1. Introduction

1.1 General

Ku-ring-gai Local Government Area (LGA) encompasses an area of 85.4km^2 on Sydney's North Shore with a number of separate catchments draining to the Lane Cove River, Middle Harbour and Cowan Creek systems. Lovers Jump Creek is one creek system within the LGA which drains to Cowan Creek and is rated as a high priority catchment in terms of risk of flooding to existing development.

Patterns of urbanisation and associated construction of drainage infrastructure dating back to as early as the 1940's, have resulted in a number of watercourses being piped or crossed by road embankments and development occurring in sometimes unsuitable locations, putting this development at risk to flooding during heavy rainfall events. Flood events have occurred in recent history in 1984, 1988, 1990, 1991, 2010, 2011 and 2012, leading to flooding and damage to properties.

Hydrologic and drainage studies have been undertaken in the study area in the past, though some of these studies are up to 10 years old and most do not define the flood behaviour to the level of detail required in the NSW Government's *Floodplain Development Manual* (2005), which forms the current guidance for management of development and flood risk in NSW. Further, a significant amount of urban redevelopment has occurred in the catchment in recent years which has the potential to increase rainfall-runoff and hence flooding.

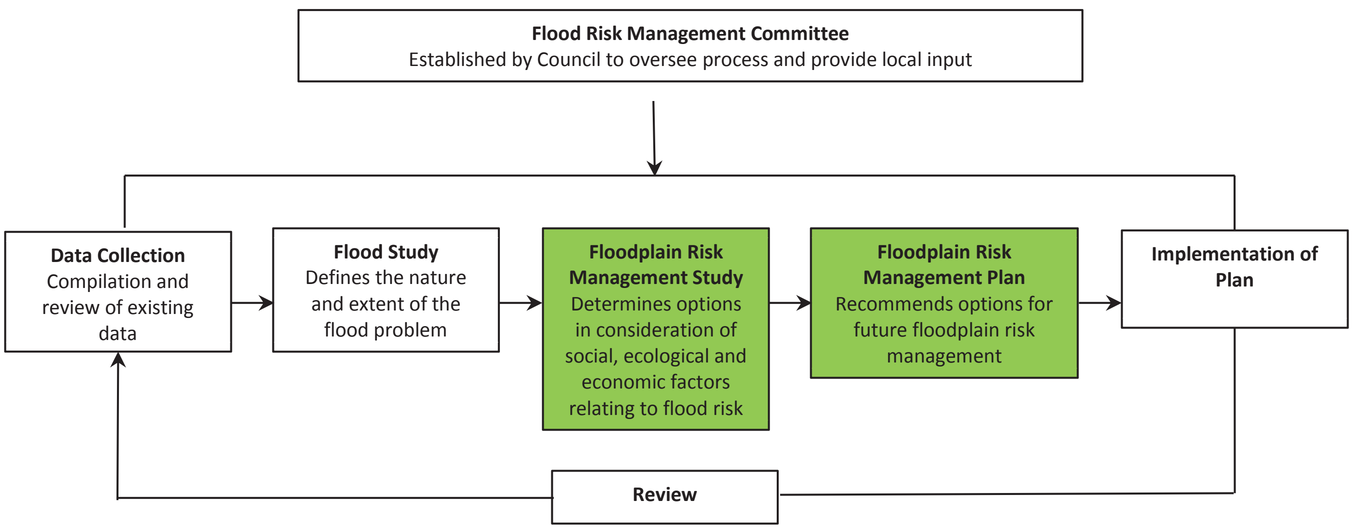
Ku-ring-gai Council ("Council") commissioned Jacobs to prepare a floodplain risk management study and draft floodplain risk management plan for the Lovers Jump Creek catchment. This report is the Draft Floodplain Risk Management Study and Plan.

1.2 Floodplain Risk Management

Council is responsible for managing the existing, continuing and future flood risk for its Local Government Area (LGA). The floodplain risk management planning process, as set out in the *Floodplain Development Manual* (NSW Government, 2005) has a number of steps which are illustrated in Figure 1-1.

The Flood Risk Management Committee (FRMC) for Council was established in 2015 and includes a number of Council Representatives, staff from the Office of Environment and Heritage (OEH), the State Emergency Services (SES), in addition to local stakeholders including community representatives.

Figure 1-1 Floodplain Risk Management Process



1.3 Purpose of this Study

The purpose of this study is to undertake a floodplain risk management study and to develop a floodplain risk management plan in accordance with the NSW Government's *Floodplain Development Manual* to address the existing, continuing and future flood risk for the study area.

Key objectives of this study are to:

- Review and update the flood study, if necessary, to the current and proposed changes in the catchment (land use, drainage and infrastructure) and to follow guidelines presented in the Australian Rainfall and Runoff, ARR 2016 (Ball et al, 2016).
- Review existing planning, policy and emergency management for gaps and inconsistencies relating to floodplain planning, then develop proposed amendments to address residual flood risk.
- Identify flood problem priority areas and identify and assess structural and non-structural mitigation measures to manage flood risk.
- Prioritise the works and measures, including economic and multi criteria appraisal of options.
- Develop an implementation program for recommended works and measures including timing, responsibility and sources of funding.
- Conduct consultation with the community and key stakeholders throughout the study to obtain information and intelligence for input into the study. Gauge the perceptions of the community on flooding matters and obtain feedback on the findings and recommendations of the study.

1.4 Structure of this Report

The Draft Floodplain Risk Management Study and Plan provides an overview of the catchment setting and flooding conditions, policy and organisational background, identifies and assesses management measures and provides a plan for adoption and implementation of measures. The report is structured accordingly:

- Section 2 Study Area – Summary of the physical setting, history of flooding and social, environmental and heritage aspects of the catchment.
- Section 3 Review of Available Information – Discusses previous studies and relevant available information and data on flooding and hydrology in the catchment.
- Section 4 Flood Policies and Planning Controls – Summary of relevant State and local government policies and planning framework.
- Section 5 Existing Flood Environment – Describes flood behaviour and flood hazard.
- Section 6 Community Consultation – Summary of consultation activities undertaken for the study.
- Section 7 Local Emergency Planning Context – Overview of existing flood emergency planning.
- Section 8 Defining the Flood Problem – Impacts of flooding on the community including high hazard properties, flood damages, land use compatibility, evacuation considerations.
- Section 9 Discussion of Floodplain Management Measures – Identifies, reviews and assesses structural and non-structural management measures.
- Section 10 Floodplain Risk Management Plan – A proposed plan of implementation for recommended floodplain risk management measures.
- Section 11 References – literature cited in this report.
- Section 12 Glossary – Definition of terms used in this report.

2. Study Area

2.1 Catchment Description

The catchment has a total area of 9.7km^2 and includes Lovers Jump Creek and a number of tributaries in the suburbs of Turramurra, North Turramurra, Warrawee, Wahroonga and North Wahroonga in the Ku-ring-gai Local Government Area. The catchment is approximately bounded by the Pacific Highway to the south, Bobbin Head Road to the east and Grosvenor Road to the west. Burns Road crosses east-west through the southern half of the catchment, while the North Shore Railway Line traverses the far southern portion of the catchment. Eastern Road passes north-south through the centre of the study area. Lovers Jump Creek joins Cockle Creek (also known as Spring Gully Creek) at the northern end of the study area, and then Cowan Creek further to the north. The study area is depicted in Figure 2-1.

Ground elevations range from 30m AHD at the catchment outlet up to and exceeding 210m AHD at the southern end of the catchment. The catchment is generally gently to moderately sloped in developed parts of the catchment, and steep to very steep in most forested portions of the catchment. The watercourses themselves are very steep in some sections, including a number of waterfalls up to 20m high. The catchment terrain is shown on Figure 2-2.

Watercourses were observed during site inspections to experience some low levels of baseflow but would otherwise be expected to be dry during periods of low rainfall. Overland flow paths through developed areas are a mix of having being filled/piped and developed, or have been retained as more natural watercourses.

2.2 Existing Land Use and Development

Land use in the catchment is predominantly low-density residential housing, with allotment size ranging from typical-sizes lots up to large lots over 2,000m^2. There are some apartment developments along the Pacific Highway and railway line, and main commercial areas in Turramurra and Wahroonga villages. Development is generally confined to the southern two-thirds of the study area as well as to the ridge tops and upper hillsides as the valleys are generally too steep for development. The valleys are vegetated with natural bushland. Refer to the land use zoning map on Figure 2-3.

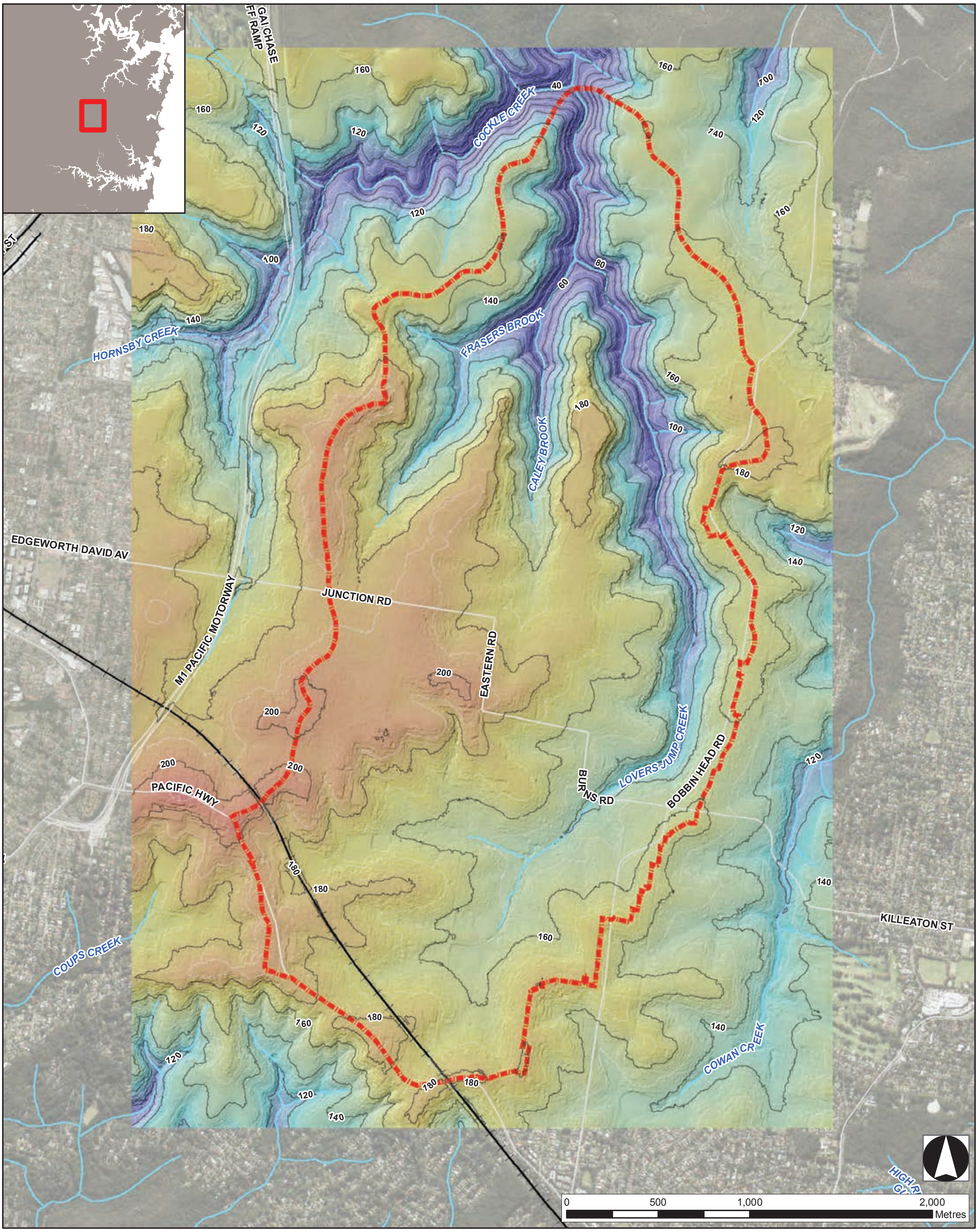
Overland flow paths and watercourses in the catchment flow through a number of private properties and are crossed by driveway culverts and bridges in addition to minor footbridges. A number of roads cross the watercourses with culvert structures. Burns Road, which crosses the main arm of Lovers Jump Creek, is the main waterway crossing in the catchment. Several roads, including Eastern Road have been constructed in fill over the overland flow paths, which have been piped under the roads. In some locations the road embankments pose significant obstructions to flow and cause ponding of floodwaters on private properties on the upstream side of the roads. The railway embankment also crosses several flow paths with the potential to pose a constraint on flows in extreme storm events.

Legend

- Study area
- Watercourse
- Railway
- Railway Station
- Main Road

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SHEET	Page of	GDA 1994 MGA Zone 56		
TITLE	Study Area			
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan			
DRAWN LC	PROJECT # IA159900	MAP # Figure 2-1	REV 1	VER 1
CHECK AH	DATE 29/01/2019		1:12,000 | A3	



Legend

Elevation (m AHD)

Value

High : 210

Low : 30

Elevation 20m contour

Elevation 10m contour

Study area

Watercourse

Railway

Main Road

JACOBS

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SHEET	Page of	GDA 1994 MGA Zone 56	
TITLE	Catchment Terrain		
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan		
DRAWN LC	PROJECT # IA159900	MAP # Figure 2-2	REV 1 VER 1
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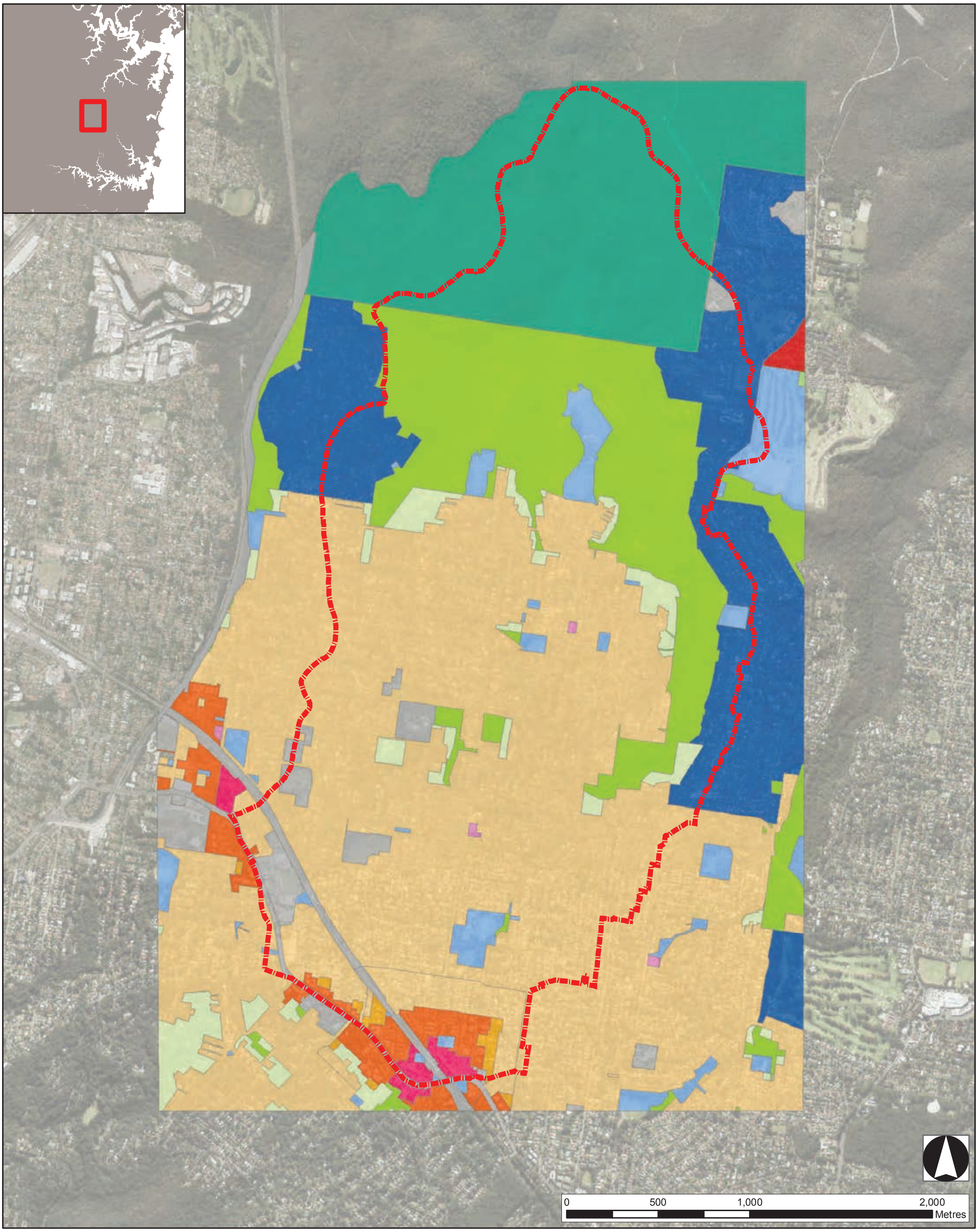

Legend

Land Use Zone

- B1 - Neighbourhood Centre
- B2 - Local Centre
- E1 - National Parks and Reserves
- E2 - Environmental Conservation
- E3 - Environmental Management
- E4 - Environmental Living
- R2 - Low Density Residential
- R3 - Medium Density Residential
- R4 - High Density Residential
- R5 - Large Lot Residential
- RE1 - Public Recreation
- RE2 - Private Recreation
- SP2 - Infrastructure
- Study area

JACOBS

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SHEET	Page of	GDA 1994 MGA Zone 56	
TITLE	Land Use Zoning		
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan		
DRAWN LC	PROJECT # IA159900	MAP # Figure 2-3	REV 1 VER 1
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2.3 History and Nature of Flooding

Given the nature of the terrain in the study area, flooding is generally confined to the well-defined flow paths and watercourses. In developed areas the watercourses are often piped and filled-in for development to occur, hence floodwaters may pass through properties and over roads causing relatively shallow overland flooding. There are some locations where flows may be obstructed, for example by road and railway embankments, causing flows to pond on the upstream side to greater depths which may then overtop the road embankment. Some properties in the catchment are situated on low areas in close proximity to the creeks that regularly experience flooding which encroaches on and surrounds the dwelling. Once flows reach the deeply-incised, forested valleys, the floodwaters are confined to within the creeks and with no risk to properties.

According to Council's records of flooding complaints and feedback from the community, significant flooding in the catchment has occurred during February 1984, April 1988, February 1990, June 1991 and February 2010, among other smaller flood events. The 1984 and 1991 flood events were particularly large, considering the high number of flooding complaints logged by Council, with the 1984 event estimated to exceed the 1% AEP event in parts of northern Sydney, including in the study area (Riley et al, 1986). It is understood from consultation with long term residents that numerous road waterway crossings were upgraded to provide greater flow capacity following the 1991 storm event.

The February 2010 event is thought to be one of the largest recent flood events, based on regular observations of flooding events by local residents.

2.4 Social Profile

Social characteristics of the study area are a key consideration for the floodplain risk management study. The Australian Bureau of Statistics (ABS) census 2016 data summarised in Table 2-1 indicates the following information on the population in the study area. The catchment is mostly within the Wahroonga (East) – Warrawee statistical area, which is assumed to be representative of the study area population.

Table 2-1 Census Data for Wahroonga (East) – Warrawee (Source: ABS 2016 Census Basic Community Profiles)

Selected Person Characteristic		Dwelling Structure	
Total Persons	~12,000*	Separate house	77%
Aged 14 years and under	19.1%	Semi-detached etc	4%
Aged 65 years and over	18.1%	Flat, unit, apartment	19%
Aboriginal/Torres Strait Islander	0.4%	Other dwelling	0%
Australian born	61.3%	**Tenure Type by Dwelling Structure**	
Born overseas	34.3%	Fully owned	43%
Speaks English only at home	74.3%	Mortgaged	40%
Speaks a language other than English at home	21.5%	Rented	11%
Other languages spoken at home (% of people) (results >2% shown)	Chinese (8%) Indo-Aryan (2%) Korean (2%)	**Household Composition**	
Completed Year 12	30.7%	Family households	83.5
Completed Year 10	4.9%	Single (or lone) person households	15.1
Did not attend school	0.2%	Group households	1.4

Selected Medians & Averages		Type of Internet Connection	
Median age	42	Internet not accessed from dwelling	5%
Median total household income ($/weekly)	$2,810	Internet accessed from dwelling	94%
Median mortgage repayment ($/monthly)	$3,000	**Population Continuity**	
Median rent ($/weekly)	$612	Persons at same address 1 year ago	83%
Average household size	3	Persons at same address 5 years ago	56%
Number of Motor Vehicles by Dwellings		**Selected Labour Force and Education % of total labour force or % of persons aged 15 years and over**	
Dwellings with 0 motor vehicles	3%	Total unemployed	3%
Dwellings with 1 motor vehicles	29%	Total labour force	61%
Dwellings with 2 motor vehicles	45%		
Dwellings with 3+ motor vehicles	21%		

Note: * Estimated based on number of properties in the study area and average household size.

The census data indicates that:

- 74% of the population speak only English at home. This suggests that the use of English in flood warnings and messages, such as brochures and signage, is likely to be adequate. The social character of Ku- ring- gai is such that a large portion of the remaining 26% of the population are likely to speak English in addition to other languages and hence single language brochures is likely to be suitable.
- 94% of households accessed internet from the dwelling, indicating a very high rate of accessibility to information on flooding on websites of Council and other agencies such as BOM and SES.
- 18% of the population are aged 65 years and over. Flood emergency, evacuation and recovery needs of this older cohort need to be considered, with aspects including communication of key messages and mobility of individuals.
- 56% of persons were at the same address five years ago, which indicates a relatively high turnover rate of the community. Messages on the flood risk in vulnerable and high risk properties may need to be communicated on a regular basis and when these properties are sold. This issue is exacerbated by the low frequency of significant flood events in the catchment and their impacts generally limited to a handful of properties. The combination of these factors suggests that flood awareness would be relatively low.
- The median total household income of $2,810 per week is high compared to the NSW average of $1,486. This does not necessarily suggest that the economic ability of households to recover from flooding events is high, as the median monthly mortgage is also high ($3,000 compared to NSW median of $1,986) and earnings may be significantly tied up in these repayments. Flood damages may be relatively high due to higher value of possessions.

2.5 Natural Environment

The catchment contains areas of bushland, typically in and adjacent to the riparian corridors, with large areas of bushland also situated in the northern section of the catchment, within Ku-ring-gai Chase National Park.

The Ku-ring-gai Development Control Plan 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.

Council has mapped Endangered Ecological Communities (EECs) occurring within the study area, refer to Figure 2-4. The EECs in the study area predominantly include Blue Gum High Forest and Sydney Turpentine Ironbark Forest, among others. The design and placement of structural floodplain management measures need to consider the presence of EECs and may require detailed site-specific environmental investigations to be undertaken to confirm biodiversity values and constraints.

2.6 Heritage

An understanding of heritage issues is required in addressing floodplain risk management for the study area. Heritage items provide information on the social and cultural context of the floodplain and their location is an important consideration for floodplain mitigation measures. Any management measures proposed should not unduly impact heritage items or the cultural fabric of the study area, and the presence of heritage items has been considered in the identification and assessment of mitigation options.

An online search of the State Heritage Inventory was undertaken. The Inventory is a list of heritage items in New South Wales including Aboriginal Places, State Heritage Register, Interim Heritage Orders, State Agency Heritage Registers and Local Environmental Plans. Those listed under the NSW Heritage Act which are located within the study area are listed in Table 2-2. There are approximately 150 additional items identified in the register listed by Council and by State government agencies. There are no Aboriginal Places listed in the OEH register under the National Parks and Wildlife Act in the study area.

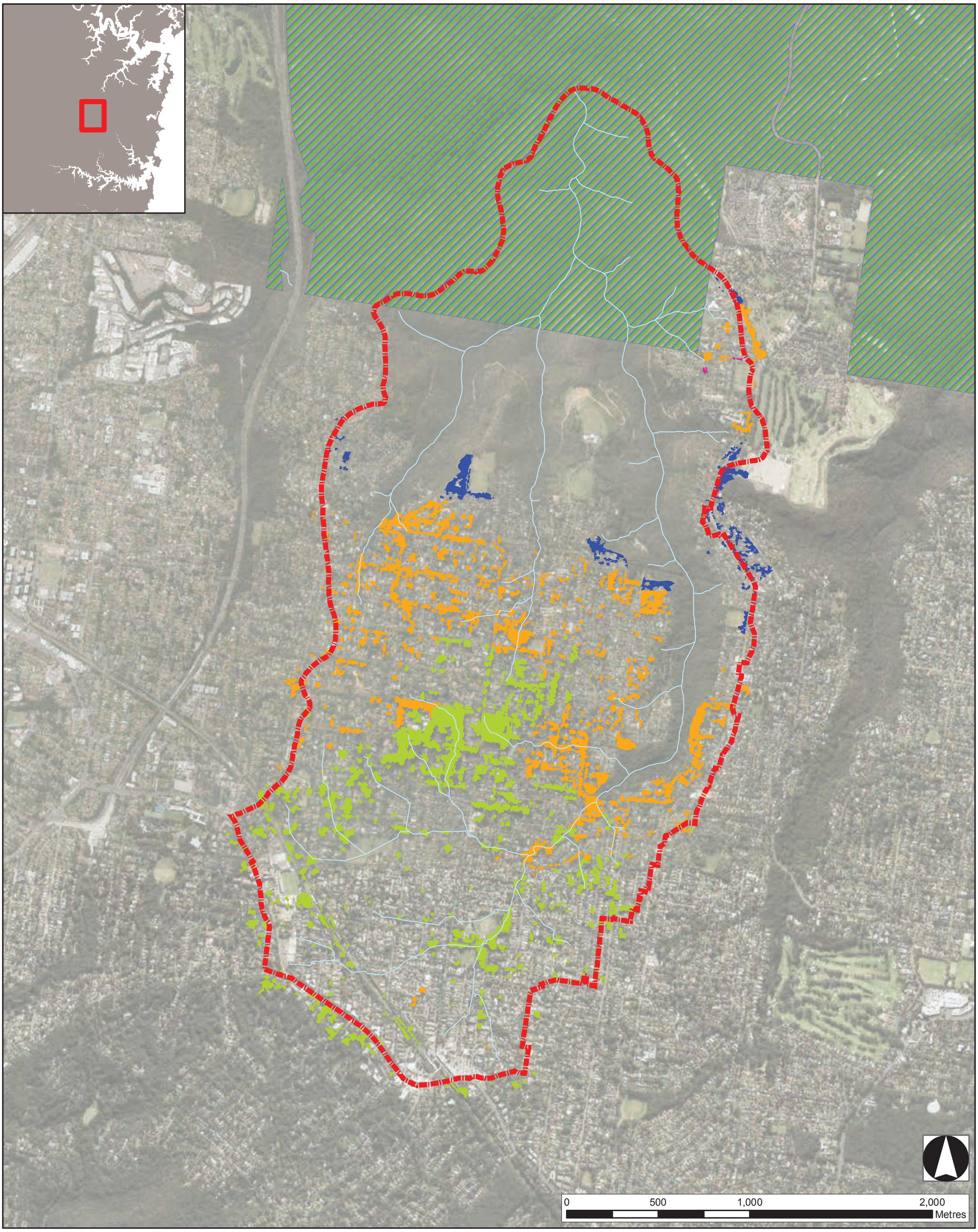
A search of the Aboriginal Heritage Items (AHIMS) found six separate listings of aboriginal heritage items. These are located in the bushland sections in North Wahroonga on high ground and away from watercourses and overland flow paths and are unlikely to be affected by proposed flood mitigation measures.

Development consent is required prior to altering heritage items; this includes demolishing or moving, altering the building by making structural changes, disturbing or excavating archaeological sites, disturbing or excavating an Aboriginal place of heritage significance, erecting a building on the land or subdividing the land where a heritage item is located.

Table 2-2 Non-Aboriginal Heritage Items in Study Area listed under NSW Heritage Act

Item Name	Address	State Heritage Register Item Number
Cossington	43-47 Ku-Ring-Gai Avenue Turramurra NSW 2074	1763
Ingleholme	17 Boomerang Street Turramurra NSW 2074	71
Evatt House	69 Junction Road Wahroonga NSW 2076	1711
Jack House	62 Boundary Road Wahroonga NSW 2076	1910
Rose Seidler House	69 Clissold Road Wahroonga NSW 2076	261

*Note, there are approximately 150 additional items identified in the register listed by Council and by State government agencies and which are not summarised here.



Legend

Endangered Ecological Communities

- Blue Gum High Forest
- Coastal Shale Sandstone Forest (complex) - Provisional
- Duffys Forest
- Sydney Turpentine-Ironbark Forest

National Park

- Ku-ring-gai Chase National Park
- Study area
- Watercourse

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Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SHEET	Page of		GDA 1994 MGA Zone 56	
TITLE	Vegetation - Endangered Ecological Communities			
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan			
DRAWN LC	PROJECT # IA159900	MAP # Figure 2-4	REV 1	VER 1
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3. Review of Available Information

3.1 Previous Studies

3.1.1 Lovers Jump Creek Flood Study (2016)

The *Lovers Jump Creek Flood Study* (Jacobs, 2016) define design flood behaviour based on a 2005 DRAINS stormwater/hydrologic model and a TUFLOW hydraulic model using a 2m grid. The 2005 DRAINS model catchment characteristics (impervious %) were retained due to minimal change in development conditions in the catchment following that study. Design rainfalls were based on Australian Rainfall and Runoff 1987. The study defined flooding behaviour for a range of flood events including the 0.2 Exceedances per Year "EY" (previously nominally denoted the 20% Annual Exceedance Probability (AEP)), 10%, 5%, 2%, 1% AEP and PMF events. The 25 and 90 minute duration events were found to be critical for the study area for events up to the 1% AEP.

3.1.2 Lovers Jump Creek Flood Study Review (2018)

Review of the 2016 Flood Study during this FRMSP identified issues with the previous flood mapping. Specifically, the mapping and analysis did not pick up on peak flood conditions (levels, depths, velocities etc.). Hence, the full risk of flooding in the catchment was not characterised in the Flood Study. The flood study was therefore updated to re-define the flood behaviour and flood risk in the study area. A stand-alone report has been produced, the *Lovers Jump Creek Flood Study Review* (Jacobs, 2018). The flood mapping and results contained in the Flood Study Review Report supersedes the 2016 Flood Study. The Flood Study Review Report has been placed on public exhibition in April – May 2018.

The number of properties affected by varying maximum flood depths is summarised in Table 3-1. The maximum flood depth typically occurs within a flow path or watercourse which passes through the property, and may not reflect the flood depth at the dwelling. The analysis is based on the land parcels spatial layer provided by Council and includes both private properties as well those occupied by Ku-ring-gai Chase National Park and other reserves and open space.

Table 3-1 Count of properties by maximum flood depth on each property

Depth (m)	AEP					
	20%	10%	5%	2%	1%	PMF
0.1 – 0.2	48	56	103	107	109	112
0.2 – 0.5	174	171	290	306	338	391
0.5 – 1.0	89	101	154	191	229	425
1.0 – 2.0	69	61	59	65	68	264
>2.0	148	138	148	151	157	239
Total	528	527	754	820	901	1,431

Provisional flood planning area mapping was prepared for areas deemed to be affected by active flows in the 1% AEP event. This has been determined by consideration of flooding depth, continuity of the mapped flood inundation, presence of incised gullies in the flow path terrain and susceptibility of existing development. The flood planning area is defined by the area below the 1% AEP flood level plus a specified freeboard. In this study a 0.3m freeboard has been adopted for areas affected by overland flooding, and a 0.5m freeboard for those affected by mainstream flooding. The number of properties to which the mainstream and overland flood planning areas apply are summarised in Table 3-2.

Table 3-2 Number of Properties with Provisional Flood Planning Area

Flood Planning Area	Number of Properties
Mainstream only (0.5m freeboard above 1% AEP flood)	161
Overland only (0.3m freeboard above 1% AEP flood)	795
Both Mainstream and Overland	36
Total	992

* Please note that the Flood Planning Area mapping has been updated as part of this Risk Management Study, Please see Section 4.3.7 for details.

3.2 Recent Development

Redevelopment of a number of properties has occurred over the last 10 years or so (since the 2005 DRAINS model), particularly in the upper parts of the catchment including the construction of high rise apartment blocks along the Pacific Highway. These developments typically replaced low density residential lots with free-standing houses.

Knox Grammar School in Wahroonga has also been progressively developed in the same period including new buildings and facilities and extended car parking areas. This has significantly increased the paved areas on the site. Comparison of current (2017) aerial photography to previous (2009) photography indicates that, in particular, the northern part of the school has increased in imperviousness from approximately 70% to over 90%. It is not known at this stage whether On-site Stormwater Detention (OSD) has been implemented at this site as a part of the redevelopment.

3.3 Changes in Drainage Infrastructure and Features

Council have confirmed that there have been a number of modifications to the drainage network relating to development applications at seven locations in the catchment, although Council's advice is that these modifications are minor and are unlikely to result in significant changes to flooding conditions. An updated DRAINS model with the modifications was provided to Jacobs. The sensitivity of flooding to the drainage modifications has been assessed in the TUFLOW model, refer to Section 5.3.2.

It is understood that there have not been any significant changes in trunk drainage, road and railway cross drainage or modifications to watercourses since the 2016 flood study. Recent creek bank works (circa 2014-15) at Challis Avenue, Turramurra, were taken into account during the flood study modelling. There have also been no significant road and other infrastructure changes in the study area which would alter flooding behaviour.

3.4 Building Footprints

Council provided a digitised GIS layer of building footprints. It was assumed that these footprints were for current conditions (2016-17). However, comparison to previous aerial imagery held by Jacobs indicates that the footprints represent 2011 conditions. Therefore, the building footprints digitised by Jacobs for the 2016 flood study hydraulic modelling (based on 2014 imagery) are more recent. Note that the flood study footprints were only digitised for those buildings affected by the PMF extent.

Review of the flood study modelling building footprints against 2016 aerial imagery indicates no recent significant changes to buildings on the floodplain. There are several lots under redevelopment on Gilroy Road, Turramurra (in the vicinity of the village centre) however, these lots are not in an overland flow path and are only affected by sheet flow in the PMF.

3.5 Land Use and Zoning

Land use zoning provided on mapping contained in Ku-ring-gai LEP 2015 and LEP (Local Centres) 2012 defines the current maximum allowable levels of development in Ku-ring-gai Local Government Area LGA. In the study area the LEPs allow for increased levels of development surrounding Turramurra town centre, with zonings R3 (Medium Density Residential) and R4 (High Density Residential) allowed. Current levels of development in this area includes a mix of low, medium and high density residential properties. There is also existing commercial and business/non-residential development in Turramurra town centre, which remains as such in the LEP.

Away from Turramurra town centre the existing land use is predominantly low density residential, with local shopping centres on Eastern Road, Turramurra, and Hampden Avenue, Wahroonga. This level and pattern of development is unchanged in the LEP.

Ku-ring-gai DCP 2016 provide guidelines for development in the LGA. This includes maximum permissible built up area (BUA) and minimum deep soil area on a lot, which depends on the land use zoning of that site. Table 3-3 summarises the maximum impervious area fractions for each land use zoning in the study area, based on interpretation of the DCP and as confirmed with Council. It is noted that the maximum impervious areas for R3 and R4 zonings of 60% are comparatively low compared with similar land zonings in other Sydney council areas, which may be 80% impervious or higher.

Table 3-3 Maximum impervious fraction for various zonings

Zoning	Description – Zoning and (DCP Section)	Note	Maximum Impervious area
R2	Low Density Residential (Dwelling houses)	Max BUA = 60%	60%
R3	Medium Density Residential (Multi-dwelling housing)	Min deep soil coverage = 40% Max site coverage = 40%	60%
R4	High Density Residential (Residential flats general)	Min deep soil coverage = 40% Max site coverage = 30%	60%
RE1	Public Recreation	No specific requirement	5%
E4	Environmental Living	No specific requirement	50%
B2, B4	Local Centre; Mixed Use/ (Non-residential, office buildings)	No specific requirement	100%
SP2	Special Uses	No specific requirement	Varies

4. Flood Policies and Planning Controls

4.1 Background

This section provides an overview on the NSW flood risk management framework, and existing policies and planning controls applicable to the study area and recommends additional controls to be considered for the study area.

4.2 NSW Flood Risk Management Framework

4.2.1 Objectives and Approach

The primary objective of the NSW Flood Risk Management (FRM) framework, as expressed within the NSW Flood Prone Land Policy (Floodplain Development Manual (FDM) 2005, page 1), is as follows:

"*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*."

Within the scope of this report, the relevance of the above objective is primarily to ensure that future redevelopment within the study area does not lead to increased flood risk to property and persons, and that the planning controls proposed to achieve this outcome form part of a consistent and coordinated strategy to reduce flood risk.

4.2.2 NSW FRM Policy and Guidelines

The NSW Flood Prone Land Policy, as identified within Section 1.1 of the FDM, places the primary responsibility for flood risk management on local councils. This provides the opportunity for FRM to be integrated within council's normal planning processes.

The NSW Flood Prone Land Policy and the FDM provide a platform for the management of floodplains following a risk management approach. The FDM provides guidance on how to implement the NSW Flood Prone Land Policy. The FDM requires the level of flood risk acceptable to the community to be determined through a process overseen by a committee comprised of local elected representatives, community members and state and local Government officials (including the SES). This process is shown in Figure 1-1.

The ultimate outcome is the preparation of a Floodplain Risk Management Plan (FRMP), which is a plan formally adopted by a local council in accordance with the NSW Flood Prone Land Policy. FRMPs should have an integrated mix of management measures that address existing, future and continuing risk.

4.2.3 2007 Flood Planning Guideline

On January 31, 2007 the NSW Planning Minister announced a new guideline for development control on floodplains (the "Flood Planning Guideline"). An overview of the new Guideline and associated changes to the *Environmental Planning and Assessment Act 1979* (EP&A Act) and *Environmental Planning and Assessment Regulation 2000* (Regulation) was issued by the Department of Planning in a Circular (PS 07-003) dated 31 January 2007. The Flood Planning Guideline issued by the Minister relates to this package of directions and changes to the EPA Act, Regulation and FDM.

This Flood Planning Guideline provides an amendment to the Floodplain Development Manual (2005). The Guideline confirms that unless there are "exceptional circumstances", Councils are to adopt the 1% AEP as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Guideline does provide that controls on residential development above the 1% AEP may be imposed subject to an "exceptional circumstance" justification being agreed to by the Department of Natural Resources (now the Office of Environment and Heritage – OEH) and the Department of Planning (now the Department of Planning and Environment – DPE) prior to the exhibition of a Draft LEP or Draft DCP.

The “Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual” defines Standards for Flood Controls for Residential Development. Whilst the flood used to define the residential FPL is a decision of Council, FDM highlights that FPLs for typical residential development would generally be based around the 1% AEP plus an appropriate freeboard (typically 0.5m).

4.2.4 Flood Risk Management Measures

The FDM provides three categories of measures for managing flood risk to life and property that are incorporated into a FRMP:

- **Property modification measures** - these comprise controls on future development of property and community infrastructure. Planning and development controls can generally be implemented for minimal cost and would ensure that the potential for flood damage does not increase in the future.
- **Response modification measures** - these modify peoples’ response to flooding and usually include measures that provide additional warning of flooding, improved public awareness of the flood risk and improvements to emergency management during floods.
- **Flood modification measures** - being structural measures such as the construction of flood walls, upgrade of stormwater network, detention basins, augmentation of culverts and bridges, etc.

This section is primarily concerned with property modification measures and secondly with response modification measures. The role of planning relates primarily to the implementation of property modification measures through flood risk policies. To a lesser extent, response modification measures can also be a part of planning, particularly the manner in which it informs the community about flood risk policies. Accordingly, the role of planning can be summarised as follows:

- **Strategic planning**: Directing strategic planning as to the location of new areas or the redevelopment of areas in a manner which does not expose people and property to unacceptable flood risk.
- **Development and building controls**: Where development is permitted in locations where flood risk remains, to ensure that planning and building controls are applied in a manner which minimises risk to acceptable levels.
- **Communication of flood risk**: Ensuring that the planning policies and controls and associated documentation communicates flood risk in a responsible manner to allow the community to make informed decisions where discretion exists.

The following issues should also be considered for the study area:

- Safety of people and potential for damage to vehicles in basement car parks.
- Emergency (e.g. fire and medical needs) access and egress to properties during flood events rarer than the 1% AEP event and during fire.
- Flood education and preparedness.
- Appropriateness of a porous fencing policy.

Refer to Section 9 for detailed discussion on flood risk management measures specific to the study area.

4.2.5 Relationship with EP&A Act

The plan-making processes under the EP&A Act, such as for the preparation of Local Environmental Plans (LEPs) and Development Control Plans (DCPs), operate independently of the preparation of FRMPs under the FDM. While these two processes could be overlapped, it has been the usual practice to undertake the processes separately. Ultimately the planning recommendations of the FRMP will need to be reflected in planning instruments and policies brought into force in accordance with the EP&A Act.

4.3 Existing Policies and Planning Controls

The imposition of planning controls can be an effective means of managing flood risks associated with future development (including redevelopment). Such controls might vary from prohibiting certain land uses to specifying development controls such as minimum floor levels and building materials.

In principle, the degree of restriction that is imposed on development due to flooding relates to the level of risk that the community is prepared to accept after balancing economic, environmental and social considerations. In practice, the planning controls that may ultimately be imposed are influenced by a complex array of considerations including state-imposed planning policy and directions, existing local planning strategies and policies and ultimately the acceptability of conditions that could be imposed through the development application process.

The following provides an outline of policy that is potentially relevant because it either directs the FRM planning controls that could be adopted or affects the way flood risk is identified in the planning controls.

4.3.1 State Environmental Planning Policies

State Environmental Planning Policies (SEPPs) are planning policies which deal with State wide matters of environmental planning significance. They are prepared in accordance with the EP&A Act by the NSW Department of Planning and Environment and approved by the Minister. Clause 1.19 of the Exempt and Complying Development Codes SEPP has been amended so that land identified as 'flood control lot' is no longer excluded from the application of the General Housing Code. Instead, specified development and development standards have been added to the General Housing Code in Clause 3.36 of the Exempt and Complying Development Codes SEPP (2008) for development on flood control lots. The development standards have been designed to ensure that complying development is not allowed on those parts of flood control lots which are defined as being floodways, flood storage areas, a flow path, a high flood hazard area or high flood risk area.

Hydraulic hazard and hydraulic categories across the study area were identified in the Lovers Jump Creek Flood Study Review (Jacobs, 2018). A number of existing properties are surrounded by floodway and/or high flood hazard areas and during future detailed planning the hazard and hydraulic categories maps should be consulted to ensure that developments are not approved on high hazard or floodway areas. Refer to Appendix B for 1% AEP flood hazard (based on FDM definition) and hydraulic category mapping, including floodways and flood storages.

Recommendation

The flood hazard and hydraulic categories mapping is to be consulted by Council in the planning and approval of proposed developments for flood-affected lots. Proposed developments are not to be approved on high hazard or floodway areas.

Note that this may conflict with proposed concept to redevelop high hazard lots with dwellings with sufficient structural integrity to permit refuge during flood events. Refer Section 9.3.2.

4.3.2 Climate Change Policies

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have a significant influence on flood behaviour at specific locations. Rainfall intensities will have a wide influence on flooding while the sea level rise will have a diminished effect as the distance from the tidal influences of coastal waters increases. The developed areas within the study area are located over 100m above the mean sea level and hence flood levels at the developed areas are not influenced by ocean tides.

Scientific data regarding the effect of climate change on rainfall intensities is not sufficiently advanced to provide specific guidance for the assessment of flood risk. No relevant planning benchmarks have been adopted by the NSW Government relating to rainfall intensity changes. However, NSW Government guidelines recommend the undertaking of a sensitivity analysis, which assumes nominal increases in rainfall intensities.

Lovers Jump Creek Flood Study Review (Jacobs 2018) identified significant impacts within the study area due to 10%, 20% and 30% increase in 1% AEP rainfall intensities, based on ARR 1987 (IEAust, 1987) design rainfalls. While the impacts due to the increased rainfall intensities were not considered in defining the provisional FPL or the FPA for the study area, some conservatism is built in to the design flood estimates which are based on ARR 1987 design rainfalls rather than the updated ARR 2016 (Ball et al, 2016) design rainfalls. ARR 2016 design rainfalls result in lower flood level estimates. Refer to Section 5.4 for discussion. Refer to Appendix B for FPA mapping.

4.3.3 Section 117 Directions

Ministerial directions pursuant to section 117(2) of the EPA Act specify matters which local councils must take into consideration in the preparation of LEPs. Direction 4.3, as currently applies, deals specifically with flood prone land and has the following two objectives:

(a) To ensure that the 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.

(b) To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

The Direction applies to all councils that contain flood prone land when an LEP proposes to "*create, remove or alter a zone or provision that affects flood prone land*." In such cases, the Direction requires draft LEPs to ensure the following:

1. *A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).*

2. *A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.*

3. *A planning proposal must not contain provisions that apply to the flood planning areas which:*

    a. *permit development in floodway areas,*

    b. *permit development that will result in significant flood impacts to other properties,*

    c. *permit a significant increase in the development of that land,*

    d. *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*

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

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

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

4.3.4 Local Environmental Plan

4.3.4.1 Ku-ring-gai Local Environmental Plan 2015

The *Ku-ring-gai Local Environmental Plan 2015* (KLEP 2015) provides land use controls for the Ku-ring-gai local government area. The Ku-ring-gai LEP does not contain a section on flood planning. However, additional local provisions relating to flooding impacts are identified in the Ku-ring-gai LEP under clause 6.2 Earthworks, clause 6.4 Riparian land and adjoining waterways and clause 6.5 Stormwater and water sensitive urban design.

4.3.4.2 Proposed Amendment to Ku-ring-gai Local Environmental Plan 2015

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

As there are currently no flood related development control provisions applying under the KLEP, there are no "flood control lots" in Ku-ring-gai. Therefore, the additional considerations and restrictions under the Exempt and Complying Development Codes SEPP (2008), refer Section 4.3.1, do not apply.

Following development of the recent Flood Studies, Council is proposing amendment to the KLEP 2015 to include the flood controls as per the Model Local Provisions for Flood Planning and link these controls to the flood mapping for those catchments where a flood study has been prepared by Council. Several options are being considered by Council for the application of the Model Provisions. The proposed amendments will allow the notification of flood control lots on Section 149 certificates (refer Section 4.3.6 for further discussion), thereby signifying that the considerations and restrictions under the Exempt and Complying Development Codes SEPP (2008) would apply to that lot.

4.3.5 Development Control Plan

The Ku-ring-gai Development Control Plan (KDCP) provides detailed guidelines to guide the design and assessment of development applications for land covered by KLEP 2015. KDCP came into effect on 24 June 2016 and Part 24 of the DCP deals with Water Management guidelines for proposed developments. In particular, the following controls apply to development over or adjacent to a natural waterbody, open channel or drainage depression within the study area:

- Where works are proposed to be undertaken adjacent to the design flood standard conveyance zone associated with a water course, open channel or drainage depression, a flood assessment must be prepared to demonstrate that the development will not:
  - be subject to inundation from flows associated with the watercourse causing damage to property or belongings; and /or
  - be subject to structural damage from flows associated with the watercourse or debris associated with the flows; and/or

- impede the passage of stormwater associated with the watercourse to cause a rise (afflux) in the flood level upstream greater than 50mm; and/or
- divert flows associated with the watercourse onto or into adjacent properties; and/or
- increase the downstream velocities of flow for the design flood standard.

- Bridges may be considered, where:
  - the underside of any bridge structure, including any attached utility services, is not less than 300mm above the level of the design flood standard;
  - the existing velocity of water in the watercourse would not be affected;
  - not more than one bridge is established per property; and
  - the watercourse and banks beneath the bridge are stabilised by rock lining or equivalent to prevent erosion that would otherwise result from reduced plant growth due to restricted solar access.

  Lower level bridges may be considered if flood impacts identified in KDCP are satisfied.
- Where identified as overland flow on the Flood Planning Area Map (refer to the mapping in Appendix B), the minimum floor level of all enclosed areas and structures, including all habitable floor areas, must be either:
  - 300mm above the design flood standard level; or
  - 300mm above the highest existing ground level along the associated overland flow path; or
  - whichever is the greater, except in the case of garages, where the minimum height must be 150mm instead of 300mm, and inground swimming pools, which must be designed in accordance with the provisions of 24D.7 (4) of KDCP.
- Where identified as mainstream flow on the Flood Planning Area Map (refer to the mapping in Appendix B), the minimum floor level for all enclosed areas, including all habitable floor areas, must be 500mm above the design flood standard level, except in the case of garages, where the minimum height must be 300mm, and inground swimming pools, which must be designed in accordance with the provisions of 24D.7 of the Ku-ring-gai DCP.

- Safety fencing that is required to reduce hazard to persons to acceptable limits may be installed in any areas that are subject to overland flow. Safety fencing must be able to withstand a velocity x depth product of $0.4m^2/s$, not impede flows or debris, and meet the minimum requirements of AS1926.1-1993: Fencing for Swimming Pools or any standard that replaces it. If fencing is not feasible, other suitable measures may be provided to restrict access to areas which exceed this limit.
- Parking areas must not be established in areas where vehicles would become buoyant in an overland flow zone, and hence unstable. A maximum velocity x depth product of $0.6m^2/s$ to $0.7m^2/s$ applies in these instances in accordance with broad guidelines in Australian Rainfall and Runoff. The criteria could be updated to refer to the AIDR flood hazard categories, which are the current standard and which are mapped in this FRMS (refer Section 5.5). This flood hazard mapping specifically defines areas where vehicle stability due to flooding is compromised. The velocity x depth was not mapped as a part of this FRMS.

The KDCP does not provide design guidelines for basement parking in flood-affected areas, such as minimum driveway entry levels and drainage pump-out. Consideration should be made for update of the KDCP to make these provisions.

KDCP does not make provisions for consideration and control of development in high flood hazard areas, and a mechanism needs to be included to allow for these provisions. Linkage with the proposed flood planning matrix as developed in the Blackbutt Creek FRMS (GHD, 2018) or similar should be considered in this regard.

KDCP does not include an open or porous fencing policy in overland flow areas. Some Councils do have an open fence policy to provide flow conveyance through property boundaries. However, it is noted in the Lovers Jump Creek catchment (and this may be the case in other catchments in Ku-ring-gai) that many properties in the floodplain have solid walls along their boundaries which may already impede overland flows in the existing case. Imposing an open fence policy may change flow behaviour resulting in flooding impacts to neighbouring properties. An open fence policy may therefore not be suitable in the study area. Redevelopments which include changes to fencing type may need to be assessed to ensure no adverse flood impacts which is already a requirement in the KDCP.

4.3.6 Section 149 Certificates

Ku-ring-gai Council, under the provisions of Section 149 of the *Environmental Planning and Assessment Act 1979* issue Certificates which are also known as planning certificates. The certificate provides information on planning controls and any development restrictions which may apply to a particular parcel of land within the Council area. They are usually required upon the sale or purchase of a property.

As discussed in Section 4.3.4, the KLEP 2015 currently does not make provision for flood controls and hence the Section 149 certificates do not specifically identify a particular lot as being a “flood control lot”. The proposed amendments would allow the notification of flood control lots on Section 149 certificates, thereby signifying that the considerations and restrictions under the Exempt and Complying Development Codes SEPP (2008) would apply to that lot. The flood information based on the adopted flood studies in Ku-ring-gai LGA, where available, should also be included on the certificates.

4.3.7 Flood Planning Area Mapping

Provisional flood planning area mapping was prepared as part of the Lovers Jump Creek Flood Study Review (Jacobs, 2018) and the mapping has been updated and finalised as part of this study to address the continuing and future flood risk for the study area to ensure consistency with the Section 117 Direction and to compliment KDCP. Refinement of the flood planning area mapping included reviews of the flood planning area extent during consultation with the community, including on-site validation of the mapped extents. Refer to the updated mapping in Appendix B. the number of properties affected by the final flood planning area are indicated in Table 3-2

Table 4-1 Number of Properties with Final Flood Planning Area

Flood Planning Area	Number of Properties
Mainstream only (0.5m freeboard above 1% AEP flood)	154
Overland only (0.3m freeboard above 1% AEP flood)	694
Both Mainstream and Overland	34
Total	882

5. Existing Flood Environment

5.1 Flood Behaviour

Given the nature of the terrain in the study area, flooding is generally confined to the well-defined flow paths and watercourses during normal rainfall events and frequent flood events. In developed areas the watercourses are often piped and filled-in for development to occur. These trunk drainage systems were constructed decades ago when design standards were typically to smaller and more frequent runoff events. Natural watercourses in the study area too generally have a flow capacity aligned with the more frequent flood events as their physical geometry has evolved to these frequent flow events.

During larger flood events the built drainage system and natural watercourse exceed their capacity and overflow, and these overflows may pass through properties and over or along roads as overland flooding. There are some locations where flows obstructed, for example by road and railway embankments, causing flows to pond on the upstream side to greater depths which may then overtop the road embankment.

Some properties in the catchment are situated on overland flow paths or on low areas within close proximity to the creeks that regularly experience flooding. Floodwaters encroach on the dwelling, isolating and in some cases submerging the dwelling during large and flood events. Driveways and road access may be cut-off to these and other properties. Flow velocities are typically moderate, up to 1m/s in most overland flow paths in the 1% AEP event. Velocities are swift in steeper flow paths and in some roadways including sections of Eastern Road and Chilton Parade, exceeding 2m/s in the 1% AEP event. Flow velocities in the watercourses are typically 2 – 4m/s in the 1% AEP event, and may impact on adjacent dwellings, accessway crossings and road crossings.

The storm events causing the worst-case flooding in the catchment are typically short duration events (up to, say, 2 hours in duration). However, these may be individual intense bursts of rainfall as a part of broader regional weather features such as East Coast Lows, which may present a number of separate bursts over the total duration of the weather event. There may therefore be several flooding peaks generated as the individual rainfall bursts occur. Rates of floodwater rise are usually fast and with minimal flood warning time. Times of inundation are generally short, in line with the typically short duration critical storm events.

Once the flood flows reach the deeply-incised, forested valleys, the floodwaters are confined to within the creeks and with no risk to properties.

5.2 Rare Flood Events

Several locations in the study area were observed to experience minor or no flooding problems in the 1% AEP event, but then highly hazardous flooding during the PMF event. These locations included drainage low points upstream of the North Shore Railway Line, where the railway cross drainage can convey the 1% AEP flow but their combined capacity is well below the PMF flow. Note that a blockage factor of 20% for the railway cross drainage was adopted in the flood study, which was selected based on site conditions assessment of the drainage inlets and availability of flood debris.

An assessment of the flooding conditions for rare flood events between the 1% AEP and PMF events was undertaken to determine if there were likely to be flooding problems in say, the 0.5% and 0.2% AEP events. Rather than running the models for these events, the climate change scenario model results for increased rainfall intensities were reviewed as a proxy for the 0.5% and 0.2% AEP events. The rainfall Intensity-Frequency-Duration (IFD) data from the flood study, based on ARR 1987, indicates that the 0.5% AEP rainfall intensity (11% higher than the design 1% AEP) is similar to the 10% rainfall increase climate change scenario, and the 0.2% AEP rainfall intensity (25% higher than the design 1% AEP) is midway between the 20% and 30% rainfall increase climate change scenarios. In comparison, the PMF rainfall intensities are 3 – 4 times higher than the design 1% AEP (ARR 1987 IFDs) rainfall intensities.

Based on the review, the increase in 1% AEP flood levels at drainage low points upstream of the North Shore Railway Line is estimated to be up to 0.2m for the 0.5% AEP event, and up to 0.45m in the 0.2% AEP event.

The maximum flood depths at dwellings is estimated as 1.5m and 1.75m for the 0.5% and 0.2% AEP events, respectively. The dwellings most affected in this location (certain properties on Winton Street) are single storey buildings and would be significantly impacted by flooding in these rare events and there is a risk to life for occupants of these buildings.

5.3 Sensitivity Assessments

Changes to recent and future development conditions in addition to recently implemented drainage infrastructure were assessed. Consideration was made on whether the change in flood behaviour from the flood study update results was sufficiently significant to warrant these new developments to be incorporated into the design flood conditions.

5.3.1 Sensitivity to Future Development Conditions

The LEP development conditions were incorporated into the hydrologic and hydraulic modelling. The impervious fractions in the DRAINS model sub-catchments were updated based on the LEP development spatial distributions and assumed maximum imperviousness of each land use zoning. The increase in the impervious fractions on the Knox Grammar School site due to progressive redevelopment of the site were considered. Refer to Section 0 and Section 3.5 for descriptions of the recent and future development conditions.

Updated inflow hydrographs were established and run in the TUFLOW model. The models were run for the 20% AEP and 1% AEP flood events based on the 2016 flood study hydrology (i.e. ARR 1987 rainfall). Changes in flood levels from the flood study modelling due to the assumed LEP catchment conditions are presented on Figure A-1 and A-2 in Appendix A.

For the 20% AEP flood event, there are slight increases of up to +0.03m in flood depths across the catchment. There are very few increases in flood depths across the catchment which are greater than +0.04m.

For the 1% AEP flood event, there are slight increases in flood depths across the catchment of up to +0.03m. There are localised increases in flood depths across the catchment of +0.05 – +0.08m which do not affect development. There are also some reductions in flood depths of up to -0.07m. The flooding conditions are not considered to be significant and it is recommended that the modelling is not updated with the drainage modifications for the purposes of the FRMSP.

The flooding conditions are not sensitive to the changes in catchment conditions due to recent and approved future development, with the flood behaviour in the 1% AEP being less sensitive than the 20% AEP event due to higher rainfall intensities in the rarer storm events and less influence of the changes in catchment imperviousness on rainfall losses and infiltration. Hence it is recommended that the design flood modelling is not updated to reflect the recent and future development conditions.

5.3.2 Sensitivity to Drainage Network Modifications

Details of the DA-related drainage modifications were determined from Council's updated DRAINS model and incorporated in the TUFLOW hydraulic model. The modifications generally consisted of extended pipe networks to service new developments, and incorporation of newly-discovered drainage assets. The new pits and pipes are mapped along with retained existing and decommissioned drainage on Figure 5-1.

The TUFLOW model was run for the 20% AEP and 1% AEP flood events based on the 2016 flood study hydrology (i.e. ARR 2016 rainfall (Ball et al, 2016)). Changes in flows and flood levels from the flood study modelling due to the updated drainage arrangements are presented on Figure A-3 and A-4 in Appendix A.

For the 20% AEP flood event, there are generally reductions of up to -0.05m in flood depths, with some localised decreases of up to -0.08m. There are localised increases in flood depths which are typically up to +0.05m, with some areas exceeding +0.1m at drainage outlets. These increases do not impact on existing development.

For the 1% AEP flood event, there are generally reductions of up to -0.05m in flood depths, with some localised decreases of up to -0.08m. There are areas with increases in flood depths of typically +0.02m, with some localised areas exceeding +0.1m at drainage outlets. These larger increases do not impact on existing development.

The impact to flooding conditions are not considered to be significant and it is recommended that the modelling is not updated with the drainage modifications for the purposes of the FRMSP.

Legend

- New pipes
- Existing pipes
- Study area

JACOBS

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SHEET	Page of	GDA 1994 MGA Zone 56	
TITLE	**Drainage Modifications**		
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan		
DRAWN LC	PROJECT # IA159900	MAP # Figure 5-1	REV 1 VER 1
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5.4 Consideration of ARR 2016 Design Rainfall and At-Site Design Rainfall on Flood Behaviour

The Lovers Jump Creek Flood Study (Jacobs, 2016) was prepared on the basis of the guidelines from the 1987 Australian Rainfall and Runoff (IEAust, 1987). These guidelines were updated in 2016 (ARR 2016 (Ball et al, 2016)), including design rainfall estimates which are based on a more extensive database, using more than 30 years of additional rainfall records and inclusion of data from an extra 2,300 rainfall stations across Australia than ARR 1987. The ARR 2016 design rainfalls were derived by combining contemporary statistical analysis and techniques with this expanded rainfall database.

Apart from the updated design rainfall depths, ARR 2016 includes revised temporal and spatial distribution of design rainfall, rainfall losses, blockage of pits and pipes etc. These changes have the potential to alter the flood behaviour adopted in the Lovers Jump Creek Flood Study.

The impacts of ARR 2016 on flood behaviour for the 1% AEP event in Lovers Jump Creek were considered and are documented in the Flood Study Review Report, including:

- Comparison of At-Site Design Rainfall Estimates;
- Impact of ARR 2016 on 1% AEP Peak Flood Levels;
- Consideration of ARR 2016 parameters:
  - Design Rainfalls
  - Areal Reduction Factor
  - Rainfall Losses; and
- Rainfall Temporal Patterns – analysis of ARR 2016 ensemble peak flow rates.

The findings and recommendations are summarised below:

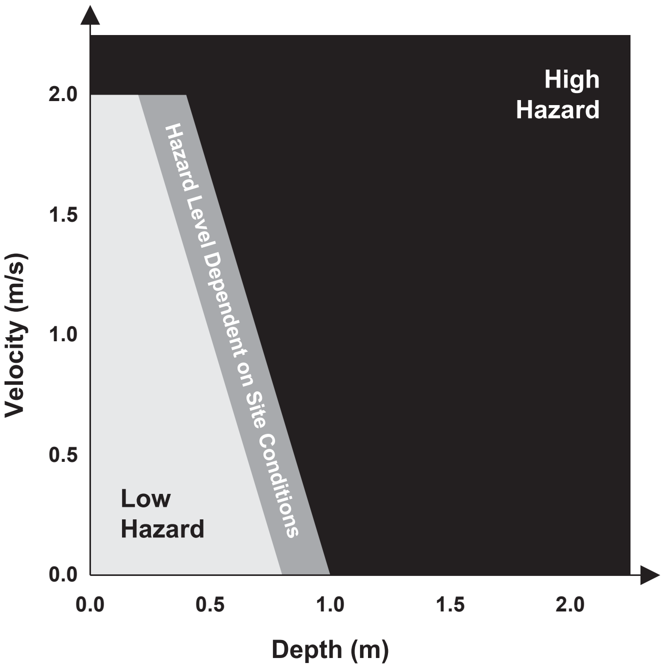
- ARR 1987 design rainfall estimates are generally higher than ARR 2016 estimates. The at-site estimates based on Sydney Water's rainfall station at Pymble (Station 566073) are generally lower than ARR 1987 and generally higher than ARR 2016.
- ARR 2016 design rainfall depths are not expected to have a significant influence on peak flows compared to ARR 1987 (approximately -5% to -10% difference). Based on the critical (maximum of ensemble medians) peak flows, the temporal patterns are expected to have a greater influence on peak flows (approximately -10% to -20% difference).
- The ARR 2016 Initial Loss – Continuing Loss rainfall losses are not recommended for use in urban catchments such as Lovers Jump Creek due to limitations in the estimation approach for these losses, but would be expected to result in a significant reduction in peak flows mainly due to the very high pervious area initial losses. The traditional DRAINS (Horton loss model) losses adopted in the flood study are recommended to be retained in the flood study review.
- Flood levels simulated for the 1% AEP event using ARR 2016 (design rainfalls only) are typically lower than the ARR 1987 flood levels by -0.2m to -0.4m on main flow paths and watercourses due to lower design rainfall depths and resultant lower flood flows and volumes.
- Based on the ARR 2016 design rainfall assessment findings it is recommended that ARR 1987 design rainfall and flood levels be adopted in the flood study review and FRMSP (i.e. no update to flood modelling). ARR 1987 provides a conservative estimate of flooding in the study area.

5.5 Flood Hazard Definition Review

5.5.1 Background

Flood hazard mapping was previously prepared in the Lovers Jump Creek Flood Study Review (Jacobs, 2018) based on the definition in the Floodplain Development Manual (NSW Government, 2005) and shown on Figure 5-2 below, where the flood hazard is rated based on the corresponding depth and velocity at any one time during a flood event. The flood planning policies and controls relevant to Ku-ring-gai generally cite the FDM in relation to the definition of “high flood hazard” areas for flood planning purposes. The FDM definition of high (and low) flood hazard conditions are generalised and do not differentiate between the susceptibility of different members of the community and of different types of assets and property.

Figure 5-2 FDM flood hazard category diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

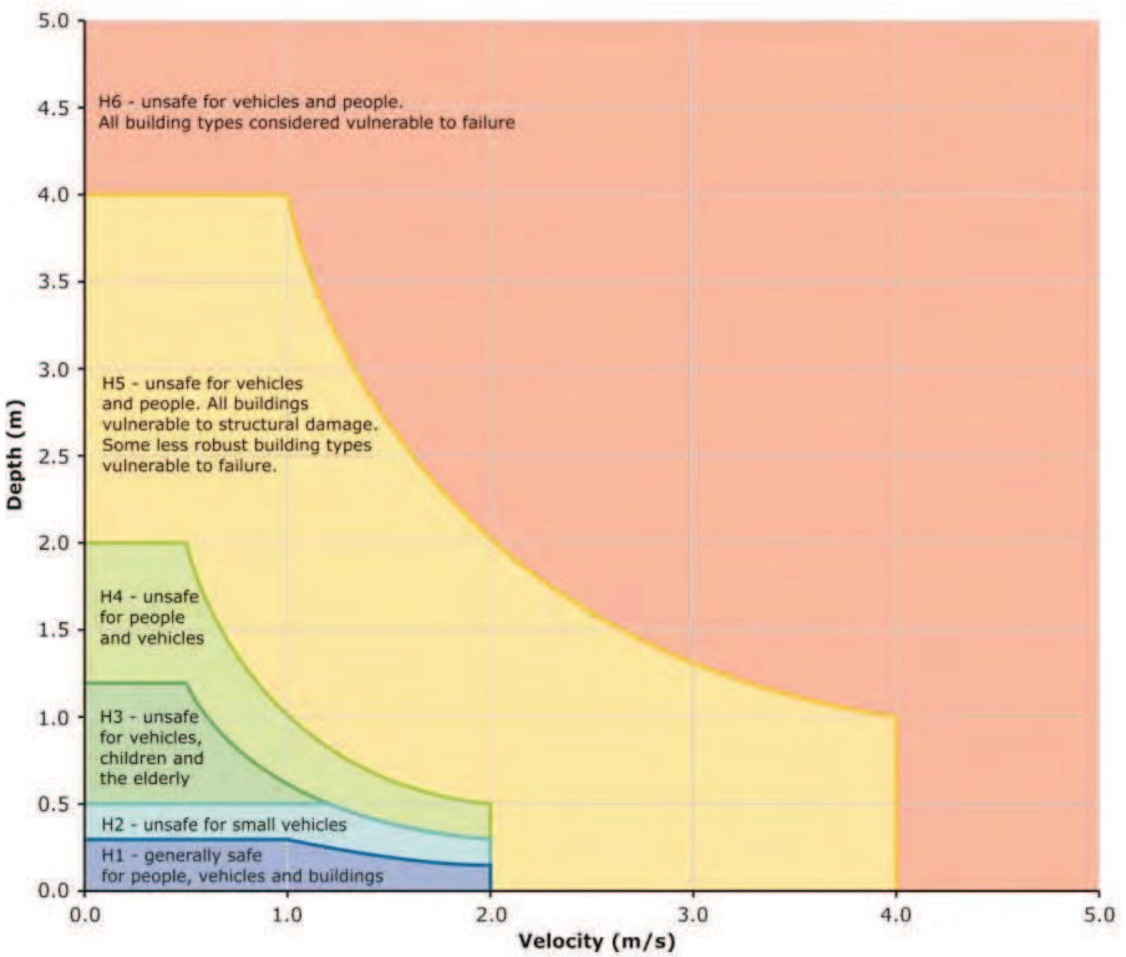


Recent research has been undertaken into the hazard that flooding poses and the vulnerability of the public and assets when interacting with floodwaters. A combined flood hazard classification is presented in *Australian Disaster Resilience Handbook 7. Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017a) and *Guideline 7-3 Flood Hazard* (AIDR, 2017b) based on this research, and is illustrated in Figure 5-3. The flood hazard categories according to the AIDR definition are:

- H1 – Generally safe for people, vehicles and buildings;
- H2 – Unsafe for small vehicles;
- H3 - Unsafe for vehicles, children and the elderly;
- H4 - Unsafe for people and vehicles;
- H5 - Unsafe for people and vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

The flood hazard classification is more discrete and provides guidance on flood hazard thresholds to different members of the community (e.g. children and elderly) and different assets (small versus larger vehicles, standard versus specialised engineered buildings). The AIDR flood hazard definition potentially provides a more suitable guideline for assessing flood hazard on the floodplain from an emergency management perspective.

Figure 5-3 General flood hazard vulnerability curves, Australian Institute for Disaster Resilience (AIDR) definition. Reproduced from Figure 6 in *Guideline 7-3: Flood Hazard* (AIDR, 2017b)



5.5.2 Provisional Flood Hazard Mapping – AIDR Categories

Provisional AIDR flood hazard mapping has been prepared for Lovers Jump Creek catchment for the 20%, 5% and 1% AEP and PMF events and is presented in Appendix B. The provisional mapping is based on direct flood modelling outputs and has not been revised to reflect the "true" flood hazard to take into consideration evacuation, isolation and other emergency management aspects.

5.5.3 True Flood Hazard Mapping – FDM and AIDR Categories

In assessing the true flood hazard, considerations have been made about aspects and characteristics of flooding and the flooding problem including the size of flood, rate of rise, effective warning times, risk to life, risk of isolation, duration of flooding and emergency access. A qualitative assessment is made in Table 5-1.

Table 5-1 Consideration of flooding aspects in defining the True Flood Hazard in the Study Area

Criteria	Weighting	Comments
Size of flood, increment in flooding between AEP events	Low	Generally, shallow overland flows, though relatively deep flows affecting the most vulnerable properties. Typically, small increment in flood depths between flood AEPs up to the 1% AEP. Relatively large increment in depth (>2m) between the 1% AEP and PMF.
Flood awareness in the community	High	Flood awareness is generally considered to be low in the study area, particularly in the context of overland flooding. Small flood events have been experienced by a limited number of residents particularly those living along the creeks and flow paths but a major flood event has not occurred in living memory.
Depth and velocity of floodwaters	Moderate	Most properties are generally affected by relatively shallow overland flooding. A limited number of properties would be impacted by high depth and/or flow velocity in the 1% AEP event.
Effective warning and evacuation times	High	No effective warning or evacuation time due to nature of short duration flash flooding.
Evacuation difficulties	Moderate/ High	A number of properties would experience high depths of flooding above floor levels in the 1% AEP event and rarer, although the number is limited. Given the nature of flash flooding in the catchment, flood events may catch residents unaware and, in their dwellings, particularly if a flood event occurred during the night. The flooding effectively renders the dwelling as a flood island as it becomes surrounded by floodwaters. There is likely to be little to no warning that a flood event would escalate from one where there is moderate risk from sheltering in place to a high risk situation. The large majority of properties in the catchment are flood-free or have rising road or overland escape route out of floodwaters.
Rate of rise of floodwaters	High	No effective warning or evacuation time due to nature of short duration flash flooding.
Duration of inundation	Low	Durations of inundation and isolation likely to be less than 6 (and mostly less than 3) hours.
Effective flood access	Low/Moderate	Many roads are undulating and may experience overland flooding themselves. Rising road access to areas outside the flow paths is present for virtually all roads but access to evacuation centres or medical centres may be limited. Main roads including Burns Road and Eastern Road are crossed by main flow paths.

The qualitative assessment above necessitates the flood hazard mapping to be updated to reflect the true flood hazard, which is mapped for the 1% AEP in Appendix B. The FDM and AIDR hazard extents (particularly the higher AIDR hazard categories of H4, H5 and H6) are revised to fill in gaps or "islands" between areas of the higher hazard ratings. This includes across affected building footprints, which are voided in the TUFLOW model and results, to emphasise the true flood hazard at those buildings.

5.5.4 Reconciling the Different Flood Hazard Definitions and Mapping for Planning Purposes

The FDM and AIDR flood hazard categories provide two alternative definitions for flood hazard. As mentioned previously, key planning policies including the Exempt and Complying Development Codes SEPP (2008) make reference to the flood hazard (specifically, high flood hazard) definition contained in the Floodplain Development Manual, refer to Clause 3.5(5) in the SEPP. Hence, it is expected that Council is bound to the FDM definition for the administration of flood planning controls in Ku-ring-gai LGA.

The AIDR definition is based on current best engineering practice and is the national guideline for flood emergency planning and management, providing the benefit of a higher discretisation of the flood hazards across the floodplain. Unfortunately, the AIDR definition does not include a "high" flood hazard and although there is some similarity in the delineation of the FDM high hazard and the AIDR delineations it is not a direct correlation. The AIDR flood hazard categories therefore cannot be treated as a subset of the FDM classifications.

There is value in Council considering both classifications in their floodplain management. One suggested option is to retain the FDM definition for flood planning purposes, while using the AIDR definition for emergency management. Notation on the relevant flood hazard maps would be required to define the purposes of each mapping classification.

It has been suggested in the industry that the FDM will shortly be revised to incorporate the nation-wide best practice and guidance as embodied in the AIDR. This may involve the updating of the flood hazard definition to match the AIDR. However, it is not expected that release of the revised FDM will occur in the near future (next few years), with draft versions likely to undergo an extensive consultation phase prior to a final version. Therefore, an interim approach such as that outlined above is recommended for consideration by Council.

Recommendation

- It is recommended that, in the interim before the release of the revised Floodplain Development Manual, Council retain the FDM (2005) definition of flood hazard for flood planning purposes, while using the AIDR definition for emergency management.
- Thereafter, if the revised FDM adopts the AIDR flood hazard classification, Council should consider the adoption of AIDR classification for flood planning purposes.

5.6 Flood Risk Precinct Mapping

Flood risk precinct mapping was derived for Lovers Jump Creek catchment to compliment the proposed updates to Council's floodplain planning and administration of planning and development controls, in particular the proposed flood planning matrix and updates to KDCP 2016. Refer to Section 9.3.5.3 and 9.3.5.4 for discussion. The flood risk precinct mapping is provided in Appendix B.

The risk precinct mapping aims to sub-divide the floodplain into zones of varying flood risk based on flood hazard and flood probability. As such, the flood risk precinct mapping combines the true flood hazard mapping for the 1% AEP event (FDM categorisation), as described in Section 5.5.1 and 5.5.3, with the PMF flood extent, which delineates the extent of the floodplain. The flood risk precincts are categorised as high, medium and low risk in accordance with the criteria in Table 5-2. Shallow depths less than 100mm have been filtered out from the Medium and Low risk precinct extents, and small, isolated patches of flooding which were not part of a main flow path have also been filtered out. Note that the flood risk precinct mapping is consistent with the flood modelling and allows for flows around buildings and does not consider potential flows through buildings. The flood risk rating for areas around a building typically applies at and to the building site.

Table 5-2 Flood Risk Precinct Definitions

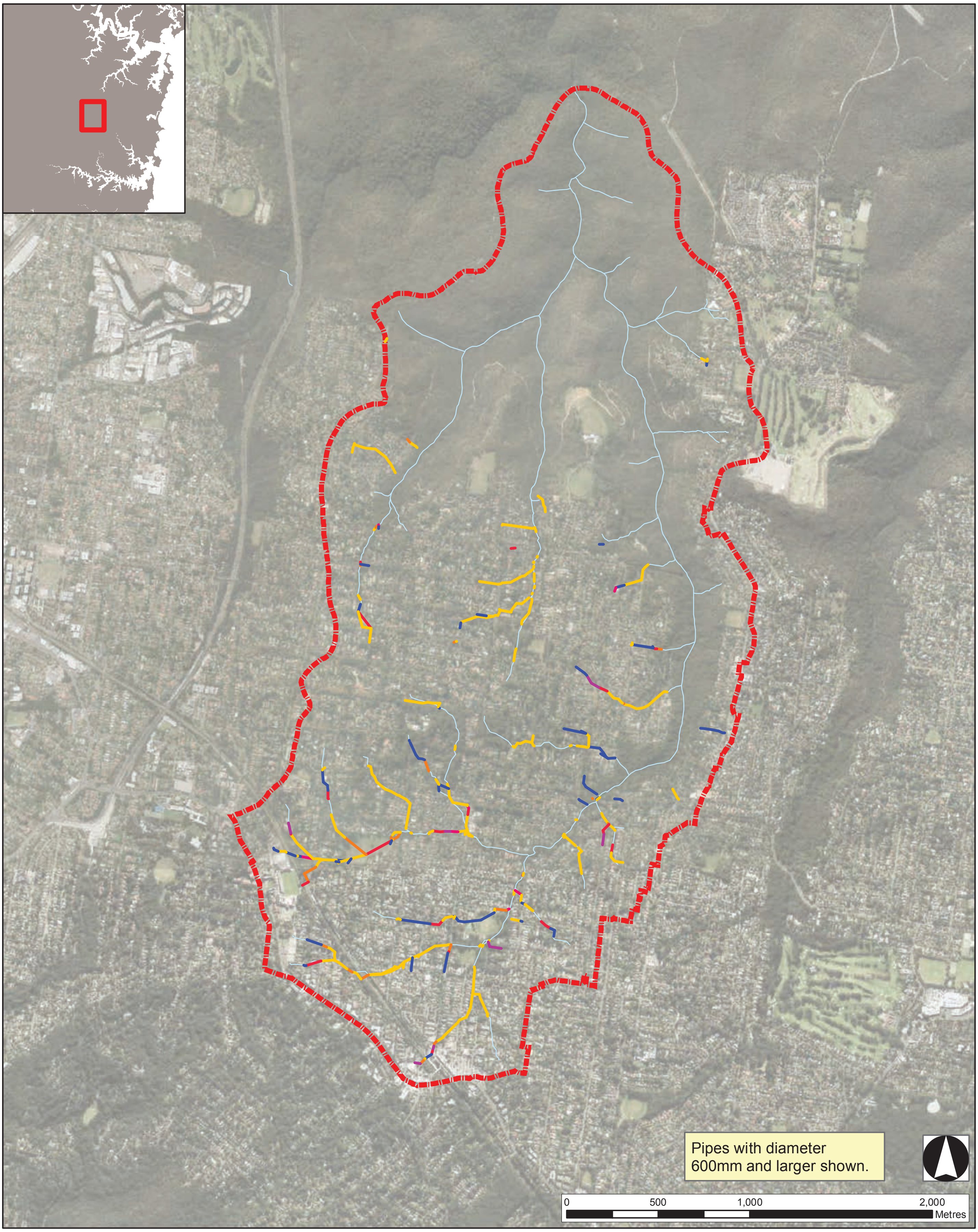
Risk Precinct	Description
High	The area of land that is subject to a high true flood hazard rating based on the *Floodplain Development Manual* categorisation, refer to Section 5.5.1 and 5.5.3 above. The High Hazard area describes areas where floodwaters present a danger to personal safety, could cause structural damage to buildings and where the resultant social disruption and financial losses could be high.
Medium	Land below the 1% AEP flood outline that is not in the High Flood Risk Precinct. Flood depths less than 100mm excluded.
Low	All remaining land within the floodplain (i.e. within the extent of the PMF) but not identified within either the High Risk or Medium Risk Precincts. Flood depths less than 100mm excluded.

5.7 Pipe Capacity Assessment

The TUFLOW model results were analysed to estimate the pipe capacity AEP for pipes of 600mm diameter and larger, to reflect the most frequent storm event AEP at which each pipe runs full. This is illustrated on Figure 5-4.

The existing drainage system capacity is observed to run full for the large majority of the system in frequent events such as the 20% AEP. There are a number of pipes which exhibit a capacity of up to 1% AEP, however, these pipes are typically running fairly full (e.g. 80% full) in all events and hence would not be able to accept a significantly higher flow.

Implications of these findings are that localised drainage upgrades for flood mitigation are unlikely to provide significant improvements to potential flood impacts unless the main drainage lines are also upgraded.



Legend

Pipe Capacity AEP
- <0.2EY
- 0.2EY
- 5% AEP
- 2% AEP
- 1% AEP
- >1% AEP

Study area

Watercourse

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Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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TITLE Existing Pipe Capacity

PROJECT Lovers Jump Creek Floodplain Risk Management Study and Plan

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA159900	Figure 5-4	1	1
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6. Community Consultation

6.1 Public Exhibition

As a part of the FRMSP project, the Lovers Jump Creek Flood Study Review report (Jacobs, 2018) was placed on public exhibition for the period of 29 March to 29 April 2018.

This Draft FRMSP was placed on public exhibition for the 4 week period up to 8 May 2019, following review and comment from the Ku-ring-gai Flood Risk Management Committee (FRMC). A community presentation and forum was held during the exhibition period, on 10 April 2019, at Council chambers.

6.2 Flood Risk Management Committee

Ongoing consultation with FRMC the has been scheduled during the course of the FRMS, and has previously included discussion on potential flood mitigation works and selection of options for detailed modelling. Consultation with the FRMC was also undertaken in June 2019 to discuss the written submissions from the community on the Draft FRMS and updates for the Final FRMSP.

6.3 Community Survey

Additional consultation in the FRMSP included advertising of the study on Council's website and via targeted newsletters. A community survey has been distributed in addition to being posted on Council's website. The survey asks residents about their awareness of flooding in the catchment, works that may have worsened or improved flooding, and views on development types which should be protected from flooding, ranking of floodplain management options and measures that Council should undertake to improve flood risk on their property.

A total of 108 responses have been received. The survey, locations of responses and summary of responses to key questions are presented in Appendix C. Findings from the survey include:

- 69% of respondents said they are aware or have some awareness of flooding in the catchment, although review of the written responses indicates that the real threat and risk of flooding might be realised mainly by the residents living in the vicinity of the main flood problem areas and who have experienced a significant flooding event.
- Approximately 30% of respondents believe that works undertaken in the catchment have negatively impacted on flooding conditions, mainly including building activities, but also obstruction to overland flows and upgraded roads.
- A small proportion of respondents believe that creek works and upgraded roads/culverts have improved flooding.
- Overall, high priority was placed on protecting residential properties and critical infrastructure from flooding; medium priority on emergency facilities, community facilities and commercial properties, and low priority on heritage items and recreational facilities.
- In terms of priority of flood management options, higher priority was placed on protecting residents and businesses from flooding, a moderate focus on providing flood free emergency access and support from SES, with lower priority on flood warning and flood signage.
- In terms of flood management measures and response from Council, most respondents said improved drainage infrastructure and flood mitigation works should be provided. The next highest ranked measures included (in order) zoning and building/development controls, upgrading roads and then public awareness and education.

Key points and issues from the survey responses are discussed below:

- Increased development density and formalised street drainage has increased creek flood response. Although perception by other residents that mandatory onsite stormwater detention on new properties is having an effect on reducing the occurrence of flooding. Formalising street drainage has helped in some areas.

- Key road crossings are under capacity and have a damming effect on upstream flows.
- Overflows due to lack of road and drainage clearing, blockage of drainage channels.
- Creek works in some areas appears to have helped locally. Others suggest further creek management works in other locations.
- One resident suggests better flood warning system with rain gauging in the catchment, flood modification works, otherwise, flood protection measures and increased education. Better development controls system, such as a planning matrix for developments, should be implemented. Develop or assist with development of flood evacuation strategy including SES access to Council flood mapping. Better flood education of residents including flood evacuation routes identified and properties on the flood path made aware of the evacuation routes.
- One resident stated that the existing flood risk is low and mitigation measures unnecessary. Best to focus on managing the increased development in the catchment and increased flooding from this.
- Another resident believes there is no risk and funding should be spent on other priorities
- One resident suggests the best approach is to relocate existing at risk properties and businesses rather than trying to protect them where they are.
- One resident suggests that no flood notifications to properties be made until Council has rectified existing drainage problems
- View by several residents that properties and mapping should not be denoted by “theoretical” flooding and rather by actual flooding. Some have based their awareness of flooding in the catchment on historic flood events, however, these are estimated to be small magnitude/higher frequency flood events. No large/rare flood events have occurred in the catchment in recent history.
- Another resident suggested a counter-view that Council should advise affected residents and property owners of their potential flood affectation (and explain what this is, what should be expected and what a resident or property owner can do to reduce their risk) on Section 149 notifications.
- There are concerns about condition of creek/creek banks eroding, exposing sewer lines by several residents.
- Some residents in proximity to the identified flood problem areas have an appreciation to the risk to life posed by flooding along parts of the creek system. Some are very concerned about the impact of flooding on their house (including impacts from actual historic flood events) such as direct damage to property, ongoing effects of flooding to the property such as mould and impacts to health. Concerns that Council is not providing sufficient support in particular from development services to manage risks of flood damage and to health.
- One resident mentioned that online flood mapping in pdf format does not provide a sufficiently detailed illustration of flooding.

7. Local Emergency Planning Context

7.1 Local Flood Plan

The Ku-ring-gai unit is the local SES unit responsible for the Ku-ring-gai area. The unit is located in the Lovers Jump Creek catchment, off Esk Street, North Wahroonga. 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.

7.2 Flood Warning Systems

There is currently no flood warning system, including any stream gauging, specific to the Lovers Jump Creek catchment. The catchment response time to rainfall events is very short and flooding is expected to occur shortly after the start of a storm event with a short time to peak (typically less than an hour in the developed parts of the catchment). Hence, a catchment specific flood warning system is not considered 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).

Relevant to Lovers Jump Creek, BOM issues forecasts and warnings of possible flood events across Australia in the form of generalised flood warnings (Flood Watch) that flooding is occurring or is expected to occur in a particular region, including flash flooding and riverine flooding. Severe Thunderstorm Warnings and Severe Weather Warnings are also issued when significant weather is expected to occur in certain areas and which may cause flash flooding.

BOM also issues Flood Warnings of minor, moderate or major flooding in areas where specialised warning systems have been installed, although these are generally for main river flooding and are not directly relevant to Lovers Jump Creek.

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.

7.3 Emergency Response Mapping

Emergency response mapping was previously prepared for the 1% AEP and PMF events as a part of the Lovers Jump Creek Flood Study Review (Jacobs, 2018). The mapping is reproduced in Appendix D.

Areas within the catchment have been classified based on the floodplain risk management guideline *Flood Emergency Response Planning – Classification of Communities* (OEH, 2016a). The classification indicates the relative vulnerability of different areas of the catchment and considers the ability to evacuate certain parts of the community. The categories identified included:

- Indirectly Affected: Areas which are not flood affected and whose access is not cut-off, but may be affected by flood impacts to services and infrastructure in the area.

- Rising Road Access: Areas that become inundated by flooding which can be evacuated by vehicles on roads with continuously rising grade to high ground.
- Overland Escape Route: Areas where vehicular access is cut-off but can be evacuated on foot to high ground.
- High Trapped Perimeter: Areas which are partially or wholly above the peak flood level but whose evacuation routes are cut-off. These areas are not surrounded by flood waters but there may be a physical barrier preventing evacuation overland.
- High Trapped Island: Areas which are above the peak flood level but surrounded by flood waters and whose evacuation routes are cut-off.
- Low Trapped Island: Areas which are surrounded by flood waters during early stages of the flood, and which become submerged as the flood peaks.

The guideline is largely geared towards classification of communities in mainstream floodplains with longer flooding response times, hence some assumptions were made to suit the shorter-duration flash flooding in the Lovers Jump Creek catchment:

- Given the relatively shallow flows in the majority of overland flow paths which would not necessarily be hazardous, areas of high flood hazard were used to indicate where flooding may pose a risk to life and hence where evacuation would be required.
- Access routes were deemed to be cut-off if fully crossed by areas of high flood hazard. Roads with patchy high hazard areas were considered to be accessible by heavy vehicle or on foot on the road verge.
- Property boundary fences were assumed to be barriers to overland escape routes on foot as they may be too high for some members of the community to climb.
- Some properties are located in depressions in the terrain and their dwellings become surrounded by high hazard flooding. While there may be a rising road evacuation route available, due to the rapid rise in flood level, there may be insufficient warning time before the dwelling is surrounded by deep floodwaters and subsequently inundated. These areas were treated as Low Level Islands since there was no information available on habitable floor levels of these dwellings at the time of map preparation.
- Properties where the dwelling is surrounded by floodwaters but have some dry land adjoining the dwelling, were deemed to be High Flood Islands.
- Properties whose street frontage is fully blocked off by high flood hazard areas in the street but which were otherwise not affected by high flood hazard areas, were classed High Trapped Perimeter. Similarly, properties located on a cul-de-sac which is cut off by high flood hazard areas, were classed as High Trapper Perimeter.
- Properties with either vehicular or foot access to the street were classed **Indirectly Affected**.

8. Defining the Flood Problem

8.1 Flood Problem Areas

Flooding problem areas have been identified in the flood study review. These have been updated with consideration of the AIDR flood hazard categorisation and are summarised in Table 8-1. These are locations where there is elevated potential for flooding to cause a hazard to people, damage to properties and disruption to transportation or evacuation routes. AIDR flood hazard categories higher than (and including) H2 are unsafe for small vehicles. **AIDR flood hazard categories higher than (and including) H5 have the potential for damage to buildings, and possible failure of less robust designs of buildings**. H5 flood hazard conditions are widespread in the PMF event and are not confined to the locations identified below, and many buildings are prone to damage and/or failure in the PMF.

Table 8-1 Flooding trouble spots

Location	Description
Selected properties on The Chase Road, including upstream properties near Eastern Road (along Lovers Jump Creek tributary)	Access may be cut-off due to creek overflows over private driveway crossings. H3-H4 flows around dwellings on the northern side of the creek in the 1% AEP. >H5 flows around dwellings on the northern side of the creek in the PMF.
Selected properties on Cudgee Street and Tennyson Avenue	Access cut-off due to creek overflows over private driveway crossings. Risk to dwelling and occupants on Cudgee Street property. H4 rated flooding in the 20% AEP. H5 and H6 flooding surrounding the dwelling in 5% AEP and rarer.
Selected properties on Alice Street	Two existing dwellings situated immediately adjacent to creek and form a choke point for flows. One dwelling protrudes into floodway area and affected by H5 hazard flooding in 5% AEP and rarer. Other dwelling also exposed to high hazard flooding to lesser degree.
Selected properties on on Chilton Parade near Raymond Avenue and Davidson Avenue	Risk to dwelling and occupants due to high hazard flooding encroaching on the dwelling in frequent events (e.g. 20% AEP). Buildings experience H5 and possibly H6 hazard flooding in events rarer than 5% AEP.
Selected properties on near the Burns Road crossing	Access from Burns Road cut-off and high hazard flooding encroaching on dwellings. H5 flood hazard affecting the side of one building in the 1% AEP. A number of buildings affected by H5 and H6 flood hazard in the PMF.
Selected properties on between Challis Avenue and The Chase Road	Risk to dwelling and occupants due to high hazard flooding encroaching on the dwelling in events as frequent as the 10% AEP. H5 flooding affecting one building in the 1% AEP and 5 buildings with >H3 hazard. A number of buildings affected by H5 and H6 flood hazard in the PMF.
Selected properties on in sag points on Eastern Road north and south of Karuah Road	Properties on high side of the road affected by flood depths of 0.8 – 1m in frequent events (e.g. 20% AEP) and up to 1.2m in the 1% AEP, generally rated H3 flood hazard. Upper value of H5 flood hazard to parts of buildings in the PMF.
Selected properties on upstream of North Shore Railway embankment (Eulbertie	Properties affected by flood depths at the dwelling of up to 1.3m in the 1% AEP and up to 4.8m in the PMF. H2-H3 flood hazard in up to 5%

Avenue, Winton Street and Lowther Park Avenue)	AEP. H4 flood hazard in the 1% AEP and H6 hazard in the PMF, although flow velocities are generally low. In a high culvert inlet blockage scenario (75% blockage) for the railway culvert near Brentwood Avenue, properties would be affected by flood depths at the dwelling of up to 1m in the 1% AEP.
Banks Avenue, North Turramurra	Sag point would not be passable in the 20% AEP event due to depths of flow exceeding 300mm, cutting off access to properties at the northern end of Banks Avenue. Could be potentially considered a drainage issue rather than a flooding issue.
Roads	
Eastern Road near Chilton Parade	Road cut off in 20% AEP event with depths up to 0.4m (H2 flood hazard). High hazard flooding (H5) in 1% AEP with depths up to 0.9m.
Challis Avenue sag point	Road cut off in 20% AEP event with depths exceeding 0.3m (H2 hazard). High hazard flooding (H5) in 1% AEP with depths up to 0.9m.
Tennyson Avenue sag point	High hazard flooding (H3-H4 hazard) over the road in 10% AEP with depths to 0.4m. High hazard flooding (H5-H6) over the road in 1% AEP with depths exceeding 0.7m.
Burns Road sag point	Road cut off in 10% AEP event with depths exceeding 0.3m (H2 hazard). High hazard flooding (H5) over the road in 1% AEP event with depths to 0.8m.
Other roads	The roads listed above are the most critical locations for flood problems and vehicle flood hazard. There are numerous other roads which may be unsafe for vehicular traffic in even frequent events, with >H2 flood hazard. Refer to AIDR flood hazard mapping in Appendix B.

8.2 Identified High Hazard Properties

Seven properties with specific high hazard flooding conditions were identified, with exposure to high hazard conditions (AIDR classification) in up to the 1% AEP. These are summarised in Table 8-2. The properties were identified in relation to the AIDR flood hazard to consider the potential risk of flooding damage to the dwelling, and hence a potential risk to safety of occupants.

Properties with high flood hazard (FDM categories), floodway or flood storage, which may be subject to planning controls, have not been specifically identified in this task.

Table 8-2 Identified properties* with dwellings affected by floodway and high hazard flooding in up to 1% AEP event

Property	Description
Property on Cudgee Street, Turramurra	Main flow path/s H5 and H6 hazard flooding surrounding the entire dwelling in 5% AEP and rarer.
Property on Cudgee Street, Turramurra	North-west corner of dwelling protruding into main flow area and affected by H5 and H6 hazard flooding in 5% AEP and rarer.
Property on Alice Street, Turramurra	Annex on eastern side of dwelling protruding into main flow area and affected by H5 hazard flooding in 5% AEP and rarer.
Property on Chilton Parade, Warrawee	H5 flood hazard in creek channel immediately adjoining dwelling with likely exposure of southern side of dwelling. In 5% AEP and rarer.
Property on Chilton Parade, Warrawee	H5 flood hazard in creek channel immediately adjoining dwelling with likely exposure of southern side of dwelling. In 5% AEP and rarer.
Property on The Chase Road, Turramurra	South-eastern corner of dwelling immediately adjacent to creek channel exposed to H5 flow conditions in 5% AEP and rarer.
Property on Burns Road, Turramurra	North-western side of dwelling exposed to H5 flows in 5% AEP and rarer.

* The full address details for the specific properties identified above have been provided to Council and are omitted from this report for confidentiality. Council should be contacted to obtain flood information on particular properties on these streets and in other areas of the study area.

Note that there are numerous buildings in the study area which are exposed to high hazard flooding in the PMF and which have not been specifically identified.

H5 and H6 hazard ratings are referred to as they relate to the susceptibility of typical residential buildings to damage and potential failure. These ratings were developed and are described by Smith et. al. (2014) as:

- H5: Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6: Unsafe for vehicles and people. “All building types” considered vulnerable to failure.

Failure or damage to buildings may occur due to a range of forces that might affect building stability including hydrostatic actions, hydrodynamic actions, debris actions, wave actions from wind and wakes, and erosion and scour due to flood actions (reference: Construction of Buildings in Flood Hazard Areas code (ABCB, 2013)).

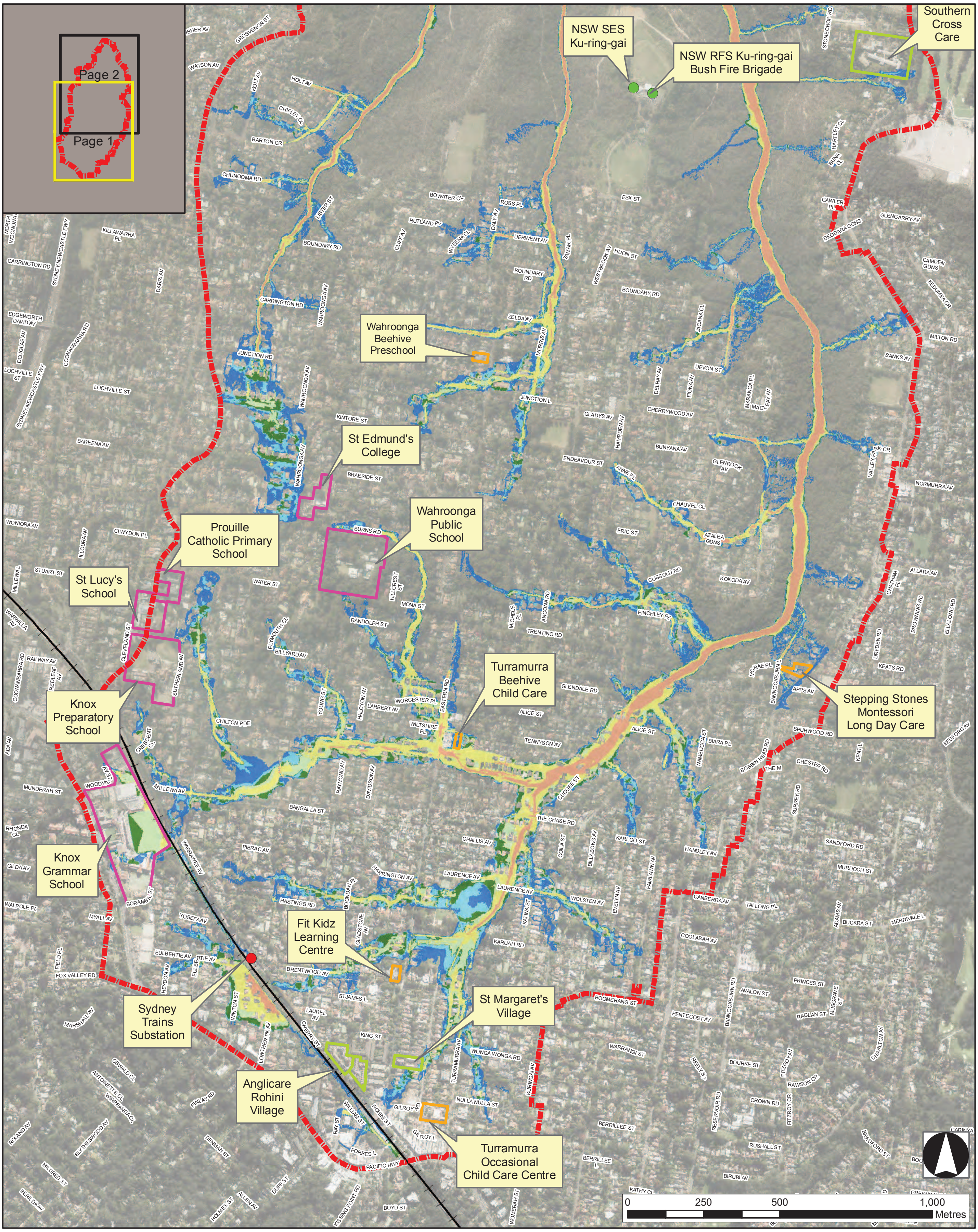
While Smith et. al. (2014) notes the generalised building susceptibility to H6 flood conditions above, they do note that in real life flooding events there have been some building types which were able to withstand the flood loadings and forces e.g. reinforced concrete buildings (hotels, etc.) in recent tsunami events in Thailand and Japan. However, it is not known which, if any, existing or proposed residential buildings in Lovers Jump Creek catchment are designed to this engineering standard.

Note that the expected short duration of flooding in Lovers Jump Creek catchment may reduce the level of damage to structures due to shorter time of exposure compared to flooding in other catchments, however, the degree of reduction is difficult to quantify based on the available information.

8.3 Mapping and Assessment of Sensitive Properties

Sensitive properties and critical infrastructure have been identified in the catchment. Certain types of properties may require specific evacuation considerations due to the vulnerability of its occupants, such as schools and pre-schools, and aged care facilities. Critical infrastructure impacted by flooding may have effects on the recovery and functioning of the community following a flood event.

The sensitive properties and critical infrastructure are mapped on Figure 8-1. The AIDR flood hazard in the PMF event is mapped on the figure.



Legend

- School
- Child Care Centre
- Aged Care Facility
- Emergency Services
- Substation
- Study area

Hazard Category (AIDR)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

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TITLE	Mapping of Sensitive Properties with PMF Flood Hazard			
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan			
DRAWN LC	PROJECT # IA159900	MAP # Figure 8-1	REV 1	VER 1
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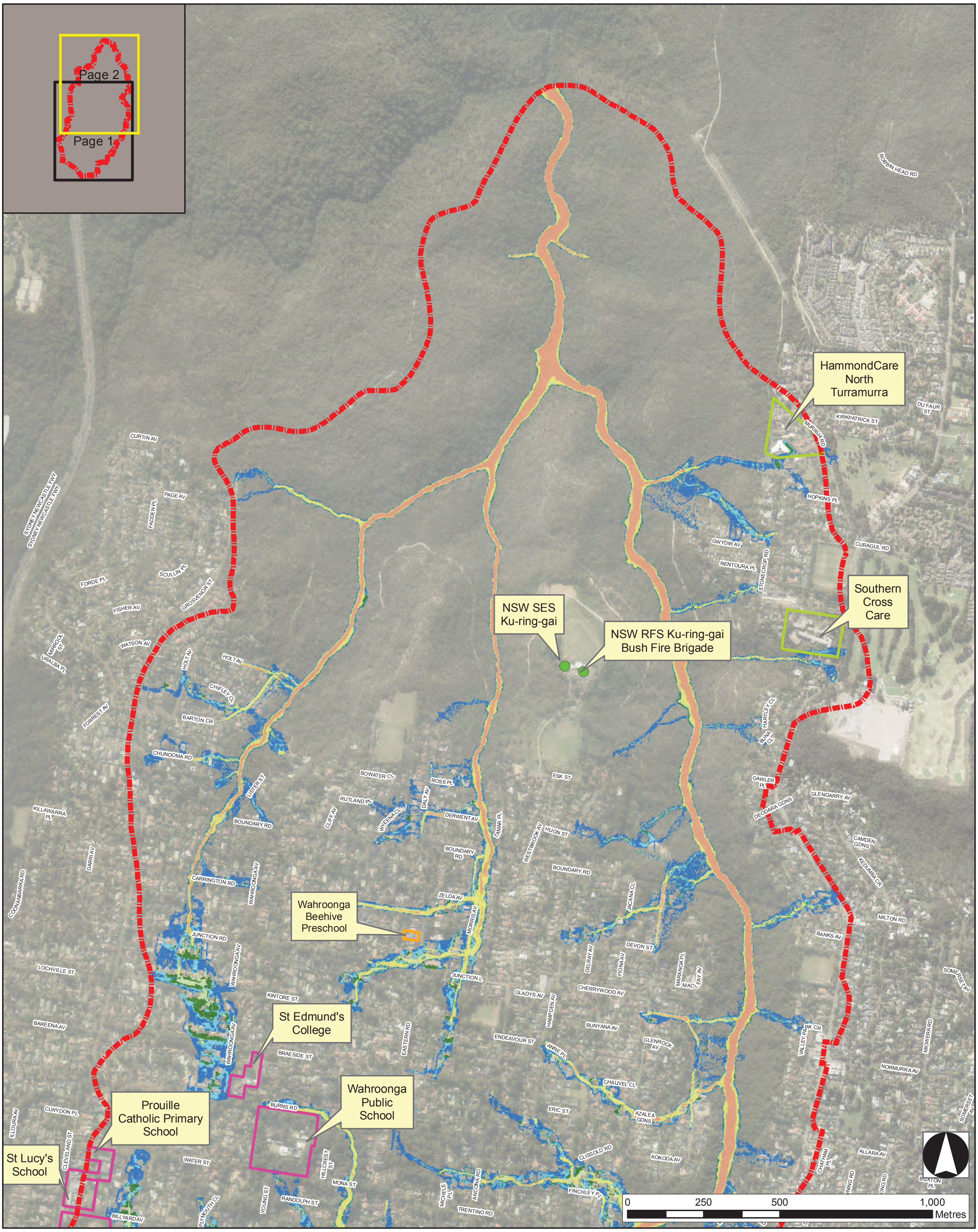

Legend

- School
- Child Care Centre
- Aged Care Facility
- Emergency Services
- Substation
- Study area

Hazard Category (AIDR)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

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Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SHEET	Page 2 of 2 — GDA 1994 MGA Zone 56
TITLE	**Mapping of Sensitive Properties with PMF Flood Hazard**
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan
DRAWN	LC
PROJECT #	IA159900
MAP #	Figure 8-1
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The mapping on Figure 8-1 indicates that sensitive properties or critical infrastructure are generally not directly impacted. Three properties are identified as having relatively minor impacts:

- Knox Grammar School: car park/open area next to aquatic centre affected by H3 hazard flooding in 1% AEP – potential hazard to vehicles and pedestrians. Up to H5 hazard in PMF on oval and buildings to north of oval with high flood depths of 2m affecting lower levels of these buildings. Most of school is flood-free.
- Turramurra Beehive Child Care, Tennyson Avenue Turramurra: minor impact in PMF only. Localised areas of H2 and H3 hazard in PMF.
- HammondCare aged care facility, North Turramurra: minor impact in PMF only. Localised areas of H3 hazard in PMF adjacent to one building.

Given the typically short duration of flooding in the catchment and typically no direct affectation by flooding in up to the PMF it may be considered appropriate that occupants of the sensitive properties are not evacuated and that they shelter in place during the flood event. Development of a flood management plan, which describes the flood hazard and identifies actions and procedures during a flood event, for Knox Grammar School is recommended.

8.4 Current and Future Land Use Flood Compatibility

The current land zoning as per KLEP 2015 is mapped on Figure 2-3. As previously mentioned, land use is predominantly low density residential with some medium density residential and commercial land use. Review of the land zoning, which reflects future approved land use, and the sensitive properties in Section 8.3 in conjunction with the design flood mapping indicates that there is generally no significant conflict or incompatibility between current and future land use and flood conditions in the catchment. There are properties currently with high hazard or floodway areas on the lot. These do not necessarily require rezoning but other planning controls and response measures may be required to address flood risk at existing and future development.

KDCP, reviewed in Section 4.3.5, requires car parking areas to not be located in overland flood areas where flow conditions may result in vehicles from becoming buoyant and potentially washing away (assumed in up to 1% AEP flood event). There are several existing parking areas within flood zones:

- Car park off Eastern Road at Turramurra Eastern Road shops (opposite Hastings Road)
- Part of northern car parking area in Knox Grammar School.

Council should consider retrofitting of bollards etc. to help prevent vehicles being washed away and potentially becoming hazardous flood debris in downstream areas.

8.5 Flood Evacuation Considerations

Flooding in the study area may generally be considered to be flash flooding in nature with rapid rates of rise, fast catchment hydrologic response and minimal warning time. The study area is interspersed with numerous flow paths which pass through properties and in roads. Most properties are affected by minor flooding which may cause damage to the dwelling but are unlikely to pose a risk to life. Hence in most cases due to short durations of flooding it would be appropriate for occupants of properties with lower flood hazard properties to shelter in place in the dwelling. Self-evacuation may place people into hazardous flooding conditions as they try to navigate to designated evacuation centres.

Occupants of high flood hazard properties would need to evaluate the appropriateness of a shelter-in-place plan, depending on the degree of the flood hazard, building structural integrity and depth of flooding above highest floor level. The emergency response mapping discussed in Section 7.3 provides guidance to emergency services on the most vulnerable properties for evacuation requirements.

8.6 Flood Damages Assessment

8.6.1 Overview

Flood events may cause damage to property with significant costs to property owners and insurers. The damage may occur due to floodwaters affecting the building façade and interior (weatherboard exterior, gyprock interior walls, carpets), electrical wiring and building contents and other property outside the dwelling (vehicles, contents of sheds and garages, etc). Structural damage to the dwelling can also occur in extreme flood conditions.

The cost of flooding is estimated to identify the magnitude of the event to a community, and subsequently provide a benchmark for the viability of potential measures for mitigating the impacts of flooding. This section describes the estimation of flood damage costs in the study area, focussing on residential and commercial properties.

8.6.2 Flood Damages Categories

The type of damages associated with floods is shown in Figure 8-2 (*Floodplain Development Manual¸ NSW Government 2005*). The cost of damage caused by floods may include tangible and intangible components. Tangible damage costs include the direct material damage and rebuilding costs to existing homes, property and infrastructure, and also the indirect costs associated with the social disruption of the floods, such as: clean-up; lost income during and after the flood event; and the cost of alternative accommodation for people displaced by the floods. A monetary value can be readily placed on the direct damages, which are the focus of this assessment.

Other social and environmental damages to which a monetary value cannot be placed are intangible damages, which include emotional stress of the flood event, injury and loss of life. While these damages cannot readily be incorporated into an economic feasibility assessment of mitigation options, it is still important to consider the potential for these intangible damages, particularly if there is an elevated risk of loss of life.

8.6.3 Estimation of Direct Tangible Flood Damage Costs

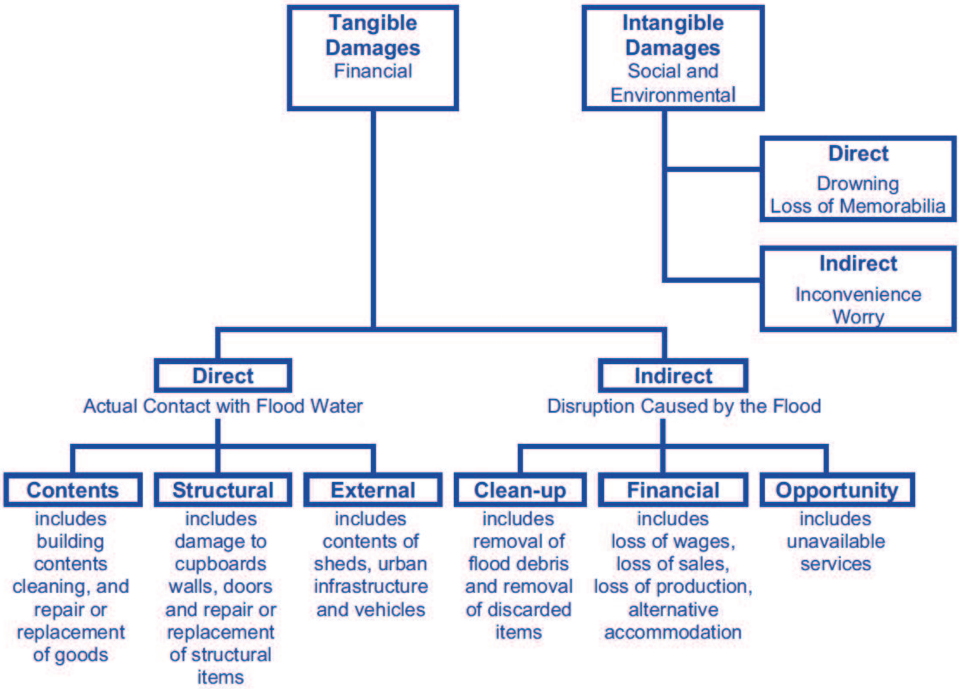
8.6.3.1 Property Information

Residential and commercial properties were identified and characterised based on knowledge and site observations of the study area.

Residential house types in the study area are generally a mixture of one and two storey houses. In floodplains with deep flooding (riverine floodplains) two storey houses would experience a second increment of flood damages as floodwaters rise and affect the second storey. Flooding in the Lovers Jump Creek catchment is typified by overland flows and shallow overbank flooding from mainstream watercourses, affecting the first storey of the house only. For the purposes of this assessment all houses were assumed to be single storey.

Flood damages are estimated based on flood depth in relation to building floor level. Floor levels were surveyed for approximately 90 selected buildings based on high hazard flooding in the 1% AEP. Remaining floor levels for residential properties were assumed to be 0.2m above the highest ground level (obtained from LiDAR data) at the building. Floor levels of non-residential and commercial buildings were estimated based on LiDAR and site observations. The applicable flood level at each building for flood damages estimation purposes was assumed to be the highest flood level for each flood event AEP.

Figure 8-2 Types of Flood Damage



8.6.3.2 Residential Property Damages

Residential flood damages guidelines and a calculation spreadsheet was developed by the NSW Office of Environment and Heritage (OEH, 2016b). The calculation spreadsheet includes a representative stage-damage curve derived for typical house types in the study area to estimate structural, contents and external damage. The amount of damage is based on the flood inundation depth, for a suite of annual exceedance probability events ranging from the 20% AEP event up to the PMF. These values are then summed to provide a total damage for each flood event analysed. The AEP of the PMF in the study area is assumed to be 1 in 10,000,000.

The stage-damage curves assume some flood damages for flood levels below the floor level. This approach accounts for flood damages to parts of the dwelling and property below the floor level and ensures that damages are not underestimated.

Various input parameters are used to define the flooding and location characteristics which derive a location specific damage curve. The parameters adopted for the study area are presented in Table 8-3. Unless otherwise stated, default parameters have been used (as recommended in the *Residential Flood Damage Guidelines* (OEH, 2016b)).

The OEH stage-damage curves within the spreadsheet are derived for late 2001 and have been updated using an Average Weekly Earnings (AWE) factor of 1.76 to November 2017. The results of the residential property flood damages assessment are provided in Section 8.6.3.5.

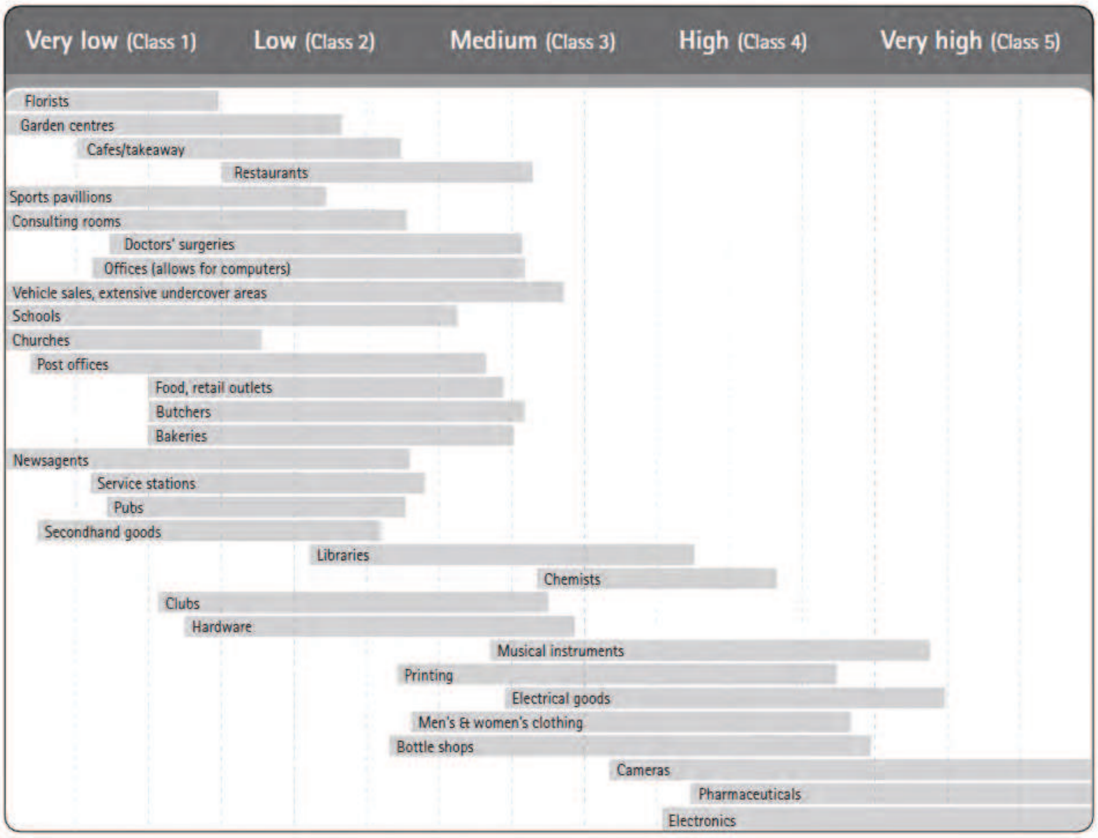
Table 8-3 Input parameters for damage calculations

Parameter	Value	Comment
Regional Cost Variation Factor	1.0	Appropriate value for a major city (Sydney)
Post flood inflation factor	1.15	
Typical duration of immersion	1 hour	
Building damage repair limitation Factor	0.85	Represents short duration flood (<12 hours) where some materials can recover from short periods of flooding and may not need replacement
Typical free-standing house size	320m^2	
Contents damage repair limitation Factor	0.75	Guidelines suggest a value of 0.75 for short duration floods
Effective warning time (hrs)	0	Only marginal improvement in damages cost when effective warning time is increased to 1 hour as a sensitivity assessment
Level of flood awareness	Low	Flood warning times are nil and it is assumed that residents are typically not aware of potential damage of flood waters and the need to act.

8.6.3.3 Commercial Property Damages

No information on commercial property flood damage costs in NSW was found during a literature search. The most relevant information obtained was published in the Queensland Government Natural Resources and Management Department's *Guidance on the Assessment of Tangible Flood Damages* (2002). This document contains flood damage curves for commercial properties over a range of property footprint areas and degrees of susceptibility to flooding and is based on information published in *ANUFLOOD: A Field Guide* (Centre for Resource and Environmental Studies (Australian National University), 1992). Different types of commercial and non-residential properties were assigned a susceptibility rating, as illustrated in Figure 8-3.

Figure 8-3 Damage categories for commercial properties (reproduced from *Guidance on the Assessment of Tangible Flood Damages* (Qld. Government, 2002)



The stage-damage data were factored up by a value of 1.76 from 2002 dollars to current values based on Average Weekly Earnings (AWE) for November 2017, similar to the approach adopted for the residential flood damages.

An additional multiplication factor of 1.6 was applied based on guidance in *Rapid-Appraisal Method (RAM) for Floodplain Management* (Victorian Government Natural Resources and Environment, 2000), which suggests that the ANUFLOOD values are underestimated and should be increased by 60%.

A total of 29 commercial and non-residential premises which are potentially flood-affected were identified in the floodplain by Streetview and ground truthing. The results of the commercial and non-residential property flood damages assessment are provided in Section 8.6.3.5.

8.6.3.4 Damages to Utilities and Infrastructure

Utilities and infrastructure in the study area which are susceptible to flooding include:

- Roads;
- Railway, including the railway formation and internal services such as signalling and electrical systems; and
- Other public infrastructure such as sewage pumping stations, electrical transformer boxes, etc.

The potential cost of damage to roads is difficult to estimate for the study area, as the nature of flooding in a significant portion of study area is typically due to relatively shallow, short-duration flows, although road damage is possible for roads conveying higher velocity overland flows (e.g. Eastern Road, Chilton Parade) and at major waterway crossings (e.g. Burns Road, Tennyson Avenue).

The roads damages guidance published in the references cited in this study are based on longer-duration mainstream flooding damages and hence are likely to significantly overestimate the flood damages to roads in the study area. Hence these costs have not been included in this assessment.

The damages to the railway and other utilities were not estimated as these damages are unlikely to be reduced by any potential mitigation options, and hence, are inconsequential to the feasibility assessment of the mitigation options.

8.6.3.5 Damage Assessment Results

The most convenient way to express flood damage for a range of flood events is by calculating the Annual Average Damage (AAD). The AAD is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. The AAD for the existing case then provides a benchmark by which to assess the merit of flood management options.

The 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.

The assessment was performed with the recommended protection level of 0.5m for mainstream flooding and 0.3m for overland flooding, and by using nominal floor levels also (no freeboard applied). External building damages were assumed to start accumulating when floodwater was within 0.5m of the nominal floor level or floor level minus protection level (i.e. the property was impacted) for buildings affected by mainstream flooding, and when floodwaters are within 0.3m of the floor level for those affected by overland flooding.

Table 8-4 summarises the residential damages, and Table 8-5 summarises the commercial and non-residential damages. The residential and commercial property flood damages include direct damages to property such as structural, external and contents damage, and indirect damages such as clean up costs and accommodation/ loss of rent costs. Infrastructure damage, vehicular damage and intangible damages are not included.

The flood damages here are “potential flood damages”, which may be reduced with increased flood awareness and preparedness in the community. The Net Present Value of the flood damages assumes a 7% discount rate over a 50 year life, as per the OEH (2016b) guidelines. The damages are in 2018 dollar values.

The total AAD (combined mainstream and overland flooding, residential and commercial properties) is $3.18 million when nominal flood levels are used, increasing to $5.88 million when the property freeboard is allowed for in the flood protection level.

Table 8-4 Estimated Tangible Flood Damages for Residential Properties

Event	Nominal Flood Levels		Nominal Flood Levels Plus Freeboard	
	Number of properties flooded above floor level	Estimated Flood Damage	Number of properties flooded above protection level	Estimated Flood Damage
Overland Flooding				
20% AEP	33	$4.33M	73	$7.93M
10% AEP	41	$4.96M	84	$9.18M
5% AEP	68	$8.30M	154	$16.40M
2% AEP	85	$10.09M	182	$19.47M
1% AEP	101	$12.41M	211	$22.88M
PMF	402	$45.53M	567	$65.18M
AAD		**$2.12M**		**$3.87M**
Mainstream Flooding				
20% AEP	11	$1.13M	19	$2.14M
10% AEP	13	$1.41M	24	$2.68M
5% AEP	18	$2.05M	29	$3.56M
2% AEP	27	$2.82M	35	$4.22M
1% AEP	29	$3.29M	45	$5.41M
PMF	63	$9.11M	64	$10.31M
AAD		**$0.55M**		**$1.12M**

Table 8-5 Estimated Tangible Flood Damages for Commercial Properties

Event	Nominal Flood Levels		Nominal Flood Levels Plus Freeboard	
	Number of properties flooded above floor level	Estimated Flood Damage	Number of properties flooded above protection level	Estimated Flood Damage
Overland Flooding				
20% AEP	2	$0.16M	2	$0.79M
10% AEP	2	$0.37M	3	$1.23M
5% AEP	3	$0.78M	6	$1.77M
2% AEP	4	$1.16M	8	$2.24M
1% AEP	5	$1.47M	11	$2.69M
PMF	19	$4.78M	20	$6.51M
AAD		**$0.15M**		**$0.43M**
Mainstream Flooding				
20% AEP	0	-	0	-
10% AEP	0	-	0	-
5% AEP	0	-	0	-
2% AEP	0	-	0	-
1% AEP	0	-	0	-
PMF	1	$0.03M	1	$0.05M
AAD		**<$0.001M**		**<$0.001M**

8.6.4 Application of Flood Damage Curves to the Study Area

It should be noted that the flood damages estimated for the study area need to be considered with care. The OEH residential stage-damage curves recommended for use in NSW have been developed based on flood damages from low-land mainstream/ flooding, where flood surface gradients are relatively flat and the depth of flooding within a dwelling is fairly uniform. Due to the steep terrain in parts of the study area and the generally shallow nature of overland flows (particularly in the more frequent flood events), flood levels may vary greatly on a property and damage may be concentrated on the uphill/upstream side of a dwelling. Flood depths are also relatively shallow so the damage incurred may be less than those suggested by the curves. Nevertheless, the stage-damage curves provide the best guidance available for estimating flood damages given the scarcity of actual flood damage data to residential properties on highland overland flow paths and have been adopted for the purposes of this study.

8.6.5 Summary

Flood damages in the Lovers Jump Creek catchment is primarily attributed to residential dwellings that are impacted by overland flooding. In terms of residential properties, there are 44 properties (combined overland and mainstream flooding) that are estimated to experience above floor flooding (nominal flood levels) for the 20% AEP event and this number increases to 130 properties for the 1% AEP event. In the PMF, 465 properties are estimated to experience above floor flooding, with damages reaching $54.64 million. The total flood damages for the 20% to 1% AEP events, however, range from $5.46 million to $15.70 million when considering flood damages using nominal flood levels only. The AAD for the study area based on nominal flood levels is $2.77 million.

These numbers increase significantly if freeboard is allowed for (0.3m for overland flooding and 0.5m for mainstream flooding). The number of properties with flooding above the protection level is 92 for the 20% AEP event and 256 for the 1% AEP event. Flood damages range from $10.07 million to $28.29 million for these events. The AAD is estimated at $4.99 million based on flooding above the protection level.

It can also be seen that the majority of costs associated with flood damages are from residential dwellings, contributing approximately 90-95% of the flood damages in each flood event. The flood damages are dominated by residential damages due to the predominantly residential land use in the catchment. The majority of commercial properties are located in the upper catchment areas (i.e. Turramurra village) and are at low to no risk of flooding. There are a limited number of commercial and non-residential properties in flood-prone areas, concentrated around the Turramurra Eastern Road village, which may be subject to overland flooding.

From the assessment, it is also evident that the flood damages due to overland flooding are far greater than those related to mainstream flooding in Lovers Jump Creek and its tributaries. Overland flooding contributes approximately 75 – 85% of the flood damages in each event.

While flood damage estimates for the study area are indicative only, they are useful in the evaluation of flood management options, aimed at reducing flood damage estimates while being economically viable to implement.