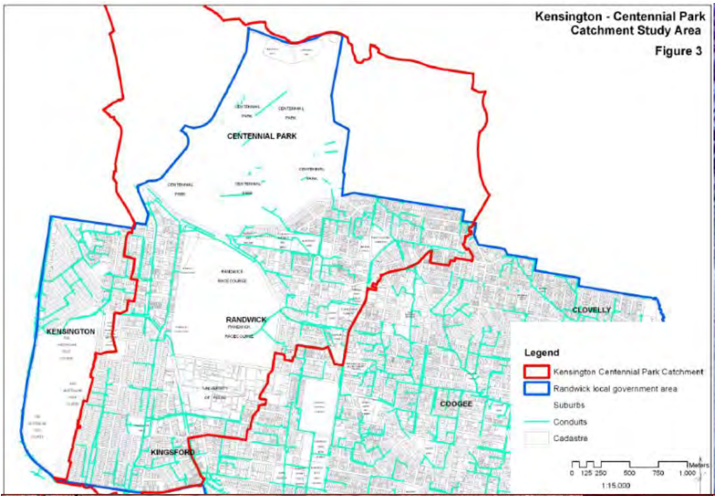
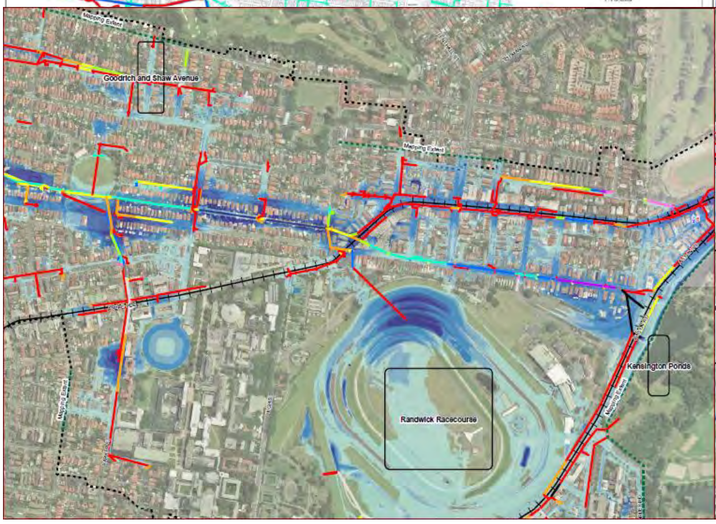
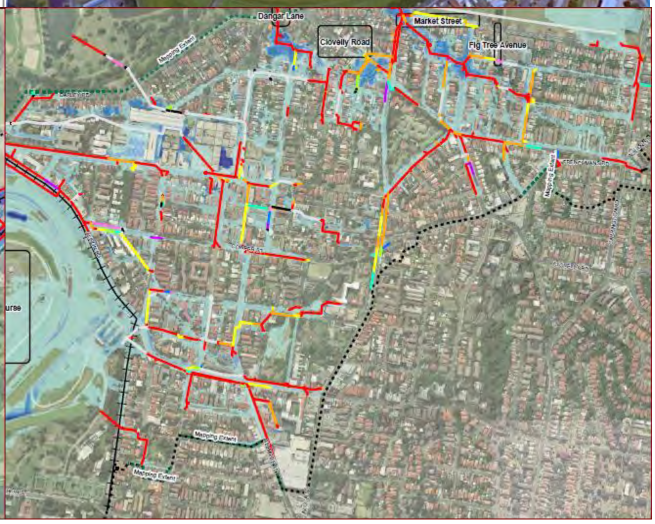
RANDWICK CITY COUNCIL

KENSINGTON – CENTENNIAL PARK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Post Light Rail FRMS







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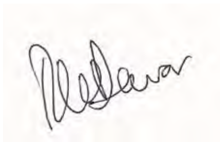
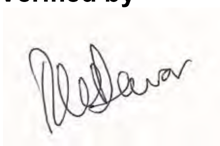
Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

KENSINGTON – CENTENNIAL PARK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

POST LIGHT RAIL FRMS

Project **Kensington – Centennial Park Floodplain Risk Management Study and Plan**	Project Number **13048**
Client **Randwick City Council**	**Client's Representative** Steve Audet Sebastien Le Coustumer
Authors Dan Morgan Richard Dewar	**Prepared by** 
Date 07 February 2019	**Verified by** 

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KENSINGTON – CENTENNIAL PARK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

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ACRONYMS

AAD	Average Annual Damages
ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Scanning Survey (LiDAR)
AR&R	Australian Rainfall and Runoff (1987 and 2016 editions)
B/C	Benefit Cost Ratio
BoM	Bureau of Meteorology
DA	Development Application
DCIA	Directly Connected Impervious Areas
DCP	Development Control Plan
DRAINS	Hydrologic computer model
DSC	Dam Safety Committee
EIA	Effective Impervious Area
EMPLAN	Emergency Management Plan
EP&A Act	Environmental Planning and Assessment Act
ERP	Emergency Response Planning
EY	Exceedances per Year
FPA	Flood Planning Area
FPL	Flood Planning Level
FMC	Floodplain Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
ICIA	Indirectly Connected Impervious Areas
ICPA	Indirectly Connected Pervious Areas
IPCC	Intergovernmental Panel for Climate Change
LEP	Local Environment Plan
LFP	Local Flood Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (also see ALS)
mAHD	Meters above Australian High Datum
Mike-Storm	Combined hydrologic and hydraulic computer model
OEH	Office of Environment and Heritage
OSD	On-site Detention
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department
SCCG	Sydney Coastal Councils Group
SES	State Emergency Services
SMS	Short Message Service
TUFLOW	A one-dimensional (1D) and two-dimensional (2D) hydraulic computer model
UNSW	University of New South Wales
UPA	Urban Pervious Areas
VP	Voluntary Purchase
WSUD	Water Sensitive Urban Design
1D / 2D	One dimensional and two dimensional computer models

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management Study***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans and Development Controls to ensure new development is compatible with the flood hazard.

The Kensington – Centennial Park Floodplain Risk Management Study and Plan (FRMS&P) constitutes the second and third stages of this management process. This study has been prepared by WMAwater on behalf of Randwick City (Council) and provides the basis for the future management of flood prone lands in the Kensington - Centennial Park area of Sydney. To inform this Management Study and Plan, the hydraulic modelling undertaken for the Flood Study was reviewed to ensure that model outputs are fit for purpose as well as taking into account any newly available data since the Flood Study modelling was undertaken. In particular the modelling was updated to include all works associated with construction of the Light Rail as well as the upgraded methodology in Australian Rainfall and Runoff 2016 (AR&R 2016).

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

EXECUTIVE SUMMARY

Introduction

This document comprises the Floodplain Risk Management Study and Plan (FRMS&P) for the Kensington – Centennial Park study area within the Randwick City local government area. Provided within is a description of the flooding problem in the study area as well as an assessment of a number of floodplain risk management measures. The Plan provides the recommended measures to be undertaken by Council.

The study area comprises the 9.7 km^2 catchment upstream of Gardeners Road at Eastlakes which includes parts of the City of Sydney, Waverley and Randwick local government areas. Within the catchment are two large areas of open space being Centennial Park and Randwick Racecourse with the remainder largely residential and commercial developments. Significant flooding occurred in November 1984 which inundated several residential and commercial buildings causing significant tangible damage, inconvenience and hardship.

Objectives of the Floodplain Risk Management Study and Plan

The objectives of this study are to:

- Develop a Floodplain Risk Management Plan that addresses the existing, future and continuing flood problems, including:
  - Review of the 2013 Flood Study and upgrading the modelling to incorporate the Light Rail as well as the upgraded methodology in Australian Rainfall and Runoff 2016 (AR&R 2016);
  - Preparation of a Floodplain Risk Management Study (FRMS) – investigating flood risk management measures and making recommendations; and
  - Preparation of a Floodplain Risk Management Plan (FRMP) – developed from the FRMS detailing how flood prone land within the study area is to be managed.

Methodology

Following a thorough engagement process, a detailed methodology has been tailored to achieve the best outcomes from the FRMS&P process for the Kensington – Centennial Park area. The key steps agreed upon are summarised as follows;

- Compilation and review of available information;
- Review of 2013 Flood Study – including revision of hydraulic modelling techniques;
  - Incorporation of the AR&R 2016 design flood methodology;
  - Incorporation of all works associated with the Light Rail project;
  - Mapping of the design event floods for the 1 EY, 0.5 EY, 0.2 EY, 10% AEP, 5%, 2%, 1%, 0.5% and 0.2% AEP events as well as the PMF including;
    - Peak flood levels, depths and velocities;

- Hydraulic categorisation – floodway, flood storage or flood fringe;
- Hydraulic hazard categorisation
- Comparison of results with the prior Flood Study 2013 results;

- Establish impacts of climate change on flood levels (for the 1% AEP event);
- Assess the flooding issue in the study area, including;
  - Identifying key locations for flood management known as flooding hot-spots;
  - Identifying emergency response classifications;
  - Flood damages assessment under current conditions and compared with costs associated with potential mitigation works;
- Review of current flood planning controls and emergency management;
- Assessment of risk management measures to identify practical options for the study area including;
  - Flood modification;
  - Property modification; and
  - Response modification.
- Community consultation through media releases, newsletters, public workshops and the floodplain management committee to obtain additional information and seek resident opinions on potential flood management measures; and finally
- The preparation of the Floodplain Risk Management Plan.

Summary of Flooding Issues

Within the urbanised parts of the catchment flooding occurs when the capacity of the piped network is exceeded and flood waters travel along roads and through private property to reach the large culverts under Gardeners Road where they exit into Eastlakes and The Lakes golf courses. In addition there are a number of trapped low points throughout the catchment where outflow is via a pipeline or infiltration into the underlying sand. In events greater than the 2% AEP the embankment within Centennial Park parallel to Alison Road will be overtopped and floodwaters will cross Alison Road and travel towards Gardeners Road.

Change in Design Flood levels

The 2018 design flood levels (Appendix B) have been reduced since the prior 2013 Flood Study due to:

- the Bureau of Meteorology lowering the design rainfalls based on analysis of sub daily rainfall data obtained in the period from approximately 1987 to 2016;
- a changed methodology in applying temporal patterns for design storms and rainfall losses in accordance with AR&R 2016 rather than the previous AR&R 1987 version;
- raising of the embankment of Centennial Park ponds adjacent to Alison Road (as part of the Light Rail construction) which has introduced considerable additional temporary floodplain storage within Centennial Park.

As a consequence of lower flood levels the annual average flood damages to the community have reduced as well as the number of properties that will be subject to Council's flood related planning controls.

Existing Flood Problem

Despite the above changes to design flood levels flooding will still occur within the catchment. It is estimated that in the 1% AEP event 328 properties are flooded above floor level (271 residential) with 67 properties flooded above floor level (57 residential) in a 0.2EY event. The average annual tangible damages (residential and commercial properties) are estimated as approximately $4 million. In addition flooding causes significant intangible damages such as inconvenience, hardship and risk to life.

Flood Risk Management Measures

A variety of flood risk management measures are possible and Council nominated approximately 20 flood modification measures as well as property and response modification measures to be investigated. In preliminary work prior to construction of the Light Rail the highest ranked flood modification measure was the raising of the Centennial Park ponds embankment along Alison Road. This was raised by 300mm as part of the Light Rail works and further raising was not considered viable due to increased flood impacts within Centennial Park. The only other viable flood modification measures are enlarging the culverts under Gardeners Road and/or providing blockage prevention devices to ensure minimal blockage occurs at the existing culverts.

The remainder of the proposed management measures are property and response modification measures. These will not only reduce damages to existing properties in the next flood but will ensure that as re-development occurs building floors will be raised above the 1% AEP + appropriate freeboard.

Recommendations

This FRMS and FRMP identified a number of management options and strategies to be considered by Council and the committee. The floodplain management measures considered are detailed in Table 20, the locations of the 20 flood modification measures are shown in Figure 4 and their ranking to be undertaken provided in the FRMP.

Public Exhibition – Model Revision

During public exhibition phase of the FRMS&P it was discovered that a section of the Light Rail Tram Yard flood mitigation structure was not incorporated into the model. The TUFLOW model was revised to incorporate the complete flood mitigation structure and the design flood events re-modelled. The revisions to the modelling resulted in changes to peak flood levels of up between +/- 0.3m in the Tram Yard and between +/- 0.2 m on properties adjacent to the Tram Yard on Alison Road and Doncaster Avenue.

The flood damages assessment for the design events was revised using the updated design flood results. The damages assessment for the proposed mitigation options was not revised as the tram yard is not located in the vicinity of any of the proposed mitigation options. The damages assessment for the mitigation options is a relative assessment and no benefit would have been gained by re-modelling all of the options as the relative differences would have still been the same.

PART A Floodplain Risk Management Study

1. INTRODUCTION

This report prepared by WMAwater on behalf of Randwick City Council comprises the Floodplain Risk Management Study and Plan for Kensington - Centennial Park. Recommendations are in accordance with best practice and NSW flood policy as per the Floodplain Development Manual (Reference 1). The NSW Floodplain Management Program places an emphasis on extreme rainfall events and protecting residential dwellings from inundation.

The new terminology for referring to flood probability has been used in this study. Details of this can be found in Appendix A.

1.1. Study Area Summary

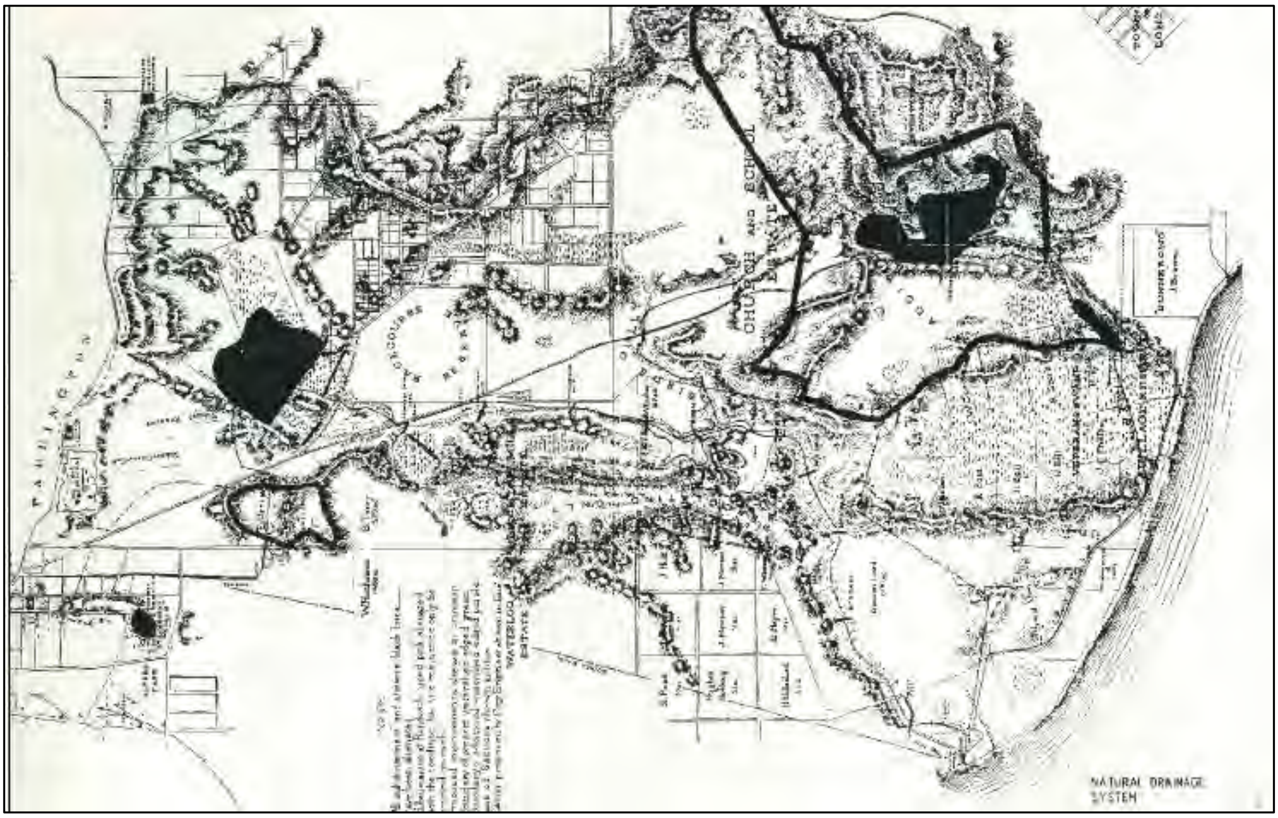
The Kensington – Centennial Park catchment is an urban catchment located in the eastern suburbs of Sydney. The study area is shown in Figure 1 and includes Council provided vegetation mapping. The catchment comprises an area of approximately 9.7 km^2 and extends east to approximately Frenchmans Road / Avoca Street, south to Gardeners Road and west to South Dowling Street. The Centennial Parklands are located in the north of the catchment.

The study area is unique within the Sydney metropolitan area given the relatively large portion of parkland and open space present within the urban catchment. The presence of sandy soils in and around the Centennial Park, Randwick Racecourse and the Kensington areas, in combination with potential flood storage in many of the open spaced areas, has pronounced effects on the catchment response to rainfall and the generation of runoff. These aspects are of particular significance for the Centennial Park area. This large open space area is drained via a series of ponds and interacts with the Botany aquifer through a series of complex and poorly understood infiltration processes.

Urbanisation has dramatically altered the nature of drainage within the catchment (refer Photograph 1 which shows a map of historical catchment conditions circa 1850-1870). The map shows a number of natural drainage paths and low-lying depressions from the site of Centennial Park extending downstream through to Kensington and Kingsford.

The drainage paths and other water features can be aligned with current development and provides the context for many of the flood problems known to exist in the area today. For example, there is a high correlation between the historical map and Council's database of reported flooding problems and areas known to have been flooded during the November 1984 events. Patterns of flood behaviour observed in the last twenty to thirty years reflect the historical pattern of drainage. Key examples include the major flowpaths formed in Doncaster Avenue and flooding experienced further downstream in the catchment (e.g. in and around Mooramie Avenue). It is evident that development has altered natural flowpaths and/or has occurred in areas likely to have been susceptible to flooding under pre-development conditions.

Photograph 1: Map of Historical Catchment Conditions circa 1850-1870



Compared to historical (pre-development) conditions, development within the catchment is likely to have exacerbated flooding as a result of:

- a major increase in the proportion of paved area and consequent reduction in pervious areas, resulting in corresponding increases in runoff (in terms of both peak flows and volumes),
- construction of buildings and infrastructure that has impeded natural flow paths and resulted in filling of the floodplain;
- modification of natural surface drainage system including encroachment of development within flowpaths across the catchment, and
- development within trapped depressions that were once swamps, resulting in flood problems in these areas.

The construction of the Centennial Park embankment adjacent to Alison Road and its subsequent raising, as part of works associated with construction of the Light Rail in 2016-2018, was designed to provide attenuation of the runoff from the upstream catchment and thus lower flood levels downstream than would otherwise occur.

1.1.1. Land Use and Heritage

The study area is within the Randwick City Council LGA and consists of the Kensington – Centennial Park drainage catchment. Land use zones as identified in the Randwick Local Environmental Plan 2012 are shown in Figure 2. 50% of the study area (Randwick LGA) comprises residential land zoning or medium and low density residential (R2 and R3) uses. The

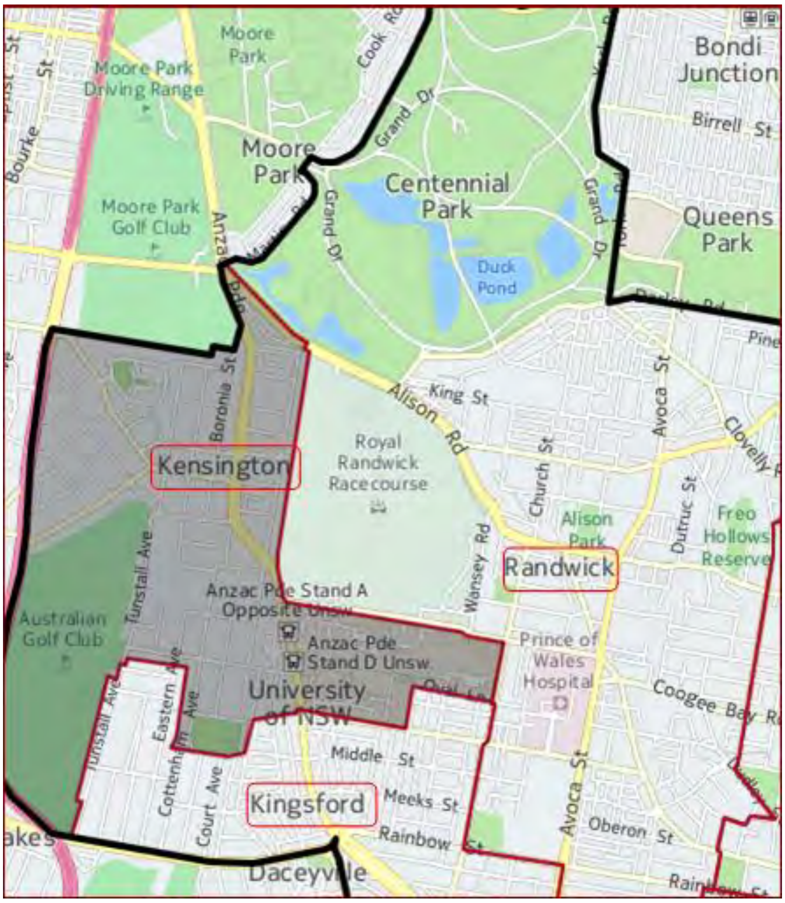
University of New South Wales (UNSW) is located in the area south of High Street, zoned as SP2 Infrastructure (10% of study area). Randwick Racecourse and Centennial Park, both zoned RE1 Public Recreation, make up 35% of the study area (Randwick LGA). Areas defined as B2 Local Centre are focussed along Anzac Parade and Belmore Road.

There are a number of heritage listed buildings in the area but none are known to be of significance from a flooding perspective. Available vegetation mapping is provided on Figure 2.

1.1.2. Social Characteristics

Understanding the social characteristics of the area can assist in ensuring that the right risk management practices are adopted. The census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population, movement of people into and from the area, all of which provide an understanding of the affected demographics. Information has been extracted from the 2016 census (Reference 2). The suburbs of Kingsford (15,500), Kensington (15,000) and Randwick (30,000) which comprise the study area have a combined population of approximately 60,000 in the Randwick LGA, though many are not within the catchment study area (refer Photograph 2). The census figures for Kensington have been adopted as being reflective of the study area and a summary is provided in the following section.

Photograph 2: Map of Suburbs



The data on population movement in recent years is of particular interest. Generally, residents who have lived in an area for an extended period of time will have a better understanding of flooding issues in their area than those who have recently moved to the area. Only 42% of the population in the Kensington area were born in Australia with 60% having both parents born overseas which is much higher than the NSW figure of 37%.

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them. Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties. Consequently, those people in rental properties are typically less aware of the flood risks unless they have been there for enough time to have experienced flooding or have been sufficiently informed by their landlords. In the Kensington area 58% of houses are rented which is higher than the NSW average of 32%. 19% lived in a separate house and 73% lived in a flat or apartment. For NSW the figures are 66% lived in a separate house and 20% in a flat or apartment.

The languages spoken by the population is also worthwhile considering as it can have implications for providing flood information to the public. In the Kensington area 47% of the population speaks only English, 47% speak another language as well.

According to the Census, 21% of the households are of Chinese ancestry compared to 5% for NSW. Of interest the % obtaining a Bachelor of Higher degree was 37% in Kensington whereupon the NSW average is only 23%, however the % who did not obtain a higher qualification or reply for Kensington is typical of the NSW average (10%).

90% of the population is employed and 10% unemployed (for NSW only 6% are unemployed).

1.2. Historical Flood Issues

The Flood Study (Reference 3) undertook a detailed review of historic floods for the study area including analysis of daily rainfall data. This enabled the identification and placement of past storm events relative to local rainfall patterns.

The well documented November 1984 storm (Reference 4) was one of the largest within the Kensington – Centennial Park study area. The storm was a significant rainfall event across the entire Sydney region and had an approximate 1% AEP intensity across several locations in Sydney.

There have been many other events in the catchment including October 1959 and January 1999. January 1999 was much smaller than November 1984 and for this reason there are few flood marks or other records. Little detail is known about October 1959 to gauge its magnitude and as it is prior to installation of nearby pluviometers (continuous record of rainfall intensities) the magnitude of this event is unknown.

1.3. Previous Studies

A number of flood studies have been undertaken within the catchment area. These studies range from small flood assessments covering limited areas to more complex investigations extending to the Botany Wetlands. The Flood Study (Reference 3) is the first comprehensive investigation that specifically provides detailed design flood information throughout the study area.

A literature review of a number of previous studies was undertaken as part of the Flood Study (Reference 3) and included the following:

- Sydney Storms November 1984 – Hydrological Aspects October 1985 (Reference 4);
- Kensington Flooding Drainage Works Investigation 1985 (Reference 5);
- Centennial Park – Kensington Pond Stormwater Flow Control Structure Restoration Works Flood Study November 2002 (Reference 6);
- Hydrologic and Hydraulic Study Botany Wetlands June 1992 (Reference 7); and
- Assessment of Hydrological and Hydraulic Modelling of Centennial Park and Kensington Catchments May 2003 (Reference 8).

1.4. Flood Study Review and Update

1.4.1. Review of 2013 Kensington-Centennial Park Flood Study (Reference 3)

A key objective of the Flood Study is to produce estimates of design flood behaviour throughout the study catchment. Outcomes facilitate the detailed analysis of potential flood management measures in this current FRMS&P. The flood study includes dynamic hydrologic and hydraulic modelling integrating the sub-surface drainage system and overland flow paths using the software programs MIKE-Storm, DRAINS and TUFLOW.

The sub-surface drainage system was represented using a one-dimensional model linked to overland flow paths. Given that drainage network data was not available for the areas of the catchment covered by Waverley Council, the drainage network and overland flow paths for this area could not be modelled in the hydraulic model. Rather this portion of the catchment was represented as a series of sub-catchments in MIKE-Storm. Runoff from these sub-catchments was applied as inflows into the hydraulic model within Queens Park. Results from the existing City of Sydney Council DRAINS model of the Fox Studios/Moore Park area were used to define upstream boundary conditions for the hydraulic model at Centennial Park and Alison Road as appropriate.

The majority of overland flooding was modelled in a two-dimensional (2D) model. Exceptions include storage and cross flow in the Centennial Parkland ponds and concrete open channels in the trunk system of the lower model which were modelled using a one-dimensional model embedded into the 2D model.

For the purpose of the FRMS&P, Council requested that the 1 EY and 0.5 EY events be considered in order to assess the extent of flooding in these small but frequent flood events.

1.4.2. Updating of the 2013 Flood Study

A draft of this FRMS and Plan was completed in 2016, however at that time design plans were being prepared for construction of the Sydney Light Rail project. Extensive flood investigation was undertaken as part of the project as it was realised that construction of the Light Rail depot to the immediate west of Randwick Racecourse and south of Alison Road, as well as other works, would impact on flood levels. The proposed mitigation works were to raise the Centennial Park embankment adjacent to Alison Road by approximately 300mm. The raising of this embankment was investigated and proposed as a viable mitigation measure as part of the 2016 draft FRMS.

Council requested that the 2013 Flood Study be updated as part of this FRMS to incorporate:

- all works associated with construction of the Light Rail in the local area. These largely include raising the embankment, construction of the Light Rail depot and culverts beneath, construction of the track and associated stormwater system;
- incorporation of the 2016 Australian Rainfall and Runoff (AR&R2016) design flood methodology (Reference 9). Further details of this methodology are provided in Appendix B but in summary include revised design rainfall intensities, temporal patterns and rainfall loss rates. The 2016 methodology supersedes the prior 1987 methodology and is being undertaken in all new flood studies. The main reason for this change is that since 1987 there have been significance advances in the approach to design flood estimation as well as changes to the design rainfall data as a result of the inclusion of rainfall data from 1987 to 2016;
- the availability of airborne laser scanning (ALS) survey data of Centennial Park which was not applied previously. Thus providing more accurate definition of the basins immediately upstream of the embankment and the flow paths emanating from near the Moore Park stadiums.

The above updates have resulted in significant changes to the design flood levels and extent of the floodplain. This meant that the modelling and analysis of possible mitigation measures as well as flood damage analysis had to be redone. In addition the extent of the Flood Planning Area (area that defines the properties subject to flood related planning controls) had to be updated.

Full details of the above analysis are provided in Appendix B.

1.5. Available Data

The Flood Study (Reference 3) provided the majority of data and modelling outputs. ALS survey data was provided by Council and this was used to represent the ground grid used in the TUFLOW model. In addition, a building floor level survey was undertaken by Sydney Surveyors.

This survey comprised 1612 residential and 182 commercial / other properties with details provided on floor levels and ground level at each property within the 1% AEP flood extent. A number of other properties were identified as vacant or car parks and these details are not provided. The floor level survey was used in identifying potential flood damages for the Kensington area (see Section 3.4). The database also included details on the number of storeys (to see if residents have a "dry" flood refuge), house size, and floor and wall construction (to see if the house could be raised). For non residential buildings the nature of the business was obtained (to get an idea of the likely magnitude of damages).

1.6. Community Consultation

The FRMS process encourages community participation throughout the process. Community engagement provides information beneficial to the study as well as facilitating the addressing of flood related concerns. Consultation also included interaction with the Centennial Park Trust, the State Emergency Services (SES) and other interested parties and organisations.

1.6.1. Flood Study Community Survey

As part of the Flood Study (Reference 3), a media release community survey was undertaken and distributed to over 1500 households, businesses and organisations throughout the study area. More than 100 responses were received in addition to a number of telephone calls and discussions with residents by Council and WMAwater. In total, 68 reports of property inundation were received including several instances in which floodwaters were reported to have entered houses and garages. Further surveys as well as a door knocking exercise were also undertaken with individual residents being interviewed.

The responses received identified a number of areas within the catchment that have been known to experience overland flooding and a number of low trapped points where water cannot drain after heavy rainfall (see Section 2.1.1). Further detail is provided in the Flood Study (Reference 3) which is available online at Council's web site.

1.6.2. Floodplain Management Committee

A Floodplain Management Committee (FMC) has been formed with the purpose of raising and discussing issues related to the floodplain risk management process. The committee facilitates community input throughout the process from start to finish. The committee includes Councillors, Council engineers and planners, members of the SES, OEH, local residents and other community representatives. During preparation of the draft report, WMAwater held several meetings, including presentations to the committee.

1.6.3. Site Visits

Several site visits were undertaken by WMAwater and Council staff throughout the duration of the project. The majority of the visits were for ground truthing to confirm the flood modelling and extent of inundation on private properties. At the same time inspections of the locations of possible management measures were undertaken. Specific inspections were made at Gardeners Road and at Centennial Park to review the potential for mitigation measures.

1.6.4. Newsletter - 2013

5,917 newsletters (Appendix E) were mailed to residents at the start of the FRMS&P project by Council in November 2013. Newsletters informed residents of the Floodplain Management Program and the ongoing work undertaken as part of the FRMS&P including the floor level survey. Residents were provided contact details to raise any concerns or provide comments.

1.6.5. Public Consultation - August / September 2018

Following endorsement of the draft report by Council and the FMC in July 2018, the report was made available for the community during a period of public exhibition. A public workshop was also held for the community to examine the report and make any comments or suggestions to the consultant or Council. Formal submissions from the community were considered by Council and the FMC before finalisation of the FRMS&P. Details and outcomes of this public exhibition are provided in Appendix E.

2. FLOOD BEHAVIOUR

This section summarises findings from the hydrological and hydraulic modelling undertaken as described in Section 1.4.

2.1. Flood Mechanisms

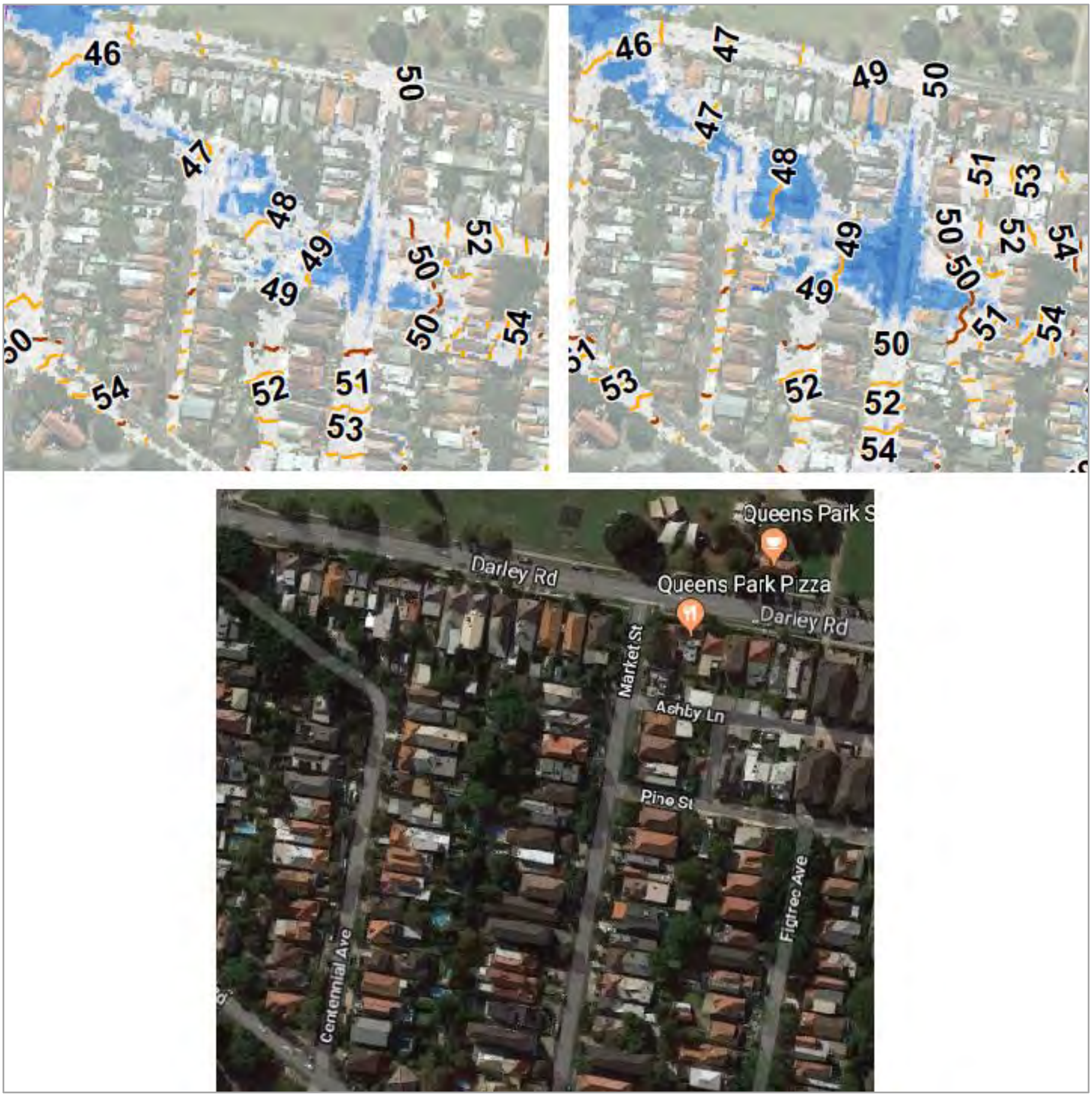
Flooding in the study area is characterised by intense rainfall exceeding the capacity of the local drainage infrastructure resulting in overland flow as well as ponding in natural depressions known as trapped low points.

2.1.1. Trapped Low Points

Through a combination of the hydraulic modelling and information provided by the community, a number of trapped low points were identified in the Flood Study (Reference 3). These are locations where water cannot drain and begins to pond during heavy rainfall. Being particularly flood prone, these areas are a focus of this FRMS&P and are a particular feature of the area and not commonly found in other areas of Sydney.

- **Aboud Avenue** – located at the downstream end of a small catchment to the west of the main catchment. Local topography is such that a number of properties lie within a natural depression and many sit lower than the roads. Extensive ponding occurred in this area in November 1984.
- **Cottenham Avenue** – affects residential properties along both Eastern and Cottenham Avenues. Unlikely to be affected by flooding from the main Kensington catchment, however the isolated nature of this trapped low point results in properties being flooded from local runoff.
- **Barker Street** – located opposite the UNSW campus and minor flooding has occurred on several occasions with some disruption to traffic. Properties on the corner of Harbourne Road and Barker Street are reported to have been inundated in the past.
- **Market Street and Centennial Avenue** – development has occurred within the natural topographic depression which falls in a westerly direction from Market Street through to Centennial Avenue and Darley Road. Depths of 1 m have been observed in the past on Market Street. A comparison between the extent of inundation in the 10% AEP and the 1% AEP flood depths and extents is shown as Photograph 3.

Photograph 3: Comparison of Peak Depths 10% AEP on left, 1% AEP on right) at Market St / Centennial Avenue Trapped Low Point



- **Wentworth Street and Dangar Lane** – no natural outlet for overland flow exists and ponding can therefore take some time to recede following a storm. Residents indicate ponding can remain for up to a day from minor rainfall events and three days following larger rainfall events.
- **Clovelly Road** – situated in a natural depression, Clovelly Road receives runoff from the steeper portions of the contributing catchment to the south. The low trapped point includes several blocks and is a mix of commercial and low-medium density residential buildings. Flooding also occurs on Castle Street and Earl Street when the sub-surface drainage system is exceeded.

In large events the depth of floodwaters will increase until overtopping of the low point occurs but there will only be a minor increase in depth as floodwaters can escape. The design event sufficient to "fill" the low point will vary change depending upon the amount of infiltration, blockage of any pipes or variations in rainfall intensity over the catchment.

2.1.2. Drainage Network Capacity

The design flood modelling was analysed to determine how frequently the stormwater pipe system capacity is likely to be exceeded throughout the catchment. Defining the maximum capacity of a pipe is not straightforward, as it depends on multiple factors including the shape of the pipe, the flow regime (e.g. upstream or downstream controlled), the inlet and outlet connections, the pipe grade, and other factors. For example, the nominal flow capacity of a pipe may increase with significant head to drive flow at the upstream end, but this “maximum” flow may be only slightly larger than when the soffit of the pipe is first exceeded, and the upstream afflux is an undesirable outcome in terms of reducing surface flooding.

TUFLOW provides output indicating the proportion of the cross-section area of the pipe that has flow in it. For the purposes of the pipe capacity assessment, pipes were assumed to be “full” when the flow area equalled or exceeded 85% of the pipe cross-sectional area. This is the point at which circular pipes tend to be close to their most efficient, since at 100% of cross-sectional area the additional friction from the top of the pipe reduces the pipe conveyance more than the slight increase in flow area. Similarly, box culverts designed for a supercritical flow regime will typically be designed for free surface flow approximately 80% of the depth of the culvert, as when flow touches the pipe soffit it will typically “trip” the flow regime to become sub-critical, resulting in lower capacity, depending on the pipe grade. Furthermore, due to energy losses associated with adjoining pits, inlets, culvert bends etc., some culverts may never become “100% full,” although they may be 90% full for a range of design flood events (e.g. from the 5% AEP through to the PMF). In such circumstances, it is informative to know the design storm for which the pipe is almost at its maximum capacity.

Once the capacity of the sub-surface drainage system is exceeded, water will surcharge from drains and pits and contribute to overland flows. The Kensington study area has limited drainage capacity and drainage exceedance is relatively common. Most drainage infrastructure (shown in Figure 4) has a capacity ranging between the 1 EY and 10% AEP event. Further development and a potentially a changing climate regime are increasing pressures on the already limited drainage capacity.

Drainage capacity for assets within the study area obtained from modelling results is shown on Figure 5. A significant number of pipes within the catchment exceed capacity in events as small as the 1 EY event, thus causing flooding. In particular, major pipe routes down Anzac Parade, Alison Road and Aboud Avenue have limited conveyance capacity.

In summary within the study area there are 1736 pipe sections in the TUFLOW model with 51% are at capacity in the 1 EY event and 73% at capacity in the 10% AEP event. This design capacity is typical of many older urban areas in Sydney which were designed with limited knowledge of flooding. It also should be noted that the design capacity of a pipe system from a numerical model should only be used as a guide as blockage and other local factors can affect the results in an actual event.

2.2. Design Event Flooding

2.2.1. Summary

Peak flood levels for the 1 EY, 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events as well as the PMF are considered. Results are summarised in terms of peak flood levels, depths and velocities and are presented in Appendix C.

Flooding is shown to occur in many of the trapped low points in events as small as the 10% AEP event. Flood depths vary across the catchment depending on local topography (see Section 2.1.1) and local drainage capacity (see Section 2.1.2). Depths in the 10% AEP event can exceed 0.5 m in some places increasing to over a metre in the 1% AEP event. High velocities occur as water flows down some streets, such as around Alison Road, where velocities can exceed 3 m/s in the 1% AEP event.

2.2.2. Brief Description of Design Events

The extent of inundation in the 10% AEP event (Figure C4) is considerable but is obviously more extensive and has greater flood depths in the 1% AEP (Figure C7). The most significant changes in downstream of Alison Road are Aboud Avenue, immediately upstream of Gardeners Road adjacent to Cottenham Avenue, Court and Doncaster Avenues, Day Lane and Anzac Parade. These are areas of extensive commercial and residential development, the flooding of which causes significant damage to property, risk to life and traffic disruption.

Upstream of Alison Road the most significant changes between the 1 EY and the 1% AEP are at Challis Lane, Clovelly Road and between Ascot and Market Streets. In other parts the depth of inundation shows only a slight change.

2.3. Hydraulic Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to define different areas of the floodplain, namely;

- Floodways;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during flood events and by definition, if blocked would have a significant effect on flood flows, velocities and/or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is usually defined as flood fringe.

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area, hydraulic modelling and previous experiences. A number of approaches, such as that of Howells et al (Reference 10), suggest the use of the product of velocity and depth as well as velocity itself to establish hydraulic categories.

Hydraulic categorisation has been mapped and is shown on Figure 6. The Flood Study (Reference 3) defined hydraulic categories according to the following;

- Flood Fringe (base layer):
  PMF extent for peak depth greater than 0.15 m.

- Flood Storage (takes precedence over Flood Fringe when overlapping):
  1% AEP extent for peak depth greater than 0.15 m.

- Floodway (takes precedence over Flood Fringe and Flood Storage when overlapping):
  Extent of 1% AEP peak velocity depth product when greater than 0.3 m^2/s; or
  Extent of 1% AEP peak velocity when greater than 0.5 m/s.

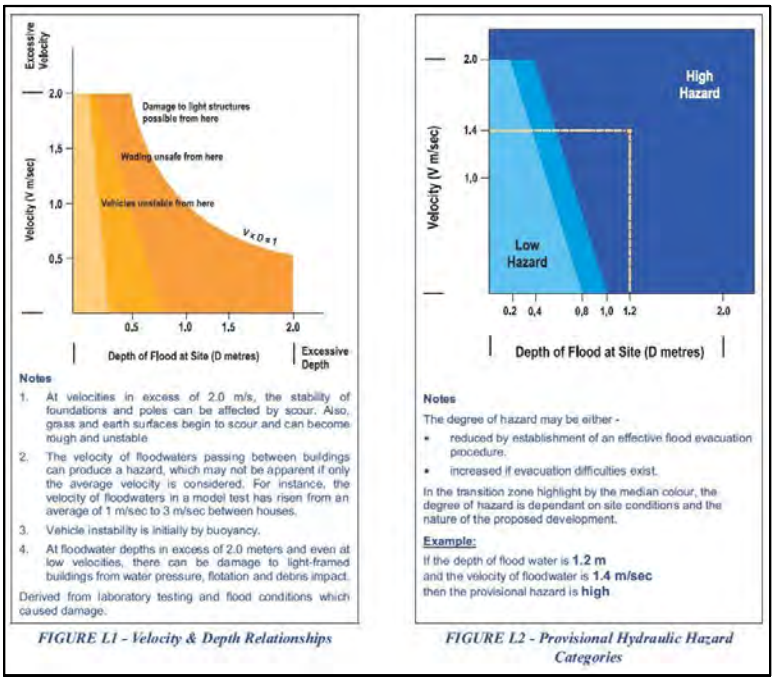
Hydraulic categorisation has been mapped and is shown on Figure 6. Floodways occur down most major roads including Alison Road, Anzac Parade, Doncaster Avenue, Mooramie Avenue, Borrodale Road, as well as others. Much of the floodway is attributed to the velocity criteria (greater than 0.5m/s).

2.4. Flood Hazard Classification

The risk to life and potential damages to buildings during floods varies both in time and place across the floodplain. In order to provide an understanding of the effects of a proposed development on flood behaviour and the effects of flooding on development and people, the floodplain can be sub-divided into hydraulic and hazard categories.

Hazard classification plays an important role in informing floodplain risk management in an area. Previously, hazard classifications were binary – either Low or High Hazard as described in the Floodplain Development Manual (Reference 1) and shown in Diagram 1.

Diagram 1: Provisional Flood Hazard Categories



Source: Extracted from the Floodplain Development Manual (Reference 1).

Figure 7 and Figure 9 provide the hazard classification for the 1% AEP and PMF events for the above classification.

During a 1% AEP event under this classification system, much of the study area is classified as low hazard to the shallow distributed nature of the flow which is considered safe for people, vehicles and all building types. More hazardous classifications on the floodplain are generally contained in non-habitable areas including parks, reserves and golf courses which are located adjacent to formalised flow paths such as drains, channels and creeks.

The Floodplain Development Manual (Reference 1) indicates that the above hazard classification is preliminary and subject to review as part of this study. To assess the true flood hazard, a number of other criteria require consideration in addition to provisional (hydraulic) hazard. Table 1 assesses true hazard for the Kensington and Centennial Park area.

Table 1: True Hazard Classification

Criteria	Weight (1)	Comment
Depth and velocity of floodwaters	Medium	The product of depth and velocity is also termed the provisional hazard (see Diagram 1). These can be influenced by the magnitude of the flood event. At depths of up to 0.3 m, wading should be possible for most mobile adults. This obviously could be more of an issue for children, elderly or disabled people. At velocities over 1 m/s shallow depths may not be a problem, although depths in excess of 1 m with low velocity would give rise to a high hazard situation.
Size of the flood	Medium	The size or magnitude of the flood can affect depths and velocities. Relatively low flood hazard is associated with more frequent minor floods while the less frequent major floods are more likely to present a high hazard situation. Within the Kensington - Centennial Park study area, flood extents do not scale significantly with event magnitude.
Rate of rise of floodwaters	High	Rate of rise of floodwaters is relative to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events. The faster the onset of flooding the more difficult warning becomes and the quicker evacuation may need to occur. As in many urban situations, the onset of flooding in the Kensington – Centennial Park area can be sudden (1 to 2 hours) following heavy rainfall.
Duration of flooding	Low	The greater the duration of flooding, the more disruption to the community and potential flood damages. A short period of inundation may allow some materials to dry and recover whereas a long duration may cause damages beyond repair. In terms of direct hazard to people, a longer duration event would give more time for thoughtless behaviour causing risk to life.
Effective warning and evacuation time	Medium	This is dependent on rate at which waters rise, an effective flood warning system and the awareness and preparedness of the community to act.
Flood awareness and preparedness of the community	High	The awareness of the community has a high weight in considering flood hazard as a more aware community will be able to better prepare and therefore potentially evacuate before hazards become high. General community awareness and preparedness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood aware community is unlikely to be wise to the impacts of a larger, less frequent, event. In areas where flood warning is limited, it is critically important for a community to be flood aware so that individuals can notice the signs of the onset of flooding and prepare for themselves.
Effective flood access	High	The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained.
Evacuation problems	Low	In addition to affected flood access, evacuation problems could also be exacerbated by the time of day during which flooding occurs. The number of people to be evacuated and limited resources of the SES and other rescue services can make evacuation difficult. As there are few significantly flood affected properties in Kensington, evacuation of streets conducted by the SES is unlikely to occur. Those subject to above floor flooding may choose to locate elsewhere in a flood event.
Type of	Low	The type of flood prone development is useful to understand the likely level of

Criteria	Weight (1)	Comment
development		occupant awareness and preparedness, mobility of people as well as population density. Longer term home owners would likely have a better level of flood awareness and preparedness than a guest at a hotel for example. Alternatively, residents from a residential care home are likely to be less mobile than average. In addition, the construction type can affect hazard. Older timber structures area more likely to be susceptible to flood damages.
Additional Concerns	Low	The impact of debris is unlikely to be a significant factor due to the low flood depths and/or velocities. However, there is always concern over floating debris causing injury to wading pedestrians or structural damages to property. Floating debris, vehicles or other items can increase hazard. In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Sewerage overflows can occur causing potential health issues.

(1) Relative weighting in assessing the hazard for Kensington – Centennial Park catchment

The flood hazard for the study area varies by location based on the relative depths, velocities and other factors. Figure 7 and Figure 9 show the provisional flood hazard for the 1% AEP and PMF events respectively based on the discussions in Table 1. However consideration should be made of the factors shown in Table 1 when considering a development.

In recent years there has been a number of developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 11) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories, listed in Table 2, which indicate the restrictions on people, buildings and vehicles. The velocity/depth relationship for each of these categories is depicted in Diagram 2.

Table 2: Hazard Categories (Reference 11)

Category	Constraint to people/vehicles	Building Constraints
H1	Generally safe	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for all vehicles, children and the elderly	*No constraints*
H4	Unsafe for all people and all vehicles	*No constraints*
H5	Unsafe for all people and all vehicles	Buildings require special engineering design and construction
H6	Unsafe for people and vehicles	All building types considered vulnerable to failure

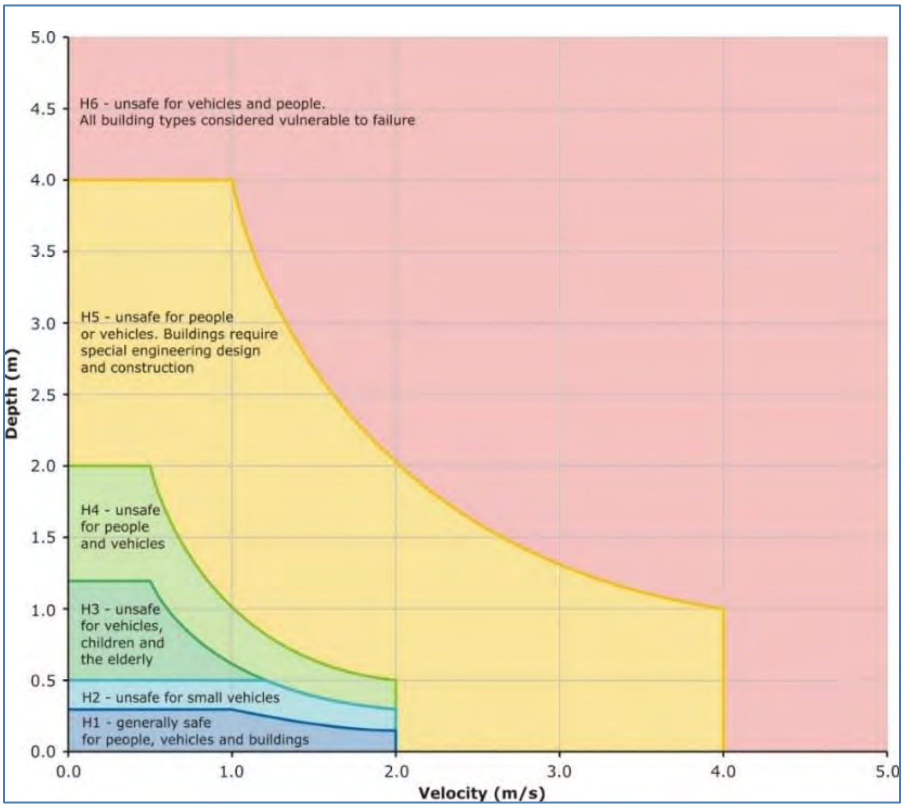


Diagram 2: Hazard Classifications (Reference 11)

Figure 8 and Figure 10 provide the hazard classification for the 1% AEP and PMF events for the above classification.

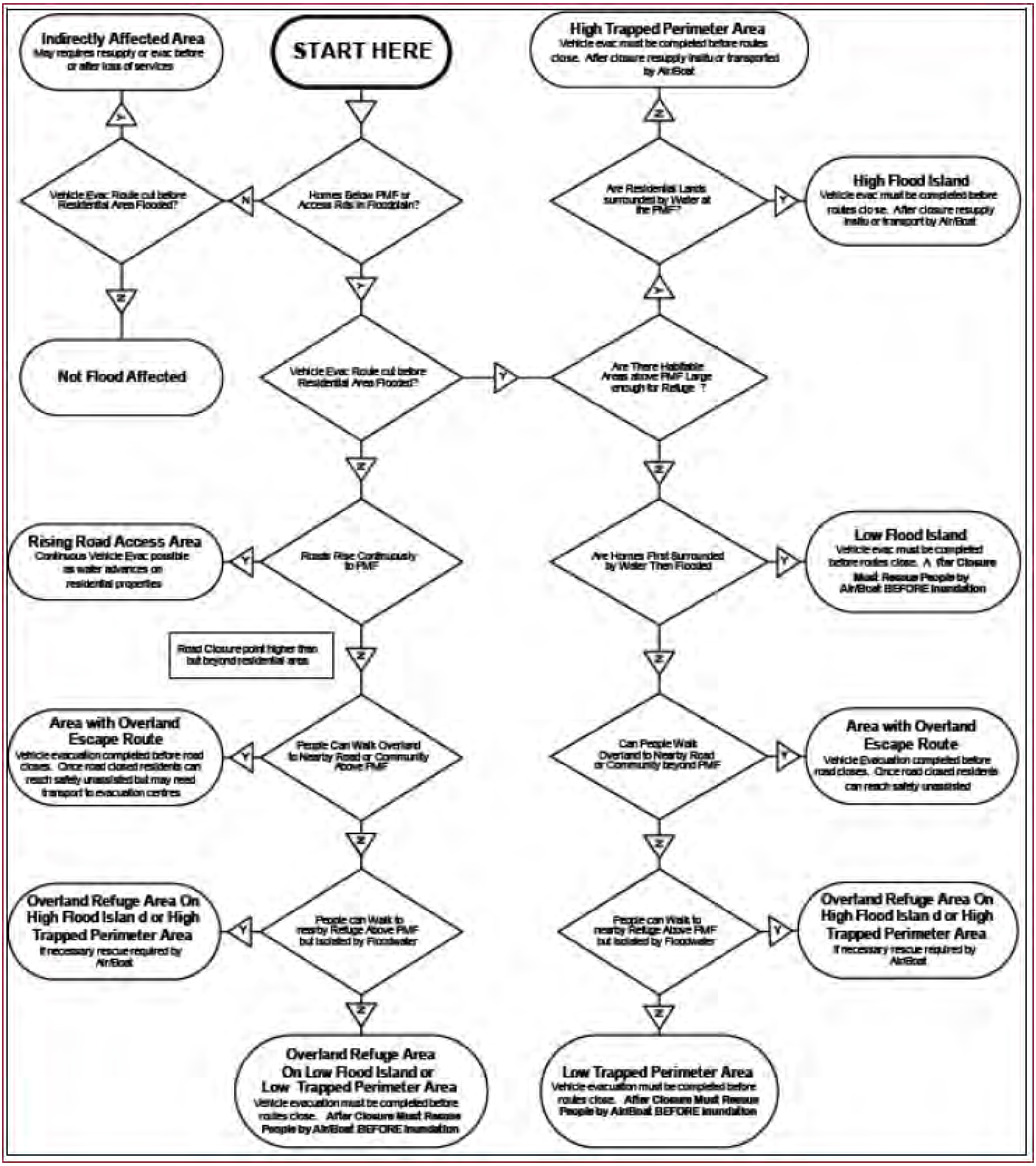
2.5. Flood Emergency Response Planning

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 12) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. The ERP classification (flow chart shown in Diagram 3) can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 3). They are based on modelling of design event flooding.

Table 3: Emergency Response Planning Classifications of Communities

	Response Required		
Classification	Resupply	Rescue/Medivac	Evacuation
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Diagram 3: Preliminary Flow Chart for Emergency Response Classification



Key considerations for flood emergency response planning in these areas include;

- Cutting of external access isolating an area;
- Key internal roads being cut;

- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres, emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
- The extent of the area flooded.

Flood liable areas of the study area have been classified according to the ERP classification and Preliminary Flow Chart (Diagram 3) above for the PMF event is shown in Figure 11. Note that shallow flood depths below 150 mm were considered to not affect egress.

Understanding flood access issues is critical to effective evacuation and flood response planning. Even at shallow depths, fast flowing velocities can occur when flood water overtops a bridge deck for example. Furthermore, once flooding has subsided, if there is significant damage to a road or water crossing then even though it may be no longer flooded, structural damage could make use unsafe. Knowing the likely timing of road closures and depths of flooding on roads can aid flood response planning, and ensure that evacuation occurs in a timely fashion before the depth of flooding hinders the evacuation process or rescue boats and helicopters are required, which may not always be available.

2.6. Flood Awareness / Preparedness and Flood Warning

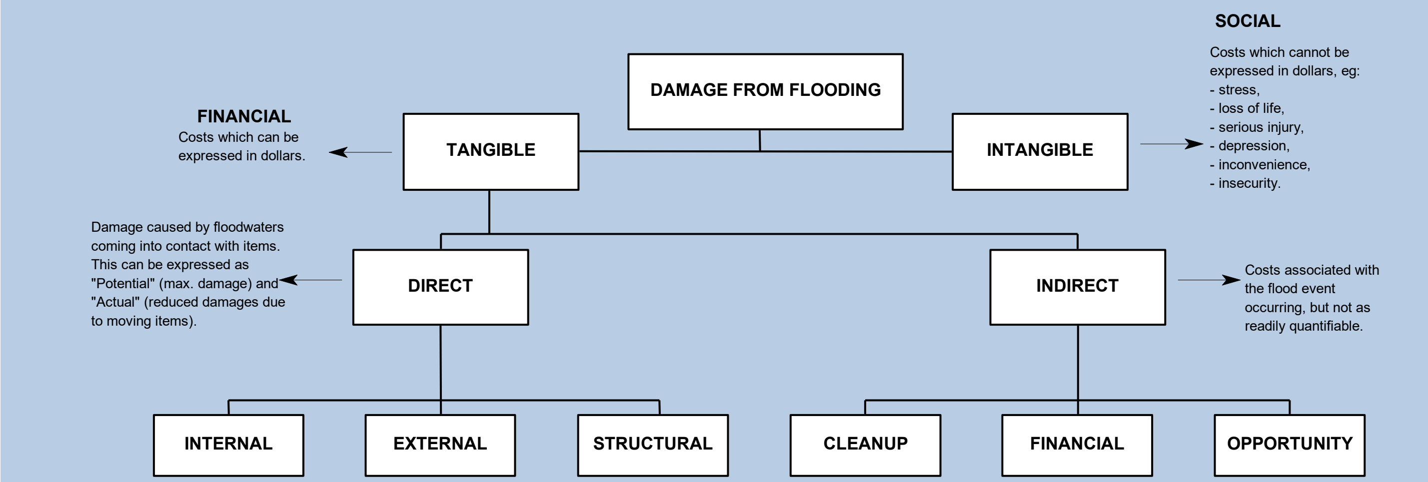
The flood awareness and preparedness of the community and the available flood warning time are important factors in reducing the potential flood damages. Based on the limited community feedback obtained (phone calls, discussions) and past experience in similar urban areas it is likely that the community has a relatively low flood awareness and preparedness. Nonetheless a number of residents have noted ponding in a number of the trapped low spots within the Kensington area. People are often aware of small high recurrence interval events and associated flooding and flood behaviour and are often unprepared for the impacts of a higher magnitude flood such as the 1% AEP event.

There is no specific flood warning system for the Kensington area and the nature of flooding often does not allow sufficient time for warning. The relative lack of awareness and preparedness combined with a very short warning time characterises flood risk in urbanised areas. Consequently, as warning times are limited, a strong emphasis should be put on community flood awareness and preparedness as a risk management measure.

3. IMPACTS OF FLOODING

Flooding has the potential to impact on a wide range of structures, services and activities and these are summarised in Table 4.

Table 4: Flood Damages Categories (adapted from Reference 1)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

3.1. Public Infrastructure

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; roads and bridges including traffic lights/signs; and costs to employ the emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to councils from flooding typically comprise;

- Clean-up costs;

- Erosion and siltation;
- Removal of fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts;
- Removal of vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

The flood damages assessment does not typically include damages to public infrastructure as they can vary significantly.

As re-development occurs measures to mitigate the impacts of flooding can be incorporated into building design encouraged through planning controls, for example flood proofing (see Section 7.4) which can reduce impacts over time. However, these measures cannot necessarily improve the existing situation and other more immediate measures may need consideration for existing public infrastructure.

3.2. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents or damage to the structure of the property. Indirect damage costs can be incurred by property occupiers from having to move away from the property while repairs are being made. A damages assessment has been undertaken for the residential properties in Section 3.4 below. Table 5 summarises the number of properties affected for each design event while Figure 12 identifies the design event which first inundates the lowest building floor level on the property.

Table 5: Property Flood Affectation

	Number of Properties Flooded Below Floor Level			Number of Properties Flooded Above Floor Level		
Event	**Residential**	**Commercial**	***TOTAL***	**Residential**	**Commercial**	***TOTAL***
PMF	1239	150	**1389**	897	130	**1027**
0.2 % AEP	831	121	**952**	388	82	**470**
0.5 % AEP	770	120	**890**	308	75	**383**
1 % AEP	714	116	**830**	272	60	**332**
2 % AEP	561	110	**671**	160	36	**196**
5 % AEP	344	89	**433**	78	18	**96**
10 % AEP	291	68	**359**	66	12	**78**
20% AEP	257	59	**316**	53	10	**63**
1 EY	166	24	**190**	30	5	**35**

Table 6 provides the maximum and average depth of above floor inundation for both residential and commercial properties for each design event.

Table 6: Maximum and Average above Floor Depth of Inundation

Event	RESIDENTIAL Depth (m) Above Floor		COMMERCIAL Depth (m) Above Floor	
	Maximum	Average	Maximum	Average
PMF	3.9	1.2	3.2	1.2
0.2 % AEP	2.1	0.5	0.9	0.2
0.5 % AEP	1.4	0.4	0.8	0.2
1 % AEP	1.3	0.3	0.7	0.2
2 % AEP	1.0	0.2	0.6	0.2
5 % AEP	0.9	0.2	0.2	0.1
10 % AEP	0.7	0.2	0.1	0.1
0.2 EY	0.6	0.2	0.1	0.1
1 EY	0.6	0.1	0.1	0.1

3.3. Commercial and Industrial Properties

Of the surveyed floor levels in the Kensington study area, approximately 10% of properties are non-residential. Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of commercial activity including:

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed but when access to it becomes available;
- Ability to move stock or assets before the onset of flooding – constraints such as large machinery and insufficient warning time can lead to significant losses; and
- Ability to transfer business to a temporary location.

A summary of the types of non residential buildings surveyed is provided in Table 7.

Table 7: Summary of Non Residential Building Types

Type	% of Total
Food	25%
Service	23%
Shop	22%
Vehicle	7%
Educational	6%
Medical	5%
Vacant	4%
Mixed	4%
Mixed with residential upstairs	3%
Utility	1%

A flood damages assessment was undertaken for these non-residential properties and is discussed below. While commercial damages have been considered, it should be noted that the Floodplain Management Program puts emphasis on prioritising protection of existing residential dwellings. Consequently, Councils often apply less stringent flood related development controls to commercial properties making them more liable to flood damages.

Commercial flood damages are more complex in nature and the tangible flood damage to commercial and industrial properties is more difficult to assess. The value of damages to commercial properties is much more varied than for residential properties and damage estimates can vary significantly.

The duration of flooding and flood depths can affect businesses differently. For example shorter duration flooding may allow businesses to re-open to trade again. If the short duration flooding is deep and causes property and stock damage then it may take some time for businesses to re-open. Some businesses are also able to operate temporarily from a different location, often albeit at a reduced capacity, such as the majority of office type businesses. Whether staff are able to get to work or have had flooding issues of their own at home also plays a part in recovery for commercial practices. The type of business also plays a major part in the impacts of flooding. For example a high quality goods electrical store may suffer more damages in terms of loss of stock compared to a stationery store. Where sufficient warning is available, businesses may be able to move stock and assets to higher levels to prevent flood damages. Businesses may also be able to implement contingency plans which allow them to work from another location while their property is inundated. However, depending on the type of commercial or industrial activity this may not always be possible.

Following the Sydney floods of 1986 a survey of damaged properties was undertaken and the result analysed (Reference 13). It was found that the commercial and industrial damages were between 3 and 27 times higher than residential damages. The amount varied considerably depending on the number and type of businesses, size of business, location of properties and extents of development within the floodplain. A number of assumptions were also made in calculating the damages for the Sydney 1986 flood, such as assuming commercial indirect losses to be 55% of direct losses whilst this was only assumed at 15% for residential properties. Where there was a higher ratio of commercial to residential properties flooded (the Georges River catchment for example) the average damage for commercial and industrial properties was three times higher than that for residential properties. After the Nyngan floods of 1990, the average damage to commercial properties was estimated to be approximately 4.4 times higher than the average damage to residential properties (Reference 14). Of damage to commercial properties, indirect financial damages were a major component accounting for 70% of commercial damages. This reflected the long period during which commercial establishments were not trading or trading at reduced levels; a total of ten weeks in many parts. In the Kensington area, flooding to commercial and industrial properties is likely to be shallow due to the overland flow nature of flooding as opposed to the mainstream nature of the flooding events referred to above.

3.4. Flood Damages Assessment

3.4.1. Tangible Flood Damages

A flood damages assessment was undertaken for the 1612 residential and 182 non-residential properties with floor level data available from the floor level survey. The assessment was undertaken based on the guidelines for residential damages provided by OEH (Reference 15 with details in Appendix F). The standard residential damages curves were used for residential properties and were adjusted to allow for the greater damages non-residential properties are likely to suffer.

Table 8 shows the potential damages for the range of design events and the resulting Annual Average Damage (AAD). This forms the base case scenario against which potential damages for a number of mitigation measures have been assessed.

Table 8: Potential Flood Damages – Existing Design Event Scenarios

Event	Residential	Non-Residential	*Combined Damages*	Contribution to AAD	% of Residential Contribution to Damages
PMF	$75,780,800	$23,854,900	$99,635,700	3%	76%
0.2 % AEP	$25,664,600	$9,767,800	$35,432,300	2%	72%
0.5 % AEP	$20,234,300	$8,132,300	$28,366,700	3%	71%
1 % AEP	$16,683,400	$6,177,300	$22,860,600	5%	73%
2 % AEP	$9,286,600	$3,569,900	$12,856,600	7%	72%
5 % AEP	$4,441,500	$1,635,000	$6,076,400	7%	73%
10 % AEP	$3,501,600	$1,107,800	$4,609,300	11%	76%
20 % AEP	$2,859,300	$831,200	$3,690,500	61%	77%
1 EY	$1,816,300	$403,800	$2,220,100	29%	82%
AAD	**$2,970,600**	**$878,300**	**$3,848,800**		77%

The small magnitude events such as the 1 EY and 50% AEP events contribute to a large percentage of the AAD (a general rule of thumb is that events up to the 50% AEP contribute to approximately 50% of the AAD). This is indicative of frequent flash flooding type issues within an urban catchment. However, the FRMS&P process typically places emphasis on the 1% AEP event when considering flood management options. Consequently, it is important for Council to consider smaller events hence the inclusion of smaller events in the benefit / cost calculations for the respective mitigation measures considered.

Although non-residential properties make up about 17% of those inundated in the 1% AEP, non-residential damages account for some 24% of the total AAD. This is attributable to the higher value of damages incurred by commercial properties relative to residential properties.

3.4.2. Intangible Flood Damages

Intangible damages are those to which a monetary value cannot be assigned and include additional costs/damages incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood from a negligible amount to several hundred times greater than the tangible damages. They are dependent on a range of factors such as the size of flood, the individuals affected, community preparedness and sentimental values. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for affected residents. For example, the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition, flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life.

During any flood event, there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. There will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas. Due to the nature of flooding in the study areas, severe health issues and deaths are unlikely. The most likely intangible damage is stress caused to residents by frequent shallow flooding.

Flooding has occurred many times in the past and thus it is unlikely that it will have any significant impact on heritage or biodiversity.

3.5. Implications of Future Climate Change

The Sydney Coastal Councils Group (SCCG) (Reference 16) considered the vulnerability of Councils in Sydney's coastal areas to climate change. The assessment included extreme heat and health effects, sea-level rise and coastal management, extreme rainfall and stormwater management, bushfire as well as affects on ecosystems and natural resources.

For the Randwick City Council LGA, the study concluded that "*Randwick City Council possesses a high degree of vulnerability to climate change relative to other Councils within the SCCG region. Relatively extensive development conspires with high average rainfall and projected increases in future rainfall extremes to create high vulnerability to extreme rainfall events and challenges for stormwater management. Development also limits the resilience of natural ecosystems to climate change. Due to its coastlines and coastal development, vulnerability to* *sea-level rise and coastal hazards was assessed to be moderate to high, although significant land areas in the LGA are not exposed to coastal hazards. Nevertheless, adaptive capacity in Randwick City Council was judged to be relatively high.*"

As well as considering increases in development in the future, the potential impacts of climate change need to be considered. In terms of increased flood risk it is anticipated that climate change will increase flooding in two ways; increases in sea level and increases to rainfall intensity. Sea level rise is not relevant for this study area as the weir in The Lakes golf course prevents any tidal influence.

An increase in rainfall intensity will produce a significant increase in flood damages. Increases in design rainfall intensity of 10%, 20% and 30% were evaluated for the 1% AEP event. The results are very varied across the catchment and full details are provided in Reference 3. Subsequently with the updating of the design flood information (Section 1.4) this work was repeated and a summary of the results from 43 sites for the 1% AEP event is provided as Table 9. Table 10 provides the increase in number of building floors and damages that would occur for the 1% AEP.

It is unclear if a climate change rainfall increase will produce a consistent % increase across all design AEPs (i.e. it may have a greater impact on the more frequent events than the rarer ones or vica versa). An indicative estimate of the increase in flood damages and building floors inundated can be made by comparing the existing results for a 5% and 1% AEP event (represents approximately a 30% increase in rainfall intensity in a 12 hour event) and the 2% and 1% AEP event (represents approximately a 10% increase in rainfall intensity in a 12 hour event).

Table 9: Summary of Rainfall Increase Results (43 sites for 1% AEP)

Increase Greater Than (m)	10% Increase		20% Increase		30% Increase	
	No	%	No	%	No	%
0.05	20	47%	28	65%	33	77%
0.1	9	21%	22	51%	26	60%
0.2	2	5%	9	21%	13	30%
0.5	2	5%	2	5%	3	7%
1	0	0%	2	5%	2	5%
1.5	0	0%	0	0%	2	5%

Table 10: Summary of Increase in Affectation and Damages for Rainfall Increase (1% AEP)

	Buildings Inundated Above Floor				Land Inundated					
	Commercial		Residential		Commercial		Residential		Total Damages	
Scenario	No	% increase	No	% increase	No	% increase	No	% increase		% increase
Existing	60		272		116		714		$22,860,600	
10% Increase	76	27%	319	17%	120	3%	773	8%	$29,604,800	30%
20% Increase	80	33%	377	39%	121	4%	819	15%	$34,399,800	50%
30% Increase	87	45%	412	51%	125	8%	857	20%	$38,573,500	69%

Table 10 illustrates the significant impact on floors inundated and flood damages that would occur if design rainfalls increase due to climate change occurred.

3.6. Implications of Future Development

Future development can cause hydrological impacts such as increased runoff due to increased area of impermeable land cover, as well as hydraulic impacts due to diversions of flows by blocking floodways or displacement of water in flood storage areas. Appropriate land zoning, planning and development controls can reduce these impacts. Good planning controls will mean that as areas regenerate they may become more flood compatible as developers are required to consider runoff from sites and impacts on overland flow paths and flood storage areas.

The most significant new development to impact on flood levels was the construction of the Light Rail in 2017 - 2018. Detailed flood studies were undertaken by the proponent to ensure that no property would be dis-advantaged as a result. The main mitigation measure to compensate for the loss of temporary floodplain storage and conveyance due to the works (largely the Light Rail storage facility) was the raising of the embankment of Centennial Park adjacent to Alison Road (refer Section 1.4 and Appendix B).

4. EXISTING FLOODPLAIN MANAGEMENT

This chapter considers the existing floodplain management within the Kensington and Centennial Park study area in terms of both policy and planning as well as flood response. Structural flood management features are also considered.

4.1. Legislative and Planning Management

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, designed to ensure that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. These can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Policies have been discussed below and subsequently reviewed in regard to flood risk management to identify potential improvements.

4.1.1. NSW Government Flood Prone Land Policy

Flooding in NSW is managed in accordance with the NSW Government's Flood Prone Lands Policy. The primary objective of this policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property as well as reduce private and public losses resulting from floods. This is achieved by undertaking studies to quantify flooding risks and potential measures in accordance with the NSW Government's Floodplain Development Manual (Reference 1) and subsequently implementing the recommended measures.

4.1.2. Randwick Local Environmental Plan 2012

A LEP comprises a written Instrument and a range of maps. It is made by Council, in consultation with the community, and approved by the NSW Minister for Planning, under the Environmental Planning and Assessment Act 1979. The Randwick LEP 2012 (Reference 17) covers the whole Randwick City Council LGA, including Kensington. The Randwick LEP provides the main legal (or statutory) document for planning in Randwick. It controls how land is used (via land use zones) and sets out provisions for how land can be developed. It also contains provisions to conserve Randwick's heritage and protect sensitive land. Clauses 6.3, Flood Planning, and 6.4, Stormwater Management, are particularly relevant to this study.

Clause 6.3 of the Randwick LEP 2012 utilises modelling outputs for flood planning and applies to "*land identified as being within the "Flood Planning Area" on the Flood Planning Map and other land at or below the Flood Planning Level"* (FPL). The FPL is defined as *"the level of a 1:100 ARI* (1% AEP) *flood event plus 0.5 metre freeboard*.". The objective of this clause seeks:

- *(a) to minimise the flood risk to life and property associated with the use of land,*
- *(b) to allow development on land that is compatible with the land's flood hazard, taking*

into account projected changes as a result of climate change,

- *(c) to avoid significant adverse impacts on flood behaviour and the environment.*

Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:
(a) is compatible with the flood hazard of the land, and
(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
(c) incorporates appropriate measures to manage risk to life from flood, and
(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

In this clause: ***flood planning level*** *means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

Clause 6.4 relates to managing stormwater within the Randwick LGA. It applies to all land in residential, business and industrial zones and has the objective to minimise the impacts of urban stormwater on land to which this clause applies and on adjoining properties, native bushland and receiving waters. In order to meet this objective, development will not be granted unless Council is satisfied that the development:

(a) is designed to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water, and
(b) includes, if practicable, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and
(c) avoids any significant adverse impacts of stormwater runoff on adjoining properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.

4.1.3. Randwick Comprehensive Development Controls Plan, 2013

A DCP provides detailed planning and design guidance for new development and supplements the provisions of the LEP. Randwick DCP 2013 (Reference 18) formally commenced in June 2013, replacing all other DCPs and some Council planning policies. General Controls Part B8 refers to water management and includes controls on stormwater management and flooding as well as other water related issues such as groundwater and water quality and has an overall focus on Water Sensitive Urban Design (WSUD) (see Section 6.8).

Part B8, Section 3, of the DCP supports the provisions for stormwater management included in Randwick's LEP 2012. It makes a number of requirements for sediment control from new developments so as to ensure the stormwater runoff is of suitable quality to protect the amenity of receiving watercourses and coastlines. In addition, the DCP stipulates requirements for on-site stormwater detention (OSD) with reference to Council's Private Storm Water Code (see Section 4.1.5). It aims to control the release of private stormwater entering the drainage system to maintain its capacity. Consideration is also given to managing water during the construction phase of development.

For all developments in proximity to public stormwater or inter-allotment drainage[1] and all developments proposing new connections to Council's drainage system, a number of controls are used to ensure stormwater infrastructure is designed to an acceptable standard to prevent adverse impacts of development on the performance and serviceability of the existing drainage systems. Design and installation of drainage infrastructure is to be in accordance with Council's Private Storm Water Code (see Section 4.1.5). Separate approval is required for development proposing to connect private stormwater to the public drainage system and drainage easements may be required for development impacting existing Council stormwater infrastructure or on an inter-allotment drainage line.

Part B8, Section 5, of the DCP supports the provisions of Randwick's LEP with regard to flooding and also provides controls for development consistent with the NSW Government's Flood Prone Land Policy (see Section 4.1.1) and the Floodplain Development Manual (Reference 1). Development controls set out in this part of the DCP apply to*:*

- *Residential development on land below the 1% Annual Exceedance Probability (AEP) flood plus the required freeboard, and*
- *All other development on land below the Probable Maximum Flood (PMF) plus the required freeboard*

The objectives are to:

- To control development at risk of flooding in accordance with the NSW Government's Floodplain Development Manual.
- To ensure that the economic and social costs which may arise from damage to property due to flooding is minimised and can be reasonably managed by the property owner and general community.
- To reduce the risk to human life and damage to property caused by flooding by controlling development on land impacted by potential floods.
- To ensure that development is appropriately sited and designed according to the site's sensitivity to flood risk.

Controls set in the DCP require development to also comply with any catchment specific

[1] Inter-allotment drainage lines carry stormwater from more than one lot across private property before connecting to the public stormwater system.

controls in an adopted FRMP in addition to the controls set out in the DCP.

The Development controls are sub divided into the following sub-headings, each with their own Objectives and Controls.

- Flood Studies and Plans;
- Flood Effects;
- Floor Levels;
- Building Components;
- Driveway Access and Car Parking;
- Safety and Evacuation;
- Management and Design.

Specific controls relating to finished floor levels are dependent on the type of development and type of flooding and Council requires that a registered surveyor certify that the floor levels are not less than the required level. Minimum required levels are presented in Table 11 below.

Table 11: Floor Levels for Buildings, Randwick Comprehensive DCP

Scenario	Floor level
Habitable Floors - all development (excluding critical facilities)	
Inundated by flooding	1% AEP + 0.5m freeboard
Inundated by overland flow path	Two times the depth of flow in the 1% AEP flood with a minimum of 0.3m above the surrounding surface
Habitable floors - Critical facilities	
Inundated by flooding	PMF + 0.5m freeboard
Inundated by overland flow path	Two times the depth of flow in the PMF with a minimum of 0.3m above the surrounding surface
Non-habitable floors – residential outbuildings (excluding garages) *	
Gross floor area less than or equal to 10 square metres.	1% AEP but not less than 0.15m above surrounding ground level
Gross floor area greater than 10 square meters.	The applicable habitable floor level
Non-habitable floors – Industrial and commercial	
Located on flooding or overland flow path	1% AEP but not less than 0.15m above surrounding ground level
Material storage locations – all development	
Materials sensitive to flood damage, or which may cause pollution or be potentially hazardous during flooding	1% AEP + 0.5m freeboard

Extracted from Randwick Comprehensive DCP 2013 (Reference 18)

4.1.4. Flooding Advice and Flood Related Development Controls Policy

Council's Flooding Advice and Flood Related Development Controls Policy (Reference 19) were adopted by Council on the 28th of February 2012. The overall objective of this policy is to provide guidance on flooding related matters as the catchments in Randwick's LGA are progressively studied. The Policy is used to establish interim flood related development controls in situations where a Council commissioned Flood Study exists but no Floodplain Risk Management Study and Plan has been adopted by Council. As such, the flood related development controls applied in any DA are as outlined in the Policy, until such time as this FRMS&P is formally adopted by Council. Development controls are applicable to all land below the 1% AEP flood level plus 0.5 m freeboard.

The Policy recognises that certain types of development have a post disaster function or specific evacuation needs during a flood event. Such facilities include schools, hospitals, nursing homes, retirement villages, aged care facilities, SES headquarters, evacuation centres, major utility facilities and emergency response facilities. These types of facilities need to consider safety issues for all floods up to an including the PMF and flood related development controls apply even if land is above the 1% AEP flood level plus 0.5 m, where it is below the PMF.

Flood related development controls are in accordance with the Floodplain Development Manual (Reference 1) and seek to ensure;

- That development causes no adverse impact on flooding, up to and including the 1% AEP flood;
- Safety of people and emergency access for all floods up to an including the PMF;
- Structural soundness and flood compatibility of building materials for all structures below the 1% AEP flood plus 0.5 m freeboard;
- Commercial flood levels and habitable residential floor levels are to be no less than the 1% AEP flood plus 0.5 m freeboard – note that this contradicts the floor level requirements set out in Randwick Comprehensive DCP (see Section 4.1.3); and
- Open car parking spaces or car ports to be no lower than the 5% AEP flood; and
- All other floor levels are to be determined on merit.

The Policy also sets out what flood related information is prescribed under section 149 of the Environmental Planning and Assessment Act 1979 and the Environmental Planning and Assessment Regulation 2000 to be included on the S149(2) certificate and what additional information may be provided on S149(5).

4.1.5. Randwick Council's Private Stormwater Code

Randwick Council issued the Private Stormwater Code in March 2013 (Reference 20). This Code outlines Council's objectives and requirements for the disposal of private stormwater within the City of Randwick. It is based largely on the methodologies and data provided in the 1987 edition of AR&R (Reference 21). The objectives of the code are:

- To provide designers, developers, builders and the general public with a guide to Council's requirements for the disposal of private stormwater;
- To prevent damage to both Council and private property and to prevent nuisance and risk to the public, by controlling the disposal of stormwater from private properties;
- To reduce the impact of new development on Council's stormwater system; and
- To direct stormwater back into the ground through infiltration where possible.

Council's OSD policy (applies to all properties except single dwelling houses) ensures that in the critical 5% AEP (20 year ARI) event the lesser of the calculated permissible site discharge or a rate of 25 litres per second is discharged to the kerb and gutter system. For events greater than the 5% AEP (20 year ARI) event an overflow system is to be constructed. New houses are required to provide an infiltration area of at least 5m^2 with overflow to the street.

4.1.6. Randwick City Council Sea Level Rise Considerations

In October 2009, the NSW Government issued a Sea Level Rise Policy Statement with the best international projection of sea level rise along the NSW coast being an increase of 0.4 m between 1990 and 2050 and an increase of 0.9 m by 2100 based on data from the Intergovernmental Panel on Climate Change (IPCC). However, since then, the NSW Government subsequently issued a statement that Councils are responsible for adopting their own estimates of sea level rise. Randwick Council has adopted the sea level rise benchmarks of 0.4 m increase by 2050 and 0.9 m increase by 2100. Sea level rise will not affect flooding within the study area.

4.2. Existing Structural Flood Management Measures

A number of floodplain management measures have been undertaken over time in order to attempt to relieve localised flooding issues including the use of Centennial Park as a detention basin facilitated by a raised embankment along Alison Road (subsequently upgraded in 2017 - 2018 as part of construction of the Light Rail).

Council also undertakes minor stormwater works such as the extension or improvement of stormwater pits and pipes. These works are specific to an area and address local drainage and not catchment wide issues. No major stormwater upgrade works such as trunk drainage amplification works have been undertaken in recent years.

Council also has existing maintenance protocols including annual cleaning of every pit as well as more frequent cleaning of critical pits.

4.3. Flood Warning, Evacuation and Response

Timely flood warning and efficient flood evacuation and response is vital in reducing flood damages. As with all urban catchments in the Sydney basin there is no official Bureau of Meteorology (BoM) warning system for the catchment due to the short time from rain falling until flooding occurs. Severe Weather Warnings and Flood Watches and Warnings are issued by the BoM. Evacuation warnings and orders are issued by the SES. The SES is the legislated combat agency for floods in NSW and is responsible for the control of flood response operations.

The SES maintains a flood intelligence system based on key flood warning gauges in NSW and develops specific flood emergency plans for LGAs which are subject to flooding. There are no flood gauges within the study area catchment and thus no flood intelligence system based on water levels.

5. FLOODPLAIN RISK MANAGEMENT MEASURES

The FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. As well as the hydraulic impacts, flood risk management measures should be assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management measures have been considered to manage existing/future flood risk.

5.1. Risk Management Measures Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, on-site detention, channel improvements, levees or floodways. Pit and pipe improvement and even pumps may also be considered in some cases.

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness / preparedness and education of the community and provision of flood insurance.

Table 12 provides a summary of typical floodplain risk management measures that can be assessed.

Table 12: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
• Flood mitigation and control dams • Retarding basins • Bypass floodways • Channel modifications and improvements • Levees • Flood gates • Pumps • Culvert and drainage structure improvements • Temporary flood defences	• Land use zoning • Voluntary purchase • Flood access • Flood proofing • House raising • Building and development controls • Flood insurance	• Community awareness and preparedness • Flood prediction and warning • Evacuation planning • Evacuation access • Flood plans and recovery plans

As taken from The Floodplain Development Manual (Reference 1)

5.2. Assessment Methodology and Measures Identified for Consideration

The Flood Study (Reference 3) in conjunction with the FMC identified flooding hot-spot areas (see Section 2.1.1 and Figure 3). These hot-spots include;

- Aboud Avenue;
- Cottenham Avenue;
- Barker Street;
- Market Street and Centennial Avenue;
- Wentworth Street and Dangar Lane; and
- Clovelly Road.

Several specific management options were noted in the brief for consideration in this FRMS and can be summarised as;

- Increasing storage volume of ponds within Centennial Park by increasing the height of the Kensington Pond embankment (subsequently omitted as the construction of the Light Rail undertook raising of the embankment to mitigate downstream impacts);
- Works within Randwick Racecourse;
- Dangar Lane trunk drainage upgrade;
- Clovelly Road trunk drainage upgrade;
- Market Street trunk drainage upgrade;
- Fig Tree Avenue trunk drainage upgrade;
- Goodrich Avenue and Shaw Avenue drainage upgrade;
- Gardeners Road culvert and channel blockage protection works;
- Upgrades to low capacity drainage around the future light-rail corridor; and
- Implementation of Kensington Pond rain and water level gauge.

A number of flood modification measures were assessed using the hydraulic model. Additionally, a range of property modification and response modification options measures have also been examined and discussed in this report. Often a combined approach is required to flood management schemes, combining flood modification works as well as response measures such as community education.

5.3. Relative Merits of Management Measures

5.3.1. Benefit/Cost Ratio

To assess the monetary benefits of the management measures, a damages assessment has been undertaken. Damages for the full range of design events were initially calculated to establish the Average Annual Damages (AAD) for existing conditions (refer Section 3.4). However this requires nine design events to be run for each management measures.

Comparison of the AAD for the full range of events against the AAD obtained from the four most representative events (1 EY, 20%, 10% and 1% AEP) shows a variation of approximately 3.5 %. On this basis only four events were run in obtaining AAD's for the mitigation measures, saving considerable time. Furthermore, calculation of the benefit of the management measure is based on the incremental advantage and therefore this difference is further negated as the mitigation AAD was compared to the existing AAD obtained from the four events.

Direct comparison of AAD gives an indication of the reduction in damages for any one year. However, to assess the full monetary benefits over the life of the project, including taking into account costs of construction and maintenance, Net Present Value (NPV) calculations are used and the benefit/cost (B/C) ratio established. The B/C approach is used to quantify the economic worth of each measure enabling the ranking against other measures. A B/C ratio is the benefits expressed in monetary terms, i.e. the reduction in AAD over the life of the project, compared to the actual likely cost of achieving those benefits, in other words; construction and maintenance costs. Where the B/C ratio is greater than one the measure is economically feasible, however, where the B/C ratio is less than one, the costs of the measure are higher than the reduction in tangible flood damages and therefore not justifiable from a purely economic basis.

The AAD per annum in today's monetary terms is assumed to apply for each year of the NPV damage calculation and is determined for each year based on a discount rate of 7% as per the recommendation in the Residential Flood Damages FRM Guidelines (Reference 15). Estimation of construction and maintenance cost using the NPV of the AAD assuming a design life of 50 years, enables the calculation of the B/C for each of the measures. Calculations of the benefits and costs are included in each of the respective mitigation measure sections.

5.3.2. Management Measures Matrix

A matrix is used to assess the management measures on other categories to which tangible damages and a B/C ratio cannot be assessed, such as environmental and social implications.

The scoring system for a range of criteria is provided in Table 13 and largely relates to the impacts in a 1% AEP event. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions. This matrix is completed for the range of management assessed in the previous sections and presented as Table 20 in the Summary section.

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- environmental and ecological benefits;
- impacts on the State Emergency Services;
- political and/or administrative issues;
- long-term performance given the likely impacts of climate change and sea level rise;
- risk to life.

Table 13: Colour Coded Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefitted	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straightforward	straight forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

6. FLOOD MODIFICATION MEASURES

The purpose of flood modification measures is to change the behaviour of the flood itself through reducing flood levels or velocities and/or excluding water from areas under threat. These measures are characterised by structural works. This section considers management measures that modify flood behaviour on a wider scale, i.e. from a catchment wide perspective. Flood modification measures at the individual property scale are called property modification measures and are included in Section 7.

Council nominated 17 flood modification measures to be assessed as shown in Table 14 and the outcomes are provided in the relevant sections.

Table 14: Council Nominated Flood Modification Measures

Report Section	OPTION	COMMENT
6.1.2	**Option A - Increase Storage of Centennial Park Detention Basin**	Excavate ponds in Centennial Park
6.1.2	**Option B - Centennial Park Detention Basin**	Investigated prior to construction of Light Rail and works undertaken as part of Light Rail included in updated design flood levels
6.1.2	**Option C - Optimise Centennial Park basin outlets**	Adjust outlet capacity
6.2.1	**Option D - Drainage Upgrade**	Dangar Lane to One More Shot Pond
6.2.2	**Option E - Drainage Upgrade**	Clovelly Road trunk drainage upgrade
6.2.3	**Option F - Drainage Upgrade**	Market Street to Centennial Park
6.2.4	**Option G - Drainage Upgrade**	Market Street to Darley Road
6.2.5	**Option H - Drainage Upgrade**	Goodrich Avenue to Shaw Avenue + Aboud Avenue to Gardeners Road
6.2.6	**Option I - Drainage Upgrade**	Increase capacity under Gardeners Road
6.2.6	**Option J - Blockage Protection at Gardeners Road culvert**	Reduces likelihood of blockage
6.1.3	**Option K - Randwick Racecourse Detention Basin**	Augment capacity of existing basin
6.2.7	**Option L - Drainage Upgrade**	Kensington Park to Gardeners Road
6.5.1	**Option M - Ground Level Modification**	Enhance overland flowpath between Kensington Oval and Bowling Club
6.1.4	**Option N - Kensington Park Oval Detention Basin**	Excavation of oval
6.5.2	**Option P - Ground Level Modification**	Lowering of Mooramie Avenue Reserve
6.2.8	**Option Q - Drainage Upgrade**	Koorinda Avenue
6.2.9	**Option R - Drainage Upgrade**	Doncaster Avenue + Mooramie Avenue

A summary of the modelling results for the above options (where results have been obtained) is provided in Table 15 and Table 16.

Table 15: Summary of Council Nominated Option Results

Option	Event	Max Decrease in Flood Level	Location	Max Increase in Flood Level	Location	OUTCOMES
A	No change in flood level					Not considered further due to nil reduction in flood level
D	1 EY	0.06	Dangar Ln and Wentworth St	-	-	Reduces the number of properties inundated above floor level by 2 in the 1% AEP however the B/C ratio of 0.03 does not justify the implementation of the measure from an economic point of view alone.
	10% AEP	0.3		-	-	
	1% AEP	0.5		-	-	
E	1 EY	-	Darley Road	-	-	The very small reductions in flood level and low B/C ratio make this option unviable.
	10% AEP	-	Clovelly Road	-	-	
	1% AEP	0.1	Clovelly Road	-	-	
F	1 EY	0.03	Market Street	-	-	Although the option reduces the number properties flooded above floor level by 4 in the 10% AEP event the B/C ratio of 0.56 does not justify the implementation of the measure from an economic point.
	10% AEP	0.2		-	-	
	1% AEP	0.2		-	-	
G	1 EY	0.01m	Market Street	-	-	The very small reductions in flood level and low B/C ratio make this option unviable.
	10% AEP	0.01m		-	-	
	1% AEP	0.03m		-	-	
H	1 EY	0.04m	Shaw Avenue	0.1m	Aboud Avenue	The small reductions in flood level and low B/C ratio make this option unviable.
	10% AEP	0.12m	Shaw Avenue	-	-	
	1% AEP	0.4m	Shaw Avenue	-	-	
I	1 EY	Depends on size of additional culverts.	Leonard, Court and Cottenham Avenue	-	-	This option produces significant reductions in flood level upstream with few adverse impacts that cannot be addressed downstream. The major drawback is the high cost of constructing additional culverts under Gardeners Road. The last major flood causing significant damage was in November 1984 (over 30 years ago).
	10% AEP			-	-	
	1% AEP			-	-	
J	1 EY	-	Leonard, Court and Cottenham Avenue	-	-	In theory a significant reduction in flood level can be achieved through construction of relatively inexpensive blockage prevention devices. However the cost effectiveness will depend upon whether blockage does actually occur in future floods. There is no known history of blockage but significant potential for it to occur.
	10% AEP	-		-	-	
	1% AEP	0.4m		-	-	
K	1 EY	-	-	-	-	The very small reductions in flood level make this option unviable
	10% AEP	-	Doncaster Avenue	0.1m	Racecourse	
	1% AEP	0.1m	Leonard Avenue	0.3m	Racecourse	
L	1 EY	0.03m	Court Avenue	-	-	Despite reducing the number of properties inundated above floor level by 44 in the 1% AEP, the feasibility is unlikely due to the constraint of placing additional large pipes through private property. Consequently, substantial associated costs result in a B/C ratio of 0.1.
	10% AEP	0.1m	Court Avenue	-	-	
	1% AEP	1.2m	Leonard Avenue	-	-	
M	1 EY	0.03m	Court Avenue	-	-	Substantial decreases in upstream damages are somewhat reduced by increases in damages downstream. While Option M is beneficial overall, it cannot be implemented without some compensatory measures due to the negatively affected properties downstream.
	10% AEP	0.1m	Court Avenue	-	-	
	1% AEP	0.7	Barker Street	0.3m	Edward Avenue	
N	1 EY	0.03m	Court Avenue	0.1 (Depth)	Kensington Oval	This option reduces flood affectation to a number of properties. 19 properties are no longer flood affected and 17 properties no longer will have above floor level flooding in the 1% AEP. However the cost of the option is likely to outweigh the benefit.
	10% AEP	0.02m	Barker Street	0.1m (Depth)	Kensington Oval	
	1% AEP	0.8m	Barker Street	1.0m (Depth)	Kensington Oval	
P	1 EY	-	-	-	-	Despite reducing the number of properties flooded above floor level by 9 in the 1%AEP, the feasibility is unlikely due to the constraint of lowering the culvert. Consequently, substantial associated costs result in a B/C ratio of <0.1.
	10% AEP	-	Day Avenue	-	-	
	1% AEP	0.2m	Day Avenue	0.01m	Barker Street	
Q	1 EY	-	-	-	-	The increase in flood levels make this option unviable.
	10% AEP	-	-	0.01m	Day Avenue	
	1% AEP	-	-	0.15m	Day Avenue	
R	1 EY	0.03	Day Avenue	-	-	The very small reductions in flood level and low B/C ratio make this option unviable.
	10% AEP	0.03	Day Avenue	-	-	
	1% AEP	0.02m	Doncaster Avenue	-	-	

Table 16: Change in Number of Above Floor Inundated Buildings for Council Nominated Options

	Council Nominated Option													
Combined	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**P**	**Q**	**R**
1% AEP	-2	-2	0	0	-5	-18	-18	-5	-44	-9	-17	-9	0	-4
10% AEP	-2	0	0	-1	-1	0	0	0	-2	-1	-1	0	0	0
0.2 EY	0	0	-4	0	-1	0	0	0	-2	-1	-1	0	0	0
1 EY	0	0	-2	0	0	0	0	0	0	0	0	0	0	0
Residential														
1% AEP	-2	-1	0	0	-5	-18	-18	-5	-44	-7	-15	-9	0	-4
10% AEP	-2	0	0	0	-1	0	0	0	-2	-1	-1	0	0	0
0.2 EY	0	0	-4	-1	-1	0	0	0	-2	-1	-1	0	0	0
1 EY	0	0	-2	0	0	0	0	0	0	0	0	0	0	0
Commercial														
1% AEP	0	-1	0	0	0	0	0	0	0	-2	-2	0	0	0
10% AEP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2 EY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 EY	0	0	0	0	0	0	0	0	0	0	0	0	0	0

6.1. Retarding Basins

DESCRIPTION

Retarding basins work by storing runoff and releasing it over time subsequent to the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

DISCUSSION

These systems are easy to implement when new development is proposed as Council can place the responsibility on the developer to provide appropriate drainage systems. This is usually implemented through development controls requiring that runoff rates from new developments be not greater than existing rates. While the 1% AEP event is typically used as the design event, flows also need to be restricted back to the pre-development rates (or less) for smaller events. Council's Stormwater Code (refer Section 4.1.5) requires that all new development, other than single dwelling houses must comply with a maximum discharge up to the 5% AEP (20 year ARI) event.

Hydraulic structures can be used to restrict the discharges rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin. When designing flood retarding basins, the performance of the basin should be assessed for a full range of storm durations including longer duration events to confirm concept design prior to detailed design.

Within the catchment, retarding basins can be used as part of the overall catchment drainage. However, in urban areas such as the Kensington study area, there is little space for new basins to be included. In some instances basins can be designed to utilise existing parks and sports fields as considered in this floodplain risk management for the Kensington Park oval.

It should be noted that large retarding basins can be a safety hazard. Consequently, appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety (Centennial Park Ponds 1 and 2 are Prescribed Dams under the DSC). This is applicable to basins identified as a possible threat to communities located downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder.

Whilst retarding basins appear to be a fairly simple and effective means of controlling runoff and water quality in urban catchments there are a number of potential issues that need to be resolved. These are summarised in Table 17 below.

Table 17: Considerations for Retarding Basins

ISSUE	COMMENT
Size:	In order to be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be. The outlet controls are also important in the design of the basin and generally comprise a low flow culvert and a weir which overtops in a large event.
Cost:	Whilst construction costs of the basin and wall in a rural or urban environment will be high, additional costs are associated with any alterations to services (gas, electricity, telephone, water, sewerage, roads, etc.) that are within or in close proximity to the proposed basin. There will also be some ongoing maintenance cost. Some sites in urban areas, which at first glance may appear suitable, are unviable due to the deposition of inappropriate fill material in the past (ex rubbish site, buried asbestos or other forms of waste).
Benefit:	Whilst any basin will provide some peak flow reduction and water quality benefit this must be balanced against the cost, and whether there are more cost effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or significant hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives. The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose has to be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these flows are generally not contained to allow the volume in the basin to be “empty” at the time of the peak inflow.

ISSUE	COMMENT
Loss of Land Use and Availability of Land:	In a rural or some urban areas the loss of land for basin construction is acceptable. However in a relatively dense rural and urban catchment, where areas of open space are very valuable, the loss of previously useable land is significant. Basins can have multi-uses, such as being used as sports fields when dry, but this can be difficult to achieve.
Environmental Impact:	In both rural and urban areas there is likely to be a high environmental impact with removal of vegetation and construction of an embankment wall. In relatively densely developed urban catchment such as Kensington the lack of a potential basin site obviously restricts the use of this mitigation measure. The most preferred sites are within golf courses or any sports ground where many of the above issues can be negated. Examples in Sydney are in Fox Hills (Prospect) and Muirfield (North Rocks) golf courses or in a soccer field at Bateau Bay.
Safety:	This is one of the most important factors to be considered when constructing a basin with a downstream urban area. Council will be changing an open space area with a low hazard potential during rainfall events to an area with a greater hazard. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing but this then precludes the use of the basin for other purposes. Generally basins deeper than say 1.2 m are unacceptable as a person cannot wade out of them. Some basins are designed to have shallow and gradual depths closer to the edges but this means less potential storage volume over the same land area. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin places a significant potential liability on Council should it cause harm to persons in flood (or even non-flood) times. Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this removes Council's responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs.

ASSESSMENT

A number of basin options were considered for retrofitting into the existing drainage network of Kensington and improving existing detention capacity.

6.1.1. Existing Basins in the Catchment

There are no formal retarding basins within the Kensington - Centennial Park catchment with the exception of the ponds in Centennial Park (Diagram 4). The ponds provide significant attenuation in the upstream catchment. The lower pond, located north of Alison Road has an outlet through the embankment which runs parallel to Alison Road. Modelling (Appendix B) indicates that the levee embankment overtops in the 2% AEP event but not in the 5% AEP event and thus the embankment has a flood immunity of between the 5% AEP and 2% AEP event. However it should also be noted that volume of runoff is a consideration and thus a less intense storm but of longer duration may cause overtopping in a more frequent AEP event. For the design flood modelling all basins in Centennial Park are assumed to be full with the exception of the lower basin which is full to the spillway level (approximately 29.2 m AHD), not to the top of the Alison Road embankment (approximately 31.8 m AHD).

Diagram 4: Ponds within Centennial Park

Diagram courtesy of Centennial Parklands

6.1.2. Option A, B & C – Increase Detention in Centennial Park

The hydraulic benefit from a retarding basin is a function of the storage within the basin, the height of the basin wall and the dimensions of the outlet structures.

Storage can be increased by excavating the existing basins or ponds (Option A). This is an expensive option unless there is some other practical use for the excavated area or the fill. Depositing fill on a Council tip may cost approximately $100+ per tonne including transport costs and this makes this option not viable. In addition the ponds or basins in Centennial Park are generally full except in a drought. For this reason the modelling of design events in the Flood Study assumes that the preceding rain fills the basin to the level of the lowest outlet. Thus

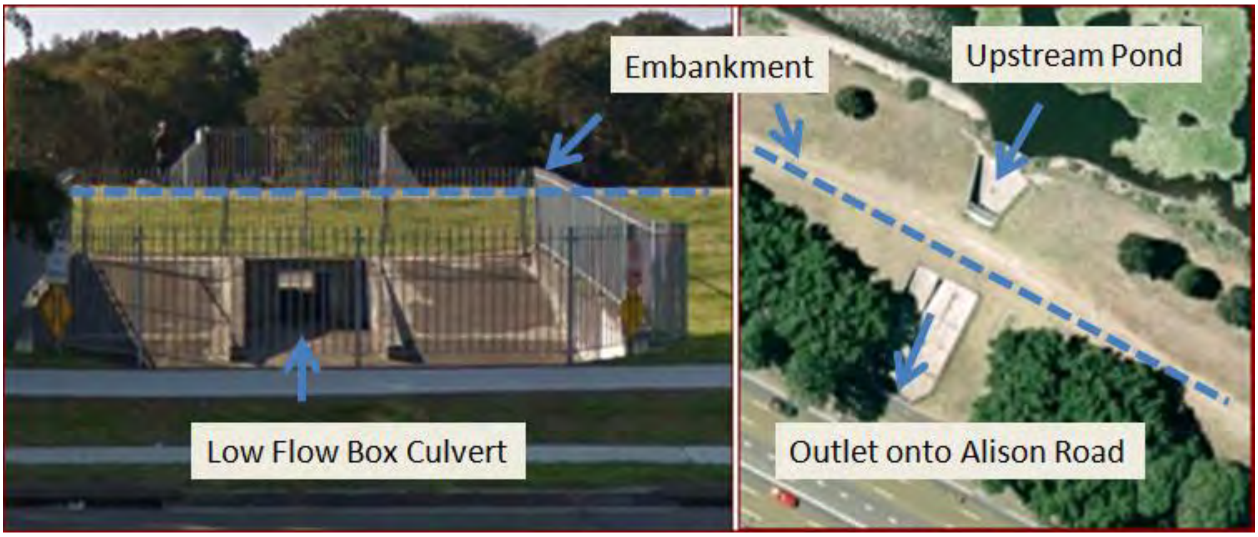
Option A, which considers excavation of the basins, will provide no hydraulic benefit for the assumed design flood conditions.

Increasing top of embankment levels (Option B) was investigated prior to the construction of the Light Rail and considered to have a B/C ration of greater than 10 and therefore would be considered a high priority measure. However, subsequently the raising of the embankment (to a level of 31.8 mAHD at the Alison Road spillway and 32.0 mAHD across the length of the embankment) has been undertaken as part of the construction of the Light Rail to negate the potential increase in flood levels due to the construction of the tram storage facility and other works in the floodplain. This option has therefore not been pursued further.

Option C was to examine the outlet structures of the main basin upstream of Alison Road (prior to construction of the Light Rail). These consisted of an underground pipe, a low flow box culvert (approximately 1m by 1m) which exits onto Alison Road and a high flow outlet over the embankment wall (Photograph 4). The outlet structures control the rate of outflow and by modifying their dimensions can be used to optimise the performance of the basin across a range of design events. If the basin is intended to reduce flows in large design events then the low flow openings should be relatively large. In this way the maximum storage volume as possible in the basin is available when the peak of the event occurs. This basin would have a greater outflow in the smaller more frequent design events than one which has a relatively small low flow outlet. The latter is optimised to provide maximum mitigation in the smaller more frequent design events.

Altering the outlet structures does not therefore provide an overall benefit across the range of design events but merely changes the range where the basin has maximum benefit. A blockage minimisation device or enlarging the culverts were considered, however any new structure would still be potentially subject to blockage and for this reason and because increasing the non overtopping flow across Alison Road could not be supported, no further assessment was undertaken on this option.

Photograph 4: Low Flow Box Culvert and Embankment Upstream of Alison Road (prior to Light Rail upgrade)



6.1.3. Option K – Detention Basin at Randwick Racecourse

Option K investigates the use of Randwick Racecourse as a retarding basin. The facility already has two small retarding basins in the south west corner and the embankment on the track will store additional floodwaters. This option considers raising the south west corner of the racecourse to contain additional runoff. The perimeter of the track was raised to 31 mAHD which equated to a rise of 0.5m to 1.5m depending on the existing track height.

The existing retarding basin is shown on Photograph 5. It is unlikely that these two basin structures were constructed with the intent of reducing peak flows from the site, rather they evolved as a result of redesign of the track over the years. However as a result they do form an effective retarding basin together with a track that is superelevated at this turn. Apart from the 900mm outlet pipe there is no formal overflow structure as such and flood waters will just exit over the crest of the track.

Impacts for the 1% AEP event from the enhancing of the informal detention basin at Randwick Racecourse are shown in Figure D1. Decreases of 0.1 m are observed along Leonard Avenue.

Option K reduces the AAD by approximately $0.003 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.04 million. The construction cost of the works is likely to be of the order of $0.5 million and require detailed consideration by Randwick Racecourse. However there will likely be significant additional costs. For example the works will affect access from the stables and possibly affect the visual amenity of the area. The works may also affect the safe running of races (changes to grade on the track). There may also be increases in inundation levels (and consequently likely duration of inundation) at the racecourse which may affect the existing level of flood protection. The biggest consideration by Randwick Racecourse will be the affectation on race meetings during the construction and recovery stages. The cost of a lost race meeting may exceed the cost of the actual works. For these reasons the true cost of the works and benefit cost ratio cannot be accurately estimated at this time.

Photograph 5: Twin Retarding Basins in Randwick Racecourse

For these reasons the relatively small reduction in damages is unlikely to make Option K economically viable. However any increase in temporary floodplain storage in the Randwick Racecourse will reduce flood levels downstream. Possibly this measure could be pursued when further changes are made in the future to the track.

6.1.4. Option N – Detention Basin at Kensington Park Oval

Option N considers lowering the oval at Kensington Park (Photograph 6) to create additional storage volume within the drainage system. A lowering from the current level of between 22.7 m and 21.5 m AHD to 20 m AHD was investigated. Additionally, a flowpath is facilitated through the lowering of levels to the east of the oval (open space and bowling greens). The gradient of the flowpath is assumed linear from road level on Barker Street to the road level on Edward Avenue, enhancing conveyance between the two points to the basin.

This option has now become impractical in 2018 as the community centre has recently been upgraded and the rear of the building is an evacuation centre.

The impacts from Option N relative to existing conditions for the 1% AEP event are shown in Figure D2. In the 1% AEP event peak flood level decreases of 0.75 m are observed. The option also marginally decreases peak flood levels in the 10% AEP event. Benefits in smaller events are not as significant as the existing depths of flooding are already shallow. There are increases in peak flood levels of up to 0.1m in properties on Leonard Street adjacent to the tennis courts and increases of 0.02m in the low point adjacent to Gardeners Road.

Photograph 6: Kensington Oval

In all design events, the use of the oval as a detention area means that previously where this area was not inundated significantly, flood depths would now reach 0.1 m in the 10% AEP event and up to 1.0 m in the 1% AEP event. Any subsurface drainage already present at the oval would need to be considered in the detailed design of this option. The flow path created from Barker Street to Edward Avenue creates a newly flooded area in all design events. The existing children's playground located on Edward Avenue would need to be modified as part of the ground lowering for this option and the flood affectation of the playground would increase. However, it is unlikely that during the heavy rains which would cause such flooding that the playground would be in use.

A further consideration is that there is a 600mm pipe (recently upgraded from a 300mm pipe) underneath the field which may restrict the depth of excavation. This would need to be considered if this option is proposed.

Option N reduces the AAD by approximately $0.084 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $1.244 million. The cost of the option is likely to exceed $1 million and incur significant public reaction due to the affectation to a high quality recreational amenity. The economic cost will likely rise as existing recreational facilities will have to be modified. The B/C ratio of 1.24 is favourable in providing impetus for this option but with the possibility of the economic cost rising due to existing recreational facilities needing to be modified this may change. The issue of increases in peak flood levels would have to be addressed if the option was to be investigated further. The use of public open space, such as a cricket field or golf course, is an excellent means of dual use in an urban floodplain and has been undertaken in other areas with success.

6.1.5. Detention Basins for New Development

In an urban situation, all new development should not increase peak flows entering the drainage system. On-site detention (OSD) techniques including detention basins assist in achieving this and this is considered further in Section 6.7.

Detention basins are only likely to be used on larger development where space allows for an area of above ground water storage.

6.1.6. SUMMARY

Use of existing open space areas such as Kensington Park Oval for stormwater detention purposes has the potential for reducing flooding. Options assessed at the oval show that a number of residential properties would benefit from reduced peak flood levels however the costs of the measure is likely to outweigh benefits.

Reconfiguration of the embankment and upstream basins in Centennial Park has been undertaken as part of the Light Rail works and has not been considered further in this Study.

RECOMMENDATIONS

The following measures are recommended for further assessment and refinement:

► **OPTION K – Detention Basin at Randwick Racecourse –** this option reduces flood affectation to a number of properties. 3 properties are no longer flood affected and 5 properties no longer experience above floor level inundation in the 1% AEP. However the cost of the option and affectation to the racecourse is likely to outweigh the benefit.

► **OPTION N – Detention Basin at Kensington Park Oval –** this option reduces flood affectation to a number of properties and has a B/C ratio of 1.24. 19 properties are no longer flood affected and 17 properties no longer experience above floor level inundation in the 1% AEP. However the social and economic cost of the option is likely to outweigh the benefit and the increases in peak flood levels will be difficult to mitigate. A further consideration is that there is a 600mm pipe (recently upgraded from a 300mm pipe) underneath the field which may restrict the depth of excavation.

The following are not recommended for improving the flooding situation:

► **OPTIONS A, B and C – Upgrade of Centennial Park Basins –** These measures have largely been implemented as part of the Light Rail works.

6.2. Drainage Network Modifications

DESCRIPTION

Modification of the existing drainage network can be made to increase the capacity of the system by installing larger/additional pits and pipes, creating diversions or enhancing flow routes. Additionally, network modification can assist in the drainage of low trapped points to reduce ponding. It is worth mentioning that while enhancing assets can mitigate flood risk, regular maintenance of the drainage network to ensure that it is operating with maximum efficiency is required to reduce risk of blockage or failure. The maintenance of existing infrastructure is considered in Section 6.3.

DISCUSSION

Section 2.1.2 and Figure 5 indicates that the majority of the drainage infrastructure is of low capacity. This is typical of all Sydney urban drainage systems. Furthermore, a number of low trapped points exist (see Section 2.1.1) where natural topographic depressions and poor drainage results in the ponding of runoff. For such areas, the only way to reduce an existing problem is to reduce the surface water reaching the area or provide additional below ground drainage to drain trapped low points.

In an urban environment such as Kensington, most flood modification floodplain risk management measures will involve modification of the existing drainage network. The drainage network is made up of a number of features including open channels, pipes, box culverts and detention basins. Often in an urbanised area with an established drainage infrastructure, a number of measures have to be taken to improve drainage. The difficulty is that the upgrade of the underground system in one area upstream facilitates more conveyance of water downstream with the potential to exacerbate flood levels there. A combined management approach requires assessment of impacts of flood improvement measures in one area onto other areas within the catchment to assess if further improvements are necessary to mitigate resulting effects.

Utilising the Flood Study (Reference 3) and through discussions with Council and the FMC, a number of areas that could benefit from upgrading of the existing drainage network have been identified. Measures considered in this assessment consist of either increasing pipe sizes or improving inlet efficiency.

Detailed costing of the drainage upgrades investigated was undertaken. Items considered included:

- General construction costs (site establishment, geotechnical survey, etc.);
- Demolition and clearing costs;
- Excavation and earthworks;
- Installation of drainage assets;
- Backfilling;
- Footpath and road surfaces relaying; and
- Traffic management costs.

Capital costs as well as yearly maintenance costs converted to net present value are summed together and used in the calculation of the B/C ratio for each of the options below.

6.2.1. Option D – Upgrade Drainage from Dangar Lane

Dangar Lane is a low trapped point where water ponds in events as low as the 20% AEP event. The option considered increasing the number of 450 mm pipes from Dangar Lane to Centennial Park to four, the number of 600 mm pipes from Wentworth Street to Dangar Lane to two and the number of 450mm pipes from Challis Lane to Wentworth Street to two. Impacts from the proposed Option D relative to existing conditions for the 1% AEP event are shown in Figure D3. A number of dwellings on Dangar Lane and Wentworth Street are flood affected in small flood events including 5 flooded above floor in the 1% AEP event. The option decreases peak flood levels by up to 0.45 m in the 1% AEP event providing benefit to dwellings and reducing over floor flood inundation for 2 properties.

Option D reduces the AAD by approximately $0.004 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.06 million. The estimated costs for Option D are $2.1 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.03 indicating that the mitigation option is not justifiable from an economic standpoint alone. However if property acquisition costs are included (estimated as $3 million) the B/C ratio reduces to 0.01.

An alternate option that does not require easement upgrades was also considered. This option consisted of increasing the number of 450 mm pipes from Dangar Lane to Centennial Park to four and the number of 600 mm pipes in Dangar Lane to two. The option decreases peak flood levels by 0.22 m in the 10% AEP. This option could be implemented by Council if it is preferable not to upgrade the easements that run through residential properties between Dangar Lane / Wentworth Street and Wentworth Street / Challis Lane.

6.2.2. Option E – Clovelly Road Trunk Drainage Upgrade

This option considered upgrading the drainage from the Clovelly Road trapped low point near Orange Lane to Centennial Park, near the intersection of Avoca Street and Darley Road (Figure D4). An initial assessment increased the number of pits and pipes under Darley Road into Centennial Park by four times (i.e. four times the existing drainage capacity) with no benefits in terms of the number of properties flood affected. Consequently, the Darley Road pits and pipes were increased by six times (i.e. six times the existing drainage capacity) and upgrades were also assumed on Avoca Street and Clovelly Road where the number of pipes and pits was doubled (i.e. twice the existing drainage capacity).

Peak flood level impacts from Option E relative to existing conditions for the 1% AEP event are presented in Figure D4. Reductions in peak flood levels of up to 0.02 m are observed at the intersection of Darley Road and Avoca Street and reductions in peak flood levels of up to 0.1m at properties on Clovelly Road and Avoca Street are observed. There are only marginal decreases in peak flood levels in the 10% AEP event.

Option E reduces the AAD by approximately $0.016 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.25 million. The estimated costs for Option E are $3.85 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.06 indicating that the mitigation option is not justifiable from an economic standpoint.

6.2.3. Option F – Market Street to Centennial Park Drainage Upgrade

A trapped low point at Market Street floods to depths of 0.2 m in a 1 EY event. Existing drainage from Market Street conveys captured runoff towards Centennial Avenue and eventually to the outfall in the lower Kensington pond (Diagram 4) near the intersection of Avoca Street and Darley Road. Improvement to the low trapped point on Market Street requires the upgrading of the entire reach of drainage line.

Option F considers replacing the existing 1.2 m pipe at Darley Road with six 1.2 m pipes and duplicating the drainage line between Market Street and Centennial Avenue. Peak flood level impacts from this option relative to existing conditions for the 1% AEP event are shown in Figure D5. Peak flood levels on Market Street are lowered by up to 0.2 m in the 10% and 1% AEP events and by up to 0.15 m in the 20% AEP event. Benefits are also observed on Centennial Avenue and Darley Road as a consequence of the pipe upgrade. In addition, minor reductions in peak flood levels (up to 0.05 m) occur on Clovelly Road due to the upgrade downstream.

Although this option provides some benefit in terms of peak flood level reductions, the 1.2 m diameter pipe running from Market Street to Centennial Avenue traverses residential blocks and therefore further investigation into this option is required to assess if there is a suitable easement for the additional pipe before detailed design is undertaken. It is also likely that some property acquisition will be required which will add to the cost.

Option F reduces the AAD by approximately $0.095. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $1.411 million. The estimated costs for Option F are $2.54 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.56 indicating that the mitigation option is not justifiable from an economic standpoint. The B/C ratio would further reduce if property acquisition costs are included.

6.2.4. Option G – Fig Tree Avenue - new pipe from Market Street to Existing 0.6 m pipe off Darley Road between Market and Avoca Streets

The aim of this option is to divert flows from the Fig Tree Avenue area to a pipe on Darley Road. An initial assessment was undertaken connecting a 0.6 m pipe from Market Street directly to Darley Road. However, little benefit in terms of reduced peak flood levels was obtained as the capacity of the Darley Road pipe was limited by the additional flows. Consequently, the assessment was amended to also double the capacity of the pipe on Darley Road.

The option was run for the 1 EY, 20% AEP, 10% AEP and 1% AEP events. In the 1 EY event, and the 20% AEP event there are only marginal reductions in peak flood levels. Peak flood level impacts for the 1% AEP event are shown in Figure D6. Although reductions in peak flood level occur over several streets, they are limited to less than 0.05 m in the 1% and 10% AEP events and no reduction in the number of properties flood affected is observed.

Option G reduces the AAD by approximately $0.003 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.05 million. The estimated costs for Option G are $1.99 million consisting of a capital and yearly maintenance costs. This results in a low B/C ratio of 0.03. The option is constrained by the low grade along the road and Option F provides a better result in decreasing peak flood levels in the Market Street low point.

6.2.5. Option H – Upgrade Drainage from Goodrich Avenue along Shaw Avenue and Aboud Avenue to Gardeners Road

The intersection of Goodrich Avenue and Shaw Avenue currently experiences flood depths of 0.3 m and 0.4 m in the 10% AEP and 1% AEP events respectively. Properties on Shaw Avenue are flood affected in events as low as the 10% AEP. Properties are flood affected on Aboud Avenue in the 1 EY event.

Option H considered the upgrade of drainage assets from Goodrich Avenue along Shaw Avenue and Aboud Avenue to Gardeners Road. The entire drainage system is duplicated and impacts for the 1% AEP event from the enhancing of the system are shown in Figure D7. Decreases in flood levels are observed on Shaw Avenue for the event. Decreased flood levels in the 1% AEP event of up to 0.25 m in the 10% AEP event and 0.35 m in the 1% AEP event occur on Shaw Avenue.

Option H reduces the AAD by approximately $0.025. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.37 million. The estimated costs for Option H are $3.28 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.11. While the option reduces the number of properties affected above floor level by 5, the works are not justified from an economic point of view alone.

6.2.6. Option I & J – Culvert Upgrade and Blockage Protection Works for Gardeners Road Culvert and Upstream Channel

Properties between Leonard, Court and Cottenham Avenues are exposed to flood depths of 0.2 m in the 10% AEP and 1 m in the 1% AEP events. This occurs primarily due to the trapped low point caused by the raised Gardeners Road acting as an embankment.

Two measures have been investigated to address this issue. Option I examines possible upgrades to the culvert capacity whilst Option J investigates the implementation of blockage protection works.

Option I: The most effective measure for reducing the depth of floodwaters upstream of Gardeners Road is to enlarge (or provide additional) the twin culverts between Leonard and Court Avenues. The main issues with this measure are the high cost ($4+ million depending upon the magnitude of the works and if including upstream and downstream works) and the impacts and affectation downstream. The land downstream is occupied by a car park for Eastlakes Golf Club which would need to be reduced in size. However a preliminary review suggests that the adverse impacts and affectation downstream could be addressed and are not insurmountable.

The other crossing of Gardeners Road is opposite Aboud Avenue (two pipes). The main issue is again the high cost (up to $1 million) and the impacts and affectation downstream. A preliminary review suggests that the downstream impacts and affectation may be more complex than for the above as the pipes exit into Sydney Water owned land and then into The Lakes golf course (leased from Sydney Water). In addition it will be difficult to include sufficient upstream inlet pits outside of private property to ensure that any pipe upgrade flows at capacity. The latter could add significantly to the cost if upstream pipes have to be upgraded and/or relocated.

The main issue with enlarging openings under Gardeners Road is the high cost. Pipe boring would be required and a detailed review of the design, geotechnical and other issues would be required to determine an accurate estimate of costs. Benefit cost analysis was undertaken assuming an 1800mm diameter pipe was bored adjacent to the existing twin culverts. Option I reduces peak flood levels by 0.4 m in the 1% AEP event with results shown in Figure D8.

Option I reduces the AAD by approximately $0.064 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.94 million. This is very close to the reduction in damages for assuming nil blockage (Option J) and reduces the number of buildings with above floor inundation by 18 in the 1% AEP. Assuming an indicative cost of $4 million provides a B/C ratio of 0.24. This option does provide significant benefits in terms of reduced depth of inundation and hazard.

Funding for either an upgrade to the main Gardeners Road culverts or those opposite Aboud Avenue (two pipes) cannot occur unless feasibility studies ($80,000 for main culverts and $40,000 for Aboud Avenue) are undertaken.

Option J: It is unclear if blockage has actually been a significant factor in the past or not during floods but best practice suggests that it may occur during floods and should be included in design flood analysis. With flooding in this area increased due to the high potential for blockage in the twin culverts under Gardeners Road (for existing conditions one culvert was assumed to be blocked by 25%).

Option J considers the implementation of blockage protection works (i.e. removal of the assumed blockage) for the culverts located beneath Gardeners Road and upstream of the open channel. The nature of the blockage prevention works will depend on a detailed assessment of the upstream reach. Having a structural blockage device fitted to culvert inlets would be unlikely to be successful as it will itself attract blockage from small debris which would otherwise safely pass through the structure. The key control devices would be installation of bollards or similar to prevent vehicles from falling into the culvert (either into the channel upstream or from Gardeners Road). However a review of the fencing adjoining the upstream channel and possibly of nearby vegetation or stored material which may fall into the channel should be undertaken to see if simple measures can be taken to reduce the likelihood of blockage.

Impacts from the blockage prevention works relative to existing conditions for the 1% AEP event are shown in Figure D9. Decreases in peak flood levels of 0.4 m are observed for the properties between Leonard, Court and Cottenham Avenues.

Option I reduces the AAD by approximately $0.064 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.94 million. While this option reduces the number of properties affected above floor level by 18 in the 1% AEP event and assuming an approximate cost of $100,000 (B/C ratio of 9), ensuring zero pipe blockage in large events is unlikely as is that blockage will necessarily occur in all events to the same extent. The implementation of this measure is fairly straightforward and has been undertaken by many Councils where there is the potential for blockage.

6.2.7. Option L – Upgrade Drainage from Kensington Oval to Gardeners Road

Barker Street is exposed to flood depths of 0.3 m in the 10% AEP and 1.8 m in the 1% AEP events. Similarly, properties between Leonard Avenue and Cottenham Avenue are flood affected by depths of up to 0.3 m in the 10% AEP and 1 m in the 1% AEP events.

Option L considers the duplication of the two culverts running from Kensington Oval to Gardeners Road. Figure D10 shows the impacts from the potential culvert enhancements for the 1% AEP event. Reduction in peak flood levels of 0.7m in the 1% AEP event are observed on Leonard Avenue and similarly reductions of 0.3 m are observed in the 10% AEP event. Decreases in peak flood levels of 0.1 m are also obtained on Borrodale Road in the 1 EY event.

Option L reduces the AAD by approximately $0.143. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $2.12 million. The estimated costs for Option L are $18.87 million which results in a B/C ratio of 0.11.

While the option reduces the number of properties affected above floor level by 44 in the 1% AEP event, the potential to upgrade the two large culverts (dimensions of 3 m x 1.5 m and 3 m x 1.9 m respectively) is constrained by the fact that the easements traverses through private properties. A new easement would therefore need to be purchased and the additional property acquisition costs make this option unviable.

6.2.8. Option Q – Upgrade Culvert at Koorinda Avenue

Koorinda Avenue experiences peak flood depths of 1.0 m in the 1% AEP event. This occurs as there is a significant dip in the road and fall from Doncaster Avenue at this point. Thus floodwaters from upstream become confined by the ground topography as well as the restrictions imposed by buildings and fencing, thus creating this large depth of floodwaters.

While realistically not feasible, Option Q considers the conceptual doubling of capacity of the culvert under Koorinda Avenue. As shown in Figure D11, negligible decreases in peak flood levels occur in the 1% AEP event and in fact a localised increase of 0.15 m occurs on Koorinda Avenue. This is to be expected as in larger events the backwater influence from downstream effectively negates the benefits of the additional culverts under Koorinda Avenue. In small events the additional culverts have some benefit but in larger events there is much less benefit as the topography and buildings still restrict the passage of floodwaters downstream.

Option Q reduces the AAD by $900. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.19 million. The estimated costs for Option Q are $0.41 million which results in a B/C ratio of 0.03.

6.2.9. Option R – Additional Pipes along Doncaster Avenue and Mooramie Avenue between Roma and Day Avenues

Roma Avenue is exposed to peak flood depths of 0.3 m in the 10% AEP event and 1.4 m in the 1% AEP event. Similarly, peak flood depths at Day Avenue potentially reach 0.2 m in the 10% AEP event and 1.2 m in the 1% AEP event.

Option R considers a new pit and pipe system along Doncaster Avenue and Mooramie Avenue with a proposed diameter of 0.9 m. Impacts from the new pipe relative to existing conditions in the 1% AEP event are shown in Figure D12. Decreases in peak flood levels of 0.02 m in properties on Roma Avenue are observed for the 1% AEP. Decreases of up to 0.04 m on Doncaster Avenue are observed in the 10% AEP.

Option R reduces the AAD by approximately $0.005 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.08 million. Four houses are no longer flooded above floor level in the 1% AEP event but there are only minor benefits in the smaller events.

An indicative cost for this option is $1million and would thus provide a B/C ratio of 0.08.

6.2.10. Summary of Council Nominated Pipe Upgrade Options

By increasing drainage capacity, larger volumes of surface water can be drained away more effectively. Enhancing the capacity of trunk drainage systems may achieve a degree of flood relief for properties exposed to flooding on a regular basis. Several drainage upgrade options were considered and have been modelled. Some were shown to be beneficial, although for others the reduction in peak flood levels was not significant enough to warrant implementation of the option, particularly when considering the capital costs of the respective options and potential increases in flood level elsewhere.

RECOMMENDATIONS

The following measures are recommended for further assessment and refinement:

► **OPTION I – Feasibility into upgrade of culverts under Gardeners Road (main culverts and at Aboud Avenue) –** Despite a low B/C ratio of 0.24 for upgrading of the main twin culverts this option should be explored further as it reduces the number of buildings with above floor inundation by 18 and provides significant benefits in terms of reduced depth of inundation and hazard. Upgrading of the Aboud Avenue culverts and potential to upgrade the pipe inlet capacity upstream should also be investigated.

► **OPTION J – Blockage device on Gardeners Road Culverts –** Difficult to ensure absolute blockage prevention to stormwater assets during large flood events but where feasible, regular pipe maintenance/cleaning should be implemented and or construction of a blockage prevention device.

The following are not recommended for improving the flooding situation:

► **OPTION L – Upgrade Drainage from Kensington Oval to Gardeners Road –** Despite reducing the number of properties inundated above floor level by 44 in the 1% AEP, the feasibility is unlikely due to the constraint of placing additional large pipes through private properties. Consequently, substantial associated costs result in a B/C ratio of 0.1 which would be further reduced if property acquisition costs are included.

► **OPTIONS – D, E, F, G, H, Q, R –** Not economically viable.

6.3. Drainage Network Maintenance

DESCRIPTION

Regular maintenance of the drainage network is important. It ensures that assets are operating with maximum efficiency and reduces but not eliminates the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network. As indicated in Section 4.2 Council has a regular maintenance program.

DISCUSSION

As part of the Flood Study (Reference 3), sensitivity of blockage of the sub surface drainage system was tested in the hydraulic model. Full blockage of the sub surface drainage system only caused nominal increases in peak flood levels for the 1% AEP event due to the fact that for larger events, the majority of flow is conveyed overland (roads etc.) rather than via the limited sub surface drainage system. However, in smaller more frequently occurring events such as the 20% AEP event, blockage is likely to have a larger impact on peak flood levels and therefore it is important for Council to undertake clearance of the sub surface drainage system.

A review of maintenance protocols or policies would ensure that drainage assets are effectively managed and regularly maintained such that they will perform at their optimum as required.

SUMMARY

Regular maintenance can reduce risk of blockage of structures during flood events and ensure that flood waters are drained efficiently. It would be beneficial for Council to review their maintenance protocols and ensure a record of all drainage infrastructure within the LGA as well as the authority, organisation or body responsible for its maintenance.

RECOMMENDATIONS

The following measures are recommended:

► **Drainage Network maintenance –** Review and identification of policies for general maintenance of pipes, drains and channels and determination of protocols for ownership maintenance and development / upgrade of infrastructure.

► **Drainage Network maintenance –** Review the database of all drainage infrastructure and its owner and authority responsible for its maintenance.

6.4. Open Channel Modifications and Maintenance

DESCRIPTION

Channel modification includes a range of measures from straightening, concrete lining, removal of structures, dredging and vegetation clearing. In some instances 'naturalising' the channel upstream can reduce peak levels downstream by slowing flows and making better use of flood storage, however this measure would increase flood levels upstream.

DISCUSSION

There are open channels in the lower catchment that are owned by Sydney Water. These channels are concrete lined and are hydraulically very efficient. There is therefore minimal opportunity to alter the open channel drainage system and maintenance is adequately undertaken by Sydney Water. Widening or deepening these channels to increase capacity is expensive (many $million) and impractical due to the high cost and lack of available easement width. There are significant social and environmental issues with construction of this measure. Extending the easement into private property will not be supported by the adjoining residents and would affect their land value. A further consideration is that in the lower reach the restricted capacity under Gardeners Road would nullify a large part of the benefit.

SUMMARY

Open channel modification measures cannot be reasonably undertaken.

The following is not recommended for improving the flooding situation:

► **Open channel modifications**

6.5. Modifying Ground Levels

DESCRIPTION

Localised high or low points in the topography can cause the built up or ponding of runoff. By modifying ground levels in these areas the flow of runoff can be aided, thereby preventing ponding. In urban areas it is often difficult to implement such measures although they can be undertaken in areas of open space and are often done so in conjunction with other management measures, such as retarding basins.

DISCUSSION

Review of the hydraulic model results indicates that a number of low trapped points exist (see Section 2.1.1 and Figure 3) where natural topographic depressions result in the ponding of runoff. For areas where reducing the surface water reaching the area is not feasible, modification in the local ground levels can be used to drain trapped low points.

ASSESSMENT

Utilising the results from the Flood Study (Reference 3) and through discussions with Council and the FMC, two areas that could benefit from adjustments in the local topography were identified and are discussed further below.

6.5.1. Option M – Lower Overland Flow Path between Kensington Oval and Bowling Club from Barker Street to Edward Avenue

Barker Street is exposed to flood depths of 0.3 m in the 10% AEP and 1.8 m in the 1% AEP events. Option M considers the lowering of ground levels between Kensington Oval and the Bowling Club. The modification consists of a continuous downward gradient from the Barker Street road levels to those at Edward Avenue.

Impacts from Option M relative to existing levels are shown in Figure D13 for the 1% AEP event. Decreases of 0.7 m are observed on Barker Street however increases of 0.3 m are observed on Edward Avenue. For the 1 EY event, decreases of 0.03 m occur on Court Avenue. Decreases of 0.03 m on Barker Street and Court Avenue occur in the 10% AEP event. Overall, properties benefit from decreases in flood levels upstream however the proposed mitigation works negatively affect some of the downstream properties.

Option M reduces the AAD by approximately $0.057 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.85 million. Substantial decreases in upstream damages are somewhat reduced by increases in damages downstream. While Option M is beneficial overall, it cannot be implemented without some compensatory measures due to the negatively affected properties downstream. Should these compensatory measures require duplicating the pipes south of the oval this option is not feasible.

6.5.2. Option P – Lower Mooramie Avenue Reserve Downstream of Open Channel

Upstream of Day Avenue there is an open channel but downstream the channel has been enclosed (i.e. a box culvert) and is termed the approximately 5m wide grass covered Mooramie Avenue Reserve. Day Avenue is exposed to peak flood depths of 0.3 m in the 10% AEP event and 1.4 m in the 1% AEP event. Option P considers the lowering of the Mooramie Avenue Reserve by 0.5 m. This is conceptually feasible however the Mooramie Avenue Reserve is ultimately an open channel with a lid on it, therefore there is no cover to lower the Reserve. Thus the channel (culvert) under the reserve requires similar lowering if the conveyance capacity is to be maintained. However with minimal fall in the land significant lowering cannot be achieved. Consequently the analysis includes the lowering of the channel as well as the cost of the drainage upgrades consisting of:

- General construction costs (geotechnical survey, provision of erosion and sediment control etc);
- Demolition and clearing costs;
- Excavation and earthworks;
- Installation of drainage assets;
- Backfilling.

Capital costs which are substantial for the 230 metre length of culvert as well as yearly maintenance costs converted to net present value are summed up and used in the calculation of the B/C ratio below.

Impacts from Option P relative to existing levels are shown in Figure D14 for the 1% AEP event. Decreases in peak flood levels of 0.2 m are observed on Day Avenue however increases of 0.1 m are observed on Barker Street.

Option P reduces the AAD by approximately $0.024 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is $0.35 million. The estimated costs for Option P are $5 million due to the large costs associated with lowering the large culvert over 230 metres. This results in a low B/C ratio of 0.07.

SUMMARY

Both options M and P while proving beneficial overall, negatively affect properties located downstream. Without alternative compensatory measures (which are unlikely given the local topography) the mitigation options cannot be implemented.

The following measures are not recommended for improving the flooding situation:

► **Option M – Lower Overland Flow Path between Kensington Oval and Bowling Club from Barker Street to Edward Avenue –** While Option M is beneficial overall, it cannot be implemented without some compensatory measures due to the negatively affected properties downstream.

► **OPTION P – Lower Mooramie Avenue Reserve –** Despite reducing the number of properties flooded above floor level by 6 in the 1% AEP, the feasibility is unlikely due to the constraint of lowering the culvert. Consequently, substantial associated costs result in a B/C ratio of <0.1.

6.6. Review of Levees

DESCRIPTION

Levees are raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a defined design height. Levees usually take the form of earth embankments but can also be constructed concrete walls where there is limited space or other constraints (Photograph 7). Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

Photograph 7: Example of Levees a) Earth Embankment b) Concrete Wall

Localised levees or bunding can be applied around individual properties. This is considered as minor property adjustments in Section 7.5.

DISCUSSION

Whilst there are some levees in urban areas in Sydney they are very difficult to retro fit to solve an existing flood problem. The main issues are loss of visual and access amenity, the need to obtain an easement, maintenance and resolution of local drainage issues.

SUMMARY

Large levees are not applicable in the Kensington – Centennial Park study area.

6.7. On-Site Stormwater Detention (OSD)

DESCRIPTION

Retarding basins are typically used on large developments and as communal temporary floodplain storage. However, other means of on-site stormwater detention can be used for the same purpose on smaller individual lots. OSD does not necessarily mean surface water must be attenuated in a basin; on the smaller scale storage areas can include flooding above ground to shallow depths, such as parking areas, or garden features. Storage can also be provided in underground systems. Randwick City Council has a comprehensive OSD policy as do the majority of other Sydney councils. In some LGAs more discretion is allowed in the application of the policy depending upon the local circumstances.

DISCUSSION

Many councils have adopted OSD policies to require that runoff from new developments are restricted to the pre-development rates. As with retarding basins, peak flow rates need to be restricted for a range of design events, not just to the 1% AEP event (as is the case at Randwick).

OSD can be beneficial in areas where overland flow is the main source of flooding. Generally, OSD is not effective in areas of the floodplain which are subject to mainstream flooding although the benefits of one individual OSD system may be minor relative to the overall scale of flooding, the encouragement or requirement for OSD on all new development will manage the cumulative impacts of increased runoff over time.

Maintenance of OSD is important to ensure it continues to function as intended. As OSD infrastructure tends to be on private property and falls under the responsibility of the property owner to maintain, there is a risk of lack of maintenance. Therefore Council should maintain a register of all OSD features within the LGA and undertake regular inspections to ensure they maintain full function over time. This notation of OSD features on a development could be provided on S149 (5) certificates to prospective owners.

OSD as a means of reducing existing flood levels is not viable because of the amount of storage that would be required. At best OSD can ensure that new development will not increase peak flows.

Whilst it is recognised that some form of OSD is required to reduce peak flood flows from new development, Council should take into account the limited developable area in Kensington and therefore measures other than detention basins may be more effective. Consequently, where appropriate, OSD should be enforced by Council, however, some flexibility should be allowed where future developments can demonstrate alternative, potentially more effective, compensatory measures. These would need to be agreed upon by Council.

SUMMARY

Where it is appropriate, providing OSD on new developments should be encouraged and can have beneficial effects in preventing exacerbation of urban flooding in the future as a result of intensification of development. However, a pragmatic approach should be taken as OSD is not applicable to all sites and alternative drainage solutions may provide greater benefits. To aid development applicants Council should provide advice on appropriate OSD and the long term maintenance requirements.

RECOMMENDATIONS

The following measures are recommended:

- ► **OSD –** Review and ensure the OSD policy is in accordance with best practice.
- ► **OSD –** Council to develop a register of all OSD features within the LGA and undertake regular inspections.
- ► **OSD –** Notation of OSD requirements and existing features on S149 (5) certificates.
- ► **OSD –** Council should ensure stormwater runoff is appropriately considered, commensurate to the size and scale of development, in all development applications.
- ► **OSD –** Council should consider how the maintenance and inspection of OSD systems can be improved upon.

6.8. Catchment Treatment and Water Sensitive Urban Design (WSUD)

DESCRIPTION

Catchment treatment is similar to OSD in that it modifies the runoff characteristics of the catchment to reduce flows and improve water quality. For an urban catchment, this involves the use of Water Sensitive Urban Design (WSUD). Appropriately designed WSUD seeks to minimise the impacts of development on the natural water cycle through technologies to reduce potable water consumption, reduce pollution from stormwater ending up in local waterways and increasing runoff. It does this through the use of rainwater tanks, gross pollutant traps (GPTs), OSD and on-site water reuse, landscaped swales and infiltration systems. These measures can reduce the volumes and peak flow of storm water runoff in relatively small, frequent events, typically up to the 20% AEP events but they have less effect in larger, less frequent events.

DISCUSSION

By increasing the permeable surface area such schemes can reduce runoff and may be suitable in mitigating areas of localised flooding. By enforcing simple policies such as standard treatment within public space, such as kerbside catchment treatment, and limiting the imperviousness of proposed developments, unless accompanied by offset works, Council can reduce flood volumes and hence reduce flooding. Requirements can also be made of new larger scale developments that some form of WSUD is included. However, the effects of small scale catchment treatment and WSUD features in terms of their reduction in flood levels are impossible to accurately quantify through hydraulic modelling and depend on a range of factors such as permeability of soil, antecedent conditions, intensity of rainfall, size of the garden etc. WSUD features can have significant water quality benefits by allowing settlement of sediments carried by the runoff. Vegetated areas also act as a filter to water, removing various particulates.

The use of WSUD in the Kensington – Centennial Park catchment is unlikely to have wide scale benefits in reducing peak flood levels in large flood events, however during smaller flood events, and from localised intense rainfall events, there will be localised flood management benefits as well as water quality benefits.

The use of WSUD is encouraged through Council's DCP (see Section 4.1.3).

SUMMARY

As a general concept, catchment treatment techniques and WSUD should be encouraged. Examples include: limiting on-site imperviousness for developments and controls on land use. Water quality and other environmental controls should also be encouraged as these approaches provide significant benefits to local drainage and overland surface water flooding.

RECOMMENDATIONS

The following measures are recommended:

► **WSUD –** Encourage the use of WSUD features in all new developments but particularly for large developments where a significant environmental gain can be achieved. This can be implemented through planning controls.

7. PROPERTY MODIFICATION MEASURES

Property modification measures refer to modifications to existing structures and/or development controls on property and community infrastructure for future development. Flood modification measures which apply at the individual property scale have also been included in this section.

7.1. National Construction Code

New performance requirements for buildings in flood hazard areas were introduced in the National Construction Code (NCC) in 2013 with *The Australian Building Codes Boards Construction of Buildings in Flood Hazard Areas* and the accompanying Handbook (Reference 22 and Reference 23). This Standard contains requirements to ensure new buildings and structures, located in flood hazard areas do not collapse during a flood when subjected to flood actions and includes consideration of appropriate construction, use of appropriate materials, electrical, plumbing and drainage installation as well as setting floor levels. It applies to residential buildings (Classes 1, 2, 3 and 4) and health care buildings (Classes 9a and 9c). The Standard is not intended to override any land use planning controls imposed by Council or the appropriate authority.

7.2. House Raising

DESCRIPTION

House raising is a means to eliminate or significantly reduce flooding of habitable floors by raising the habitable floor level of the dwelling above a given flood level. An existing house is simply raised above the ground and supported by piers; usually brick or steel and sometimes a non-habitable room, such as a garage, can be created beneath.

DISCUSSION

The main benefit of house raising is in eliminating or reducing frequency of above floor flooding and consequently reducing flood damages. Floor levels are usually raised above a chosen design flood level, for example the 1% AEP flood level, dependent on a number of factors such as the ability to raise the house and building height requirements. The occurrence of a flood larger than the design flood may mean that above floor flooding still occurs. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency. House raising is not recommended in areas of high hazard or in floodways where other measures such as voluntary purchase would be considered preferable to remove the population from high hazard areas.

The type of construction of a house can make raising an unfeasible option and house raising is not suitable for all building types, being more suitable for non-brick single storey buildings. Raising a brick property can be structurally difficult and also incur significantly higher costs than a timber property. For timber properties house raising can be in the order of $ 80,000 when taking into account the full project costs including cost of raising, design costs, fees and relating plumbing and electrics.

As the majority of buildings in the study area are of brick construction this measure is not viable.

For new developments, floor level requirements (see Section 4.1.4) will negate the need for future raising or properties.

SUMMARY

House raising is not considered to be the most cost effective measure in the Kensington - Centennial Park study area and no houses have been identified for raising. Flood proofing is more appropriate and cost effective for flooding at shallow depths where the house construction is brick. Most of the flood affected buildings are of brick construction and therefore impractical to raise.

The following is not suggested for improving the flooding situation:
► **House Raising –** No buildings have been identified as suitable for house raising.

7.3. Voluntary Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of flood affected properties, in particular those subject to high hazard flows and/or located within defined floodways. Once purchased, the residence is demolished to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain; the temporary floodplain storage volume and waterway area.

DISCUSSION

Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high hazard flooding to an existing property and it is more appropriate to cease occupation to meet the risk management objectives. It is often a measure that is used as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Management Program (Reference 24) as long as a number of complying criteria are met. Voluntary purchase areas are not classified under any specific land use in the Standard Instrument LEP. However, Council can consider creating Voluntary Purchase Zones through their DCP or requiring that voluntary purchase zones apply to all flood prone areas also identified as being high hazard floodway.

Although measures such as flood proofing or raising could reduce flood damages for these properties during smaller events, the high flood hazard means that conditions are unsafe for people and they would still need to be evacuated before the onset of flooding. Voluntary purchase of the properties would allow the areas to be given over to public open space and more importantly, would be the only way of reducing flood risk and hazard for those residents by encouraging them to move to a less flood hazardous area. The purchased properties should be demolished and the land rezoned as appropriate use such as Environmental Conservation or similar in the LEP so that no development may take place. The land can also be defined as floodway in Council's DCP.

Estimating the value of property at $2,500,000 (median house price for Randwick from realestate.com.au in June 2018, Kensington is $2,700,000) and given the high density of housing in the Kensington – Centennial Park area, voluntary purchase is unlikely to be feasible. Furthermore the inclusion of purchase fees, legal costs and demolition costs means that the economic viability of the option is highly improbable.

SUMMARY

Voluntary purchase is not considered to be the most cost effective option for the type of flooding occurring in the Kensington – Centennial Park area and no houses have been identified for voluntary purchase. Flood proofing, discussed in Section 7.4, is more appropriate and cost effective for flooding at shallow depths.

The following are not suggested for improving the flooding situation:

► **Voluntary Purchase –** No properties have been identified as suitable for voluntary purchase.

7.4. Flood Proofing of Buildings

DESCRIPTION

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times by the choice of materials which are resistant to flood water and facilitate draining and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, temporary flood barrier methods can also be achieved by the use of sandbags in conjunction with plastic sheeting or private flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding (Photograph 8).

For existing residential and non residential buildings the use of temporary flood barrier methods to reduce flood damages is supported. However, due to the very infrequent nature of flooding it is likely that a flood will occur and for some reason the barrier will not be installed. Thus this method should not be relied upon unless there is some rigorous installation approach undertaken. For example, the barrier shown in Photograph 8 is installed every night at lock up time on the commercial premises. It is unlikely that relying on some form of flood warning before installation will ensure success.

Photograph 8: Flood Barrier at Front Door of Residential Property

DISCUSSION

Retro fitting permanent flood proofing measures can be difficult and permanent flood proofing is best achieved during construction. Temporary flood proofing can be achieved during flooding although relies on someone to implement flood barriers or similar and therefore effective flood warning times and the time of flooding can affect their efficiency.

Fitting non-return valves on plumbing can be useful to prevent back up of sewerage systems. During a flood event, sandbagging in bathrooms and toilets is beneficial, as although water may be prevented from entering the dwelling through doors and windows, backing up through the plumbing could still occur.

Whilst it is a requirement of the *Floodplain Development Manual* (Reference 1) that new residential properties have their floor levels above the 1% AEP event plus a suitable freeboard, commercial properties are not subject to such requirements unless stipulated by Council. New commercial buildings can be required to be flood proofed to a nominated level when constructed, which would include consideration of suitable materials, electrical and other services installation and efficient sealing of any possible entrances for water. Council would make these requirements through the DCP and various planning controls. Council's current Flood Policy (see Section 4.1.4) requires that finished floor levels for commercial development is no less than the 1% AEP flood plus 0.5 m freeboard. No comment is made with regard to industrial development. This is considered reasonable, however, for new commercial development raised floor levels can cause issues with access for customers or goods supply. Some councils allow commercial / industrial development to have lower floor levels subject to flood proofing measures to the FPL. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing to be used, and for temporary flood gate options to also be included in building design for low person risk, non-habitable developments.

SUMMARY

Flood proofing is a good solution to reducing flood risk to commercial and industrial properties and should be encouraged for all new developments of this type, particularly if floors are allowed to be lower than the FPL. Consideration of appropriate construction materials is still needed for those residential developments where floor levels will be raised above the 1% AEP flood level but the structure can still become inundated below the floor level.

Temporary flood proofing techniques may be deployed for existing buildings that are inundated, although lack of warning time may limit their efficiency and they should be considered as a secondary option to more permanent measures being implemented.

RECOMMENDATIONS

The following measure is recommended:

► **Flood Proofing –** Include requirements for flood proofing, wet or dry as appropriate, in development controls. This approach should be the minimum flood related requirement for non-habitable buildings such as commercial or industrial developments where existing or proposed floor levels are below the FPL. However Council cannot undertake flood proofing measures on individual properties. The funding and application of any flood proofing measures is up to the individual owner and has therefore not been included in the Plan.

7.5. Minor Property Adjustments

DESCRIPTION

In overland flow areas, minor property adjustments can be made to manage overland flow passing through private property. Such adjustments can include low level bunding (small levees) or drainage channels around individual properties, amendments to fences or construction of fences which act as deflector levees, modifying gardens and ground levels etc. all of which can affect the local continuity of overland flow paths.

DISCUSSION

Property adjustments can be used to manage overland flows through private property and minimise impacts on dwellings by helping to divert local overland flows away from dwellings and access points. However, if not designed well, adjustments on one property may impact on adjoining properties, or require modifications on neighbouring properties to be effective.

Therefore any works in flood prone areas which could modify the localised flood behaviour should be shown to have no significant impact on adjoining properties and be subject to approval from Council.

SUMMARY

Minor property adjustments can have localised benefits however they should be assessed for their impact on neighbouring properties. At properties within a floodway or subject to above floor flooding, minor property adjustments may not always be sufficient and other management measures may need consideration, such as pipe upgrades.

RECOMMENDATIONS
The following measure is recommended:
► **Minor property adjustments –**- are supported but no individual location has been identified.

7.6. Protecting Key Infrastructure

DESCRIPTION
It is important to protect key infrastructure from flooding which could cause failure of systems such as electricity, telecommunication or sewerage supply. Protection can be by relocation to areas outside of the PMF flood extents, or where this is not possible, ensuring that the operation will not be flood affected through incorporation of minor property modifications or flood proofing.

DISCUSSION
For future development, Council's current policy for flood prone land (see Section 4.1.4) recognises that some development types are more vulnerable to flooding than others. The Policy recognises that certain types of development have a post disaster function or specific evacuation needs during a flood event, such as schools, hospitals, nursing homes, retirement villages, aged care facilities, SES headquarters, evacuation centres, major utility facilities and emergency response facilities. These types of facilities need to consider safety issues for all floods up to an including the PMF and flood related development controls apply even if land is above the 1% AEP flood level plus 0.5 m, where it is below the PMF. This is considered to be a suitable policy.

SUMMARY
Council's flood policy requires higher floor level and protection for more vulnerable developments which are needed to function during flooding. This is considered to be an appropriate development control as there are large flood free areas within the catchment in which this more vulnerable type of development could be located. Consideration may want to be given to all utility facilities (sewerage and electricity).

RECOMMENDATIONS
The following measure is recommended:
► **Protecting key infrastructure –** is supported but no individual location has been identified.

7.7. Flood Insurance

DESCRIPTION
Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments.

DISCUSSION
It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance

companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

SUMMARY

Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this Kensington - Centennial Park Flood Study and Risk Management Study and Plan. This planning must include consideration of the future risk from climate change.

RECOMMENDATIONS

The following measure is recommended:

► **Flood Insurance –**is supported but is up to the land owner to consider and implement and has not been included in the Plan.

8. RESPONSE MODIFICATION MEASURES

Flood response measures encompass various means of modifying the response of the population to the flood threat.

8.1. Flood Emergency Management

DESCRIPTION

Planning for emergency response can reduce losses due to flooding. Emergency response for flooding is detailed in the Local Flood Plan (LFP). LFPs are subordinate plans of the Emergency Management Plan (EMPLAN) which describes emergencies and the responsible combat and support agencies. The SES is the lead combat agency for flooding in NSW and responsible for coordinating evacuation in a flood event. The LFP is prepared and used by the NSW SES and describes the risk to the community, outlines roles and responsibilities for the SES plus supporting agencies and describes how the SES will manage flood events.

DISCUSSION

The LFP usually sets out responsibilities of various response agencies, details how evacuation should occur, those access points which may become impassable, and locations for emergency evacuation centres. The preparation of a LFP aids to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, location of resources and roles and responsibilities. It is the role of the SES to develop a LFP for vulnerable communities and, at present, the NSW SES has no specific LFP for the Kensington – Centennial Park catchment area.

Council can, in conjunction with the NSW SES, prepare Local FloodSafe Guides which can be made available to the public in community centres and online. The FloodSafe Guides inform the public of how to prepare for and act during a flood or severe weather event. Information is available to the public on the SES's StormSafe.com.au and FloodSafe.com.au websites.

Although flood warning is limited and the number of properties requiring evacuation is also small, a local disaster plan or LFP should be continually updated to include the latest information on design flood levels and details on roads, properties, and other facilities which would be flood affected. The LFP is based on data from hydraulic modelling and should be updated to include hazard mapping and emergency response classifications (see Section 2.5) for a range of design events. The hydraulic modelling for the Kensington – Centennial Park catchment, as per Appendix B of this FRMS&P, should be used.

SUMMARY

Despite the reduced flood warning time available, planning for response during a flood event can still be highly beneficial. Council should ensure there is appropriate disaster planning for the Kensington – Centennial Park catchment area either in the form of Council's own local disaster plan for an NSW SES prepared LFP. This should also take into account those properties not directly flood affected but which may have had access cut and become flood islands. This plan should be regularly kept up to date and should include feedback from recent flood events and the recommendations of this FRMS&P once adopted.

RECOMMENDATIONS

The following measures are recommended:

► **Flood Emergency Management –** Council should prepare local disaster plan using information provided in this FRMS and from the NSW SES.

AND/OR

► **Flood Emergency Management –** The SES should prepare a Local Flood Plan for the Kensington - Centennial Park catchment.

8.2. Flood Warning and Evacuation Planning

DESCRIPTION

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Severe weather warnings and thunderstorm warnings are provided by the BoM and are issued when severe weather or thunderstorms are expected. The warning may also note the hazards associated with the storm including damaging wind gusts, large hail and flash flooding. The BoM will also, for some areas, issue a flood watch covering a particular river basin or catchment. This can be upgraded to a flood warning when flooding is expected to occur or is happening.

Evacuation warnings are issued by the SES and advise that people should prepare for the instance that an Evacuation Order may be issued. Evacuation Orders require that all people evacuate the area and may be issued through door knock, radio, automated telephone and/or other forms of media (SMS etc.). Once the risk has subsided an All Clear is issued.

DISCUSSION

Flood warning can significantly reduce damages and risk to life and studies have shown that flood warning systems generally have a high B/C ratio if sufficient warning time is provided. Adequate warning can give residents time to move goods and cars above the reach of floodwaters, raise house contents onto tables and worktops and evacuate from the area. However, flood warning time in the Kensington – Centennial Park catchment is low due to the nature of the overland flow flooding which can occur very quickly, within 2 hours.

The success of any flood warning system and the evacuation process in reducing flood losses and damages depends on;

- *Flood Awareness*: How aware is the community of the flood threat? Has it been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the residents to evacuate

households to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

Due to the fast onset of overland flooding that characterises the Kensington – Centennial Park catchment, residents would be likely to have noticed rising flood waters before evacuation warnings are issued. To aid the SES emergency response, residents can be made aware through community awareness schemes how to act on BoM weather warnings prior to SES evacuation orders. Many Councils prepare a Local FloodSafe brochure in collaboration with the SES to advise residents in this regard.

The November 1984 event resulted in residents requiring assistance from the SES.

SUMMARY

Due to the nature of flooding in the study area, flood warnings are limited in effectiveness. It should be noted that there are few areas where a full scale evacuation would be necessary during most flood events. Severe weather warnings should be used as a caution to potential onset of flooding. These are available through BoM and could also be made available on Council's website.

RECOMMENDATIONS

The following measures are recommended:

► **Flood Warning –** Severe Weather Warnings and Thunderstorm Warnings should be provided on Council's website and in local media.

► **Flood Warning –** Council can produce a Local FloodSafe brochure in collaboration with the SES.

8.3. Flood Access

DESCRIPTION

Evacuation can be improved by ensuring adequate evacuation routes and appropriate warning as to when the routes will become impassable. For example, roads could be raised or low spots eliminated to ensure routes are not blocked. In addition, emergency services could be exposed to lower hazards in carrying out their duties.

DISCUSSION

Due to the nature of flooding in the Kensington – Centennial Park catchment, local change to ground levels such as raising roads could have significant implications in terms of flooding for local properties. Consequently, major raising of road levels is not advised.

Instead other measures should be investigated such as improving drainage to reduce flood levels (see Section 6). The hydraulic modelling undertaken for assessment of potential flood management options has shown that this would be a more appropriate solution.

SUMMARY

Raising existing roads within the Kensington – Centennial Park catchment should be done with caution and an assessment of appropriate compensatory drainage should be made.

The following are not suggested for improving the flooding situation:
► **Flood Access –** No access improvements have been identified.

8.4. Community Awareness / Preparedness Programme

DESCRIPTION

Public information and the level of public awareness and preparedness is key in reducing flood damages and losses. A more aware and prepared community is likely to be more prepared and will suffer less losses and damage than an unprepared community. Raising community awareness and preparedness can be achieved through a number of means such as leafleting, local posters, media releases, Council and SES attendance at community events.

DISCUSSION

The level of flood awareness / preparedness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including frequency and impact of previous floods, history of residence, and whether an effective community awareness / preparedness program has been implemented. Generally community awareness / preparedness will decline as the time since the last flood increases and a difficulty with flood awareness / preparedness campaigns is often convincing residents that major floods will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. Community awareness / preparedness can be raised as a result of community flood or climate change awareness programs. A community with high flood awareness / preparedness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation.

Following a flood event it is important to collect available information but to also let the community know that Council is aware of the problems and are managing it. On-going post flood data collection by Council in conjunction with the SES should occur after every flood event to enable improved understanding of the flooding situation and ensure data is always the most recent to allow better decision making for flood management.

It is generally considered that the benefits of community awareness / preparedness far outweigh the costs. Costs can be low if awareness / preparedness media is issued with regular Council media such as newsletters or local community leaflets.

Table 18 provides examples of possible further methods to raise community flood awareness / preparedness that may be developed and supported by Council.

Table 18: Community Flood Awareness / Preparedness Methods

Method	Comment
Letter/pamphlet from Council	Sending with information already being sent to residents, such as rate notices, would reduce costs. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of on-going implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council's website already provides good information on the flood management within their LGA. Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Groups	Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council. The current FMC includes representatives from Council, OEH, and local residents (see Section 1.6.2).
School project or local historical society	This provides a means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	On-going articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of data from future floods	Collection of data (including photographs and recorded flood levels) assists in reinforcing to the residents that Council is aware of the problem. Collected data can also be used to update hydrologic and hydraulic model calibration and ensures that the design flood levels are as accurate as possible.
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the S149 certificate during the purchase process. Council has a policy on providing flooding advice (see Section 4.1.4). Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period. Some Councils have conducted briefing sessions with real estate agents and conveyancers.
Establishment of a flood effects database and post flood data collection program	A database would provide information on a number of issues such as which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event and updated with input from the community.
Flood preparedness	Providing information to the community regarding flooding helps to

Method	Comment
program	inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The NSW SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as blockage of drains or such like. This process can be linked to water quality or other water related issues. The specific approach can only be developed in consultation with the community.

SUMMARY

Although this flood risk management process had raised community awareness/ preparedness through its community consultation program, continuingly ensuring community awareness / preparedness of flood risks is important in reducing overall damages and losses. Therefore Council should undertake regular community awareness / preparedness program to ensure that there is continuous flood awareness / preparedness.

Flood insurance and flood proofing have not been included as individual measures in the Plan as their application is up to the individual property owners. However any community awareness program should highlight these measures as a means of addressing the flood problem.

The specific flood awareness / preparedness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

RECOMMENDATIONS

The following measures are recommended:

► **Community awareness –** Undertake regular community awareness and preparedness campaigns. Set Council policy to ensure a new campaign is undertaken on a regular basis, for example every two years.

9. PLANNING AND DEVELOPMENT CONTROL MEASURES

9.1. Land Use Zoning

DESCRIPTION

Defining appropriate land uses in flood prone areas can prevent inappropriate development from occurring and thus reduce flood risk. Land uses zones are governed by the LEP. To make any significant changes to land use zones within the LEP a planning proposal usually has to be submitted to the Department of Planning and Infrastructure and subject to some public consultation.

DISCUSSION

The current land uses for the Kensington – Centennial Park area are presented in Figure 2. The developed nature of the catchment means that significant land use changes are unlikely. Nevertheless it is worth ensuring that flood affected area that are currently recreational are not rezoned as residential and similarly that low residential areas are not rezoned as medium/high density residential.

SUMMARY

Appropriate land use planning can assist in reducing future flood risk and ensuring development in flooded areas is flood compatible.

RECOMMENDATIONS

The following measures are recommended:

► **Land use zoning –** Reconsider the planned revisions to the LEP land use zones to reduce future areas of residential development from the floodplain.

9.2. Flood Planning Area and Property Tagging

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied and a FPA map is a required outcome of the FRMS&P. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. As suggested by the Floodplain Development Manual (Reference 1), the FPA is typically based on the flood extent formed by the 1% AEP mainstream flooding event plus freeboard (0.5 m). Therefore planning controls may be applied to development which is not necessarily within the 1% AEP flood extent but is in the FPA. The purpose of extending the FPA past the 1% AEP flood extents is to allow for any future increases in flood extents due to climate change as well as an allowance for differences between flood behaviour during events due to wave action or other effects.

The LEP permits a Flood Planning Area map to be included as a layer imposed across all land zones.

DISCUSSION

While the 1% AEP + 0.5 m criteria is appropriate for areas of mainstream flooding (rivers and other watercourses), it is not always appropriate for areas subject to flooding from overland flows. Much of the study area is overland flooding for which depths are characteristically lower than mainstream flooding and do not tend to scale much for rarer events. Whilst the open channel upstream of Gardeners Road is a watercourse all the study area has been heavily urbanised with kerb and guttering and a sub surface pipe network.

In light of this, and through discussions with Council, the following approach has been adopted for defining the FPA (and property tagging) in areas subject to overland flow:

- All flood depths less than 0.15 m are discounted as "rainfall drainage" - it is considered too unsubstantial to be called flooding, given the relatively shallow depth.
- Whilst the open channel upstream of Gardeners Road is a watercourse, for consistency and ease of application of Council's policies all the study area has been described as "major overland flow" and not "mainstream" flooding. As flood liability is due to major overland flows and not mainstream flooding, only those lots which are impacted by substantial floodwaters (for example more than 10% of the lot) are selected for inclusion in the FPA.

The above process is undertaken by comparing Council’s cadastre with the peak flood levels, depths and extents of the 1% AEP design event.

To ensure that the cadastral lots tagged by this method are reasonable a ground truthing exercise was undertaken. Engineers from WMAwater spent several days in the Kensington area reviewing the computer generated outputs and manually making amendments where necessary. For example, where all lots on one street were identified as flood prone except one, a review was undertaken on that property, looking at the hydraulic model outputs, ALS and survey data and on site to assess if it should be included.

The final FPA and tagged cadastral lots has been submitted to Council in a separate report.

Flood tagging of a property is generally perceived as a negative by the property owner but will ensure the following:

- In the next large flood a newly built house will not be inundated in the 1% AEP event;
- Neighbouring houses will have to ensure that there is no increase in flood level on surrounding properties;
- By identifying flood liable lands Council and the State Government can implement appropriate management measures.

SUMMARY

Defining the FPA is crucial as the FPA is a key concept referred to in Council’s LEP. It is important to define a FPA to efficiently apply flood related development controls to only the relevant areas of the Kensington – Centennial Park catchment area. The 1% AEP flood level plus 0.5 m freeboard is not considered appropriate for the Kensington area as flooding is mainly overland flows. Instead an alternative method has been developed and properties tagged as flood prone have been verified through on site inspection.

RECOMMENDATIONS
The following measure is recommended:
► **Flood Tagging of properties –** of properties based on 10% of the lot flooded to depths more than 150 mm criteria in the 1% AEP. A separate report has been issued to Council.

9.3. Flood Planning Levels

DESCRIPTION
The *Construction of Buildings in Flood Hazard Areas Standard* (Reference 22) states that, unless otherwise specified by the appropriate authority (e.g Council), the finished floor level of all habitable rooms must be above the Flood Hazard Level[2] and the finished floor level of enclosed non-habitable rooms must be no more than 1 m below the Defined Flood Level[3].

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual, 2005 (Reference 1) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.

The Floodplain Development Manual (Reference 1) states that in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard, typically 0.5 m. According to the Floodplain Development Manual (Reference 1) the purpose of the freeboard is to provide reasonable certainty, that the reduced flood risk exposure provided by selection of a particular flood, as the basis of a FPL, is actually provided given the following factors;

- Uncertainties in estimates of flood levels;
- Differences in water level because of local factors;
- Climate change (rainfall intensity increase);
- Increases due to wave action; and
- The cumulative effect of subsequent infill development on existing zoned land.

Typically the FPL is used to define the minimum level at which habitable floor levels should be constructed but can also be used to define requirements for flood proofing and site access.

DISCUSSION
In determining a suitable FPL, the FMC and Council must balance the cost to the community by restricting development in flood prone areas with the benefits of the reduction in damages,

[2] The Standard defines the Flood Hazard Level (FHL) as "*the flood level to be used to determine the height of floors in a building and represent the defined flood level (DFL) plus the freeboard*".
[3] The DFL is defined in the Standard as "*the flood level associated with the defined flood event*". Therefore the FHL is effectively the same as the FPL.

frequency and danger to life caused by flooding. The FPL can be varied depending on the use, and the vulnerability of the building/development to flooding. For example, residential development could be considered more vulnerable whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Developments more vulnerable to flooding such as critical facilities including hospitals, schools, electricity sub-stations, senior's housing etc., should consider rarer events than the 1% AEP when determining their FPL or be situated outside of the floodplain where possible. For the less vulnerable commercial and industrial developments, flood proofing a building can be considered where raising floor levels is not an option or is not feasible, but should not be allowed for residential developments or other vulnerable uses.

Council's current floor level requirements in the Comprehensive DCP (Reference 18) are provided in Table 19.

Table 19: Current Floor Level Requirements (taken from Reference 18)

Scenario	Floor level
Habitable Floors - all development (excluding critical facilities)	
Inundated by flooding	1% AEP + 0.5m freeboard
Inundated by overland flow path	Two times the depth of flow in the 1% AEP flood with a minimum of 0.3m above the surrounding surface
Habitable floors - Critical facilities	
Inundated by flooding	PMF + 0.5m freeboard
Inundated by overland flow path	Two times the depth of flow in the PMF with a minimum of 0.3m above the surrounding surface
Non-habitable floors – residential outbuildings (excluding garages) *	
Gross floor area less than or equal to 10 square metres.	1% AEP but not less than 0.15m above surrounding ground level
Gross floor area greater than 10 square meters.	The applicable habitable floor level
Non-habitable floors – Industrial and commercial	
Located on flooding or overland flow path	1% AEP but not less than 0.15m above surrounding ground level
Material storage locations – all development	
Materials sensitive to flood damage, or which may cause pollution or be potentially hazardous during flooding	1% AEP + 0.5m freeboard

Table 19 requires that critical facilities have floor levels above the PMF flood level plus freeboard. Seeing as the PMF is the largest flood that can conceivably occur, adding such a freeboard can be considered an unnecessary restriction to development. Where possible such critical facilities should be located outside of both the FPA and the PMF extents (whichever is greater). Where this is not possible, floors and access should be raised above the greater of the PMF or the 1% AEP plus 0.5 m level.

For non-habitable commercial and industrial uses floor levels could be subject to a lower level conditional to flood proofing to the FPL. As well as suitable materials and construction, this includes locating unsealed electrical circuits at least above the designated FPL for the area to reduce risk of electrocution (see Section 7.4).

It is appropriate to use a reduced freeboard for areas subject to overland flow flooding rather than mainstream flooding as depths tend to be shallower. However, rather than identify a variable freeboard dependent on depths as the current DCP does, a fixed freeboard is recommended. For areas of overland flow a reduced freeboard of 0.3 m may be appropriate. A single freeboard with reference to a flood level has benefit over a variable freeboard based on depth as it is less subjective to define. In all locations subject to flooding a minimum height of floor level above ground is also recommended if lower than the 1% AEP flood level plus freeboard.

SUMMARY

The FPL is the 1% AEP flood level plus a given freeboard (either 0.5m or the depth of inundation for overland flow areas). It should be used to set finished floor levels requirements for residential development. Less vulnerable uses such as commercial developments could be subject to lower floor level requirements but it is recommended that they should be subject to flood proofing to the FPL where floor levels are lower.

Anthropomorphic induced climate changes have the potential to increase design rainfall intensities and consequently design flood levels and the associated flood related planning controls. This issue has been examined and quantified in Section 3.5. At this time (2016) the potential rainfall increase has not been incorporated into Council's flood related planning controls for the following reasons:

- there is insufficient firm advice from expert authorities (CSIRO, BoM, Institute of Engineers etc) regarding the likely rainfall increase;
- Council has adopted a freeboard of 0.5m for residential floors which is considered conservative for the largely shallow depth overland flow flooding in the catchment (it can be argued that the freeboard should not exceed the depth of inundation in the design event). Freeboard includes some allowance for climate change;
- this study has quantified a range of design rainfall intensity increases (Section 3.5) and for approximately 80% of the 37 locations considered (Table 10) the increase in depth of inundation for a 10% rainfall increase is 0.2m or less and thus equates to less than 50% of the freeboard allowance.

RECOMMENDATIONS

The following measures are recommended:

- ► **Flood Planning Levels –** Make consistent requirements for floor levels between Council's DCP and the Flood Policy.
- ► **Flood Planning Levels –** Continually monitor best practice advice regarding anthropomorphic induced rainfall increases. At a minimum every 2 years Council should provide a statement outlining the status of the best practice advice and whether Council's adopted design rainfall, flood levels and associated flood related planning controls should be adjusted as a result.
- ► **Flood Planning Levels –** The Flood Planning Level (FPL) is adopted as:
  - ⏩ Areas subject to overland flow flooding: 1 % AEP flood level plus the depth of inundation as freeboard;
  - ⏩ Areas subject to mainstream flooding: 1% AEP flood level plus 0.5 m freeboard.
- ► **Flood Planning Levels –** Variable requirements for floor levels dependent on type of flooding and development use (recommendations are given in Table 19).
- ► **Flood Planning Levels –** For commercial or industrial developments where finished floor levels are not set at the FPL (1% AEP plus freeboard), flood proofing measures will be required to the FPL.
- ► **Flood Planning Levels –** Most vulnerable developments such as hospitals, schools, services including power supplies should be encouraged to be located outside of the PMF or FPA extents or at the very least have floors and/or essential machinery above the FPL or PMF level, whichever is higher.

9.4. Modification to S149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. A certificate issued under Section149(2) provides information about the zoning of the property, the relevant state, regional and local planning controls and other property affectations such as land contamination and road widening. A certificate issued under Sections 149(2) and 149(5) provides both the information available in a Section 149(2) certificate and additional information such as advice from other authorities, subdivision history and easements where Council has information available. While the certificate will state all the relevant planning instruments that apply to the property, it does not provide specific development standards or terms of the instruments.

Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. Under Part 2, it is compulsory for Council to advise if they are aware of flood risk or of any other known risks such as bush fire, land slip etc., while Part 5 provides additional details and may not be made known to the purchaser unless it is specifically requested.

DISCUSSION

Council's Flooding Advice and Flood Related Development Controls Policy (see Section 4.1.4) provides details on the provision of flood information on both S149(2) and S149(5) certificates. Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). It should be noted that the Section 149 certificate only relates to the subject land and not any specific building on the property.

The following flood risk information should be included in Part(2) of the S149 certificate:

- Whether or not the property is in a FPA;
- Any development control due to siting of the property in the FPA;
- Responsibility for maintenance and compliance for OSD features; and
- Highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in Part(5) of the S149 certificate as standard practice. This ensures that residents are fully made aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in Part(5) could include:

- Flood levels / depths at the property;
- Percentage of property flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

SUMMARY

Data from the hydraulic modelling used in this FRMS&P should be incorporated into Council's S149 certificates. As Council information for S149 Certificates is currently obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site. As a result of this FRMS&P a database of flood prone properties has been prepared in a GIS format, linked to Council's own cadastre dataset.

RECOMMENDATIONS

The following measures are recommended:

► **S149 Certificates –** Update and re-issue S149 certificates based in this FRMS&P.

► **S149 Certificates –** Allow residents to request flooding information for their property through Council's website.

10. ACKNOWLEDGMENTS

This study was carried out by WMAwater and funded by Randwick City Council and the NSW State Government through its Floodplain Management Program. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- The Kensington – Centennial Park Catchment Flood Management Committee;
- Residents of the Kensington – Centennial Park study area;
- Centennial Park and Moore Park Trust;
- Randwick City Council;
- State Emergency Services;
- NSW Office of Environment and Heritage.

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PART B Floodplain Risk Management Plan

FLOOD RISK MANAGEMENT MEASURES CONSIDERED

A matrix of possible management measures was prepared and evaluated in the Flood Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures including flood mitigation dams and voluntary purchase of all flood liable buildings which are clearly not viable.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method for using the time value of money to compare the reduction in flood damages (benefit) with the capital and on going cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was developed for the study area, allowing benefit/cost estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

The full range of measures was evaluated in Sections 5 to 9 and the outcomes are summarised in Table 20. Table 13 details the matrix scoring system and Table 15 provides a summary of results for the drainage upgrade options.

Community opinion on the full range of options has been canvassed during the public exhibition period in Section 1.6.5, however, it should be noted that these outcomes may change in the future and/or as an outcome of further more detailed investigation subsequent to this project.

► **OPTIONS A, B and C – Upgrade of Centennial Park Basins –** These measures have largely been implemented as part of the Light Rail works and have not been considered further in the Management Plan.

TABLE 20: Kensington - Centennial Park Floodplain Risk Management Plan

The flood mitigation and management measures set out below for the Kensington – Centennial Park Floodplain Risk Management Plan are assessed according to the criteria described in Table 13. These measures have been identified through the floodplain risk management process in accordance with the NSW Government Flood Prone Land Policy and the Floodplain Development Manual (2005).

	Report Ref	OPTION	COMMENT	B/C Ratio	Impact on Flood Behaviour	Number of Properties Benefitted	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental\ Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	TOTAL	RANK
Flood Modification	Section 7.2.6	**Option J - Blockage Protection**	Gardeners Road Culvert	19.0	3	3	3	2	1	2	0	0	0	-3	0	11	1
Flood Modification	Section 7.2.6	**Option I - Feasibility Study to Upgrade Main Culverts at Gardeners Road**	Benefit depends on size of culvert upgrade	0.2	3	3	-3	2	2	-3	0	0	0	3	1	8	2
Flood Modification	Section 7.2.6	**Option I - Feasibility Study to Upgrade Culverts at Aboud Avenue at Gardeners Road**	Benefit depends on size of culvert upgrade		3	2	-3	2	2	-3	0	0	0	3	1	7	3
Flood Modification	Section 7.2.3	**Option F - Drainage Upgrade**	Market Street to Centennial Park	0.6	1	2	0	0	1	0	0	0	0	2	0	6	4
Flood Modification	Section 7.2.7	**Option L - Drainage Upgrade**	Kensington Park to Gardeners Road	0.1	3	3	2	-3	-2	1	0	0	0	2	0	6	4
Flood Modification	Section 7.2.1	**Option D - Drainage Upgrade**	Dangar Lane to One More Shot Pond	<0.1	1	1	1	1	-1	0	0	0	0	2	0	5	6
Flood Modification	Section 7.1.3	**Option K - Randwick Racecourse Detention Basin**	Measure already informally in place - augmentation considered		1	1	1	1	-1	1	0	0	-2	3	0	5	6
Flood Modification	Section 7.2.2	**Option E - Drainage Upgrade**	Clovelly Road trunk drainage upgrade	<0.1	1	1	1	1	-2	0	0	0	0	2	0	4	8
Flood Modification	Section 7.2.4	**Option G - Drainage Upgrade**	Market Street to Darley Road	<0.1	1	1	1	1	-2	0	0	0	0	2	0	4	8
Flood Modification	Section 7.2.5	**Option H - Drainage Upgrade**	Goodrich Avenue to Shaw Avenue + Aboud Avenue to Gardeners Road	0.1	1	1	1	1	-2	0	0	0	0	2	0	4	8
Flood Modification	Section 7.2.8	**Option Q - Drainage Upgrade**	Koorinda Avenue	<0.1	1	1	1	0	-2	1	0	0	0	2	0	4	8
Flood Modification	Section 7.1.4	**Option N - Kensington Park Oval Detention Basin**	Requires excavation of present oval	1.2	1	1	-1	0	-1	0	0	1	-1	2	1	3	12
Flood Modification	Section 7.5.1	**Option M - Ground Level Modification**	Enhance overland flowpath between Kensington Park and Bowling Club		0	0	1	-2	-1	2	-1	0	0	3	0	2	13
Flood Modification	Section 7.5.2	**Option P - Ground Level Modification**	Lowering of Mooramie Avenue Reserve	<0.1	2	2	-3	-1	-3	-3	-1	0	0	3	0	-4	14
Property Modification	Section 7.3	**Review Maintenance of Drainage Infrastructure**	Optimises efficiency		1	3	1	3	1	3	0	0	3	0	0	15	2
Property Modification	Section 10.1	**Revision of Land Use Zones**	Ensures flood problem is not exacerbated		0	3	3	1	1	3	0	0	0	3	0	14	4

	Report Ref	OPTION	COMMENT	B/C Ratio	Impact on Flood Behaviour	Number of Properties Benefitted	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental\ Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	TOTAL	RANK
	Section 10.2	**Flood Tagging of Properties**	Ensures negative impact is not imposed on public/private property from new development		0	3	3	0	3	3	0	0	-1	3	0	14	4
	Section 10.3	**Flood Planning Levels**	Ensures flood problem is not exacerbated		0	3	3	1	1	3	0	0	0	3	0	14	4
	Section 10.4	**Modification to 149 Certificate**	Ensures most up to date information is readily available		0	0	0	3	3	3	0	0	0	3	0	12	7
	Section 7.7	**On Site Detention**	Mitigate effects of urbanisation		0	0	3	0	0	3	1	0	0	0	0	7	9
	Section 7.8	**Catchment Treatment and WSUD**	Modifies runoff quantity and quality		0	1	-1	1	-1	-1	3	0	0	0	0	2	10
Response Modification	Section 9.4	**Public Information and Flood Awareness / Preparedness Raising**	Council and SES to provide information to residents.		0	3	3	2	1	2	0	3	0	2	1	17	1
Response Modification	Section 9.2	**Flood Warning and Evacuation Planning**	Ensures maximum possible warning time is available to minimise damage and enable safe evacuation		0	0	0	3	2	3	0	3	0	3	1	15	2
Response Modification	Section 9.1	**Flood Emergency Management**	Can reduce losses in a flood		0	0	0	1	3	3	0	3	0	0	0	10	8

FLOOD RISK MANAGEMENT MEASURES IN PLAN

The Kensington – Centennial Park Floodplain Risk Management Plan summarises the outcomes from the Management Study as a series of measures which will assist in reducing flooding for existing and future developments. The mix of measures has been developed following consideration of the ranking developed in the management options matrix in the study (Table 20) as well as discussions with the Floodplain Management Committee and as a result of community consultation.

The recommended measures are described below (according to the ranking in Table 20). The priority rating (High, Medium, Low) is based upon a qualitative assessment of the rankings in Table 20 and the ease of implementation (availability of funds, responsibility). It should be noted that both Council and Sydney Water are responsible for the key drainage assets within the catchment. Upgrading of major drainage works may therefore require the participation of both organisations.

Further detail and insight into each measure is provided in the relevant section of the Kensington – Centennial Park Floodplain Risk Management Study.

The provision of benefit/cost ratios (i.e. the benefit in terms of reduction in flood damages compared to the cost of the works) cannot be adequately provided for all floodplain management measures because the benefit is often the reduction in intangible damages (risk to life, injury etc.) which cannot be assigned a monetary value.

The measures have been ranked and sub divided into structural and non structural measures.

STRUCTURAL HIGH Priority

1. **(Rank 1) Management of Blockage at Gardeners Road Culverts (Option J).**
   - **Cost:** $100,000
   - **Responsibility:** Council and Sydney Water
   - **Timeframe:** by the year 2020

STRUCTURAL HIGH Priority

1. **(Rank 2) Feasibility Study to Upgrade Main Culverts at Gardeners Road (Option I).**
   - **Cost:** $80,000
   - **Responsibility:** Council and Sydney Water
   - **Timeframe:** by the year 2020

2. **(Rank 3) Feasibility Study to Upgrade Culverts at Aboud Avenue at Gardeners Road (Option I).**
   - **Cost:** $40,000
   - **Responsibility:** Council and Sydney Water
   - **Timeframe:** by the year 2020

NON STRUCTURAL HIGH Priority

1. **(Rank 1) Public Information and Flood Awareness / Preparedness Raising.**
   - **Cost:** low will depend on approach
   - **Responsibility:** Council, SES
   - **Timeframe:** ongoing

2. **(Rank 2=) Review Maintenance of Drainage Infrastructure.**
   - **Cost:** low
   - **Responsibility:** Council, Sydney Water
   - **Timeframe:** 2019

3. **(Rank 2=) Flood Warning and Evacuation.**
   - **Cost:** low will depend upon approach
   - **Responsibility:** Council, SES
   - **Timeframe:** ongoing

4. **(Rank 4=) Revision of Land Use Zones.**
   - **Cost:** low
   - **Responsibility:** Council, State Government
   - **Timeframe:** ongoing

5. **(Rank 4=) Flood Tagging of Properties.**
   - **Cost:** low
   - **Responsibility:** Council
   - **Timeframe:** 2018

6. **(Rank 4=) Enforce Flood Planning Levels.**
   - **Cost:** low
   - **Responsibility:** Council
   - **Timeframe:** 2018

7. **(Rank 7) Modification to 149 Certificate.**
   - **Cost:** low
   - **Responsibility:** Council
   - **Timeframe:** 2018

8. **(Rank 8) Flood Emergency Management.**
   - **Cost:** low will depend upon approach
   - **Responsibility:** SES, Council
   - **Timeframe:** ongoing

NON STRUCTURAL MEDIUM Priority

1 **(Rank 9) Enforce On Site Detention policy.**
   a. **Cost:** low construction costs by property owner
   b. **Responsibility:** Council, property owner
   c. **Timeframe:** ongoing

2 **(Rank 10) Enforce Catchment Treatment and WSUD.**
   a. **Cost:** low
   b. **Responsibility:** Council and in places Sydney Water
   c. **Timeframe:** ongoing

The following structural measures were not considered viable enough (based on ranking) to be included in the Plan.

Options A, B & C - Upgrades to improve performance	Centennial Park basin
Option D - Drainage Upgrade	Dangar Lane to One More Shot Pond
Option E - Drainage Upgrade	Clovelly Road trunk drainage upgrade
Option F - Drainage Upgrade	Market Street to Centennial Park
Option G - Drainage Upgrade	Market Street to Darley Road
Option H - Drainage Upgrade	Goodrich Avenue to Shaw Avenue + Aboud Avenue to Gardeners Road
Option K - Randwick Racecourse Detention Basin	Measure already informally in place - augmentation considered
Option L - Drainage Upgrade	Kensington Park to Gardeners Road
Option M - Ground Level Modification	Enhance overland flowpath between Kensington Park and Bowling Club
Option N - Kensington Park Oval Detention Basin	Requires excavation of present oval
Option P - Ground Level Modification	Lowering of Mooramie Avenue Reserve
Option Q - Drainage Upgrade	Koorinda Avenue
Option R - Drainage Upgrade	Doncaster Avenue + Mooramie Avenue

Figures

FIGURE 1
STUDY AREA

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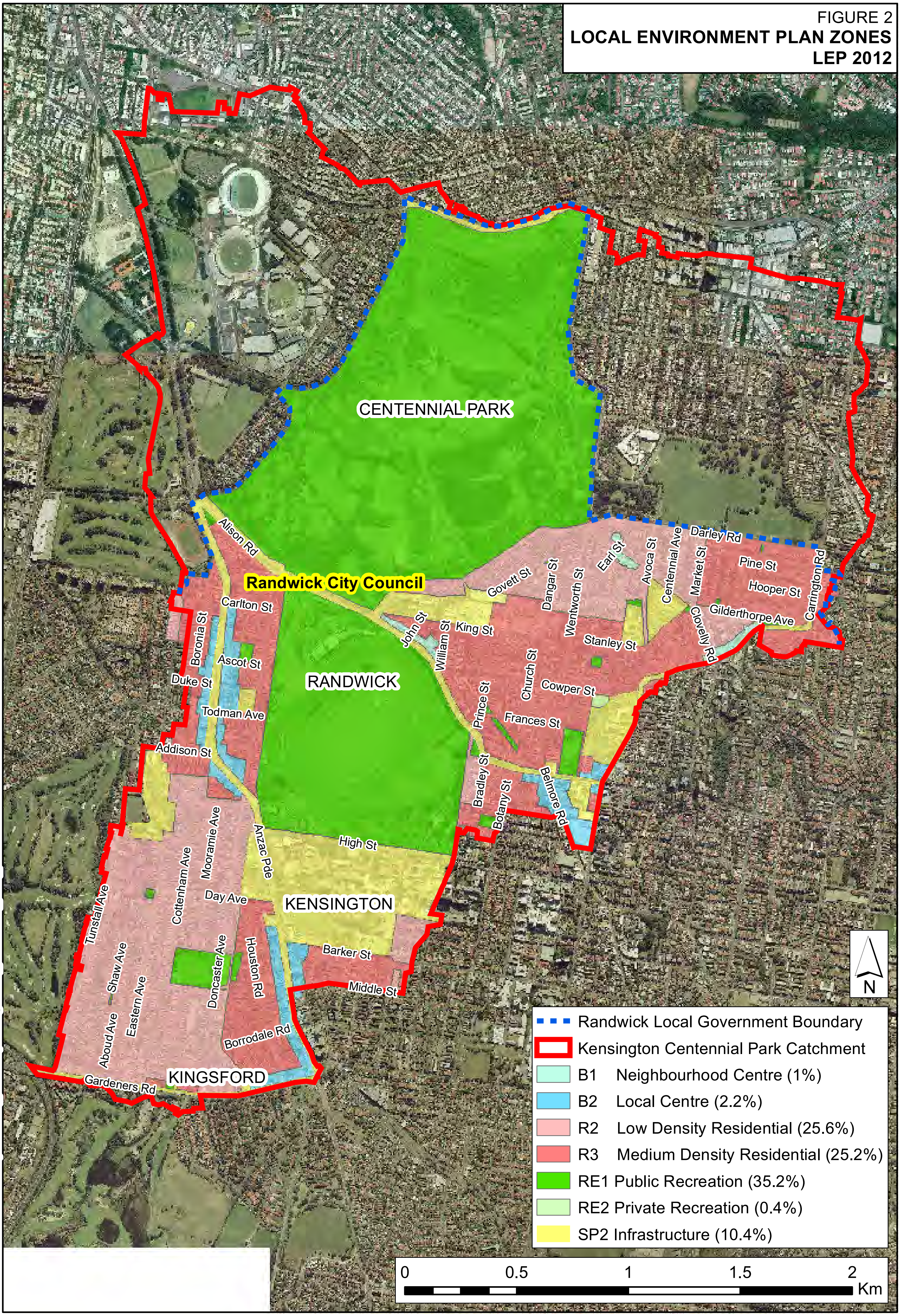
FIGURE 2
LOCAL ENVIRONMENT PLAN ZONES
LEP 2012



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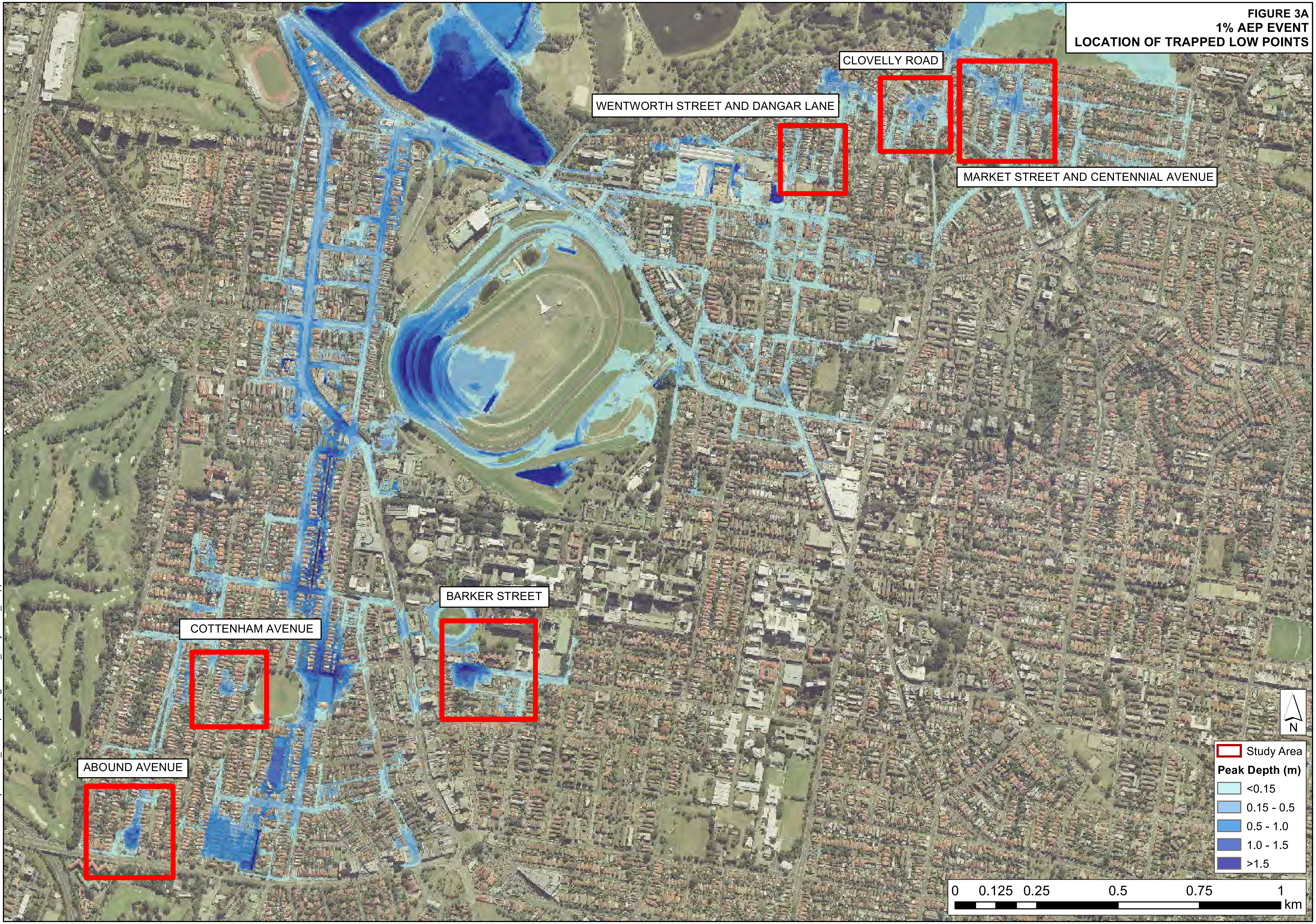

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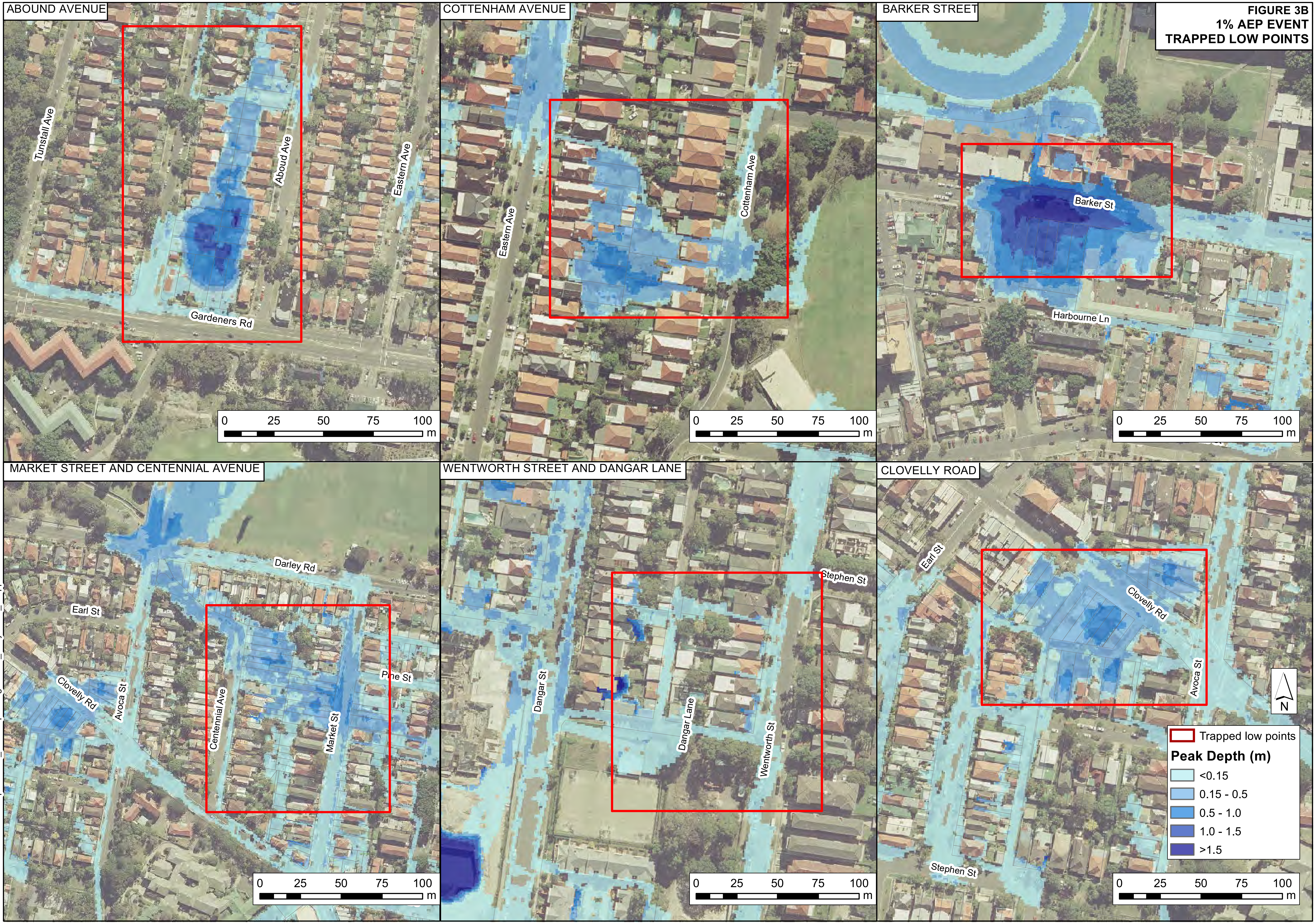

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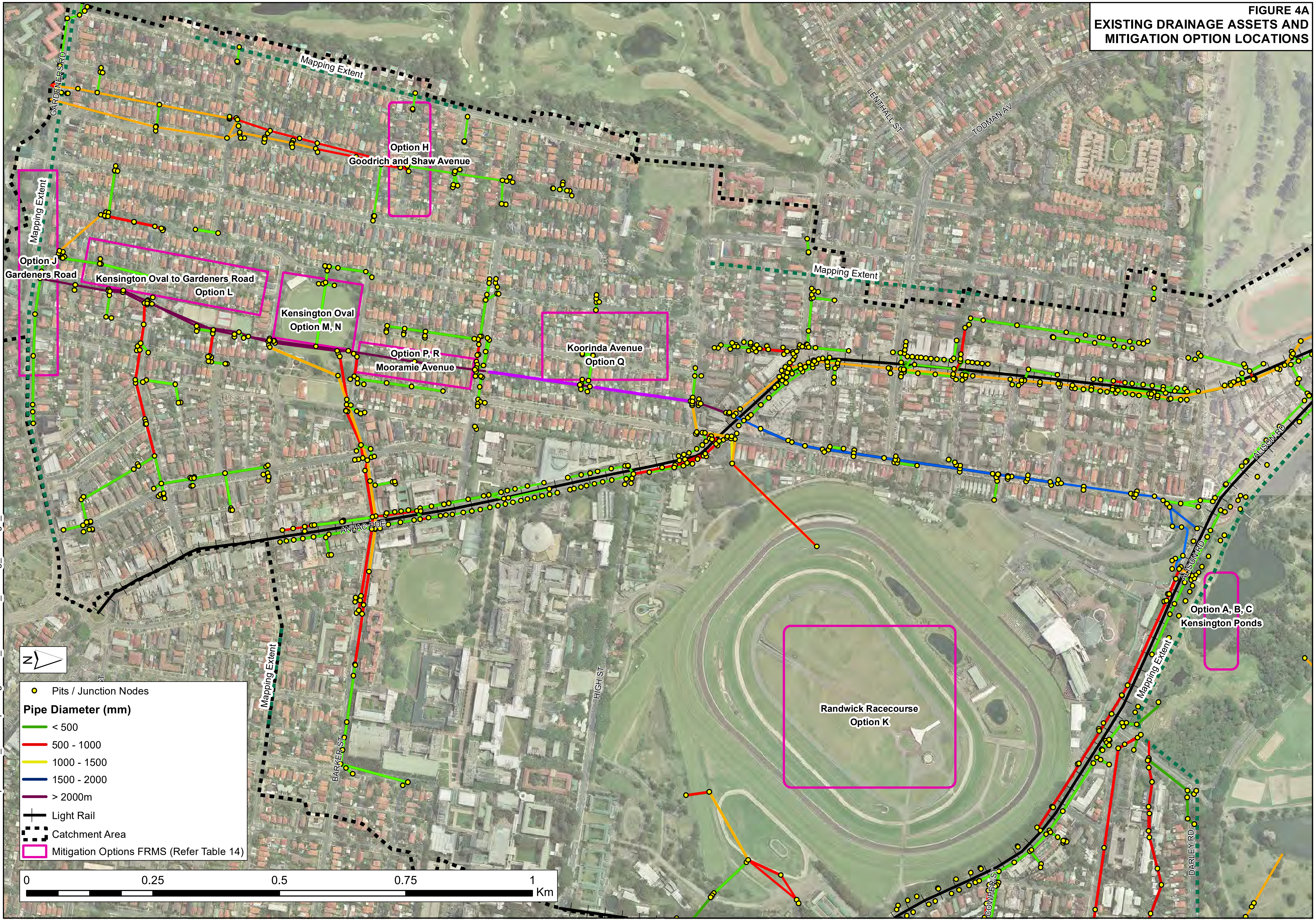

FIGURE 4A
EXISTING DRAINAGE ASSETS AND MITIGATION OPTION LOCATIONS

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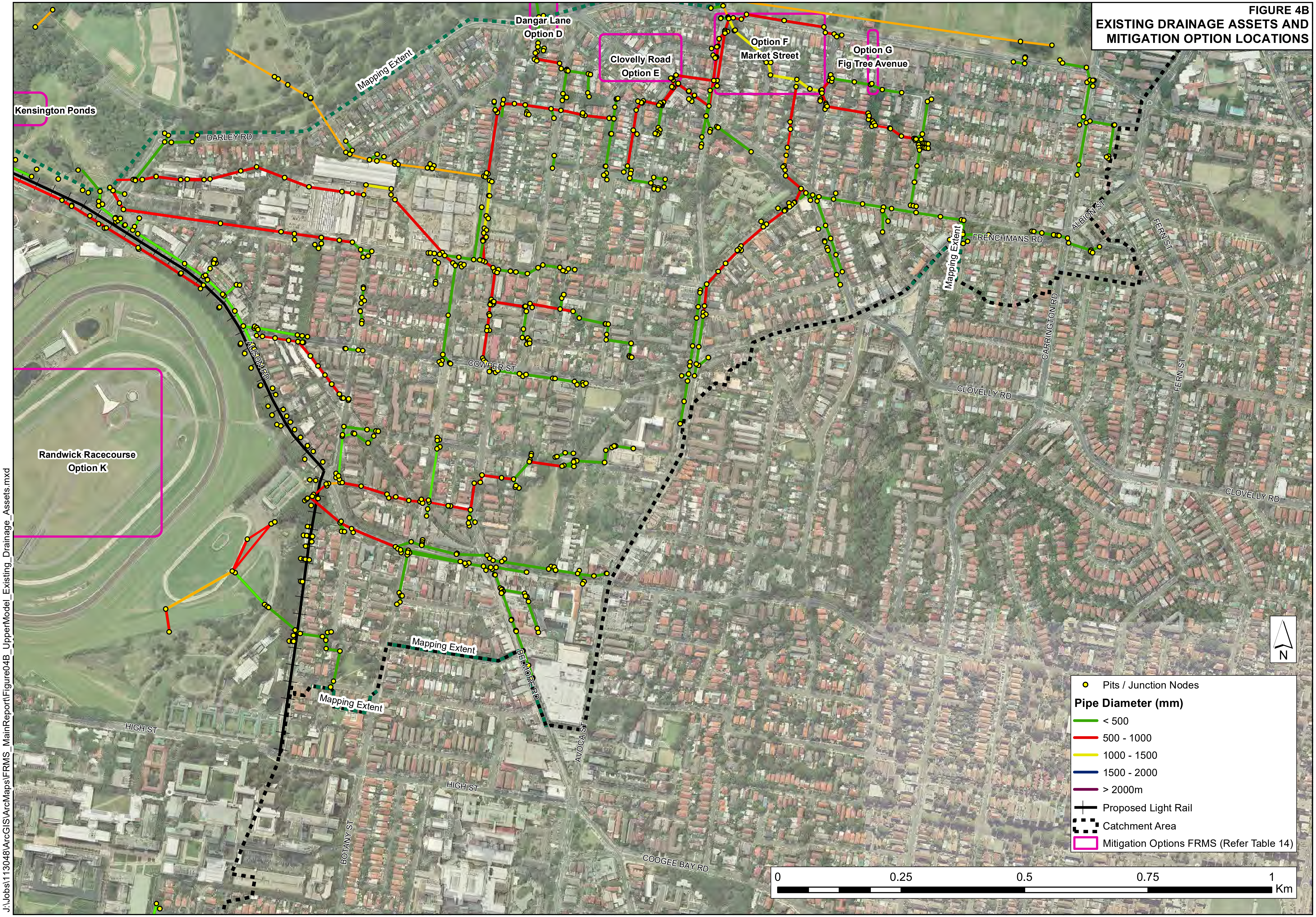

FIGURE 4B
EXISTING DRAINAGE ASSETS AND
MITIGATION OPTION LOCATIONS
Dangar Lane
Option D
Clovelly Road
Option E
Option F
Market Street
Option G
Fig Tree Avenue
Kensington Ponds
Randwick Racecourse
Option K
Mapping Extent
DARLEY RD
ALISON RD
COWPER ST
FRENCHMANS RD
ALBION ST
FERN ST
CARRINGTON RD
CLOVELLY RD
BELMORE RD
AVOCA ST
HIGH ST
BOTANY ST
COOGEE BAY RD
N
Pits / Junction Nodes
Pipe Diameter (mm)
< 500
500 - 1000
1000 - 1500
1500 - 2000
> 2000m
Proposed Light Rail
Catchment Area
Mitigation Options FRMS (Refer Table 14)
0
0.25
0.5
0.75
1
Km
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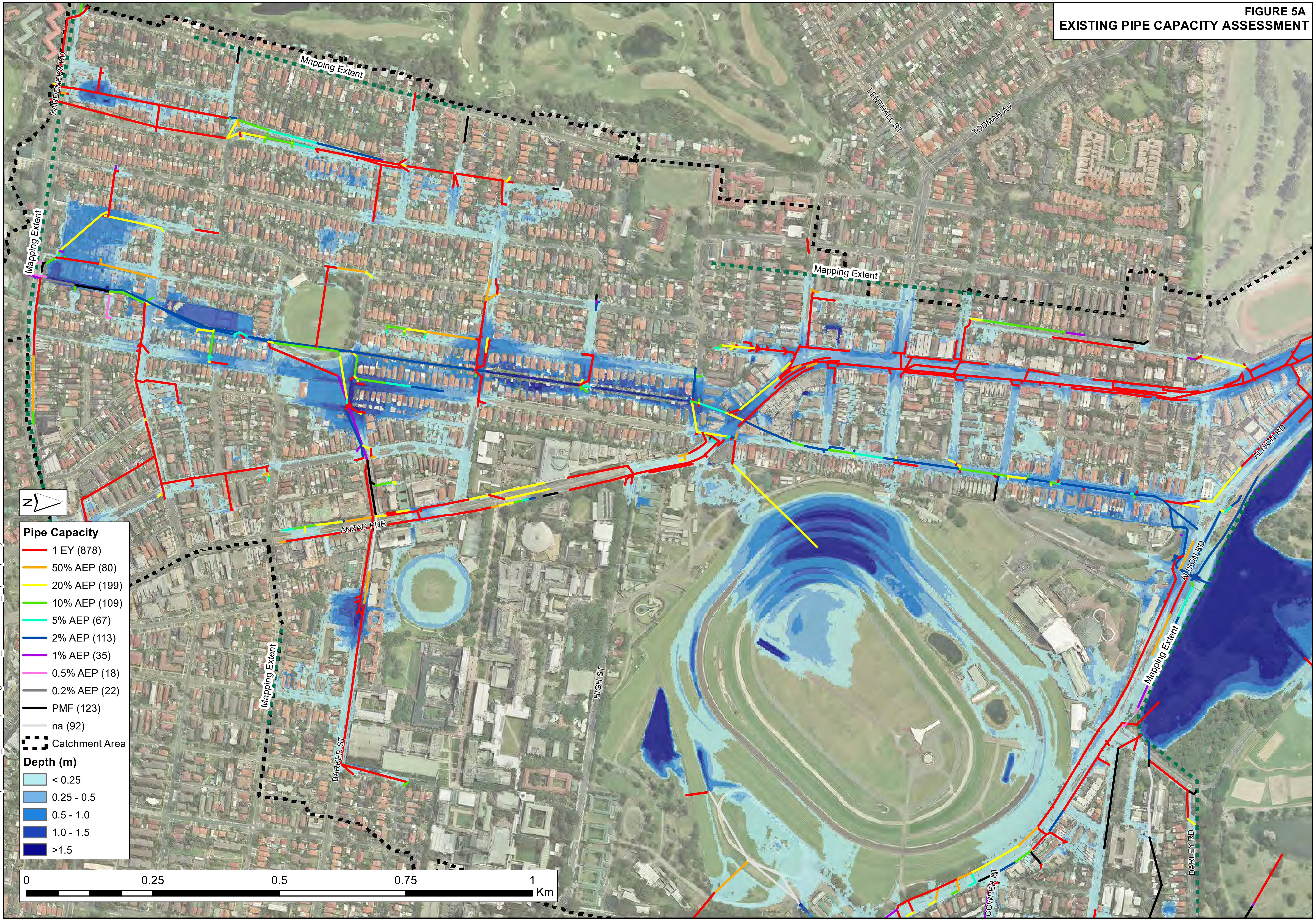
FIGURE 5A
EXISTING PIPE CAPACITY ASSESSMENT
Mapping Extent
GARDENERS RD
LENTHALL ST
TODMAN AV
ANZAC PDE
ALISON RD
BARKER ST
HIGH ST
COWPER ST
DARLEY RD
Pipe Capacity
1 EY (878)
50% AEP (80)
20% AEP (199)
10% AEP (109)
5% AEP (67)
2% AEP (113)
1% AEP (35)
0.5% AEP (18)
0.2% AEP (22)
PMF (123)
na (92)
Catchment Area
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
>1.5
0
0.25
0.5
0.75
1
Km
N
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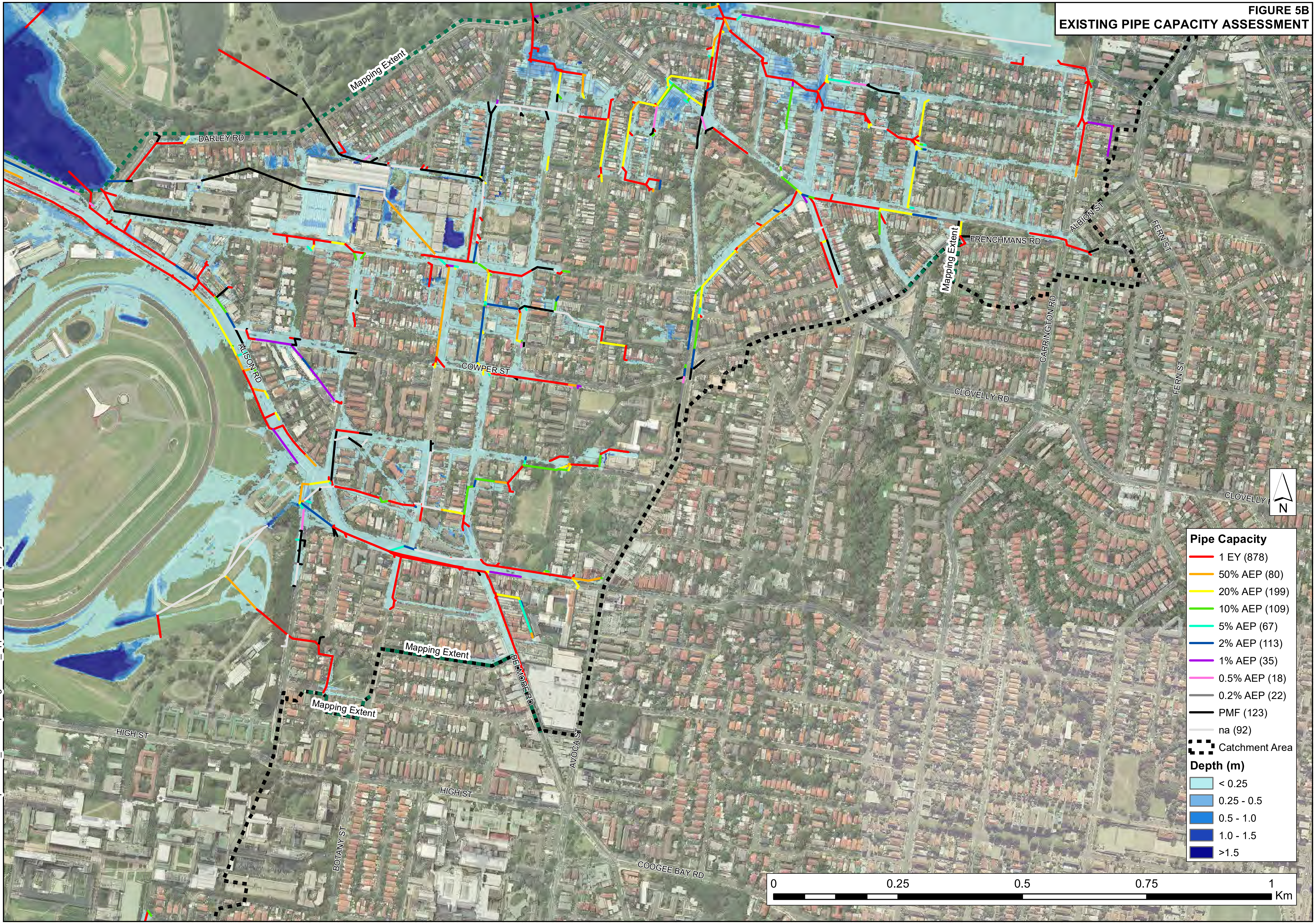

FIGURE 5B
EXISTING PIPE CAPACITY ASSESSMENT

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FIGURE 6A
HYDRAULIC CATEGORISATION BASED ON 1% AEP & PMF EVENTS

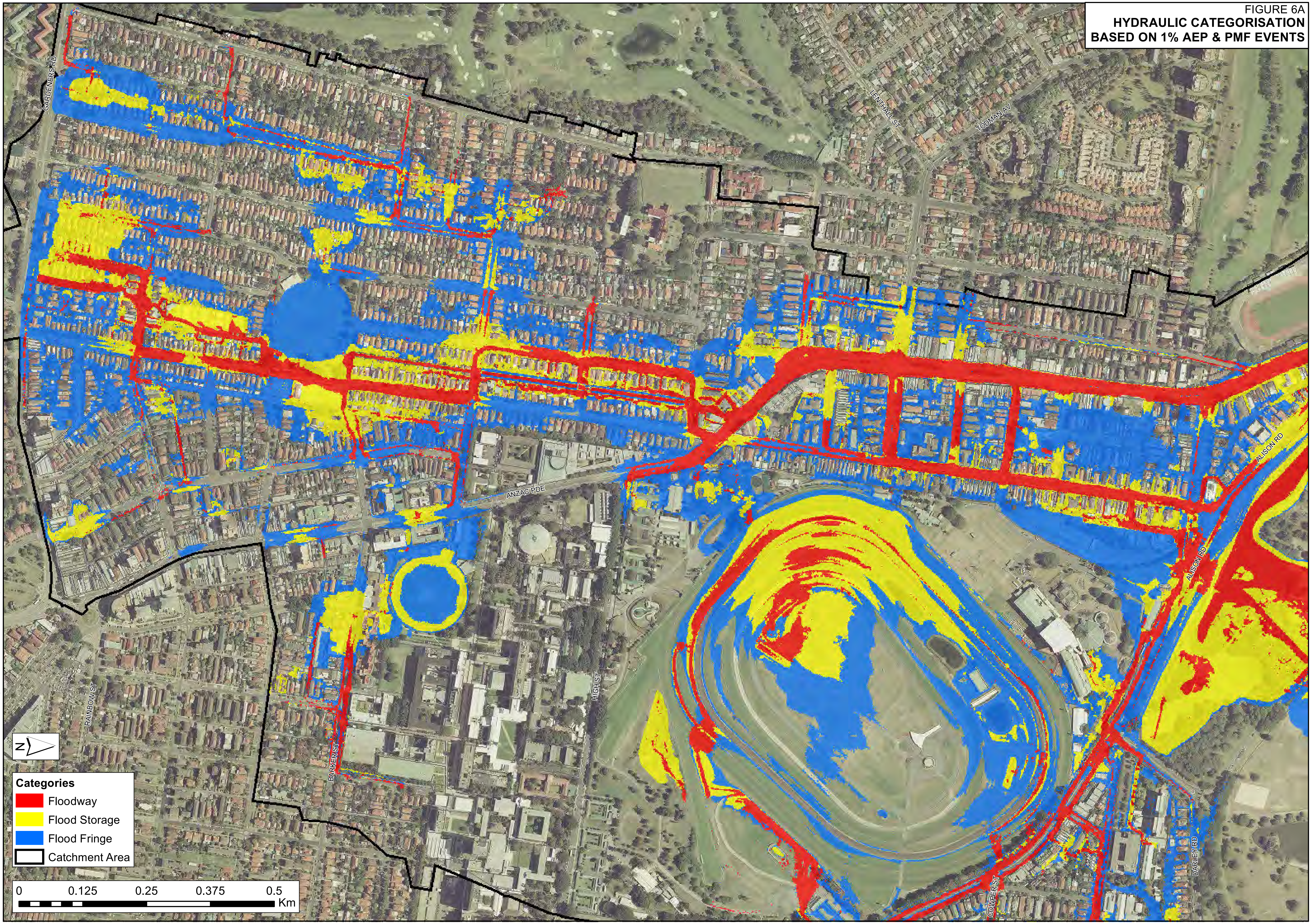

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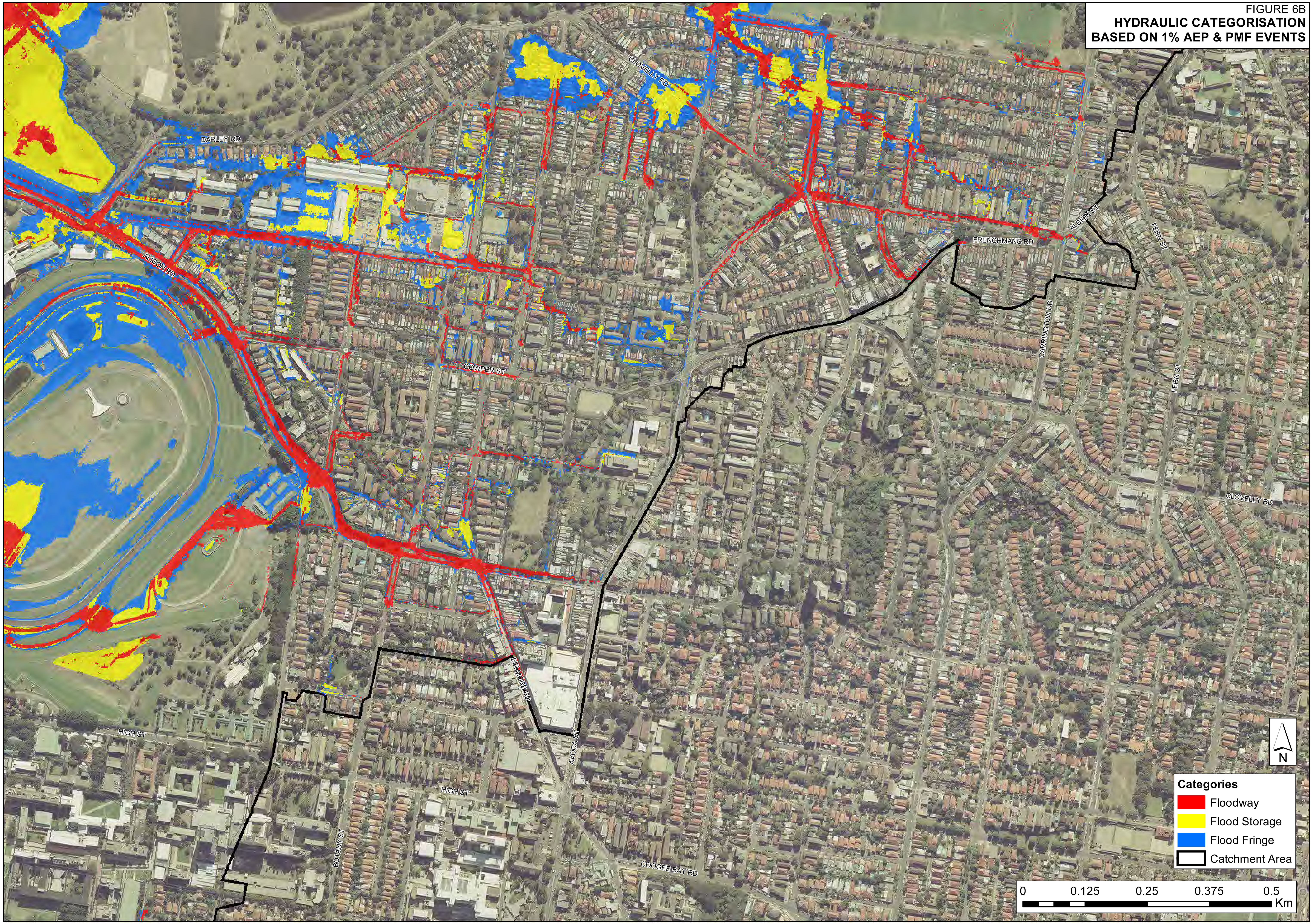
FIGURE 6B
HYDRAULIC CATEGORISATION BASED ON 1% AEP & PMF EVENTS



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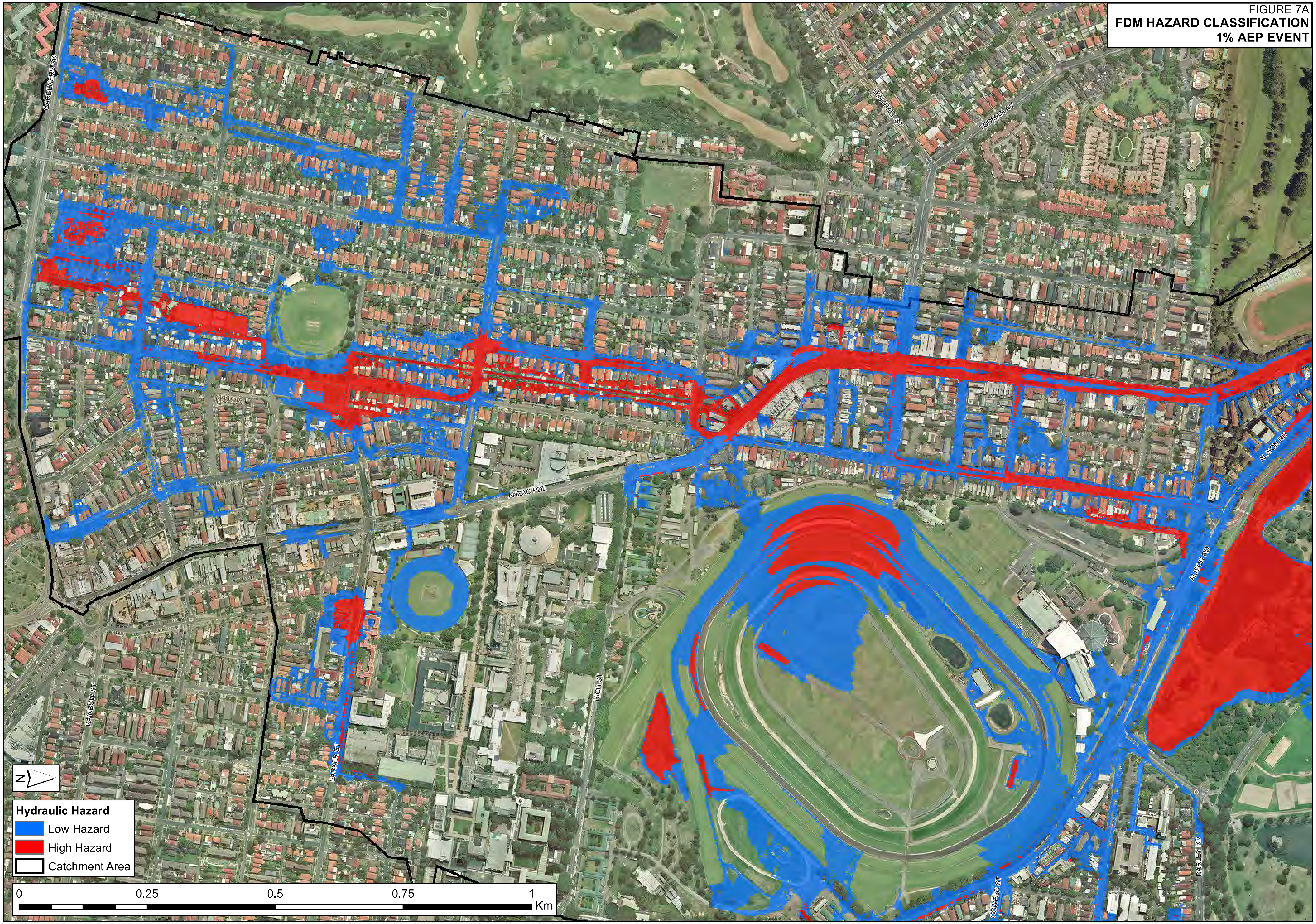

FIGURE 7A
FDM HAZARD CLASSIFICATION
1% AEP EVENT
GARDENERS RD
LENTHALL ST
TODMAN AV
ANZAC PDE
ALISON RD
HIGH ST
BARKER ST
COWPER ST
DARLEY RD
Hydraulic Hazard
Low Hazard
High Hazard
Catchment Area
0
0.25
0.5
0.75
1
Km
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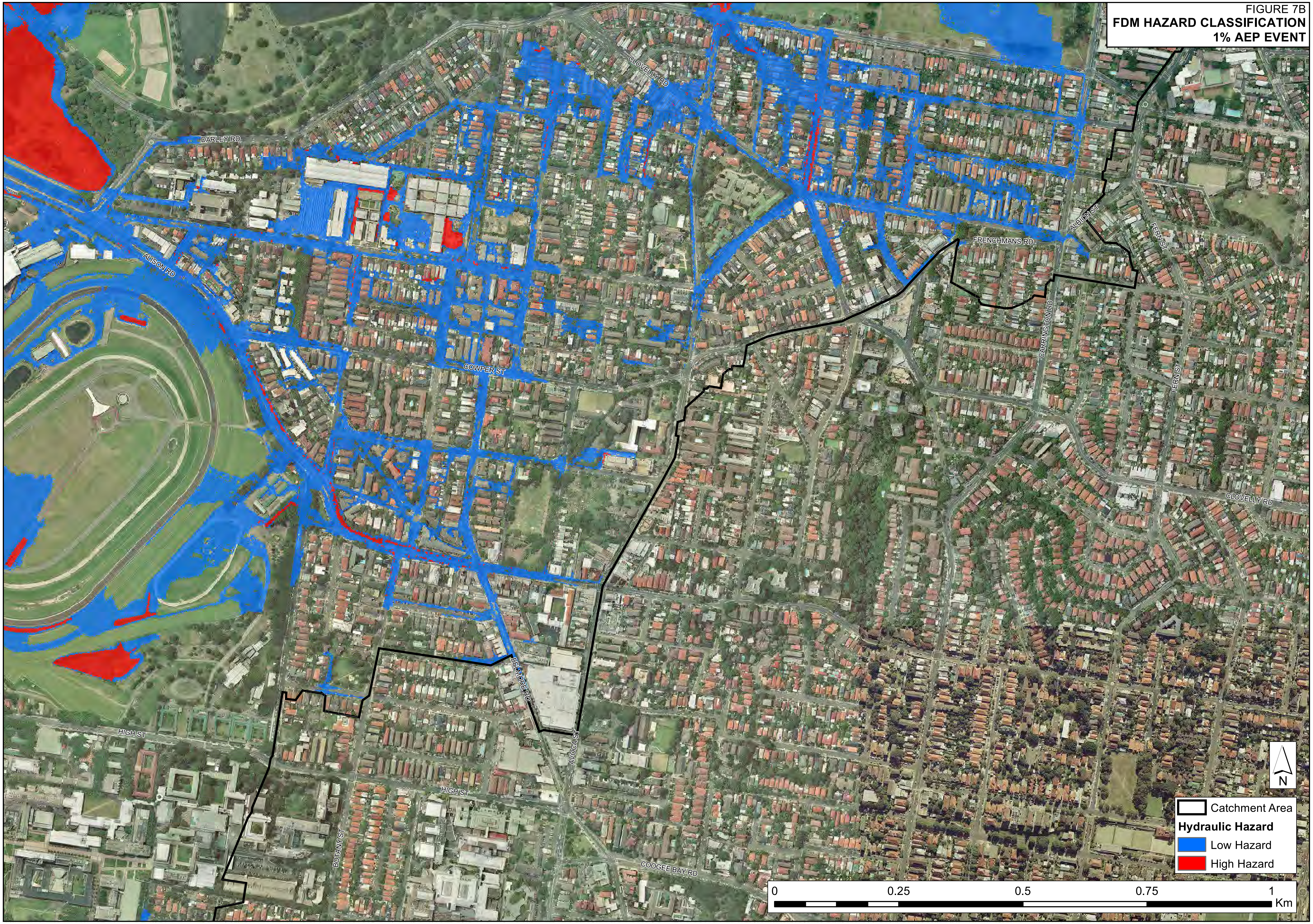
FIGURE 7B
FDM HAZARD CLASSIFICATION
1% AEP EVENT



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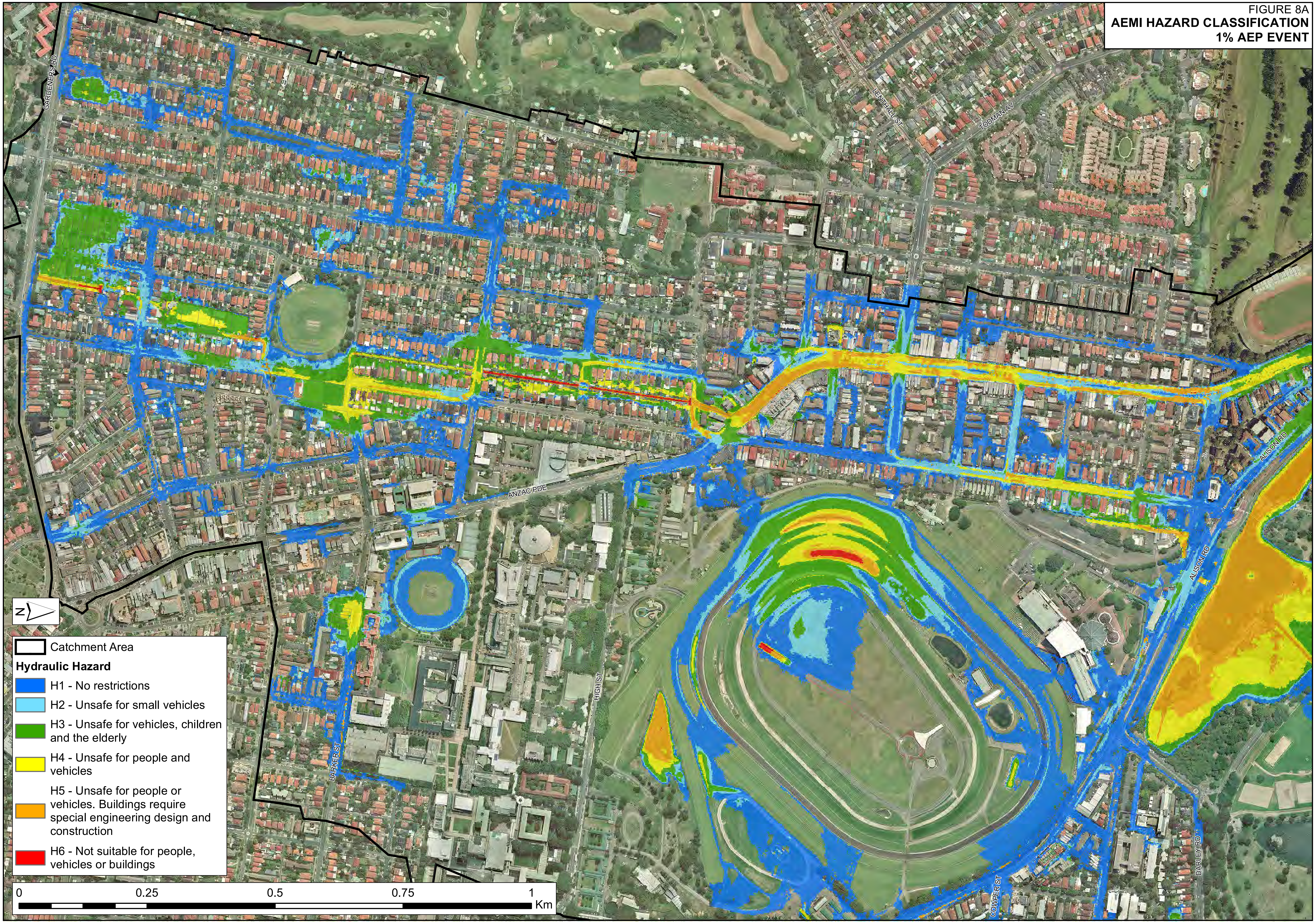

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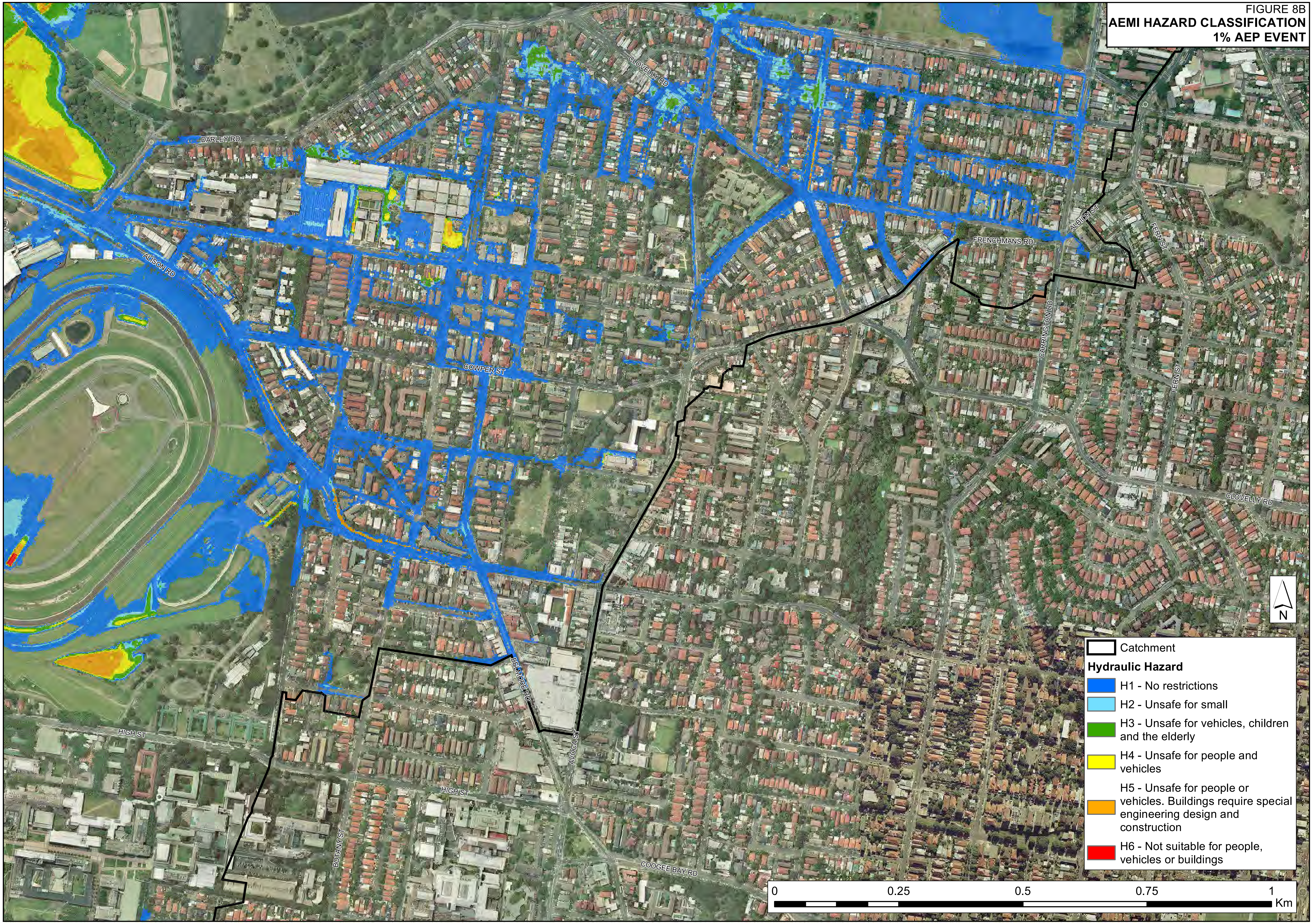

FIGURE 8B
AEMI HAZARD CLASSIFICATION
1% AEP EVENT

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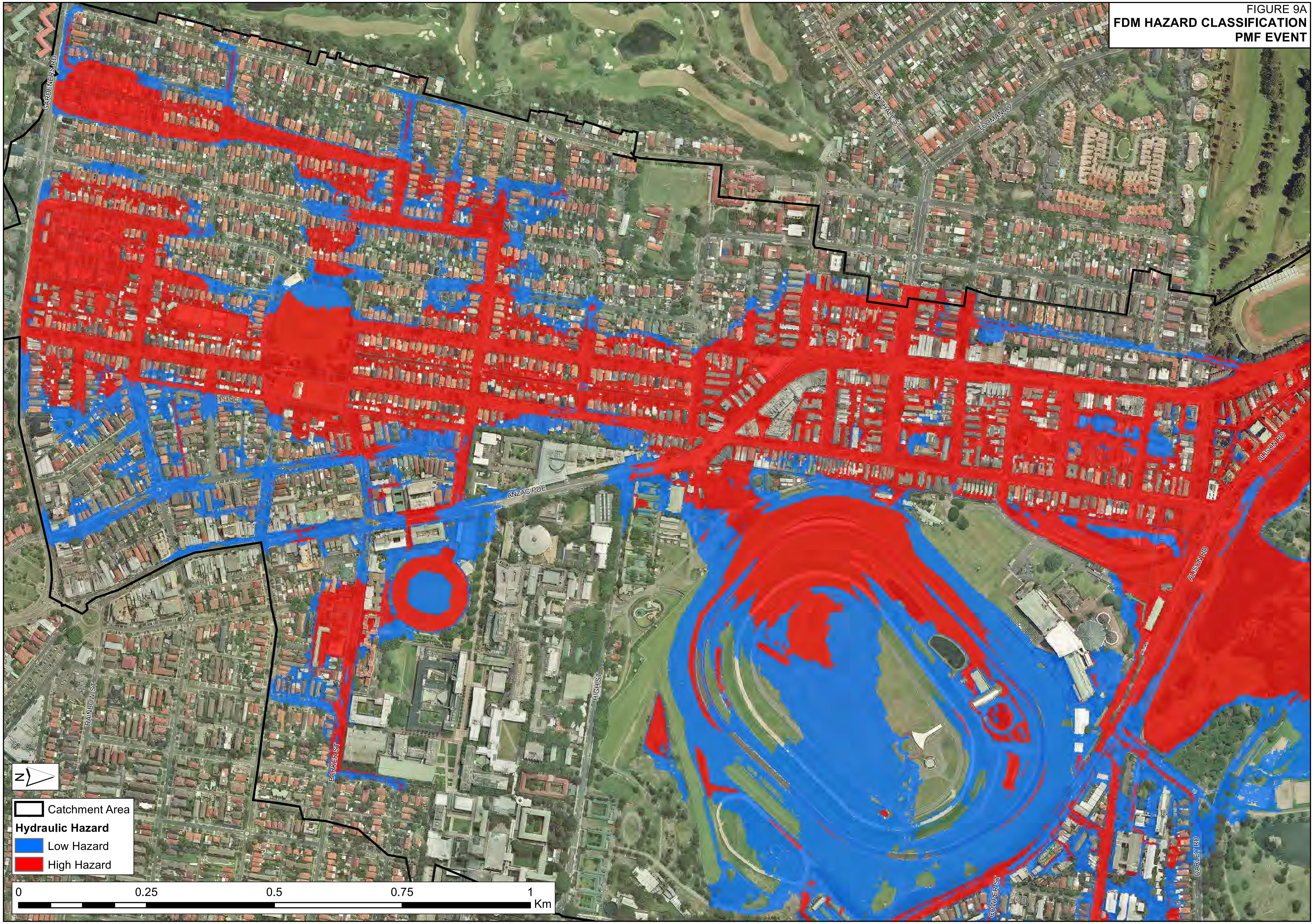
FIGURE 9A
FDM HAZARD CLASSIFICATION
PMF EVENT
GARDENERS RD
KENDALL ST
TODMAN AV
ANZAC PDE
ALISON RD
RAINBOW ST
BARKER ST
HIGH ST
COWPER ST
DARLEY RD
Catchment Area
Hydraulic Hazard
Low Hazard
High Hazard
0
0.25
0.5
0.75
1
Km
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FIGURE 9B
FDM HAZARD CLASSIFICATION
PMF EVENT

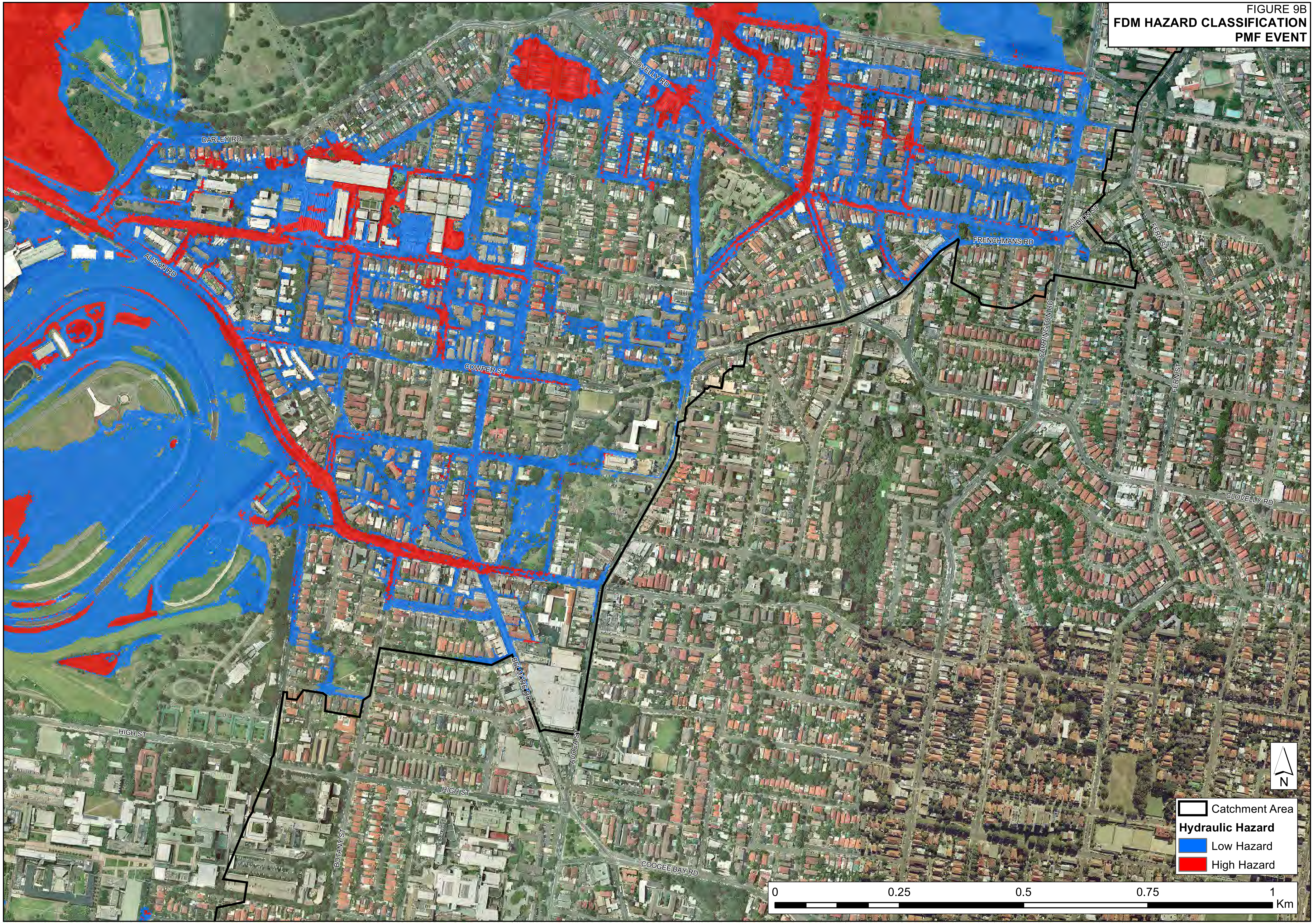

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FIGURE 10A
AEMI HAZARD CLASSIFICATION
PMF EVENT

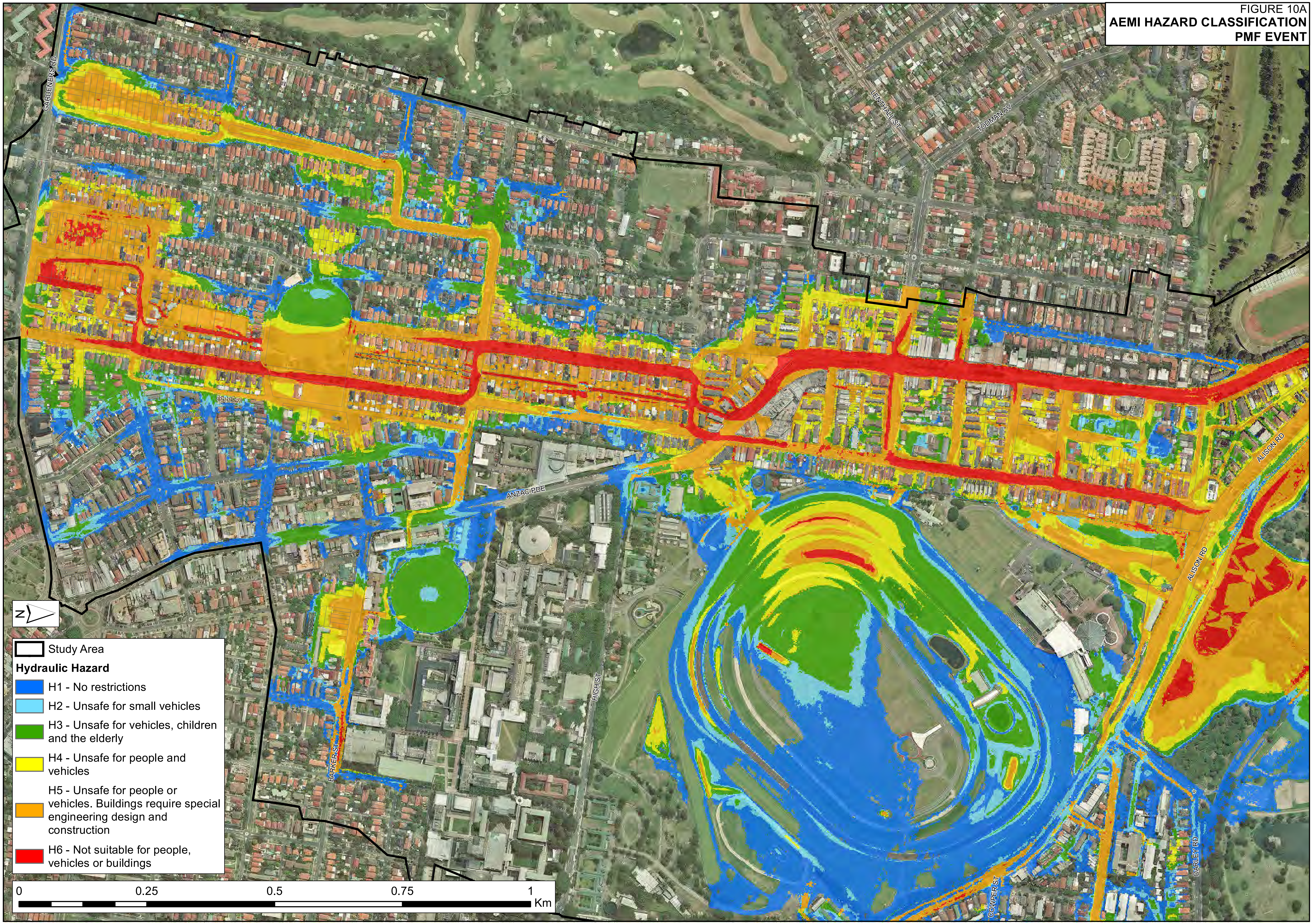

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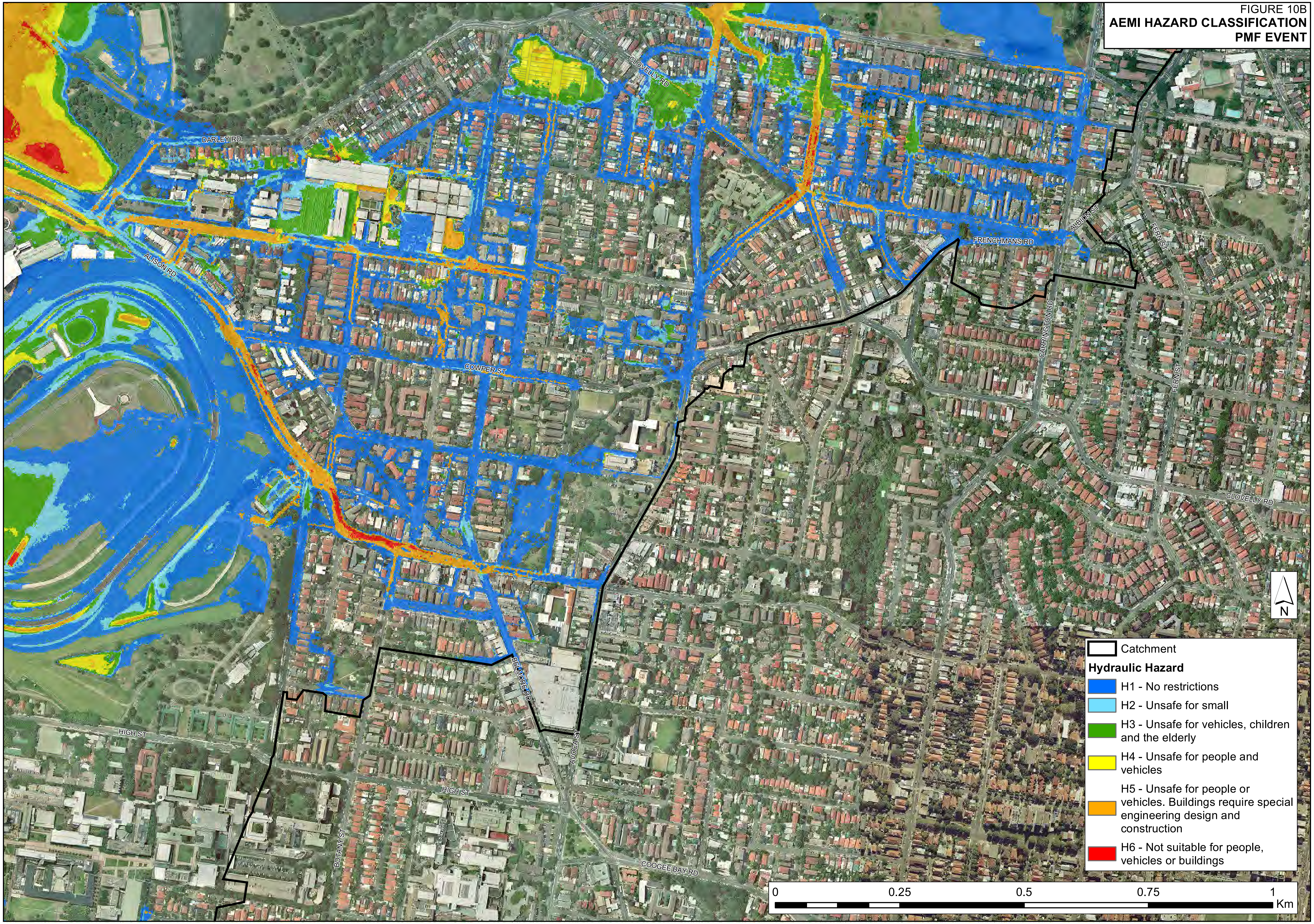
FIGURE 10B
AEMI HAZARD CLASSIFICATION PMF EVENT



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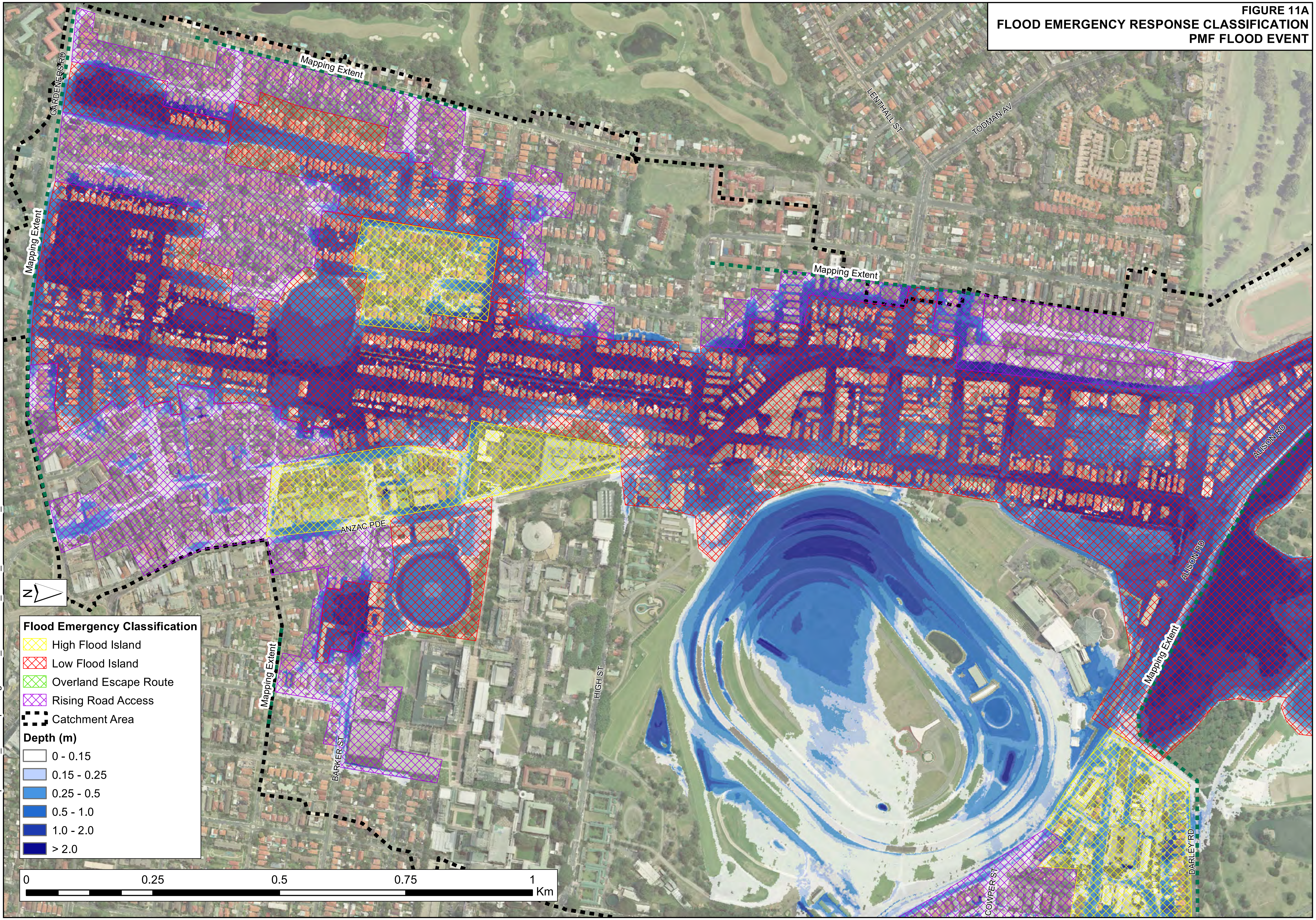
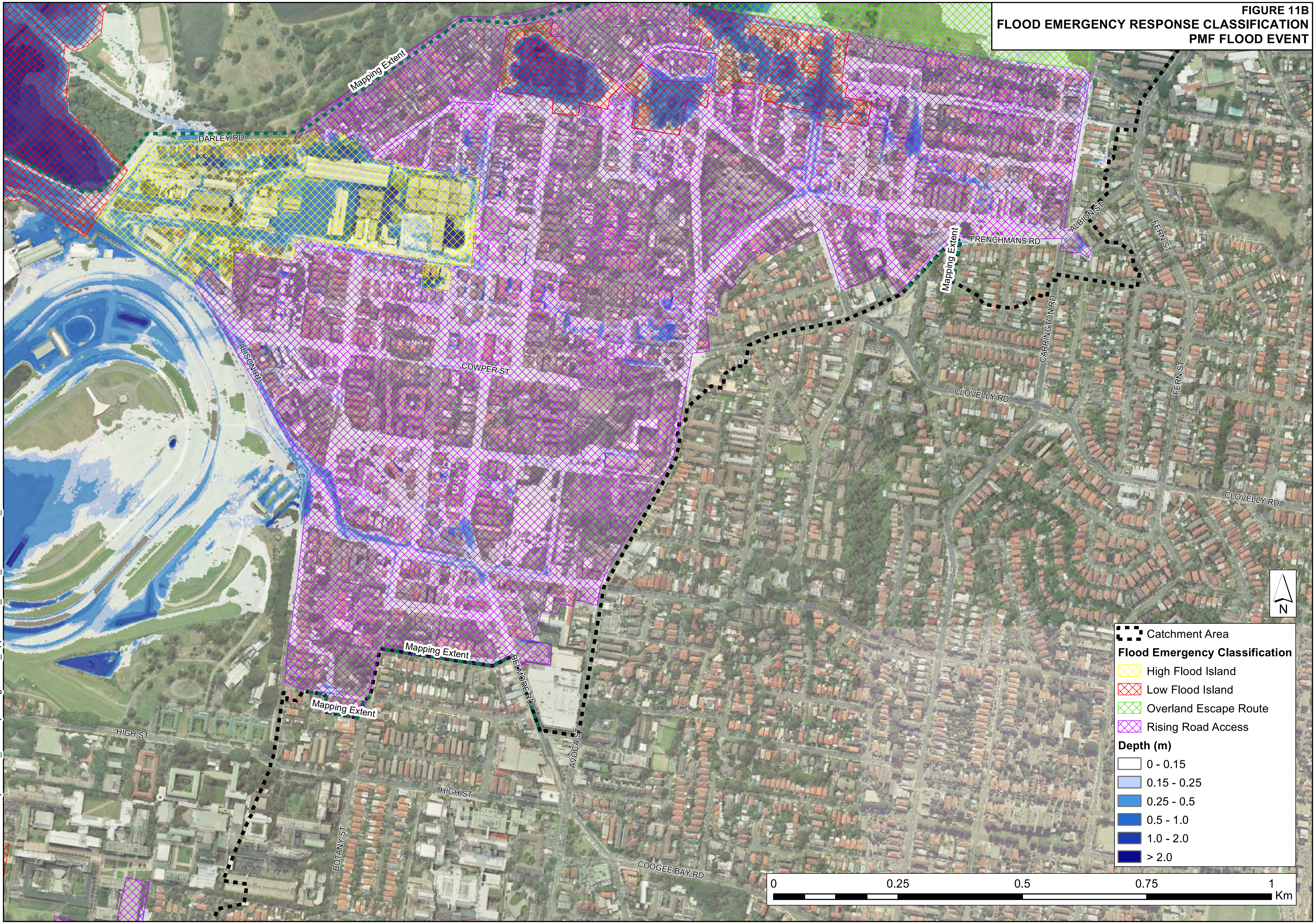


FIGURE 11A
FLOOD EMERGENCY RESPONSE CLASSIFICATION
PMF FLOOD EVENT
Mapping Extent
GARDENERS RD
LENTHALL ST
TODMAN AV
ANZAC PDE
ALISON RD
HIGH ST
BARKER ST
COWPER ST
DARLEY RD
N
Flood Emergency Classification
High Flood Island
Low Flood Island
Overland Escape Route
Rising Road Access
Catchment Area
Depth (m)
0 - 0.15
0.15 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 2.0
> 2.0
0
0.25
0.5
0.75
1
Km
J:\Jobs\113048\ArcGIS\ArcMaps\FRMS_MainReport\Figure11A_LowerModel_FERP_Classification_PMF.mxd

FIGURE 11B
FLOOD EMERGENCY RESPONSE CLASSIFICATION
PMF FLOOD EVENT



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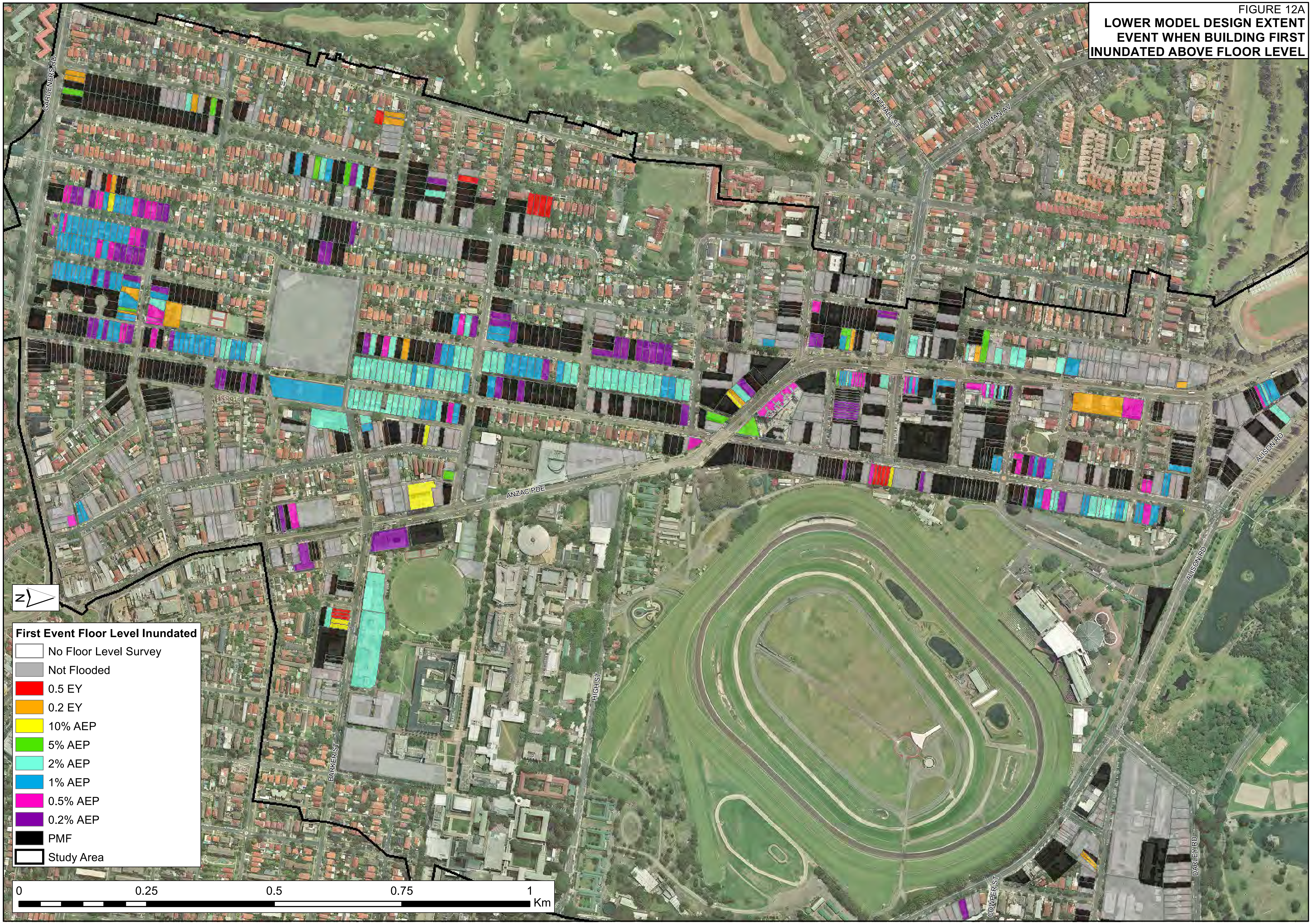

FIGURE 12A
LOWER MODEL DESIGN EXTENT EVENT WHEN BUILDING FIRST INUNDATED ABOVE FLOOR LEVEL

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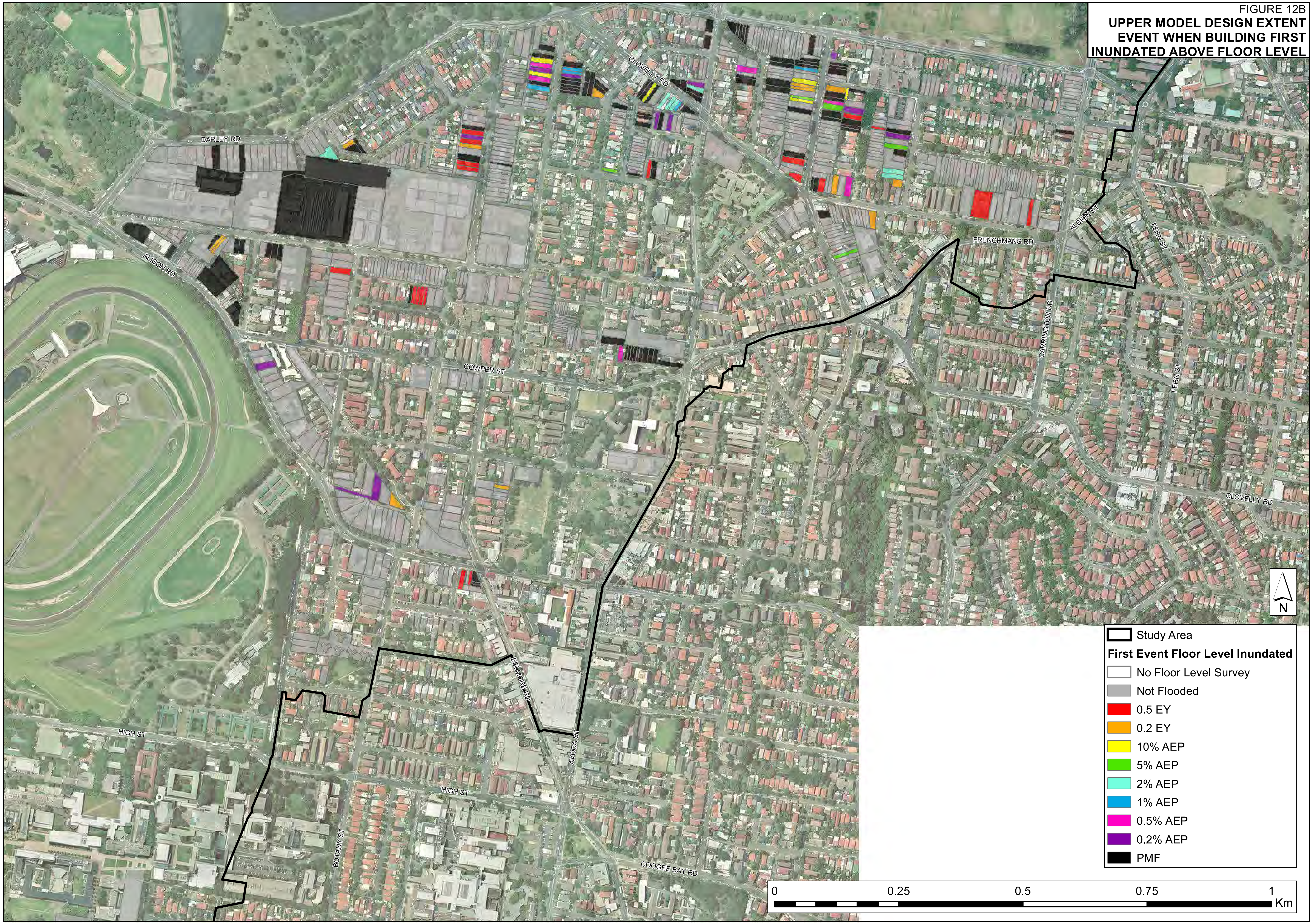
FIGURE 12B
UPPER MODEL DESIGN EXTENT EVENT WHEN BUILDING FIRST INUNDATED ABOVE FLOOR LEVEL



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Appendix A

APPENDIX A TERMINOLOGY AND GLOSSARY

A1 Probability Terminology

Australian Rainfall and Runoff (AR&R) has produced a set of guidelines for appropriate terminology when referring to the probability of floods. In the past, AEP has generally been used for those events with greater than 10% probability of occurring in any one year, and ARI used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, EY.

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the AR&R terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the AR&R terminology guidelines and uses % AEP for the 50% AEP and events greater and EY for all events smaller and more frequent than this. The image below provides the relationship between the various terminologies.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

A2 Glossary

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
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. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
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.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill 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. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions,

	actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice 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.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information

	describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store

	valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

	minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to "water level". Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B: FLOOD STUDY AND MODELLING REVIEW

B.1 BACKGROUND

Hydraulic modelling undertaken as part of the 2013 Kensington-Centennial Park Flood Study (Reference 3) is typically used to inform the FRMS&P. This hydraulic modelling defines the potential flood behaviour for a range of design events under current conditions and is termed the base case scenario. A number of mitigation options are then assessed against the base case to establish the impacts of potential measures. Model results are also used to inform the damages assessment and benefit/cost ratio of potential measures.

The Kensington-Centennial Park Flood Study was completed in May 2013 (Reference 3) and since then there has been the following major changes and developments:

1) Introduction of Australian Rainfall and Runoff 2016 (AR&R2016) (Reference 9). The release of AR&R2016 provides a new industry standard for design rainfall estimation, flood estimation and flood modelling;
2) Reduction in modelling simulation time due to faster computers allowing the two separate TUFLOW hydraulic models from the Flood Study (Reference 3) to be combined into one model of the entire catchment. This also included more accurate modelling of the basins in Centennial Park;
3) The April 2016 City of Sydney Centennial Park Flood Study (Reference 25) was completed by WMAwater providing inflow data into Centennial Park from Moore Park and the surrounding areas within the City of Sydney LGA;
4) Major changes to the Kensington-Centennial Park catchment with the addition of the Light Rail infrastructure and raising of the embankment wall of Centennial Park adjacent to Alison Road.

As part of this study the coupled modelling package consisting of a hydrologic and a hydraulic model have been reviewed and updated to include the four major changes and developments mentioned above. The study area is shown in Figure B1 and excludes the City of Sydney LGA area. The changes and updates to the modelling package are discussed in detail in the following sections.

It should be noted that when interpreting the model results to derive flood level estimates, care should be taken to review both the estimated level and depth results together with detailed survey to confirm an appropriate flood level, particularly where the estimated depths are reasonably shallow (e.g. less than 0.3 m for the 1% AEP event). In these instances, the peak levels approach the limit of accuracy of the underlying survey data, however the depths are still accurate.

B.2 AVAILABLE DATA

Additional data was required in order to undertake the model upgrade. Only the additional data utilised as part of this model upgrade is discussed below with the data utilised in the previous May 2013 Flood Study (Reference 3) discussed in that report.

Topographic Data

There are significant modifications to the topography throughout the catchment due to construction of the Light Rail. The Centennial Park embankment that runs parallel to Alison Road has been raised in order to mitigate increases in flood levels that would otherwise arise with construction of the Light Rail. There are also modifications due to the Light Rail track on Anzac Parade, Alison Road and the tram stabling yard on Alison Road adjacent to Randwick Racecourse. The topographic data was provided by Randwick Council in 12D format and modified to be compatible with the TUFLOW hydraulic model. The extent of the topographic data that has been included in the model upgrade is shown in Figure B2.

Pit and Pipe Data

There are also significant drainage network modifications and additions due to the construction of the Light Rail. The following data sets were provided in PDF and Excel format and converted to a format applicable with TUFLOW:

- Zone D – Randwick stabling yard;
- Zone K – Anzac Parade;
- Zone R – Alison Road.

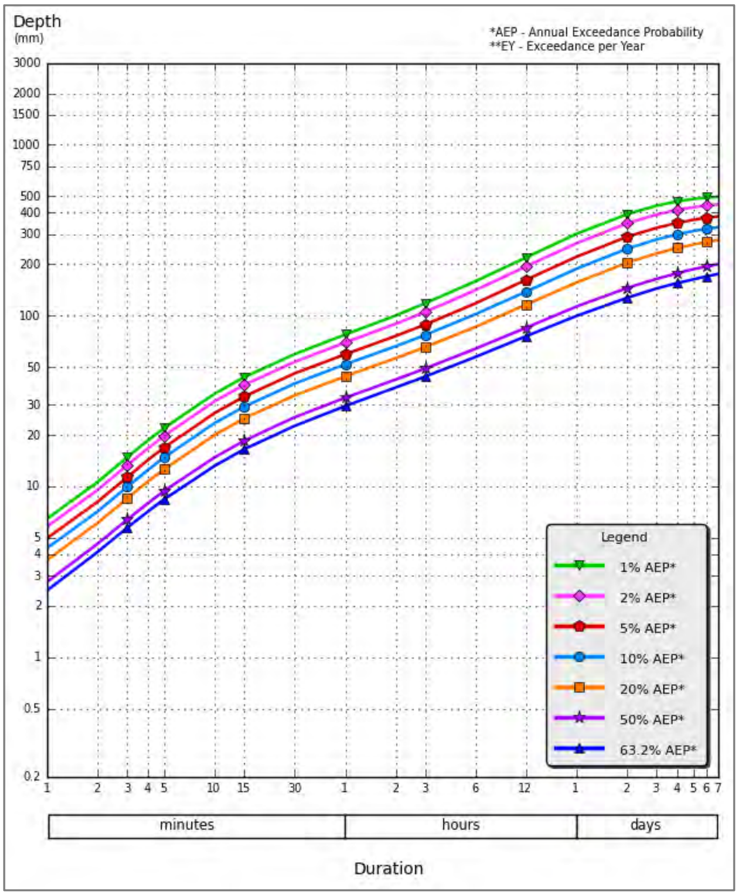
The locations of the pit and pipe data provided by Randwick Council and the Light Rail are shown on Figure B3 and the hydrologic and hydraulic model layouts on Figure B4 and Figure B5.

Rainfall Intensity Frequency Duration (IFD)

The 2016 IFD data obtained from the BoM website for the Kensington-Centennial Park catchment is shown in Table B1 and the IFD chart is shown in Graph B1.

Table B1 - Kensington-Centennial Park BoM 2016 Rainfall Depths

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	2.46	2.76	3.70	4.35	4.98	5.82	6.47
2 min	4.13	4.61	6.11	7.13	8.13	9.52	10.6
3 min	5.72	6.38	8.48	9.92	11.3	13.3	14.8
4 min	7.14	7.98	10.7	12.5	14.3	16.7	18.6
5 min	8.41	9.42	12.6	14.8	16.9	19.8	22.0
10 min	13.2	14.8	20.0	23.5	26.9	31.5	34.9
15 min	16.5	18.5	25.0	29.3	33.6	39.3	43.6
30 min	22.6	25.4	34.1	40.0	45.9	53.6	59.5
1 hour	29.5	33.0	44.1	51.8	59.3	69.5	77.4
2 hour	37.9	42.2	56.3	66.1	75.9	89.4	100
3 hour	43.9	49.0	65.3	76.9	88.6	105	118
6 hour	57.3	64.0	85.9	102	118	141	159
12 hour	75.7	84.9	116	138	162	194	219
24 hour	99.5	113	156	188	221	265	301
48 hour	127	145	204	246	289	347	392
72 hour	144	164	231	279	326	390	440
96 hour	155	177	249	299	349	416	466
120 hour	163	187	261	313	364	431	482
144 hour	170	194	270	322	374	441	491
168 hour	175	200	277	329	381	447	496



Graph B1 - Kensington-Centennial Park IFD Curves

Design Storm Temporal Patterns – Pre Burst Depths - Rainfall Losses

The design storm data required to be utilised in conjunction with the AR&R 2016 IFD data was obtained from the AR&R 2016 Data Hub. The data included the temporal pattern ensembles, pre burst depths and ratios and recommended rainfall losses (refer following sections).

B.3 BACKGROUND TO AR&R 2016 UPDATE

Since the last edition of AR&R in 1987, numerous technological developments and a larger set of data have been available for updating the AR&R guideline on design rainfall depths and temporal patterns. This set of rainfall data includes a larger number of rainfall gauges which continuously record rainfall (pluviometers) and a longer record of storms (inclusion of events from approximately 1985 to 2015).

B.3.1 AR&R 2016 – DESIGN RAINFALL UPDATE

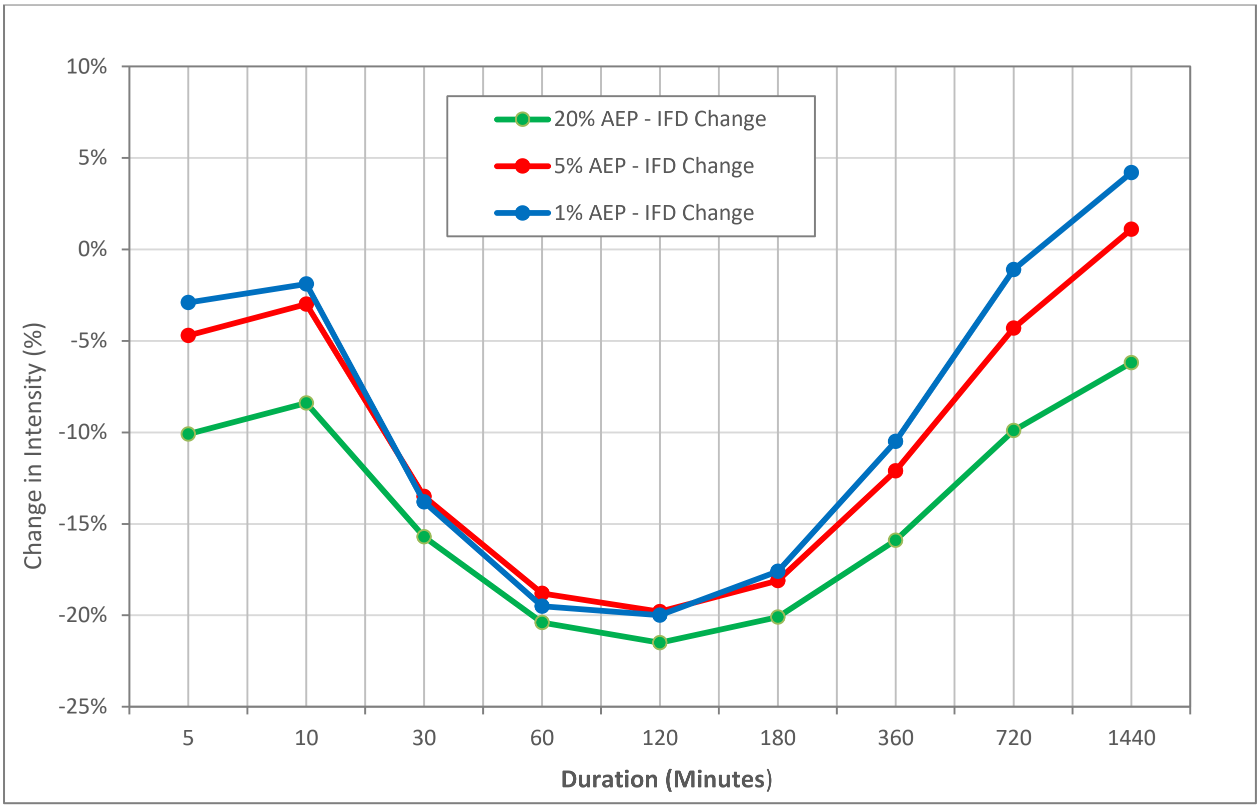
Three major changes have been made to the approach adopted in AR&R 1987:

1. The IFD rainfall data and the initial and continuing rainfall loss values across Australia have been updated;
2. AR&R 2016 assumes a pre burst rainfall depth for all storm events that is then removed from the initial loss;
3. The approach for adopting design temporal patterns has been significantly revised. AR&R 2016 recommends 10 temporal patterns are analysed for each storm duration in order to determine the critical storm event. The critical storm event is not the event producing the maximum peak value but the temporal pattern of the duration which produces the peak value just above the mean peak value from the 10 storms. If the peak value from the 10 patterns was taken that would result in adopting an event with an AEP rarer than what is defined by the IFD data. This principle is termed AEP neutrality whereby the AEP of the rainfall produces a flood of the same AEP.

B.3.2 IFD DATA

Revised IFD curves are available on the BoM website (Graph B1) with Graph B2 indicating the percentage change in depth between the 1987 and 2016 IFD data sets for the study area. The graph displays the 20%, 5% and 1% AEP events for the 5 minute duration through to the 1440 minute duration. The following are noted:

- there is an overall decrease in design rainfall intensities up to the 12 hour duration;
- there is a 15% decrease in intensity for the 30 minute duration for the 20%, 5% and 1% AEP events;
- there is approximately a 20% decrease in intensities in the 20%, 5% and 1% AEP events for the 60 minute to 180 minute durations;
- for the 720 minute duration the 1% AEP event is relatively unchanged, there is a 5% decrease in the 5% AEP event and there is a 10% decrease in the 20% AEP event.



Graph B2 - % Change in IFD data AR&R 2016 v AR&R 1987

B.3.3 PRE BURST RAINFALL AND LOSSES

The pre burst value is the depth of rainfall before the storm burst occurs. It varies for every AEP and duration and is removed from the initial loss value. Therefore all design storms have different initial loss values. The AR&R 2016 data hub provides pre burst values for all storm durations and the median values are shown on Table B2.

Table B2: Median Pre Burst Depth Value

Duration	Annual Exceedance Probability (AEP)					
(min)	50%	20%	10%	5%	2%	1%
60	12	8.3	5.9	3.5	2.1	1.1
120	9.3	8.4	7.9	7.3	4.3	2
180	8	7.1	6.6	6.1	7.2	8.1
360	11.8	21.4	27.8	33.9	25.2	18.6
720	3.5	10	14.4	18.5	26.3	32.2
1080	3.9	9.3	12.9	16.4	26.4	33.8
1440	1	5.4	8.3	11.1	20.7	27.9
2160	0	2.3	4.3	6	9.2	11.6
2880	0	0	0	0	1.8	3.2
4320	0	0	0	0	0.9	1.5

Table B2 indicates that for the 50% to the 2% AEP the median value increases significantly after the 180 minute duration, reducing gradually thereafter. For the 1% AEP there is minimal pre burst up to the 180 minute storm (maximum of 8mm) but this rises to 18.6mm (360 minutes) and peaks at 33.8mm at 1080 minute duration. However, it should be noted that in a longer duration event the impact of pre burst rainfall is much less significant than in a short duration event. Also of note is that it varies between AEPs, for example for the 360 minute event the pre burst increases from 11.8mm in the 50% AEP to 21.4mm in the 20% AEP and peaks at 33.9mm for the 5% AEP, reducing to 18.6mm in the 1% AEP.

The recommended losses prior to the removal of pre-burst are outlined in the AR&R 2016 data hub. The recommended loss values for the Kensington-Centennial Park catchment are:

- Initial Loss = 28 mm;
- Continuing Loss = 1.6 mm/h.

The recommended initial loss values after the pre-burst has been removed for each combination of event and duration are shown in Table B3. It should be noted that the losses outlined in AR&R 2016 are for rural areas or large open spaces like Centennial Park or sporting fields. For pervious land uses in residential / commercial / industrial areas the initial loss rate should be 60% to 70% of the calculated value in AR&R 2016. The continuing loss value will have a typical value of between 1mm/h and 3 mm/h for normal catchments and can be adjusted based on engineering judgement for catchments like Kensington-Centennial Park which have a variety of ground conditions.

Table B3: Calculated Initial Loss Values

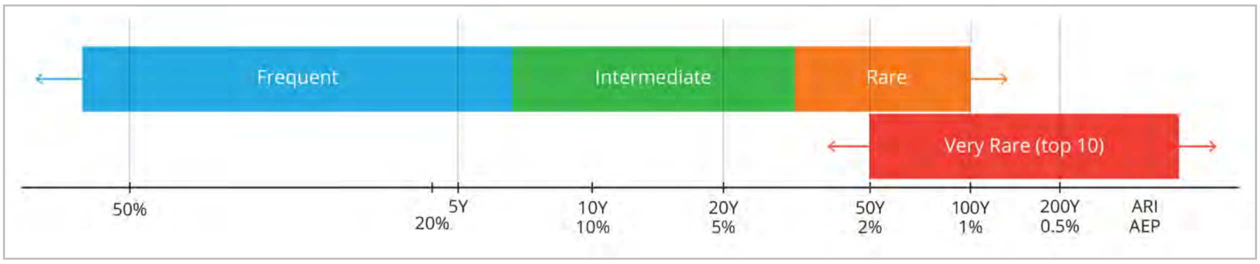
Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	16	19.7	22.1	24.5	25.9	26.9
120	18.7	19.6	20.1	20.7	23.7	26
180	20	20.9	21.4	21.9	20.8	19.9
360	16.2	6.6	0.2	0	2.8	9.4
720	24.5	18	13.6	9.5	1.7	0
1080	24.1	18.7	15.1	11.6	1.6	0
1440	27	22.6	19.7	16.9	7.3	0.1
2160	28	25.7	23.7	22	18.8	16.4
2880	28	28	28	28	26.2	24.8
4320	28	28	28	28	27.1	26.5

B.3.4 STORM TEMPORAL PATTERNS

The most significant change is in the application of storm temporal patterns. AR&R 1987 provided a single temporal pattern for events less than and another for greater than a 30 year ARI for each storm duration. AR&R 2016 now provides several patterns for each duration which are divided into four AEP bins.

These temporal patterns are different for each region in Australia and have been extracted from the storms already recorded in each region. The data hub provides a table with all the temporal patterns that could be used at a given location using coordinates. The temporal patterns are grouped in bins based on the intensity of the recorded storms. There are 4 bins ranging from frequent to very rare (Graph B3). The 1% AEP event is part of the rare bin and the 5% AEP event is part of the intermediate bin. AR&R 2016 recommends using 10 temporals patterns for all durations. Each of the 10 temporal patterns uses the same total rainfall depths and the difference is in how the rainfall is distributed within that storm duration. For example, some storms have the most intense rainfall at the start, some in the middle and some at the end. The different patterns can therefore produce different peak flood levels depending upon the topography of the catchment.

The adopted temporal pattern out of the 10 is the pattern which produces the peak flow or peak flood depth / level just greater than the average of the 10 peak flow or peak flood depth / levels. Thus the temporal pattern adopted does not produce the largest peak flow or peak flood depth / level for that storm duration. The critical storm duration is the temporal pattern which produces the maximum average peak flow or maximum average peak flood depth / level at the location.



Graph B3: Temporal Pattern Bins

B.3.4 CHANGES TO CATCHMENT CONDITIONS SINCE 1984

There have been a number of significant changes within the catchment since the November 1984 floods. Hence, the existing conditions hydraulic model was modified to account for these changes. For example, much of the trunk drainage network downstream of Centennial Park was upgraded following the November 1984 events (including both sub-surface drainage and the sections of open channel downstream of Roma Street). To account for these works, the TUFLOW hydraulic model was extensively modified to represent 1984 conditions on the basis of information found in Reference 5. Detailed information of the trunk drainage infrastructure present in 1984 was also obtained from surveyed data contained in Works-As-Executed drawings for the Kensington drainage works provided by Council at the time.

B.3.5 HISTORICAL PEAK HEIGHT DATA

To calibrate/verify the models requires a sufficient amount of recorded peak height data within the modelling extent. Although other major floods are known to have occurred within the catchment (e.g. in 1933, 1958, 1975 and 2003), the two storms in November 1984 are the largest of recent events for which there is a sufficient amount of flood height data available. The records for the November 1984 events have been sourced from the 1985 Kensington Flooding Drainage Works Investigation (Reference 5) and replicated on Figure B6 and Figure B9 for the 5-6th and 8-9th of November 1984 events respectively. It is acknowledged that there are likely errors with the data due to:

- wrong recording of locations;

- errors in height measurements;
- recorded levels may not actually represent the peak level, they could be higher due to wave action or lower if a debris mark has subsided after the peak;
- the recorded level may be as a result of local affects which are not reflected in the hydraulic model;
- mapping errors in Reference 5. This is likely to be a significant issue, particularly where there is a sloping land property and the location refers to the front of the property but the recorded level was taken in the rear adjacent to the channel. The alternative situation may also arise. An example of this at the intersection of Barker Street and Mooramie Avenue on the north side of Kensington Oval (refer Photo B1). The covered channel is located in the rear of the properties (white arrow) on the eastern side of Mooramie Avenue and at a lower level than the front of the houses on Mooramie Avenue (21m compared to 23m AHD on Mooramie Avenue). Points 18, 31 and 29 for 5th November 1984 appear consistent and are located on Mooramie Avenue but likely represent the flood level above the covered channel in the rear of the properties and not the location where they are plotted. This theory is supported as the recorded peak heights for 8th November 1984 event immediately upstream of these properties and located in the rear yard show levels approximately 0.3m higher (point 56 - 21.7 mAHD and 57 - 21.7 mAHD).

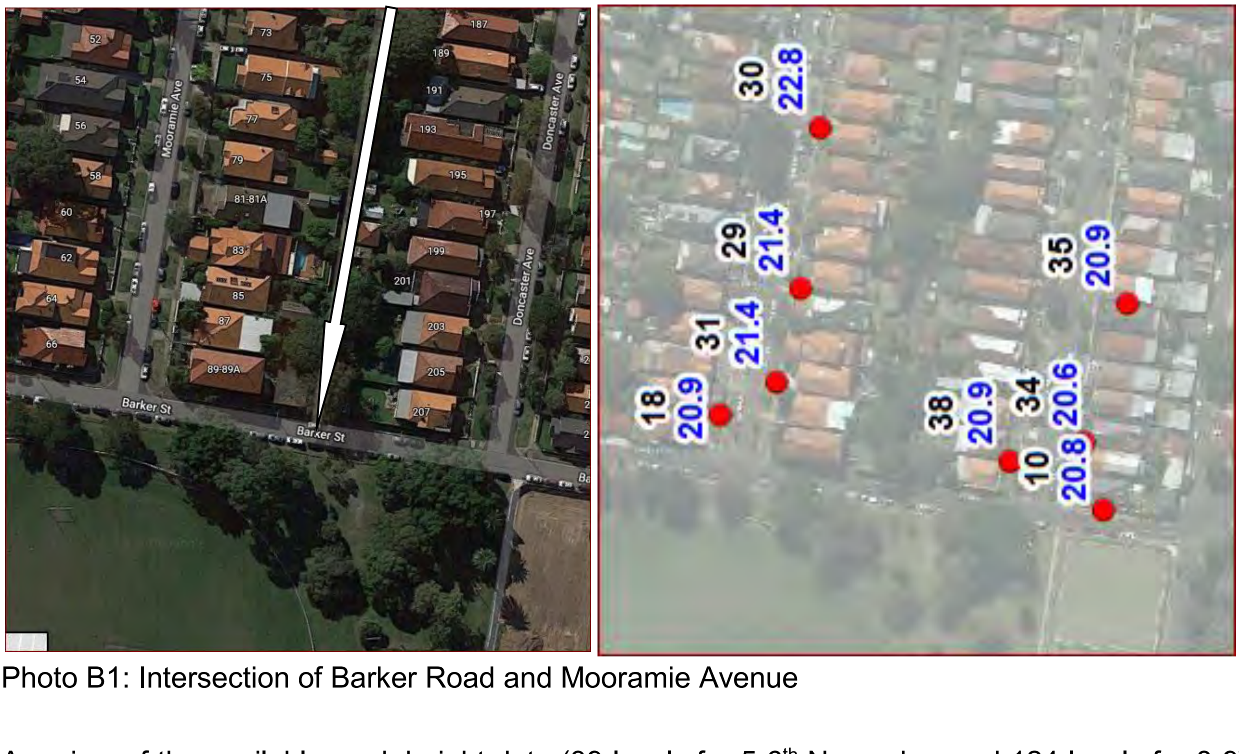


Photo B1: Intersection of Barker Road and Mooramie Avenue

A review of the available peak height data (39 levels for 5-6th November and 124 levels for 8-9th November) indicates many anomalies (the numbering of the points is in the same order as provided in Reference 5):

- extreme high or low levels which are clearly wrong (point 37 - 27.6 mAHD for 5th November and point 104 - 19.0 mAHD for 8th November);
- point 8 – 27.4 mAHD for 5th November which would need Anzac Parade inundated to a depth of approximately 2m; and likely point 7 - 28.8 mAHD for 5th November;

- adjacent points much higher than upstream points (point 36 - 21.7 mAHD, point 27 – 22.3 mAHD and points 26 – 22.0 m AHD and point 25 - 21.9 m AHD for 5th November);
- adjacent points much lower (point 4 – 20.3 mAHD, point 3 – 19.6 mAHD and point 0 – 19.7 mAHD for 5th November);
- adjacent points much lower (point 43 – 22.6 mAHD, point 42 – 22.2 mAHD and point 44 – 22.3 mAHD for 8th November);
- adjacent points much lower (point 47 – 22.6 mAHD, point 48 – 21.7 mAHD and point 49 – 21.7 mAHD for 8th November);
- adjacent points much higher (point 104 – 19.0 mAHD, point 60 – 20.6 mAHD and point 61 – 20.6 mAHD for 8th November);
- adjacent points higher (point 77 – 18.2 mAHD, point 78 – 18.4 mAHD and point 76 – 18.5 mAHD for 8th November).

As there is no source of the original data any errors cannot be confirmed and for this reason all data provided in Reference 5 has been recorded in the present study at the same locations as in Reference 5 on Figure B6 and Figure B9. Due to the obvious errors contained in Reference 5 there is a question over the validity of the entire dataset.

B.4 UPDATING OF THE HYDROLOGIC AND HYDRAULIC MODELLING UNDERTAKEN FOR THE FLOOD STUDY (REFERENCE 3)

The hydrologic and hydraulic models have both been updated as part of this study to reflect the recent technical developments from AR&R 2016, the changes to the catchment from construction of the Light Rail, the completion of the City of Sydney Centennial Park Flood Study (Reference 25) and changes to the TUFLOW modelling, notably in Centennial Park.

B.4.1 HYDROLOGIC MODEL

The 2013 Flood Study utilised a MIKE-Storm model for the Kensington-Centennial Park catchment and DRAINS model for the Fox Studios / Moore Park catchment. For the current study the outflows from the Fox Studios / Moore Park catchment were extracted from the City of Sydney Centennial Park Flood Study (Reference 25) which consisted of a coupled DRAINS and TUFLOW modelling package. For the remainder of the catchment the previous Mike-Storm model was converted into two DRAINS model. Two DRAINS models were created for a simpler application of the percentage imperviousness of the land uses and different rainfall losses. The two DRAINS models are shown in Figure B4 and described below.

- Open Space Model – The open space DRAINS model consists of Centennial Park and Randwick Racecourse pervious areas;
- Residential Model – The residential model consists of the Queens Park, Randwick and Kensington residential and commercial areas.

<u>Effective Impervious Area</u>

AR&R 2016 considers that there are four separate types of surfaces to be considered when estimating runoff from urban catchments:

- Directly Connected Impervious Areas (DCIA), which are impervious areas directly connected to the drainage system e.g. roads;
- Indirectly Connected Impervious Areas (ICIA), which are impervious areas from which runoff will flow over pervious surfaces before reaching the drainage system e.g. runoff from a roof that discharges onto a lawn;
- Indirectly Connected Pervious Areas (ICPA), that interact with ICIA e.g. a lawn that receives runoff from a roof; and
- Urban Pervious Areas (UPA), which do not interact with impervious areas e.g. parklands and bushland.

The Effective Impervious Area (EIA) is comprised of the impervious portion of the catchment connected directly to the drainage network (DCIA) plus a contribution from the impervious areas which discharge onto pervious areas (ICIA) before entering the drainage system (whose contributing pervious surfaces rapidly saturate and act in a similar manner to an impervious area).

The EIA selected for this study based on analysis of this catchment and similar catchments in the Sydney metropolitan area and the remaining pervious area is shown in Table B4.

Table B4: Effective Impervious and Pervious Area

Hydrologic Model	Effective Impervious Area	Pervious Area
Open Space	0%	100%
Residential	62%	38%

The loss rates adopted for the design events for the two hydrological models are shown in Table B5. The continuing loss rate of 10 mm/h for pervious areas is less than the adopted loss rates from the previous study. Initial modelling of the 1.6 mm/h recommended in AR&R 2016 was determined to be unrealistic considering that the catchment is located on top of the Botany aquifer. There is no guidance in AR&R 2016 on what losses to apply to this unique catchment and the literature available is inconclusive. The continuing loss of 10 mm/h for pervious areas was adopted as a reasonable estimate for all design events.

Table B5: Adopted Design Loss Rates

Hydrologic Model	Area	Initial Loss	Continuing Loss
Open Space	Pervious Area	28 mm – Pre Burst	10 mm/h
Residential	Effective Impervious Area	1 mm	0 mm/h
	Pervious Area	70% of (28mm – Pre Burst)	10 mm/h

B.4.2 HYDRAULIC MODEL

The hydraulic model developed for the Flood Study (Reference 3) consisted of two TUFLOW models; an upper and lower model. The upper model comprised Queens Park, Centennial Park and east of Randwick Racecourse while the lower model comprised Alison Road at the entrance of Randwick Racecourse south to Gardeners Road, including overflow from Centennial Park. In summary the updating of the modelling has been undertaken to incorporate:

- combining the previous Upper and Lower models together to create one TUFLOW model;
- incorporation of ALS survey within Centennial Park. This provided increased definition of the flood extents in the lower basins in Centennial Park;
- all works associated with construction of the Light Rail in the local area. These largely include raising the Centennial Park embankment, construction of the Light Rail depot and culverts beneath, construction of the rail track and associated stormwater system. Works as executed plans were not available as the works were not complete at the time of this study (up to June 2018) and thus relied on design plans. Any significant changes to the design would require a review of the modelling;
- incorporation of the AR&R 2016 design flood methodology (Reference 9). Further details of this methodology are provided in Section B3. The AR&R 2016 methodology supersedes the prior AR&R 1987 methodology and is being undertaken in all new flood studies. The main reason for this change is that since 1987 there have been significance advances in the approach to design flood estimation as well as changes to the design rainfall data as a result of the inclusion of rainfall data from 1987 to 2016;
- Changes in the inflows from the Moore Park sporting complex and surrounds. This arose because the City of Sydney undertook the April 2016 Centennial Park Flood Study (Reference 25), the study area of which is shown in Photo B2. The modelling package from the April 2016 Centennial Park Flood Study was modified to incorporate the AR&R 2016 methodology and to provide inflows into the TUFLOW model from the current study.

Photo B2: Study Area for the City of Sydney April 2016 Centennial Park Flood Study

B.5. CALIBRATION

B.5.1 OVERVIEW

It is desirable to test the performance of the hydrologic/hydraulic models against observed flood behaviour from past events within the catchment to ensure the accuracy. In this way the assumed model parameters can be adjusted so that the modelled behaviour best reproduces the historical patterns of flooding. The process of adjusting model parameters to best reproduce observed flood behaviour is known as model calibration. Usually, the models are calibrated to a single flood event for which there is sufficient flood and rainfall data available (e.g. peak flood levels, observations regarding flow paths or flood extents, pluviometer data etc.). The performance of the calibrated model can then be tested by simulating other historical floods and comparing the ability of the calibrated models to reproduce the observed behaviour without further adjustment of model parameters. This process is known as model validation or verification.

Calibration / verification of the Kensington-Centennial Park modelling systems was undertaken for the two events occurring on the 5th and 8th of November 1984 which are the same events undertaken in the Centennial Park West Kensington Flood Study 2013 (Reference 3). Further details on why these events were selected and not others are provided in that reference.

B.5.2 APPROACH

B.5.2.1 RAINFALL

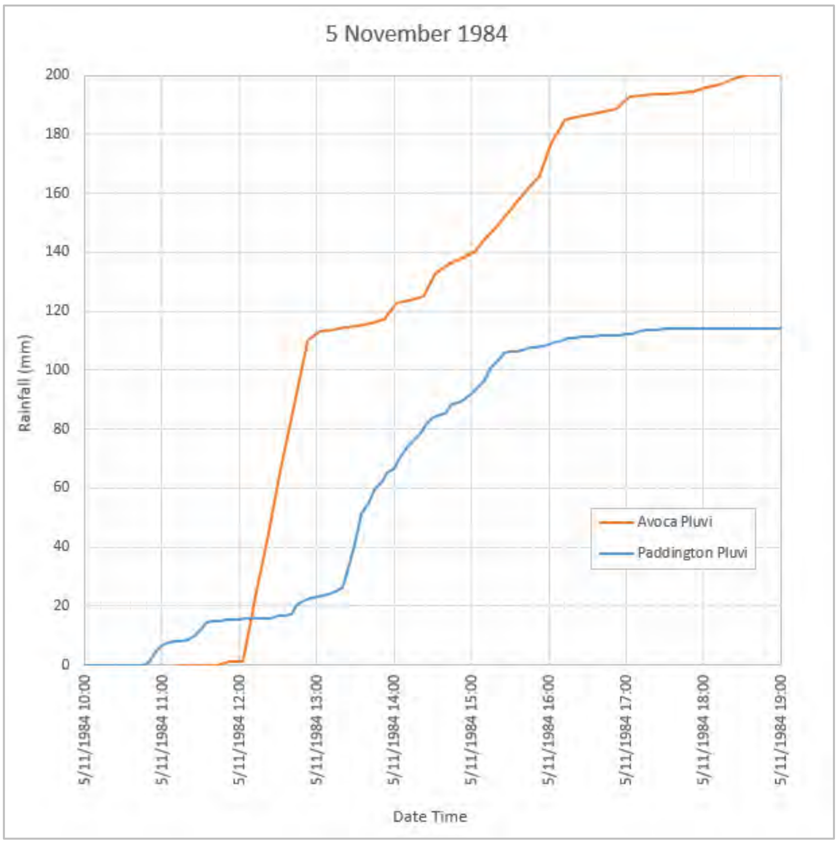
As discussed in Section B4 the hydrologic model from Reference 3 was converted to a DRAINS model and the Upper and Lower TUFLOW calibration TUFLOW models from Reference 3 were combined into one model. As was the case in Reference 3 the Centennial Park ponds storage area and outflow structure were not modelled in TUFLOW due to insufficient data available to replicate the outlet structure that existed at the time. The outflow from Centennial Park for each calibration event was thus modelled as per Reference 3 and applied directly to the TUFLOW model on Alison Road adjacent to the outflow structure.

For both events the following two pluviometers were available:

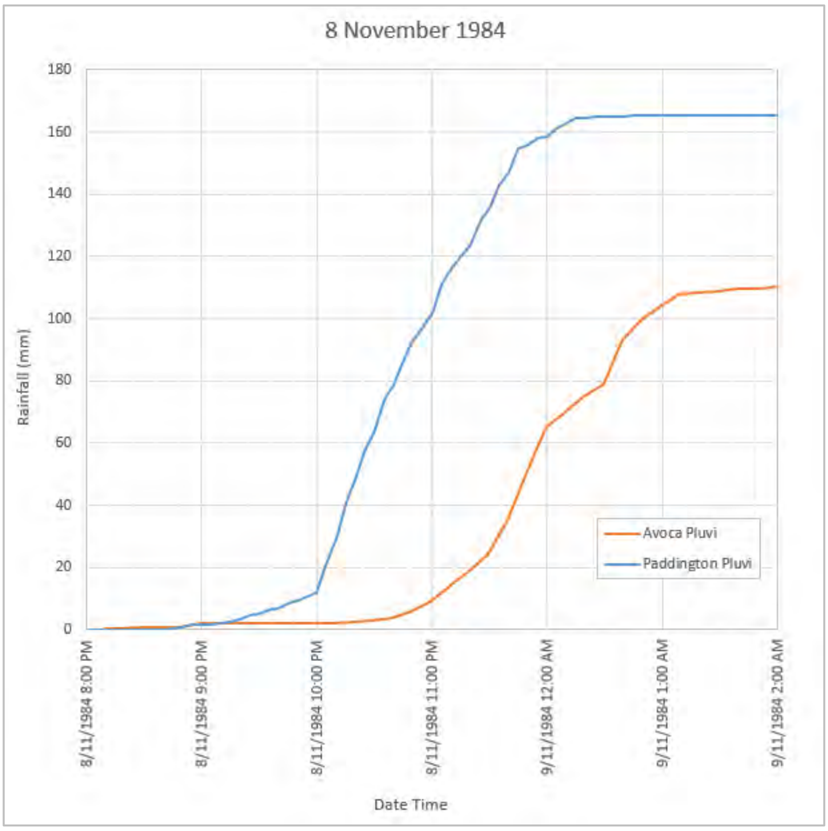
- MWS&DB (Sydney Water) station at Paddington (sourced from Sydney Water data records);
- UNSW station at Avoca Street (sourced from the 1985 Kensington Flooding Drainage Works Investigation - Reference 5 as no original data available).

Each event was modelled with a single pluviometer pattern (rather than allocating rainfall across the catchment based on the relative location to each pluviometer) with their rainfall patterns shown in Graph B4 and Graph B5. This approach was adopted due to the significant difference in the recorded rainfall patterns at each pluviometer for both events.

It was noticed that the pluviometer data provided in Reference 5 for the Paddington gauge for both events did not exactly match the Sydney Water data records.



Graph B4: 5th November 1984 Recorded Rainfall



Graph B5: 8-9th November 1984 Recorded Rainfall

The rainfall patterns indicate that there was a large degree of spatial and temporal variance of rainfall across the catchment for both events modelled. For the event of 5th November 1984 the Avoca pluviometer recorded approximately 80% more rainfall than the Paddington pluviometer with the majority between 12 pm to 1 pm. For the storm of the 8th November 1984 the reverse occurred and the Paddington pluviometer recorded approximately 50% more than at the Avoca pluviometer with the entire storm nearly finished before half the rainfall had fallen at the Avoca pluviometer.

There is no rigorous approach to applying this variance on a subcatchment to subcatchment basis across the entire study area. In the 2013 Centennial Park West Kensington Flood Study (Reference 3) rainfall was adjusted to achieve a best fit to the peak height data. For the present study for the two events the entire catchment was modelled with each separate pattern to demonstrate the rainfall dependent nature of the catchment response.

The loss values adopted for these historical events are shown in Table B6. The initial loss values correspond to the values used in Reference 3 and the continuing loss value is the maximum value available in DRAINS.

Table B6: Calibration Initial Loss and Continuing Loss Values

Hydrologic Model	**Area**	**Initial Loss**	**Continuing Loss**
Open Space 5th November 1984	Pervious Area	100 mm	10 mm/h
Residential 5th November 1984	Effective Impervious Area	1 mm	0 mm
	Pervious Area	100 mm	10 mm/h
Open Space 8th November 1984	Pervious Area	50 mm	10 mm/h
Residential 8th November 1984	Effective Impervious Area	1 mm	0 mm
	Pervious Area	40 mm	10 mm/h

B.5.2.2 PEAK HEIGHT DATA

When flooding occurs within the catchment in the future, it is recommended that Council collect any available information (rainfall data, flood heights etc) as soon as practicable after the event (including after smaller, more frequent flooding such as would be expected in the 20% AEP or greater events).

As the flood of 8-9th November was distinctly larger than the preceding 5-6th November flood, the main focus was on the match to the 8-9th November event rather than the 5-6th November event. The sole sources of recorded peak height data are provided on Figure B6 and Figure B9.

B.5.3 CALIBRATION RESULTS

The results for the 5-6th November 1984 event at each recorded location are shown on Table B7. The locations of the reporting points are shown in Figure B6 with flood extents for the Paddington and Avoca pluviometers shown in Figure B7 (Paddington pluviometer) and Figure B8 (Avoca pluviometer) respectively. The Avoca pluviometer overestimates peak flood levels at the majority of locations and modelling produces a flood extent greater than the calibration flood extent from the previous study. The Paddington pluviometer underestimates peak flood levels at most locations or does not show flood inundation at all at recorded locations. The modelled flood extent from the Paddington pluviometer is substantially less than the calibrated flood extent from the previous study. The results therefore suggest that a mix of the recorded rainfalls would provide a match to the recorded data.

Table B7: Calibration Results and Previous Study Comparisons 5th November 1984

ID Rows in red are likely an incorrect recorded level or location	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
0	19.69	19.66	-0.03	20.02	0.33	19.46	-0.23
1	20.07	19.68	-0.39	20.1	0.03	Not Inundated	Not Inundated
2	19.36	19.7	0.34	20.13	0.77	19.09	-0.27
3	19.56	19.51	-0.05	19.9	0.34	19.52	-0.04
4	20.27	19.74	-0.53	19.9	-0.37	19.67	-0.6
5	18.88	19.12	0.24	19.9	1.02	18.86	-0.02
6	18.87	18.91	0.04	19.9	1.03	18.77	-0.1
7	28.78	27.98	-0.8	28.11	-0.67	28	-0.78
8	27.36	25.74	-1.62	25.87	-1.49	25.57	-1.79
9	23.59	23.65	0.06	24.08	0.49	23.26	-0.33
10	20.84	21.13	0.29	21.72	0.88	20.67	-0.17
11	23.34	23.22	-0.12	23.61	0.27	Not Inundated	Not Inundated
12	23.51	23.11	-0.4	23.47	-0.04	Not Inundated	Not Inundated
13	23.58	23.24	-0.35	23.62	0.04	Not Inundated	Not Inundated

ID Rows in red are likely an incorrect recorded level or location	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
14	23.82	23.25	-0.57	23.63	-0.19	Not Inundated	Not Inundated
15	23.23	23.16	-0.07	23.38	0.15	23.23	0
16	23.76	23.58	-0.18	23.96	0.2	Not Inundated	Not Inundated
17	21.83	21.64	-0.19	22.38	0.55	21.12	-0.71
18	20.89	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
19	22.93	22.83	-0.1	23.05	0.12	22.81	-0.12
20	22.75	22.23	-0.52	22.61	-0.14	22.3	-0.45
21	22.31	22.36	0.05	22.6	0.29	Not Inundated	Not Inundated
22	22.21	21.64	-0.57	22.21	0	Not Inundated	Not Inundated
23	21.95	21.64	-0.31	22.39	0.44	21.13	-0.82
24	22.08	21.64	-0.44	22.21	0.13	Not Inundated	Not Inundated
25	21.86	21.68	-0.19	22.21	0.35	Not Inundated	Not Inundated
26	21.96	21.69	-0.27	22.21	0.25	21.31	-0.65
27	22.29	21.79	-0.5	22.21	-0.08	21.83	-0.46
28	22.1	22.1	0	22.22	0.12	22.15	0.05
29	21.37	23.01	1.64	23.08	1.71	23.04	1.67
30	22.77	22.72	-0.05	22.75	-0.02	22.69	-0.08
31	21.39	23.14	1.75	23.11	1.72	Not Inundated	Not Inundated
32	23.13	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
33	23.16	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
34	20.61	21.13	0.52	21.72	1.11	20.67	0.06
35	20.92	21.13	0.21	21.72	0.8	20.97	0.05
36	21.68	21.69	0.01	22.21	0.53	21.59	-0.09
37	27.65	21.5	-6.15	22.22	-5.43	Not Inundated	Not Inundated

The results for the 8th - 9th November 1984 event are shown on Table B8. The locations of the reporting points are shown in Figure B9 with flood grids for the Paddington and Avoca pluviometers shown in Figure B10 (Paddington pluviometer) and Figure B11 (Avoca pluviometer) respectively. The Paddington and Avoca pluviometers are a reasonable match to recorded flood levels for the majority of the catchment upstream of Borrodale Road. For the remaining section of the catchment between Borrodale Road and Gardeners Road, flood levels are overestimated by up to 0.7 m with the Avoca pluviometer and by up to 2.2 m with the Paddington pluviometer. The reason for this change downstream of Borrodale Road is due to the influence of Gardeners Road and the capacity of the culverts beneath where a small change in peak flow can result in a relatively large difference in flood level as floodwaters quickly dam up behind Gardeners Road.

Table B8: Calibration Results and Previous Study Comparisons 8th - 9th November 1984

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
1	30.53	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
2	28.28	28.56	0.28	28.62	0.34	28.63	0.35
3	28.28	28.41	0.13	28.48	0.2	28.5	0.22
4	28.21	28.4	0.2	28.48	0.27	28.5	0.29
5	28.18	28.34	0.16	28.43	0.25	28.45	0.27
6	28.15	28.01	-0.14	28.09	-0.06	28.11	-0.04
7	27.9	27.86	-0.04	27.96	0.06	27.96	0.06
16	27.91	27.65	-0.27	27.74	-0.17	27.75	-0.16
15	27.88	27.82	-0.06	27.91	0.03	27.91	0.03
14	27.66	27.45	-0.21	27.55	-0.11	27.53	-0.13
8	27.36	27.4	0.04	27.48	0.12	27.47	0.11
9	26.91	26.86	-0.05	26.94	0.03	26.93	0.02
10	27.04	26.81	-0.23	26.87	-0.17	26.87	-0.17

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
11	26.84	26.57	-0.27	26.62	-0.22	26.62	-0.22
12	23.83	24.02	0.19	23.97	0.14	23.99	0.16
13	24.36	24.06	-0.3	24.17	-0.19	24.24	-0.12
17	24.37	24.06	-0.31	24.07	-0.3	24.07	-0.3
18	25.17	Not Inundated	Not Inundated	24.74	-0.43	24.97	-0.2
19	23.9	24.01	0.11	23.89	-0.01	23.93	0.03
20	23.9	23.86	-0.04	23.95	0.05	23.96	0.06
21	24.07	24.03	-0.04	23.88	-0.19	23.93	-0.14
22	23.44	23.41	-0.03	23.34	-0.1	23.36	-0.08
23	23.7	23.59	-0.11	23.46	-0.24	23.5	-0.2
24	23.66	23.67	0.01	23.62	-0.04	23.65	-0.01
25	23.35	23.39	0.04	23.56	0.21	23.56	0.21
26	23.07	23.17	0.1	23.04	-0.03	23.18	0.11
27	23.27	23.11	-0.16	22.97	-0.3	23.14	-0.13
28	23.03	23.01	-0.02	22.91	-0.12	23.07	0.04
29	23.21	23.11	-0.1	22.98	-0.23	23.18	-0.03
30	23.23	22.94	-0.29	Not Inundated	Not Inundated	22.84	-0.39
31	22.89	22.59	-0.3	22.41	-0.48	22.51	-0.38
32	23.06	22.92	-0.14	Not Inundated	Not Inundated	22.81	-0.25
33	22.67	22.59	-0.08	22.41	-0.26	22.51	-0.16
34	22.65	22.57	-0.08	22.41	-0.24	22.51	-0.14
35	22.43	22.43	0	22.06	-0.37	22.31	-0.12
36	22.38	22.22	-0.16	22.17	-0.21	22.22	-0.16

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
37	22.35	22.18	-0.17	22.03	-0.32	22.16	-0.19
38	22.26	22.18	-0.08	22.03	-0.23	22.17	-0.09
39	22.28	22.41	0.14	22.06	-0.22	22.29	0.01
40	22.3	22.18	-0.12	22.03	-0.27	22.17	-0.13
41	22.22	22.16	-0.06	22.04	-0.18	22.15	-0.07
42	22.16	22.18	0.02	22.03	-0.13	22.17	0.01
43	22.63	22.18	-0.45	22.03	-0.6	22.17	-0.46
44	22.29	22.18	-0.11	22.06	-0.23	22.17	-0.12
45	22.23	22.16	-0.07	22.02	-0.21	22.16	-0.07
46	22.14	21.89	-0.25	21.86	-0.28	21.93	-0.21
47	22.27	21.68	-0.59	21.57	-0.7	21.74	-0.53
48	21.66	21.69	0.03	21.58	-0.08	21.75	0.09
49	21.66	21.68	0.02	21.57	-0.09	21.74	0.08
50	21.66	21.68	0.02	21.57	-0.09	21.74	0.08
51	21.6	21.68	0.08	21.57	-0.03	21.74	0.14
52	21.63	21.68	0.05	21.57	-0.06	21.74	0.11
53	21.64	21.68	0.04	21.57	-0.07	21.74	0.1
54	21.67	21.68	0.01	21.57	-0.1	21.74	0.07
55	21.7	21.68	-0.02	21.57	-0.13	21.74	0.04
56	21.68	21.75	0.07	21.58	-0.1	21.76	0.08
57	21.66	21.8	0.14	21.72	0.06	21.77	0.11
58	21.63	21.68	0.05	21.57	-0.06	21.74	0.11
59	23.05	22.71	-0.34	22.7	-0.35	22.74	-0.31

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
60	20.56	20.31	-0.25	20.2	-0.36	20.38	-0.18
61	20.64	20.14	-0.5	20.03	-0.61	20.17	-0.47
62	20.22	20.13	-0.09	20.02	-0.2	20.17	-0.05
63	20.17	20.13	-0.04	20.02	-0.15	20.17	0
64	20.07	20.1	0.03	20.01	-0.06	20.16	0.09
65	20.31	19.85	-0.46	19.93	-0.38	20.15	-0.16
66	19.83	19.71	-0.12	19.67	-0.16	20.14	0.31
67	20.73	19.77	-0.96	19.76	-0.97	20.15	-0.58
68	19.76	19.68	-0.08	19.55	-0.21	20.14	0.38
69	19.19	19.11	-0.08	19.16	-0.03	20.14	0.95
70	19.83	19.93	0.1	19.83	0	20.15	0.32
71	20.73	20.34	-0.39	20.24	-0.49	20.39	-0.34
72	19.25	19.68	0.43	19.5	0.25	20.14	0.89
73	21.64	21.62	-0.02	21.54	-0.1	21.69	0.05
75	19.21	19.19	-0.02	19.41	0.2	20.14	0.93
76	18.5	18.6	0.1	18.84	0.34	20.14	1.64
77	18.17	18.27	0.1	18.8	0.63	20.14	1.97
78	18.43	18.15	-0.28	18.8	0.37	20.14	1.71
79	18.11	18.12	0.01	18.8	0.69	20.14	2.03
80	17.97	18.12	0.15	18.8	0.83	20.14	2.17
81	18.13	18.12	-0.01	18.8	0.67	20.14	2.01
82	18.1	18.11	0.01	18.8	0.7	20.14	2.04
83	17.19	16.81	-0.38	16.47	-0.72	16.53	-0.66

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
84	17.04	16.77	-0.27	16.46	-0.58	16.51	-0.53
85	16.88	16.73	-0.15	16.41	-0.47	16.46	-0.42
86	16.47	16.54	0.07	16.32	-0.15	16.37	-0.1
87	16.54	16.54	0	16.31	-0.23	16.36	-0.18
88	16.43	16.39	-0.04	16.25	-0.18	16.3	-0.13
89	16.59	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
90	16.49	16.28	-0.21	16.17	-0.32	16.21	-0.28
91	16.47	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
92	16.42	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
93	30.21	30.09	-0.12	29.75	-0.46	29.85	-0.36
94	25.05	24.97	-0.08	24.75	-0.3	24.86	-0.19
95	24.88	24.66	-0.22	24.66	-0.22	24.67	-0.21
96	24	24.04	0.04	24.01	0.01	24.01	0.01
97	23.97	24.03	0.07	23.89	-0.08	23.93	-0.04
98	24.12	24.37	0.25	24.35	0.23	24.32	0.2
99	25.4	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
100	25.87	25.79	-0.08	25.87	0	25.86	-0.01
101	24.03	23.93	-0.1	23.92	-0.11	23.96	-0.07
102	23.13	23	-0.13	22.91	-0.22	23.07	-0.06
103	21.64	21.68	0.04	21.57	-0.07	21.74	0.1
104	18.97	20.13	1.16	20.02	1.05	20.17	1.2
105	20.19	20.13	-0.06	20.02	-0.17	20.17	-0.02
106	20.44	20.13	-0.31	20.02	-0.42	20.17	-0.27

ID Rows in red are likely an incorrect level or location. Rows in green are downstream of Borrodale Road.	Recorded Levels (mAHD)	Previous Study Modelled Levels (mAHD)	Previous Study Difference in Levels (mAHD)	Current Study Avoca Pluviometer Modelled Levels (mAHD)	Current Study Avoca Pluviometer Differences (m)	Current Study Paddington Pluviometer Modelled Levels (mAHD)	Current Study Paddington Pluviometer Differences (m)
107	18.25	18.11	-0.14	18.8	0.55	20.14	1.89
108	18.32	18.11	-0.21	18.8	0.48	20.14	1.82
109	18.36	18.11	-0.25	18.8	0.44	20.14	1.78
110	29.29	29.34	0.05	29.4	0.11	29.4	0.11
111	29.39	29.42	0.03	29.44	0.05	29.46	0.07
112	29.52	29.57	0.05	29.75	0.23	29.75	0.23
113	30.64	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated	Not Inundated
114	29.85	29.75	-0.1	29.83	-0.02	29.84	-0.01
115	28.61	28.65	0.04	28.7	0.09	28.72	0.11
116	28.6	28.67	0.07	28.72	0.12	28.74	0.14
117	25.09	24.68	-0.41	24.74	-0.35	24.97	-0.12
118	22.45	22.36	-0.09	22.25	-0.2	22.43	-0.02
119	21.53	21.65	0.12	21.55	0.02	21.71	0.18
120	21.53	21.61	0.08	21.52	-0.01	21.66	0.13
121	21.6	21.61	0.01	21.52	-0.08	21.67	0.07
122	22.33	22.43	0.1	22.06	-0.27	22.31	-0.02
123	21.62	21.68	0.06	21.57	-0.05	21.74	0.12
124	29.5	28.69	-0.81	28.84	-0.66	29.38	-0.12

B.5.4 CONCLUSIONS FROM CALIBRATION

Due to the large discrepancies in total rainfall depth as well as the temporal variance in the recorded rainfall patterns plus the variability in recorded flood levels, achieving a good match between modelled and recorded flood levels at all locations cannot be achieved. We could assign different pluviometer patterns to different subcatchments based on a linear or other distribution across the catchment. However we have no basis for assigning a distribution across the catchment and have taken the approach of showing the modelled levels using each pluviometer individually. We have generally assumed that the lines shown in red on Table B7 and Table B8 are anomalous and downstream of Borrodale Road for 8th November 1984 accurate calibration is not possible due to the influence of Gardeners Road and the culverts.

In the 5th November event there is an approximate difference of 90 mm in total rainfall depth and 2 hours in the timing of the rainfall between the Avoca and Paddington pluviometers as shown Graph B4. How to apply this variance on a subcatchment basis without additional data is impossible and as the modelling demonstrates the resulting flood levels are extremely rainfall dependent with Avoca over estimating and Paddington under estimating the recorded flood levels with a good fit to recorded flood levels somewhere in between.

In the 8th November event the Avoca and Paddington pluviometers achieve a reasonable match to recorded flood levels considering that each rainfall pattern does not represent the conditions for the entire catchment. This is except for the trapped low point just upstream of Gardeners Road where flood levels are overestimated by up to 0.7m and 2.2m respectively. Considering the Mascot pluviometer recorded a total rainfall depth of 68 mm for the event it is impossible to determine how much rainfall actually fell on the lower reaches of the catchment which would have a bearing on flood levels in the trapped low point upstream of Gardeners Road.

B.6 DESIGN EVENT MODELLING

Design flood levels in the catchment are a combination of inflows from the City of Sydney Centennial Park modelling package which covers the Moore Park area and rainfall over the remainder of the Kensington-Centennial Park catchment.

B.6.1 CRITICAL DURATION

The critical duration analysis was undertaken for the following three temporal pattern bins outlined above in Graph B3. The largest AEP event of each bin was analysed to determine the critical duration of that bin, namely:

- Frequent – 20% AEP event;
- Intermediate – 5% AEP event;
- Rare – 1% AEP event.

At the present time there are no patterns available for events greater than the 1% AEP event and the temporal pattern chosen for the 1% AEP event was used for the 0.5% and 0.2% AEP events. Each of the following durations and the corresponding 10 temporal patterns were analysed for each of the three temporal pattern bins; 1hr, 2hr, 3hr, 6hr, 9hr, 12hr, 24hr (210 runs).

Technique

The following technique was utilised in order to determine the critical duration of each temporal pattern bin:

- Model the ten temporal patterns in each duration in the coupled modelling package (DRAINS and TUFLOW);
- Determine the mean enveloped depth across the catchment from the 10 temporal pattern grids for each duration;
- Undertake a traditional critical duration analysis using the mean depth grids for each duration to determine the critical duration for each temporal pattern bin.

The durations that were determined to be critical for the three temporal pattern bins are shown in Table B9. The results of the critical duration analysis for the 1% AEP event is shown in Figure B12. (note in the early stages of analysis it was determined that the 24 hour event would not be critical).

Table B9: Mean Pre Burst Depth Value

Temporal Pattern Bin	Critical Duration
Frequent	1 hour
Intermediate	1 hour
Rare	1 hour and 12 hour

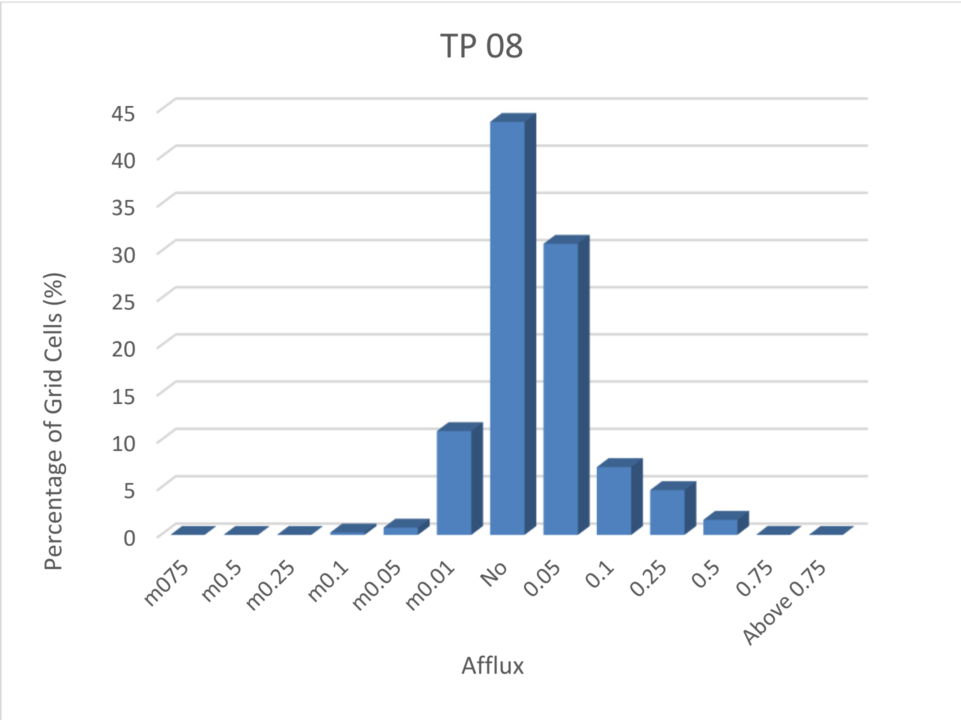
B6.2 TEMPORAL PATTERN SELECTION FOR THE CRITICAL DURATION

Once the critical duration has been selected the ten temporal patterns were analysed to determine the pattern that produced a flood depth across the catchment just above the mean enveloped flood depth. The following technique was utilised to determine the design temporal pattern.

- Produce a mean flood depth grid from the 10 temporal pattern grids for the critical duration event;
- Produce flood difference grids and mapping of each of the 10 temporal patterns versus the mean flood depth grid. The flood difference mapping for the 1% AEP event 12 hour duration pattern for the adopted critical duration pattern (pattern 08) is shown on Figure B13;
- Statistically analyse the difference grids utilising the mean, min and max. The analysis for the 1% AEP event 12 hour duration is shown in Table B10;
- Statistically analyse the difference grids to produce histograms of the difference at each grid cell across the catchment as a percentage of total grid cells. The histograms for the 1% AEP event 12 hour duration temporal pattern is shown in Graph B6;
- The grid that produces statistics that is the closest to just above the mean depth grid across the catchment was chosen, and then checked that it produced results that were a reasonable match to the mean across the catchment.

Table B10: 1% AEP 12 hour Duration Afflux Grid Statistical Analysis

Temporal Pattern	Min Afflux	Maximum Afflux	Mean Afflux
TP01	-0.819	0.783	**-0.038**
TP02	-0.972	0.942	**-0.056**
TP03	-0.202	1.493	**0.053**
TP04	-2.489	0.618	**-0.025**
TP05	-0.171	2.222	**0.076**
TP06	-0.812	1.281	**-0.031**
TP07	-2.393	0.401	**-0.081**
TP08	-0.818	1.179	**0.023**
TP09	-0.317	2.6	**0.145**
TP10	-1.217	0.65	**-0.006**



Graph B6: TP08 Afflux Histogram

By utilising the above examples of the statistical analysis techniques the temporal patterns chosen for the design events are shown in Table B11.

Table B11: Temporal Pattern Selection

Event	Duration	Pattern	AR&R Pattern ID	Duration	Pattern	AR&R Pattern ID
1 EY	1 hr	TP05	4578	-	-	-
50% AEP	1 hr	TP05	4578	-	-	-
20% AEP	1 hr	TP05	4578	-	-	-
10% AEP	1 hr	TP10	4567	-	-	-
5% AEP	1 hr	TP10	4567	-	-	-
2% AEP	1 hr	TP08	4559	12 hr	TP08	4785
1% AEP	1 hr	TP08	4559	12 hr	TP08	4785
0.5% AEP	1 hr	TP08	4559	12 hr	TP08	4785
0.2% AEP	1 hr	TP08	4559	12 hr	TP08	4785
PMP	1 hr	GSAM	-	-	-	-

B.6.3 ENVELOPE OF DESIGN RUNS

For the 2% to 0.2% AEP events the 1hr and 12hr durations are critical across separate sections of the catchment and thus the modelling results have been enveloped across the catchment.

B.6.4 RESULTS

The results for the revised Kensington / Centennial Park Flood Study are presented in the following figures:

- Peak Flood Depth and Levels – Figure C1 to Figure C10;
- Peak Flood Velocities – Figure C11 to Figure C20;
- Hydraulic Categories – Figure 6;
- Hydraulic Hazard – Figure 7 to Figure 10;
- Flood Emergency Response Classification – Figure 11.

Peak Flood Depths

The peak flood depths recorded at the locations displayed in Figure B14 are shown in Table B12.

Table B12: Peak Flood Depths (m)

ID	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	0.27	0.29	0.32	0.37	0.4	0.39	0.41	0.43	0.45	0.8
2	0.3	0.33	0.38	0.44	0.49	0.5	0.53	0.56	0.61	1.47
3	0.01	0.01	0.03	0.05	0.06	0.07	0.07	0.08	0.13	0.66
4	0.06	0.06	0.15	0.23	0.3	0.38	0.43	0.48	0.54	1.1
5	0.17	0.19	0.22	0.25	0.3	0.4	0.46	0.51	0.58	1.06
6	0.07	0.11	0.27	0.31	0.35	0.44	0.51	0.57	0.67	1.91
7	0.05	0.06	0.06	0.06	0.07	0.09	0.09	0.1	0.11	0.44
8	0.1	0.12	0.23	0.36	0.41	0.46	0.49	0.5	0.53	0.7
9	0.02	0.03	0.04	0.05	0.07	0.07	0.09	0.09	0.11	0.54
10	0.13	0.16	0.22	0.25	0.27	0.41	0.48	0.5	0.55	1.84
11	1.54	1.73	2.05	2.26	2.45	3.58	3.63	3.65	3.68	4.05
12	0.14	0.18	0.24	0.27	0.33	0.58	0.69	0.75	0.82	1.78
13	0.31	0.34	0.4	0.44	0.52	0.63	0.79	0.87	0.96	2.02
14	0.05	0.05	0.06	0.06	0.07	0.12	0.14	0.16	0.19	1.92
15	0.17	0.18	0.2	0.21	0.22	0.4	0.51	0.55	0.63	2.1
16	0.25	0.3	0.37	0.4	0.43	0.42	0.44	0.46	0.49	0.94
17	0.13	0.15	0.19	0.22	0.27	0.45	0.6	0.67	0.78	2.69
18	0.02	0.04	0.12	0.15	0.2	0.41	0.54	0.6	0.68	2.23
19	0.01	0.01	0.02	0.04	0.05	0.36	0.55	0.63	0.77	2.97
20	0.26	0.32	0.52	0.67	0.81	1.48	1.77	1.91	2.1	3.93
21	0.85	0.96	1.32	1.59	1.83	2.98	3.37	3.49	3.69	5.43
22	na	na	na	na	na	0.41	0.81	0.92	1.07	2.36
23	0.06	0.08	0.12	0.15	0.18	0.76	1.31	1.45	1.65	3.36
24	0.76	0.86	1.1	1.26	1.43	1.93	2.79	3.29	4.2	5.98
25	na	na	0.02	0.15	0.19	0.26	0.93	1.43	2.35	4.11
26	0.36	0.65	0.72	0.75	0.74	0.9	0.93	0.95	1.1	3.46
27	0.57	0.7	1.04	1.21	1.36	1.5	1.58	1.64	1.73	3.02
28	0.18	0.22	0.3	0.35	0.4	0.46	0.49	0.51	0.54	1.26

Peak Flood Levels

The peak flood levels recorded at the locations displayed in Figure B14 are shown in Table B13.

Table B13: Peak Flood Levels (mAHD)

ID	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	46.81	46.83	46.86	46.91	46.94	46.93	46.95	46.97	46.99	47.34
2	45.61	45.63	45.68	45.74	45.79	45.8	45.84	45.86	45.92	46.77
3	47.06	47.06	47.09	47.1	47.11	47.12	47.13	47.14	47.19	47.71
4	49.19	49.19	49.27	49.35	49.43	49.5	49.56	49.6	49.66	50.23
5	48.17	48.18	48.22	48.25	48.3	48.39	48.46	48.51	48.57	49.06
6	46.35	46.4	46.55	46.59	46.63	46.72	46.79	46.85	46.95	48.19
7	36.96	36.97	36.97	36.97	36.98	37	37	37.01	37.02	37.35
8	43.59	43.61	43.72	43.85	43.9	43.95	43.98	43.99	44.02	44.19
9	31.39	31.39	31.4	31.42	31.43	31.44	31.45	31.45	31.47	31.9
10	29.42	29.45	29.51	29.54	29.56	29.7	29.77	29.79	29.84	31.13
11	29.97	30.16	30.47	30.69	30.88	32.01	32.06	32.08	32.11	32.48
12	30.04	30.07	30.13	30.16	30.23	30.48	30.58	30.64	30.71	31.67
13	29.87	29.91	29.96	30.01	30.08	30.2	30.35	30.43	30.53	31.59
14	29.04	29.04	29.05	29.06	29.06	29.11	29.13	29.15	29.18	30.91
15	27.34	27.35	27.38	27.39	27.39	27.57	27.68	27.73	27.8	29.28
16	29.2	29.25	29.33	29.36	29.39	29.38	29.4	29.41	29.45	29.9
17	26.56	26.59	26.63	26.66	26.71	26.89	27.03	27.11	27.22	29.13
18	24.6	24.62	24.7	24.73	24.78	24.99	25.12	25.18	25.26	26.8
19	23.81	23.81	23.83	23.84	23.85	24.17	24.36	24.44	24.58	26.77
20	20.77	20.89	21.29	21.58	21.86	22.64	22.93	23.07	23.26	25.08
21	19.96	20.07	20.45	20.72	20.97	22.11	22.5	22.63	22.83	24.57
22	na	na	na	na	na	21.4	21.8	21.92	22.06	23.35
23	18.98	19	19.04	19.07	19.1	19.68	20.23	20.37	20.57	22.28
24	16.58	16.68	16.92	17.08	17.25	17.75	18.61	19.11	20.02	21.8
25	-9999	-9999	17.69	17.83	17.87	17.94	18.61	19.11	20.03	21.79
26	18.49	18.79	18.85	18.88	18.88	19.03	19.06	19.08	19.24	21.59
27	26	26.13	26.47	26.63	26.79	26.93	27.01	27.06	27.15	28.45
28	22.51	22.56	22.64	22.69	22.74	22.8	22.83	22.85	22.88	23.6

Peak Flood Level Differences

The peak flood level differences between the current study and the previous 2013 Kensington-Centennial Park Flood Study (Reference 3) at the locations displayed in Figure B14 are shown in Table B14. Figure B15 provides a comparison between the 1% AEP peak flood depths from the 2013 and 2018 (present) Flood Study.

Table B14: Peak Flood Level Differences Between Current and 2013 Kensington-Centennial Park Flood Study (Reference 3)

ID	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	-0.02	-0.05	-0.08	-0.06	-0.06	-0.09	-0.09	-0.1	-0.12	0.14
2	-0.08	-0.17	-0.23	-0.22	-0.24	-0.28	-0.31	-0.32	-0.29	0.29
3	-0.03	-0.04	-0.07	-0.1	-0.17	-0.22	-0.26	-0.29	-0.29	0.08
4	-0.11	-0.22	-0.3	-0.3	-0.3	-0.28	-0.28	-0.28	-0.29	0.12
5	-0.02	-0.08	-0.18	-0.22	-0.25	-0.23	-0.22	-0.22	-0.23	0.06
6	-0.21	-0.25	-0.21	-0.25	-0.31	-0.34	-0.36	-0.37	-0.39	-0.19
7	0.06	0.05	0.04	0.02	0	-0.01	-0.03	-0.05	-0.07	0.09
8	-0.33	-0.41	-0.35	-0.24	-0.2	-0.17	-0.16	-0.16	-0.15	-0.02
9	-0.15	-0.16	-0.16	-0.15	-0.15	-0.17	-0.19	-0.23	-0.27	-0.07
10	0.44	0.41	0.43	0.43	0.36	0.42	0.42	0.36	0.24	0.46
11	na	na	na	na	na	na	na	na	na	na
12	0.04	0	-0.36	-0.44	-0.49	-0.35	-0.32	-0.34	-0.37	-0.05
13	na	-0.07	-0.2	-0.3	-0.41	-0.49	-0.43	-0.45	-0.46	-0.02
14	-0.01	-0.02	-0.06	-0.11	-0.2	-0.21	-0.21	-0.22	-0.36	0.3
15	-0.03	-0.04	-0.04	-0.1	-0.26	-0.25	-0.26	-0.33	-0.41	0.2
16	0.08	0.09	0.12	0.14	0.14	0.1	0.08	0.05	0.02	0.06
17	-0.04	-0.08	-0.2	-0.29	-0.4	-0.46	-0.47	-0.53	-0.59	0.12
18	na	-0.15	-0.13	-0.24	-0.35	-0.32	-0.3	-0.34	-0.38	0.08
19	na	-0.03	-0.11	-0.29	-0.49	-0.41	-0.39	-0.46	-0.51	0.05
20	-0.54	-0.89	-0.93	-1.03	-1.17	-0.75	-0.66	-0.7	-0.71	-0.3
21	-0.52	-0.84	-1.12	-1.3	-1.58	-0.81	-0.61	-0.65	-0.65	-0.16
22	na	na	na	na	na	-0.59	-0.34	-0.33	-0.32	-0.2
23	-0.1	-0.17	-0.22	-0.24	-0.92	-0.74	-0.41	-0.44	-0.65	-0.11
24	-0.32	-0.54	-0.71	-0.68	-0.94	-1.34	-1.3	-1.4	-1.07	-0.14
25	na	na	-0.3	-0.21	-0.23	-1.15	-1.31	-1.41	-1.07	-0.15
26	-0.01	-0.02	-0.18	-0.27	-0.47	-0.53	-0.71	-0.84	-0.89	-0.25
27	-0.38	-0.55	-0.45	-0.38	-0.34	-0.31	-0.35	-0.37	-0.4	0.01
28	-0.12	-0.19	-0.19	-0.18	-0.16	-0.13	-0.13	-0.13	-0.12	-0.05

Overall there is a reduction in flood levels for all events across the entire catchment which can be attributed to the adoption of the ARR 2016 guidelines which includes:

- decrease in the IFD rainfall data for the catchment;
- application of temporal pattern ensembles which are derived from real storms.

Further reasons include the additional storage provided by the raising of the Centennial Park embankment that runs parallel to Alison Road due to the Light Rail construction. The latter reduces the volume and peak flow of floodwater overtopping the embankment that is conveyed down Doncaster Avenue. The area that records the greatest reduction in peak flood levels is the trapped low point just upstream of Gardeners Road where reductions in peak flood levels of up to 1.3 m in the 1% AEP event occur.

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Appendix E

Kensington – Centennial Park
Floodplain Risk Management Study and Plan

Randwick City Council
a sense of community

Randwick City Council is currently preparing a Floodplain Risk Management Study and Plan for the catchment which drains Centennial Park towards Kensington - an area of approximately ten square kilometres. Council has appointed WMAwater, Water Engineers, to undertake this Study.

The Floodplain Management Process

The State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. Under the Policy, local government has responsibility for managing flood liable land.

The Policy encourages the development of:

- solutions to existing flood problems in developed areas and
- strategies for ensuring that new development takes account of the flood hazard and does not create additional flooding problems in existing developed areas.

What Next?

The Floodplain Management Process is already underway with the Kensington - Centennial Park Flood Study being completed in May 2013 after a period of public exhibition. The Flood Study developed a hydraulic model of the study area which can subsequently be used in the assessment of potential flood management measures.

The next stage is to prepare the Floodplain Risk Management Study which will identify where flood management measures can be implemented to provide flood relief for both existing and future development. The Study will recommend a Management Plan setting out how Council will deal with future flood risk. The Plan will focus on reducing current flood risk and ensuring that future development does not worsen existing levels of flood risk.

Kensington – Centennial Park

Floodplain Risk Management Study and Plan

There have been a number of floods in the Kensington - Centennial Park catchment in the past. The November 1984 storm inundated many houses above floor level. There have also been a number of smaller floods over the years including recently in April 2007 and April 2012. Although you may not have personally experienced flooding, flooding will occur in the future and can be worse than the event in 1984.


November 1984 – Floodmark at Eastern Ave

What did the Flood Study find?

Urbanisation has significantly altered the nature of drainage in the catchment with development located along many of the existing drainage paths from Centennial Parklands south to Botany Bay. The Flood Study identified that flood problems typically occur from ponding in trapped low points. In the past these depressions drained by infiltration to the underlying aquifer. However, with increased hard standing areas, flooding in these areas has worsened. The hydraulic modelling identified key areas within the catchment to be focused on in the subsequent Floodplain Risk Management Study and Plan. The current Floodplain Risk Management Study and Plan will identify potential options for flood relief, such as upgraded drainage infrastructure, as well as recommend development controls to manage flood risk into the future.


April 2007 – Floodmark at Clovelly Road


April 2012 – Centennial Park

Floor Level Survey

A floor level survey will be carried out for a number of residential and commercial properties within the Study Area. Properties selected for survey have been identified from Council's flood database. This will be used in the calculation of potential flood damage costs and these estimates will be used to assess the benefit-cost ratio and practicality of flood mitigation works. Sydney Surveyors have been appointed to carry out the survey. The surveyors will be working in the area and may visit your property in the coming weeks to record floor levels. This is a standard task of the project and is required for the flood damages assessment.

Can I Get Involved?

Community involvement in the Study is important. A floodplain risk management committee including members from Council, Office of Environment And Heritage, the State Emergency Services and local residents is currently in operation. At a later date the Study and Plan will be placed on public exhibition and comments will be invited from the public.


1966 – Parkes Drive in Centennial Park

Further Information

If you would like to know more or have any information on flooding which would assist in the Study, please get in touch.

Randwick City Council
Drainage Engineer
(02) 9399 0999
general.manager@randwick.nsw.gov.au

wma water
KCP@wmawater.com.au

Community Consultation Report:

Kensington Centennial Park Floodplain Risk Management Study and Plan

20 August to 16 September 2018

Prepared by: Amanda Mather, Community Consultation Officer

Contents

1.0 Overview

A community consultation program was undertaken on the Kensington Centennial Park Floodplain Risk Management Study and Plan. The consultation strategy aimed to inform Randwick City residents about the study, seek their feedback and educate interested stakeholders on the issue of flooding.

2.0 Consultation activities

Your Say Randwick project page	https://www.yoursayrandwick.com.au/KensingtonCentennialFloodplain The site included a downloadable copy of the Floodplain Study and Plan, FAQs, a Q&A forum and online submission option.
Advertising	*The Southern Courier* 21 August 2018
Randwick News (weekly email bulletin sent to 22,000 subscribers)	29 August 2018. 401 unique clicks on the article
Mail out	4,656 letter to residents in the Kensington Centennial Park floodplain catchment
Randwick Council website	Notification on the front page of Council's website and on the 'Current Consultations' page
Precinct committees	Notification to all Resident Precinct Committees
Information session	5 September 2018. Drop in session for residents to speak with Council staff and the consultants undertaking the study – around 30 persons attending
Hardcopies	Hardcopies of the Floodplain Study and Plan were available at the Council Administration Building and all libraries

3.0 Examples of communications

Southern Courier – 21/8/18

Public notice

Kensington Centennial Park Floodplain Risk Management Study and Plan

Council has just completed the draft Kensington Centennial Park Floodplain Risk Management Study and Plan to assess a variety of management approaches we can take to reduce the impact of flooding on residents in the catchment area. This study has been revised to include the light rail development and the new rainfall data standard. This follows on from our 2013 Flood Study which determined the behaviour and extent of flooding in the Kensington Centennial Park catchment. To have your say, visit one of our libraries or www.yoursay.randwick.nsw.gov.au. Consultation closes 9am, Monday 17 September 2018.

Randwick News (email bulletin) – 29/8/18

Is your home at risk of flood?

Do you live around Kensington or Centennial Park? View the draft Kensington Centennial Park Floodplain Risk Management Study and Plan and let us know your thoughts. [More]

4.0 Your Say summary and results

Days open	28 days
Number of visits to Your Say Randwick	729 visits, 600 unique visitors
Document downloads	• 239 downloads of the *Floodplain Risk Management Study and Plan* • 148 downloads of the *Flood affected area map 1 of 2 – North* • 133 downloads of the *Flood affected area map 2 of 2 – South* • 26 downloads of the *FAQs*
Number of survey submissions and Q&A forum	10 submissions

5.0 Submissions

- 10 submissions were received via Your Say Randwick
- Council's Drainage Engineer also answered 9 telephone enquiries
- Council received 1 letter

Kensington centennial Park FRMSP

#	Type of request	Request	Response
1	Phone call	General question about the process and the aim of the study	Content of the document explained
2	Phone call	General question about the process and the aim of the study	Content of the document explained
3	Phone call	General question about the process and the aim of the study	Content of the document explained
4	Phone call	Living at this address for 36 years and never get flooded. Resident challenge the tagging and request that it should be reviewed. Resident claimed that she never received previous information or public consultation regarding flooding. She would like to have information regarding previous public consultation.	Tagging has been reviewed by WMAWater Sebastien look for previous public consultation documents
5	Yoursay	What are the changes impacting flood risk caused by light rail?	Answered over the phone, explained that modeling was redone with Light Rail infrastructure and raise of the levy + ARR 2016. Overall les properties flooded and less water.
6	Phone call	Implication of the study on a DA	Tagging and minimum floor level assessment explained
7	Phone call and Yoursay	Our property at ******* Avenue appears to be on your list and map as flood-prone. We have lived here since June 1983 and have never been flooded. During the flood many years ago, the water came through our back fence from Winburn Ave and covered the back lawn but did not ever enter the house. Since then the Brereton Drain has been built and any heavy or flooding rain does not even cover the back lawn. I therefore request that our property be removed from your flood-prone list.	Tagging has been reviewed by WMAWater
8	Yoursay	How does the inclusion of my property in the flood-prone zone affect the value and insurance situations?	The value of any property is determined by the buyer and the seller. The effect of this flood study will depend on each individual's interpretation of the significance of this information, just as aircraft noise, views, construction of new units in the area, nearness of schools etc. are taken into account when valuing a property. Insurance premiums are determined by insurance companies based on the level of risk (for fire, theft and other factors). How the results of this flood study will be taken account of in assessing risk will be up to each companies experts.
9	Yoursay	Does the flood plan for Kensington properties take into account the proposed "increasing in height of the embankment along Alison Road to provide additional flood storage in Centennial Park (option B)" p 109 of in the report submitted to the 24 July 2018 Council Meeting. If not, would an increase in height change the flood levels for individual properties in the future?	Yes the increase in height of the Centennial Park embankment along Alison Road has been taken into account when undertaking this study.
10	Phone call	Resident provided historical information regarding flooding in the area. Family is living there since 1935. Floods were more frequent in the past. Memories of people rowing in Doncaster Avenue. In Nov 84 the water is lapping the house.	Noted
11	Phone call and Yoursay	Our house has never been flooded in 40years that we have been here . The family that we had purchased the property off had lived here 60years never had been in a flood . Why are you calling this a flood area ? What have you done or doing to make this a flood risk? What is the council doing to stop this issue?	Response over the phone explaining the process and that 100 year storm is bigger than the Nov 84 storm. Property is only marginally flooded. Council will ensure that floor level are above the 100 year storm + freeboard when redevelopment occur.
12	Yoursay	The trams at allison rd has compromised the flood levy at centennial park. So they redirected the water via pipes to push the water down doncaster ave to the golf courses and leaving residents in a flood zone the trams works created. The planning and implementation of the Trams is a disgrace.	The embankment at Centennial Park was raised during construciton of the Light Rail by approximately 0.3 m after significant lobbying of the Light Rail consortium by Randwick City Council and to a lesser extent WMAwater. There has been no change to the Centennail Park low flow outflow structure and the culverts under Alison Road that drain the Centennial Park Ponds. The culverts from CentennialPark have historically always connected to the Doncaster Avenue drainage system, they were just redirected slightly to accomodate the tram yard and the detention pits inside the tram yard.
13	Yoursay	Richard and Sebastien have been extremely patient and helpful in explaining the flood implications on specific properties. Many residents were completely unaware that their properties were flood impacted until Council's letter of 15 August 2018 which specifically identifies properties. The previous letter of 2013 to residents did not specify their property so many did not identify that the flood study impacted them. Many have been caught completely unaware never having had any previous specific notification that their properties are flood affected! Many would still be in the dark. There are implications for resale – flood on 149 Certificate, redevelopment – increased bldg height above ground, possible increased insurance premiums etc. There is a feeling in the community that residents have now become flood affected because of light rail works and government is covering itself in the event of a flood event for which light rail works might be responsible. Despite the mitigation wall at Centennial Park! There are many mitigation works identified in the Report which will most probably never be implemented based on cost benefit analysis done. I respond that if a street needs remedial drainage works for instance then that should be planned for with a stated year for implementation. As a ratepayer I would request that occur as there is huge cost benefit to the ratepayer - possible risk reduction brings reduced resident cost in premiums, home damage, safety etc. Can properties be identified in terms of risk e.g. very low, low, medium, high, very high etc. and the change in that risk level of mitigation?	There was extensive flood modelling undertaken by the Light Rail Consortium to address the issues of flood affectation. WMAwater can only be guided by the work that was undertaken which stipulated that flood levels would not be increased in the catchment. We can state that the raising of the embankment in Centennial Park will reduce flood levels between Alison Road and Gardeners Road. This study focusses on flood mitigation and unfortunately only options that present with a good benefit cost ratio which is based on a reduction in flood damages to residential and commercial properties can be recommended. Any drainage works that do not meet the required b/c ratio have to be considered by Council on a case by case basis as no state funding will be available for their implementation. The 149 certificate only indicates that some part of the property is flood affected. Some Councils choose to advise residents the % of the land that is inundated as in many cases it is only a small part of the land
14	Phone call	Resident wants to know why the property is flooded and more information about the flood study process.	Process explained as well as extent of flooding in the area.
15	Yoursay	Section 6.2.1 Option D Dangar Lane The mitigation of flood levels is desirable for both the affected properties and through traffic in north Randwick. The existing stormwater pipe capacity to One Shot pond appears undersized, at a rating of 1 EY (Figure 5B) given the classification of the area as a trapped low point. We question the data presented and the minimal community benefit assessed resulting from the modelled doubling of the drainage capacity to the Park.	The flood damages used in the benefit cost analysis are determined from the depth of flooding on each property with more weight given to flood depths that exceed building floor levels. The benefit cost ratio is determined from a reduction in flood damages over the range of design events. Unfortunately with only two houses having above floor flooding the reduction in annual flood damages was not enough to off set the cost of the drainage upgrade. The Office of Environment and Heritage will not provide funding for flood mitigation options with a low benefit cost analysis.
16	Letter	See letter next page	Noted
17	Yoursay	We now have flooding due too light rail effecting centennial park drainage which courses localized flooding throughout Kingsford and Kensington, Which should be fixed and payed for by the N.S.W government as they cause the problem with the implementation of the light rail.	See response of request 12.
18	Yoursay	Plan is very extensive with the outcome being that Council have lots of works to do to ensure that flood mitigation can be undertaken. State Government should be approached to assist with the upgrading of the stormwater system in Randwick due to the nature of the system being so old and unable to cater for the capacity expected	Noted

Appendix F

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.01 June 2011 plus 2014 LW Edits | **Queries to duncan.mcluckie@environment.nsw.gov.au**

PROJECT	DETAILS	DATE	JOB No.
Kensington Centennial Park	**Residential Only**	**12/05/2014**	**113048**

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*						
Post late 2001 adjustments	1.50	*Changes in AWE see AWE Stats Worksheet*						
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*				
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*						
	Regional City				*Regional Town*			
		Houses Affected		*Factor*	*Houses Affected*			*Factor*
Small scale impact	*<*	*50*		*1.00*	*<*	*10*		*1.00*
Medium scale impacts in Regional City		*100*		*1.20*		*30*		*1.30*
Large scale impacts in Regional City	*>*	*150*		*1.40*	*>*	*50*		*1.50*
Typical Duration of Immersion	1.00	hours						
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*				*long duration*
		Suggested range		*0.85*		*to*		*1.00*
Typical House Size	240	m^2	*240*	*m^2 is Base*				
Building Size Adjustment	1.0							
Total Building Adjustment Factor	**1.28**							

CONTENTS

Average Contents Relevant to Site	$ 60,000		*Base for 240 m^2 house*	*$ 60,000*		
Post late 2001 adjustments	1.50	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*			*long duration*
Sub-Total Adjustment Factor	1.13	*Suggested range*	*0.75*		*to*	*0.90*
Level of Flood Awareness	LOW	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	0	hour				
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor				
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**1.13**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.13**					

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.50	*From above*	10050
External Damage	$	*$6,700 recommended without justification*	

	6,700				
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*			
Likely Time in Alternate Accommodation	3	weeks			
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*			

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	115%	Single Storey Slab on Ground

Base Curves

AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-0.100	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.01 June 2011 plus 2014 LW Edits **Queries to duncan.mcluckie@environment.nsw.gov.au**

PROJECT	**DETAILS**	**DATE**	**JOB No.**
Kensington Centennial Park	**Commercial\Industrial Only (uses same curve as Residential)**	**12/5/2014**	**113048**

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*						
Post late 2001 adjustments	1.50	*Changes in AWE see AWE Stats Worksheet*						
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*				
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*						
	Regional City				*Regional Town*			
	Houses Affected			*Factor*	*Houses Affected*			*Factor*
Small scale impact	*<*	*50*		*1.00*	*<*	*10*		*1.00*
Medium scale impacts in Regional City		*100*		*1.20*		*30*		*1.30*
Large scale impacts in Regional City	*>*	*150*		*1.40*	*>*	*50*		*1.50*
Typical Duration of Immersion		hours						
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*				*long duration*
		Suggested range		*0.85*		*to*		*1.00*
Typical House Size	500	m^2	*240*	*m^2 is Base*				
Building Size Adjustment	2.1							
Total Building Adjustment Factor	**2.66**							

CONTENTS

Average Contents Relevant to Site	$ 125,000	*Base for 240 m^2 house*	*$ 60,000*	$ 187,500.00	
Post late 2001 adjustments	1.50	*From above*			
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*		*long duration*

Sub-Total Adjustment Factor	1.13	*Suggested range*	*0.75*	*to*	*0.90*
Level of Flood Awareness	LOW	*low or high only. Low default unless otherwise justifiable.*			
Effective Warning Time	0	hour			
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*			
Total Contents Adjustment Factor AFD <= TTBH	**1.13**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.13**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.50	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 9,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	3	weeks
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification (for residential)*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	115%	Single Storey Slab on Ground

Base Curves

AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-0.100	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		