Ku-ring-gai Council

Blackbutt Creek
Floodplain Risk Management Study and Plan

14 August 2018

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Executive Summary

The Blackbutt Creek catchment is located in the northern suburbs of Sydney. The catchment covers approximately five square kilometres, and incorporates parts of the suburbs of Killara, Gordon, West Pymble and Pymble.

The catchment is substantially urbanised, with the majority of development comprising residences. Historically an area with predominantly free-standing homes, the character of the catchment is slowly tending towards higher density development. In addition to the residential areas are two golf courses and mixed use commercial and retail development. Heavily vegetated riparian corridors are still present in the lower reaches of the catchment.

The catchment includes Blackbutt Creek and its tributaries, being Amaroo Gully, Falls Creek, Links Creek, Honeysuckle Creek and a number of unnamed watercourses. Blackbutt Creek drains to the Lane Cove River a short distance south of Lady Game Drive and east of Ryde Road.

A number of properties in the catchment have been subject to flooding in recent history, with notable events including in June 2007, February 2010, February 2011 and April 2012.

A flood study for the Blackbutt Creek catchment was previously completed in 2014 using hydrology from an earlier study and a TUFLOW flood model, the latter being developed specifically for the Flood Study.

GHD was commissioned by Ku-ring-gai Council to undertake the Floodplain Risk Management Study and Plan for the Blackbutt Creek Catchment.

This floodplain risk management study builds on the results of the 2014 flood study. A number of new developments had been built in the catchment since completion of the Flood Study. A sensitivity analysis exercise was undertaken to assess the influence of these developments on the outcomes of the flood study. It was found that whilst localised changes were present, no widespread changes to flood results occurred and the flood study flood maps were not updated.

A Floodplain Management Committee was formed by Council to assist in steering the direction of the study. Members of the community are represented on this Committee.

Community consultation was undertaken as part of the floodplain management process. A flood questionnaire survey was distributed to 2,395 households within the catchment to inform the community of the study, gather any additional flood information available, and assist in understanding community preferences in flood mitigation options.

A range of potential flood management options were assessed as part of this study. This included options within the following categories:

- *Property Modification Measures*
- *Response Modification Measures*
- *Flood Modification Measures.*

Each of the options was assessed in the flood model where necessary. Options were assessed against hydraulic effectiveness, costs, social and environmental criteria. Options that were found to be impractical were recommended to be discarded.

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<tr><td>Airborne Laser Scanning (ALS)</td><td>See LiDAR</td></tr>
<tr><td>Australian Height Datum (AHD)</td><td>A common national plane of level approximately equivalent to the height above sea level.</td></tr>
<tr><td>Annual Exceedance Probability (AEP)</td><td>The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. A 1 per cent event is a rainfall event with a 1 per cent chance of being exceeded in magnitude in any year. In accordance with current Australian Rainfall and Runoff recommendations (Commonwealth Government, 2016), annual exceedance probability terminology has been used in this document.</td></tr>
<tr><td>Average recurrence interval (ARI)</td><td>The average recurrence interval, like the annual exceedance probability, is also a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.
For example, a 100-year average recurrence interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is a long term average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random.
Average recurrence intervals of greater than 10 years are closely approximated by the reciprocal of the annual exceedance probability. A 1 in 100-year average recurrence interval is therefore approximately equivalent to a 1 per cent annual exceedance probability event.
ARI terminology is not used in this document, except where quoting from external sources, but is included in the glossary for its common usage in matters related to flooding. A conversion table between ARI and AEP is provided below (after Bureau of Meteorology, 2016):

<table><tr><th>ARI (years)</th><th>AEP (%)</th></tr><tr><td>1</td><td>63</td></tr><tr><td>2</td><td>39</td></tr><tr><td>5</td><td>18</td></tr><tr><td>10</td><td>10</td></tr><tr><td>20</td><td>5</td></tr><tr><td>50</td><td>2</td></tr><tr><td>100</td><td>1</td></tr></table></td></tr>
<tr><td>Benefit/Cost Ratio</td><td>The ratio of the benefit expressed as a currency unit, calculated by the quantifying the benefit of implementing a given idea, strategy or option when compared to the current cost of doing nothing, over the cost of implementing the given idea, strategy or option.
This ratio can be used to summarise the overall value to the given idea, strategy or option. All benefits and costs should be expressed in discounted present values.</td></tr>
<tr><td>Catchment</td><td>The area drained by a stream or body of water or the area of land from which water is collected.</td></tr>
<tr><td>Design Flood</td><td>A flood event which is based on the probability of recurrence in any one year, or predefined event which is considered as part of</td></tr>
</table>

	the design process. A bridge may be designed to be overtopped in the 1 in 100 year ARI event or 1% AEP flood event.
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which: escapes from, is released from, is unable to enter, or overflows from the normal confines of: a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood Fringe Areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which the potential to cause damage to the community.
Flood Prone Land	Land susceptible to inundation by the PMF event (see Probable Maximum Flood). Flood prone land is synonymous with flood liable land.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood event.
Flood Planning Area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood Planning Levels (FPLs)	A combination of flood levels (derived from significant historical flood events or floods of specific AEP's) and freeboards selected for floodplain risk management purposes, as determined in Floodplain Risk Management Studies and incorporated into Floodplain Risk Management Plans.
Flood Storage Areas	Those parts of the floodplain important for the temporary storage of water during the passage of a flood.
Floodway Areas	Those areas of the floodplain where significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that even if only partially blocked, would cause significant redistribution of flood flow, or a significant increase in flood levels.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of waterways.
Geographical Information System (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 as defined in the Floodplain development manual with consideration of velocity and depth of flood water.
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrograph	A graph which shows how a water level at any particular location changes with time.
Hydrology	The study of rainfall and surface water runoff processes.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.

LiDAR	LIDAR —Light Detection and Ranging — is a remote sensing method used to examine the surface of the Earth. Also known as ALS.
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.
Mathematical / computer models	The mathematical representation of the physical process involved on 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.
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.
Overbank	The portion of the flow that extends over the top of waterway banks.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that is reasonably possible at a given location.
Probable maximum precipitation (PMP)	The probable maximum precipitation is the greatest amount of rainfall which can theoretically occur over a given duration (period of time) for a particular geographical location.
Reach	Defined section of a stream with uniform character and behaviour.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.(Consider using KLEP definitions and refer to LEP Maps?)
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Stormwater Flooding	Inundation by local runoff. Stormwater flooding may become apparent when the capacity of the stormwater network is exceeded by the local runoff.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Topography	Representation of the features and configuration of land surfaces.

Note: Where Possible, terminology in this Glossary has been adapted from the NSW Government Floodplain Development Manual, 2005.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DCP	Development Control Plan
FPA	Food Planning Area
FPL	Flood Planning Level
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
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second
NSW	New South Wales
OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service
1 EY	1 Exceedance per Year event

1. Introduction

1.1 Background

The Blackbutt Creek floodplain is located in the Ku-ring-gai Local Government Area in the suburbs of Killara, Gordon, West Pymble and Pymble. The total catchment area is approximately 5 square kilometres (km^2). Flood impacts during rainfall events can rapidly manifest into flash flooding. Such flooding has occurred in recent history in June 2007, February 2010, February 2011 and April 2012, leading to widespread flooding and damage to properties. The February 2010 event was particularly severe, with flooding of a number of properties exceeding 1m in depth and at depths above floor levels. The Blackbutt Creek Flood Study (Jacobs, 2014) showed that there are significant areas of high hazard flooding in the catchment.

1.2 Purpose of the Plan

The primary objective of the New South Wales Government's Flood Prone Land Policy (the Policy) is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

In NSW, Local Government has primary responsibility for managing flood prone land. As part of their statutory planning responsibility, Ku-ring-gai Council (Council) has to plan and manage flood prone land in accordance with its flood exposure. Preparation of this management plan and associated studies is an important step in this process, as it informs councils' decisions. Through the Office of Environment and Heritage (OEH), the Department of Planning and Environment and the State Emergency Service (SES), the NSW Government provides funding and specialist technical assistance to local government to assist Council with its responsibilities on all flooding and land use planning matters. The Floodplain Development Manual (NSW Government, 2005) (the Manual) is provided to assist councils to meet their obligations through the preparation of floodplain risk management plans. It provides councils with a framework for implementing the policy to achieve the primary objective.

To meet this objective, councils in New South Wales prepare Floodplain Risk Management Plans within their Local Government Areas to define how they will reduce flood impact. As shown in Figure 1-1, the Manual sets out a process by which this can be achieved, this includes:

- Preparation of a Flood Study - to define the existing flooding behaviour within the catchment
- Preparation of a Floodplain Risk Management Study - to determine potential flood mitigation/reduction options as well as planning and emergency management measures considering social, economic and environmental factors
- Preparation of a Floodplain Risk Management Plan - to provide a plan for implementation of mitigation and management options through a process of public consultation
- Plan Implementation.

As shown in the figure, the implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan. This formalises outcomes of a floodplain risk management study and present the necessary information to enable Ku-ring-gai Council to plan for the future. It presents floodplain management measures incorporating both structural and non-structural measures to manage flood risk in the floodplain of Blackbutt Creek.

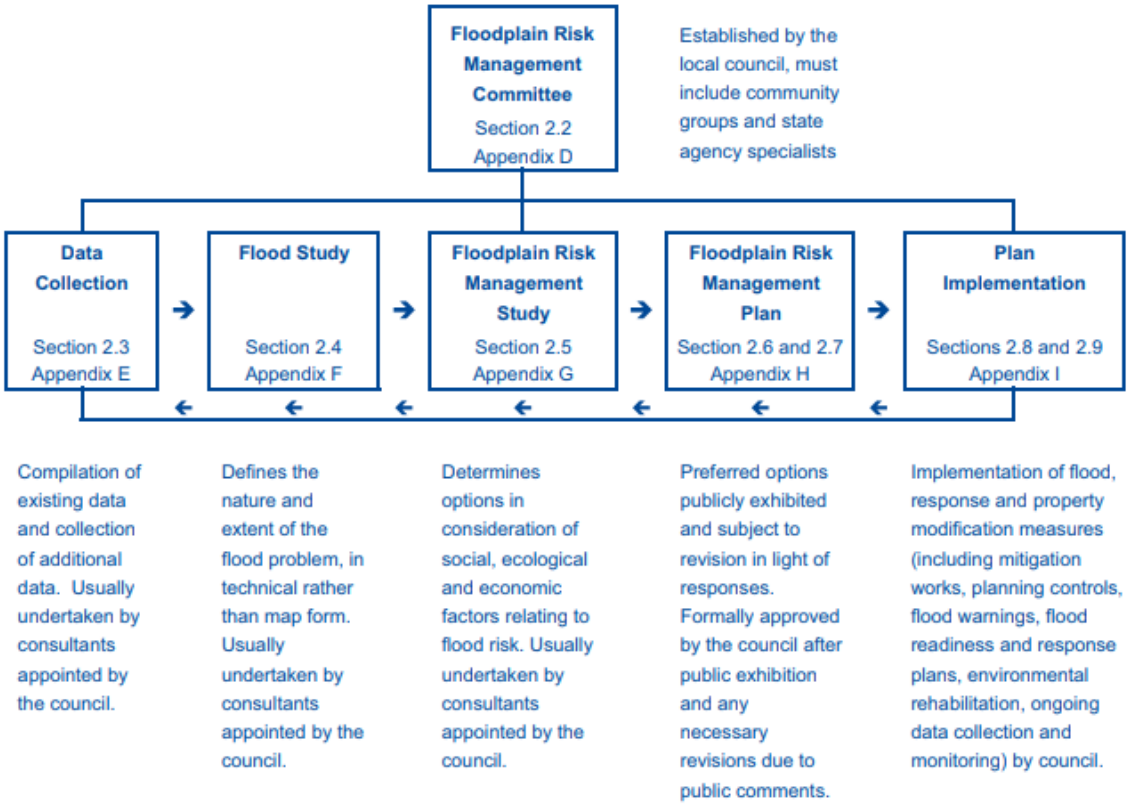

Figure 1-1 Floodplain Risk Management Process (Floodplain Development Manual, April 2005)

1.3 Current Status

Finalisation of the Plan of Implementation is currently being undertaken following the public exhibition of the Plan.

2. Flood Situation

2.1 General

Details of the catchment characteristics and key structures were provided in the Blackbutt Creek Flood Study (Jacobs, 2014). A summary is provided in this report but further details may be found in the Flood Study.

2.2 Study Extent

The Blackbutt Creek Catchment is approximately 5 km^2 in size and incorporates the suburbs of Killara, Gordon, West Pymble and Pymble.

Significant features include:

- Ryde Road, which traverses the catchment near the northern extent in a south-west/north-east direction
- The Pacific Highway, which forms the eastern boundary of the catchment for much of its length
- Gordon Golf Course and Killara Golf Course
- Part of the Gordon Local Centre.

The study extent lies entirely within the Ku-ring-gai Council Local Government Area (LGA).

A study area locality plan is included as Figure A - 1 (Appendix A).

2.3 Available Data

2.3.1 Previous Studies and Reports

A summary of the previous relevant studies obtained and reviewed as part of this Floodplain Risk Management Study is presented in Table 2-1.

Table 2-1 Previous studies and reports reviewed

Study	Description
Blackbutt Creek Flood Study (Jacobs, 2014)	Catchment wide flood study involving TUFLOW hydraulic modelling with calibration to actual flood levels taken during two flood events within the catchment. Flood behaviour was defined for the 20%, 5%, 2%, 1% and 0.5% AEP and Probable Maximum Flood (PMF) events.
DRAINS hydrologic and stormwater drainage model (URS, 2005)	DRAINS hydrologic model for the entire catchment including existing stormwater drainage infrastructure.
Ku-ring-gai Council Preliminary Flood Mapping Report (Mott McDonald, 2011)	Preliminary flood extents for 5%, 1% AEP and PMF events using a 1 dimensional HEC-RAS model of waterways within the catchment.

2.4 Catchment Characteristics

The catchment of Blackbutt Creek drains generally in a southerly and south-westerly direction. Blackbutt Creek discharges to the Lane Cover River a short distance south of Lady Game Drive and east of Ryde Road in the Lane Cove National Park.

Ground levels in the catchment range between 8 metres above Australian Height Datum (8 mAHD) to 110 mAHD in the upper reaches. The steepest part of the catchment is the northern extent.

Development in the catchment is predominantly low density residential, though more recent development includes units and apartment blocks. A retail and commercial precinct is present in the north east area.

Named creeks in the catchment include Blackbutt Creek, Falls Creek, Links Creek and Honeysuckle Creek. A number of minor unnamed watercourses exist in a combination of open channels and subsurface drainage network.

2.5 Flood Study

The Flood Study defined flood behaviour within the catchment under existing conditions and was calibrated to two historical events (February 2010 and April 2012). Modelled design events included the 20%[1], 5%, 2%, 1% and 0.5% AEP and Probable Maximum Flood (PMF) events.

The hydrology for the catchment was modelled using the DRAINS stormwater modelling software to estimate inflows throughout the catchment, and the TUFLOW two-dimensional, unsteady flow modelling package was used to determine the hydraulic characteristics of the catchment flooding. The topography of the catchment is represented in the model using a 2 metre square grid. This level of precision in the grid is considered necessary in order to represent detailed flood behaviour in a fully developed catchment.

The existing DRAINS model (URS, 2005) represents the entire stormwater pit and pipe system in the Blackbutt Creek catchment, which was divided into 736 sub-catchments. The model was used in this study primarily to estimate sub-catchment runoff hydrographs for subsequent input into the hydraulic model.

LiDAR data collected in 2007 was provided by Council. AUSIMAGE aerial photography dated 2011 was obtained by Jacobs for the study area, and was the latest available imagery at the time of the study commencement.

The model incorporated a stormwater drainage network using TUFLOW's one-dimensional component, ESTRY. Inflows to the TUFLOW model were derived from the DRAINS model.

Both the DRAINS and TUFLOW models were adopted for this floodplain risk management study. Of further note, sensitivity testing has been undertaken on the flood study models (both DRAINS and TUFLOW) to the Australian Rainfall & Runoff 2016 (AR&R 2016) changes to rainfall intensities. The memorandum report on this testing can be found in Appendix D.

2.6 Historic

Recent flooding in the catchment occurred during June 2007, February 2010, February 2011 and April 2012. The February 2010 event was particularly severe, with flooding of a number of properties exceeding 1m in depth and above floor levels.

[1] The Flood Study estimated the 5-year ARI event, which is equal to a 18% AEP (refer glossary). For ease of reference, in this document the 18% AEP has been approximated to the 20% AEP and is referred to as such throughout.

2.7 Flood Behaviour

The Blackbutt Creek Flood Study (Jacobs, 2014) prepared flood mapping together with hydraulic and flood hazard categorisation mapping. During the course of this Floodplain Risk Management Study and Plan, analysis was undertaken of new development in the catchment that occurred since the Flood Study commenced. It was found that no significant changes to flood conditions were expected from those developments (refer also to Section 3). The mapping of flood extents and the flood planning area therefore remains as per the Flood Study and has not been reproduced in this report.

Key flooded areas based both on the Flood Study findings and the outcomes of the preliminary community consultation include the following, where the presence of overland flow paths or convergent flows causes flood impacts to properties:

- St Johns Avenue
- Vale Street and Dumaresq Street
- Norfolk Street and Essex Street
- Bolwarra Avenue
- Mooree Street
- Calvert Avenue
- Corner of Ryde Road and Nadene Place
- Corner of Ormiston Avenue and Bushlands Avenue.

2.8 Pipe Capacity Assessment

A pipe capacity assessment was been carried out on Flood Study TUFLOW modelling results. This assessment was carried out for the range of events presented in the flood study including the 20%, 5%, 2%, 1%, 0.5% AEP and PMF events.

The following processes were undertaken to establish the capacity of the pipe system:

- The TUFLOW results for the individual 1 dimensional pipes for each event duration were interrogated to determine the maximum flow during a single AEP or the PMF
- The capacity of the individual pipes were compared to the maximum flow to determine the AEP when the pipe began flowing full
- The pipe was determined to have a capacity less than this event and therefore was assigned a capacity as less than this AEP or PMF event.

The limitations of this approach noted below:

- Inlet controlled segments of the network are not accounted for using this approach given the assessment relies solely on the flow through the pipe system
- The flow through the pipe does not account for hydraulic grade of the flow through the pipe, the flow is compared to the theoretical capacity of the pipe to give it a capacity for a given event.

The results of this assessment are presented on Figure A - 1, Figure A - 2 and Figure A - 3 in Appendix A.

2.9 Flood Emergency Planning

2.9.1 State Emergency Management Plan and Flood Plan

The NSW State Emergency Management Plan (EMPLAN) documents the planning for emergencies across the state.

The NSW State Flood Plan is a sub plan of the EMPLAN and outlines arrangements for response to flooding in NSW. The State Flood Plan defines responsibilities of the State Emergency Services (SES) and other state and local agencies in relation to flood preparedness and prevention, flood response and recovery efforts.

Under the State Flood Plan, local councils also have a number of responsibilities in assisting the SES with flood preparedness, flood response and flood recovery efforts.

2.9.2 Local Flood Plan

The Ku-ring-gai unit is the local SES unit responsible for the Ku-ring-gai area. No local flood plan for Ku-ring-gai is available.

However, the Hornsby Ku-ring-gai Local Emergency Management Committee plans for hazards such as floods and bushfires. The committee is responsible for:

- Preventing and preparing for emergencies
- Coordinating emergency responses
- Helping with recovery efforts.

The committee includes representatives from the NSW Police, the Ku-ring-gai State Emergency Services (SES) and the NSW Rural Fire Service.

2.9.3 Catchment Response Time

Emergency response activities may be influenced by the catchment response time, which is how quickly a flood occurs following the onset of a rainfall event. The Blackbutt Creek catchment responds quickly, most notably in the upper reaches of the catchment. Generally in the lower reaches of the catchment the water levels peak during a 2 hour storm duration for the design flood event.

2.9.4 Flood Warning Systems

There is currently no flood warning system specific to the Blackbutt Creek catchment. Due to the speed at which flooding may occur, a catchment specific flood warning system may not be an appropriate option for implementation.

General sources of real time information currently available during the event of a flood are:

- Bureau of Meteorology (BoM)
- State Emergency Service (SES).

The BoM National Flood Warning Service provides forecasts to warn for possible flood events across Australia in the form of:

- Early advice of possible flooding if flood-producing rain is expected in the near future
- A generalised flood warning that flooding is occurring or is expected to occur in a particular region

- Warnings of minor, moderate or major flooding in areas where specialised warning systems have been installed
- Predictions of expected river height at a town or other important locations and the time that this height will be reached
- Rainfall and river height maps and bulletins that summarise observed rainfalls and river heights (in metres) at selected locations within river basins.

SES uses information provided by the BoM and assists in communication flood warnings and recommendation on what action communities should take before, during and after flood events.

Refer also to Chapter 8.

2.9.5 Flood Emergency Response Planning Classification

To assist in the planning and implementation of response strategies, the State Emergency Service (SES) classifies communities according to the impact flooding has on them. Flood affected communities are those in which the normal functioning of services is altered either directly or indirectly because of 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 outlined in OEH's guideline (Flood Emergency Response Classification of Communities, DECC, 2007b):

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)
- *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 flood waters).

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 impassable 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)
- *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 flood waters).

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)
- *Areas with Rising Road Access* (access roads rise steadily uphill and away from the rising floodwaters).

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

Overland Refuge Areas: Areas 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.

Table 2-2 summarises the response required for different flood emergency response planning classifications.

Table 2-2 Response Required for Different Flood Classifications

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Areas with Rising Road Access	No	Possibly	Yes
Areas 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

Source: Flood Emergency Response Classification of Communities, DECC, 2007b

2.9.6 Review and Findings

Proposed final flood emergency response classifications were determined and included the following changes from the Flood Study:

- All areas of the flood extent were considered to contribute to a potential need to evacuate (i.e. areas of low flood hazard were considered)
- A number of properties previously identified as high trapped perimeter were reclassified as indirectly affected due to apparent access from the property frontage to the street and an appropriate evacuation route from the property
- Multiple classifications on a single property were simplified to a single classification per property only.

A summary of the changes are detailed below at properties along the following roads:

- Pymble Avenue
- Livingstone Avenue
- Minnamurra Avenue
- Craigend Avenue
- McIntyre Street
- Dumaresq Street
- Moree Street
- Vale Street
- Browns Road
- Yarrabah Avenue

- Essex Street
- Norfolk Street
- Warwick Street
- Calvert Avenue
- Penrhyn Avenue
- Ellison Place
- St Johns Avenue
- Cecil Street.

The proposed final emergency response classifications are shown on the maps in Figure A - 5, Figure A - 6 and Figure A - 7 of Appendix A.

The mapping presented in the figures is intended to be used as a guide for flood response by Council and, possibly SES, and is not for zoning purposes. Due to the nature of flooding throughout the catchment being predominantly 'flash flooding' in nature, this limits the ongoing impacts on the community. Also, this classification should not be interpreted as flooding affecting the entire property, as in many instances, flooding may only affect a particular portion of the property.

2.10 Flood Hazard

2.10.1 Provisional Flood Hazard

Provisional flood hazard is determined in accordance with the Floodplain Development Manual (2005). Flooded areas are defined as being either Low or High Hazard based on a combination of velocity and depth. Flood hazards are defined in the Glossary section of this report. This "velocity-depth" product is measured in square metres per second (m^2/s) and recognises that both the velocity of flood waters and the depth of flood waters influence the potential flood hazard. Provisional flood hazard was defined in the Flood Study.

2.10.2 True Flood Hazard

There are a range of factors in addition to hydraulic considerations which influence flood hazard. The "true" flood hazard takes into consideration these additional factors and, where appropriate, allows for revision of provisional flood hazard categories. Factors which may influence true flood hazard (as defined in the Floodplain Development Manual (2005) are:

- Size of flood
- Effective warning time
- Flood readiness
- Rate of rise of floodwaters
- Depth and velocity of floodwaters
- Duration of flooding
- Evacuation problems
- Effective flood access
- Type of development.

In the Blackbutt Creek catchment, many of these factors do not alter true hazard identification. Despite this, each element of true hazard has been addressed for catchment specific relevance.

Size of flood

The size of the flood influences the nature and extent of flooding and so directly affects the risks to people and property. Flood hazard has been assessed for a range of storms for this study. These include the 20%, 5% and 1% AEP and Probable Maximum Flood (PMF) events. Due to individual consideration of a range of flood events, true hazard has not been modified further based on flood size.

Effective warning time

The catchment of Blackbutt Creek is relatively small and is characterised by a steep upper catchment area. The critical storm duration for the downstream catchment area is approximately 90 minutes in the main channel and flooding can occur during or soon after intense rainfall.

Flash flooding, as described by the Bureau of Meteorology (BOM), *results from relatively short intense bursts of rainfall, commonly thunderstorms. This flooding can occur in any part of Australia, but is a particularly serious problem in urban areas where drainage systems may not cope and in very small creeks and streams. Flash floods tend to be quite local and it is difficult to provide effective warning time because of their rapid onset.*

Due to the flash flooding nature of the catchment, warning would rarely be possible.

The effective flood warning time relates to the time that the community is actually mobilised to take action in advance of a flood event and is the time available once dissemination of warnings has actually occurred. Without a formal flood warning system in operation, the effective warning time at present could be less than a day for warning of regional flooding and minimal to none for warning of an event specific to the Blackbutt Creek catchment.

Even if warnings of flooding could be issued well in advance of a rainfall event, the extent and severity of flooding would be less predictable than for a flatter catchment. As effective warning time will likely be minimal for the entire catchment area, it is difficult to justify altering hazard categories in specific locations within the catchment area. It would also be unwise to reduce the flood hazard throughout the area as a consequence of flood warning time. As an alternative, it is recommended as part of the Plan, to increase community awareness of the flash flooding nature of the catchment, to help with flood preparedness (refer also to Chapter 8).

Flood readiness

Flood readiness is a measure of how readily and effectively a community takes action in response to flood warnings. It is influenced by factors such as a general level of flood education and awareness as well as experience of past flooding events.

There have been multiple flooding events in recent years as outlined in the Blackbutt Creek Flood Study (Jacobs, 2014), with flood events occurring during June 2007, February 2010 and April 2012. The February event was particularly severe, with flooding of a number of properties exceeding 1 m and above floor levels. Based on these recent events, it is expected that community members have a high awareness of potential for flooding within the catchment area. It is suggested for residents who have recently moved to the Blackbutt Creek catchment to be aware of potential flood risks to their property, and aware of procedures that should be followed in the event of a flood.

The Ku-ring-gai SES is an active group of volunteers assisting during emergencies in the area. It is recommended for community members to be made aware of the services and understand the procedure during a flood event. It is also recommended for new community members to be made aware of this information through newsletter updates or letterbox drops, where suitable. It is also recommended for the SES to be aware of the Blackbutt Creek local flood plan,

recommended as part of this study, and to adopt and necessary actions identified (refer to Chapter 8).

Some members of the Blackbutt Creek community would have experienced flooding in the past, although it is not accepted that they would have a plan of action in place in the event of imminent flooding. No adjustment has been made to true hazard due to flood readiness for this Study and Plan. This is because there is no evidence that one particular part of the catchment is likely to be any more prepared for a flood than another.

Rate of rise of floodwaters

The rate at which flood depths increase has bearing on the consequences of a flood event. The faster flood waters rise, the more those affected may be caught unawares or trapped in vulnerable locations. This has implications for evacuation of residents and potential loss of life.

Flood results show that flood waters rise to peak levels within half an hour for most of the extents. The consistency of rate of rise on flood waters through the catchment area indicates that no area has a considerably faster or slower rate of rise of floodwaters, and hence no local adjustments to hazard would be suitable for this assessment.

Depth and velocity of flood waters

Depth and velocity have both been considered during development of the hydraulic hazard category and most of these considerations are consistent with true hazard. Areas that have been modified for true hazard mapping have been based on considerations other than depth and velocity exclusively. For this reason, true hazard mapping has not been modified based only on depth and velocity of flood waters.

Duration of flooding

Duration of flooding in the catchment is typically short (within approximately 3 to 3.5 hours) due to its steep nature and relatively small area. Review of hydrograph model results did not show the time for flood waters to return to the level before inundation, and results were extrapolated for the purposes of this assessment. Irrespective of this, duration of flooding is not considered a key issue for the catchment, and hazard categorisation has not been altered based on this factor.

Evacuation problems

As discussed in Section 4.2.2, reports of flooding were received for the following roads:

- Ryde Road
- Bushlands Avenue
- Livingstone Avenue
- McIntyre Street
- Calvert Avenue
- Pacific Highway.

Inspection of flood extents shows flooding over the following roads:

- Dumaresq Street
- Merriwa Street
- St Johns Avenue
- Essex Street

- Gleneagles Avenue
- Bridge Street
- Pymble Avenue
- Minnamurra Avenue.

As previously mentioned, the nature of flooding in the Blackbutt Creek catchment area is generally considered to be flash flooding. While the area's urban proximity could suggest high accessibility, evacuation routes may not be available in some locations due to limited warning time available. As such, modifications to provisional flood hazard classifications are proposed for areas in the Blackbutt Creek catchment that have access roads cut during the onset of the flood event. Note these have also been identified through the classification of communities as high flood island, high trapped perimeter or areas with overland escape routes.

Effective flood access

Effective flood access is considered in both the Emergency Response Classification of Communities in Section 2.9.5 of this study, and in the areas categorised as High True Hazard due to evacuation problems. The availability of effective flood access routes to flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for a duration that is long enough to evacuate people and possessions.

As previously stated in this section, access roads are cut quickly following the onset of a flood event in the Blackbutt Creek catchment area. Consequently, properties that have had access cut are categorised as High Hazard due to evacuation problems.

Type of development

Some specific considerations have been made for sensitive properties such as schools, hospitals and retirement villages, which may be vulnerable even though they are not hydraulically categorised as High Hazard. It is likely that people with a reduced physical capability and mobility, will be present in these locations, and overland evacuation may take more time or be more difficult logistically. These properties are proposed for categorisation as High True Hazard due to type of development as discussed below.

Special evacuation needs

Particular types of development may have specific evacuation needs in the event of a flood due to the vulnerability of residents located there. For example, residents of aged care facilities or children attending school may require greater assistance in the event that evacuation is required.

A number of areas, which may have specific evacuation needs, have been identified within the catchment. These are:

- Killara Public School, Ridgeland Ave, Killara
- Gordon West Public School, Ryde Road West Pymble
- Pymble Ladies College, Avon Road, Pymble
- Acre Woods Childcare, Bridge Street, Pymble
- Pinjarra Children Services, St Johns Ave, Gordon
- Yuruga Children's Cottage, Browns Road Gordon.

Pymble Ladies College, Pinjarra Children Services and Gordon West Public School were shown to be either outside of the PMF extents or only slightly impacted and hence the hazard level was not modified for these properties. All other properties identified in this section are proposed for elevation from Low provisional to High True Hazard for the 1% AEP event and PMF due to potential for special evacuation needs. A map of vulnerable properties is provided in Figure A - 4 of Appendix A.

Level of occupant awareness

Occupants of developments, such as hotels and caravan parks, may be unfamiliar with the area and with local flooding. This can result in higher consequences when floods do occur. There are no such developments in the catchment and hence no properties have been determined High Hazard due to level of occupant awareness. Note that flood readiness is discussed in more detail above in this section.

True flood hazard classifications

The hazard maps in Appendix A (Figure A - 8, Figure A - 9, Figure A - 10 and Figure A - 11) show:

- Provisional hydraulic hazard as defined in the Flood Study
- Locations identified for proposed reclassification to High Hazard areas on the basis of the considerations outlined in this section including:
    - Effective flood access; and/or
    - Type of development.

The mapping presented in the figures is intended only to be used as a guide for flood response by Council and, possibly SES, and is not for zoning purposes. Due to the nature of flooding throughout the catchment being predominantly ‘flash flooding’ in nature, this limits the ongoing impacts on the community. Also, this classification should not be interpreted as flooding affecting the entire property, as in many instances, flooding may only affect a particular portion of the property.

3. Changes in the Catchment

3.1 Introduction

A number of recent developments within the catchment have been identified which were not included in the modelling carried out as part of the Flood Study. Council requested that GHD include these developments in the original Flood Study model and assess the flood impacts of the changes on flood behaviour and the Flood Study results. As part of the assessment, it was agreed the model would be simulated for the 1% AEP and PMF. Details of the changes to the model included:

- the inclusion of the building footprints at a number of new properties throughout the catchment that have been developed since the Flood Study was finalised
- a new road (Beans Farm Road) that intercepts an overland flow path
- new stormwater drainage infrastructure and modifications to existing infrastructure.

3.2 Findings

The assessment showed there was a limited change in flooding conditions across most of the catchment due to the new infill developments.

The findings of the modelling and subsequent information provided by Council indicated that, based on the information available, development in the catchment subsequent to the Flood Study release would not result in significant changes to the results of the Flood Study. The original flood study models and results were therefore taken forward for use in the Floodplain Risk Management Plan. Full details of the modelling assessment undertaken on the infill developments is provided in the memorandum in Appendix B.

4. Stakeholder Consultation

4.1 Introduction

To inform the development of the Study and Plan, initial community consultation was undertaken at the study commencement.

Further consultation with the community, and other stakeholders has been undertaken via the Floodplain Management Committee, and feedback from the public exhibition of this report will be incorporated into the final Study and Plan.

A community consultation action was undertaken to inform local residents of the Floodplain Risk Management Study and to provide them with the opportunity to share their local flood knowledge, particularly regarding flooding which may have occurred since the Flood Study was undertaken, and to express their opinions on flood management measures.

The following is a summary of the consultation findings, which have been incorporated into this Floodplain Risk Management Study and Plan report.

4.2 Historic Flooding

Council sent information letters and questionnaires to residents of 2,395 properties in the catchment during September 2016.

4.2.1 Overview

In summary:

- A total of 213 responses were received
- 33 respondents indicated that they had experienced flooding at their property (however one of these was located outside the study area in the adjacent catchment)
- All of the properties where respondents indicated flooding had occurred were residences (rather than commercial premises), though some residents also ran businesses from their homes
- A further 20 had not experienced flooding at their property but provided other information regarding flooding in the area with their responses
- Of the 33 residents reporting flooding, 7 respondents indicated that flooding had been experienced above floor level (with the resident outside the study area being one of these).

4.2.2 Locations of Flooding

Experiences of flooding ranged from minor ponding of water in back gardens during rain events, to flood depths in excess of one metre and above-floor flooding of homes.

Reports of flooding were received throughout the catchment but were concentrated in key areas, most of which had previously been identified during the Flood Study.

Responses from more than one property on each of the following roads were received:

- Ryde Road
- Bushlands Road
- Livingstone Avenue
- McIntyre Street
- Calvert Avenue
- Pacific Highway.

Above-flooring flooding was reported at properties on:

- Ryde Road
- Calvert Avenue
- Gleneagles Avenue
- Vale Street
- Sarnia Crescent
- Yarran Street
- McIntyre Street.

The Flood Study community consultation also provided information regarding above-floor flooding in the catchment. This information was considered further in developing floodplain management options.

4.2.3 Flood Events

Reports were received of flooding during the events listed in Table 4-1.

Table 4-1 Reported flood events affecting properties

Year	Month
197? (1970s)	Not provided
1981	November
198? (mid-1980s)	Not provided
1995	Not provided
2007	June
2008	Not provided
2009	Not provided
2010	February
2011	February, July
2012	April
2014	December
2015	June / July, December
2016	March, June, July

The February 2010 and June 2016 flood events were mentioned by several respondents.

4.2.4 Causes of Flooding

The most common cause of flooding cited by residents was inadequate or blocked stormwater drains, either on Council property or from drains within private properties.

Other concerns included:

- Overflows from the dam at Killara golf course resulting in erosion downstream
- Inadequate drainage within properties causing localised flooding (e.g. townhouse developments)
- Proposals for changes to Gordon Golf Course and the potential for any future works to impact flooding
- Flooding of the Pacific Highway near Livingstone Avenue
- Blocking of an overland flow path by a development resulting in flooding (the respondent noted this had since been mostly rectified)
- Overflows from sewers.

4.2.5 Flood Impacts

Many respondents noted the time taken to clear and clean the damage to their property following a flood event and the general disruption caused.

Damage caused by flooding included to goods, vehicles, wiring, fencing and a range of appliances, furnishings and fittings. Estimated costs of damages ranged from no cost to tens of thousands of dollars in one case.

4.3 Floodplain Management

The questionnaire asked respondents to rank a list of generic floodplain management measures that they believed would be best to reduce flooding at their own property.

Around two thirds of the respondents who had experienced flooding at their property selected “upgrading stormwater drainage” as the highest priority for implementation to manage flooding at their property. A number of respondents clarified that this included maintenance of existing drainage infrastructure.

The second highest priority was listed as “zoning, building and development controls”.

The same respondents were also asked to rank a list of measures that should be applied to future developments to manage flood risks. Of this, “upgrading stormwater drainage” was listed as the highest priority (from around two thirds of respondents). Upgrading roads was listed as the second priority, with a number of respondents also indicating their preference for “zoning, building and development controls” as the second highest priority as well.

5. Flood Damages

Residential damage calculations were undertaken using the recommended methods of the Floodplain Management and Coastal Support Section of the former Department of Natural Resources (DNR, now Office of Environment and Heritage). No commercial areas were found to be in the flood zone for damage assessment with the floodplain so this was not considered in the damage assessment. In addition to the estimated direct damages, this damage assessment includes additional indirect/ intangible damages applied to the tangible damages.

The Annual Average Damages (AAD) value is determined by multiplying the damages that can occur in a given flood by the probability of that flood actually occurring in a given year and then summing across a range of floods. This method allows smaller floods, which occur more frequently to be given a greater weighting than the rarer catastrophic floods. Adopted parameters for damages curves are summarised Table 5-1.

Table 5-2 lists the numbers of properties in the Blackbutt Creek catchment affected by above-floor flooding based on the estimated floor level taken during the site visit conducted for areas with known flooding issues within the catchment. A total of 8 properties were noted as being within the PMF flood extent of the properties with known flooding issues. The table also identifies the damages estimates for each flood event.

Table 5-3 identifies the properties contributing to the AAD.

Table 5-1 Adopted parameters for damages curves

Parameter	Value
Regional Cost Variation Factor	1
Post late 2001 Adjustments	2.27[2]
Post Flood Inflation Factor	1
Typical Duration of Immersion (hours)	1
Building Damage Repair Limitation Factor	0.75
Typical House Size (m^2)	230
Average Contents Relevant to Site	$55,000
Contents Damage Repair Limitation Factor	0.75
Level of Flood Awareness	Low
Effective Warning Time (hours)	1
Typical Table/Bench Height (m)	0.9
External Damage	$6,700
Clean Up Costs	$4,000
Likely Time in Alternate Accommodation (weeks)	2
Additional Accommodation costs/loss of rent	$220

[2] National average weekly household earnings have been used in calculating this factor. (Noted 04/07/2018 subsequent to the endorsement of this Floodplain Risk Management Study & Plan by Ku-ring-gai Council at the Ordinary Meeting by Council on 26/06/2018).

Table 5-2 Dwellings likely to experience over floor flooding

Flood AEP	Event Damage	Contribution to AAD	Number of Properties
20%	$507,294	$-	7
5%	$630,079	$85,303	8
2%	$658,289	$19,326	8
1%	$683,334	$6,708	8
0.5%	$699,630	$3,457	8
PMF	$852,220	$3,880	8

Table 5-3 Specific properties contributing to AAD

Location	Contribution to AAD
Vale St property	$20,699
McIntyre St property	$11,361
McIntyre St property	$11,416
Vale St property	$16,741
Pymble Ave property	$11,101
Vale St property	$9,189
Bolwarra Ave property	$20,085
Calvert Ave property	$8,522

The damage for flooding in the Blackbutt Creek catchment was calculated to have a Net Present Value (NPV) of $1,157,000 over 20 years at 7%. A summary of the damages is shown in Table 5-4.

Table 5-4 Damage Summary

Residential	Direct ($)
Annual Average Damage (AAD)	109,113
Net Present Value (NPV, 20 years at 7%)	1,157,000

Also it should be noted in this section that no other infrastructure damage costs have been factored in to these calculations. All properties that experience above floor flooding across the catchment have had been included in the calculation are residential properties. Also, it was noted that other factors to include in the damages calculation like commercial properties, were not factored in as throughout the catchment, commercial properties generally only exist in the upper reaches of the catchment.

6. Planning and Environment

6.1 Urban Planning Context

Appropriate land use planning is one of the most effective measures available to floodplain managers, both to reduce existing flood risks as redevelopment occurs, and to control future risk. The management and development of flood prone land must be undertaken within the current NSW legislative, policy and planning framework. This chapter summarises relevant legislation and policy as well as recent reforms by the NSW Government relating to the flood development controls. This provides a basis for the review of land use planning in the Blackbutt Creek floodplain in section 8.2.1.

6.2 Environment

The catchment contains areas of bushland, typically in and adjacent to the riparian corridors.

The Ku-ring-gai Development Control Plan (refer also to section 6.7) identifies the “Greenweb”, which “*includes lands containing significant strategic biodiversity values, considered important in the support of native flora, fauna and ecological processes and has a particular focus on key vegetation communities, threatened populations, species and their habitats*”.

The lands identified in the Greenweb are divided into several categories in relation to biodiversity values, but all pose a potential constraint for development.

Core biodiversity areas are identified in the catchment in bushland areas, with important supporting lands and linking biodiversity corridors also present.

Any structural floodplain management measures would require detailed site-specific environmental investigations to be undertaken to confirm biodiversity values and constraints.

6.3 Heritage

6.3.1 Aboriginal Heritage

The Blackbutt Catchment area is located within the Sydney Metropolitan Aboriginal Land Council. A basic search was conducted of the online Aboriginal Heritage Information Management System on in July 2017 and 2 known or potential Aboriginal heritage sites were determined to be located within the study area.

Any structural flood mitigation option within the catchment area that is selected as a result of the present study would require a detailed investigation into the specific site to check if any Aboriginal archaeological or cultural heritage site is location within the proposed construction site. Any Aboriginal heritage site identified should be left undisturbed. An Aboriginal Heritage Impact Permit (AHIP) must be sought from OEH before any potential works can proceed.

Land Rights and Native Title Claims

Native Title allows traditional land owners to claim compensation for, or gain access to any previous land which may have previously been dispossessed. A search was conducted of the Native Title Tribunal’s Native Title register and no Native Title areas were determined to reside within the study area.

6.3.2 Non-aboriginal Heritage

Listings of non-Aboriginal origin sites may fall into national, state or local heritage items. The significance of a site is determined through a set of criteria which assesses historical, scientific, cultural, social, archaeological, architectural, natural and aesthetic values. A number of

resources were investigated in order to determine the presence of any local, state or nationally listed heritage listed items. These include:

- Australian Heritage Database (incorporates World Heritage List, National Heritage List, Commonwealth Heritage List)
- NSW Heritage Office – State Heritage Register
- Local Government (Ku-ring-gai Council).

Two sites identified on the Australian Heritage Database within the study area were listed on the Register of the National Estate (RNE), which is an archived list of heritage features. The register provides a list of heritage features and properties though there are no statutory requirements applying to items on this register. The two sites were the Killara Golf Links Urban Conservation Precinct and the Pymble Hotel. The Pymble Hotel is located at 1134 Pacific Highway and the Killara Golf Links Urban Conservation Area was previously identified by the National Trust as a Heritage Conservation Area but was not included in the final list of Heritage Conservation Areas adopted by Council (see local government areas below).

The state Heritage Register provides listings of places which are of particular importance to the people of NSW. The statutory register provides legal protection, which in NSW comes from the *Heritage Act, 1977* (amended 1998) and the *Environmental Planning and Assessment Act 1979*. The state Heritage Register maps show a listed substation located at 982-984 Pacific Highway Pymble.

The Ku-ring-gai LEP identifies properties of heritage significance including adopted Heritage Conservation Areas. A number of heritage items and properties are identified in the LEP mapping within the Blackbutt Creek catchment.

A detailed heritage assessment may need to be undertaken if any structural mitigation options are proposed in close proximity to LEP heritage items as development restrictions may apply (refer to chapter 8 for discussion of particular options).

6.4 Legislative Context

6.4.1 NSW Environmental Planning and Assessment Act 1979

Background

The *Environmental Planning and Assessment Act 1979* (EP&A Act) creates the mechanism for development assessment and determination by providing a legislative framework for development and protection of the environment from adverse impacts arising from development. The EP&A Act outlines the level of assessment required under State, regional and local planning legislation and identifies the responsible assessing authority.

Prior to development taking place in New South Wales, a formal assessment and determination must be made of the proposed activity to ensure it complies with relevant planning controls and, according to its nature and scale, conforms with the principles of environmentally sustainable development.

Section 117 Directions of the Environmental Planning and Assessment Act 1979 – Direction No. 4.3 (Flood Prone Land)

Pursuant to the EP&A Act, Section 117 Direction No 4.3 (Flood Prone Land) was reissued on the 19 July 2007 by the Minister for Planning replacing all existing directions previously in operation. This applies to councils that contain flood prone land within their Local Government

Area and any draft LEP that creates, removes or alters a zone or provision that affects flood prone land.

Key objectives of Direction 4.3 are:

- To ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the *Floodplain Development Manual* 2005 (including the Guidelines or Development Controls on Low Flood Risk Areas)
- To ensure that the provisions of an LEP on flood prone land are consistent with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Under Direction 4.3, when preparing draft LEPs, Councils must not include provisions that apply to the flood planning areas which:

- permit development in floodway areas
- permit development that will result in significant flood impacts to other properties
- permit a significant increase in the development of that land
- are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services
- permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, building or structures in flood ways or high hazard areas), roads or exempt development.

The Direction also requires that Councils must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General. In the case of Ku-ring-gai Council, the development control plan is consistent with this Direction.

Environmental Planning and Assessment Amendment (Flood Related Development Controls Information) Regulation 2007

Schedule 4, clause 7A of the *Environmental Planning and Assessment Regulation 2000* (EP&A Act Regulations) was amended in 2007 to include references to flood related development and is referred to as the *Environmental Planning and Assessment Amendment (Flood Related Development Controls Information) Regulation 2007*. This amendment requires councils to distinguish where flood related development controls are for nominated types of residential development and all other development. Nominated residential development includes dwelling houses, dual occupancies, multi dwelling housing and residential flat buildings, but does not include group homes or seniors living.

6.5 State Environmental Planning Policies (SEPP)

6.5.1 SEPP Exempt and Complying Development Codes 2008

SEPPs are the highest level of planning instrument and generally will prevail over LEPs. *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria.

The SEPP defines 'Flood Control Lots' as property where 'flood-related development controls apply' i.e. this would have a notation on its Section 149 Certificate. These development

controls may apply through an LEP or DCP. Exempt development is not permitted on Flood Control Lots but some complying development is allowed on Flood Control Lots.

Complying development is permitted on Flood Control Lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a:

- flood storage area
- floodway area
- flow path
- high hazard area
- high risk area (see Clause 3.36C).

The SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability, flood affectation, safe evacuation, car parking and driveways (see Clause 3.36C).

Flood control lots have not been specifically defined as part of the FRMS&P. A flood control lot, however is any property within the Flood Planning Area (FPA) as identified in the Flood Study.

6.5.2 SEPP Infrastructure 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent.

Clause 15 governs public authorities' consultation with councils for development with impacts on flood liable land (as defined by the PMF).

Part 3 Division 7 specifies that development for the purpose of flood mitigation work may be carried out by a public authority without consent.

Part 3 Division 20 specifies that development for the purpose of stormwater management systems may be carried out by a public authority without consent.

6.6 NSW Flood-Related Policies and Planning Controls

6.6.1 Floodplain Development Manual, 2005

The *Floodplain Development Manual* 2005 (the Manual) was gazetted on 6 May 2005 and relates to the development of flood liable land. It incorporates the NSW Flood Prone Land Policy, which aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. To implement this policy and achieve these objectives, the Manual develops a merit based framework to assist with floodplain risk management. The Manual indicates that responsibility for management of flood risk remains with local government. It assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

The Manual builds upon and replaces the 2001 Floodplain Management Manual. Key changes include outlining altered agency roles in floodplain risk management and clarifying the State Government's position on development standards.

6.6.2 Guidelines on Development Controls in Low Flood Risk Areas, 2007

The Guidelines on Development Controls on Low Flood Risk Areas – Floodplain Development Manual (the Guidelines) were issued on 31 January 2007 as part of Planning Circular PS 07-

003 at the same time as the S117 Directive described in Section 3.1.2. The Guidelines are intended to be read as part of the *Floodplain Development Manual*. They have been created to supply additional guidance on matters within the Manual, including determining the appropriate flood planning level (FPL) for councils and appropriate flood related development controls on residential development in low flood risk areas. Strategic consideration of a number of key issues which must be addressed include safety to existing and future occupants of flood prone land, management of the potential damage to property and infrastructure and the cumulative impacts of development.

The Guidelines do not strictly conform with the Manual's merit based approach to selection of appropriate flood planning levels (FPLs), however they recognise the need to consider the full range of flood sizes, up to and including the probable maximum flood (PMF) and the corresponding risks associated with each flood.

The Guidelines state:

- Councils are responsible for determining the appropriate flood planning levels for land within their local government area. Whilst the flood used to determine the residential FPL is a decision of the local council, the Manual highlights that FPLs for typical residential development would generally be based around the 100 year flood plus an appropriate freeboard (typically 0.5m).

  This Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood

- Unless there are exceptional circumstances, Councils should not impose flood related development controls on residential development on land with a low probability of flooding, that is, land above the residential FPL (low flood risk areas).NSW State Flood Plan.

Refer to section 2.9 of this report for a discussion of applicable emergency planning documents.

Local Environmental Planning

An integral part of the NSW state planning system is the inclusion of Local Environment Plans (LEPs). The Standard Instrument LEP Program was initiated in 2006 to create a consistent structure for LEP's across NSW. The aim of the program was to have one LEP for each local government area.

Land zonings categorise development works within the local government area and determines what may be permissible at any one location.

In accordance with *Standard Instrument (Local Environmental Plans) Order 2006*, a Ku-ring-gai Local Environmental Plan (KLEP) was prepared by Council and approved on 2 April 2015.

6.7 Flood Planning Within the KLEP

The KLEP 2015 does not include flood controls for flood liable land with flood related controls currently are only contained in Council's DCP. Hence, these are non-statutory controls and are not accompanied by an enabling clause within the LEP.

It is prudent for Council to consider inclusion of flood controls as per the Model Local Provisions for Flood Planning into the KLEP and link these controls to the KDCP provisions, eg Flood Study flood mapping and specific development controls. Note that advice from NSW Planning and Environment is that model local clauses are local clauses that have been settled by the

Parliamentary Counsel's Office which address common topics raised by councils in their standard instrument LEP preparation.

This amendment to the KLEP is addressed in Section 8.2.1.

The Existing KLEP

As discussed, the KLEP does not contain clauses exclusively addressing flood planning, however, the following clauses have relevance to flood planning:

- Part 6.4 *Riparian land and adjoining waterways*
- Part 6.5 *Stormwater and water sensitive urban design*
- Land Use Table.

Part 6.4 addresses the objectives of protecting and improving riparian lands and waterways including water quality, bed and bank stability, ecological systems and processes, scenic and heritage values. Development consent can be granted under this part for developments constituting stormwater and flooding measures.

Part 6.5 addresses the objective of avoiding and minimising adverse impacts of urban stormwater on land on which development is carried out, as well as adjacent or surrounding land and biodiversity.

Part 6.5 requires that development consent for any development not be granted without confirming that riparian, stormwater and flooding measures are integrated.

The Land Use Table identifies those categories of land use where floodplain measures are permitted with consent, being:

- R2, low density residential
- R3, Medium density residential
- R4, high density residential
- R5, large lot residential
- SP2, infrastructure
- RE1, Public recreation
- RE2, private recreation
- E2, environmental conservation
- E3, environmental management
- E4, environmental living.

Within the LEP, flood mitigation work is defined as "work designed and constructed for the express purpose of mitigating flood impacts. It involves changing the characteristics of flood behaviour to alter the level, location, volume, speed or timing of flood waters to mitigate flood impacts. Types of works may include excavation, construction or enlargement of any fill, wall, or levee that will alter riverine flood behaviour, local overland flooding, or tidal action so as to mitigate flood impacts".

Under SEPP 2007 (refer to section 6.5.2), Council would, however be able to undertake flood mitigation works without development consent within the Ku-ring-gai LGA.

6.8 Ku-ring-gai Development Control Plan (KDCP) 2016

The Ku-ring-gai Development Control Plan (KDCP) provides guidelines to guide the design and assessment of development applications for land covered by the Ku-ring-gai Local Environmental Plan 2015 (majority of Ku-ring-gai). The Ku-ring-gai Development Control Plan has been amended and came into effect on 24 June 2016.

The DCP complements the Ku-ring-gai Local Environmental Plan 2015 although as discussed in Section 6.7, amendments to the KLEP are recommended to provide a statutory link between the Plans. The aims of the KDCP include to *"ensure the appropriate management of risks, such as flooding"*. It outlines the context, background and controls necessary for addressing existing flood risk and future flood risk through land use planning.

Key relevant sections of the KDCP in relation to flooding are summarised in Table 6-1.

The following definitions apply under the KDCP:

- Average recurrence interval - the long term average number of years between floods which will equal or exceed the selected event
- Flood - a relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a waterbody
- Flood standard conveyance zone - the zone in a plan view of the 100 year ARI flow (1% AEP flow) through the property
- Riparian land - land adjoining a waterway (including a piped waterway) and the waterway itself, but not including land adjoining an artificial waterbody. This includes all land identified within the Riparian Lands Map in the Ku-ring-gai LEP 2015.

Aspects of the KDCP pertaining to flood-related development controls were reviewed during the Floodplain Risk Management Study to assess their suitability for application in the Blackbutt Creek catchment.

Part 24 of the KDCP provides Council with adequate measures to manage flood risk in the Blackbutt Creek catchment and Council LGA. It includes areas of the floodplains that are covered by a catchment wide flood study with a flood planning area map (and hence Flood Risk Precincts) and all other areas where Council deems a separate flood study is necessary.

The addition in the KDCP of specific land use planning measures applying to floodplains covered by Flood Planning Area mapping would strengthen and clarify Council's management of the flood risk. A flood planning matrix could be adopted that considers the Flood Risk Precincts (FRP), land use categories and a mix of appropriate planning controls. Further discussion of the KDCP and any proposed modifications are discussed in Section 8.2.1.

Table 6-1 Relevant parts of the KDCP

Item and description	Controls
Part 17 Riparian Lands *Guides development on land identified with the riparian lands in the LEP and supports the aims of the LEP in providing for development controls on these lands.*	Part 17 supports the aims of the LEP in providing for development controls on these lands. Part 17 includes the objective of maintaining natural waterways and floodplain processes. Development on riparian lands is required to take into consideration location relative to the 1% AEP flood level.
Part 24 Water Management *Covers stormwater management and flood control and minimisation.*	In relation to existing drainage systems, the DCP requires that: • Natural watercourses and floodplain processes are maintained • The impact of flood events is not increased • To protect new development from inundation or flood damage.
Part 24.C On-site Stormwater Management *Guides development in relation to on site management of stormwater*	The objectives of this part include ensuring that developments do not increase runoff to neighbouring properties. Controls include that stormwater must be managed efficiently on-site and runoff controlled to assist in the prevention of flooding of public and private properties. On-site detention is typically required.
Part 24.D Existing Drainage Systems *Guides development in relation to existing drainage systems.*	Development controls apply where it is proposed to undertake development adjacent to or over an existing drainage system or natural water body. The development controls include: • Development must be kept clear of floodways • Development must not impede overland flows • Development in the vicinity of drainage systems must not result in:

Item and description	Controls
	o Increase incidences of flooding o Damage to property and belongings o Risk to life o Loss of environmental amenity or integrity or o Difficulty in maintaining or upgrading an associated drainage system
24D.2 Flood studies and flood design standard *Relates to requirements for undertaking flood studies and applicable design flood standards*	Council may request a flood study be undertaken where it considers that a development proposal associated with a nearby drainage system may be subject to inundation from overland flows causing damage to property or belongings; and /or • be subject to structural damage from overland flows or debris associated with the overland flows • impede the passage of stormwater associated with the design flood standard to cause a rise (afflux) in the flood level upstream greater than 50mm • divert overland flows onto or into adjacent properties • increase the downstream velocities of flow for the design flood standard • The DCP defines the 'flood standard conveyance zone' as the zone in plan view of the 1% AEP flow through the property. The DCP also sets out a design flood standard which must be calculated based on the greater of: • the overland flow associated with the 1% AEP storm event with any above-ground channels and underground pipes / culverts operating at a maximum of 50% capacity • the overland flow associated with the 20% AEP storm event with any above-ground channel or underground pipes / culverts fully blocked.

Item and description	Controls
	Council may require the adoption of a longer recurrence interval design storm such as the Probable Maximum Flood (PMF) where it is considered that the proposed works pose a greater than usual risk to persons and/or property. Where a flood study has been completed and the site is identified on the flood planning area map any development proposal must demonstrate: • Development will not exacerbate flooding on adjoining properties; and • Development is confined to a part of the site which is flood free; or • All dwellings are set at or above the specified freeboard.
24D.3 Development over/adjacent to natural waterbody, open channel and drainage depression	Where works are proposed to be undertaken adjacent to the design flood standard conveyance zone associated with a watercourse, open channel or drainage depression, and Council considers it to be necessary, a flood study must be prepared to demonstrate that the development: • Will not be subject to inundation from flows causing damage to property/belongings • Be subject to structural damage from flows or associated debris • Impede the passage of stormwater and cause afflux • Divert flows onto adjacent properties • Increase downstream velocities for the design flood standard. Controls also apply to the installation of bridges. Floor level controls are in place for new structures such that: • Where peak flow rates in the Design Flood Standard are less than $20m^3/s$ or are identified on the Flood Planning Area Map, the minimum floor level of all enclosed areas and structures must be the greater of either o 300 mm above the design flood standard level

Item and description	Controls
	o 300 mm above the highest existing ground level along the associated flow path o Except in the case of garages, where the minimum height must be 150 mm instead of 300 mm, and swimming pools to which other development controls apply • Where the design flood standard exceeds 20m^3/s, or as identified as mainstream flow on the Flood Planning Area Map, the minimum floor level for all enclosed areas, including all habitable floor areas, must be 500 mm above the design flood standard level, except in the case of garages, where the minimum height must be 300 mm, and in-ground swimming pools, to which other development controls apply. There are provisions for Council to nominate drainage easements or areas on which no structures may be placed on the title of a property Safety fences are required to reduce hazards to people in accordance with various stipulations in the DCP. Parking areas are not permitted to be established in areas where vehicles would become buoyant in an overland flow zone.
24D.4 to 24D.7 *Relating to miscellaneous development including sports facilities, fencing etc.*	Development controls apply to development over or adjacent to underground pipelines (including stormwater drainage), sports development such as tennis courts and fencing. In particular: • No fence of any construction type may be established within the cross-section of the main flow channel associated with watercourses • No fence of solid construction may be established over a natural watercourse, open channel or drainage depression • Fences, whether located at boundaries or within a property, must not obstruct any overland flow path associated with a watercourse, open channel, easement or drainage depression

Item and description	Controls
	• Any fence located within an overland flow path as defined by the flood design standard must be of open construction to at least 300 mm above the flood design standard level.
24R.7 Flood Study Requirements *Sets out the requirements of flood studies associated with new developments*	The flood study requirements document detailed information that must be included in flood studies pertaining to new development including calculations that are to be undertaken and a list of information that must be provided. The requirements include consideration of: • The 1% AEP flood event • 50% blockage of the drainage network in a 1% AEP event • Complete blockage of the drainage network in a 20% AEP event.

7. Overview of Floodplain Management

In accordance with the Manual, this report considers various floodplain risk management measures. These measures can be grouped into three main categories as shown in Figure 7-1.

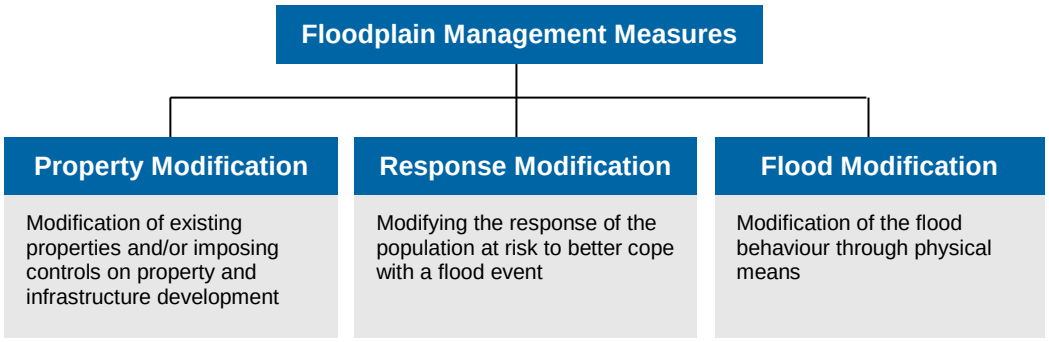

Figure 7-1 Floodplain Management Measures (Floodplain Development Manual, 2005)

A floodplain management plan needs to consider all three types of management measures and adopt an integrated and effective mix. Each floodplain and its catchment constitute a unique set of characteristics and flooding issues. It is therefore important that the measures are specific to the circumstances of the individual flood prone community and should not follow a generic plan.

This section of the report describes the most common types of floodplain risk management options within each of these measure types, including some of their advantages and suitability for application within this plan.

7.1 Property Modification Measures

Property modification measures refer to modifications to existing developments that are susceptible to flood inundation. This may also include development controls to existing properties and controls on future infrastructure developments. Property modification measures may include:

- **Land use planning including zonings and development controls**, which are being recommended as part of this floodplain management plan
- **Voluntary purchase of properties**, which in this catchment is not considered viable due to high property prices, large cost and relatively small impact on risk and damages
- **House re-building and flood proofing**, which are not considered viable as a catchment wide option but may have merit at an individual property scale
- **Land swaps**, which is not seen as viable due to the lack of undeveloped land appropriate for development within the catchment
- **Council redevelopment**, which has very limited potential within the catchment
- **Voluntary house raising** which is not seen as viable for similar reasons as discussed under house re-building.

An important focus for implementing property modification measures is to steer inappropriate developments away from areas with a high potential for flood damage and to limit any potential flood damage to acceptable levels, by means of minimum floor levels.

Whilst these modifications may reduce damages and risk to life and property, they will not prevent flooding of the land. Thus, they will not necessarily address all the social impacts of flooding.

7.1.1 Development Control Planning

Appropriate zoning provides control on future land uses considering the flood risk. Development control planning may take into consideration the following aspects:

- Access to the site during flood events
- Fill or excavation in the floodplain
- Freeboard
- Floor levels
- Differences between land uses
- Services
- Impact on flood behaviour
- Structural soundness when flooded
- Building materials
- Fencing.

7.1.2 Land Use Planning

Land use planning and controls are an essential and effective means of managing flood risk. For example, areas within a floodplain identified to be of high hazard should not be rezoned as habitable dwellings for future development.

7.1.3 Voluntary Purchase of High Hazard Properties

In certain high hazard areas it may be impractical or uneconomical to mitigate or reduce the severity of flooding to the existing properties. In such circumstances, it may be appropriate to cease occupation of such properties to mitigate the risks to both residents and rescuers alike, and to minimise the cost of future floods. This may be achieved by the purchase and removal of these properties as part of a floodplain risk management plan. The properties should be purchased at a price that is considered fair and equitable in relation to market value.

7.1.4 Voluntary House Raising

Voluntary house raising includes the elevation of a property's floor level to above a safe flood level, minimising the potential for inundation. In the instance that a dwelling is located within a flood zone, and whereby no other modification measures are appropriate, voluntary house raising may be a viable option. Home owners generally have strong sentimental and emotional attachments to their dwellings and house raising can contribute positively towards social impacts compared with vacating the premise through house purchase.

Avoidance of flood damage by house raising may achieve the following:

- A reduction in personal loss
- The costs of servicing isolated people who remain in their homes to protect possessions
- A reduction in stress and post-flood trauma.

Capital costs for house raising may be significant, and is dependent on the property's predominant construction material.

In general, voluntary house raising is a suitable management measure only for low hazard areas on the floodplain. In high hazard areas, this option does not mitigate against other potential risk factors such as high flood velocities, deep flood depths and isolation.

7.1.5 Flood Proofing

Flood proofing of building involves the design and construction of buildings with appropriate water resistant building materials to reduce flood damage. This solution reduces damage to the building structure but in most cases does not protect building contents. In this situation, flood proofing will need to be retro-fitted to existing buildings or included as a development control.

Since much of the Blackbutt Creek catchment comprises substantial dwellings, flood proofing is not considered as a broad floodplain risk management option. *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas* (Hawkesbury-Nepean Floodplain Management Steering Committee 2006) discusses some flood compatible materials suitable for use in the area.

7.2 Response Modification Measures

Flood response measures encompass various means of modifying the response of the population to the flood threat. Such measures include plans for:

- Flood warning and effective warning time
- The protection and/or evacuation of an area
- The relief of evacuees
- The recovery of the area once the flood subsides.

Planning for these measures are generally incorporated in the local flood plan guide usually prepared under the guidance of the SES. The local flood plan is complementary to the floodplain risk management plan, currently there is no local flood plan known of specific to Blackbutt Creek. It is recommended that a local flood plan be developed.

7.2.1 Flood Warning Systems

Flood warning systems and evacuation plans are used to prepare a community for an impending flood. Depending on the warning time and resources available, flood warning systems and evacuation plans can be used to protect buildings, evacuate people and provide relief to evacuees and recover the flood affected areas. The Blackbutt Creek catchment area is associated with the likelihood of flash flooding due to the nature of topography and it is not likely sufficient time would be available for evacuation dissemination or response.

7.2.2 Public Awareness and Evacuation Plan

A public awareness and evacuation plan would assist in raising flood awareness and readiness, and increase the appreciation of the flood problem and prevention activities. Implementation of a flood awareness scheme assists in minimizing the social and economic impacts of flooding. Measures to increase flood awareness could include:

- the dissemination of a Flood Information Pack that could be sent to all owners, business operators and residents of potential flood impacted properties
- the dissemination of flood information on a regular basis which would inform each property owner of the flood situation at their particular property and provide flood data and advice
- SES publicises flood safe evacuation plans and information on becoming flood ready. Residents in the Blackbutt Creek catchment area should be aware of this information
- signage in flood prone areas giving notification of potential and historical flood levels

- make real time data (rainfall) available to the public, and providing a readily accessible information portal on Council's website.

7.3 Flood Modification Measures

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat. It is essential that these measures do not adversely impact on other areas. Such measures include:

- Flood mitigation dams
- Levees
- Channel enlargement
- Detention basins
- Stormwater infrastructure upgrades.

7.3.1 Detention Basins

A detention basin is a small dam that provides temporary storage for floodwaters. Detention basins are being used increasingly as a means of controlling the peak discharge from newly urbanised areas. Some of these basins are becoming quite large, and in fact, are more properly regarded as small dams and have to be designed as such.

In urban areas, detention basins are most suitable for small streams that respond quickly to rapidly rising flooding. In particular, detention basins are associated with the following points:

- require a substantial area to achieve the necessary storage
- where they involve multi-purpose uses, safety aspects during flooding need to be addressed
- long durations multi-peak storms (when the basin is filled by the first peak) can increase the likelihood of overtopping or embankment breaching or failure, and resulting personal danger and damage
- they provide no attenuation when overtopping occurs.

There are few vegetated open spaces within the Blackbutt Creek catchment and no suitable locations for new detention basins were identified. Modification to an existing dam at the golf course was considered and is described in the following chapter of this report.

7.3.2 Creek and Stormwater Infrastructure Upgrade

Stormwater infrastructure upgrades include the improvement of Council's local stormwater drainage network or waterways. This may be in the form of amplifying the dimensions of an existing pipe network, culvert or channel, supplementing an existing drainage line with additional pipes, or the servicing of new areas currently not covered by the existing drainage system.

The benefits of providing drainage work upgrades could include allowing for a greater flow conveyance and pipe capacity. In addition, it could also redirect flows away from properties or targeted flood prone areas.

Typically, local drainage networks across NSW are designed to pass through peak storm events of between the 20 to 10% AEP event. Newer drainage networks in highly urbanised areas may be designed for up to the 5% AEP event. A number of locations in the catchment were identified where creek enhancement or stormwater infrastructure upgrades have the potential to

provide benefit. The majority of flood modification options considered fall into this type and are discussed in detail in the following chapter of this report.

7.3.3 Bunds

Bunds are a type of constructed retaining wall used to control flooding and prevent them from inundating desired areas. They are commonly considered to be an economically attractive option in flood prone areas and may be used in conjunction with artificially created overland flow paths to further encourage the flow of floodwaters to other locations. A bund would typically be of earthen construction however, in an urban context, other features such as solid walls or barriers may perform the same function.

The benefit and effectiveness of a bund is dependent on various factors including local topography and physical inundation of the site for any one specific event.

In large events (i.e. 1% AEP or PMF events), bunds may have little to no effect due to the relatively large flood extents when compared with a smaller flood event. When considering a bund as a potential flood mitigation option, it is important to consider the likely extent of the larger lower frequency events to design a mitigation option that will effectively protect the intended area.

7.3.4 Vegetation management

In areas where flood modification measures are proposed, floodplain risk management studies should include an assessment of the condition and diversity of riparian vegetation. An assessment of the impact of the proposed measure on ecological communities and aquatic ecosystems should be undertaken.

The nature of vegetation at any point in the floodplain affects the velocity associated with flow discharge. Flowing water loses energy and slows down due to frictional resistance. Rough surfaces characterised by vegetation, trees, tree roots and outcrops of rock produce greater frictional resistance than smooth surfaces, such as, croplands and concrete lined channels. Potential flood modification options identified in the Blackbutt Creek catchment were in urban areas and related primarily to the stormwater drainage network and overland flow paths through roads. Impacts on ecological communities would therefore be expected to be limited where identified through detailed environmental assessment at each site. Environmental considerations for the options are discussed further in the following chapter.