Final Floodplain Risk Management Study and Plan

Nepean River Floodplain Risk Management Study and Plan

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Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood 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.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain modification measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee –

   Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection –

   The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study –

   Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

   Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

   Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

   Implementation of actions to manage flood risks for existing and new development.

This Nepean River Floodplain Risk Management Study is developed from the previous Flood Study, completed in 2015.

Glossary

Acid Sulfate Soils (ASS)	Acid sulfate soils (ASS) are naturally occurring sediments and soils containing iron sulfides (mostly pyrite). When these sediments are exposed to the air by excavation or drainage of overlying water, the iron sulfides oxidise and form sulphuric acid. ASSs are widespread among low lying coastal areas of NSW, in estuarine floodplains and coastal lowlands.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example, a 20 year ARI flood would occur on average once every 20 years.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.

Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.

Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The local runoff, travelling through properties and /or roads, before it discharges into a stream, river, estuary, lake or dam.
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.
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.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see AEP and Average Recurrence Interval.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Intervals
AR&R	Australian Rainfall and Runoff
BCR	Benefit Cost Ratio
BoM	Bureau of Meteorology
DCP	Development Control Plan
DPIE	Department of Planning, Industry and Environment
FDM	Floodplain Development Manual
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second
NPV	Net Present Value
NSW	New South Wales
OEH	Office of Environment and Heritage (now Department of Planning, Industry and Environment – The Department)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
NSW SES	State Emergency Service

Executive Summary

Introduction

Cardno were commissioned by Camden Council to undertake a Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Draft Plan (FRMP) for the Nepean River catchment.

This FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damages and risks.

Study Objective

The overall objective of this study is to develop a FRMP that addresses the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Manual (NSW Government, 2005).

Catchment Description

The study is focused on the Nepean River and its tributaries within the Camden Local Government Area (LGA). The Study Area encompasses the catchment of the Upper Nepean River and its tributaries which include - Narellan Creek, Navigation Creek, Matahil Creek (includes Matahil East and Matahil West), Sickles Creek, Cobbitty Creek, and Bringelly Creek.

Historical flooding events show that flows escaping from the Nepean River are known to inundate the low lying areas of Camden and certain sections within South Camden and Elderslie. Floodplain areas along many of the tributaries of the river (particularly Narellan Creek and Matahil Creek) are also known to be affected by backwater flooding from the Nepean River during flood events. Flooding along Narellan Creek can be attributed to both local catchment flooding as well as flooding from the Nepean River.

Previous Studies

The Flood Study for the Nepean River was completed in 2015 by Worley Parsons. The Flood Study of the Narellan Creek subcatchment was a separate study to the Nepean River Flood Study prepared by Worley Parsons. Narellan Creek Flood Study, 2015 focused on the local catchment flooding for the Narellan Creek as well as backwater flooding from Nepean River. This study has been superseded by the Update of Narellan Creek Flood Study (2017b), prepared by Public Works Advisory for Camden Council.

The Nepean River Flood Study (2015) and Update of Narellan Creek Flood Study (2017b) formed the basis for this Floodplain Risk Management Study. The Narellan Creek Flood Study (2017b) has been updated as part of this study including the flood mapping.

Existing Flooding Behaviour

The Nepean River catchment is subject to mainstream riverine flooding, local catchment tributary flooding and overland flows. Details on the existing flood behaviour is provided in **Section 5** of this Floodplain Risk Management Study. The table below identifies the number of properties within the Study Area that are affected by flooding under different frequency storm events. In 1% AEP event 347 properties will be flooded out of which 271 houses will be indundated above floor level.

The impact of climate change on catchment inflows, due to increases in design rainfall intensities, has been considered in this study. With the 10% increase to rainfall intensity, an additional 118 residential and 65 commercial lots are impacted with overground flooding in the 1% AEP storm event.

Flood Event	Properties with over floor flooding	Properties with above ground flooding
2 year ARI	6	10
20% AEP	13	18
5% AEP	147	190
1% AEP	271	347
0.5% AEP	361	454
0.2% AEP	519	629
PMF	2306	2505

An economic analysis of the impact of flooding within the Study Area has been undertaken and detailed in **Section 6** of this Floodplain Risk Management Study. Based on a total damage assessment using residential, commercial and industrial damage curves, the average annual damage for the Nepean River catchment under existing conditions is expected to be approximately $5,685,793.

Floodplain Management Measures

A range of flood risk management options were considered to reduce the flood risk including flood modification, emergency response modification and property modification.

Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the Study Area. Thirty-four (34) possible flood modification measures were identified, some of which are outside the Camden LGA. Fifteen (15) options were assessed across the study area. A summary of all options assessed is provided in **Section 12** of this Floodplain Risk Management Study. Hydraulic modelling and an economic analysis (option cost verses reduction in flood damages) was undertaken for each of the flood modification option assessed.

Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than modifying the flood behaviour, these measures aim to modify properties so that there is a reduction in flood risk. Property modification assessed for the study area included opportunities to improve the flood compatibility of at risk properties.

Emergency response modification measures aim to reduce the consequences of flood risks, by modifying the behaviour of people during a flood event. A range of emergency response options were assessed including actions to improve public awareness of flood risk and improved flood warning systems.

Multi-Criteria Assessment

All of the viable flood risk management options were assessed using a Multi-Criteria Assessment (MCA) matrix. This assessment provided for a triple bottom line approach to account for the performance of the various options with respect to economic, social and environmental criteria. This assessment is detailed in **Section 14** of this Floodplain Risk Management Study. The outcomes of the ranking process of the options have been used to guide the implementation strategy which is the primary component of the Floodplain Risk Management Plan.

The highest ranking flood modification options identified by the MCA include:

> FM1.15 – Building a levee from Saunders Road and along McCrae Drive;

> FM2.5 – Modify existing detention basin at Mount Anan High School; and

> FM 2.4 – Redirect flows to Kenny Creek near Farm House place via new channel.

The highest ranking property and emergency response modification options identified by the MCA include:

> PM1 – LEP update;

> PM2 – Building and developments controls and flood policy update; and

> EM2 – Flood and Flash warning system.

Key Outcomes

The overall recommendations of this study find that it is impractical to eliminate all flood risks from the study area. Instead, the aim of the recommendations of this FRMS is to ensure that existing and future development is exposed to a reduced level of risk.

The recommendations resulting from this Floodplain Risk Management Study (FRMS) and the proposed implementation strategy is outlined in the Nepean River Floodplain Risk Management Plan (FRMP).

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1 Introduction

Cardno (NSW/ACT) Pty Ltd ('Cardno') was commissioned by Camden Council to undertake a Floodplain Risk Management Study and Plan (FRMS&P) for the Nepean River catchment. This FRMS&P process has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk.

1.1 Study Context

The NSW Floodplain Management process progresses through six (6) steps in an iterative process:

1. Formation of a Floodplain Management Committee
2. Data Collection
3. Flood Study
4. Floodplain Risk Management Study
5. Floodplain Risk Management Plan
6. Implementation of the Risk Management Plan

The initial key stage of the process has been undertaken with the completion of the Nepean River Flood Study (Worley Parsons, 2015) and Update of Narellan Creek Flood Study (Public Works Advisory, 2017b). Cardno has been commissioned to prepare the next key stage of the process, the Floodplain Risk Management Study and the preparation of a Floodplain Risk Management Plan.

1.2 Study Objectives

The overall objective of this study is to develop a Floodplain Risk Management Plan for the Nepean River catchment within the Camden LGA to reduce the impacts of flooding and improve flood preparedness by addressing the existing, future and continuing flood problems, taking into account the potential impacts of climate change.

1.2.1 Floodplain Risk Management Study

The objectives of the Floodplain Risk Management Study are to:

> Review the Nepean River Flood Study and Update of Narellan Creek Flood Study and re-assess the design flood discharges, velocities, flood levels, hazards and other relevant flood information for the Study Area;

> Update the Nepean River tributary flood study;

> Undertake overland flood assessment for the Nepean River and its tributaries, and assess the design flood discharges, velocities, flood levels, hazards and other relevant flood information;

> Distinguish mainstream and overland flooding in the Narellan Creek catchment;

> Review Council's existing environmental planning policies and instruments including Councils long-term planning strategies for the Study Area;

> Identify works, measures and controls aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;

> Assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future, taking into account the potential impacts of climate change;

> Consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised taking into account the potential impacts of climate change;

> Define the flood risk precincts and develop appropriate flood related development controls based on the land use and flood characteristics;

> Review the local flood plan, identify any deficiencies in information and address the issues;

> Examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements;

> Examine ways in which the river and floodplain environment may be enhanced without having a detrimental effect on flooding; and

> Identify modifications that are required to current policies in light of the investigations.

1.2.2 Floodplain Risk Management Plan

The objectives of the Floodplain Risk Management Plan are to:

> Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;

> Reduce private and public losses due to flooding;

> Be consistent with the objectives of relevant state policies, in particular, the Government’s Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act 1979;

> Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms;

> Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans; and

> Establish a program for implementation and mechanism for the funding of the plan which should include priorities, funding, responsibilities, constraints, and monitoring.

2 Catchment Description

The study is focused on the Nepean River and its tributaries within the Camden LGA. Camden, located in the Greater Sydney Region, 65km west of Sydney, covers an area of 215km2 and lies in the upper reaches of the wider Hawkesbury-Nepean catchment area.

The Study Area is shown in **Figure 2-1** and it encompasses the catchment of the Upper Nepean River and its tributaries within the Camden LGA. These include:

> Narellan Creek;

> Navigation Creek;

> Matahil Creek (includes Matahil East and Matahil West);

> Sickles Creek;

> Cobbitty Creek; and

> Bringelly Creek.

The entire catchment of the Upper Nepean River, including the Narellan Creek Catchment within the LGA covers an area of some 14,345 hectares being approximately two thirds of the area of Camden LGA. The population of the Nepean River Catchment is approximately 90 % of the total population of Camden LGA.

Camden locality has the suburbs of Camden, Camden South, Cobbitty, Ellis Lane, Grasmere and Kirkham. Furthermore, a new subdivision known as Spring Farm commenced in 2007, and has introduced approximately 4000 new lots to the northern side of the Nepean River. The other new subdivisions currently developing in Harrington Grove and Mater Dei to the east of the Nepean River will introduce approximately 1400 new lots.

Historical flooding events show that flows escaping from the Nepean River are known to inundate the low lying areas of Camden and certain sections within South Camden and Elderslie. Floodplain areas along many of the tributaries of the river (particularly Narellan Creek and Matahil Creek) are also known to be affected by backwater flooding from the Nepean River during flood events.

Narellan Creek with a catchment of 3,415 ha is the major tributary of the Nepean River in the Camden LGA. The Narellan Creek local catchment contains the suburbs of Narellan, Narellan Vale, Smeaton Grange, Harrington Park, Currans Hill, Mount Annan, Elderslie and Kirkham (Figure A2.6). The tributaries of Narellan Creek are Herbert Rivulet, Oxley Rivulet, Condron Creek, Cross Creek, Campbell Rivulet, Howe Creek, Kenny Creek and Annan Creek.

The Narellan Creek subcatchment area has recently undergone a period of rapid urbanisation, with many areas that were previously farmland being converted to residential areas. Since 2002, significant urbanisation has taken place in Harrington Park, Mount Annan, Narellan Vale, Smeaton Grange and Elderslie areas. Portions of the catchment are also located within the South West Growth Centre for NSW and expect to undergo growth in the future. Flooding along Narellan Creek can be attributed to both local catchment flooding as well as flooding from the Nepean River. The Nepean River Valley has a history of frequent flooding and has a catchment that extends as far as Mittagong in the Southern Highlands. The catchment covers an area of approximately 1,400 km^2 upstream of Narellan Creek.

The majority of developed areas in the Narellan Creek catchment are above the level of flooding from the Nepean River. However, these properties face a risk of flooding due to local catchment runoff. As the area is favoured by young families, the majority of residents have lived in Narellan less than 15 years. As such, there is limited public memory of flooding in Narellan Creek.

The Study Area is subject to mainstream riverine flooding, local catchment tributary flooding and overland flows.

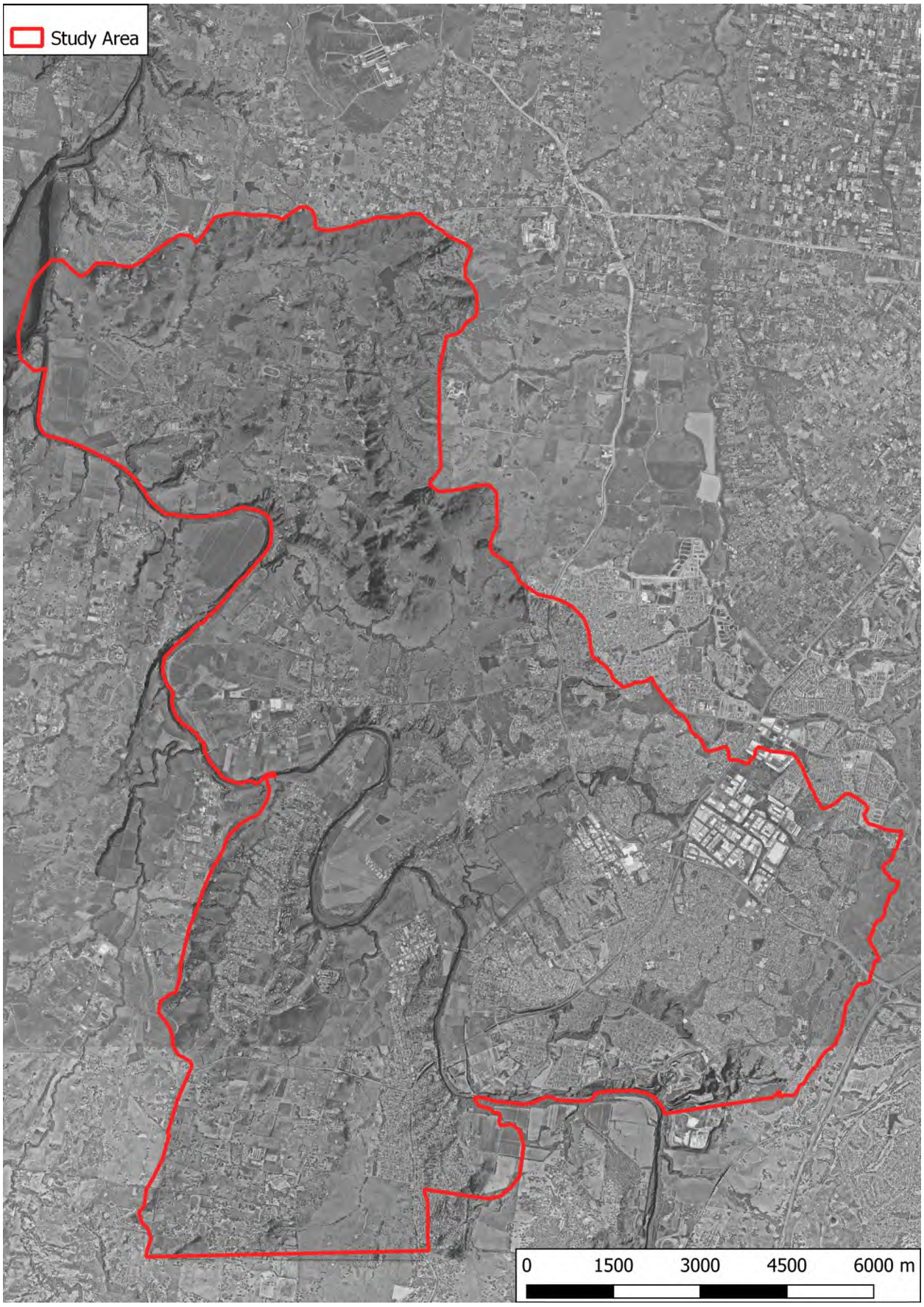

Figure 2-1 Nepean River Study Area

3 Data Collection & Review

3.1 Previous Studies

The Flood Study for the Nepean River was completed in 2015 (Worley Parsons, 2015). The Flood Study defined flood behaviour in the catchment under existing and future climate change conditions for the 2 year ARI, 20%, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and the Probable Maximum Flood (PMF). The Flood Study of the Narellan Creek subcatchment was a separate Flood Study to the Nepean River Flood Study prepared by Worley Parsons. Narellan Creek Flood Study, 2015 focused on the local catchment flooding for the Narellan Creek as well as backwater from Nepean River. This study has been superseded by the Update of Narellan Creek Flood Study (2017b), prepared by Public Works Advisory for Camden Council.

The Nepean River Flood Study, 2015 and Update of Narellan Creek Flood Study, 2017 formed the basis for this Floodplain Risk Management Study.

3.2 Nepean River Flood Study, 2015 Flood Model

3.2.1 Hydrology

Hydrological modelling for the Study Area was undertaken using XP-RAFTS. The hydrology of the wider catchment was modelled by the previously constructed RORB model from the Upper Nepean River Flood Study (1995). The RORB model generated an inflow at Menangle Weir at the upstream extent of the Study Area, with the XP-RAFTS model defining the hydrology within the Study Area.

The XP-RAFTS package was adopted for the Flood Study as:

> It can account for spatial and temporal variations in storm rainfalls across a catchment;

> It can accommodate variations in catchment characteristics;

> It can be used to estimate discharge hydrographs at any location within a catchment; and,

> It has been widely used across eastern NSW and therefore, where suitable calibration data is not available, the results from modelling of other similar catchments can be used as a guide in the determination of model parameters.

Subcatchments were defined from the LGA wide LiDAR data, and refined using high resolution drainage line data where available.

The hydrological model was calibrated to three historical events from 1978, 1988 and 1990 for which sufficient data was available. The recurrence interval of these events was approximately 12 years (8% AEP), 7 years (13.3 % AEP) and 3 years (28.3% AEP) respectively. The calibration led to the adoption of initial and continuing losses of 15 mm/hr and 2.5 mm/hr respectively.

The hydrological model was used to generate sub catchment hydrographs that were then applied to the hydraulic model.

3.2.2 Hydraulics

Hydraulic modelling for the Study Area was undertaken using TUFLOW. The model was extended from Menangle Weir (4.5km upstream of the Camden LGA boundary) to the Nepean River's confluence with the Warragamba River, near Warragamba Park.

The model adopted an 8m grid cell size. As TUFLOW samples the grid at both cell edges and cell centres, this resulted in a 4m sampling frequency of the LiDAR data. The Nepean River and its tributaries were included in the 2D domain. Within the 1D domain, were 27 hydraulic structures including culverts, bridges and railway underpasses. The model also included six weirs along the Nepean River with the Study Area. The weirs were included in the 2D domain and incorporated via raising the one row of grid cells to the height of the weir crest.

Local inflows were applied at the watercourses, from hydrographs extracted from the XP-RAFTS model.

As no river rating table was available for the downstream boundary, a storage-discharge relationship was developed from the Manning's Equation to serve as the downstream boundary.

The hydraulic model was calibrated to three historical events from 1978, 1988 and 1990 using data from recorded levels, previous study levels and community observations.

The calibrated model was used to define flood behaviour for the 2 year ARI, 20%, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and the Probable Maximum Flood (PMF).

3.3 Update of Narellan Creek Flood Study, 2017 Flood Model

3.3.1 Hydrology

The XP-RAFTS model was used for hydrological modelling. As part of the update, the initial losses for pervious areas were set at 15mm and the continuous losses at 2.5mm/hour. For impervious areas, initial and continuous losses were set at 0mm and 1mm/hr respectively. The study states that these losses were validated through simulation of the 2007, 2008 and 2013 events.

An additional calibration of the updated model was completed using the data collected following the June 2016 flood event. Details of this is provided in **Appendix A**. The recurrence interval of this event was approximately 10% AEP event as per the 1987 IFDs and 5% AEP event as per the 2013 IFDs. The results of the calibration for the June 2016 event were providing substantial confidence in the ability of the developed XP-RAFTS models to reliably simulate design discharges and flood behaviour across the Study Area.

The hydrological model was used to generate subcatchment hydrographs that were then applied to the hydraulic model.

3.3.2 Hydraulics

Hydraulic modelling for the Study Area was undertaken using TUFLOW. The original TUFLOW model was based on a 5m grid created from the 2011 LiDAR data. As part of the update the terrain was modified to reflect a number of developments that have occurred since the 2011 LiDAR data.

Key structures have been incorporated as 1-dimensional elements linked to the 2- dimensional domain except for large structure able to be modelled in the 2-dimensional domain directly. Blockage sensitivity was completed based on the AR&R 2016 methodology guidelines for major culverts and structures.

Local inflows were applied at the watercourses, from hydrographs extracted from the XP-RAFTS model. Upstream boundaries of the TUFLOW model included the XP-RAFTS subcatchment runoff. The downstream boundary of the model was taken as the Nepean River and a “flow-through” boundary condition. The Nepean River inflows and downstream water level were assumed to be constant for each design flood modelling scenario. A flow equivalent to a 20% AEP flood event from the Nepean River was adopted as downstream boundary for all design events except for the 2 year ARI AEP event for which the 2 year ARI AEP Nepean River condition was adopted.

The updated hydraulic model was calibrated to June 2016 flood event. Overall the results of the post flood behaviour analysis provides confidence in the ability of the TUFLOW model to reproduce recorded flood levels.

The calibrated model was used to define flood behaviour for the 2 year ARI, 20%, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and the Probable Maximum Flood (PMF).

3.4 Survey Information

3.4.1 Topography

The hydraulic model was constructed utilising LiDAR data collected in March 2011 and hydrographic survey of Hawkesbury Nepean Valley undertaken in 2012. The LiDAR data was used to define levels of the wider floodplain, while the hydrographic survey was used to generate cross sections for the rivers and creeks.

It is not expected that major changes will have occurred to the river and creek systems since the hydrodynamic survey was collected, and this data is considered suitable for undertaking the Floodplain Risk Management Study.

Additional terrain survey has been provided in order to update the LiDAR data based on development that has occurred in the Study Area since the data was collected. This updated terrain data has been incorporated into the model, so that the terrain data is reflective of current catchment conditions.

3.4.2 Property Level Survey

Schlencker Mapping were commissioned to collect floor and ground levels of properties affected by flooding in the PMF event by remote LiDAR. This was undertaken in March and April 2017 and a total of

3,400 properties were surveyed all of which were located within the PMF extent. This information was then utilised to undertake damages assessment of flood affected areas as discussed further in **Section 6**.

3.5 GIS Data

The following Geographic Information System (GIS) data was provided by Council as part of the study:

> Cadastre;

> Rivers, creeks and waterways;

> Aerial image of the Study Area;

> Land-use and Council zoning regions; and,

> Catchment extent polygon.

4 Community Consultation

Consultation with the community and stakeholders is an important component in the development of a Floodplain Risk Management Study and Plan. Consultation provides an opportunity to collect feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

In 2012 during the Flood Study stage a total of 126 questionnaires were completed and returned by the local residents as part of the community consultation process of the Nepean River Flood Study, primarily within the town centre of Camden. Of these, nine contained location and peak water level information that was specific enough to be utilised as historical flood level data.

4.1 Public Exhibition

The Draft Floodplain Risk Management Study and Plan was placed on public exhibition for a period of one month from 21 July 2022 to 22 August 2022 and an extended period till 26 August 2022. The document was made available to the public online at 'Your Voice Camden' and hard copies at the Council libraries.

The purpose of the exhibition period was to obtain feedback from the community on the findings of the study, in particular, the options recommended for implementation. Twelve (12) written submissions were received. A summary of the submissions received are provided in **Appendix K**. The responses from both Cardno and Council are provided, along with the actions taken as an outcome of the submission.

The key outcomes from the submissions received include:

> Impact of the 2022 NSW Flood Inquiry report recommendations which was released during the public exhibition stage - The recommendations from this report are strategic in nature and will take time to manifest in policies and directions from the NSW State Government that Council will be directed to consider or adopt. The FRMS and FRMP have been developed in accordance with the current NSW Flood Prone Land Policy. The FRMP is regarded as a dynamic document and the outcomes of the Flood Inquiry report will be reviewed by Council during future updates to the Plan.

> Consideration of the recent large flood events that occurred in 2021 and 2022 – Since the commencement of the study in 2016, some recent large flood events have occurred which have not been considered in the study. Council has undertaken an in-house comparison and the outcomes of these are presented in **Appendix K**.

> Lack of justification on the climate change assessment - The setting of Flood Planning Levels under a changing climate on the Nepean River floodplain in the Camden LGA was informed by a Discussion Paper prepared in February 2020. This Discussion Paper is attached in **Appendix K**. **Section 5.8** of this report has been updated to provide further discussion.

5 Flood Behaviour

5.1 TUFLOW Model Update

The Nepean River TUFLOW model was built in March 2015 for the flood study. The model was revised to take account of current and future catchment conditions. This involved:

> Updates to the model topography; and

> Updates to the model extent.

These updates are detailed below.

5.1.1 Topography Update

The Nepean River Flood Study was completed in March 2015. Since the model was completed, the catchment has undergone a substantial amount of development. In order to ensure that the TUFLOW model is suitable for determining the existing flood risks and hazards within the study area, and is suitable for future assessments, the following was incorporated into the model:

> The terrain details of developments constructed since the flood study;

> The terrain details of developments currently under construction; and,

> The terrain details of developments currently approved for construction.

Figure 5-1 shows the areas where the model terrain was updated.

5.1.2 Tributary Extension

5.1.2.1 Model Revision

In addition to updating the terrain based on development within the study area, the model area was also increased to include a larger reach of the Nepean River tributaries. The tributaries that were extended were:

> Bringelly Creek;

> Cobbitty Creek;

> Sickles Creek;

> Matahil Creek East;

> Matahil Creek West; and,

> Navigation Creek.

In the previous model, these tributaries were included up to the peak Nepean River flood backwater extent. The tributaries were extended to either the LGA boundary or the catchment extent, whichever was the closer. The creeks and extension areas are shown in **Figure 5-2**.

5.1.2.2 Results

The model was run for the 1% AEP and peak levels were compared against the previous model.

The peak 1% AEP flood depths are shown in **Figure 5-3**. The difference plot is shown in **Figure 5-4**.

The results from the extended tributary models were found to be a close match to the base case results across the majority of the model, with peak results within 2cm between models.

There were two main areas that showed differences in excess of 2cm namely:

> Upstream reach of Bringelly Creek

> Upstream reaches of Matahil Creek east and west

In both instances, the levels in the extended tributary model results are lower than the levels of the base model, generally by 0.1 – 0.3m.

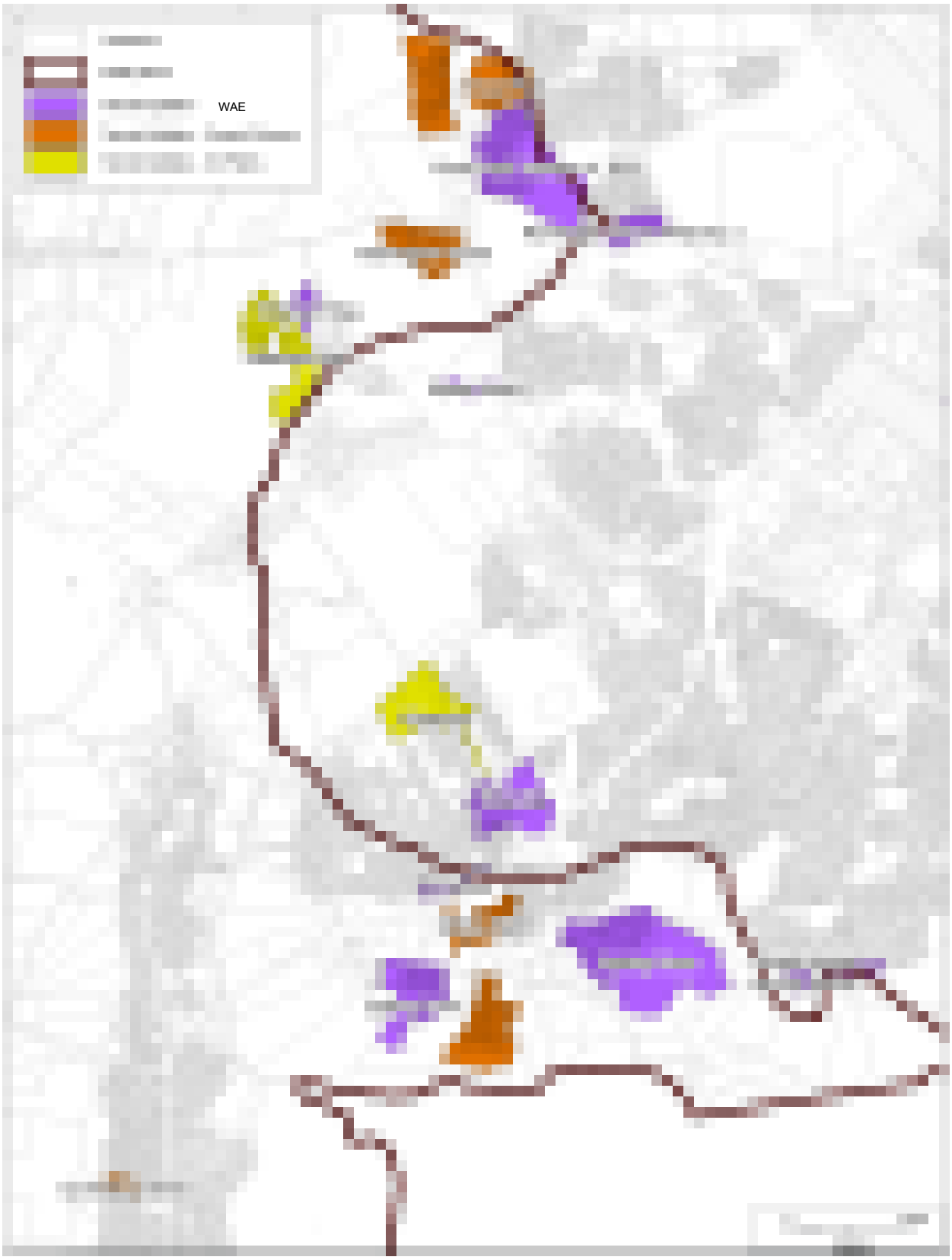

Figure 5-1 Updated Model Terrain

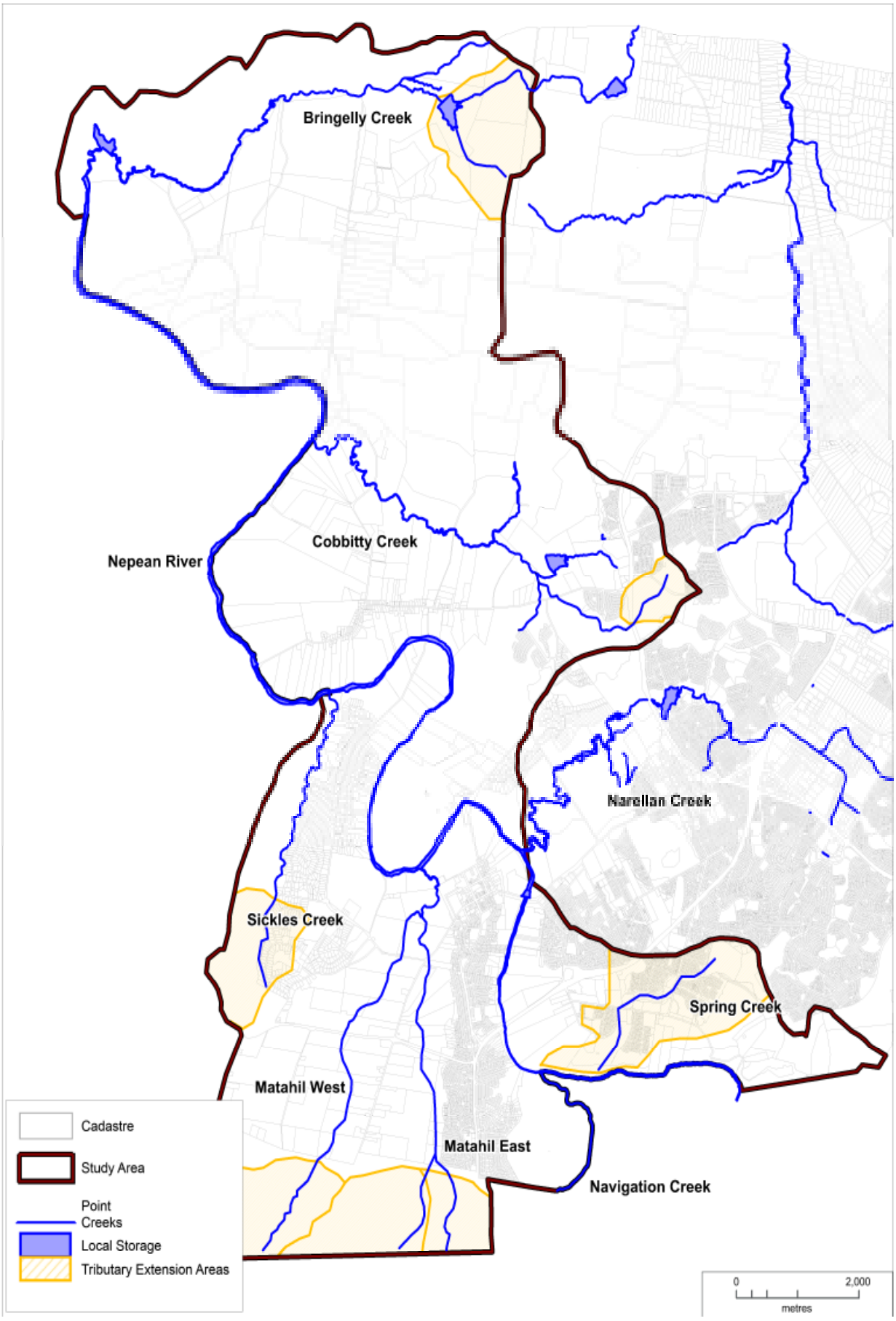

Figure 5-2 Tributary Extension Areas

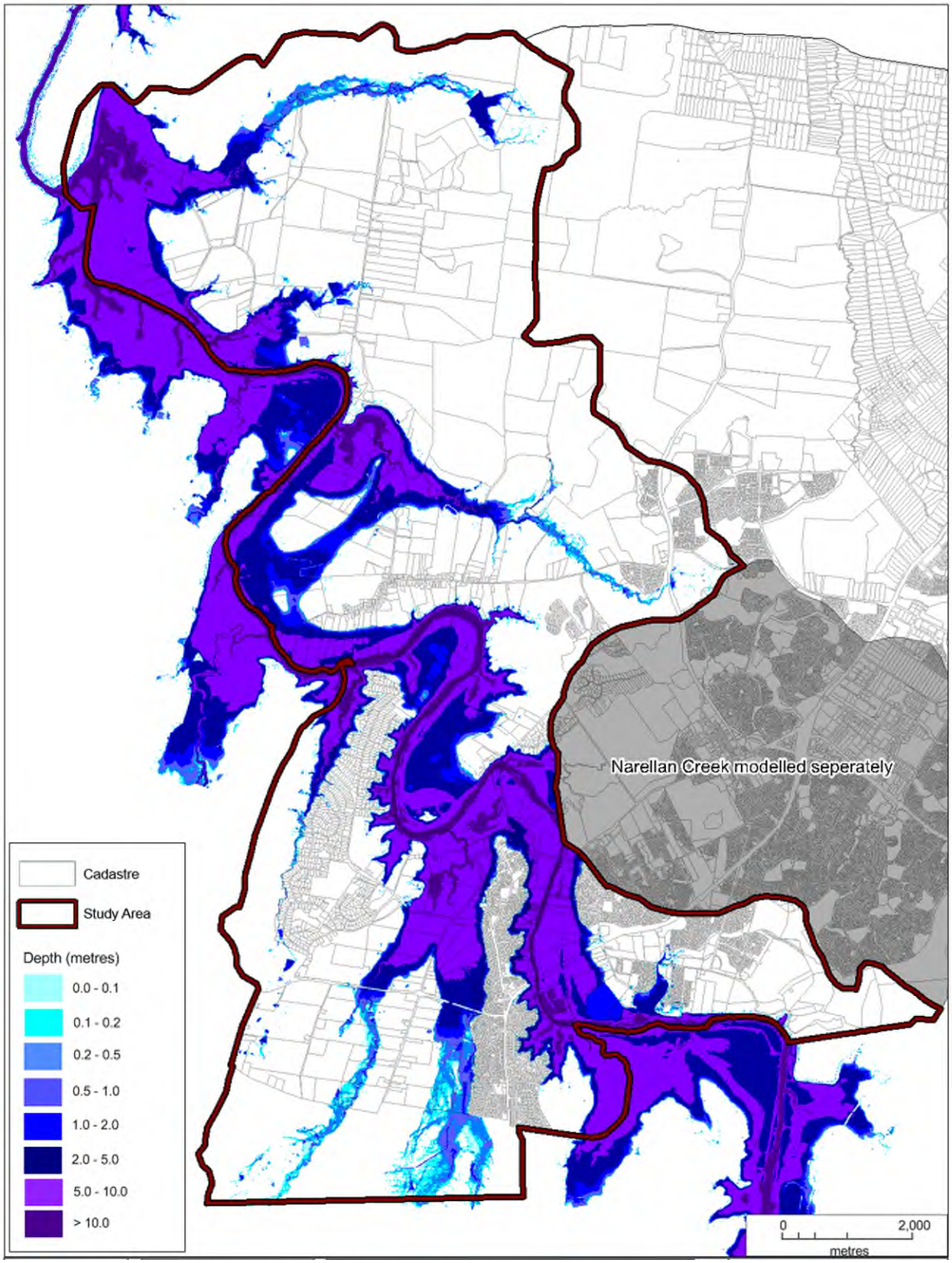

Figure 5-3 Peak 1% AEP flood depth with model extension

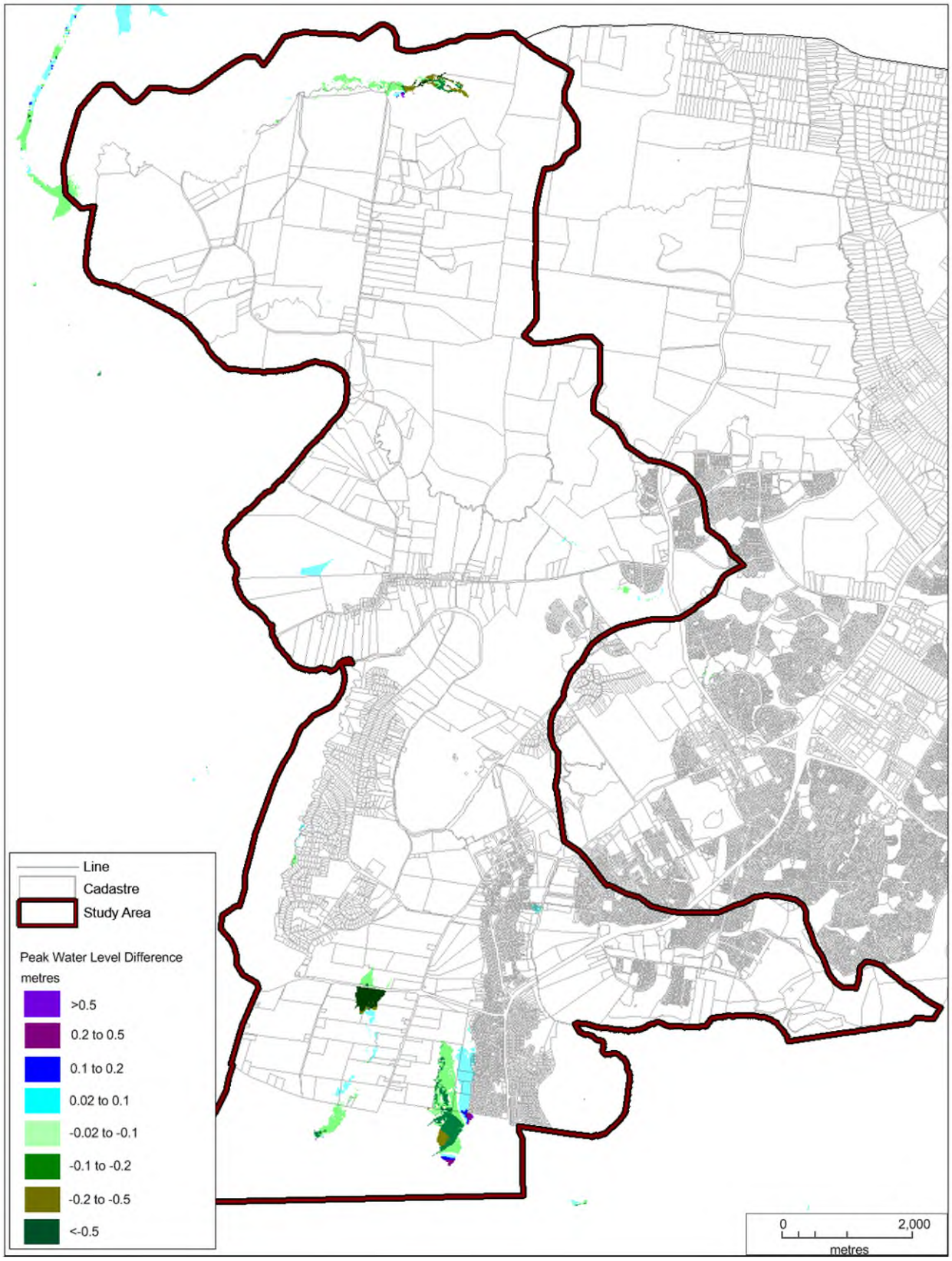

Figure 5-4 1% AEP Peak Level Difference

This was due to the better definition of the upstream hydrographs in the extended tributary model. Additional subcatchments were included in the RAFTS model in order to provide inflows at the new boundary of the extended model and flows were required to be conveyed through additional lengths of 2D reaches.

This additional discretisation resulted in the hydrograph becoming a marginally longer and lower as the flow through the 2D model took longer than the lag time assumed in the RAFTS model. As a result, the peak flow was slightly reduced in the extended tributaries model, which resulted in lower peak water levels.

The changes in peak levels occurred over open space and did not affect properties or development.

5.1.2.3 Tributary Extension Outcome

The results show that the extended tributary model provides comparable results to those reported in the Flood Study. The minor differences that did occur were restricted to upstream locations near the revised boundaries, and did not affect developed areas.

As such, it was concluded that the extended tributaries model is suitable for developing and accessing mitigation options as part of the Floodplain Risk Management Study.

5.2 Tributary Flood Study

The tributaries in the Nepean River flood model currently extend only as far as the Nepean River backwater effect. As part of this study, a tributary flooding investigation was undertaken which involved extension of the tributaries in the flood model to either the LGA boundary or the catchment extent, whichever was closer.

In addition to mainstream flooding, overland flows have also been assessed for the Nepean River and Narellan Creek catchment. A rainfall on grid model was developed across the study area to identify flowpaths for the entire catchment.

The investigation included:

> Updating the XP-RAFTS model to determine the critical duration of the tributaries;

> Updating the TUFLOW model to ensure that the full tributary reaches are included in the model;

> Running the TUFLOW model for the full range of design events to define tributary flooding, with Nepean River baseflow and without Nepean River baseflow; and

> Preparing a rainfall on grid version of the model to define overland flowpaths.

A number of criteria including depth limit and depth x velocity product limit were considered to define and/or differentiate overland and mainstream flows. These approaches were not successful due to the flood behaviour in the catchment. To address this issue a methodology was developed to define the tributary mainstream and overland flooding within the Study Area. This is discussed further in the following section.

5.2.1 Defining Mainstream and Overland Flooding

To determine whether the flooding is mainstream or overland flow, the stream order classification approach was adopted. This included:

> Utilising the model DEM data;

> Obtaining the hydro line spatial data from the NSW Department of Planning, Industry and Environment (https://www.industry.nsw.gov.au/water/licensing-trade/hydroline-spatial-data). Hydro line spatial data is a dataset of mapped watercourses and waterbodies in NSW;

> Using the DEM data and the hydro lines from The Department to define the site specific hydro lines;

> Assigning the stream orders to the hydro lines based on the Stahler Stream Order Classification as shown in **Figure 5-5**;

> Sections of stream identified as Stream Order 1 were defined as overland flooding, and Stream Order 2 or greater were defined as mainstream flooding. It should be noted that only the Stream orders 2 to

5 were identified as shown in **Figure 5-5**. The remainder upper reaches flood extents were classified as overland flows.

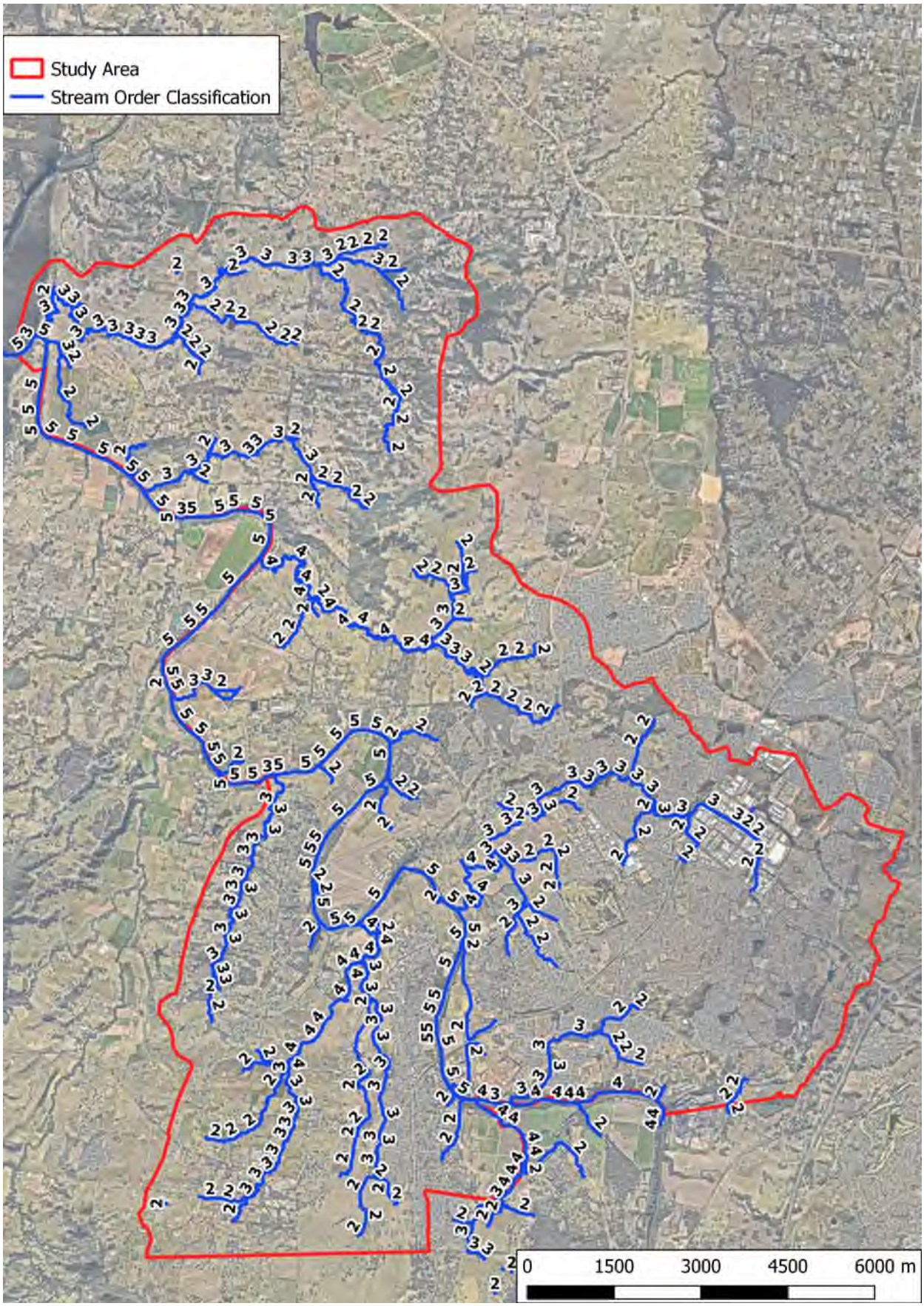

Figure 5-5 Stream Order Classification (NSW Government, 2018)

5.3 Model Results

Following these updates the model was rerun for the 2 year ARI, 20%, 5%, 1%, 0.5%, 0.2% AEP and the PMF events. The flood results and mapping have been updated based on the new runs. These results are provided in **Appendix B** and include:

> Flood Extents;

> Peak Water Levels and Contours;

> Peak Depth and Velocity;

> Hydraulic Category Mapping;

> Provisional Hazard Mapping based on NSW Floodplain Development Manual;

> Provisional Hazard Mapping based on the ARR2016 hazard categorisation; and

> True Hazard Mapping.

The results show that the mainstream riverine flooding occurs as a result of long duration rainfall across the large upstream catchment of the Nepean River basin. Critical duration are in the order of thirty-six (36) to forty-eight (48) hours for the design events. The flooding is characterised by significant flows and depths through the Nepean River, resulting in substantial overbank flows that affect adjacent development. A long section of the peak water levels in the Nepean River is shown in **Figure 5-6** for all the design events.

The Nepean River has a number of tributaries within the Study Area, the largest of which is Narellan Creek. These systems also experience flooding as a result of local rainfall. Critical durations are much shorter, in the order of two (2) to nine (9) hours. While overbank flows affect adjacent development, peak flow and depth in the tributaries is significantly lower than what occurs in the Nepean River. It is noted that the Narellan Creek results are based on the Update of Narellan Creek Flood Study, 2017.

Local catchment rainfall also results in the activation of overland flow paths within the Study Area. These flowpaths are typically of shallower depths and are the cause of nuisance flooding through a number of properties in the Study Area.

The results presented in this study have adopted an envelope approach whereby the worst case flooding condition from each of these modes is combined into a single flood envelope.

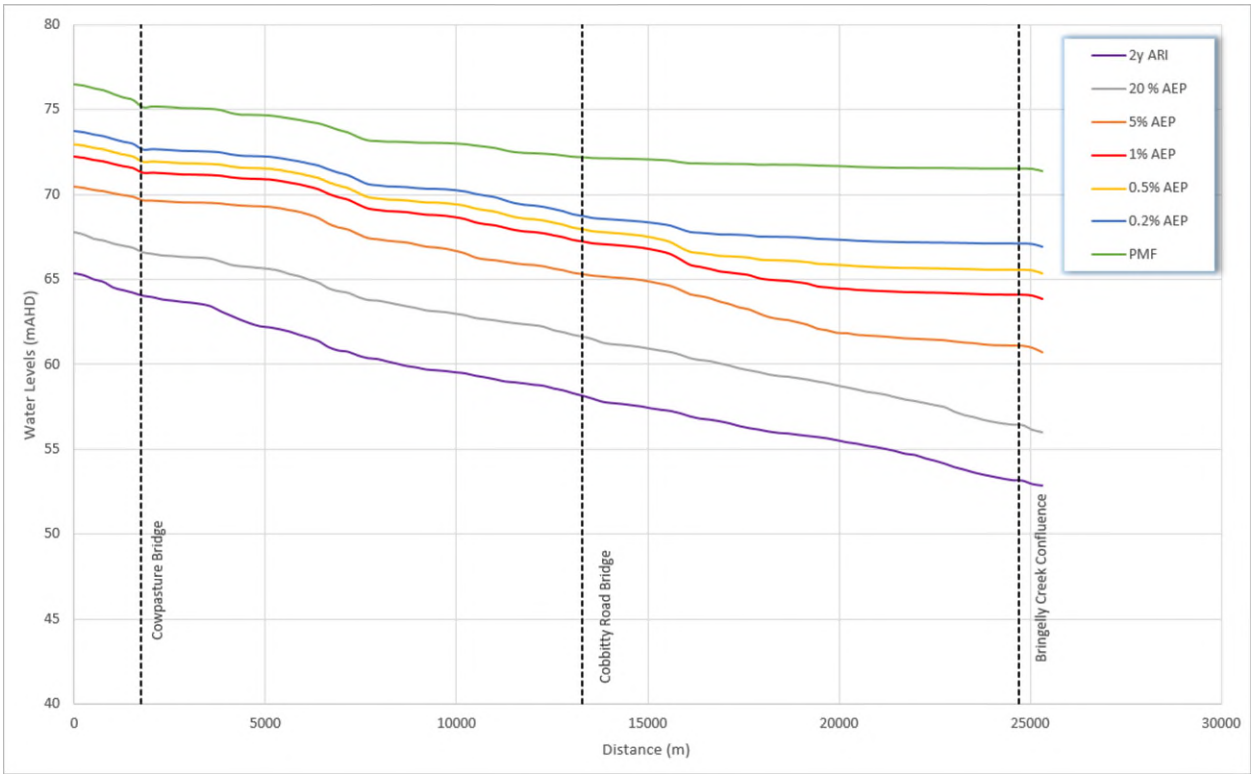

Figure 5-6 Nepean River Long Section of Peak Water Levels

5.3.2 Ground Truthing

The results generated by the hydraulic modelling provides a guidance to identify properties affected by overland flow within the Study Area, as well as the flood behaviour for these properties. In order to verify the hydraulic modelling results, ground truthing was undertaken to refine the 1% AEP flood risk precincts.

Ground truthing was undertaken on 11th November 2018 and 16th January 2019. A field team comprising of Council representatives and engineers from Cardno conducted the site inspection.

Within the Study Area, approximately fifteen (15) areas affected by overland flows were identified for site inspection. These areas were outside of the mainstream flood extents and the purpose of the inspections were to review the site conditions and compare with the study outcomes.

The site inspection involved a subjective analysis of hydraulic model results based on observed site conditions such as natural landforms, the presence of any major hydraulic structures such as open channels or culvert systems, and the presence of any major flow obstructions in the vicinity. All properties identified for ground truthing were identified in a GIS layer. Photos of most properties were taken using GPS Camera with coordinate information compatible with the GIS layer.

For the majority of sites visited, it was concluded that the modelled flow behaviour was appropriate on the basis of observed site conditions. However, at some locations it was found that the conditions observed on site were not reflected accurately in the hydraulic model. This was often due to the presence of local features that were not identified in the LiDAR data at the time of LiDAR captured. Alteration of the 1% AEP flood extents for these properties has been undertaken to account for these local features to better align study results with observed site conditions.

The ground truthing of properties was undertaken to determine whether the modelled risk was appropriate. This was undertaken after the modelling, and was used to confirm the model results with two categories identified:

> No Change – this was applicable to properties identified to be at risk based on site inspections;

> Remove – this was applicable to properties identified to be at a low risk from site inspection. A number of factors may have influenced this at the time, including verification of the pipe network, review of the terrain information, etc.

No additional properties were identified that need to be included within the flood extents.

5.4 Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

> Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

> Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.

> Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined for the 1% AEP event by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. Previous mapping of the floodway was performed along the primary Nepean River watercourse as part of the Nepean River Flood Study (Worley Parsons, 2015). The criteria used to define the floodways are described below:

> As a minimum, the floodway was assumed to follow the creekline from bank to bank.

> All areas previously marked as floodway as part of the Nepean River Flood Study (Worley Parsons, 2015) were included based on the following depth and velocity criteria to define a floodway in the Study Area:

- Velocity x Depth product must be greater than 3 m^2/s ; and
- Velocity is greater than 1 m/s.

> Flows were compared at several cross sections and observations indicated that the 5% AEP extent provided a good correlation to the floodway by conveying 80% of the peak flow outside the primary watercourse in the Study Area.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below:

> To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.5m. Thus the criteria used to determine the flood storage is:

- Depth greater than 0.5m
- Not classified as floodway.

All flood areas that were not categorised as Floodway or Flood Storage are represented as Flood Fringe within the identified flood extents.

Hydraulic category mapping has been undertaken as for the 1% AEP, 0.2% AEP and the PMF. The results are presented in **Appendix B.**

5.5 Flood Hazard

5.5.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations.

Historically, the criteria for these relationships has been taken from the NSW Floodplain Development Manual (Appendix L; NSW Government, 2005). The Manual defines two major categories for provisional hazard – high and low. A third minor transitional category is also included that requires further investigation of the site in question to define the hazard category.

The FDM hazard curves are shown in **Figure 5-7**.

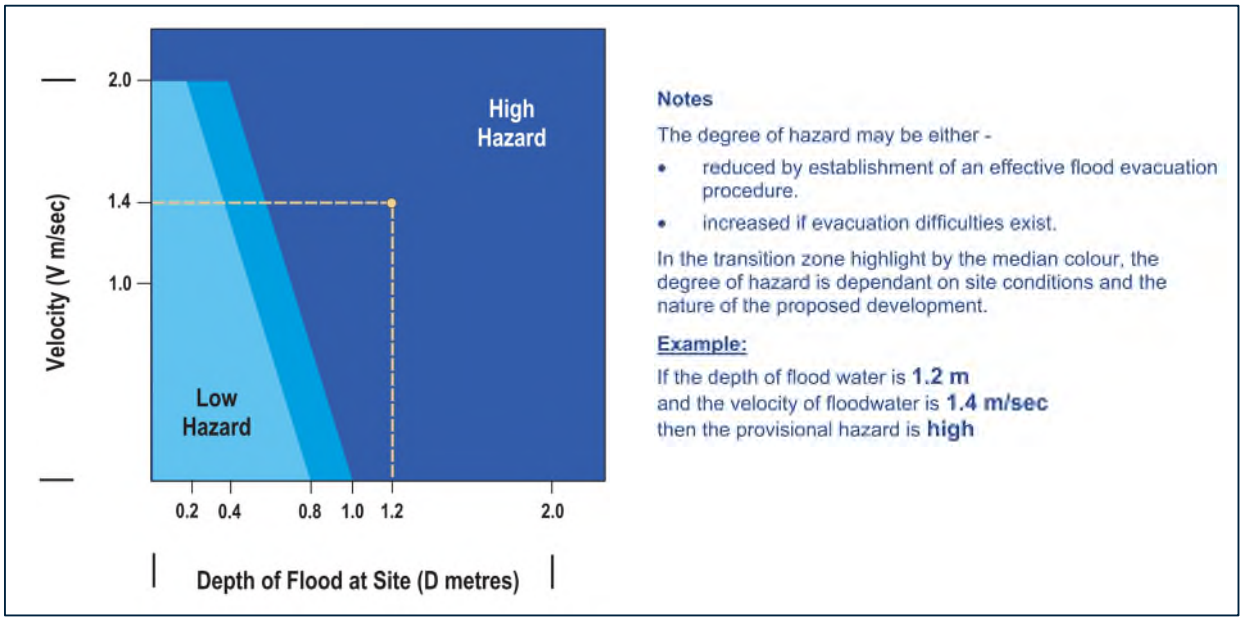

Figure 5-7 Provisional Hazard Categories from Appendix L of the Floodplain Development Manual

Recently, a new method of hazard categorisation has been developed by the revised AR&R manual (Book 6: Flood Hydraulics, Section 7.2.7). The classification is still based on depth and velocity, but utilises six categories based on the stability of children, adults, the elderly, vehicles in flood waters and the potentiality of structural damage to buildings.

The AR&R hazard curves are shown in **Figure 5-8**.

The results based on the hazard mapping are provided in **Appendix B**.

Within the Nepean River, flood hazard is predominately high, as a result of the significant depths that occur not just within the river channel but also on the overbank areas. The depths and velocity make mainstream Nepean River flooding hazardous for both pedestrians and vehicles. As a result of the steep terrain, the fringe of low hazard is relatively small. That is, the transition from high hazard to flood free occurs very quickly, with little low hazard flooding occurring in between.

For the tributaries, the hazard mapping shows that 1% AEP high hazard flows are largely contained within creek and river systems. The exception to this is the downstream reaches of Matahil Creek East, which has a high hazard region extending beyond the creek banks. This high hazard zone is largely driven by depths, which are over 1m in the 1% AEP. The further discretised AR&R hazard categories indicates that this region is unsafe for all people and vehicles.

For other tributary systems, the overbank flows that do occur are classified as low hazard, and are generally safe for people, vehicles and buildings, based on the AR&R hazard categories.

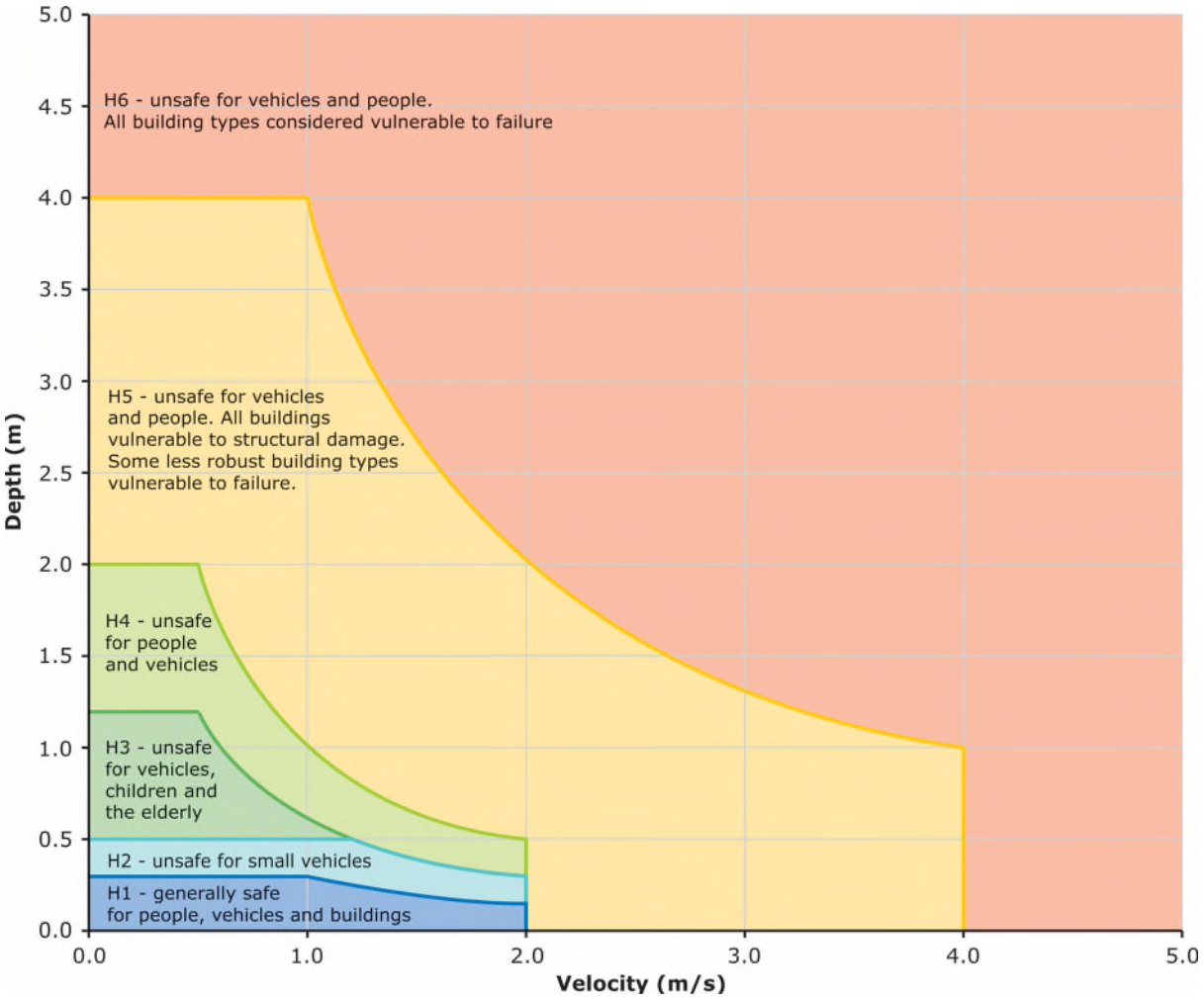

Figure 5-8 Provisional Hazard Categories from AR&R

During the PMF event, high hazard regions dominate the flood extent with only the outer flood fringe classified as low hazard. These high hazard regions impact developments along Matahil Creek East upstream of Burragorang Road. Further upstream along Matahil East Creek, property flooding is classified as low hazard, as is the PMF flooding occurring across properties along Spring Creek.

The AR&R hazard ratings indicated that the flooding upstream of Barragorang Road is classified as unsafe for all people. The flooding further upstream along Matahil Creek East and along Spring Creek is classified as being generally safe for people and vehicles.

5.5.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters, does not consider a range of other factors that influence the “true” flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

> Size of the flood;

> Effective warning time;

> Rate of rise of floodwaters;

> Duration of flooding;

> Ease of evacuation;

> Effective flood access; and,

> Flood readiness.

True flood hazard maps are provided for the 5%, 1% AEP and the PMF events in **Appendix B**.

5.5.2.1 Size of Flood

A comparison of peak flood levels for the design events is shown in **Figure 5-9**. The section is taken across the Nepean River, at the Argyle Street Bridge crossing, upstream of the Narellan Creek confluence. The figure shows that:

> The 2 year ARI is fully contained within the channel;

> Flooding breaks the banks of the Nepean River in the 20% AEP;

> There is a significant increase of 3.05m from the 20% AEP to the 5% AEP;

> There is a relatively small increase from the 5% AEP to the 1% AEP; and,

> A second significant increase of 4.05m was observed from the 1% AEP to the PMF.

This demonstrates that the Study Area has a significant residual flood risk that will be present even if buildings are constructed above the FPL (refer **Section 9** for further details).

In order to demonstrate this on the true hazard mapping, an additional hazard classification, *Residual Risk*, has been added to the true hazard maps. This hazard area shows regions that are flood free in the 1% AEP, but are prone to high hazard flooding in the PMF event.

5.5.2.2 Depth and Velocity of Flood Waters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. This provisional hazard mapping has been used as the basis for determination of true flood hazard.

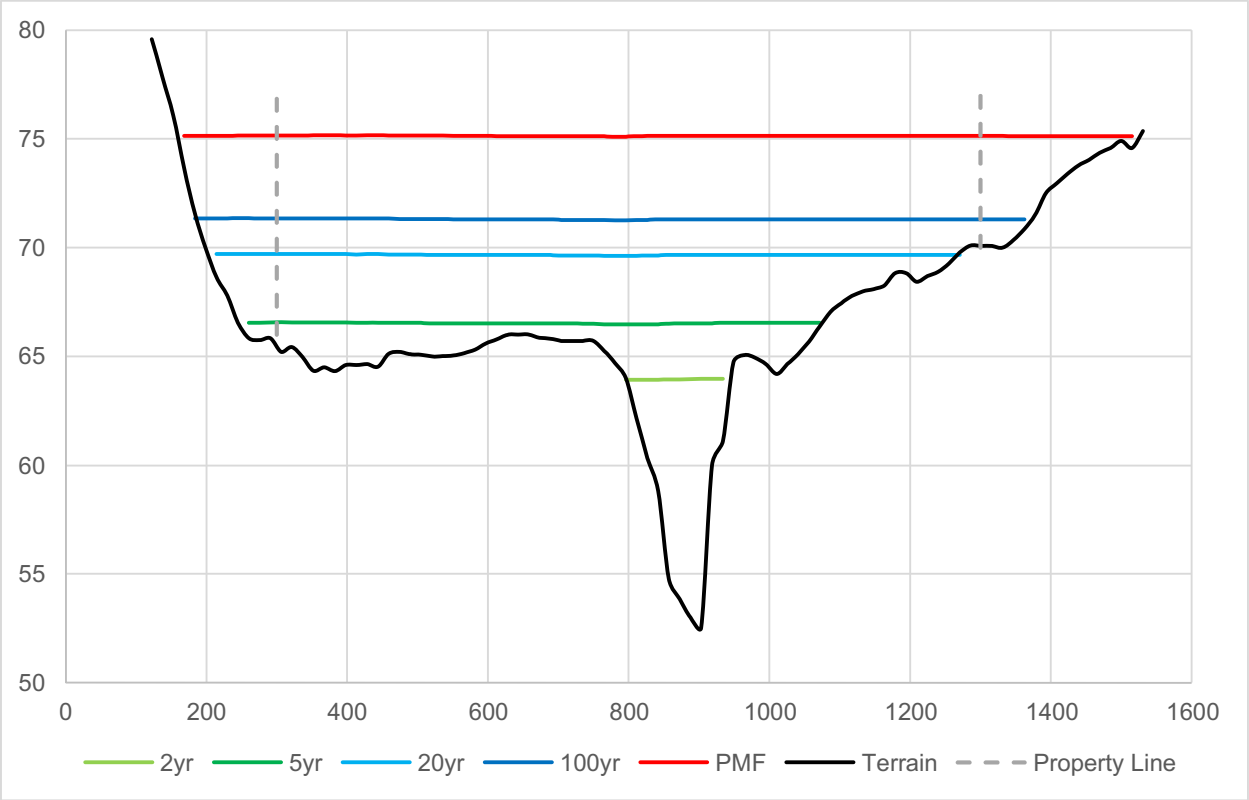

Figure 5-9 Comparison of Peak Flood Heights across Nepean River at Argyle St Bridge Crossing

5.5.2.3 Effective Warning Time

The effective warning time is the actual time available during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuate). The effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The critical duration storm for the Study Area ranges from:

> 1% AEP event
  - Thirty-six (36) to forty-eight (48) hours for the Nepean River;
  - Nine (9) hours for the tributaries;
> PMF event
  - Twelve (12) hours for the Nepean River; and
  - Two (2) hours for the tributaries.

The smaller overland flow systems have shorter critical durations, but these do not have as much impact on properties as the longer duration systems, such as the Nepean River. However, as discussed in **Section 10**, the shorter duration, non-critical storms in the Nepean River still result in significant flooding.

As can be observed the critical durations for Nepean River is generally larger than that from the tributaries. Consequently, there is an opportunity to implement a warning system for the Nepean River so the long durations associated with Nepean River events are able to provide long warning times for residents.

For many residents elsewhere in the study area, the first warning they may have of a flood occurring is inundation of their property or loss of access along roadways.

In the true hazard mapping, any flooding that results in overfloor flooding of properties has been classified as high hazard, given the current lack of warning time available to residents.

5.5.2.4 Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 0.5 m was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 0.5 m flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (NSW Government, 2005).

In the Study Area, there are 129, 150 and 527 properties with flow behaviour within these constraints for the 5% or 1% AEP events or PMF events respectively, which are not already selected by the provisional high hazard criteria in the Study Area.

5.5.2.5 Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally twenty (20) hours from mainstream, less than six (6) hours for tributaries, and around one (1) to three (3) hours for overland flooding. Those properties affected by longer periods of inundation are already selected by the provisional high hazard criteria.

5.5.2.6 Ease of evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

> The number of people requiring assistance;

> Mobility of those being evacuated;

> Time of day;

> Warning time;

> Availability of suitable evacuation equipment;

> Distance from other population centres;

> Presence of suitable evacuation routes; and

> Availability of emergency response agencies to assist evacuation.

Although the duration of flooding in the catchment is relatively short (in the order of hours as opposed to days), the region is affected by several of the factors listed above. These include little warning, high water velocity and depth, a lack of suitable evacuation routes (given the early loss of regional routes) and limited availability of emergency response agencies to assist in evacuations given the early loss of these access route.

In addition to these factors, it can reasonably be assumed that a significant proportion of able bodied adults leave the region to travel to their place of work. This results a significant change in the population demographics of the town during these periods, exacerbating evacuation difficulties.

Therefore, ease of evacuation for the majority of the catchment is considered to be an issue, particularly for properties that experience overfloor flooding in the 1% AEP and PMF events that do not have a second floor. This allows for limited opportunities for residents to escape the inundation within their properties.

In the true hazard mapping, any flooding up to PMF that results in overfloor flooding of properties has been classified as high hazard.

5.5.2.7 *Effective Flood Access*

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potentially reduce damages. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Access is a major concern for the region as access roads are often cut well in advance of properties becoming flood effected, with the result that by the time residents may be aware of the flood, the opportunity for regional evacuation has already been lost.

In the true hazard mapping, properties that are isolated as a result of flooding of access roads have been identified on the maps.

5.5.2.8 *Flood Readiness*

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond efficiently to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. While there have been minor to moderate flood events in recent history, the catchment has not experienced a major storm event in living memory. The largest flood event on record occurred in 1964, and was estimated to be in the order of a 5% to 10% AEP event.

Recent events in 2016 where largely local catchment driven events, and did not result in major Nepean River flooding.

As such, while the community is, to some extent, aware that flooding occurs, they are not fully cognizant of the risks and flood behaviour that would be expected in a major flood event. While residents have a sense that the region is affected by flooding, the community in general had little understanding of how serious the risk of flooding in the region is and how vulnerable certain portions of the region are to extreme flood events.

This lack of awareness of the actual flood risk increases the hazard faced by the community, as it heightens the chance that residents will respond inappropriately and undertake unsafe actions during flood events.

5.6 Weir Assessment

There are a number of weirs along the Nepean River that are currently not functioning. While not functioning at present, the removal of these weirs may still result in flood impacts both upstream and downstream of the weir. Therefore an assessment of the flood behaviour at these locations was undertaken at identify the advantages, disadvantages and risks or retaining or removing these weirs.

A total of eight (8) weirs along the Nepean River were modelled as part of the study. **Table 5-1** shows the comparison of the weir crest levels to the peak flood levels in different design storms. All the existing weirs would be submerged in an order of 4.50m to 9.50m in a 2 year ARI. This demonstrates that the removal of the weirs would not have any major flood impacts upstream and downstream of the weir in a 2 year ARI event or above. However, there may be minor impacts for design storms less than the 1 year ARI event. Flood modelling for smaller storms could be undertaken at further stages to check the peak flood level impacts and velocities in vicinity of the weirs along the Nepean River.

It is also recommended to undertake geomorphology and environmental impact assessments if the weirs are to be removed.

Table 5-1 Flood Levels at Weirs (mAHD)

Weir Location	Crest Level	2 Year ARI	10% AEP	5% AEP	1% Year ARI
Menangle Weir (Menangle Rd/ Menangle Rail Bridge)	61.60	69.95	73.35	76.30	78.05
Camden Weir (Confluence of Nepean River and Narellan Ck)	57.00	63.75	66.40	69.60	71.25

Weir Location	Crest Level	2 Year ARI	10% AEP	5% AEP	1% Year ARI
Sharpes Weir (Mooresfield Ln/ Phoenix Aero Club)	54.10	60.70	64.25	68.00	69.75
Cobbitty Weir (Sunnyside Dr/ Ellis Ln)	50.50	59.10	62.60	66.15	68.20
Mt Hunter Rivulet Weir (Cobbitty Rd/ Werombi Rd)	49.50	57.90	61.45	65.25	67.10
Brownlow Hill Weir (Werombi Rd/ Stanhope Rd)	48.00	57.35	60.85	64.80	66.70
Theresa Park Weir (Gulguer Trail/ Campbells Ford Trail)	46.50	51.10	54.15	58.50	61.20
Wallacia Weir (Silverdale Rd Mulgoa Rd)	26.50	32.90	36.35	41.10	43.75

5.7 ARR2016 Assessment

Since the time of the flood modelling undertaken as part of this study, the release of ARR 2016 has resulted in a different method for development of design rainfall and hydrological conditions.

On 25 November 2016 Geosciences Australia announced that:

> *The ARR 2016 Guidelines have now been officially finalised, providing engineers and consultants with the guidance and datasets necessary to produce more accurate and consistent flood studies and mapping across Australia, now and into the future.*

ARR consists of different data to enable and support the guidelines.

A sensitivity assessment is undertaken for the hydrology modelling to compare the ARR1987 methodology results with the new ARR 2016 rainfall conditions. Details of this assessment in provided in **Appendix C**.

5.8 Climate Change Assessment

The impact of climate change on catchment inflows, due to increases in design rainfall intensities has been considered in this study.

The Australian Rainfall and Runoff (ARR) Data Hub provides a table of temperature increases and percentage increase in rainfall for a set of forecast years and RCP 4.5, RCP 6 and RCP 8.5 emissions scenarios (CSIRO and BoM, 2015). ARR recommends the use of RCP 4.5 and 8.5 values. **Table 5-2** lists the values for Sydney (within the East Coast South Cluster).

Table 5-2 Interim Climate Change Factors for NRM East Coast South (Design Rainfall Increase in %) (Source: ARR Datahub)

Year	RCP4.5	RCP8.5
2030	4.3%	4.9%
2040	5.3%	6.8%
2050	6.4%	9.0%
2060	7.5%	11.5%

Year	RCP4.5	RCP8.5
2070	8.5%	14.2%
	9.2%	16.9%
2090	9.5%	19.7%

Increase in flood producing rainfall events due to climate change has been assessed by applying a 10% increase to rainfall intensity for the Study Area for the 1% AEP storm event. These equates to rainfall increases by 2090 under RCP4.5 and by 2050 under RCP8.5.

The peak flood depth, levels and velocity results with the increased rainfall intensities are provided in **Appendix B**. A comparison has been undertaken of the climate change scenario flood levels with the existing flood levels and is shown in **Figure 5-10**.

As can be observed, the increase in rainfall intensity has resulted in up to 0.25m increase in flood levels within the tributaries floodplain. For the mainstream floodplain, majority of the increases are within 0.5m to 0.75m. Downstream of Nepean River, at its confluence with Bringelly Creek, increases in flood levels greater than 1.5m are observed.

With the 10% increase to rainfall intensity, an additional 118 residential and 65 commercial lots are impacted with overground flooding in the 1% AEP storm event. **Figure 5-11** to **Figure 5-14** show the location of these additional lots.

5.9 Pipe Capacity Assessment

An assessment of the culverts within the Nepean River catchment and major trunk drainage within the Narellan Creek catchment was undertaken. The modelled pipe flows for each design event were extracted from the model and the design events at which the pipes are running full were determined.

The results of this assessment are provided in **Appendix B**.

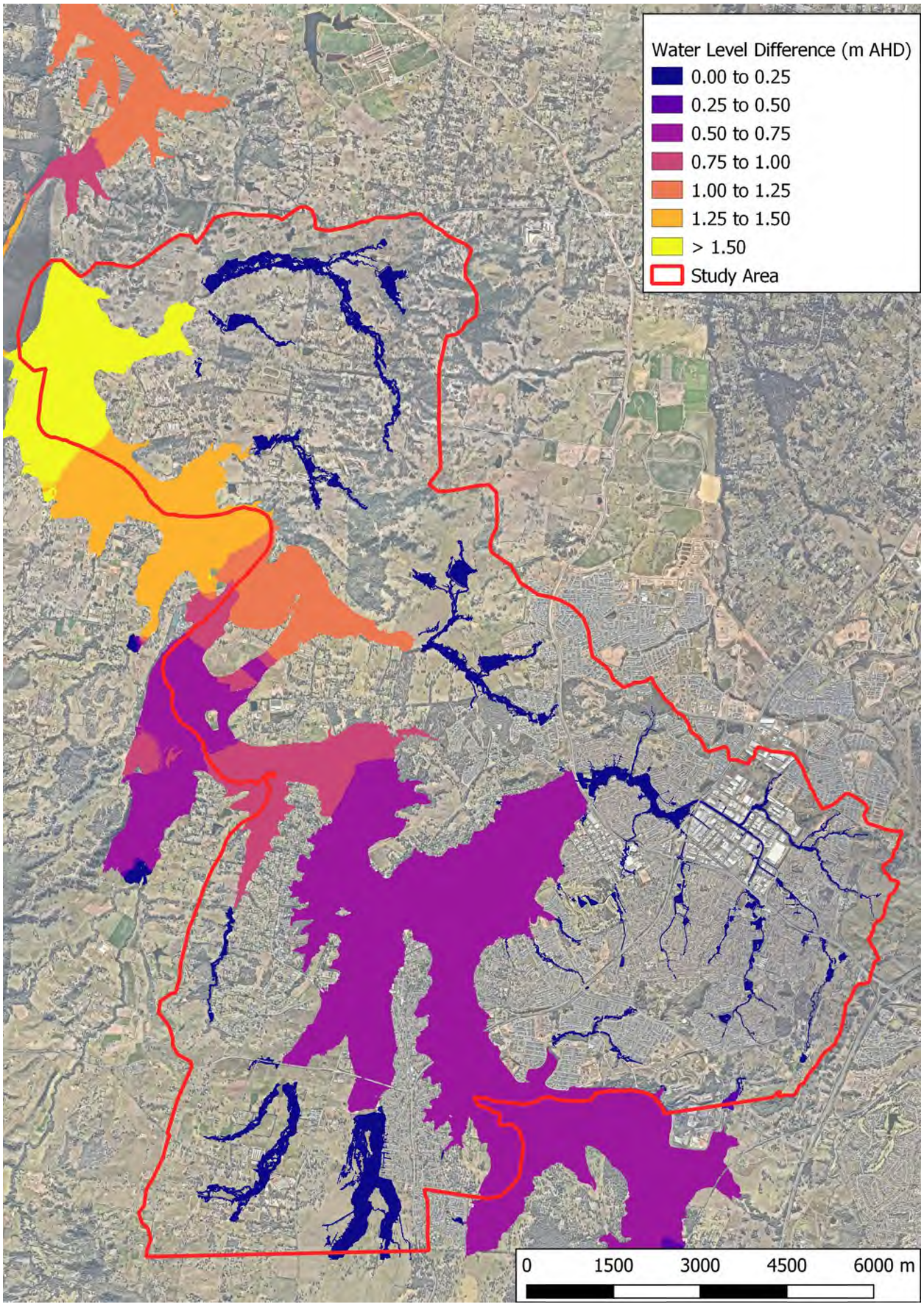

Figure 5-10 Comparison of Climate Change Flood Depths with Existing

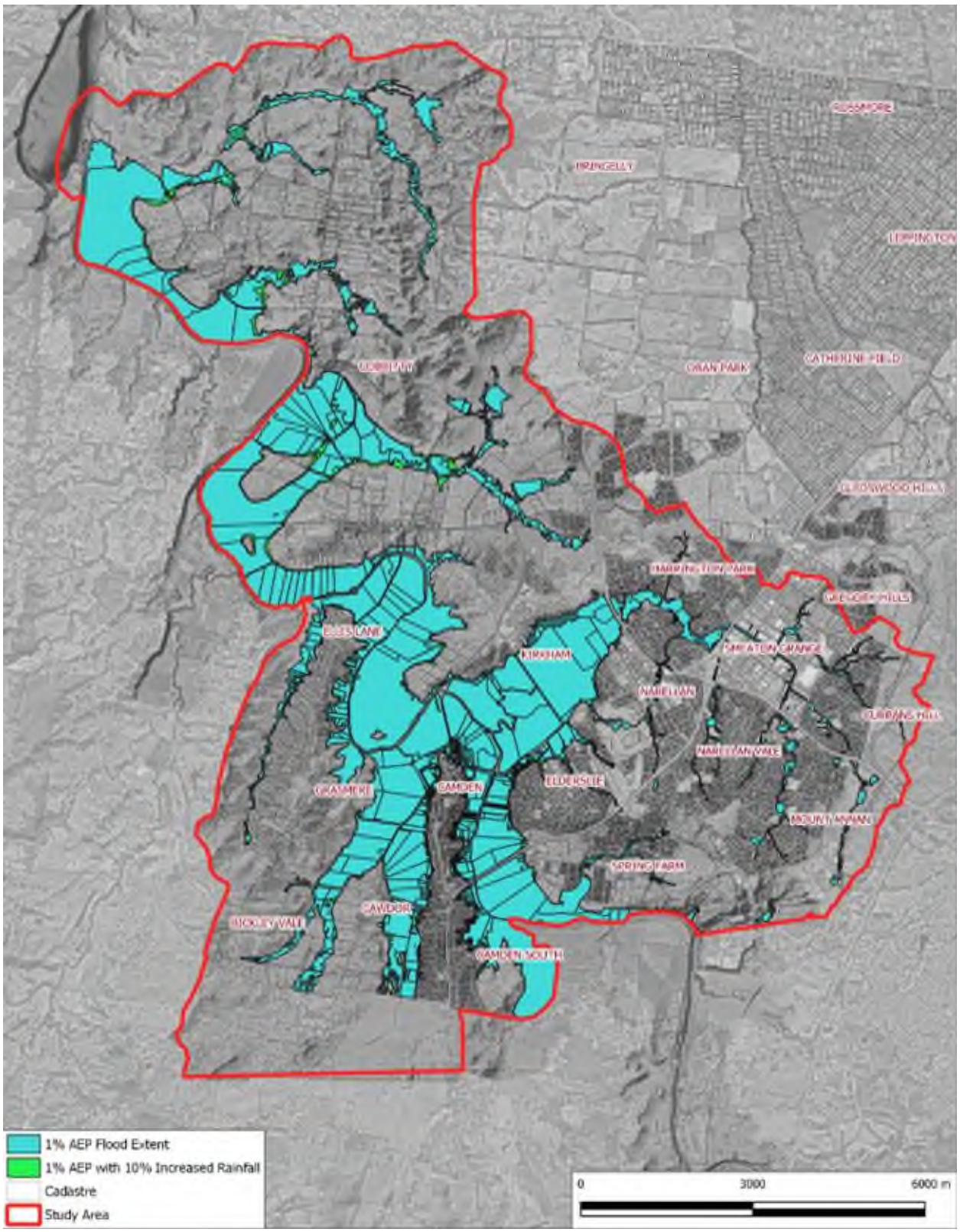

Figure 5-11 Additional Properties Impacted by the 1% AEP + 10% Increase in Rainfall Intensity

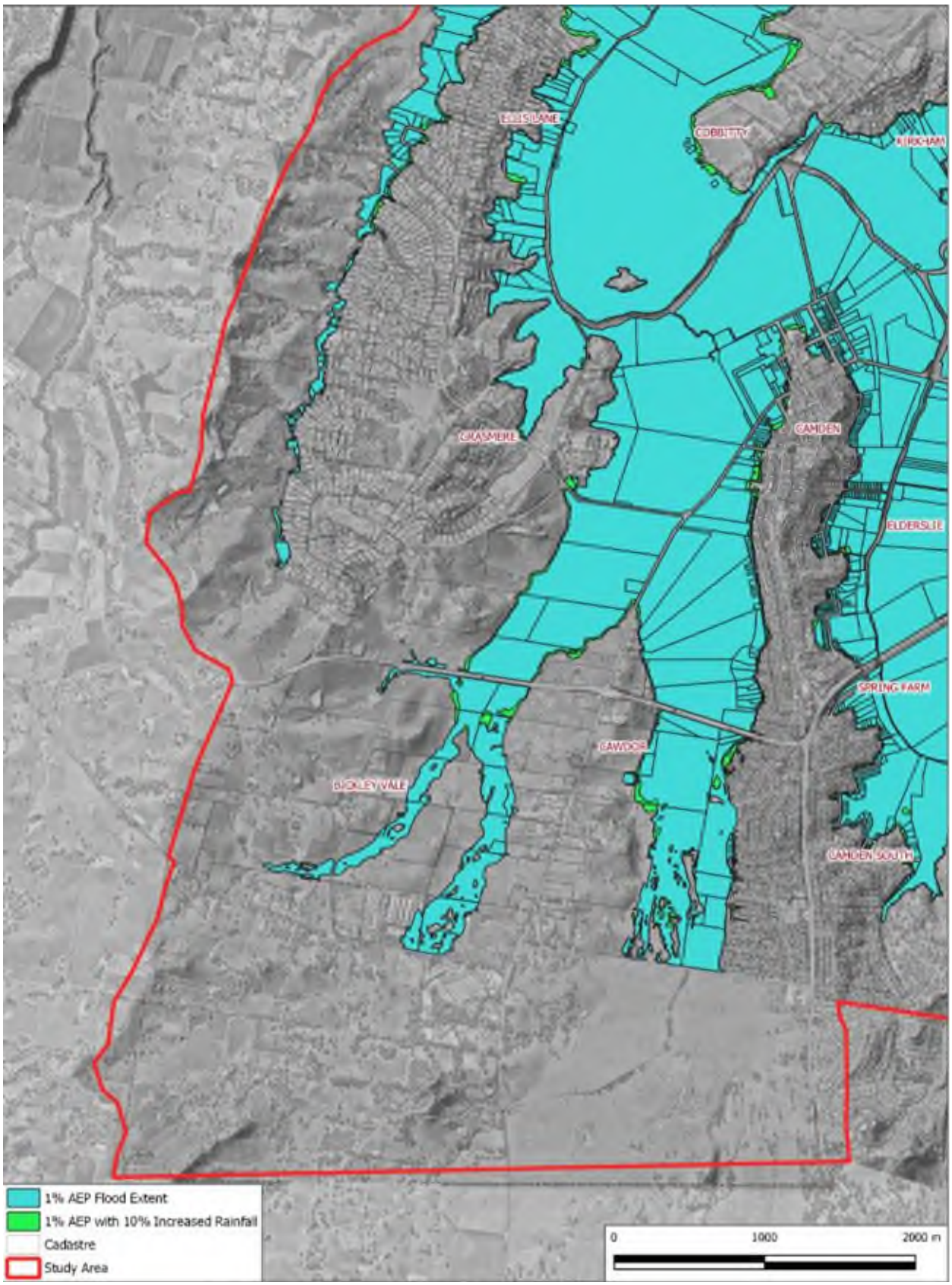

Figure 5-12 Additional Properties Impacted by the 1% AEP + 10% Increase in Rainfall Intensity – Inset A

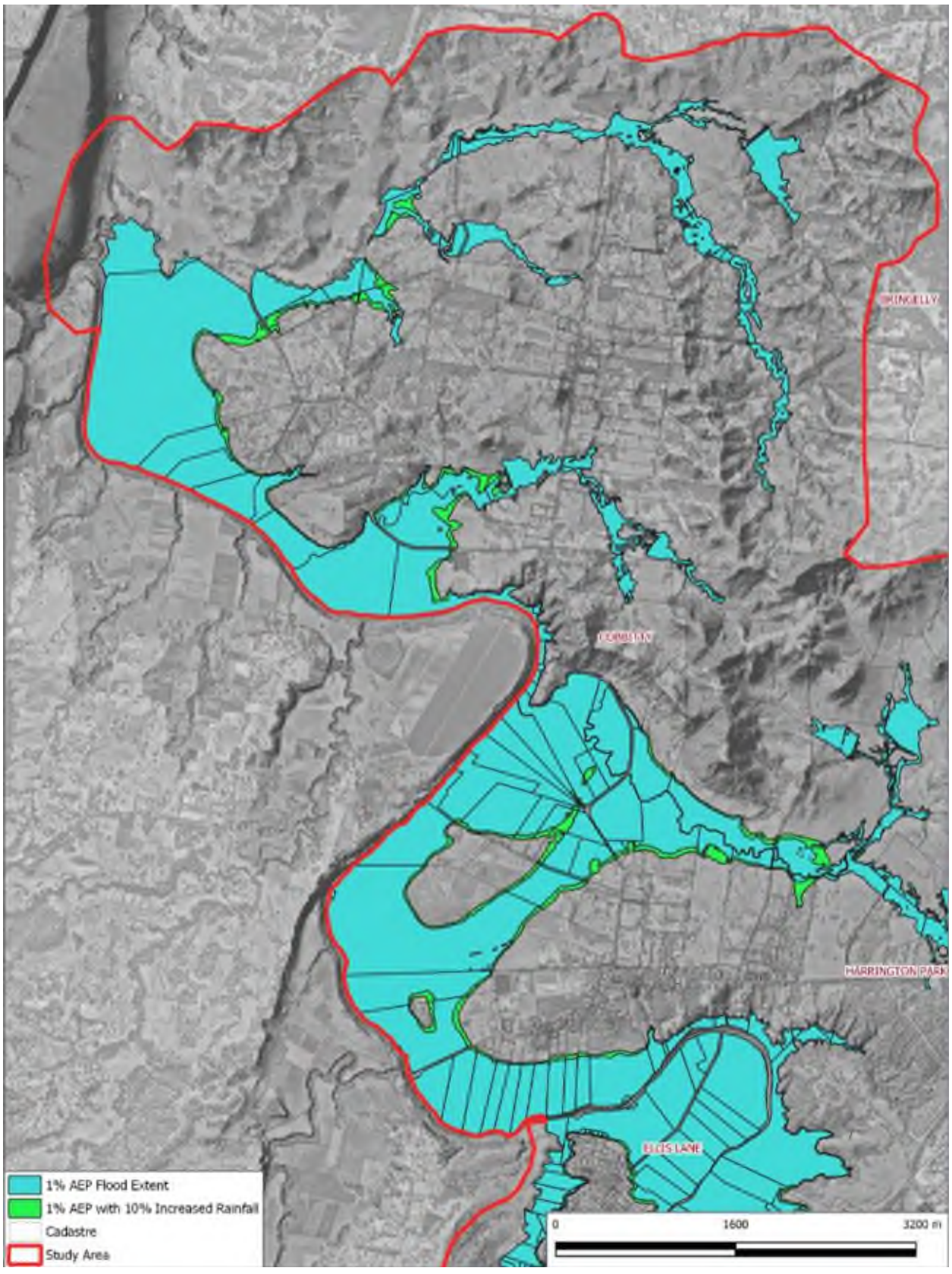

Figure 5-13 Additional Properties Impacted by the 1% AEP + 10% Increase in Rainfall Intensity – Inset B

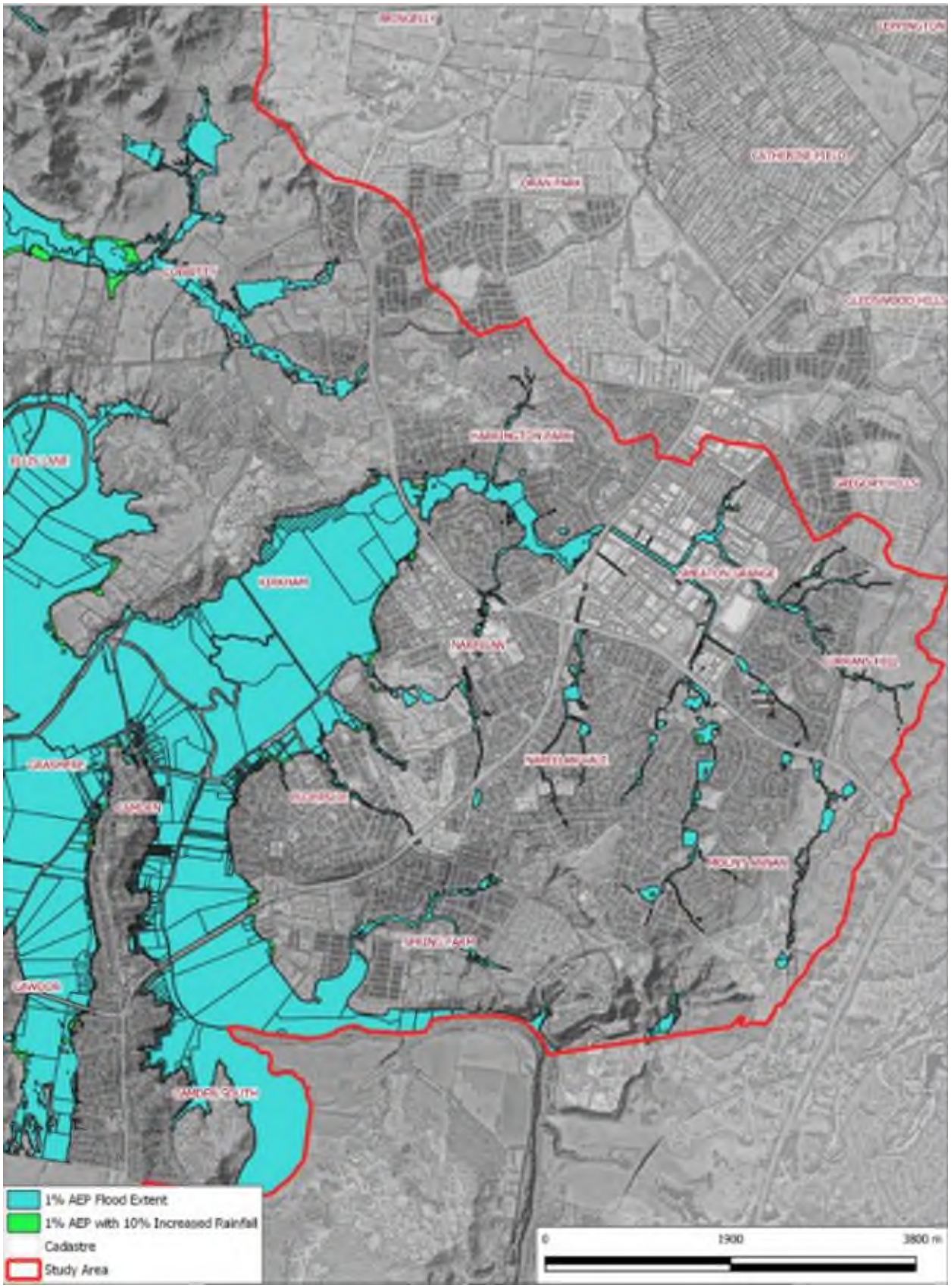

Figure 5-14 Additional Properties Impacted by the 1% AEP + 10% Increase in Rainfall Intensity – Inset C

6 Economic Impacts of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as various types; these types are summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

Type	Description
Direct	Building contents (internal)
	Structural damage (building repair)
	External items (vehicles, contents of sheds, etc.)
Indirect	Clean-up (immediate, removal of debris)
	Financial (loss of revenue, extra expenditure)
	Opportunity (non-provision of public service)
Intangible	Social (increased levels of insecurity, depression, stress)
	Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spread-sheets. For the purposes of this project, generic spread-sheets have been used based on a combination of The Department (previously OEH) residential damage curves and FLDamage.

6.2 Input Data

A survey of 3,400 properties was undertaken in 2017 for all the properties located with the PMF extent for the Nepean River catchment. This comprised of ground levels and floor levels of habitable buildings. This data was used to complete the flood damages assessment.

6.3 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments, and available research in the area, is used as a substitute.

The Department (previously OEH) has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties. The Department methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. However, the guideline is required to ensure consistency across the State regarding the calculation of the benefit cost ratio of recommended management options.

The following sections set out the methodology for the determination of damages within the Nepean River catchment.

6.3.1 Residential Damage Curves

The draft DNR (now Department of Planning, Industry and Environment) Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (NSW Government, 2005) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings, namely:

> Single story, slab on ground,

> Two story, slab on ground,

> Single story, high set.

Damages are generally incurred on a property prior to any over floor flooding. The Department curves allow for a damage of $12,492 (May 2016 dollars) to be incurred when the water level reaches the base of the house. We have assumed that this remains constant until overfloor flooding occurs. A nominal $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped by more than 0.3m of depth but only up to 0.3m below the floor of the house. This may occur on steeper properties and larger properties where the garden and fences may be impacted, but the floodwaters do not reach the house.

There are a number of input parameters required for the Department curves, such as floor area and level of flood awareness. The following parameters were adopted:

> A value of 100m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain. For larger houses, a value of 1000m^2 was adopted.

> The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents and hence reducing the potential damages of household contents,

> The township is a relatively small part of the regional area, and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in regional areas where re-construction resources are limited and large floods can cause a strain on these resources.

6.3.1.1 Average Weekly Earnings

The Department curves are derived for late 2001 and were updated to represent May 2016 dollars. General recommendations by the Department are to adjust the values in residential damage curves by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). The Department proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data from the Australian Bureau of Statistics at the time of this study was for May 2016. Therefore, all ordinates in the residential flood damage curves were updated to May 2016 dollars. In addition, all damage curves include GST as per the Department recommendations.

The Department guidelines were derived in November 2001, which allows us to use the November 2001 AWE statistics (issued quarterly) for comparison purposes. May 2016 AWE values were taken from the Australian Bureau of Statistics website. Both are shown in **Table 6-2**. Consequently, damages have been increased by 64%, which includes the increase due to GST, have been included compared to 2001 values.

Table 6-2 Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$673.60
May	2016	$1,516.00

6.3.2 Commercial Damage Curves

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

> Low value commercial,

> Medium value commercial,

> High value commercial.

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual commercial properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to December 2016 dollars, using data from the Australian Bureau of Statistics (ABS, 2016) shown in **Table 6-3**. The FLDamage data was in June 1990 dollars. Consequently, commercial damages have been increased by 105.1% and GST has been included compared to 1990 values.

Table 6-3 CPI Statistics for Commercial Damage Curves

Month	Year	CPI
June	1990	$102.50
Dec	2016	$210.21

6.3.3 Industrial Damage Curves

Cardno, as part of a previous floodplain management study (Cardno, 1998) conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. We therefore have used these damage curves for this study.

The curves were prepared for three categories:

> Low value industrial,

> Medium value industrial,

> High value industrial.

Within the Study Area, there are no properties considered to be representative of high value industrial properties, and hence these curves were not used. Medium and low value industrial curves were used based on the size of the floor area.

The floor areas for the industrial properties were estimated during the floor level survey. To normalise the damages for property size, the curves have been factored to account for floor area.

The survey conducted only accounts for structural and contents damage to the property. Clean-up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies Pty Ltd, 1992). Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made. The values were adjusted to May 2016 dollars using the CPI statistics show in **Table 6-4**.

Consequently, damages have been increased by 74% and GST has been included compared to the 1998 values.

Table 6-4 CPI Statistics for Industrial Damage Curves

Month	Year	CPI
June	1998	$121.00
Dec	2016	$210.21

6.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6-1**. For purposes of illustration, the commercial and industrial damage curves are shown for a property with a floor area of 100m^2, although the size will be individually determined for each commercial / industrial property when calculating catchment damages.

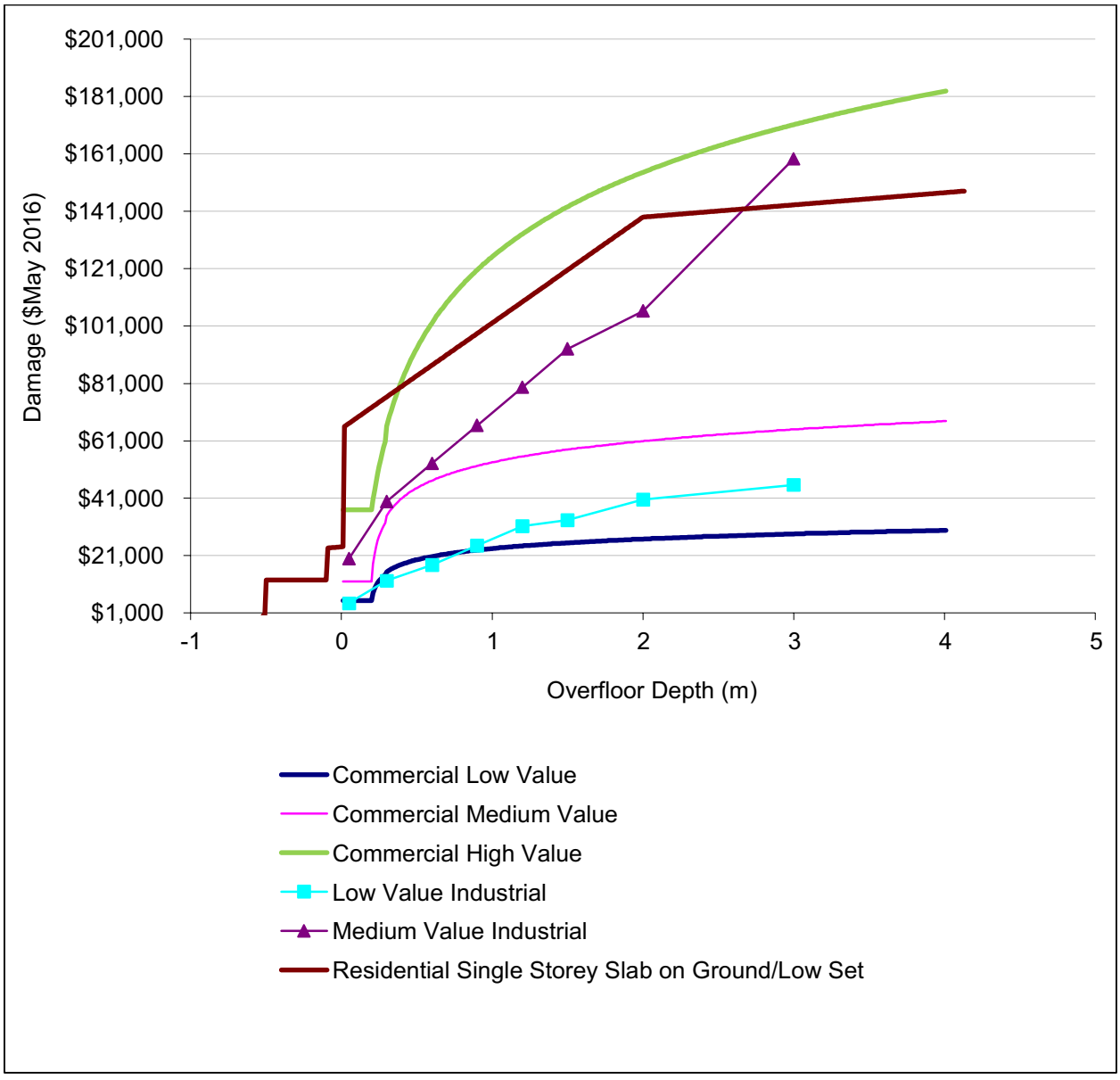

Figure 6-1 Adopted Damage Curves

6.5 Damages Results

The results from the damage analysis are shown in **Table 6-5** including:

The number of residential, commercial and industrial properties with overfloor flooding;

The average depth of overfloor flooding for residential, commercial and industrial properties;

The maximum depth of overfloor flooding for residential, commercial and industrial properties; and

Total damage value for the catchment.

It should be noted that these results are for Nepean River and its tributaries. The above results are listed for all design events; 2 year ARI, 20%, 5%, 1%, 0.5%, 0.2% AEP and the PMF event.

Table 6-5 Nepean River Existing Damage Analysis Results

	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damages ($)
PMF					
Residential	2071	1.53	10.40	2265	$218,636,674
Commercial	231	2.45	10.69	235	$155,366,574
Industrial	4	2.49	6.23	5	$601,935
PMF Total	2306			2505	$374,605,183
0.2% AEP					
Residential	431	1.65	7.69	541	$46,851,579
Commercial	86	2.83	8.19	86	$60,401,487
Industrial	2	2.19	3.69	2	$610,787
0.5% AEP Total	519			629	$107,863,853
0.5% AEP					
Residential	283	1.68	6.93	374	$31,777,759
Commercial	76	2.48	7.47	78	$49,784,573
Industrial	2	1.47	2.96	2	$449,088
1% AEP Total	361			454	$82,011,419
1% AEP					
Residential	200	1.66	6.23	276	$23,173,984
Commercial	70	2.05	6.83	71	$41,184,610
Industrial	1	2.21	2.31	0	$415,784
2% AEP Total	271			347	$64,774,378
5% AEP					
Residential	108	0.89	4.47	146	$10,568,762
Commercial	38	1.49	5.18	44	$18,700,854
Industrial	1	0.56	0.66	0	$170,026
5% AEP	147			190	$29,439,642

	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damages ($)
20% AEP					
Residential	11	0.31	1.55	17	$795,671
Commercial	2	0.94	2.03	1	$263,192
Industrial	0	0.00	0.00	0	$-
10% AEP Total	13			18	$1,058,863
2 year ARI					
Residential	5	0.08	0.17	9	$311,126
Commercial	1	1.16	1.35	1	$241,497
Industrial	0	0.00	0.00	0	$0
2 year ARI Total	6			10	$552,622

6.5.2 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event. Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

The AAD value attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event. For example, the 1% AEP design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve.

While the PMF event has a theoretical probability of 0% of occurring, to inform the calculation of AAD a representative probability of 0.0001 (or 0.01%) has been adopted for the PMF event (equivalent to a 10,000 year ARI event). Through this method, the PMF accounts for extremely rare flood events in the AAD calculation.

Further information of the calculation of AAD can be found in Appendix M of the Floodplain Development Manual (NSW Government, 2005).

Based on the analysis described above, the average annual damage for the Nepean River and its tributaries floodplain, including Narellan Creek, under existing conditions is **$5,685,793**.

7 Social & Environmental Characteristics

7.1 Demographic Characteristics

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, in the consideration of emergency response or evacuation procedures, information may need to be presented in a range of languages and/or additional arrangements may need to be made for less mobile members of the community.

The Upper Nepean River catchment comprises part or all of the suburbs of:

> Camden;

> Camden South;

> Cawdor;

> Cobbitty;

> Currans Hill;

> Elderslie;

> Ellis Lane;

> Grasmere;

> Harrington Park;

> Kirkham;

> Mount Annan;

> Narellan;

> Narellan Vale;

> Oran Park;

> Smeaton Grange; and

> Spring Farm.

As these suburbs make up approximately 90% of the Camden LGA, demographic data of the Camden LGA was assumed to be representative of the Study Area. Demographic data, sourced primarily from the Australian Bureau of Statistics (ABS) 2016 Census, from the Camden LGA was reviewed to gain an appreciation of the social characteristics of the area.

Analysis has been based on data for the Camden LGA, which is a defined area for Census data amalgamation. Census data showed that the population within Camden LGA in 2016 was 78,236, with a median age of 33 years, which was slightly lower than the median for NSW (38). A summary of the age distribution is provided in **Table 7-1**.

More than half (56%) of the people in the LGA suburbs are aged between 15-54 years, which suggests that the community is likely to be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures. Approximately 13% of the population is made up of the very young (0-4 years) and the elderly (>75 years) and it is important to consider these members of the community in flood risk management planning.

Approximately 85% of households are family or group households, so it is likely that most people in the community would have assistance from friends or family during evacuation events if needed.

Within the Camden LGA, 81% of people spoke only English at home. Other languages spoken included Arabic (1.4%), Italian (1.3%), Spanish (1.3%), Hindi (0.9%) and Mandarin (0.7%). This suggests that language barriers (e.g. during evacuation, or for flood education), are unlikely to be a significant issue in this area.

The median house price is $628,500 (www.realestate.com.au, 2015), compared with a median property price for houses in NSW of $476,000 (APM, 2015). The median unit price is $447,550

(www.realestate.com.au, 2015), compared with a median unit price of $390,000 (APM, 2015). This information has implications for the economic damages incurred during a flood event.

Table 7-1 Age Structure of the Catchment (ABS, 2016)

Age Group	Persons in Camden LGA	% of Total in Camden LGA	% of Total Persons in NSW
0-4 years	6,552	8.4	6.2
5-9 years	6,321	8.1	6.4
10-14 years	5,830	7.5	5.9
15-19 years	5,357	6.8	6
20-24 years	4,846	6.2	6.5
25-29 years	5,693	7.3	7
30-34 years	6,206	7.9	7.2
35-39 years	5,848	7.5	6.7
40-44 years	6,110	7.8	6.7
45-49 years	5,240	6.7	6.6
50-54 years	4,601	5.9	6.5
55-59 years	3,961	5.1	6.3
60-64 years	3,415	4.4	5.6
65-69 years	2,970	3.8	5.1
70-74 years	2,014	2.6	3.9
75-79 years	1,356	1.7	2.9
80-84 years	936	1.2	2.1
85 years and over	980	1.3	2.2
TOTAL	*78,236*	*100%*	*100%*

7.2 Topography & Soils

The Nepean River catchment is relatively flat with localised high points, particularly in the north of the Study Area at Cobbitty. At Mount Annan, the Study Area has a slight rise towards the south-east.

Geotechnical and soil investigations may be required for larger-scale structural floodplain risk management options that are proposed to ensure that environmental risks are considered and mitigated. A review of the Soil Landscape Map of Sydney (Scale 1:100,000) indicates that the Nepean River Study Area is located on several soil landscape groups, and some limitations to development may be present. Key soil limitations are outlined below in **Table 7-2** and these may need to be considered during floodplain risk management options development and design:

Acid sulphate soils are not expected to be present in the Study Area.

Table 7-2 Soil Types in Study Area

Soil Types	Process	Limitations
Nepean River Floodplain	Alluvial	
South Creek	Alluvial	Generally some limitations to development including waterlogging and flood hazard
Cranebrook	Stagnant Alluvial	
Luddenham	Erosional	
Disturbed Terrain	Disturbed Terrain	
Picton	Colluvial	
Picton variant a	Colluvial	
Blacktown	Residual	Generally minor limitations to development, though soils may experience waterlogging, Generally moderate erosion hazard but ranges from low to very high.
Menangle	Transferral	
Second Ponds Creek	Transferral	

7.3 Contaminated Land & Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the Contaminated Land Management Act 1997. Contamination issues need to be considered at the flood management options development and design stage.

The Department of Planning, Industry and Environment The Department (previously OEH) regulates contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online the Department Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA, on 19 February 2016. A total of seven (7) premises were listed. There are four (4) services stations, a gasworks, a landfill, and an unclassified site. It is important to note that there are limitations to the registers and sites may be contaminated that are not listed.

A search of the *Protection of the Environment Operations Act 1997* (PoEO Act) licensed premises public register on 19 February 2016 identified 27 premises within the catchment that have, or previously had, pollution discharge licences.

A list of the contaminated land and licensed discharge sites is provided in **Appendix D**.

7.4 Threatened Flora and Fauna

A search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2016) undertaken in February 2016 indicated that five threatened ecological communities may occur in the area, namely:

> Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered);

> Cooks River / Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered);

> Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (Critically Endangered);

> Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered); and

> Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered).

The Bionet Atlas of NSW Wildlife (The Department, 2016) was searched for threatened ecological communities listed under the Threatened Species Conservation (TSC) Act within the Study Area and the

Commonwealth's Environment Protection and Biodiversity Conservation (EPBC) Database. Seventeen communities were found.

The Bionet Atlas of NSW Wildlife (The Department, 2016) was searched in February 2016 for threatened species listed under the TSC Act and EPBC Act:

> Approximately 795 threatened flora sightings, consisting of 67 species, have been recorded within the Camden LGA; and

> Approximately 163 threatened or migratory fauna sightings have been recorded in the within the Camden LGA, consisting of three amphibian species, two reptile species, 44 bird species, 15 mammal species, and two gastropods.

A search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2016) undertaken in February 2016 indicated that a total 31 threatened species and 14 migratory species are known, likely or may occur in the area.

Small areas of threatened ecological communities are present within the catchment. Records for both threatened flora and fauna are scattered across the wider area, with clusters tending to form in more vegetated areas and along the Nepean River.

The large number of threatened communities and species that occurs or has the potential to occur within the LGA should be considered in the development and implementation of any proposed flood modification options or flood protection works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

Details of the threatened flora and fauna identified are provided in **Appendix D**.

The locations of the threatened flora and fauna species are shown in **Figure 7-1**.

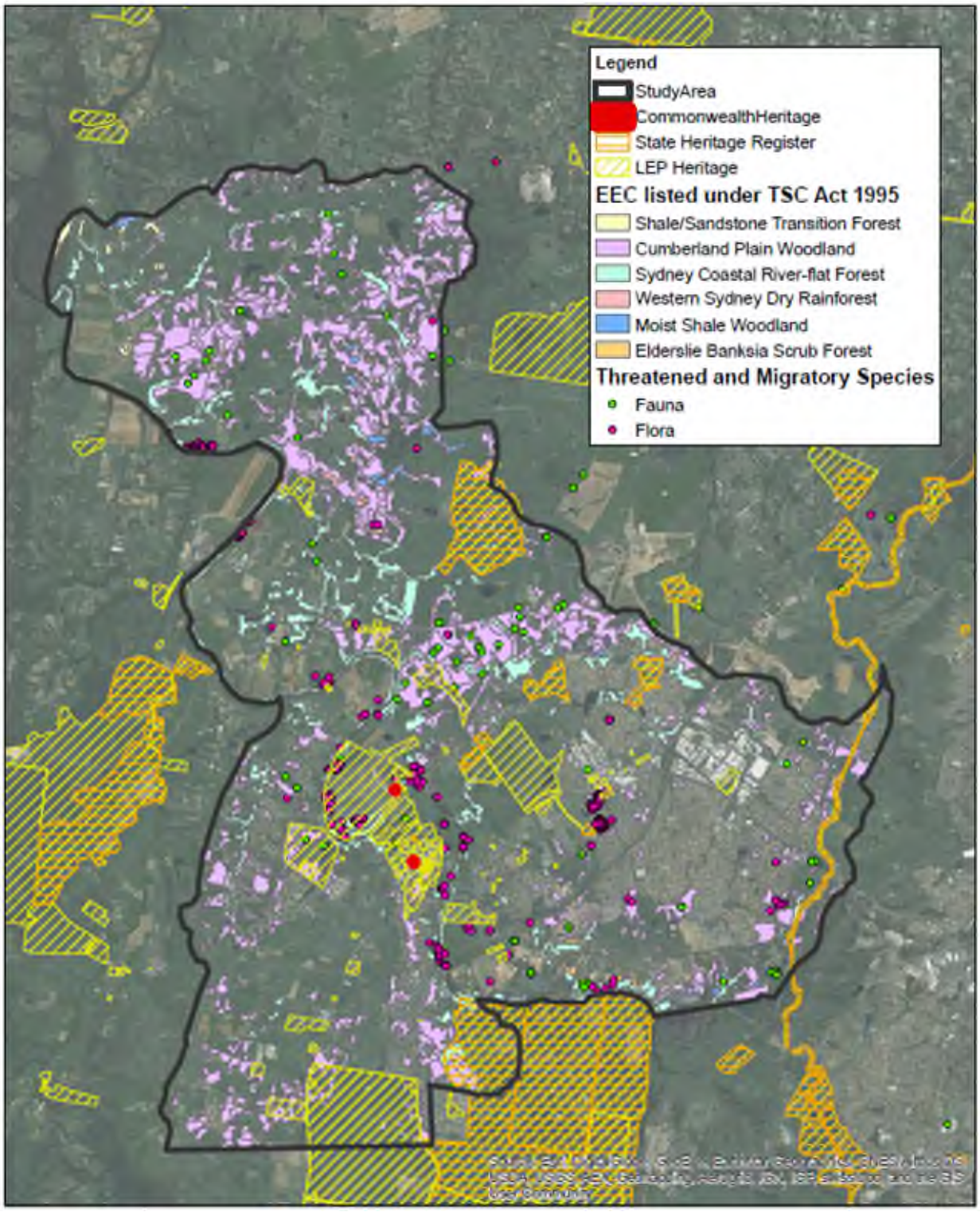

Figure 7-1 Environmental Features within the Study Area

7.5 Heritage

7.5.1 Aboriginal Heritage

'Traditional Custodians' is the term to describe the original Aboriginal or Torres Strait Islander people who inhabited an area (DLG, n.d). Traditional custodians today are descendants of the original inhabitants and have ongoing spiritual and cultural ties to the land and waterways where their ancestors lived.

Camden sits at the intersection of three Aboriginal tribal boundaries: the people of the Camden town location, the western Cowpastures and the adjoining mountainous areas are Gundungurra; the eastern Cowpastures are Tharawal, and the people to the northeast of the Nepean River are Dharug (CC, n.d.).

The Camden LGA along with Campbelltown and Wollondilly sit within the Tharawal Local Aboriginal Land Council (LALC) boundaries.

A preliminary investigation of Aboriginal heritage was undertaken by searching the online Aboriginal Heritage Information Management System (AHIMS) on 22 February 2016 (The Department, 2016b) for known or potential Aboriginal archaeological or cultural heritage sites within or surrounding catchments. The AHIMS search returned at least 480 records of Aboriginal sites recorded in or near catchment.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and therefore any management options that will impact upon Aboriginal sites must include this in their design. Known Aboriginal sites should be left undisturbed if possible, however if a management option requires their destruction, an Aboriginal Heritage Impact Permit (AHIP) must be sought from The Department. Under the NPW Act it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area.

7.5.2 Non-Indigenous Heritage

Non-Indigenous heritage can be classified into three statutory listing classifications based on significance, namely Commonwealth, State and local. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Indigenous heritage was undertaken for the Camden LGA. Searches were undertaken of the following databases:

> Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List);

> State Heritage Register; and

> Local Council Heritage.

One item was identified as being a listed place on the Commonwealth Heritage List, one item was listed as an indicative place (no formal nomination has been made):

> Camden Post Office 135 Argyle St, Camden NSW (Listed place, Commonwealth Heritage List); and

> Cottage rear Macquarie Grove House, Macquarie Grove Rd, Camden NSW (Indicative Place, Commonwealth Heritage List).

An additional 33 places are listed on the Register of the National Estate (non-statutory archive).

Eleven heritage items were identified as being listed under the *NSW Heritage Act* 1977 and a further eleven heritage items were identified as being listed by State Agencies under Section 170 of the *NSW Heritage Act* 1977.

Details of the heritage items are provided in **Appendix D**.

The Study Area falls within the South West Growth Centre. One heritage item is listed under the State Environmental Planning Policy (Sydney Region Growth Centres) 2006:

> Denbigh Curtilage, Cobbitty.

Within the Study Area, at least 140 items of local heritage are listed under the Camden Local Environment Plan 2010, and another eight local heritage items are listed under the Wollondilly Local Environment Plan 2011.

Where alteration of a heritage item is proposed, the proponent must refer to Part 5, Clause 5.10 of the Camden Local Environment Plan 2010 or Wollondilly Local Environment Plan 2011. Depending on the nature of any structural floodplain risk management works proposed, a more detailed heritage assessment may be required to assess potential impacts on these features.

8 Policies & Planning Review

The Study Area lies within the Camden LGA were development in controlled through the Camden Local Environment Plan (CLEP2010) and the Camden Development Control Plan (DCP2011). The CLEP2010 is a planning instrument that designates land uses and developments within the LGA, while the DCP2011 regulates developments with specific guidelines and parameters.

8.1 Local Environment Plan (CLEP2010)

The New South Wales Planning Reforms require all local governments to prepare their planning instruments in accordance with a new standard instrument LEP. The key features of these reforms are:

> An objective of reducing the number and layers of planning instruments;

> Provision of a standard LEP template for Councils to conform to;

> All mandatory controls to be included in the LEP;

> Mandatory timeframe for Council to prepare a new LEP (3-5 years);

> Rationalise and clarify the Development Control Plan (DCP) relationship to LEP; and

> Replace Master Plans with DCPs and staged development applications.

Under this process, Camden Council has developed an LEP which was gazetted in 2010. An important aspect of the LEP is to provide opportunities for controlling development within various land use zones so that it manages flood risk in a safe manner.

Land use zoning for the Study Area is indicated on **Figure 8-1**. The land use zonings designate the types of development that are permissible (either with or without consent) or not permissible in accordance with the objectives of each particular zone.

Flood planning is included in Clause 7.1 of the LEP. Clause 7.1 outlines the objectives, areas of application and controls for floodplain management in the LGA. Clause 7.1 applies to areas within the extent of the Flood Planning Level (FPL), which is defined in the LEP as the 1% AEP flood level plus 600mm freeboard. All land uses of the LEP are subject to the provisions of flood control if the land parcel, or a portion of it, is located within the Flood Planning Area (FPA).

Further consideration of flooding and stormwater management is included in Clause 6.3 of the LEP. This clause requires that land development be undertaken under the provision of a Development Control Plan, which set out suitable plans and strategies to ameliorate environmental hazards such as flooding.

8.2 Current Land Use & Zoning

A range of land uses are located within the Study Area. Summarised in **Figure 8-1** are the land use zones within the Study Area, and the extent to which these zones are mainstream flood affected by the 1% AEP.

Over half of the Study Area (52%) is zoned as primary production. Other major land uses within the Study Area are low density residential (13%) and environmental conservation (5%).

The major flood affected uses are mixed use and public recreation which have 70% and 78% of their total area inundated in the 1% AEP. The high percentage of flood affected public recreation land is due to these areas storing and / or conveying flows during flood events.

With regard to residential development, 6% of low density residential, 0.2% of medium residential and 22% of large lot residential zones are flood affected in the 1% AEP.

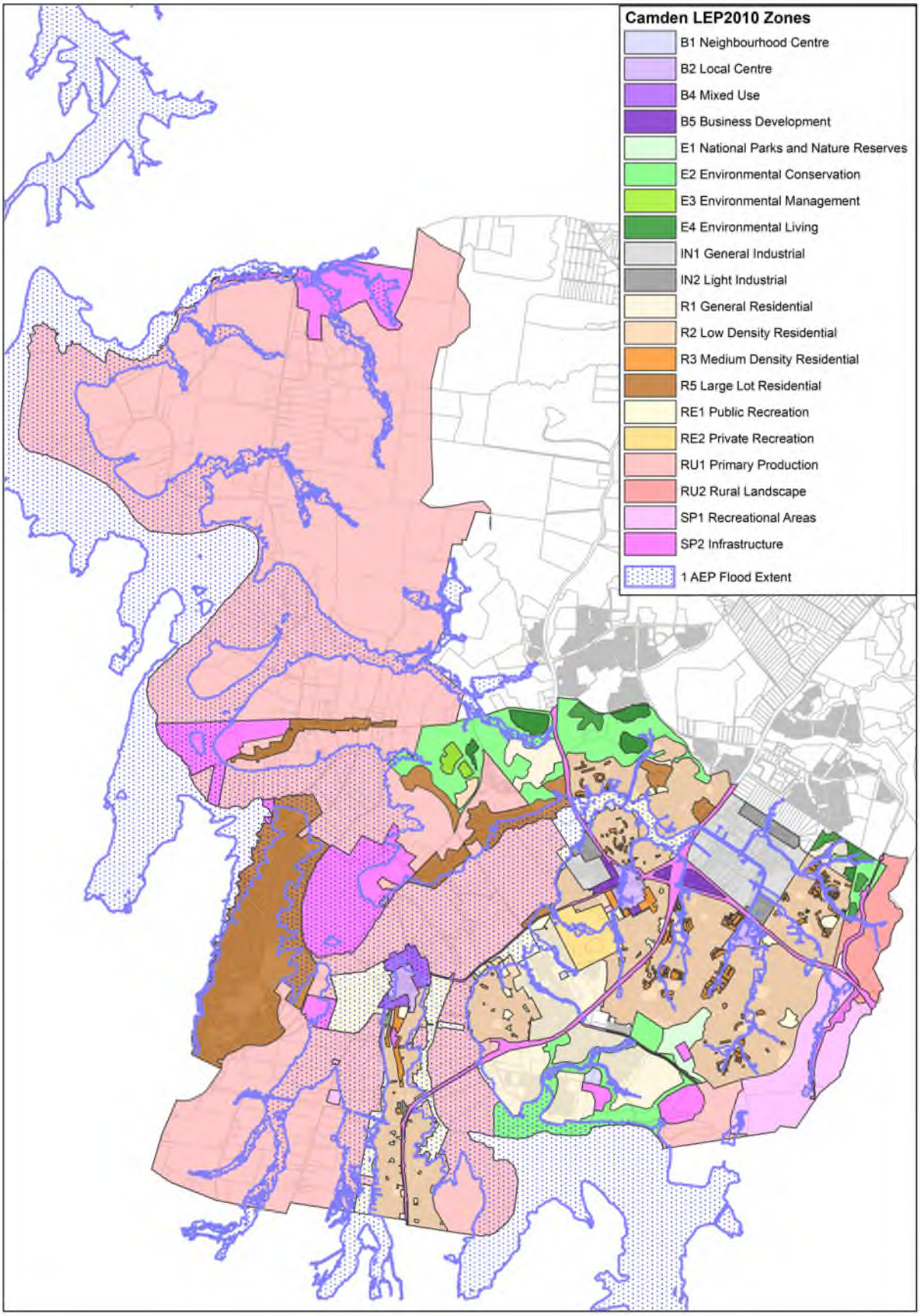

Figure 8-1 LEP Zones within the Study Area

Table 8-1 Land Use Zones within the Study Area

Zone	Land Use	Area within study boundary (ha) (% of total catchment area)	Flood affected area within study boundary (ha) (% of total land use area)
B1	Neighbourhood Centre	11 (0.1%)	1 (1.1%)
B2	Local Centre	74 (0.6%)	15 (20.3%)
B4	Mixed Use	36 (0.3%)	25 (69.4%)
B5	Business Development	31 (0.3%)	*Not flooded*
E1	National Parks and Nature Reserves	43 (0.4%)	*Not flooded*
E2	Environmental Conservation	545 (4.6%)	105 (19.4%)
E3	Environmental Management	16 (0.1%)	*Not flooded*
E4	Environmental Living	86 (0.7%)	1 (0.5%)
IN1	General Industrial	236 (2%)	14 (5.8%)
IN2	Light Industrial	55 (0.5%)	2 (4%)
R1	General Residential	510 (4.3%)	17 (3.4%)
R2	Low Density Residential	1,507 (12.6%)	92 (6.1%)
R3	Medium Density Residential	98 (0.8%)	1 (0.2%)
R5	Large Lot Residential	763 (6.4%)	169 (22.2%)
RE1	Public Recreation	322 (2.7%)	254 (78.1%)
RE2	Private Recreation	85 (0.7%)	8 (9.7%)
RU1	Primary Production	6,253 (52.4%)	2372 (37.9%)
RU2	Rural Landscape	173 (1.4%)	2 (1.3%)
SP1	Recreation Areas & Special Activities	260 (2.2%)	13 (5.2%)
SP2	Infrastructure	828 (6.9%)	349 (42.5%)

8.3 Camden Development Control Plan

Within the Camden DCP (2011), Section B1.11 Flood Hazard Management provides development controls for flood affected areas.

The DCP does not include these controls, but rather refers to two additional Council documents:

> Council's Engineering Specifications; and

> Council's Flood Management Policy.

8.3.1 Camden Engineering Specifications

The Design Specification has been prepared for the guidance of Owners, Applicants, Superintendents, Consultants, Contractors and representatives thereof to outline Council's engineering specifications for the design of subdivisions and the development of land within the Camden Council area.

Flood related controls are provided in *Section 3.8 Flood Liable Land* and Section *4.5.5 Site Regrading of Flood Prone Land*.

8.3.2 Camden Flood Risk Management Policy

The Camden Floodplain Risk Management Policy establishes flood risk management planning and development procedures for all flood prone land within the Camden Local Government Area (LGA). The primary method of Flood Risk Management in the Camden LGA is through the application of development controls, with the use of a development matrix, on flood prone lands up to the extent of the PMF. Council seeks to manage development on flood prone property that minimizes financial and personal risk to the community.

The aims and objectives of the flood risk management policy are to:

> Inform applicants of Council's Development Controls in flood risk areas;

> Adopt a Flood Planning Level (FPL);

> Alert the community to the extent and hazard of flooding in the Camden LGA;

> Reduce the impact of flooding on individual properties;

> Limit private and public liability resulting from flooding;

> Limit the potential risk to life and property resulting from flooding;

> Prevent non-compatible development in flood prone areas and ensure development in flood prone areas is sympathetic with the character of the surrounding land uses;

> Ensure, where practical, that buildings and services required for evacuation and emergency needs are located above the Probable Maximum Flood (PMF); and

> Assess all proposed developments on flood prone properties on a 'merits based' approach taking account of social, economic, environmental and flooding considerations.

8.3.3 State Environment Planning Policy (Sydney Region Growth Centres) 2006

The South West Growth Centre (SWGC) has been designated for long-term development over the coming decades to respond to the increasing population demands placed on the greater Sydney region. Portions of the SWGC include land located within the Camden LGA. Only a small part of Nepean River Catchment including Narellan Creek lies within Growth Area.

Land within the SWGC is controlled by a specific planning instrument, the State Environmental Planning Policy (SEPP) Sydney Region Growth Centres 2006. Before land is rezoned, both the SEPP and the CLEP2010 apply. Once rezoned, the CLEP2010 no longer applies, and all planning controls are applied via the SEPP.

The CLEP2010 provides much more explicit controls, while the SEPP2006 includes broad statements that applicants must demonstrate compliance with. These statements require the consent authority to consider:

> Whether or not the development will adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties,

> Whether or not the development will alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain;

> Whether the development will enable safe occupation of the flood prone and major creeks land;

> Whether or not the development will detrimentally affect the floodplain environment or cause avoidable erosion, siltation, salinity, destruction of riparian vegetation or a reduction in the stability of the riverbank/watercourse;

> Whether or not the development will be likely to result in unsustainable social and economic costs to the flood affected community or general community, as a consequence of flooding;

> Whether or not the development is compatible with the flow conveyance function of the floodway;

> Whether or not the development is compatible with the flood hazard;

> In the case of development consisting of the excavation or filling of land, whether or not the development:

- will detrimentally affect the existing drainage patterns and soil stability in the locality;
- will significantly impact on the likely future use or redevelopment of the land;
- will adversely impact on the existing and likely amenity of adjoining properties;
- will minimise the disturbance of relics; and
- will adversely impact on any watercourse, drinking water catchment or environmentally sensitive area.

Council and The Department have developed a process to ensure that the developments undertaken are in line with Council's flood policy. This process involves applying the State Environmental Planning Policies (SEPP) to the development, followed by the Camden Growth Area DCP and then referring to the Camden Council Flood Risk Policy.

8.4 Recommended Changes to the Camden Flood Risk Management Policy

As a result of the investigation into planning controls, a number of recommendations are proposed to increase the effectiveness and clarity of the Camden DCP.

These recommendations are set out in **Table 8-2**. It is noted that Council is currently preparing their Local Strategic Planning Statement. It is recommended that Council consider this floodplain risk management plan when developing the Local Strategic Plan.

Table 8-2 Recommended changes to flood planning controls in the Risk Management Policy

Existing Control	Comment
2.1 Floor Level: Habitable floor levels to be the 1% AEP [100 year ARI] plus 600mm freeboard	A detailed review of the FPL is provided in **Section 9** of this report.
2.2 Local Overland Flooding: Flood maps provided by the Policy generally include mainstream flooding and do not consider overland flow. The Policy identifies that there is a difference between flooding arising from overland and mainstream flows and discusses various types of overland flow examples. The Policy does not quantify what constitutes overland flow or how it should be identified by an Applicant.	Mapping of overland flow has be undertaken as part of this FRMSP. It is recommended that these maps be included or referenced in the Policy.
2.3 Reliable Safe Flood Access: Every development application on flood prone land, must demonstrate that effective warning time and reliable safe flood access for the evacuation of people to a communal refuge is available in the event of a flood event.	Council should update the local emergency plan for management of flooding in consultation with SES for the rare design floods.

Existing Control	Comment
3.2 Hazard Categories Taking all issues into account, particularly the limited warning time and generally rapid rise of water levels in the catchments within the Camden LGA, all areas in the floodplain are considered to be High Hazard. This hazard rating is not intended to sterilise the land for any use. Rather, it is a signal that any development that occurs in the floodplain should be planned with due attention to the flood related issues and that strict implementation of flood related development controls is essential for the reduction of flood damages.	Various development controls relating to high hazard rating of the Policy are considered onerous. Particularly for areas of the floodplain where low flood depth and low flood velocity is estimated. For example filling may be accommodated to a certain extent within such areas without impacting on neighbouring properties. It is suggested that the approach to the designation of High Hazard throughout the floodplain be reviewed so that a more conventional designation of hazard be applied. High hazard areas within Camden LGA has been identified by flood modelling and the maps are provided in **Appendix B**.
4.2 Voluntary Purchase & **4.3 House Raising** Both these sections refer to the Department of Infrastructure, Planning and Natural Resources as the agency managing funding assistance for these options.	The state agency responsible is now the Department of Planning, Industry and Environment.
4.7 Flood Proofing Buildings Engineers report required to prove that any portion of a structure can withstand the force of flood water, debris and buoyancy, up to and including the PMF flood event.	Refer to the Development Matrix provided in **Appendix E**.
4.10 Basement Parking Accesses to basement car parks are to be above the level of the PMF. In addition evacuation routes from the basement car park is required.	Refer to the Development Matrix provided in **Appendix E**. Evacuation routes are required for basement carparks and would theoretically never become inundated if the carpark entry is at PMF level.

Existing Control	Comment
6.3 Development Guideline Matrix Council has prepared a development guidelines matrix that applies to a particular type of development based on the land use and hydraulic categories. Three categories are identified based on the three hydraulic categories described in the 2005 Floodplain Development Manual as assessed in a 1% AEP flood while the fourth category is all land that lies between the 1% AEP flood level and the PMF. Prior to identifying the development guideline standards, the flood categories should be determined at the location of the proposed development by a qualified engineer with suitable specialist experience in hydraulic engineering and flood risk management (engaged by the applicant). The flood category must be determined in accordance with the methods and definitions specified in the NSW Government Floodplain Management Manual.	Refer to the development matrix identified in **Appendix E**.

8.5 Nepean River Catchment Development Control Plans

Specific development controls have been prepared for the Nepean River floodplain through the mapping of Flood Risk Precincts and preparation of a Development Control Matrix that are located in **Appendix E**. More generic floodplain management controls have been documented by the recommended Policy revisions in **Section 8.4** and the Urban Stormwater Detention (USD) guidelines in **Appendix F**. The preparation of the development controls has been a high priority in order to manage the planned and ongoing land development in the Study Area. Stakeholders such as the Department, Council, SES, and Community Groups have been consulted and the Development Controls shall be put on public exhibition followed by subsequent review and endorsement by Council. As such the rigour applied to the refinement of the controls reflects the importance allocated to ensure that flood risk is managed appropriately for existing properties and future development.

9 Flood Planning Level Review

9.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 m – 0.5m for residential properties, and can vary for industrial and commercial properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain. Consequently, different types of land use need to be accounted for in the setting of a FPL.

The 2005 NSW Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

> Risk to life;

> Land availability and needs;

> Existing and potential land use;

> Current flood level used for planning purposes;

> FPL for flood modification measures (levee banks etc.);

> Changes in potential flood damages caused by selecting a particular flood planning level;

> Consequences of floods larger than the flood planning level;

> Flood warning, emergency response and evacuation issues;

> Flood readiness of the community (both present and future);

> Land values and social equity; and

> Duty of care.

These issues are considered collectively in the following sections.

9.2 Planning Circular PS 07-003

The Planning Circular was released by the NSW Department of Planning (2007a), and provides advice on a number of changes concerning flood-related development controls on residential lots. The package included:

> An amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in section 10.7 planning certificates;

> A revised ministerial direction regarding flood prone land (issued under section 9.1 of the Environmental Planning and Assessment Act 1979); and

> A new Guideline concerning flood-related development controls in low flood risk areas.

The Guideline states that, unless there are exceptional circumstances, councils should adopt the 1% AEP +0.5m as the FPL for residential development. The need for another FPL to be adopted would be based on an assessment local flood behaviour, flood history, associated flood hazards or a particular historic flood, which would have to demonstrate that exceptional circumstances exist within the Study Area to warrant a different FPL.

The Circular establishes the 1% AEP +0.5m as the default typical FPL for residential development. The following sections assess the conditions in the Study Area against a range of criteria to determine if the 1% AEP +0.5m is a suitable FPL for mainstream flooding in the Study Area.

Please note that this document is currently under revision.

9.3 Council's Current FPL

Council currently defines the Flood Planning Level in the CLEP2010, Section 7.1 Flood Planning. Clause 5 which states that:

> *In this clause **flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.6 metre freeboard.*

No exceptions are made in the CLEP2010 for different types of developments. Consequently, this FPL is applicable to all developments; residential, commercial and industrial.

It is noted that this definition is currently under revision with the Department to change freeboard to 0.5m in accordance with that adopted in Nepean River Flood Study (2015) and Upper South Creek Floodplain Risk Management Study and Plan (2019).

9.4 Likelihood of Flooding

As a guide, **Table 9-1** has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 9-1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the intangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 0.5% AEP magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 9-1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16
0.5%	30	5

9.5 Risk to Life

Flooding in Camden and the surrounding regions poses a significant risk to life for the community.

Access roads throughout the Study Area are cut in events as frequent as the 20% AEP, which results in the region becoming fragmented. Access roads outside of the catchment area are also likely to be cut during flood events which will restrict the ability of emergency personnel to service the community.

These risks increase with flood severity. Unless the PMF is adopted as the FPL, there will be a residual flood risk within the community, even if all development is built at the FPL. This residual risk for the Camden region is significant given the substantial flood depths experienced in the PMF event.

The community should be helped to understand that adhering to flood development controls does not mean that they are free of flood risk. A community education program is provided in **Section 11** to assist in building this community awareness.

9.6 Existing and Potential Land Use

The hydrological regime of the catchment can change as a result of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. Given the significant development proposed within the Camden LGA, it is important to consider the changing nature of the catchment area in defining the FPL.

DCP2011 restricts building within the floodway, and recommends against filling in flood storage areas. In general, DCP2011 manages development in flood prone regions.

Controls developed for precincts require that post-development flows are equal to or less than pre-development flows in order to reduce the risks of off-site impacts arising from the precinct development.

Given this, and other controls within the DCPs (refer **Section 8**), this is not considered to be a significant issue within the catchment.

9.7 Land Availability and Needs

The Camden LGA is undergoing a phase of rapid and intensive development in order to cater to western Sydney's growing population. Housing availability is an important issue currently being investigated and reviewed by the State Government.

As a result of these development pressures, it is important that available land be used in an appropriate, sustainable way, in order to meet the needs of both the growing population, as well as ecosystem health and services.

Whilst the flood extent from the Nepean River covers a relatively large area, there is still substantial flood free areas available for development. Given the significant risks posed by flooding along the Nepean River, it is not recommended that flood controls be softened to allow additional development. Higher density development in flood free or low hazard zones is a safer, and more ecologically sustainable method of meeting future housing needs.

9.8 Changes in Potential Flood Damages caused by Selecting a Particular Flood Planning Level

Based on an approximate typical overfloor flood damage for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals is shown in **Table 9-2**. The table shows the AAD of a residential property that experiences overfloor flooding in each design event, and the net present value (NPV) of those damages over 30 years at 7%.

Table 9-2 indicates that the largest incremental difference between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 20% and 5% and 1% to 0.5% AEP events. It can be seen that the differences between the 0.5% AEP event and the PMF are relatively small, suggesting that increasing the FPL beyond the 0.5% AEP level does not significantly alter the savings achieved from a reduction in flood damages.

Table 9-2 Differential Damage Costs between AEP Events

Event (AEP)	Incremental AAD	Properties with overfloor flooding	Average AAD per Property	Change in AAD	NPV of AAD	Change in NPV
2 year ARI	$77,781	5	$15,556	-	$193,038	-
20%	$166,019	11	$15,092	$464	$187,286	$5,753
5%	$852,332	108	$7,891	$7,201	$97,932	$89,354
1%	$674,855	200	$3,374	$4,518	$41,872	$56,060
0.5%	$137,379	283	$485	$2,889	$6,024	$35,848
0.2%	$117,944	431	$273	$212	$3,396	$2,628

Event (AEP)	Incremental AAD	Properties with overfloor flooding	Average AAD per Property	Change in AAD	NPV of AAD	Change in NPV
PMF	$265,488	2071	$128	$145	$1,591	$1,805

9.9 Incremental Height Differences between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the average incremental height difference between events is shown in **Table 9-3** and **Table 9-4**, and the maximum height difference is shown in **Table 9-5**, for selected events for Nepean River flooding and tributary flooding respectively. These are determined based on the flood levels at each of the properties within the catchment as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 20% AEP event.

Table 9-3 Average Differences Between Design Flood Levels for Flood Affected Properties For Mainstream Nepean River

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)	Difference to 5% AEP (m)
1%	1.63	-	-
5%	2.66	1.03	-
20%	2.91	1.28	0.25

Table 9-4 Average Differences Between Design Flood Levels for Flood Affected Properties For Tributaries including Narellan Creek

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)	Difference to 5% AEP (m)
1%	0.43	-	-
5%	0.44	0.01	-
20%	0.48	0.05	0.04

Table 9-5 shows the maximum water level differences within the study area.

Table 9-5 Maximum Differences Between Design Flood Levels for Flood Affected Properties for both Nepean River and Narellan Creek

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)	Difference to 5% AEP (m)
1%	3.86	-	-
5%	5.51	1.65	-
20%	8.66	4.80	3.15

The tables show that flood levels varying by a significantly larger degree for Nepean River floods than for tributary floods. The average difference between the 20% AEP and the PMF in the Nepean River is 2.91 m, compared to an average difference of 0.48 m for the tributaries.

Table 9-3 indicates that there are large increases in levels between all events. For properties that experience flooding in the 20% AEP from the Nepean River, levels are 1.28 m higher in the 1% AEP and 2.91 m higher in the PMF. This indicates that the selection of the flood event for the definition of the FPL will result in substantially different planning levels for properties along the Nepean River.

Table 9-4 indicates a small difference in flood level between all events. The change between the 5% and 1% AEP events is marginally small (0.01m), suggesting that the adoption of the 1% AEP event would

provide an increased level of risk reduction over the 5% event without a significant effect on flood planning levels.

Table 9-5 indicates that there are significantly large increases in maximum flood levels between all events. For properties that experience flooding in the 20% AEP, levels are 4.8 m higher in the 1% AEP and 8.66m higher in the PMF.

9.10 Consequences of floods larger than the Flood Planning Level

As shown above, there is a significant height difference between the 1% AEP and the PMF, with an average height difference at flooded properties of 1.63 m and maximum height difference at flooded properties of 3.86 m. This means that for properties built at an FPL of 1% +0.5m, the PMF would result in overfloor flooding depths of 1.73m at some properties. Given these flood depths, second stories would be suitable for flood refuge for some properties in the PMF event, provided that these properties are structurally sound to withstand the force of water.

Coupled with limited, or no warning, and an under appreciation of flood risks by the community, the PMF flood depths may result in a significant residual risk for properties along the Nepean River.

The use of the PMF level as the FPL is not economically feasible and not standard practice in NSW and may conflict with other development/ building controls in the Councils DCP.

Given the risk of exposure outlined in **Table 9-1**, it is recommended that emergency response facilities be located outside of the floodplain and any other future planning ensure critical facilities be limited to areas outside of the floodplain. Modification to existing critical facilities within the floodplain are suggested to have a floor level at the PMF level.

9.11 Impacts of Climate Change

Potential impacts from climate change were assessed by modelling the flood behaviour arising from a 10% increase in rainfall, which may be considered as estimates of flood behaviour at 2050 as discussed below.

The results showed that the Study Area is prone to large flood level increases as a result of the increased rainfall (**Section 5.8**). Under the 10% rainfall increase, levels increased by 0.5m to 0.75m at Camden CBD, with levels increasing downstream to over 1.5 at the confluence of Bringelly Creek.

Chapter 6, Book 1 of the ARR 2016 Guidelines provides an approach to address the risks from climate change in projects and decisions that involve estimation of design flood characteristics while further research is undertaken to reduce key uncertainties. The chapter uses output from the Climate Futures web tool developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Four Representative Concentration Pathways (RCPs) are identified for greenhouse gas and aerosol concentrations. The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and use of RCPs 4.5 and 8.5 (low and high concentrations, respectively) is recommended for climate change impact assessment.

A desktop assessment was undertaken to identify the protection that the FPL freeboard of 0.5m would provide for the 1% AEP flood levels in comparison to the 1% AEP with 10% increase in rainfall intensity flood levels. This comparison is shown in **Table 9-6**. The range of years is based on the rise in flood waters which varies across the catchment from 0.5m to 2m.

Table 9-6 Freeboard Analysis based on the ARR2016 Climate Change Guidelines

Option	RCP 4.5 (Best Case Scenario)	RCP 8.5 (Worst Case Scenario)
Until what year the floor levels will be protected for the 1% AEP flood event plus 0.5m freeboard	2030 – 2100	2030 – 2053
Until what year the floor levels will be protected for the 1% AEP with 10% increase in rainfall intensity flood event plus 0.5m freeboard	>2100	2072 - 2090

These results suggest that if rainfall intensities increase in line with the current assumptions, 1% AEP peak flood levels will have increased in 2030 to the point where there will no longer be any freeboard available to the existing properties. Based on these impacts, it is suggested that Council consider adopting the following FPL:

> Mainstream and Tributary Flooding – 1% AEP with 10% increase in rainfall intensity levels plus 500mm freeboard; and

> Overland Flooding – 1% AEP with 10% increase in rainfall intensity levels plus 500mm or 300mm freeboard.

Should Council elect to adopt FPL's based on the 1% AEP (2050) flood levels under climate change scenario, it is recommended that the following is undertaken:

> A climate change policy be prepared to guide the assumptions made in determining future flood levels. It is noted that Council does not have a formal climate change policy; and

> Definition of the FPL in the CLEP2010 be revised to clarify the approach. Such wording may be:

*In this clause **flood planning level** means the level of a 1% AEP flood event, at the appropriate planning horizon, plus freeboard. Freeboard is described in Council's relevant Floodplain Risk Management Study.*

9.12 Flood Warning and Emergency Response

A discussion on flood warning and emergency response issues relating to the Nepean River region is provided in **Section 10**. The assessment found that:

> Warning times will be limited, and potentially non-existent. The first indication that many residents will have that a flood is occurring will be inundation of their dwelling. Some form of warning is likely to be provided by the BoM storm warnings, but it is not guaranteed that these warnings would reach residents at risk;

> The ability of emergency services to respond to flooding in the region will be limited by the flooding of roads both to and within the Study Area;

> Flooding occurs over the course of some hours, which also inhibits the ability of emergency services to provide assistance, as by the time they are able to access regions of the Study Area, the flood waters are likely to have receded; and

> The community will need to be flood resilient, as they will need to largely manage flood concerns themselves.

A recommendation of this study is that a warning system be investigated for the Camden region (refer **Section 12.4**). For commercial and industrial developments within the Camden CBD that have floor levels below the FPL, it is recommended that they be encouraged to develop flood response plans, linked to alerts from any future flood warning system.

9.13 Social & Heritage Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. A requirement for higher floor levels also imposes additional construction costs on new developments.

Heritage issues are also a concern in the Study Area, with historic regions of the Camden Town Centre having been constructed well below the 1% AEP flood level. The Town Centre is a region of active redevelopment, and the FPL and planning controls adopted have the potential to significantly impact the type and style of this redevelopment. Council is desirous to retain the existing scale and street frontages in the Town Centre, which would result in lots experiencing large overfloor flood depths in both the 1% AEP and the PMF. The final selection of the FPL will need to balance the social and heritage needs in the Camden Town Centre, against Council's responsibility to protect its residents from flooding risks.

9.14 Alternative FPL's for Commercial and Industrial Lots

Consideration could be given to Commercial and/or Industrial properties adopting a higher frequency flood event such as the 5% AEP planning level but only where it can be demonstrated that any staff, workers and/or visitors can be safely evacuated to manage the risk to life during floods greater than an adopted benchmark flood. These occupiers can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots don't generally provide an

income to offset losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen economic loss during a flood event.

While a consistent FPL is recommended for all development through much of the Study Area, there is some merit in exploring a lower benchmark for commercial properties in Camden CBD.

The Camden CBD is an established commercial centre, with a number of historical buildings which are low-rise nature with street level entrances and modest development heights. Regions of the CBD first become inundated in the 5% AEP event.

Based on the existing flood behaviour, the average incremental height difference between events is shown in **Table 9-7**, and the maximum height difference is shown in **Table 9-7**, for selected events for Nepean River flooding. These are determined based on the flood levels at each of the properties within the catchment as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 5% AEP event.

Table 9-7 Average Differences Between Design Flood Levels For Flood Affected Properties For Commercial and Industrial Lots

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)
1%	1.71	-
5%	2.39	0.68

Table 9-8 Maximum Differences Between Design Flood Levels For Flood Affected Properties For Commercial and Industrial Lots

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)
1%	3.92	-
5%	5.51	1.66

Table 9-7 and **Table 9-7** indicated there are large increases in levels between the 5% AEP and 1% AEP events. For all commercial and industrial properties that experience flooding in Camden CBD in the 5% AEP from the Nepean River, levels are 0.68 m (average) higher in the 1% AEP and 2.39 m (average) higher in the PMF. This indicates that the selection of the flood event for the definition of the commercial FPL will result in substantially different planning levels for commercial and industrial properties within Camden CBD.

It should be noted that alternate floor levels may be considered for commercial and industrial developments, but only within the Camden CBD. Other areas, and all residential development, would have floor levels set by the general, higher planning level.

9.15 Freeboard Selection

The freeboard may account for factors such as:

> Changes in the catchment;

> Changes in the creek/channel vegetation;

> Accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area);

> Model sensitivity:

  - Local flood behaviour (e.g. due to local obstructions etc.);
  - Wave action (e.g. such wind-induced waves or wash from vehicles or boats); and
  - Culvert blockage.

The impact of typical elements factored into a freeboard can be summarised as follows:

> Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (Gillespie, 2005);

> Local wave action (allowances of ~0.1 m are typical) (truck wash etc.);

> Accuracy of ground/ aerial survey ~ +/-0.15m; and

> Sensitivity of the model ~ +/-0.15m (based on a 10% change in model parameters).

Based on this analysis, the total sum of the likely variations is in the order of 0.5m.

Given the above, a freeboard allowance of 0.5m is appropriate to account for model sensitivity and local flood actions during events.

9.16 Flood Planning Level Recommendations

The FPL investigation above supports Council's approach to update the FPL to 1% AEP +0.5m (excluding sensitive and critical development).

The FPL will inform the Flood Planning Area (FPA) under which flood controls will be applied. Different floor level controls within the FPA could be applied in the Camden CBD based on the planning controls for different land uses. However, by virtue of being within the FPL, development in the CBD region will trigger Council's DCP, in which special provisions for the CBD can be made.

As such, it is recommended that:

> Council adopt the FPL as recommended in the Development Control Matrix; and

> The CDCP2011 is revised to:

  - Apply this FPL to the Nepean River and tributaries floodplain.

It is also recommended that the CDCP2011 be updated to provide additional requirements for commercial properties constructed at this level. Such requirements should be done to minimise risks to persons and property and may include such measures as:

> Using flood-proof material below the 1% AEP flood level plus freeboard;

> Ensuring that types of business that are not able to cope with flood risks are not permitted. For example:

  - entertainment venues and/or hotels which may significantly increase the number of persons at risk and who may need to be evacuated during a major flood; or

  - commercial premises where significant flood damages could occur due to an inability to raise goods or equipment to higher levels in a timely manner;

> Mandating the preparation of emergency response plans.

It is also recommended that Council consider developing a climate change policy in order to inform long term planning decisions. Climate change has the potential to significantly increase flood heights along the Nepean River. While some Councils are able to absorb the minor impacts they experience within the freeboard allowance, the height increases in mainstream flooding along the Nepean River are such that they will potentially be greater than the recommended freeboard by 2050.

Based on these impacts, it is suggested that Council consider adopting the following FPL for precinct development, large land subdivisions, major developments and major infrastructure such as transport infrastructure to address the climate change impacts. For redevelopment and infill development the following FPL to address the climate change impacts should be considered on merit base with the surrounding environment.

• Mainstream and Tributary Flooding:

➢ 1% AEP within 10% increase in rainfall intensity levels plus 300mm freeboard; for precinct development, large land subdivisions, major developments and major infrastructure;

➢ 1% AEP levels plus 500mm freeboard; for minor development;

• Overland Flooding High Risk Precinct:

➢ 1% AEP within 10% increase in rainfall intensity levels plus 300mm freeboard; for precinct development, major land subdivisions and major infrastructure;

➢ 1% AEP levels plus 500mm freeboard, for minor development; and

• Overland Flooding Low Risk Precinct – 1% AEP levels with no freeboard.

The above 300 mm freeboard for 1% AEP with 10% increase in rainfall intensity levels is recommended allowing 200 mm of traditional 500mm to absorb climate change impacts as current practice.

A FPL set at the 1% AEP + 0.5m level will still result in significant over floor flooding in the PMF event of up to a maximum of 3.67m. It is noted that achieving the 1% AEP + 0.5m FPL will be difficult in certain areas where the 1% AEP flooding depths are greater than 10m.

However, the majority of flood affected properties in the PMF are single storey, and as such, not currently able to provide a safe refuge during the PMF. It is therefore important that other strategies are put in place, such as evacuation, education and community awareness measures and the provision of flood refuges, to address this risk to life. These responses to the residual risk are further discussed in **Section 12**.

9.17 Duty of care

As noted above the adoption of the 1% AEP +0.5m level as the FPL for Camden, while suitable, results in a significant residual flood risk for some properties affected by the PMF. It is important that these properties be made aware of the residual risk, and that they are assisted in developing appropriate strategies to manage their safety during large flood events.

Further information on the options available to manage this residual risk are provided in **Section 10**, and strategies for engaging with the community to educate them on this risk are provided in **Section 11**.

10 Emergency Response Review

Flood emergency measures are an effective means of reducing the risks of flooding and managing the continuing and residual risks on the floodplain. Current flood emergency response arrangements for managing flooding in Camden LGA are discussed below.

10.1 Emergency Response Plans

The hierarchy of plans which guide the planning for floods in NSW is shown in **Figure 10-1**.

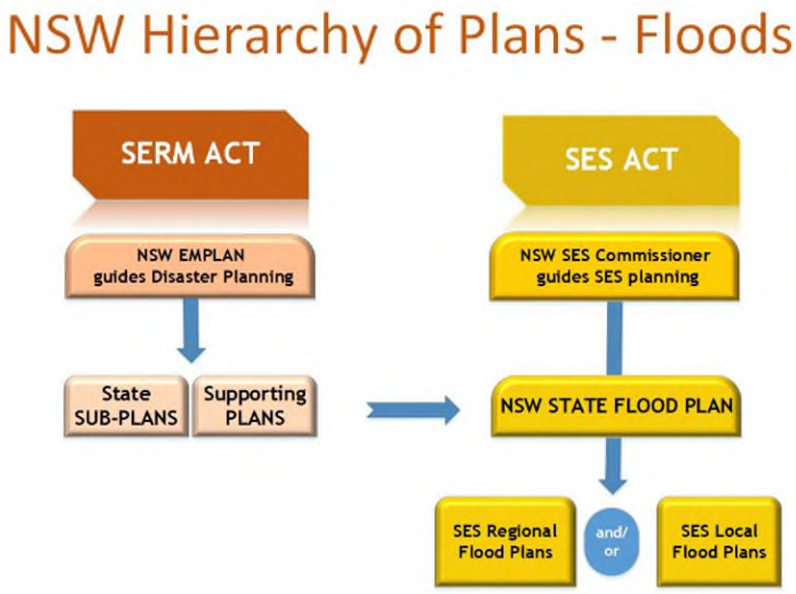

Figure 10-1 NSW Hierarchy of Plans – Floods

10.1.1 2017 NSW State Flood Plan

The NSW State Flood Plan is a sub plan of the State Emergency Management Plan (EMPLAN) (NSW Government, 2017). It has been prepared in accordance with the provisions of the State Emergency Service Act 1989 (NSW) and is authorised by the State Emergency Management Committee in accordance with the provisions of the State Emergency and Rescue Management Act 1989 (NSW).

The latest plan was provisionally endorsed by the State Emergency Management Committee at Meeting 107 held on 5 December 2017.

The purpose of this plan is to set out the arrangements for the emergency management of flooding in New South Wales

As described by the Plan:

> *The Plan sets out the emergency management aspects of prevention; preparation; response and initial recovery arrangements for flooding and the responsibilities of individuals, agencies and organisations with regards to these functions.*
>
> *The Plan recognises the existence of the problem of coastal inundation and erosion caused by severe weather. The management system for dealing with episodes of coastal erosion is described in the New South Wales State Storm Plan.*
>
> *The Plan recognises the existence of the threat posed by tsunami to NSW coastal communities. The arrangements for the emergency management of tsunami are contained within the State Tsunami Emergency Sub Plan.*
>
> *This Plan is intended to be read in conjunction with:*
>
> *(a) The New South Wales State Emergency Management Plan (EMPLAN), of which the State Flood Sub Plan is a sub-plan;*

(b) *The New South Wales State Storm Plan, which covers arrangements relating to severe storm events; and*

(c) *NSW Floodplain Development Manual.*

10.1.2 2017 South West Metropolitan Regional Emergency Management Plan

The 2017 South West Metropolitan Regional Emergency Management Plan details arrangements for, prevention of, preparation for, response to and recovery from emergencies within the South West Region of Sydney (NSW Government, 2017). It encompasses arrangements for:

> emergencies controlled by combat agencies ;

> emergencies controlled by combat agencies and supported by the Regional Emergency Operations Controller (REOCON) ;

> emergency operations for which there is no combat agency;

> circumstances where a combat agency has passed control to the REOCON; and,

> demobilisation and transition of control from response to recovery.

As described by the Plan:

The objectives of this plan are to:

> *support Local Emergency Management Plans (EMPLANs) and augment them when required;*

> *identify trigger points for regional level activation, escalation and demobilisation;*

> *define participating organisation and Functional Area roles and responsibilities in preparation for , response to and recovery from emergencies;*

> *set out the control, co-ordination, support and liaison arrangements at the Regional level;*

> *detail activation and alerting arrangements for involved agencies at the Regional level;*

> *detail arrangements for the acquisition and co-ordination of resources at the Regional level;*

> *maintain a governance over the Local Emergency Management Committees within its area of responsibility; and*

> *provide/facilitate emergency management training at a local and regional level*

The plan describes the arrangements at Regional level to prevent, prepare for, respond to and recover from emergencies and also provides policy direction for the preparation of Sub Plans and Supporting Plans. Further:

> *This plan relies on effective implementation of the Governance framework for Emergency Management;*

> *Arrangements detailed in this plan are based on the assumption that the resources upon which the plan relies are available when required; and*

> *The effectiveness of arrangements detailed in this plan are dependent upon all involved agencies preparing, testing and maintaining appropriate internal instructions, and/or standing operating procedures.*

This plan is to be read in conjunction with the arrangements stipulated in the NSW State-EMPLAN

10.1.3 Local Disaster Plan (DISPLAN)

Flood emergency management for the former Camden LGA is outlined in the Camden Local Emergency Management Area Local Disaster Plan (2006) which has been issued under the authority of the *State Emergency and Rescue Management Act, 1989* (as amended).

The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

> Roles and responsibilities in emergencies;

> Preparedness measures;

> Conduct of response operations; and

> Co-ordination of immediate recovery measures.

The Local Disaster Plan outlines the key responsibilities of the different organisations involved in emergency management. It is generally the responsibility of the NSW State Emergency Service (SES), as the “combat” agency, to respond to and coordinate the flood emergency response. It is the responsibility of Council and the Department to manage flood prevention / mitigation through development controls, the floodplain management process and mitigation schemes.

The Plan identifies flood hazard as an extreme risk with the region. It should be noted that this categorisation is a general one for the whole LGA.

10.1.4 Local Flood Plan

A sub-plan to the DISPLAN has been prepared by the SES in conjunction with Council. The Camden Local Flood Plan was prepared in 2010 and updated in 2016 and covers the preparation, response and recovery of flooding emergencies for the Camden LGA.

The Flood Plan focuses exclusively on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event.

This Local Flood Plan encompasses the key components as follows:

> Define the key responsibilities of the different response organisations in preparation for, response to and recovery from emergencies;

> Develop floodplain management plan and implementation strategies, and develop flood intelligence and warning systems, public education programs and training in preparing emergencies;

> Define the roles and procedures for different organisations in emergency response operations; including preliminary deployments, warning, evacuation, and flood rescue;

> Details co-ordination, liaison between different organisations and resources arrangement; and

> Develop the plan for long term recovery operations and implementation strategies.

The Local Flood Plan also notes key roads that can be flood affected and details evacuation centres for flood affected areas of Camden. The Flood Plan documents the need for update in response to floodplain risk management, changes in land use and improvements in flood intelligence. Therefore it is recommended that the Flood Plan be updated to reflect the outcomes of this study, especially considering the ongoing and projected changes in land use. The Plan was due for review in August 2015 and with the preparation of this Floodplain Risk Management Study it is considered timely to update the Local Flood Plan to reflect the findings herein.

The following amendments to the Flood Plan are recommended for the Nepean River floodplain:

> Include a section describing the flood behaviour and effects for the Nepean River floodplain, including the emergency response classification;

> Update the flood warning dissemination method to include the electronic media and television stations;

> Update details of the population in the floodplain and subsequent service requirements for the flood refuge centres. It is likely that a far greater number of residents would be affected by an extreme flood following urban development in the Study Area;

> Identify additional flood refuge centres as listed in the **Table 10-2** for parts of the floodplain that are unable to access the existing flood refuge centres; and

> The flooding of key access roads/evacuation routes should be updated with the data presented **Section 10.3**.

10.2 Emergency Service Operators

The Nepean River floodplain lies within the Sydney Southern Region of the State Emergency Service (SES). The SES is the legislated combat agency for floods and is responsible for the control of flood operations including the coordination of other agencies and organisations for flood management tasks. The Camden SES Local Controller is responsible for flood response in the study. The SES is primarily a volunteer organisation and in times of emergency operates a paging service for on-call volunteers.

The key emergency services for the Nepean River floodplain are outlined in **Table 10-1**.

Table 10-1 Emergency Service Providers Locations

Emergency Service	Location	Phone
Camden Hospital	Menangle Road, Camden	02 4634 3000
Police Station	278 Camden Valley Way, Narellan	02 4632 4499
Fire Station	192 MacArthur Road, Elderslie	02 4658 1688
Camden SES	19 Queen Street, Narellan	02 4647 0319

10.3 Access & Movement during Flood Events

Any flood response suggested for the Study Area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation of residents from flood affected areas, medical personnel attempting to provide aid, or NSW SES personnel installing flood defences.

10.3.1 Access Road Flooding

A summary of road flooding in the Study Area is listed in **Table 10-2** with locations shown in **Figure 10-2**.

Access roads for which access is lost are highlighted. Access is considered lost when depths exceed 0.2m as shown in the AR&R hazard curves, **Figure 5-8**. The table highlights a key flooding issue in the Study Area. As a result of the large jumps between flood levels for different recurrence intervals, as soon as roads are flood affected, they quickly become flooded to large depths.

Due to the relatively large flood depths that occur in even minor events, many roads experience loss of access in the 20% AEP event, with overtopping depths ranging from 0.1 m to 2.8 m. Camden Bypass is the only crossing that is accessible for up to the PMF event.

Table 10-2 Access Road Flood Depths (m)

ID	Location	20% AEP	5% AEP	1% AEP	PMF
A	Cut Hill Road (A)	0.3	3.7	6.3	13.6
B	Coates Park Road	-	-	0.1	1.3
C	Cut Hill Road (B)	2.3	6.0	8.0	14.5
D	Chittick Lane	-	-	1.1	7.6
E	Cobbitty Road (B)	0.1	0.1	0.2	0.8
G	Ellis Lane	0.9	4.5	6.6	11.1
H	Macquarie Grove Road	7.6	11.0	12.6	16.4
L	Argyle Street	2.5	5.5	7.1	11.0
I	Kirkham Lane	3.0	6.2	7.9	11.8
Q	Camden Bypass	-	-	-	-
P	Burragorang Road (B)	-	-	-	2.3
O	Burragorang Road (A)	-	-	-	2.6
F	Cobbitty Road (A)	4.5	8.2	10.1	15.1
N	Sheathers Lane	3.6	7.3	8.9	12.6
M	Cawdor Road	2.8	6.4	8.0	11.8
J	The Northern Road	-	-	-	1.4
K	Harrington Parkway	-	-	-	1.4
R	Springs Road	-	-	-	0.2

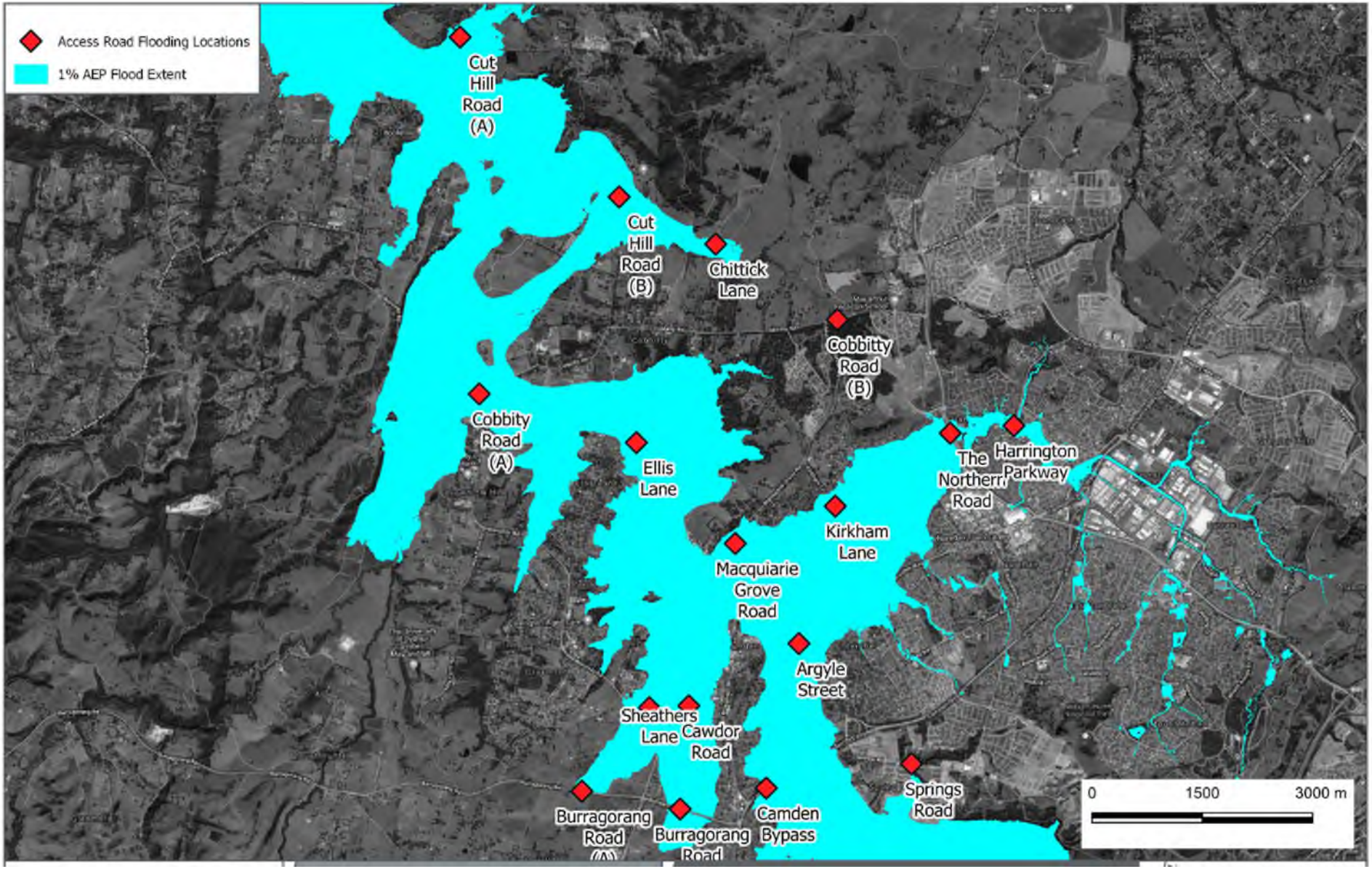

Figure 10-2 Access Road Flooding Locations

The results demonstrate that evacuation of the floodplain using major roads is not a safe emergency management strategy in the case of flood. It is recommended that flood depth gauges are installed as signs on all major road crossings. Marking historic and design floods on the flood gauges would also provide additional information to the community and highlight the significant risk present.

10.3.2 Driving Condition Analysis

Movement during a storm event is likely to be undertaken by car, or a similar vehicle. The safety of operating such a vehicle needs to be determined if movement options are to be recommended.

During an extreme rainfall event, the intensity of rainfall as well as other factors (such as wind and debris), would make driving either difficult or potentially more dangerous than sheltering in place. These factors would not be unique to a floodplain, and would be equally as dangerous if an extreme event were to occur in any location. It would be expected that the risk to life of driving in these conditions would increase with the increasing severity of rainfall events.

A review was therefore undertaken of driver safety related to rainfall events.

A study into rainfall effects on single-vehicle crash severities based on an analysis of crash and traffic data for the Wisconsin, USA area for the period 2004-2006 found that rainfall events with a mean rainfall intensity of 3.16 mm/hr resulted in an increased likelihood of crashes ranging in severity from fatal to possible injury (Jung, Qin, & Noyce, 2009).

An analysis of data for the cities of Calgary and Edmonton, Canada during 1979-1983 concluded that the overall accident risk during rainfall conditions was found to be 70% higher than normal (Andrey, 1993).

Andreescu and Frost (1998) in an analysis of data for Montreal, Canada 1990-1992, found that a best fit line of data found a linear increase in number of accidents in relation to increased daily rainfall intensity (mm/day). This data is reproduced in **Figure 10-3**. It is noted that there is significant scatter in the source data and that the correlation is relatively weak. However, the data does demonstrate a link between daily rainfall and accidents.

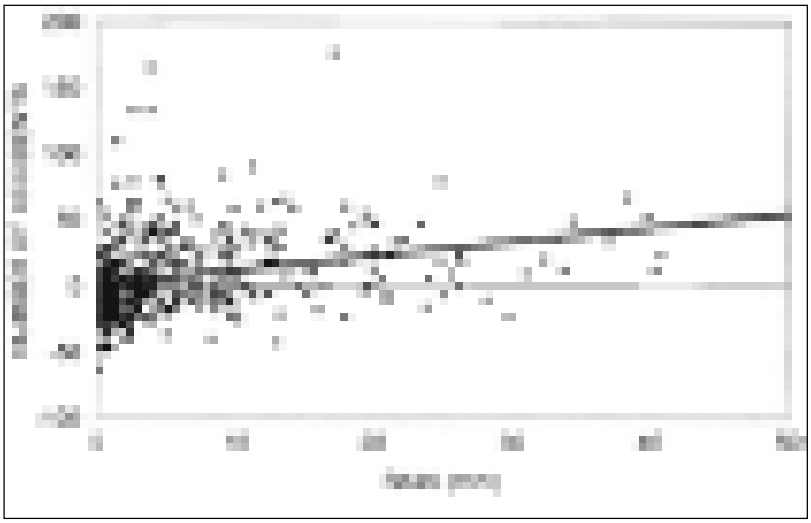

Figure 10-3 Accidents per day vs daily rainfall (Andreescu & Frost, 1998)

The NSW Governments Roads and Traffic Authority (RTA) *Road User's Handbook* (2010) states that "Driving during unpredictable and severe weather events and conditions such as extreme heatwaves, storms, flooding and bushfires should be avoided. When it cannot be avoided, drive with caution and adjust your travel speed in poor visibility and wet conditions."

The temporal distribution of rainfall intensity for the 1% AEP 9 hour event (after ARR, 1987) is shown in **Figure 10-4**. It is noted that these are exclusive of climate change impacts on rainfall intensities.

The figure shows that rainfall intensities are generally greater than 10 mm, with peaks of 17 mm and 28 mm in 3 hours and 5 hours into the storm respectively.

The literature evaluated does not give a definitive threshold of rainfall intensity for which unsafe driving can be expected (with the exception of Jung (2009) which suggests a very low intensity of only 3 mm/hr, which can be expected in relatively frequent events).

However, average rainfall intensities for the 1% AEP 9 hour event are well in excess of the values identified in the literature as beginning to have an impact on driving risk.

From the above, it is not recommended that people attempt to drive during a significant rain event. As the most intense rainfall will be associated with short duration storms, the safer option is to wait for the rain to lessen before attempting to drive. During longer duration events where flood warning may be possible, the rainfall intensity will be reduced, and may allow evacuation whilst the rain is falling. However, in general, it is recommended that driving not be undertaken during intense rainfall periods unless there is a risk to life at the property resulting from rising floodwaters.

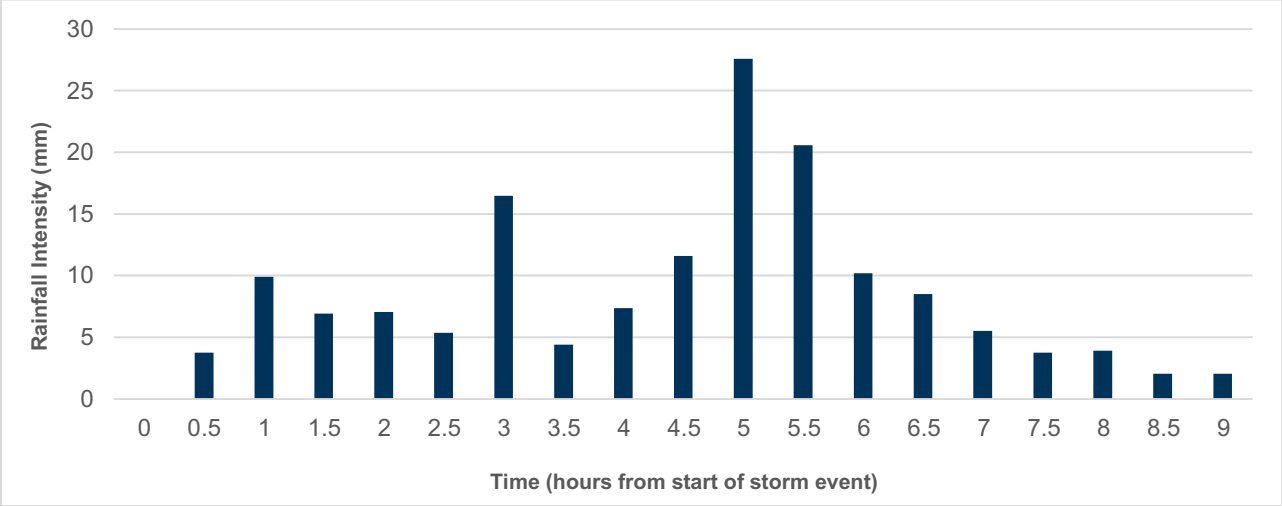

Figure 10-4 Nepean River 1% AEP 9hr Temporal Rainfall Distribution

10.3.3 Flood Response

To minimise the flood risk to residents, staff and/or workers, it is important that properties have provisions to respond to flood emergencies. There are two main forms of flood emergency response that may be adopted by people within the floodplain:

> Shelter-in-place: The movement of residents, staff and/or workers to a building that provides vertical refuge on the site or near the site before a property becomes flood affected; and

> Evacuation: The movement of residents, staff and/or workers out of the floodplain before a property becomes flooded.

Each of these options have particular requirements given the nature of flooding within the Study Area, and associated advantages and disadvantages. Each option is discussed below.

10.3.3.1 Shelter-in-Place

The key concerns with shelter-in-place include:

> the need for access to a safe refuge above the PMF level,

> the duration of isolation (short durations would be acceptable but long durations, say greater than 6-9 hours, are likely to be of concern regarding the safety of any persons sheltering in place and the time delay which would occur in accessing the location in the event of a medical or other emergency), and

> the integrity of the building under extreme flood conditions

Given the significant height difference between the PMF level and the level of more frequent floods, a key concern with the use of shelter-in-place on the Nepean River floodplain is that it would require buildings to be structurally sound to withstand the force of water, and constructed with sufficient storeys in order to ensure that the top floor is above the PMF. The top floor may be a loft or attic space rather than a complete floor. Such a space would have to be accessible during a flood event, which would necessitate safe, flood proof internal access and be capable of safely sheltering all residents, staff and/or workers within the building who would otherwise be flooded.

It should be noted that shelter-in-place would only be suitable for new buildings which are structurally sound to withstand the force of water, and constructed with sufficient storeys in order to ensure that the top floor is above the PMF. Existing properties that are flood effected would not be able to adopt a shelter-in-place response to flooding as many do not have a habitable floor located above the PMF level.

Controls to achieve shelter-in-place for new developments would require Council to be able to enforce flood related development controls outside of the flood planning area, which would require special approval under PS 07-003.

NSW SES have expressed concerns about the reliance on shelter-in-place on floodplains. Their concerns relate to the safety of residents, staff and/or workers during floods with the potential for medical emergencies, fire and structural deficiencies in the building leading to increased risk of death or need for an emergency response by SES. NSW SES does not support the use of shelter-in-place.

10.3.3.2 Evacuation

The two key requirements for an evacuation strategy are sufficient prior warning to allow evacuation, and a safe refuge in an evacuation centre.

At present, the community does not have sufficient warning time to allow evacuation in the absence of a flood warning system. The first knowledge many will have of flooding will be inundation of their property, by which time either access from their property, or access to the refuge, may be unsafe.

Unlike shelter-in-place that would require significant redevelopment to existing properties in order to be effective, evacuation could be facilitated for existing properties by ramps or regraded front yards, in order to provide rising access from flood affected properties.

As evacuation would be undertaken on a local scale, significant warning time would not be required, as residents will be able to evacuate relatively rapidly. A warning time of 2 to 4 hours would give residents sufficient time to relocate some household items, pack some belongings, and walk to the evacuation centre. This warning could be provided by a warning linked to a water level gauge on the Nepean River (refer **Section 12.4**). It should be noted that evacuation would need to be undertaken prior to access being cut.

Table 10-3 Potential Evacuation Shelters

ID	Evacuation Shelter	Property Address
1	Mount Annan High School	248 Welling Dr, Mount Annan NSW 2567
2	Narellan Vale Public School	46 Waterworth Dr, Narellan Vale NSW 2567
3	Elizabeth Macarthur High School	38 Waterworth Dr, Narellan Vale NSW 2567
4	Spring Farm Public School	Barley Road Spring Farm NSW 2570
5	Mawarra Public School	MacArthur Rd, Elderslie NSW 2570
6	Camden High School	300 Cawdor Rd, Camden NSW 2570
7	Narellan Library	Corner Queen & Elyard Street, Narellan NSW 2567
8	NSW SES Camden Unit	31 Queen St, Narellan NSW 2567
9	Camden Council Office Oran Park	70 Central Ave, Oran Park NSW 2570

10	Cobbitty Public School	306 Cobbitty Rd, Cobbitty NSW 2570

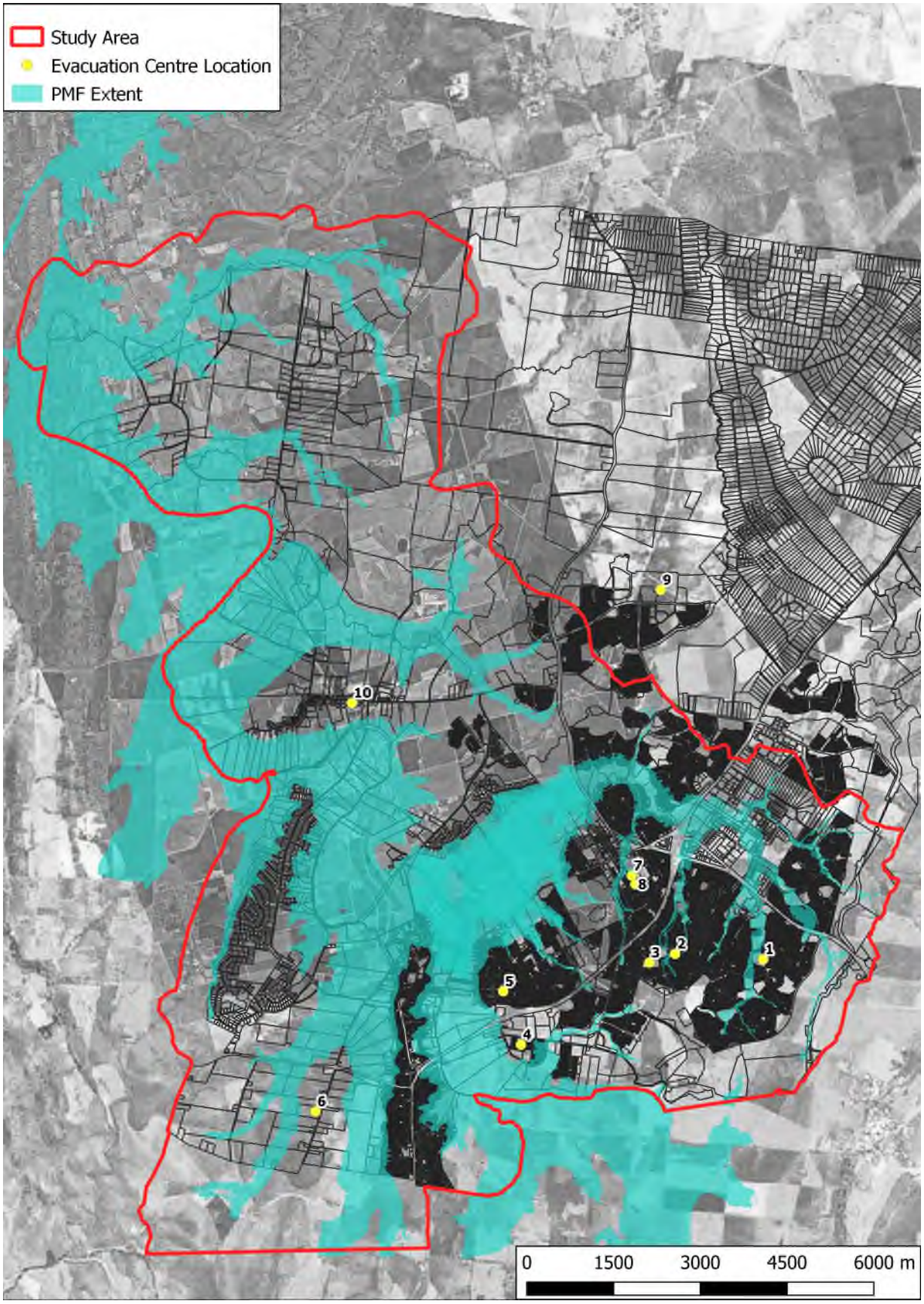

Figure 10-5 Evacuation regions within the Study Area

In the case of the Camden region, multiple shelters would be required as road inundation results in the region becoming fragmented during flood events. In order for all residents who would experience overfloor flooding in the PMF to have access to a flood shelter, a number of new potential sites have been identified in **Table 10-3** that may be suitable to function as evacuation shelters during and following a flood. The locations of these shelters are shown in **Figure 10-5**.

10.4 Flood Warning Systems

There is no official flood warning system for the Study Area. However, sources of real-time flood intelligence during times of flooding are:

> Bureau of Meteorology (BoM):
  - Flood Watches: typically provide 24 hours - 48 hours' notice that flooding is possible based upon current catchment conditions and future rainfall;
  - Severe Weather Warnings: provide warnings of possible flash flooding;
  - Severe Thunderstorm Warning: provide 0.5 hours - 2 hours' notice of impending severe storms;
> Sydney Southern SES Region Headquarters provides information on flooding and its consequences including those in nearby council areas; and
> Active reconnaissance. The SES Local Operations Controller coordinates the monitoring of known problem areas, predominantly in the Nepean River basin.

Warnings from these sources are provided as follows:

> BoM Flood Watches: If there are signs of impending floods, a Flood Watch may be incorporated in SES Flood Bulletins released to radio stations by the Illawarra South Coast SES Region Headquarters;
> BoM Severe Weather Warnings are issued when developing weather conditions indicate that flash flooding may occur. On receipt of such warnings, the SES Local Operations Controller will:
  - Advise Camden Council and the Camden Local Emergency Operations Controller;
  - Provide the Sydney Southern SES Region Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding;
> Evacuation Warnings are disseminated as follows:
  - Notification to Council Mayor;
  - By direct access to community radio; and
  - In SES Flood Bulletins from regional to local offices.

10.5 Recovery

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery phase. The Department of Community Services is responsible for the long-term welfare of the affected community. However, immediate action is likely to be undertaken by the NSW SES Local Controller.

10.6 Flood Emergency Response Planning Classification

To assist in the planning and implementation of response strategies the State Emergency Service (SES) classifies communities according to their flood impact. Flood affected communities are those in which the normal functioning of services is altered either directly or indirectly because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. The classifications adopted by the SES are (2007c):

> **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:

- High Flood Island - the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground; and
- Low Flood Island - the flood island does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by floodwaters.

> **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:

- High Trapped Perimeter - the area contains enough flood-free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground; and
- Low Trapped Perimeter - the area does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by floodwaters.

> **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.

- Areas with Overland Escape Route - access roads to flood free land cross lower lying flood prone land; and
- Areas with Rising Road Access - access roads rise steadily uphill and away from the rising floodwaters.

> **Indirectly Affected Areas.** These are areas that are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood-damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

> **Overland Refuge Areas**. These are locations that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The flood emergency response planning classifications in a 1% AEP event for the floodplain are mapped in **Figure 10-6**.

Table 10-4 outlines the response required for different flood emergency response planning classifications. Due to the predominant classification of the floodplain as areas with rising road access and overland escape routes the emergency response requirement is most likely evacuation to local refuge centres if the residents cannot take stock in their property.

Table 10-4 Emergency Response Requirements

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

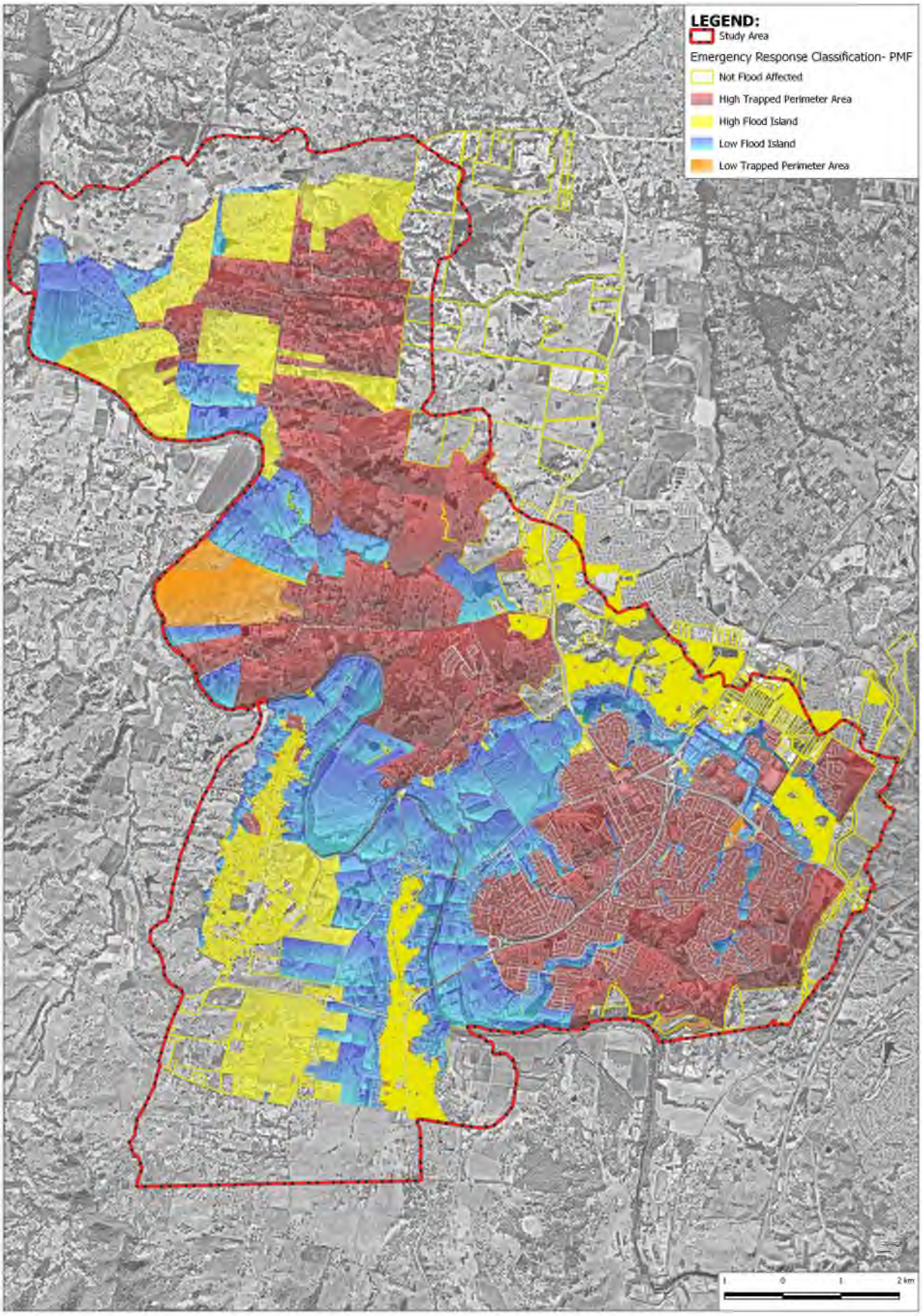

Figure 10-6 Flood Emergency Response Classification

11 Community Education & Awareness

Community awareness of flood behaviour and flood risks is essential to minimise risk to life during flood events. An aware and educated population will be able to respond to flood events quickly and appropriately, reducing risks to themselves, their property and to others.

11.1 Current Community Awareness of Flood Behaviour and Risk

Community consultation was undertaken as part of the Nepean River Flood Study (2015). A questionnaire was distributed to the residents to collect flood intelligence. A total of 126 completed questionnaires were received from local residents. The majority of these residents were within the town centre of Camden. Of these 126 responses, nine (9) provided the details of any specific recollections they may have with respect to observed peak flood levels or known debris marks that could reliably be utilised as historical flood level data to determine the flood extents.

11.2 Building Community Awareness

Discussed below are strategies that may be implemented to raise community knowledge and awareness of flooding within the Study Area.

11.2.1 Short Term

11.2.1.1 Targeted Correspondence with High Risk Properties

The investigations undertaken as part of this study has shown properties that are at particular risk in flood events. These properties begin to experience high hazard flows and loss of access in the 5% AEP, and have peak flood depths of over 3.5m in the PMF. The properties within the high hazard in a 5% AEP event for the floodplain are shown in **Figure 10-6**. It is recommended that these properties be contacted following the adoption of this study in order to inform them of the outcomes, and what these outcomes mean for residents. It is suggested that part of the correspondence include:

- A summary of peak flood levels for properties for the design events, along with the level observed in recent historical events for comparison,
- A summary of flood timings for their region, noting that there will be very little warning of imminent flooding,
- Direction to the NSW SES FloodSafe resources; and
- Contact details for sources of additional information.

The purpose of this initial correspondence would be begin a discussion with these high risk residents, to assist them in understanding the flooding risks in their location and to guide them in developing a personal flood plan.

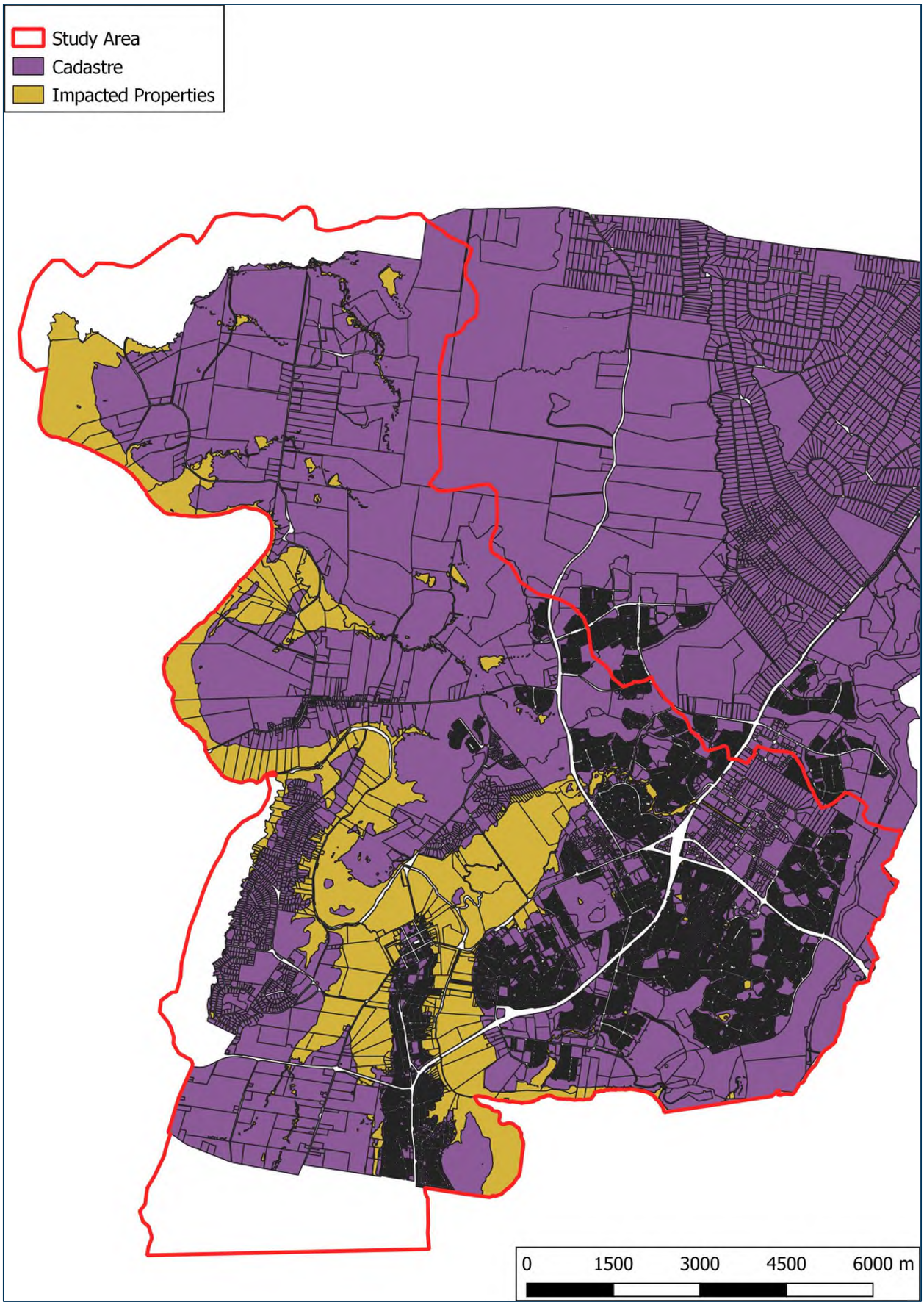

Figure 11-1 Properties within High Hazard in 5% AEP

11.2.1.2 Develop a Post-Flood Data Collection and Mail-out Strategy

It is recommended that the data collected as part of this study is used to create information that will help the community to better understand the flood event and general catchment flood behaviour. This may include the collection / determination of data such as:

> The approximate recurrence internal of the rainfall intensity and peak river / creek flows;

> The approximate recurrence interval of any major overland flooding;

> A comparison of the storm event with previous historical events and design events. Comparison could be made against rainfall, flows or depths;

> Timings of peak flows or levels; and

> The timing and duration of road overtopping / closures.

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 1% AEP or PMF event, would give them a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event.

11.2.2 Medium Term

11.2.2.1 Flood Height Indicators within the Study Area

A recommendation of this study is to place flood depth markers at key flooding locations (refer **Section 12.4**). In order to further increase the flood information conveyed from these markers, it is recommended that the flood height of historical events be marked, along with the design flood event heights. The purpose of these markings would be to demonstrate to the community both the relative size of historical events, as well as the flood depths that can be expected in large flood events.

The height markings would serve as a visual aid to assist the community in understand the significant flood heights that occur along the Nepean River during large flood events.

11.2.2.2 Develop FloodSafe Brochure and FloodSafe Toolkit

The NSW SES has developed Local FloodSafe Guides, which give specific information for areas at risk of floods. These guides are produced in collaboration with Council and regional and local NSW SES units. The NSW SES recommends that these guides are reviewed every 5 years.

The NSW SES has also prepared templates allowing Local Guides to be prepared for individual regions. Different guides may be prepared for general township flooding, flash flooding and rural flooding. Development of the forms can be organised through contacting the NSW SES.

The NSW SES FloodSafe website (www.floodsafe.com.au) also allows for the creation of personal plans and business plans. Variations of plans are also available for riverine and flash flooding regions. It is recommended that a reference to this tool be made in the FloodSafe Guide to make residents and owners aware of this tool, and that residents and businesses are encouraged to prepare a household or business plan.

11.2.2.3 Develop a Flood Information Package for New Residents

The documents prepared for the Flood Safe initiative will provide new residents an introduction to flood behaviour and risks within the Study Area. It is recommended that an information package be distributed to new residents that contains a short letter from Council discussing the current flood management program, the flood safe documents, links to further information, and contact details of Council staff should they have any further queries or concerns.

11.2.2.4 Hold a FloodSafe Launch Event

Following the development of the FloodSafe documents, a public launch may be held to inform the community of the availability of this material and to provide an opportunity for the community to discuss flooding issues with Council and NSW SES.

11.3 Triggers for Education & Awareness Actions

11.3.1 Actions Resulting from a Large Flood Event

Immediately following a large flood event is a good time to encourage residents to take an interest in flood behaviour in the catchment. At this time many residents actively seek flood information on the event and general flood behaviour. This should also be seen as an opportunity to encourage residents to develop personal flood response plans with the flood event still clear in their minds.

It is recommended that the following actions be undertaken following a large flood event in the catchment:

> Undertake the post-flood data collection;

> If mitigation strategies have been adopted, asses their effectiveness in the flood event;

> Prepare the post flood mail-out for the event; and

> Undertake the post flood mail-out to inform residents about the recent flood.

11.3.2 Actions Resulting from a Period of 5 years without a Large Flood Event

After a period of time without a large flood event, there is a risk that community flood awareness will begin to fall.

As such, it is recommended that if a period of five years elapses without a large flood event, a community mail-out be undertaken to inform / remind residents of flood risks within the catchment.

This mail-out may include a short letter from Council detailing the reasons for the mail-out and discussing historical flood events, the FloodSafe brochures, any previous post-flood mail-out forms, and links to other information sources.

The aim of this exercise is to ensure that residents remain aware of both flood risks within the catchment and appropriate risk management actions to take in flood events.

12 Floodplain Risk Management Options

12.1 Background

Flood risk can be categorised as existing, future or residual risk:

> **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding;

> **Future Flood Risk** – buildings and developments that may be built on flood prone land, or on land that may become flood affected in the future. Such buildings and developments would be exposed to a flood risk when they are built; and

> **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it will be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 12-1**.

Table 12-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention basins
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

> **Flood modification measures** – Flood modification measures are structural options aimed at preventing / avoiding or reducing the likelihood of flood risks through modifying the flood behaviour;

> **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks; and

> **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks through modifying the way the community and emergency services respond during a flood event

12.2 Flood Modification Options

12.2.1 Methodology of Identifying Options

The identification of appropriate flood risk management options for assessment within the Nepean River floodplain has been achieved through the following steps:

> Assess flood behaviour throughout the Study Area to determine the areas with frequent and significant flooding in larger events. These are the locations where flood risk management measures are most in need;

> Identify the locations of recorded flooding issues experienced by Council and reported flooding hotspots identified by the SES. Flood risk management measures were identified at these locations;

> Formulate a preliminary list of feasible flood risk management options at each location; and

> Based on the review of preliminary options, identify a final list of options which can be further assessed in detail, through hydraulic modelling, costing, flood damages assessment, and multi-criteria

assessment. This detailed assessment provides sufficient basis for their potential adoption within the Floodplain Risk management Plan.

12.2.2 Preliminary Flood Modification Options

For the Nepean River catchment a wide range of modification measures were considered including:

- Detention basins: Detain floodwaters to reduce the extent of inundation downstream. Suitable locations for this flood modification option are large public reserves in the catchment that can provide sufficient flood storage to significantly reduce peak discharges;
- Levees / flood wall: Act as barriers to flood water;
- Channel works: The primary focus of these works are to increase the capacity and/or hydraulic efficiency of existing channels and creeks through removal of debris and vegetation management;
- Drainage upgrades: Aim to improve the conveyance capacity of trunk drainage lines to reduce overland flow by increasing the size and/or number of trunk drainage pipes where pipe capacity was found to be the limiting factor on drainage capacity and/or new drainage pipes which divert floodwaters to main channels with additional capacity; and
- Road / bridge raising: Reduce flows over roadways by raising roads / bridges and/or by diverting floodwaters into adjoining areas.

In total, thirty-four 34 preliminary flood modification options were identified for the Nepean River floodplain excluding Narellan Creek floodplain and seventeen (17) preliminary flood modification options were identified for the Narellan Creek floodplain. These options were developed to address all of the flood affected areas where practicable. The complete list of the preliminary options including location is provided in **Appendix G**.

12.2.3 Final Flood Modification Options

An initial desktop assessment was undertaken of the preliminary flood modification options based on likely cost, number of flood affected properties benefitting, and likely constraints. From the list of preliminary options, a final list of options was compiled in consultation with Council and the Department to determine which options were to be assessed through detailed hydraulic modelling. A summary of the final fifteen (15) flood modification options selected for assessment is presented in **Table 12-2**.

Table 12-2 Final List of Floodplain Risk management Options

Option ID	Option Details
FM1.2	This option involves building a levee behind the properties on Lerida Avenue, between Macquarie Avenue and Chellaston St. The proposed levee would be approximately 380m long and the height would range from 0.83m to 8.72m. This option aims to reduce mainstream flooding from the Nepean River for properties near Lerida Avenue.
FM1.6	This option involves the construction of a levee running north to south between Alpha road and the Rotary Cowpasture Reserve. The levee is approximately 430m long and starts at height of 8.22m in the north and transitions to a height of 5m in the south. The option is expected protect the properties to the west of the levee along Alpha road from Nepean River flooding.
FM1.7	This includes raising the Macquarie Grove Road at its intersection with the Nepean River. The road would be raised by a maximum of 12.92m directly above the river. To the north of the river it would transition back to ground level near 133 Macquarie Grove Road, and to the south of the river it would transition back to ground level near the Macquarie Grove Road and Exeter Street intersection. While this option is expected to prevent the floodwaters from overtopping the road level, increases in flood levels upstream maybe expected as the raised road creates a barrier in the floodplain.
FM1.7a	This option is an extension to FM1.7 and includes raising the road such that it acts as a bridge. This would then allow floodwaters to flow under the road / bridge and prevent floodwaters from overtopping the road level while preventing upstream increases in flood levels.

FM1.8	This option involves constructing new box culverts underneath Cawdor Road south of its intersection to Sheathers Lane. The proposed culverts are 1200mm wide and 450mm high and there would be 4 in series. This option will allow floodwaters to traverse underneath Cawdor road preventing the build-up of floodwaters behind Cawdor road.
FM1.9	This option involves building a levee behind the properties on Little Street and Pindari Avenue, from Little Byrne Street to Engesta Ave. The levee spans 1,070m and has a starting height of 2.43m above ground level in the north, this increases to the peak height of 5.97m near the Pindari Avenue and Annabella Road intersection then decreasing down to a height of 0.57m near Engesta Ave. This option is expected to reduce flood levels for the properties to the west of the levee.
FM1.13	This option involves expanding the existing channel along Matahil Creek near Ron Dine Memorial Reserve. The channel works would occur from Lawson Ave to Copwer Drive. The channel expansion would be 20m wide and 510m long. It is expected that this option will reduce flood levels along McCrae Drive but may potentially cause increases downstream through the increase of the floodwaters through the channel.
FM1.15	This option involves building a levee west of McCrae Drive from Saunders Avenue to Cunningham Place. The proposed levee is 450m long and varies in height from 0.70m to 1.70m from north to south with a peak height of 2.00m above the existing ground level. This option is expected to reduce flood levels for properties along McCrae Drive.
FM1.23	Sickles Creek currently travels under Werombi road and this option involves constructing a new road bridge. The bridge would have a constant deck level of 63.4mAHD and a length of 80m. The proposed bridge is expected to allow more flows to travel under Werombi road reducing the flood levels upstream. However, this option could potentially increase the flood levels for the downstream properties.
FM1.26	This option involves raising Cut Hill Road. The length of road to be raised is 2km. The road would be raised by a maximum of 11m directly above the creek. To the north of the creek it would transition back to ground level near 305 Cut Hill Road and to the south of the creek it would transition back to ground level near 110 Cut Hill Road. The raised road is expected to provide an access route for events up to the 1% AEP event.
FM1.32	There is an existing road crossing at Cut Hill Road over Bringelly Creek. This option includes constructing 2 new box culverts under the road crossing. Each box culvert has a proposed width of 4.2m and a height of 1.2m. It is expected that this option will reduce flood levels upstream of the road crossing.
FM2.1	This option involves construction of a new offline detention basin on the south east side of Mount Annan Drive and Narellan Road intersection. The proposed basin will capture flows coming from the north and release them into Annan Creek running south via a 500mm diameter outlet pipe.
FM2.2	An existing 1650mm diameter pipe runs from Narellan Road along Paddy Miller Avenue. This pipe will be upgraded to a 2250mm diameter. This option is expected to decrease flood levels along Paddy Miller Avenue by discharging more flows to the downstream network.
FM2.4	This option involves the construction of a new channel behind the properties along Woolshed Place, Farmhouse Place and Horseman Place. This channel will connect to Kenny Creek near Farm House Place. The proposed channel would be 12m wide and 260m long. This option is expected to alleviate flooding in properties along Woolshed Place redirecting floodwaters to Kenny Creek.
FM2.5	The existing detention basin at Mount Annan High School has an embankment height of 98.5 mAHD. It is proposed to raise the embankment height by 1m to 99.5 mAHD. This change in embankment height will increase the storage capacity of the basin and is expected to lower flood levels downstream of the basin along Narellan Creek.

FM 2.6	This option involves upgrading the existing drainage that runs behind Mount Annan High School along Narellan Creek. Two pipes would be upgraded from a 675mm and 1000mm diameter pipes to 1800mm and 2100mm diameter pipes respectively. This increase in storage and flow capacity is expected to reduce flood levels upstream of the drainage upgrade.

12.2.4 Flood Modification Options Preliminary Assessment

To test the feasibility of the final flood modifications options, they were hydraulically assessed. The options were run for the 2 year ARI, 20%, 5%, 1%, 0.5%, 0.2% AEP and PMF events to ensure that they provided the expected benefits and did not result in adverse flood behaviour. The results of this analysis are summarised below in **Table 12-3**. The table summarises the outcome for the 20% and 1% AEP runs, and whether the option should be considered for further analysis. Impact plots for the 20% and 1% AEP runs storm events have been prepared for each option and these are provided in **Appendix H**.

Table 12-3 Options Preliminary Assessment Outcome

No	Option ID	Assessment Outcome
1	FM1.2	In the 1% AEP event there are reductions in flood levels of more than 0.5m. This option has benefits with reduction in overfloor flooding for properties near Lerida Avenue in events greater than 20% AEP.
2	FM1.6	In the 1% AEP event there are reductions in flood levels ranging from typically 0.01 m to 0.1m along Alpha Road. However, increases typically up to 0.03m are observed upstream of proposed levee extending further upstream of Camden Bypass.
3	FM1.7	In the 1% AEP event there are reduction along Nepean River, downstream of raised Macquarie Groove Road of more than 0.5m. However, there are widespread increases along Nepean River upstream of the road impacting residential properties. These increases are observed for all the design storm events.
4	FM1.7a	In the 1% AEP event there are reductions along Nepean River, downstream of raised Macquarie Groove Road of up to 0.03m. However, there are increases along Nepean River, upstream of the road of up to 0.2m. This option will benefit to wider community as it provides an access route during flood events up to 1% AEP event.
5	FM1.8	In 1% AEP event there is no impact on the flood levels. However, there are localised decreases of up to 0.03m upstream and increase of 0.03m downstream of Cawdor Road at Matahil Creek (West) in the 50% AEP event. Due to the nature of flooding - wide floodplain and higher flood depth, this option did not provide much benefit in larger storm events.
6	FM1.9	In the 1% AEP event there are reductions in flood levels ranging from typically 0.01m to 0.1m along Pindari Avenue.
7	FM1.13	The proposed widened channel has shown reductions in flood levels ranging from typically 0.01m to 0.05m near McCrea Drive along Matahil Creek, however, increases typically up to 0.05m are observed downstream of proposed channel widening extending till Burragorang Road. This option will benefit the properties along McCrea Drive.
8	FM1.15	This option results in reductions of flood levels to the properties along east of the levee for the 1% AEP event. The reduction is up to 0.2m. However, there are increases typically up to 0.05m at southern end and west of levee. This

		option has greater benefits with major reductions in overfloor flooding properties in all the storm events.
9	FM1.23	In 1% AEP event there is no impact on the flood levels. However, there are reductions in flood levels of up to 0.5m upstream of Werombi Road. Due to wide floodplain and higher flood depth, this option did not provide any benefits on events greater than 20% AEP event.
10	FM1.26	This option results is widespread reduction of flood levels along Cobbitty Creek and Nepean River, downstream and upstream of Cut Hill Road. However, there are increases typically up to 0.5m towards south west of Cut Hill Road. This option will benefit to wider community as it provides an access route during flood events up to 1% AEP event. NOTE: During the concept design stage there is an opportunity for Council to modify this option such that it does not have any adverse impacts during the smaller storm events.
11	FM1.32	In 1% AEP event there is no impact on the flood levels. However, there are localised decreases of up to 0.5m at Bringelly Creek, upstream of Cut Hill Road in 50 % AEP event. Due to the nature of flooding - wide floodplain and higher flood depth, this option did not provide much benefit in larger storm events.
12	FM2.1	The detention basin option at southern corner of Mount Annan Dr and Narellan Road junction results in localised reduction of flood levels in an order of 0.01m to 0.1m along Annan Creek in the events up to 5% AEP.
13	FM2.2	This option resulted in no impact. The drainage network size downstream of the option limited the flow despite of the increased pipe sizes along Paddy Miller Avenue.
14	FM2.4	In 1% AEP event there are increases of up to 0.05 m along Kenny Creek near Farmhouse Place. However this option has prevented flooding up to 0.2% AEP event through the properties near Woolshed Pl and Farmhouse place.
15	FM2.5	In the 1% AEP event there are reductions in flood levels ranging from typically 0.01m to 0.2m along Narellan Creek, downstream of basin. However, increases of more than 0.5m are observed upstream of proposed bund on existing basin. There are also increases of up to 0.2m at eastern side of the basin, in Mount Annan School ground.
16	FM2.6	In 1% AEP event there are reductions in flood levels ranging from 0.01m to 0.2m along Narellan Creek upstream of Waterworth Drive. However, increases of typically 0.01m to 0.05m are observed downstream of water worth Drive where drainage network spills to open channel.

12.2.5 Harrington Park Flood Modification Options

A Flood Mitigation Option Study was undertaken in 2014 for Harrington Park, the area between Camden Valley Way (CVW) and The Northern Road, within the Narellan Creek Catchment, as part of Narellan Creek Flood Study. Ten flood mitigation options, including combined options were investigated with recommendations for preferred options. Public Works Advisory (PWA) was engaged by Camden Council to review these mitigation options. Investigation and Design Harrington Park Mitigation Works, Narellan – Nepean was completed by PWA (2017a). Summary of the assessment of all the short-listed options are presented in **Table 12-4**. The 2017 study identified two options as the preferred solutions, for further investigation, those being:

> Fairwater Gardens flood levee – this option involves an earth embankment levee in the Fairwater Gardens development to protect it from inundation during the 1% AEP event; and

> Lake 2 spillway widening and channelization of downstream overbank areas – this option includes increasing the width of Lake 2 spillway, excavation of 1m to 2.5m deep channel with 10 m base width,

for an approximate distance of 300m downstream from the spillway and, provision of a footbridge over the channel in vicinity of the tennis courts.

> Vegetation Management – this option reduces the hydraulic roughness to maintain existing flood levels. Even though this option has low BCR score it is considered as important to maintain hydraulic roughness. .

Table 12-4 Summary of Harrington Park Flood Mitigation Option (Source: Investigation & Design Harington Park Mitigation Works, Narellan – Nepean Stage I & Stage II Report (PWA, 2017))

Option	Description	Fairwater Gardens	Other	Expected Impact on WQMS	Recommendation
Option 1	Vegetation Management	Reduction of less than 0.05m	Reductions of 0.05-0.10m about 500m downstream of Camden Valley Way	Nil	Not recommended - has some merit but relatively temporary measure with environmental impacts and likely low BCR
Option 2	Fairwater Gardens levee	Adjacent properties protected	Negligible impact elsewhere	Nil	Consider subject to prevention of pit surcharging and BCR
Option 3	Lake 2 Spillway Widening & Channelization of downstream overbank areas	Reductions of 0.28m	Levels marginally higher downstream of Lake 2 by up to 0.04 m	Negligible	Consider subject to BCR, environmental and heritage impacts
Option 3B	Additional 0.1m lowering of Lake 2 spillway	Negligible difference to Option 3	Negligible difference to Option 3	Negligible-Minor	Not recommended-negligible difference to Option 3, potential for increased impact on WQMS
Option 3C	Reduced extent of overbank lowering	Levels ~0.08m higher than Option 3	Levels 0.05-0.10 m higher than Option 3 between tennis courts and Harrington Parkway bridge	Negligible	Consider - may have advantages in terms of cost (reduced excavation & avoid need for footbridge/culvert) and heritage, however does not take advantage of nearby low areas
Option 4	Diversion of Tributary 1	Negligible benefit	Negligible benefit	Minor	Not recommended
Option 5	Lowering of overbank US of HP bridge	No benefit	Reductions of ~0.05m between tennis courts and immediate upstream of	Negligible-Minor	Consider in conjunction with Options 3 subject to BCR

Option	Description	Fairwater Gardens	Other	Expected Impact on WQMS	Recommendation
			Harrington Parkway bridge, negligible impact elsewhere		
Option 6	Lowering of overbank DS of HP bridge	No benefit	Reductions of ~0.05m between tennis courts and immediate downstream of Harrington Parkway bridge, negligible impact elsewhere	Negligible-Minor	Consider in conjunction with Option 3 subject to BCR and access issues
Option 7	Lowering of Lake 3D embankment	No benefit	Reductions of ~0.05m between tennis courts and vicinity of Harrington Plaza, negligible impact elsewhere	Negligible-Minor	Consider in conjunction with Option 3 subject to BCR
Option 8	Lowering of overbank at discharge to Lake 3A	No benefit	Negligible benefit	Nil	Not recommended
Combinations					
Option 3 & Option 5	Combination	Levels immediately DS of Lake 2 up to 0.04m lower than Option 3	Negligible difference to Option 3	Negligible-Minor	Not recommended
Option 3 & Option 6	Combination	Levels immediately DS of Lake 2 ~0.02m lower than Option 3	Levels ~0.04 m lower than Option 3 in immediate vicinity of Harrington Parkway bridge	Negligible-Minor	Not recommended
Option 3 & Option 7	Combination	Levels immediately DS of Lake 2 up to 0.04m lower	Levels up to 0.05m lower than Option 3 between tennis courts and	Negligible-Minor	Consider subject to BCR, environmental and heritage impacts

Option	Description	Fairwater Gardens	Other	Expected Impact on WQMS	Recommendation
		than Option 3	vicinity of Harrington Plaza		

12.2.6 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works which applies to most of the flood mitigation options in **Table 12-3**. Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors.

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

> Flood mitigation works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997;

> Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999; and

> A license to harm threatened species, populations or ecological community or damage habitat under the Fisheries Management Act 1999.

12.3 Property Modification Options

The following property modification options were identified for consideration for implementation in the Study Area:

> LEP Update;

> Building and Development controls;

> Voluntary House Raising;

> House Rebuilding;

> Voluntary Purchase;

> Land Swap;

> Council Redevelopment;

> Flood Proofing; and

> Rezoning of Primary Production Land.

12.3.1 PM1 – LEP Update

Local environment plans are prepared by councils as per EP&A Act to guide planning decisions for local government areas. Through zoning and development controls, the LEP allows councils to supervise the ways in which land is used.

The Camden Local Environment Plan (CLEP2010) is the statutory planning instrument that establishes what forms of development and land use are permissible and/or prohibited on all land within the Camden Local Government Area.

The Camden LEP is discussed in **Section 8.1**. It has been recommended that Council adopt an LGA wide FPL of the 1% AEP + freeboard, freeboard is 0.5m for mainstream flooding and 0.5m or 0.3 m for overland flow. The flood planning level review and recommendation is discussed in details in **Section 8.5**. It is also recommended that the LEP is updated following the improved understanding of flood behaviour as a result of this study.

12.3.2 PM2 – Building and Development Controls and Flood Policy Update

The key document for flood related controls in the Camden LGA is DCP2011, Section B1.11 The Camden DCP 2011 is discussed in **Section 8.3** and a number of recommendations are discussed in **Section 8.4**. It is also recommended to update the Flood Policy in the LEP and DCP.

12.3.3 PM3 – Voluntary House Raising

House raising is a measure designed to reduce the incidence of over-floor flooding of existing buildings through works funded by Council, and with assistance from the Department. The Guidelines for voluntary house raising schemes (The Department, 2013a) sets out ineligibility criteria for house raising under the Voluntary House Raising (VHR) scheme and include the following:

> Properties which are already benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee, and those that will be under future plans; and

> Properties that would not achieve a positive benefit through damage reduction relative to cost (i.e. benefit-cost ratio less than 1). Consideration may be given to lower benefit-cost ratios where there are substantial social and community benefits, or where the VHR is compensatory work for the adverse impacts of other mitigation works.

The scheme should involve raising residential properties above a minimum design level, generally the council's flood planning level (FPL), and comply with the council's relevant development control requirements. This option is not applicable for properties which are "slab on ground" construction.

While house raising can reduce the occurrence of overfloor flooding, there are issues related to the practice, including:

> The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages etc.;

> Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists – i.e. there will still be a residual risk;

> Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounding a property;

> Ensure new footings or piers can withstand flood-related forces; and

> Potential conflict with height restrictions imposed for a specific zone or locality within the local government area.

For a single storey property, the flooding damage that occurs for overfloor flooding in the depth range of 0-0.5m is approximately $80,000. **Table 12-5** provides the approximate Average Annual Damage (AAD) for overfloor flooding commencing in different AEP events for individual residential properties. Note that damages as a result of overground flooding only are not included for the purpose of this calculation. It assumes that overfloor flooding damage is constant at $40,000 for each overfloor flooding event. This provides a typical AAD for an individual property which can be used as a guide.

Table 12-5 Estimates of AAD and NPV for various Overfloor Flooding Scenario

Event (AEP)	Properties with overfloor flooding	Annual Average Damage per Property	Net Present Value (30 yrs) per Property
2 year ARI	5	$15,556	$193,038
20%	11	$15,093	$187,286
5%	108	$7,892	$97,932

1%	200	$3,374	$41,872
0.5%	283	$485	$6,024
0.2%	431	$274	$3,396
PMF	2071	$128	$1,591

All residential properties that experience overfloor flooding in the 5% AEP event (108 houses) could be considered for this option.

12.3.4 PM4 – House Rebuilding

Under a rebuilding scheme, the property owner would have the option of utilising the subsidy for house raising described above for reconstruction instead. In a number of cases, the ability to raise properties can be difficult and therefore rebuilding may be the only option. The advantage of this option is that the new structure can also be built in a flood compatible way (such as including a second storey for flood refuge above the PMF level). The subsidy could be used to cover any additional costs associated with flood proofing a development in a high risk location (for example, flood compatible materials and setting floor levels above the FPL). All residential properties that experience overfloor flooding in the 5% AEP event (108 houses) could be considered for this option.

One of the issues associated with this option is that there is still a significant cost for the property owner to redevelop their land. In addition, this provides an inequitable situation for those properties that are subject to the subsidy and those that are not. It can have the effect of skewing the property redevelopment market, where those properties subject to the subsidy are more attractive for development than those properties that are not.

12.3.5 PM5 – Voluntary Purchase

Voluntary purchase is the optional purchase of pre-selected properties funded jointly by Council and the State Government. It would free both residents and emergency services personnel from the hazard of future floods by removing the risk, and is achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be re-zoned under the LEP to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

The Department has prepared the *Guidelines for voluntary purchase schemes* (OEH, 2013) to assist in determining when and where voluntary purchase schemes may be suitable. The guideline recommends that voluntary purchase be considered where:

> There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;

> A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function; and/or

> Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

Typical prices of properties in the Nepean River floodplain, are in the order of $700,000 (based on a search of the listed property prices for the area through www.realestate.com.au). All residential properties that experience overfloor flooding in the 5% AEP event (108 houses) could be considered for this option.

12.3.6 PM6 – Land Swap

An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land outside of the flood prone area, such as an existing park, for a parcel of flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land re-zoned under the LEP to open space.

All residential properties that experience overfloor flooding in the 5% AEP event (108 houses) could be considered for this option.This option would benefit individual properties and not the catchment as a whole. For the purposes of costing it has been assumed $200,000 per house for the demolition of existing building and infrastructure and rezoning.

12.3.7 PM7 – Council Re-development

This option also provides an alternative to the Voluntary Purchase (Option PM5) scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them for re-development under certain development controls.

The following provides an estimate of the various costs involved for a single residential development, where Council redevelopment occurs only on those properties identified in for voluntary purchase. Purchase cost of the property estimated as per PM5 above.

> Purchase of property = $700,000

Council would need to sell the property at approximately $1,050,000 in order to break even on the development, in a one-for-one development approach. This excludes other costs such as transaction expenses.

It is noted that there are significant risks for Council in undertaking this option. In particular, the property market may vary during the construction period, resulting in a difficulty in re-selling the property or re-selling the property at a price lower than the purchase price and it requires a large upfront cost to Council. An alternative would be to consider the acquisition of multiple flood-affected properties, and redevelopment with a high density, flood compatible development where possible and as permitted in the zoning under the LEP.

12.3.8 PM 8 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce the damage caused to the property by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

> All structural elements below the flood planning level shall be constructed from flood compatible materials (refer Table 7.5 in Camden Council's Flood Risk Management Policy 3.19);

> All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the FPL. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF; and

> All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the flood planning level.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties. It is noted that there are 39 commercial / industrial properties that experience flooding in the 5% AEP event or greater.

These measures should be carried out according to a pre-arranged plan. These measures may include:

> Raising belongings by stacking them on shelves or taking them to a second storey of the building;

> Secure objects that are likely to float and cause damage;

> Re-locate waste containers, chemical and poisons well above floor level; and

> Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

The NSW SES business *Flash Flood Tool Kit* (SES, 2012) https://www.ses.nsw.gov.au/media/1214/nsw-flash-flood-business-fstk-booklet.pdf provides businesses with a template to create a flood-safe plan and

to be prepared to implement flood proofing measures. It is recommended that this tool kit is distributed to the flood affected businesses within the floodplain.

NOTE: This option can be incorporated as part of Option EM3 – Public Education and Awareness which is discussed further in **Section 12.4.3**. This option has not been considered for further assessment as part of this study.

12.3.9 PM 9 – Rezoning of the Primary Production Land

As can be observed in **Section 8**, **Table 8-1**, primary production land has 38% of its total area inundated in the 1% AEP. This presents an opportunity wherein during future rezoning, there is potential to rezone this land in to flood compatible residential and/or commercial land use.

NOTE: It is recommended that Council consider this option during rezoning of land uses within the Nepean River catchment. This option has not been considered for further assessment as part of this study.

12.4 Emergency Response Modification Options

The following emergency response modification options have been assessed for the Nepean River floodplain:

> Information transfer to the NSW SES;

> Flood and flash flood warning system;

> Public awareness and education; and

> Flood warning signs at critical locations.

These options are discussed in detail below.

12.4.1 EM 1 – Information Transfer to NSW SES

The findings of this Flood Risk Management Study and Plan provide an extremely useful data source for the NSW SES and Council. Transfer of the flood intelligence from this study, such as road overtopping depths and timings, the locations of flood affected properties, and the flood behaviour of high risk regions, would be communicated to the NSW SES to assist in their flood response strategies.

This data will also be provided to SES to update the Local Flood Plan and DISPLAN.

12.4.2 EM 2 – Flood and Flash Flood Warning System

The longer duration flooding that occurs along the Nepean River allows for warnings to be issued in advance of imminent flooding to allow local evacuation of affected properties. Warnings issued from a gauge installed at Menangle Weir, or a similar location with proximity to the Camden CBD could provide warnings times of approximately 1 – 2 hours, depending on the trigger levels used to issue warnings.

The warning would be triggered when either overfloor flooding of properties or loss of access to properties was imminent. Such a warning would only allow the immediate evacuation of residents to local flood refuges. It would not provide sufficient time to move or evacuate belongings.

Should a system be implemented, it will be important for the community to understand the operation of the system and its limitations. A key point to inform the community will be the likely frequency of warnings issued from the gauge. In order for the warning to be effective, it will need to be issued before property flooding commences. This will result in small events triggering the warning. The community will need to understand that there will be false positives reported from the system, and that for the system to be effective, they will need to continue to respond to the evacuation warning, even after a number of issued warnings that were not followed by subsequent flooding.

It should also be noted that the warnings will only be applicable to flooding occurring from the Nepean River. The smaller, local tributaries experience short duration flooding that is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

12.4.3 EM 3 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

A strategy to manage and improve public awareness and education is discussed in **Section 11**.

12.4.4 EM 4 – Flood Warning Signs at Critical Locations

A number of public places in the Study Area experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that additional depth gauges be installed at road crossings listed below which are subject to inundation in frequent events as discussed in **Section 10.3.1**.

> Cut Hill Road;

> Ellis Lane;

> Macquarie Grove Road;

> Argyle Street;

> Kirkham Lane;

> Cobbitty Road;

> Sheathers Lane; and

> Cawdor Road.

13 Economic Assessment of Options

13.1 Preliminary Costing of Options

Preliminary cost estimates have been prepared for those options that allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages (**Table 13-1**). For other measures (Emergency Management), costs were estimated only on the basis of cost to implement, and were done for the purpose of comparison in the multi-criteria assessment detailed in **Section 14** of this report.

Prior to a measure proceeding it is recommended that, in addition to detailed analysis and design of the measure, these costs be revised to achieve a more accurate assessment for overall budget allocation. Detailed rates and quantities will also be required at the detailed design phase. A cost breakdown for each option is provided in **Appendix I**.

Table 13-1 Cost Estimates for Quantitatively Assessed Options

Option ID	Option	Capital Cost (excl. GST)	Ongoing Annual Cost (excl. GST)*
FM1.2	Building a Levee near Lerida Avenue	$7,210,000	$72,096
FM1.6	Building a Levee near Alpha Road	$14,368,000	$143,681
FM1.7	Macquarie Grove Road raising	$28,802,000	$288,020
FM1.7a	Macquarie Grove Road raising and widening of the bridge	$71,991,000	$719,907
FM1.8	Sheathers Lane Drainage Augmentation	$401,000	$4,014
FM1.9	Building a Levee near Little Street	$7,770,000	$77,702
FM1.13	Channel works at Matahil Creek near Ron Dine Memorial Reserve	$1,751,000	$17,510
FM1.15	Building a Levee near from Saunders Road and along McCrae Drive	$778,000	$7,784
FM1.23	Werombi Road Drainage Augmentation	$8,461,000	$84,613
FM1.26	Cut Hill Road raising at Cobbitty Creek crossing	$28,830,000	$288,296
FM1.32	Cut Hill Road Drainage Augmentation at Bringelly Creek	$1,094,000	$10,942
FM2.1	Construct Detention Basin near Mount Annan Dr and Narellan Road	$1,176,000	$11,764
FM2.2	Drainage Augmentation from Narellan Road along Paddy Miller Avenue	$3,539,000	$35,389
FM2.4	Redirect flows to Kenny Creek near Farm House place via new channel	$688,000	$6,876
FM2.5	Raise embankment of existing Detention Basin at Mount Anan High School	$312,000	$3,121
FM2.6	Drainage augmentation of Basin at Mount Anan High School	$739,000	$7,388
PM1	Review of LEP	N/A	$0**
PM 2	Building and DCP Controls and Flood Policy Update	N/A	$0**
PM3	Voluntary House Raising***	$8,240,000	$0**
PM4	House Rebuilding***	$8,240,000	$0**
PM5	Voluntary Purchase***	$72,100,000	$0**

Option ID	Option	Capital Cost (excl. GST)	Ongoing Annual Cost (excl. GST)*
PM6	Land Swap***	$20,600,000	$0**
PM7	Council Redevelopment	$36,050,000	$0**
EM1	Information transfer to SES	$5,000	$0**
EM2	Flood and Flash Flood warning system including infrastructure	$450,000	$45,000
EM3	Public awareness and education	$25,000	$250
EM4	Flood and Flash Flood warning signs at critical locations	$25,000	$250

**The ongoing costs have been based on an estimate of 1% of the capital cost.*

***There are no ongoing costs associated with these options.*

**** 108 properties have been considered for each of these options. These options can be used in combination for the 108 properties.*

13.2 Annual Average Damages Assessment

An assessment of AAD for the existing condition was presented in **Section 6**. As the flood modification options selected are predominantly concerned with the reduction of local flood impacts, rather than assess the catchment wide damages, the reduction in damages resulting from local decreases in flood depths and extents has been considered. The results are summarised in **Table 13-2**, noting that the AAD under existing conditions is **$5,685,793**.

Table 13-2 Reduction in Damages Associated with Each Option

Option ID	Option	Total AAD (excl. GST)	Total Reduction in AAD (excl. GST)
FM1.2	Building a Levee near Lerida Avenue	$5,479,583	$206,210
FM1.6	Building a Levee near Alpha Road	$5,588,822	$96,971
FM1.7	Macquarie Grove Road raising	$14,614,011	-$8,928,218
FM1.7a	Macquarie Grove Road raising and widening of the bridge	$5,684,853	$940
FM1.8	Sheathers Lane Drainage Augmentation	$5,685,793	$0
FM1.9	Building a Levee near Little Street	$5,685,714	$79
FM1.13	Channel works at Matahil Creek near Ron Dine Memorial Reserve	$5,654,593	$31,200
FM1.15	Building a Levee near from Saunders Road and along McCrae Drive	$5,609,125	$76,668
FM1.23	Werombi Road Drainage Augmentation	$5,685,793	$0
FM1.26	Cut Hill Road raising at Cobbitty Creek crossing	$5,685,793	$0
FM1.32	Cut Hill Road Drainage Augmentation at Bringelly Creek	$5,685,793	$0
FM2.1	Construct Detention Basin near Mount Annan Dr and Narellan Road	$5,658,344	$27,449
FM2.2	Drainage Augmentation from Narellan Road along Paddy Miller Avenue	$5,685,793	$0
FM2.4	Redirect flows to Kenny Creek near Farm House place via new channel	$5,657,456	$28,337

FM2.5	Raise embankment of existing Detention Basin at Mount Anan High School	$5,658,137	$27,656
FM2.6	Drainage augmentation of Basin at Mount Anan High School	$5,658,050	$27,743
PM1	Review of LEP	*N/A**	
PM 2	Building and DCP Controls and Flood Policy Update	*N/A**	
PM3	House Raising	$4,520,929	$1,164,864
PM4	House Rebuilding	$4,520,929	$1,164,864
PM5	Voluntary Purchase	$4,088,371	$1,597,422
PM6	Land Swap	$4,088,371	$1,597,422
PM7	Council Redevelopment	$4,088,371	$1,597,422
EM1	Information transfer to SES	*N/A**	
EM2	Flood and Flash Flood warning system	*N/A**	
EM3	Public awareness and education	*N/A**	
EM4	Flood and Flash Flood warning signs at critical locations	*N/A**	

**Since the reduction in flood affection from these options cannot be defined, these options do not have AAD costs associated with them.*

13.3 Benefit Cost Ratio of Options

The economic evaluation of each option was performed by considering the reduction in the amount of flood damages incurred for the design events and then comparing this value with the cost of implementing the option.

The existing condition was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data derived from the desktop floor level assessment along with damage curves for other similar areas. The flood extents for all the design events were considered for this evaluation. The preliminary costs of each measure were used to undertake a benefit-cost analysis on a purely economic basis.

Table 13-3 summarises the results of the economic assessment of each of the option. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (BCR), which is based on the net present worth (NPW) of the benefits (reduction in AAD) and the costs (of implementation), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance.

> Where the benefit-cost ratio is greater than one (BCR >1) the economic benefits are greater than the cost of implementing the measure.

> Where the benefit-cost is less than one but greater than zero (0 < BCR < 1) there is still an economic benefit from implementing the measure, but the cost of implementing the measure is greater than the economic benefit.

> Where the benefit-cost is equal to zero (BCR = 0), there is no economic benefit from implementing the measure.

> Where the benefit-cost is less than zero (BCR < 0), there is a negative economic impact of implementing the measure.

Table 13-3 Summary of Economic Assessment of Options

Option ID	NPW of reduction in AAD	NPW of Cost of Implementation of Option	Benefit Cost Ratio	Economic Ranking
FM1.2	$206,210	$8,277,000	0.37	9

Option ID	NPW of reduction in AAD	NPW of Cost of Implementation of Option	Benefit Cost Ratio	Economic Ranking
FM1.6	$96,971	$16,495,000	0.09	13
FM1.7	-$8,928,218	$33,065,000	-4.00	21
FM1.7a	$14,000	$82,646,000	0.00	15
FM1.8	$0	$461,000	0.00	16
FM1.9	$2,000	$8,921,000	0.00	14
FM1.13	$462,000	$2,011,000	0.23	12
FM1.15	$1,135,000	$894,000	1.27	3
FM1.23	$0	$9,714,000	0.00	16
FM1.26	$0	$33,097,000	0.00	16
FM1.32	$0	$1,257,000	0.00	16
FM2.1	$407,000	$1,351,000	0.30	11
FM2.2	$0	$4,063,000	0.00	16
FM2.4	$420,000	$790,000	0.53	7
FM2.5	$410,000	$359,000	1.14	5
FM2.6	$411,000	$849,000	0.48	8
PM 1	*N/A**	$50,000	*N/A**	
PM2	*N/A**	$50,000	*N/A**	
PM3	$17,241,000	$8,240,000	2.09	1
PM4	$17,241,000	$8,240,000	2.09	1
PM5	$23,644,000	$72,100,000	0.33	10
PM6	$23,644,000	$20,600,000	1.15	4
PM7	$23,644,000	$36,050,000	0.66	6
EM1	*N/A**	$5,000	*N/A**	
EM2	*N/A**	$161,000	*N/A**	
EM3	*N/A**	$29,000	*N/A**	
EM4	*N/A**	$29,000	*N/A**	

**Since the NPW reduction in AAD for these options cannot be defined, these options cannot be assigned a BCR ratio.*

The top five highest ranking flood management options based on BCR are PM3, PM4, FM1.15, and PM6.

It is noted that the economic analysis has only incorporated changes to economic damages to properties, and does not consider social factors, risk to life and environmental factors. These types of benefits are difficult to quantify in dollar terms.

So, while an option may have a BCR less than one, it may still be a worthwhile option to implement due to other factors such as making a road flood free, which doesn't have any damages reduction associated with it.

The multi criteria analysis (**Section 14**) incorporates some of these non-quantifiable impacts into the decision making process.

13.4 Economic Assessment of Harrington Park Flood Modification Options

An economic analysis of the preferred two options has been undertaken as part of the Harrington Park Mitigation Works Report (PWA 2017). This has been summarised in **Table 13-4**.

Table 13-4 Harrington Park Flood Mitigation Options Benefit Coast Analysis

	Fairwater Gardens Levee	Lake 2 Spillway widening & channelization of downstream overbank areas	Vegetation Management
Total AAD	$24,000	$16,000	Not costed
Total NPW*	$355,000	$237,000	Not costed
Total benefits	$104,000	$222,000	Not costed
Estimated Capital Cost	$591,391	$987,823	(i) $703,200 (ii) $1,617,480
Benefit Cost ratio	0.18	0.23	N/A

** Based on a 7% discount rate and an implementation period of 50 years.*

(i) over 2 years to reduce hydraulic roughness

(ii) other vegetation management in the area over 2 years

NOTE: Vegetation Management is also a recommended option for maintaining roughness to maintain flood levels, however this has not been assessed for the BCR.

14 Multi Criteria Assessment

To assist Council in identifying the flood mitigation options that provide the most benefits for the community, all options need to be compared against each other based on factors including but not limited to the reduction in flood risk and economic flood damages.

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Impacts associated with flooding include risk to assets and also risk to life. Urban areas impacted by flooding are valued in a number of ways by communities, organisations and individuals. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by community and stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In doing so, one can consider different floodplain management options in the context of economic criteria as well as other criteria such as social, political or environmental aspects. Community and stakeholders can also assign explicit weights to those values to reflect their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of community and stakeholders in the analysis.

A MCA approach was used for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach uses a subjective scoring system to assess the merits of each option. The principal value of such a system is that it allows comparisons to be made between alternatives using a common index. In addition, the MCA makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis).

However, this approach does not provide an absolute “right” answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which Council, community and stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring system simple a framework has been developed for each criterion.

14.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion. The criterion adopted includes:

Economic	Benefit cost ratio
	Capital costs
	Operating costs
Social	Reduction in social disruption
	Reduction in risk to life
	Community support
	Compatible with policies and plan
Environmental	Compatible with water quality objectives
	Ground Water
	Fauna / Flora
	Heritage

The scoring system is shown in **Table 14-1** for the above criteria.

Table 14-1 Details of Adopted Scoring System

Category	Category Weighting %	Criteria	Metric	Criteria Weighting %	Score				
					-2	-1	0	1	2
Economic	50	Benefit Cost Ratio	BCR	25	<-1	-1 to -0.5	0 to 0.5	0.5 to 1	>1
		Capital Costs	Capital Costs of Option	15	Extreme >$20 million	High $10 million - $20 million	Medium $5 million - $10 million	Low $1 million - $5 million	Very Low $0 - $1 million
		Operating Costs	Operating Cost of Option	10	Extreme >$200,000 per year	High $100,000 - $200,000 per year	Medium $50,000 - $100,000 per year	Low $10,000 - $50,000 per year	Very Low $0 - $10,000 per year
Social	30	Reduction in Risk to Life	Change in number of properties with over floor flooding in 1% AEP event and reduced flooding for sensitive land uses (e.g. schools, child care facilities, aged care)	9	Impacts > 10 properties	Impacts to 2 to 10 properties	0-1 (Reduction or Impacts to properties)	Reduction to 2 to 10 properties and/or a sensitive land use and net overall reduction in risk	Reduction < 10 properties and/or sensitive land use and net overall reduction in risk
		Reduction in Social Disruption	Flood depth and duration changes for transport routes	6	Significant increase in main road flooding	Minor increase local or main road flooding	No change to social disruption	Minor decrease local or main road flooding	Significant decrease in main road flooding
		Community Support	Level of agreement from community, Council and related agencies	6	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	Level of Compatibility	6	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	20	Compatibility with Water Quality Objectives	Compatibility of objectives	5	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Groundwater	Impact on ground water	5	Likely interception of groundwater flow contamination of groundwater quality during construction or after implementation	Possible interception of groundwater flow contamination of groundwater quality during construction or after implementation	No impact on groundwater flow or quality	Possible improvements to groundwater flow or quality	Likely improvements to groundwater flow or quality
		Fauna/Flora Impact	Impacts or benefits to flora / fauna or passive/active recreational areas	5	Likely to impact on EECs, wetlands, seagrasses or large areas of vegetation. Restricts connectivity between areas of habitat and waterways	Possible impacts on EECs, wetlands, seagrasses or removal of isolated trees / vegetation. Restricts connectivity between degraded habitat and waterways	No impact	Restoration of small areas of habitat	Restoration of large areas of habitat
		Heritage	Impacts to heritage items, including consideration of heritage items.	5	Destruction of State or National Heritage Item	Likely impact on State or National Heritage Item or possible impact on local heritage item5	No likely impact	Some benefit	Considerable benefit

14.1.2 Economic Assessment

The economic assessment involved an appreciation of:

> Benefit Cost Ratio;

> Capital and Operating Costs; and

> Reduction in Risk to Property.

Capital and operating costs for options were quantitatively assessed for the hydraulically modelled options, whilst a judgement of the likely capital and recurrent costs was made for the remaining options by experienced engineers.

It is noted that the Benefit Cost Ratio incorporates both the capital & operating costs, and the reduction in the Risk to Property. However, these are included to provide an overall measure of both the affordability of an option (the magnitude of the cost) as well as the overall benefit of the option. The Benefit Cost Ratio, while providing a representation of the economic efficiency of the option, does not provide this information.

14.1.3 Social Impact Assessment

The social impact assessment involved an appreciation of:

> Reduction in Social Disruption;

> Reduction in Risk to Life;

> Compatibility with Policies and Plans; and

> Community Support.

The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

The community support for a particular option was derived by discussions with Council and their knowledge of community concerns. This will be updated following community workshops and exhibition of the draft report, and feedback from the community

The compatibility with Council policies and plans were assessed based on the policies and plans review undertaken (**Section 8** and **Section 8.5**).

14.1.4 Environmental Assessment

The environmental impact assessment involved an appreciation of:

> Surface water quality;

> Groundwater affectation;

> Flora and fauna impact; and

> Heritage.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system.

14.2 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix J**. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 14-1**. It is noted that both structural (flood modification) and non-structural (property modification and emergency response) options have been considered separately. It is

difficult to directly compare these two types of measures. Furthermore, funding sources and implementation timeframes for the two different types of measures are typically different.

Table 14-2 Summary of MCA Evaluation of Options

Option ID		MCA Score	Overall Rank
Structural Options			
FM1.15	Building a levee near Saunders Road and along McCrae Drive	1.34	1
FM2.5	Raise embankment of existing Detention Basin at Mount Anan High School	1.29	2
FM2.4	Redirect flows to Kenny Creek near Farm House place via new channel	1.06	3
FM1.8	Sheathers Lane Drainage Augmentation	0.58	4
FM2.6	Drainage augmentation of Basin at Mount Anan High School	0.53	5
FM2.1	Construct Detention Basin near Mount Annan Dr and Narellan Road	0.41	6
FM2.2	Drainage Augmentation from Narellan Road along Paddy Miller Avenue	0.35	7
FM1.32	Cut Hill Road Drainage Augmentation at Bringelly Creek	0.33	8
FM1.13	Channel works at Matahil Creek near Ron Dine Memorial Reserve	0.33	8
FM1.2	Building a Levee near Lerida Avenue	0.28	10
FM1.9	Building a Levee near Little Street	0.10	11
FM1.23	Werombi Road Drainage Augmentation	0.08	12
FM1.6	Building a Levee near Alpha Road	-0.19	13
FM1.7a	Macquarie Grove Road raising and widening of the bridge	-0.35	14
FM1.26	Cut Hill Road raising at Cobbitty Creek crossing	-0.49	15
FM1.7	Macquarie Grove Road raising	-1.53	16
Non-Structural Options			
PM1	LEP Update	0.92	1
PM2	Building and Development Controls	0.92	1
EM2	Flood and Flash Flood warning system	0.92	1
EM1	Information transfer to SES	0.86	4
EM3	Public awareness and education	0.86	4

Option ID		MCA Score	Overall Rank
EM4	Flood and Flash Flood warning signs at critical locations	0.86	4
PM3	Voluntary House Raising	0.7	7
PM4	House Rebuilding	0.7	7
PM6	Land Swap	0.58	9
PM7	Council Redevelopment	0.33	10
PM5	Voluntary Purchase	0.08	11

The overall score for the option is then calculated by the weights for each of the categories.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix J**.

Of the structural options investigated, the top three identified by the multi-criteria analysis were:

> FM1.15 – Building a levee from Saunders Road and along McCrae Drive;

> FM2.5 – Modify existing detention basin at Mount Anan High School; and

> FM 2.4 – Redirect flows to Kenny Creek near Farm House place via new channel.

Of the non-structural options assessed, the top three identified by the multi-criteria analysis were:

> PM1 – LEP update;

> PM2 – Building and developments controls; and

> EM2 – Flood and Flash warning system.

This ranking is proposed to be used as the basis for prioritising the options in the *Floodplain Risk Management Plan*. It must be emphasised that the scoring shown in **Appendix J** is not “absolute” and the proposed scoring and weighting should be reviewed at regular intervals to ensure they are still representative.

14.2.2 Multi-Criteria Assessment of Harrington Park Flood Modification Options

A multi-criteria analysis of the preferred two options has been undertaken as part of the Harrington Park Mitigation Works Report (PWA 2017). This has been summarised in **Table 14-3**. This ranking is proposed to be used as the basis for prioritising the options in the Floodplain Risk Management Plan.

Table 14-3 Harrington Park Flood Mitigation Options Benefit Coast Analysis

Assessment Criteria	Fairwater Gardens Levee	Lake 2 Spillway widening & channelization of downstream overbank areas
Impact on flood behaviour	4	5
Number of properties benefitted	4	5
Technical feasibility	2	3
Economic merit	1	1
Financial feasibility	3	3

Assessment Criteria	Fairwater Gardens Levee	Lake 2 Spillway widening & channelization of downstream overbank areas
Environmental and ecological benefits	2	2
Impact on risk to life	3	3
Impacts on SES	3	3
Long-term performance	4	3
Legislative & permissibility requirements	2	4
Social impact / community acceptance	2	4
RANK	**2**	**1**

The Vegetation Management Plan option has been recommended but not further assessed as part of this study.

15 Floodplain Risk Management Plan

The Floodplain Risk Management Plan (FRMP) describes how flood prone land in the Nepean River catchment is to be used and managed, and presents the preferred floodplain risk management options identified in the FRMS.

15.1 Purpose of Plan

The preparation of the Nepean River Floodplain Risk Management Study and Plan followed on from the 2015 Nepean River Flood Study (Worley Parsons, 2015) and the 2017 Update of Narellan Creek Flood Study (Public Works Advisory, 2017b). This FRMP represents the fifth stage of the floodplain risk management process as defined in the 2005 Floodplain Development Manual (NSW Government, 2005):

1. Formation of a Floodplain Management Committee;
2. Data Collection;
3. Flood Study;
4. Floodplain Risk Management Study;
5. Floodplain Risk Management Plan; and
6. Implementation of the Floodplain Risk Management Plan.

The objectives of the Floodplain Risk Management Plan are to:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;
- Reduce private and public losses due to flooding;
- Be consistent with the objectives of relevant state policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act 1979;
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms; and
- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.

Establish a program for implementation and mechanism for the funding of the plan which should include priorities and funding, and responsibilities.

15.2 Floodplain Management Issues

The FRMS identified the following key issues in the Nepean River floodplain.

- Flooding of existing developed areas (residential and commercial) results in adverse economic and social impacts (e.g. damage to property, social disruption);
- Flooding damages public assets and critical infrastructure;
- There are several areas in the catchment that are proposed for urban development. Development controls have been proposed to ensure that that development does not increase the flood risk in the catchment;
- Access road flooding is a key issue since the roads become quickly inundated to large depths; and
- Climate change-related increases in rainfall intensity are predicted to exacerbate current flooding and to increase flood levels.

These issues form the basis of the options identification and assessment presented in the FRMS, and the FRMP seeks to address these issues through the implementation of identified actions.

15.3 Implementation Program

The floodplain management options outlined in **Table 14-3** are recommended for implementation as an outcome of the Floodplain Risk Management Study. In order to achieve the implementation of relevant management actions, a program of implementation has been developed.

The steps in progressing the floodplain risk management process from this point onwards are:

> The Floodplain Risk Management Committee will consider the Draft Plan and make recommendations;

> Council will adopt the final Plan;

> Recommended management actions will be implemented in accordance with the established priorities as funds become available from the DPIE, the Commonwealth, other state government agencies and/or from Council's own resources; and

> In some cases implementation will require more detailed cost benefit analysis, assessment and mitigation of environmental impacts and / or detailed design.

15.4 Implementation Plan

The list of recommended management options has been transformed into an implementation plan provided in **Table 14-3**. It lists the following information relevant to the implementation of the management actions:

> An estimate of implementation costs over a 50 year period (including capital and recurrent costs) for each structural action;

> The multi-criteria assessment scores;

> The agency or organisation likely to be responsible for the action and/or funding; and

> The priority for implementation (high, medium, or low) as an outcome of the FRMS. The priority reflects the urgency of the option from a reduction in flood risk perspective, particularly to reduce the risk to life.

The flood modification measures identified in **Table 14-3** represent a capital outlay of approximately $5.4M over the life of the plan.

It is noted that a specific timeframe for the Plan has not been explicitly identified. Experience with these types of Plans has identified that the works are undertaken when and as funding becomes available, as well as when various opportunities might arise specifically for an option. In general:

> Non-structural measures can generally be implemented in the short term (1 to 3 years), as they are relatively low in capital expenditure and generally revolve around policy and information; and

> Structural measures can generally be implemented in the medium term (3 to 10 years) to long term (10 to 20 years), and will be implemented as funding and opportunities arise, including land availability.

15.5 NSW Floodplain Management Authority Project Assessment and Priority Ranking

A multi-criteria assessment approach has been adopted to better understand the reduction in flood risk and other benefits and impacts of the various options considered. The recommendations of the FRMP have been based on the outcomes of this assessment. Funding and implementation of these recommendations will not necessarily be undertaken in accordance with the ranking of the options.

The NSW Government's floodplain management grants support local government to manage flood risk. The funding for these grants comes from two programs, the NSW Floodplain Management Program and the Floodplain Risk Management Grants Scheme (jointly funded by the NSW Office of Emergency Management and the Commonwealth Government).

Applications for funding can be made by Council for the implementation of actions identified in a FRMP. The information provided in the applications for each management action is used to rank the priority for funding of all actions across NSW.

The information presented in this study can be used to complete the relevant applications for funding.

Table 14-3 Implementation Plan

Option ID	Description	Capital Cost & Maintenance Cost* (excl. GST)	Catchment	MCA Rank	Priority**	Responsibility / Comment
PM1	LEP Update		Nepean River	1	H	Council responsibility
PM2	Building and DCP Controls and Flood Policy Update		Nepean River	1	H	Council responsibility
EM2	Flood and Flash Flood Warning Systems	$450,000 includes infrastructure as well Maintenance $50,00 per year for few years	Nepean River	1	H	State Grant Funding + Council contribution SES, The Department, BoM, Water NSW and Council collaboration
EM1	Information transfer to SES	$5,000	Nepean River	1	H	Council / SES /The Department responsibility
EM3	Public Awareness and Education	$25,000	Nepean River	5	H	Council / SES responsibility
EM4	Flood Warning Signs at Critical Locations	$25,000	Nepean River	5	H	Council / SES /The Department responsibility
	The following preliminary structural options needs further investigations to assess the feasibility and financial viability of these options					
FM1.15	This option involves building a levee west of McCrae Drive from Saunders Avenue to Cunningham Place. The proposed levee is 450m long and varies in height from 0.70m to 1.70m from north to south with a peak height of 2.00m above the existing ground level. This option is expected to reduce flood levels for properties along McCrae Drive.	$778,406 & 10% annual maintenance	Nepean River	7	H	State Grant Funding + Council contribution to undertake further investigations for feasibility of this option
FM2.4	This option involves the construction of a new channel behind the properties along Woolshed Place, Farmhouse Place and Horseman Place. This channel will connect to Kenny Creek near Farm House Place. The proposed channel would be 12m wide and 260m long. This option is expected to alleviate flooding in properties along Woolshed Place redirecting floodwaters to Kenny Creek.	$687,609 & 10% annual maintenance	Narellan Creek	8	H	State Grant Funding + Council contribution to undertake further investigations for feasibility of this option
	Harrington Park Mitigation Options considered under *Investigation & Design Harrington Park Mitigation Works (Public Works Authority)* **Separate ranking system has been used in this study (Ranking A for 1 and B for 2; this ranking is not comparable with other ranking)**					
Option 3	This option includes increasing the width of Lake 2 spillway, excavation of 1m to 2.5m deep channel with 10 m base width, for an approximate distance of 300m downstream from the spillway and, provision of a footbridge over the channel in vicinity of the tennis courts.	$987,823 Maintenance not estimated	Harrington Park	A	M	BCR is low (0.2) and not eligible for State Grant funding. However, this reduces flood levels slightly in the vicinity.

Option ID	Description	Capital Cost & Maintenance Cost* (excl. GST)	Catchment	MCA Rank	Priority**	Responsibility / Comment
Option 2	This option involves an earth embankment levee in the Fairwater Gardens development to protect it from inundation during the 1% AEP event	$591,391 Maintenance not estimated	Harrington Park	B	M	BCR is low (0.2) and not eligible for State Grant funding. However, this reduces flood levels slightly near Fairwater Gardens.
Option ID	**Description**	**Capital Cost & Maintenance Cost (excl. GST)**	**Catchment**	**MCA Rank**	**Priority****	**Comment**
Option 1	Vegetation management and ongoing maintenance to maintain hydraulic roughness (Manning roughness as in initial design / flood modelling) to maintain / control flood levels in Harrington Park The program is (i) over 2 years to reduce hydraulic roughness, and (ii) other vegetation management in the area over 2 years	(i) $703,200 (ii) $1,617,480		N/A	H	Low BCR and not eligible for State Grant funding. However, this option helps to maintain roughness (of vegetation) and to maintain flood behaviour / flood levels.
	Other Property Modification Options					
PM3	House Raising***	$8,240,000		9	L	Need further investigations and State Grant funding
PM4	House Rebuilding***	$8,240,000		9	L	Need further investigations
PM6	Land Swap***	$20,600,000		10	L	Need further investigations
PM7	Council Re-development	$36,050,000		11	L	Need further investigations
PM5	Voluntary Purchase***	$72,100,000		12	L	Need further investigations and State Grant funding

* Net present worth of cost of implementation, incorporating both capital and maintenance costs over the implementation period of 50 years.

** H = higher priority; M = medium priority; L = lower priority.

*** 108 properties have been considered for each of these options. These options can be used in combination for the 108 properties.

16 Conclusion

This report presents the findings of the Floodplain Risk Management Study and Plan stages of the Flood Risk Management Process for the Nepean River catchment within the Camden LGA, in accordance with the Floodplain Development Manual (NSW Government, 2005). The investigations undertaken as part of this process identified a number of issues within the floodplain; including but not limited riverine flooding, the flooding of access roads, and the impact of increases in rainfall intensity due to climate change. To address these issues, a series of floodplain management options were developed and recommended.

The outcomes of the multi-criteria assessment provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangements to reduce the impact of flooding on property and life. The implementation strategy may not necessarily approach the options from “highest ranking to lowest ranking” but will also need to incorporate various other considerations such as existing works programs, availability of funding and other opportunities to combine floodplain works with other activities.

The assessment of management options in the Floodplain Risk Management Study facilitated the identification of the most beneficial options (in terms of hydraulics, economics, environmental and social issues). A priority list has been recommended in the Floodplain Risk Management Plan that is a mix of structural and non-structural options to reduce the likelihood and / or consequence of flooding at locations in the catchment.

This plan should be regarded as a dynamic plan requiring review and modification over time. The catalysts for change include new floods and enhanced collection of flood data, legislative change, alterations in the availability of funding and reviews of Council planning policies. Notwithstanding these catalysts for review, a review every five years or so is warranted to ensure the ongoing relevance of the Plan.

17 Qualifications

This report has been prepared by Cardno for Camden Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the data provided.

Study results should not be used for purposes other than those for which they were prepared.

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Nepean River Floodplain Risk Management Study and Plan

APPENDIX A

JUNE 2016 EVENT ASSESSMENT

Nepean River Floodplain Risk Management Study and Plan

APPENDIX B

FLOOD MAPS

Nepean River Floodplain Risk Management Study and Plan

APPENDIX C

ARR 2016 ASSESSMENT

Nepean River Floodplain Risk Management Study and Plan

APPENDIX D

ENVIRONMENTAL ASSESSMENT

Table B1 List of NSW Contaminated Sites Notified to the EPA in the catchment area

Suburb	Site description	Address	Activity that caused contamination	EPA site management class
Camden	Caltex Service Station	21 Barsden Street	Service Station	Under assessment
Camden	Camden High School (former)	John STREET	Gasworks	Regulation under CLM Act not required
Camden South	Shell Coles Express Service Station	273 Old Hume Highway	Service Station	Under assessment
Mount Annan	Great Southern Railways Aqueduct	Off Narellan Road	Unclassified	Regulation under CLM Act not required
Narellan	Former Landfill	1 Elyard Street	Landfill	Regulation under CLM Act not required
Narellan	Caltex Service Station	31 The Northern Road	Service Station	Under assessment
Narellan	Caltex Service Station	Narellan Rd, Cnr Maxwell Place	Service Station	Under assessment

Table B2 POEO Licences in the catchment area

Name	Location	Licence Status	Issued date
A.C.N. 090 135 836 Pty Ltd	1037 The Northern Road, Bringelly, NSW 2171	Surrendered	28-Aug-01
Boral CSR Bricks Pty Limited	Lot 2 Greendale Road, Bringelly, NSW 2556	Issued	10-Aug-00
Hi-Quality Waste Management Pty Ltd	761 The Northern Road, Bringelly, NSW 2556	Issued	18-Oct-00
Leppington Pastoral Co Pty Ltd	1675 The Northern Road, Bringelly, NSW 2556	Issued	3-Apr-02
W2R Pty Ltd	769 The Northern Road, Bringelly, NSW 2556	Issued	18-Oct-01
Camden Council	-, Camden, NSW 2570	Surrendered	28-Aug-00
T.J. & R.F. Fordham Pty Ltd	Argyle Street, Camden, NSW 2570	Surrendered	5-Feb-01
AGL Upstream Investments Pty Limited	Westbrook Road , Cawdor, NSW 2570	Surrendered	17-Sep-02
M Collins & Sons Holdings Pty Ltd	Cut Hill Road, Cobbitty, NSW 2570	Issued	1-Aug-00
Nepean Quarries Pty Ltd	Richardson Road, Elderslie, NSW 2570	Surrendered	9-Aug-00
Nepean Quarries Pty Ltd	149 Macarthur Road, Elderslie, NSW 2570	Surrendered	15-Jan-03
Sydney Water Corporation	Corner Of Sheathers And Ferguson Lanes, Grasmere, NSW 2570	Issued	25-May-00
EDL LFG (NSW) Pty Ltd	275 Richardson Road, Mount Annan, NSW 2567	Issued	15-Oct-99
Boral Resources (NSW) Pty Ltd	Graham Hill Road, Narellan, NSW 2567	No longer in force	30-May-00
Georgiou Group Pty Ltd	Between Old Northern Road And Peter Brock Drive, NARELLAN, NSW 2567	Issued	27-May-15
GQ Products Pty Limited	Richardson Road, Narellan, NSW 2567	Surrendered	29-Dec-00
Holcim (Australia) Pty Ltd	9 Grahams Hill Road, Narellan, NSW 2567	No longer in force	22-Dec-99
Sada Services Pty Limited	1 Glenlee Road, Cnr Springs And Richardson Roads, Narellan, NSW 2567	Issued	7-Sep-00
Landcom	Various Areas At, Oran Park, NSW 2570	Surrendered	4-Sep-09
Landcom	The Northern Road, Oran Park, NSW 2570	Surrendered	15-Sep-10
Concrite Pty Ltd	169 Hartley Road, Smeaton Grange, NSW 2567	No longer in force	17-Apr-00

Name	Location	Licence Status	Issued date
Endeavour Energy	17 & 19A Mcpherson Road, Smeaton Grange, NSW 2567	Issued	7-Jan-09
Rollers Australia Pty Limited	8-10 Sedgwick Street, Smeaton Grange, NSW 2567	No longer in force	17-Aug-07
M Collins & Sons Holdings Pty Ltd	214 Macarthur Road, Spring Farm, NSW 2570	Issued	8-Jan-01
SITA Australia Pty Ltd	275 Richardson Road, Spring Farm, NSW 2570	Issued	2-Jul-01
SITA Australia Pty Ltd	Richardson Road, Spring Farm, NSW 2570	Issued	10-Oct-06
SITA Australia Pty Ltd	275 Richardson Road, Spring Farm, NSW 2570	Issued	30-Sep-11

Table B3 Threatened Ecological Communities listed under State and Commonwealth legislation in the catchment (DPIE, 2015a)

Community	Status (NSW)	Status (C'wealth)
Agnes Banks Woodland in the Sydney Basin Bioregion	E4B	
Blue Gum High Forest in the Sydney Basin Bioregion	E4B	CE
Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion	E3	CE
Castlereagh Scribbly Gum Woodland in the Sydney Basin Bioregion	V2	E
Castlereagh Swamp Woodland Community	E3	
Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	E3	CE
Cumberland Plain Woodland in the Sydney Basin Bioregion	E4B	CE
Elderslie Banksia Scrub Forest in the Sydney Basin Bioregion	E4B	
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3	
Moist Shale Woodland in the Sydney Basin Bioregion	E3	CE
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3	
Shale Gravel Transition Forest in the Sydney Basin Bioregion	E3	CE
Shale Sandstone Transition Forest in the Sydney Basin Bioregion	E4B	CE
Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion	E3	
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3	
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3	
Western Sydney Dry Rainforest in the Sydney Basin Bioregion	E3	CE

E4B = Critically Endangered Ecological Community (TSC Act), E3 = Endangered Ecological Community (TSC Act), V2 = Vulnerable Endangered Ecological Community (TSC Act), CE = Critically Endangered Ecological Community (EPBC Act), E = Endangered Ecological Community (EPBC Act)

Table B4 Flora Records within the catchment (DPIE, 2015a)

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Apocynaceae	*Cynanchum elegans*	White-flowered Wax Plant	E1,P	E
Apocynaceae	*Marsdenia viridiflora subsp. viridiflora*	Marsdenia viridiflora	E2	
Casuarinaceae	*Allocasuarina glareicola*		E1,P	E
Convolvulaceae	*Wilsonia backhousei*	Narrow-leafed Wilsonia	V,P	
Dilleniaceae	*Hibbertia puberula*		E1,P	
Dilleniaceae	*Hibbertia sp. Bankstown*		E4A,P	CE
Dilleniaceae	*Hibbertia sp. Turramurra*	Julian's Hibbertia	E4A,P,2	
Dilleniaceae	*Hibbertia superans*		E1,P	
Elaeocarpaceae	*Tetratheca glandulosa*		V,P	
Ericaceae	*Epacris purpurascens var. purpurascens*		V,P	
Ericaceae	*Leucopogon exolasius*	Woronora Beard-heath	V,P	V
Ericaceae	*Leucopogon fletcheri subsp. fletcheri*		E1,P	
Euphorbiaceae	*Chamaesyce psammogeton*	Sand Spurge	E1,P	
Fabaceae (Faboideae)	*Dillwynia tenuifolia*		V,P	
Fabaceae (Faboideae)	*Pultenaea parviflora*		E1,P	V
Fabaceae (Faboideae)	*Pultenaea pedunculata*	Matted Bush-pea	E1,P	
Fabaceae (Mimosoideae)	*Acacia bynoeana*	Bynoe's Wattle	E1,P	V
Fabaceae (Mimosoideae)	*Acacia gordonii*		E1,P	E
Fabaceae (Mimosoideae)	*Acacia pubescens*	Downy Wattle	V,P	V
Grammitidaceae	*Grammitis stenophylla*	Narrow-leaf Finger Fern	E1,P,3	
Gyrostemonaceae	*Gyrostemon thesioides*		E1,P,3	

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Haloragaceae	*Haloragis exalata subsp. exalata*	Square Raspwort	V,P	V
Haloragaceae	*Haloragodendron lucasii*		E1,P	E
Hygrophoraceae	*Camarophyllopsis kearneyi*		E1,P	
Hygrophoraceae	*Hygrocybe anomala var. ianthinomarginata*		V,P	
Hygrophoraceae	*Hygrocybe aurantipes*		V,P	
Hygrophoraceae	*Hygrocybe austropratensis*		E1,P	
Hygrophoraceae	*Hygrocybe collucera*		E1,P	
Hygrophoraceae	*Hygrocybe griseoramosa*		E1,P	
Hygrophoraceae	*Hygrocybe lanecovensis*		E1,P	
Hygrophoraceae	*Hygrocybe reesiae*		V,P	
Hygrophoraceae	*Hygrocybe rubronivea*		V,P	
Juncaginaceae	*Maundia triglochinoides*		V,P	
Lobeliaceae	*Hypsela sessiliflora*		E1,P,3	X
Malvaceae	*Commersonia prostrata*	Dwarf Kerrawang	E1,P	E
Malvaceae	*Lasiopetalum joyceae*		V,P	V
Marsileaceae	*Pilularia novae-hollandiae*	Austral Pillwort	E1,P,3	
Myrtaceae	*Callistemon linearifolius*	Netted Bottle Brush	V,P,3	
Myrtaceae	*Darwinia biflora*		V,P	V
Myrtaceae	*Darwinia peduncularis*		V,P	
Myrtaceae	*Eucalyptus benthamii*	Camden White Gum	V,P	V
Myrtaceae	*Eucalyptus camfieldii*	Camfield's Stringybark	V,P	V
Myrtaceae	*Eucalyptus sp. Cattai*		E4A,P	

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Myrtaceae	*Melaleuca biconvexa*	Biconvex Paperbark	V,P	V
Myrtaceae	*Melaleuca deanei*	Deane's Paperbark	V,P	V
Myrtaceae	*Micromyrtus minutiflora*		E1,P	V
Myrtaceae	*Syzygium paniculatum*	Magenta Lilly Pilly	E1,P	V
Orchidaceae	*Caladenia tessellata*	Thick Lip Spider Orchid	E1,P,2	V
Orchidaceae	*Genoplesium baueri*	Bauer's Midge Orchid	E1,P,2	E
Orchidaceae	*Pterostylis saxicola*	Sydney Plains Greenhood	E1,P,2	E
Poaceae	*Deyeuxia appressa*		E1,P	E
Polygonaceae	*Persicaria elatior*	Tall Knotweed	V,P	V
Proteaceae	*Grevillea juniperina subsp. juniperina*	Juniper-leaved Grevillea	V,P	
Proteaceae	*Grevillea parviflora subsp. parviflora*	Small-flower Grevillea	V,P	V
Proteaceae	*Grevillea parviflora subsp. supplicans*		E1,P	
Proteaceae	*Persoonia bargoensis*	Bargo Geebung	E1,P	V
Proteaceae	*Persoonia glaucescens*	Mittagong Geebung	E1,P	V
Proteaceae	*Persoonia hirsuta*	Hairy Geebung	E1,P,3	E
Proteaceae	*Persoonia mollis subsp. maxima*		E1,P	E
Proteaceae	*Persoonia nutans*	Nodding Geebung	E1,P	E
Rhamnaceae	*Pomaderris brunnea*	Brown Pomaderris	E1,P	V
Rubiaceae	*Galium australe*	Tangled Bedstraw	E1,P	
Rutaceae	*Zieria involucrata*		E1,P	V
Santalaceae	*Thesium australe*	Austral Toadflax	V,P	V
Thymelaeaceae	*Pimelea curviflora var. curviflora*		V,P	V
Thymelaeaceae	*Pimelea spicata*	Spiked Rice-flower	E1,P	E
Zannichelliaceae	*Zannichellia palustris*		E1,P	

P = Protected, V = Vulnerable, E1 = Endangered (TSC Act), E2 = Endangered Population (TSC Act), E4A = Critically Endangered (TSC Act), E = Endangered (EPBC Act), CE = Critically Endangered (EPBC Act).

Table B5 Fauna Records within the catchment (DPIE, 2015a)

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Amphibia				
Myobatrachidae	*Heleioporus australiacus*	Giant Burrowing Frog	V,P	V
Myobatrachidae	*Pseudophryne australis*	Red-crowned Toadlet	V,P	
Hylidae	*Litoria aurea*	Green and Golden Bell Frog	E1,P	V
Reptilia				
Varanidae	*Varanus rosenbergi*	Rosenberg's Goanna	V,P	
Elapidae	*Hoplocephalus bungaroides*	Broad-headed Snake	E1,P,2	V
Aves				
Anatidae	*Oxyura australis*	Blue-billed Duck	V,P	
Anatidae	*Stictonetta naevosa*	Freckled Duck	V,P	
Columbidae	*Ptilinopus superbus*	Superb Fruit-Dove	V,P	
Apodidae	*Hirundapus caudacutus*	White-throated Needletail	P	C,J,K
Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork	E1,P	
Ardeidae	*Ardea ibis*	Cattle Egret	P	C,J
Ardeidae	*Botaurus poiciloptilus*	Australasian Bittern	E1,P	E
Ardeidae	*Ixobrychus flavicollis*	Black Bittern	V,P	
Accipitridae	*Circus assimilis*	Spotted Harrier	V,P	
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	P	C
Accipitridae	*Hieraaetus morphnoides*	Little Eagle	V,P	
Accipitridae	*Lophoictinia isura*	Square-tailed Kite	V,P,3	
Accipitridae	*Pandion cristatus*	Eastern Osprey	V,P,3	
Falconidae	*Falco subniger*	Black Falcon	V,P	
Burhinidae	*Burhinus grallarius*	Bush Stone-curlew	E1,P	
Jacanidae	*Irediparra gallinacea*	Comb-crested Jacana	V,P	
Rostratulidae	*Rostratula australis*	Australian Painted Snipe	E1,P	E
Scolopacidae	*Calidris canutus*	Red Knot	P	C,J,K
Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper	E1,P	CE,C,J,K

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Scolopacidae	*Gallinago hardwickii*	Latham's Snipe	P	C,J,K
Scolopacidae	*Limicola falcinellus*	Broad-billed Sandpiper	V,P	C,J,K
Scolopacidae	*Limosa limosa*	Black-tailed Godwit	V,P	C,J,K
Cacatuidae	*Callocephalon fimbriatum*	Gang-gang Cockatoo	V,P,3	
Cacatuidae	*Calyptorhynchus lathami*	Glossy Black-Cockatoo	V,P,2	
Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	V,P	
Psittacidae	*Lathamus discolor*	Swift Parrot	E1,P,3	E
Psittacidae	*Neophema pulchella*	Turquoise Parrot	V,P,3	
Strigidae	*Ninox connivens*	Barking Owl	V,P,3	
Strigidae	*Ninox strenua*	Powerful Owl	V,P,3	
Tytonidae	*Tyto novaehollandiae*	Masked Owl	V,P,3	
Tytonidae	*Tyto tenebricosa*	Sooty Owl	V,P,3	
Meropidae	*Merops ornatus*	Rainbow Bee-eater	P	J
Climacteridae	*Climacteris picumnus victoriae*	Brown Treecreeper (eastern subspecies)	V,P	
Acanthizidae	*Chthonicola sagittata*	Speckled Warbler	V,P	
Meliphagidae	*Anthochaera phrygia*	Regent Honeyeater	E4A,P	CE
Meliphagidae	*Epthianura albifrons*	White-fronted Chat population in the Sydney Metropolitan Catchment Management Area	E2,V,P	
Meliphagidae	*Epthianura albifrons*	White-fronted Chat	V,P	
Meliphagidae	*Grantiella picta*	Painted Honeyeater	V,P	V
Meliphagidae	*Melithreptus gularis gularis*	Black-chinned Honeyeater (eastern subspecies)	V,P	
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	V,P	
Petroicidae	*Melanodryas cucullata cucullata*	Hooded Robin (south-eastern form)	V,P	
Petroicidae	*Petroica boodang*	Scarlet Robin	V,P	
Petroicidae	*Petroica phoenicea*	Flame Robin	V,P	
Estrildidae	*Stagonopleura guttata*	Diamond Firetail	V,P	

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Mammalia				
Dasyuridae	*Dasyurus maculatus*	Spotted-tailed Quoll	V,P	E
Phascolarctidae	*Phascolarctos cinereus*	Koala	V,P	V
Burramyidae	*Cercartetus nanus*	Eastern Pygmy-possum	V,P	
Petauridae	*Petaurus australis*	Yellow-bellied Glider	V,P	
Petauridae	*Petaurus norfolcensis*	Squirrel Glider	V,P	
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox	V,P	V
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	V,P	
Molossidae	*Mormopterus norfolkensis*	Eastern Freetail-bat	V,P	
Vespertilionidae	*Chalinolobus dwyeri*	Large-eared Pied Bat	V,P	V
Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	V,P	
Vespertilionidae	*Miniopterus australis*	Little Bentwing-bat	V,P	
Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing-bat	V,P	
Vespertilionidae	*Myotis macropus*	Southern Myotis	V,P	
Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat	V,P	
Muridae	*Pseudomys novaehollandiae*	New Holland Mouse	P	V
Gastropoda				
Camaenidae	*Meridolum corneovirens*	Cumberland Plain Land Snail	E1	
Camaenidae	*Pommerhelix duralensis*	Dural Woodland Snail		E

P = Protected, V = Vulnerable, E1 = Endangered (TSC Act), E4A = Critically Endangered (TSC Act), E = Endangered (EPBC Act), CE = Critically Endangered (EPBC Act). J = Japan-Australia Migratory Bird Agreement (JAMBA), C = China-Australia Migratory Bird Agreement (CAMBA), K = Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)

Table B6 Australian Heritage Database Heritage Records in the catchment

Item	Suburb	Listing
Camden Airport Airport Rd	Camden	(Indicative Place) Register of the National Estate (Non-statutory archive)
Camden Courthouse 31 John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
Camden Park Camden Park Estate Rd	Camden Park	(Registered) Register of the National Estate (Non-statutory archive)
Camden Post Office 135 Argyle St	Camden	(Listed place) Commonwealth Heritage List
Camelot Kirkham La	Kirkham	(Registered) Register of the National Estate (Non-statutory archive)
Camelot Gardeners Lodge Kirkham La	Kirkham	(Registered) Register of the National Estate (Non-statutory archive)
Camelot Stables Kirkham La	Kirkham	(Registered) Register of the National Estate (Non-statutory archive)
Cobbitty Weir Ellis La	Ellis Lane	(Indicative Place) Register of the National Estate (Non-statutory archive)
Cottage 39 John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
Cottage rear Macquarie Grove House Macquarie Grove Rd	Camden	(Interim List) Register of the National Estate (Non-statutory archive)
Cottage rear Macquarie Grove House Macquarie Grove Rd	Camden	(Indicative Place) Commonwealth Heritage List
Denbigh including Slab Outbuildings and Grounds The Northern Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)
Harrington Park Homestead Camden Valley Way	Harrington Park	(Registered) Register of the National Estate (Non-statutory archive)
Heber Chapel Cobbitty Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)
Home Farmhouse Camden Park Estate Rd	Camden South	(Registered) Register of the National Estate (Non-statutory archive)
John Street Group John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
Kirkham Stables and Curtilage Kirkham La	Kirkham	(Registered) Register of the National Estate (Non-statutory archive)

Item	Suburb	Listing
Macaria 37 John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
Macarthur Family Cemetery Camden Park Estate Rd	Camden South	(Registered) Register of the National Estate (Non-statutory archive)
Macquarie Grove House Macquarie Grove Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)
Maryland Garden and Setting The Northern Rd	Bringelly	(Registered) Register of the National Estate (Non-statutory archive)
Maryland and Outbuildings The Northern Rd	Bringelly	(Registered) Register of the National Estate (Non-statutory archive)
Mount Hunter Rivulet Weir Werombi Rd	Theresa Park	(Indicative Place) Register of the National Estate (Non-statutory archive)
National Australia Bank Argyle St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
Police Station and Residence 33-35 John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St John the Evangelist Anglican Church Menangle Rd	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St Johns Anglican Church Group Menangle Rd	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St Johns Hill and John Street Conservation Area	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St Johns Rectory and Stables Menangle Rd	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St Pauls Anglican Church Group Cobbitty Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)
St Pauls Anglican Church and Graveyard Cobbitty Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)
St Pauls Catholic Church John St	Camden	(Registered) Register of the National Estate (Non-statutory archive)
St Pauls Rectory Cobbitty Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)

Item	Suburb	Listing
Studley Park Camden Valley Way	Narellan	(Registered) Register of the National Estate (Non-statutory archive)
Wivenhoe including Conservatory Macquarie Grove Rd	Cobbitty	(Registered) Register of the National Estate (Non-statutory archive)

Table B7 Heritage items within the catchment listed under *NSW Heritage Act 1977*

Item Name	Address	Suburb	Listing
Camden Park	Elizabeth Macarthur Avenue	Camden Park	State Heritage Register
Camden Park Estate and Belgenny Farm	Elizabeth Macarthur Avenue	Camden South	State Heritage Register
Camelot	Kirkham Lane	Narellan	State Heritage Register
Denbigh	421 The Northern Road	Cobbitty	State Heritage Register
Harrington Park	1 Hickson Circuit	Harrington Park	State Heritage Register
Kirkham Stables and Precinct	Kirkham Lane	Narellan	State Heritage Register
Macquarie Grove	Aerodrome Road	Cobbitty, Camden	State Heritage Register
Nant Gwylan and Garden	Exeter Street	Camden	State Heritage Register
Orielton	179 Northern Road	Narellan	State Heritage Register
Studley Park	Camden Valley Way	Narellan	State Heritage Register
Upper Canal System (Pheasants Nest Weir to Prospect Reservoir)		Prospect	State Heritage Register
Belgenny Cottage	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries
Belgenny Farm	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries
Camden Courthouse	John Street	Camden	Section 170 – NSW State Agency Heritage Register Attorney General's Department
Camden District Hospital	84 Broughton Street	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Health
Camden Police Station	33-35 John Street	Camden	Section 170 – NSW State Agency Heritage Register NSW Police Service
Cottage Monument	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries
Dairy No 2	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries
Macarthur Family Cemetery	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries

Item Name	Address	Suburb	Listing
Macarthur's Original Bloodline Sheep Flock	Camden Park Drive	Camden	Section 170 – NSW State Agency Heritage Register NSW Department of Primary Industries
Theresa Park Weir	Nepean River	Camden	Section 170 – NSW State Agency Heritage Register State Water Corporation

Nepean River Floodplain Risk Management Study and Plan

APPENDIX E

DEVELOPMENT CONTROL PLANS

Nepean River Floodplain Risk Management Study and Plan

APPENDIX F

OSD GUIDELINES

Nepean River Floodplain Risk Management Study and Plan

APPENDIX G

FLOOD MODIFICATION OPTIONS

Nepean River Floodplain Risk Management Study and Plan

APPENDIX H

OPTIONS ASSESSMENT RESULTS

Nepean River Floodplain Risk Management Study and Plan

APPENDIX I

OPTION COSTINGS

Nepean River Floodplain Risk Management Study and Plan

APPENDIX J

MULTI CRITERIA ASSESSMENT

Nepean River Floodplain Risk Management Study and Plan

APPENDIX K

PUBLIC EXHIBITION RESPONSES