfall gauges could be considered by Council to potentially serve as inputs to a wider flood warning system. Installation of additional rainfall gauges would also assist in providing valuable inputs as part of future flood study revisions for the catchment and may also assist in providing some advanced warning for higher risk properties located between Adelaide Street and Hobart Street in the PMF (as discussed in Section 10.2.5). Opportunities to setup a telemetered gauge with automated rainfall triggers is also considered to be a worthwhile pursuit in the medium term, particularly for the Adelaide Street to Hobart Street area.

Regardless of whether such gauges are installed in the future, the practicality of evacuation will be highly reliant on individual households interpreting available warning information and taking appropriate actions. In this regard, providing education materials on what warning information is available (severe weather or storm warnings from the BOM), where this information can be accessed and how this information is to be interpreted would be beneficial. Having household or business flood plans enacted, as discussed in Section 10.2.4, would also be critical to ensure required evacuations actions are identified before the flood. In summary, flood warning in the Little Creek catchment should focus on helping occupants in the catchment in better understanding the potential flood implications for their properties and responding appropriately to severe weather warnings from the Bureau of Meteorology and their own observations.

10.3.2 RM8 – Raising of Great Western Highway

The Great Western Highway is the main east - west transportation link through Little Creek catchment and one of the main transportation links contained within the Penrith LGA. The section of the highway that is contained within the Little Creek catchment is predicted to be cut during floods as frequent as the 0.5EY event. This presents a number of potential issues:

- Relatively frequent disruption to local traffic;
- Reduced potential for people of evacuate away from floodwaters; and
- More frequent temptation for people to drive through floodwaters.

As discussed in Chapter 8, two flood modification options were explored in the vicinity of the Great Western Highway (refer Section 8.3.1 and Section 8.5.1). Although both options served to reduce inundation depths across the road, they were not sufficient to remove the potential for inundation. Therefore, raising the road level was investigated.

Several different road raising options were explored. It was ultimately determined that raising the highway by 0.5 metres would be required to remove inundation during floods up to and including the 1% AEP event. However, the flood level difference mapping shown in **Plate 44** indicates that raising the road level by this amount would result in significant adverse flood impacts across multiple properties to the south of the highway. Therefore, simply elevating the highway is not considered feasible without associated mitigation measures.

In this regard, an additional 1% AEP flood simulation was completed with the elevated roadway in combination with the upgraded culvert investigated as part of FM1 (refer Section 8.3.1). The flood level difference mapping from this simulation is provided in **Plate 45**.

Plate 45 shows that even the provision of an upgraded culvert is not sufficient to fully mitigate the flood level increases to the south of the highway. Furthermore, the additional flow that is passed through the larger culvert is predicted to direct additional water downstream resulting in flood level increases across multiple properties between the Oxley Park Public School and the Sydney Street and Canberra Street intersection.

Therefore, it appears very difficult to strike a balance between increasing the level of service afforded by the highway during events up to and including the 1% AEP and not adversely impacting on flood behaviour elsewhere across the catchment.

However, the emergency response benefits of raising the road are significant when considering the frequency that the southern half of the highway is currently inundated (during floods equal to and greater than a 5% AEP flood) along with the significant amount of traffic that traverses this roadway. Therefore, there is likely to be merit in pursuing a road raising option as part of any road upgrades in the future. However, this may need to be a more modest road raising option (for example, providing flood free access during events up to and including the 2% AEP rather than the 1% AEP flood). Alternatively, it could be revisited in conjunction with other options that are recommended for implementation such as the Oxley Park Basin upgrade (FM8) which may assist in reducing the downstream flood impacts.

10.3.3 RM9 – Raising of Glossop Street

Glossop Street serves as the main north-south transportation link and evacuation route in the Little Creek catchment. Although this road is not as heavily trafficked as the Great Western Highway, it is still predicted to be inundated during floods equal to and greater than the 5% AEP flood. Therefore, the potential benefits of raising Glossop Street were also explored.

Several road raising iterations were completed to determine how much the existing road profile would need to be elevated to provide flood free access up to and including the 1% AEP flood. This determined that the road elevation would need to be increased by 0.2 metres. However, the resulting flood level difference mapping (refer **Plate 46**) shows that this is predicted to generate flood level increases that extend into adjoining residential and commercial properties. Therefore, like the Great Western Highway raising, simply elevating the road is not considered feasible without associated mitigation measures.

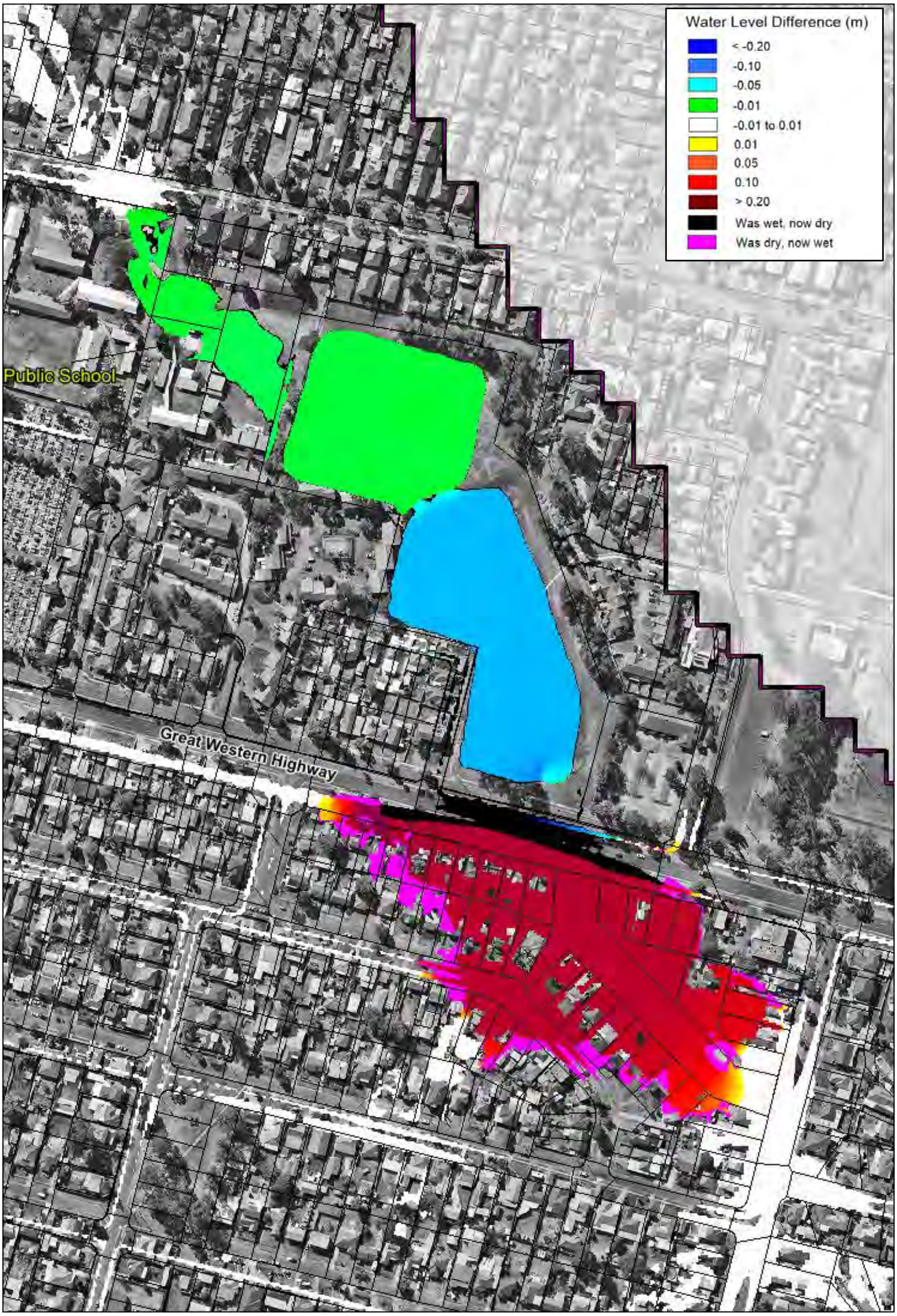


Plate 45 1% AEP flood level difference map for RM8 (elevated roadway only)

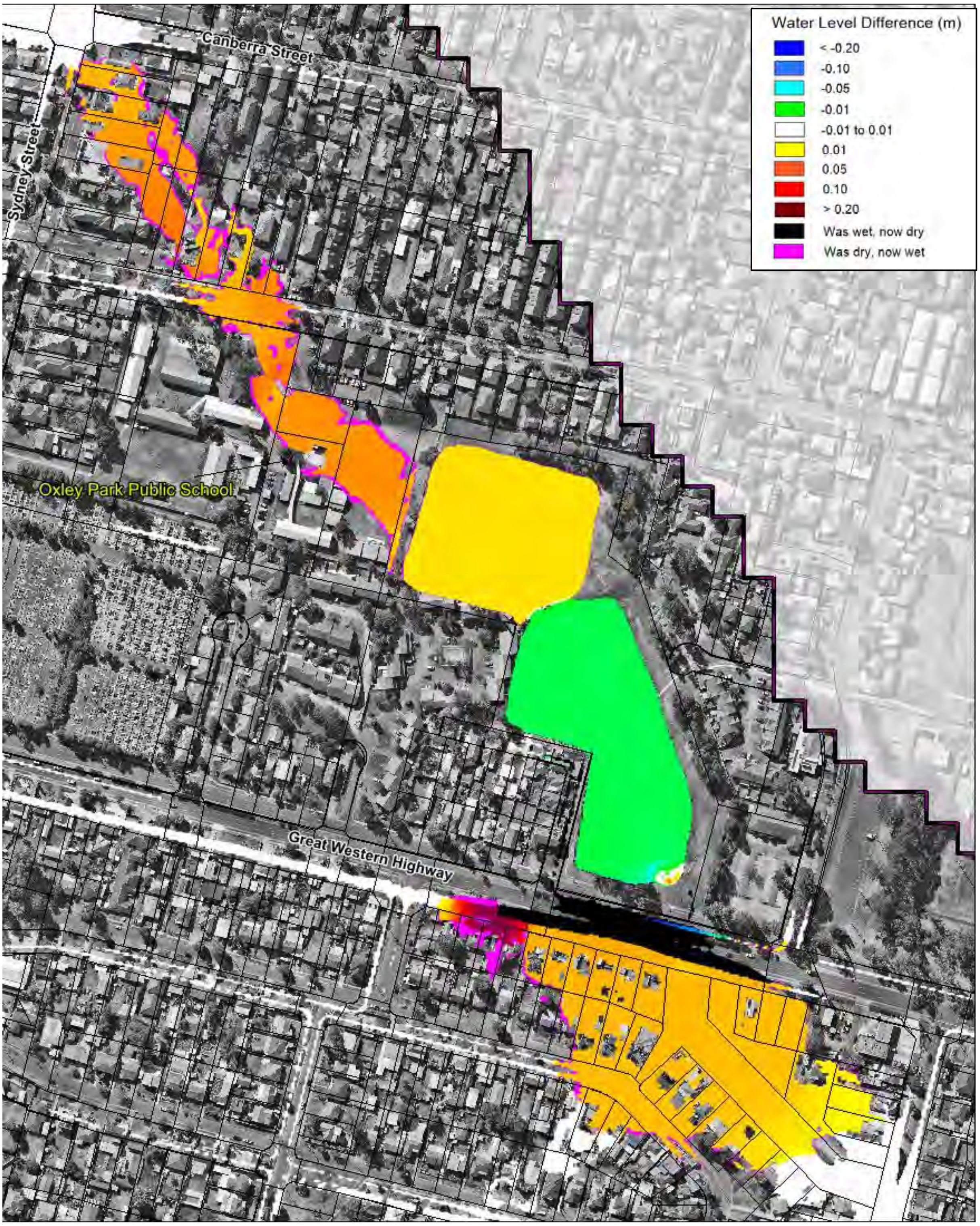


Plate 46 1% AEP flood level difference map for RM8 (elevated roadway and FM1 culvert upgrade)

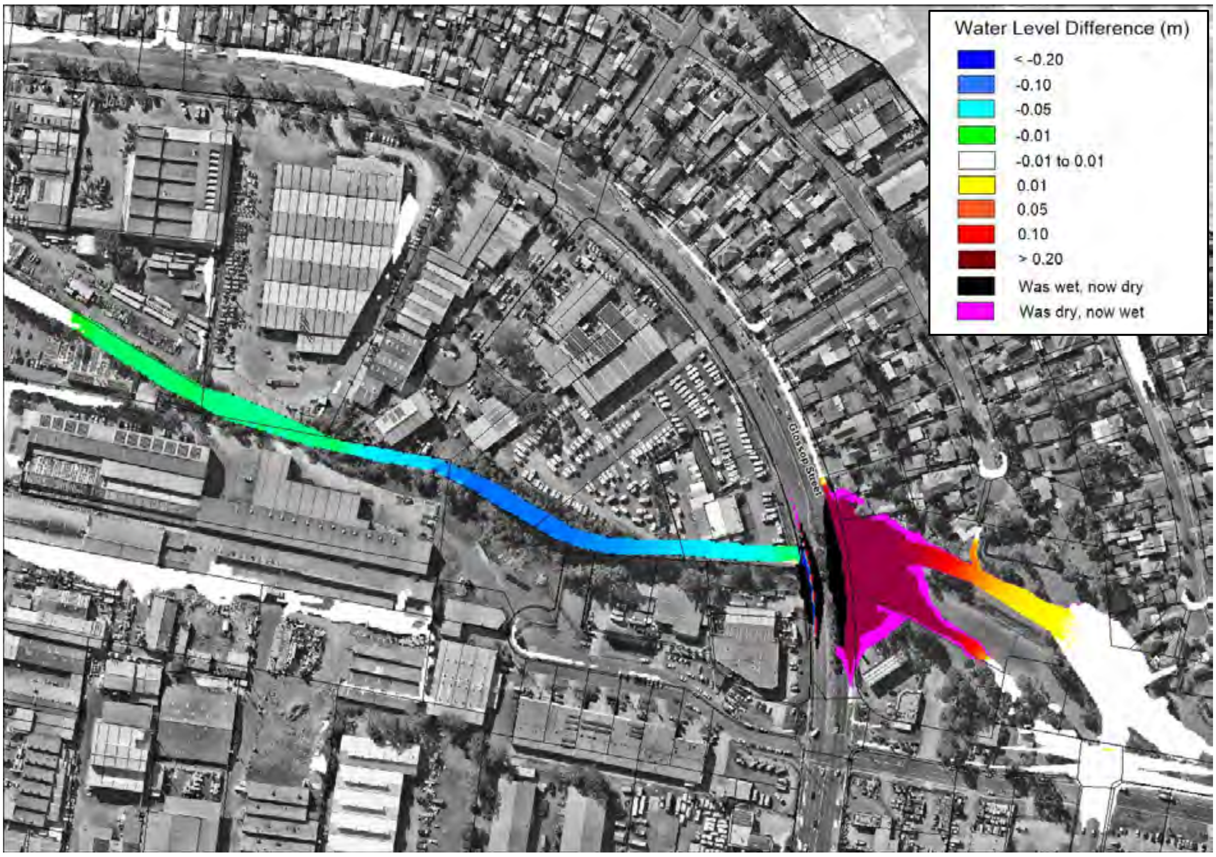


Plate 47 1% AEP flood level difference map for RM9 (elevated roadway only)

Therefore, an additional simulation was completed incorporating the elevated road along with the culvert upgrade explored as part of FM3 (refer Section 8.3.3). The 1% AEP flood level difference map from this simulation is presented in **Plate 47**.

Plate 47 shows that the inclusion of the culvert is predicted to result in flood extents across Glossop Street reducing such that at least one (1) lane in each direction of travel would be available during the 1% AEP flood. It also shows that flood levels upstream of the roadway would reduce (i.e., properties adjoining Glossop Street would not be adversely impacted). However, the additional water that is directed downstream would increase the flood liability of Forrester Road.

Nevertheless, the flood level reductions that are predicted would ensure that at least one lane of traffic would remain open in both directions. This is considered to be a significant emergency response benefit.

Overall, it is recommended that raising of Glossop Street is considered as a long-term option particularly if road upgrades are proposed or FM3 is implemented.

10.4 Options to Assist in Post-Flood Recovery

10.4.1 RM10 – Local Flood Plan Updates to Accommodate Recovery Planning

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.

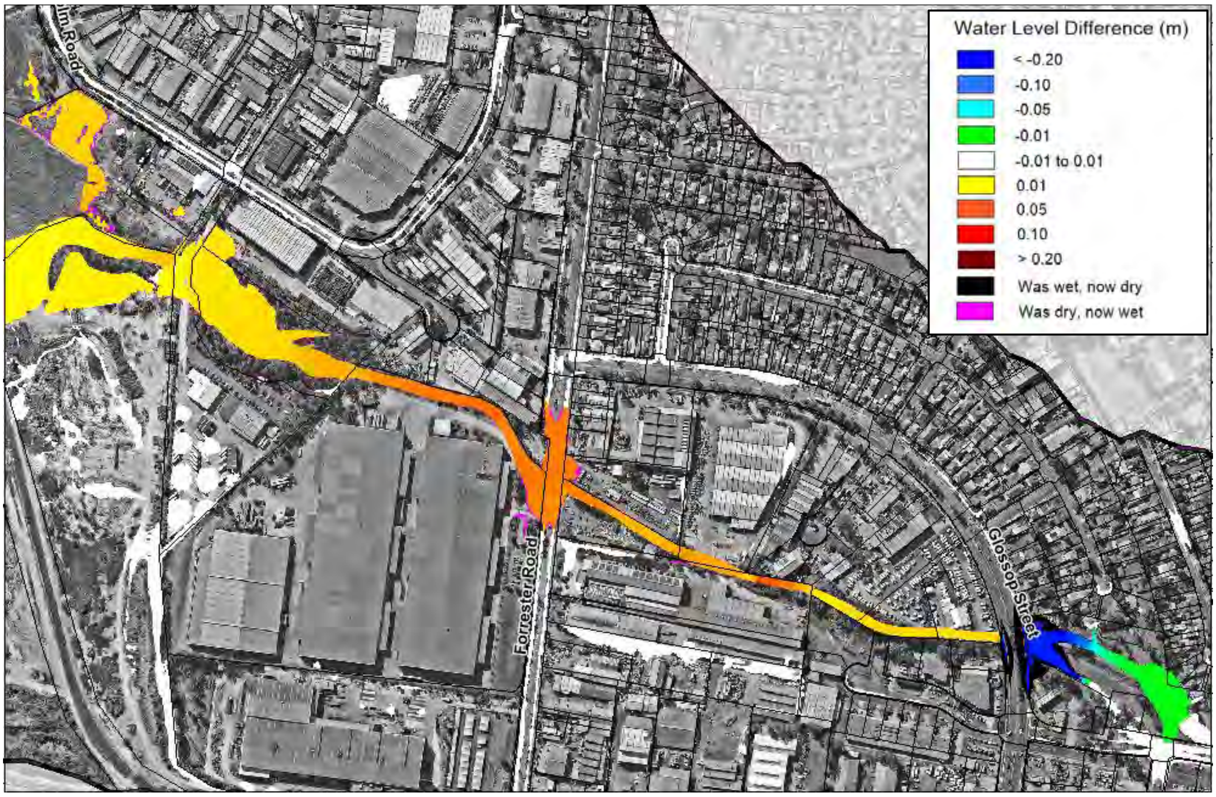


Plate 48 1% AEP flood level difference map for RM9 (elevated roadway and FM1 culvert upgrade)

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.

10.5 Recommendations

Based on the assessment presented in this chapter, the emergency response modification options included in Table 45 are recommended for implementation.

Some other options that were investigated yielded some notable emergency response improvements. However, they also yielded adverse flood impacts across some properties. Therefore, they are not recommended for implementation in their current form but should be considered as part of any future road upgrades or in combination with other flood modification options. This includes:

- RM8 – Raising of Great Western Highway; and
- RM9 – Raising of Glossop Street.

Table 45 Response Modification Options Recommended for Implementation

Option		Comments and Recommendations
RM1	Community education strategy	- Develop local Floodsafe documents, develop educational messages targeting dangerous behaviours during a flood. - Undertake localised and tailored education campaigns for high hazard areas, particularly the Hobart Street area.
RM2	Make property level flood information available	- Develop a standardised approach for presenting flooding information across all catchment. - Work towards incorporating available flood information into an online flood portal.
RM3	Local flood plan updates to accommodate response planning	- Update Penrith Local Flood Plan to align with new SES LFP template and to incorporate the review findings documented in Section 6 of this study.
RM4	Home flood plans	- Promote the preparation of Home Emergency Flood Plans. - These plans should highlight the vulnerability of and disruption to the road network during flood times and provide advice on potential alternate evacuation routes.
RM5	Business flood plans	- Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plan.s
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	- Council and SES to arrange targeted education activities to highlight nature and extent of flood risk. - Promote the preparation of flood emergency kits and home flood plans. - 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 BoM could explore the potential for installing a rainfall gauge that could serve to issue automated flood warnings based on rainfall depth triggers.
RM10	Local Flood Plan Updates to Accommodate Recovery Planning	- Update Local Flood Plan to reflect additional flood recovery responsibilities for various agencies.

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.

11 RECOMMENDATIONS

11.1 Recommended Options

This Floodplain Risk Management Study has assessed a range of structural and non-structural options for better managing the existing, future and continuing flood risk across the Little Creek catchment.

Based on the outcomes of the assessment, a number of options are recommended for inclusion in the Floodplain Risk Management Plan for the catchment. These options are summarised in:

- Flood Modification (FM) Options: **Table 46**
- Property Modification (PM) Options: **Table 47**
- Emergency Response Modification (RM)Options: **Table 48**

As a medium to long term goal, it is recommended that all flood modification options listed in **Table 46** are ultimately implemented as a "combined" option. If each of the individual options are implemented progressively, care will need to be taken with the implementation schedule to ensure that there are no adverse flood impacts (i.e., FM8 is implemented before FM1).

11.2 Other Options that Could Be Considered

In addition, several flood and response modification options were determined to provide reductions in flood levels but did not perform well from an economic standpoint or produced some adverse flood impacts. Therefore, although they are unlikely to gain support under the NSW Government's floodplain management program, Council and asset owners (e.g., TfNSW) should consider these options for implementation as part of ongoing works programs, asset replacement, road upgrades etc. These options are summarised below:

- FM3: Glossop Street culvert upgrade
- FM5: Glossop Street stormwater upgrades
- FM6: Lee Holm Drive stormwater upgrades
- FM9: Great Western Highway median modifications
- RM8: Raising of Great Western Highway; and
- RM9: Raising of Glossop Street.

Table 46 Flood Modification Options Recommended for Floodplain Risk Management Plan

Option		Description of Option	Economic Assessment			Comments
			Cost of proposed work ($ millions)	Reduction in Flood Damages Costs ($ millions)	Benefit Cost Ratio	
FM1	Great Western Highway Culvert upgrade	Replace the existing triple 1.5 metre diameter culverts with three 1.5m wide by 1.8m high box culverts	0.62	0.35	0.6	• This option provides the most significant reduction in above floor flooding but is predicted to generate flood level increases downstream of the Oxley Park basins. Therefore, it is important that FM8 is completed first to ensure no properties are impacted by flood level increases because of the highway culvert upgrade.
FM2	Railway Hobart Street Culvert Upgrade	Replace existing pipe, box & arch culverts between Hobart St and Plasser Cres with 2.7m wide x 2.1 m high box culvert	1.03	0.93	0.9	• This option provides the highest flood level reductions across one of the most significantly flood-affected areas of the catchment (i.e., Hobart Street). • It provides a benefit cost ratio of just below 1. • It was ranked third in the multi-criteria assessment.
FM4	Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades	Provide new 1.2m diameter stormwater pipe along Canberra Street, Sydney Street and Brisbane Street plus new stormwater inlets to drain runoff into new pipe.	1.29	0.82	0.6	• This option provides flood level reductions across the highest number of properties of all options considered. • It provides a benefit cost ratio of 0.6. • It was ranked the equal second option in the multi-criteria assessment. • more detailed investigations should be completed to confirm service locations and refine design and cost estimate.
FM8	Oxley Park Basin Augmentation	Provide additional storage volume in existing detention basins located between Great Western Highway and Oxley Park Public School. This will include lowering existing basin invert and increasing height of basin walls	0.53	0.56	0.8	• This option affords notable reductions in flood levels and flood hazard across the Oxley Park Public School as well as a number of downstream residential properties. • It provides the benefit cost ratio of just below 1. • It was ranked equal second in the multi-criteria assessment.

Table 47 Property and Planning Modification Options Recommended for Floodplain Risk Management Plan

Option		Comments and Recommendations
PM1	Changes to LEP	• Make the flood planning area map related to flood related development controls publicly available in an easy to find and easy to understand location. • Update Clause 7.2 to better cater for all land impacted by flood related development controls. • Include an additional "Floodplain Risk Management" clause for areas between the flood planning area and the limit of the floodplain. • Consider rezoning properties that are purchased as part of PM4 to a more flood compatible land use (e.g., open space).
PM2	Changes to DCP	• Amend Penrith DCP 2014 considering the detailed review presented in Section 5.3.2 of this report and other adopted floodplain risk management plans. • Incorporate additional controls in DCP for high flood risk properties contained between Adelaide Street and Hobart Street at St Marys to ensure structural integrity of buildings during the PMF
PM3	Update Section 10.7 Certificates	• Update Section 10.7 certificate to reference updated design flood information generated as part of the current study.

Table 48 Emergency Response Modification Options Recommended for Floodplain Risk Management Plan

Option		Comments and Recommendations
RM1	Community education strategy	• Develop local FloodSafe documents, develop educational messages targeting dangerous behaviours during a flood. • Undertake localised and tailored education campaigns for high hazard areas, particularly the Hobart Street area.
RM2	Make property level flood information available	• Develop a standardised approach for presenting flooding information across all catchments. • Work towards incorporating available flood information into an online flood portal.
RM3	Local flood plan updates to accommodate response planning	• Update Penrith Local Flood Plan to align with new SES LFP template and to incorporate the review findings documented in Section 6 of this study.
RM4	Home flood plans	• Promote the preparation of Home Emergency Flood Plans. • These plans should highlight the vulnerability of and disruption to the road network during flood times and provide advice on potential alternate evacuation routes.
RM5	Business flood plans	• Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans.
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	• Council and SES to arrange targeted education activities to highlight nature and extent of flood risk. • Promote the preparation of flood emergency kits and home flood plans.

Option		Comments and Recommendations
		- 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 andBoM could explore the potential for installing a rainfall gauge that could serve to issue automated flood warnings based on rainfall depth triggers.
RM10	Local Flood Plan Updates to Accommodate Recovery Planning	- Update Local Flood Plan to reflect additional flood recovery responsibilities for various agencies.

12 REFERENCES

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13 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.

APPENDIX A

COMMUNITY CONSULTATION

LITTLE CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

INFORMATION SHEET

INTRODUCTION

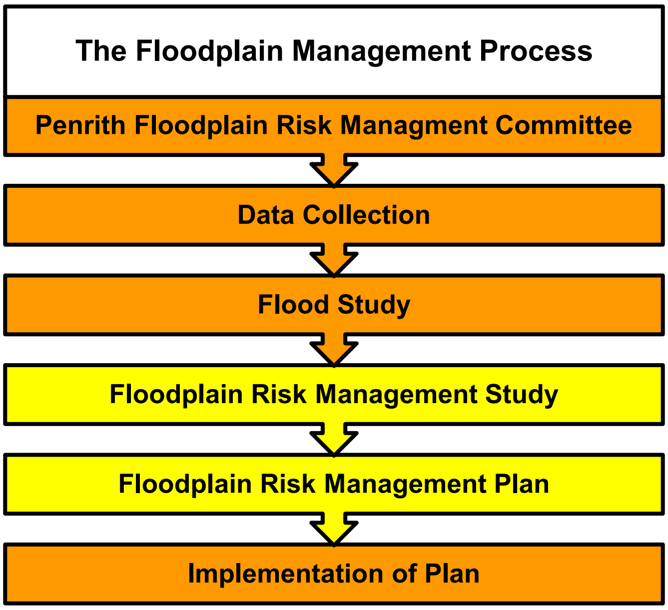
In 2017, Penrith City Council completed a detailed flood study for your local catchment. Council is now preparing a Floodplain Risk Management Study and Plan for the Little Creek catchment, and we would like your help. The study will inform us about the flood management measures needed and help us plan for and manage known flood risks. Sound flood management based on local knowledge will help Council reduce flood damage, enhance resilience and improve social and economic opportunities.

Council has appointed engineering consultants Catchment Simulation Solutions to prepare the study and plan on our behalf. The study will be overseen by the Penrith Floodplain Risk Management Committee and receive financial support from the State Government under its Floodplain Management Program.

WHY HAVE A FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN?

The Penrith Local Government Area (LGA) is dominated by rivers, creeks and natural and piped waterways. The risk of flood is real, and Council wants to ensure proper plans are in place in accordance with the NSW Government Flood Prone Land Policy.

The policy sets out the staged process we are following, which includes data collection; a flood study; a floodplain risk management study and plan; and the implementation of the plan. Council is now starting the floodplain risk management phase for the Little Creek catchment as highlighted in yellow below.



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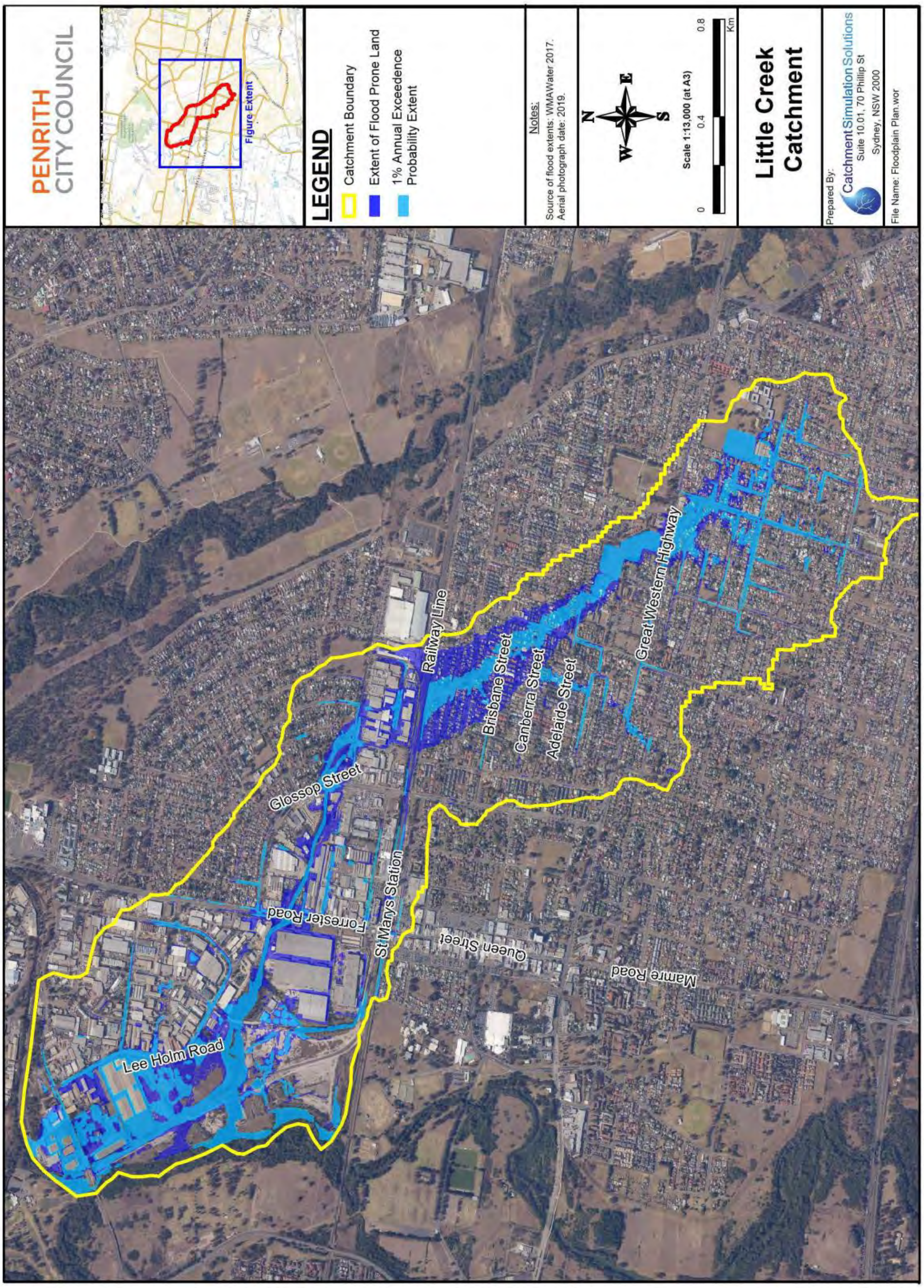
The Floodplain Risk Management Study identifies and evaluates measures that could be incorporated into the Floodplain Risk Management Plan to reduce the risk and cost of flooding to the community; assist with emergency management and guide future development. The process also looks at making the community more resilient and prepared, including evacuation, education and preparation.

MAP OF CATCHMENT AREA UNDER CONSIDERATION



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WHAT'S INVOLVED IN PREPARING A FLOODPLAIN RISK MANAGEMENT STUDY?

A considerable amount of work goes into preparing a Floodplain Risk Management Study and Plan, including:

- identifying areas at risk of flooding, through the use of the computer modelling (completed in 2017) and from information you provide in the community questionnaire.
- developing a range of options for managing flood risk, such as: modifying creek channels, stormwater upgrades, constructing levees, enforcing planning controls for new development and planning for evacuation, education and awareness.
- analysing the options, considering environmental, social and economic benefits, as well as their potential to reduce flood risk.
- preparing a Floodplain Risk Management Report; which summarises the outcome of all stages of the investigation and makes recommendations to be carried forward to the Floodplain Risk Management Plan.

HOW CAN YOU BE INVOLVED?

Your local knowledge and personal experience of living in the area is invaluable when identifying flood 'trouble spots' and developing floodplain risk management measures that are practical, comprehensive and effective.

The study team will consult with the community in two stages:

1. **Questionnaire** – Please complete the questionnaire included with this information sheet and share with us your experiences of local flooding and opinions on flood management options. This study is focusing on the local and overland flooding associated with the Little Creek Catchment rather than flooding from South Creek (being undertaken through a separate process).
2. **Community drop-in session** – once the draft Floodplain Risk Management Study report is prepared, a community drop-in session will be held to give you an opportunity to review the report and ask questions about the flood management options investigated. Any comments and feedback received during this community drop-in session will be reviewed and addressed as part of the final report.

STAY UP TO DATE

Our website will be updated throughout the study and plan process to provide the latest available information including details of the above community consultations. Go to the Flood Management page of www.penrith.city

MORE INFORMATION

If you have any questions or would like to submit any information you think may be helpful to the study, please contact:

Dr Elias Ishak - Penrith City Council
PO Box 60, Penrith NSW 2751
Phone: 4732 7777
Email: Elias.Ishak@penrith.city

PENRITH

COMMUNITY QUESTIONNAIRE

LITTLE CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

COMPLETING THE QUESTIONNAIRE

In 2017, Council completed a detailed flood study for your local catchment. Council is now seeking your assistance in the creation of a Floodplain Risk Management Study and Plan for the Little Creek Catchment. Giving information based on your local knowledge and experience will help us to create a Plan that is shaped by local knowledge and information that would otherwise go unrecorded.

Please complete the survey and return it by Thursday 24 October 2019.

You can do this by:

- going online to yoursaypenrith.com.au, and completing it there
- filling out the enclosed survey and emailing it to david.tetley@ccse.com.au, or
- filling out the enclosed survey and post it to us, using the enclosed pre-paid envelope.

Council has appointed Catchment Simulation Solutions to prepare the study and there are more details in the enclosed Information Sheet and on the "Flood Management" page of the Penrith City Council web page www.penrith.city .

Please answer as many questions as you can and give as much detail as possible (attach additional pages if necessary).

If you have any questions or require further information, please contact:

1. Council's Senior Engineer – Stormwater, Dr Elias Ishak on 4732 7777, or
2. Catchment Simulation Solutions - Director, Mr David Tetley on 8355 5501.

CONTACT DETAILS

Please provide your street and suburb details.

Street Address: ____

____

Suburb: ________________________________ **Postcode:** ____________

Providing full contact details is optional, but useful so we can contact you for more information if required. If you choose to provide full contact details, this information will remain confidential at all times and will not be published.

Name: ____

Phone number: ____

Email: ____

Please indicate if and how you would like us to contact you for more information or to provide you with study updates:

☐ Yes – telephone/ email/ mail (circle your preferred method of contact)

☐ No

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ABOUT YOUR PROPERTY

1. Please select as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ I own the property
- ☐ I rent the property
- ☐ Other – please describe

2. How long have you been at this address?

- ☐ Less than 1 year
- ☐ 1 to 5 years
- ☐ 5 to 20 years
- ☐ More than 20 years

3. Property type:

- ☐ House
- ☐ Villa/ townhouse
- ☐ Unit/ flat/ apartment
- ☐ Industrial unit or warehouse
- ☐ Vacant land
- ☐ Shop/ retail
- ☐ Other

4. Do you know if your property has a risk of being flooded?

- ☐ My property is beyond the extent of all potential floods
- ☐ My property could be flooded
- ☐ No, I don't know/I'm not sure whether my property could be flooded

DEVELOPMENT CONTROLS AND COMMUNICATION

5. Please rank the following development types according to which you think are the most important to protect from floods

1=highest priority to 6= lowest priority

- ☐ Commercial
- ☐ Residential
- ☐ Essential community facilities
- ☐ Critical Utilities
- ☐ Minor developments and additions
- ☐ New residential developments

6. What level of control do you think Council should place on new development to minimise flood-related risks?

Tick only one box

(In addition to being favoured by the community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- ☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)
- ☐ Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks
- ☐ Provide no advice about potential flood risks or measures that could minimise those risks
- ☐ Don't know

7. What notifications do you think Council should give about the potential flood affectation of individual properties?

Tick one or more boxes

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other – please describe

FLOOD RESPONSE

8. How would you respond in a major flood in the area?

Tick one box

- ☐ Evacuate early to an evacuation centre
- ☐ Remain at my house
- ☐ Don't know/not sure
- ☐ Other – please describe

---

9. If you are likely to evacuate, what factors are most important?

Tick one or more boxes

- ☐ Discomfort/inconvenience/cost of being isolated by floodwater
- ☐ Need for access to medical facilities
- ☐ Safety of our family
- ☐ Other – please describe:

---

10. If you are likely to remain at your house, what factors are most important?

Tick one or more boxes

- ☐ Discomfort/inconvenience/cost of evacuating
- ☐ Need to care for animals
- ☐ My house cannot be flooded, and we can cope with isolation
- ☐ Concern for security of my property if I evacuate
- ☐ Other – please describe:

OTHER INFORMATION

11. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?

Tick one or more boxes

- ☐ Council's website
- ☐ Articles in local newspaper
- ☐ Open days or drop-in days
- ☐ Community workshops
- ☐ Public meetings
- ☐ Council's Floodplain Management Committee
- ☐ Other (please specify)

FLOODPLAIN RISK MANAGEMENT MEASURES AND CONTROLS

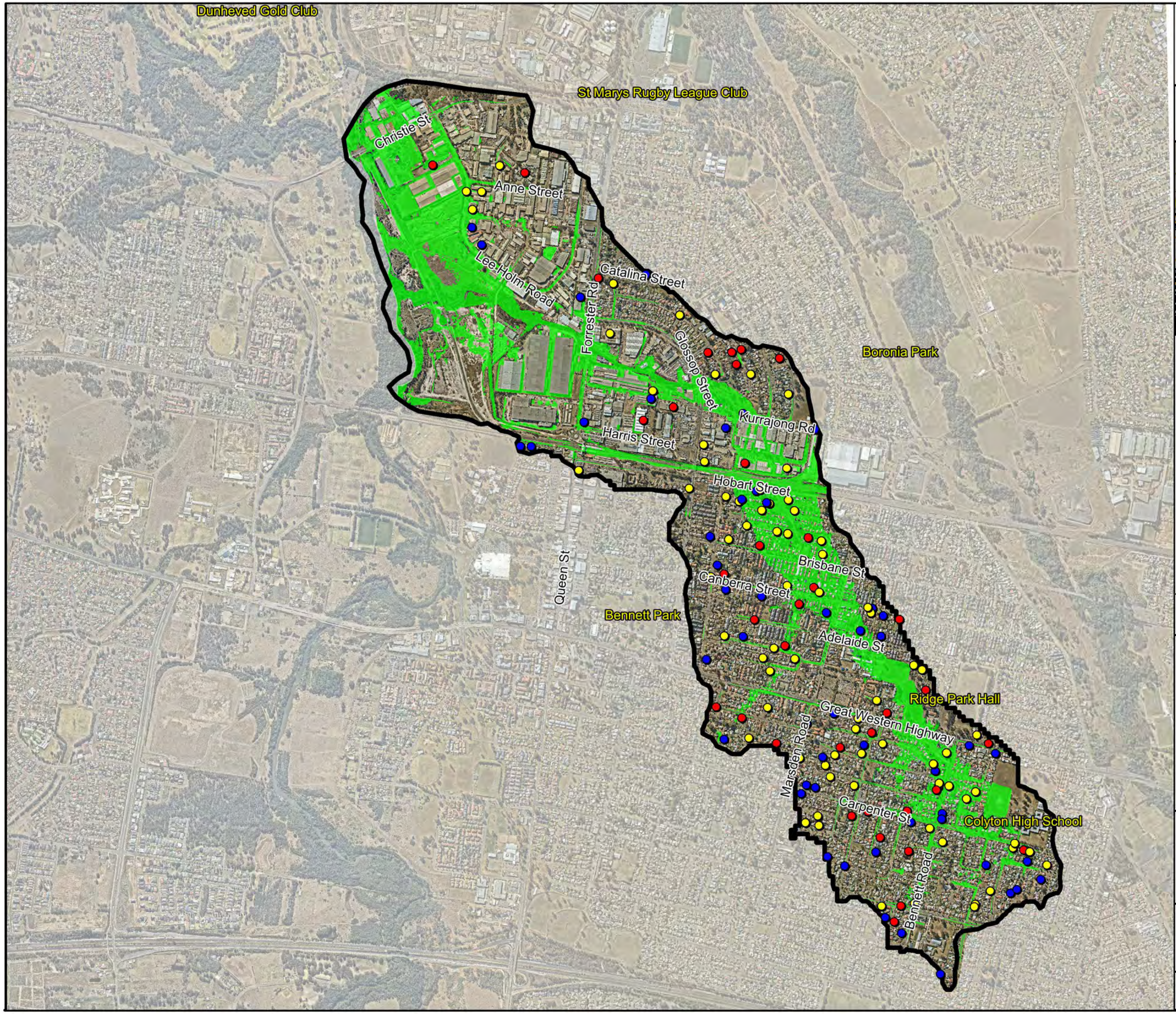
12. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Study Area (see plan on attached Fact Sheet).

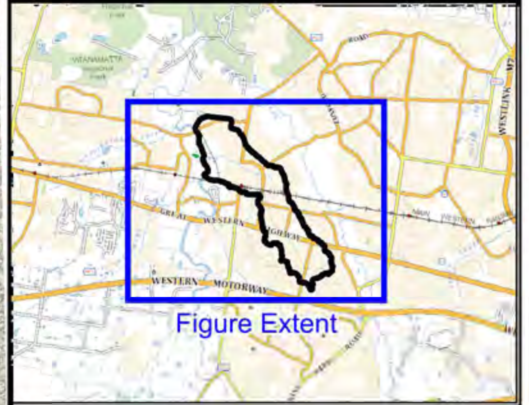
This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes", or "no" to indicate if you favour the option or "don't know" if undecided. (In addition to being favoured by the Community, management options would also need to comply with legislation and be capable of being funded).

Option	Yes	No	Don't Know
Management of vegetation and silt in stormwater pits, pipes and open channels			
Widening and/or concrete lining of open channels			
Construct detention basins			
Upgrade stormwater drainage system (i.e. bigger / more pipes and/or more inlet pits)			
Upgrade culverts (i.e. bigger pipes under roads)			
Removal of floodplain /overland flowpath obstructions			
Requiring rainwater tanks on all developments			
Voluntary purchase of the most severely affected flood-liable properties			
Provide funding or subsidies to raise houses above major flood level			
Flood proofing of individual properties			
Improve flood warning and evacuation procedures			
Community education, participation and flood awareness programs.			
Ensuring all residents and business owners have Flood Action Plans			
Specify controls on future development in flood-liable areas (e.g. extent of filling, minimum floor levels, etc.)			
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.			
Installation of signs/boom gates at roadway overtopping locations			
Ensuring all information about the flood risks is available to all residents and business owners			

THANK YOU

Thank you for taking the time to complete this questionnaire. This means your Council is now better informed about your local area and, as a result, our decisions about managing flooding in your neighbourhood will be better informed.





PENRITH CITY COUNCIL

Little Creek Catchment Flood Risk Management Study and Plan

LEGEND

Catchment Extent

PMF Extent

Questionnaire Response Locations
Do you know if your property has a risk of being flooded?

Yes

No

I don't know

Notes:

N S W E

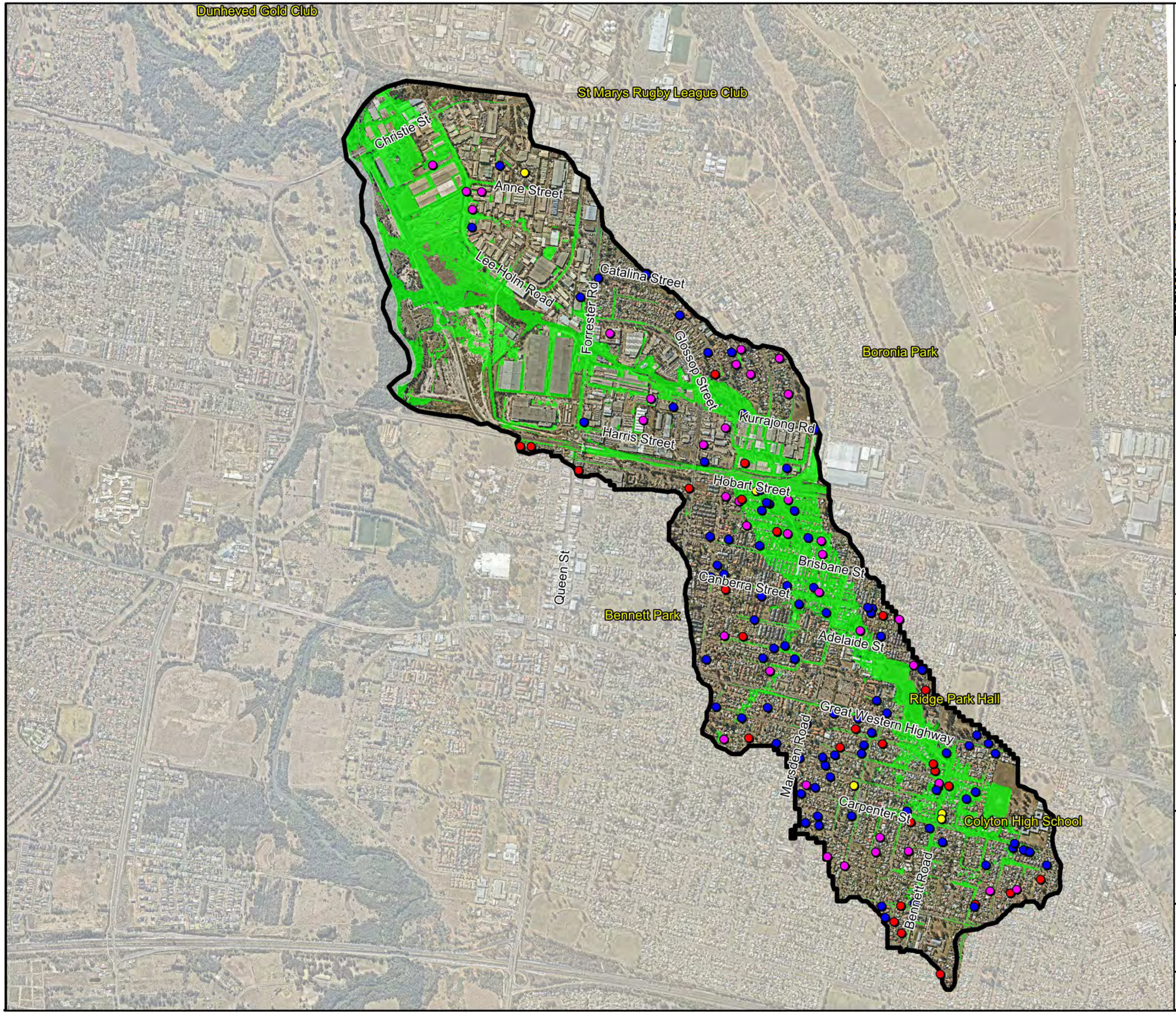
Scale 1:18,000 (at A3)

0 0.5 1.0 Km

Figure A1: Flood Awareness

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Flood awareness.wor



PENRITH CITY COUNCIL

Little Creek Catchment Flood Risk Management Study and Plan

LEGEND

- Catchment Extent
- PMF Extent

Questionnaire Response Locations
How would you respond in a major flood in the area?

- Don't know/not sure
- Remain at my house
- Evacuate early to an evacuation centre
- Other

Notes:

N W E S

Scale 1:18,000 (at A3)

0 0.5 1.0 Km

Figure A2: Spatial distribution of flood response types

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Spatial distribution of flood response types.wor

Table A1 - Property Information

#	Please indicate if and how you would like us to contact you for more information or to provide you with study updates	About your property				Please rank the following development types according to which you think are the most important to protect from floods						What level of control do you think Council should place on new development to minimise flood-related risks?					
		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
1	Yes	I am a resident	More than 20 years	House	My property could be flooded	6	1	3	2	5	4			Yes			
2	No	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods	5	3	4	1	6	2	Yes					
3	Yes	I own the property	1 to 5 years	House	My property could be flooded	3	2	4	1	5	6	Yes					
4	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	4	3	2	1	5	6				Yes		
5	Yes	I own the property	More than 20 years	Industrial unit or warehouse	My property could be flooded	2	3	4	1	5	6				Yes		
6	Yes	I own the property	Less than 1 year	House	No, I don't know/I'm not sure whether my property could be flooded	2	1	3	4	5	6		Yes				
7	Yes	I am a resident	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	4	2	1	5	6				Yes		
8	No	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	6	1	3	2	4	5		Yes				
9	Yes	I own the property	5 to 20 years	House	My property could be flooded	4	2	3	1	6	5			Yes			
10	No	Work for the owner of this commercial property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	5	3	2	1	6	4				Yes		
11	No	I own the property	1 to 5 years	House	My property could be flooded	3	1	4	2	6	5				Yes		
12	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	5	6			Yes			
13	No	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
14	No	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	2	1	3	4	5	6			Yes			
15	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	3	2	5	6		Yes				
16	Yes	I am a resident	More than 20 years	House	My property could be flooded	4	1	3	2	6	5	Yes					
17	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	2	3	1	4	6			Yes			
18	Yes	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods	2	1	4	3	6	5						Yes
19	Yes	I am a business owner	1 to 5 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	6	2	4	5	3	1			Yes			
20	Yes	I am a resident	1 to 5 years	House	My property could be flooded	1	3	2	4	6	5		Yes				
21	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	1	2	3	4	5	6				Yes		
22	Yes	I am a business owner	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	4	3	2	1	6	5		Yes				
23	Yes	I own the property	Less than 1 year	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	2	3	5	6			Yes			
24	Yes	I am a resident	Less than 1 year	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded									Yes			
25	Yes	I own the property	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	3	6	4			Yes			
26	No	I own the property	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	3	2	5	6		Yes				
27	No	I own the property	1 to 5 years	Villa/ townhouse	My property is beyond the extent of all potential floods	6	2	3	1	4	5		Yes				
28	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	3	2	5	6	Yes					
29	No	I am a resident	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	3	1	4	2	5	6	Yes					
30	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	3	2	1	5	6			Yes			
31	Yes	I own the property	1 to 5 years	House	My property could be flooded	5	2	4	1	6	3				Yes		
32	Yes	i own the property and rent it out	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5			Yes			
33	No	I am a resident	More than 20 years	House	My property could be flooded	2	4	3	5	6	1		Yes				
34		I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	2	4	1	6	5			Yes			
35	Yes	I own the property	More than 20 years	House	My property could be flooded	4	3	2	1	6	5				Yes		
36	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	2	3	1	5	6				Yes		
37	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	3	1	4	2	6	5	Yes					
38	No	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	3	5	6	2				Yes		
39	Yes	I own the property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	6	3	2	1	5	4			Yes			
40	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	3	3	1	1	5	5		Yes				
41	Yes	I own the property	More than 20 years	House	My property could be flooded	6	2	4	1	5	3				Yes		

#	Please indicate if and how you would like us to contact you for more information or to provide you with study updates	About your property				Please rank the following development types according to which you think are the most important to protect from floods						What level of control do you think Council should place on new development to minimise flood-related risks?					
		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
42	Yes	I own the property	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	2	1	4	3	5	6		Yes				
43	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	2	4	1	6	5	Yes					
44	Yes	I am a resident	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded								Yes				
45	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	3	5	4	1	6	2				Yes		
46		I am a resident	More than 20 years	House													Yes
47	Yes	I own the property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	3	6	4				Yes		
48		I own the property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	5	1	3	2	6	4				Yes		
49	Yes	I own the property	5 to 20 years	Vacant land	No, I don't know/I'm not sure whether my property could be flooded	2	1	3	4	5	6				Yes		
50	Yes	I own the property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	6	1	3	2	5	4	Yes			Yes		
51	Yes	I own the property	1 to 5 years		No, I don't know/I'm not sure whether my property could be flooded	3	1	2	4	5	6						Yes
52	Yes	I own the property	More than 20 years	Industrial unit or warehouse		4	1	3	2	6	5				Yes		
53	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5		Yes	Yes			
54	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	3	4	6				Yes		
55	Yes	I am a resident	More than 20 years	House	My property could be flooded	3	1	4	2	6	5	Yes					
56	No	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded								Yes				
57	Yes	I am a resident	More than 20 years	House	My property could be flooded							Yes					
58	No	I own the property	1 to 5 years	Villa/ townhouse	My property is beyond the extent of all potential floods	4	1	5	2	6	3				Yes		
59	No	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	5	4	6	2			Yes			
60	No	I own the property	1 to 5 years	Villa/ townhouse	My property is beyond the extent of all potential floods	4	1	2	3	5	6		Yes				
61	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded												Yes
62		I own the property	More than 20 years	House	My property could be flooded	5	2	3	1	6	4		Yes				
63	Yes	I own the property	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	4	1	2	3	6		Yes		Yes		
64	Yes	I own the property	Less than 1 year	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	3	2	1	6	5				Yes		Yes
65	Yes	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods	5	3	2	1	6	4		Yes				
66		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	4	3	6	2	Yes					
67	No	I am a resident	1 to 5 years	Villa/ townhouse	My property is beyond the extent of all potential floods	6	1	5	2	3	4		Yes				
68	No	I own the property	Less than 1 year	Villa/ townhouse	My property is beyond the extent of all potential floods	3	4	2	1	6	5	Yes					
69	Yes	I am a resident	Less than 1 year	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	1	3	2	5	6	Yes					
70																	
71																	
72	No	I am a resident	Less than 1 year	House	No, I don't know/I'm not sure whether my property could be flooded	5	2	1	3	6	4	Yes	Yes	Yes			
73	No	Other – please describe	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5				Yes		
74	No	I am a resident	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	6	4	5	3	2	1		Yes				
75	Yes	I own the property	More than 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	3	2	1	4	6	5						Yes
76	No	I own the property	More than 20 years	House	My property could be flooded	4	3	1	2	5	6		Yes				
77	Yes	I am a resident	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5	Yes					
78	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods		1	3	5	6	2	Yes					
79	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	6	5	1	2	3	4	Yes					
80	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded									Yes			
81	Yes	I am a resident	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	3	2	1	6	4				Yes		
82		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	3	2	1	5	6	Yes					
83	Yes	I own the property	More than 20 years	Shop/ retail	No, I don't know/I'm not sure whether my property could be flooded	3	4	1	2	5	6				Yes		
84		I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods	1	3	4	5	6	2		Yes				

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		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
85	Yes	Other – please describe	1 to 5 years	Industrial unit or warehouse	My property could be flooded									Yes			
86	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	5	3	2	1	6	4	Yes					
87		I rent the property	5 to 20 years	House							X		Yes				
88	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	6	4	2	1	3	5		Yes				
89		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
90		I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	5	4	3	2	6	1	Yes					
91	Yes	I am a resident	More than 20 years	House	My property could be flooded	6	3	2	1	5	4						Yes
92		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded												
93		I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods												
94	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	3	1	2	6	5		Yes				
95	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	6	1	2	2	5	4		Yes				
96	MAIL	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded										Yes		
97	Yes	I am a resident	5 to 20 years	House	My property could be flooded	4	2	1	3	6	5			Yes			
98	Yes	I am a resident	More than 20 years	House	My property could be flooded	1	1	1	1	1	1	Yes					
99	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	1	2	3	5	6	Yes					
100	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	4	2	6	5	Yes					
101	Yes	I own the property	Less than 1 year	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	2	1	4	3	5	6			Yes			
102	No	I am a business owner	More than 20 years	Industrial unit or warehouse	My property could be flooded	4	3	2	1	5	6		Yes				
103	No	I am a business owner	More than 20 years	Industrial unit or warehouse	My property could be flooded	4	3	2	1	6	5		Yes				
104		I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods	4	3	2	1	5	6	Yes					
105	Yes	I am a business owner	5 to 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	1	2	3	4	5	6		Yes				
106	No																
107		I am a resident	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	3	1	2	5	6	Yes					
108	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	3	1	2	6	4		Yes				
109	Yes	I am a resident	5 to 20 years	House	My property could be flooded	4	1	2	3	6	5	Yes					
110	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	6	6	1	1	2	6	Yes					
111	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	2	1	3	5	6	4						Yes
112	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	3	2	1	5	6		Yes				
113	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	5	1	3	2	6	4	Yes					
114	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	1	4			3	2	Yes					
115		I own the property	5 to 20 years	House	My property could be flooded		X					Yes					
116	No	I own the property	1 to 5 years	House	My property is beyond the extent of all potential floods	6	1	3	2	4	5			Yes			
117		I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	1	3	4	5	6	2		Yes				
118	No	I am a resident	More than 20 years	House	My property could be flooded		X										Yes
119	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	6	1	3	2	5	6			Yes			
120	Yes	I own the property	1 to 5 years	House	My property is beyond the extent of all potential floods	3	2	4	1	5	6				Yes		
121		I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	3	1		2			Yes					
122		I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	6	5	1	2	4	3	Yes					
123	Yes	I am a resident	5 to 20 years	House	My property could be flooded	4	1	3	2	6	5		Yes				
124	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	3	6	4	Yes					
125		I am a resident	5 to 20 years	House	My property could be flooded										Yes		
126	No	I am a resident	5 to 20 years	House	My property is beyond the extent of all potential floods	5	6	1	2	3	4						Yes
127	No	I am a resident	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	5	2	4	3	6	1		Yes				

#	Please indicate if and how you would like us to contact you for more information or to provide you with study updates	About your property				Please rank the following development types according to which you think are the most important to protect from floods						What level of control do you think Council should place on new development to minimise flood-related risks?					
		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
128	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods						X	Yes					
129		I own the property	5 to 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	6	6	6	6	6	6			Yes	Yes	Yes	
130	Yes	I own the property	More than 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	4	1	2	3	6	5	Yes					
131		I am a resident	Less than 1 year	Villa/ townhouse	My property could be flooded	1	2	4	3	5	6	Yes					
132	Yes	I rent the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
133		I am a business owner	More than 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	5	1	4	3	6	2	Yes					
134	Yes	I am a resident	Less than 1 year	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	5	1	3	2	6	4	Yes					
135	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	4	3	2	1	5	6		Yes				
136	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	2	1	3	5	6	Yes					
137	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	3	2	4	1	5	6				Yes		
138	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	3	5	2	1	4	6	Yes		Yes	Yes		
139	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	6	1	5	2	4	3	Yes					
140	Yes	I am a business owner	More than 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	2	2	2	1	3	2	Yes					
141	Yes	I am a resident	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	5	2	4	3	1	6				Yes		
142		I own the property	More than 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	3	1	2	4	6	5			Yes			
143		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	3	4	6	Yes					
144	No	I am a resident	5 to 20 years	Villa/ townhouse	My property is beyond the extent of all potential floods	3	2	4	1	6	5	Yes					
145	Yes	I am a resident	5 to 20 years	House	My property is beyond the extent of all potential floods						X				Yes		
146		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded												
147	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	3	2	4	1	5	6		Yes				
148	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	4	1	3	2	5	6		Yes				
149	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded								Yes				
150	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods												
151	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded										Yes		
152	Yes	I am a resident	More than 20 years	House		4	1	2	3	6	5	Yes					
153	Yes	I am a business owner	5 to 20 years		My property could be flooded	3	1	2	4	6	5	Yes					
154		I own the property	More than 20 years	House	My property could be flooded	3	1	2	5	6	4				Yes		
155	Yes	I own the property	5 to 20 years	House	My property could be flooded	4	3	2	1	6	5	Yes					
156	Yes	I am a resident	5 to 20 years	House	My property is beyond the extent of all potential floods	4	2	3	1	5	6				Yes		
157	No	I own the property	More than 20 years	House								Yes					
158	Yes	I own the property	More than 20 years	House	My property could be flooded	6	4	5	3	2	1	Yes		Yes	Yes		
159	Yes	I own the property	5 to 20 years		My property is beyond the extent of all potential floods				X			Yes					
160	Yes	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods				6			Yes					
161	Yes	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods				6			Yes					
162	No	I am a resident	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded												Yes
163	Yes	I am a resident	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	6	2	5	4	Yes					
164	Yes	I own the property	More than 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	3	4	2	1	5	6				Yes		
165	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	3	2	1	5	6				Yes		
166		I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	3	5	6	Yes					
167	Yes	I am a business owner	More than 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	3	4	2	1	6	5					Yes	

#	Please indicate if and how you would like us to contact you for more information or to provide you with study updates	About your property				Please rank the following development types according to which you think are the most important to protect from floods						What level of control do you think Council should place on new development to minimise flood-related risks?					
		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
168	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded	4	3	2	1	5	6		Yes				
169																	
170	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	5	2	1	3	6	Yes					
171	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	6	2	3	1	4	5		Yes				
172	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	3	5	6	Yes					
173	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	3	1	5	4	6	2	Yes					
174	No	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods												Yes
175	No	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods								Yes				
176	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	5	2	4	6	Yes					
177		I own the property															Yes
178	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	2	3	5	6			Yes			
179	Yes	I am a resident	More than 20 years	House	My property could be flooded	4	2	3	1	5	6	Yes					
180		I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods							Yes	Yes	Yes	Yes		
181	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods											Yes	
182	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	5	1	3	2	4	6		Yes				
183	Yes	I am a business owner	More than 20 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	2	1	4	5	6	3	Yes					
184		I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
185	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property is beyond the extent of all potential floods												
186	Yes		1 to 5 years	Industrial unit or warehouse	No, I don't know/I'm not sure whether my property could be flooded	4	3	2	1	5	6						Yes
187																	
188	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	2	3	5	6			Yes			
189	No	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	4	2	5	6		Yes				
190	Yes	I own the property	More than 20 years	House	My property could be flooded	4	3	2	1	5	6	Yes					
191	No	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded								Yes				
192	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	6	4	2	1	3	5				Yes		
193	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	3	5	6	Yes					
194	No	I own the property	5 to 20 years	House	My property is beyond the extent of all potential floods							Yes					
195	No	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	5	3	2	1	6	4				Yes		
196	No	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	4	3	1	2	6	5				Yes		
197	No	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
198		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	3	1	2	4	6			Yes			
199	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	5	6	3				Yes		
200	Yes	I own the property	1 to 5 years	House	My property is beyond the extent of all potential floods								Yes				
201	Yes	I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	6	1	2	3	4	5		Yes				
202	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	5	1	2	3	6	4	Yes					
203		I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
204		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	3	1	4	2	6	5			Yes			
205		I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5			Yes			
206	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
207	Yes	I own the property	More than 20 years	House	My property could be flooded									Yes			
208	Yes	I rent the property	5 to 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	1	2	6	5	4	3				Yes		
209	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods										Yes		

#	Please indicate if and how you would like us to contact you for more information or to provide you with study updates	About your property				Please rank the following development types according to which you think are the most important to protect from floods						What level of control do you think Council should place on new development to minimise flood-related risks?					
		Please select as appropriate	How long have you been at this address?	Property Type	Do you know if your property has a risk of being flooded?	Commercial	Residential	Essential community facilities	Critical Utilities	Minor developments and additions	New residential developments	Prohibit all new development on land with any potential to flood	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties	Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks	Provide no advice about potential flood risks or measures that could minimise those risks	Don't know
210																	
211		I am a resident	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes	Yes	Yes	Yes		
212	Yes	I own the property	1 to 5 years	House	My property is beyond the extent of all potential floods	1	3	5	2	6	4	Yes					
213	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	2	5	6	1	4	3				Yes		
214		I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded						X	Yes					
215		I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded						X	Yes					
216	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	5	3	6						Yes
217	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded												Yes
218	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods	5	1	6	2	3	4	Yes					
219	Yes	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods									Yes			
220	Yes	I own the property	1 to 5 years	House	My property could be flooded	2	1	3	4	6	5				Yes		
221	No	I am a resident	5 to 20 years	House	My property is beyond the extent of all potential floods	2	1	3	5	4	6	Yes					
222	Yes	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	3	2	6	5				Yes		
223	No	I own the property	More than 20 years	House	My property is beyond the extent of all potential floods		1					Yes					
224	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	4	1	2	3	6	5	Yes					
225	Yes	I am a business owner	More than 20 years	Industrial unit or warehouse	My property is beyond the extent of all potential floods	2	1	3	4	5	6	Yes					
226	Yes	I own the property	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded	6	1	4	5	2	3				Yes		
227	No	I rent the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	4	1	3	2	6	5	Yes					
228	Yes	I own the property	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	2	3	1	6	5	Yes					
229	No	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded							Yes					
230	Yes	I own the property	5 to 20 years	Villa/ townhouse	My property could be flooded										Yes		
231	Yes	I am a resident	More than 20 years	House	My property is beyond the extent of all potential floods	5	1	4	3	6	2	Yes					
232	No	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded						X				Yes		
233	Yes	I own the property	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	1	5	2	6	3				Yes		
234	Yes	I am a resident	1 to 5 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	6	1	5	2	3	4	Yes					
235	Yes	I own the property	1 to 5 years	House		4	3	2	1	5	6				Yes		
236	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	3	1	2	4	6		Yes				
237	Yes	I am a resident	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded		1	2					Yes				
238	No	I own the property	5 to 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	4	6	1	2	3						Yes
239	Yes	I own the property	More than 20 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	2	4	6	3		Yes				
240	Yes	I am a resident	1 to 5 years	Villa/ townhouse	My property could be flooded	4	1	3	2	5	6			Yes			
241	No	I am a resident	5 to 20 years	Villa/ townhouse	No, I don't know/I'm not sure whether my property could be flooded	4	1	5	3	6	2		Yes				
242	Yes	I own the property	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded												
243		I own the property	1 to 5 years	House	No, I don't know/I'm not sure whether my property could be flooded	5	1	3	2	6	4				Yes		

Table A2 - Communication and Flood Response

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
1	Yes						Yes					Yes	
2			Yes				Yes					Yes	
3	Yes					Yes						Yes	
4	Yes							Yes				Yes	
5	Yes												
6	Yes					Yes				Yes			
7			Yes							Yes			
8	Yes					Yes				Yes			
9	Yes							Yes				Yes	
10	Yes							Yes				Yes	
11	Yes					Yes						Yes	
12			Yes				Yes					Yes	
13	Yes							Yes				Yes	
14	Yes					Yes				Yes			
15	Yes							Yes				Yes	
16	Yes					Yes						Yes	
17	Yes							Yes				Yes	
18	Yes							Yes				Yes	
19	Yes											Yes	
20	Yes					Yes						Yes	
21	Yes							Yes				Yes	
22			Yes			Yes						Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
23	Yes											Yes	
24	Yes					Yes						Yes	
25	Yes					Yes						Yes	
26			Yes			Yes						Yes	
27			Yes			Yes				Yes			
28	Yes					Yes						Yes	
29	Yes					Yes						Yes	
30	Yes					Yes						Yes	
31								Yes				Yes	
32								Yes		Yes			
33	Yes						Yes					Yes	
34			Yes					Yes				Yes	
35	Yes							Yes				Yes	
36	Yes		Yes				Yes					Yes	
37				Yes					I'm only the LandLord N/A	Yes			
38	Yes					Yes						Yes	
39	Yes					Yes						Yes	
40		Yes					Yes						
41	Yes						Yes		On my flat Concrete roof			Yes	
42	Yes					Yes						Yes	
43	Yes		Yes			Yes						Yes	
44	Yes		Yes					Yes			Yes	Yes	
45	Yes					Yes						Yes	
46	Yes					Yes					Yes		
47		Yes				Yes						Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
48		Yes				Yes						Yes	
49		Yes				Yes						Yes	
50		Yes				Yes						Yes	
51	Yes	Yes				Yes						Yes	
52			Yes										Assess situation and keep informed
53	Yes					Yes				Yes		Yes	
54			Yes				Yes				Yes		
55	Yes		Yes			Yes						Yes	
56	Yes		Yes			Yes				Yes	Yes	Yes	
57	Yes		Yes			Yes				Yes	Yes	Yes	
58	Yes					Yes				Yes			
59	Yes					Yes						Yes	
60			Yes			Yes						Yes	
61	Yes						Yes				Yes		
62		Yes					Yes				Yes		
63	Yes		Yes			Yes				Yes	Yes	Yes	
64	Yes							Yes		Yes			
65	Yes					Yes						Yes	
66	Yes					Yes					Yes	Yes	
67	Yes	Yes	Yes			Yes				Yes			
68	Yes		Yes			Yes						Yes	
69	Yes							Yes			Yes		
70													
71													
72	Yes		Yes			Yes	Yes					Yes	
73	Yes	Yes						Yes		Yes	Yes	Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
74			Yes					Yes				Yes	
75		Yes	Yes									Yes	
76			Yes		Regular Info/warnings via Media or Print			Yes		Yes	Yes	Yes	
77	Yes					Yes						Yes	
78	Yes					Yes						Yes	
79	Yes					Yes				Yes	Yes	Yes	
80	Yes					Yes						Yes	
81		Yes						Yes					
82	Yes	Yes	Yes			Yes				Yes		Yes	
83			Yes				Yes						
84		Yes							Yes			Yes	
85	Yes	Yes	Yes						We Would utilize spare tanks to hold water before slowly restored			Yes	
86			Yes			Yes						Yes	
87							Yes						
88	Yes			Yes		Yes						Yes	
89	Yes		Yes					Yes				Yes	
90			Yes			Yes					Yes		
91	Yes		Yes			Yes					Yes	Yes	
92	Yes							Yes				Yes	
93													
94			Yes					Yes					
95	Yes					Yes				Yes	Yes	Yes	
96	Yes					Yes						Yes	
97		Yes				Yes						Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
98	Yes		Yes			Yes				Yes	Yes	Yes	
99	Yes		Yes			Yes					Yes	Yes	
100			Yes					Yes				Yes	
101	Yes		Yes			Yes					Yes	Yes	
102	Yes						Yes			Yes			
103	Yes						Yes			Yes			
104	Yes								It would depend on information ladline from eYesperts			Yes	
105	Yes					Yes				Yes			
106													
107	Yes		Yes			Yes						Yes	
108	Yes		Yes				Yes				Yes	Yes	
109	Yes		Yes					Yes					Whether covered by cleance
110	Yes		Yes			Yes					Yes	Yes	
111	Yes					Yes						Yes	
112	Yes						Yes					Yes	
113	Yes		Yes			Yes				Yes		Yes	
114			Yes				Yes					Yes	
115	Yes		Yes			Yes				Yes	Yes	Yes	
116			Yes			Yes						Yes	
117		Yes							Never seen flood at this property			Yes	
118	Yes		Yes			Yes						Yes	
119	Yes					Yes						Yes	
120	Yes	Yes				Yes						Yes	
121	Yes		Yes			Yes				Yes	Yes		

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
122			Yes			Yes						Yes	
123	Yes					Yes				Yes	Yes	Yes	
124				Yes			Yes					Yes	
125	Yes					Yes					Yes	Yes	
126		Yes					Yes				Yes		
127	Yes					Yes				Yes			
128	Yes	Yes	Yes			Yes				Yes	Yes	Yes	
129	Yes		Yes			Yes				Yes	Yes	Yes	
130			Yes			Yes						Yes	
131	Yes					Yes				Yes			
132		Yes					Yes					Yes	
133	Yes					Yes						Yes	
134	Yes							Yes		Yes	Yes	Yes	
135	Yes					Yes					Yes		
136	Yes							Yes		Yes		Yes	
137			Yes				Yes				Yes	Yes	
138	Yes		Yes			Yes				Yes	Yes	Yes	
139	Yes		Yes					Yes			Yes	Yes	
140	Yes					Yes				Yes			
141	Yes		Yes			Yes						Yes	
142	Yes							Yes					
143	Yes						Yes			Yes			

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
144	Yes					Yes						Yes	
145	Yes	Yes	Yes	Yes			Yes					Yes	
146		Yes				Yes					Yes	Yes	
147	Yes		Yes			Yes				Yes		Yes	
148	Yes						Yes						
149					Council Covering there arse			Yes				Yes	
150	Yes						Yes						
151	Yes							Yes				Yes	
152	Yes	Yes	Yes				Yes				Yes		
153	Yes		Yes			Yes				Yes		Yes	
154	Yes		Yes					Yes			Yes	Yes	
155		Yes	Yes			Yes				Yes	Yes	Yes	
156			Yes				Yes					Yes	
157			Yes			Yes						Yes	
158		Yes					Yes			Yes			
159		Yes	Yes			Yes						Yes	
160		Yes	Yes			Yes						Yes	
161		Yes	Yes			Yes						Yes	
162	Yes					Yes						Yes	
163	Yes		Yes			Yes						Yes	
164	Yes				As Above on each rate notice			Yes				Yes	
165			Yes				Yes				Yes	Yes	
166			Yes				Yes						
167		Yes											

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
168	Yes					Yes						Yes	
169													
170	Yes							Yes		Yes		Yes	
171	Yes						Yes					Yes	
172	Yes	Yes	Yes				Yes			Yes	Yes	Yes	
173	Yes		Yes						I believe our property in st marys will ever be affacted by flood	Yes			
174					I DON'T KNOW				BECAUSE I HAVE NEVER HAD A FLOOD			Yes	
175			Yes			Yes						Yes	
176	Yes		Yes			Yes				Yes		Yes	
177	Yes					Yes					Yes	Yes	
178			Yes			Yes						Yes	
179	Yes					Yes						Yes	
180	Yes					Yes					Yes		
181		Yes				Yes						Yes	Yes
182	Yes		Yes			Yes				Yes	Yes	Yes	
183	Yes							Yes					
184	Yes							Yes				Yes	
185	Yes					Yes				Yes			
186	Yes							Yes					Yes
187													
188	Yes		Yes			Yes				Yes	Yes	Yes	
189	Yes					Yes					Yes	Yes	
190	Yes		Yes			Yes				Yes	Yes	Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
191	Yes								NEVER FLOODED			Yes	
192			Yes			Yes						Yes	
193	Yes	Yes	Yes			Yes				Yes	Yes		
194	Yes			Yes				Yes		Yes			
195	Yes					Yes						Yes	
196			Yes					Yes			Yes		
197	Yes							Yes		Yes		Yes	
198	Yes					Yes					Yes	Yes	
199		Yes				Yes						Yes	
200		Yes						Yes				Yes	
201	Yes		Yes					Yes		Yes		Yes	
202	Yes		Yes			Yes						Yes	
203			Yes			Yes						Yes	
204	Yes					Yes					Yes	Yes	
205	Yes		Yes			Yes						Yes	
206	Yes		Yes			Yes						Yes	
207	Yes							Yes				Yes	
208	Yes							Yes				Yes	
209		Yes				Yes				Yes		Yes	
210													
211	Yes		Yes				Yes			Yes	Yes		
212	Yes					Yes						Yes	
213	Yes		Yes			Yes						Yes	
214	Yes		Yes					Yes				Yes	
215	Yes				Yes			Yes				Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
216	Yes		Yes					Yes		Yes		Yes	
217			Yes			Yes					Yes	Yes	
218	Yes							Yes				Yes	
219	Yes						Yes				Yes		
220		Yes						Yes		Yes		Yes	
221	Yes						Yes					Yes	
222	Yes		Yes				Yes			Yes	Yes	Yes	
223			Yes					Yes				Yes	
224	Yes	Yes	Yes				Yes			Yes			
225	Yes		Yes			Yes					Yes	Yes	
226	Yes	Yes	Yes			Yes				Yes		Yes	
227		Yes	Yes					Yes		Yes		Yes	
228	Yes					Yes						Yes	
229	Yes							Yes				Yes	
230			Yes			Yes				Yes			
231	Yes		Yes			Yes					Yes		
232				Yes				Yes				Yes	
233		Yes				Yes					Yes	Yes	
234		Yes				Yes						Yes	
235	Yes					Yes				Yes	Yes	Yes	
236			Yes			Yes						Yes	
237		Yes						Only whole nurssary			Yes		Am diabetic as thantic flood pressure kidney problem
238	Yes					Yes				Yes		Yes	
239	Yes					Yes						Yes	

#	What notifications do you think Council should give about the potential flood affectation of individual properties?					How would you respond in a major flood in the area				If you are likely to evacuate, what factors are most important?			
	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise only those who enquire to Council about the known potential flood threat	Advise prospective purchasers of property of the known potential flood threat.	Provide no notifications	Other – please describe	Evacuate early to an evacuation centre	Remain at my house	Don't know/not sure	Other – please describe	Discomfort/inconvenience/cost of being isolated by floodwater	Need for access to medical facilities	Safety of our family	Other – please describe
240	Yes		Yes					Yes		Yes		Yes	
241	Yes		Yes					Yes		Yes	Yes	Yes	
242	Yes					Yes						Yes	
243	Yes							Yes		Yes	Yes	Yes	

Table A3 - Flood Response and Project Updates

#	If you are likely to remain at your house, what factors are most important?					11. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
1				Yes							Yes	
2				Yes					Yes			
3		Yes									Yes	
4				Yes						Yes		
5												
6	Yes					Yes						
7				Yes								letter in council rate notices
8				Yes		Yes						
9	Yes							Yes				
10				Yes		Yes						
11						Yes						
12				Yes								
13												Send an email with details
14				Yes		Yes						
15			Yes							Yes		
16				Yes		Yes						
17				Yes					Yes			
18	Yes					Yes						
19					DON'T LIVE IN THE PROPERTY IT'S A COMMERCIAL WAREHOUSE							
20				Yes						Yes		
21	Yes						Yes					
22				Yes			Yes					
23	Yes					Yes						
24			Yes			Yes						
25				Yes		Yes						

#	If you are likely to remain at your house, what factors are most important?					11. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
26				Yes							Yes	
27	Yes					Yes						
28				Yes		Yes						
29	Yes					Yes						
30	Yes							Yes				
31				Yes		Yes						
32				Yes		Yes						
33	Yes										Yes	
34				Yes								Rates
35		Yes				Yes	Yes				Yes	
36		Yes	Yes				Yes					
37					N/A					Yes		
38	Yes								Yes			Mail
39				Yes		Yes	Yes				Yes	
40			Yes				Yes					
41				Yes		Yes						
42				Yes		Yes	Yes	Yes				
43	Yes						Yes					
44	Yes					Yes	Yes			Yes		
45	Yes					Yes						
46				Yes			Yes					
47	Yes	Yes	Yes	Yes		Yes				Yes		
48	Yes	Yes	Yes	Yes		Yes				Yes		
49	Yes	Yes	Yes	Yes		Yes				Yes		
50	Yes	Yes	Yes	Yes		Yes				Yes		
51				Yes								Mail
52		Yes									Yes	

#	If you are likely to remain at your house, what factors are most important?					11.5 What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
53	Yes			Yes		Yes						
54				Yes			Yes					
55				Yes			Yes				Yes	
56	Yes			Yes		Yes	Yes					
57						Yes	Yes	Yes	Yes	Yes		
58				Yes		Yes					Yes	
59	Yes					Yes						
60			Yes			Yes						
61				Yes							Yes	
62				Yes		Yes	Yes					
63	Yes			Yes		Yes						
64	Yes											
65				Yes		Yes						
66				Yes			Yes					
67	Yes			Yes							Yes	
68				Yes		Yes						
69				Yes								Letters/questions like this
70												
71												
72	Yes	Yes				Yes	Yes					
73		Yes		Yes		Yes	Yes	Yes	Yes	Yes		
74				Yes				Yes	Yes			
75		Yes		Yes			Yes					
76	Yes			Yes		Yes	Yes		Yes	Yes		
77		Yes					Yes	Yes				
78		Yes					Yes					
79						Yes	Yes					

#	If you are likely to remain at your house, what factors are most important?					11.5 What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
80						Yes					Yes	
81						Yes						
82	Yes											Dont Know
83				Yes		Yes						
84				Yes		Yes						
85				Yes		Yes	Yes					Letters
86			Yes			Yes	Yes					
87			Yes			Yes				Yes		
88	Yes			Yes						Yes		Comunication by mail
89		Yes		Yes		Yes	Yes					
90				Yes						Yes		
91				Yes		Yes	Yes					
92					Yes				Yes			
93												
94			Yes				Yes					
95	Yes			Yes		Yes	Yes					
96				Yes							Yes	
97				Yes		Yes		Yes		Yes	Yes	
98				Yes				Yes		Yes		
99	Yes					Yes				Yes		
100	Yes	Yes				Yes	Yes	Yes	Yes	Yes	Yes	
101				Yes		Yes	Yes	Yes	Yes	Yes	Yes	
102	Yes			Yes		Yes						
103	Yes			Yes		Yes						
104	Yes	Yes				Yes	Yes	Yes	Yes	Yes	Yes	Mail
105							Yes					
106												

#	If you are likely to remain at your house, what factors are most important?					11.5 What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
107		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	
108		Yes		Yes		Yes	Yes				Yes	Door knocking in knwown Flood area
109		Yes		Yes					Yes	Yes		Local Media Facebook
110	Yes			Yes		Yes	Yes	Yes		Yes	Yes	
111			Yes			Yes	Yes					
112			Yes			Yes					Yes	
113	Yes			Yes		Yes	Yes				Yes	
114			Yes			Yes						
115	Yes	Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	
116	Yes					Yes						
117				Yes		Yes						
118	Yes			Yes		Yes						
119	Yes										Yes	
120				Yes			Yes	Yes	Yes			
121	Yes	Yes		Yes		Yes	Yes					
122		Yes				Yes						
123	Yes	Yes		Yes		Yes	Yes					
124	Yes	Yes		Yes								SEND A LETTER
125	Yes	Yes				Yes				Yes		
126				Yes			Yes					
127				Yes							Yes	
128	Yes	Yes	Yes				Yes	Yes	Yes	Yes	Yes	
129	Yes	Yes				Yes			Yes	Yes		
130	Yes			Yes		Yes	Yes					
131	Yes	Yes		Yes			Yes					
132	Yes											by letter or email or mail

#	If you are likely to remain at your house, what factors are most important?					11.What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
133				Yes						Yes		
134	Yes	Yes				Yes	Yes	Yes	Yes	Yes	Yes	it should be done using mail and all property onwers should be notified that u are skeeing input
135		Yes					Yes					
136	Yes			Yes					Yes			
137				Yes		Yes	Yes					
138				Yes		Yes	Yes	Yes		Yes		
139			Yes	Yes			Yes	Yes				
140				Yes		Yes	Yes				Yes	
141	Yes	Yes		Yes		Yes	Yes	Yes		Yes		
142												
143	Yes										Yes	send out letters like this
144			Yes							Yes		
145			Yes			Yes						
146				Yes						Yes		
147			Yes			Yes	Yes			Yes	Yes	
148				Yes		Yes				Yes	Yes	
149				Yes								Come and take to the people
150			Yes	Yes			Yes	Yes		Yes		mail boYes drop to affected residents
151				Yes							Yes	
152	Yes	Yes		Yes			Yes					
153	Yes					Yes	Yes					
154		Yes		Yes			Yes				Yes	
155		Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	
156			Yes									servey like this
157				Yes			Yes				Yes	
158			Yes				Yes					

#	If you are likely to remain at your house, what factors are most important?					11.5 What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
159				Yes			Yes					
160			Yes	Yes			Yes					
161			Yes				Yes					
162				Yes			Yes					
163				Yes		Yes	Yes					
164	Yes	Yes										mail
165	Yes	Yes					Yes					
166			Yes							Yes		
167					Yes			Yes	Yes	Yes		
168				Yes		Yes					Yes	
169												
170	Yes			Yes		Yes	Yes					
171			Yes			Yes	Yes			Yes		Get off your arise and walk around and knock on doors and talk to the olders before their knowledge is lost
172	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	
173			Yes			Yes	Yes					
174			Yes								Yes	
175			Yes				Yes					
176			Yes				Yes	Yes				
177		Yes		Yes			Yes					
178				Yes			Yes					
179				Yes					Yes			
180	Yes						Yes			Yes		
181			Yes	Yes		Yes	Yes			Yes	Yes	
182				Yes			Yes			Yes		
183												Yes

#	If you are likely to remain at your house, what factors are most important?					11. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council’s website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council’s Floodplain Management Committee	Other (please specify)
184				Yes		Yes						
185				Yes								
186					Yes							Yes
187												
188	Yes			Yes		Yes	Yes	Yes	Yes	Yes		
189	Yes	Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	
190		Yes				Yes	Yes		Yes		Yes	
191			Yes			Yes						
192	Yes			Yes		Yes	Yes					
193	Yes	Yes	Yes				Yes	Yes	Yes	Yes	Yes	
194			Yes				Yes					
195				Yes								BY MAIL AS YOU HAVE DONE FOR THIS SURVEY
196		Yes		Yes		Yes	Yes					
197	Yes			Yes		Yes						
198	Yes			Yes		Yes	Yes			Yes	Yes	
199				Yes								Yes
200				Yes								BY MAIL
201			Yes	Yes		Yes	Yes			Yes		
202			Yes							Yes		
203				Yes			Yes					
204				Yes			Yes					
205	Yes			Yes		Yes						
206	Yes						Yes					
207				Yes		Yes	Yes	Yes	Yes	Yes	Yes	
208			Yes			Yes						
209	Yes			Yes		Yes	Yes	Yes				
210												
211	Yes			Yes					Yes	Yes		

#	If you are likely to remain at your house, what factors are most important?					11.5 What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
212				Yes			Yes					
213			Yes							Yes		
214				Yes						Yes	Yes	
215				Yes						Yes	Yes	
216			Yes	Yes							Yes	
217		Yes		Yes			Yes					
218		Yes		Yes		Yes	Yes				Yes	
219				Yes							Yes	
220	Yes			Yes				Yes	Yes		Yes	
221	Yes					Yes						
222	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	
223		Yes								Yes		
224	Yes			Yes			Yes					
225		Yes	Yes									Radio
226	Yes		Yes	Yes		Yes			Yes		Yes	
227	Yes			Yes		Yes		Yes				Mail
228											Yes	
229		Yes		Yes						Yes		
230	Yes					Yes					Yes	
231				Yes		Yes	Yes	Yes		Yes		
232				Yes		Yes						
233					Yes	Yes						
234				Yes		Yes						
235	Yes					Yes	Yes	Yes	Yes	Yes	Yes	Yes
236	Yes	Yes					Yes					
237	Yes			Yes	my mondtioned condition	Yes						EMAIL
238	Yes	Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes

#	If you are likely to remain at your house, what factors are most important?					11. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?						
	Discomfort/inconvenience/cost of evacuating	Need to care for animals	My house cannot be flooded, and we can cope with isolation	Concern for security of my property if I evacuate	Other – please describe:	Council's website	Articles in local newspaper	Open days or drop-in days	Community workshops	Public meetings	Council's Floodplain Management Committee	Other (please specify)
239	Yes						Yes		Yes			
240				Yes		Yes	Yes				Yes	
241	Yes			Yes		Yes					Yes	
242		Yes				Yes						
243	Yes			Yes				Yes		Yes		

Table A4 - Potential Flood Risk Management Options

Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Study Area (see plan on attached Fact Sheet)

#	Management of vegetation and silt in stormwater pits, pipes and open channels	Widening and/or concrete lining of open channels	Construct detention basins	Upgrade stormwater drainage system (i.e. bigger / more pipes and/or more inlet pits)	Upgrade culverts (i.e. bigger pipes under roads)	Removal of floodplain /overland flowpath obstructions	Requiring rainwater tanks on all developments	Voluntary purchase of the most severely affected flood-liable properties	Provide funding or subsidies to raise houses above major flood level	Flood proofing of individual properties	Improve flood warning and evacuation procedures	Community education, participation and flood awareness programs.	Ensuring all residents and business owners have Flood Action Plans	Specify controls on future development in flood-liable areas (e.g. extent of filling, minimum floor levels, etc.)	Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.	Installation of signs/boom gates at roadway overtopping locations	Ensuring all information about the flood risks is available to all residents and business owners
1	Yes	Don't know	Don't know	Yes	Yes	Don't know	Yes	Don't know	Don't know	Don't know	Yes	Yes	Yes	Yes	Yes	Don't know	Yes
2	Yes	No	Yes	No	No	Yes	Yes	No	No	No	No	Yes	No	Yes	No	Yes	Yes
3	Don't know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	Yes	Yes	Yes	Yes	Yes	No	Don't know	No	No	No	Yes	Don't know	Don't know	Yes	Yes	No	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	Yes
6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes	No	Yes
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	Yes	Don't know	Don't know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Don't know	Yes	Yes	Don't know	Yes	Don't know	Yes	Yes	Yes	Yes	Don't know	Don't know	Don't know	Don't know	Yes
11	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	No	Don't know	Don't know	Yes	Yes	Yes	Don't know	Don't know	Yes	Yes
12	Yes	No	Yes	No	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	Yes	Don't know	Yes	Don't know	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Don't know	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	Yes	Yes	Yes	Yes	Yes	Don't know	Yes	Yes
17	Yes	Don't know	Don't know	Don't know	Don't know	Don't know	Yes	No	Don't know	Yes	Yes	Yes	Yes	Yes	Don't know	Don't know	Yes
18	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
19	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
20	Yes	No	Don't know	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	Yes
21	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
22	Yes	No	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
23	Yes	Yes	Don't know	Yes	Yes	Don't know	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
24	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
25	Yes	Yes	Don't know	Yes	Yes	Yes	Don't know	No	Don't know	Don't know	Yes	Yes	Yes	Yes	Don't know	Don't know	Yes
26	Yes	Yes	Don't know	Yes	Yes	Don't know	Yes	Don't know	No	Yes	Yes	Yes	Yes	Yes	Yes		Yes
27	Don't know	Don't know	Don't know	Yes	Yes	Don't know	Yes	Don't know	Don't know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
28	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
29	Yes	Yes	Don't know	Yes	Yes	Don't know	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
31	Yes	Yes	Don't know	Yes	Don't know	Don't know	Yes	Don't know	Yes	Yes	Don't know	Don't know	Yes	Yes	Yes	Yes	Yes
32	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Don't know	Yes	Don't know	Yes	Yes	Don't know	Yes
33	Yes	No	Yes	Don't Know	Don't Know	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Yes
34	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes	No	No	Don't Know	No	No	Yes	Yes	Yes	Yes
35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	No	Yes	Yes	Yes	Yes	Yes	No	Yes
37				Yes			Yes			No							Yes
38	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
39	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
40	Yes	No	No	Yes	Yes	Yes	Yes	Don't Know		No	Yes	Yes	No	Yes	No	No	Yes
41	Yes	Yes	Don't Know	Yes	Yes	Yes	No	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Yes
42	Don't Know	Yes	Don't Know	Yes	Yes	Don't Know	Yes	Don't Know	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

#	Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Study Area (see plan on attached Fact Sheet)															
	Management of vegetation and silt in stormwater pits, pipes and open channels	Widening and/or concrete lining of open channels	Construct detention basins	Upgrade stormwater drainage system (i.e. bigger / more pipes and/or more inlet pits)	Upgrade culverts (i.e. bigger pipes under roads)	Removal of floodplain /overland flowpath obstructions	Requiring rainwater tanks on all developments	Voluntary purchase of the most severely affected flood-liable properties	Provide funding or subsidies to raise houses above major flood level	Flood proofing of individual properties	Improve flood warning and evacuation procedures	Community education, participation and flood awareness programs.	Ensuring all residents and business owners have Flood Action Plans	Specify controls on future development in flood-liable areas (e.g. extent of filling, minimum floor levels, etc.)	Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.	Installation of signs/boom gates at roadway overtopping locations	Ensuring all information about the flood risks is available to all residents and business owners
43	Yes	Yes	Don't Know	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	Don't Know	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes
44	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
45	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Don't Know	Yes	Yes
46	Yes	Yes	Yes	Yes													Yes
47	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
48	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
49	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
50	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
51	Don't Know	Don't Know	Don't Know	Yes	Yes	Don't Know	No	Yes	No	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	No	Yes
52		Yes	No	Don't Know	Don't Know	Yes	Yes	Don't Know	No		Don't Know	Don't Know	Don't Know	Yes	Yes	Yes	Yes
53	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
54	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
55	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
56	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
57	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
58	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
59	Yes	Yes	Don't Know	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
60	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes
61	Yes	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know
62	Don't Know	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes
63	Yes	Yes	Yes	Yes	Yes			Yes	Yes			Yes		Yes			Yes
64	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Yes	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes
65	Yes	Yes	Yes	Don't Know	Don't Know	Yes		Yes	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes
66	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
67	Yes	Yes	Don't Know	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
68	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Yes	No	No	Don't Know	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes
69	Don't Know	Yes	Yes	Yes	Don't Know	Yes	Don't Know	No	Yes	Yes	Yes	Don't Know	No	Don't Know	Don't Know	Don't Know	Don't Know
70																	
71																	
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No		Yes	Yes		Yes
73	Yes	Don't Know	Yes	Yes	Don't Know	Don't Know	Yes	No	Don't Know	Don't Know	Yes	Yes	Yes	Yes	No	Yes	Yes
74	Don't Know	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
75	Don't Know	Yes	Don't Know	Yes	Yes	Don't Know		Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
76	Yes	Yes	Yes	Yes	Yes	Don't Know	No	No	Yes	Don't Know	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes
77	Yes	No	No	Yes	Yes	Yes	No	No	No	No		Yes	Yes	Yes	Yes	Yes	Yes
78	Don't Know	Don't Know	Don't Know	Yes	Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes
79	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
80							Yes			Yes			Yes			Yes	
81	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
82	Don't Know	Yes	Don't Know	Yes	Yes	Yes	No	Don't Know	No	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	Yes	Yes
83	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes
84	Yes	Don't Know	Yes	Yes	Yes	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	No	Don't Know	No	Yes
85	Yes	Don't Know	Don't Know	Yes	Yes,Don't Know	Don't Know	Yes	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know	Yes
86	Yes	Don't Know	Don't Know	Yes	No	Yes	Don't Know	No	No	No	Don't Know	Don't Know	Yes	Yes	Yes	Don't Know	Yes
87	Yes	Yes									Yes						

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88	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Yes	Yes	No	No	Don't Know	Don't Know	Don't Know	Yes
89	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes
90	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
91	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
92	Don't Know			Yes	Yes	Yes	No	Don't Know	Don't Know	Yes	Yes	Don't Know	Don't Know		Yes	Yes	Yes
93																	
94	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
95	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Don't Know	Don't Know	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
96	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes
97	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Don't Know	No	No	Don't Know	Yes	Don't Know	Yes	Don't Know	No	Yes
98	Yes	Don't Know	Yes	Yes	Yes	Don't Know	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
99	Yes	Yes	Don't Know	Yes	Don't Know	Yes	Yes	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	Don't Know	Yes	Yes	Yes
100	Yes		Yes	Yes	Yes			Yes			Yes	Yes					Yes
101	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
102	Yes	Yes	Yes	Yes	Yes		Yes	Don't Know	Yes	Yes	Yes	No	Yes	Don't Know	Yes	Yes	Yes
103	Yes	Yes	Yes	Yes	Yes		Yes	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes
104	Yes	Don't Know	No	No	Yes	Don't Know	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
105	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
106	No	Yes	No	Yes	Yes		Don't Know	Yes	Yes	Don't Know	Yes	Yes	Yes	Don't Know	Don't Know	Yes	Yes
107	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know	Yes	Yes	Don't Know	Yes	Yes	Yes	Yes
108	Yes	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know	No	No	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Yes
109	Yes	Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
110	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
111	Yes	Yes	Don't Know	Yes	Yes	Don't Know	Yes	No	Yes	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
112	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
113	Yes	Yes	Don't Know	Yes	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Don't Know	Yes
114	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
115	Yes	Yes	Don't Know	Yes	Yes	Don't Know	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
116	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Don't Know	Don't Know	Yes	Yes	Yes	No	Yes
117	Yes	Don't Know	Yes	Yes	Yes,Don't Know		Yes	Don't Know	Don't Know	Don't Know	Don't Know	Yes	Don't Know	No	Don't Know	No	Yes
118	Don't Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
119	Don't Know	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know	Yes	Yes	Yes	Yes	Don't Know	Don't Know	Yes
120	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes
121	Yes	Yes	Yes	Yes	Yes	Don't Know	Yes	Don't Know		Don't Know	Yes	Don't Know	Yes	Don't Know	Yes	Yes	Yes
122	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
123	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes
124	Yes	Yes	Yes	Yes	Yes	Dont 'Know	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	No	No
125	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
126	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes
127	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
128	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
129	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know
130	Yes	No	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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131		Yes		Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
132	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
133	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
134	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
135	Yes	Dont 'Know	Yes	Yes	No	No	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes
136				Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Yes
137	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes
138	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
139	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
140	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
141	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
142	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes
143	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
144	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
145	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
146	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes
147	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
148	Yes	Yes	No	Yes	No		Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
149	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	No	No	Yes
150	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	No	Yes	Dont 'Know	Yes	Yes
151	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes
152	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
153	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
154	Yes	No	Dont 'Know	Yes	No	Dont 'Know	No	Dont 'Know	No	No	Dont 'Know	No	Yes	Yes	Yes	No	Yes
155	Yes	No	Dont 'Know	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
156	Yes	No	Yes	No	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes
157	Yes	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes
158	Yes	No	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
159	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes
160	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes
161	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes
162	Yes	Dont 'Know	Dont 'Know	Yes	Yes	No	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes
163	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
164	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes
165	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	No	No	No	No	No	Yes	Yes	Dont 'Know	Dont 'Know
166	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	No	No	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes
167	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	No	No	Yes	Dont 'Know
168	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	No	No	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
169																	
170	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know		Yes
171	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes

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172	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
173	Yes	Yes		Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes
174	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
175	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	No	No	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes
176	Yes	Yes	Yes								Yes	Yes	Yes		Yes		Yes
177	Dont 'Know	Dont 'Know	Dont 'Know		Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes
178	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
179	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
180	Yes										Yes		Yes				
181	Yes			Yes						Yes	Yes				Yes		Yes
182	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
183	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes
184	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
185																	
186	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
187																	
188	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	No	Dont 'Know	Yes	Yes	Yes	Yes	Yes	No	Dont 'Know	Yes
189	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
190	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
191	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
192	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
193	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
194	Yes	Dont 'Know	Dont 'Know	No	No		Yes	Yes	Yes	Yes		Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes
195	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	No	No	Yes	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes
196	Dont 'Know	Yes	Dont 'Know	Yes	Yes	No	Yes	No	Yes	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes
197	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
198	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes
199	Yes	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
200																	
201	Yes	No	No	Yes	Yes	Dont 'Know	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
202	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
203	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
204	Yes	Yes	Yes	Yes	Yes	Yes	No	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes	Yes
205	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
206	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
207	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes
208	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
209	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes
210																	
211	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
212	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
213	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Dont 'Know	Yes
214	Yes			Yes	Yes	Dont 'Know	Yes	No	No	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes
215	Yes			Yes	Yes		Dont 'Know	Yes	No	No	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes
216	Dont 'Know	Dont 'Know	Dont 'Know	Yes		Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	No	Yes

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217							Yes				Yes						
218	Yes	Yes	Yes	Yes	Yes	Dont 'Know	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
219	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
220	Yes	Yes	Dont 'Know	Yes	Yes	No	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes
221	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
222	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
223	Dont 'Know	Dont 'Know	No	No	No	Dont 'Know	No	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	No	No	Dont 'Know	No
224	Yes			Yes		Yes	Yes					Yes		Yes	Yes		Yes
225	Yes	No	No	No	No	Dont 'Know		Yes	No	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes
226	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
227	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
228	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
229	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Dont 'Know	No	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes
230	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
231	Yes	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
232	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	No
233	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	No	Yes	Dont 'Know	Dont 'Know	Yes	Yes	No	Dont 'Know	Dont 'Know	Dont 'Know	Yes
234	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes
235	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
236	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes,Dont 'Know	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
237	Dont 'Know	No	No	No	No	No	No	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Dont 'Know	Yes
238	Yes	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
239	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
240	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes
241	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Dont 'Know	Yes	Yes	Yes	Yes	Yes	Yes	Yes
242																	
243	Yes	Yes	Yes	Yes	Yes	Dont 'Know	Dont 'Know	Dont 'Know	Yes	Yes	Yes	Yes	Dont 'Know	Yes	Yes	Yes	Yes

Appendix B

Flood Damage Assessment

B1 - Flood Damage Calculations

1.1 Introduction

To quantify the likely financial impact that flooding has on residents, business owners and infrastructure providers within the Little Creek catchment, the number of properties subject to over floor flooding and the flood damage cost that would likely be incurred during the full range of design floods was calculated. The approach that was adopted to estimate the flood damage costs is presented below.

1.2 Property Database

A property database was developed as part of the study to enable damage calculations to be prepared across residential, commercial and industrial properties. The database was developed in GIS and included the details of all building floor levels located within potentially flood liable sections of the catchment (i.e., properties contained within the PMF extent). For residential dwellings, the lowest habitable floor level was estimated, with the lowest operation or functioning floor level of commercial and industrial properties also estimated.

The following information was collected and included as fields within the GIS database for each building:

- Property type (i.e., residential, commercial or industrial);
- Building floor level;
- Building floor area (average or large);
- Residential building type (i.e., two story, single level high set, single level low set or multi-dwelling);
- Building material type (brick, weatherboard, cladded);
- Number of buildings on the lot;
- Commercial and industrial property contents value (low, medium or high value);
- A photo of the building.

In general, the information listed above was populated using a "drive by" survey. This was completed using Google Street View and was supplemented with site visits where buildings were not visible in Street View. A total of 839 properties were incorporated in the property database with approximately 100 of these properties visited in the field.

1.2.1 Building Floor Levels

As outlined above, it is necessary to have information describing the floor height / level of every building within the PMF extent. Floor levels were estimated using the following approach:

1. The height of the floor of each building above the adjoining ground level was estimated. This was most commonly determined by counting the number of bricks or steps from the ground to floor (a brick height of 85mm or a step height of 170mm was most commonly adopted although unique heights were estimated for concrete and irregular steps);

2. The ground level at the point where the floor height was estimated was extracted from the 2019 LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1) to the ground elevation (calculated in step 2).

It was acknowledged that the floor level elevations were estimates only. Therefore, a floor level sensitivity assessment was completed to understand how variations in the floor levels may impact on the flood damage calculations. The outcomes of this assessment are discussed in Section 1.7.

1.3 Types of Damage Costs

The damage costs associated with floodwater inundation can be broken down into a number of categories, as shown in **Plate 1**. However, broadly speaking, damage costs fall under two major categories;

- tangible damages; and
- intangible damages.

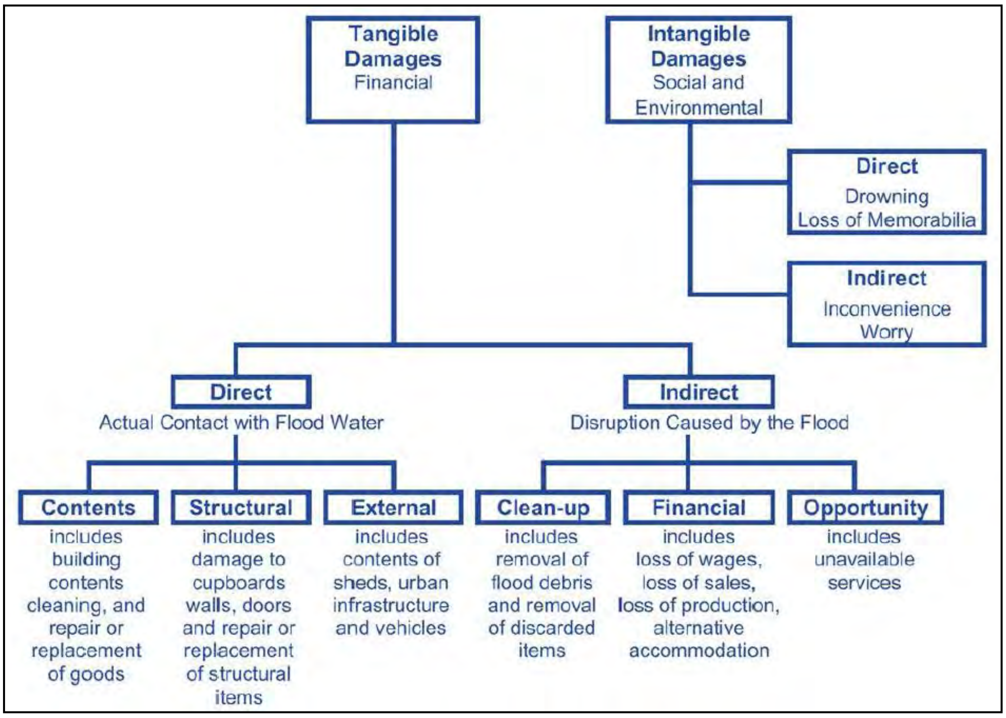


Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by waters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific inundation event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Only tangible damages costs were estimated as part of the study due to the difficulty/uncertainty associated with assigning dollar values to intangible items.

1.4 Flood Damage Calculations

Flood damages are most commonly estimated using curves that relate the damage costs relative to the depth of above floor flooding for residential, commercial and industrial properties. Further information on the flood damage curves that were used as part of the study is provided below.

1.4.1 Residential Properties

The NSW Department of Planning, Industry and Environment (DPIE) has prepared a spreadsheet that provides a standardised approach for deriving depth-damage curves for residential properties (version 3.00, October 2007). The spreadsheet requires a range of parameters to be defined to enable a meaningful damage estimate to be derived. The parameters that were adopted for the current study are provided on the following page.

As shown on the following page, building floor area serves as one of the residential damage curve inputs that must be adapted to the local catchment. Building floor areas for each residential building in the catchment were calculated using building footprints within GIS. Average building floor areas were calculated for:

- Single dwellings where there is only one building per lot. The average building area was determined to be 150m^2,
- Medium density residential development comprising two or three buildings on the lot (these lots were assumed to have six residential dwellings with two storeys per dwelling). The average building area was determined to be 600m^2,
- High density residential development comprising four or more buildings on the lot (these lots were assumed have eight dwellings on them with two storeys per dwelling). The average building area was determined to be 720m^2.

The damage curves for medium and high density residential properties were developed using the two storey residential damage curves as a 'base'. However, the floor area was adjusted in line with the assumptions listed above to reflect the higher density development levels and the associated increased damage potential.

The resulting residential depth-damage curves (shown on the following pages) incorporate a damage allowance for 'negative' above floor flooding depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, sheds, belongings stored below the building floor). The damage curves for 'single storey low set' and 'two storey' properties and 'single storey high set' commence at -0.9 metres in the Little Creek catchment. This value was based on comparing the building floor levels of properties within the PMF extent against the minimum ground elevation within each cadastral lot (i.e., the minimum elevation within each cadastral lot at which inundation will first occur and, therefore, where damage is likely to commence). This determined that the median difference between the building floor level and minimum ground level within the corresponding lot was about 0.9 metres. Accordingly, all residential damage curves were adjusted so that damage commenced only when the flood water was at a level less than 0.9metres below the floor level.

On top of the direct flood damage costs, additional factors are incorporated in the residential damage curves to help quantify the indirect damages that may be incurred as a result of flood damage at a residential property. This includes the time and cost associated with alternate accommodation and costs associated with cleaning up after the flood. These factors are included in the residential damage curves presented on the following pages.

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT							
Version 3.00 October 2007							
PROJECT	**DETAILS**			**DATE**		**JOB No.**	
Little Creek FRMS&P	**Residential Buildings** Flood Damages Assessment			**1/06/2016**			
BUILDINGS							
Regional Cost Variation Factor	1.00	*From Rawlinsons*					
Post late 2001 adjustments	1.87	*Changes in AWE see AWE Stats Worksheet*					
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*			
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					
	Regional City			*Regional Town*			
	Houses Affected		*Factor*	*Houses Affected*		*Factor*	
Small scale impact	*<*	*50*	*1.00*	*<*	*10*	*1.00*	
Medium scale impacts in Regional City		*100*	*1.20*		*30*	*1.30*	
Large scale impacts in Regional City	*>*	*150*	*1.40*	*>*	*50*	*1.50*	
Typical Duration of Immersion	2	hours					
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*		*long duration*	
		Suggested range		*0.85*	*to*	*1.00*	
Typical House Size	150	m^2		*240 m^2 is Base*			
Building Size Adjustment	0.6						
Total Building Adjustment Factor	**1.00**						
CONTENTS							
Average Contents Relevant to Site	$ 59,758		*Base for 240 m^2 house*		*$ 60,000*		
Post late 2001 adjustments	1.87	*From above*					
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*		*short duration*		*long duration*	
Sub-Total Adjustment Factor	1.41	*Suggested range*		*0.75*	*to*	*0.90*	
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*					
Effective Warning Time	0	hour					
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor					
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*					
Total Contents Adjustment Factor AFD <= TTBH	**1.41**	AFD = Above Floor Depth					
Total Contents Adjustment Factor AFD > TTBH	**1.41**						
Most recent advice from Victorian Rapid Assessment Method							
Low level of awareness is expected norm (long term average) any deviation needs to be justified.							
Basic contents damages are based upon a DRF of	*0.9*						
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***		
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*		
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*		
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*		
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*		
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*		
Effective Warning time (hours)	*0*	*3*	*0*				
Site Specific iterations	*1.00*	*0.89*	*1.00*				
ADDITIONAL FACTORS							
Post late 2001 adjustments	1.87	*From above*					
External Damage	$ 6,700	*$6,700 recommended without justification*					
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*					
Likely Time in Alternate Accommodation	4	weeks					
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*					
TWO STOREY HOUSE BUILDING & CONTENTS FACTORS				**-0.5**			
Up to Second Floor Level, less than	2.6	m		70%	Single Storey Slab on Ground		
From Second Storey up, greater than	2.6	m		110%	Single Storey Slab on Ground		
Base Curves		AFD = Above Floor Depth					
Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres		
Structure with GST	AFD	greater than	-0.9	m			
Validity Limits	AFD	less than or equal to		6	m		
Single Storey High Set	16586	+	7454	x	AFD		
Structure with GST	AFD	greater than	-0.9 m				
Validity Limits	AFD	less than or equal to		6	m		
Contents	20000	+	20000	x	AFD		
Contents with GST	AFD	greater than		0			
Validity Limits	AFD	less than or equal to		2			

Plate 2 Residential Flood damage curve inputs

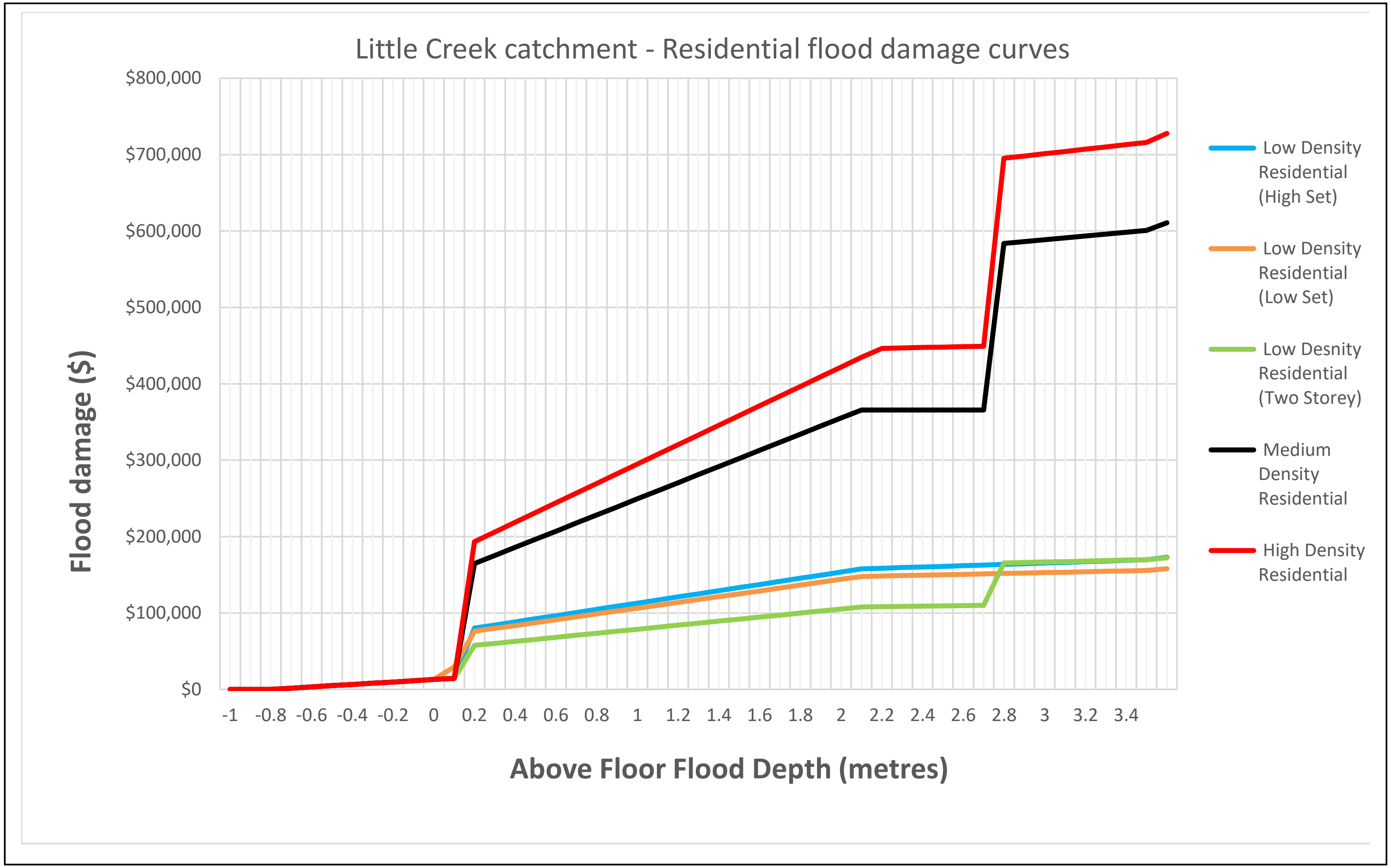


Plate 3 Residential Flood damage curves

The NSW Government flood damage curves do not explicitly account for multi-unit dwellings which are common across the Little Creek catchment (e.g., dual occupancies or townhouse style developments on a single lot). Therefore, separate damage curves were calculated for these types of developments using the two storey residential curves as a base. The size of each individual residence, along with the number of individual residences per building, and the number of buildings per lot were estimated based on desktop site analysis and field visits. This provided additional flood damage curves for "medium density" and "high density" developments.

1.4.2 Commercial/Industrial Properties

Unlike residential flood damage calculations, there are no standard curves available for estimating commercial and industrial flood damages in NSW. Commercial property types include offices and shops, and industrial properties include facilities such as warehouses and automotive repairs.

The flood damage curves that had been applied for other recently completed floodplain risk management study and plans in the Penrith LGA were reviewed to determine whether they were appropriate for use in the Little Creek catchment. This review determined that flood damage curve information was not available for the 'St Marys (Byrnes Creek) Floodplain Risk Management Study and Plan' (Lyall and Associates, July 2019). However, the 'Penrith CBD Floodplain Risk Management Study and Plan' (Molino Stewart, March 2020) contained a range of information on flood damage estimates for non-residential damages. The flood damage curves used the following categories for these non-residential damages:

- commercial
- industrial
- education
- healthcare
- emergency services
- police

After reviewing the commercial and industrial land uses in the Little Creek, particularly in the Dunheved Business Park, it was evident that there was a large range of commercial and industrial properties types and the use of a single damage curve for commercial and industrial properties (as was adopted in the Penrith CBD study) would not provide a reliable representation of the variation in flood damage potential across the catchment. For example, Dunheved Business Park contains industrial developments that range from 80 square metres to almost 25,000 square metres. There is also significant variation in the value of the contents contained within each commercial and industrial development (e.g., some properties have high value contents such as automated machines for industrial processing purposes, with others having low value contents, such as police or ambulance stations).

The 'South Creek Floodplain Risk Management Study' (Advisian, 2020) included low, medium and high commercial and industrial damage curves based on the size of the footprint of the building within each lot. This provided a better representation of the potential flood damage costs, however, does not account for the value of the contents within each building. Therefore, more catchment-specific flood damage curves were developed so the variation in commercial and industrial property values were better represented.

Catchment Simulation Solutions has prepared flood damage curves as part of floodplain risk management studies for other local government areas. These damage curves were originally developed based on flood damage information that was compiled following the Nyngan and Inverell floods during the 1990s, as well as data gained from interviews of 41 businesses in Gloucester. The curves were subsequently adjusted based upon new flood damage information that was collected by Tweed Shire Council following the 2017 floods at Murwillumbah (the "old" curves were found to underestimate the reported damages). It was considered appropriate to use these curves for the current study, which are based on recorded flood damage information, for the current study. However, the base damage curves were updated to 2019 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics before application to the calculations (this is reflected in the "post late 2011 adjustments" in Plate 2).

In order to apply the damage curves, it was necessary to categorise each commercial and industrial property according to the use of the land and the associated value of the contents contained within each building (i.e. low, medium, high and very high value contents/damage potential). **Table 1** provides a summary of common commercial and industrial property types and the associated contents value that each would fall under.

Table 1 Content Value Categories for Commercial and Industrial Property Types

Low Value	Medium Value	High Value	Very High Value
Recreation Uses	Mixed commercial such as chemists, food shops, clothing stores, newsagencies or electrical shops	Medium sized industrial developments	Industrial with a Gross Floor Area over 2,000m^2
Environmental Uses	Police Station	High Schools	High value and large commercial properties such as car yard sales and showrooms
Church	SES building	Primary school	
Ambulance station	Electricity sub-substation	Aged care	
Fire Stations	Office	Child care / pre school	
	Heritage sites	Water and sewer infrastructure i.e. sewer pump station	
		Medical facilities	
		Areas zoned as special activity (SP1 and SP2)	
		University / TAFE	

Land uses that are non -residential, however not necessarily commercial or industrial, were considered as part of the commercial and industrial damage land uses. These include parks and recreation areas, as well as buildings such a fire stations and ambulance stations. Each of these facilities were considered as a low value commercial/industrial development for the flood damage calculation process.

No specific allowance is included in the commercial and industrial damage curves for indirect losses, such as clean-up costs and loss of income while clean-up occurs. The indirect losses for large industrial properties can be significant, as floodwaters can damage large scale machinery or assets that would require significant time to repair/replace and return to full working condition. The recovery for commercial and small-scale industrial developments is typically less of a financial impact as the contents of these developments are generally smaller and simpler to replace.

In line with other floodplain risk management studies, indirect damage costs were estimated as 20% of the direct flood damages for commercial and small industrial developments and 50% of the direct flood damages for medium and large industrial developments. These inflation factors were added to the direct damage costs to determine the total flood damage cost curves for commercial and industrial properties.

The adopted commercial and industrial depth-damage curves are presented on the following page.

1.4.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, internet, electricity and telephone. Where major assets are known to exist (e.g. sewer pump stations), they were included as part of the commercial/industrial damages. For the remainder of the infrastructure that are distributed across the catchment, such as roads and telecommunication assets, the damage was incorporated as a percentage of the total residential, commercial and industrial damages. More specifically, the base flood damage estimates were inflated by a further 15% to account for infrastructure damage.

1.4.4 Potential versus Actual Damages

The residential, commercial and industrial damage calculations outlined above assume that no actions are taken by residents and business owners to reduce the potential damage. However, if some warning is provided of the impending flood, there may be sufficient time for residents and business owners to undertake actions to reduce the potential damage costs incurred during a flood. For example, residents/business owners could potentially 'sandbag' properties to prevent the ingress of floodwaters, relocate vehicles to high ground and/or elevate belongings onto tables or shelves. As a result, actual flood damages will typically be lower than the potential calculated flood damages.

Only very limited data has been collected in Australia to assist in quantifying how flood warnings can reduce potential flood damages. Information presented by Water Studies (1992) infers that direct residential property damages can be reduced by up to 50% with some effective warning time (although no specific information is provided on the minimum warning time required to achieve this).

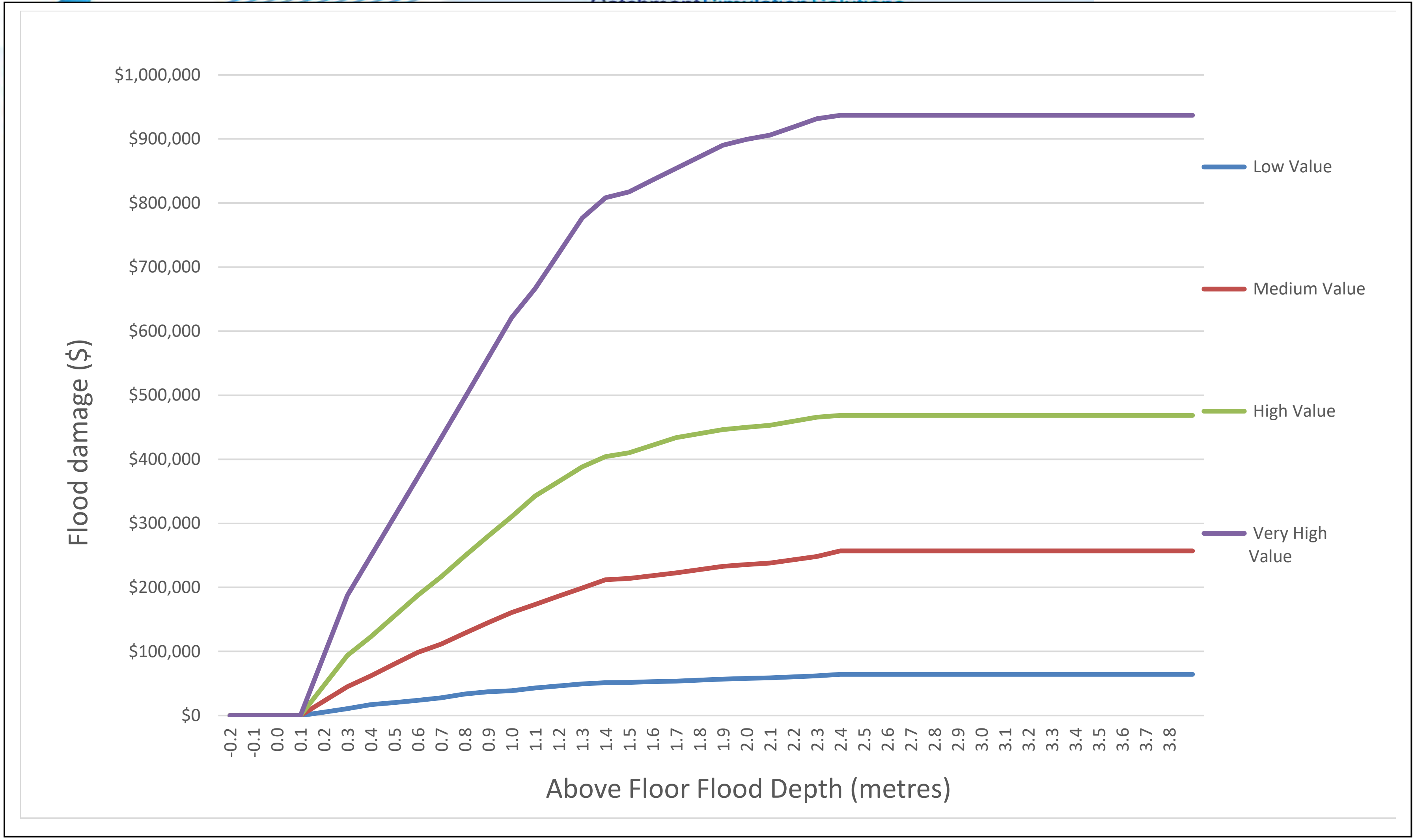


Plate 4 Commercial and Industrial Flood damage curves

More extensive research in flood damage reductions associated with effective flood warning has been completed across Europe. This research notes that the flood damage reduction potential is not only dependent on the amount of warning time provided, but also how effectively this warning information is disseminated, the reliability of the warning information, the proportion of households that are proactive with the warning information and how well these households respond to the warning information (Parker, 1991). The Flood Hazard Research Centre (FHRC) also published the following table which relates the potential flood damages avoided (PFA) with respect to variations in depth of flooding and flood warning time for short duration floods (Penning-Rowsell et al, 2013).

Table 8.3: Calculation of Potential Flood Damages Avoided (PFA) for a short duration flood (<12 hour) for residential property

Depth of Flooding (m)	Total Potential Damage £	Total Potential Household Inventory Damage £	Flood warning lead times							
			Up to 2hours		2-4 hours		6 hours		8 hours	
			PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage
1.2	33,040	20,423	8,359	25.3	11,795	35.7	12,786	38.7	13,447	40.7
0.9	31,265	20,237	8,254	26.4	11,756	37.6	12,694	40.6	13,319	42.6
0.6	29,268	19,051	7,463	25.5	10,888	37.2	11,766	40.2	12,351	42.2
0.3	26,105	18,046	7,832	30.0	10,990	42.1	11,774	45.1	12,296	47.1
0.1	13,507	9,977	3,309	24.5	4,430	32.8	4,835	35.8	5,105	37.8

It indicates that reductions in direct flood damages of around 25% are typical with up to 2 hours warning time increasing to reductions of over 40% with 8 hours warning time. The FHRC also noted that reductions in potential flood damages above 50% are unlikely as only 40-50% of potentially damageable items can be relocated/moved.

Flooding in the Little Creek catchment is very “flashy” with floodwaters typically peaking within 30 minutes to 60 minutes of the onset of rainfall. This is considered to be insufficient warning time for residents or business owners to undertake sufficient preparations to reduce flood damages, such as lifting objects from the ground or moving vehicles. As such, it was considered inappropriate to apply any flood damage reduction factors within the Little Creek catchment.

1.5 Summary of Flood Damage Costs

1.5.1 Damage Costs

Above floor flooding depths were estimated for each design flood for each potentially flood affected property within the catchment. This was completed using peak design flood levels generated by the TUFLOW model in conjunction with the building floor level information discussed in Section 1.2. This enabled the number of residential, commercial and industrial properties subject to above floor flooding during each design flood to be estimated, which is summarised in **Table 2**. The number of properties subject to property damage (even if above floor flooding is not predicted) are also provided in **Table 2**. This includes damage to external items such as fences, sheds and garages.

Table 2 Number of Properties Incurring Flood Damages

Flood Event	Residential		Commercial/ Industrial		Total Number	
	External Damage only	Above Floor Inundation	External Damage only	Above Floor Inundation	External Damaged only	Above Floor Inundation
0.5EY	8	0	2	2	10	2
20% AEP	21	0	3	3	24	3
10% AEP	34	1	3	3	37	4
5% AEP	49	6	4	4	53	10
2% AEP	78	16	13	13	91	29
1% AEP	83	24	13	13	96	37
0.5% AEP	99	28	13	13	112	41
0.2% AEP	106	45	18	18	124	63
PMF	112	307	76	76	188	383

The above floor flooding depths were combined with the appropriate depth-damage curves to estimate the damage cost incurred at each property during each design flood. The individual property damage estimates were subsequently summed with infrastructure damage cost estimates to calculate the total flood damages for each design event, which is summarised in **Table 3.**

Table 3 Total Flood Damage Cost Estimates

Flood Event	Flood Damages ($ millions)			Incremental Contribution to Average Annual Damage
	Residential	Commercial/ Industrial	Total Damages	
0.5EY	0.06	0.01	**0.07**	$9,819
20% AEP	0.20	0.02	**0.22**	$42,551
10% AEP	0.37	0.07	**0.44**	$32,956
5% AEP	0.73	0.12	**0.85**	$32,397
2% AEP	1.83	0.88	**2.71**	$53,424
1% AEP	2.48	0.97	**3.45**	$30,797
0.5% AEP	3.02	1.06	**4.08**	$18,840
0.2% AEP	4.13	1.36	**5.49**	$14,364
PMF	37.58	13.35	**50.93**	$56,397
			TOTAL AAD	**$291,545**

The flood damage estimates provided in **Table 3** shows that if a 1% AEP type flood was to occur, nearly $3.5 million worth of damage could be expected to occur. The majority of the damages are predicted across residential properties. Therefore, residential property owners in the study area would largely be responsible for the flood damage bill.

It was noted that there is a significant "jump" in the number of impacted properties during the PMF. However, a review of these properties indicates that they are only subject to minor inundation (i.e., the inundation varies from between 5 and 20 m^2 on each lot). These properties do not experience inundation in any other flood event other than the PMF. As noted previously, the damage calculations in this study were based on the assumption that damage starts to be incurred to each residential lot when floodwaters reach a depth of 0.9 metres below the floor level. Examination of the floor levels and the areas impacted by this minor flooding in the PMF indicate that the depth of flooding on these lots is at levels less than 0.9 metres below the floor level of the building. As such, the flood damage across these lots are considered negligible and have not been included in the flood damage calculations of this study.

1.5.2 Average Annual Damages

The total flood damages for each flood event were subsequently used to estimate the Average Annual Damage (AAD) cost for the Little Creek catchment. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe. The AAD for the study area for existing conditions was calculated as **$291,545**.

1.6 Limitations of Damage Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared. However, the estimates are exactly that – estimates. Actual damage costs during future floods may vary. Land uses may also change in future, which would impact on potential flood damages.

It should also be noted that the damage estimates do not include damages that may be incurred as a result of flooding from South Creek or the Hawkesbury Nepean River as this has been accounted for in previous investigations. Therefore, the damages that are reported above may underestimate the total flood damage costs that would be incurred in the lower reaches of the Little Creek catchment should inundation from one of these other waterways occur.

1.7 Sensitivity Assessment

As discussed in Section 1.2.1, the floor levels that were used as part of the damages assessment were estimated based on a "drive by" survey. To gain an understanding of how inaccuracies in the floor level estimate may impact on the results of the damages assessment, a floor level sensitivity assessment was completed. This involved changing the estimated floor level elevations by ±0.1 metres and re-calculating the flood damage results. The 0.1 metre bounds were considered to provide upper and lower limits of the actual floor levels.

The outcomes of the floor level sensitivity assessment are summarised in **Table 4**. It shows that increasing the floor levels by 0.1 metres will reduce AAD by around $50,000 (i.e., less than a 20% change). However, reducing the floor level estimates by 0.01 metres would increase AAD by more than $100,000 (i.e., a 40% increase). However, a review of the damage calculations showed that, in some instances, reducing the floor levels by 0.1 metres actually reduced the floor levels to less than the ground level. Therefore, it is likely that some of the increased damages estimates are unrealistically high.

Table 4 Building Floor Level Damage Sensitivity Results

Flood Event	**Total Flood Damages** ($ millions)		
	"Base" Case Floor Levels	**Floor Levels -0.1 metres**	**Floor Levels +0.1 metres**
0.5EY	0.07	0.08	0.05
20% AEP	0.22	0.38	0.22
10% AEP	0.44	0.70	0.40
5% AEP	0.85	1.44	0.73
2% AEP	2.71	3.49	1.66
1% AEP	3.45	4.67	2.31
0.5% AEP	4.08	5.42	2.90
0.2% AEP	5.49	6.88	3.64
PMF	50.93	55.12	45.00
TOTAL AAD	**$291,545**	**$409,597**	**$234,245**

In general, all floor levels are considered to be accurate to better than 0.1 metres and the actual differences would be located well within the upper and lower bounds indicated in **Table 4**. As a result, it is likely that that the "true" flood damage estimates are contained within 20% of the damage costs estimates as part of the current study.

APPENDIX C

ROAD OVERTOPPING INFORMATION

Road Overtopping Point ID*	0.5EY				20% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
1								
2	0.68	1.14	0.29	0.32	1.30	0.77	0.38	0.35
3					0.13	0.22	0.15	1.37
4	2.58	0.29	0.20	0.56	2.70	0.22	0.23	0.67
5								
6								
7								
8	3.93	0.00	0.39	0.06	3.93	0.00	0.39	0.07
9	1.02	0.98	0.37	0.42	1.79	0.61	0.41	0.44
10								
11								
12	0.00	0.00	0.15	0.73	0.35	0.55	0.35	0.64
13								
14	0.74	1.54	0.33	0.36	1.09	1.80	0.53	0.50
15								
16								
17								
18					0.06	0.29	0.20	0.41
19								
20	0.92	1.44	0.49	0.59	1.57	1.10	0.55	0.70
21								
22								
23					0.37	0.55	0.30	0.19
24					0.22	0.65	0.22	0.73
25					0.27	0.51	0.24	0.14
26	1.36	1.33	0.47	0.39	1.80	0.98	0.56	0.40
27	0.16	0.54	0.18	0.17	0.63	0.60	0.31	0.14
28								
29					0.47	0.61	0.22	0.45
30								

Road Overtopping Point ID*	0.5EY				20% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
31								
32					0.00	0.00	0.15	0.41
33	0.03	0.05	0.15	0.23	0.54	0.71	0.23	0.63
34	0.87	0.96	0.22	0.41	1.60	0.45	0.28	0.53
35	0.41	0.48	0.24	0.56	0.46	0.80	0.28	0.64
36	0.50	1.14	0.30	0.44	0.61	1.18	0.33	0.59
37	0.44	0.71	0.23	0.52	0.50	1.06	0.34	0.54
38								
39	0.66	1.45	0.41	0.26	0.97	1.31	0.57	0.37
40								
41	2.27	0.42	0.66	0.22	2.78	0.36	0.74	0.25
42					0.15	0.61	0.18	0.71
43	0.35	1.14	0.25	1.03	0.63	1.02	0.30	1.02
44	0.59	1.55	0.31	0.12	0.86	1.23	0.37	0.18
45	0.20	0.49	0.18	0.37	0.52	1.20	0.25	0.44
46								
47								
48								
49								
50					0.31	0.59	0.23	0.95
51								
52								
53								
54	0.01	0.23	0.16	0.90	0.18	0.47	0.20	1.10
55	0.18	0.96	0.17	0.40	0.35	0.90	0.21	0.53
56					0.00	0.00	0.16	1.17
57								
58								
59								

Road Overtopping Point ID*	0.5EY				20% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
60								
61								
62								
63	0.17	1.12	0.21	0.68	0.28	0.43	0.26	0.93
64	0.47	1.27	0.20	0.56	1.08	1.01	0.23	0.65
65								
66	0.38	1.06	0.20	0.85	0.62	1.30	0.23	0.96
67					0.13	0.39	0.15	0.18

NOTE: * Please refer to Figures 25-29 for road overtopping point locations

Road Overtopping Point ID*	10% AEP				5% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
1								
2	2.45	1.34	0.41	0.37	3.15	1.24	0.48	0.38
3	0.20	0.66	0.17	1.43	0.29	0.59	0.20	1.53
4	3.32	0.29	0.24	0.74	3.35	0.28	0.29	0.79
5								
6	0.11	0.61	0.19	0.80	0.19	0.95	0.23	0.78
7								
8	3.93	0.00	0.40	0.09	3.93	0.00	0.40	0.12
9	1.76	1.24	0.42	0.47	2.12	0.97	0.51	0.50
10								
11	0.23	0.56	0.18	0.47	0.31	0.84	0.28	0.49
12	0.43	0.62	0.40	0.72	0.46	0.95	0.43	0.74
13								
14	1.82	1.59	0.79	0.53	2.07	1.53	1.00	0.55
15	0.02	0.19	0.15	0.87	0.06	0.29	0.15	0.91
16								
17								
18	0.26	0.61	0.30	0.48	0.31	0.92	0.35	0.50
19								
20	1.88	1.51	0.59	0.78	2.04	1.40	0.64	0.84
21								
22								
23	0.50	0.59	0.35	0.29	0.63	1.60	0.39	0.31
24	0.29	0.77	0.25	0.72	0.35	1.02	0.30	0.72
25	0.39	0.52	0.28	0.28	0.45	0.80	0.30	0.32
26	1.98	1.43	0.62	0.46	2.06	1.38	0.68	0.51
27	0.79	1.52	0.34	0.14	1.08	1.60	0.38	0.15
28	0.13	0.58	0.23	0.28	0.28	0.95	0.28	0.32
29	0.70	1.49	0.27	0.47	0.83	1.64	0.32	0.34
30	0.04	0.21	0.16	0.90	0.09	0.32	0.18	0.97

Road Overtopping Point ID*	10% AEP				5% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
31								
32	0.02	0.54	0.19	0.63	0.17	0.81	0.25	0.66
33	0.64	1.78	0.28	0.81	0.82	1.69	0.36	0.91
34	1.93	1.43	0.37	0.63	2.28	1.43	0.50	0.72
35	0.97	1.29	0.31	0.69	1.09	1.22	0.34	0.72
36	1.32	1.41	0.34	0.70	1.50	1.30	0.35	0.78
37	0.90	1.30	0.38	0.55	1.07	1.21	0.43	0.56
38								
39	1.50	1.52	0.60	0.43	1.78	1.41	0.65	0.45
40					0.12	0.39	0.19	1.07
41	3.74	0.78	0.78	0.27	3.76	0.72	0.85	0.28
42	0.38	0.63	0.22	0.75	0.42	0.90	0.25	0.78
43	0.78	1.29	0.32	1.03	1.18	1.38	0.34	1.03
44	1.46	1.45	0.40	0.30	1.81	1.36	0.43	0.35
45	0.62	1.27	0.26	0.47	1.11	1.48	0.29	0.50
46					0.00	0.00	0.17	1.46
47					0.20	0.41	0.16	0.95
48								
49	0.00	0.00	0.17	0.78	0.07	0.31	0.19	0.85
50	0.50	1.41	0.26	1.24	0.69	1.54	0.34	1.44
51	0.05	0.62	0.17	0.96	0.22	0.93	0.19	1.02
52					0.00	0.00	0.16	0.68
53								
54	0.25	0.64	0.23	1.23	0.29	1.06	0.25	1.43
55	0.43	1.24	0.25	0.76	0.70	1.15	0.28	0.89
56	0.19	0.61	0.26	1.19	0.29	0.94	0.27	1.21
57	0.05	0.17	0.20	1.18	0.05	0.25	0.25	1.20
58								
59								

Road Overtopping Point ID*	10% AEP				5% AEP			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
60								
61	0.08	0.34	0.18	1.17	0.22	0.60	0.22	1.21
62								
63	0.34	1.47	0.29	1.03	0.61	1.33	0.30	1.15
64	1.39	1.38	0.24	0.70	1.51	1.27	0.26	0.71
65								
66	0.94	1.34	0.25	1.06	1.17	1.24	0.26	1.12
67	0.19	0.50	0.17	0.23	0.26	0.79	0.19	0.26

Road Overtopping Point ID*	1% AEP				0.5%			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
1								
2	3.29	0.75	0.59	0.40	3.42	0.69	0.62	0.41
3	0.52	0.57	0.29	1.46	0.57	0.50	0.31	1.53
4	3.50	0.54	0.34	0.75	3.51	0.48	0.35	0.77
5	0.73	0.76	0.34	0.57	0.84	0.66	0.38	0.58
6	0.41	0.30	0.25	0.70	0.48	0.28	0.29	0.77
7								
8	3.93	0.00	0.41	0.18	3.93	0.00	0.42	0.19
9	2.87	1.78	0.74	0.48	3.15	1.78	0.78	0.51
10								
11	0.59	0.56	0.40	0.47	0.70	0.47	0.42	0.48
12	0.83	1.02	0.46	0.82	0.86	1.19	0.47	0.83
13	0.22	0.64	0.20	0.95	0.26	0.55	0.20	1.05
14	3.12	1.00	1.64	0.40	3.32	0.93	1.82	0.39
15	0.16	0.37	0.16	0.96	0.22	0.30	0.17	0.99
16								
17	2.43	0.76	0.60	0.97	2.74	0.75	0.61	1.03
18	0.94	0.34	0.40	0.49	1.10	0.30	0.42	0.51
19	0.44	0.63	0.22	0.68	0.63	1.71	0.25	0.69
20	3.25	0.76	0.71	0.97	3.53	0.34	0.87	1.02
21	0.02	0.07	0.16	0.80	0.15	0.64	0.18	0.82
22	0.45	0.31	0.17	1.15	0.48	0.28	0.18	1.21
23	1.19	1.42	0.43	0.28	1.40	1.31	0.44	0.31
24	0.74	1.48	0.36	0.78	0.83	1.88	0.38	0.80
25	0.73	0.33	0.32	0.34	0.74	0.28	0.32	0.36
26	3.22	0.63	0.80	0.55	3.47	0.61	0.83	0.57
27	2.14	1.40	0.47	0.17	2.31	1.31	0.50	0.19
28	0.38	0.42	0.32	0.25	0.52	0.38	0.32	0.28
29	1.89	1.45	0.42	0.31	2.09	1.32	0.45	0.33
30	0.28	0.43	0.20	1.03	0.34	0.39	0.21	1.08

Road Overtopping Point ID*	1% AEP				0.5%			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
31								
32	0.29	0.31	0.28	0.79	0.32	0.46	0.29	0.80
33	2.16	1.39	0.45	1.07	2.39	1.28	0.47	1.11
34	3.15	1.20	0.71	0.83	3.39	1.14	0.79	0.86
35	1.84	0.67	0.37	0.74	2.01	0.41	0.38	0.76
36	2.04	0.81	0.37	0.73	2.13	0.76	0.38	0.77
37	2.57	2.23	0.59	0.60	2.89	2.07	0.69	0.73
38	0.09	0.32	0.16	0.93	0.13	0.29	0.18	0.97
39	2.33	1.08	0.72	0.45	2.44	0.97	0.74	0.45
40	0.21	0.31	0.25	1.23	0.24	0.30	0.27	1.24
41	3.81	0.25	0.95	0.31	3.82	0.24	0.98	0.32
42	0.79	1.96	0.31	0.77	0.93	1.37	0.33	0.78
43	1.69	1.17	0.36	1.03	1.82	1.72	0.37	1.04
44	2.77	0.93	0.48	0.51	2.97	0.81	0.50	0.61
45	1.72	1.33	0.32	0.54	1.89	1.22	0.33	0.59
46	0.21	0.55	0.22	1.53	0.30	0.58	0.26	1.55
47	0.40	0.37	0.19	0.95	0.42	0.34	0.20	0.96
48								
49	0.30	0.42	0.21	1.03	0.39	0.34	0.23	1.10
50	2.61	1.72	0.43	1.30	2.74	1.29	0.46	1.37
51	0.41	0.45	0.22	1.11	0.46	0.43	0.23	1.11
52	0.26	0.45	0.19	0.78	0.35	0.55	0.20	0.84
53								
54	0.58	0.94	0.25	1.45	0.67	0.93	0.25	1.49
55	1.08	0.99	0.30	0.93	1.26	1.16	0.31	0.96
56	0.50	0.32	0.28	1.24	0.54	0.26	0.30	1.26
57	0.29	0.42	0.30	1.20	0.34	0.39	0.32	1.22
58					0.06	0.31	0.16	0.93
59								

Road Overtopping Point ID*	1% AEP				0.5%			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
60	0.03	0.24	0.16	1.59	0.09	0.51	0.18	1.65
61	0.47	0.46	0.26	1.20	0.54	0.42	0.27	1.20
62	0.36	0.79	0.21	0.86	0.53	0.77	0.24	0.96
63	1.07	1.14	0.31	1.20	1.17	1.03	0.32	1.26
64	2.08	0.85	0.27	0.72	2.18	0.83	0.28	0.74
65								
66	1.90	1.00	0.27	1.16	2.02	1.64	0.28	1.16
67	0.50	0.45	0.21	0.30	0.57	0.41	0.22	0.31

Road Overtopping Point ID*	0.2%				PMF			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
1					1.30	0.56	0.20	1.38
2	3.65	0.44	0.66	0.41	3.79	0.21	1.10	0.41
3	0.63	0.62	0.33	1.47	1.89	0.39	0.44	1.53
4	3.51	0.44	0.36	0.80	2.94	0.26	0.43	0.81
5	1.09	2.36	0.42	0.59	2.45	0.39	0.71	0.94
6	0.62	0.27	0.35	0.77	1.82	0.34	0.47	1.06
7					1.39	0.40	0.40	0.44
8	3.93	0.00	0.43	0.23	3.93	0.81	0.71	0.43
9	3.42	1.42	0.83	0.51	3.07	0.30	1.24	0.53
10	0.07	0.28	0.16	1.46	1.42	0.34	0.24	1.82
11	0.81	0.40	0.44	0.50	2.07	0.24	0.48	0.51
12	1.04	1.21	0.49	0.84	2.08	0.23	0.58	0.87
13	0.41	0.62	0.21	1.11	2.41	0.29	0.25	1.12
14	3.47	0.76	2.08	0.39	3.82	0.21	6.26	0.29
15	0.29	0.25	0.17	1.03	1.59	0.31	0.20	1.18
16					0.74	0.46	0.17	1.01
17	3.03	0.27	0.62	1.02	2.28	0.22	0.72	1.10
18	1.86	1.98	0.46	0.56	3.78	0.22	1.95	0.85
19	1.20	1.64	0.29	0.69	3.73	0.30	0.91	1.20
20	3.71	0.29	1.13	1.08	3.81	0.23	5.31	1.21
21	0.29	0.62	0.23	0.84	1.83	0.40	0.52	1.03
22	0.54	0.87	0.19	1.26	1.85	0.41	0.25	1.70
23	1.57	1.26	0.45	0.36	2.11	0.23	0.50	0.40
24	1.49	1.37	0.41	0.84	2.26	0.38	0.81	0.92
25	1.09	1.12	0.33	0.37	2.01	0.37	0.38	0.44
26	3.74	0.44	0.89	0.62	3.79	0.23	4.97	1.01
27	2.57	1.13	0.53	0.22	2.83	0.26	1.00	0.30
28	0.61	0.30	0.32	0.35	1.84	0.23	0.36	0.44
29	2.30	1.23	0.49	0.35	2.68	0.26	0.98	0.43
30	0.44	0.31	0.22	1.09	1.76	0.31	0.28	1.26

Road Overtopping Point ID*	0.2%				PMF			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
31	0.05	0.29	0.16	0.78	1.52	0.32	0.27	0.53
32	0.37	0.36	0.31	0.78	1.75	0.25	0.36	1.31
33	2.70	1.14	0.52	1.17	3.73	0.28	3.42	1.67
34	3.74	1.02	0.92	0.91	3.82	0.23	1.84	1.04
35	2.19	0.34	0.40	0.79	2.06	0.25	0.53	0.88
36	2.35	0.98	0.40	0.73	2.21	0.30	0.53	0.93
37	3.22	1.83	0.80	0.84	3.87	0.25	1.85	1.36
38	0.20	0.54	0.20	1.08	1.69	0.39	0.32	1.41
39	2.56	0.84	0.77	0.49	2.41	0.21	0.88	0.52
40	0.33	0.44	0.30	1.28	1.80	0.32	0.42	1.92
41	3.84	0.22	1.02	0.35	3.84	0.19	1.46	0.41
42	1.36	1.23	0.36	0.79	2.05	0.30	0.47	0.80
43	2.02	1.09	0.38	1.03	2.03	0.25	0.45	0.98
44	3.23	0.72	0.54	0.43	3.79	0.22	2.49	1.43
45	2.14	1.10	0.34	0.67	2.25	0.26	0.48	1.14
46	0.41	0.49	0.29	1.57	1.83	0.26	0.43	1.72
47	0.54	0.36	0.22	1.00	1.80	0.29	0.30	1.01
48					0.69	1.72	0.56	0.22
49	0.46	0.40	0.25	1.18	2.39	0.26	0.41	1.31
50	2.85	1.21	0.50	1.51	3.78	0.23	0.94	1.80
51	0.56	0.34	0.25	1.19	2.38	0.28	0.75	1.50
52	0.49	0.48	0.25	1.02	1.85	0.34	0.35	1.55
53					0.46	1.78	0.33	0.16
54	0.94	1.18	0.26	1.59	1.88	0.26	0.28	1.70
55	1.58	1.09	0.32	1.01	1.96	0.26	0.37	1.28
56	0.59	0.26	0.30	1.28	1.84	0.25	0.33	1.49
57	0.43	0.43	0.35	1.26	1.80	0.25	0.43	1.30
58	0.16	0.43	0.17	0.99	1.59	0.38	0.24	1.23
59					1.38	0.52	0.27	0.97

Road Overtopping Point ID*	0.2%				PMF			
	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity	Duration Cut (hours)	Time Road First Cut (hours)	Peak Depth	Peak Velocity
60	0.18	0.36	0.19	1.70	1.60	0.41	0.24	1.92
61	0.62	0.38	0.29	1.20	1.91	0.26	0.37	1.42
62	1.19	2.08	0.28	1.09	3.61	0.42	0.92	1.83
63	1.49	0.81	0.33	1.27	1.96	0.25	0.39	1.29
64	2.48	0.99	0.29	0.73	2.04	0.27	0.33	0.79
65					1.63	0.58	0.36	0.13
66	2.34	0.99	0.30	1.17	2.03	0.26	0.36	1.13
67	0.65	1.64	0.24	0.33	1.85	0.27	0.36	0.41

Appendix D

Critical facility Assessment

Facility Type		Address		ID*	Significantly Impacted in Any Floods?	5%AEP								
						Is access to/from facility cut?	Amount of time before access is cut (hours)	Amount of time after access is cut that facility is isolated (hours)	Time at which inundation of facility first commences (hours)	Total duration of inundation of facility (hours)	Maximum depth of inundation across facility (m)	Maximum flow velocity across facility (m/s)	Maximum flood hazard	Above Floor Flooding Depth (m)
Critical Facilities	Fire Stations	Fire and Rescue NSW St. Marys Fire Station	1 Marsden Rd, St Marys NSW 2760		No				1.14	1.26	0.30	1.92	H1	
	Infrastructure	Pump station	76A Christie St, St Marys NSW 2760		No	Yes	0.99	1.21						
		Electricity Substation	94/98 Desborough Rd, Colyton NSW 2760		No									
Vulnerable Facilities	Pre-Schools / Child Care	Young Explorers Early Learning Centre	143 Adelaide St, St Marys NSW 2760	1	PMF				1.62	1.37	0.34	1.52	H2	
		Evergreen Early Education Centres	68 Sydney St, St Marys NSW 2760	2	PMF									
		First Memories Early Learning Centre	54 Ball St, Colyton NSW 2760	3	No	Yes	0.54	0.23						
		Five Sense Childcare	14 Bennett Rd, Colyton NSW 2760	4	PMF	Yes	0.22	0.02	1.61	1.67	0.20	0.53	H1	
		Ridge-Ee-Didge Child Care Centre	17 Woodland Ave, Oxley Park NSW 2760	5	No									
		Keymer Child Care Centre	27-29 Bentley Rd, Colyton NSW 2760	6	No	Yes	0.46	0.19	0.83	2.84	0.22	0.50	H1	
		Busy Bees Long Day Child Care Centre	146 Glossop St, St Marys NSW 2760	7	No									
		St Marys Blinky Bills Preschool	263 Great Western Hwy, St Marys NSW 2760	15	No									
	Primary Education	Oxley Park Public School	114-130 Adelaide St, St Mary NSW 2760	16	PMF									
		Bennett Road Public School	100-114 Bennett Rd, Colyton NSW 2760	17					1.55	2.91	0.39	1.14	H2	
	Secondary Education	Colyton High School	37-53 Carpenter St, Colyton NSW 2760	14	No									
	Churches	St Marys Presbyterian Church	14 Marsden Rd, St Marys NSW 2760	8	No				0.86	0.18	0.19	1.33	H1	
		St Marys Samoan Seventh Day Adventist Church	253 Great Western Hwy, St Marys NSW 2760	9	No									
		St Mary's District Baptist Church	253 Great Western Hwy, St Marys NSW 2759	10	No									
		St. Demetrios' Greek Orthodox Church	47 Hobart St, St Marys NSW 2760	11	No									
		Salvation Army	Morris St, St Marys NSW 2760	12	No									
		Colyton Church	100/114 Bennett Rd, Colyton NSW 2760	13	No				1.28	0.45	0.30	1.65	H2	

NOTE: * please refer to Figure 4 for location of facilities

Facility Type		Address		ID*	Significantly Impacted in Any Floods?	1%AEP								
						Is access to/from facility cut?	Amount of time before access is cut (hours)	Amount of time after access is cut that facility is isolated (hours)	Time at which inundation of facility first commences (hours)	Total duration of inundation of facility (hours)	Maximum depth of inundation across facility (m)	Maximum flow velocity across facility (m/s)	Maximum flood hazard	Above Floor Flooding Depth (m)
Critical Facilities	Fire Stations	Fire and Rescue NSW St. Marys Fire Station	1 Marsden Rd, St Marys NSW 2760		No				0.99	1.73	0.30	1.89	H1	
	Infrastructure	Pump station	76A Christie St, St Marys NSW 2760		No	Yes	0.27	1.79			0.00	0.02	H1	
		Electricity Substation	94/98 Desborough Rd, Colyton NSW 2760		No									
Vulnerable Facilities	Pre-Schools / Child Care	Young Explorers Early Learning Centre	143 Adelaide St, St Marys NSW 2760	1	PMF				1.35	1.86	0.38	1.66	H2	
		Evergreen Early Education Centres	68 Sydney St, St Marys NSW 2760	2	PMF				2.66	2.19	0.50	0.69	H3	
		First Memories Early Learning Centre	54 Ball St, Colyton NSW 2760	3	No	Yes	0.48	0.26	0.44	0.16	0.18	0.29	H1	
		Five Sense Childcare	14 Bennett Rd, Colyton NSW 2760	4	PMF	Yes	0.56	0.47	1.27	2.50	0.29	0.70	H1	
		Ridge-Ee-Didge Child Care Centre	17 Woodland Ave, Oxley Park NSW 2760	5	No									
		Keymer Child Care Centre	27-29 Bentley Rd, Colyton NSW 2760	6	No	Yes	0.45	0.49	0.71	3.04	0.23	0.52	H1	
		Busy Bees Long Day Child Care Centre	146 Glossop St, St Marys NSW 2760	7	No									
		St Marys Blinky Bills Preschool	263 Great Western Hwy, St Marys NSW 2760	15	No									
	Primary Education	Oxley Park Public School	114-130 Adelaide St, St Mary NSW 2760	16	PMF				2.58	2.94	0.43	1.05	H2	
		Bennett Road Public School	100-114 Bennett Rd, Colyton NSW 2760	17					1.15	3.01	0.40	1.12	H2	
	Secondary Education	Colyton High School	37-53 Carpenter St, Colyton NSW 2760	14	No				2.77	3.96	0.14	0.64	H1	
	Churches	St Marys Presbyterian Church	14 Marsden Rd, St Marys NSW 2760	8	No				0.46	1.65	0.19	1.43	H1	
		St Marys Samoan Seventh Day Adventist Church	253 Great Western Hwy, St Marys NSW 2760	9	No									
		St Mary's District Baptist Church	253 Great Western Hwy, St Marys NSW 2759	10	No									
		St. Demetrios' Greek Orthodox Church	47 Hobart St, St Marys NSW 2760	11	No									
		Salvation Army	Morris St, St Marys NSW 2760	12	No									
		Colyton Church	100/114 Bennett Rd, Colyton NSW 2760	13	No				1.20	0.77	0.31	1.67	H2	

NOTE: * please refer to Figure 4 for location of facilities

Facility Type		Address		ID*	Significantly Impacted in Any Floods?	PMF								
						Is access to/from facility cut?	Amount of time before access is cut (hours)	Amount of time after access is cut that facility is isolated (hours)	Time at which inundation of facility first commences (hours)	Total duration of inundation of facility (hours)	Maximum depth of inundation across facility (m)	Maximum flow velocity across facility (m/s)	Maximum flood hazard	Above Floor Flooding Depth (m)
Critical Facilities	Fire Stations	Fire and Rescue NSW St. Marys Fire Station	1 Marsden Rd, St Marys NSW 2760		No				0.40	1.90	0.37	1.91	H2	
	Infrastructure	Pump station	76A Christie St, St Marys NSW 2760		No	Yes	0.19	3.38	1.14	3.18	0.19	0.81	H1	
		Electricity Substation	94/98 Desborough Rd, Colyton NSW 2760		No									
Vulnerable Facilities	Pre-Schools / Child Care	Young Explorers Early Learning Centre	143 Adelaide St, St Marys NSW 2760	1	PMF				0.50	2.30	0.57	2.25	H5	
		Evergreen Early Education Centres	68 Sydney St, St Marys NSW 2760	2	PMF	Yes	0.21	3.78	1.49	3.63	2.24	1.88	H5	1.33
		First Memories Early Learning Centre	54 Ball St, Colyton NSW 2760	3	No	Yes	0.24	1.85	0.64	1.84	0.23	0.92	H1	
		Five Sense Childcare	14 Bennett Rd, Colyton NSW 2760	4	PMF	Yes	0.35	2.13	0.57	3.13	0.85	2.00	H5	
		Ridge-Ee-Didge Child Care Centre	17 Woodland Ave, Oxley Park NSW 2760	5	No									
		Keymer Child Care Centre	27-29 Bentley Rd, Colyton NSW 2760	6	No	Yes	0.26	1.92	0.40	2.17	0.29	0.74	H1	
		Busy Bees Long Day Child Care Centre	146 Glossop St, St Marys NSW 2760	7	No									
		St Marys Blinky Bills Preschool	263 Great Western Hwy, St Marys NSW 2760	15	No									
	Primary Education	Oxley Park Public School	114-130 Adelaide St, St Mary NSW 2760	16	PMF	Yes	0.18	3.81	1.22	3.81	1.43	3.58	H6	0.94
		Bennett Road Public School	100-114 Bennett Rd, Colyton NSW 2760	17					0.29	2.14	0.43	1.16	H2	
	Secondary Education	Colyton High School	37-53 Carpenter St, Colyton NSW 2760	14	No				0.98	3.96	0.28	0.96	H1	0.24
	Churches	St Marys Presbyterian Church	14 Marsden Rd, St Marys NSW 2760	8	No				0.45	3.71	0.29	1.59	H1	
		St Marys Samoan Seventh Day Adventist Church	253 Great Western Hwy, St Marys NSW 2760	9	No									
		St Mary's District Baptist Church	253 Great Western Hwy, St Marys NSW 2759	10	No						0.01	0.22	H1	
		St. Demetrios' Greek Orthodox Church	47 Hobart St, St Marys NSW 2760	11	No									
		Salvation Army	Morris St, St Marys NSW 2760	12	No									
		Colyton Church	100/114 Bennett Rd, Colyton NSW 2760	13	No				0.39	1.99	0.39	1.64	H2	

NOTE: * please refer to Figure 4 for location of facilities

APPENDIX E

FUTURE CATCHMENT DEVELOPMENT DIFFERENCE MAPS

<u>Future Catchment Development</u>

Figure E1: 5% AEP Flood Level Difference Map

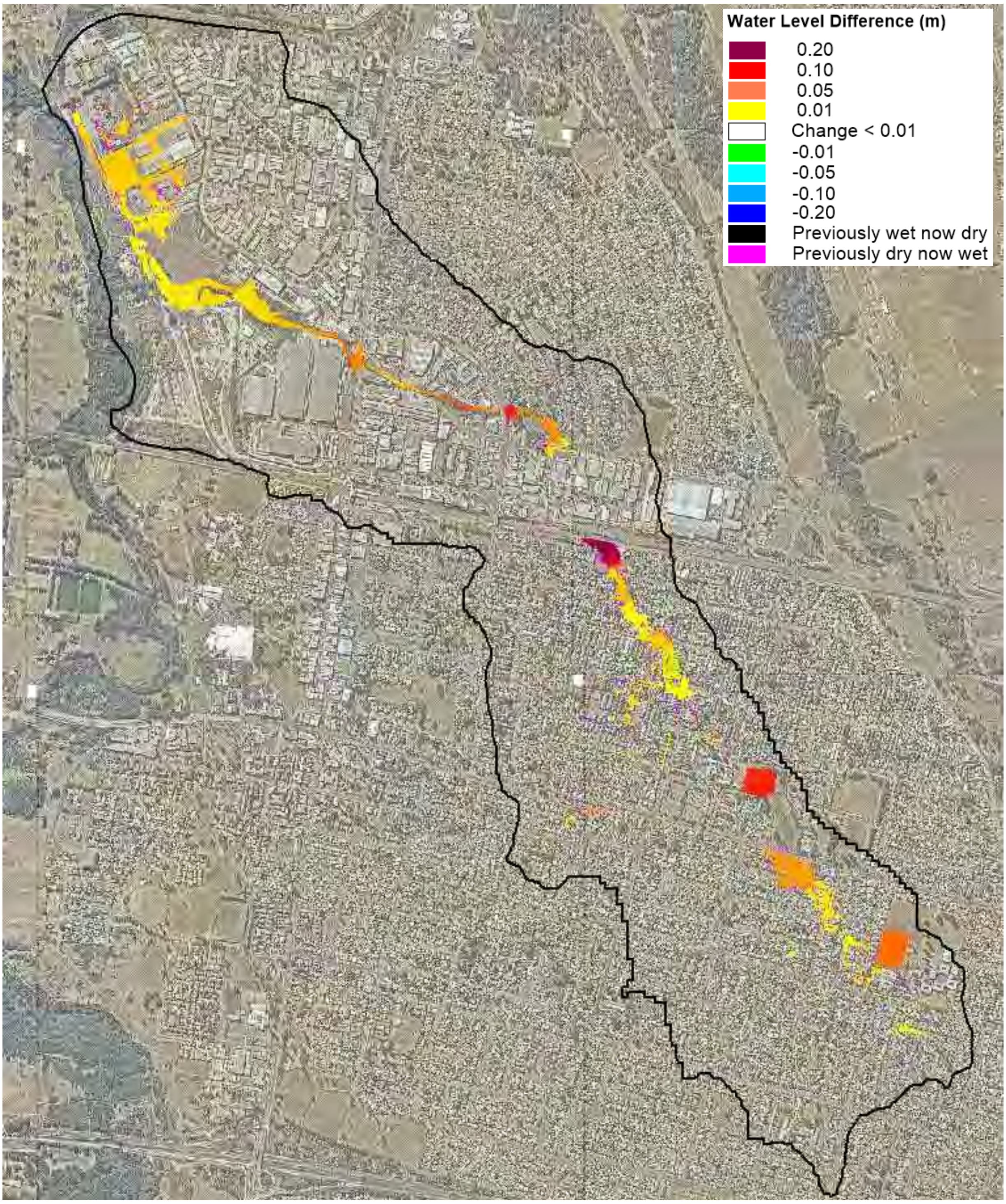


Figure E2: 1% AEP Flood Level Difference Map

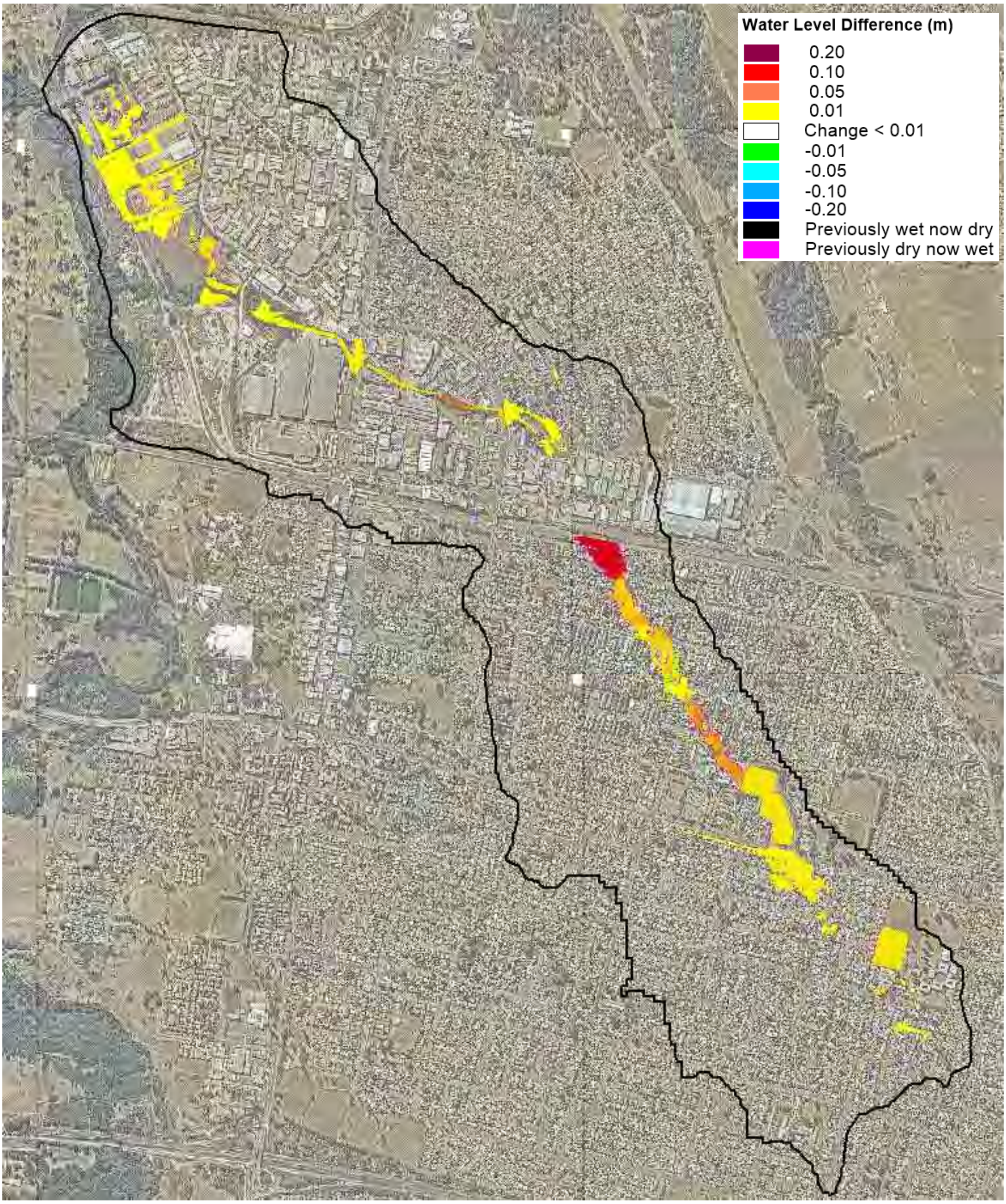


Figure E3: 0.5% AEP Flood Level Difference Map

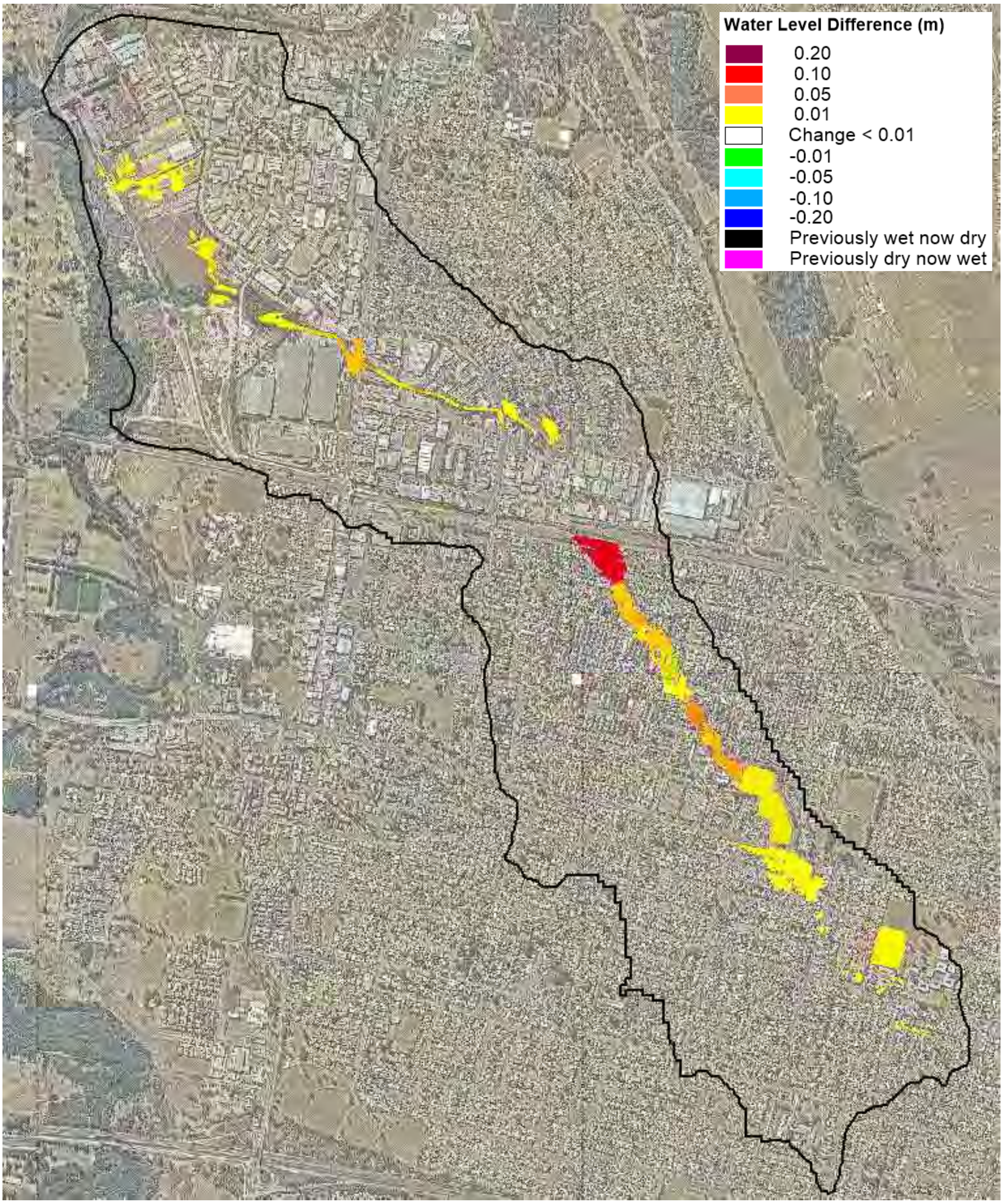


Figure E4: 0.2% AEP Flood Level Difference Map

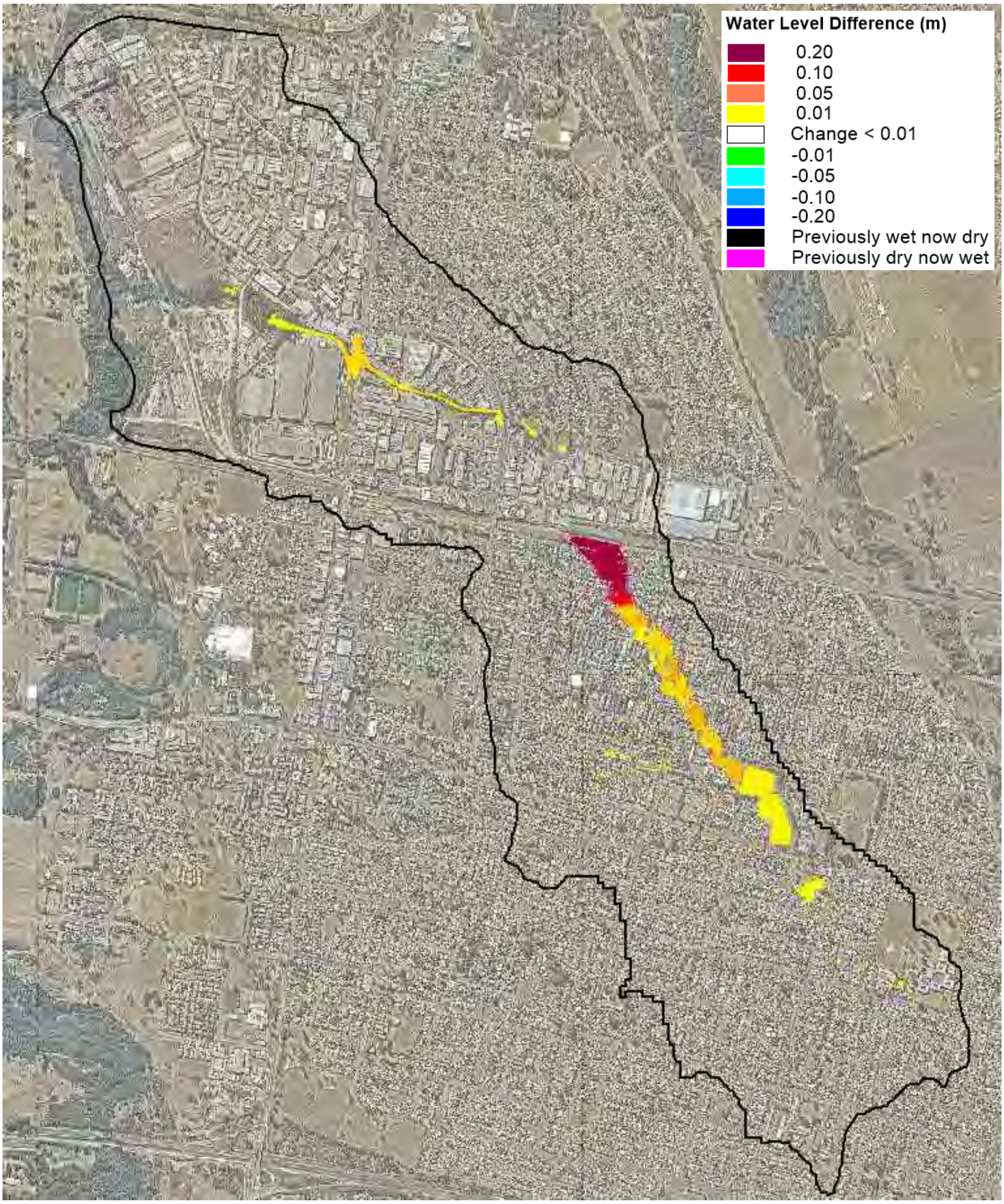
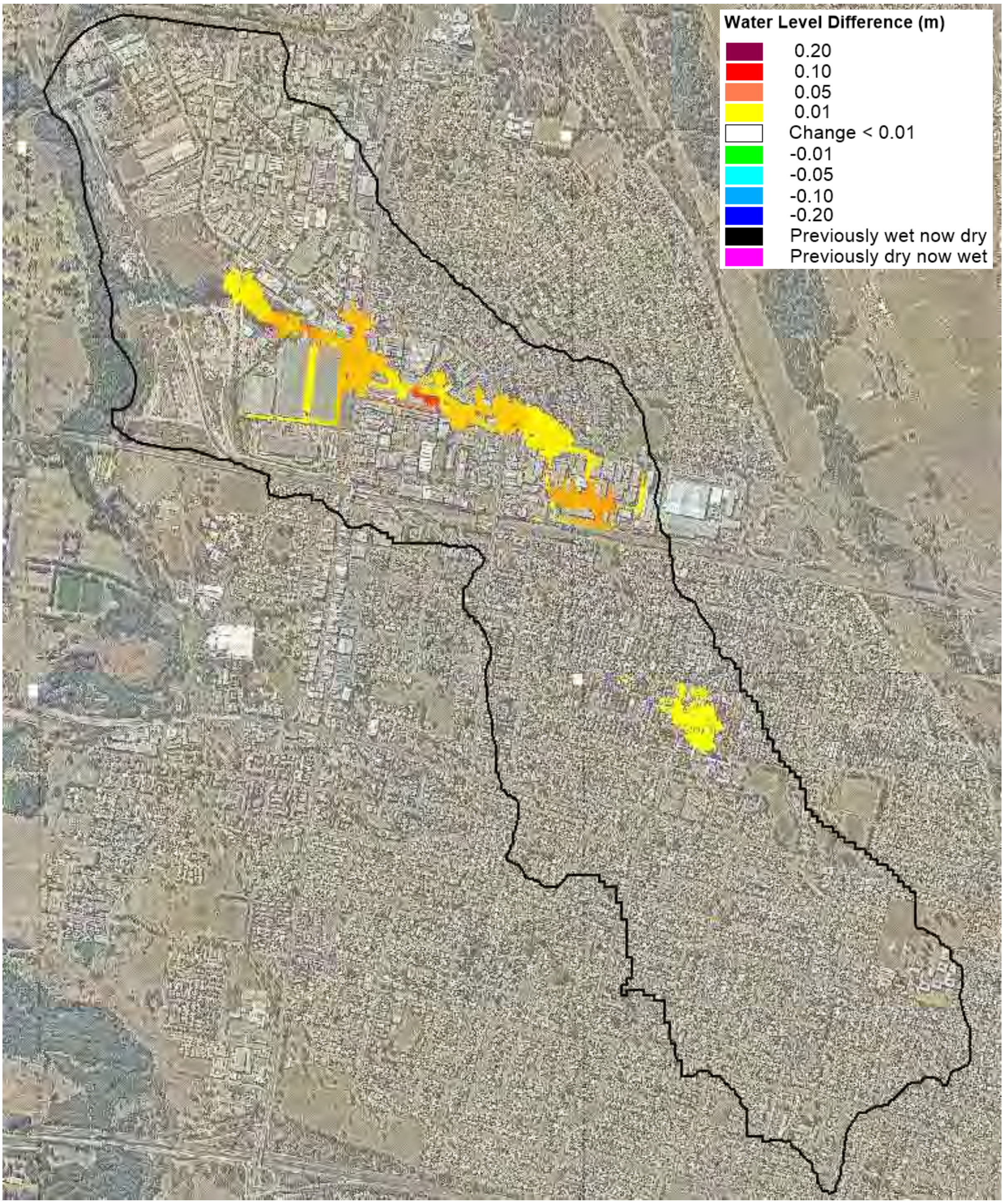


Figure E5: PMF Flood Level Difference Map



APPENDIX F

FLOOD PLANNING LEVEL ASSESSMENT

Catchment Simulation Solutions

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F1 Flood Planning Level Assessment

Flood Planning Levels (FPLs) are an important tool in the management of flood risk. FPLs are typically derived by adding a freeboard to the "planning" flood. The suitability of Council's current planning flood and freeboard in managing the existing and future flood risk across the full range of possible floods is discussed below.

For the purposes of this assessment, the following definitions of flooding are provided:

- **Mainstream Flooding**: inundation associated with defined creeks/watercourses overtopping their banks. This includes the main Little Creek channel extending from Kurrajong Road down to South Creek.
- **Overland Flooding**: inundation of normally dry areas that are located away from defined channels and watercourses. Overland flooding is most common in "built up" areas and is typically associated with the capacity of the local stormwater/drainage system being exceeded.

1.1 Suitability of Planning Flood

A major consideration of this study involved the determination of an appropriate flood planning level for the Little Creek catchment. Therefore, a review of the suitability of the current standard outlined in the Penrith City Council LEP 2010 was completed as part of the current study.

The NSW Government's *'Floodplain Development Manual'* (2005) states that "…FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific ARIs) and freeboards selected for floodplain risk management purposes, as determined in risk management studies and incorporated in risk management plans." The Manual also notes that it is generally not feasible or justifiable to adopt the PMF as the planning flood.

The Penrith City Council LEP 2010 defines the flood planning level (FPL) across the Penrith City Council LGA as "the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard". This wording is taken from the standard LEP template for NSW and effectively applies a "one size fits all" approach for defining the flood planning level across the LGA.

Using the 1% AEP flood for deriving flood planning levels is common across Australia. It is considered to provide a reasonable compromise between the risk associated with occupation of flood liable areas and the value that this occupation provides in most areas.

Although this approach is easy to apply and understand, it fails to consider the variable flood characteristics that are evident across the LGA (including areas subject to relatively shallow overland flow) and does not follow the merits-based approach that is encouraged in the *'Floodplain Development Manual'* (NSW Government, 2005). More specifically, the Manual advocates consideration of a range of factors in determining the most appropriate flood planning event. These include the risk to life across the full range of design flood events, flood behaviour, social issues, land availability/needs, duration of flooding, the value of land, existing level of development and the current FPL for planning purposes.

As noted in Section 9.2.1 of the report, there are some areas located beyond the "standard" flood planning area (1% AEP level + 0.5 metres freeboard) that are predicted to be exposed to a significant flood hazard/risk during the PMF. More specifically, some properties located outside of the FPA between Adelaide Street and Hobart Street would likely be exposed to a flood hazard within the building of greater than H4 which may be sufficient to result in loss of life. Accordingly, for these properties, the standard FPL definition provided in the Penrith LEP may not be sufficient to adequately manage the full range of potential flood risks.

Furthermore, development types whose occupants may be particularly vulnerable to floodwaters such as childcare centres and aged care facilities would likely benefit from being located outside of the floodplain completely/located above the peak level of the PMF. However, it is considered that controls such as minimum floor levels for vulnerable and critical facilities can best be managed through the Development Control Plan rather than expanding the flood planning area to be based on, for example, the PMF plus freeboard.

However, the fact remains that there are areas located beyond the current FPA that would be exposed to an unacceptable hazard during the PMF if evacuation is not completed. Therefore, although the adoption of the 1% AEP flood as the planning flood is likely to manage the flood risk across most areas during the full range of floods, it may not be suitable across all areas.

Therefore, strong consideration should be given to providing more flexibility in the definition of the planning flood in the LEP where a significant hazard is predicted above the FPL/outside of the FPA. Although basing the FPA on the PMF is not considered necessary and would not be consistent with the merits-based approach across much of the catchment, it is suggested that properties exposed to ≥H4 hazard during the PMF be included as a minimum within the FPA.

As outlined in the following sections, adoption of the 0.5% AEP event as the "planning flood" may be a suitable means of overcoming the additional uncertainty associated with design flood level estimates in the Hobart Street area. At the same time, it would also elevate the FPL sufficiently to include most (but not all) of the properties exposed to ≥H4 hazard during the PMF within the FPA.

Potential modifications to the LEP and DCP to allow more flexibility in the definition of the FPL/FPA is provided in Section 9.2 of the report.

1.2 Suitability of Freeboard

At the other end of spectrum, there may be a case to support adopting a freeboard that is lower than 0.5 metres across some areas. The freeboard is, in essence, a "factor of safety" that is used to cater for uncertainties in the estimation of the planning flood (1% AEP flood). The uncertainties that are accounted for in the freeboard include:

- Modelling uncertainty (i.e., uncertainty associated with modelling inputs such as topography, Manning's "n" roughness and potential blockage of stormwater pits).
- Factors that can't be explicitly represented in the modelling (e.g., parked cars, flow obstructions from debris mobilised during a flood: refer **Plate F1**).

Modelling uncertainty can be quantified by undertaking various simulations and using the outputs from these simulations to prepare a "confidence limit" layer. This "confidence limit" layer effectively quantifies how much confidence we can place in the "base" 1% AEP flood levels at various locations and therefore, how much of an allowance needs to be incorporated within the freeboard to ensure we can cater for this modelling uncertainty. A 99% confidence interval layer was prepared based on the results of the sensitivity simulations completed as part *the 'Little Creek Catchment Overland Flow Flood Study'* (2017) and is provided in **Plate F2**. Yellow colours indicate small confidence limits (i.e., high confidence in results) and magenta colours indicate higher confidence limits (i.e., less confidence in results).

Plate F1 Examples of urban flow obstructions that cannot be explicitly represented in computer model

Plate F2 shows that across the upper catchment, where overland flooding is the dominant flooding mechanism, the model confidence is generally high (i.e., < 0.10 metres confidence). The confidence limits increase to more than 0.1 metres in areas along and adjacent to Little Creek. The area of highest uncertainty is immediately upstream of the railway line (e.g., Hobart Street), where the modelling confidence is predicted to exceed 0.5 metres. The higher uncertainty at this location is driven by the significant impact that blockage of rainfall culvert/inlet can have on 1% AEP flood levels across this area.

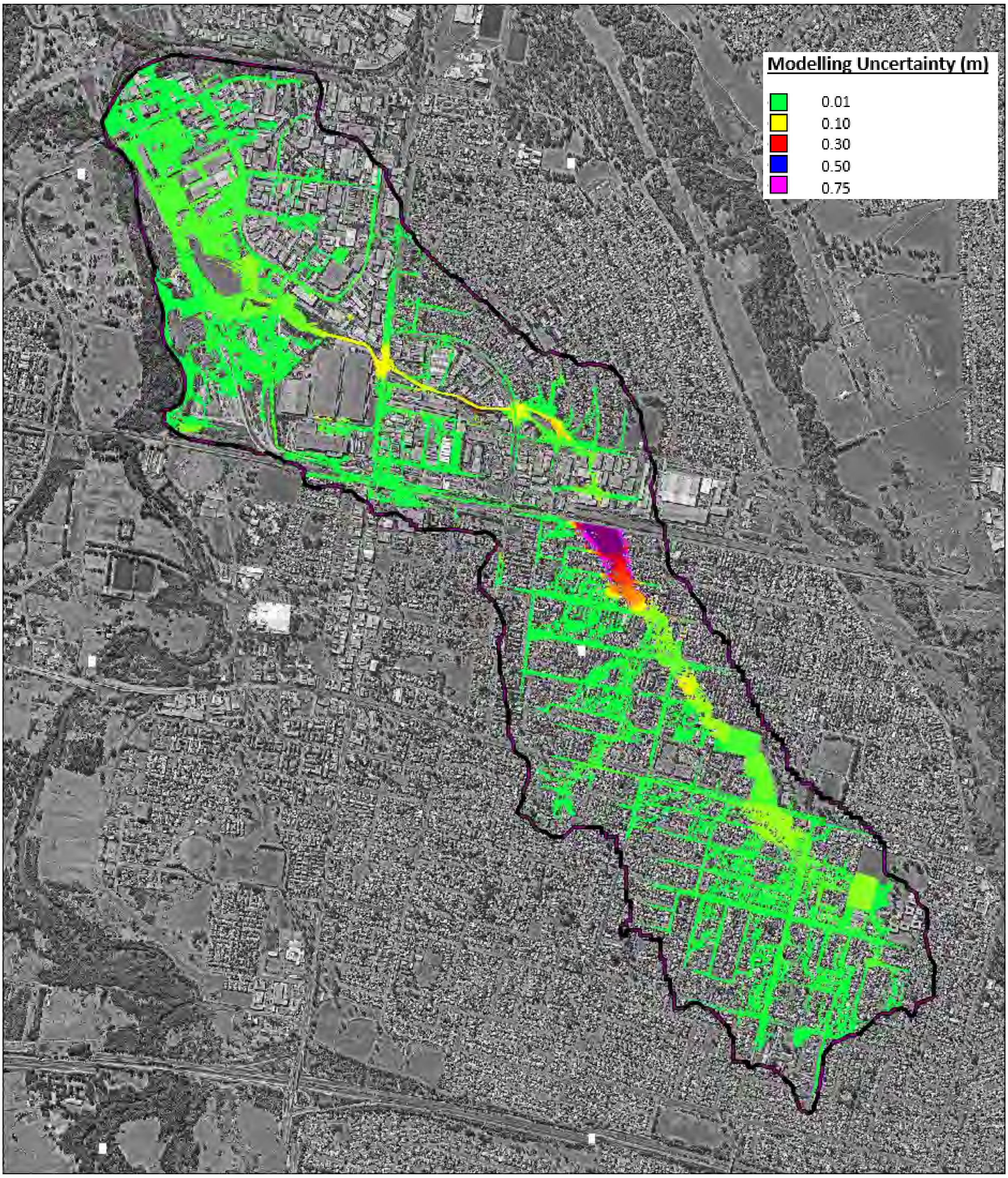


Plate F2 99% confidence interval grid for 1% AEP water levels (quantifies modelling uncertainty) based on 2017 flood study results

Unfortunately, it is more difficult to quantify an allowance for factors that cannot be explicitly represented by the model such as parked cars (refer **Plate F1**). However, it is argued that the potential impact of these "other" factors is proportional to the flow velocity. That is, there is a greater potential for a flow obstruction to alter flood behaviour in areas of faster moving water relative to areas of "ponded" water. Therefore, a greater allowance should be made for "other" factors in areas of fast-moving water.

The impacts of flow obstructions that are commonly encountered in flood modelling (e.g., bridge piers) is quantified by multiplying an empirical loss coefficient (K) by the velocity head ($v^2/2g$) at a particular location. The velocity head can be calculated at any location using the computer model outputs for the 1% AEP flood. The appropriate loss coefficient will vary depending on the location and the type of obstruction. Unfortunately, loss coefficients are not readily documented for the types of flow obstructions typically encountered in an urban environment where above ground flow is the predominant conveyance mechanism. Furthermore, Franz and Melching (1997) note that flow through an abrupt transition is a complex phenomenon and evaluation of hydraulic losses is difficult. It also notes that the adoption of a loss coefficient / velocity head to calculate hydraulic losses is an approximation only, however there is currently no suitable replacement or alternative method that is readily available. Therefore, the velocity head approach was employed as it is considered to be a useful appraisal of potential freeboard factors.

The *'HEC-RAS River Analysis System - Hydraulic Reference Manual'* (US Army Corp of Engineers, 2016) notes that loss coefficients will not exceed 1.0 and will generally be higher for subcritical flows than supercritical flows. It goes on to note that:

- A contraction/expansion coefficient of 0.8 is generally appropriate for "abrupt" transitions in cross-sectional area where subcritical flow is evident.
- A contraction/expansion coefficient of 0.2 is generally appropriate for "abrupt" transitions in cross-sectional area where supercritical flow is evident.

It was considered that the types of flow obstructions shown in **Plate F1** would represent an "abrupt" change in flow conveyance so the above loss coefficients were considered appropriate to use to assist in quantifying the potential uncertainty in flood level estimates associated with these "other" factors. The following steps were subsequently employed for developing a layer describing the potential variation in 1% AEP water levels associated with "other" factors.

- Calculate the 1% AEP Froude number and velocity head at each model grid cell;
- If the Froude number is greater than 1 (i.e., supercritical flow), multiply the velocity head by a loss coefficient of 0.2; and,
- If the Froude number is less than 1 (i.e., subcritical flow), multiply the velocity head by a loss coefficient of 0.8.

However, the above approach did introduce some discontinuities in areas that transitioned between supercritical and subcritical flow. Therefore, the approach was refined so that the loss coefficient was linearly transitioned between 0.8 and 0.2 when the Froude number was between 0.9 and 1.1.

The resulting water level uncertainty grid associated with "other" factors is shown in Plate F3. It shows that the uncertainty associated with other factors is predicted to be less than 0.1 metres across most of the catchment. However, there are areas located within and adjacent to Little Creek where "other" uncertainty is predicted to exceed 0.3 metres.

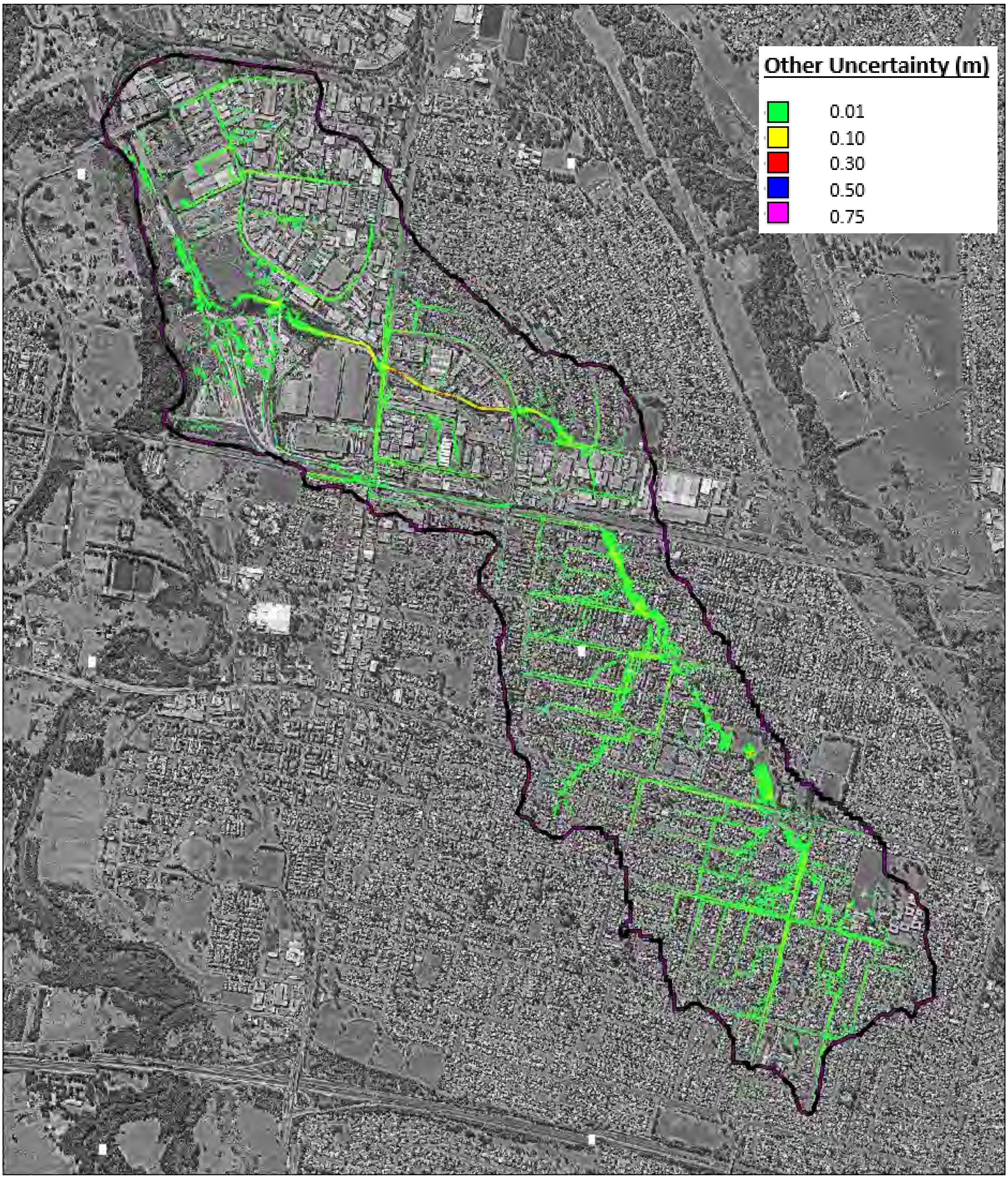


Plate F3 Water level uncertainty grid for other factors that cannot be represented in flood model

The impact of wave action cannot be calculated using model results. However, across the study area, the wind fetch length is small, water depths are generally shallow and any boats or cars travelling through floodwaters would typically be operating at low speeds. As shown in **Plate F4**, under these circumstances, the waves generated by cars are unlikely to exceed

0.15 metres (the license plate height for this car is 0.11m) and dissipate significantly in height by the time the wave reaches the edges of the road (i.e., most likely less than 0.1 metres is height). Therefore, a wave action allowance of 0.15 metres is considerd to be a sufficient allowance.

Plate F4 Example of cars driving through flood waters and generating waves

The following approach was then used to calculate the minimum required freeboard for each location in the catchment:

- The modelling confidence limit grid was added to the uncertainty grid for 'other' factors to represent the total water level uncertainty at a particular location.
- An additional 0.15 metre allowance was adopted to account for wave action for all locations. This was added to the uncertainty grid calculated in the previous step to determine the minimum required freeboard at all locations

The resulting minimum freeboard grid is shown in Plate F5. It shows that the minimum freeboard across much of the upper catchment (i.e., overland flooding areas) is less than 0.3 metres (i.e., yellow & orange areas). However, the minimum freeboard requirement exceeds 0.3 metres and approaches 0.5 metres across a number of areas (i.e., red & blue areas). This includes all areas located adjacent to the main Little Creek channel.

Plate F5 also shows that the main overland flow path located between Brisbane Street and Hobart Street would require more than a 0.3 metre freeboard. In fact, much of this area would require more than a 0.5 metre freeboard to suitably account for uncertainty in the 1% AEP flood estimates (a 0.6 metre freeboard would be required across this area).

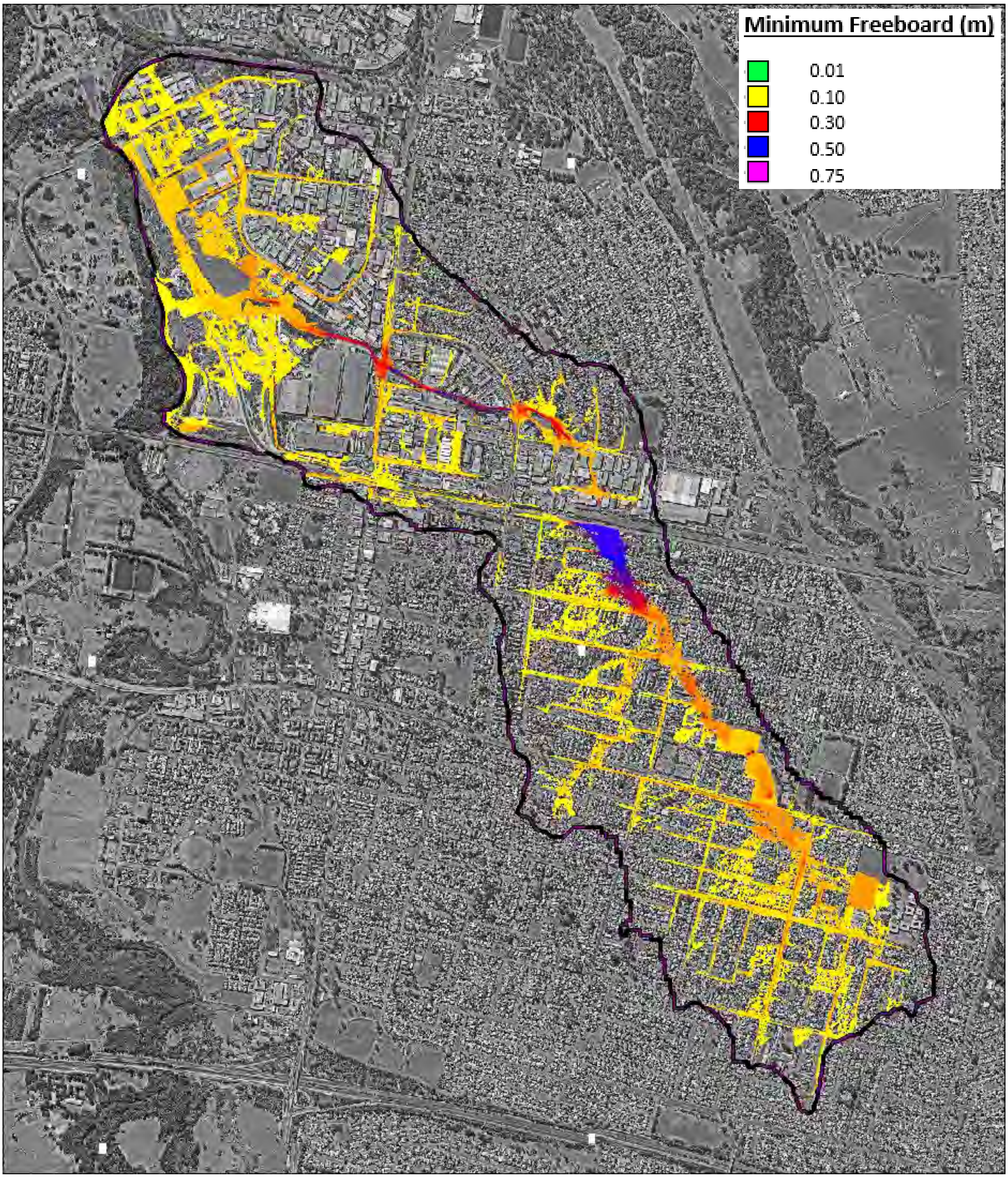


Plate F5 Minimum required freeboard grid that considers model uncertainty as well as other uncertainty that cannot be explicitly represented in the modelling.

Therefore, a 0.5 metre freeboard is considered sufficient to cater for uncertainty across most sections of the catchment, but a higher freeboard may be desirable across the area contained between Hobart Street and Brisbane Street.

As discussed in Section 1.1 of this appendix, consideration could be given to adopting a design flood larger than the 1% AEP event as the "planning flood" in the Brisbane Street to Hobart Street area. This could potentially replace the need for a marginally higher freeboard in this same area. For example, the 0.5% AEP flood level is around 0.2 metres higher than the 1% AEP flood level in Hobart Street. Therefore, adopting the 0.5% AEP event as the planning flood would be a way of accounting for the additional flood risk in the Hobart Street area while also accounting for the greater uncertainty in flood level estimates and not needing to vary the standard 0.5 metre freeboard.

Therefore, it is suggested that consideration be given to adopting the 0.5% AEP event as the planning flood in the Brisbane Street to Hobart Street area and retaining the standard 0.5 metre freeboard.

APPENDIX G

COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
FM1 - Great Western Highway Culvert Upgrade

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$80,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	5,000	$5,000
	1.02	QA & ITP	Lump sum	1	10,000	$10,000
	1.03	Management of Traffic	Lump sum	1	60,000	$60,000
	1.04	OHS&R Plan	Lump sum	1	5,000	$5,000
2		**SERVICES RELOCATION**				**$70,000**
	2.01	Sydney Water sewer and water main relocation	lin.m	60	1,000	$60,000
	2.02	NBN cable relocation	lin.m	10	1,000	$10,000
3		**EARTHWORKS**				**$147,160**
	3.01	break up and remove bitumen paving with basecourse under	m^3	300	73	$21,960
	3.02	excavation and backfilling of trench within roadway for box culverts	m^3	500	212.00	$106,000
	3.03	composite roadway surface reforming	m	40	480.00	$19,200
4		**DRAINAGE INFRASTRUCTURE**				**$163,870**
	4.01	Inlet with grates - includes square precast concrete pit and Class D cast iron gully grating	No.	1	1,650	$1,650
	4.02	1.5w x 1.8h box culverts - 3 off, aproximate 20m length each	m	60	2,090	$125,400
	4.03	headwall to suit culvert in reinforced concrete	m^3	70	526	$36,820
	4.04	scour protection - riprap upstream and downstream using rock filling	m^3	35	93	$3,255
					SUBTOTAL	**$461,030**
5		**ENGINEERING DESIGN**				**$46,103**
	5.01	Preparation of engineering design plans (10% of implementation cost)				$46,103
6		**PROJECT MANAGEMENT**				**$23,052**
	6.01	Supervision, Project Management etc (5% of implementation cost)				$23,052
7		**OTHER CONTINGENCIES**				**$92,206**
	7.01	General (20% of implementation cost)				$92,206
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$620,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
FM2 - Hobart Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$70,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	5,000	$5,000
	1.02	QA & ITP	Lump sum	1	10,000	$10,000
	1.03	Rail Management	Lump sum	1	30,000	$30,000
	1.04	Management of Traffic	Lump sum	1	20,000	$20,000
	1.05	OHS&R Plan	Lump sum	1	5,000	$5,000
2		**SERVICES RELOCATION**				**$110,000**
	2.01	Sydney Water sewer main relocation	lin.m	100	1,000	$100,000
	2.02	NBN cable relocation	lin.m	10	1,000	$10,000
3		**EARTHWORKS**				**$21,504**
	3.01	Excavate roadway, base and ground for coring machine access point (4 access points) including backfilling - soft rock	m^3	120	73	$8,784
	3.02	Excavate and backfill for new 1.35m diameter pipe	m^3	60	212	$12,720
4		**CULVERT TUNNEL JACKING/BORING**				**$360,000**
	4.01	Tunnel Coring under Railway line and lining including site establishment costs, microtunnelling, insertion of jacking culverts/lining and connections	m	40	9,000	$360,000
5		**DRAINAGE INFRASTRUCTURE**				**$149,280**
	5.01	Inlet with grates - includes square precast concrete pit and Class D cast iron gully grating	No.	4	1,650	$6,600
	5.02	2.7w x 2.1h box culvert - 2off, approximate 20m length each	m	40	3,270	$130,800
	5.03	New 1.35m RCP pipe, 12m long	m	12	990	$11,880
6		**RAIL WORKS**				**$50,000**
	6.01	Safety mechanism and formwork to support railway during work	Lump Sum	1	50,000	$50,000
					SUBTOTAL	**$760,784**
7		**ENGINEERING DESIGN**				**$76,078**
	7.01	Preparation of engineering design plans (10% of implementation cost)				$76,078
8		**PROJECT MANAGEMENT**				**$38,039**
	8.01	Supervision, Project Management etc (5% of implementation cost)				$38,039
9		**OTHER CONTINGENCIES**				**$152,157**
	9.01	General (20% of implementation cost)				$152,157
		TOTAL at 7% NPV (Rounded to nearest $10,000)				**$1,030,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
FM3 - Glossop Street culvert upgrade	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$50,950**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	Management of Traffic	Lump sum	1	40,000	$40,000
	1.05	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.06	Erosion and Sediment control - Geotextile Silt Fence around site	m	300	16.50	$4,950
2		**SERVICES RELOCATION**				**$40,000**
	2.01	Sydney Water sewer main relocation	lin.m	10	1,000	$10,000
	2.02	NBN cable relocation	lin.m	10	1,000	$10,000
	2.03	Jemena network conduit relocation	lin.m	10	1,000	$10,000
	2.04	Endeavour Energy	lin.m	10	1,000	$10,000
3		**EARTHWORKS**				**$182,370**
	3.01	break up and remove bitumen paving with basecourse under	m^2	600	3.45	$2,070
	3.02	excavation and backfilling of trench within roadway for 3 off 4.2w x 1.2h box culverts	m^3	600	212.00	$127,200
	3.03	dewatering shallow system	m^2	600	56.50	$33,900
	3.04	composite roadway surface reforming	m	40	480.00	$19,200
4		**DRAINAGE INFRASTRUCTURE**				**$213,637**
	4.01	4.2w x 1.2h box culverts - 3off, approximate 7m length each	m	21	8,553	$179,605
	4.02	headwall to suit culvert in reinforced concrete	m^3	10	445	$4,272
	4.03	Scour protection rip-rap - River gravel filling	m^3	320	93	$29,760
					SUBTOTAL	**$486,957**
5		**ENGINEERING DESIGN**				**$48,696**
	5.01	Preparation of engineering design plans (10% of implementation cost)				$48,696
6		**PROJECT MANAGEMENT**				**$24,348**
	6.01	Supervision, Project Management etc (5% of implementation cost)				$24,348
7		**OTHER CONTINGENCIES**				**$97,391**
	7.01	General (20% of implementation cost)				$97,391
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$660,000**

Catchment Simulation Solutions

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$46,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	Management of Traffic	Lump sum	1	40,000	$40,000
	1.05	OHS&R Plan	Lump sum	1	1,000	$1,000
2		**SERVICES RELOCATION**				**$308,000**
	2.01	Sydney Water sewer main relocation	lin.m	100	1,000.00	$100,000
	2.02	NBN cable relocation	lin.m	100	1,000.00	$100,000
	2.03	Jemena network conduit relocation	lin.m	100	1,000.00	$100,000
	2.04	Endeavour Energy	lin.m	8	1,000.00	$8,000
3		**EARTHWORKS**				**$127,200**
	3.01	Excavate roadway, base and ground along culvert alignment (including backfilling/compaction) (Excavate trench >2m deep in soft rock)	m^3	600	212.00	$127,200
4		**DRAINAGE INFRASTRUCTURE**				**$472,475**
	4.01	0.45m RCP Class 2, 2off, approximate 5m length each	m	10	192	$1,838
	4.02	0.75m RCP Class 2, 2off, approximate 32.5m length each	m	65	386	$25,090
	4.03	0.90m RCP Class 2, 1off, approximate 10m length each	m	10	565	$5,650
	4.04	1.2m RCP Class 2, 8off, approximate 525m length total	m	525	807	$423,675
	4.05	Grated pit - includes square precast concrete pit and Class D cast iron gully grating	No	10	1,806	$18,060
					SUBTOTAL	**$953,675**
5		**ENGINEERING DESIGN**				**$95,368**
	5.01	Preparation of engineering design plans (10% of implementation cost)				$95,368
6		**PROJECT MANAGEMENT**				**$47,684**
	6.01	Supervision, Project Management etc (5% of implementation cost)				$47,684
7		**OTHER CONTINGENCIES**				**$190,735**
	7.01	General (20% of implementation cost)				$190,735
		TOTAL at 7% NPV (Rounded to nearest $10,000)				**$1,290,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM5 - Glossop Street stormwater upgrade

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$50,950**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	Management of Traffic	Lump sum	1	40,000	$40,000
	1.05	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.06	Erosion and Sediment control - Geotextile Silt Fence around site	m	300	16.50	$4,950
2		**SERVICES RELOCATION**				**$40,000**
	2.01	Sydney Water sewer main relocation	lin.m	10	1,000	$10,000
	2.02	NBN cable relocation	lin.m	10	1,000	$10,000
	2.03	Jemena network conduit relocation	lin.m	10	1,000	$10,000
	2.04	Endeavour Energy	lin.m	10	1,000	$10,000
3		**EARTHWORKS**				**$363,860**
	3.01	break up and remove bitumen paving with basecourse under	m^2	800	3.45	$2,760
	3.02	excavation and backfilling of trench within roadway for upgraded pipe system	m^3	1000	212.00	$212,000
	3.03	dewatering shallow system	m^2	600	56.50	$33,900
	3.04	composite roadway surface reforming	m	240	480.00	$115,200
4		**DRAINAGE INFRASTRUCTURE**				**$114,351**
	4.01	0.6m diameter reinforced concrete pipe - 125m	m	125	231	$28,875
	4.02	0.9m diameter reinforced concrete pipe - 105m	m	105	492	$51,660
	4.03	headwall to suit pipe outlets in reinforced concrete	m^3	150	93	$13,950
	4.04	grated pit - includes square precast concrete pit and Class D cast iron gully grating	no	11	1,806	$19,866
					SUBTOTAL	**$569,161**
5		**ENGINEERING DESIGN**				**$56,916**
	5.01	Preparation of engineering design plans (10% of implementation cost)				$56,916
6		**PROJECT MANAGEMENT**				**$28,458**
	6.01	Supervision, Project Management etc (5% of implementation cost)				$28,458
7		**OTHER CONTINGENCIES**				**$113,832**
	7.01	General (20% of implementation cost)				$113,832
		TOTAL at 7% NPV (Rounded to nearest $10,000)				**$770,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
FM7 - Colyton Park Basin	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$20,850**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	900	16.50	$14,850
2		**EARTHWORKS AND LEVEE WALL**				**$677,907**
	2.01	Excavate over site to reduce levels - in clay	m^3	22155	29.40	$651,357
	2.02	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000.00	$2,000
	2.03	Excavate and backfill for new 0.15m diameter pipe	m^3	11	212.00	$2,290
	2.04	Excavate and backfill for new 0.525 diameter pipe	m^3	105	212.00	$22,260
3		**DRAINAGE INFRASTRUCTURE**				**$3,402**
	3.01	0.15m RCP (Class 2) - 1off, approximate 18m length	m	18	100	$1,800
	3.02	Headwall replacement	No	2	801	$1,602
4		**LANDSCAPING**				**$7,040**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m^2	22000	0.32	$7,040
5		**ENGINEERING CERTIFICATION**				**$310,000**
	5.01	Dam break assessment and monthly inspections over 50 year life cycle	no	1	310,000	$310,000
					SUBTOTAL	**$1,019,199**
6		**ENGINEERING DESIGN**				**$101,920**
	6.01	Preparation of engineering design plans (10% of implementation cost)				$101,920
7		**PROJECT MANAGEMENT**				**$50,960**
	7.01	Supervision, Project Management etc (5% of implementation cost)				$50,960
8		**OTHER CONTINGENCIES**				**$203,840**
	8.01	General (20% of implementation cost)				$203,840
		TOTAL at 7% NPV (Rounded to nearest $10,000)				**$1,380,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM8 - Oxley Park Basin

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$20,850**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	900	16.50	$14,850
2		**SERVICES RELOCATION**				**$10,000**
	2.01	Sydney Water sewer main investigation and relocation	lin.m	10	1,000	$10,000
3		**EARTHWORKS AND LEVEE WALL**				**$320,041**
	3.01	Excavate site to lower basin	m^3	8000	30.80	$246,400
	3.02	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000.00	$2,000
	3.03	Constructing wall and spillway from clay (including consolidation)	m^3	492	86.00	$42,312
	3.04	Fill material for construction of basin wall	m^3	192	60.90	$11,693
	3.05	Labour forming sloping edge to basin crest/spillway	m	240	2.65	$636
	3.06	Rock scour protection around spillway	m^3	200	85.00	$17,000
4		**DRAINAGE INFRASTRUCTURE**				**$14,442**
	4.01	1m RCP (Class 2) - 1off, approximate 15m length	m	15	856	$12,840
	4.02	Headwall replacement	No	2	801	$1,602
5		**LANDSCAPING**				**$9,000**
	5.01	Turf, layer, rolled and watered for 2 weeks along basin crest and other disturbed area	m^2	1000	9.00	$9,000
6		**ENGINEERING CERTIFICATION**				**$310,000**
	6.01	Dam break assessment and monthly inspections over 50 year life cycle	no	1	310,000	$310,000
					SUBTOTAL	**$684,333**
7		**ENGINEERING DESIGN**				**$68,433**
	7.01	Preparation of engineering design plans (10% of implementation cost)				$68,433
8		**PROJECT MANAGEMENT**				**$34,217**
	8.01	Supervision, Project Management etc (5% of implementation cost)				$34,217
9		**OTHER CONTINGENCIES**				**$136,867**
	9.01	General (20% of implementation cost)				$136,867
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$920,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM9 - Great Western Highway Median Modification

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$28,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	10000	$10,000
	1.02	OHS&R Plan	Lump sum	1	8000	$8,000
	1.03	Traffic/Pedestrian Management	Lump sum	1	10000	$10,000
2		**EARTHWORKS**				**$65,700**
	2.01	Excavate median, roadway, base and ground in median footprint (Excavate trench >2m deep in soft rock)	m^3	300	219	$65,700
3		**ROAD WORKS**				**$47,060**
	3.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering removed median	m^2	1300	36.2	$47,060
					SUBTOTAL	**$140,760**
4		**ENGINEERING DESIGN**				**$14,076**
	4.01	Preparation of engineering design plans (10%)				$14,076
5		**PROJECT MANAGEMENT**				**$14,076**
	5.01	Supervision, Project Management etc (10%)				$14,076
6		**OTHER CONTINGENCIES**				**$28,152**
	6.01	General (20%)				$28,152
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$200,000**

APPENDIX H

QUALITATIVE ASSESSMENT OF OPTIONS

TABLE H1 - Raw score of flood modification options for Little Creek Catchment

	OPTION	Weighted Score							
		Impact on flood behaviour or flood risk	Technical feasibility	Environmental Impacts	Economic Benefit	Cost	Impacts on Emergency Response	Community Support	Score
Detention Basins									
1	Colyton High School Basin modifications	2	1	0	1	-1	2	1	6
2	Great Western Highway above ground Detention Basin	2	-1	0	2	-1	1	1	4
3	Great Western Highway below ground Detention tank	1	-1	0	2	-2	1	1	2
4	Oxley Park Basin modifications (between Great Western Highway and Adelaide Street)	1	2	0	1	0	2	1	7
5	Brisbane Street Detention Basin	1	0	0	1	-1	1	1	3
6	Hobart Street Detention Basin	1	1	0	1	-2	0	1	2
Culverts/Bridges Modifications									
7	Great Western Highway culvert upgrade	2	1	0	2	0	2	2	9
8	Railway/Hobart Street culvert upgrade	2	1	0	2	-1	2	2	8
9	Glossop Street culvert upgrade	1	-1	0	1	1	2	2	6
10	Forrester Road culvert upgrade	2	-1	0	0	0	1	2	4
Stormwater Modification									
11	Kent Place to Bennet Road stormwater upgrades	1	0	0	1	0	0	2	4
12	Bennet Road to Great Western Highway stormwater upgrades	1	0	0	1	0	1	2	5
13	Canberra Street / Sydney Street stormwater upgrades	2	0	0	0	0	1	2	5
14	Great Western Highway to Canberra Street stormwater upgrades	1	-2	0	1	-1	1	2	2
15	Brisbane Street to Hobart Street stormwater upgrades	1	0	0	1	-1	1	2	4
16	Plasser Crescent stormwater upgrades	1	0	0	0	0	1	2	4
17	Kurrajong Road stormwater upgrades	1	0	0	1	0	1	2	5
18	Glossop Street stormwater upgrades	2	0	0	1	1	1	2	7
19	Forrester Road stormwater upgrades	1	0	0	0	1	1	2	5
20	Lee Holm Drive stormwater upgrades	2	-1	0	2	0	1	2	6
21	Stormwater flood gates	0	1	0	1	2	0	2	6
22	Hobart Street Upgrade inlet capcity of existing culvert under railway	1	-1	0	1	-1	2	2	4
Channel Modification									
23	Bennet Road Swale	1	1	-1	1	1	0	1	4
24	Oxley Park Public School Overland flow path	1	-1	0	1	0	0	1	2
25	Vegetation removal/maintenance	1	-1	-1	1	1	0	2	3
26	Lee Holm Drive Swale	1	-2	0	1	1	0	1	2
Levee Modifications									
27	Industrial levee	0	2	-1	1	-1	1	-1	1
Miscellaneous Modifications									
28	Great Western Highway Median Modification	2	2	0	2	0	2	2	10
29	Open fencing	1	2	0	1	2	0	0	6
Evacuation Route Upgrades									
30	Great Western Highway upgrade	2	-2	0	2	-1	2	2	5
31	Glossop Street upgrade	1	0	0	1	0	2	2	6
32	Lee Holm Road upgrade	2	-1	0	1	0	2	1	5
33	**Flood warning system**	0	-1	0	0	1	1	2	3

TABLE H2 - Weighted score of flood modification options for Little Creek Catchment

		Weighted Score							
OPTIONS		Impact on flood behaviour or flood risk	Technical feasibility	Environmental Impacts	Economic Benefit	Cost	Impacts on Emergency Response	Community Support	Score
Detention Basins									
1	Colyton High School Basin modifications	0.5	0.15	0	0.1	-0.1	0.2	0.2	1.05
2	Great Western Highway above ground Detention Basin	0.5	-0.15	0	0.2	-0.1	0.1	0.2	0.75
3	Great Western Highway below ground Detention tank	0.25	-0.15	0	0.2	-0.2	0.1	0.2	0.4
4	Oxley Park Basin modifications (between Great Western Highway and Adelaide Street)	0.25	0.3	0	0.1	0	0.2	0.2	1.05
5	Brisbane Street Detention Basin	0.25	0	0	0.1	-0.1	0.1	0.2	0.55
6	Hobart Street Detention Basin	0.25	0.15	0	0.1	-0.2	0	0.2	0.5
Culverts/Bridges Modifications									
7	Great Western Highway culvert upgrade	0.5	0.15	0	0.2	0	0.2	0.4	1.45
8	Railway/Hobart Street culvert upgrade	0.5	0.15	0	0.2	-0.1	0.2	0.4	1.35
9	Glossop Street culvert upgrade	0.25	-0.15	0	0.1	0.1	0.2	0.4	0.9
10	Forrester Road culvert upgrade	0.5	-0.15	0	0	0	0.1	0.4	0.85
Stormwater Modification									
11	Kent Place to Bennet Road stormwater upgrades	0.25	0	0	0.1	0	0	0.4	0.75
12	Bennet Road to Great Western Highway stormwater upgrades	0.25	0	0	0.1	0	0.1	0.4	0.85
13	Canberra Street / Sydney Street stormwater upgrades	0.5	0	0	0	0	0.1	0.4	1
14	Great Western Highway to Canberra Street stormwater upgrades	0.25	-0.3	0	0.1	-0.1	0.1	0.4	0.45
15	Brisbane Street to Hobart Street stormwater upgrades	0.25	0	0	0.1	-0.1	0.1	0.4	0.75
16	Plasser Crescent stormwater upgrades	0.25	0	0	0	0	0.1	0.4	0.75
17	Kurrajong Road stormwater upgrades	0.25	0	0	0.1	0	0.1	0.4	0.85
18	Glossop Street stormwater upgrades	0.5	0	0	0.1	0.1	0.1	0.4	1.2
19	Forrester Road stormwater upgrades	0.25	0	0	0	0.1	0.1	0.4	0.85
20	Lee Holm Drive stormwater upgrades	0.5	-0.15	0	0.2	0	0.1	0.4	1.05
21	Stormwater flood gates	0	0.15	0	0.1	0.2	0	0.4	0.85
	Hobart Street Upgrade inlet capcity of existing culvert under railway	0.25	-0.15	0	0.1	-0.1	0.2	0.4	0.7
Channel Modification									
22	Bennet Road Swale	0.25	0.15	-0.1	0.1	0.1	0	0.2	0.7
23	Oxley Park Public School Overland flow path	0.25	-0.15	0	0.1	0	0	0.2	0.4
24	Vegetation removal/maintenance	0.25	-0.15	-0.1	0.1	0.1	0	0.4	0.6
25	Lee Holm Drive Swale	0.25	-0.3	0	0.1	0.1	0	0.2	0.35
Levee Modifications									
26	Industrial levee	0	0.3	-0.1	0.1	-0.1	0.1	-0.2	0.1
Miscellaneous Modifications									
27	Great Western Highway Median Modification	0.5	0.3	0	0.2	0	0.2	0.4	1.6
28	Open fencing	0.25	0.3	0	0.1	0.2	0	0	0.85
Evacuation Route Upgrades									
29	Great Western Highway upgrade	0.5	-0.3	0	0.2	-0.1	0.2	0.4	0.9
30	Glossop Street upgrade	0.25	0	0	0.1	0	0.2	0.4	0.95
31	Lee Holm Road upgrade	0.5	-0.15	0	0.1	0	0.2	0.2	0.85
32	**Flood warning system**	0	-0.15	0	0	0.1	0.1	0.4	0.45

Table H3 - Ranking of FM options for Little Creek catchment with and without weightings applied

Rank Raw	Option Name	Rank weighted	Option Name
1	Great Western Highway Median Modification	1	Great Western Highway Median Modification
2	Great Western Highway culvert upgrade	2	Great Western Highway culvert upgrade
3	Railway/Hobart Street culvert upgrade	3	Railway/Hobart Street culvert upgrade
=4	Oxley Park Basin modifications (between Great Western Highway and Adelaide Street)	4	Glossop Street stormwater upgrades
	Glossop Street stormwater upgrades	=5	Colyton High School Basin modifications
=6	Colyton High School Basin modifications		Oxley Park Basin modifications (between Great Western Highway and Adelaide Street)
	Glossop Street culvert upgrade	7	Lee Holm Drive stormwater upgrades
	Lee Holm Drive stormwater upgrades	8	Canberra Street / Sydney Street stormwater upgrades
	Stormwater flood gates	9	Glossop Street upgrade
	Open fencing	10	Great Western Highway upgrade
	Glossop Street upgrade	11	Glossop Street culvert upgrade
=12	Bennet Road to Great Western Highway stormwater upgrades	=12	Stormwater flood gates
	Bennet Road to Great Western Highway stormwater upgrades		Open fencing
	Canberra Street / Sydney Street stormwater upgrades	=14	Forrester Road culvert upgrade
	Kurrajong Road stormwater upgrades		Bennet Road to Great Western Highway stormwater upgrades
	Forrester Road stormwater upgrades		Kurrajong Road stormwater upgrades
	Bennet Road to Great Western Highway stormwater upgrades		Forrester Road stormwater upgrades
=18	Great Western Highway above ground Detention Basin		Lee Holm Road upgrade
	Forrester Road culvert upgrade	=19	Great Western Highway above ground Detention Basin
	Kent Place to Bennet Road stormwater upgrades		Kent Place to Bennet Road stormwater upgrades
	Brisbane Street to Hobart Street stormwater upgrades		Brisbane Street to Hobart Street stormwater upgrades
	Plasser Crescent stormwater upgrades		Plasser Crescent stormwater upgrades

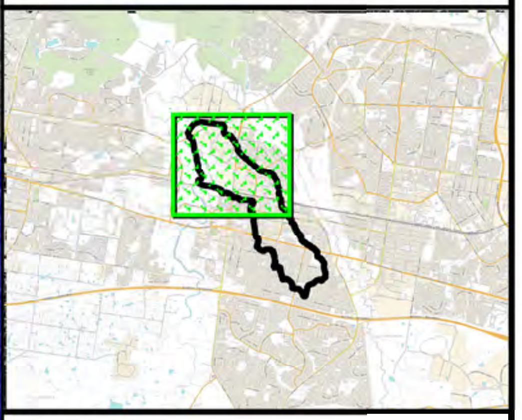
	Hobart Street Upgrade inlet capacity of existing culvert under railway	=23	Hobart Street Upgrade inlet capcity of existing culvert under railway
	Bennet Road Swale		Bennet Road Swale
=25	Brisbane Street Detention Basin	25	Vegetation removal/maintenance
	Vegetation removal/maintenance	26	Brisbane Street Detention Basin
	Brisbane Street Detention Basin	27	Hobart Street Detention Basin
=28	Great Western Highway below ground Detention tank	28	Great Western Highway to Canberra Street stormwater upgrades
	Hobart Street Detention Basin	29	Flood warning system
	Great Western Highway to Canberra Street stormwater upgrades	=30	Great Western Highway below ground Detention tank
	Oxley Park Public School Overland flow path		Oxley Park Public School Overland flow path
	Lee Holm Drive Swale	32	Lee Holm Drive Swale
33	Industrial levee	33	Industrial levee

APPENDIX I

SOUTH CREEK AND HAWKESBURY-NEPEAN RIVER INUNDATION MAPS

PENRITH CITY COUNCIL

Little Creek Catchment Floodplain Risk Management Study and Plan



LEGEND

Catchment Boundary

South Creek 0.2% AEP Extent
Please refer to 'South Creek Floodplain Risk Management Study' (Advisian, 2020) for more information

Notes:

N W E S

Scale 1:9,000 (at A3)

0 0.25 0.5 Km

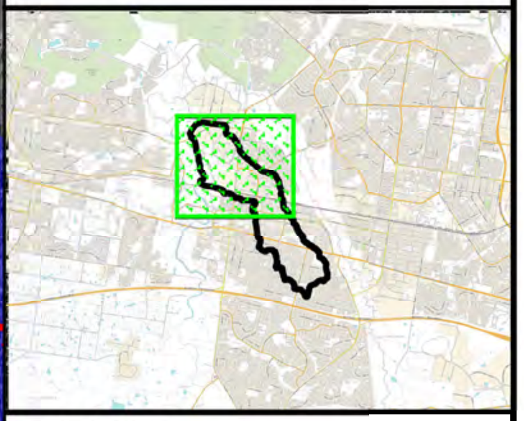
Figure I1
South Creek Inundation Extent for the 0.2% AEP Flood

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Figure I1 South Creek Inundation Extent for the 0.2% AEP Flood.wor

PENRITH CITY COUNCIL

Little Creek Catchment Floodplain Risk Management Study and Plan



LEGEND

- Catchment Boundary
- Hawkesbury-Nepean PMF extent. Please refer to 'Hawkesbury-Nepean Valley Regional Flood Study' (WMAwater,2019) for more information
- South Creek PMF Extent. Please refer to 'South Creek Floodplain Risk Management Study' (Advisian, 2020) for more information

Notes:

N
W E
S

Scale 1:9,000 (at A3)

0 0.25 0.5 Km

Figure I2
South Creek and Hawkesbury-Nepean Inundation Extent for the PMF

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Figure I2 South Creek and Hawkesbury-Nepean Inundation Extent for PMF.wor

APPENDIX J

ARR2019 ASSESSMENT

1.1 Introduction

The following appendix describe the inputs and methodology that was employed to develop updated design flood estimates for the Little Creek catchment. The design flood estimates were developed based on *'Australian Rainfall and Runoff: A Guide to Flood Estimation'* (Ball et al, 2019) (ARR2019).

1.2 Hydrology

1.2.1 Rainfall

Point design rainfall depths were downloaded from the Bureau of Meteorology's IFD webpage for a range of storm frequencies and durations. A copy of the design rainfall depths are provided in **Table 1**.

Table 1 Design Rainfall Depths

DURATION	**Average Rainfall Depth** (mm)								
	0.5EY	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMP**
10 min	13.8	17.4	20.8	24.2	28.8	32.3	35	39.5	N/A
15 min	17.2	21.7	26.0	30.3	36	40.5	43.8	49.5	N/A
20 min	19.7	24.9	29.8	34.7	41.2	46.3	50.1	56.7	N/A
25 mins	21.6	27.2	32.6	37.9	45.1	50.6	54.9	62.2	N/A
30 min	23.2	29.1	34.9	40.5	48.2	54.2	58.8	66.6	230
45 min	26.7	33.3	39.8	46.2	54.9	61.8	67.2	76.2	291
1 hour	29.3	36.3	43.3	50.2	59.7	67.3	73.2	82.9	339
1.5 hour	33.2	40.8	48.5	56.2	66.9	75.5	82.1	93.0	387
2 hours	36.3	44.3	52.6	61	72.8	82.2	89.3	101	432
3 hours	41.5	50.3	59.7	69.2	82.7	93.6	101	115	485
4.5 hours	47.9	57.9	68.7	79.9	95.6	108	117	132	N/A
6 hours	53.3	64.7	76.8	89.5	107	122	131	148	605
9 hours	62.8	76.7	91.3	107	128	145	156	176	N/A
12 hours	70.8	87.1	104	122	147	166	179	202	N/A
24 hours	94.7	120	145	171	206	233	252	286	N/A
48 hours	123	160	196	233	279	315	360	416	N/A
72 hours	138	182	225	268	320	360	404	462	N/A

NOTE: N/A indicates a design rainfall is not available for the nominated storm duration

Probable Maximum Precipitation (PMP) depth estimates were not re-extracted as the PMP procedures have not been revised as part of the ARR2019 updates. However, the PMP depths are included in **Table 1** for comparison purposes.

1.2.2 Areal Reduction Factors

The design rainfall intensities presented in the preceding section are only applicable for catchment areas of up to 1 km^2. Therefore, ARR2019 includes areal reduction factors that recognise that there is unlikely to be a uniformly high rainfall intensity across all sections of large catchments.

The primary input variable to calculate the areal reduction factors is the contributing catchment area. A review of the subcatchment areas was completed and determined that most subcatchments located south of the railway line (i.e., the most problematic section of the catchment) have a contributing upstream catchment of less than 1 km^2 (approximately 96% of the catchment draining to the railway has a contributing catchment area of less than 1 km^2). Therefore, application of no areal reductions would be appropriate for approximately 96% of the study area located south of the railway line.

For the remaining 4% of the catchment located south of the railway line, the total contributing catchment area south of the railway did not exceed 2 km^2. Therefore, the areal reduction factor for these remaining subcatchments is unlikely to exceed 5% (i.e., only a small reduction in rainfall would be applied). For the balance of the catchment located north of the railway, a higher areal reduction factor would be appropriate, however, flooding is not as problematic in this area.

As the majority of subcatchments within the most problematic sections of the catchment comprise a contributing catchment area of less than 1 km^2 and the remaining subcatchments would only require application of a small reduction factor or are not faced with as significant flooding issues, no areal rainfall reductions factors were applied to the point rainfall depths.

1.2.3 Rainfall Losses

The *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017) included the development of a DRAINS computer model to simulate catchment hydrology. The DRAINS software takes advantage of the ILSAX rainfall loss model.

ARR2019 recommends a hierarchical approach for determining the most appropriate rainfall losses to apply as part of design simulations. The hierarchy of approaches recommends the adoption of calibrated rainfall loss information in preference to more generic rainfall loss information, such as that located on the ARR2019 Data Hub.

The DRAINS model was calibrated as part of the *'Little Creek Overland Flow Flood Study'*. In line with ARR2019 recommendations, the calibrated soil and loss parameters were retained as part of the revised design simulations and are summarised below:

- Paved Area Depression Storage (Initial Loss) = 1.0mm
- Grassed Area Depression Storage (Initial Loss) = 5.0mm
- Soil Type = 3 (slow infiltrated rates)

- Antecedent moisture conditions = 3 (rather wet with total rainfall in 5 days preceding storm = 12.5 to 25mm)

1.2.4 Effective Impervious Area

Historically, impervious areas in hydrologic models were represented as the "total impervious area". This concept assumes that with the exception of the initial wetting of the catchment, all impervious areas contribute fully to runoff. However, research (e.g., Cherkaver, 1975, Beard and Shin, 1979) highlights the importance of using the "Effective Impervious Area" (EIA) in preference to the TIA to better account for impervious areas that are not directly connected to the drainage system (referred to as indirectly connected impervious areas).

An example of an indirectly connected impervious area is a foot path which is adjoined by a grassed area. In instances such as this, any runoff from the footpath will flow onto the grassed area and this runoff will have an additional opportunity to infiltrate into the underlying soils, thereby reducing the contribution of runoff.

Accordingly, Book 5 of ARR2019 advocates the use of EIA when modelling urbanised catchments to ensure urban runoff volumes and peak flows are not overestimated. The Drains software incorporates "Supplementary Areas" for each subcatchment which are 'impervious areas not directly connected to the drainage system, draining onto the grassed area' (Watercom, 2018). Therefore, the supplementary areas are intended reflect indirectly connected areas and can be directly accounted for in the Drains model.

The flood study assumed that supplementary areas comprised 5% of each subcatchment. As this yielded good calibration outcomes, this value was retained as part of the current study to represent indirectly connected areas.

1.2.5 Temporal Patterns

ARR2019 employs 10 different temporal patterns for each AEP/storm duration to define the time variation in rainfall during each storm. The use of a variety of different temporal patterns is intended to reflect the natural variability of a typical rainfall event (i.e., no two storms will be the same).

The temporal patterns for the study area were downloaded from the ARR data hub and were used to simulate the temporal distribution of rainfall for each design storm. In accordance with ARR2019 for catchments with an area less than 75 km^2, the "point" temporal patterns rather than "areal" temporal patterns were selected to describe the temporal variation in rainfall.

ARR2019 groups the temporal patterns into "frequent", "intermediate" and "rare" bins, which were applied to each design storm as follows:

- Frequent temporal patterns: 0.5EY and 20% AEP
- Intermediate temporal patterns: 10% AEP and 5% AEP
- Rare temporal patterns: 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP

1.2.6 Results

The DRAINS model was also used to simulate rainfall-runoff processes based upon ARR2019. The hydrographs generated by the DRAINS model were then applied to the TUFLOW hydraulic model and the TUFLOW model was used to route the flows across the Little Creek catchment. The design 0.5EY, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP storms were simulated in addition to the PMP.

As outlined in the previous section, a suite of ten temporal patterns were used to represent the temporal variation in rainfall for each design flood frequency and duration. The peak water levels from the full suite of temporal patterns for each design event were reviewed to determine the average peak flood level for each storm duration. The average water levels were then reviewed across all storm durations to determine the duration that produced the highest average water level. This was selected as the critical duration at each location. The results of the analysis indicate that the critical duration across the catchment generally varies between 15 minutes and 120 minutes. However, along the main drainage line, the critical duration was most commonly 45-minutes. **Plate 2** shows the spatial variation in critical duration for the 1% AEP storm.

The range of water level results for each critical duration were also reviewed to select a representative temporal pattern for each storm. The representative temporal pattern was selected as the temporal pattern that produced the next highest peak water level above the average water level. A summary of the adopted critical durations and temporal patterns across the Little Creek catchment are provided in **Table 2**.

1.3 Hydraulics

1.3.1 Boundary Conditions

Inflow Boundaries

As discussed in the previous section, a DRAINS model was used to simulate the transformation of rainfall into runoff and generate discharge hydrographs throughout the study area. The discharge hydrographs generated by the DRAINS model was used to define inflow boundary conditions for the TUFLOW models.

The storm durations and temporal patterns that were adopted as part of the design simulations are summarised in **Table 2**.

Downstream Water Level Boundary

In addition to flooding from local catchment runoff generated by the Little Creek catchment, flooding across the downstream sections of the catchment can also be influence by elevated water levels in South Creek.

The *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017) adopted the following peak flood levels in South Creek along the downstream model boundary. These levels were retained as part of the current study:

- 0.5EY to 10% AEP: 19.5 to 20 mAHD
- 5% AEP to PMF: 22.1 to 22.6 mAHD

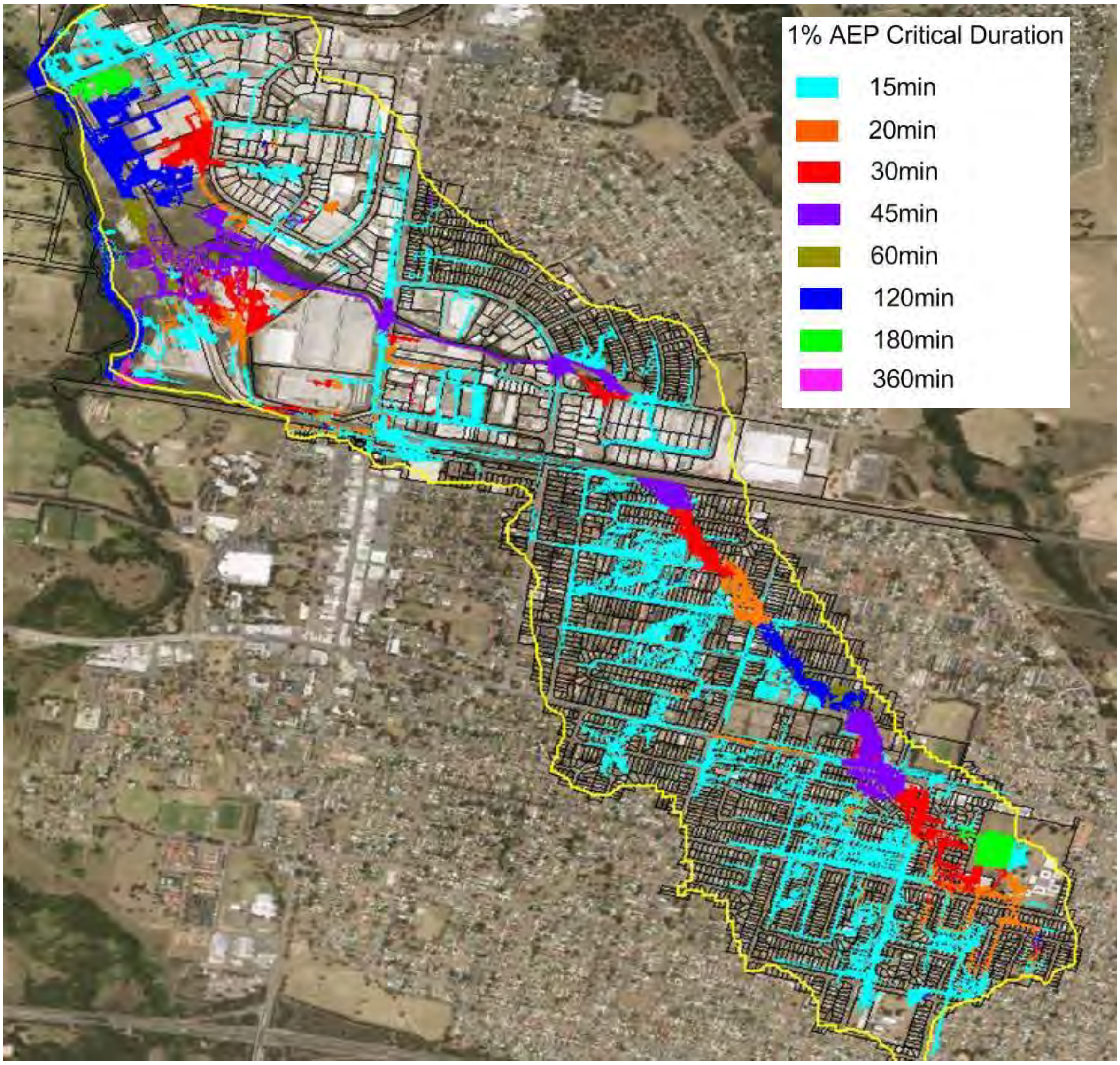


Plate 1 1% AEP ARR2019 Critical Duration Map

Table 2 Adopted temporal patterns and storm durations for hydraulic analysis

Design Storm	Storm Durations and Temporal Pattern ID								
	15 mins	20 mins	25 mins	30 mins	45 mins	60 mins	90 mins	120 mins	180 mins
0.5EY			4485		4552		4608	4641	
20% AEP		4453			4551		4607	4635	
10% AEP		4434				4568	4594		4659
5% AEP	4412			4513		4569		4623	4659
2% AEP	4401		4394		4528			4614	
1% AEP		4429			4528	4555			4653
0.5% AEP		4429			4528	4555			4653
0.2% AEP		4429			4528	4555			4653

1.3.2 Blockage

Culvert and Bridge Blockage

Blockage factors for each bridge and culvert were estimated as part of the *'Little Creek Overland Flow Flood Study'* (WMAwater, 2017) based upon recommendations in 'Blockage of Hydraulic Structures' (Engineers Australia, 2015). The blockage factors were reviewed and were determined to be appropriate for application as part of the current study. As shown below, the blockage factors vary according to the severity of the events. This reflect the fact that during larger floods, there is greater potential for mobilisation and transportation of debris.

- 0.5EY up to 10% AEP: 25% blockage
- 5% AEP up to 0.5% AEP: 50% blockage
- 0.2% AEP and PMF: 75% blockage

Stormwater Blockage

Stormwater pit and grate blockage factors were assigned in the TUFLOW model based upon Penrith City Council's blockage policy. The adopted blockage factors are summarised in **Table 3**.

1.3.3 Design Flood Envelope

As discussed, a range of design storms were simulated for each design flood. Therefore, the results from each simulation for each design flood were combined to form a "design flood envelope" for each design flood. It is this "design flood envelope" comprising the most critical depths, velocities and levels from a risk management perspective that forms the basis for the results documented Chapter 4 of the report.

Table 3 Adopted Stormwater Pit Blockage Factors

Pit Type	Blockage Factor
Side entry (Sag)	20%
Grated (Sag)	50%
Combination (Sag)	Side inlet capacity only (i.e., complete blockage of grate)
Letterbox (Sag)	50%
Side entry (On-Grade)	20%
Grated (On-Grade)	50%
Combination (On-Grade)	10%

Appendix K

Historic Flood Photos

MARCH 2014 FLOOD PHOTOS

Flood photographs at Edmonson Ave, St Marys (March 2014)