Parramatta River - Ryde Sub catchments Flood Study and Floodplain Risk Management Plan

DRAFT FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

- Draft
- April 2014

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1. Introduction

1.1. General

Ryde Local Government Area (LGA) encompasses an area of 40.7km^2 in northern Sydney covering a number of catchments draining to the Parramatta River and the Lane Cove River. The area of focus for this study includes five catchments in the southern part of the LGA, draining to the Parramatta River. Patterns of urbanisation and associated construction of drainage infrastructure dating back to as early as the 1930's, have resulted in a number of watercourses being piped and development occurring in sometimes unsuitable locations, putting this development at risk to flooding during heavy rainfall events. Such flooding has occurred in 1984, 1986, 1988 (twice), 1989 (twice) and 1990, leading to widespread flooding and damage to properties.

A number of major drainage improvement projects have been completed in the study area to alleviate the flooding problems. The storm events in May 1998 and April 2003 caused significant problems but not to the extent as those in the late 1980's due to the drainage upgrades. However, there are numerous locations where existing development may be at risk from flooding.

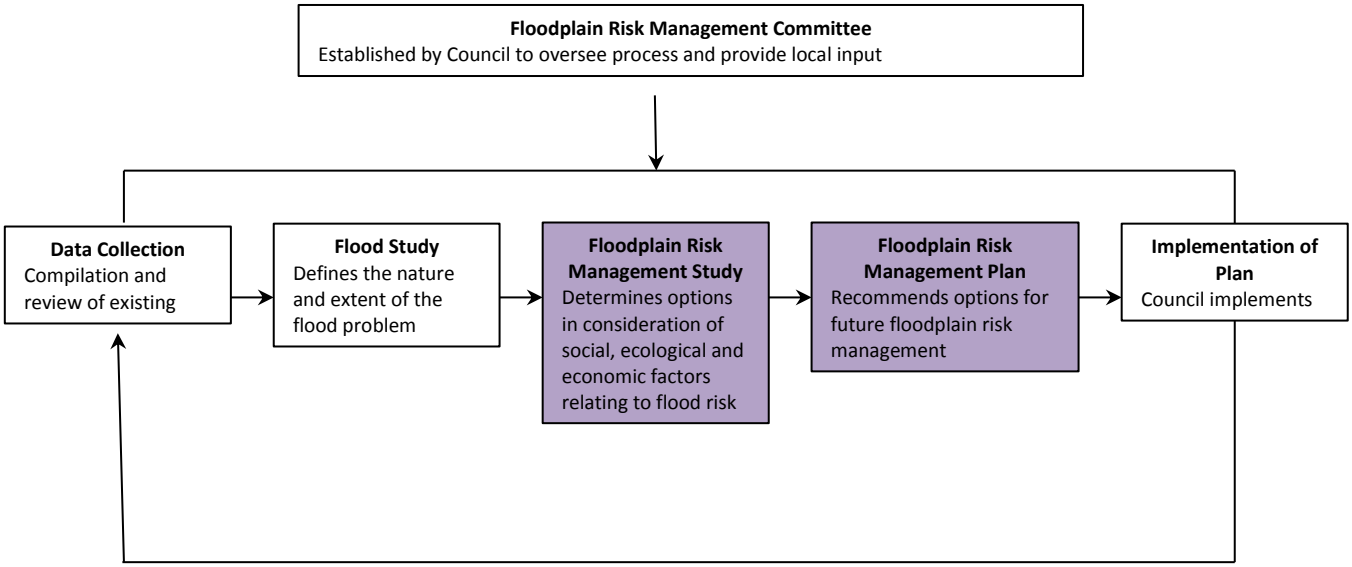
Hydrologic and drainage studies have been undertaken in the study area in the past, though some of these studies are up to 20 years old and most do not define the flood behaviour to the level of detail required in the NSW Government's *Floodplain Development Manual* (2005), which forms the current guidance for management of development and flood risk in NSW. Additionally, some catchments have been assessed in a disjointed manner and not been considered as a whole.

The City of Ryde ("Council") commissioned SKM to undertake a Floodplain Risk Management Study (FRMS) and Plan for five catchments with a total area of 12.7km^2. This FRMS follows on from the flood study portion of the project to determine the existing nature of flooding in the study area.

1.2. Floodplain Risk Management

City of Ryde 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 Floodplain Risk Management Committee for City of Ryde was established in 2011 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.



- **Figure 1-1 Floodplain Risk Management Process**

The FRMS forms the basis for the development of a Floodplain Risk Management Plan (FRMP). The FRMP may be used by Council and other stakeholders to reduce the impact of flooding on the community and assist in managing future development of the area. The main purpose of the FRMS is to identify and compare various floodplain risk management options. This Floodplain Risk Management Study draws together the results of the Flood Study, extensive local consultation and the data collection phase. The broad objectives of this Management Study and Plan are to:

- Provide information on flood behaviour and hazard from the Flood Study
- Propose options for floodplain risk management
- Assess the impact of these potential options on flood behaviour and flood hazard.

2. Study Area

2.1. Catchment Description

The Parramatta River – Ryde subcatchments study area is situated in the southern part of the Local Government Area (LGA). The sub catchments extend from Melrose Park in the west to Gladesville in the east. The catchments are bounded to the north by Victoria Road and Blaxland Road, and to the south by the northern banks of the Parramatta River. The study area includes the suburbs of Denistone West, Denistone West Ryde, Meadowbank, Putney, Tennyson Point. Council has divided the area into five sub catchments; Archer Creek, Denistone, Charity Creek, River, Gladesville (as shown in **Figure 2-1**). The combined area of the five sub catchments is 12.7km^2. The stormwater drainage infrastructure in the catchments, which are listed west-to-east, is summarised in **Table 2-1**. Maps of the catchment elevations and LEP Zones are shown in **Figure 2-2** and **Figure 2-3**, respectively.

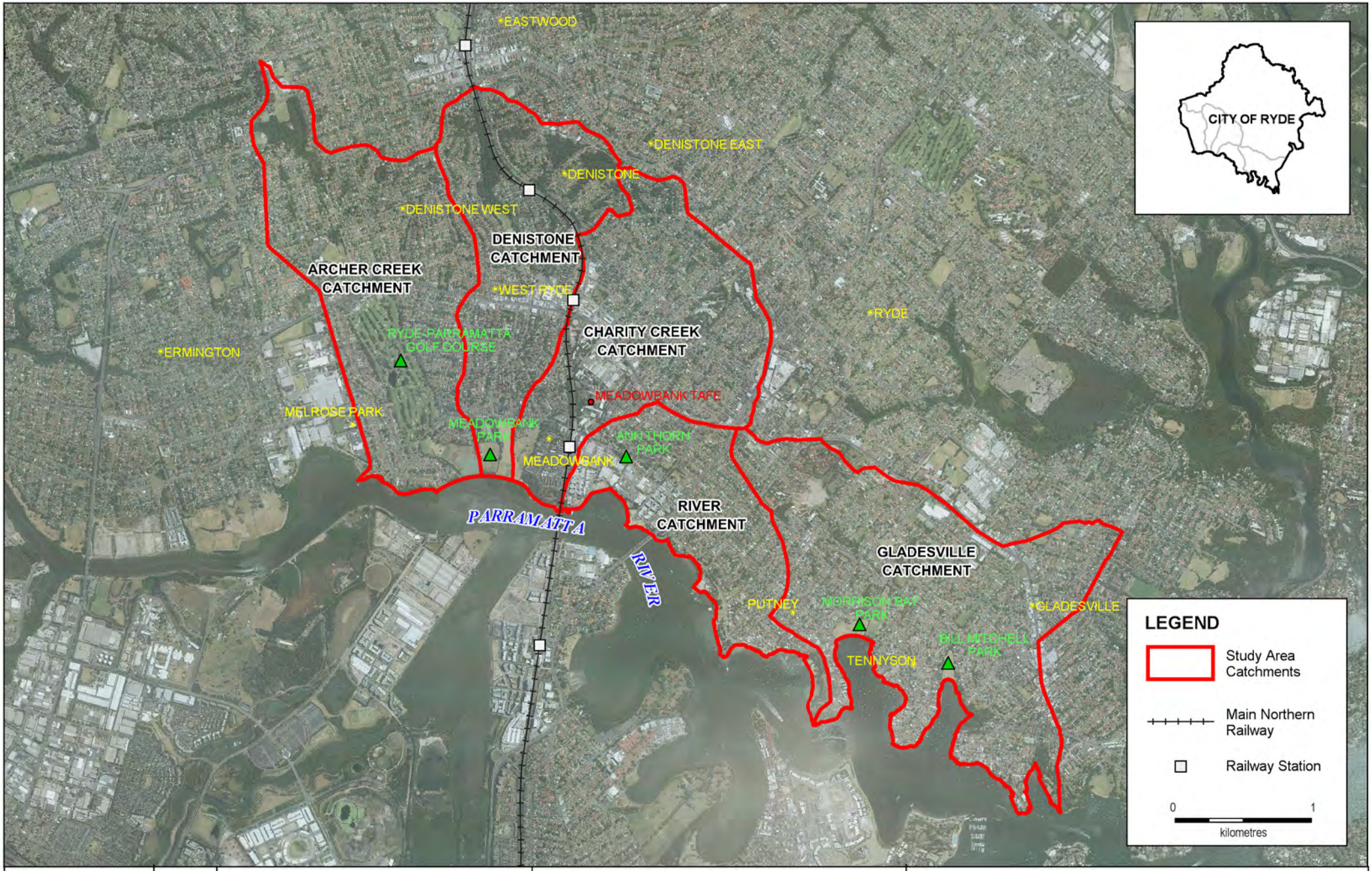
- **Table 2-1 Stormwater Infrastructure per Catchment**

Catchment	Area (ha)	Length of Stormwater Pipes (km)	Number of Stormwater Pits
Archer Creek	286	15.8	736
Denistone	215	16.5	632
Charity Creek	247	20.2	810
River	158	10.6	470
Gladesville	366	22.7	987
Total	1,272	85.8	3,635

Archer Creek Catchment has an area of 286ha within Ryde LGA and has an additional portion of the catchment of 50ha located to the west of Wharf Road, in the Parramatta Local Government Area (LGA). Drainage in the catchment mainly consists of a mix of pipes and natural and developed flow paths. Archer Creek flows through the Ryde – Parramatta Golf Course as a series of constructed channels and ponds. Downstream of the Golf Course and Andrew Street, Archer Creek flows in a culvert and then in a concrete-lined channel through Meadowbank Park, before discharging into the Parramatta River.

Charity Creek originates in Denistone and runs through the residential areas of West Ryde and Meadowbank. The catchment consists mainly of a piped drainage system with developed flow paths through the urban areas.

The Northern Railway Line runs through the south-western portion of the catchment. The Railway is constructed on a raised fill embankment just to the north of Meadowbank Station and is an obstruction to overland flows. It represents an informal flood storage in this area. Victoria Road between Falconer Street and Linton Avenue is a raised control to overland flow from the north.



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Coordinate System: MGA Zone 56
Datum: GDA 1994

Parramatta River - Ryde Sub-Catchments
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Figure 2-1
Study Area Catchments and Locations

Denistone Catchment originates in Denistone and runs through the residential areas of West Ryde and Meadowbank. The catchment consist a mix of pipes, trunk drainage tunnels and natural and developed flow paths. A concrete-lined channel forms the main flow path downstream of Constitution Road, where it flows through Meadowbank Park, before discharging into the Parramatta River.

The West Ryde stormwater tunnel was built in 1999 from Miriam Rd, West Ryde to Meadowbank Park to alleviate the flooding in West Ryde Town Centre area. Victoria Road to the south of the Town Centre is raised and is a significant control on overland flooding in West Ryde.

The Northern Railway Line runs through the north-eastern portion of the catchment. The Railway is constructed on a raised fill embankment in several sections and is an obstruction to overland flows. It represents an informal flood storage in the area.

River Catchment is the smallest catchment within the study area. It originates from south of Ryde and runs through the residential areas of Putney. The catchment is drained by a piped system, with a number of overland flow paths draining surface flows to the Parramatta River. Constitution Road in the vicinity of Ann Thorn Park is constructed on a raised embankment and is an obstruction to overland flow into, and upstream of, Ann Thorn Park.

More high density residential development in the Meadowbank area at the western side of the River Catchment is proposed in the short to medium term. Drainage systems at the western side of River Catchment were upgraded recently to allow increased flows from future development.

Gladesville Catchment is the largest catchment within the study area. It originates from south of Ryde and runs through the residential areas of Putney, Gladesville and Tennyson Point. The catchment is drained by a pipe network and several main overland flow paths, including a concrete-lined channel flowing through Morrison Bay Park and discharging into the Parramatta River. One overland flow path drains into the adjacent Hunters Hill LGA to the east, in the vicinity of Pittwater Road and Cambridge Street, Gladesville.

A detention basin/stormwater quality pond has recently been constructed at the Royal Rehabilitation Centre Sydney, Ryde, in the north-western portion of the catchment.

Elevations in the study area vary from 114m AHD in the upper catchment to 0m AHD in the lower reaches at the Parramatta River. The varying elevations in the catchment are shown in **Figure 2-2** based on the ALS data provided by Council.

The study area is heavily urbanised with land use varying across the five sub catchments (**Figure 2-3**). Land use across the study area is predominantly low density residential. Denistone and Charity Creek have a greater mix of land uses comprising mixed use, high density residential and infrastructure, all of which are concentrated in the West Ryde area. There is a small scattering of recreation land use in the upper part of the catchments, including Darvall Park and Denistone Park. The largest recreational land use is found in Archer Creek catchment and covers the Ryde Parramatta golf course. Moving further south, recreational land use is found along the foreshore of the Parramatta River extending across the five sub catchmentsError! Reference source not found..

LEGEND

Ground Level Contour
10m Interval

0 200

metres

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Datum: GDA 1994

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Parramatta River - Ryde Sub-Catchments
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Figure 2-2

Digital Elevation Model

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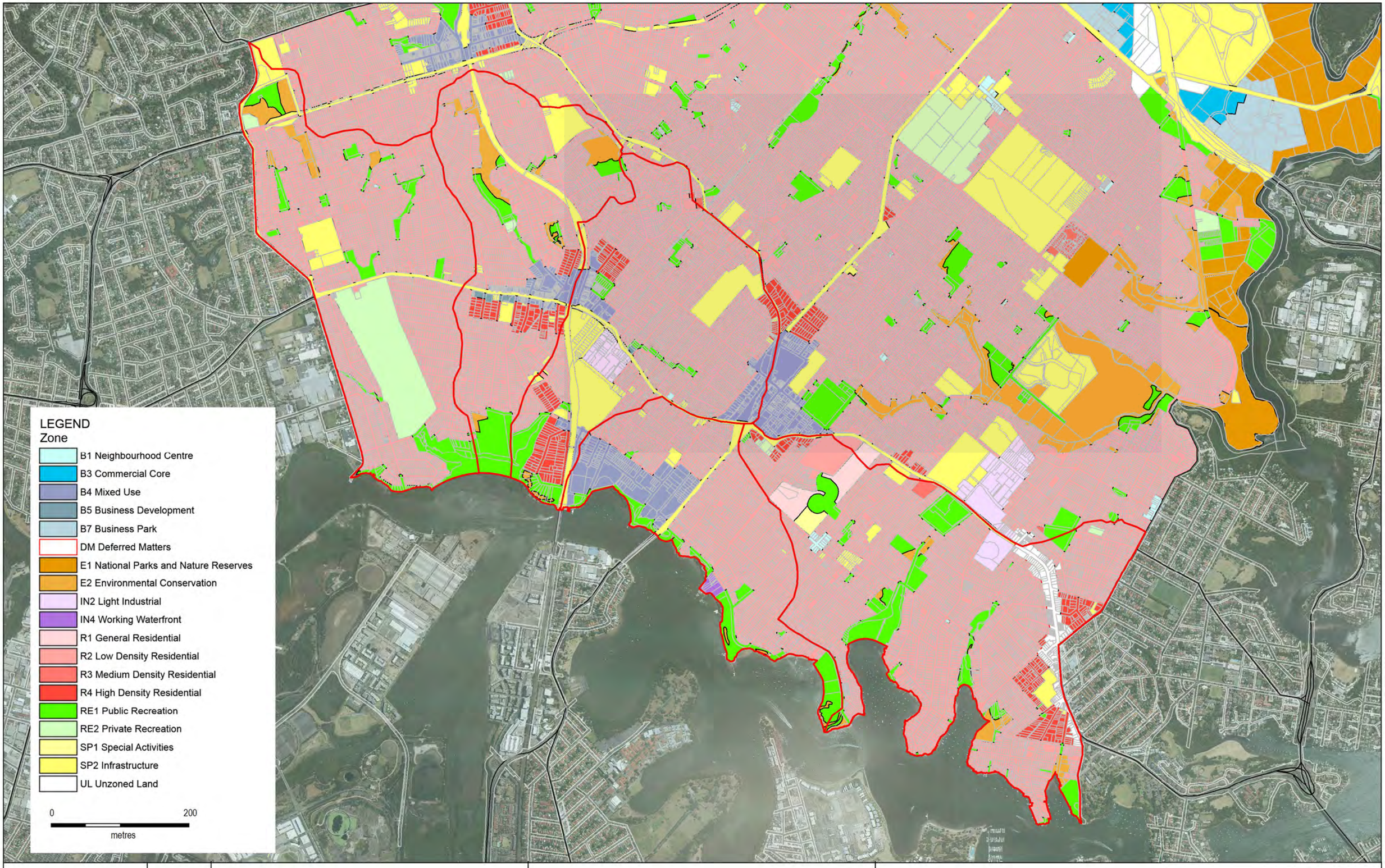

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Figure 2-3
LEP2010 Zones

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2.2. Flood History

A number of historic flood events have occurred in the study area in the last 30 years, including events during 1984, 1986, 1988, 1990, 2005, 2009, 2010 and 2011 as reported by residents during this study. Particularly notable was the November 1984 event, which caused significant flooding in the West Ryde town centre, with some commercial properties experiencing depths of flooding of two (2) metres, prompting Council to commission the construction of the West Ryde Stormwater Tunnel to improve drainage and alleviate the flood risk to the area. The Tunnel was completed in 1999.

A questionnaire used to gather information about flooding of personal property and local flood experiences was mailed to 1726 residents. A total of 319 responses were received (18%) and these were reviewed alongside additional information from Council's data base of historic flood events. From the responses received, 75 observations were reported in total. Out of the total number of observations, 71 could be located on a map, though there is uncertainty about the date and exact location of some of these observations, and in some instances a depth was not reported.

A count of the number of observations per flood event revealed that the most number of observations were reported for the November 1984 event (13 responses) and the February 1990 event (7 responses). These are shown on **Figure 2-4.**

Observations made during the November 1984 flood event were predominantly in Archer, Denistone and Charity Creek catchments. Flood depth observations ranged from 0.3m in the upper drainage paths of Archer Creek (locations 4 and 6) to 1.5m observed at the West Ryde Arcade (location 9). Additional observations were obtained from the previous flooding and drainage studies in the study area.

The following photos of historic flooding were provided by local residents.

- **Plate 2-1 Flooding in Cobham Avenue, Melrose Park, 1988 storm event (courtesy G. Parry)**

- **Plate 2-2 Flooding and surcharging stormwater pit in Cobham Avenue, Melrose Park, 1988 storm event (courtesy G. Parry)**

- **Plate 2-3 Overland flood damage to yard, Gladesville, 1989 storm (courtesy R. Tuckwell)**

- **Plate 2-4 High water marks on exterior wall and damaged carpets, Gladesville, 1989 storm (courtesy R. Tuckwell)**

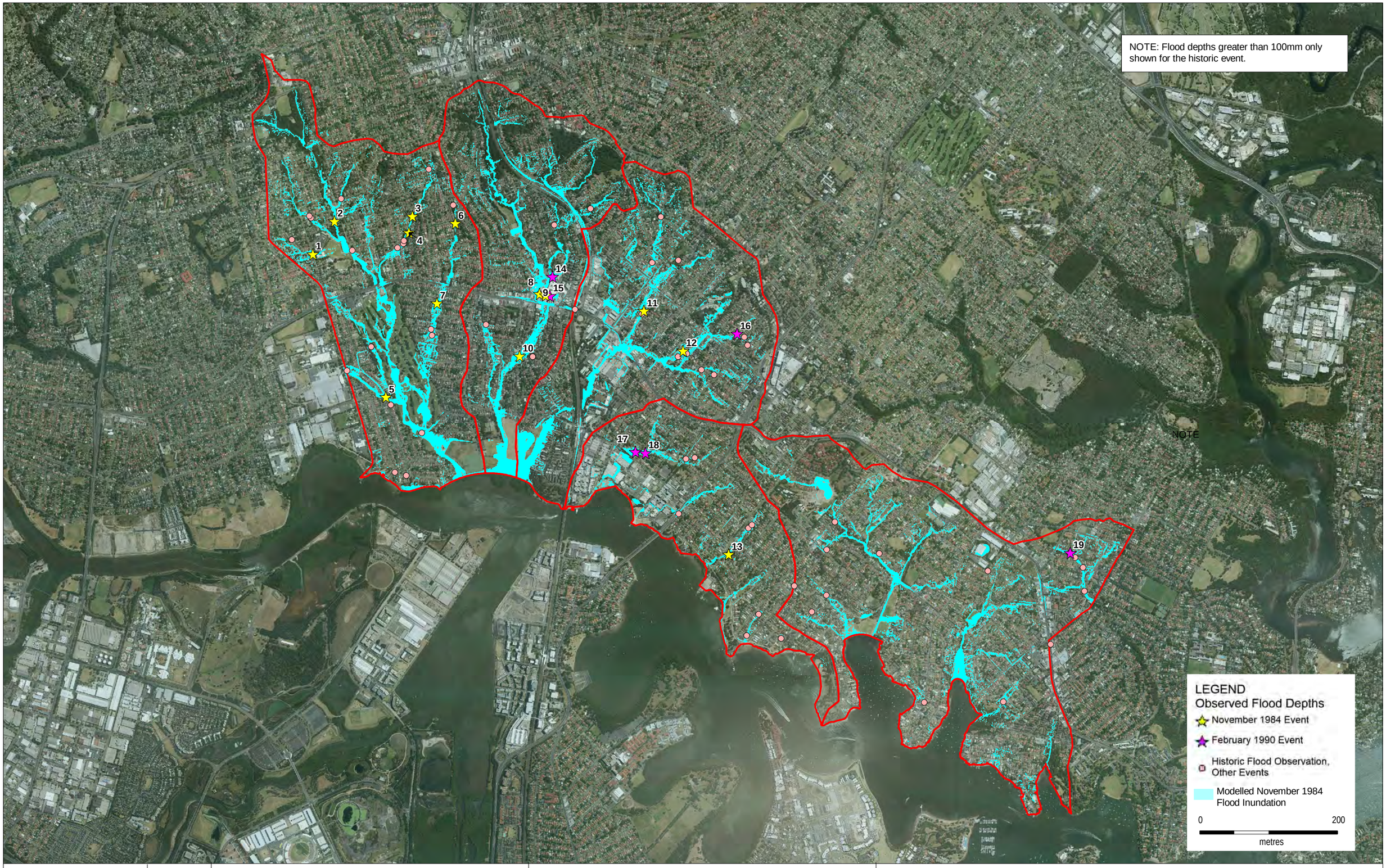

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Figure 2-4

Historic Flood Depth Observations for Model Verification Events

2.3. Social Profile

Social characteristics of the catchments are a key consideration for the floodplain risk management study. Data from the 2011 Census (ABS 2011) was extracted for the City of Ryde LGA and salient points are provided in **Table 2-2**.

A significant proportion of people in the City of Ryde were born overseas (40.1%) and speaking a language other than English at home (38.5%). Mandarin, Cantonese, Korean and Italian are the most common languages spoken other than English. Another feature is that over 40% of the population weren't in their current house 5 years ago. Both of these factors indicate that community consultation needs to be multilingual and repeated regularly to provide effective communication. Also, over 30% of the population is in the younger and older age groups (less than 14 and older than 70) and communication strategies need to accommodate these groups.

Additional community information is available from Council's Community Profile website. Salient aspects in relation to flooding are:

- that in some areas there are communities with non-English speaking backgrounds that represent 75% of the population in those areas, and similarly
- in many areas people older than 70 years represent up to 15% of the population.

2.4. Services and Facilities

Community services identified within the study area which may be disrupted by flooding include Meadowbank TAFE, community centres, over 40 preschools and long day care centres, retirement villages and Aged Care facilities and many other community facilities.

2.5. 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.

The *Ryde Local Environmental Plan 2010* provides a schedule of heritage items within the Local Government Area which are classified as having Local, Regional or State significance. Those which are located within the study area are listed in **Table 2-3**. 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 Census Data for City of Ryde

Source: 2001 Census Basic community Profiles (ABS)

Selected Person Characteristic		Number of Motor Vehicles by Dwellings	
Total Persons	162,845	Dwellings with 0 motor vehicles	11%
Aged 14 years and under	17.1%	Dwellings with 1 motor vehicles	41.0%
Aged 65 years and over	14.8%	Dwellings with 2 motor vehicles	33.8%
Aboriginal/Torres Strait Islander	0.3%	Dwellings with 3+ motor vehicles	11.9%
Australian born	55.8%	Average number of motor vehicles per occupied private dwelling	1.5
Speaks English only at home	40.1%	**Dwelling Structure**	
Speaks a language other than English at home	57.8%	Separate house	55.8%
Australian citizen	38.5%	Semi-detached etc	11.9%
Selected Medians & Averages		Flat, unit, apartment	25.7%
Median age	38	Other dwelling	6.6%
Median individual income ($/wk)	$659	**Tenure Type by Dwelling Structure**	
Median household income ($/wk)	$1,603	Fully owned	35.2%
Average household size	2.7	Being purchased	31.7%
Language Spoken at Home		Rented	30.2%
English	57.8%	**Type of Internet Connection**	
Other language as % of all other languages	Mandarin 18.9	No Internet connection	13.8%
	Cantonese 17.3	**Population Continuity**	
	Korean 9.4	Persons at same address 1 year ago	82.2
	Italian 5.1	Persons at same address 5 years ago	57.4

Table 2-3 Heritage items in the study area

Suburb	Item Name	Address	Significance	Item Number
Eastwood	Road	Great North Road, Bedlam Point to	State	54
Gladesville	House	19A Amiens Street	Local	3
Gladesville	Houses	23, 25, 27, 29 and 31 Amiens Street	Local	4
Gladesville	Glades Bay	45 Ashburn Place	Local	6
Gladesville	Wharf	Bedlam Point	Local	11
Gladesville	House	10 Cambridge Street	Local	23
Gladesville	Substation	38–42 Pittwater Road	Local	93
Gladesville	Banjo	38 Punt Road	Local	98
Gladesville	“Rockend	40 Punt Road	State	99
Gladesville	Monash	142 Ryde Road	Local	112
Gladesville	Drill Hall	144 Ryde Road	State	113
Gladesville	House	3 Tyrell Street	Local	135
Gladesville	House	42 Tyrell Street	Local	136
Gladesville	School	172–180 Victoria Road	Local	138
Gladesville	House	37 Wharf Road	Local	166
Gladesville	Houses	43 and 45 Wharf Road	Local	167
Gladesville	House	55 Wharf Road	Local	168
Gladesville	House	76 Wharf Road	Local	169
Meadowbank	Shops	58, 60, 62 and 64 Constitution Road	Local	37
Meadowbank	Memorial	2 Meadow Crescent	Local	72
Meadowbank	Fountain	(Corner) See and Angas Streets	Local	115
Meadowbank	The Laurels	34–38 See Street	Local	116
Putney	House	60 Pellisier Road	Local	86
Putney	Putney Park	99 Pellisier Road	Local	87
Putney	Kissing	24 Waterview Street	Local	157
Ryde	Ryde Park	7 Blaxland Road	Local	13
Ryde	Ebenezer	22 Blaxland Road	Local	14
Ryde	Top Ryde	115–121 Blaxland Road	Local	15
Ryde	Masonic	142 Blaxland Road	Local	16
Ryde	“Hattons	158 Blaxland Road	Local	17
Ryde	Fountain	(Corner) Blaxland and Victoria Roads	Local	19
Ryde	Church	74A Bowden Street	Local	20
Ryde	House	95 Bowden Street	Local	21
Ryde	Church and	25–27 Church Street	Local	27
Ryde	Hall	27 Church Street	Local	28
Ryde	Former	42 Church Street	State	29
Ryde	St Anne’s	46 Church Street	State	30
Ryde	St Anne’s	46 Church Street	State	31
Ryde	Terraces	76, 78 and 80 Church Street (80 also known	Local	32
Ryde	Bridge	Church Street	Local	33
Ryde	Obelisk	Devlin Street	Local	49
Ryde	“Crowle	8 Junction Street	Local	57
Ryde	“Mayfield”	281 Morrison Road	Local	77
Ryde	Shop	312 Morrison Road	Local	78
Ryde	“Woolbrook”	7 Regent Street	Local	102
Ryde	House	5 Storey Street	Local	119
Ryde	Ryde Public	2 Tucker Street	State	130
Ryde	“Westward	8 Turner Street	Local	131
Ryde	“Parsonage”	12 Turner Street	Local	132
Ryde	Holy Cross	499–521 Victoria Road	State	143

Suburb	Item Name	Address	Significance	Item Number
Ryde	Chapel	512–550 Victoria Road	Local	144
Ryde	“Squireville”	512–550 Victoria Road	Local	145
Ryde	Cemetery	562–586 Victoria Road	Local	146
Ryde	St Charles	562–582 Victoria Road	State	147
Ryde	Dalton	642–648 Victoria Road	Local	148
Ryde	“Willandra”	770–772 Victoria Road	State	149
Ryde	Police	808 Victoria Road	State	150
Ryde	Court House	812 Victoria Road	Local	151
Ryde	“Addington”	813–815 Victoria Road	State	152
Ryde	“The	817 Victoria Road	State	153
Ryde	“Wallametta	826 Victoria Road	Local	154
Tennyson	“Harwin”	79 Champion Road	Local	24
Tennyson	House	85 Champion Road	Local	25
Tennyson	Shops	113–115 Tennyson Road	Local	121
Tennyson	House	139 Tennyson Road	Local	122
West Ryde	Houses	61, 63, 65, 67, 69, 71, 73, 75 and 77	Local	51
West Ryde	House	4 Linton Avenue	Local	63
West Ryde	Church	7–9 McPherson Street	Local	64
West Ryde	Church	7 Maxim Street	Local	69
West Ryde	“Milton”	22 Maxim Street	Local	70
West Ryde	House	24 Maxim Street	Local	71
West Ryde	House	71 Station Street	Local	117
West Ryde	“Uplands”	72 Station Street	Local	118
West Ryde	Pumping	948 Victoria Road	Local	155
West Ryde	House	958 Victoria Road	Local	156

2.6. Natural Environment

The City of Ryde has a diverse natural and built environment. There is 265 hectares of local open space in the Ryde City LGA inclusive of the natural areas of Archers Creek, the Denistone catchment, Kitty's Creek, Porters Creek, Shrimpton's Creek, Terrys Creek, Buffalo Creek, Pages Creek, the Parramatta River foreshores, and Lane Cove National Park.

For the study area, the geography and settlement pattern of Ryde is defined by its natural features, most particularly the Parramatta River. The River foreshore and open spaces support a considerable variety of native bushland and associated flora and fauna. It has Ramsar protected wetlands of international significance for migrating birds and a number of reasonably intact, regionally significant ecological communities, particularly the remnant salt marshes of the Parramatta River foreshores at Melrose Park. Many hundreds of species of native birds, animals and plants have been recorded in Ryde, some of which are remnants of formerly significant ecological communities in the Sydney Basin as a whole.

As a result of its essentially urban nature, Ryde’s natural environment consists mostly of relatively isolated pockets of remnant vegetation, often located within riparian areas along the River and major creeks. Ryde’s remnant plant and animal communities are surviving in an area, which is

subject to significant urban growth and a great range of urban impacts, ranging from stormwater pollution and weed infestation to feral cat predation.

Important open space areas in the study area are:

- Numerous parks/reserves along the Parramatta River foreshore
- Darvall Park
- West Denison Park
- Denistone Park
- Brush Farm Park
- Monash Park
- Anzac Park.

2.7. Legislation and Planning

Consent for developments on flood prone land is most often the Council acting as the consent authority having the function to determine a development application for land use under the EP&A Act. However, legislation or an Environmental Planning Instrument (EPI) may specify a Minister or public authority (other than a Council), or the Director General of OEH, as having the function to determine an application. Development is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

This section describes the statutory and planning framework within which the FRMS has been undertaken. It identifies and describes the existing policies, environmental planning instruments and other environmental legislation of relevance to flood risk management in the study area, and the corresponding considerations for the FRMS. The policies, planning instruments and environmental statutes identified within this section are restricted to those that have either direct or potential relevance to the FRMS.

2.7.1. State Government Policies

The *Floodplain Development Manual* was gazetted on 6 May 2005 as the manual relating to the development of flood liable land for the purposes of section 733(5)(a) of the Local Government Act 1993. Coupled with the State's floodplain management grant program, the *Floodplain Development Manual* (2005) highlights the Government's ongoing commitment to managing flood risks and the impacts of floods on the people of NSW.

The *Floodplain Development Manual* (2005) incorporates the *NSW Flood Prone Land Policy* (2005), the primary objectives of which are 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. The Policy also recognises the benefits of use, occupation and development of flood prone land.

The Floodplain Development Manual places the responsibility for management of flood risk with local government and accordingly assists councils to balance the conflicting objectives of floodplain development through a risk management process. The NSW Government also provides local government with technical, financial and policy assistance in floodplain risk management.

The Floodplain Development Manual outlines a merits based approach to floodplain risk management. At the strategic level this allows for the consideration of social, economic, ecological, and cultural issues to determine strategies for the management of flood risk.

2.7.2. Ryde Local Environment Plan (LEP)

The *Ryde Local Environmental Plan 2010* applies to all land within the City of Ryde LGA as shown on the Land Application Map (Ryde LEP, 2010). The aims of the LEP are:

- to create a broad framework of controls for the future development of all land in Ryde,
- to encourage the management and development of land to provide a range of land uses, employment activities and housing types that respond to the welfare of the citizens of Ryde,
- to conserve items and places in Ryde that are of natural, indigenous, cultural, social and historical significance,
- to manage development of Ryde to create a better environment.

2.7.3. City of Ryde Development Control Plan (DCP), Part 8.2 Stormwater Management

Part 8.2 of the DCP applies to all lands within the City of Ryde area. The purpose of the part is to guide all development in the methods of managing water within the City of Ryde. Objective 5 of Part 8.2 is to ensure no increase (and where reasonable a reduction) in the frequency and adversity of flooding. Detailed objectives for stormwater inundation of Council land are:

- to minimise the impact of any development on adjoining properties any work on the property must not increase the quantity of flow through an adjoining property, concentrate or redirect flow or otherwise aggravate stormwater overland flow characteristics on adjoining properties.
- to minimise the impact of any proposed work all work must be compatible with the existing constraints of the site, including the overland flow of stormwater.
- site improvements must be designed to ensure there will be no significant damage caused by stormwater runoff within the property.
- to ensure a safe environment, people, particularly children, must not be placed at risk of being swept away by overland flow. Any development proposal must not modify the way in which overland flow is conveyed through a property in a way that makes it hazardous, or promote the increased use of a property (or part of a property) that has an existing stormwater inundation safety hazard.

- to ensure all proposed property improvements are compatible with Council's stormwater management plans for the area. In the absence of such a plan, the proposal should not reduce the opportunity to undertake any reasonable options to redress existing overland flow problems.

As noted in the plan, the design standard for consideration of hazard and property inundation is the 100-year Average Recurrence Interval (ARI) storm event. Council may require the adoption of a longer recurrence interval design storm such as the Possible Maximum Flood (PMF), in instances of high danger to persons or greater risk of significant property damage.

3. Community Consultation

3.1. Consultation Process

The local community has a key role to play in the development and ongoing implementation of a Floodplain Risk Management Plan. Engaging the community early in the project provides people with the opportunity to actively contribute to the flood risk management process. This is important for City of Ryde as many residents have experienced the flooding events in recent decades and have local knowledge of the area which can be useful when understanding the flood behaviour.

3.2. Objectives and Method

The objectives of community consultation were to:

1) Examine the flood awareness and preparedness of residents
2) Identify flood related issues of concern within the community
3) Raise public awareness of the project
4) Facilitate discussions between Council and members of the community.

The Community consultation process involved the following steps:

- The study was advertised in on City of Ryde website
- At the start of the study a newsletter/flier was circulated to residents via a letterbox drop (organised by Council)
- A questionnaire was circulated via a letterbox drop for residents to respond to. This was also advertised on the website and could be completed online.
- Consultation letters were sent to key stakeholders

3.3. Floodplain Risk Management Committee (FRMC)

The objective of the FRMC is to assist Council in the development and implementation of one or more floodplain risk management plans for its service area. The committee comprises City of Ryde Councillors, City of Ryde technical staff, SES representatives, Office of Environment and Heritage (OEH) Representatives and local residents.

3.4. Questionnaire and summary of responses

A newsletter and questionnaire was issued to the local community to inform residents about the floodplain risk management study and how they can get involved. The newsletter and questionnire are included in **Appendix A**. Included in the newsletter were contact details for Council and SKM to enable residents to provide feedback on the floodplain risk management mitigation measures considered.

Questionnaires were issued to all dwellings and commercial buildings located within the study area. This targeted questions on experience of flooding, priorities for development and the perception of flood risk within the area. Twenty four responses were received; these were analysed and feedback from the local community is summarised as follows:

- Location/Ownership

  58% have property within the study area

  33% have experienced flooding on their property (only 1 of these refer to 1974).

- Flood Damage

  17% reported that their property has been subject to flood damage from events in 1952, 1956 and 1974. The flooding caused major disruption to 2 properties and minor disruption to 3 properties.

- Flood Perception and Key issues

  A number of residents identified the desire for homes and businesses to be protected from flooding. Most responses ranked this as the most important item with regards to flood risk management. The need for reliable and consistent flood warning was ranked 2 by the majority of the responses.

Key issues raised in the comments received include the following:

- Planning controls: why some 'people' are allowed to build in the floodplain and others are not
- Drainage: concern that runoff due to further development is impacting existing properties
- Construction adjacent to the river: owners should be able to build at their own risk and Council should not be liable for flood damage
- Stormwater Drainage: Backing up of stormwater in the Audley Street/Bolton Street system.

The questionnaire responses and additional information from Council's data base were reviewed for observations of historic flood events. Out of 1,726 questionnaires distributed by Council, 319 responses were received, with 75 observations reported in total. Out of the total number of observations, 71 could be located on a map, though there is uncertainty about the date and exact location of some of these observations, and in some instances a depth was not reported.

A count of the number of observations per flood event revealed that the most number of observations were reported for the November 1984 event (13 responses) and the February 1990 event (7 responses). The DRAINS and TUFLOW models were therefore run for the 1984 and 1990 storm events. Note that since these events pre-date the construction of the West Ryde Stormwater Tunnel, the inlets to the Tunnel were blocked off in the TUFLOW model for the simulation of the historic events.

4. Flood Behaviour in the study area

4.1. Existing Flood Behaviour

A flood study was prepared for Council (SKM August 2103) for the five drainage catchments in Ryde Local Government Area (LGA), which drain to the Parramatta River. Development in the study area is at risk to flooding during heavy rainfall events due to the nature of the urban environment and the limited capacities of the natural and built drainage network. Such events have occurred in 1984, 1986, 1988 (twice), 1989 (twice) and 1990, leading to widespread flooding and damage to properties.

A number of major drainage improvement projects have been completed in the study area to alleviate the flooding problems. The storm events in May 1998 and April 2003 caused significant problems but not to the extent as those in the late 1980's due to the drainage upgrades. However, there are numerous locations where existing development is at risk from flooding.

The Study defined the existing flood behaviour in the five catchments, being: Archer Creek; Denistone; Charity Creek; River and Gladesville. Flooding occurs primarily as overland flows in the majority of the study area, while mainstream flooding is experienced adjacent to the watercourses. Flood extents, depths and levels and main flow paths have been determined.

The flood modelling indicates that there would be a number of areas within the study area where development would be subject to flood depths exceeding 2m in the 1% AEP event, including parts of Meadowbank TAFE, several locations upstream of the Main Northern Railway and several residential and industrial areas. Up to 44 individual roads would experience maximum depths of flooding exceeding 0.3m in the 20% AEP event along the road centreline, rising to 79 roads in the 1% AEP event. This depth of flooding is indicative of these roads becoming impassable to vehicles, although the safe depth of flooding may be lower depending on the overland flow velocity. Up to 588 properties (including private and public lot parcels) have been categorised as provisional high flood risk.

Hydrologic modelling of rainfall-runoff processes was conducted using the DRAINS modelling software, to determine storm event flows in the catchments. A separate DRAINS model was developed for each of the five catchments, based on the stormwater asset data base provided by Council.

Hydraulic modelling was undertaken using TUFLOW, which defines the surface of the catchments in 2D using a 3m grid of the topography, while allowing features such as the stormwater pit and pipe network, trunk drainage channels, culverts and bridges as 1D objects. The hydraulic roughness of the catchments was varied according to land use. Buildings were defined as solid obstructions to overland flow. Partial blockage of pits, culverts, bridges and mesh-type fencing at waterway crossings was applied for the design case.

Inflow hydrographs from the DRAINS models were input at the sub-catchment outlets in the TUFLOW model, with stormwater pit inlets intercepting the flows up to the system capacity. Excess flows surcharge and form overland flow, which flows over the 2D model domain in patterns according to the topography and modelled obstructions.

4.2. Flood Mapping

Comprehensive mapping results were provided to Council in the Flood study (SKM August 2013).

Flood behaviour was defined for the 20%, 10%, 5%, 2% and 1% AEP and Probable Maximum Flood (PMF) events. Flood depths were mapped for all events, while flood levels were mapped for the 1% AEP and PMF events. Flood planning areas were defined based on the 1% AEP flood surface plus 0.3m freeboard. Note that the flood mapping had areas with depths less than 100mm filtered out, to avoid these areas, which are affected by shallow sheet flow, being denoted as "flood-affected".

4.3. Climate change sensitivity

The impact of climate change on flooding in the study area has been investigated by analysing three scenarios of storm event rainfall intensity increase (10%, 20% and 30%) coupled with two sea level rise scenarios (2050 and 2100 scenarios, corresponding with 0.4m and 0.9m sea level rise, respectively, on top of the 5% AEP ocean level at Fort Denison).

The analysis indicates that flood levels are not sensitive to sea level rise except at the outlets of the catchments and along the Parramatta River, with a number of low-lying riverside residential properties at risk from increased sea level alone, without river or overland flooding. Where flow depths are typically shallow, results weren't sensitive to the increased rainfall intensity (less than 0.03m increase), while flood depths in flow paths and storage areas were more sensitive to the increase in rainfall intensity. In the extreme 30% rainfall intensity increase scenario, depths typically increased by up to 0.4m in flow paths and storages, although depths may increase by up to 1.35m in some areas, including the informal storage upstream of the Main Railway Line, downstream of the Meadowbank TAFE.

4.4. Flood Risk and overland flow Precincts

Flood and Provisional Risk Precinct mapping were provided to Council in the Flood Study (SKM August 2013).

Flood risk is the potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods (NSW Government, 2005). A comprehensive analysis of flood hazard to establish risk can only be made from within the strategic framework of a floodplain risk management study. The study requires the detailed results of a flood study and an assessment of all other floodplain factors, such as flood warning, flood awareness, flood readiness, possible evacuation problems, etc. The process involves firstly evaluation of hazard level from pure hydraulic principles, and then refining the

hydraulic hazard category in light of other relevant factors affecting the safety of individuals. Hence, Risk is based upon the consideration of the consequences of the full range of flood behaviour (probability) on communities and their social settings, and the natural and built environment.

The Flood Study's TUFLOW modelling results were used to assist in the delineation of flood risk precinct areas, as agreed with Council, for the study area from interpretation of the 1% AEP and PMF event results, based on the flood risk precinct definitions described in **Table 4-1.** The flood risk precinct definitions were derived, in part, from the hydraulic hazard category diagram presented in the *Floodplain Development Manual* (NSW Government, 2005) and from discussion with Council about flood risk to developments in the catchments. These definitions, although not the same as used in the Manual, were adopted by City of Ryde for the Macquarie Park catchment Study and are also in common use with other Councils, such as Fairfield, Liverpool, Bankstown and Sutherland.

Table 4-1 Provisional Flood Risk Precinct Definitions

Risk Precinct	Description
High	The area of land below the 1% AEP flood outline that is subject to high hydraulic hazard as defined by Figure L2 of Appendix L in the *Floodplain Development Manual*. 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 Risk Flood Precinct
Low	All other land within the floodplain (i.e. within the extent of the PMF) but not identified within either the High Risk or Medium Risk Precincts.

The Risk Precinct mapping is presented **Appendix B**.

5. Flood Damage Assessment

5.1. Overview

Flood events may cause damage to property with significant costs to property owners and insurers. 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.

5.2. Flood Damages Categories

The type of damages associated with floods is shown in **Figure 5-1 (***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.

5.3. Estimation of Direct Tangible Flood Damage Costs

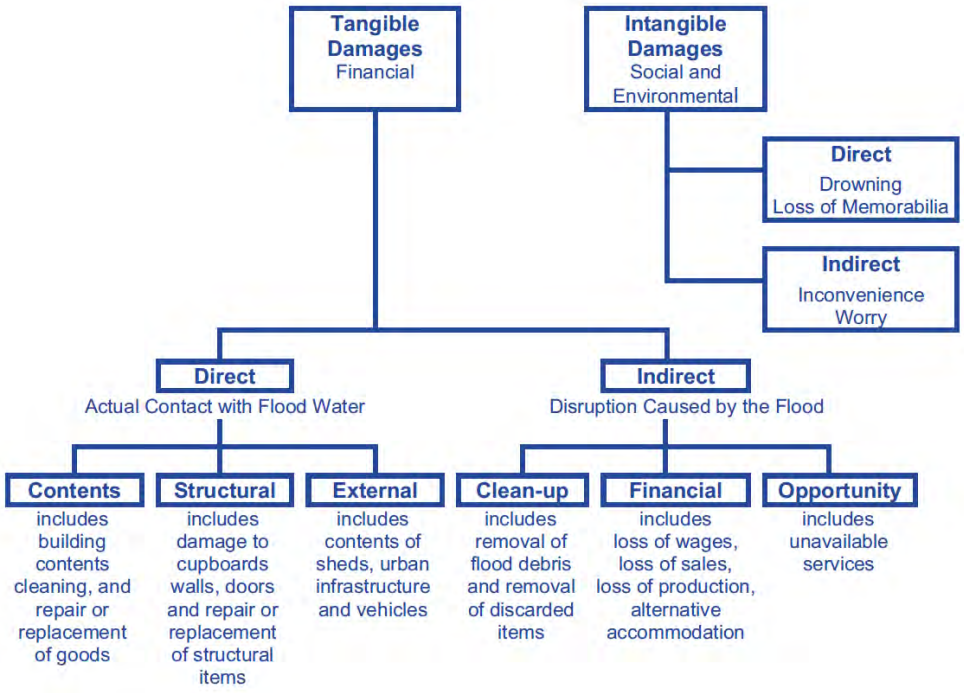
5.3.1. Property Information

Residential and commercial properties were identified based on Council's zoning code for each cadastral parcel object.

For residential lots, house types in the study area were observed during site inspection to generally be a mixture of one and two storey houses. The building polygons adopted in the TUFLOW hydraulic model, which were derived from the ALS buildings data points, were filtered in GIS assuming that the largest building polygon on each residential cadastre parcel object was the house on that parcel. House types were categorised as single storey, two storey or multi-storey apartments based on ALS-derived building height. The floor levels of the houses were assumed to be 0.3m above the highest ground level at the building. The applicable flood level at each house for flood damages estimation purposes was assumed to be the highest flood level for each flood event ARI.

The commercial buildings were categorised based on footprint area for the assessment, as the estimated flood damage is based on the size of the premises. Floor levels were assumed to be at the highest ground level at the building. The applicable flood level at commercial buildings for flood damages estimation purposes was assumed to be the highest flood level for each flood event ARI.

- **Figure 5-1 Types of Flood Damage**



5.3.2. Residential Property Damages

A residential flood damages spreadsheet was developed by the former NSW Department of Environment and Climate Change (DECC), now the NSW Office of Environment and Heritage (OEH). 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 5 year ARI event up to the PMF. These values are then summed to provide a total damage for each flood event analysed. The AEP of the Probable Maximum Flood has been estimated using the chart from Book VI of *Australian Rainfall and Runoff* (Engineers Australia, 2001). The ARI of the PMF in the study area is 10,000,000 years based upon a catchment area of approximately 1km^2.

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 5-1.**. Unless otherwise stated, default parameters have been used (as recommended in the *Residential Flood Damage Guidelines* (DECC, 2007)).

The stage-damage curves for both types of single storey house and two storey houses are default curves in the DECC calculation spreadsheet. The multi-storey apartments were treated as having the same curve equations as a two storey house but factored up based on the footprint area.

The DECC stage-damage curves within the spreadsheet are derived for late 2001, and have been updated using an Average Weekly Earnings (AWE) factor to May 2013 (ABS, 2013).

A total of 2,376 residential buildings were identified in the floodplain. The results of the residential property flood damages assessment are provided in **Section 5.3.5.**

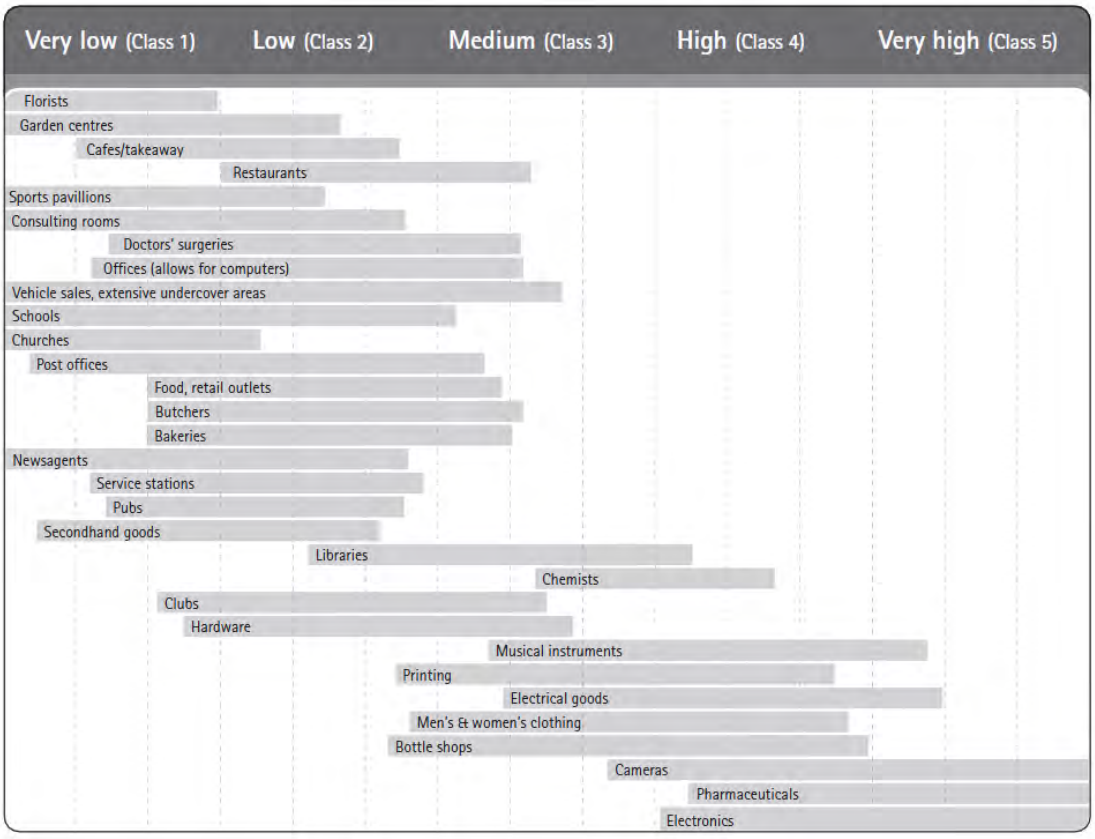
- **Table 5-1 Input parameters for damage calculations**

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	
Typical apartment block size	See comment	Damage curve based on two storey house and factored up based on footprint area (relative to typical house area)
Contents damage repair limitation Factor	0.75	Guidelines suggest a value of 0.75 for short duration floods
Effective warning time (hrs)	0	
Level of flood awareness	Low	Properties in the study area floodplain are typically not along significant watercourses and it is assumed that residents are typically not aware of potential damage of flood waters and the need to act.

5.3.3. 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 5-2**.

- **Figure 5-2 Damage categories for commercial properties (reproduced from *Guidance on the Assessment of Tangible Flood Damages* (Qld. Government, 2002)**



Based on **Figure 5-2** and observations on the types of businesses in the study area, the typical susceptibility class adopted for the flood damages assessment was the “Low” flood damage susceptibility class.

The stage-damage data were factored up by a value of 1.61 from 2002 dollars to current values based on Average Weekly Earnings (AWE) for November 2012, 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 192 commercial buildings were identified in the floodplain. The results of the commercial and non-residential property flood damages assessment are provided in **Section 5.3.5**. The adopted commercial property flood damages curves (after adjustment) are presented in **Appendix C**.

5.3.4. 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 sub-stations and 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, particularly in the upper sections, is typically due to relatively shallow, short-duration flows. 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.

5.3.5. Economic Analysis

5.3.6. 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.

Combined Annual Average Damages for residential and commercial properties in the study area in the existing situation is provided in **Table 5-2** separated by catchment. 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 DECC (2007) guidelines. The damages are in 2013 dollar values.

- **Table 5-2 Summary of Combined* Property Flood Damage by Catchment**

Catchment	Damage in Flood Event ($M)				Average Annual Damage ($M)	Net Present Value of Damage ($M)
	5yr	20yr	100yr	PMF		
Archer Creek	1.75	2.35	3.38	22.14	0.54	8.04
Charity Creek	3.58	4.31	5.20	24.96	0.93	13.76
Denistone	0.59	0.78	0.97	11.61	0.20	2.97
Gladesville	2.12	2.68	3.40	16.72	0.58	8.55
River	0.80	0.97	1.19	6.85	0.21	3.17
Total	**8.83**	**11.10**	**14.16**	**82.29**	**2.47**	**36.49**

* Residential and commercial property direct flood damages. Indirect damages, infrastructure damage, vehicular damage and intangible damages not included.

Points to note about the results include:

- The 5 year ARI property flood damages are $8.83M.
- The 20 year ARI property flood damages are $11.10M.
- The 100 year ARI property flood damages are $14.16M.
- The estimated property flood AAD is $2.5M per year.
- The trend of increase in event damages between the different ARI events is not linear. The damage value increases at a modest and reducing rate with increasing flood ARI. This confirms that the more frequent events such as the 5 year ARI contribute proportionally more to the accumulated damage value over a long period of time due to the relatively high event total damages and the higher likelihood of occurrence in any given year.
- The catchments most susceptible to property flood damage are (in reducing order of susceptibility) Charity Creek, Gladesville and Archer Creek, with relatively high AAD compared to Denistone and River catchments.
- Indirect damages, infrastructure damage, vehicular damage and intangible damages have not been included in the estimates. These may be estimated separately by applying a proportional multiplier (typically 0.1 – 0.2, DECC (2007)) to the total damages.

5.4. Note on the 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 DECC residential stage-damage curves recommended for use in NSW have most likely 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 Ryde Parramatta River Catchments study area, 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.

6. Floodplain Risk Management Measures

6.1. Overview

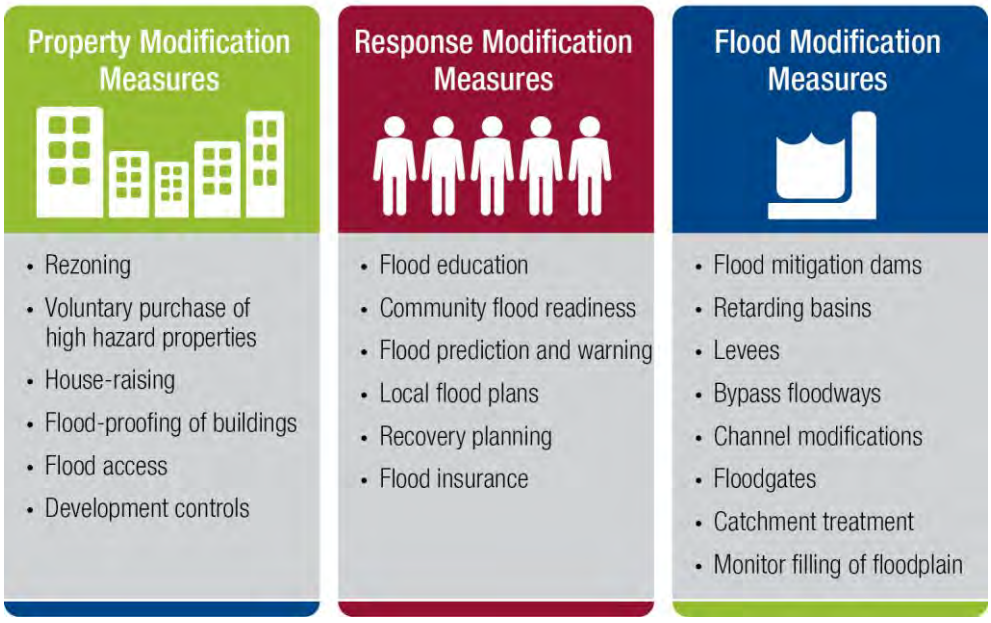
One of the objectives of this Floodplain Risk Management study is to identify and compare various floodplain risk management options to deal with existing flood risk in the study area, considering and assessing their social, economic, ecological and cultural impacts and their ability to mitigate flood impacts. A Floodplain Risk Management Option can be formulated by a combination of Floodplain Risk Management Measures for a specific area of the floodplain.

The *Floodplain Development Manual* (NSW Government, 2005) describes floodplain risk management measures in three broad categories:

- Property modification measures involve modifying existing properties (for example, house-raising) and/or imposing controls on new property and infrastructure development (for example, floor height restrictions);
- Response modification measures involve modifying the response of the population at risk to better cope with a flood event (for example improving community flood readiness); and
- Flood modification measures involve modifying the behaviour of the flood itself (for example, construction of a levee to exclude floodwaters from an area).

A detailed description of floodplain risk management measures are provided in Chapter 7 and a summary is provided in **Figure 6-1**.

- **Figure 6-1 Floodplain Risk Management Measures** *(Source: Floodplain Development Manual, 2005)*



6.2. Protecting properties

A number of properties in the study area (particularly Charity, Denistone and Archer Creek) have experienced flood damage in recent years. This has included parts of the Meadowbank TAFE, West Ryde Town Centre, several locations upstream of the Main Northern Railway and several residential and industrial areas. Flood protection measures can include flood barriers (temporary or permanent) but these are often only appropriate where there is adequate warning of a flood and/or the duration of the flood event requires property protection over a number of hours or days. This is not the case in the Ryde sub catchments. Consideration needs to be given to the most effective way of protecting existing buildings and future development from flooding.

6.3. Isolation and evacuation difficulties

Due to the nature of flood events in the Ryde catchment areas, isolation of communities is not a primary concern. Flood durations are short-lived and in contrast to rural areas, long periods where communities are isolated due to surrounding flood waters are not a common occurrence. There are 54 roads in the study area which would experience maximum depths of flooding exceeding 0.3m in the 20% AEP event, increasing to 91 roads in the 1% AEP event. These areas present obstacles to evacuation routes or safety concerns for mobilisation during a flood event, particularly for densely populated areas (for example Meadowbank TAFE and West Ryde Town Centre). Consideration needs to be given to areas where roads are accommodating large overland flows and alternative access routes proposed.

6.4. Support from SES

The NSW SES undertakes flood planning as a legislative responsibility to determine how best to respond to floods as the combat agency. The *NSW State Flood Plan* (2008) outlines arrangements for responding to floods in NSW. Local Flood Plans (LFP) are subordinate plans of the Emergency Management Plan (EMPLAN) which describes emergencies and responsible combat agencies. Currently there is no standalone LFP for the Ryde Local Government Area. However, the Ryde SES Unit operate a Facebook page which is used for local updates on weather and status of emergencies. The SES is located at Wicks Road, Macquarie Park, north of the study area so they are well placed to assist the area during flood events. It is important that local residents and businesses understand the role of the SES and their responsibilities during a flood event. This needs to be a consideration in the development of the FRMP, particularly when communicating the FRMP to the community. It is noted that there is a *Multicultural Rainbow Meeting Presentation by the SES* in Ryde on 17 April 2014. This is a presentation to new migrants to Ryde LGA in English, Korean and Chinese on who the SES are and what they do[1].

[1] http://www.stormsafe.com.au/local-storm-information-and-events/sydney-northern-region#events-and-activities

6.5. Flood Warning

Provision of accurate and timely flood warning is problematic for flashy urban catchments, such as those found in the study area. Due to the rapid response of the catchment, there is insufficient time to establish reliable warnings and disseminate to the local community. The use of rainfall gauges for warning triggers leads to an increase in false alarms and the use of river level triggers does not allow sufficient time for response, or does not capture the localised nature of the storm event.

In the absence of a flood warning system for the Ryde LGA, the FRMP needs to consider what improvements can be made to raising awareness of flood impacts for the local communities.

7. Evaluation of Floodplain Risk Management Measures

7.1. Overview

Locations have been identified in consultation with Council from the TUFLOW model results as flooding "hot-spots", where existing development is at risk from flood damage and capital works may be feasible for flood mitigation. Potential mitigation options have been identified in agreement with Council and tested in the TUFLOW model to evaluate the reduction in flood damages. Indicative capital costs have been estimated for proposed works to permit a benefit-cost assessment of each option, whereby the reduction in Annual Average Damages ("Benefit") are divided by the capital cost ("Cost"). A benefit-cost ratio greater than 1.0 would indicate that the capital cost of the works would be less than the savings in flood damages over the life of the works, and vice-versa for a ratio less than 1.0.

For the purposes of this assessment, a design life of 50 years has been assumed for the capital works with a discount rate of 7% for the economic assessment.

In some cases, the proposed option results in adverse flood impacts elsewhere or are not hydraulically effective, and these options were not costed or considered further.

7.2. Floodplain Risk Management Measures

7.2.1. 79-81 Cobham Avenue, Melrose Park (Archer Creek Catchment)

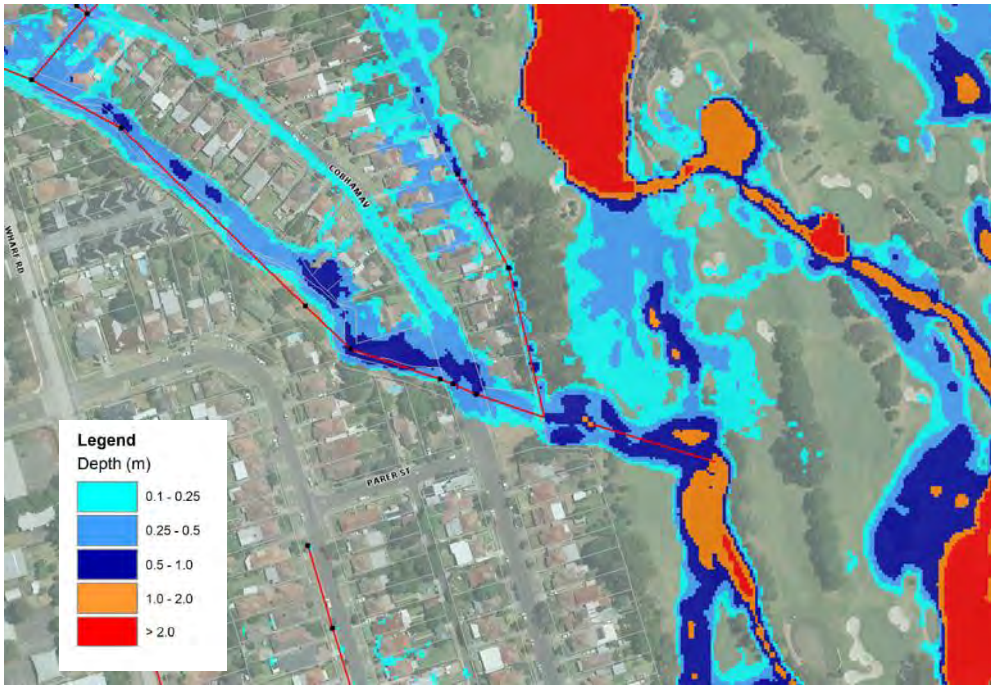
Flooding in this area (refer to **Figure 7-1**) affects the rear of 79 and 81 Cobham Avenue to a depth of 0.6m in the 1% AEP event, in addition to the sag point of the road, where flood depths are up to 0.6m. There is an existing floodway and easement at the rear of the properties on Cobham Avenue which follows the natural creek line, however, localised undulations in the ground surface in the floodway act as minor flow obstructions and also divert flows onto the residential properties. A high road verge on the eastern side of Cobham Avenue prevents surface flows from draining away from the sag freely.

Minor earthworks in the floodway and the road verge were tested at this location. This option was successful at reducing 1% AEP peak flood levels at a number of properties. However, many of the properties benefitting from this option are not affected by more frequent flood events such as the 20% AEP event, which are typically greater contributors to the Annual Average Damages than rarer events. This results in a relatively low benefit-cost ratio.

Indicative capital cost: $50,000

Benefit-cost ratio: 0.2

- **Figure 7-1 Cobham Avenue, Melrose Park, with 1% AEP flood Depth**



7.2.2. West Ryde Town Centre (Denistone Catchment)

West Ryde town centre has historically been a problem area for flooding, and the West Ryde stormwater tunnel has significantly improved flooding conditions (refer **Figure 7-2**).

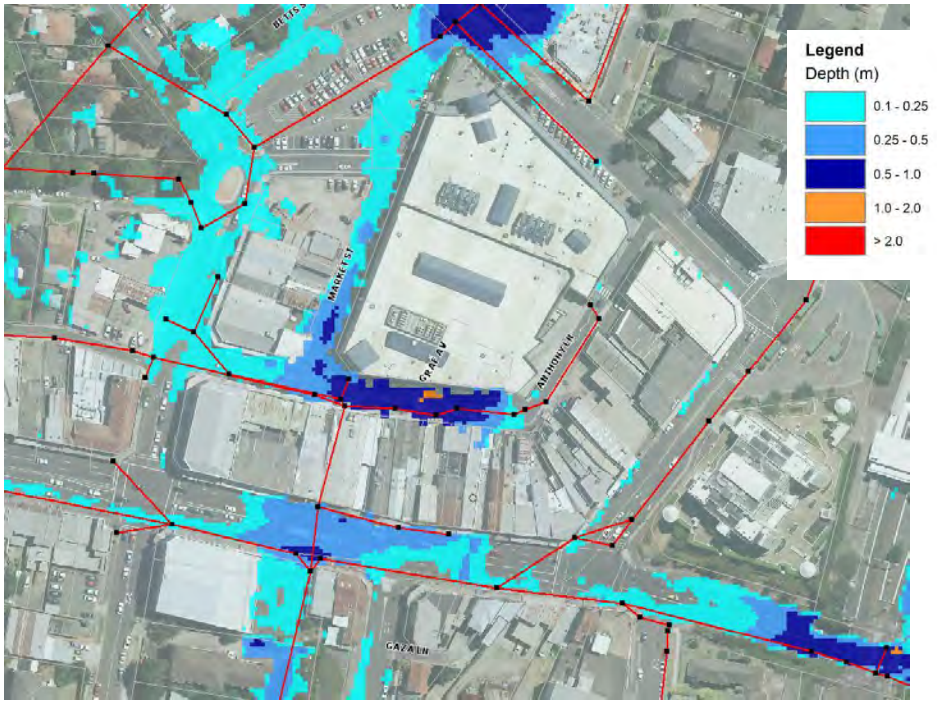
The baseline case agreed with Council for the stormwater drainage infrastructure does not include several proposed or recently constructed drainage upgrades in Graf Avenue, Anthony Road and Reserve Street. These upgrades were represented in the TUFLOW model for the mitigation case runs for completeness, and resulted in significant reductions in flood levels and depths of up to 0.3m in the 1% AEP event in Graf Avenue. As these drainage upgrades have already been constructed or are approved for construction, they were not costed for this study.

A new pipe branch connection to the stormwater tunnel, which appears to have redundant capacity, is likely to be prohibitively expensive and was not considered further.

Indicative capital cost: N/A (proposed drainage upgrades have recently been constructed or are approved for construction)

Benefit-cost ratio: N/A

- **Figure 7-2 West Ryde Town Centre with 1% AEP flood Depth**



7.2.3. Gaza Road – Station Street – Federal Road, West Ryde (Denistone Catchment)

Flooding occurs mainly at the rear of on Gaza Road and Station Street, with flooding depths up to 0.75m in the 1% AEP event. The same flow path continues across Mons Avenue and onto the front of properties on Federal Road (refer **Figure 7-3**).

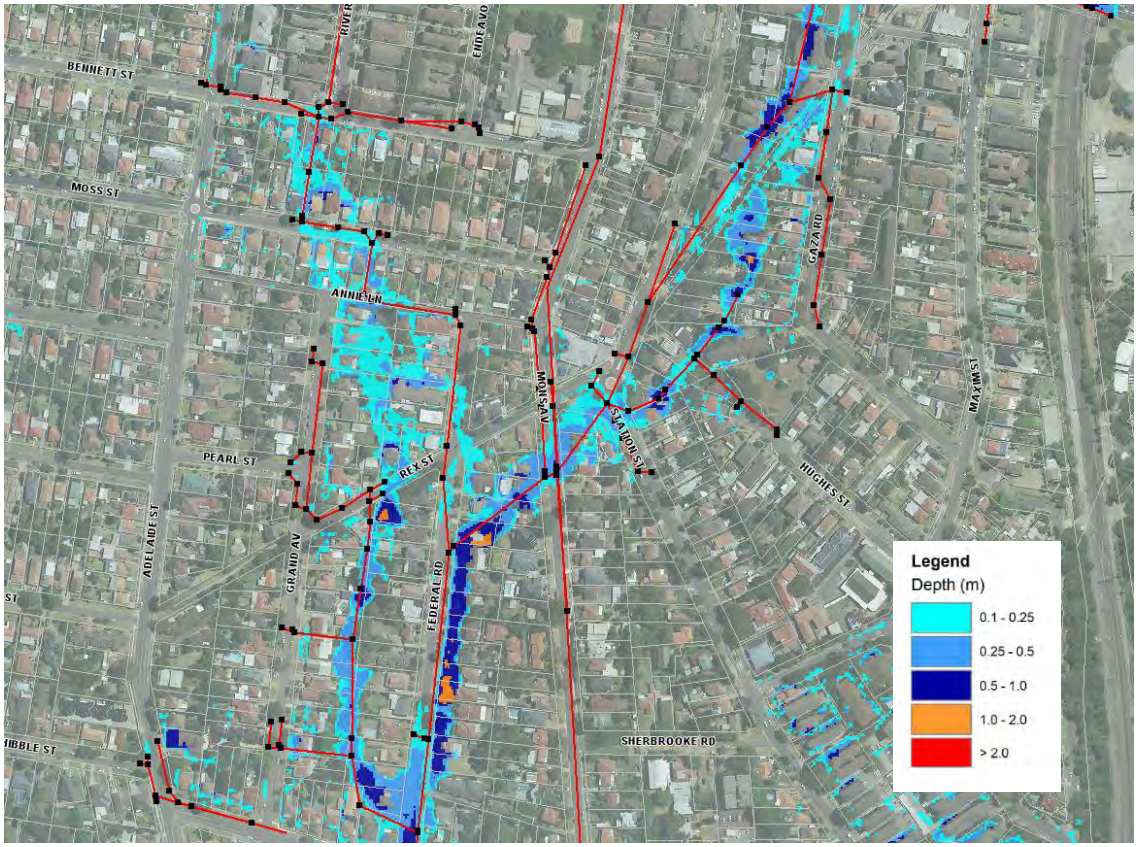
Most of the Federal Road properties have a defined floodway and their driveways include a dip to accommodate this overland flow. However, this has not been provided at 26 Federal Road, which causes a 1m high obstruction to flows from 24 Federal Road and depths up to 1.3m. There also may not be any provision to drain the ponded water away from 24 Federal Road. The properties downstream of 26 Federal Road do not appear to have a well defined floodway as present upstream. It is observed that the habitable floor levels are above the 1% AEP flood level, though it is likely that floodwaters would enter the garage and lower levels of the houses.

Two mitigation scenarios were assessed for this area:

Scenario 1

- Upgraded pits and a new sag pit on Gaza Road residential properties.
- Regraded driveway and front yard on 26 Federal Road to remove flow obstruction.
- New 2.1m x 0.9m culvert inlet on 28 Federal Road to intercept flows from floodway and dispose into existing pipe network.
- Regraded driveway and road verge at 34 Federal Road.

- **Figure 7-3 Gaza Road ,Station Street and Federal Road flow path, with 1% AEP flood Depth**



Scenario 2

- In addition to Scenario 1, connect existing main stormwater pipe branch to West Ryde Stormwater Tunnel at Mons Avenue.

Scenario 1 results in flood level reductions of up to 0.05m in the 1% AEP event upstream of Mons Avenue due to the pit upgrades, though there are localised minor increases in flood levels of up to 0.04m downstream of Mons Avenue in this scenario. Flood levels on properties on Federal Road are improved by up to 0.2m due to the proposed works in that location.

Scenario 2 results in flood level decreases in the 1% AEP event typically between 0.1 – 0.2m between Station Street and Constitution Road, with improvements of up to 0.5m immediately upstream of 26 Federal Road. These improvements are significant, although the high cost of the new connection to the Stormwater Tunnel may be prohibitively expensive.

The proposed and recently constructed drainage upgrades at West Ryde Town Centre have been modelled in conjunction with the Gaza Road to Federal Road works.

Scenario 1

Indicative capital cost: $120,000

Benefit-cost ratio: 0.8

Scenario 2

Indicative capital cost: >$400,000

Benefit-cost ratio: 0.5

7.2.4. Falconer Street near Wattle Street, West Ryde (Charity Creek Catchment)

Several properties are at risk to flooding in the 1% AEP event, with depths of between 0.8m and 1.2m, due to the overland flow path low point being located at the rear of these properties and Falconer Street raised about 1m above the low point, trapping floodwaters at the rear of the properties. The two properties with the deepest flooding are 57 and 59 Falconer Street. There does not appear to be a sag pit/s draining the low points on these properties (refer **Figure 7-4**).

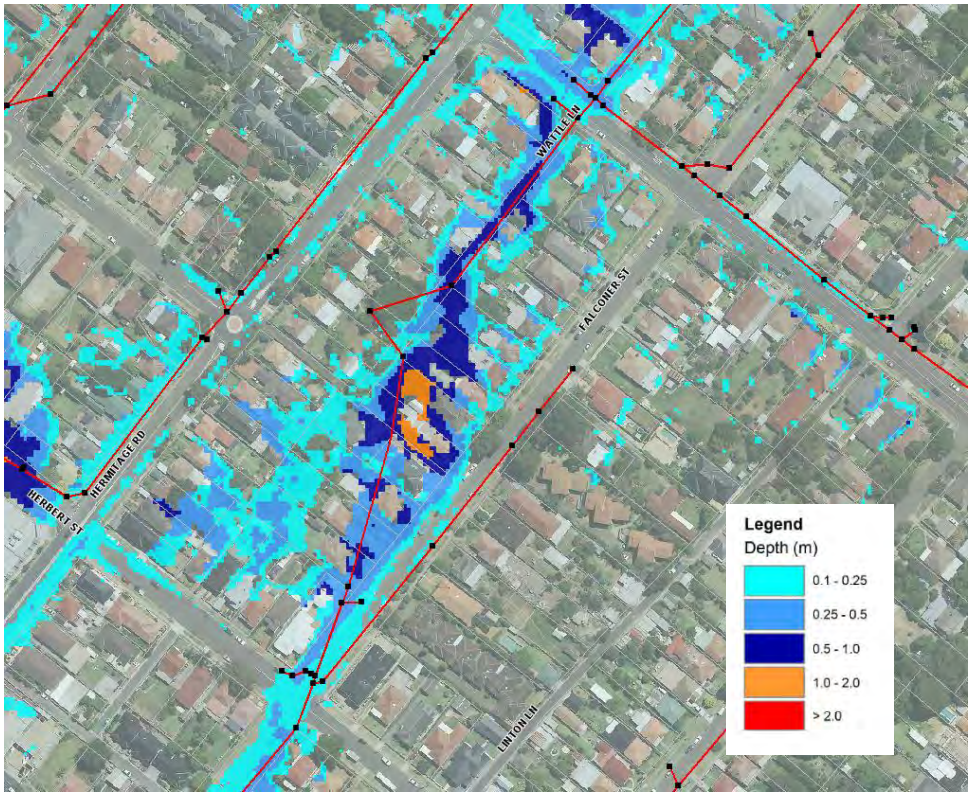
The agreed option for testing involved regrading the road levels of Wattle Lane to remove the existing road sag and crest, and construction of a low brick wall on the low side of the lane to retain floodwaters in the lane.

The TUFLOW model indicated that floodwaters would not be retained fully within the laneway, and that there would be significant increases in 1% AEP flood levels of up to 1m at the rear of properties between Wattle Lane and Hermitage Road. This is considered to be an excessive adverse impact and hence was not costed or considered further.

Indicative capital cost: N/A (not costed due to adverse flood impacts)

Benefit-cost ratio: N/A

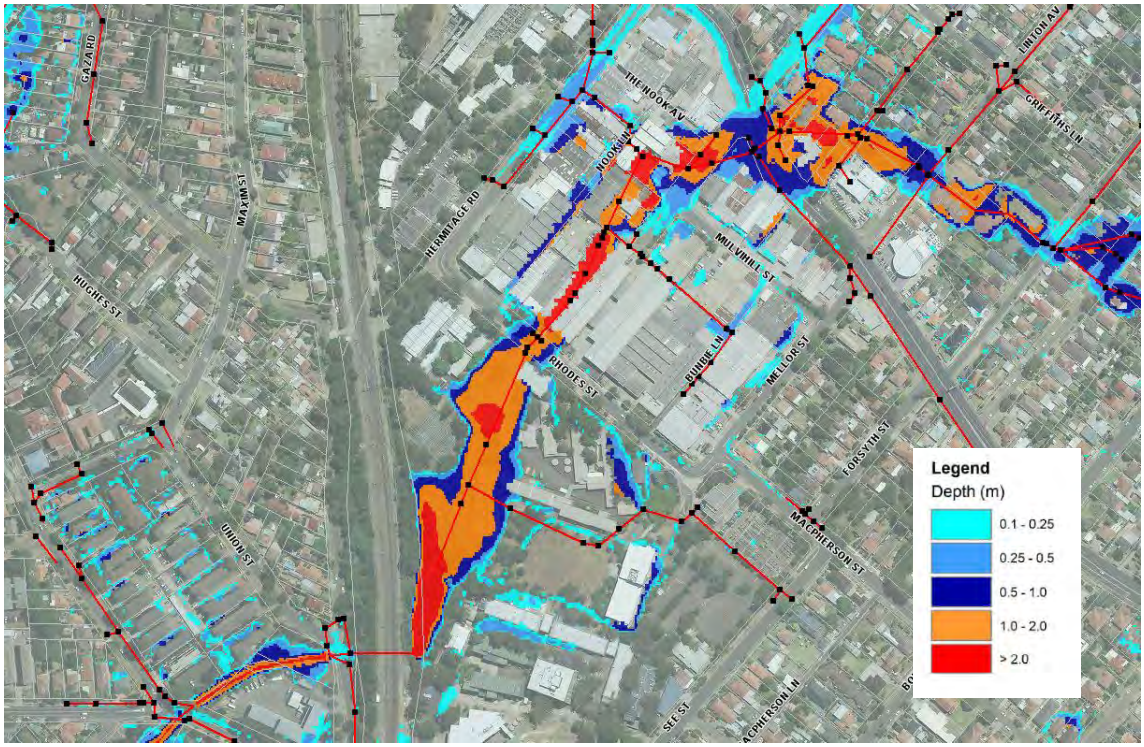
- **Figure 7-4 Falconer Street near Wattle Street flow path, with 1% AEP flood Depth**



7.2.5. Industrial area at Mulvihill Road and Rhodes Street, West Ryde (Charity Creek Catchment)

This area contains the main floodway of the Charity Creek catchment and has been developed with a number of industrial properties being built on fill in the natural watercourse (refer **Figure 7-5**). Some of these properties each have a depression in the ground surface with only relatively small sump pits to drain these low points. Further, there are sheds and possibly concrete boundary walls obstructing flow along the floodway. Downstream of the industrial complex, Rhodes Street and Meadowbank TAFE is built in fill which traps floodwaters on the industrial property at 11 Rhodes Street, particularly in the 20% AEP event. Further downstream, there are irregularities in the ground surface on the TAFE grounds which obstruct flow in the 20% and 5% AEP events, while the Main Northern Railway embankment is a significant obstruction to flow in the 5% and 1% AEP events, with backwater effects up into the industrial area.

- **Figure 7-5 Industrial Area at Mulvihill Street to Rhodes Street and the area downstream, with 1% AEP flood Depth**



The trunk drainage line running through the industrial area is at capacity in the 5% AEP event, hence pit capacity amplification will not have a significant effect on flooding conditions.

It was agreed with Council to assess a debris deflector at the inlet to the railway culvert, downstream of the TAFE. This would reduce the likelihood and degree of blockage due to flood debris.

While flood level reductions of 0.2 – 0.5m would be experienced on properties upstream of the railway, it was observed that there would be increases of 0.05 – 0.3m on properties downstream of the railway. This is considered to be an excessive adverse impact and hence was not costed or considered further.

Indicative capital cost: N/A (not costed due to adverse flood impacts)

Benefit-cost ratio: N/A

7.2.6. Gerrish Street – Cambridge Street – Pittwater Road, Gladesville (Gladesville Catchment)

Floodwaters flow through residential properties on 22 and 22A Cambridge Street at depths of up to 1m from the low point of Gerrish Street onto Cambridge Street, then tend to cut the corner and flow through 48 Pittwater Road (refer **Figure 7-6**). The apartment block on this property has its basement car park built below the surrounding ground level and there is potential for floodwaters to enter and become trapped in the basement.

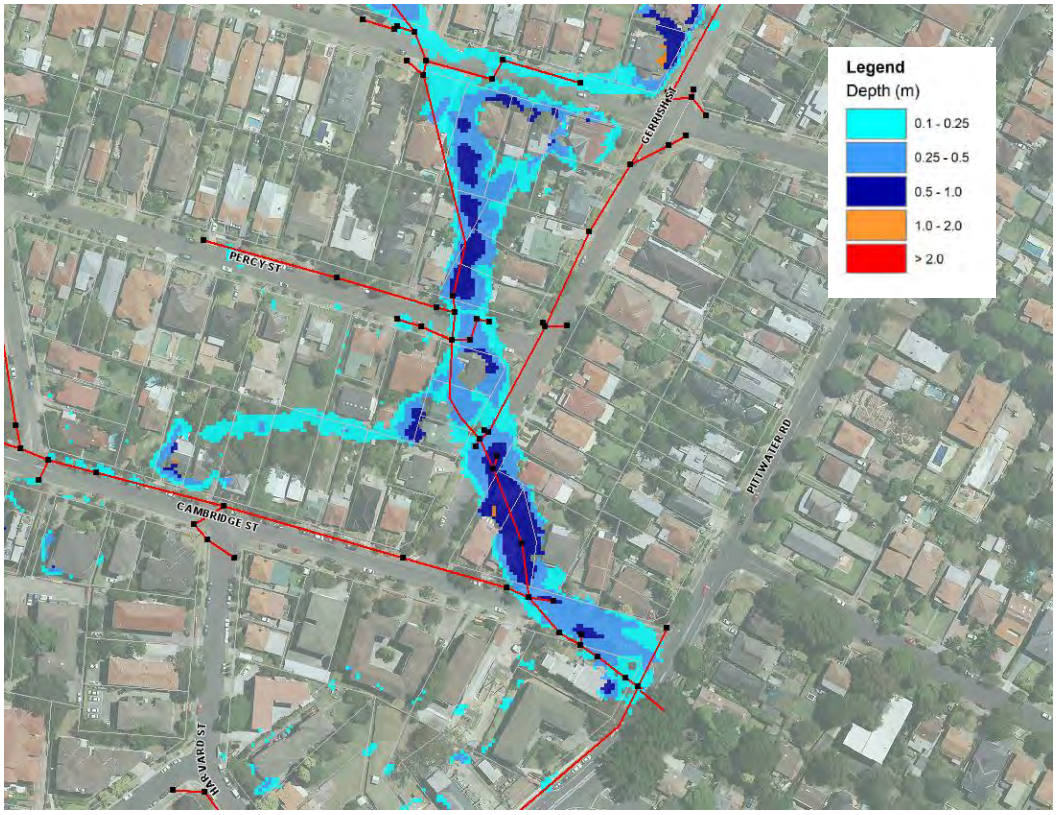
The residences on 22 and 22A Cambridge Street are not built in the low point, however, above floor and garage flooding may occur on these properties. It is not possible to divert flows from the Gerrish Street low point to Cambridge Street via the road corridor due to the high surface level at the road junction. There is no redundant capacity in the pipe network to accept additional flows. Additionally, Cambridge Street is not raised and does not obstruct or trap flows from 22A Cambridge Street so re-profiling the footpath or street is not a potential option. Other non-structural measures (e.g. development controls) would need to be considered for these properties.

A diversion structure such as a low block wall is proposed and will assist in reducing the volume of floodwater entering the basement car park of 48 Pittwater Road. The wall would need to be approximately 0.4m in height and would need to be tied-in with the existing footpath and accessways, including steps up to the apartment entrance and down into the basement. Existing ventilation holes would need to be filled in and relocated above flood level.

Indicative capital cost: $10,000

Benefit-cost ratio: 0.8

- **Figure 7-6 Gerrish Street Area, Gladesville, with 1% AEP flood Depth**



7.2.7. Morrison Road at Gregory Street, Putney (Gladesville Catchment)

The natural flow path is through the back of properties on Morrison Road, with flooding depths of up to 1.3m experienced in the 1% AEP event (refer **Figure 7-7**). The dwellings of most of the properties are located on higher ground out of the flow path, with the exception of a few of the properties near the intersection with Gregory Road. The property at 141 Morrison Road is the worst-affected by flooding in this location.

Both Morrison Road and Gregory Street are raised above the natural surface and obstruct floodwaters from freely flowing off 141 Morrison Road. There are some raised areas at the northern end of Morrison Bay Park, which are approximately 0.3m higher than the crown of Morrison Road.

Two scenarios were considered at this location:

Scenario 1

- Remove existing large fig tree and regrade raised areas to improve outflow from Morrison Road sag and into concrete channel. This resulted in a 0.02 – 0.06m decrease in flood levels on private properties.

Scenario 2

- In addition to Scenario 1, regrade (lower) road surface of Morrison Road and Gregory Street roundabout to provide further improvements to flooding. This resulted in a 0.06 – 0.1m decrease in flood levels on private properties.

Amplifying the pit inlet capacity along the flow path is not likely to be effective as the pipe branch along the flow path is at capacity.

Detention basins in Mallee Reserve and Cudal Reserve have been considered to mitigate flooding at this location, however, these possible basin sites are off the main flow path and hence are unlikely to have a major impact on flooding at Morrison Road.

Scenario 1

Indicative capital cost: $40,000

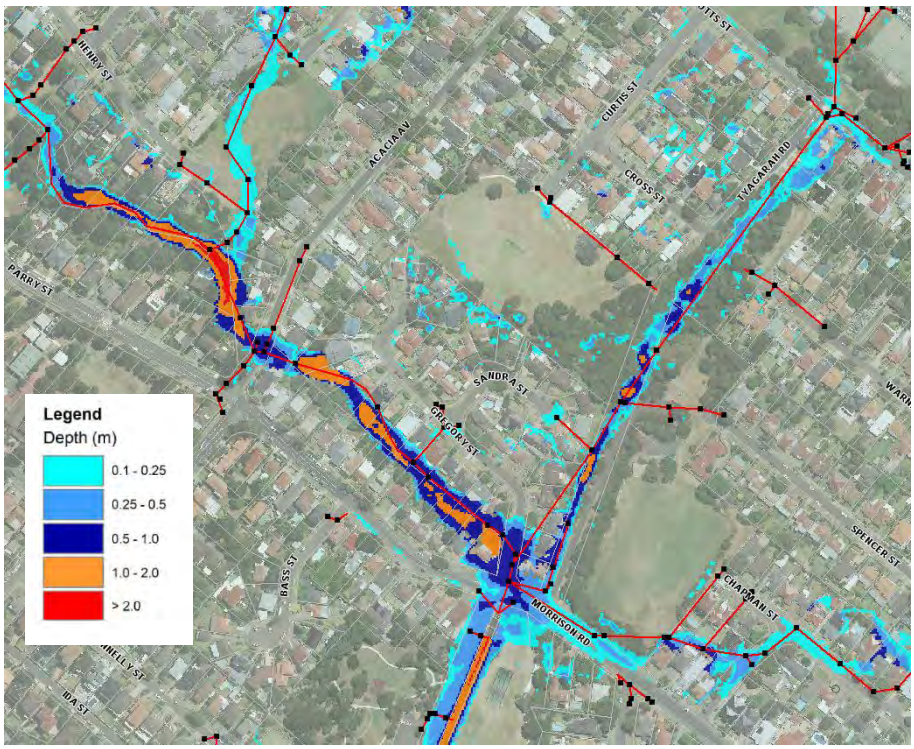
Benefit-cost ratio: 1.4

Scenario 2

Indicative capital cost: >$100,000

Benefit-cost ratio: 0.7

- **Figure 7-7 Morrison Road at Gregory Street and upstream overland flow paths, with 1% AEP flood Depth**



7.2.8. Victoria Road near Gardeners Lane to Deakin Street, West Ryde (Archer Creek Catchment)

The overland flow path in this area flows from north of Victoria Road and through six neighbourhood blocks of residential development before entering Ryde-Parramatta Golf Course and joining the main branch of Archer Creek (refer **Figure 7-8**). The overland flows cut through the neighbourhood blocks as the streets are aligned laterally to the overland flow direction. Depths of flow are typically 0.3 – 0.5m, however, the area of affectation is extensive.

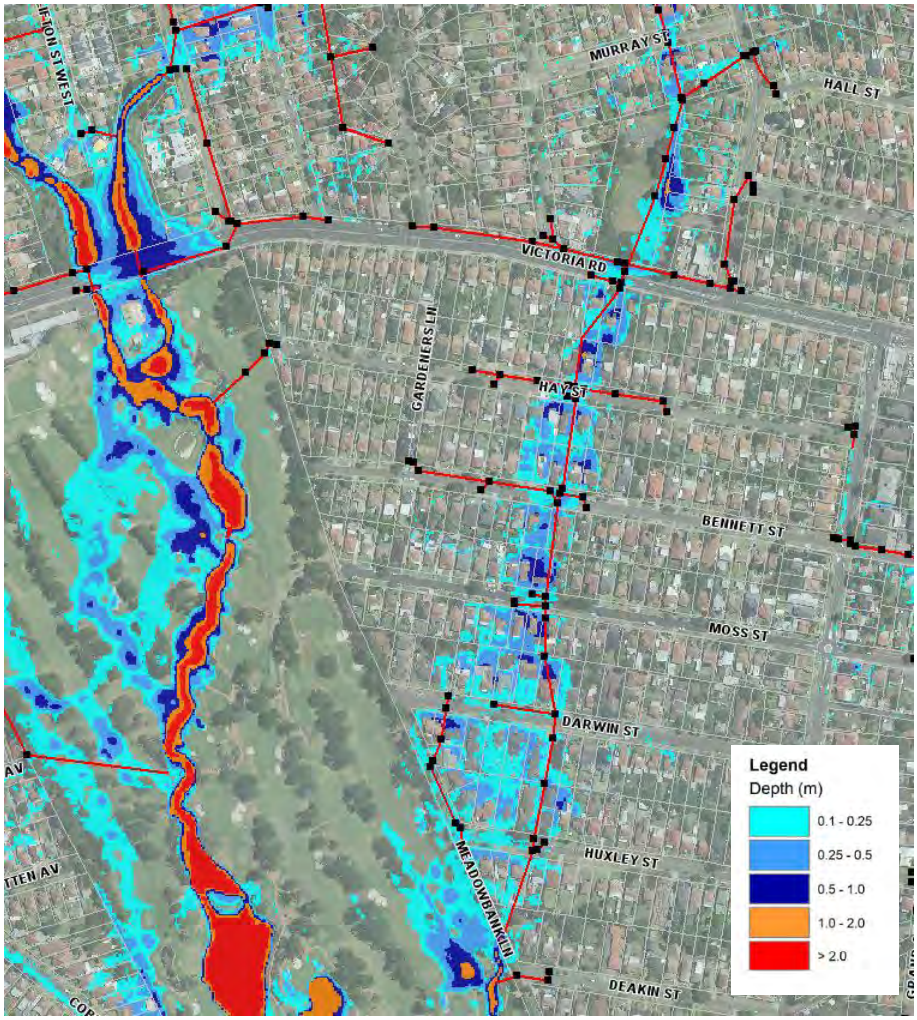
A 2,000m^2 detention basin in Lions Park, north of Victoria Avenue, was tested in the TUFLOW model. This would reduce, but not eliminate, overland flows through this problem area since there would be a significant volume of local catchment runoff entering the flow path downstream of Victoria Road. Hence, pit inlet upgrades to eleven existing pits on Victoria Road, Hay Street, Bennett Street and Moss Street are proposed to further reduce flooding downstream of Victoria Road.

Flood level reductions of up to 0.2m, typically around 0.1m, are experienced in the 1% AEP event. Overland flows across Victoria Road would be reduced from 5.9m^3/s to 2.2m^3/s .There would be approximately five fewer houses with above floor flooding in the 1% AEP flood with the proposed measures in place.

Indicative capital cost: $380,000

Benefit-cost ratio: 1.9

- **Figure 7-8 Victoria Road near Gardeners Lane, to Deakin Street, with 1% AEP flood Depth**



7.2.9. Belmore Street to Shepherd Street, Ryde (Charity Creek Catchment)

This area is at the headwaters of the Charity Creek catchment (refer **Figure 7-9**). Flooding of residential properties occurs in two separate flow paths through the properties, which converge at Shepherd Street. Flow depths are typically 0.3 – 0.4m.

The terrain is gently sloping in this area so construction of low earth berms approximately 0.3m high in the verge on the lower side of selected roads was considered as an option to reduce the amount of runoff flowing off the road and into the overland flow paths running through the properties. Works are proposed for Nicoll Avenue, Primrose Avenue, Addington Avenue, Sewell Street and Shepherd Street. Increasing the flow depths in the road is likely to also increase inflows into the pipe system, where there is some redundant capacity. Flows converging at the Shepherd Street sag point would then flow through the corridor of vacant lots previously purchased by Council to form a floodway down towards Victoria Road.

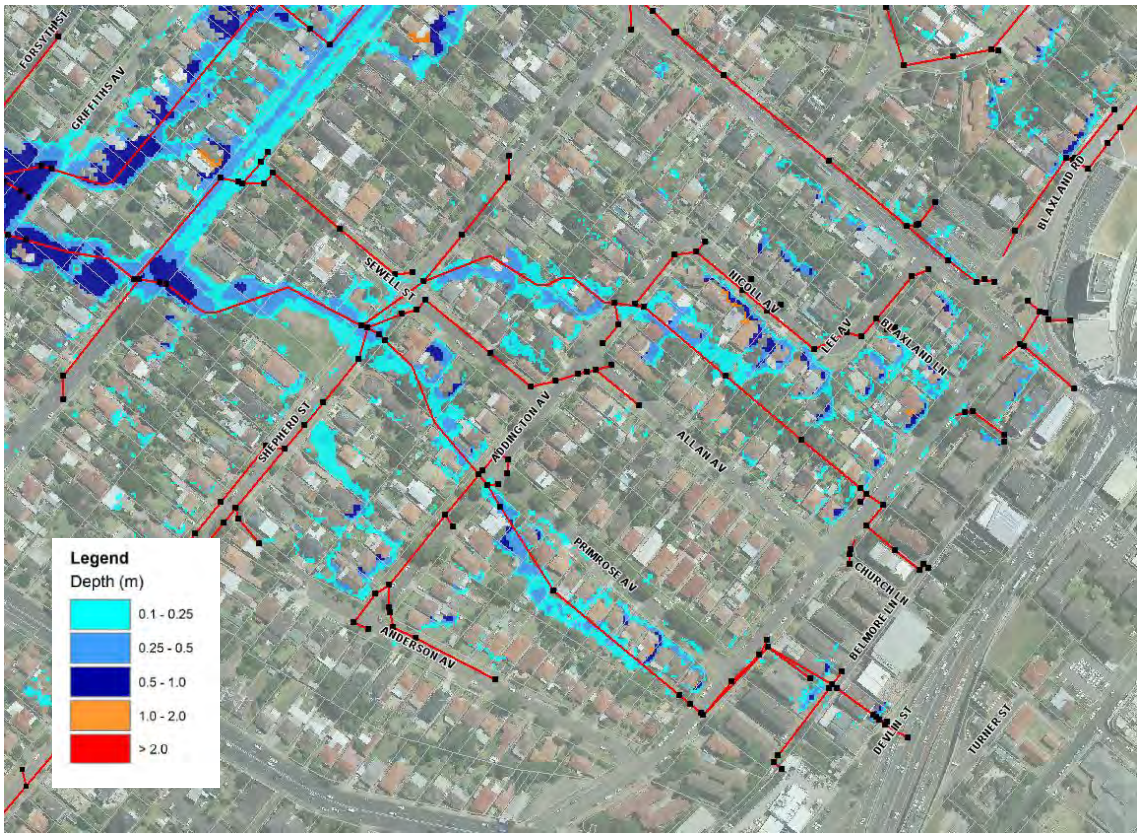
This option would also require modification (raising) of a number of affected driveways which may be an adverse impact on local residents.

Flood level reductions of up to 0.25m are experienced in the 1% AEP event, although minor increases of 0.02m may occur on some properties.

Indicative capital cost: $50,000

Benefit-cost ratio: 8.4

- **Figure 7-9 Belmore Street to Shepherd Street, with 1% AEP flood Depth**



7.2.10. Princes Street, Putney, from Morrison Road to Waterview Street (River Catchment)

Flooding in this area occurs in an overland flow path which flows through properties on Princes Street (refer **Figure 7-10**). Flood depths are typically 0.3 – 0.4m in the 1% AEP event. Runoff to the flow path originates from Regent Street to the west and Boulton Street to the east.

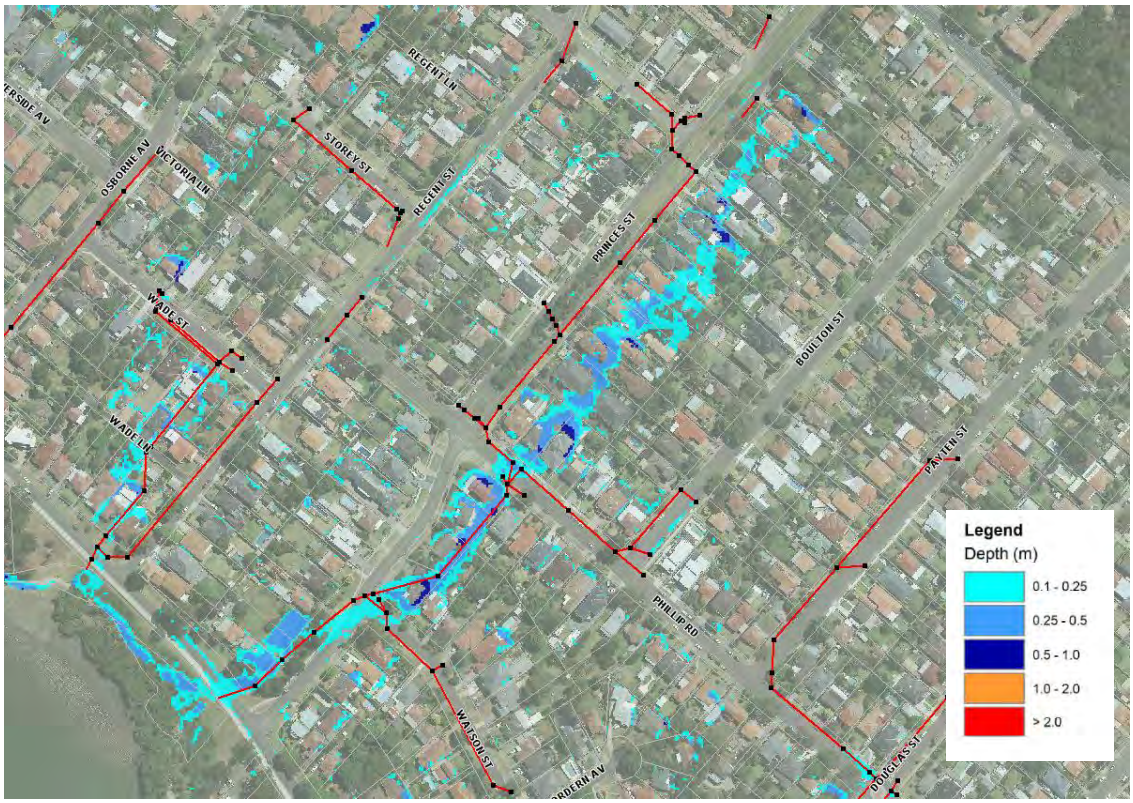
Princes Street is a dual-carriageway road with a 10m wide median grassed and vegetated strip. It was agreed to assess modifying the median including raising the height of the median to retain flows on the higher side of Princes Street. Floodwaters would then flow to the south-west to Phillip Road, where the flows would join the main flow path.

Testing of this option in the TUFLOW model indicated minimal reductions to flood levels in the main flow path, due to only a minor portion of the total catchment flow being redirected. This option was not considered hydraulically effective and hence was not costed or considered further.

Indicative capital cost: N/A (not costed due to minimal improvements to flooding)

Benefit-cost ratio: N/A

- **Figure 7-10 Princes Street, between Morrison Street and Waterview Street, with 1% AEP flood Depth**



7.2.11. 128 – 130 Cobham Avenue, Melrose Park (Archer Creek Catchment)

Flooding on these and the adjacent properties is caused by flows overflowing from the sag point in Cobham Avenue. The ground elevations at the rear of the properties is raised which obstructs flows and prevents floodwaters from flowing off the properties and into open space on the Ryde-Parramatta Golf Course. The sag is drained by two pits and a 375mm diameter pipe.

Mitigation works trialled at this location included:

- Removing the high ground at the rear of the properties to improve outflows away into the golf course; and
- Increasing pit and pipe capacity in the Cobham Avenue sag, including amplifying the existing pipe to a 750mm diameter pipe.

The tested mitigation works reduced flood levels at the rear of the properties by up to 0.2m, however, the works only provide minor reductions (0.02m) in the peak flood levels on the properties, which occur at the front of the properties, and would have a minimal effect on flood damages.

Indicative capital cost: $80,000

Benefit-cost ratio: < 0.1

7.3. Summary of Floodplain Risk Management Options

A summary evaluation table of the mitigation options is presented in **Table 7-1.**

Table 7-1 Summary of Floodplain Risk Management Options

Location	Description	Modelled change to 1% AEP flooding	Reduction of Dwellings with above floor flooding in 1% AEP		Financial Feasibility		Economic Merit		Impact on Flood Behaviour	Consequences in Extreme Floods	Technical Feasibility or Difficulty	Priority for Further Consideration (1 = highest; 3 = lowest)	Additional Comments
				No. Dwellings		Capital Cost		Benefit-Cost Ratio					
79 and 81 Cobham Avenue, Melrose Park (Archer Creek Catchment)	Earthworks in existing floodway corridor and road verge to remove flow constrictions and enhance capacity	Up to 250mm reduction on some properties. Recommended for costing	0	0	++	$50,000	--	0.2	++	0	++	2	Relatively low B-C ratio as this option does not affect the flood immunity of properties in more frequent events (many dwellings not affected in 20% AEP event).
West Ryde Town Centre (Denistone Catchment)	Incorporated recently constructed and proposed drainage upgrades - additional to Council-agreed design case. No obvious location for new Stormwater Tunnel connection.	Significant reductions in flooding. Recently constructed or proposed. Does not require costing	0	0	+ (Assumed)	Not costed	++	High	++	+	+	(1)	Modelled in mitigation assessment for completeness.
Gaza Road – Station Street – Federal Road, West Ryde (Denistone Catchment)	**Scenario 1** Upgraded pits and a new sag pit on Gaza Road residential properties. Regraded driveway and front yard on 26 Federal Road to remove flow obstruction. New 2.1m x 0.9m culvert inlet on 28 Federal Road to intercept flows from floodway and dispose into existing pipe network.	Up to 200mm decreases. Recommended for costing	0	0	+	$120,000	0	0.8	+	0	0	1	Preferred over Scenario 2 at this location. Omission of drainage upgrades on Gaza Road properties could be considered (minor improvements by these works).
	Scenario 2 In addition to works in Scenario 1, connect existing stormwater main branch pipe to West Ryde Stormwater Tunnel at Mons Avenue	450mm decreases Recommended for costing	0	0	-	> $400,000	-	0.5	++	0	--	3	Difficult and complex construction involving very deep excavation make Scenario 2 unfavourable, despite high reductions in flood levels.

Key to Qualitative Ratings in the Table Above
++ Highly favourable
+ Favourable
0 Neutral
- Unfavourable
-- Highly unfavourable

Location	Description	Modelled change to 1% AEP flooding	Reduction of Dwellings with above floor flooding in 1% AEP		Financial Feasibility		Economic Merit		Impact on Flood Behaviour	Consequences in Extreme Floods	Technical Feasibility or Difficulty	Priority for Further Consideration (1 = highest; 3 = lowest)	Additional Comments
				No. Dwellings		Capital Cost		Benefit-Cost Ratio					
Falconer Street near Wattle Street, West Ryde (Charity Creek Catchment)	Regrade Wattle Lane to remove sag/crest. Build brick wall on lower side of the laneway to keep flows in the lane.	Flows are not contained in laneway and cause flooding on new lots. Laneway vehicle access to garages on a number of properties would be cut off by the proposed wall. **Not for costing**	--	N/A	N/A	N/A	N/A	N/A	--	--	-	3	Highly disruptive to laneway access of existing properties and causes flooding of additional properties.
Industrial area at Mulvihill Road and Rhodes Street, West Ryde (Charity Creek Catchment)	Install debris guard at railway culvert inlet to minimise culvert blockage.	Reductions upstream of railway but causes localised increases downstream of 300mm. **Not for costing**	-	N/A	N/A	N/A	N/A	N/A	--	+,-	++	3	Adverse impacts of flooding downstream of the railway embankment are contributed to by limited capacity of existing concrete channel.
Gerrish Street – Cambridge Street – Pittwater Road, Gladesville (Gladesville Catchment)	Brick wall along Cambridge Street frontage of 48 Pittwater Road apartment block to deflect flows and prevent them from entering the garage. Infill ventilation holes in garage wall to prevent inflows. There is not sufficient capacity in existing pipe network to accommodate pit inlet amplification	Eliminates flooding from garage. Recommended for costing	0	0	++	$10,000	--	0.8	++	0	++	1	Localised measure for single property.

Key to Qualitative Ratings in the Table Above
++ Highly favourable
+ Favourable
0 Neutral
- Unfavourable
-- Highly unfavourable

7.4. Other Floodplain Management measures

7.4.1. Voluntary House Raising/Redevelopment

Voluntary house raising has long been a traditional response to flooding in New South Wales, as demonstrated by the number of raised houses in frequently flooded urban areas such as Lismore and Fairfield (Floodplain Development Manual, 2005). There are advantages associated with house raising which are noted as follows (Frost and Rice, 2003).

- A reduction of flood damages due to personal items being stored above the nominated flood level
- A reduction in danger to personal safety and a reduction in the cost of potentially needing to evacuate residents
- Cost-effective alternative to voluntary purchase, with positive social outcomes (i.e. home owners who have strong sentimental value on their properties can remain in the same location)

In Fairfield Council's experience, some of the disadvantages include:

- Residents' concern over security and privacy due to an open, expose ground floor
- Accessibility issues for the elderly or people with a disability
- Following raising, residents may develop a false sense of security from impacts. This can result in a belief that they will not be impacted by flooding or reluctance to evacuate when required.
- Over time and when flooding has not occurred, residents may be inclined to utilise the ground floor and converting it to a habitable area.

Whilst house raising can be considered for a range of building types, it is easiest and cheapest for timber-framed houses clad with non-masonry materials. The majority of houses in the study area are of single or double brick construction which are considered costly and impractical for raising. An alternative solution for these dwellings is to demolish and rebuild the house at a higher level (whether this is done by the existing owner or purchased by Council and re-sold with appropriate development controls).

Due to the factors outline above, house raising is not considered feasible as a mitigation measure for dwellings within the Ryde LGA.

7.4.2. Flood-proofing

Flood proofing refers to the design and construction of buildings with appropriate water resistant materials such that flood damage to the building itself (structural damage) and possibly its contents, is minimised should the building be inundated. It is regarded as a complimentary mitigation measure, rather than a primary way to mitigate the impact of flooding on properties. *Reducing Vulnerability of Buildings to Flood Damage* (Hawkesbury-Nepean Floodplain Management Steering Committee, 2007) describes the various options for building design to minimise the impact of flooding. City of Ryde (through the DCP, 2010) outlines requirements for new developments (or changes to existing developments) to consider stormwater management and flood compatible building materials.

Flood proofing of residential properties is generally a measure that can be pursued by individual property owners in low hazard areas to prevent above floor inundation. Consideration would have to be given to the potential impacts to surrounding properties and maintaining safety if the measure failed. It is recommended that flood proofing is investigated for the properties at 22 and 22A Cambridge Street, where flood depths of up to 1m occur in the 1% AEP event. City of Ryde may wish to consider offering subsidies or grants for flood proofing works to be carried out at these individual properties. Fairfield City Council provided subsidies of up to $20k for double-brick or two storey houses to assist in flood proofing the lower ground floor by raising electrical power points, installing a water sensor device to shut off power, replacing building materials liable to flood damage, and constructing local flood walls so long as adjoining properties were not adversely affected (Frost and Rice, 2003).

7.4.3. Planning and development controls

Land use planning and development controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately.

Planning controls including flood planning levels and flood related development control plans are discussed in the previous sections. As noted previously Council is currently undertaking a formal review of the Draft Flood Risk Management DCP and Draft Stormwater Drainage Management DCP, thus within this study no recommendations are provided for updating these planning aspects.

It is noted that in many other Council areas within Sydney, flood related planning controls are being applied in overland flow areas such as the upper catchment. The inclusion of these areas needs to be considered by Council as part of any review of the current policies.

7.4.4. Improve flood warning system

Flood warning services are provided by the Bureau of Meteorology (BOM) and the SES augments the Bureau's predictions with additional information and further warning services. The SES is equipped with local knowledge which can be used to disseminate required warnings in a suitable and timely fashion.

The study area includes small urban catchments where flash flooding occurs. Flash flood catchments are those defined as catchments in which less than six hours may elapse between heavy rainfall and flooding (NSW SES, 2008). Due to the short time available, an effective flood warning system is difficult to establish. Whilst it is difficult to establish, a basic flash flood warning system is currently being developed for the Northern Beaches. The Flood Warning and Information Network program is a joint partnership venture between Pittwater, Warringah and Manly Councils with guidance from Office of Environment (OEH) and BOM. The aim of the program is to develop a basic flash flood warning system for the community by strategically installing rainfall, water level and flow gauges (Millener *et al*, 2013).

Flash flooding usually results from relatively short intense bursts of rainfall, commonly from thunderstorms. This is problematic in urban areas where drainage systems may not cope and in very small creeks and streams. Flash floods tend to be quite local and it is difficult to provide effective warning because of their rapid onset (BOM, 2014). The reasons for this have been outlined identified for flash flood catchments as follows (McKay, 2004, 2008):

- Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models
- For flash floods, there is insufficient time to develop reliable flood warnings and for effective the dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness
- A reliance on rainfall triggers increases the frequency of false alarms
- The use of river level triggers does not allow sufficient time for response

Due to the reasons stated above, it is not possible for the Bureau to issue specific predictions for flash flood catchments. More importance is placed on the role of the SES to interpret the regional warnings which are provided by BOM to warn the community of the potential road closures and damage as a result of the predicted flood. The Ryde SES Unit has its own Facebook page which provides updates on weather warnings and estimated impacts. (https://www.facebook.com/nswsesrydeunit)

7.4.5. Improve Emergency Management Planning

Preparing for floods through flood emergency planning, exercising and community engagement enables a proactive response to flooding to be developed. Without preparation, flood response would become primarily reactive, reducing the opportunities to respond in the optimal time frames and with maximum efficiency through warning, evacuation, rescue, property protection and other activities. The most effective flood responses are likely to be those which have been thought about and planned for in advance. Preparing properly for floods, therefore, is likely to result in increased public safety, reduced property damage and faster community recovery (Commonwealth of Australia, 2009).

The City of Ryde does not have a Local Flood Plan (LFP) ; these typically describes the risk to the community, outlines roles and responsibilities for the SES and supporting agencies and describes how the SES will manage flood events.

As City of Ryde complete a number of Floodplain Risk Management Studies and Plans, it is recommended that a LFP is prepared for the study area. Particular attention should be paid to locations where high density populations are located (e.g. West Ryde Shopping Centre and Meadowbank TAFE). Also, guidance should be provided on the expected flood levels at various locations across the catchments, particularly where roads may be cut due to flooding.

7.4.6. Improve Public Flood Readiness

An increase in web based information and sharing via social media can benefit the "readiness" of a community for a flood event. City of Ryde is proactive in raising the profile of flood awareness in a number of ways:

- Advertising current activities via the Council website (Floodplain risk management plans, SES briefing meetings etc)
- Newsletters and questionnaires circulated to residents in addition to website postings
- Public exhibition of floodplain risk management plans

Suggested improvements for flood readiness include:

- Promotion of the SES FloodSafe website (http://www.floodsafe.com.au/) or a specific FloodSafe brochure being prepared for the study area. This would allow people to further understand how they can prepare for flooding and what to do during a flood event. These could be circulated following the SES presentations (the next session is being held in April 2014)
- Signage on key overland flow routes indicating where past flood levels have reached or providing warning signs where roads can become hazardous during flood events
- Improved cataloguing of flood risk information for the LGA so residents could locate their properties on a GIS platform and understand what their current risk is and how they can prepare for flooding in their area.

8. Draft Floodplain Risk Management Plan

8.1. Purpose of the Plan

{Drafting note – to be completed after feedback from Council on FRMS}

8.2. Prioritisation of floodplain risk management measures

{Drafting note – to be completed after feedback from Council on FRMS}

8.3. Funding and Implementation

{Drafting note – to be completed after feedback from Council on FRMS}

8.4. On-going Review of Plan

{Drafting note – to be completed after feedback from Council on FRMS}

9. References

City of Ryde (2010) Ryde Local Environmental Plan

City of Ryde (2010) Ryde Development Control Plan

City of Ryde (2011) Ryde Community Profile

Commonwealth of Australia (2009) Flood Preparedness.

Department of Environment and Climate Change (October 2007) *Floodplain Risk Management Guideline, Residential Flood Damage.*

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10. Glossary

Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Development	Is defined in Part 4 of the EP&A Act In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban

	services.
Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage (refer Section C6) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood liable land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards

	selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. (See Section K5). Freeboard is included in the flood planning level.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cusecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Overland flowpath	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flowpaths can occur through private property or along roads.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the

	interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.
Stage	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
Stage hydrograph	A graph that shows how the water level at particular location changes with time during a flood. It must be referenced to a particular datum.

Appendix A Community Consultation

Community Bulletin 1

Ryde Sub-Catchments Flood Study And Floodplain Risk Management Study And Plan

City of Ryde

This Community Bulletin has been issued to inform the residents of Ryde of the Flood Study and Floodplain Risk Management Study (FRMS) being prepared for your City. It is the first of a series of Bulletins planned to inform residents.

The purpose of the study is to provide a base for the development of a Floodplain Risk Management Plan. The Plan will be used by Council and other stakeholders to reduce the impact of flooding on the community, and assist in managing future development of the area.

An integral part of the study process is community consultation and involvement. This element of the process allows the needs and values of the community to be surveyed, so that they can be incorporated in the development of the Floodplain Management Plan. The management of flood prone land is primarily the responsibility of Councils and follows a number of stages.

Floodplain Risk Management Committee

A Floodplain Risk Management Committee has been formed which includes representatives from State Agencies, Emergency Service, Council and the Local Community. The Committee will meet regularly to oversee and guide the floodplain risk management process.

The Study Area

The study area includes five stormwater catchments, which flow into the Parramatta River. These are: Archer Creek, Denistone, Charity Creek, River and Gladesville catchments. The five catchments contain major stormwater drainage systems, which generally originate in the residential areas south of Blaxland Road and Lane Cove Road, flowing from north to south.

For more information contact City of Ryde on (02) 9952 8222
or visit www.ryde.nsw.gov.au

Flood Problem

The City of Ryde experienced several large storm events in 1984, 1986, 1988 and 1990, which caused widespread flooding. Heavy rainfall in 1998 and April 2003 also caused significant problems. Most of the stormwater pipes are in the latter part of their service life and generally do not have adequate capacity to accommodated large storm events. This can result in overland flows along streets and between developments.

Objectives of the Study

1) Understand the current flooding patterns in the study area
2) Construct a computer flood model which can be used to simulate the size and extent of potential future floods.
3) Develop options which will enable Council to manage future floods to reduce flood damage and improve social and economic opportunities.

Have you experienced flooding?

Some of the most important information for the study is collected from residents and local business operators. We would be very interested to receive records of flooding in your area including photographs, flood markings or some comments on your experience. You can help us with this information by completing the **questionnaire** which will be distributed in the mail. It is also available for completion online at:
www.ryde.nsw.gov.au

How can you get involved?

Engagement of the community in the floodplain risk management process is very important to Council. We will be providing a number of opportunities for the community to have input to the floodplain risk management plan. These are outlined below.

- **Community Bulletins**
  - Background to the study and context
  - Bulletins to update community on the project progress
- **Flood Questionnaire**
  - An opportunity to tell us about flooding in your area (via a questionnaire)
- **Community Forums**
  - Opportunity to find out more about flood risk management plans for your area and provide some feedback
- **Council website**
  - Contact details for queries relating to the study and how you can be involved.

Timeframes

Completion of Flood Study – May 2012

Completion of Floodplain Risk Management Study and Plan – March 2013

For more information contact City of Ryde on (02) 9952 8222
or visit **www.ryde.nsw.gov.au**

Flood Questionnaire

City of Ryde

Ryde Sub-Catchments Flood Study And Floodplain Risk Management Study And Plan

We need your help!

City of Ryde is undertaking a Flood Study and Floodplain Risk Management Study and Plan and would like to receive feedback from the community on a number of issues and topics related to flooding in your area. The purpose of the study is to provide a base for the development of a Floodplain Risk Management Plan. The Plan will be used by Council and other stakeholders to reduce the impact of flooding on the community, and assist in managing future development of the area.

An integral part of the study process is community consultation and involvement. This element of the process allows the needs and values of the community to be surveyed, so that they can be incorporated in the development of the Floodplain Management Plan.

If you cannot answer any question, or do not wish to answer a question, then leave it unanswered and proceed to the next question. **Your input to this important study will be greatly appreciated.** If you need additional space, please add sheets.

If you would prefer to provide a letter with your comments or respond to this questionnaire by speaking to Council by telephone, this would also be welcomed. To discuss any aspects of this questionnaire, please call

Guna Veerasingham, City Of Ryde
9952 8441
fax 02 9952 8110 or
email: gunav@ryde.nsw.gov.au

Please complete the Questionnaire by (date) and post in the envelope provided to:

City Of Ryde
Operations Centre, 1 Constitution Road, Ryde NSW 2112

Place a tick in the relevant box or write answers.

Question		Question and Answer
1.	☐ ☐	**Do you live (reside) in the study area shown on the attached plan?** Yes (Please mark the location on the plan.) No (Go to Question 3)
2.	☐ ☐ ☐	**Do you own or rent your residence in the study area?** Own Rent How long have you lived in the study area? (Please write number of years.)…….

Question		Question and Answer
3.	☐ ☐	**Do you own or manage a business in the study area?** Yes, For how many years? ……. No (go to Question 5)
4.	☐ ☐ ☐ ☐ ☐	**What kind of business?** Home based business Shop/commercial premises Light industrial Heavy industry Others, please write type of business ……
5.	☐ ☐	**Have you any experience of flooding in and around where you live or work?** Yes **No (Go to Question 15)**
6.	☐ ☐ ☐ ☐ ☐	**How deep was the floodwater in the worst flood that you experienced?** Please estimate the depth …….. What was the year of this flood?…… Where was this flood? □ At your house? □ At work? □ Elsewhere? Can you please provide a street location for this flood? ……..
7.	☐ ☐ ☐	**How long did the floodwaters stay up?** Few minutes Less than one hour More than one hour
8.	…….. …… …… …….. …… …….. ☐ ☐	**If the flooding was where you lived, what damage resulted from this flood?** (Please indicate either “none”, "minor", "moderate" or "major". Damage to Garden, lawns or backyard Damage to external house walls Damage to Internal parts of house (floor, doors, walls etc) Damage to Possessions (fridge, television etc) Damage to car Damage to Garage Other damage, please list…… What was the cost of the repairs, if any?…….
9.	…… …… …… ……	**If the flooding was at your business, what damage resulted from this flood?** (Please indicate either “none”, "minor", "moderate" or "major".) Damage to surroundings? Damage to building Damage to stock Other damages, please list…….. What was the cost of the repairs, if any?…….

Question		Question and Answer
10.		**Was vehicle access to/from your property disrupted due to floodwaters during the worst flooding?**
	☐	Not affected
	☐	Minor disruption (roads flooded but still driveable)
	☐	Access cut off
11.		**What information can you provide on past floods?** (You can tick more than one box). Please write any descriptions at the end of the questionnaire
	☐	(a) No information
	☐	(b) Information on extent or depth of floodwater at particular locations, newspaper clippings or other images on the past floods
	☐	(c) Any permanent marks indicating maximum flood level for particular floods
	☐	(d) memory of flow directions, depth or velocities
12.		**Do you consider that flooding of your property has been made worse by works on other properties, or by the construction of roads or other structures?**
	☐	Yes (please provide further details. Attach extra page if necessary. Provide sketch if possible.
	☐	Unsure
	☐	No
13.		**Do you have any photographs of past floods that would be useful for to further understand the area flooded or other flood effects?** If possible please attach the photographs (with dates and location) which will be copied and returned.
	☐	Yes (either attach and we will contact you to arrange for a copy to be made and returned)
	☐	No
14.		**Do you expect to undertake any further development on your land in the future?**
	☐	No (go to Question 16)
	☐	Minor extensions
	☐	New building
	☐	unsure
	☐	Other (please specify) _____
15.		**Have you undertaken any steps to obtain approvals for further development on your land?**
	☐	No
	☐	Made preliminary enquires with Council
	☐	Engaged someone to prepare plans
	☐	Lodged plans with Council
	☐	Have approved plans but not proceeded

Question		Question and Answer
16.		**Please rank the following development types according to what you consider should be assigned greatest priority in protecting from flooding** (1 = greatest priority to 7 = least priority).
	☐	Commercial
	☐	Industrial
	☐	Residential
	☐	Community facilities (schools, halls, etc)
	☐	Critical utilities (power substations, telephone exchanges, etc.
	☐	Minor development and additions
	☐	Recreation areas and facilities
17.		**What notifications do you consider Council should give about the potential flood affectation of individual properties?** (Tick more than one box if required.)
	☐	Advise every resident and property owner on a regular basis of the known potential flood affectation
	☐	Advise every resident and property owner on a regular basis of Council's policies on the control of land potentially affected by flooding
	☐	Advise prospective purchasers/developers on the control of development on land potentially affected by flooding
	☐	Provide no notifications
18.		**Please rank from 1 to 4 (1 = highest importance) the following:**
	☐	Protecting Residents/business from flooding
	☐	Protecting land of residents/businesses from flooding
	☐	Maintaining flood free access to property
	☐	Providing flood warning
19.		**Please rank from 1 to 4 (1 = highest importance) the following:**
	☐	Preservation of creeks and waterways in a natural state
	☐	Improving water quality
	☐	Removing litter from creeks and rivers
	☐	Protecting plants and animals in the study area
20.		**Are you satisfied with City of Ryde service in the following areas, (please indicate, very satisfied, satisfied, dissatisfied, very dissatisfied)? If you have no opinion on any of these questions, write NA.**
	……	Flood protection during minor storms
	……	Flood protection in major storms
	……	Effectiveness of Street drainage
	……	Protection of plants and animals in the study area
	……	Advice from Council staff on flood issues
21.		**Do you wish to comment on any other issues associated with the development of the Floodplain Risk Management Plan? Please add comments at the back of the questionnaire.**
22.		**Do you wish to remain on the mailing list for further details, Newsletters etc?**
	☐	Yes (please provide contact details, see next question)
	☐	No

Question		Question and Answer
23.		If you would like, please provide details of where you live and how we can contact you if we need to follow up on some details or seek additional comment. Can you please also mark the location of your residence/business with a clear dot on the attached plan. **Name:……** **Address…….** **…….** **Telephone:……** **Fax:……** **Email:……**
		Space for additional comments

Study Area

Appendix B Flood Precinct Mapping

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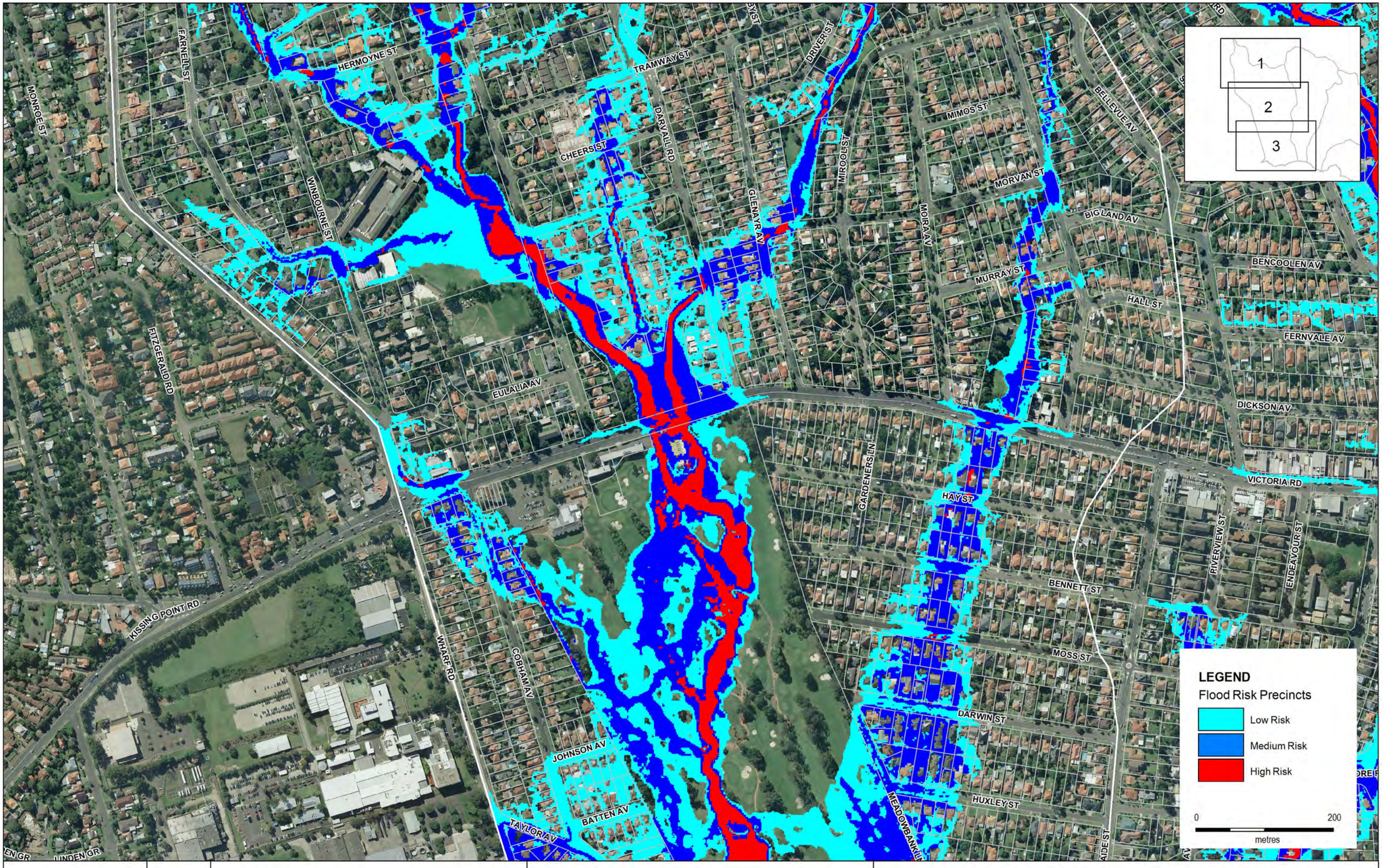
Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Archer Creek Catchment Sheet 1 of 3



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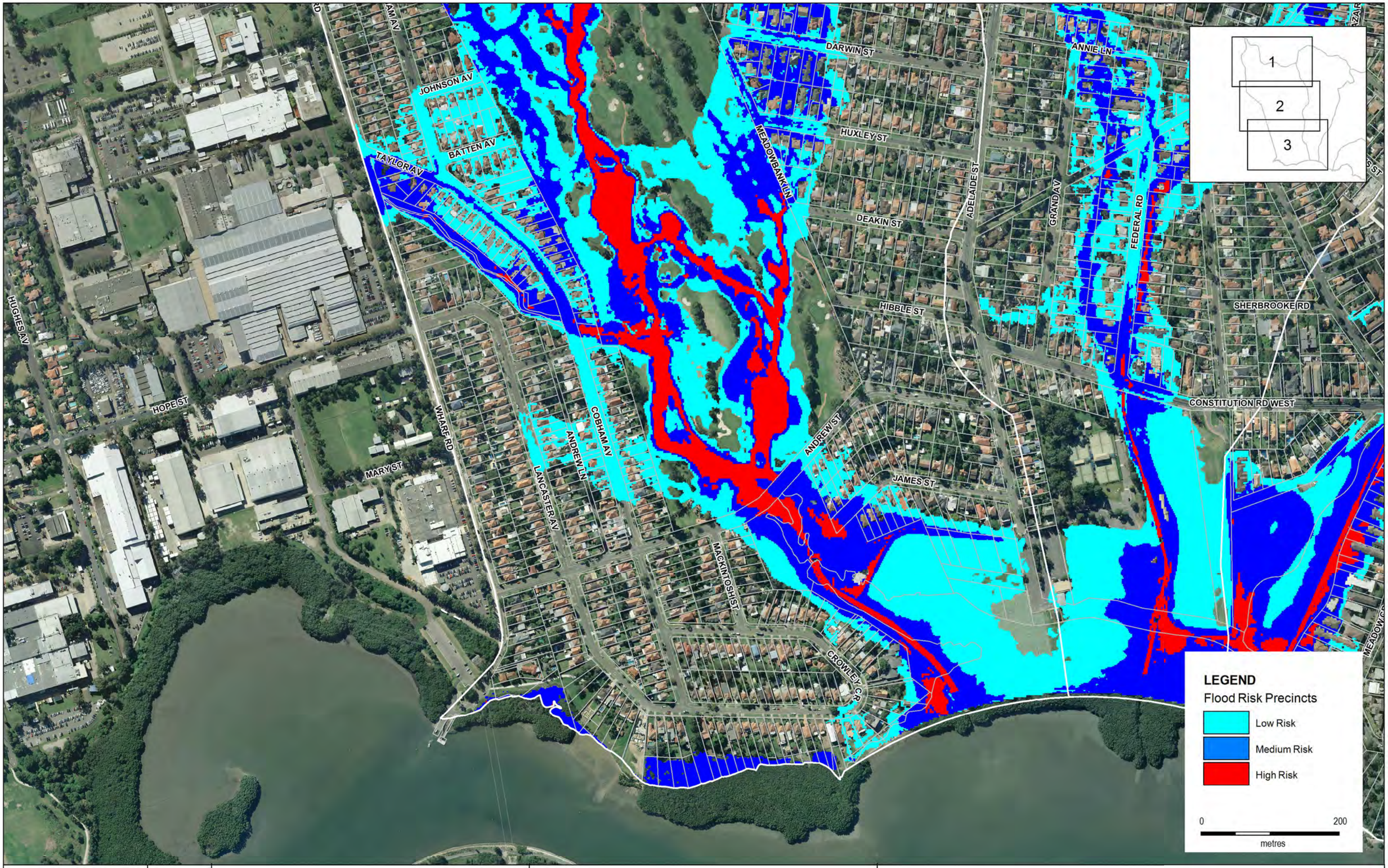
Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Archer Creek Catchment Sheet 2 of 3



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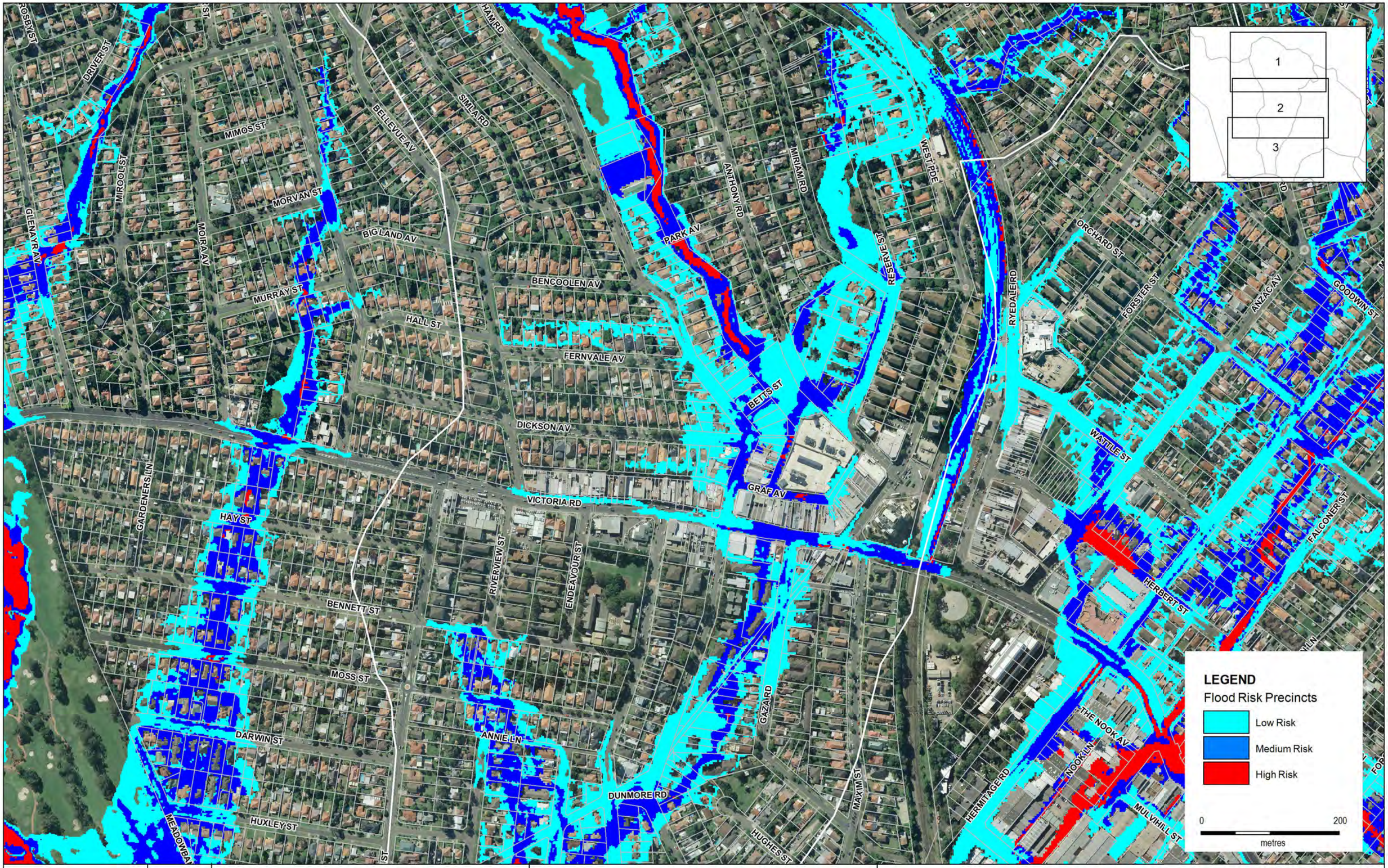
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Archer Creek Catchment Sheet 3 of 3

SINCLAIR KNIGHT MERZ SKM	N	**Datum:** GDA 1994 **Coordinate System:** MGA Zone 56	Parramatta River - Ryde Sub-Catchments Flood Study and Floodplain Risk Management Plan	**Flood Risk Precincts** **Denistone Catchment Sheet 1 of 3**



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Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Denistone Catchment Sheet 2 of 3

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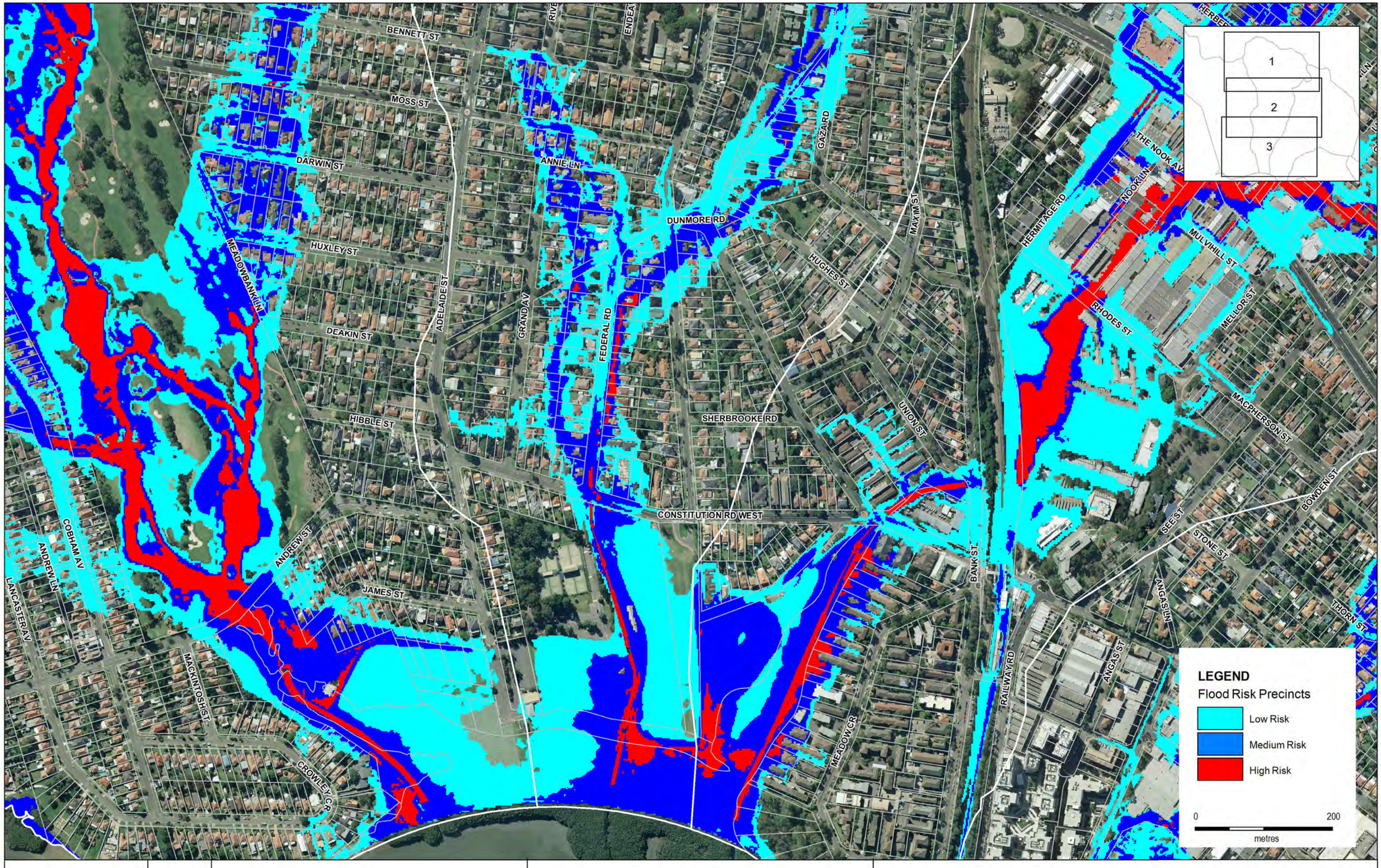

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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Denistone Catchment Sheet 3 of 3

SINCLAIR KNIGHT MERZ SKM

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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Charity Creek Catchment Sheet 1 of 2

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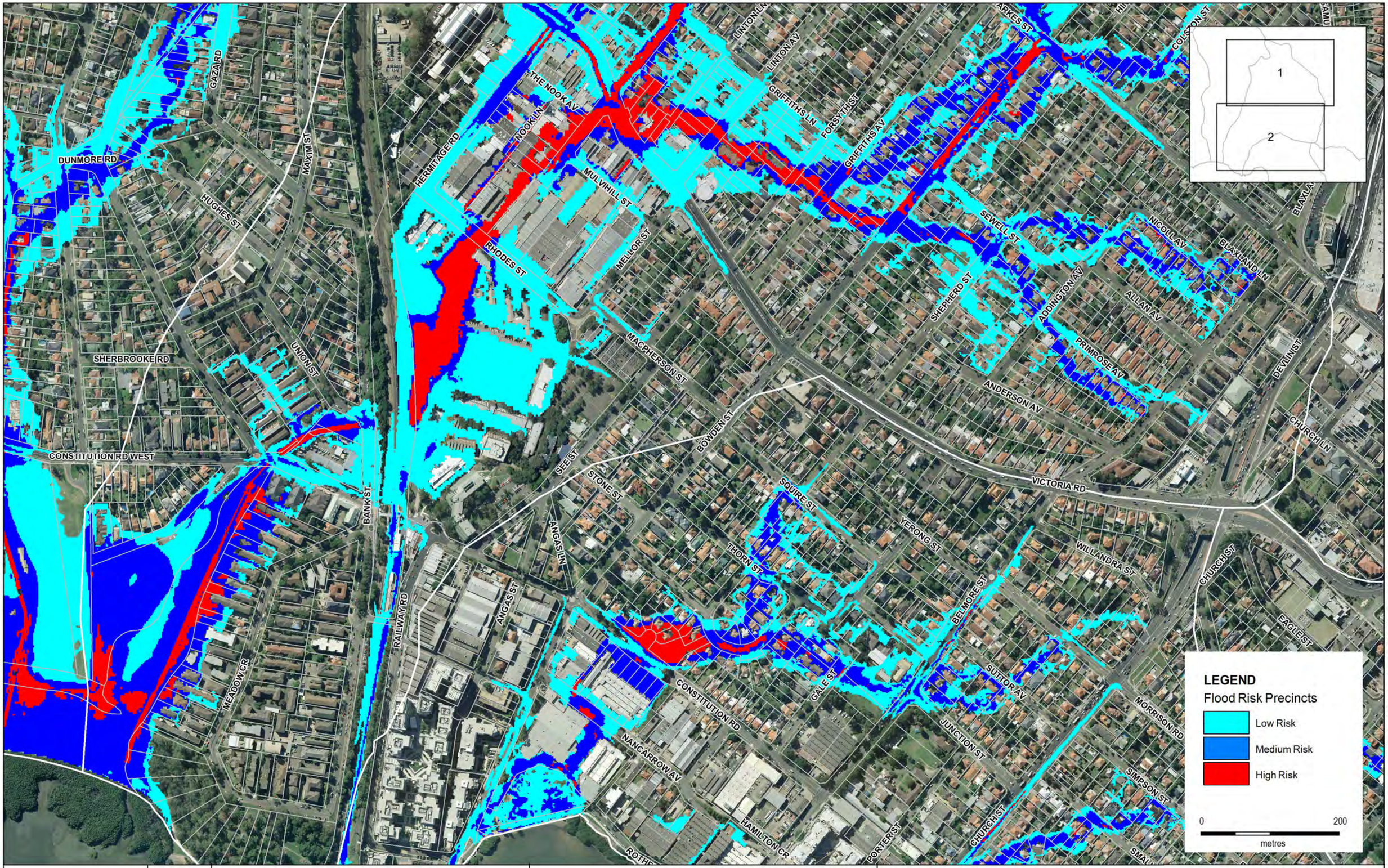

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Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Charity Creek Catchment Sheet 2 of 2

SINCLAIR KNIGHT MERZ SKM

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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

River Catchment Sheet 1 of 2

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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

River Catchment Sheet 2 of 2

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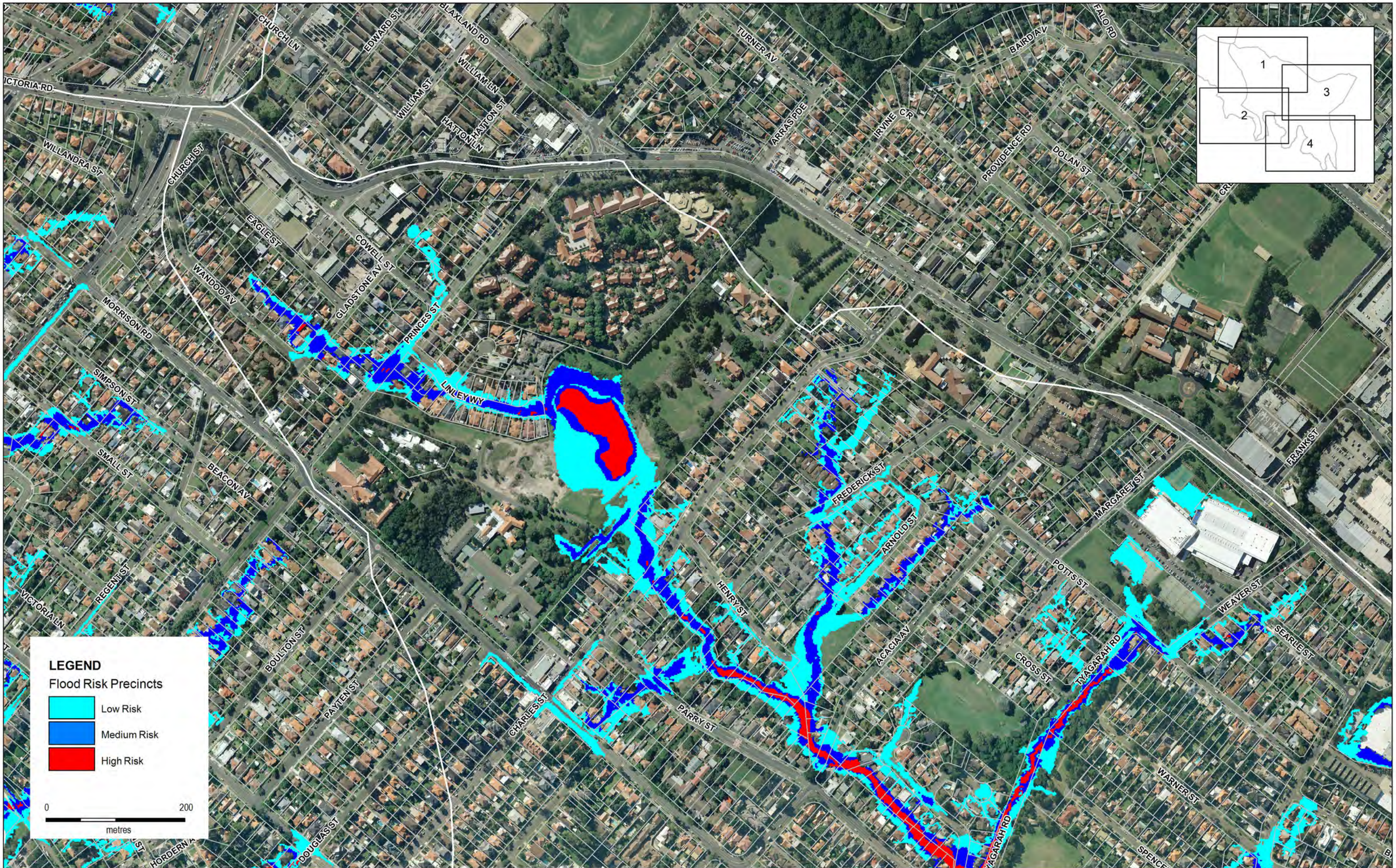

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Datum: GDA 1994
Coordinate System: MGA Zone 56

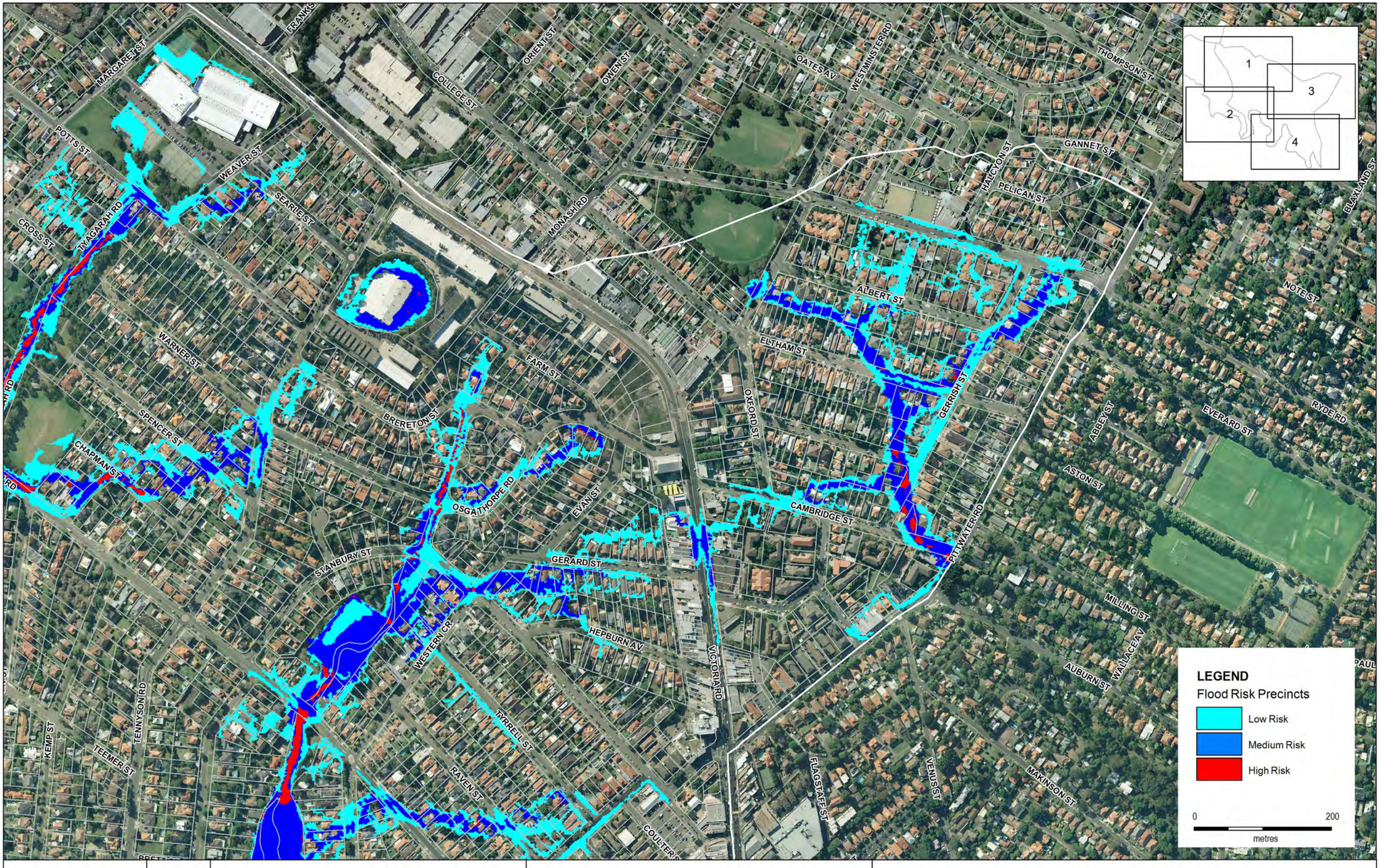
Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Gladesville Catchment Sheet 1 of 4

April 2, 2013 | SUA_FloodRisk_1 of 4_FRMS.mxd

SINCLAIR KNIGHT MERZ SKM	N	**Datum:** GDA 1994 **Coordinate System:** MGA Zone 56	Parramatta River - Ryde Sub-Catchments Flood Study and Floodplain Risk Management Plan	**Flood Risk Precincts** **Gladesville Catchment Sheet 2 of 4**



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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Gladesville Catchment Sheet 3 of 4

April 2, 2014 | SLA_FloodRisk_3 of 4_FRMS.mxd

SINCLAIR KNIGHT MERZ

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Datum: GDA 1994
Coordinate System: MGA Zone 56

Parramatta River - Ryde Sub-Catchments
Flood Study and Floodplain Risk Management Plan

Flood Risk Precincts

Gladesville Catchment Sheet 4 of 4

Appendix C Commercial Property Flood Damages Curves

Table C-1 Adopted Commercial Stage-Flood Damage Curves

	Small Commercial Properties					Medium Commercial Properties					Large commercial properties*				
	Floor area <186sqm					Floor area 186-650sqm					Floor area >650sqm				
Depth/Class	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
0m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.25m	$5,672	$11,347	$22,692	$45,384	$90,771	$17,968	$35,930	$71,860	$143,718	$287,438	$ 18	$ 39	$ 82	$157	$314
0.75m	$14,183	$28,364	$ 56,731	$113,462	$226,925	$43,493	$86,986	$173,975	$347,951	$695,899	$ 98	$201	$397	$793	$1,595
1.25m	$21,273	$42,550	$85,096	$170,194	$340,385	$66,185	$132,373	$264,743	$529,559	$1,058,978	$209	$417	$840	$1,672	$3,341
1.75m	$23,637	$47,275	$ 94,552	$189,104	$378,206	$73,274	$146,556	$35,510	$586,220	$1,172,441	$340	$688	$1,373	$2,743	$5,484
2m	$25,054	$50,114	$100,387	$200,449	$400,898	$78,004	$156,013	$312,021	$624,041	$1,248,082	$410	$819	$1,638	$3,277	$6,556

* units in $/sqm

Ref: QldGovt NRM (2002) Guidance on the Assessment of Tangible Flood Damages