INNER WEST COUNCIL

DOBROYD CANAL AND HAWTHORNE CANAL FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

DRAFT FOR PUBLIC EXHIBITION

JUNE 2019

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Project **Dobroyd Canal and Hawthorne Canal Floodplain Risk Management Study and Plan**	**Project Number** **116043**
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Dobroyd Canal and Hawthorne Canal Floodplain Risk Management Study and Plan

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LIST OF ACRONYMS

AAD	Average Annual Damages
AEP	Annual Exceedance Probability
AFAC	Australian Fire and Emergency Service Authorities Council
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
B/C	Benefit Cost Ratio
BOM	Bureau of Meteorology
DCP	Development Control Plan
EMPLAN	State Emergency Management Plan
EP&A Act	NSW Environmental Planning and Assessment Act 1979
ERP	Emergency Response Planning
EY	Exceedance per Year
FLARE	Flash Flood Advisory Resource
FPA	Flood Planning Area
FPL	Flood Planning Level
GIS	Geographic Information System
HHWS	High High Water Springs Tide
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Airborne Light Detection and Ranging
mAHD	meters above Australian Height Datum
LEMC	Local Emergency Management Committee
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SEPP	State Environmental Planning Policy
SES	State Emergency Services
SWC	Sydney Water Corporation
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as "recurrence interval" and "return period" are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. 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.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report uses percentage AEP for all events rarer than the 10% AEP and EY for all events more frequent than this.

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	

FOREWORD

The NSW State Government's Flood Prone Land 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 five sequential stages:

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

The Dobroyd Canal Flood Study and Hawthorne Canal Flood Study were completed in late 2014 and early 2015 respectively and constituted the first stage of the Floodplain Risk Management Process described above. The Flood Studies were undertaken on behalf of the former Ashfield Council, former Marrickville Council and Burwood Council.

Since the completion of the Flood Studies, the former Ashfield Council, Marrickville Council and Leichhardt Council have amalgamated to form the Inner West Council.

The Dobroyd Canal and Hawthorne Canal Floodplain Risk Management Study and Plan (FRMS&P) (this document) constitutes the second and third stages of the process. The study area includes the former Ashfield Council and former Marrickville Council Local Government Area (LGA).

DOBROYD CANAL AND HAWTHORNE CANAL FLOODPLAIN RISK MANAGEMENT PLAN

The Dobroyd and Hawthorne Canal Floodplain Risk Management Plan, which follows on from the Dobroyd and Hawthorne Canal Floodplain Risk Management Study for the area has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the study area, overfloor flooding of residential, commercial and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event. Various measures aimed at managing this flood risk were assessed for their efficacy across a range of criteria, which allows options to be recommended as part of the this Floodplain Risk Management Plan for the area.

Flood Prone Land Policy Framework

The NSW Government Flood Prone Land Policy supported by the Floodplain Development Manual provides a framework for the assessment and management of flood risk across the state. Specifically, the Floodplain Development Manual guides Councils in the development and implementation of detailed local floodplain risk management plans in order to plan for and manage flood risk. The Floodplain Development Manual outlines the process and the roles and responsibilities of the various stakeholders involved in the process.

Council (both elected members and Council staff) are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. The Floodplain Management Committee assists Council in the development and implementation of these strategies by providing a forum for discussion of the differing viewpoints within the study area, identifying management options and considering and making recommendations to Council on appropriate measures and controls with the primary objective of achieving an equitable result for the study area. The committee is the driving force behind the study and may be required to vote to determine the majority opinion if consensus cannot be reached.

State Government agencies provide funding and technical support to assist Council and the committee in developing a robust Floodplain Risk Management Plan. In most cases a specialist consultant is engaged by Council to undertake the required technical investigations and assessment. The committee directs the consultant through this investigation and receives this information from the consultants to assist with their deliberations.

WMAwater has undertaken the investigation and assessment for this Dobroyd and Hawthorne Canal Floodplain Risk Management Study and Plan under the guidance and direction of the Floodplain Management Committee.

Background

The Dobroyd Canal and Hawthorne Canal catchments discharge into Iron Cove on the Parramatta River. The open channel sections are concrete-lined, tidal and extend up to Norton Street along the Dobroyd Canal and up to Pigott Street along the Hawthorne Canal. Sydney Water Corporation own and maintain the open channel and major stormwater drainage network that discharges into the open channel. Council own and maintain the local stormwater drainage network that discharges into the SWC network. The upstream and downstream portions of the catchments are separated by the embankment that forms the Western Rail Track and the Light Rail Track bisects the Hawthorne Canal catchment; at times in the form of an embankment and at others as cuttings.

Existing Flood Environment

The Dobroyd Canal catchment has approximately double the number of properties and floors inundated as the Hawthorne Canal catchment as shown in the table below.

	DOBROYD CANAL			HAWTHORNE CANAL		
Event	**Number of Properties Flood Affected**	**No. of Buildings Flooded Above Floor Level**	**Total Tangible Flood Damages**	**Number of Properties Flood Affected**	**No. of Buildings Flooded Above Floor Level**	**Total Tangible Flood Damages**
0.5 EY	1328	23	$8,138,000	442	12	$4,018,000
0.2 EY	1531	66	$13,100,000	542	37	$6,141,000
10% AEP	1646	132	$18,245,000	596	53	$7,413,000
5% AEP	1750	209	$24,400,000	670	75	$9,269,000
2% AEP	1844	301	$30,812,000	729	100	$10,830,000
1% AEP	1922	399	$38,823,000	798	120	$12,921,000
PMF	2598	1339	$139,656,000	1378	537	$53,320,000
	AAD		**$9,921,000**	**AAD**		**$4,369,000**

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the area. The assessment was based on surveyed and estimated flood levels for over floor inundation. The total tangible damages for the range of flood events are shown in the table above. However, it also should be noted that the cost to the community of intangible damages (damages that cannot be quantified such as inconvenience, hardship, injury, worry) may equal or exceed the monetary value of the tangible damages.

Floodplain Risk Management Options

The Floodplain Risk Management Study has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multi criteria analysis, which considered not only flood impacts, but also affectation on emergency services, economic merits, technical feasibility, environmental impacts and community / stakeholder and policy alignment. These measures have been grouped into the following general categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) by undertaking structural works in particular areas of the floodplain. Among the flood modification options considered are.

Property modification measures modify the existing land use or buildings as well as development controls for future development. These measures primarily involve updating policies and regulations which relate to development on the floodplain. Property Modification Options including flood proofing were assessed, as well as a broad range of planning measures that aim to reduce flood risk to life, to proposed development and to the wider floodplain.

Response modification measures are aimed at changing and enhancing the community's response to the potential hazards of flooding. This is achieved by educating the property owners and the wider community about flooding, its behaviour and potential damages, so that they can make better informed decisions. The Response Modification Options considered in this study are generally to 'continue and improve' the current flood emergency management systems and practices.

Recommended Options

The outcomes of the analysis undertaken in the Floodplain Risk Management Study are presented in this report and from that information the Floodplain Management Committee has made recommendations detailed in the table below. The Draft Floodplain Risk Management Study and Plan will be placed on public exhibition to allow the broader community and stakeholders to provide feedback on the recommendations.

Ref	Option	Description	Benefits	Concerns	Priority
FM0403A & FM0403B (Section 10.2.9.1)	Hawthorne Canal - Grosvenor Crescent and Smith Street flow path pipe upgrade, above ground detention basin and levee wall	The option uses Darrell Jackson Gardens, Summer Hill skate park and the tennis courts as an above-ground detention basin. The proposed option includes additional drainage at a topographical low point in Grosvenor Crescent which travels under the railway embankment to Carlton Crescent.	Retain flood water to allow additional capacity in the stormwater system. Flood levels are reduced in Hardie Avenue and Lackey Street. The frequency of overfloor inundation (and hence property damage) is reduced for up to 6 properties across the full range of events. The option is considered to be economically viable with a benefit cost ratio of 5.1.	The detention basin would flood the playground which is located along the rear of the IGA building, as well as the tennis courts. This could pose a community safety risk, particular as flood depths are in excess of 1 m even for frequent events. The spillway located along the pedestrian walkway may also pose a risk to safety with fast flowing water. Mitigation of these risks should be considered in any further assessment of the option. Signage and education would be required to improve public safety. Impacts of temporarily stored water on the skate park and equipment would require further consideration.	High
FM0404C (Section 10.2.9.2)	Hawthorne Canal - Nowranie Street to Hawthorne Canal pipe upgrade	The option proposes the duplication of the existing Council drainage network system between Morris Street and Hawthorne Canal.	Diverts additional runoff into the stormwater pipe to reduce flooding along the overland flowpath. Moderate reduction in flood levels along the flow path, most significantly at Nowranie Lane. The frequency of overfloor inundation (and hence property damage) is reduced for up to 3 properties across the full range of events.	Below ground construction through existing properties could present a challenge.	Medium

Ref	Option	Description	Benefits	Concerns	Priority
FM0501G (Section 10.2.9.3)	Hawthorne Canal - Petersham Park above-ground detention basin, with access moved to southern corner	The option involves the use of Petersham Park as an above-ground detention basin during flood events.	Retain flood water to allow additional capacity in the stormwater system. Flood levels are reduced in the downstream flowpath including at Station Street. The frequency of overfloor inundation (and hence property damage) is reduced for up to 5 properties across the full range of events.	The detention basin would temporarily store flood water resulting in potential damage and loss of use of the fields. Could pose a community safety risk. Mitigation of these risks should be considered in any further assessment of the option. Signage and education would be required. The site has potential heritage and environmental constraints as is a known Bandicoot habitat.	Medium
FM0605C (Section 10.2.9.4)	Hawthorne Canal - Sloane Street pipe upgrade	The option involves the duplication of the existing drainage network from the intersection of Sloane Street and Parramatta Road to Hawthorne Canal.	Flood levels are reduced on Parramatta Road by up to 0.2m. The frequency of overfloor inundation (and hence property damage) is reduced for up to 7 properties across the full range of events. The NSW Ambulance site is adjacent to this intersection. The option is considered to be economically viable with a benefit cost ratio of 2.5.	Challenges with below ground construction exist. Coordinating construction on a major road would be challenging.	High
FM0703 (Section 10.2.9.6)	Dobroyd Canal - Pratten Park and Arthur Street under-ground detention basin	The option involves the construction of an underground detention basin in Pratten Park and beneath the tennis courts (Arthur Street).	Retains flow to allow greater capacity within the drainage system to reduce overland flooding down to Dobroyd Canal. Flood levels are reduced through the flow path by up to 0.15m. The frequency of overfloor inundation (and hence property damage) is reduced for up to 50 properties across the full range of events. The option is considered to be economically viable with a benefit cost ratio of 1.2.	Private ownership of tennis courts may present a challenge. The detention basin would temporarily store flood water resulting in potential damage and loss of use of the fields. This could also pose a community safety risk. Mitigation of these risks should be considered in any further assessment of the option. Signage and education would be required.	High

Ref	Option	Description	Benefits	Concerns	Priority
RM01 (Section 10.4.1)	Flash flood warning system - Heighway Avenue and Fred Street	Various measures to continue and improve flood warning systems, both to enhance flood forecasting and dissemination of information to the public.	Improved warning systems will better increase the accuracy and timeliness of flood predictions and improve the communication methods to deliver accurate and persuasive messages during flooding. This allows action to be taken to minimise the impacts of flooding.	The catchment has a short warning time which may limit the implementation of such a system.	High
RM02 (Section 10.4.2)	Update flood intelligence and other plans with FRMS&P data	Review and update current Council and SES emergency flood response documents, drawing from latest modelling and recent floods.	Improved flood planning reduces flood risk to life and property, assisting residents of flood prone areas better prepare themselves and their property for flooding.	There are a number of documents to be updated and coordinated.	High
RM03 (Section 10.4.3)	Community education program	Ongoing community engagement is key to maintaining flood awareness, which can wane as time between flood events increases.	A flood aware community is generally better prepared for flooding, more responsive to evacuation orders and more resilient in recovery.	Over engagement can lead to the community ignoring messages.	High
PM01 (Section 10.3.1)	Flood planning levels	Setting minimum floor levels with the aim to reduce ongoing flood damage as redevelopment occurred.	Reduction in flood damages in the longer term.	Can be challenges due to streetscape changes and can be perceived as an added cost by some developers.	High
PM02 (Section 10.3.2)	Flood proofing	Allow for flood proofing as an alternative where increased floor levels are not feasible (such as refurbishment).	Reduction in flood damages in the longer term.	Can be less guaranteed that increasing floor levels.	High

1. INTRODUCTION

1.1. Overview

The Dobroyd Canal Flood Study and Hawthorne Canal Flood Study (Reference 1 and 2) were completed in late 2014 and early 2015 respectively. This Floodplain Risk Management Study and Plan (FRMS&P) builds on the understanding of flood behaviour provided by the Flood Study investigations, to consider and compare various options to manage the flood risk to the study area. These management options have the primary aim to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk.

1.2. Study Objectives

The overall objective of this study is to develop floodplain risk management plans for the Dobroyd Canal and Hawthorne Canal study areas which address the existing, future and continuing flood risk. The Study will take into account the potential impacts of climate change, in accordance with the NSW Government's Flood Prone Land Policy, as detailed in the *Floodplain Development Manual* (Reference 3). The overall study will be undertaken in two phases:

Phase I – a floodplain risk management study in which the floodplain management issues confronting the study areas are assessed, management options investigated, and recommendations made

Phase II – a floodplain risk management plan developed from the floodplain risk management study detailing how flood prone land within the study area is to be managed.

Specific objectives of the FRMS&P have been identified by Council as:

1. Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
2. Reduce private and public losses due to flooding.
3. Protect and where possible enhance the river and floodplain environment.
4. Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979.
5. Ensure that the floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.
6. Ensure actions arising out of the plan are sustainable in social, environmental, ecological and economic terms.
7. Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.

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

1.3. Previous Studies and Reports

1.3.1. Dobroyd Canal Flood Study, WMAwater 2014 (Reference 1)

The Dobroyd Canal Flood Study was undertaken on behalf of the former Ashfield Council and Burwood Council by WMAwater in 2015 (Reference 1).

The primary objectives of the Flood Study were to:

- determine the existing flood behaviour for the study area in terms of peak flood levels, depths, velocities, flows and extents. These were determined for the 0.5EY, 0.2EY, 10% AEP, 5% AEP, 2% AEP, 1% AEP and PMF events. The flood mechanisms assessed included local overland runoff and coincidental tidal influences;
- establish a model that can determine the effects of future developments on flood behaviour;
- assess the provisional hydraulic categories and provisional hazard, preliminary emergency response classifications and Flood Planning Areas (FPAs); and
- assess the sensitivity of flood behaviour to potential climate change effects, such as increases in rainfall and sea level rise.

A total of 1446 lots were identified for flood related development controls as part of the FPA investigation in the former Ashfield LGA. The flood mechanisms that determined inclusion in the FPA are shown in Table 1.

Table 1: Dobroyd Canal Flood Study – Flood Planning Area

No. properties identified in FPA	Mainstream flooding	Overland flooding	Both Mainstream and Overland	Total
Ashfield LGA	95	885	466	1446

1.3.2. Hawthorne Canal Flood Study, WMAwater 2015 (Reference 2)

The Hawthorne Canal Flood Study was undertaken on behalf of the former Ashfield Council and former Marrickville Council by WMAwater in 2014 (Reference 2) and had the same objectives as for Reference 1.

A total of 607 lots were identified for flood related development controls as part of the FPA investigation in the former Ashfield LGA; and 429 properties were identified in the former Marrickville LGA. The flood mechanisms that determined inclusion in the FPA are shown in Table 2.

Table 2: Hawthorne Canal Flood Study – Flood Planning Area

No. properties identified in FPA	Mainstream flooding	Overland flooding	Both Mainstream and Overland	Total
Ashfield	60	386	161	607
Marrickville	33	304	92	429
Total	93	690	253	1036

1.4. Available Data

The Dobroyd Canal Flood Study (Reference 1) and Hawthorne Canal Flood Study (Reference 2) provided the majority of data that was used in this study. The available data includes existing hydrological and hydraulic models, GIS layers including cadastral data, roads, zoning etc. As part of the FRMS&P, some of the existing data was superseded or supplemented with the most up to date information. These are described below.

1.4.1. LiDAR

Airborne Light Detection and Ranging (LiDAR) survey of the catchment and its immediate surroundings was obtained from Land and Property Information, which is a division of the NSW Department of Finance, Services and Innovation. It was indicated that the data were collected in 2013. These data typically have accuracy in the order of:

- +/- 0.15m (for 70% of points) in the vertical direction on clear, hard ground; and
- +/- 0.75m in the horizontal direction.

The accuracy of the LiDAR data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of the survey. The 1 m by 1 m Digital Elevation Model generated from the LiDAR formed the basis of the two-dimensional TUFLOW hydraulic modelling for the studies.

1.4.2. Pit and Pipe Data

An existing pit and pipe network was provided as part of the Flood Studies. The dataset was provided by Ashfield, Burwood and Marrickville Councils as well as Sydney Water Corporation and is made up of underground pipes and open channels. Since the completion of the flood study, there have been a number of revisions and these changes are detailed in Section 21.

1.4.3. Floor Level Survey

Building floor levels are required in order to undertake an assessment of potential flood damage and to estimate Average Annual Damages (AAD) for the purpose of comparing floodplain management strategies. A database of estimated building floor levels was produced for all properties (residential and commercial) that were within the preliminary Probable Maximum Flood (PMF) extent. Floor levels were compiled by using LiDAR to estimate ground levels at each building and adding a height-above-ground estimate for floor level heights above ground. These height-above-ground estimates were determined via site inspection, desktop analysis (i.e. "Google Streetview") or other available documents such as Development Applications. Various techniques were used to determine a height-above ground estimate. These include counting the number of bricks or steps from ground level to floor level, or other approximation methods. This technique provides a sufficient level of accuracy for undertaking flood damages assessment. Table 3 details the number of the floor levels estimates collected for the study.

Table 3: Floor Level Survey: Dobroyd and Hawthorne

Floor Level Survey Method	Hawthorne Canal	Dobroyd Canal
Site Visit	462	537
Desktop Analysis	1879	2491
Supplementary Data (ie. DA Plans)	7	0
Total	**2348**	**3028**

2. CATCHMENT BACKGROUND

2.1. Physical Characteristics

The Dobroyd Canal and Hawthorne Canal catchments discharge into Iron Cove on the Parramatta River. The open channel sections are concrete-lined and extend up to Norton Street along the Dobroyd Canal and up to Pigott Street along the Hawthorne Canal. The open channels are tidal to upstream of Parramatta Road and the average slope along the open channel in the downstream portion of the catchments is less than 1%. Elevations in the upstream portion of the catchments reach approximately 55 m AHD with slopes of between 2% and 4%.

Sydney Water Corporation (SWC) own and maintain the open channel and major stormwater drainage network that discharges into the open channel. Council own and maintain the local stormwater drainage network that discharges into the SWC network.

The upstream and downstream portions of the catchments are separated by the embankment that forms the Western Rail Track (T1 Line), orientated east to west. The Light Rail Track (L1 Line) bisects the Hawthorne Canal catchment in a north-south orientation; at times in the form of an embankment and at others as cuttings. The Western Rail Track and Light Rail Track are owned and maintained by Transport NSW.

The Study Areas for the Dobroyd Canal and Hawthorne Canal catchments are shown in Figure A1 and Figure B1 respectively.

2.2. Current Land Use

The land use zones as identified in the Ashfield LEP 2013 and Marrickville LEP 2011 are shown on Figure A2 and Figure B2. The majority of the study area is zoned for low density residential. Areas of medium and high density residential are located around the Light Rail Track, the Western Rail Track and towards Parramatta Road. Along Parramatta Road, the area is zoned as an enterprise corridor for business. Mixed use development is zoned for along Liverpool Road / Hume Highway. Public recreation areas are scattered around the study area, with some bands located along the open channel area of Dobroyd Canal and Hawthorne Canal.

2.3. Historical Development

The historical development of the study area provides important insights into the current flood issues and the key mechanisms driving those flood issues.

Records from publishers and lithographers Higinbotham & Robinson map the area circa 1885-1890, shown in Figure A3 and Figure B3. Within this, Dobroyd Canal is identified as Iron Cove Creek and Hawthorne Canal is identified as Long Cove Creek. During this period, the watercourses were in their natural state and conveyed stormwater and sewage from the relatively large population that had settled in the area.

In 1890, the then Minister for Public Works, the Hon. Bruce Smith, proposed stormwater drainage be constructed across Sydney. The purpose of such works was to assuage the city's public health problems. The Dobroyd Stormwater Channel and Hawthorne Stormwater Canal were among the first nine built, with construction having commenced in 1892 and 1890 respectively. Both are identified as having local heritage significance due to the original brickwork construction, with the Hawthorne Canal considered to represent the best example as it is currently the most intact of the nine that were built.

2.4. Cultural and Heritage Considerations

There are a number of locations within the study area that are registered as being of historical significance. From the Heritage Council of NSW under the NSW Heritage Act (including listings on the State Heritage Register, an Interim Heritage Order or protected under Section 136 of the NSW Heritage Act), the following heritage items were located in the study area:

- Croydon Railway Station Group;
- Petersham Railway Station Group;
- Lewisham Railway Viaducts over Long Cove Creek;
- Lewisham Sewage Aqueduct (Grosvenor Crescent East);
- Sewer Vent (The Boulevarde, Lewisham);
- Relay Test Centre (11 St Davids Road, Haberfield);
- St David's Uniting Church (51-53 Dalhousie Street, Haberfield);
- Bunyas (5 Rogers Avenue, Haberfield);
- Derrylyn (16 Deakin Avenue, Haberfield);
- Yasmar (185 Parramatta Road, Haberfield); and
- Egyptian Room Scottish Temple (23-25 New Canterbury Road, Petersham).

The Ashfield LEP 2013 and Marrickville LEP 2011 identify several additional locations as having heritage significance; either by way of a heritage item or a heritage conservation area, shown on Figure A4 and Figure B4. Of note from this is that large portions of Haberfield, located north of Parramatta Road, are designated heritage conservation areas.

The main consideration of these heritage issues for the purposes of this study is the potential conflict with flood-related planning controls or property modification measures. For example, house raising or flood proofing may not be compatible with heritage requirements for some houses and shops, and minimum floor level controls may conflict with streetscape requirements in heritage areas.

2.5. Environmental Considerations

The study area is largely urbanised and the open channels are currently concrete-lined with limited associated ecology. Concurrent and separate to this study, SWC have commissioned Jacobs to investigate the naturalisation of the Dobroyd Canal and Hawthorne Canal, which is owned and maintained by SWC. The outcomes of this investigation were incorporated into this study and further details are provided in Section 4.2.

2.6. Social Characteristics

The study area includes the suburbs of Ashfield, Haberfield, Summer Hill and parts of Petersham, Lewisham, Dulwich Hill and Croydon. Information is available from the 2016 census (www.abs.gov.au) which helps to define the social characteristics of the study area. Understanding the social characteristics of the area can help to inform the risk assessment process through providing metrics for some of the aspects which influence the vulnerability of a community. These include:

- physical vulnerability; measured through age demographics with the young (<14) and the elderly (>65 as defined by the United Nations);
- flood awareness; measured through years lived in current location, mortgage or home owners, ability to speak English, and having access to the internet at home;
- mobility; measured through having access to a car at home, and the number of people per dwelling; and
- financial resilience; measured through average incomes.

Table 4 below shows the 2016 census statistical for the available State Suburbs compared to the NSW average. Understanding the social characteristics of the area can help in ensuring that the most appropriate floodplain risk management practices are adopted, and shape the methods used for community engagement.

Table 4: Census Statistics Summary

	NSW	Ashfield	Haberfield	Summer Hill	Petersham	Lewisham	Dulwich Hill	Croydon
Population demographics:								
Median age	38	34	44	36	35	36	37	40
0 – 14 years	18.5%	12.3%	18.6%	14.6%	13.9%	12.9%	15.7%	16.5%
15 - 64 years	65.1%	73.6%	61.7%	71.7%	76.2%	74.0%	72.2%	66.0%
> 65 years	16.2%	14.1%	19.6%	13.7%	9.9%	13.1%	12.1%	17.5%
Average people per dwelling	2.6	2.5	2.8	2.5	2.3	2.3	2.3	2.9
Average children per family	1.9	1.5	1.9	1.6	1.6	1.6	1.7	1.8
Own/mortgage property	64.5%	45%	79%	52%	47%	52%	53%	66%
Rent property	31.8%	51%	19%	45%	49%	45%	44%	29%
Moved into area:								
- within last year	19.4%	28%	16%	25%	28%	31%	25%	19%
- within last five years	38.9%	56%	34%	50%	54%	55%	49%	41%
No vehicles at dwelling	9.2%	22%	9%	19%	21%	19%	16%	12%
Average vehicles per dwelling	1.7	1.2	1.7	1.3	1.1	1.2	1.2	1.5
Speak only English at home	68.5%	40%	65%	54%	70%	72%	62%	50%
Households where non-English is spoken	26.5%	54%	44%	27%	27%	28%	35%	51%
Other languages spoken (top 3 by percentage spoken)		Mandarin 14% Nepali 7% Cantonese 5%	Italian 21% Greek 2% Mandarin 2%	Mandarin 6% Greek 5% Italian 4%	Portuguese 3% Greek 3% Spanish 2%	Greek 3% Portuguese 2% Spanish 2%	Greek 6% Arabic 3% Vietnamese 3%	Mandarin 11% Cantonese 6% Italian 6%
Internet not accessed at home	14.7%	12%	17%	13%	11%	10%	12%	13%
Median weekly income	$1,802*	$1,643	$2,164	$1,777	$1,966	$1,974	$1,809	$1,846
< $650 gross per week	16.3%*	18%	15%	16%	14%	16%	15%	17%

* **Note**: for median weekly income and percentage earning below $650 gross, the Sydney (urban centre and locality) data is reported rather than the NSW average

Overall the demographics of the suburbs showed a greater than average 14 - 65 population, which suggests physical vulnerability is not likely to be a major contributor to community vulnerability.

With the exception of Haberfield and Croydon, the other suburbs in the study area had a much higher proportion of renters than mortgage / owners compared to the NSW average, and a higher proportion of newly arrived residents. This suggests maintaining an ongoing awareness of flooding in the study area may be pragmatic as the population is considered more transient than other areas in NSW. This is compounded by a very large population of households where non-English languages are spoken at home (for the suburbs of Ashfield, Haberfield, Dulwich Hill and Croydon), which means ongoing education and awareness activities may not be effective unless communicated in a range of languages. There is a wide variety of other languages spoken in the catchment, only the top 3 (by percentage) are shown in Table 4. Effective communication of key flood risk and emergency management information to this diverse audience will be a challenge.

Overall the area generally had a higher proportion of the community without access to a motor vehicle at home, however the average people per dwelling and the average number of children per dwelling was generally lower than the NSW average, suggesting mobility is not likely to be a major influence on vulnerability.

Ashfield was noted as having a potentially higher proportion of financially vulnerable residents, with the weekly average income being nearly 10% lower than the Sydney average, and a higher proportion of low income (considered to be those earning less than $650 per week) residents.

2.7. Vulnerable Properties

Table 5 and Table 6, Figure A5 (Dobroyd Canal) and Figure B5 (Hawthorne Canal) provide a summary of the vulnerable properties in the study area. These are important to note as the presence of vulnerable properties must be considered when determining evacuation measures, should they be shown to be at risk of flooding.

Table 5: Vulnerable Property by Use Located within the Hawthorne Canal catchment

Site Address	Flooding Description
Medical Services	
Zagarella S 252 Queen Street, Ashfield	The site is not affected by flooding. However, two shallow overland flowpaths originating from the east and travel west across and perpendicular to Queen Street on either side of the site may restrict access to the site.
Childcare centres	
KU Children's Services Henson Street & Short Street, Summer Hill	This site is not flood affected. However, the site is located in an area where all access roads in the vicinity are affected by shallow overland flow (typically less than 0.1 m such as Drynan Street) or become cut-off (>0.3 m depth) from the 0.5 EY event (Smith Street and Hensen Street).

Schools	
Trinity Grammar School 119 Prospect Road, Summer Hill	The site is affected by minor overland flooding but it does not affect buildings and does not restrict access completely
Summer Hill Public School Moonbie Street, Summer Hill	The west and southern boundary are affected by shallow overland flow (< 0.1 m) from as frequent as the 0.5 EY event. This event does not affect buildings and does not restrict access completely.
St Patrick's Catholic Primary School 9 Drynan Street, Summer Hill	The site is not affected by flooding, however minor overland flooding is present at the north east boundary but does not restrict access completely.
Yeo Park Infants School Victoria Street, Ashfield	The property is located along an overland flow path originating from the east and travelling west affecting the southern boundary of the site. The site is located between both Victoria Street and Old Canterbury Road that becomes cut off (>0.3 m depth) in a 0.5 EY event. It is recommended that inhabitants evacuate to the north of the side where road access is available to the north of the site along Victoria Street.
Ashfield Early Learning Centre 10 Norton Street, Ashfield	The site is not affected by flooding, however minor overland flooding present at the north east boundary does not restrict access completely.
Summer Hill Children's Centre Corner Moonbie & Lorne Streets, Summer Hill	This site is not flood affected. However, the site is located in an area where all access roads in the vicinity are affected by shallow overland flow (typically less than 0.1 m) or become cut-off (>0.3 m depth) from the 0.5 EY event (including Moonbie Street, Morris Street and Hensen Street).
Aged care services	
Mary MacKillop Outreach 1-5 Rogers Avenue, Haberfield	Not flood affected. Access is not completely restricted to the site.
Windermere Aged Care Facility 5 Henson Street, Summer Hill	This site is not flood affected. However, the site is located in an area where all access roads in the vicinity are affected by shallow overland flow (typically less than 0.1 m such as Drynan Street) or become cut-off (>0.3 m depth) from the 0.5 EY event (Smith Street and Hensen Street).
Hardi Aged Care/ Wyoming Nursing Home 47 Grosvenor Crescent, Summer Hill	The site is affected by flooding during the PMF event along the southern portion of the property where depths at the access point on Grosvenor Crescent reach 0.3 m depth, affecting access to the site. No buildings are affected by flooding. In frequent flood events, access to the site via Grosvenor Crescent from the east is cut-off from the 0.5 EY event, where flood depths reach 0.7 m.
Bupa Aged Care Ashbury 16 Hardy Street, Ashfield	Not flooded affected. Access is not completely restricted to the site.
Woodfield Retirement Village Nursing Home 51/61 Parramatta Road, Haberfield	Shallow overland flow is located along the southern boundary located adjacent to Parramatta Road. No buildings are affected by flooding.

Saint Joan of Arc Villa 7 Tillock Street, Haberfield	The site is located within an overland flow path that originates from the east, then travels west through the site, and continues west. All buildings (4) within the site are flood affected and surrounded by floodwaters in the 0.5 EY event where flood depths are typically the deepest on the upstream side of the buildings. Access to the site via Tillock Street is cut-off from the 0.5 EY event where the flood depths exceed 0.3 m at the driveway entrance.
Summer Hill Aged Care Services Nursing Home, 102 Prospect Road, Summer Hill	The site becomes affected by shallow overland flow (<0.1 m) along the east (Prospect Road) and the northern boundary in a 0.5 EY event. Access to the site (on Prospect Road) is restricted during all design flood events above the 0.5 EY event, however do not become cut-off (<0.3 m).

Table 6: Vulnerable Property by Use Located within the Dobroyd Canal catchment

Site Address	Flooding Description
Medical Services	
The Sydney Private Hospital, 63 Victoria Street, Ashfield	Shallow ponding (<0.2 m depth) occurs at the site carpark in the 0.5 EY event. Access to Queen Street via Robert Street is cut at events above the 0.2 EY, however, access is still available via Clissold Street. Deep ponding (<0.5 m depth) occurs around the property in the PMF event, restricting access to the site via Victoria Street and Robert Street.
MultiCare Dental, 240 Liverpool Road, Ashfield	The site is not flood affected. Access to Elizabeth Street via Brown Street is restricted (2.5 m depth) in the 0.5 EY event and rarer.
Hercules Street Family Medical Practice, 32 Hercules Street, Ashfield	The site is not flood affected. Access to Elizabeth Street via Brown Street is restricted (2.5 m depth) in the 0.5 EY event and rarer.
Brandt's Physiotherapy Clinic Suite 101B, 2 Holden Street, Ashfield	The site is not flood affected. Road access west of the site is cut on Liverpool Road (0.7 m depth), Elizabeth Street (0.6 m depth), and Arthur Street (0.5 m depth) in events rarer than the 5% AEP event.
Haberfield Medical Centre/The Ramsay Street Medical Centre, 112 Ramsay Street, Haberfield	The site is affected by overland flow (<0.2 m depth) along Gillies Avenue and Ramsay Street boundaries in a 0.5 EY event. The building is affected by depths <0.2 m on the southern side during a 10 % AEP event or rarer. Access to the site is cut on Ramsay Street in the PMF event (<0.6 m depth), and depths <0.4 m occur on the southern and western sides of the building.
Your Doctors, 37 Henry Street, Ashfield	The site is affected in the PMF event by depths less than 0.2 m on the southern side of the building. Access north of the site on Frederick Street is cut (<1.2 m depth) although the site remains accessible via Henry Street.
Modern Specs, 274 Liverpool Road, Ashfield	The site is not flood affected in any modelled event. Road access west of the site is cut on Liverpool Road (<0.7 m depth), Elizabeth Street (0.5 m depth), and Norton Street (<0.7 m depth) in the 10% AEP event and rarer.
Childcare centres	
KU Croydon Preschool, 6 Railway Street, Croydon	The site is flood affected in the PMF event at depths up to 0.6 m along the south east boundary. Access to Elizabeth is restricted (<0.3 m depth) in the 0.5 EY event and rarer.

Kindy Patch Ashfield, 89 Frederick Street, Ashfield	The site is flood affected in the PMF event, with minor flooding occurring on the southern side of the building (<0.2 m depth). However, access is cut on Frederick Street in both directions (<0.2 m depth) in the 10% AEP event and rarer.
Hosanna Childcare Centre, 46 Queen Street, Ashfield	The site is affected by overland flow on the western side along Queen Street (<0.3 m depth) and the northern side along Robert Street (<0.2m depth) in the 10% AEP event and rarer. Access from these roads is restricted (0.3 m – 0.5m depths) in the 5% AEP event and rarer.
Woodstock Child Care Centre, 1 Watson Avenue, Croydon Park	The site is flood affected along the western side of the building in the 0.5 EY event and rarer. Watson Avenue south of the site is cut in this event (<0.3 m depth).
Schools	
Guardian Early Learning Centre, 183 Parramatta Road, Haberfield	The site it not flood affected in any modelled event. Parramatta Road is cut (<0.3 m depth) in the 0.5 EY event and rarer.
GoodStart Early Learning, 25 Rogers Avenue, Haberfield	The site is not flood affected in any modelled event. Access to Parramatta Road via Rogers Avenue is maintained in events as rare as the PMF event.
Uniting Ella Early Learning Haberfield, 1 Winchcombe Avenue, Haberfield	The site is not flood affected in any modelled event. Ramsay Street, north of the property is cut (<0.3 m depth) in the 0.2 EY event.
St Joan of Arc 0SH, 88 Dalhousie Street, Sydney, Haberfield	The site is affected by pooling (<0.7 m depth) on the northern side of the building. Road access is not cut in large events, including the PMF.
The Hope Centre, 15-17 Rawson Street, Haberfield	The site is not flood affected. Access to the site via Ramsay Street is cut (0.3 m depth) in the 0.2 EY event and rarer. However, access from the northern side of Rawson Street or the eastern side of Martin Street is not restricted.
St John's Pre-School Ashfield Inc. 64 Bland Street, Ashfield	The site is not flood affected. Access to the site is restricted from both sides of Bland Street in the 10% AEP event and rarer. Access to Elizabeth Street via Julia Street is not restricted in events as rare as the PMF.
Rainbow Educational Child Care Centre, 181 Elizabeth Street, Ashfield	The site is flood affected in events as frequent as the 0.5 EY, with water pooling (0.2 m depth) on the western side of the building. Access is restricted from all streets surrounding the site in the 5% AEP event and rarer. This event causes significant pooling (0.4 m depth) on the western side of the building.
Little VIPs Child Care Haberfield, 113 Dobroyd Parade, Haberfield	Access to the site is restricted via Parramatta Road (0.4 m depth) and Dobroyd Parade (<0.5 m depth) in the 5% AEP event and rarer. The site becomes flood affected in the PMF event, water surrounding the property range in depth from 1 m to 2 m.
Croydon Montessori Academy, 57 Edwin Street South, Croydon	The site is affected by ponding (0.3 m depth) at the rear of the building in events as frequent as the 0.5% AEP. The PMF event causes 0.8 m to 1.2 m depths on the northern and eastern sides of the building. Access to the site is cut via Heighway Avenue (0.5 m depth), Thomas Street (<0.4 m depth), and Paisley Road (>1 m depth) in the 0.2 EY event and rarer. However, access to Liverpool Road via Edwin Street is maintained.
De La Salle College, Ashfield, 24 Bland Street Ashfield	The site is not flood affected. Access to the site is restricted to the north on Bland Street (<0.3 m depth) and to the south on Bland Street (>3 m depth) in the 2% AEP event and rarer. Access to Elizabeth Street east of the property is maintained.

St Vincent's Primary School, Ashfield, 30-34 Charlotte Street, Ashfield	The site is not flood affected. Access to the site is restricted to the north on Charlotte Street (>0.4 m depth) in the PMF event. Access to Elizabeth Street via Webbs Avenue is maintained in this event.
Haberfield Public School, Bland Street, Haberfield	The site is not flood affected. Access to the site via Tinana Street is maintained in events as rare as the PMF.
Dobroyd Point Public School, Waratah Street, Haberfield	The site is not flood affected. Access east via Loudon Avenue and Waratah Street is maintained in events as rare as the PMF.
Bethlehem College, 18 Bland Street, Ashfield	The site is not flood affected. Access to the site is cut from lower Bland Street, where flood depths reach 3.5 m in the PMF event.
Business	
Sabaidee Ashfield Thai Massage, 208 Liverpool Road, Ashfield	The site is not flood affected. Access to the site is restricted to the north via Brown Street (2.5 m depth) and to the south via Holden Street (0.3 m depth) in events as frequent as the 0.2 EY event. Access to the site is maintained via Norton Street in events as rare as the PMF.
Aged care services	
Presbyterian Aged Care, 40 Charlotte Street, Ashfield	The site is not flood affected. Access via Charlotte Street (<0.3 m depth), northern Bland Street (0.4 m depth), and southern Bland Street (>4 m depth) is cut in the PMF event. However, access to Elizabeth Street west of the site via Webbs Avenue is maintained.
Bupa Aged Care Ashfield, 126-128 Frederick Street, Ashfield	The site is not flood affected except for ponding (0.4m depth) on the northeast side of the building in the PMF event. Access via Frederick Street is cut in both directions, ranging in depths of 0.7 m to 1 m. However, access is maintained via southern Church Street through minor ponding (0.2 m depth).
Pittwood Nursing Home, 23 Charlotte Street, Ashfield	The site is not flood affected. Access to Elizabeth Street is maintained via Webbs Avenue.
Uniting Abrina Ashfield, Abrina Convalescent Home, 19 Victoria Street, Ashfield	The site is not flood. Arthur Street is affected by shallow overland flow (0.2 m depth) in the PMF event. Access is maintained via Victoria Street and Norton Street.
The Willows Private Nursing Home Pty Ltd, 84 Orpington Street, Ashfield	The site is not flood affected. Access is cut west of the site on Orpington Street (0.3 m depth) in events as frequent as the 0.2 EY, however, access to Parramatta Road is maintained via east Orpington Street and Loftus Street.
Eremea Home Care Services, 350 – 352 Ground Floor, Liverpool Road, Ashfield	The site is flood affected in events as frequent as the 10% AEP event. The northern most building is surrounded by flood depths of up to 0.8 m, and the building south of it is affected by depths up to 0.4 m on the northern side. All buildings are surrounded by water at depths up to 1.7 m in the PMF event. Access is cut from all surrounding roads with depths greater than 1 m in the PMF event.
Presbyterian Aged Care,169-173 Parramatta Road, Haberfield	The site is not flood affected. Parramatta Road north of the site is affected by shallow overland flow (<0.3 m depth) in the 1% AEP event. Access to Parramatta Road south of the property is maintained in all events.
Disability Services	
Sunnyfield Ashfield Short-term Accommodation, 1 Hampden Street, Sydney	The site is not flood affected. Access to the site is maintained via Norton and King Street, however, access east via Arthur Street is cut (>1 m depth).

Wesley LifeSkills Ashfield, 193 Norton Street, Ashfield	The site is not flood affected. Access east via Liverpool Road is cut (>0.5 m depth) in events as frequent as the 10% AEP. Access is maintained in King Street via Norton Street for events as rare as the PMF.
Juvenile Correction Centres	
Juvenile Justice - Yasmar Training Facility, 185 Parramatta Road, Haberfield	The site is not flood affected in any modelled event. Access to the site to Tinana Street via Chandos Street is maintained in events as rare as the PMF.

3. COMMUNITY CONSULTATION

3.1. Summary

Community consultation was undertaken over the course of January and February 2017 to inform residents of the next stage of the floodplain risk management process as well as to gather further flood information within the former Ashfield and Marrickville LGAs. This included distribution of an information sheet and a questionnaire. The questionnaire requested information such as details about length of residency in the catchment, descriptions of any experiences of flooding, descriptions of flood affection and evidence of flood heights or extents such as photographs of flood marks.

The full set of results from the community consultation questionnaire are summarised in Figure A6(A) and Figure B6(A). The locations of the community consultation respondents are shown in Figure A6(B) and Figure B6(B). Details of the areas where multiple respondents have reported flooding are discussed below.

In total, 111 responses were received, with respondents evenly distributed across the study areas. From this, it was found that 68% of residents reported some experience of flooding. The April 2015 event was identified as the most extreme event with 58% of respondents saying they had experienced the event. The October 2014 and January 2016 events were also identified as being significant events. Rainfall data for these three storm events including rainfall distributions of both depth and AEP estimates are shown in Appendix E.

The April 2015 event was found to be a short, intense burst storm event; with relatively high approximate AEPs for the 30-minute duration. Across both the Dobroyd and Hawthorne Canal catchments, the approximate AEP ranged from 1 EY to 20 % AEP where the most affected area was located along the border between both catchments.

The October 2014 event was found to have an approximate AEP of between a 0.5 EY and a 5 % AEP. Whilst this event recorded the highest AEP, the rainfall fell over a period of 3 hours (critical duration across the catchment is 1 hour) which resulted in less severe flood affectation.

The January 2016 event was found to be highly localised to the south east of the study areas. Within the Dobroyd Canal and Hawthorne Canal catchment area this event was found to have an approximate AEP range of 1 EY to 0.2EY.

75% of the respondents reported flooding on roads and footpaths. Low lying areas, drainage deficiencies, and pit blockage due to leaves and hail were identified most commonly as the cause of flooding by respondents. High tides and overdevelopment were also reported as causes of flooding.

3.2. Petersham Park (Petersham)

Residents around Petersham Park including Station Street, Brighton Street, West Street and Palace Street reported overland flooding with April 2015 and January 2016 being the most commonly identified events. During flood events, it was reported that flow enters properties along Palace Street where a low point causes flow to overtop the footpath and move north-west through properties. Station Street (along the eastern boundary of Petersham Park) serves as a formalised overland flow path where respondents reported overflow onto footpaths and entering properties. Inadequate drainage and blocked drains were identified as causes of flooding. Significant damage to cars and properties was reported in this area.

Photo 1: Debris blocking drains on Station Street

Photo 2: Flooding on Station Street

3.3. Sloane Street / Parramatta Road (Haberfield)

Reports of flooding along an overland flowpath downstream of the Sloane Street and Parramatta Road intersection were reported for multiple events including the January 2016, April 2015 and October 2013 events. Residents reported flooding within the house/business (3), yard (2) and in the street above the footpath (6). The main reasons for flooding are considered by the respondents to be drain blockage (leaves and other debris), and inadequate drainage forcing water to overtop the gutters and enter properties. The damage incurred to cars, and house and contents were described as significant. Clearing of pipes and increased drainage infrastructure were suggested as mitigation options.

Photo 3: Intersection of Parramatta Road and Sloane Street, Looking East along Parramatta Road – 14 October 2014 (Source: Ty Oliver via news.com.au)

3.4. Hawthorne Parade (Haberfield)

Over 19 instances of overland and/or mainstream flooding have been reported along Hawthorne Parade. Eight residents reported flooding in the street and over the footpath but only one respondent reported flooding within the house/business. Responses noted flood affectation due to king tides and higher-than-average tides that overtopped the canal and inundated low lying ground in the vicinity of Hawthorne Parade. Responses also mentioned that water back flowing through the stormwater system had been known to surcharge into the low lying road gutters.

Photo 4: Flooding in backyard adjacent to Hawthorne Canal

Photo 5: Flooding at the intersection of Hawthorne Parade and Lord Street, Haberfield

Photo 6: Flooding due to King Tide on Hawthorne Parade – upstream of the City West Link Bridge (5 June 2016)

Photo 7: Flooding due to King Tide under the City West Link Bridge (5 June 2016)

3.5. Flood of 7 February 2017

The 7 February 2017 event was a relatively short duration burst event (with a 1 hour duration) that moved across Sydney in a generally south-west to north-east direction. It was not reported in the community consultation as it occurred post the submissions. At the Canterbury Racecourse gauge located to the south of the catchment, the rainfall peaked between 9am and 10am; with an approximate EY of between a 0.5 to 0.2 EY event for a 1 hour storm burst. At the Ashfield Bowling Club gauge, located on the boundary between the Dobroyd Canal and Hawthorne Canal catchments, the rainfall peaked between 10am and 11am; with similar EYs for a 1 hour storm burst. The following photographs were obtained from news sources and indicate that even for a relatively frequent flood event there is a considerable amount of overland flow and ponding in roads.

Photo 8: Railway Terrace, Looking North – 7 February 2017 (Source: Steven Siewert via the Sydney Morning Herald)

The Parramatta Road intersection is known to experience flooding in relatively small rainfall events; such as the 7 February 2017 event. From this event, video footage was posted online by the ABC showing cars driving through floodwater at this intersection (with selected video frames shown in Photo 9 and Photo 10). Additionally, Transport for NSW reported traffic affected in all directions on Parramatta Road with a person trapped in a flooded car at this intersection around 10:55 am on the 7 February 2017.

Photo 9: Intersection of Parramatta Road and West Street, Looking West Along Parramatta Road – 7 February 2017 (Source: ABC News)

Photo 10: Intersection of Parramatta Road and West Street, Looking South Towards West Street – 7 February 2017 (Source: ABC News)

4. MODEL REVIEW AND REVISION

4.1. Peer Review

The Flood Studies (Reference 1 and Reference 2) described previously in Section 1.3.1 and Section 1.3.2 were peer reviewed. The peer review process was completed by Grantley Smith of UNSW Water Research Laboratory. This consisted of a request for more information (Smith, G., 25 May 2016), a response to the request (Gray, S., 7 October 2016) and a final summation of peer review (Smith, G., 13 October 2016). These are included as Appendix D. From this, the peer review determined that the methodology used in the Flood Studies was sound.

4.2. Model Revision

The flood models developed in the flood studies (Reference 1 and Reference 2) have been revised as part of the FRMS&P where guidelines have been updated, further data has been released or for consistency with other studies that are in progress. Table 7 details revisions undertaken and to which flood model these revisions relate to, with further detail provided in the corresponding sections below.

Table 7: Model Revision Summary

Model Revision	Hawthorne Flood Model	Dobroyd Flood Model
Downstream boundary Conditions (Section 4.2.1)	Yes	Yes
Model resolution (4.2.2)	Yes	No
Topographic Data (Section 4.2.3)	Yes	No
Building Delineation (Section 4.2.4)	Yes	No
Topographic Modifications (Section 4.2.54.2.4)	Yes	Yes
Building Footprints (Section 4.2.6)	Yes	Yes
Hydrology Model	Yes	No
1D Modelling	Yes	Yes

4.2.1. Downstream Boundary Conditions

Subsequent to the completion of the Flood Studies further guidance from the Office of Environment and Heritage (OEH) has been released, namely the *Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* guide (Reference 4). The guide presents a multivariate approach for hydraulic modelling of coastal and catchment interactions and was applied in this study.

Given the short duration of the critical storm burst for design events, the simplistic approach using a steady state ocean boundary was considered sufficient. The catchment was defined as Entrance Type A (open oceanic embayment) and is located south of Crowdy Head; resulting in the 1% AEP and 5% AEP ocean levels as those shown in Table 8.

Table 8: Combinations of Catchment Flooding and Oceanic Inundation Scenarios

Design AEP for Peak Flood Levels	Catchment Flood Scenario	Ocean Water Level Scenario
0.5 EY	0.5 EY rainfall	HHWS ocean level 1.25 m AHD
0.2 EY	0.2 EY rainfall	HHWS ocean level 1.25 m AHD
10% AEP	10% AEP rainfall	HHWS ocean level 1.25 m AHD
5% AEP	5% AEP rainfall	HHWS ocean level 1.25 m AHD
2% AEP	2% AEP rainfall	5% AEP ocean level 1.40 m AHD
1% AEP (Enveloped)	5% AEP rainfall	1% AEP ocean level 1.45 m AHD
	1% AEP rainfall	5% AEP ocean level 1.40 m AHD
PMF	PMF rainfall	1% AEP ocean level 1.45 m AHD

4.2.2. Model resolution

For consistency with other comparable studies, the Digital Elevation Model used to represent the ground topography for the Hawthorne Canal Catchment was refined from a 3 m cell size to a 2 m cell size, with updates to the 1D model also made as required.

4.2.3. Topographic Data

The LiDAR used in the Dobroyd Canal and Hawthorne Canal Flood Studies was collected in 2007 by AAMHatch. However, for consistency with current studies, the LiDAR collected in 2013 by Land and Property Information was used for the Hawthorne Canal FRMS&P. As part of this update, various other topographical adjustments were made, including kerbs and gutters and modifications to terrain alongside the open channel.

4.2.4. Building Developments

Subsequent to the Flood Studies, a number of large scale developments have been approved and/or undertaken in the study area. These include:

- Arlington Grove (6-22 Grove Street, Dulwich Hill);
- 1A Hill Street, Dulwich Hill;
- 78-90 Old Canterbury Road, Lewisham; and
- Summer Hill Flour Mill (2-32 Smith Street, Summer Hill.

Drainage and/or pit inlet upgrades have also been undertaken along:

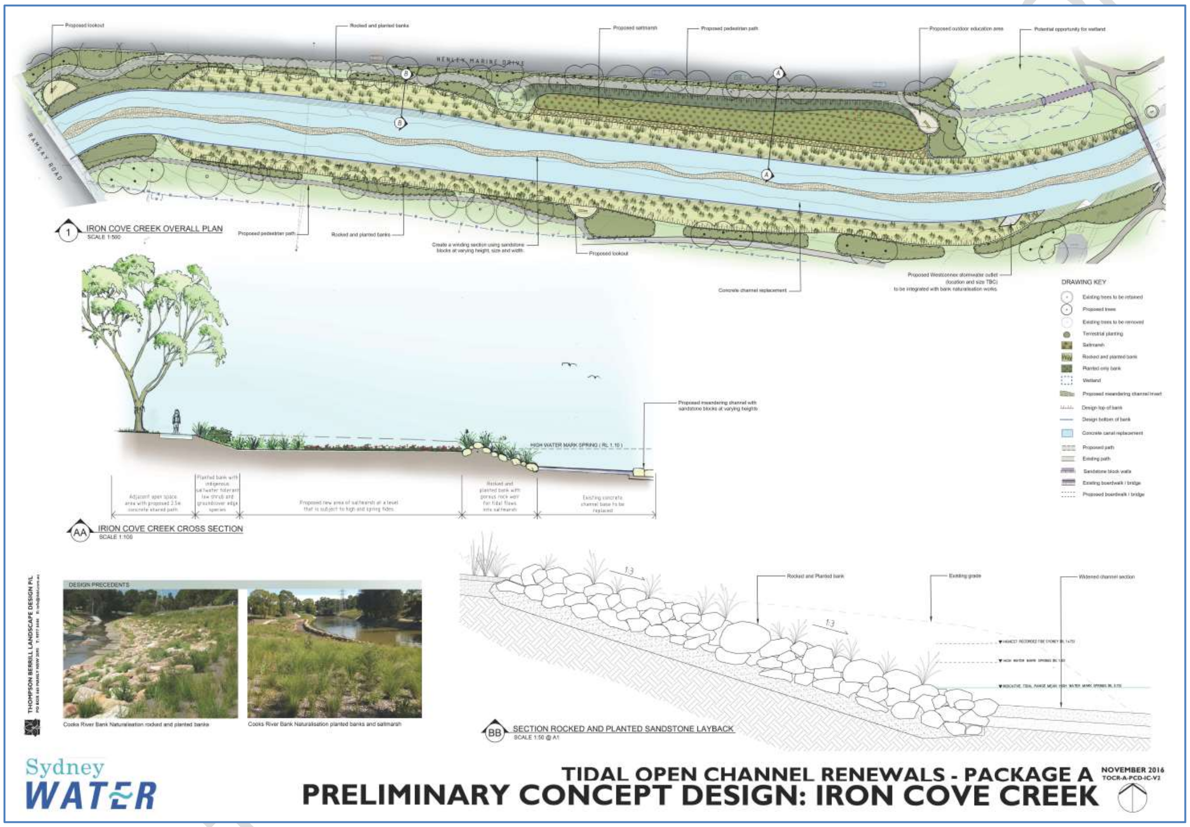
- Cobar Street; and
- Old Canterbury Road.

The hydraulic model has been revised to include these developments and changes to the study area.

4.2.5. Topographic Modifications

SWC is currently investigating the rehabilitation of Dobroyd Canal via the naturalisation of the channel extending from Ramsay Street to the confluence of Iron Cove. The preliminary design was incorporated into the TUFLOW model where the channel roughness and topography was refined to represent the naturalised state of the area. A schematisation of the preliminary concept design is shown in Photo 11.

Photo 11: Preliminary Concept Design: Iron Cove Creek (November 2016)



4.2.6. Building Footprints

Buildings and other significant objects likely to obstruct flow were incorporated into the existing flood studies based on building footprints defined from aerial photography. These types of features were modelled as impermeable obstructions to flow and thus had no assumed flood storage capacity. The building delineation was revised as part of this study to include all flood affected properties within the PMF extent. Further, the building delineation was validated in key overland flow areas via a desktop analysis using Google “Streetview” photographs or a site visit. Revisions to the building schematisations included;

- Updating buildings footprints based on new development or changes to existing building footprints. This was done using the latest aerial information.

- Updating building footprints for Hawthorne Canal where necessary due to the change in model resolution (3 m to 2 m grid cell size).
- An assessment was completed to identify locations where it was found that flood water was being detained upstream of buildings. Where the assessment found the upstream detention of flood water to be artificial, the model schematisation of building extents was altered in order to ensure that where in reality flow could travel downstream, the same could also occur in the hydraulic model to allow flow paths between buildings to function more efficiently.

5. FLOOD BEHAVIOUR

5.1. Overview

The changes to flood behaviour as a result of revisions to the hydraulic model were assessed by comparing the results from the Flood Study and the updated model from the FRMS&P. The changes in peak flood levels (impacts) due to the model changes for the 1% AEP are shown in Figure A7 and Figure B7. Across both of the study areas, the changes in flood levels observed are not unexpected based on the model revisions made to each of the hydraulic models.

The differences within the Dobroyd catchment are mostly observed along the trunk drainage system and result from the downstream boundary, topographic modifications and 1D modelling changes to the open channel. Small increases in flood levels and flood extents are also observed across the catchment due to changes to building footprints which alters the flow path.

The flood impacts across the Hawthorne Canal catchment are more widespread, which is consistent with the amount of modifications, in particular, the change in grid cell size change and a new LiDAR. A smaller cell size enables more efficient flow paths between buldings as well as providing a better representation of small topographic features including kerbs and gutters.

The topography within both catchments vary from steep surface slopes in excess of 15% on the western side to the near flat lower catchment in areas adjacent to both Iron Cove Creek (Dobroyd Canal) and Long Cove Creek (Hawthorne Canal). The catchments therefore have regions where surface water runoff within the road network has high velocity with shallow depths, whilst in the lower catchment surface water is more likely to pond in sag points with typically lower flow velocities. The lower reaches of the catchment fringing Iron Cove are potentially affected by elevated water levels within Sydney Harbour.

5.2. Pipe Capacity

The pipe capacity assessment for each catchment is shown on Figure A8 and Figure B8. The majority of the pipes were found to be operating at capacity in the 0.5 EY event, including sections of the major drainage network operated by SWC. Small individual sections of pipe had a capacity greater than the 0.5 EY event, however this provided limited benefit as these pipes discharge into pipes with a lower AEP capacity.

5.3. Flood Hazard

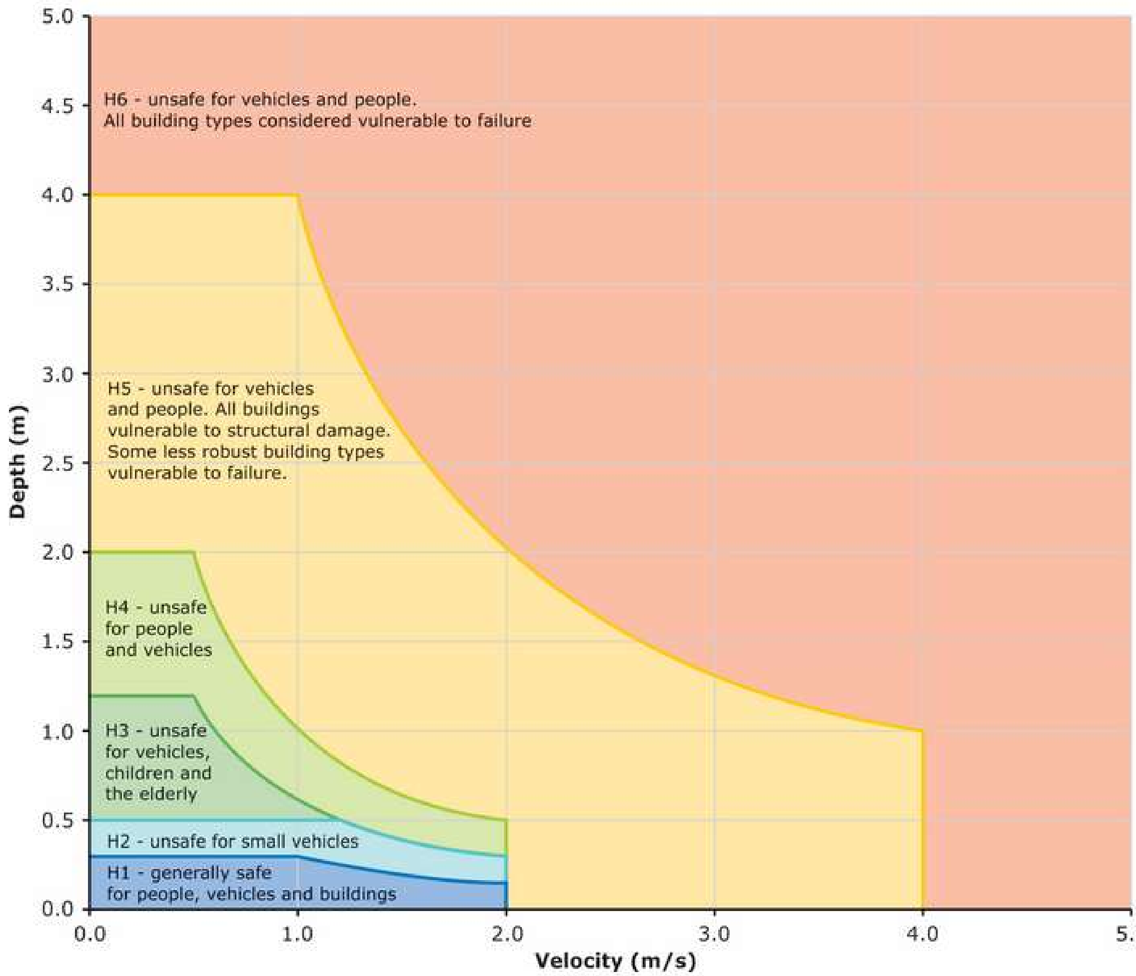
Subsequent to the Flood Studies, revisions to Australian Rainfall and Runoff have been finalised. From this, guidelines on Hazard classification have been released and were investigated as part of this study.

Diagram 1 and Table 9 have been extracted from Book 6 Chapter 7.2.7 of ARR2016 for general flood hazard curves.

Table 9: Combined Hazard Curves – Vunlerability Thresholds Classifiction Limits

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity)V)
H1	D*V ≤ 0.3	0.3	*2.0*
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V ≤ 4.0	-	-

Diagram 1: Combined Flood Hazard Curves



The Flood Hazard was calculated for the 0.2 EY, 1% AEP event and PMF events, and are shown in Figure A9A16 - A18 and Figure B9B16 – B18 for the Dobroyd Canal and Hawthorne Canal catchments respectively.

In the Dobroyd Canal catchment, the H6 classification was concentrated in the open channel sections across the range of events investigated. In the 0.2 EY event, the Brown Street underpass (beneath Western Rail Track) was classified as H5; and small areas of H4 were located within Algie Park, Queen Street Croydon and Paisley Road, Croydon (within the Burwood LGA). In the 5% AEP event, the H4 sections expanded in area and additionally were located along Carshalton Street (north of Arthur Street) and in the low point of Hugh Street to Carlisle Street; Heighway Avenue to Thomas Street was classified as H3. In the 1% AEP event, additional areas of H5 classification were located along Carshalton Street (north of Arthur Street) and in the low point of Hugh Street to Carlisle Street; and areas on Heighway Avenue to Thomas Street were classified as H4.

In the Hawthorne Canal catchment, the H6 classification was concentrated in the open channel sections across the range of events investigated. In the 0.2 EY event, the Light Rail Track under Davis Street was classified as H5; and areas of H4 classification were located along the Light Rail Track (between Hill Street and Denison Road) and along Darley Road (within the former Leichhardt LGA). In the 5% AEP event, additional H5 classifications were located along the Light Rail Track (between Hill Street and Denison Road) and Smith Street (east of Chapman Street); and the Light Rail Track under Old Canterbury Road was classified as H4. In the 1% AEP event, additional areas of H5 classification were located along Smith Street (east of Lackey Street); and H4 classifications were located along Marion Street and along the boundary between properties on Elizabeth Avenue and Cobar Street (corresponding to the SWC major drainage line).

5.4. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* describes flood prone land as belonging to one of the following three hydraulic categories:

- Floodway,
- Flood Storage, and
- Flood Fringe.

<u>Floodways</u> are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

<u>Flood storage</u> areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The Howells et. al. (2003) method utilising the following criteria has been used to define the hydraulic categorisation for the Dobroyd and Hawthorne Canal catchments.

- Floodway is defined as areas where:
    - The peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s **AND** peak velocity > 0.25 m/s, **OR**
    - Peak velocity > 1.0 m/s **AND** peak depth > 0.15 m
- The remainder of the floodplain is either Flood Storage or Flood Fringe,
    - Flood Storage is areas outside the floodway where peak depth > 0.5 m; and
    - Flood Fringe is areas outside the floodway where peak depth ><0.5 m

There is no 'one size fits all' method of defining a floodway with the applied approach requiring specific tailoring to suit a study area. The goal is to produce floodway extents that match flow behaviour so that the areas which need to be retained for flow are identified whilst other parts of the flood extent can be developed as appropriate.

Hydraulic categorisation of the 0.2 EY, 1% AEP and PMF events is presented on Figure A16 to Figure A18 and Figure B16 to Figure B18.

5.5. Property Inundation

The floor level data has been used to identify the events which properties (water encroaching the cadastral boundary) and floor levels are first inundated. Table 10 and Table 11 summarise the number of impacted properties, which are also shown on Figure A129 and Figure B199.

Table 10: Flood Affected Residential Properties - Dobroyd Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level
0.5 EY	1328	23
0.2 EY	1531	66
10% AEP	1646	132
5% AEP	1750	209
2% AEP	1844	301
1% AEP	1922	399
PMF	2598	1339

Table 11: Flood Affected Residential Properties - Hawthorne Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level
0.5 EY	442	12
0.2 EY	542	37
10% AEP	596	53
5% AEP	670	75
2% AEP	729	100
1% AEP	798	120
PMF	1378	537

The Dobroyd Canal catchment has a large proportion of affected properties, even in the smaller more frequent events. This is substantially properties where the grounds are inundated, however in a 1% AEP event 399 properties are anticipated to be flooded above floor level.

Whilst the Hawthorne Canal catchment has a smaller number of affected properties, there are still 12 identified as having above floor inundation in the 0.5 EY event, and 120 properties estimated to be flooded above floor level in the 1% AEP event.

5.6. Access and Movement During Flood Events

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

Each catchment area has several arterial roads that are flood affected, and a number of other local residential roads where traffic will be impeded in a flood event. The main arterial roads that become affected by flooding within the Hawthorne catchment, in some cases, affected in more than one location include Parramatta Road, Old Canterbury Road and Marion Street. Within the Dobroyd catchment the Georges River Road, Hume Highway\ Liverpool Road, Great Western Highway \ Parramatta Road are affected by flooding. A number of residential roads are also flood affected across both catchments.

As shown in Table 12 and Table 13, the depth of inundation on the roads varies from 0.0 to 0.7 m in a 0.5 EY event, up to 1.7 m in a 1% AEP and up to 4.3 m in the PMF. This depth refers to the accumulation in the gutter on either side of the road, while the road centre will typically have less depth. At some locations there is a substantial increase in depth during the PMF, this is a result of a much larger area of inundation during this much rarer event. Figure A13 and Figure B20 show the reported locations.

Table 12: Major Road Peak Flood Depths (m) – Hawthorne catchment

Road	Location	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Parramatta Road	Between Sloane Street and Hawthorne Parade	0.3	0.4	0.5	0.5	0.5	0.6	0.9
Parramatta Road	Between George Street and Flood Street	0.4	0.5	0.6	0.7	0.8	0.9	1.9
Old Canterbury Road	Henry Street intersecting Old Canterbury Road	0.2	0.3	0.4	0.4	0.5	0.5	1.7
Old Canterbury Road	Between Maddock Street and Hampstead Road	0.2	0.2	0.2	0.2	0.3	0.3	0.8
Old Canterbury Road	Between Elizabeth Avenue and Cobar Street	0.2	0.3	0.3	0.4	0.4	0.5	0.9
Smith Street	Between Edward Street and Flour Mill Way	0.1	0.3	0.4	0.5	0.6	0.6	3.5
Dixson Avenue	Between Elizabeth Avenue and Cobar Street	0.6	0.7	0.7	0.8	0.9	1.0	1.8
Abergeldie Road	Between Dixson Avenue and Union Street	0.3	0.4	0.5	0.6	0.6	0.7	1.3
Abergeldie Road	Between Union Lane and Abergeldie Street	0.2	0.3	0.3	0.3	0.4	0.4	0.9
Windsor Street	Between Terry Road and Davis Street	0.3	0.4	0.5	0.5	0.6	0.6	1.4
Gelding Street	Between Hampstead Road and Maddock Street	0.1	0.2	0.2	0.3	0.3	0.4	0.9
Ramsay Street	Between O'Connor Street and Haberfield Road	0.1	0.2	0.2	0.3	0.3	0.3	0.6
Tressider Street	Between O'Connor Street and Hawthorne Parade	0.2	0.2	0.3	0.3	0.3	0.3	0.6
Marion Street	Between Marion Light rail stop and Hawthorne Parade	0.3	0.3	0.4	0.4	0.5	0.5	1.7
Station Street	Park Street intersecting Station Street, Petersham Park	0.4	0.5	0.6	0.7	0.7	0.8	1.5
Lotos Street	Along Lotos Street	0.1	0.3	0.4	0.5	0.5	0.6	1.1
Fred Street	Between Fred Street and Eltham Street	0.1	0.1	0.2	0.2	0.3	0.5	3.4
Victoria Street	Between Henry Street and Jubilee Street	0.4	0.5	0.6	0.7	0.7	0.7	1.3
Edward Street	Chapman Street and Smith Street intersection	0.1	0.2	0.2	0.3	0.4	0.5	3.2
Spencer Street	Spencer Street and Smith Lane intersection	0.1	0.2	0.3	0.3	0.4	0.4	2.0
Nowranie Street	Between Smith Street and Wellesley Street	0.4	0.5	0.6	0.6	0.7	0.7	1.4
Lackey Street	Between Carlton Crescent and Smith Street	0.4	0.5	0.6	0.6	0.7	0.7	1.5
Grosvenor Street	Between Pembroke Avenue and Sloane Street	0.7	0.9	1.0	1.2	1.4	1.5	2.1
Hawthorne Street	Between Waratah Street and Dobroyd Parade	0.3	0.3	0.4	0.4	0.4	0.4	1.5

Table 13: Major Road Peak Flood Depths (m) – Dobroyd catchment

Road	Location	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Palace Street	Between Holden Street and Milton St	0.4	0.5	0.5	0.6	0.6	0.6	0.9
Park Avenue	Between Park Lane and Shepherd Street	0.3	0.4	0.4	0.5	0.5	0.5	0.9
Joseph Street	Between Arthur Street and Robert Street	0.6	0.8	0.8	0.9	1.0	1.0	1.5
Holden Street	Between Arthur Street and Robert Street	0.4	0.6	0.6	0.7	0.7	0.8	1.3
Hugh Street	Between Norton Street and Arthur Street	0.6	0.8	0.9	1.0	1.1	1.2	1.9

Carlisle Street	Between North Street and Arthur Street	0.7	0.9	1.0	1.1	1.2	1.3	2.0
Liverpool Street	Between Milton Street and Lapish Avenue	0.4	0.6	0.7	0.9	1.0	1.1	2.0
Frederick Street	Between Thomas Street and Beatrice Street	0.3	0.4	0.4	0.5	0.5	0.6	3.4
Milton Street	Between Frederick Street and Weatherill Street	0.3	0.3	0.3	0.3	0.4	0.5	2.5
Thomas Street	Between Milton Street and Wetherill Street	0.3	0.4	0.5	0.7	0.8	1.0	4.3
Norton Street	Between Carshalton Street and Cromwell Street	0.5	0.7	0.8	0.9	1.0	1.1	1.9
Alt Street	Around Alt Street and Ashfield Street intersection	0.3	0.4	0.5	0.5	0.6	0.6	1.0
Queen Street	Between Ivanhoe Road and Jones Street	0.3	1.1	1.4	1.5	1.6	1.7	2.5
Cecil Street	Between Loftus Street and Chandos Street	0.2	0.3	0.3	0.3	0.3	0.4	0.8
Chandos Street	Curt Street and Chandos Street intersection	0.2	0.3	0.4	0.4	0.5	0.6	1.0
Alt Street	Between Ilfort Avenue and Parramatta Road	0.2	0.3	0.3	0.4	0.4	0.4	0.8
Frederick Street	Between Henry Street and Parramatta Road (front of Bunnings Ashfield)	0.3	0.4	0.5	0.6	0.7	0.7	1.3
Earle Avenue	Between Henry Avenue and Parramatta Road	0.3	0.4	0.5	0.6	0.7	0.8	1.5
Page Avenue	Between Henry Avenue and Parramatta Road	0.5	0.8	1.0	1.1	1.3	1.4	2.5
Dobroyd Avenue	Dobroyd Parade and Parramatta Road intersection	0.1	0.2	0.3	0.4	0.5	0.5	1.4
Robinson Street	Between Queen Street and MacGregor Street	0.4	0.5	0.5	0.5	0.6	0.6	1.6
Wright Street	Between Murphys Lane and Queen Street	0.3	0.4	0.5	0.5	0.6	0.6	1.7
Palace Street	Between Holden Street and Milton Street	0.4	0.5	0.5	0.6	0.6	0.6	0.9
Park Avenue	Between Park Lane and Shepherd Street	0.3	0.4	0.4	0.5	0.5	0.5	0.9

5.7. Impacts of Climate Change

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities. The sensitivity of the simulated peak flood levels to climate change was investigated.

Sensitivity analysis was undertaken for both rainfall increases and sea level rise, for the 1% AEP rainfall event with the 5% AEP ocean level.

- **Rainfall Increase:** Sensitivity to rainfall/runoff estimates were assessed by increasing the rainfall intensities by 10%, 20% and 30% as recommended under current guidelines;
- **Sea Level Rise:** Sea level rise scenarios of 0.4 m and 0.9 m were assessed.

The results indicate that generally speaking, each incremental 10% increase in rainfall results in an approximately 0.1 m increase in peak flood levels at the more sensitive locations analysed. The 1% AEP event with a rainfall increase of 30% is approximately equivalent to a 0.2% AEP event in present day conditions and an impact on flood levels is not unexpected. Sea level rise scenarios were found to not have a significant impact upon peak levels in the lower reaches of both catchments.

5.8. "Hotspot" Identification

Additional areas of interest were identified by Council, in some cases based upon flooding concerns raised by residents prior to commencement of the Flood Studies. These hotspots were used to identify several locations across each catchment where flooding management options may be targeted.

The following section describes these hotspots and areas of interest in further detail, in particular the over-floor flood affectation within these areas and peak flood levels and depths. Where flow occurs in defined flowpaths information regarding peak flows is also provided. The Flood Studies identified some locations in the catchment which were sensitivity to blockage of structures. In these locations, the flood behaviour is reported based on the assumed blockage scenario, as specified below. Hotspots for the Dobroyd and Hawthorne Canal catchments are shown on Figures A1 and B1, respectively.

It is important to note that these areas may not be the only areas within the catchment to experience flooding but have been identified specifically through the study and are therefore included below.

5.8.1. Dobroyd Hotspot 1 – Heighway Avenue, Croydon

The main open channel in the Dobroyd Canal catchment is crossed by the Western Rail Track embankment downstream of this location (with Heighway Avenue aligned parallel and directly upstream of the embankment). The top of the embankment is more than 6 m around the surrounding streets. The contributing catchment area is approximately 286 hectares and two culverts convey flow underneath the railway embankment with a cross-sectional area of approximately 14.7 m^2 and 5.3 m^2.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland via Frederick Street are shown in Table 14. The eastern culvert was found to be operating at capacity in events greater than and including the 0.2 EY event, whereas the western culvert was found to have capacity up to the PMF event. This was due to the obvert of the western culvert being 14.9 m AHD, which is above the elevation of the Frederick Street roadway at 14.0 m AHD. As such, overflow occurs through the Frederick Street roadway tunnel prior to the submergence of the western culvert. This is observed in the large PMF event where significant overflow travels through the Frederick Street roadway tunnel.

Table 14: D01 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Under Railway Embankment – Heighway Avenue	Overland (Frederick Street)	0.0	0.0	0.0	0.0	0.1	0.6	93.0
	Pipe/Channel	13.0	20.3	27.1	31.6	36.6	40.3	78.8

The peak flood levels and depths at this location are shown in Table 15. These flood levels are very sensitive to the consequences of blockage, with 50% blockage in the 1% AEP event resulting in increases in peak flood levels greater than 1 m. Under this scenario flow is not able to enter the drainage system and is constrained by the capacity of the canal at the railway line. During large events the capacity of the canal at the railway line also has a significant influence on flood depths in the area.

Table 15: D01 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Heighway Avenue	Level	13.21	13.26	13.44	13.64	14.00	14.33	17.69
	Depth	0.32	0.38	0.55	0.75	1.12	1.44	4.80

Over-Floor Building Flood Affection

Given the sensitivity to blockage found at this location, the Flood Study adopted a 20% blockage which was singularly applied to the culverts under the Western Rail Track embankment at this location. This resulted in the following over-floor flood affectation along Heighway Avenue (Table 16):

Table 16: D01 – Buildings First Inundated by Flood Event, 20% blockage scenario

Heighway Avenue	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	16	18	25	38	44	48	56

5.8.2. Dobroyd Hotspot 2 - Queen Street, Croydon

The Queen Street low point is located in the roadway adjacent to the south-east edge of Centenary Park. The park grounds are separated from the roadway with a retaining wall and have an elevation greater than the roadway by approximately 3 to 4 m. The front yards of the properties opposite the park are at approximately the same elevation as the roadway.

The pipe draining this area is owned and maintained by SWC. It is roughly oval shaped, with dimensions of 2.28 m (width) by 1.53 m (height) and a cross-sectional area of approximately 2.6 m^2.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland are shown in Table 17. The capacity of this pipe and the surrounding pipes in this location was found to be less than the 0.5 EY event. Significant overland flow begins to occur in the 10% AEP event and a substantial increase occurs in the large PMF event.

Table 17: D02 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Queen Street	Overland	0.0	0.0	1.6	3.5	5.9	8.0	108.9
	Pipe/Channel	8.0	8.6	8.5	8.5	7.9	8.5	8.1

The peak flood levels and depths on Queen Street are provided in Table 18.

Table 18: D02 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Queen Street	Level	7.61	8.45	8.77	8.87	8.96	9.03	9.86
	Depth	0.29	1.14	1.46	1.56	1.64	1.71	2.54

Over-Floor Building Flood Affectation

Along Jones Street (directly downstream of the Queen Street low point), the following over-floor flood affectation (Table 19) was estimated:

Table 19: D02 – Buildings First Inundated by Flood Event

Jones Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	-	-	-	-	-	2	9

The majority of properties along this street benefit from the Queen Street low point retarding flows that are conveyed through this area.

5.8.3. Dobroyd Hotspot 3 – Brown Street, Ashfield

The vehicle and pedestrian road tunnel underneath the Western Rail Track embankment has a lower elevation than either of the two streets that approach it, namely Bland Street and Brown Street. Bland Street, which approaches the tunnel from the north side, increases in elevation by approximately 5 m from the tunnel to the junction with Elizabeth Street. Brown Street to the south of the embankment has a similar elevation rise from the tunnel to the junction with Foxs Lane. As such, the road under the railway embankment acts as a trapped low point.

Parallel to the road tunnel and approximately 70 m to the east is a pedestrian tunnel underneath the embankment. It has an approximate elevation 4 m higher than that of the road tunnel.

Underneath the Bland Street road tunnel is a box culvert with a width of 1.2 m and a height of 0.9 m. Although there are inlet pits at the start and end of this roadway tunnel, the pipes connecting these inlets to the box culvert are smaller than 450 mm in diameter and have a likely capacity of the 0.2 EY.

An additional feature at this location that is pertinent to the flood behaviour is an adjacent underground car park. It is located on Brown Street to the south of the Western Rail Track embankment and has an entrance approximately level with the low point of the roadway. Overland flow is likely to enter the carpark during flood events. The detail of this behaviour was unable to be represented in the model due to the lack of data, particularly relating to volume capacity and private pipe drainage infrastructure. By excluding the unofficial flood storage that would be provided by the car park, the model may produce a conservative over-estimation of flood levels at this location.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland are shown in Table 20.

Table 20: D03 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Bland Street	Overland	0.3	1.4	2.2	3.2	4.2	5.3	23.0
	Pipe/Channel	0.6	0.7	0.7	0.7	0.7	0.7	0.7

The peak flood levels and depths on Brown Street are provided in Table 21.

Table 21: D03 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Brown Street	Level	21.91	22.14	22.23	22.34	22.43	22.52	23.24
	Depth	2.10	2.33	2.43	2.53	2.63	2.72	3.43

Over-Floor Building Flood Affectation

Along Bland Street, the following over-floor flood affectation (Table 22) was estimated:

Table 22: D03 – Buildings First Inundated by Flood Event

Bland Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	1	2	2	2	3	3	3

These estimates are considered to be conservative given the exclusion of the underground car park (south of the embankment) flood storage volume.

5.8.4. Dobroyd Hotspot 4 – Downstream Sections of Dobroyd Canal

The Dobroyd Canal open channel sections are concrete-lined and extend from Iron Cove up to Norton Street. The open channel becomes progressively wider as it proceeds downstream. The areas downstream of Parramatta Road are of concern to residents due to the interaction of catchment flows and tidal conditions at the outlet.

Flood Behaviour

The open channel of Dobroyd Canal is tidal up to Parramatta Road and receives mainstream flow from the larger upstream catchment area. Additionally, local overland flow from the Haberfield area crosses Ramsay Street and Dobroyd Parade to converge with the mainstream/tidal flow. The peak flood levels and depths at this location are provided in Table 23.

Table 23: D04 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Open Channel – Upstream of Parramatta Road	Level	2.8	3.0	3.2	3.4	3.6	3.9	6.6
	Depth	1.8	1.9	2.1	2.3	2.6	2.9	5.5
Open Channel – Upstream of Timbrell Drive	Level	1.28	1.31	1.34	1.41	1.62	1.82	2.88
	Depth	2.33	2.35	2.38	2.45	2.64	2.83	3.82

Over-Floor Building Flood Affectation

The following over-floor flood affectation (Table 24) was estimated along Dobroyd Parade, north of Martin Street:

Table 24: D04 – Buildings First Inundated by Flood Event

Dobroyd Parade	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	-	-	-	1	2	4	20

5.8.5. Dobroyd Hotspot 5 – Church and Alexandra Streets, Croydon

Church Street traverses the main Dobroyd Canal open channel. Alexandra Street does not cross the open channel and is aligned generally perpendicular to the channel alignment. It is located upstream of Church Street, adjacent to the junction between the main open channel and the trunk drainage system originating from the Burwood-Croydon branch.

Flood Behaviour

The peak flood levels and depths at this location are shown in Table 25. From this, the two flood mechanisms of mainstream flooding and overland flooding can be observed (with high ground levels and flood levels in the street comparative to the flood level in the open channel across the majority of events).

Table 25: D05 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Open Channel Upstream of Church Street	Level	3.98	4.33	4.66	4.97	5.18	5.36	8.09
	Depth	1.91	2.25	2.56	2.86	3.06	3.22	5.91
Church Street	Level	6.49	6.51	6.52	6.53	6.54	6.56	7.93
	Depth	0.13	0.15	0.16	0.17	0.19	0.20	1.58
Open Channel Adjacent to Alexandra Street	Level	4.02	4.37	4.69	5.01	5.22	5.39	8.11
	Depth	1.73	2.06	2.36	2.64	2.84	2.99	5.69
Alexandra Street	Level	4.90	4.90	4.91	5.03	5.24	5.41	8.16
	Depth	0.14	0.14	0.15	0.27	0.48	0.66	3.40

Over-Floor Building Flood Affectation

Along Church Street and Alexandra Street, the following (Table 26) over-floor flood affectation was estimated:

Table 26: D05 – Buildings First Inundated by Flood Event

Church Street & Alexandra Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	-	-	-	-	1	1	8

The majority of properties within this area were not affected by over-floor flooding until the PMF, likely due to the majority of the buildings being slightly elevated above ground level and accessed via a few steps.

5.8.6. Dobroyd Hotspot 6 – Algie Park, Haberfield

The ground level inside Algie Park is generally lower than the surrounding property. A concrete wall is situated along the western boundary adjacent to residential property and a grassed ridge is located along the northern boundary. Collectively, these features form a detention basin within Algie Park.

Flood Behaviour

Flows enter Algie Park via overland flow and pipes from the east, south and west. The pipes convey flow from Bland Street, Empire Street and Ramsay Street to converge into one 0.9 m diameter pipe entering the Algie Park grounds. The pipe network draining the Algie Park detention basin consisted of two pipes with a 0.9 m diameter. The peak flows entering and discharging from the park are shown in Table 27.

Table 27: D06 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Inflow	Pipe	1.5	1.7	1.8	1.9	1.9	1.9	2.0
	Overland	5.1	7.3	8.8	10.5	11.8	13.5	35.6
Outflow	Pipe (east)	1.5	1.8	1.9	1.9	1.9	1.9	1.9
	Pipe (west)	0.9	1.0	1.0	1.3	1.4	1.4	1.5
	Overland (spillway)	0.0	0.0	0.1	1.0	2.0	3.4	21.7
	Overland (bypass)	0.4	1.0	1.5	2.1	2.7	3.2	5.0

The grass ridge and concrete wall have an elevation of approximately 7.0 m AHD at the northern boundary. A spillway is located on the grass ridge and has a width of 20 m and an elevation of 6.5 m AHD. The lowest point within the detention basin is approximately 4.8 m AHD. When depths on the oval reach 1.7 m the spillway is activated.

The lowest elevation on the Ramsay Street roadway upstream of the park is approximately 8.7 m AHD. The backyard of the properties to the east of the detention basin had a lower elevation than the roadway, with elevations of 6.0 m AHD in some locations. Although a small wall is located on the southern boundary of these properties, flow that is impeded from exiting the detention basin will accumulate and extend upstream through the park whereby the backyards of properties to the east of the concrete wall will act as an alternative flow-path. The peak flood levels and depths within Algie Park and the streets downstream of the park are shown in Table 28.

Table 28: D06 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Algie Park	Level	6.24	6.46	6.57	6.67	6.75	6.82	6.58
	Depth	1.32	1.53	1.65	1.75	1.83	1.90	1.66
Laneway Downstream of Algie Park	Level	4.20	4.24	4.28	4.35	4.42	4.48	4.92
	Depth	0.35	0.39	0.43	0.50	0.57	0.63	1.07
Alt Street	Level	3.59	3.62	3.64	3.71	3.79	3.86	4.55
	Depth	0.21	0.25	0.26	0.33	0.41	0.48	1.17

Over-Floor Building Flood Affectation

Along Ramsay Street and Alt Street (which bounds Algie Park), the following (Table 29) over-floor flood affectation was estimated:

Table 29: D06 – Buildings First Inundated by Flood Event

Ramsay Street & Alt Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	2	2	2	2	3	3	9

5.8.7. Hawthorne Hotspot 1 - Queen Street, Ashfield

Several instances of flooding were reported along Queen Street from the community consultation undertaken for the Flood Study. The overland flow-path from Queen Street to Yeo Park is orientated perpendicular to the roadway alignment. From Old Canterbury Road to Dixson Avenue, the overland flow-path is parallel to the roadway alignment of Cobra Street and Elizabeth Avenue. This flow-path occurs along the boundary of properties located on the two roadways. Between Dixson Avenue and Arlington Recreation Reserve, the overland flow-path is again orientated perpendicular to the roadway.

The contributing catchment area upstream of Queen Street is approximately 10 hectares, which is drained via a 0.6 m diameter pipe. Two 0.6 m diameter pipes drain Service Avenue and Victoria Street is drained via a 0.6 m and a 0.75 m diameter pipe. The contributing catchment area upstream of Old Canterbury Road is approximately 34 hectares and is drained by a 1.05 m diameter pipe.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland are shown in

Table 30. The pipe system from Queen Street along to Dixson Avenue was found to be functioning at capacity in the 0.5 EY event.

Table 30: H01 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Queen Street	Overland	1.4	2.2	2.7	3.3	3.8	4.5	16.3
	Pipe	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Service Avenue	Overland	2.7	4.2	5.2	6.4	7.4	8.6	30.9
	Pipe 1	0.4	0.4	0.4	0.5	0.5	0.5	0.5
	Pipe 2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Victoria Street	Overland	3.1	4.8	5.8	7.2	8.4	9.7	35.0
	Pipe 1	0.3	0.3	0.3	0.3	0.3	0.3	0.4
	Pipe 2	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Old Canterbury Road	Overland	4.9	7.4	9.0	11.2	12.9	14.9	53.2
	Pipe	1.7	1.7	1.7	1.7	1.7	1.7	2.0
Dixson Avenue	Overland	6.1	9.5	11.5	14.4	16.9	19.6	74.3
	Pipe	2.2	2.3	2.3	2.3	2.3	2.3	2.4

The peak flood levels provided in Table 31 were found to be relatively insensitive to blockage, increasing by 0.03 m in the case of 50% blockage. The results shown in Table 31 assume no blockage.

Table 31: H01 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Queen Street	Level	40.29	40.31	40.34	40.38	40.40	40.42	40.78
	Depth	0.03	0.06	0.08	0.12	0.14	0.17	0.53
Old Canterbury Road	Level	34.74	34.80	34.83	34.87	34.91	34.95	35.35
	Depth	0.25	0.32	0.34	0.39	0.42	0.46	0.86
Dixson Avenue	Level	29.67	29.80	29.86	29.94	30.01	30.08	30.91
	Depth	0.54	0.68	0.74	0.82	0.89	0.95	1.78

Over-Floor Building Flood Affectation

Along Queen Street, the following (Table 32) over-floor flood affectation was estimated:

Table 32: H01 – Buildings First Inundated by Flood Event

Queen Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	1	1	1	1	2	2	7

The majority of properties within this area were not affected by over-floor flooding until the PMF, likely due to the majority of the buildings being slightly elevated above ground level and accessed via a few steps.

5.8.8. Hawthorne Hotspot 2 – Grosvenor Crescent, Summer Hill

Grosvenor Crescent is located to the north of the Western Railway Line that bisects the Hawthorne Canal catchment in an east-west direction. Between Liverpool Street and Summer Hill train station, the railway is situated on an embankment with the Grosvenor Crescent roadway and surrounding area forming a topographical low point. At this location the embankment has an elevation of approximately 28 m AHD and the roadway has an elevation of approximately 25.2 m AHD. Surface flows tend to pond in this low point against the railway line to a depth of 2.08m in the PMF event. Overland flow overtops the railway embankment at approximately 1.5m depth. A 0.55 m diameter pipe conveys flow underneath the railway embankment towards Carlton Crescent. The contributing catchment area is approximately 6.4 hectares.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland via the Western Rail Track embankment are shown in Table 33. From this, the pipe was found to be functioning at capacity in events greater than and equal in magnitude to a 0.5 EY event.

Table 33: H02 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Grosvenor Crescent	Overland	0.0	0.0	0.0	0.0	0.0	0.1	9.1
	Pipe	0.6	0.6	0.6	0.7	0.7	0.7	0.8

The peak flood levels and depths at this location are provided in Table 34. Blockage of the pipes underneath the railway was tested, and it was found that a 50% blockage resulted in increases to the 1% AEP peak flood level of approximately 0.12 m. The results shown below have no blockage.

Table 34: H02 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Grosvenor Crescent	Level	25.92	26.16	26.31	26.48	26.65	26.79	27.36
	Depth	0.64	0.88	1.03	1.20	1.37	1.51	2.08

Over-Floor Building Flood Affectation

At this location, the following (Table 35) over-floor flood affectation was estimated:

Table 35: H02 – Buildings First Inundated by Flood Event

Grosvenor Crescent	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	2	2	2	3	3	4	4

5.8.9. Hawthorne Hotspot 3 – Light Rail Track

The Light Rail Track (L1 Line) bisects the Hawthorne Canal catchment in a north-south orientation. To the north of the Western Rail Track (T1 Line), the Light Rail Track acts as an embankment, running parallel and to the east of Hawthorne Canal until it turns east, running alongside the City West Link. To the south of Hill Street, the Light Rail Track (L1 Line) is lower in elevation than the surrounding ground and forms the primary overland flow-path through this area. Connecting these locations, the light rail alternates several times between functioning as a flow-path and forming an embankment.

The light rail has been discussed in the previous hotspots where it interacts with other infrastructure.

Flood Behaviour

The peak flows conveyed along the Light Rail Track under the Constitution Road bridge are provided in Table 36.

Table 36: H03 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Constitution Road	Along Light Rail Track under the Road Bridge	3.6	7.3	9.4	12.5	15.6	18.9	80.1

The peak flood levels and depths along the Light Rail Track under the Constitution Road Bridge are shown in Table 37.

Table 37: H03 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Constitution Road	Level	20.64	20.92	21.02	21.15	21.28	21.39	22.42
	Depth	0.48	0.75	0.85	0.99	1.12	1.22	2.25

Along the Light Rail Track, from Davis Street to New Canterbury Road the Flood Hazard (discussed in Section 5.3) in the 1% AEP event was classified as H5, which is unsafe for vehicles and people. Although the standards refer to road vehicles, it would not be inconceivable that some danger may be posed to the Light Rail Trains (and passengers) due to the depths and flows calculated along this stretch of track.

Over-Floor Building Flood Affection

Of primary concern at this location is the operational safety of the Light Rail Network during times of flooding. Typically the route would require closure during times of flood.

5.8.10. Hawthorne Hotspot 4 – Sloane Street, Summer Hill / Haberfield

The intersection of Sloane Street and Parramatta Road is a localised topographical low point. Sloane Street rises in elevation in both directions leading away from the intersection, with a grade of between 2% and 3%. Parramatta Road has a steeper rise in elevation leading away from the intersection to the north-west, with a grade of approximately 4.5%. To the south-east of the intersection, Parramatta Road gently slopes away, with a grade of less than 1%. This downward slope occurs over a distance of approximately 25 m, after which the road rises in elevation again. The contributing catchment area is approximately 19.3 hectares and a 0.9 m diameter pipe conveys flow downstream.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland are shown in Table 38. From this, the pipe was found to be functioning at capacity in events greater than and equal to a 0.5 EY event. The water that cannot be conveyed via the pipe consequently flows along Parramatta Road to the south-east. Where Parramatta Road begins to rise to the south-east of the intersection, the only provision for the flow is through properties to the north of Parramatta Road.

Table 38: H04 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Sloane Street	Overland (Parramatta Road)	1.3	2.5	3.2	4.2	5.1	6.0	20.4
	Overland (Sloane Street)	0.4	0.4	0.6	0.9	1.2	1.5	7.3
	Pipe	1.8	1.8	1.8	1.8	1.9	1.9	1.9

The peak flood levels and depths at the intersection are provided in Table 39. The 1% AEP peak flood level at this location was found to be relatively insensitive to blockage, increasing by 0.03 m in the case of 50% blockage.

Table 39: H04 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Intersection of Sloane Street and Parramatta Road	Level	10.94	11.04	11.09	11.14	11.18	11.21	11.59
	Depth	0.29	0.38	0.43	0.48	0.52	0.55	0.93

Over-Floor Building Flood Affectation

At this location, the following (Table 40) over-floor flood affectation was estimated:

Table 40: H04 – Buildings First Inundated by Flood Event

Sloane Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	4	5	5	5	5	5	7

5.8.11. Hawthorne Hotspot 5 – Tressider Avenue, Haberfield

The primary flow-path through this location occurs along the south-west / north-east axis. Across Stanton Road, Ramsay Street and Tressider Avenue, this flow-path is orientated perpendicular to the roadway alignment. Shallow overland flow from the north-west crosses O'Connor Street to merge with the primary flow-path.

The contributing catchment area upstream of Tressider Avenue and along the south-west flow-path is approximately 297 hectares. Along this drainage line, the pipe draining Stanton Road to Ramsay Street has a diameter of 0.6 m and the pipe draining Tressider Avenue, through Battalion Circuit, has a diameter of 0.9 m. The contributing catchment area upstream of O'Connor Street is approximately 150 hectares. The pipe conveying flow through Battalion Circuit from O'Connor Street has a 1.35 m diameter.

Flood Behaviour

The peak flows conveyed downstream of this location by the stormwater pipes and overland are shown in Table 41.

Table 41: H05 – Peak Flows (m^3/s)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Ramsay Street	Overland	2.9	4.9	6.0	7.7	9.2	10.8	41.8
	Pipe	0.4	0.4	0.4	0.4	0.4	0.4	0.5
O'Connor Street	Overland	1.8	2.9	3.6	4.6	5.4	6.4	23.6
Battalion Circuit	Overland	4.8	7.5	9.2	11.9	14.3	17.1	68.1
	Pipe (from Tressider Avenue)	1.2	1.2	1.2	1.2	1.2	1.2	1.3
	Pipe (from O'Connor Street)	1.4	1.6	1.7	1.8	1.9	1.9	2.1

The peak flood levels provided in Table 42 were found to be insensitive to blockage at this location, increasing by 0.01 m in the case of 50% blockage in the 1% AEP event.

Table 42: H05 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Tressider Avenue	Level	4.50	4.55	4.57	4.60	4.62	4.64	4.92
	Depth	0.20	0.26	0.28	0.31	0.33	0.35	0.63

Over-Floor Building Flood Affectation

Along Tressider Avenue and O'Connor Street, the following (Table 43) over-floor flood affectation was estimated:

Table 43: H05 – Buildings First Inundated by Flood Event

Tressider Av & O'Connor Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	4	4	4	4	4	4	10

5.8.12. Hawthorne Hotspot 6 – Hawthorne Canal

The Hawthorne Canal open channel sections are concrete-lined and extend up to Pigott Street. The open channel becomes progressively wider as it proceeds downstream.

Flood Behaviour

The open channel of Hawthorne Canal is tidal up to Parramatta Road and receives mainstream flow from the larger upstream catchment area. Additionally, local overland flow from the Haberfield area crosses Hawthorne Parade to converge with the mainstream/tidal flow. The peak flood levels and depths at this location are provided in Table 44.

Table 44: H06 – Peak Flood Levels (m AHD) and Depths (m)

Location	Type	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Open Channel – Upstream of Marion Street	Level	1.8	2.2	2.4	2.8	3.1	3.4	5.9
	Depth	1.9	2.3	2.5	2.9	3.2	3.6	6.0
Open Channel – Upstream of the City West Link	Level	1.0	1.0	1.0	1.4	1.4	1.4	2.5
	Depth	2.7	2.7	2.7	3.0	3.0	3.0	4.1

Over-Floor Building Flood Affectation

Along Hawthorne Parade, between Parramatta Road and Marion Street, the following (Table 45) over-floor flood affectation was estimated:

Table 45: H06 – Buildings First Inundated by Flood Event

Hawthorne Parade, between Parramatta Road & Marion Street	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	2	5	5	5	5	5	41

The majority of these properties were affected by above-ground flooding at the rear of the property but not over-floor flooding until the PMF. This is due to the substantial slope on the ground levels across the properties; where often the rear of the property is 2 to 4 m lower than the front with the building located on the higher ground.

Along Hawthorne Parade, between Marion Street and the City West Link, the following (Table 46) over-floor flood affectation was estimated:

Table 46: H06 – Buildings First Inundated by Flood Event

Hawthorne Parade, between Marion Street & City West Link	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Number of buildings first inundated above floor	1	1	1	2	2	9	72

The majority of properties within this area were not affected by over-floor flooding until the PMF. The reason being, that the majority of the buildings are slightly elevated and accessed via a few steps.

6. ECONOMIC CONSEQUENCES OF FLOODING

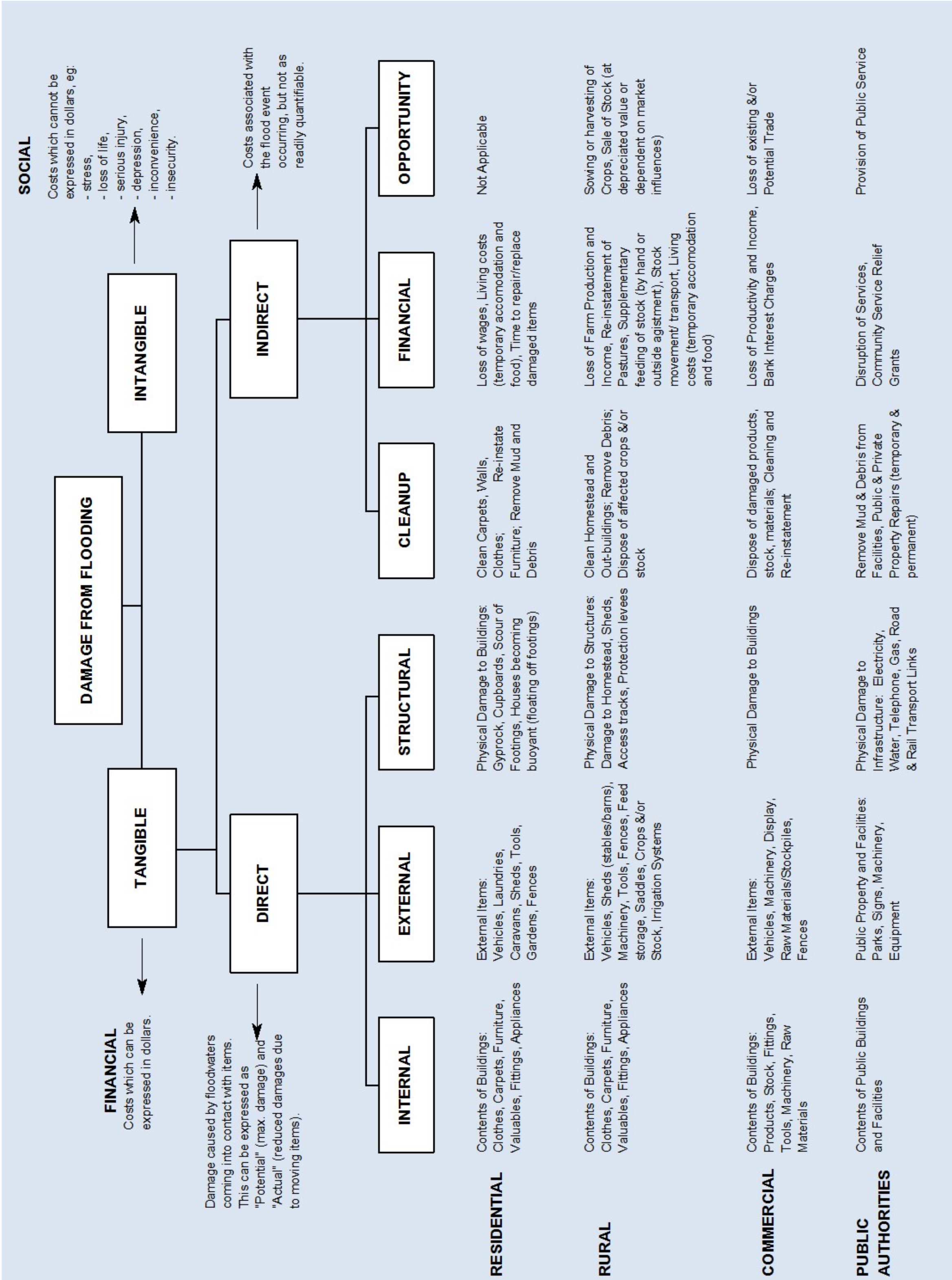
6.1. Overview of Flood Damages

Economic consequences of flooding can be quantified in the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the economic merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damages for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the social and ecological cost/benefits associated with flooding. Flood damages can be defined as being "tangible" or "intangible". Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress and anxiety, injury, loss of life, etc.). A summary of the types of flood damages is provided in Diagram 2.

Diagram 2: Flood Damages Categories (including damage and losses from permanent inundation)



6.2. Tangible Flood Damages

Tangible flood damages comprise two basic categories, direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or a reduction in their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages, gardens). Indirect damages are the additional financial losses caused by the flood including the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages value in any given flood event is useful to give an indication for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, damages estimates are useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process. This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in small floods.

The standard way of expressing flood damages is in terms of Average Annual Damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. This forms the base case scenario against which damages from a number of mitigation measures can be assessed.

Damages were calculated for residential and commercial\industrial properties separately and the process and results are described in the following sections. The combined results are provided in Table 47 for Dobroyd Canal and Table 48 for Hawthorne Canal. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements damages can be underestimated. On a study-area wide basis these exclusions are considered reasonable.

The database compiled for undertaking damages calculations including floor level information and design flood levels will be provided to Council as part of the handover information for this project. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 47: Estimated Total Flood Damages (residential & non-residential) for Dobroyd Canal catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.5 EY	1328	23	$8,138,000	$6,100
0.2 EY	1531	66	$13,100,000	$8,600
10% AEP	1646	132	$18,245,000	$11,100
5% AEP	1750	209	$24,400,000	$13,900
2% AEP	1844	301	$30,812,000	$16,700
1% AEP	1922	399	$38,823,000	$20,200
PMF	2598	1339	$139,656,000	$53,800
AAD			**$9,921,000**	

Table 48: Estimated Total Flood Damages (residential & non-residential) for Hawthorne Canal catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.5 EY	442	12	$4,018,000	$9,100
0.2 EY	542	37	$6,141,000	$11,300
10% AEP	596	53	$7,413,000	$12,400
5% AEP	670	75	$9,269,000	$13,800
2% AEP	729	100	$10,830,000	$14,900
1% AEP	798	120	$12,921,000	$16,200
PMF	1378	537	$53,320,000	$38,000
AAD			**$4,369,000**	

The assessment of flood damages not only looks at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding as shown on Figure A129 and Figure B199 for the Dobroyd Canal and Hawthorne Canal catchments respectively.

6.2.1.1. Residential Damages Results

Residential properties suffer damages from flooding in a number of ways; direct and indirect, as discussed in Section 6.2. For this analysis, a floor level database was developed using the methods outlined in Section 1.4.3

In assessing various mitigation measures it is important to compare them using a suitable metric. By applying a monetary value to property damages and then comparing damage estimates for the existing situation with assumed mitigation work (approximately costed) a benefit/cost (B/C) ratio can be calculated which is readily comparable. A flood damages assessment was undertaken for all residential properties flooded in the PMF event in order to identify flood damages for a range of design events.

Table 49 (Dobroyd Canal catchment) and Table 50 (Hawthorne Canal catchment) shows the damages to residential properties only for a range of design events and the AAD.

Table 49: Estimated Residential Flood Damages for Dobroyd Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.5 EY	1208	21	$7,160,000	$5,900
0.2 EY	1393	57	$11,664,000	$8,400
10% AEP	1499	121	$16,069,000	$10,700
5% AEP	1592	194	$21,347,000	$13,400
2% AEP	1677	280	$27,035,000	$16,100
1% AEP	1746	361	$33,435,000	$19,200
PMF	2363	1204	$115,604,000	$48,900
AAD			**$8,708,000**	

Table 50: Estimated Residential Flood Damages for Hawthorne Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.5 EY	400	2	$2,313,000	$5,800
0.2 EY	494	20	$3,729,000	$7,500
10% AEP	546	32	$4,746,000	$8,700
5% AEP	617	52	$6,072,000	$9,800
2% AEP	671	75	$7,378,000	$11,000
1% AEP	734	94	$9,196,000	$12,500
PMF	1285	486	$44,443,000	$34,600
AAD			**$2,731,000**	

For the both catchments, more than half of the total AAD can be attributed to events from the 0.2 EY and smaller.

6.2.1.2. Non-Residential Damages Results

The tangible flood damage to commercial and industrial properties is more difficult to assess. Commercial and industrial damage estimates are more uncertain and often larger than residential damages. Commercial and industrial damage estimates can vary significantly depending on:

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in these catchments there may not be sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

Costs to business can occur for a range of reasons, some of which will affect some businesses more than others depending on the magnitude of flooding and the type of business. Common flood damage costs to businesses are:

- Removal and storage of stock before a flood if warning is given (not applicable here);
- Loss of production – caused by damaged stock, assets and availability of staff;
- Loss of stock and/or assets;
- Reduced stock through reduced or no supplies;
- Trade loss – by customers not being able to access the business or through business closure;
- Cost of replacing damages or lost stock or assets; and
- Clean-up costs.

No specific guidance is available for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the methodology for residential properties but with the costs/damages increased to a value which is consistent with commercial/industrial development. For commercial properties damages were calculated by the summation of direct (over-floor) flooding with a commercial property loading of 55%. For direct flooding, damages were calculated on the multiplication of:

- An input damages curve, with values dependent on the size of the commercial property and the height of the flood above the floor level; and
- A floor area multiplier for commercial properties greater than 650 m^2.

Though the OEH guidelines for flood damages calculations are not applicable to non-residential properties, they can still be used to create comparable damage figures. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and for benefit-cost analysis.

A summary of the commercial/industrial flood damages for the Dobroyd Canal catchment is provided in Table 51 and in Table 52 for Hawthorne Canal catchment. The AAD for surveyed commercial/industrial properties is substantially lower than residential damages in the Dobroyd Canal catchment, and approximately half that of residential damages in the Hawthorne Canal catchment. This reflects the lower number of non-residential properties in the catchments.

Table 51: Estimated Commercial and Industrial Flood Damages Dobroyd Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property	% contribution of Total Tangible Damages
0.5 EY	120	2	$978,000	$8,100	12%
0.2 EY	138	9	$1,436,000	$10,400	11%
10% AEP	147	11	$2,177,000	$14,800	12%
5% AEP	158	15	$3,053,000	$19,300	13%
2% AEP	167	21	$3,776,000	$22,600	12%
1% AEP	176	38	$5,388,000	$30,600	14%
PMF	235	135	$24,051,000	$102,300	17%
AAD			**$1,213,000**		

Table 52: Estimated Commercial and Industrial Flood Damages Hawthorne Canal Catchment

Event	Number of Properties Flood Affected	No. of Buildings Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property	% contribution of Total Tangible Damages
0.5 EY	42	10	$1,705,000	$40,600	15%
0.2 EY	48	17	$2,412,000	$50,200	29%
10% AEP	50	21	$2,668,000	$53,400	32%
5% AEP	53	23	$3,197,000	$60,300	34%
2% AEP	58	25	$3,452,000	$59,500	36%
1% AEP	64	26	$3,725,000	$58,200	39%
PMF	93	51	$7,877,000	$84,700	42%
AAD			**$1,638,000**		

6.3. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are 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) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. 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 the 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 for the flood victims.

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. Within the study area, the high hazard areas generally correspond with the major drainage lines and trapped low points with high flood depths. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

A range of criteria have been identified with the aim of capturing the potential change to the impacts of these intangible damages. These criteria are considered when assessing potential mitigation options and include:

- Economic merits;
- Technical & implementation complexity;
- Staging of works;
- Impact on emergency services;
- Emergency access;
- Impact on critical and/or vulnerable facilities;
- Impact on properties;
- Impact on flood hazard;
- Community flood awareness;
- Social disruption;
- Community and stakeholder support;
- Impacts on flora & fauna (including street trees);
- Heritage conservation areas and heritage items;
- Acid sulfate soils and contaminated land;
- Financial feasibility and funding availability;
- Compatibility with existing council plans, policies and projects or measures (such as environmental).

7. FLOOD EMERGENCY RESPONSE ARRANGEMENTS

7.1. Flood Emergency Response

Due to their small size and urban character, inundation in the Dobroyd Canal and Hawthorne Canal catchments is ‘flash flooding’, occurring within minutes of heavy rain. Design flood hydrographs for hotspots in the study area show that the 1% AEP flood rises to peak between about 30 minutes and 1 hour after the commencement of rain (Reference 1 and 2). The PMF would be even faster to rise.

Given the limited amount of time between the start of the storm and the peak of the flood, there is generally limited warning that can be provided to the community. Furthermore, the short duration (generally receding within an hour) of inundation generally means that there is not sufficient time for evacuation, in fact, evacuation may expose evacuees to greater hazard than safely sheltering in place.

This section provides an overview of the existing emergency response strategies and policies, responsible services, flood warning and evacuation considerations. These elements form the basis of response modification options developed and recommended in Section 10.4.

7.2. Emergency Service Operators

The emergency response to any flooding in NSW will be coordinated by the lead combat agency, the SES, and for this study area from their Local Command Centres at Haberfield and St Peters. Inner West Council has also established a Local Emergency Management Committee (LEMC) to carry out emergency management as the responsible authority for the Inner West LGA. This committee is responsible for an all-agencies comprehensive approach to emergency planning to prepare the community for disasters. Committee members include SES and agencies with functional responsibilities. The committee has a planning function only. It is specifically excluded from becoming involved in operations.

The LEMC consists of:

- A senior representative of Council of the area, or combined local government area who is the chair of the LEMC (the Act requires that the person appointed by Council must have the authority of Council to co-ordinate the use of Council's resources for emergency management purposes);
- a local emergency management officer, usually a senior executive within the operation coordinates council resources during an emergency event;
- The senior local representative of each of the emergency services organisations operating in the local area;
- Representatives of such organisations providing support services in the relevant local government area as the Councils of that area may from time to time determine;

- Allowance is made for others to attend to give technical and other relevant advice i.e. Council Officers; and
- The Local Emergency Operations Controller. This is at the time of writing (October 2018) the Superintendent of Ashfield local area command of the NSW Police Force. The Superintendent attends with separate representation from the NSW Police Force.

The relevant flood information from the Flood Studies (References 1 and 2) should be provided to the LEMC.

7.3. Flood Emergency Response Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in the Dobroyd and Hawthorne Canal catchments are discussed as follows.

7.3.1. EMPLAN

The Dobroyd and Hawthorne Canal catchments (and the Inner West as an LGA) are located within the Metro and South West Metro Emergency Management Regions. Flood emergency management for the study area is organised under the NSW State Emergency Plan (2012) (EMPLAN). The State Emergency Management Plan (EMPLAN) describes the NSW approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies. The Plan is supported by hazard specific sub plans and functional area supporting plans.

The EMPLAN details emergency preparedness, response and recovery arrangement for NSW to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies. The EMPLAN has been prepared to coordinate the emergency management options necessary at State level when an emergency occurs, and to provide direction at regional and local level.

Consistent with the State Emergency and Rescue Management Act 1989, the objectives of the EMPLAN are to:

a) provide clarity as to command and control, roles and coordination of functions in emergency management across all levels;
b) emphasise risk management across the full spectrum of prevention, preparation, response and recovery;
c) emphasise community engagement in the development and exercise of plans as well as in their operational employment;
d) ensure that the capability and resourcing requirements of these responsibilities are understood.

7.3.2. NSW State Flood Sub-Plan

The State Flood Sub-plan is a sub-plan to the state EMPLAN. The Sub-plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding and the responsibilities of agencies and organisations with regards to these functions.

There is a requirement for the development and maintenance of a Flood Sub-plan for:

- The State of NSW;
- Each SES region; and
- Each Council area with a significant flood problem. In some cases the flood problems of more than one Council area may be addressed in a single plan or the problems of a single Council area may be addressed in more than one plan.

Annex B of the Sub-plan lists the Local Flood Sub Plans that exist or are to be prepared in New South Wales and indicates which river, creek and/or lake systems are to be covered in each plan. Inner West Council is not listed in Annex B. However, the LEMC should prepare a Consequent Management Guide – Flood to outline the following details:

- Evacuation centres in close proximity to the floodplain which allow flood free access to the centres and are flood free sites;
- Inclusion of a description of local flooding conditions;
- Identification of potentially flood affected vulnerable facilities; and
- Identification of key access roads subject to flooding.

The information in the Flood Studies (Reference 1, Reference 2) and this document can support the preparation of development of this guide.

7.3.3. Local Flood Plan

The Inner West Council Local Emergency Management Plan was adopted in November 2016. Part 1 describes the purpose of the plan, its objectives and scope. Part 2, titled Community Context, provides an overview of the community, describes the hazard and risks, and the supporting plans and policies. Part 3, which was unsighted due to its restricted access, provides further information regarding community assets, vulnerable facilities and the consequence management guidelines.

The risk assessment considers Cyclone / East Cost Low as Critical, Flash Flooding as High, Riverine Flooding as High, and Storm has High, all with SES responsibility. Consequence Management Guidelines were made available for Riverine Flooding, Flash Flooding and Severe Storm. Each guideline describes the risk, the control agency, command / coordination, triggers and strategies. This information should be reviewed with the data provided by this FRMS&P, particularly the description of the risk and the triggers.

7.3.4. Emergency Response Guideline for Flash Flooding

The Australian Fire and Emergency Service Authorities Council (AFAC) released a guideline on emergency planning for flash flood events in 2013 (Reference 9). The *Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events Section 3* recognises that the safest place to be in a flash flood is well away from the affected area. Evacuation is the most effective strategy, provided that evacuation can be safely implemented. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome.

However, AFAC recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flash flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater. Nevertheless, AFAC argues that remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning: '*where the available warning time and resources permit, evacuation should be the primary response strategy*'.

The risks of a 'shelter-in-place' strategy include:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with no known basis for determining a tolerable duration of isolation;
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment);
- People's immobility (not being able to reach the highest part of the building);
- The difficulty of servicing medical emergencies (pre-existing condition or sudden onset e.g. heart attack) during a flood;
- The difficulty of servicing other hazards (e.g. fire) during a flood.

7.4. Flood Warning Systems

For flash flood catchments like these, the provision of an effective flood warning service is problematic. The 'total flood warning system' has five components that need to be completed during a flood emergency – prediction, interpretation, message construction, communication and appropriate response (Reference 5). But several challenges to the effective operation of such a system have been identified for flash flood catchments (References 6 and 7):

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

For these reasons, the BoM traditionally has not issued specific flood predictions for flash flood catchments. The BoM (Reference 6, www.bom.gov.au) does offer more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding, shown in Table 53.

Table 53: BoM Warning Services of Potential Benefit in Flash Flood Catchments

General Weather forecast

General weather forecasts may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours' notice.

Severe Weather Warning

- A Severe Weather Warning is issued for synoptic scale events when one or more of the following hazardous phenomena are forecast:
- Gale force winds (average 10-minute wind speed exceeding 62 km/hr)
- Damaging winds (peak wind gusts exceeding 89 km/hr)
- Destructive winds (peak wind gusts exceeding 124 km/hr)
- Torrential rain and/or flash flooding
- Damaging surf conditions leading to significant beach erosion

Severe Thunderstorm Warning

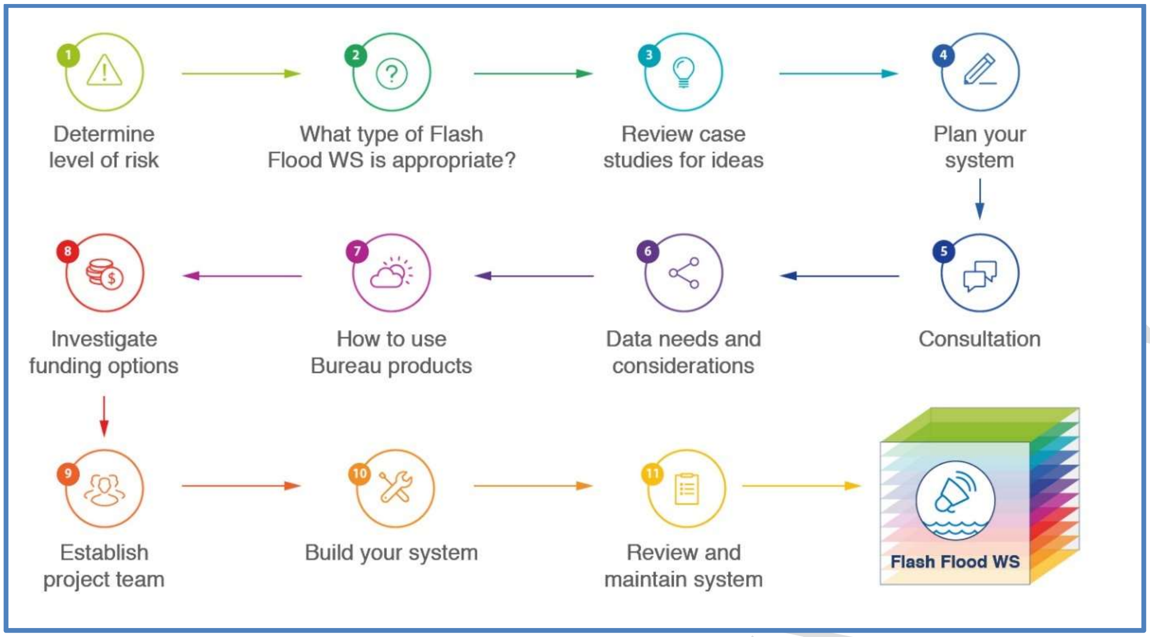
A Severe Thunderstorm Warning is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation. For the Greater Sydney region the Bureau issues more detailed graphical Severe Thunderstorm Warnings when actual thunderstorms have been detected.

Flood Watch

A Flood Watch is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours' notice that flooding is *possible* based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.

In recent times, the BoM has also developed a Flash Flood Advisory Resource (FLARE), created to assist local councils to design, implement and manage fit-for-purpose flash flood warning systems. FLARE provides best practice information to support local councils to develop flash flood warning systems. The steps involved in developing a flash flood warning system are set out in Diagram 3.

Diagram 3: Steps to develop a flash flood warning system (Source: FLARE - BoM)



7.5. Evacuation Centres

As part of the Inner West Council Local Emergency Management Plan, Council is (2019) in the process of determining evacuation centres and their locations. When this information is available, the Inner West Council Local Emergency Management Plan should be updated accordingly.

7.6. Flood Emergency Response Planning Classifications

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 the evacuator and subsequent constraints. These Emergency Response Planning (ERP) classifications (Reference 8) 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. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Access Areas; Trapped Perimeter Areas or Indirectly Affected Areas and when used with the SES Requirements Guideline (Reference 8). The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 54).

Table 54: 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

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 within the study area have been classified according to the ERP classification above, with the additional criteria of flood depths being greater than 0.1 m. If only the flood extent was used in the Dobroyd Canal and Hawthorne Canal catchments, areas surrounded by less than 0.1 m would be classified as flood islands, when in reality, people could move through this water without concern. Therefore, all flood depths of less than 0.1 m were removed from the PMF flood extents prior to classification. The ERP classifications for the Dobroyd Canal and Hawthorne Canal study areas are shown in Figure A23 and Figure B20 respectively.

8. POLICIES AND PLANNING

8.1. NSW State Planning Context

It is important to understand the state legislation that overarches all local legislation to enable appropriate floodplain risk management measures to be proposed that are in keeping with both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

8.1.1. NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

The objects of this Act are as follows:

a) *to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,*
b) *to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,*
c) *to promote the orderly and economic use and development of land,*
d) *to promote the delivery and maintenance of affordable housing,*
e) *to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,*
f) *to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),*
g) *to promote good design and amenity of the built environment,*
h) *to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,*
i) *to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,*
j) *to provide increased opportunity for community participation in environmental planning and assessment.*

8.1.2. Ministerial Direction 4.3

The EP&A Act provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

(1) The objectives of this direction are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

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

Clause (3) of Direction 4.3 states:

(3) *This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.*

Clauses (4)-(9) of Direction 4.3 state:

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

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

(6) *A planning proposal must not contain provisions that apply to the flood planning areas which:*

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

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

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

(9) *A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:*

(a) *the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or*
(b) *the provisions of the planning proposal that are inconsistent are of minor significance.*

8.1.3. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

(a) *to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and*

(b) *to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.*

The NSW Floodplain Development Manual 2005 (Reference 3), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

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

The Floodplain Development Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain.

8.1.4. Planning Circular PS 07-003

Planning Circular PS 07-003 (31 January 2007) provides advice on a package of changes concerning flood-related development controls for land above the 1-in-100 year flood and up to the PMF.

Councils can make an application to the Department of Planning and Environment for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in its Local Environmental Plan (LEP), as per Planning Circular PS 07-003. This can be useful for areas where there are significant increases in flood risk associated with increased flood magnitude above the 1% AEP event. Some Councils, where this is an issue, choose to prohibit critical and vulnerable land uses below the PMF.

8.1.5. State Environmental Planning Policy (Exempt and Complying Development Codes) 2008

The State Environmental Planning Policy (SEPP) (Exempt and Complying Development Codes) 2008 aims to "*provide streamlined assessment processes for development that complies with specific development standards*".

"Exempt" development includes minor renovations or alterations with low impact which don't require planning or building approval. "Complying" development is straightforward development that can be approved by Council or a private certifier if it meets the SEPP codes. The requirements are identical for new and existing dwellings.

Subdivision 9 Clause 3.36C of this Policy applies to development on "flood control lots" (the specification of which is determined by Council) and must satisfy the following criteria:

1) *This clause applies:*
    a. *to all development specified for this code that is to be carried out on a flood control lot, and*
    b. *in addition to all other development standards specified for this code.*

2) *The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering as not being any of the following:*
   a. *a flood storage area,*
   b. *a floodway area,*
   c. *a flow path,*
   d. *a high hazard area,*
   e. *a high risk area.*
3) *The development must, to the extent it is within a flood planning area:*
   a. *have all habitable rooms no lower than the floor levels set by the council for that lot, and*
   b. *have the part of the development at or below the flood planning level constructed of flood compatible material, and*
   c. *be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and*
   d. *not increase flood affectation elsewhere in the floodplain, and*
   e. *have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and*
   f. *have open car parking spaces or carports that are no lower than the 20-year flood level, and*
   g. *have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.*
4) *A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:*
   a. *can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or*
   b. *will not increase flood affectation elsewhere in the floodplain.*

Development occurring under this Policy would bypass Council's full Development Application requirements, including some of the flood-related requirements of the DCP. While the SEPP requirements echo the broader requirements outlined in the DCP, they are less nuanced in some regards.

8.2. Local Planning Context

Appropriate planning restrictions and ensuring that development is compatible with flood risk can significantly reduce flood damages. Environmental planning instruments such as Local Environmental Plans (LEPs) guide land use and development by zoning all land, identifying appropriate land uses allowed in each zone, and controlling development through other planning standards and Development Control Plans (DCPs). LEPs are made under the EP&A Act. In 2006, the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. LEPs can also be used to facilitate evacuation and disaster management planning to better reduce flood risks to the existing population. As at 2019, the recently amalgamated Inner West Council was working towards a LGA-wide LEP by the end of 2019, however the individual LEPs of each constituent LGA were still current. The *Ashfield LEP 2013* and the *Marrickville LEP 2011* are applicable to the Dobroyd Canal and Hawthorne Canal study area, and are described below. Within the amalgamated Council area, the Leichhardt LEP 2013 also applies and has been included below for the purposes of comparison.

In the context of floodplain management, Councils also use DCPs to control development on flood prone land. DCPs provide detailed planning and design guidelines to support the planning objectives in the LEP. For development within the study area, the *Inner West Comprehensive Development Control Plan (DCP) 2016 for Ashbury, Ashfield, Croydon, Croydon Park, Haberfield, Hurlstone Park and Summer Hill* and the *Marrickville DCP 2011* are applicable and are described below. Whilst not applicable to the study area, the *Leichhardt DCP 2013* has also been considered below to provide a Council wide comparison. An overall LGA-wide DCP is due to be completed by June 2020.

8.2.1. Ashfield LEP 2013

This planning instrument provides overall objectives that specify Council's requirements for a range of matters associated with the use and development of land, some of which are related to flood planning. Clause 6.2 of the Ashfield LEP states the following:

1) *The objectives of this clause are as follows:*
    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.*
2) *This clause applies to land at or below the flood planning level.*
3) *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 the river banks of waterways, and*
    e) *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*
4) *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.*
5) *In this clause,* ***flood planning level*** *means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

8.2.2. Marrickville Local Environment Plan 2011

This planning instrument provides overall objectives that specify Council's requirements for a range of matters associated with the use and development of land, some of which are related to flood planning. Clause 6.3 of the Marrickville LEP is consistent with Clause 6.2 of the Ashfield LEP (presented in Section 8.2.1 of this study).

8.2.3. Leichhardt Local Environment Plan 2013

This planning instrument provides overall objectives that specify Council's requirements for a range of matters associated with the use and development of land, some of which are related to flood planning. Clause 6.3 of the Leichhardt LEP is consistent with Clause 6.2 of the Ashfield LEP (presented in Section 8.2.1 of this study), with the exception of the minor differences identified below (shown with underline).

1) *The objectives of this clause are as follows:*
   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.*
2) *This clause applies to:*
   a) *land at or below the projected sea level risk, and*
   b) *other land at or below the flood planning level*
3) *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 the river banks of waterways, and*
   e) *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*
4) *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.*
5) *In this clause:*
   flood planning level *means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*
   projected sea level rise *means the 2050 and 2100 sea level rise planning benchmarks as specified in the NSW Coastal Planning Guideline: Adapting to Sea Level Risk (ISBN 978-1-74263-035-9) published by the NSW Government in August 2010.*

8.2.4. Comprehensive Inner West DCP 2016

This DCP applies to suburbs within the Inner West LGA located to the west of Hawthorne Canal, and includes Ashbury, Ashfield, Croydon, Croydon Park, Haberfield, Hurlstone Park and Summer Hill. Its purpose is to supplement the Ashfield LEP 2013 and provide more detailed guidance on development that requires Council approval. The DCP supports the Ashfield LEP 2013 by providing guidelines that will encourage good urban design, complementing zone objectives and key development standards contained in the Ashfield LEP 2013.

Part 3 relates to Flood Hazard, and is applicable to land identified as being flood prone land (defined as that which is within the flood planning area for mainstream flooding and/or in the flood planning level for overland flooding) for both the Dobroyd and Hawthorne Canal catchment areas. The purpose of this section is:

- *To minimise risk to human life and damage to property.*
- *To maintain the existing flood regime and flow conveyance capacity.*
- *To enable the safe occupation of, and evacuation from, land to which flood management controls apply.*
- *To avoid significant adverse impacts upon flood behaviour.*
- *To avoid significant adverse effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the river bank/watercourse.*
- *To limit uses to those compatible with flow conveyance function and flood hazard.*

The DCP then stipulates controls and design solutions tailored to development use, including new residential, additions and alterations (habitable and non-habitable), non-residential, change of use, subdivision, filling of flood prone land, and garages. The general performance criteria require:

- *…consideration must be given to such matters as the likely depth and nature of possible floodwaters, flood classification of the area (where applicable) and the risk posed to the development by floodwaters.*
- *The applicants must demonstrate:*
  - *That the development will not increase the flood hazard or risk to other properties and that details have been provided of the structural adequacy of any building works associated with the development with regard to the effects of possible floodwaters;*
  - *That the proposed building materials are suitable;*
  - *That the development is sited in the optimum position to avoid floodwaters and allow evacuation; and*
  - *That all electrical services associated with the development are adequately flood proofed.*

Further controls, based on development type, are provided which relate to minimum floor levels, use of flood compatible materials (with a schedule of flood compatible materials for a variety of building components provided within the DCP), provision of flood free access, location of sensitive equipment, flood affectation, emergency response plans, flood warning systems and signage.

8.2.5. Marrickville Development Control Plan 2011

The purpose of this planning instrument is to provide more detailed guidance and provisions for implementing the broader development control objectives outlined in the Marrickville LEP 2011. The DCP applies to the suburbs of Camperdown, Dulwich Hill, Enmore, Lewisham, Marrickville, Newtown, Petersham, Stanmore, St Peters, Sydenham and Tempe. Part 2.22 of the Marrickville DCP relates to Flood Management, and complements Clause 6.3 (Flood Planning) of Marrickville LEP 2011.

The DCP applies to land identified in the Flood Planning Area and the Flood Liable Land Maps. The DCP details that the Flood Planning Area is defined based on the "100 year" Cooks River flood including an allowance for sea level risk, with a 500 mm freeboard, or the "100 year" local overland flood. Flood Liable Land is that which is within the Cooks River PMF event but not with Flood Planning Area. The objectives of this section are:

O1 To maintain the existing flood regime and flow conveyance capacity.
O2 To enable the safe occupation of, and evacuation from, land to which flood management controls apply.
O3 To avoid significant adverse impacts upon flood behaviour.
O4 To avoid significant adverse effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the river bank/watercourse.
O5 To limit uses to those compatible with flow conveyance function and flood hazard.

The DCP then stipulates controls and design solutions tailored to development use, including any new development requiring development consent (located within the Flood Planning Area), as well as caravan parks, child care centres, correctional centres, emergency services facilities, hospitals, residential accommodation (with some exceptions), and tourist and visitor accommodation located within the Flood Liable Land area.

The general performance criteria require:

- *…consideration must be given to such matters as the likely depth and nature of possible floodwaters, flood classification of the area (where applicable) and the risk posed to the development by floodwaters.*
- *The applicants must demonstrate:*
  - *That the development will not increase the flood hazard or risk to other properties and that details have been provided of the structural adequacy of any building works associated with the development with regard to the effects of possible floodwaters;*
  - *That the proposed building materials are suitable;*
  - *That the development is sited in the optimum position to avoid floodwaters and allow evacuation; and*
  - *That all electrical services associated with the development are adequately flood proofed.*
- *…Consideration must be given to whether structures or filling are likely to affect flood behaviour and whether consultation with other authorities is necessary*

Further controls, based on development type, are provided which relate to minimum floor levels, use of flood compatible materials (with a schedule of flood compatible materials for a variety of building components provided within the DCP), provision of flood free access, location of sensitive equipment, flood affectation, emergency response plans, flood warning systems and signage.

8.2.6. Leichhardt Development Control Plan 2013

The purpose of this planning instrument is to provide more detailed guidance and provisions for implementing the broader development control objectives outlined in the Leichhardt LEP 2013. Part E: Water includes consideration of flooding, as part of wider Sustainable Water and Risk Management objectives. The flood-related objectives of the overall Section are:

O1 *c. reduce and manage the social, environmental and economic risks and impacts associated with major flood or tidal inundation events.*
O3 *To maximise retention and absorption of surface drainage water on site*
O4 *To minimise obstruction to the surface and underground flow of water*
O5 *To avoid, minimise and mitigate adverse impacts*
O8 *To implement risk management measures in relation to flooding which*

- *a. minimise the adverse consequences of floods on the community and environment including potential danger to personal safety and damage to property, whilst taking into account the potential effects of climate change and sea level rise;*
- *b. implement risk management measures in relation to tidal inundation and wave impact from Parramatta River and Sydney Harbour which minimise the adverse consequences on the community and environment including potential danger to personal safety and damage to property, taking into account the potential effects of climate change and sea level rise.*

Section E1.1.14 specifies that a Flood Risk Management Report is required for applications that are identified as flood control lots within the specified maps. The report is not required where the assessed value is less than $50,000, except where Council considers the works are likely to substantially increase the risk of flood to adjoining or nearby sites. Section 2 of Appendix E provides further details of the requirements of the report, which is used to establish the flood planning level, the probable maximum flood level, the hazard category and an on-site response and evacuation plan.

Under Section E1.3.1 Flood Risk management, contains further controls. The objective of these are to *manage development of flood control lots and flood prone land to reduce the risks and costs associated with flooding.*

In addition to the requirements of the Flood Risk Management Report, further controls, based on development type, are provided which relate to minimum floor levels, flood affectation and access.

8.2.7. Summary of Local Policy

There is strong consistency between the planning documents relevant to the study area. The two LEPs (Ashfield and Marrickville) contain the same Flood Planning clauses, and the two DCPs contain only minor differences. As a result, until such time that an amalgamated policy is produced, development in the study area which triggers such controls is likely to achieve similar outcomes should the policies be applied as stated.

A comparison was also made with the Leichhardt LEP and DCP (2013) which apply to the rest of the amalgamated Council area, beyond the study area. The LEP is consistent, with the minor exception of including a clause for sea level rise. The DCP takes a different format to the Inner West and Marrickville DCP, and uses a different approach to applying the controls. Whilst the same principles are considered, consistency in the development outcomes may not necessarily be achieved due to these differences. A more detailed analysis would be required to accurately determine the extent of this based on different land uses and development types, however a summary of the key aspects are provided in Table 55 below. The primary intention of the DCP is to support the LEP, providing more detailed guidance and provisions for implementing the broader development control objectives outlined in the LEP. In addition to be consistent with the NSW state government legislation and related policy.

Table 55: Comparison of Inner West, Marrickville and Leirchhardt DCP Flood Controls

	Inner West DCP and Marrickville DCP	Leichhardt DCP	Comment
Land & development to which DCP applies	Land identified as flood prone on the Flood Control Lot Map, which consists of land which is in the flood planning area for mainstream flooding and/or in the flood planning level for overland flooding.	Land identified as flood control lots on provided maps, for works where the assessed value is greater than $50,000 or where Council considers the works are likely to substantially increase the risk of flooding on or near the site.	Both controls aim to achieve generally the same purpose. Clause should clearly identify land shown on any mapping, in the FPA and below the FPL, in the case where mapping may not exist. Consider if value ($) of works is appropriate, footprint of works may be more appropriate.
Specified development types	• New residential development • Minor alterations – residential development • Non habitable additions or alterations • New non-residential development • Non-residential development – additions • Change of use of existing buildings • Subdivison • Filling of flood prone lands	• Single dwelling residential or dual occupancy development • Multi unit residential development for 3 or more dwellings • Commercial, industrial and mixed use development • Subdivision • Special uses (emergency services, accommodation or treatment of children, the aged, disabled or vulnerable)	Categories should be aligned with zoning and contain sub-categories such as: • New development, • Replacement development, • Extension, • Non habitable, • Etc.

	• Land uses on flood prone land identified on flood control maps • Underground garages	• Other • Land with a High Hazard Category • Car parking facilities and basements • Flood mitigation and modification works	
Floor level controls	For new residential development, habitable floors must by a minimum 0.5m above the standard flood level (0.3m considered for minor overland flow defined as a flood depth of 300mm or less or overland flow of $2m^3/s$ or less)	100y ARI plus 500 mm, with some exceptions. For special uses the higher of either the PMF or FPL	Inclusion of reduced freeboard for overland areas is suitable, as is higher floor level control for vulnerable and critical uses. Include clause to cover additions and alterations and dwelling replacement.
Flood compatible materials	Applicant must demonstrate the structural adequacy of any building works associated with the development with regard to the effects of possible floodwaters, and that the proposed building materials are suitable.	Recommendations to be provided in Flood Risk Management Report to ensure the structural integrity of the development for immersion and impact of velocity and debris for the 100 y ARI event	Both controls aim to achieve generally the same purpose. Consideration of structural adequacy above the 1% AEP may be warranted.
Access / egress	Applicant to demonstrate that the development is sited in the optimum position to avoid floodwaters and allow evacuation For new residential development, flood free access must be provided where practicable. All land uses on flood liable land (identified on the Flood Liable Land Map) require an adequate flood warning systems, signage and exits to allow safe and orderly evacuation without an increased reliance upon emergency services personnel, as well as reliable access for pedestrians and vehicles.	Recommendations to be provided in Flood Risk Management Report for a flood evacuation strategy. For developments identified as being within high hazard areas, the principle entries are located above the higher of the PMF or FPL and an evacuation route clear of the floodway must be provided.	It is appropriate for development to consider the potential flood evacuation risk, however guidance should be provided on what is considered to be a reasonable strategy. Aspects such as site position, provision of flood free access, differing levels of controls for different hazard areas, should be considered.

Emergency response and warning systems	All land uses on flood liable land (identified on the Flood Liable Land Map) require a site emergency response flood plan for the PMF flood; adequate flood warning systems, signage and exits	Recommendations to be provided in Flood Risk Management Report for an on-site response plan to minimise flood damage and provide adequate storage for hazardous materials and valuable goods above the flood level.	Clarification of name of map and related clause for areas within FPA but not necessarily mapped. Both existing clauses include important requirements, including consideration of the appropriate site specific response and storage requirements for hazardous materials.
Location of sensitive equipment	Applicant to demonstrate that all electrical services associated with the development are adequately flood proofed.	Recommendations to be provided in Flood Risk Management Report for waterproofing methods, including electrical equipment, wiring, fuel lines or any other service pipes or connections	Both controls aim to achieve generally the same purpose.
Flood affectation	Applicant must demonstrate that the development will not increase the flood hazard or risk to other properties. Filling of flood prone land is not permitted in flood ways or high hazard areas. In other areas it will be considered if flood levels are not increase by more than 0.01m, downstream velocities are not increased by more than 10%, flows are not redistributed by more than 15%, minimal cumulative impacts of fill, surrounding properties not adversely affected, flood liability of surrounding buildings is not increased, and filling does not create local drainage flow/runoff problems	If Flood Risk Management Report identifies the development as being in a High Hazard category, the development must demonstrate that: a. there is no net loss in flood storage and floodway area as a result of the development; b. the development will not increase velocity, volume or direction of flood waters. Flood modification or mitigation works are permitted subject to not having an adverse impact on any surrounding property.	Both existing controls aim to achieve the same outcome however the following comments are made: • The floodway and flood storage areas are the parts of the floodplain where development is likely to result in external impacts, while these areas often align with high hazard, they are not one and the same. • The Inner West DCP clause covers off well the issues that should be considered when quantifying impacts.

9. FLOOD PLANNING AREA AND LEVEL REVIEW

9.1. Flood Planning Area (FPA)

The Flood Planning Area (FPA) is an area within Council's LGA to which flood planning controls are applied. 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. It is also important to define the FPA on criteria consistent with the Floodplain Development Manual (Reference 3).

The FPA can comprise of mainstream and overland flow elements. Typically different criteria are used to generate the mainstream and overland flow FPA extents and then these are combined. Since the study area is subject to both mainstream and overland flow flooding, both elements were considered.

The FPA extent defines those properties subject to flood related development controls under the Section 10.7 (2) notification under the EP&A Act.

Whilst for mainstream flooding the FPA can be defined simply as the 1% AEP event plus freeboard (typically 500 mm), such a method is sometimes not appropriate for areas subject to overland flow flooding which often do not reach the depths that could occur from mainstream flooding and additionally, where depths do not tend to increase significantly for rarer events. This is particularly an issue in urban areas such as the study area where the 1% AEP flood level plus 500 mm freeboard is consistently higher than the PMF flood level in areas of overland flow.

Due to the nature of flooding in the study area, the following method was used to establish the FPA:

- **Mainstream flooding:** Any of the cadastral area is affected by mainstream flooding in the 1% AEP event. This has been defined as the peak flood level within the open channel section of Dobroyd Canal and Hawthorne Canal plus a 500 mm freeboard, with the level extended perpendicular to the flow direction.
- **Overland flooding:** Greater than or equal to 10% of the "active" cadastral area is affected by the 1% AEP peak flood depth of greater than 150 mm. The "active" cadastral area was considered to be the cadastral area excluding the building area that was modelled as impermeable.

9.2. Flood Planning Level (FPL)

The FPL is the height at which new building floor levels should be built. Due to the mixture of residential and commercial development in the study area, a variety of FPLs may be applicable depending on where in the catchment development is being considered and also based on the type of development being proposed.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual (Reference 3) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc.);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding; and
- Duty of care.

In situations where a cadastral lot is subject to both mainstream flooding and overland flooding, the mechanism that produces the highest FPL often applies, although both levels can be provided for flood education purposes.

9.3. Exceptional Circumstances Assessment

The sensitivity of the FPA to blockage and climate variations has been assessed for both study areas. Table 56 summarises the number of additional properties identified in the FPA in these sensitivity scenarios.

Table 56: Exceptional Circumstances Summary

Scenario	No. Properties inside FPA	
	Dobroyd Canal Catchment	Hawthorne Canal Catchment
Current 10.7 (2) – 1% AEP event	1446	1036
Blockage of 20%	1466	1147
Blockage of 50%	1474	1170
2050 Sea Level Rise	1459	1144
2100 Sea Level Rise	1470	1151
10% Rainfall Increase	1543	1181
20% Rainfall Increase	1622	1227
30% Rainfall Increase	1689	1334
PMF event	2332	1938

It should be noted that the above numbers are not always directly comparable as the current 10.7 (2) Planning Certificate FPA has been "ground-truthed" (minor adjustments based on field inspection), whereas the sensitivity scenario FPA's have not been.

10. POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES

10.1. Introduction

The Floodplain Development Manual (Reference 3) identifies three categories of flood risk to be managed via the implementation of a Floodplain Risk Management Plan. The broad risk categories are:

- **Existing flood risk,** relating to risks of damage and personal danger for existing flood-affected communities and properties.
- **Future flood risk,** associated with any new development on flood prone land.
- **Continuing flood risk,** or the remaining risk to current and future flood-affected communities after implementing floodplain risk management measures. This includes risk of larger floods than those directly managed by physical works or development controls, and the risk of failure of mitigation works such as levees.

The Floodplain Development Manual also separates floodplain management measures into three broad categories:

- **Flood modification measures** modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins, on-site detention, channel modifications, diversions, levees, floodways, flood gates or catchment treatment.
- **Property modification measures** modify land use including development controls. This is generally accomplished through such means as flood proofing (e.g. house raising or sealing entrances), planning and building regulations (such as zoning) or voluntary purchase, among others.
- **Response modification measures** modify the community's response to flood hazard by informing flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

10.2. Flood Modification Measures

Flood modification measures are structural measures that change flood behaviour, and are intended to reduce flood risk and property damages. The types of flood modification options available are discussed in Sections 10.2.1 to 10.2.8. In total, 56 flood modification options were modelled across both catchments. Of those, 50 options were not considered to warrant further investigation and are documented in Appendix C. However, six options were identified for more detailed assessment, as summarised in Section 10.2.9. A full list of options grouped by Hotspot is provided in Appendix F.

10.2.1. Levees and Embankments

Levees involve the construction of raised embankments between a watercourse/channel and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller bunds.

Once constructed, levee systems generally have a low maintenance cost though the levee system needs to be inspected on a regular basis. Although a levee can keep out flood waters, flooding can occur behind the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event and uncertainties.

Table 57 provides a summary of the key issues to be considered with levee construction.

Table 57: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
"Environmentally Sensitive Measure"	A well-designed vegetated earthen embankment set back far enough from the riverbank to retain floodplain access, and that does not interrupt local drainage, can have minimal environmental impact providing that the natural wetland hydrology is not affected. However, in many locations it is hard to meet all these criteria.
Protects a large number of buildings.	A levee system can protect a large number of buildings from being inundated up to the 1% AEP or even larger flood event.
Can provide a high level of protection	At many locations in the study area this is not possible due to the large height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure (of say flood gates) will generally be small (say less than $10,000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy overlooking a creek or open space area because of the visual attraction and a (say) 2.0 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m to 1 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the land take and associated costs (possible services re-location and access) which add considerably to the cost.

Low benefit cost ratio	Whilst the levee system may protect a number of buildings from being inundated in a (say) 1% AEP event it is likely to have a low benefit cost ratio unless the levee can include buildings inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP). Typically these frequently inundated buildings are not concentrated in an area that can readily be protected by a levee.
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the creek itself. In some places local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the creek system.	Access to the creek or open space area for recreational activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points.
Increase in flood levels elsewhere	Levees by their very nature prevent inundation of part of the floodplain. The floodwaters that previously entered the protected area must now travel elsewhere and in so doing increase flows and flood levels elsewhere. The increase in level depends upon whether the area to be leveed was a flood storage area with no or little cross flow or the area was an area of active flow, termed a floodway.
Tying the levee into high ground	Unless the levee is a ring levee it must tie into high ground. This is likely to be a significant issue as it may require raising roads or significantly extending the levee alignment.

Four of the 56 options identified involved levee construction, with the following two assessed in detail:

Option ID	Catchment	Description	Report Section
403A & 403B	Hawthorne Canal	Grosvenor Crescent and Smith Street flow path pipe upgrade, above ground detention basin and levee wall	10.2.9.1
702A	Hawthorne Canal	Waratah Street to City West Link Hawthorne Canal levee	10.2.9.5

10.2.2. Temporary Flood Barriers

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times.

The short warning time available in the Dobroyd and Hawthorne Canal catchments significantly limits the opportunities to deploy temporary flood barriers on a large scale. This type of option is more suitable for riverine flooding in rural towns where there are fewer unprotected properties, and significantly longer warning time, as their deployment requires substantial resources (both man hours and vehicles for transportation of barriers from storage to the site).

While temporary flood barriers may provide some benefit as a property-level protection measure, they are not recommended for wide scale implementation in this study area, and no options were identified.

10.2.3. Floodway and Diversion Channels

Floodway or bypass channels redirect a portion of the flood waters away from the main channel. The opportunities for their implementation are limited by topography, availability of land, potential flood level impacts and ecological considerations.

In a heavily urbanised and well established catchment like Dobroyd and Hawthorne Canals, there is little opportunity to create significant diversion channels due to lack of available land and/or high costs associated with land acquisition. No options were identified in this study.

10.2.4. Channel Modification

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/creek system. This includes a range of measures from straightening, concrete lining and removal/augmentation of structures.

Duplication of the Dobroyd Canal was considered as an option for the Dobroyd Canal catchment but was discounted due to the impact on flood behaviour (increase in flood levels) and very high construction costs.

10.2.5. Drainage Modification

Drainage modification measures are undertaken to improve the conveyance of the existing drainage system, in this case the stormwater pipe network. Measures may include increasing pipe sizes or number of pipes, altering system layouts, or removing potential constrictions.

Drainage modification works were extensively investigated for both Dobroyd Canal and Hawthorne Canal catchments. Of the 26 pipe upgrade options considered (four of which are in combination with other measures), three have been identified for further assessment, namely:

Option ID	Catchment	Description	Report Section
403A & 403B	Hawthorne Canal	Grosvenor Crescent and Smith Street flow path pipe upgrade, above ground detention basin and levee wall	10.2.9.1
404C	Hawthorne Canal	Nowranie Street to Hawthorne Canal pipe upgrade	10.2.9.2
605C	Hawthorne Canal	Sloane Street pipe upgrade	10.2.9.4

10.2.6. Drainage Maintenance

Ongoing maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. For natural channels, environmental policy can govern how the creek channel is maintained by restricting creek clearing and vegetation management.

Blockage has the potential to considerably increase flood levels in the catchment. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Blockage of structures can be reduced through the establishment of ongoing maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. Regular clearing of leaf litter and other debris from the channel banks will reduce the available material which may block structures. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

No drainage maintenance options were specifically modelled.

10.2.7. Detention Basins

Detention basins work by storing floodwaters during an event and then controlling the release of the water once the peak has passed. These can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to assist in alleviating existing flood problems.

Depending on their capacity, detention basins can significantly reduce peak flows and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the water level in the detention basin.

Detention basins can be located above or below ground. Like the rest of the drainage system, detention basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

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. Importantly it should be noted that basins only reduce flood levels downstream not upstream. Unless considerable excavation is undertaken the flood levels at the site of the basin and possibly upstream will increase. These are summarised in Table 58 below.

Table 58: Considerations for Retarding Basins

ISSUE	COMMENT
Size and Location:	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. It is difficult therefore to find a location which can accommodate a basin and is not used for some other purpose.
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.

ISSUE	COMMENT
	However, in these events there is often only minor above floor damage or minor 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.
Competing 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 catchments, 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 dense urban catchment such as in the study area 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. Construction of a basin will change an open space area with a low hazard potential during rainfall events to an area with a greater hazard potential. 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 can be designed to have shallow and gradual depths closer to the edges. However 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 may place a significant potential liability on the construction authority 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 the construction authority's responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs.

Detention basins were extensively investigated for both Dobroyd Canal and Hawthorne Canal catchments. Of the 31 basin options considered (four of which are in combination with other measures), the following three have been identified for further assessment.

Option ID	Catchment	Description	Report Section
403A & 403B	Hawthorne Canal	Grosvenor Crescent and Smith Street flow path pipe upgrade, above ground detention basin and levee wall	10.2.9.1
501G	Hawthorne Canal	Petersham Park above-ground detention basin, with access moved to southern corner	10.2.9.3
703	Dobroyd Canal	Pratten Park and Arthur Street under-ground detention basin	10.2.9.6

10.2.8. Dams

Dams are built to control and store large quantities of water often on large river systems. They are built for a variety of purposes, including water supply, irrigation, flood control, environmental control and hydro-electricity. They may be built to solely serve one of these objectives, or multiple purposes.

Dams serve a flood mitigation role by impounding flood waters and releasing them at lower, controlled rates, thereby reducing flood levels downstream of the dam.

In small creek catchments that are heavily urbanised and developed such as the Inner West the opportunity to implement new dams is nil. No options were identified for either catchment.

10.2.9. Flood Modification Options Considered

The hotspots discussed in Section 5.8 were used to guide locations which might benefit the most from flood modification measures. In total, 56 flood modification options were considered, six of which have been identified for more detailed assessment as below. Appendix C provides a preliminary assessment of flood modification options which after assessment were considered unviable and were not investigated further.

Each option was quantitatively assessed for impacts on flood behaviour and property affectation, as well as a qualitative assessment for impacts on emergency services, economic assessment, technical feasibility, environment impacts and community/policy alignment. The results of the Multi-criteria assessment documented in Section 11.

10.2.9.1. Hawthorne Canal – Option FM0403A & FM0403B Combined: Grosvenor Crescent and Smith Street flowpath pipe upgrade and detention basin

Overview

This option aims to alleviate flooding in Grosvenor Crescent and the downstream flowpath along Smith Street. The modelled option uses Darrell Jackson Gardens, Summer Hill skate park and the tennis courts as an above-ground detention basin. The proposed design includes the construction of a new pedestrian walkway between Summer Hill IGA and former NSW Ambulance site to form the eastern wall of the detention basin. The new footpath will be raised by approximately 1.2 m to a level of 21.3 m AHD, directly between the tennis courts and IGA. The walkway will ramp down from 21.3 m AHD to 19.9 m AHD (gradient of ~ 8%, or as required for accessibility) to tie in with existing ground levels. An impermeable levee wall is also proposed along the eastern side of the tennis courts extending from the NSW Ambulance Site to the pedestrian walkway. This proposed design includes a 600 mm diameter pipe installed at a topographical low point in Grosvenor Crescent which travels under the railway embankment to Carlton Crescent.

There may be some opportunity to combine water quality benefits for smaller scale flows through the future design stages.

Figure B22 shows a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood behaviour and property affectation

In the 0.2 EY event, peak flood levels typically decrease by less than 0.1 m from directly downstream of the proposed detention basin to Hawthorne Canal. The largest decrease in flood levels is observed by between Hardie Avenue and Lackey Street, particularly within the shopping centre carpark and commercial building fronting Lackey Street.

In the 1% AEP event, peak levels typically decrease up to 0.1 m along the overland flowpath, whilst flood levels within Hawthorne Canal upstream of the railway line decrease by around 0.35 m.

Table 59 shows the impact on properties as a result of the option, with above floor level inundation reduced in all modelled events.

Table 59: Number of Properties Impacted, Option FM0403A & FM0403B

Event	Total Properties Affected		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	442	439	12	10	-2
0.2 EY	542	540	37	32	-5
10% AEP	596	593	53	47	-6
5% AEP	670	666	75	72	-3
2% AEP	729	728	100	96	-4
1% AEP	798	793	120	116	-4

Emergency services, response and community awareness

The reduced property flooding across the full range of flood events will provide some benefit to emergency services and response. However, during events, the detention basin would flood the playground which is located along the rear of the IGA building, as well as the tennis courts and playground. This could pose a community safety risk, particular as flood depths are in excess of 1 m depth even for frequent events. The spillway located along the pedestrian walkway may also pose a risk to safety with fast flowing water. Mitigation of these risks should be considered in any further assessment of the option.

The option may have a slight benefit to community awareness if signage around the detention basin was provided to describe the role the area plays in flood risk management.

Economic assessment

This option would reduce the AAD by approximately $390,000 or 9%. The estimated cost of this option is $970,000 giving a B/C ratio of 5.1.

Technical feasibility
At a high level the option is considered technically feasible, however challenges may exist in aligning the pipe upgrade. This may be identified after detailed survey is undertaken.

Environmental impacts
There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment. The temporary storage of water during events may have some impacts on the vegetation and landscaping in the immediate area of the detention basin but this is not considered significant. Standard erosion and sediment control measures would need to be deployed during construction.

10.2.9.2. Hawthorne Canal – Option FM0404C: Nowranie Street to Hawthorne Canal pipe upgrade

Overview
This option proposes the duplication of the existing Council drainage network system between Morris Street and Hawthorne Canal. The duplication is proposed to commence upstream of Nowranie Street at Morris Street, and follow the existing easement through properties from Morris Street through to Carrington Street. From here, the pipeline continues beneath the road, heading north along Carrington Street then east along Smith Street to Hawthorne Canal. The aim is to divert additional runoff into the stormwater pipe to reduce flooding along the overland flowpath.

Figure B23 shows a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood behaviour and property affectation
In the 0.2 EY event, the peak flood levels between Morris Street and Hawthorne Canal decrease by 0.01 m and 0.5 m. The properties located on the downstream side of Nowranie Lane have a decrease in flood levels of around 0.3 m to 0.5 m whilst downstream of this, the flood levels typically decrease by 0.1 to 0.15 m.

In the 1% AEP event, the peak flood levels typically decrease by up to 0.1 m between Morris Street and Hawthorne Canal. Properties along Nowranie Lane benefit from the largest decreases in flood levels.

Table 60 shows the impact on properties as a result of the option, with above floor level inundation reducing for 3 properties in the 0.2 EY event and reducing for 21 properties in the PMF.

Table 60: Number of Properties Impacted, Option FM0404C

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	442	432	12	12	0
0.2 EY	542	531	37	34	-3
10% AEP	596	589	53	50	-3
5% AEP	670	662	75	72	-3
2% AEP	729	726	100	97	-3
1% AEP	798	795	120	120	0
PMF	1378	1375	537	516	-21

Emergency services, response and community awareness
The reduced property inundation will provide some benefit to emergency services and response. As the option involves upgrades to underground pipes only, there would be no impact on community awareness of flooding.

Economic assessment
This option would reduce the AAD by approximately $151,000 or 3.5%. The estimated cost of this option is $2,070,000 giving a B/C ratio of 0.93.

Technical feasibility
The option is generally considered technically feasible, although below-ground construction in a heavily developed area is likely to present significant challenges, and access to properties for construction may be difficult.

Environmental impacts
There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment. Standard erosion and sediment control measures would need to be deployed during construction.

Community /stakeholder/policy alignment
Augmentation of the existing pipe network is unlikely to be contentious. Disruption during construction may create a nuisance for the community, and depending on the pipe alignment, private property access may be required.

10.2.9.3. Hawthorne Canal – Option FM0501G: Petersham Park above-ground detention basin, with access moved to southern corner

Overview

The option involves the use of Petersham Park as an above-ground detention basin during flood events. At the eastern boundary of Petersham Park (parallel to Station Street) the ground levels would be raised to 14 m AHD for approximately 165 m length along the pedestrian walkway that surrounds the oval. Current vehicle access at the eastern side of the park would be moved to the southern corner to allow for greater flood storage.

Figure B24 shows a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood behaviour and property affectation

In the 0.2 EY event, peak flood levels between Petersham Park and Hawthorne Canal typically decrease by up to 0.1 m. The largest decreases in flood levels are observed within the properties along Station Street with decreases of up to 0.2 m. The detention basin does not overtop during this event.

In the 1% AEP event, there is a decrease in flood levels of between 0.1 m to 0.5 m along the downstream flowpath with the largest decrease observed along Station Street (around 0.3 m) and between George Street and Upward Street (0.5 m). When the capacity of the detention basin is exceeded flow overtops predominately around the western side of the cricket field, newly flooding the north western portion of Petersham Park. There is no increase in flood levels to any properties.

Table 61 shows the impact on properties as a result of the option, with above floor level inundation reducing for three properties in the 2% AEP event, and six in the PMF event. It should be noted that the property counts below in Table 61 only considers those located within the former Marrickville LGA. Those properties in the former Leichhardt LGA are considered in another study. In order to fully evaluate the benefits of this option, data from that study has been utilised to make an estimate of properties benefitted between Parramatta Road and Hawthorne Canal (Table 62). These results show reduction in property affectation across the full range of events.

Table 61: Number of Properties Impacted – Study Area, Option FM0501G

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	442	442	12	12	0
0.2 EY	542	543	37	37	0
10% AEP	596	596	53	53	0
5% AEP	670	670	75	75	0
2% AEP	729	730	100	97	-3
1% AEP	798	793	120	117	-3
PMF	1378	1378	537	531	-6

Table 62: Number of Properties Impacted – Leichhardt Study Area, Option FM0501G

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	15	14	7	5	-2
0.2 EY	17	16	9	9	0
10% AEP	18	17	13	12	-1
5% AEP	19	17	14	12	-2
2% AEP	21	19	16	14	-2
1% AEP	22	20	18	15	-3
PMF	34	34	32	31	-1

Emergency services, response and community awareness

The reduced property inundation will provide some benefit to emergency services and response, albeit marginal.

The option may have a slight benefit to community awareness if signage around the detention basin was provided to describe the role the area plays in flood risk management.

Economic assessment

This option would reduce the AAD by approximately $47,000 across both the former and Marrickville and Leichhardt LGA (particularly on Tebbutt Street, Beeson Street and Darley Road). The estimated cost of this option is $900,000 giving a B/C ratio of 0.77. It is noted that the cost reflects the fairly limited civil works needed to convert the already sunken field into a formalised detention basin, however costs associated with detailed design and survey, planning and approvals and environmental impact assessments may reduce the economic viability of this option and should be considered if this option were to progress.

Any works recommended and implemented as part of the study in the former Leichhardt LGA may either contribute to or reduce the effectiveness of this option, and as such should be considered in conjunction.

Technical feasibility

At a high level the option is considered technically feasible, though heritage constraints may pose challenges to the embankment design.

Environmental impacts

There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment and localised construction works required. Consideration should be given to the local bandicoot habitats within the park, particularly in the western corner of Petersham Park, which is where the basin outlet would be located. The temporary storage of water during events may have some impacts on the vegetation in the immediate area of the detention basin but this is not considered significant. Standard erosion and sediment control measures would need to be deployed during construction.

Community /stakeholder/policy alignment

There would be considerable disruption to the park and entrance. Whilst a retarding basin can be suitably located in a park any increase in flood levels (and therefore risk to life) must be considered. In addition the facility may be unusable and amenity reduced for a period following an event.

10.2.9.4. Hawthorne Canal – Option FM0605C: Sloane Street pipe upgrade

Overview

This option aims to reduce flooding on Parramatta Road near Sloane Street and the downstream flowpath. The option involves the duplication of the existing drainage network from the intersection of Sloane Street and Parramatta Road to Hawthorne Canal. Currently, there is a 0.6 m diameter pipe that travels under Parramatta Road and then becomes a 0.9 m for the rest of the drainage network.

Figure B25 shows a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood behaviour and property affectation

In the 0.2 EY event, the peak flood levels decrease within the road corridor of Parramatta Road by approximately 0.2 m. However, the road still becomes cut-off during the rainfall event. Due to the decreases in flood levels, flooding no longer impacts two properties fronting Parramatta Road whilst four other properties have decreases in flood levels of up 0.3 m. Decreases in flood levels are observed downstream of Parramatta Road, ranging between 0.1 m and 0.3 m. Shallow overland flow that previously affected Hawthorne Parade is no longer flooded allowing for safer evacuation of residents.

In the 1% AEP event, peak flood levels decrease by up to 0.1 m between Parramatta Road to Hawthorne Parade. Increases in flood levels of approximately 0.01 m are observed within Hawthorne Canal and a number of adjacent properties.

Table 63 shows the impact on properties as a result of the option.

Table 63: Number of Properties Impacted, Option FM0605C

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	442	432	12	12	0
0.2 EY	542	532	37	35	-2
10% AEP	596	589	53	46	-7
5% AEP	670	664	75	68	-7
2% AEP	729	724	100	96	-4
1% AEP	798	792	120	115	-5
PMF	1378	1375	537	512	-25

Emergency services, response and community awareness

As the option involves upgrades to underground pipes only, there would be no impact on community awareness of flooding.

Economic assessment

This option would reduce the AAD by approximately $154,000 or 3.5%. The estimated cost of this option is $786,000 giving a B/C ratio of 2.5.

Technical feasibility

The option is generally considered technically feasible, although below-ground construction in a heavily developed area is likely to present access to properties along Parramatta Road may be difficult.

Environmental impacts

There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment. Standard erosion and sediment control measures would need to be deployed during construction.

Community /stakeholder/policy alignment

Augmentation of the existing pipe network is unlikely to be contentious. Disruption during construction may create a nuisance for the community. The NSW Ambulance site is located at the corner of Sloane Street and Parramatta Road. Works could potentially be coupled with future Roads and Maritime Services works.

10.2.9.5. Hawthorne Canal – Option FM0702A, FM0702B: Waratah Street to City West Link Hawthorne Canal levee

Overview

This option proposes a levee along Hawthorne Canal between Waratah Street to City West Link. A number of respondents during the community consultation period suggested raising the canal walls to alleviate out of bank flooding, particularly during a king tide. The proposed design includes installing a levee along an existing shared path (north side of Hawthorne Canal). The levee will be raised 2 m above the existing ground levels, which currently vary between 1.25 m AHD to 2 m AHD. This will allow greater capacity of Hawthorne Canal and reduce out-of-bank flooding, therefore reducing the flood affectation for properties located along Hawthorne Canal.

Two options were assessed; FM0702A and FM0702B. The same proposed design was adopted for both cases. However, a different storm was analysed:

- FM0702A - Uses the standard rainfall design events as adopted in this study. This is used to assess the impacts that a rainfall event would have on both mainstream flooding and overland flooding.
- FM0702B - Assesses the levee for various tidal events (i.e. no rainfall is applied). The 0.2 EY event uses the HHWS (High High Water Springs) tidal event of 1.25 m AHD, whilst the 1% AEP event uses a 1% AEP ocean level of 1.45 m AHD. Further details of ocean levels used for this study are provided in Section 4.2.1.

Figure B26a and 26b show a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood Behaviour and Property Affectation

FM0702A

In both the 0.2 EY event and 1% AEP event there is no discernible reduction in peak flood within Hawthorne Canal. However, there is a large increase in both flood levels and flood extent along Hawthorne Parade. This is due to shallow overland flow becoming trapped behind the levee. In both events, a number of properties become newly flood affected along Hawthorne Parade, typically only flooding the front yards in the 0.2 EY event, whilst a large portion of the property lot becomes inundated in the 1% AEP event.

Table 64 shows the impact on properties as a result of the option, with above floor level inundation increasing for events ranging from the 0.2 EY to 1% AEP. In the PMF, 3 properties are no longer flooded above floor level.

Table 64: Number of Properties Impacted, Option FM0702A

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	442	449	12	12	0
0.2 EY	542	561	37	38	1
10% AEP	596	617	53	54	1
5% AEP	670	698	75	77	2
2% AEP	729	755	100	105	5
1% AEP	798	821	120	125	5
PMF	1378	1379	537	534	-3

Emergency services, response and community awareness

As the option involves levee banks, there would be a need to educate the public on the relative benefits and risks of levees.

Economic assessment

This option would reduce the AAD by approximately $79,000 or 1.8%. The estimated cost of this option is $2,700,000 giving a B/C ratio of 0.37, indicating the option is not economically feasible.

Technical feasibility
At a high level this option is considered technically feasible, however the requirement for substantial through-levee drainage pipes is likely to present challenges in the design stage.

Environmental impacts
There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment. However visual impacts would need to be considered. Standard erosion and sediment control measures would need to be deployed during construction.

Community /stakeholder/policy alignment
This option was identified in the community consultation and had wide support. However, the visual amenity of the levee may deter some residents, and alternative solutions may be preferred.

This option is not recommended for implementation or inclusion in the Floodplain Risk Management Plan.

Alternative Options
The Floodplain Risk Management Study acknowledges the community's desire to address nuisance flooding from Hawthorne Canal during elevated tides. However, the technical assessment has shown that a levee may not be the best way to resolve this issue, as it restricts the free drainage of local runoff into the canal, which would worsen local flooding during rain events. In addition, the visual impact of a levee of this height (2 m) is likely to be undesirable to residents, and would significantly change the aesthetics of the foreshore area.

The Inner West Flood Management Advisory Committee discussed a range of alternative approaches to be implemented in Hawthorne Parade, including the upgrade and maintenance of flood valves to prevent backwatering of local pits and pipes during elevated tides, and ongoing community education via letterbox drop during king tide seasons (around Christmas and mid-winter) and seasonal signage. Ongoing strategies such as these will help alleviate nuisance flooding, and reduce damages to cars (parked along Hawthorne Parade), without construction of an imposing levee wall that may worsen local flooding.

10.2.9.6. Dobroyd Canal – Option FM0703: Pratten Park and Arthur Street under-ground detention basin

Overview
The option involves the construction of an underground detention basin in Pratten Park and beneath the tennis courts (Arthur Street). This aim is to divert overland flow as well as stormwater pipe flow. This allows greater capacity for flow from overland flow paths to enter the pipe network to reduce overland flooding down to Dobroyd Canal.

The proposed design of the Pratten Park detention basin includes directing water from two existing Council owned pipes (0.9 m diameter) at the southern boundary of Pratten Park into a detention basin (dimensions L130 m x W 80 m x H 1.2 m) beneath Pratten Park. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing pipe (0.75 m diameter). This option also includes removing an existing 0.9 m pipe under Pratten Park. There may be some opportunities to combine stormwater harvesting and water quality aspects, that can be considered in later design stages.

For the detention basin beneath the tennis courts, the proposed design includes directing water from an existing SWC owned pipe (approximately 1.0 m diameter) at the eastern boundary of the tennis courts into a 1.2 m diameter pipe before discharging into a detention basin (dimensions L 70 m x W 40 m x H 3 m) beneath the tennis courts. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing pipe (approximately 1.0 m diameter pipe). Figure A22 shows a schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

Flood behaviour and property affectation

In the 0.2 EY event, the peak flood levels typically decrease by 0.15 m downstream of the proposed detention basin to Dobroyd Canal. In the 1% AEP event, the peak flood levels decrease by up to 0.1 m along the flowpath downstream. At Liverpool Road and Heighway Avenue, the decreases in flood levels are in the order of 0.15 m.

Table 65 shows the impact on properties as a result of the option, with above floor level decreasing across the full range of flood events. The greatest impacts are seen in the 5% AEP event where 50 properties are no longer flooded above floor level.

Table 65: Number of Properties Impacted, Option FM0703

Event	Total Properties Impacted (internal and external)		Total Properties Inundated Above Floor Level		
	Existing	Option	Existing	Option	Difference
0.5 EY	1328	1292	23	19	-4
0.2 EY	1531	1488	66	46	-20
10% AEP	1646	1601	132	89	-43
5% AEP	1750	1721	209	159	-50
2% AEP	1844	1829	301	257	-44
1% AEP	1922	1911	399	357	-42
PMF	2598	2592	1339	1323	-16

Emergency services, response and community awareness

This option would significantly reduce the number of buildings and risk to life, thus greatly benefiting the SES.

Economic assessment

This option would reduce the AAD by approximately $1,200,000 or 10%. The estimated cost of this option is $12,700,000 giving a B/C ratio of 1.2.

Technical feasibility

At a high level this option is considered technical feasible. It is noted that the tennis courts are privately owned, and land acquisition and other additional costs may be required.

Environmental impacts
There are unlikely to be any significant environmental impacts due to the heavily urbanised and developed nature of the catchment. Standard erosion and sediment control measures would need to be deployed during construction.

Community /stakeholder/policy alignment
Whilst the resulting basin is unlikely to contentious disruption during construction may create a nuisance for the community and for the use of the park and associated activities.

10.2.9.7. Recommendations

The above analysis and the multi criteria assessment documented in Section 11, considered a range of impacts for each of the options identified for more detailed assessment. Impacts considered include flood behaviour, property damage, environmental, economic, technical feasibility, visual impacts, flood response and broader policy alignment.

Based on the above analysis and in consideration of the results of the multi criteria assessment shown in Table 68, the following options have been recommended for inclusion in the Floodplain Management Plan and Council's future works planning:

- Hawthorne Canal – Option FM0403A & FM0403B Combined: Grosvenor Crescent and Smith Street flowpath pipe upgrade and detention basin.
- Hawthorne Canal – Option FM0404C: Nowranie Street to Hawthorne Canal pipe upgrade.
- Hawthorne Canal – Option FM0501G: Petersham Park above-ground detention basin, with access moved to southern corner.
- Hawthorne Canal – Option FM0605C: Sloane Street pipe upgrade.
- Dobroyd Canal – Option FM0703: Pratten Park and Arthur Street under-ground detention basin.

10.3. Property Modification Measures

10.3.1. Option PM01: Flood Planning Area and Flood Planning Levels

The FPL is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings, garages, driveways and even commercial floors as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided. The *Floodplain Development Manual* provides guidance and indicates that:

..the FPL (minimum floor level) for standard residential development would be the 1% AEP flood event plus a freeboard (typically 0.5m)….

The main aim of the FPLs is to reduce the damages experienced by the property owner during a flood. Elevating a house floor level above the FPL will ensure that flood damages are significantly reduced. Council have specified FPL requirements in the *Comprehensive Inner West DCP* and *Marrickville DCP,* that currently apply to the study areas.

The Flood Planning Area has been defined based on the criteria outlined in Section 9.1 and should be adopted.

It is recommended that the currently applied controls are maintained that allow for variation of the freeboard for areas considered to be minor overland flow based on set criteria. In addition, consideration should be given to higher FPLs for vulnerable and special uses.

10.3.2. Option PM02: Flood Proofing

An alternative to house raising for buildings that are not compatible or not economically viable, is flood proofing or sealing off the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. Flood proofing requires sealing of doors and possibly windows (new frame, seal and door); sealing and re-routing of ventilation gaps in brick work; sealing of all underfloor entrances and checking of brickwork to ensure there are no gaps or weaknesses in mortar. It is generally only suitable for brick buildings with concrete floors and it can prevent ingress from outside depths of up to one metre. Greater depths may cause structural problems (buoyancy) unless water is allowed to enter. Generally an existing house can be sealed for approximately $10,000. New development and extensions allow the opportunity for use of flood compatible materials and designs, meaning the actual cost of flood proofing can be significantly less when compared to buildings requiring retro-fitting of flood proofing measures.

Flood proofing should also consider suitable electrical installation to as to avoid the risk of electrocution. A minimum aim should be to have all properties in flood hazard areas to, at least, be fitted with a circuit breaker although ideally for all new development all unsealed electrical circuits should be above the FPL.

Additionally, flood proofing can involve the raising of easily damaged/high cost items such as commercial stock, equipment and machinery. New buildings should have floor levels above the FPL.

Permanent flood proofing options are more suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Care must be taken to ensure flood proofing measures do not conflict with other regulations such as fire safety, maintenance or access issues. However, flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate.

Minimising the chance of electrocution by turning off the electricity supply during a flood should be standard practice for both residents and commercial owners during floods. The risk of electrocution can also be reduced by installing electrical circuits above, at least, the FPL.

Responsibility for flood-proofing in the Dobroyd Canal and Hawthorne Canal catchments should fall to property owners, and should be initiated by the appropriate DCP. Commercial premises are varied in nature, with the degree of flood risk often dependant on a store's contents and its location relative to the ground. This means that different flood-affected premises require different types of flood-proofing. The building owners can determine the most appropriate options for their property, depending on the degree of flood affectation and the nature of the commercial premises, and carry out suitable flood proofing. It is recommended that Council carry out a consultation program with flood affected properties (i.e. those in flooding hotspots) in order to provide information to building owners about possible flood proofing options.

10.4. Response Modification Measures

Response modification measures aim to reduce risks to life and property damage in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities and planning, and through better flood-educated communities.

10.4.1. RM01: Flood Warning Systems

10.4.1.1. Overview

Flood warning systems aim to provide advice on impending flooding so people can take action to minimise its negative impacts. Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high benefit cost ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately. Flood warning systems and their challenges are described in Section 7.4.

10.4.1.2. Discussion

Consideration has been given to the need and practicality of enhancing the flood warning system in the Dobroyd Canal and Hawthorne Canal study area.

Heighway Avenue has been identified as possibly the most serious hotspot in the study area. Using the FLARE toolkit (Diagram 3), flood risk for Heighway Avenue is 'medium', based on the potential for a 'high' consequence (multiple loss of life given the flood depths) in an 'unlikely' event (the 1% AEP flood). FLARE suggests that for this level of risk, an *advanced* flash flood warning system may be required. The components of an advanced flash flood warning system are set out in Table 66.

Developing such a system would require investments in monitoring, including real-time rain gauges and water level recorders positioned in the concrete canal. The warnings triggered when pre-determined thresholds are exceeded would need to be automatically distributed to community members via landline or SMS messages.

Table 66 Components of an Advanced Flash Flood Warning System (Source: FLARE - BoM)

Total Flood Warning System element	Advanced Flash Flood Warning System components
Monitoring and Prediction	• Severe weather warnings • Severe thunderstorm warnings • Flood Watches • Access to real-time information from weather radar. • Real-time information from rain gauges installed in the flash flood area. • Rainfall triggers (depth/duration e.g. 30mm in an hour) set to warn of onset of flooding. • Real-time information from river or drain/pipe gauges installed in the flash flood locality. • READY (monitor), SET (prepare), GO (act) based on Bureau warnings, observed rainfall triggers and observed river/drain level triggers respectively.
Interpretation	• Some flood studies and flood modelling/mapping may have been carried out. • Interpretation from historical data and SES flood intelligence to link triggers to impact on the ground.
Message Construction	• Standard Bureau messages for weather warnings and flood watches. • Predefined flash flood warning messages for READY, SET, GO phases.
Communication	• Bureau warnings and information available on the web, and broadcast by the media. • Direct and automatic dissemination of warnings to the affected community e.g. via SMS
Response	• Generally proactive community and SES response underpinned by local recurrent public flood awareness and education program. • Good community awareness of flooding and personal actions required; some community members have personal flood plans prepared. • A Municipal Flood Emergency Plan (MFEP) or response plan exists but has gaps or requires updating.
Review	• Review performance of the system (including each individual element) after each significant flash flood event. • Regular and scheduled reviews of the readiness and maintenance of system components such as gauges, communications, public education and planning.

In terms of the practicality, it is clear from design flood hydrographs that available warning times are very short. The rate of rise in a PMF allows negligible time to respond. Although rainfall triggers would provide slightly more warning time, they would also lead to a higher proportion of false alarms, which may over time erode confidence in the warning system causing people to disregard future alerts. However relying on water level recorders would reduce the time available to respond to just a few minutes – if a water level recorder was installed just below the crest level of the drain upstream of Heighway Avenue, only about 18 minutes would be available before depths in the street reached 0.5m, based on the 1% AEP design hydrograph. And evacuating through floodwater to higher ground is generally not advisable, going against public SES messaging never to drive, ride, walk or play in floodwater. Plus, if people evacuate and the flood subsequently fails to inundate their houses, they may (incorrectly) perceive that evacuation was unwarranted, which could also erode confidence in the warning system causing them to be slow to respond to, or ignore, future warnings to evacuate.

Although on paper it may be possible to establish for Heighway Avenue a Ready-Set-Go system as suggested in Table 66, the very short available warning times suggest that establishing and sustaining an *effective* flash flood warning system in this setting would be very difficult, relying heavily on intensive community education to persuade residents to evacuate immediately when the Go message is received. If any part of the system fails – e.g. water level recorder is damaged by debris, radio telemetry malfunctions, phone numbers not maintained, people asleep do not hear warnings, people delay or unable to evacuate, etc. – the risk of disaster in a severe flood is significant. A more rigorous approach to managing the risk to life in Heighway Avenue would be through deeper-seated changes to the urban architecture promoted though upzoning (see Section 0).

Given the rising road access available up to about the 1% AEP flood, and the relatively short distance required to traverse to reach flood-free ground, there may be marginally more potential to establish an effective flash flood warning system for Fred Street. This would require installation of a water level recorder near the top of the canal banks where modelling shows floodwater commences to spill. As soon as the sensor is reached, a siren could be activated. Ongoing education would be required so that owners and tenants understand the meaning of a siren and are prepared to evacuate very quickly. Should any hydrological infrastructure be installed, it might also be used (and possibly co-funded) by the Inner West Light Rail.

10.4.1.3. Recommendations

Although marginal benefits might be had by installing water level recorders in canals and setting up direct dissemination methods, the very limited time for residents to respond suggests that it would be very difficult to establish and maintain an effective flash flood warning system. If other measures to more radically reduce the risk in the Heighway Avenue and Fred Street hotspots are not pursued, consideration should be given to setting up flash flood warning systems for these areas, despite their limitations.

10.4.2. RM02: Emergency Management Planning

10.4.2.1. General

Effective planning for emergency response is a vital way of reducing risks to life and property. The SES is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is based on detailed flood planning.

However, the amalgamation of Councils has complicated the process of preparing local flood plans. In particular, the former Ashfield Council is within the Sydney Western SES Region but the former Marrickville Council is within the Sydney Southern SES Region. It is unclear whether the SES will redraw the boundaries of its Regions so that all Inner West Council is within the one SES Region. It is also unclear whether the SES will move to prepare a consolidated local flood plan for the entire LGA. There is also discussion about shifting away from LGA-based local flood plans to catchment-based Flood Plans, for example, for the Cooks River and the Parramatta River. There is also discussion about preparing a separate local flood plan for areas subject to flash flooding, since the traditional focus of these in on mainstream, riverine flooding.

In any event, it is clear that local flood plans and other SES intelligence systems require renewal. The current Marrickville local flood plan needs to be expanded to match the new SES template. For example, Volume 2 of the template has sections for the flood threat (landforms and river systems, weather systems and flooding, characteristics of flooding, flood history, flood mitigation systems, extreme flooding) and the effects on the community (including detailed assessments of the flood hazard, exposure and vulnerability for distinct communities, road closures, and isolated properties). Volume 3 of the template has chapters on flood warning systems and arrangements and response arrangements by sector.

Flood intelligence from the Dobroyd Canal and Hawthorne Canal Flood Studies and this FRMS&P needs to be incorporated into SES plans. This includes a listing of the hotspots, such as Heighway Avenue, Croydon and Fred Street, Lewisham, which would also benefit from active reconnaissance during heavy rain.

However in the Dobroyd Canal and Hawthorne Canal study areas, floods can rise so quickly that it is unlikely that SES personnel will be able to assist flood-prone residents prior to or even during flooding. Whilst the SES has ample rescue capability there may be inadequate time to deploy these resources. Given the time constraints upon official responders, it is then vital than the flood-prone residents are themselves capable of responding appropriately during a rising flood.

10.4.2.2. RM02: Response Strategies

A major point of contention in contemporary emergency management policy and practice relates to the advantages and disadvantages of evacuation compared to sheltering-in-place, particularly for flash flood catchments such as those identified in the Dobroyd Canal and Hawthorne Canal study area.

Evacuation

AFAC's (2013) *Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events* (Reference 9) is considered to represent best practice on this issue and is described in Section 7.3.4. For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater (Reference 10). Pre-incident planning therefore needs to include a realistic assessment of evacuation timelines (both time available and time required for evacuation), including assessment of resources available. Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (often as short as 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation.

Initiating evacuation of large numbers of people from areas prone to flash flooding based only on forecasts may be theoretically defensible in a purely risk-avoidance context but it is likely to be viewed as socially and economically unsustainable. Frequent evacuations in which no flooding occurs, which statistically will be the outcome of forecast-based warning and evacuation, could also lead to a situation where warnings are ignored by the community.

Flood behaviour, impacts and risks in the Dobroyd Canal and Hawthorne Canal study area are described in the Flood Studies (Reference 1 and 2) and in this report. The following salient features are noted:

- Deep flooding upstream of constrictions, where pipes/culverts are undersized;
- Rapid rates of rise;
- Short duration;
- Flooding of many roads;
- Limited opportunity for the emergency services to reach flooded areas prior to flooding.

Although there is scope for marginal improvements to flood warning systems (see Section 10.4.1), the inescapably 'flashy' nature of flooding in the study area suggests that it will always be difficult to ensure people in the floodplain evacuate prior to flooding of roads. In many cases, it may be safer to shelter-in-place above the reach of floodwater. Council may need to give consideration to new development controls to ensure that where safe evacuation cannot be guaranteed, and where the flood height range from the 1% AEP flood to the PMF is significant, new housing is required to design for shelter-in-place through elevated PMF refuges and resilient building structures.

It is noted, however, that the depths in extreme floods would pose a threat to many existing houses and people sheltering in those houses. These areas need to be identified in SES flood plans, and will require active reconnaissance and, potentially, flash flood warning systems, allowing people time to evacuate, until redevelopment of these areas more effectively reduces the risk.

It is also noted that some residents would require assistance to evacuate. 2016 Census data shows that 17% of Inner West LGA residents do not have a motor vehicle (compared to 9% for NSW). However, having a vehicle is no guarantee that people will be able to self evacuate, and consideration for the elderly or those with a disability or suffering a chronic illness is essential when drafting a flood emergency management plan that involves evacuation.

Other Flood Plans

In addition to the SES local flood plans, other agencies need to prepare or update their flood plans to incorporate the flood intelligence from the Dobroyd Canal and Hawthorne Canal Flood Studies and this FRMS&P. One significant flood risk that needs to be managed is the risk to the Inner West Light Rail service. The Hawthorne Canal Flood Study (Reference 2) shows how the light rail network itself conveys flood flows. This can occur even in relatively frequent floods, with a depth of 0.23 m for the light rail line upstream of Longport Street in a 0.5 EY flood. A depth of 1.33 m for the light rail line will occur upstream of the Old Canterbury Road embankment in the 1% AEP flood. Thus, it is vital that the operators of the Inner West Light Rail service have systems in place to detect when the track is at threat of inundation and cease operations before that occurrence.

10.4.2.3. Recommendations

It is recommended that the SES update their flood intelligence and plans to incorporate flood intelligence from the Dobroyd Canal and Hawthorne Canal Flood Studies and this FRMS&P and to align with the new SES local flood plan template.

It is also recommended that the operators of the Inner West Light Rail service develop or review its procedures for preparing for, responding to and recovering from inundation of the light rail track, to maximise safety and minimise damage to assets.

10.4.3. RM03: Community Education

10.4.3.1. General

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the [SES], with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced'* (Reference 11).

Although a number of flood and property modification measures are available to manage flood risk, communities living and working in floodplains in the Dobroyd Canal and Hawthorne Canal study area will never be totally protected from the impacts of flooding. Nor can emergency authorities such as the SES ensure the safety of all residents. Therefore, it is vital that through community education the flood-affected communities are aware of the flood risk, are prepared for floods, know how to respond appropriately and are able to recover as quickly as possible.

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; and
- Are ongoing programs rather than one-off, un-integrated campaigns with activities varied for the learner.

10.4.3.2. Messages

A basic message to continue to communicate to the public is that floods are a genuine hazard within the study area and that effort should be made to prepare for flooding. The response rate of only 6-7% to the community questionnaires issued for the Flood Studies suggests that the majority of residents are uninterested in flooding. Census data (2016) reveal that a relatively high proportion of residents in Inner West LGA are tenants (44% compared to 32% for NSW) and that 49% of residents had lived at a different address five years previously (compared to 42% for NSW). This provides an indication of the limited experience of flooding many residents would have, as well as the need for ongoing efforts to provide flood information and preparedness tips to ever-changing communities.

For some highly flood-prone communities, it will be important to communicate the flood risk and help residents develop their own emergency plans. If any local flash flood warning systems are constructed, it will obviously be essential to inform residents about the warning system.

For motorists, it will be important to communicate the message never to drive, ride, walk or play in floodwater.

10.4.3.3. Methods

Certificates/letters
Best practice teaches that a key measure for raising and maintaining people's awareness of their flood risk is via the regular issuing of flood certificates to all occupiers of the floodplain. Flood certificates inform individual property owners of flood levels at their particular property. It is the site-specific nature of this advice (i.e. not a generic brochure) that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. Tips could also be included to help people prepare for flooding (e.g. refer SES web site). Translation services should be offered for the main non-English languages.

Website
The former Leichhardt Council makes available flood mapping products via a website (http://www.leichhardt.nsw.gov.au/Environment---Sustainability/Projects-and-Programs/Floodplain-Risk-Management-Study-and-Plan-#FloodTool). This service could potentially be expanded to cover the entire Inner West LGA. A 'one-stop shop' website could include links to flood reports and generic advice.

Meet-the-street events

An option to directly engage residents is via 'meet-the-street' events, which involves SES and Council setting up a stall at an appropriate and visible location at a time that people will be at home. The 'meet-the-street' should be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of SES banners and materials, with Council staff equipped with laptops enabling residents to understand how floods behave at their locality (preferably with animations to show the dynamic progress of flooding). These meetings are used to engage with people and make them aware of their particular flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. A meeting could also encourage owners and tenants to develop self-help networks, particularly so that people check on neighbours if a flood is imminent. Considering the existing flood risk, at least the following two sites would benefit from this approach:

- Heighway Avenue, Croydon; and
- Fred Street, Lewisham.

One point of caution for meet-the-street events relates to the potential for conflicting advice in relation to whether to attempt to evacuate or to shelter-in-place. Council and SES personnel will need to ensure that they are presenting a clear and consistent message for each location, so that residents know how they need to respond in a flood emergency.

Signage

Permanent signage can be of value in a variety of contexts, showing:

- that an area or road is subject to flooding;
- the potential depths of flooding;
- evacuation routes;
- safety messages (e.g. don't enter floodwater).

Flood depth indicators up to 1m high could be of value where flood modelling shows important roads to be inundated to high levels in frequent events. However, it is noted that depth indicators in isolation can be unhelpful, as they do not clearly convey whether it is safe to enter the floodwater. For consistency with SES messaging (i.e. to never enter floodwater), depth indicators should be accompanied by appropriate signage.

Four sites have been identified to be flooded to >0.5 m in the 0.5 EY flood:

- Parramatta Road at West Street/Flood Street, Petersham;
- Grosvenor Crescent, Summer Hill;
- Trafalgar Street, Petersham;
- Dixson Avenue, Dulwich Hill.

Given the traffic volumes on Parramatta Road, there would be merit in installing a water level sensor that triggers flashing lights located on the approaches to the low point. Consultation may need to be conducted to gain the acceptance of nearby residents, given fears of adverse impacts of signage on property values.

10.4.3.4. Recommendations

Four methods are recommended to raise flood readiness in the study area:

- Regularly issue flood certificates;
- Enhance the flood pages of Council's website;
- Run meet-the-street events at two sites, and continue these at regular intervals to build and sustain a culture of flood preparedness;
- Installing signage at four road low-points, and flashing lights linked to a water level sensor at one of these.

11. MULTI CRITERIA ASSESSMENT

11.1. Overview

The Floodplain Development Manual (Reference 3) recommends the use of multi-criteria assessment matrices when assessing flood risk mitigation measures. A multi-criteria matrix provides a method by which options can be assessed against a range of criteria and offer a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages for example. Such additional criteria may include social, political and environmental considerations, and stakeholders may choose to assign an explicit weighting to different criteria to reflect their values. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an multi-criteria matrix will not give a definitive 'right' answer, but will provide a tool to debate the relative merits of each option.

11.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criterions: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further.

The scoring system is presented in Table 67 with the matrix provided on Table 68.

Table 67 Multi Criteria Matrix Scoring System

	Criteria	Metric	Score -3	Score -2	Score -1	Score 0	Score 1	Score 2	Score 3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
Economic	Technical & Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome easily	No constraints or uncertainties	No construction requirements
Economic	Staging of Works	*Ability to stage proposed works*	NA	NA	NA	Works cannot be staged	Some minor components of the works may be staged	Some major components of the works may be staged	NA
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
Social	Emergency Access	*Flood depths and duration changes for critical transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
Social	Impact on critical and/or vulnerable facilities[1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
Social	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
Social	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
Social	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
Social	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-5 days	No Change to acess but facilities disrupted for 0-2 days	No Change	Reduces duration of access disruption or facility disruption by 0-2 days	Reduces duration of access disruptioin or facility disruption by 3-5 days	Prevents disruption of access or facility altogether
Social	Community and stakeholder support	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
Environmental	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
	Acid Sulfate Soils and Contaminated Land	*Disruption of PASS and/or Disruption of Contaminated Land*		Any works within Class 1 or 2 ASS area or Excavation >1m within Class 3 ASS area or Excavation >1m within Class 4 ASS area	Surface works within Class 2 ASS area or Excavation <1m or surface works within Class 3 ASS area or Excavation <2m or surface works within Class 4 ASS area	Works not within areas identified as PASS or contaminated land	NA	NA	NA
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies and projects or measures (such as environmental)	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

(1) Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

Table 68 Multi Criteria Matrix

Criteria		Economic			Social								Environmental			Other		Total
ID	Option	Economic Merits	Technical & Implementation Complexity	Staging of Works	Impact on Emergency Services	Emergency Access	Impact on critical and/or vulnerable facilities	Impact on Properties	Impact on Flood Hazard	Community Flood Awareness	Social disruption	Community and stakeholder support	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Acid Sulfate Soils and Contaminated Land	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies and projects or measures (such as environmental)	
FM0403A & FM403B	Hawthorne Canal - Grosvenor Crescent and Smith Street flow path pipe upgrade, above ground detention basin and levee wall	3	-2	2	-1	1	0	2	-1	1	-1	TBC	-1	-1	-1	-1	0	**0**
FM0404C	Hawthorne Canal - Nowranie Street to Hawthorne Canal pipe upgrade	-1	-3	2	1	1	0	2	1	0	0	TBC	-1	-2	-1	-1	0	**-2**
FM0501G	Hawthorne Canal - Petersham Park above-ground detention basin, with access moved to southern corner	-1	-2	0	-1	1	0	3	-1	1	-2	TBC	-1	-1	-1	-1	0	**-8**
FM0605C	Hawthorne Canal - Sloane Street pipe upgrade	3	-3	2	1	1	0	3	1	0	0	TBC	-1	-1	-1	-1	0	**4**
FM0702A, FM0702B	Hawthorne Canal - Waratah Street to City West Link Hawthorne Canal levee	-2	-2	0	-2	0	0	-2	0	-1	0	TBC	-1	-1	-1	-1	0	**-13**
FM0703	Dobroyd Canal - Pratten Park and Arthur Street under-ground detention basin	1	-2	2	1	1	0	3	1	0	1	TBC	-1	-1	-1	-1	0	**4**
RM01	Flash flood warning system - Heighway Avenue and Fred Street	1	-1	0	2	0	0	0	0	1	0	TBC	0	0	0	1	0	**4**
RM02	Update flood intelligence and other plans with FRMS&P data	1	2	1	3	0	0	0	0	3	0	TBC	0	0	0	2	0	**12**
RM03	Community education program	1	2	2	3	0	0	0	0	3	0	TBC	0	0	0	2	0	**13**
PM01	Flood planning area and flood planning levels	0	2	0	1	0	1	3	0	1	2	TBC	0	-1	0	0	2	**11**
PM02	Flood proofing	1	1	0	1	0	1	2	0	1	1	TBC	0	-1	0	0	1	**8**

12. ACKNOWLEDGEMENTS

WMAwater wish to acknowledge the assistance of the Inner West Council staff and the Floodplain Management Committee in carrying out this study as well as the NSW Government (Office of Environment and Heritage) and the residents of the Dobroyd Canal and Hawthorne Canal catchments. WMAwater also wish to acknowledge the contribution of Stephen Yeo regarding the emergency management and flood response modification measures.

This study was jointly funded by the Inner West Council and the NSW Government.

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14. GLOSSARY of TERMS

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 and 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)	FPLs 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 A

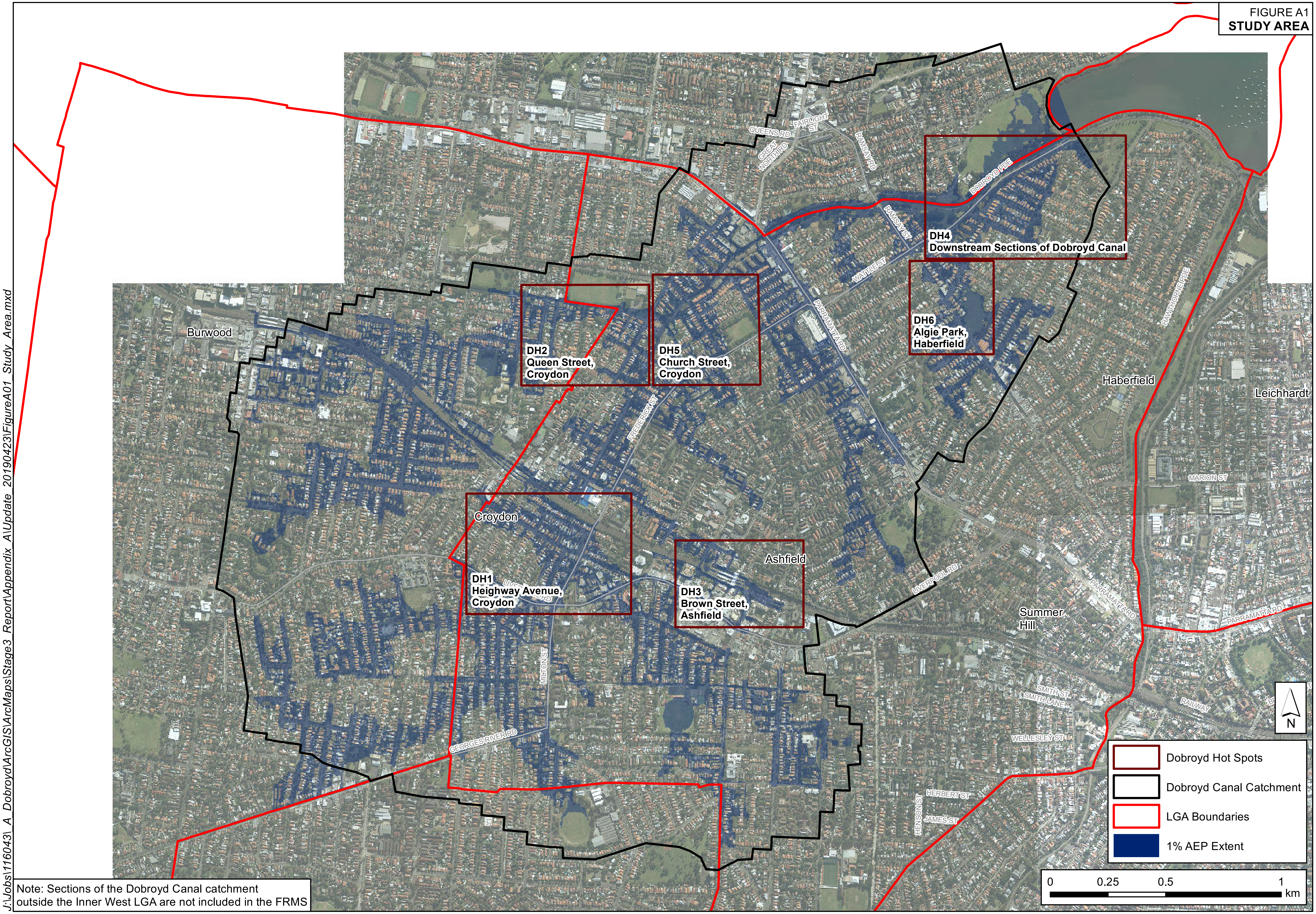
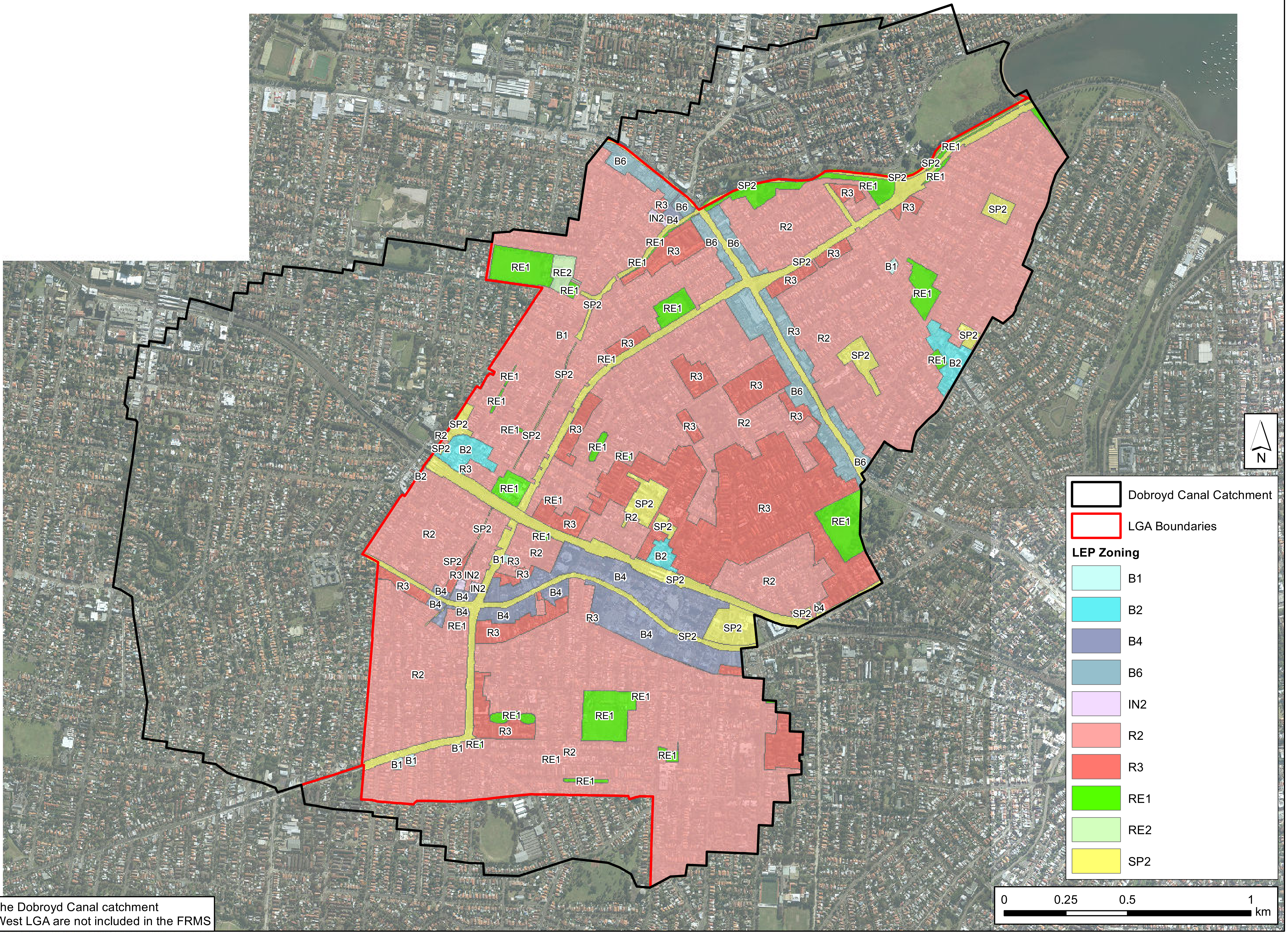


FIGURE A1
STUDY AREA

FIGURE A2
LAND USE MAP



Note: Sections of the Dobroyd Canal catchment outside the Inner West LGA are not included in the FRMS

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FIGURE A3
MAP FROM 1885 - 1890

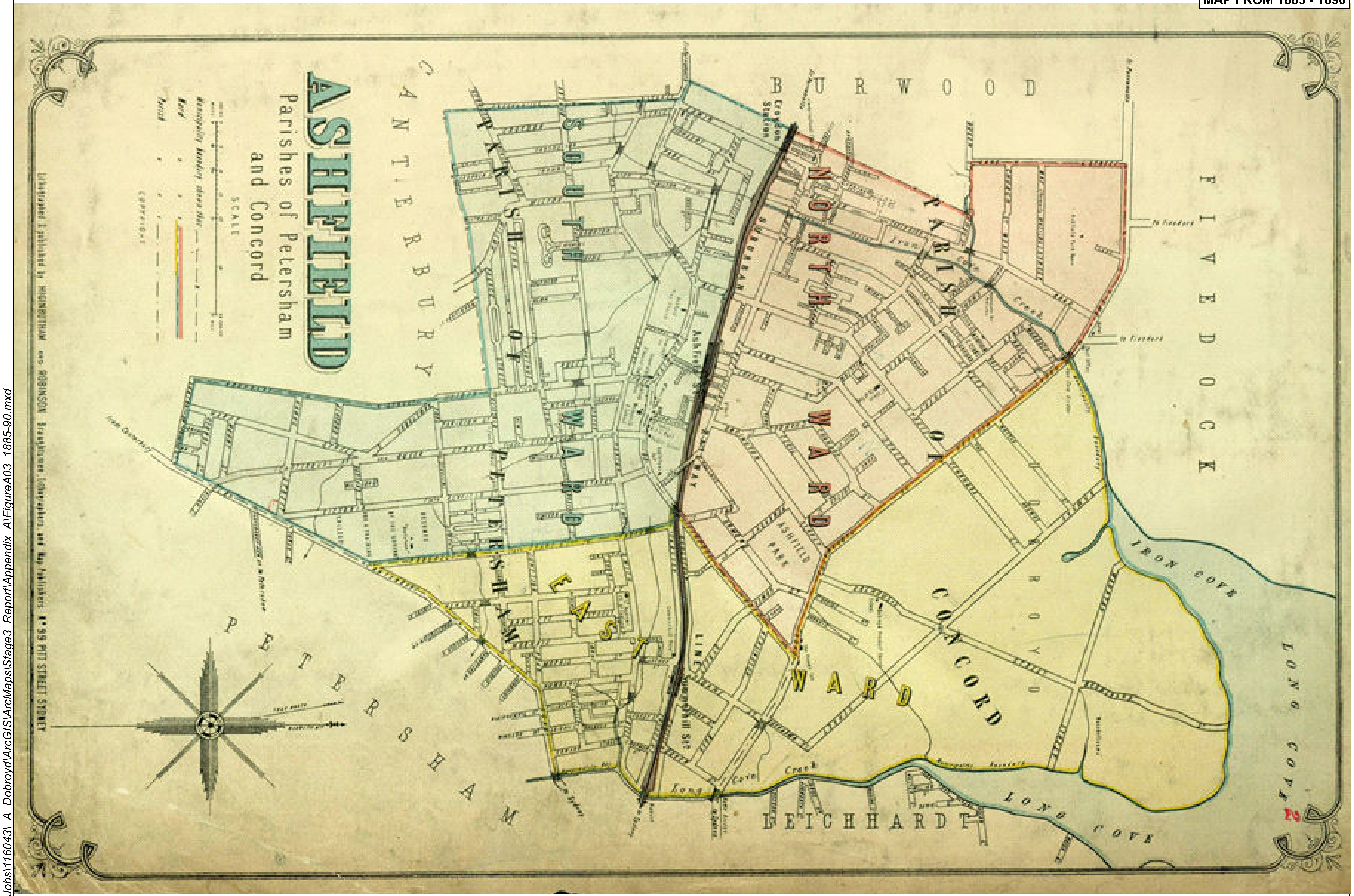

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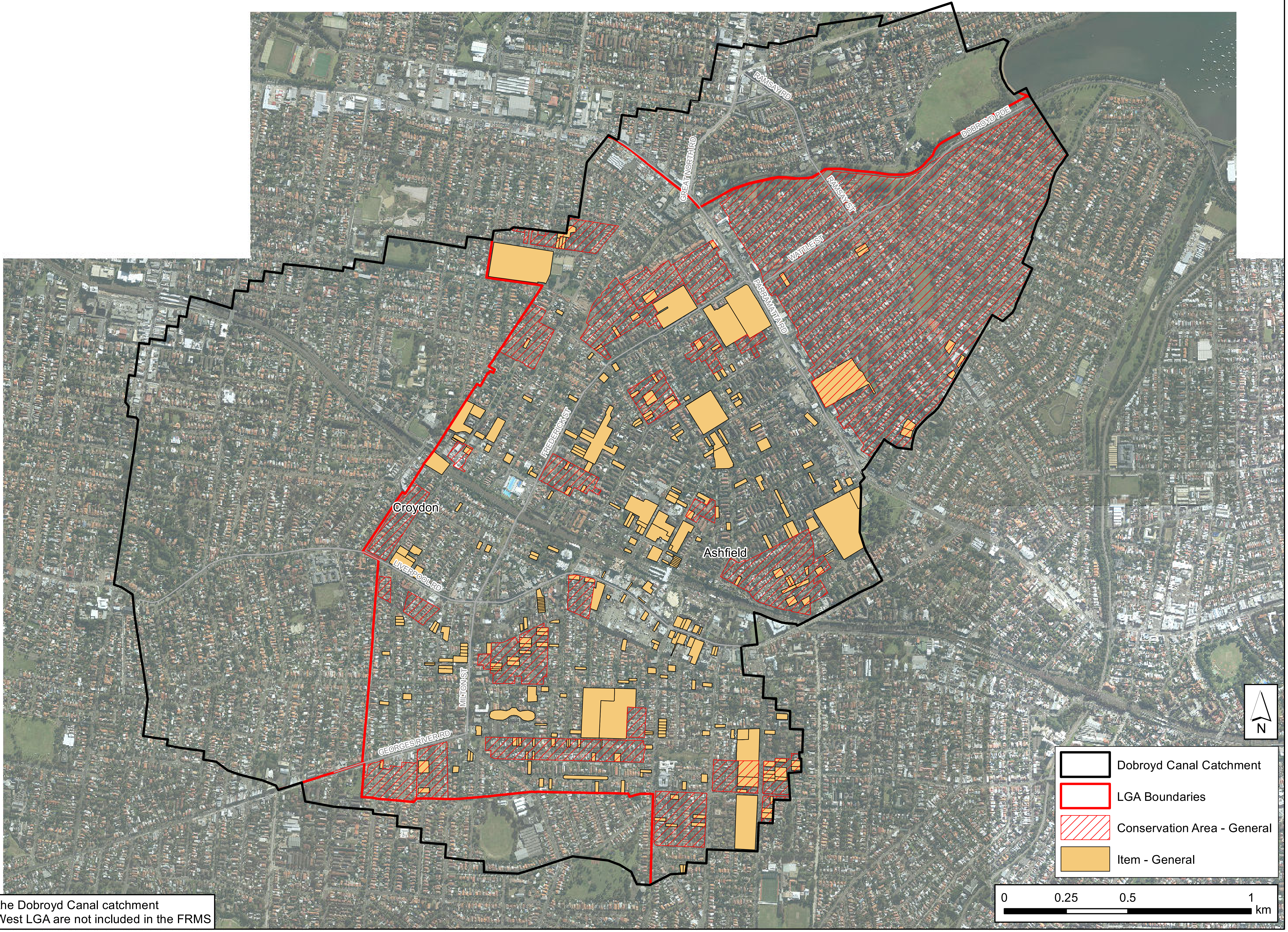
FIGURE A4
HERITAGE MAP



Note: Sections of the Dobroyd Canal catchment outside the Inner West LGA are not included in the FRMS

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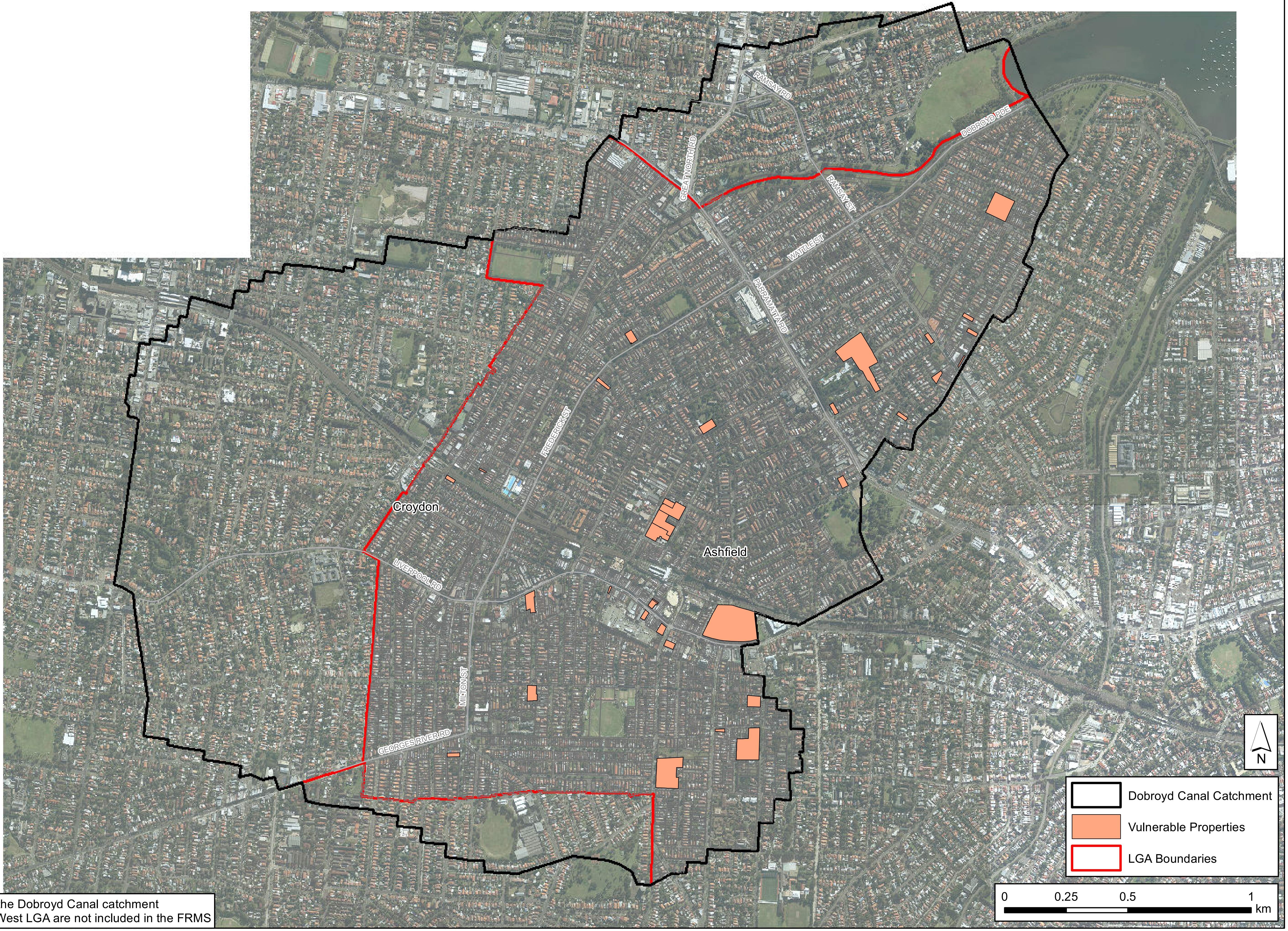
FIGURE A5
VULNERABLE PROPERTIES



Note: Sections of the Dobroyd Canal catchment outside the Inner West LGA are not included in the FRMS

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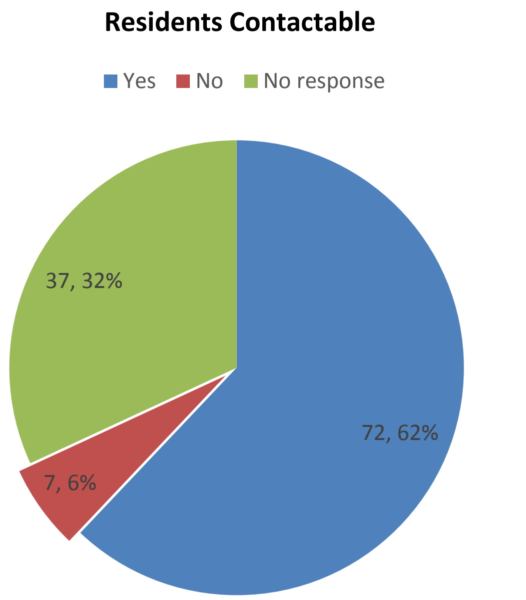
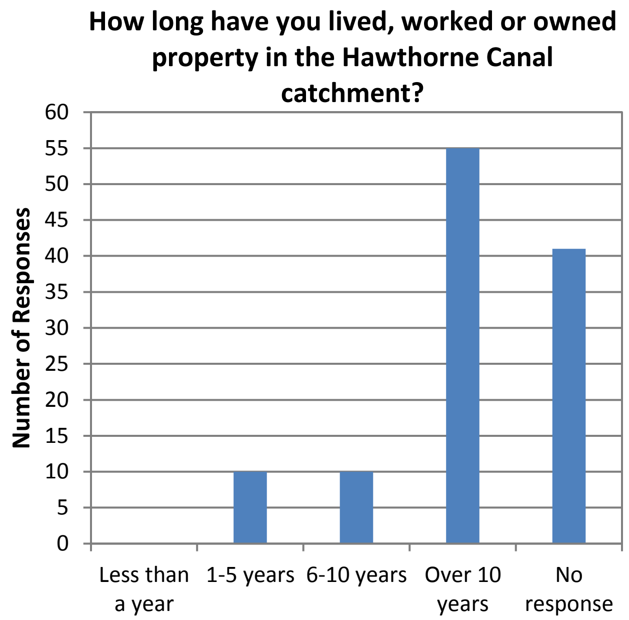
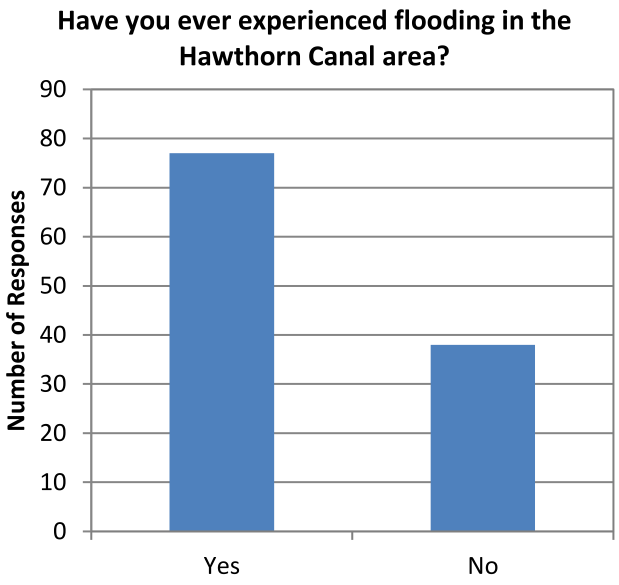
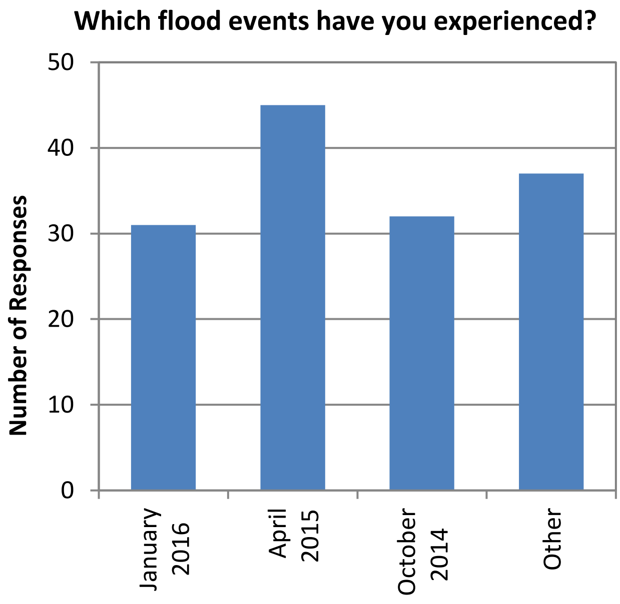
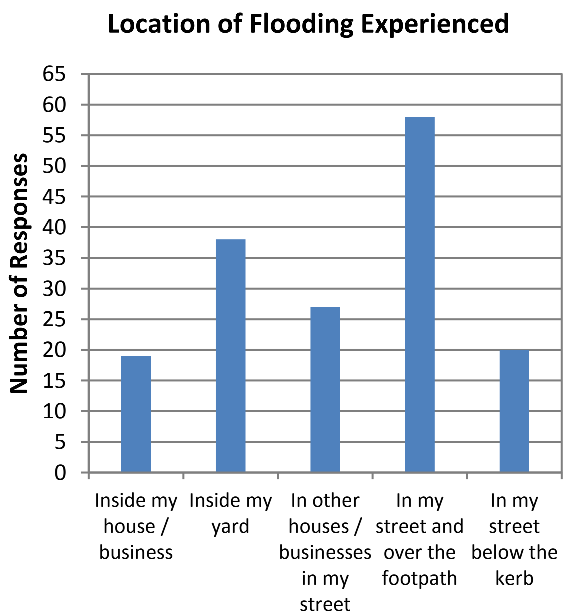
FIGURE A6A
COMMUNITY CONSULTATION RESULTS











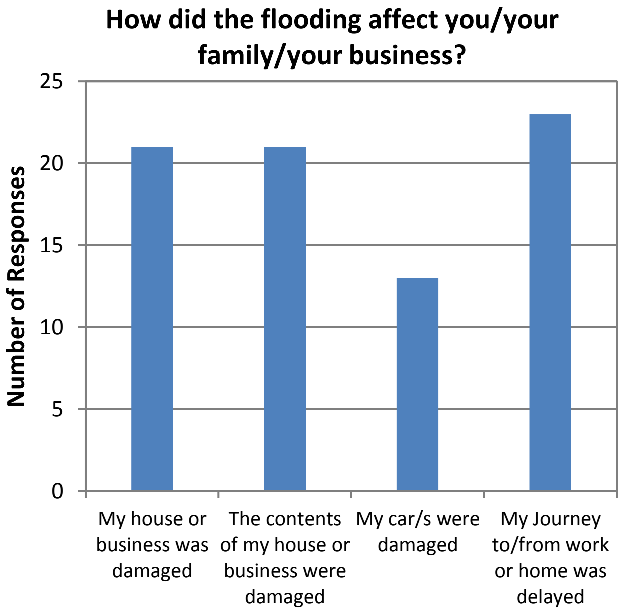


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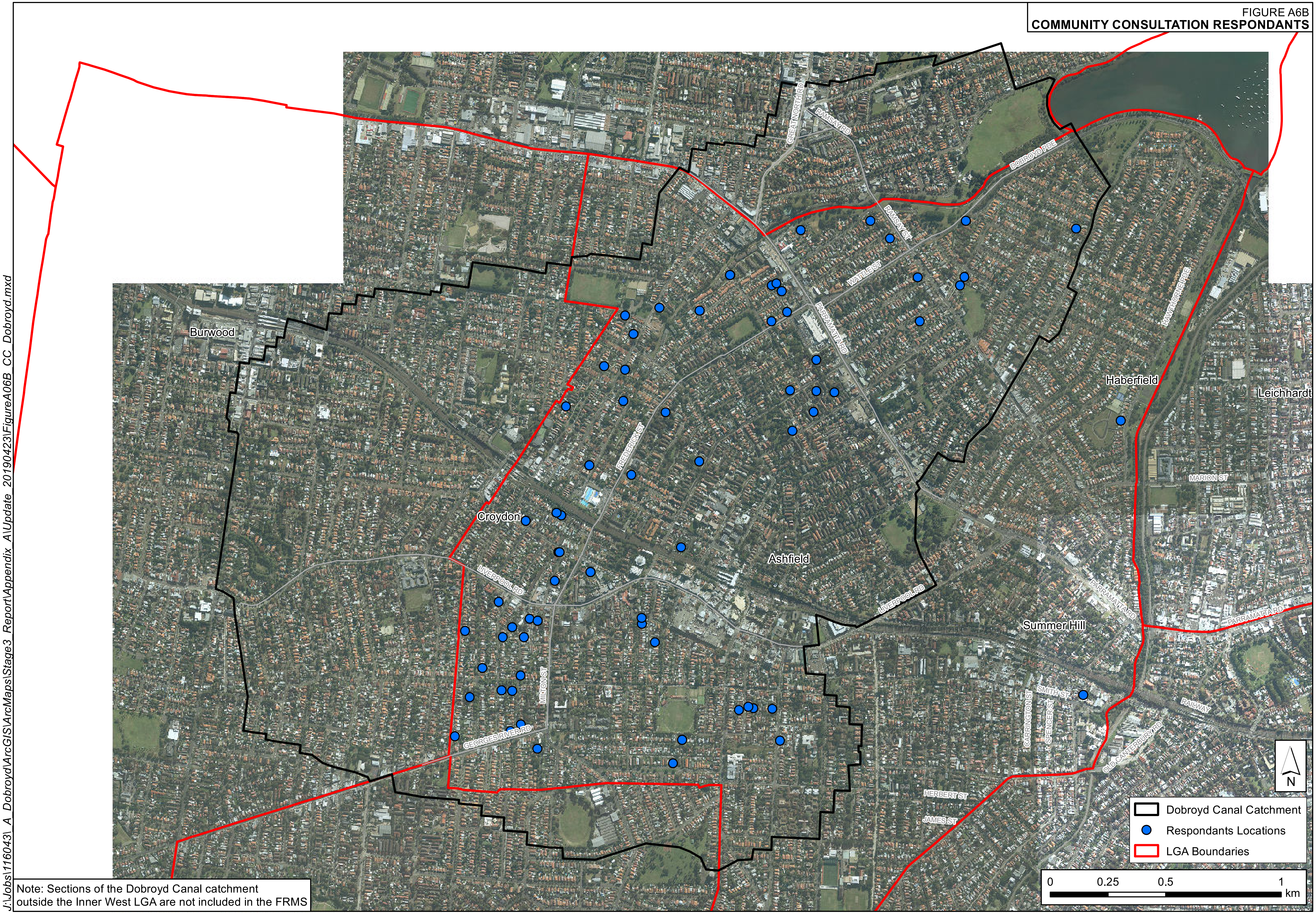
FIGURE A6B
COMMUNITY CONSULTATION RESPONDANTS



Note: Sections of the Dobroyd Canal catchment outside the Inner West LGA are not included in the FRMS

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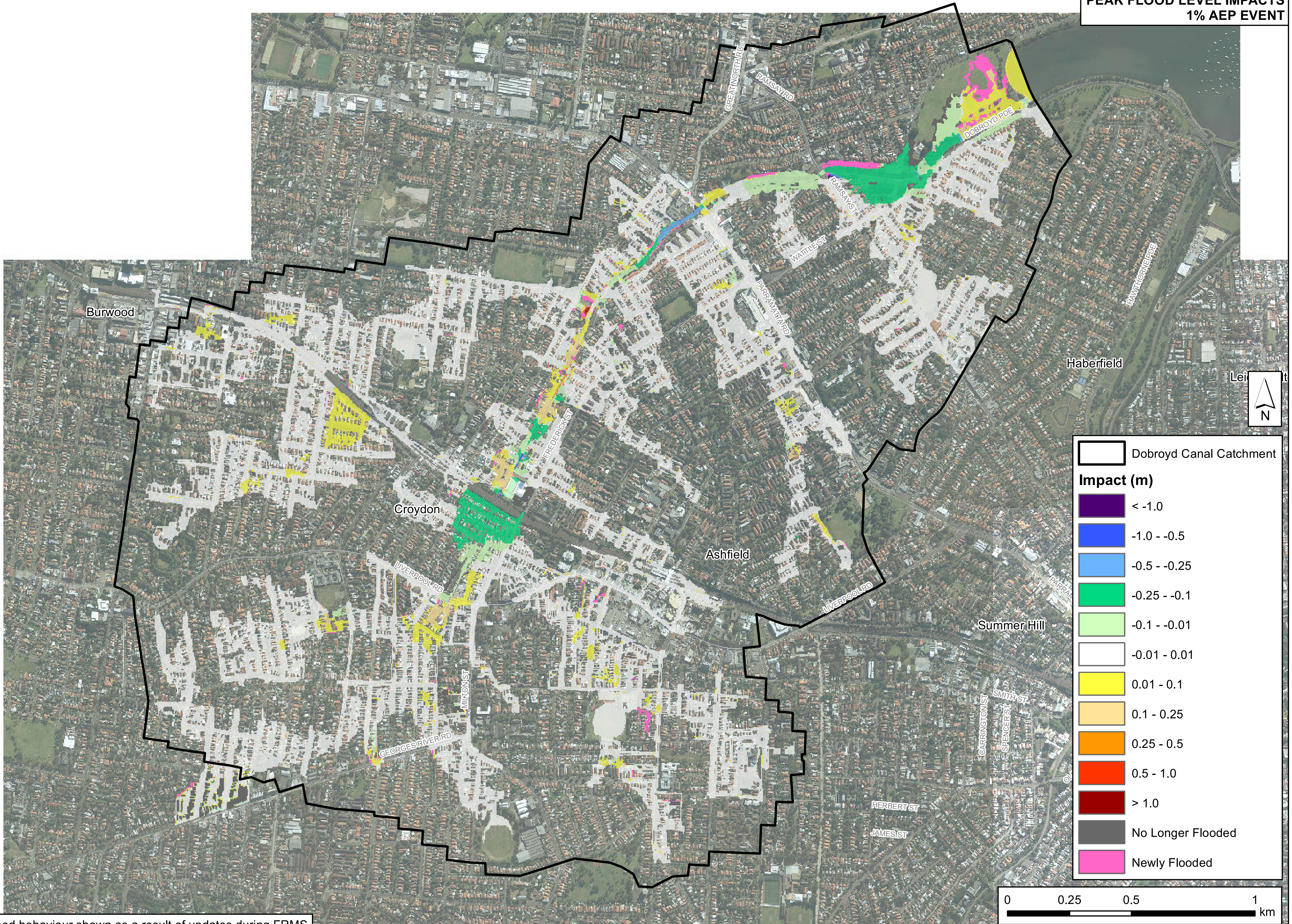
FIGURE A7
MODEL REVISION
PEAK FLOOD LEVEL IMPACTS
1% AEP EVENT



Note: Change in flood behaviour shown as a result of updates during FRMS

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FIGURE A8
PIPE CAPACITY
FIRST EVENT EXCEEDED

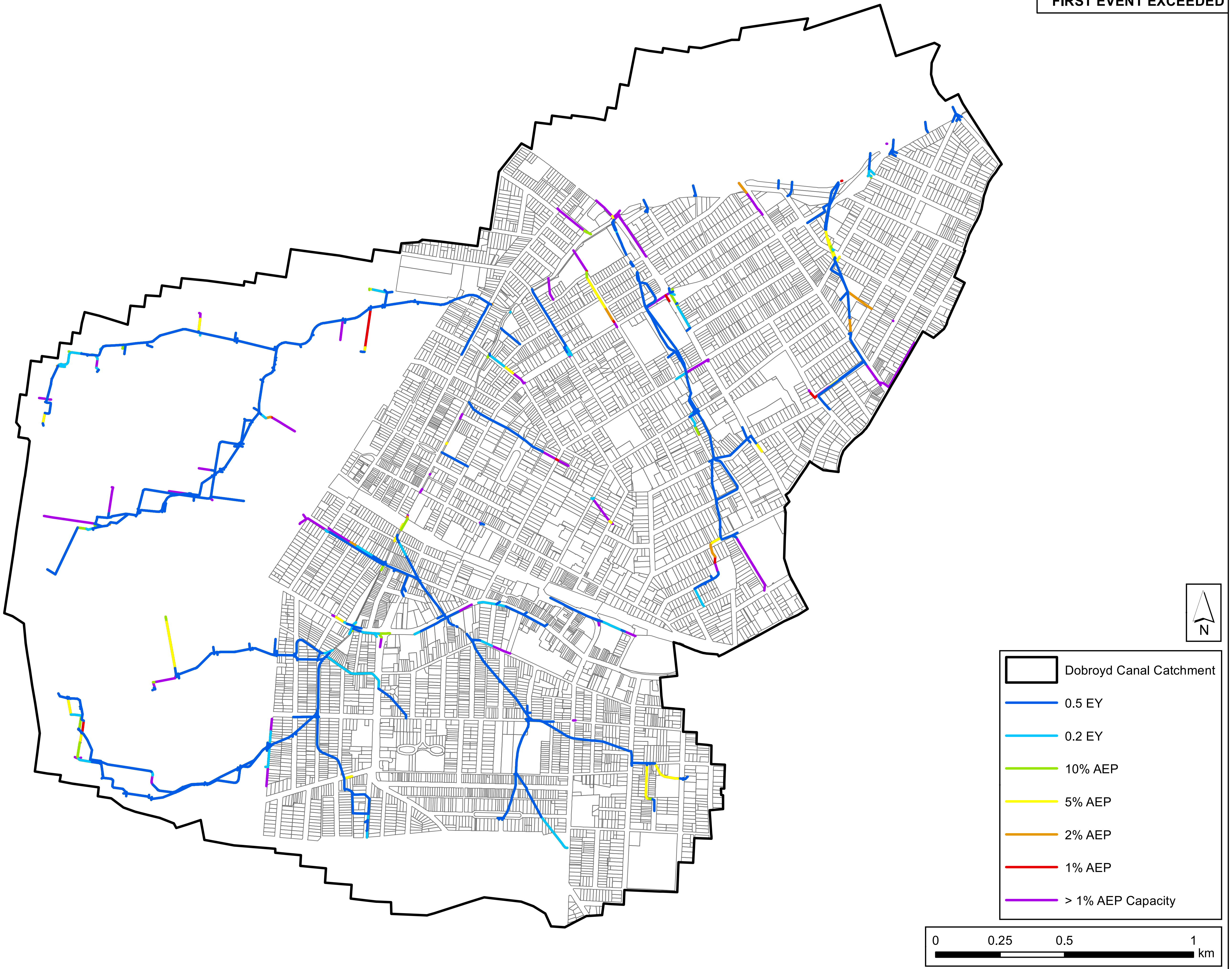

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FIGURE A9
PEAK FLOOD DEPTHS
0.5 EY EVENT

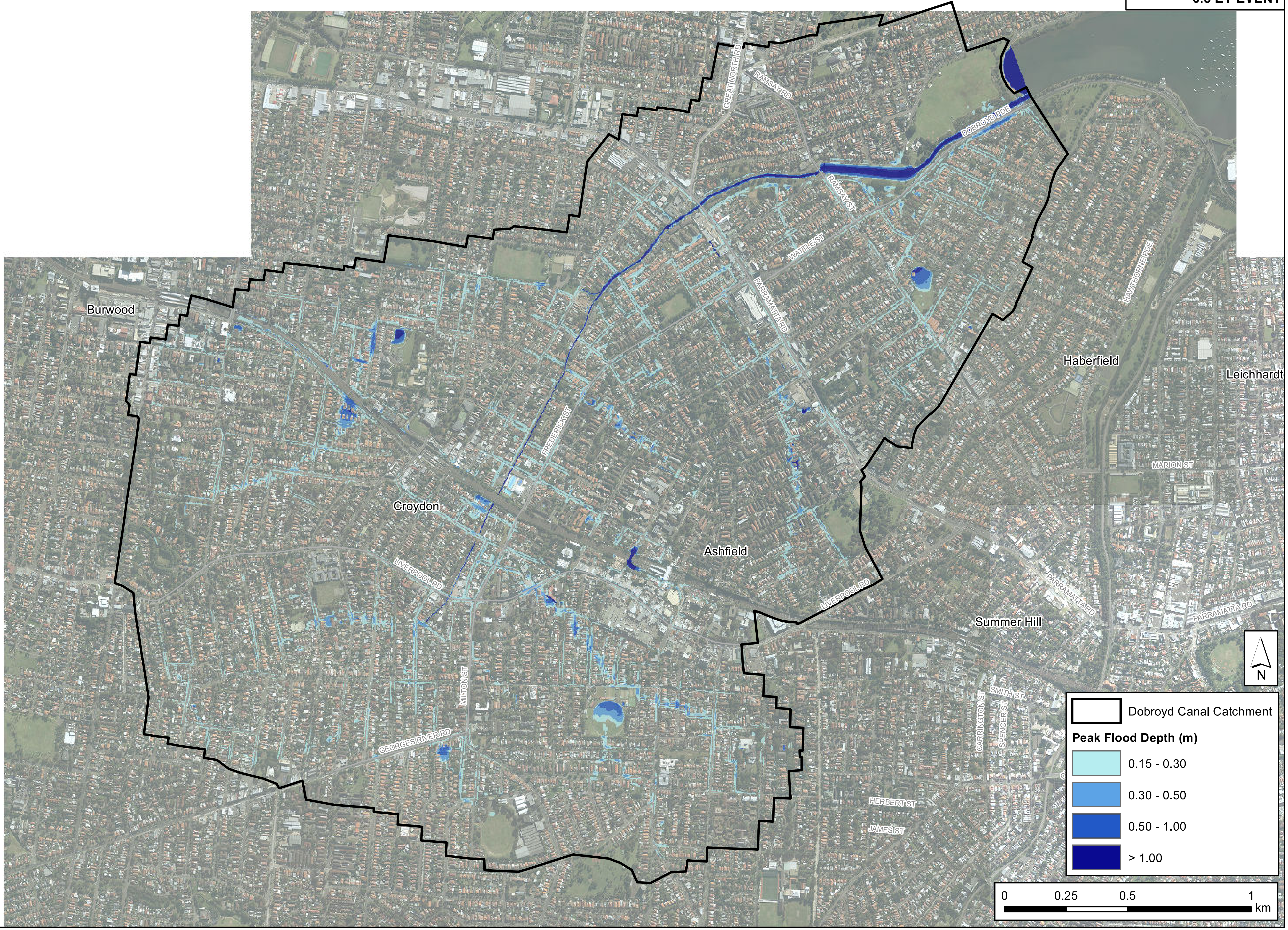

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FIGURE A10
PEAK FLOOD DEPTHS
0.2 EY EVENT

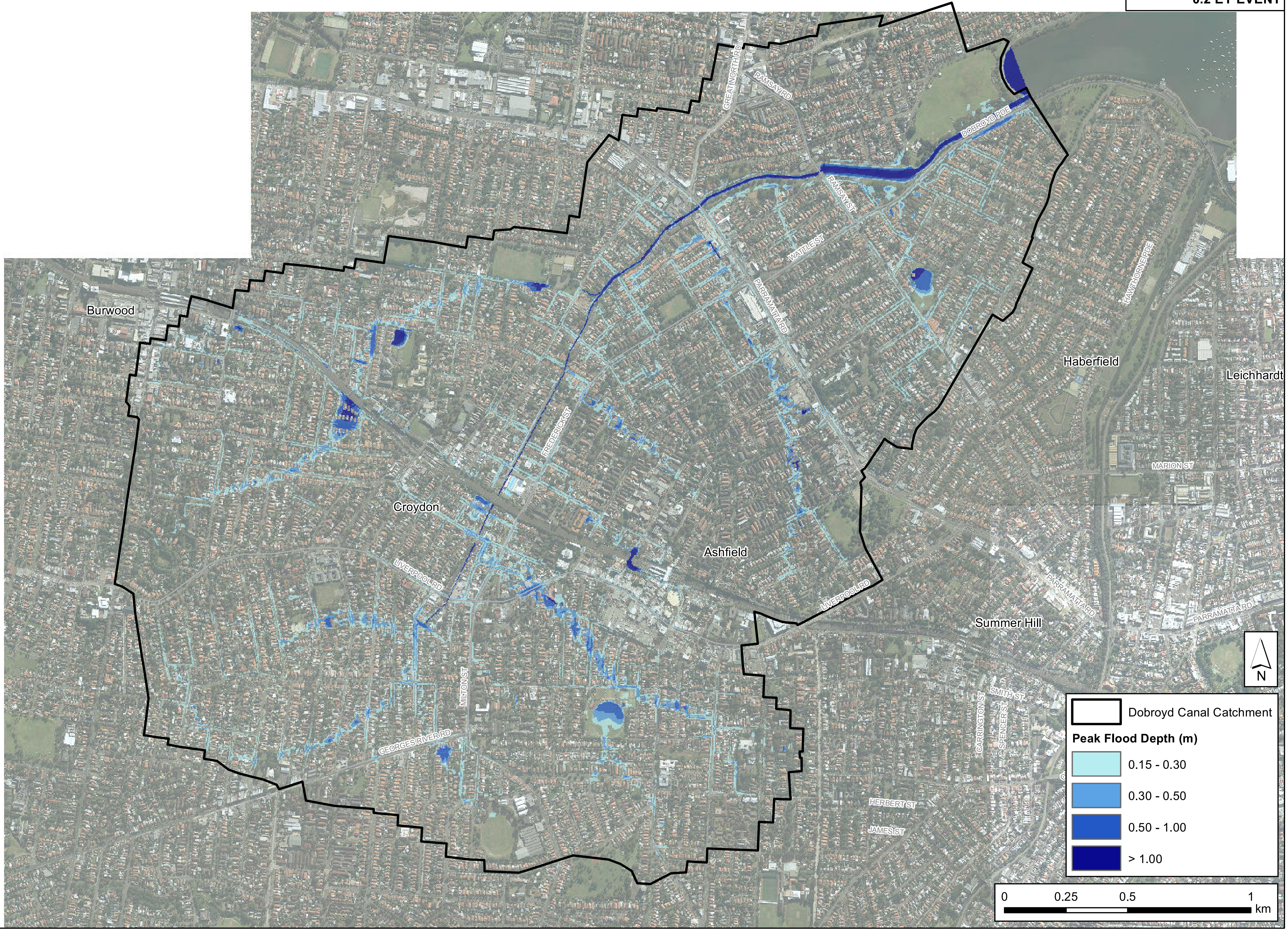

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FIGURE A11
PEAK FLOOD DEPTHS
10% AEP EVENT

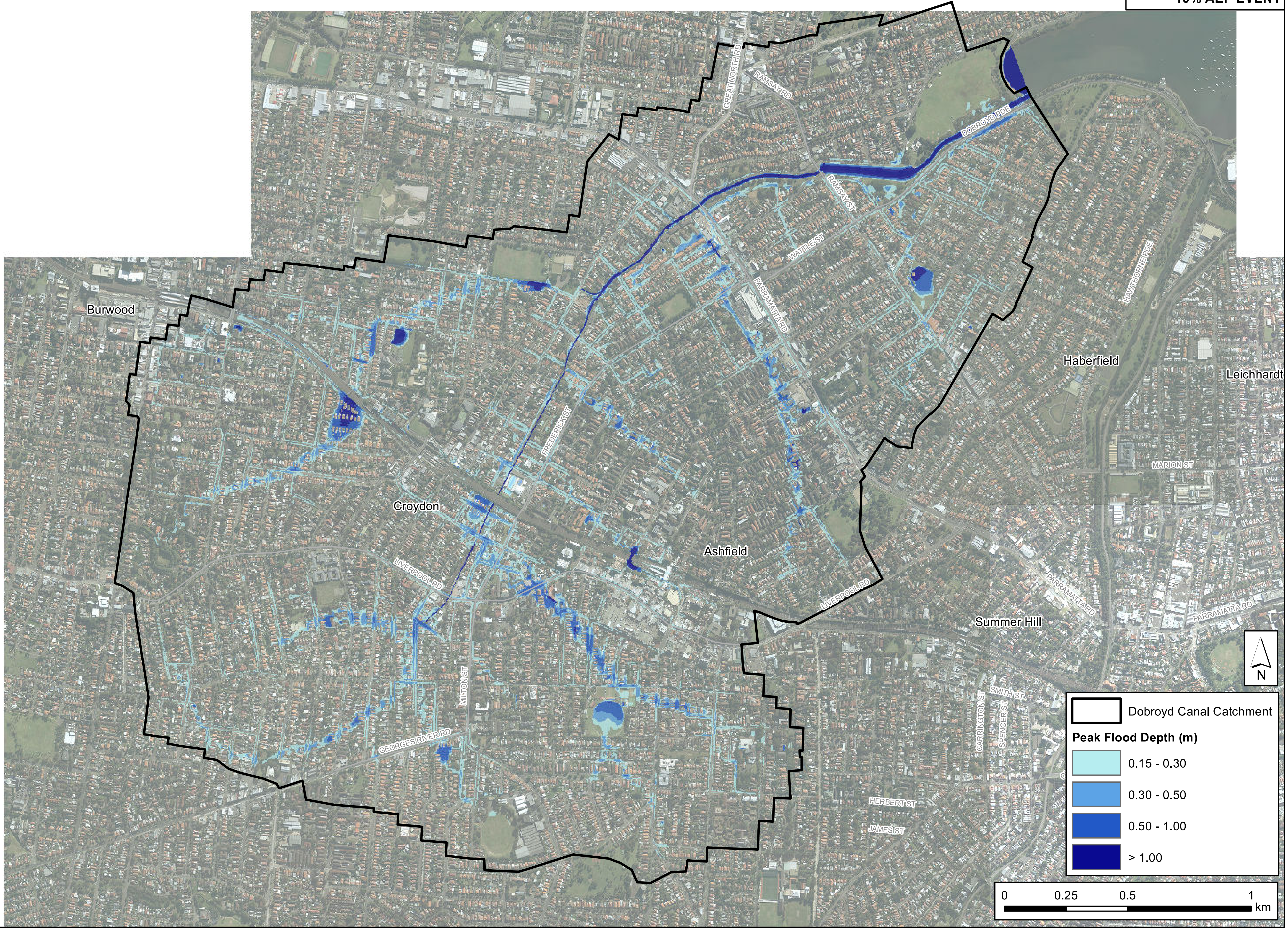

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FIGURE A12
PEAK FLOOD DEPTHS
5% AEP EVENT

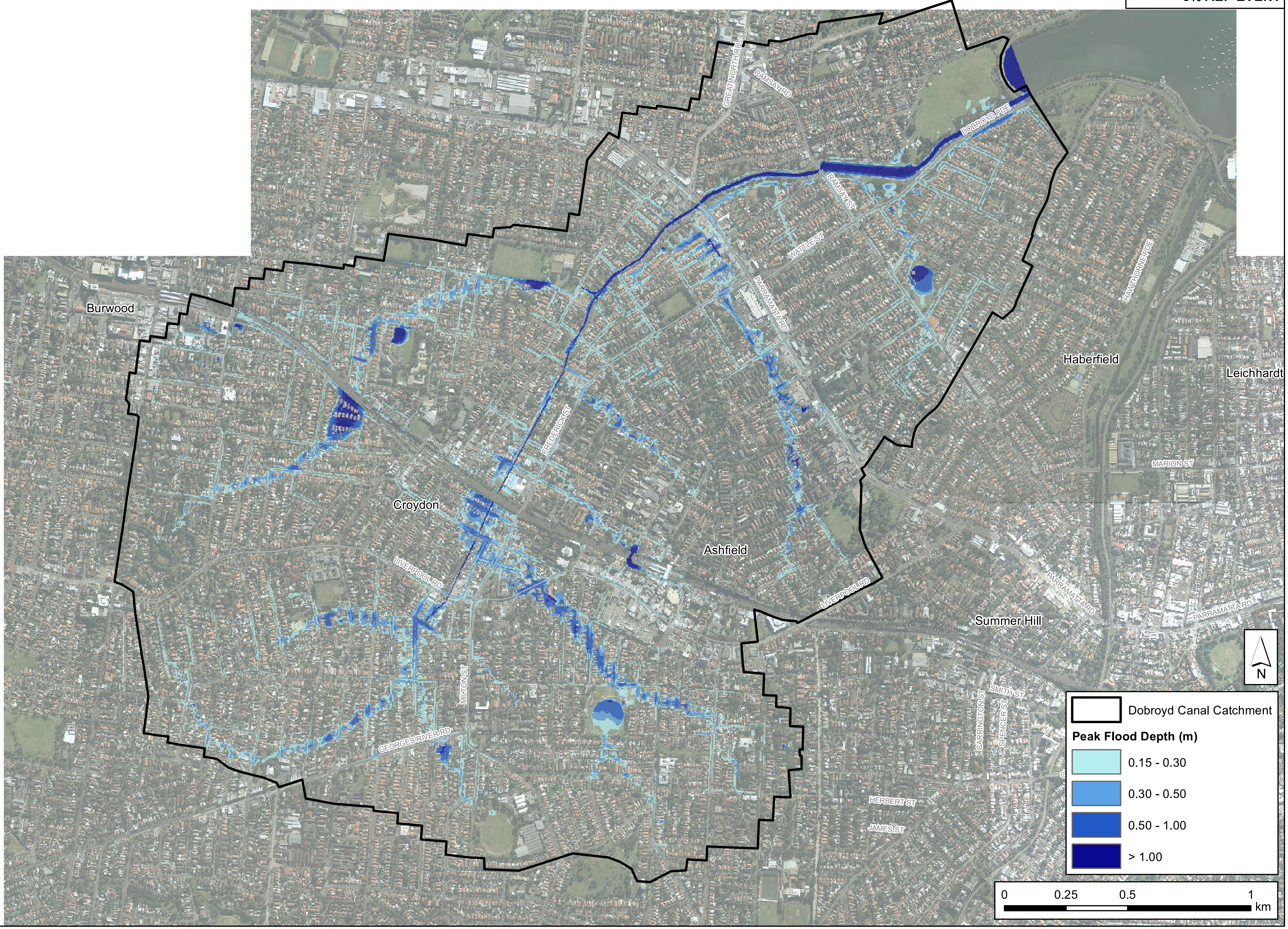

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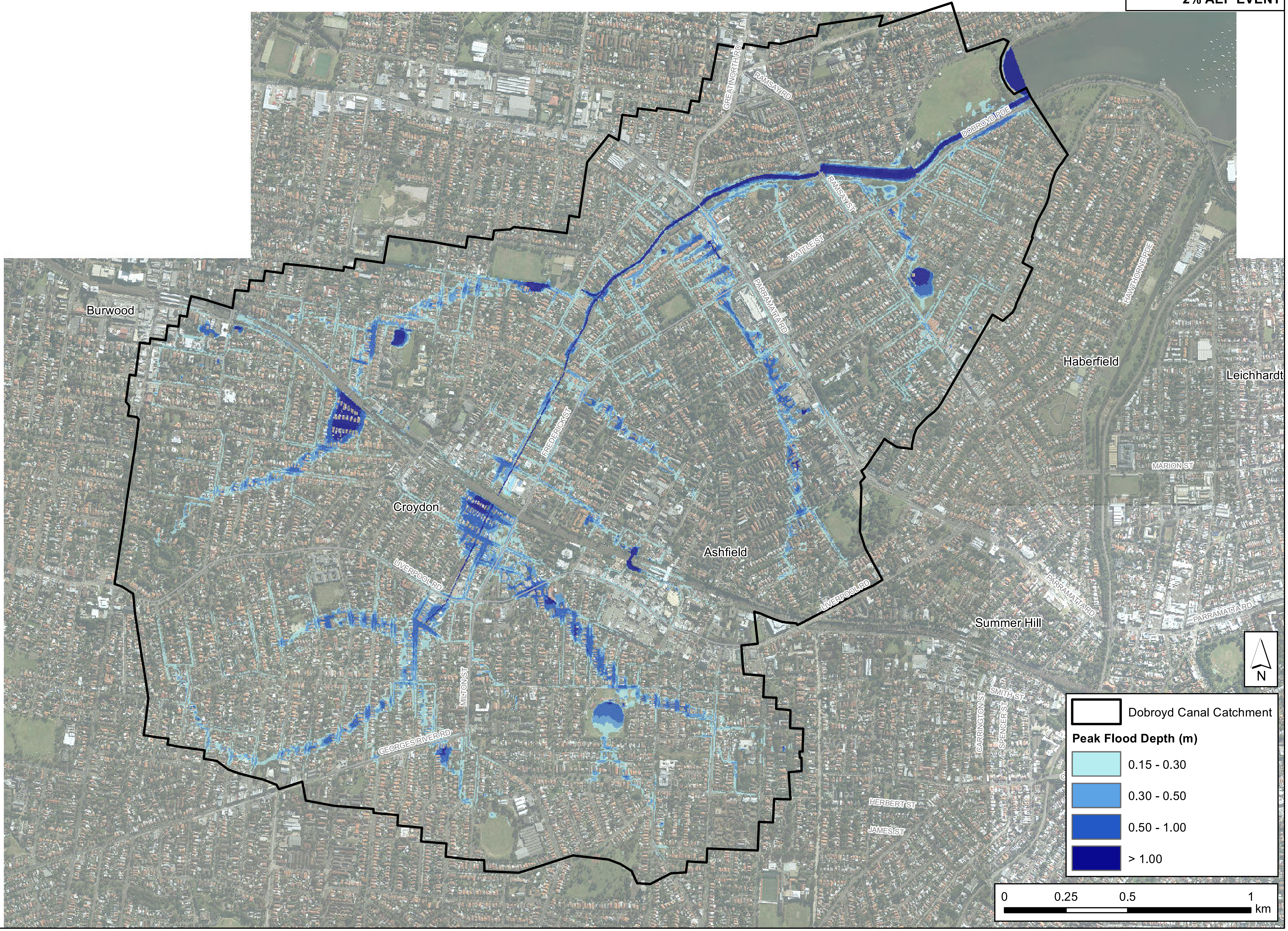
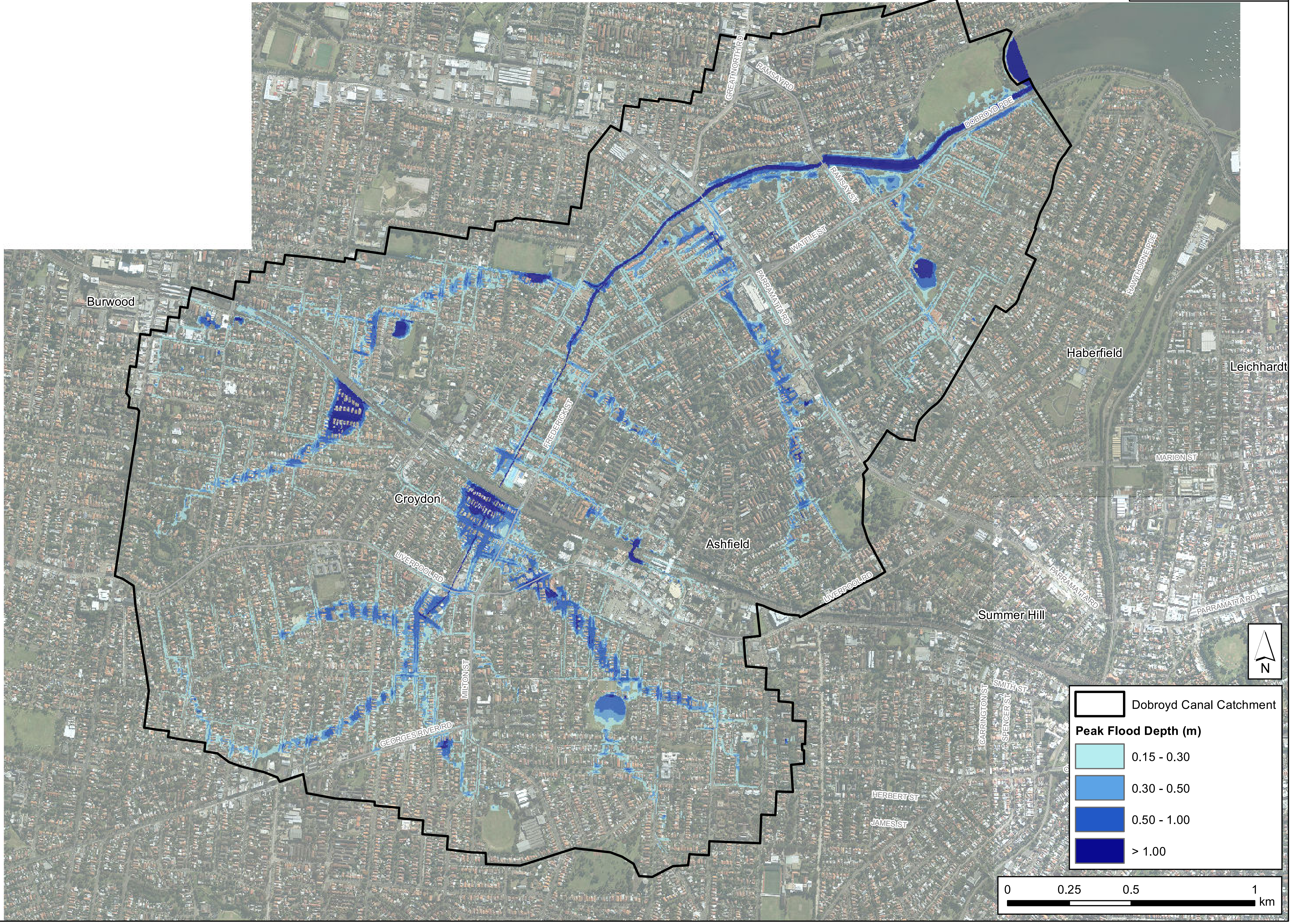
FIGURE A13
PEAK FLOOD DEPTHS
2% AEP EVENT



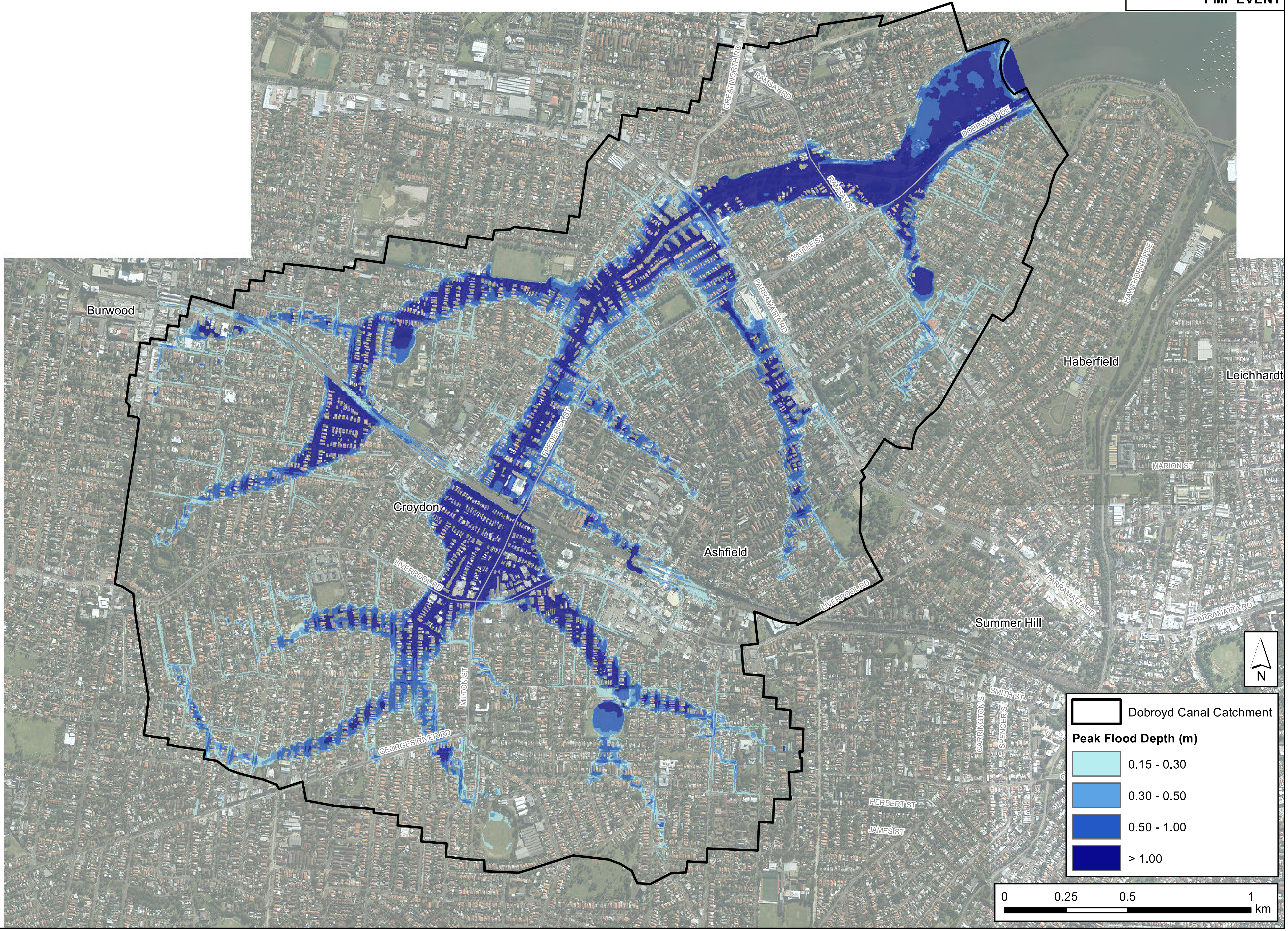
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190423\FigureA13_Depths_2%AEP.mxd

FIGURE A14
PEAK FLOOD DEPTHS
1% AEP EVENT



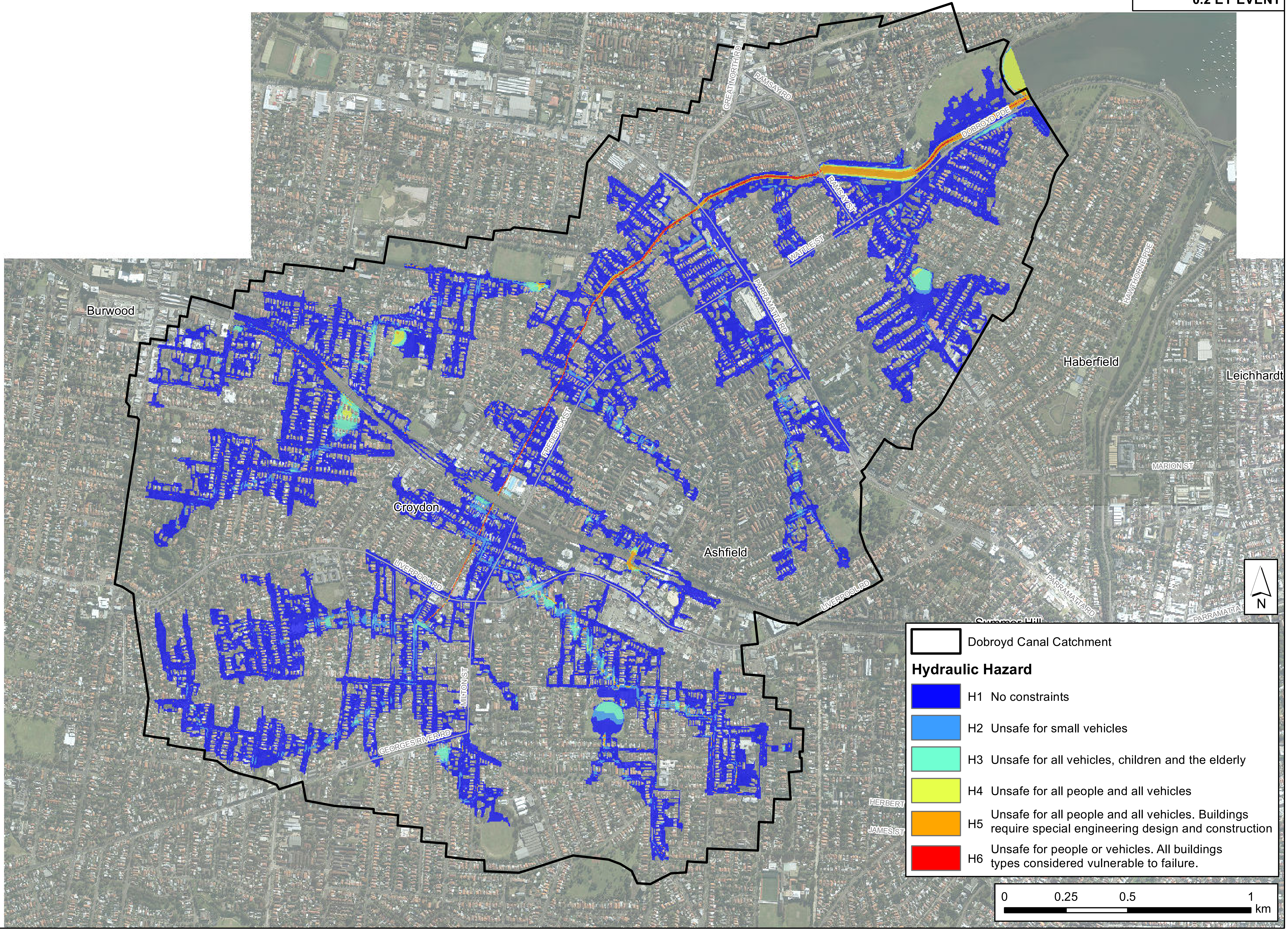
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190423\FigureA14_Depths_1%AEP.mxd

FIGURE A15
PEAK FLOOD DEPTHS
PMF EVENT



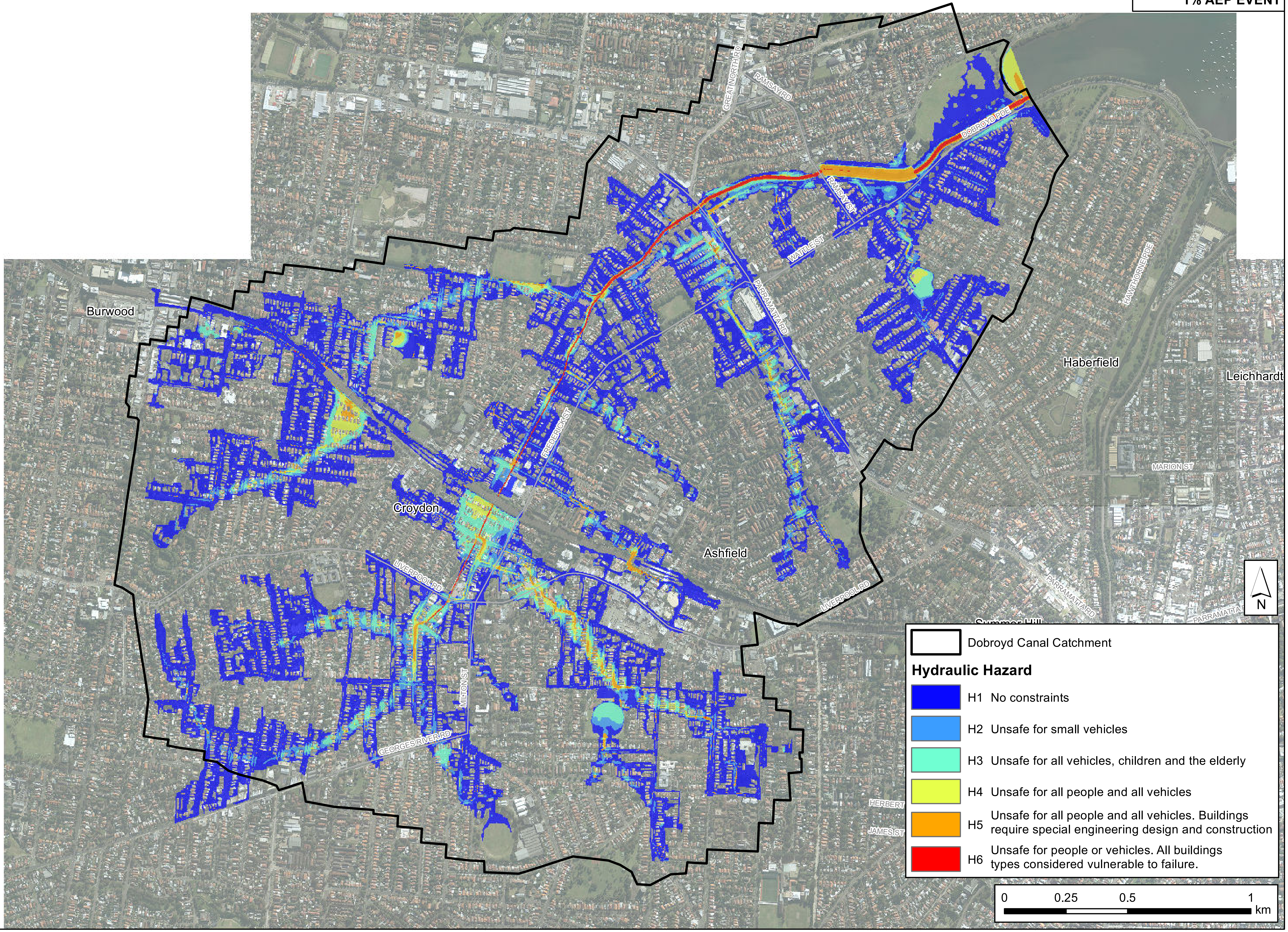
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190423\FigureA15_Depths_PMF.mxd

FIGURE A16
HYDRAULIC HAZARD
0.2 EY EVENT



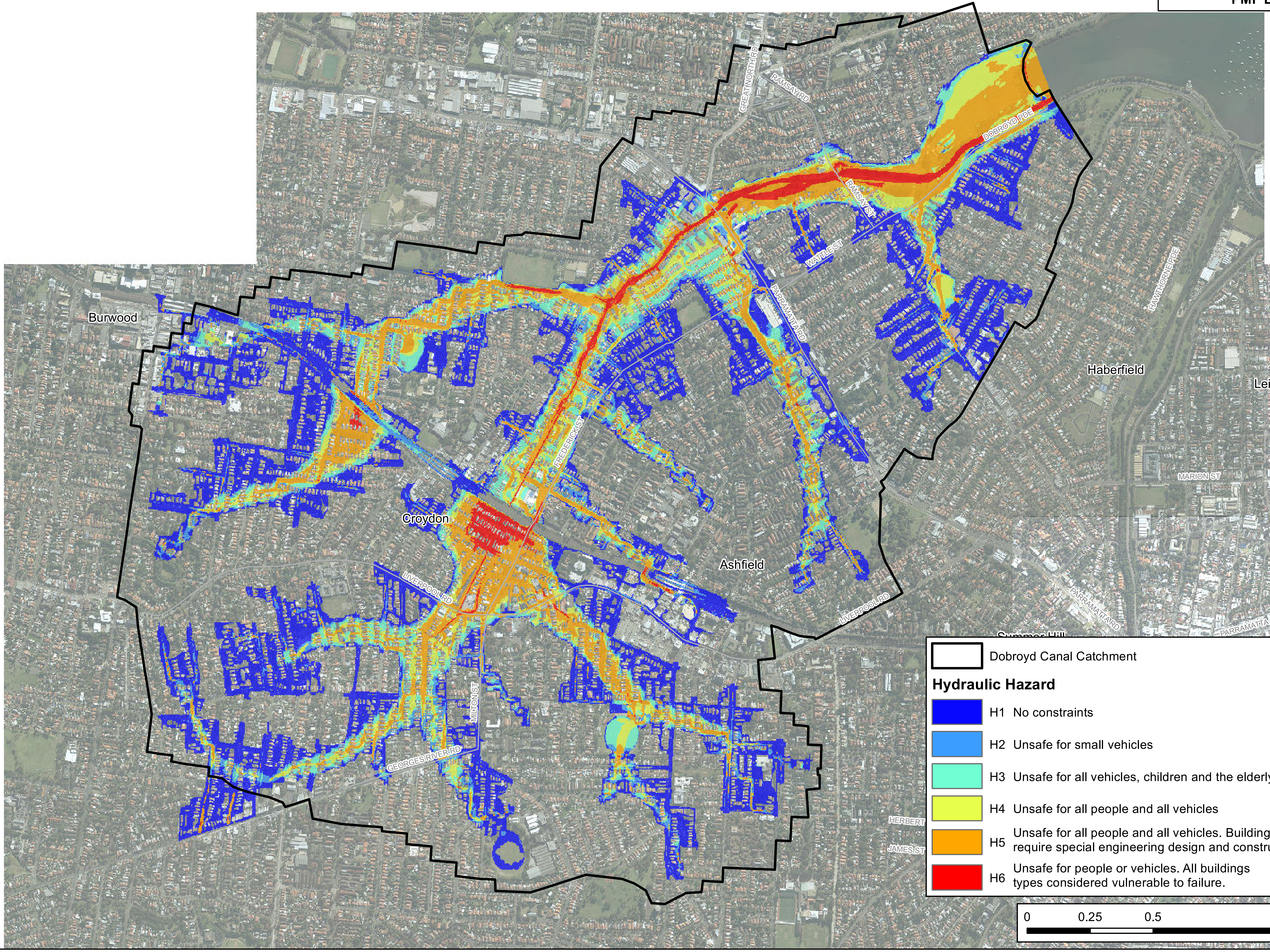
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190423\FigureA16_Hazard_0.2EY.mxd

FIGURE A17
HYDRAULIC HAZARD
1% AEP EVENT



J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190423\FigureA17_Hazard_1%AEP.mxd

FIGURE A18
HYDRAULIC HAZARD
PMF EVENT



Dobroyd Canal Catchment

Hydraulic Hazard

- H1 No constraints
- H2 Unsafe for small vehicles
- H3 Unsafe for all vehicles, children and the elderly
- H4 Unsafe for all people and all vehicles
- H5 Unsafe for all people and all vehicles. Buildings require special engineering design and construction
- H6 Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

0 0.25 0.5 1 km

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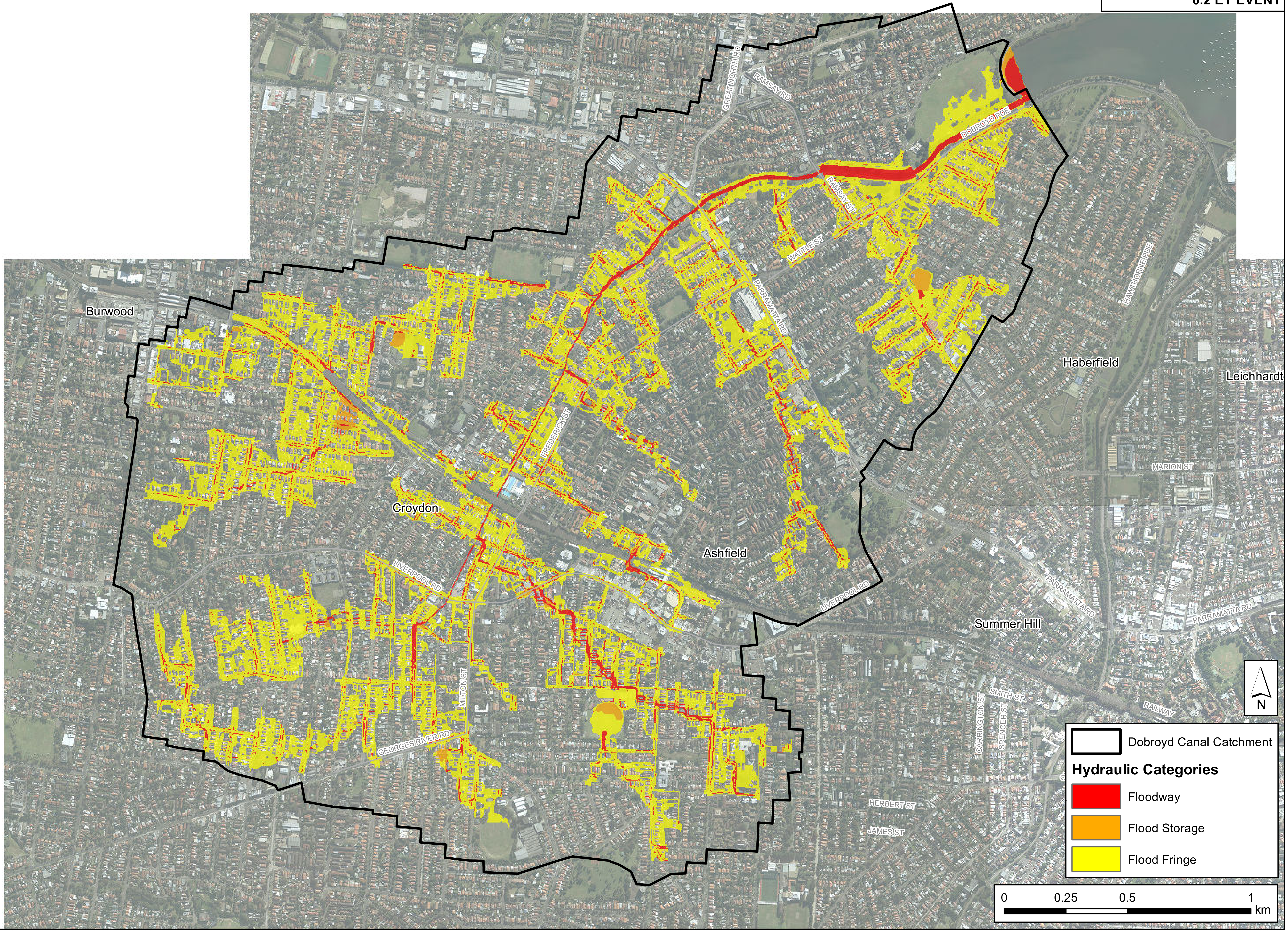
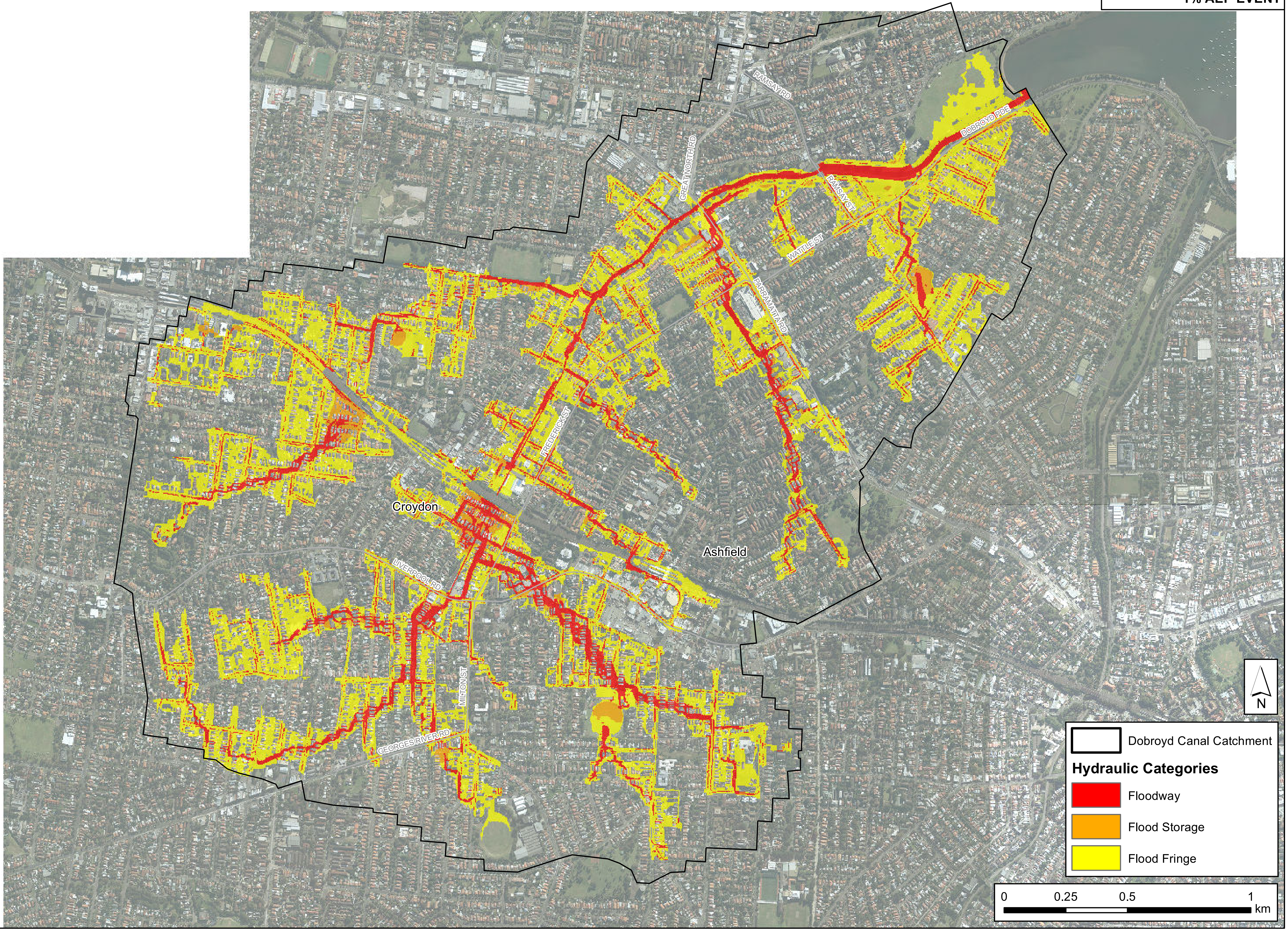
FIGURE A19
HYDRAULIC CATEGORIES
0.2 EY EVENT



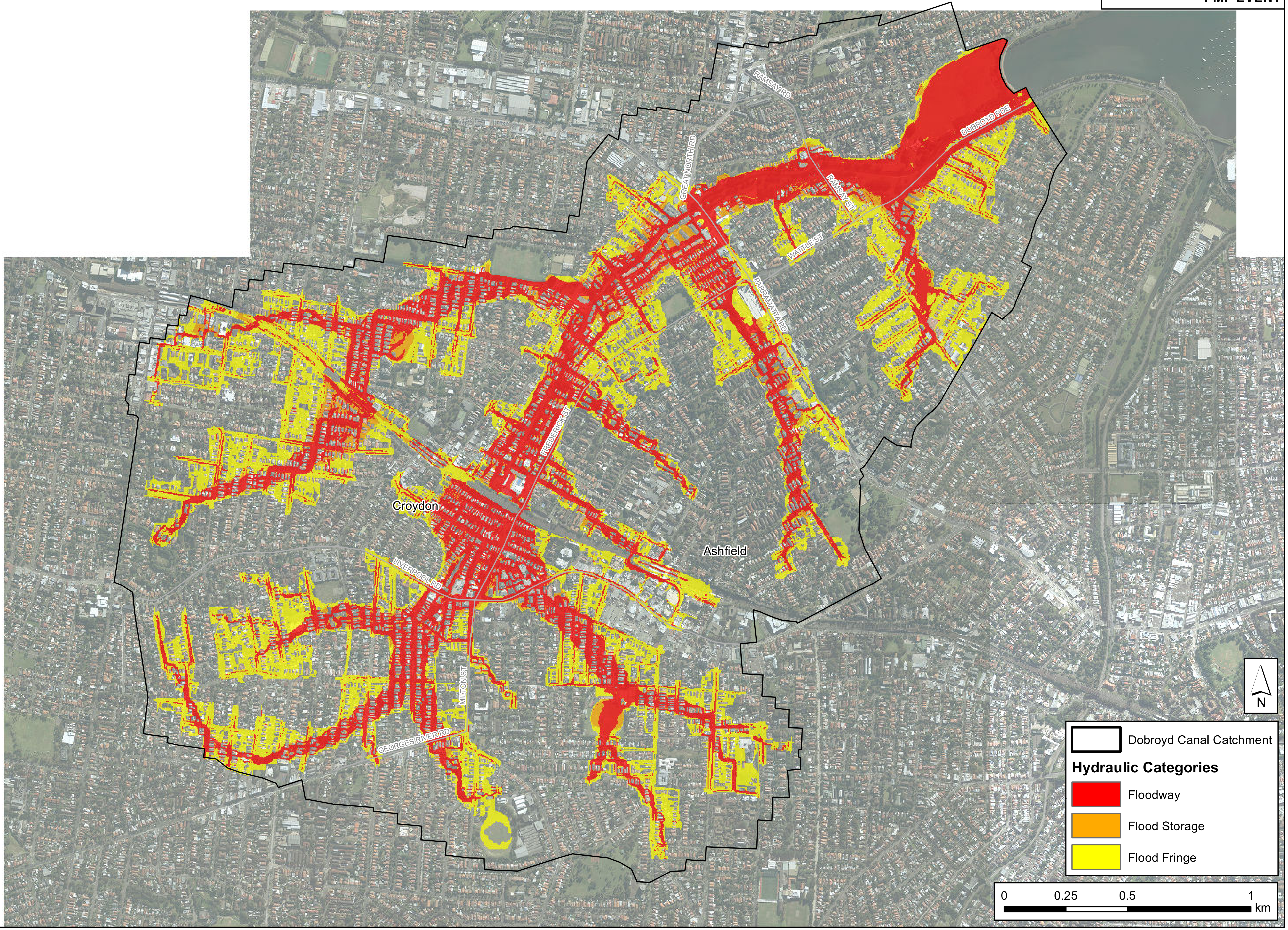
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190621\FigureA19_Hydraulic_Category_0.2EY.mxd

FIGURE A20
HYDRAULIC CATEGORIES
1% AEP EVENT



J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190621\FigureA20_Hydraulic_Category_1%AEP.mxd

FIGURE A21
HYDRAULIC CATEGORIES
PMF EVENT



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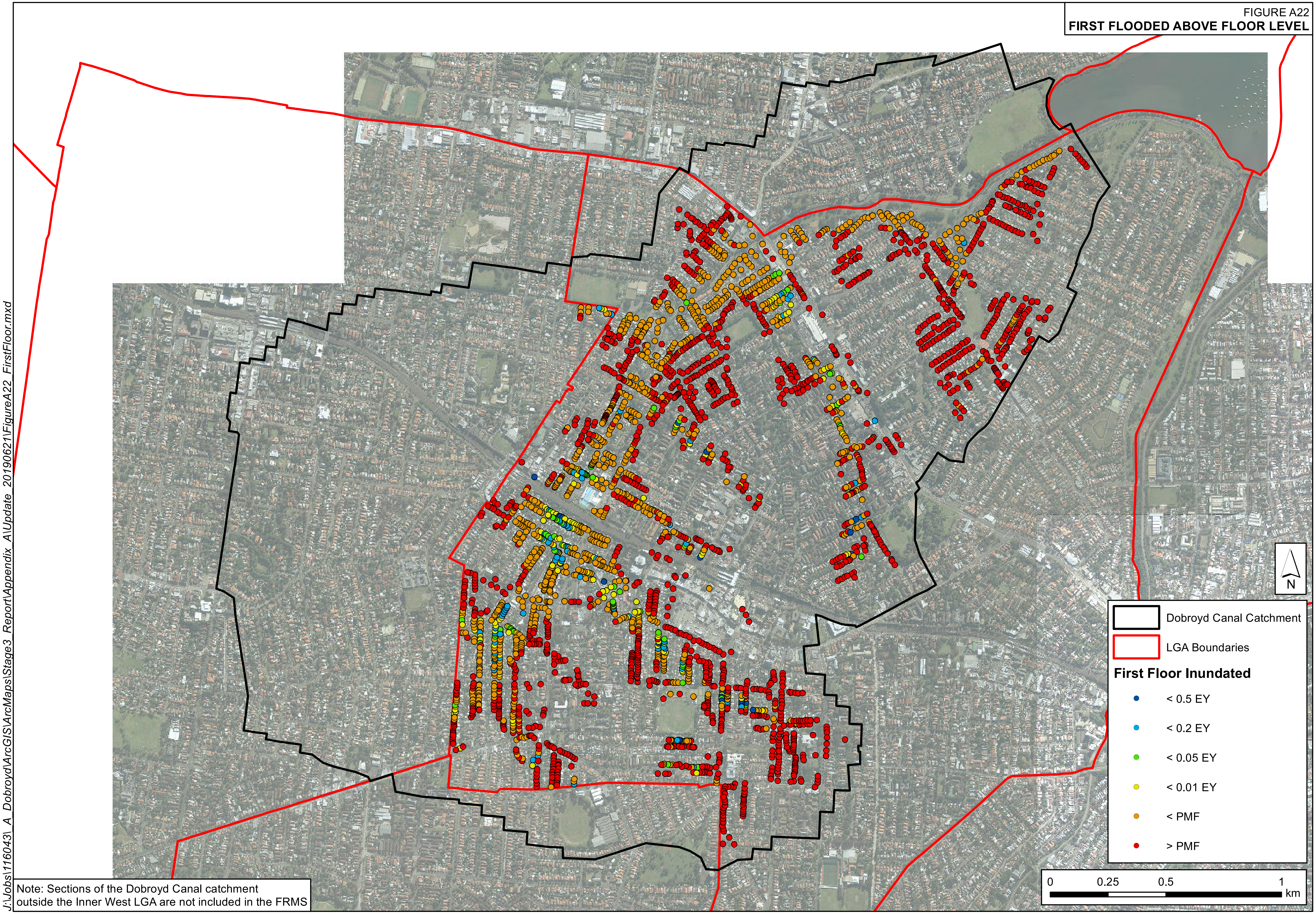
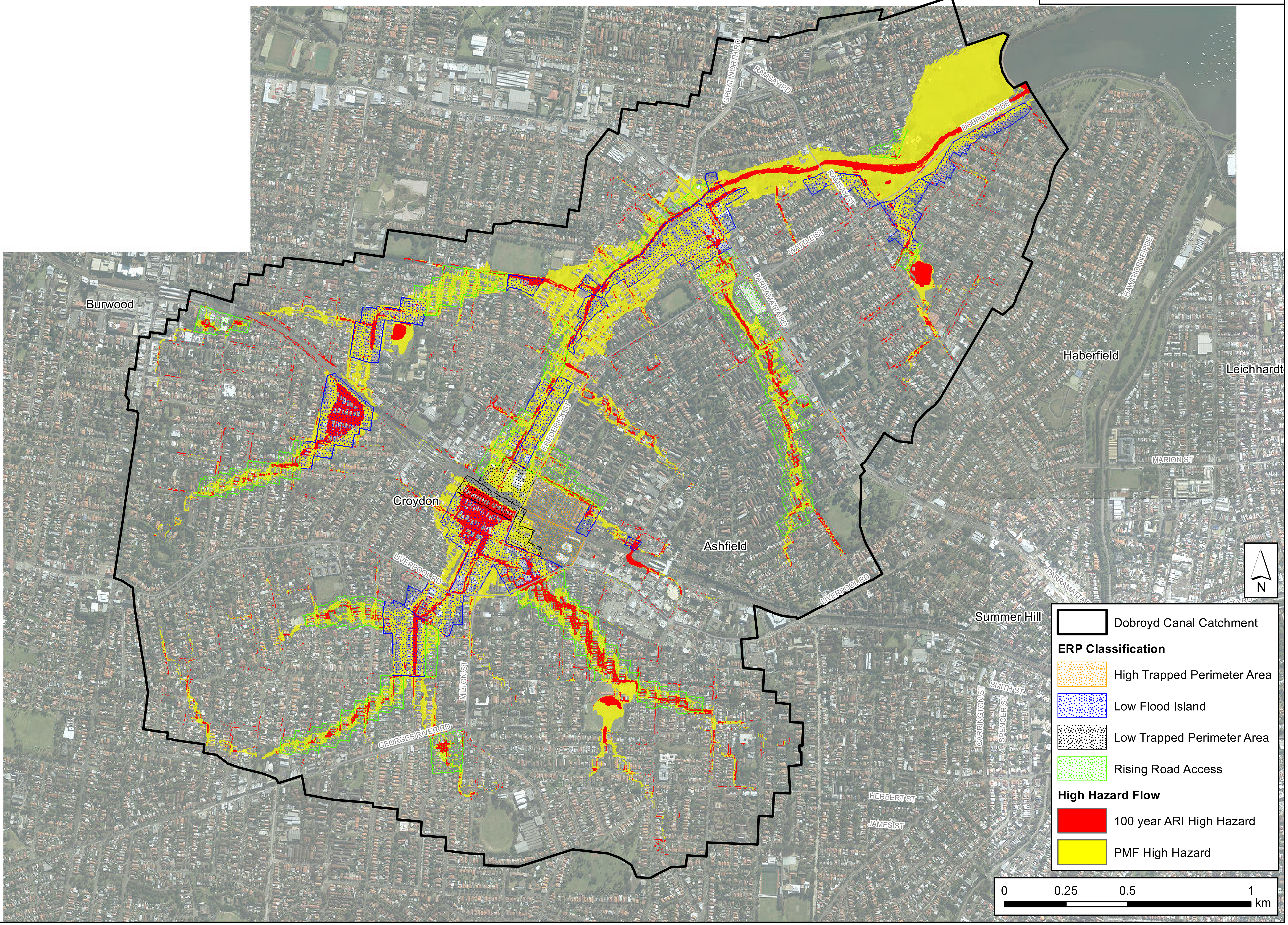
FIRST FLOODED ABOVE FLOOR LEVEL



Note: Sections of the Dobroyd Canal catchment outside the Inner West LGA are not included in the FRMS

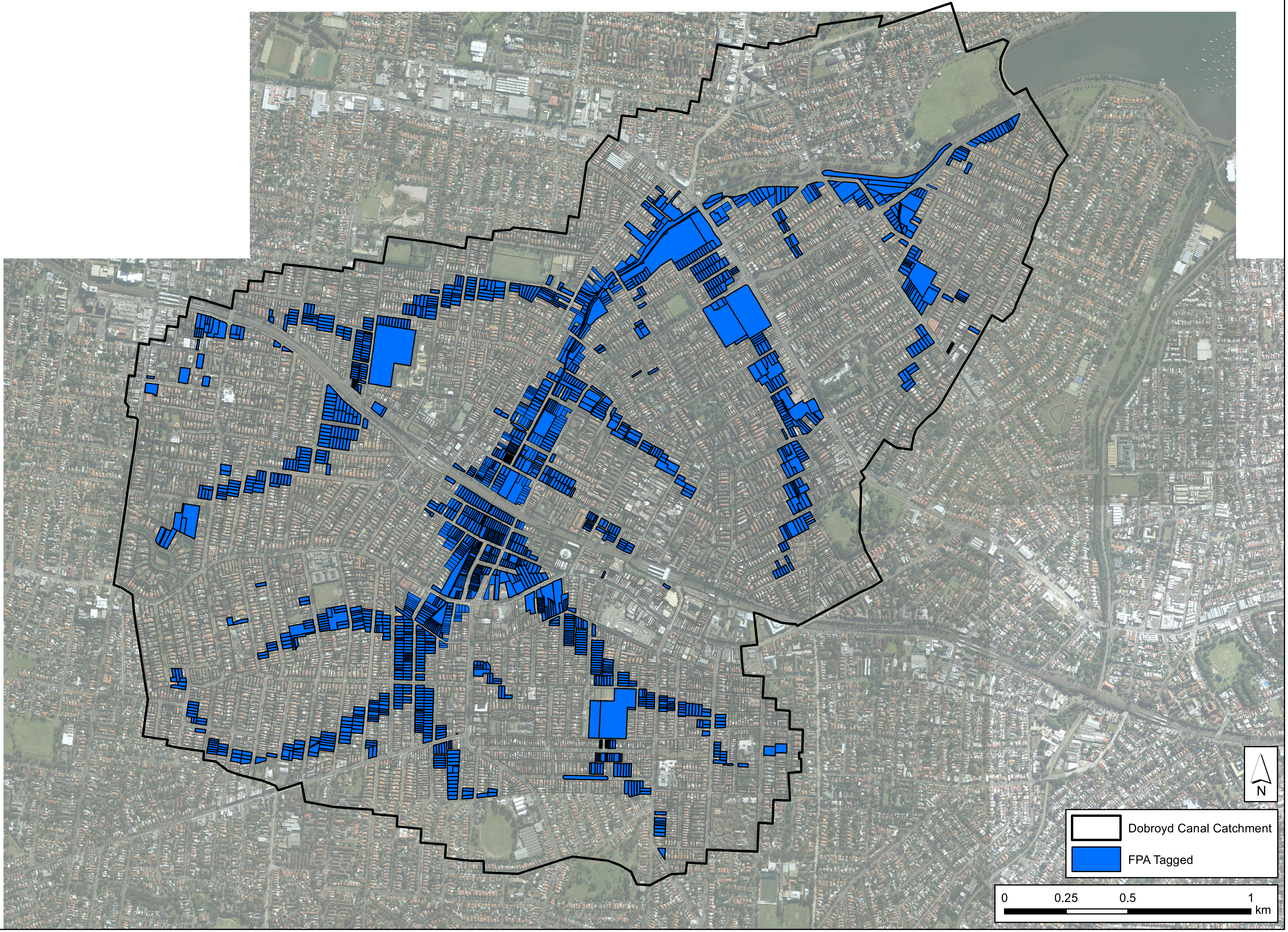
J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190621\FigureA22_FirstFloor.mxd

FIGURE A23
FLOOD EMERGENCY RESPONSE CLASSIFICATION OF COMMUNITIES

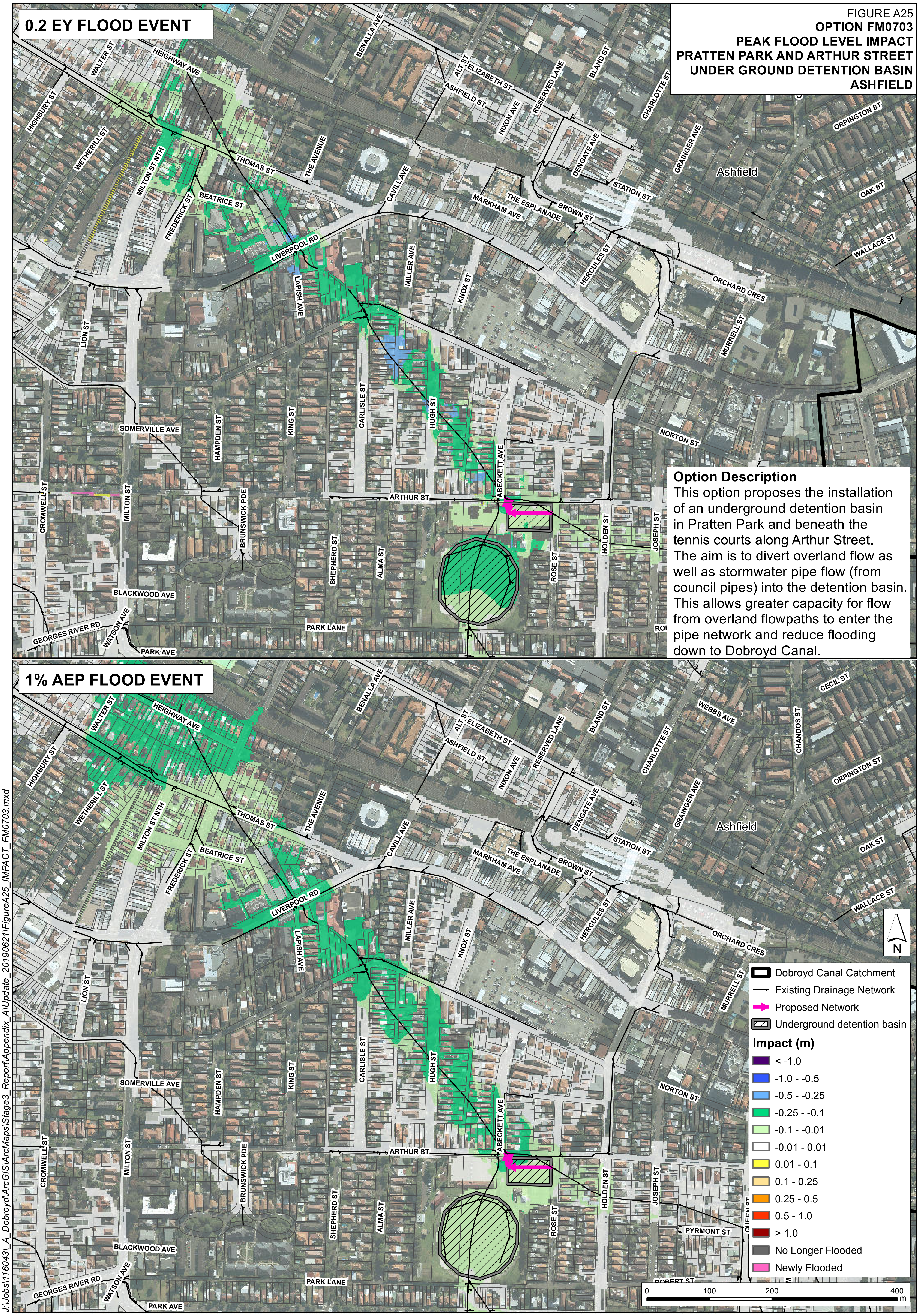


J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190621\FigureA23_ERP_PMF.mxd

FIGURE A24
FLOOD PLANNING AREA



J:\Jobs\116043_A_Dobroyd\ArcGIS\ArcMaps\Stage3_Report\Appendix_A\Update_20190621\FigureA24_Flood_Planning_Area_Update.mxd



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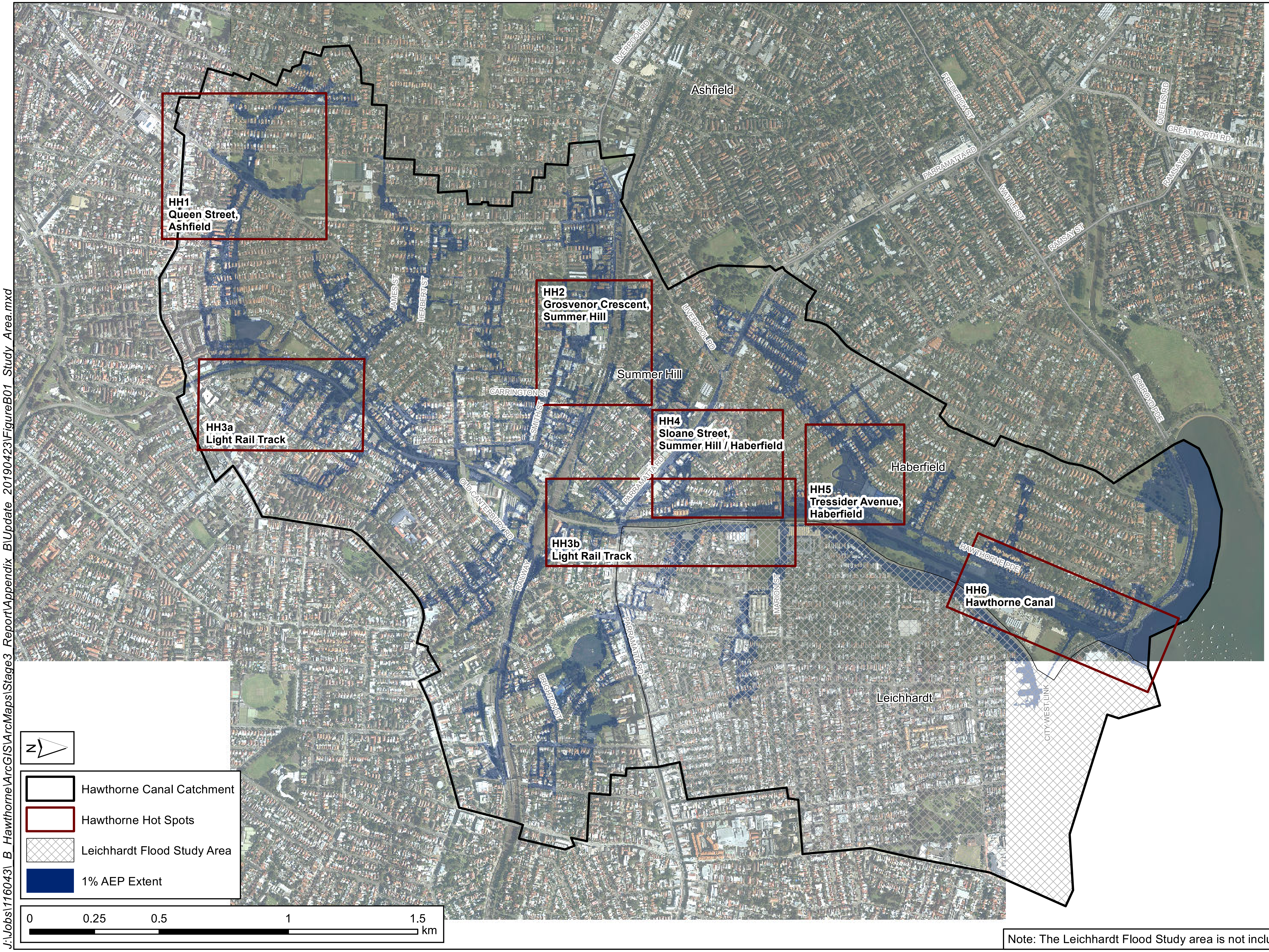
Appendix B

FIGURE B1
STUDY AREA



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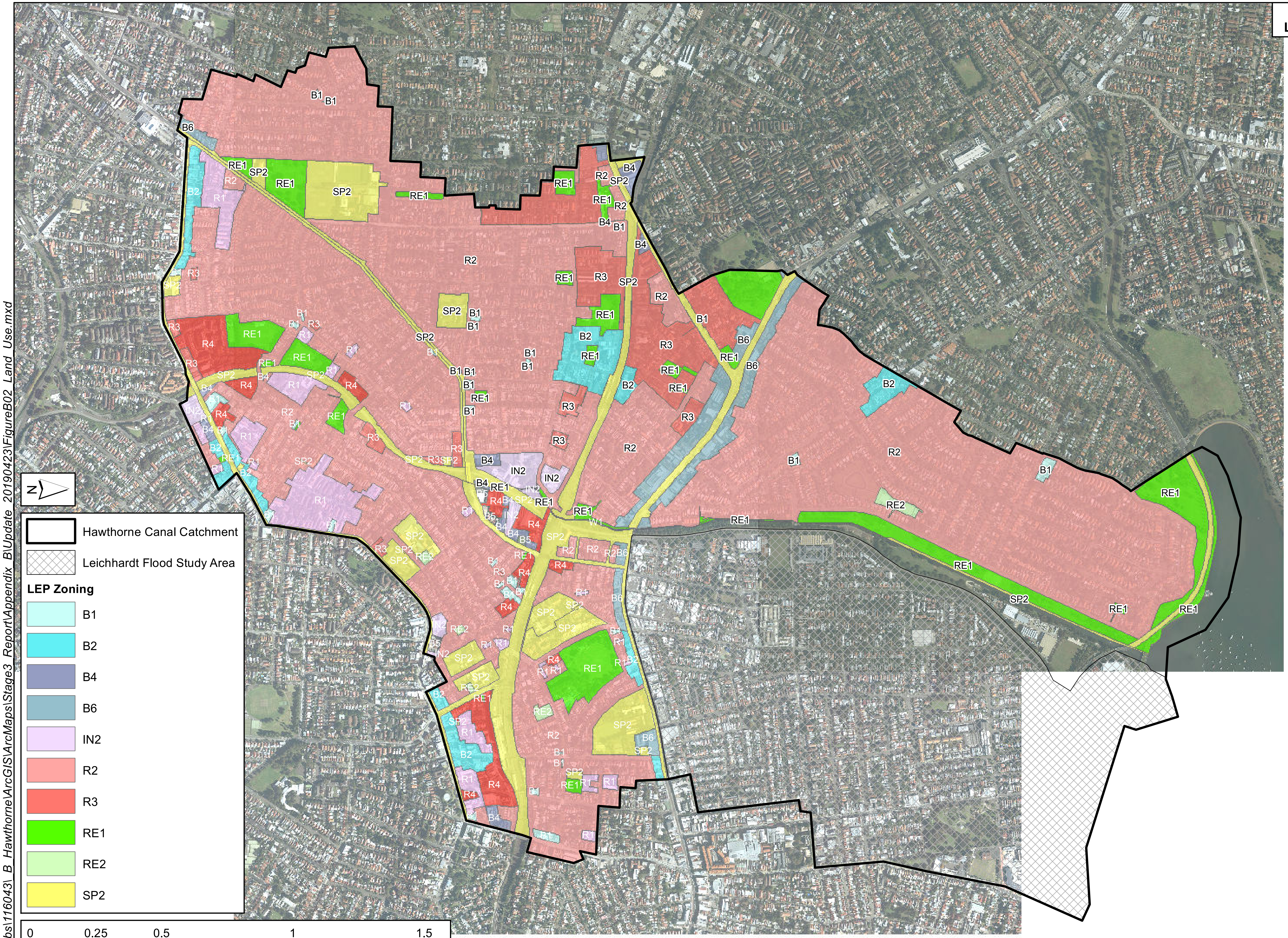
Note: The Leichhardt Flood Study area is not included in this FRMS

FIGURE B2
LAND USE MAP



Note: The Leichhardt Flood Study area is not included in this FRMS

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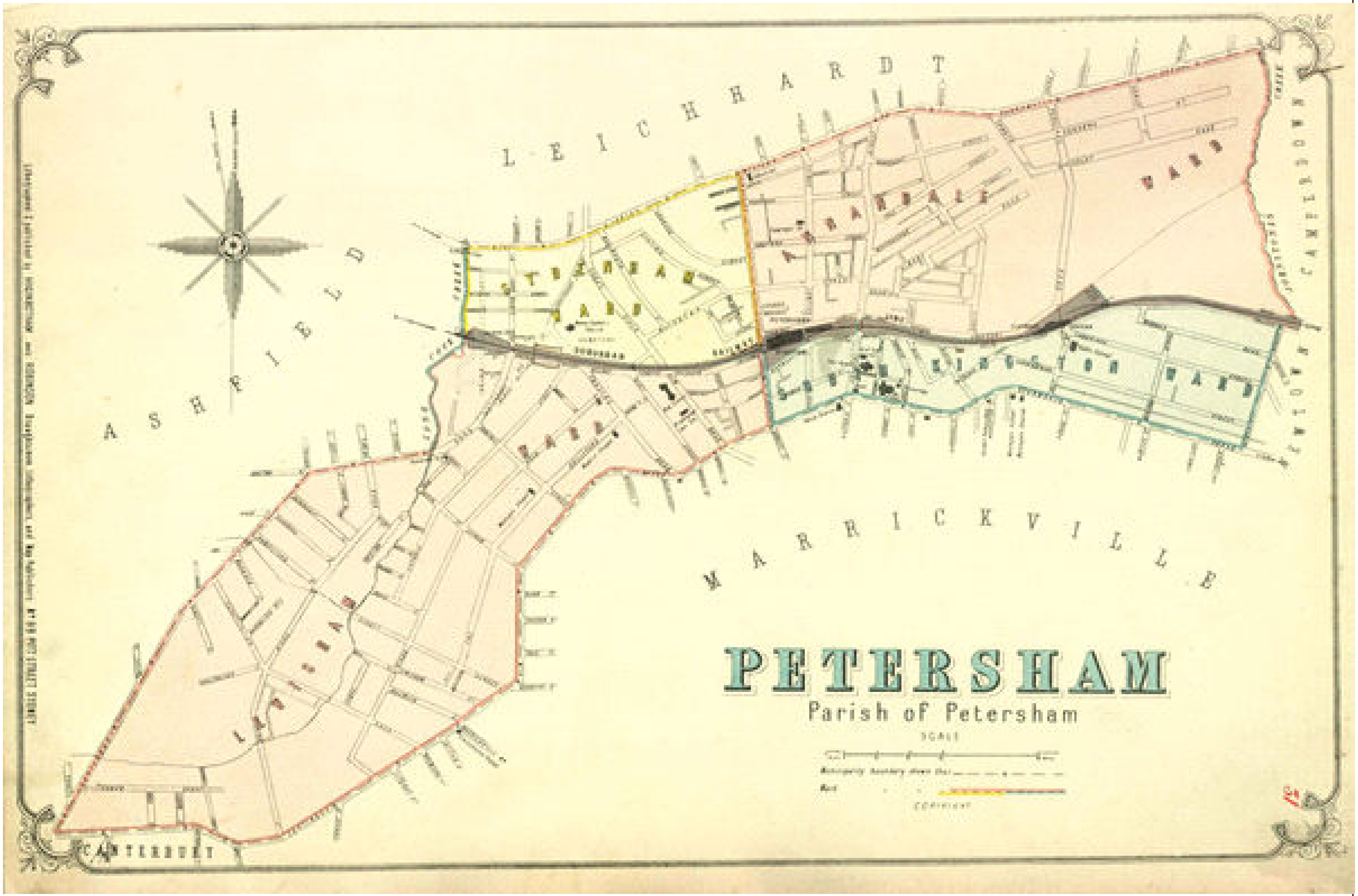
PETERSHAM
Parish of Petersham
LEICHHARDT
ASHFIELD
MARRICKVILLE
CANTERBURY
KINGSTON WARD

FIGURE B4
HERITAGE MAP

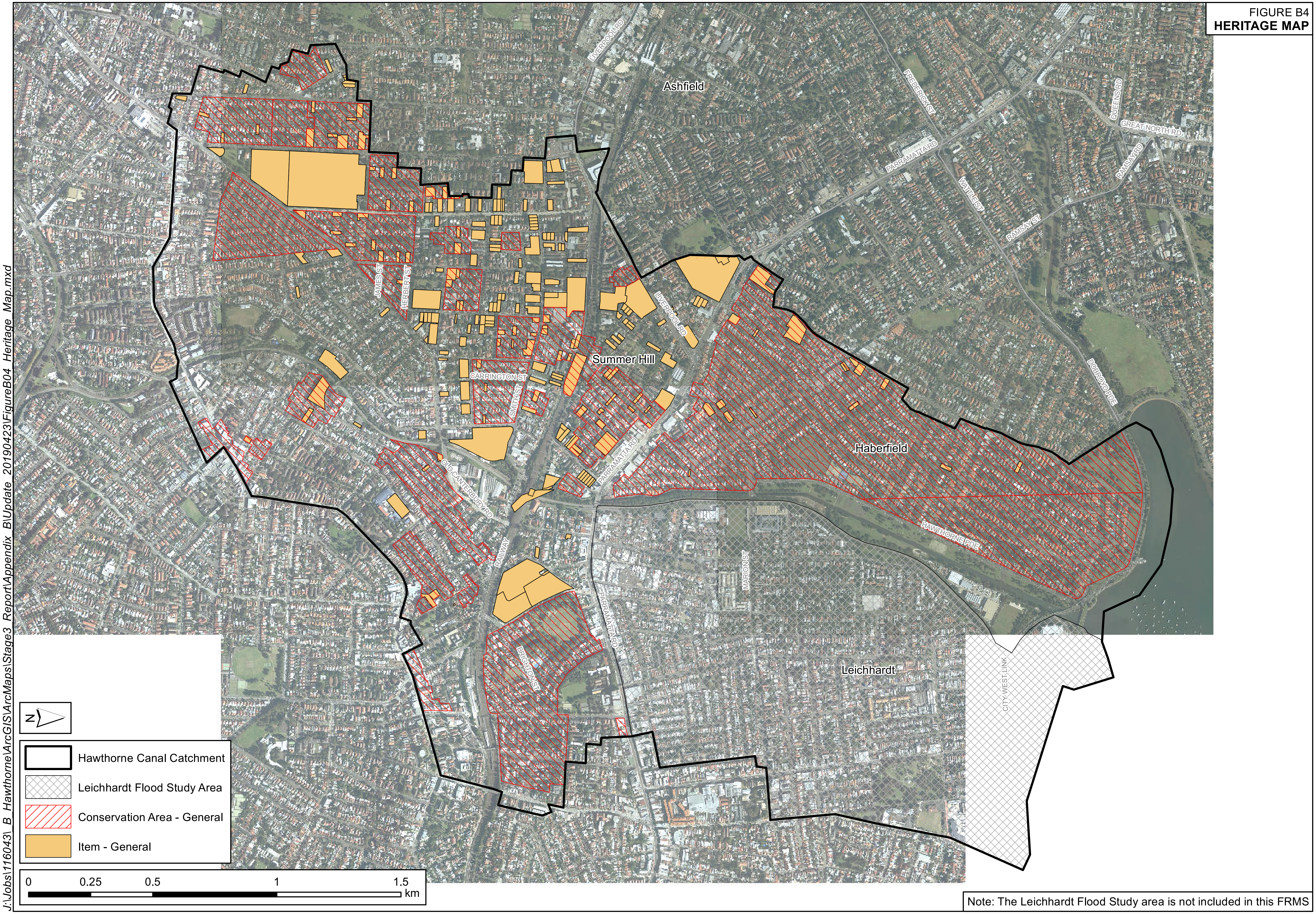

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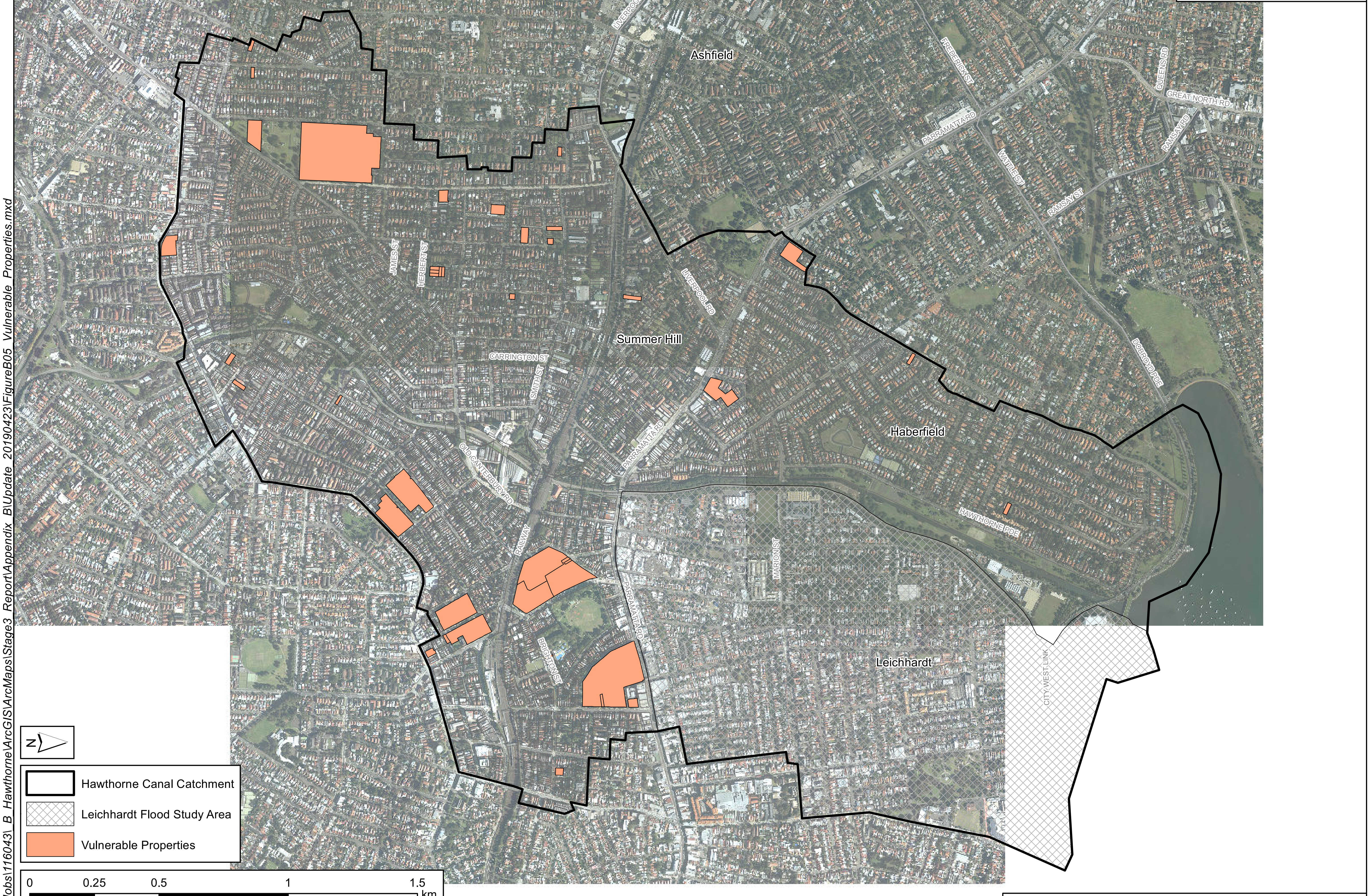
FIGURE B5
VULNERABLE PROPERTIES

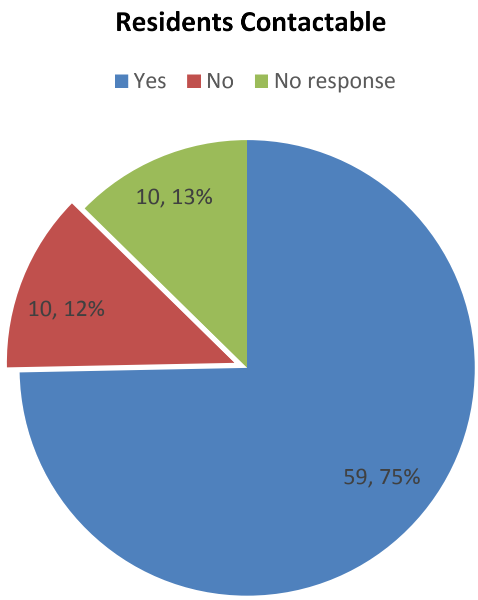


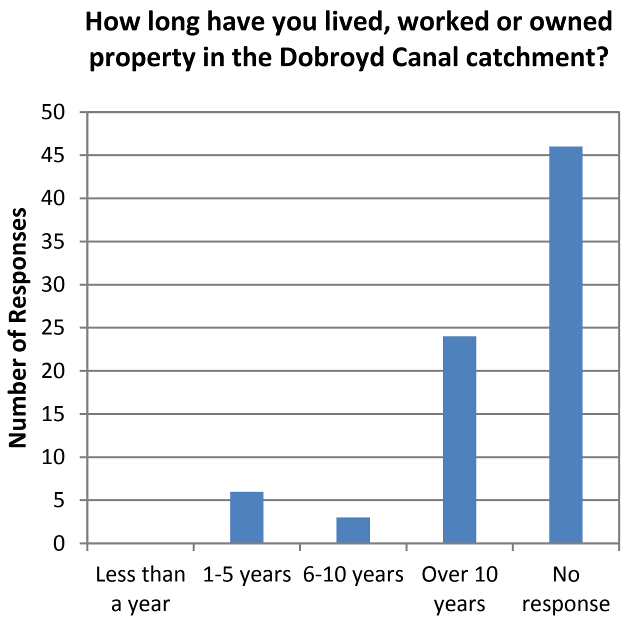
Note: The Leichhardt Flood Study area is not included in this FRMS

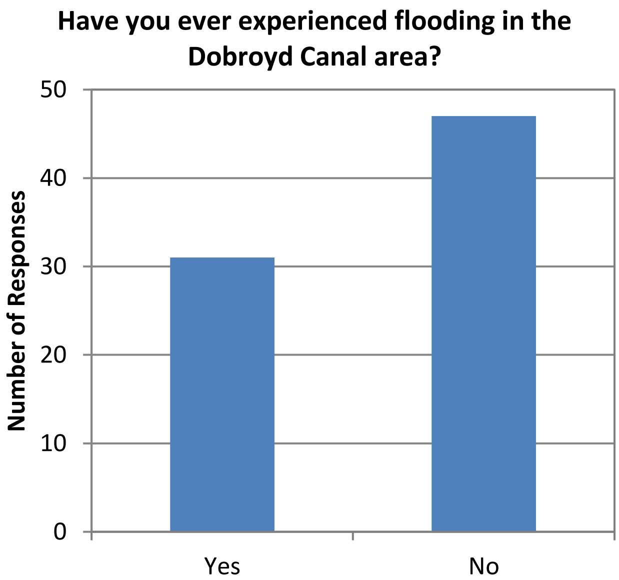
J:\Jobs\116043\ B Hawthorne\ArcGIS\ArcMaps\Stage3 Report\Appendix B\Update 20190423\FigureB05 Vulnerable Properties.mxd

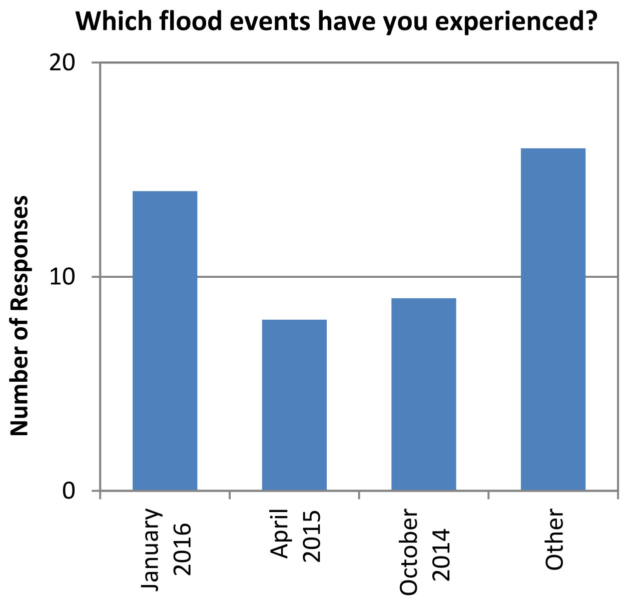
FIGURE B6A

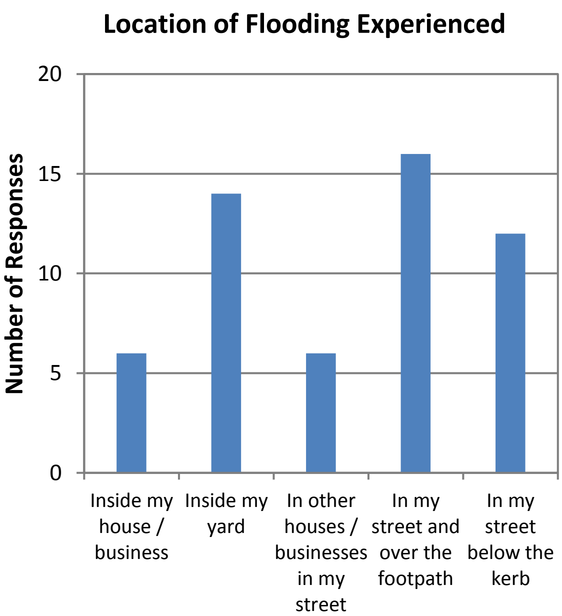
COMMUNITY CONSULTATION RESULTS

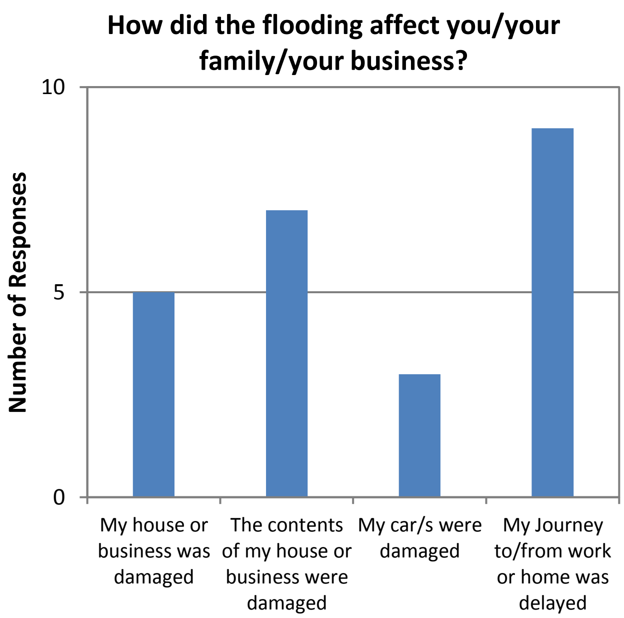






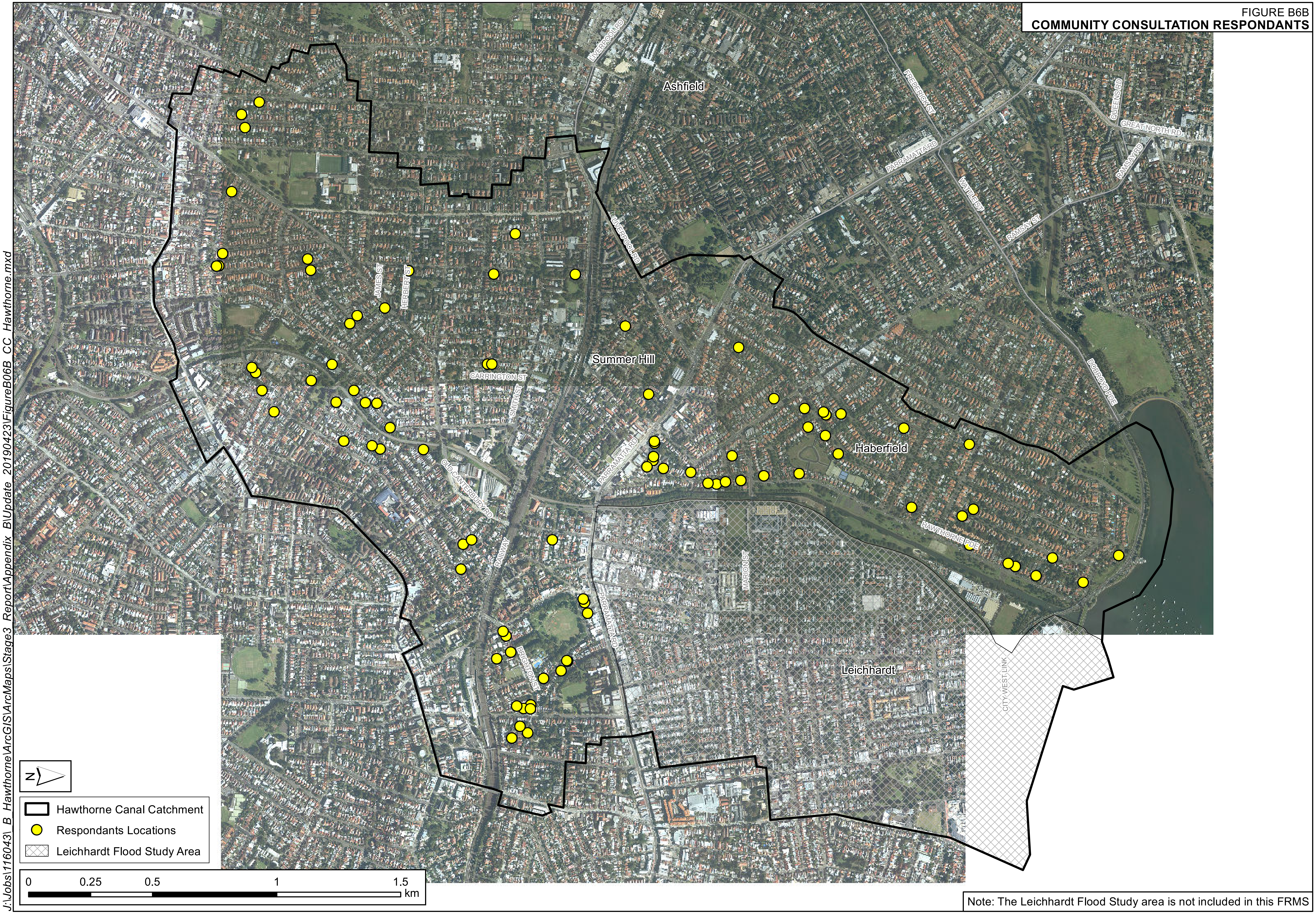






J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190314\Dobroyd_Hawthorne_CommunityConsultation_B6A.xlsx

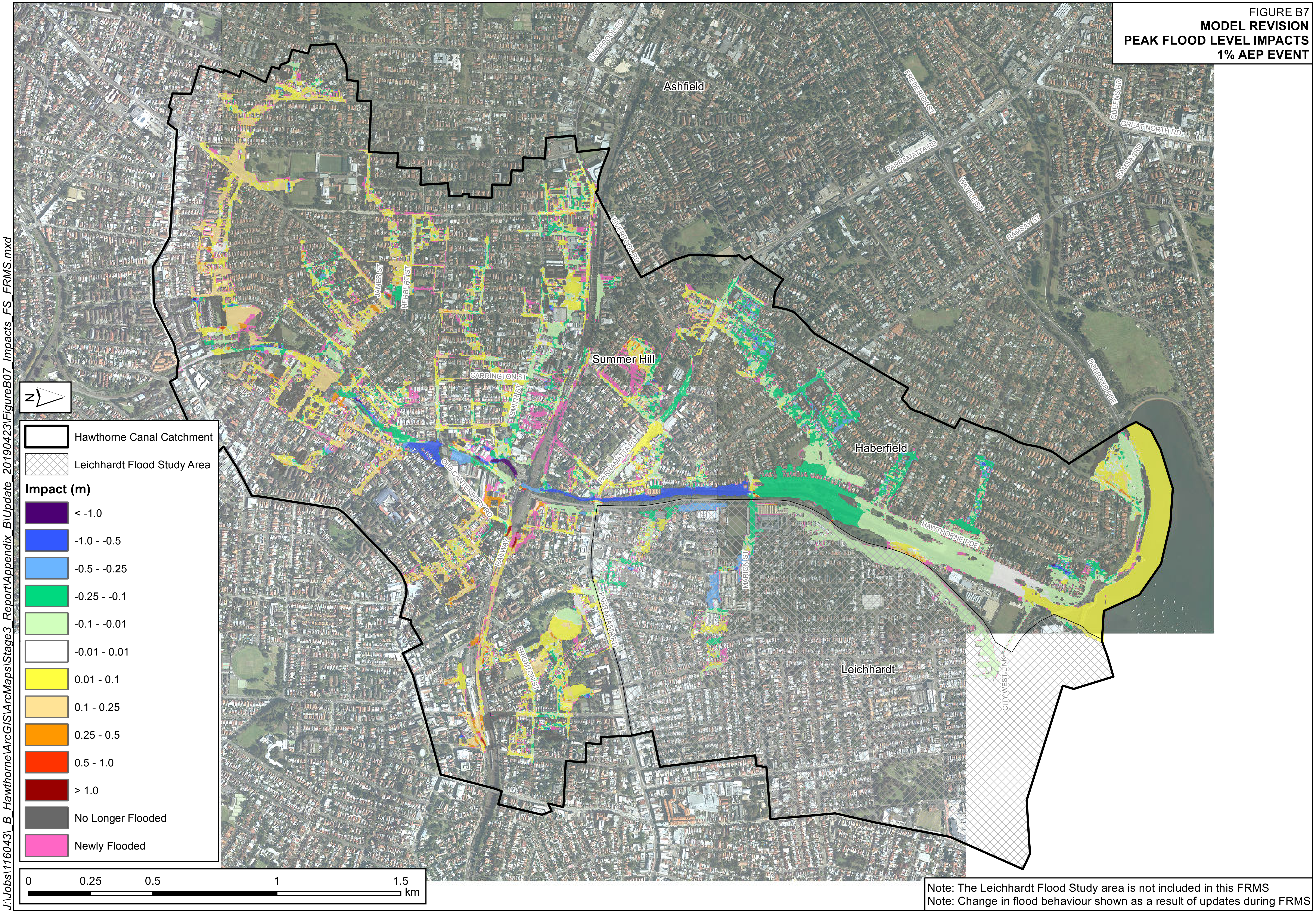
FIGURE B6B
COMMUNITY CONSULTATION RESPONDANTS



J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB06B_CC_Hawthorne.mxd

Note: The Leichhardt Flood Study area is not included in this FRMS

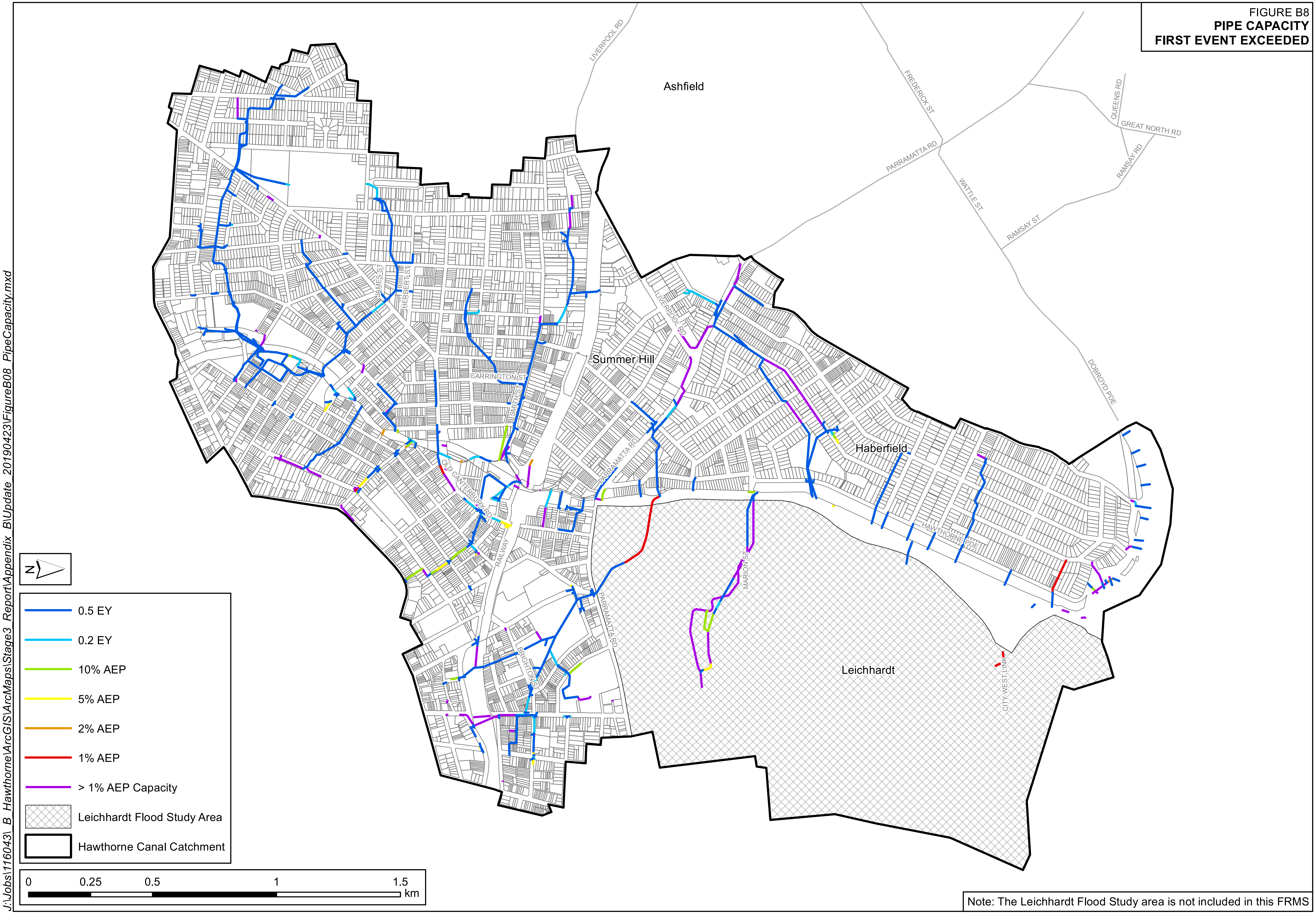
FIGURE B7
MODEL REVISION
PEAK FLOOD LEVEL IMPACTS
1% AEP EVENT



Note: The Leichhardt Flood Study area is not included in this FRMS
Note: Change in flood behaviour shown as a result of updates during FRMS

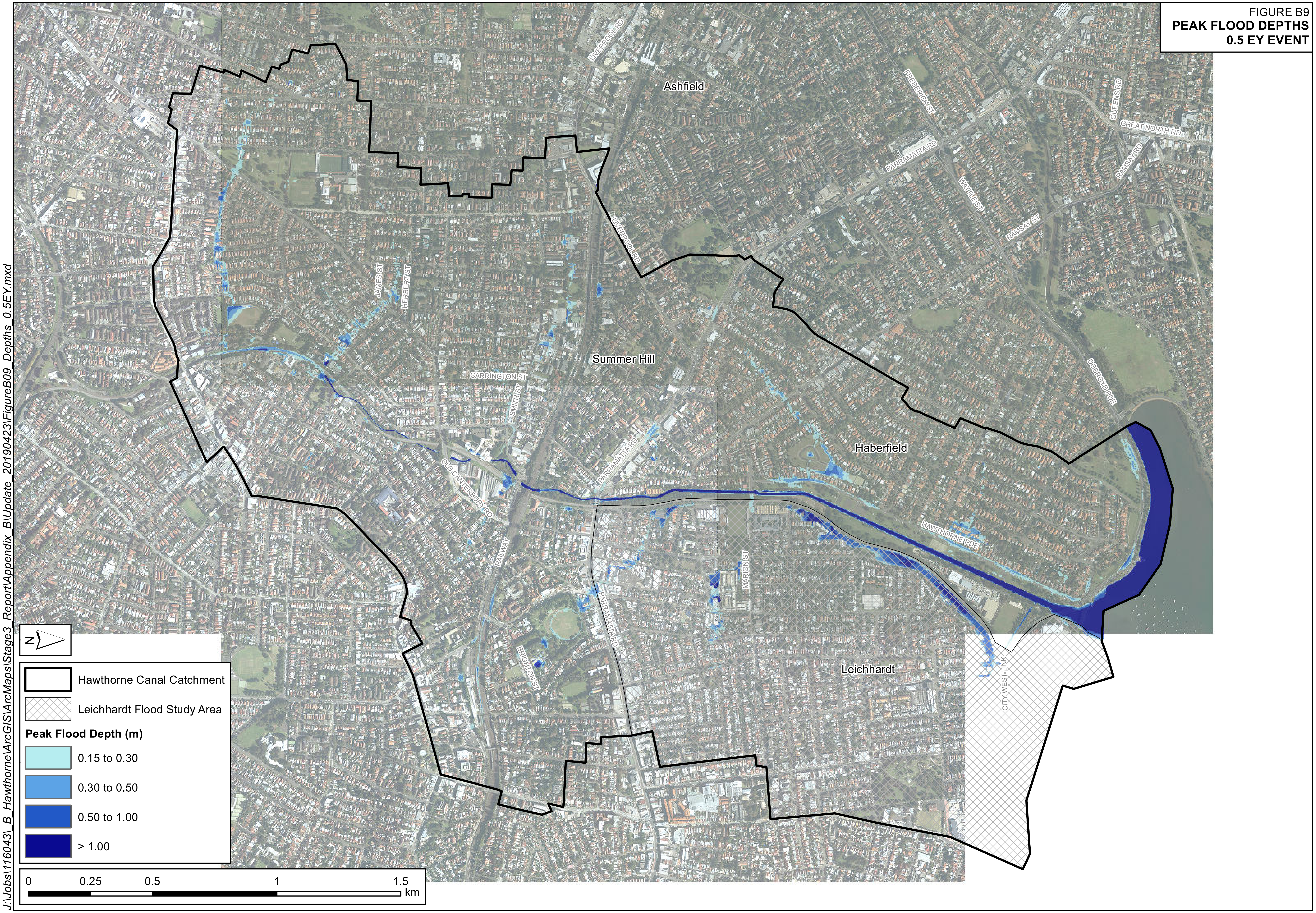
J:\Jobs\116043\ B Hawthorne\ArcGIS\ArcMaps\Stage3 Report\Appendix B\Update 20190423\FigureB07 Impacts FS FRMS.mxd

FIGURE B8
PIPE CAPACITY
FIRST EVENT EXCEEDED



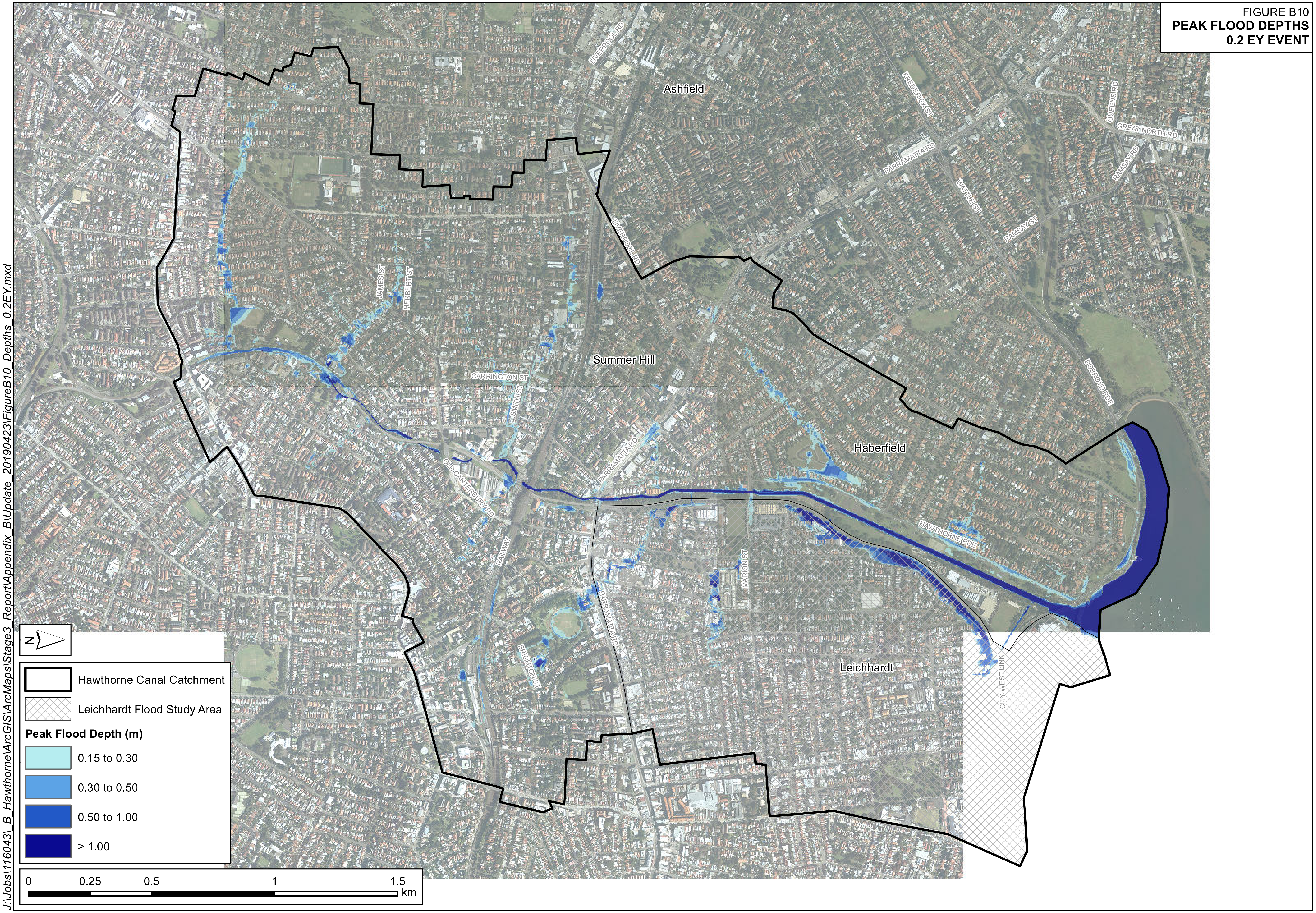
Note: The Leichhardt Flood Study area is not included in this FRMS

FIGURE B9
PEAK FLOOD DEPTHS
0.5 EY EVENT



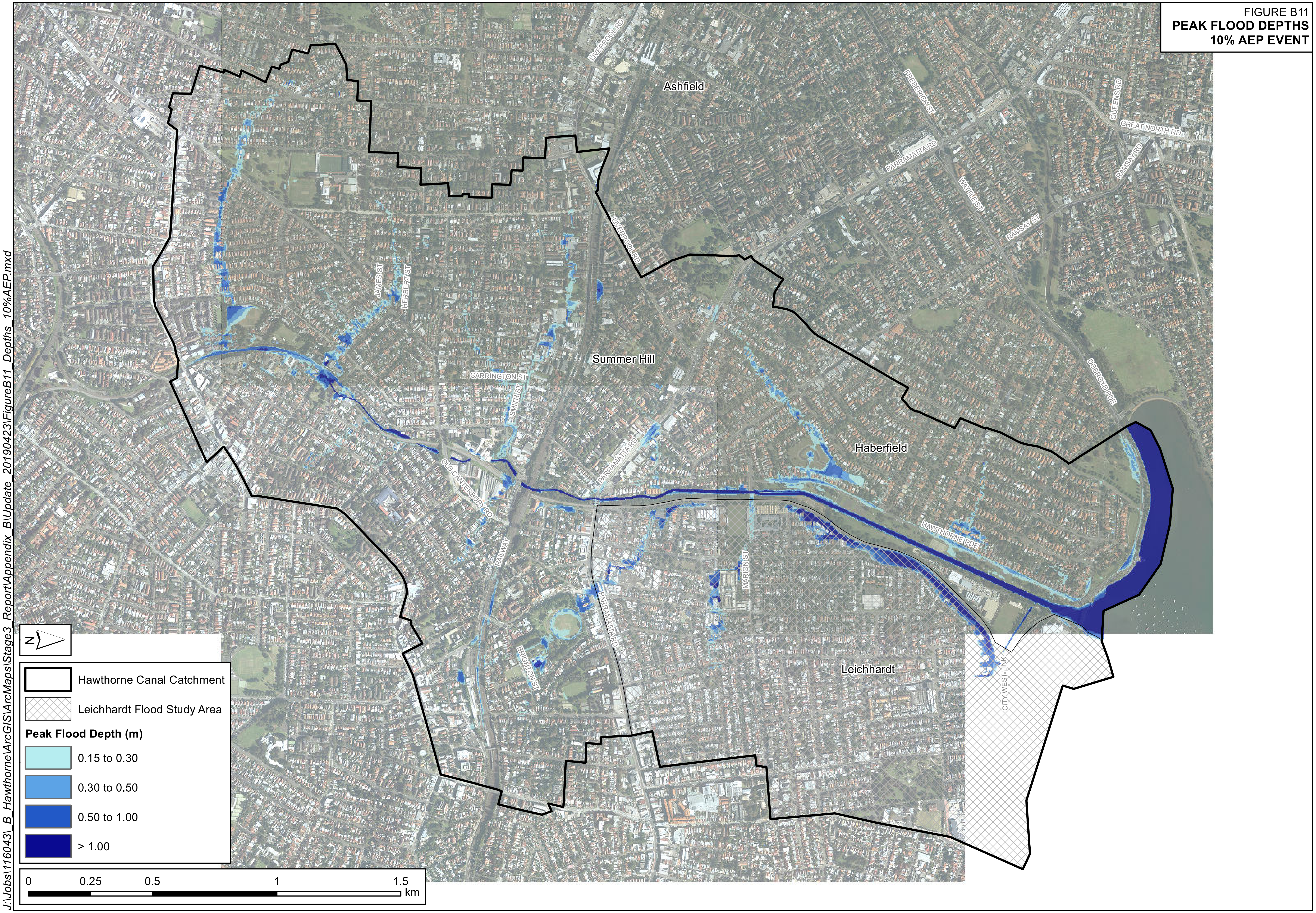
J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB09_Depths_0.5EY.mxd

FIGURE B10
PEAK FLOOD DEPTHS
0.2 EY EVENT



J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB10_Depths_0.2EY.mxd

FIGURE B11
PEAK FLOOD DEPTHS
10% AEP EVENT



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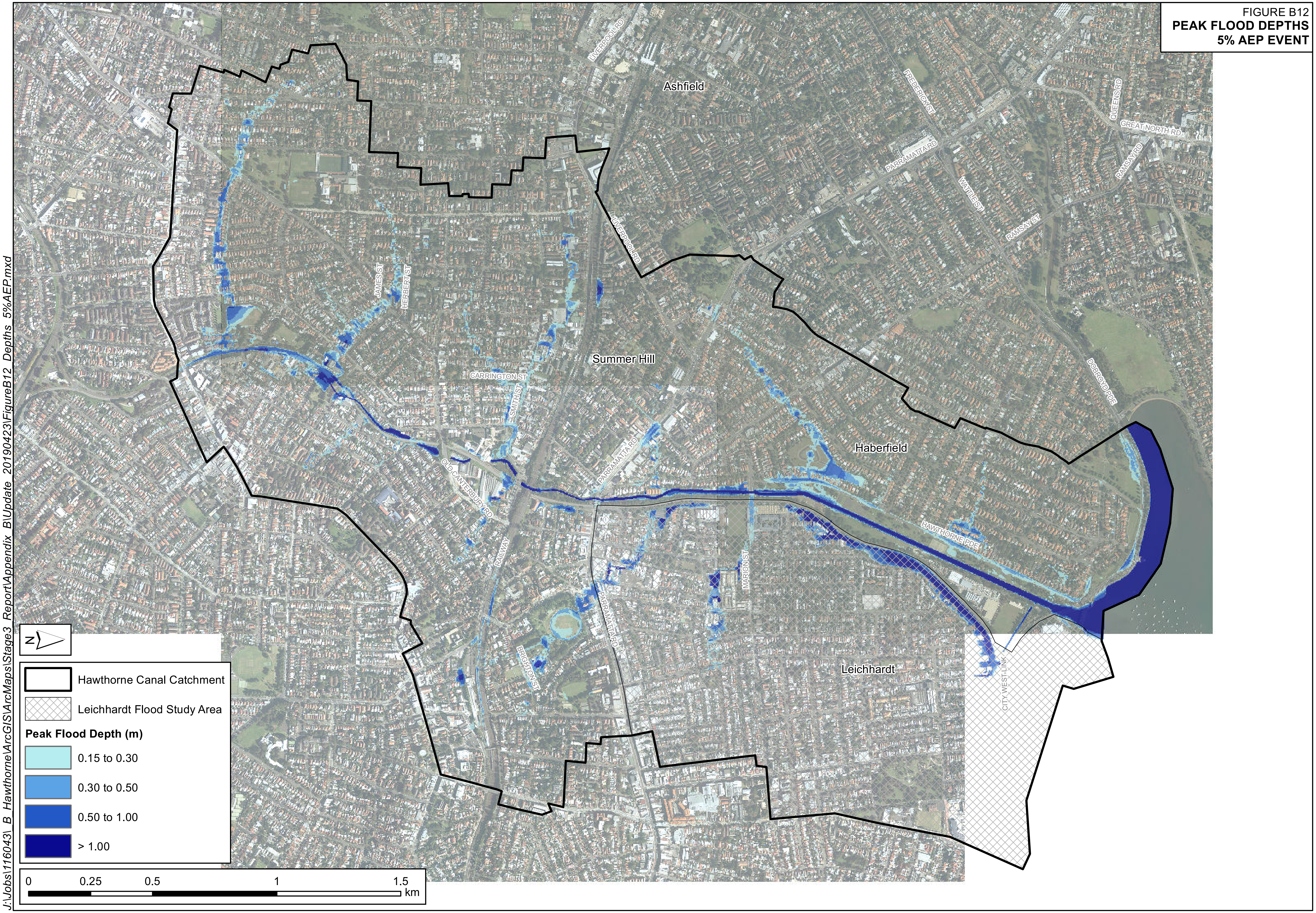

FIGURE B12
PEAK FLOOD DEPTHS
5% AEP EVENT

J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB12_Depths_5%AEP.mxd

FIGURE B13
PEAK FLOOD DEPTHS
2% AEP EVENT

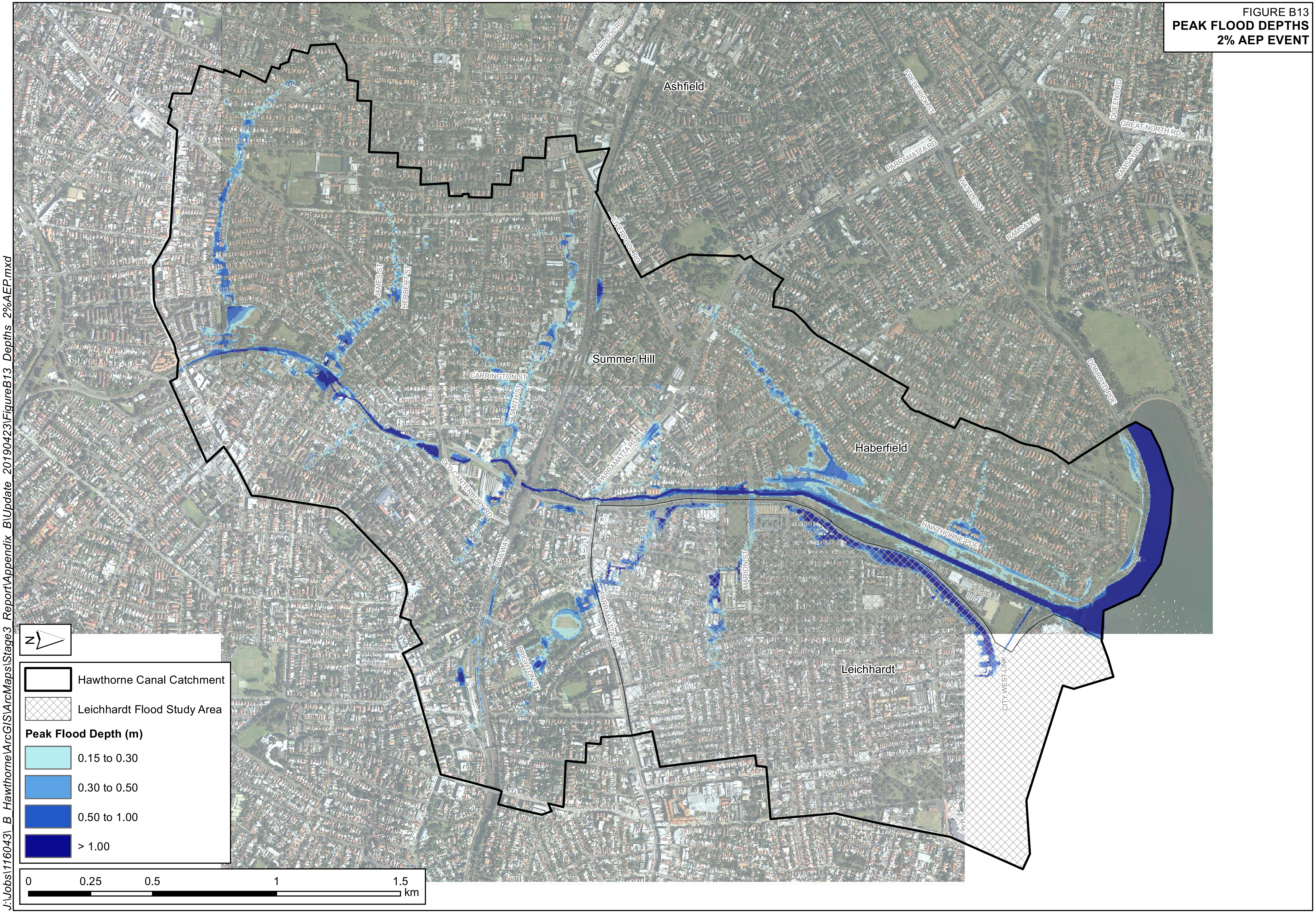

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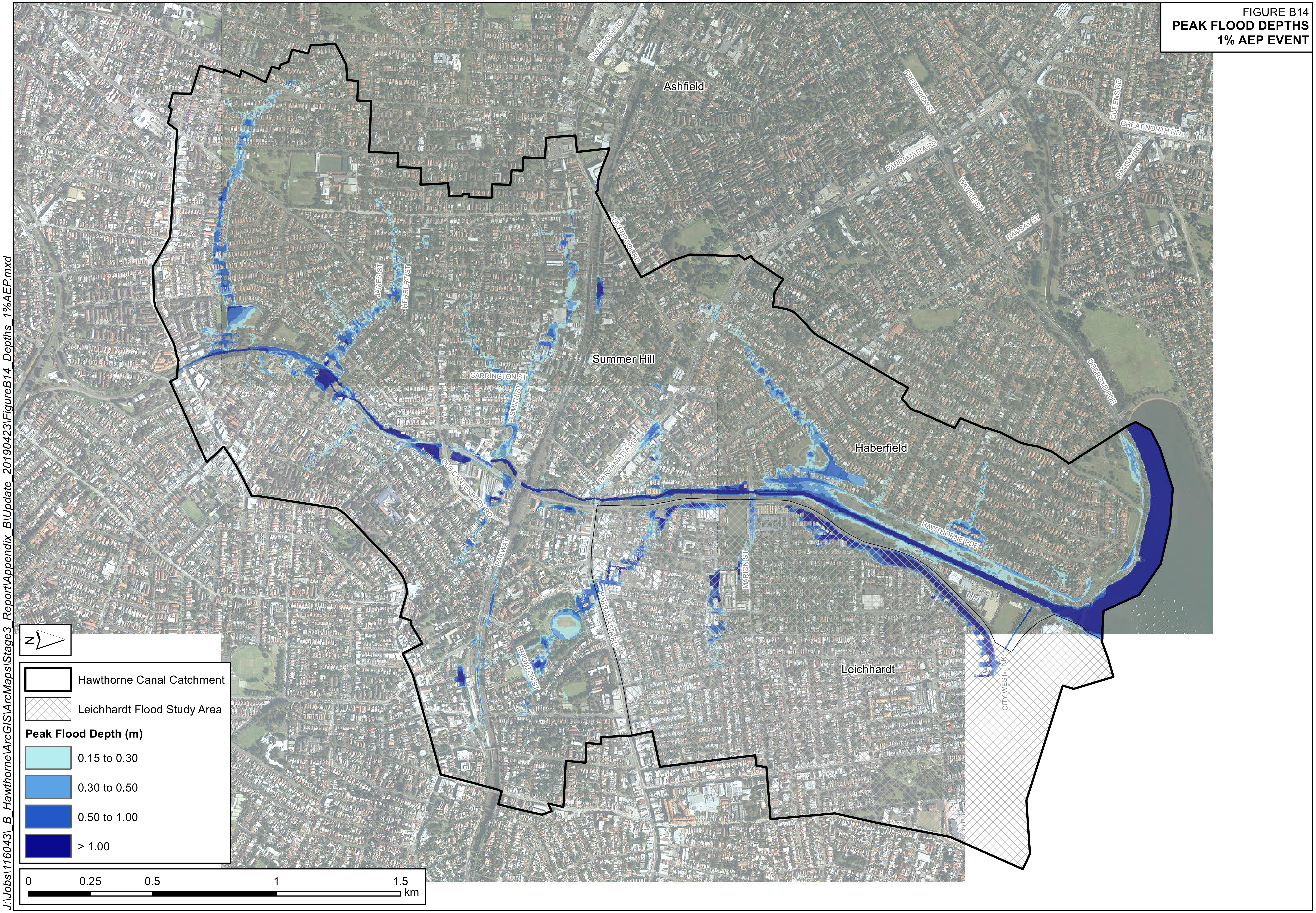
FIGURE B14
PEAK FLOOD DEPTHS
1% AEP EVENT



J:\Jobs\116043_B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB14_Depths_1%AEP.mxd

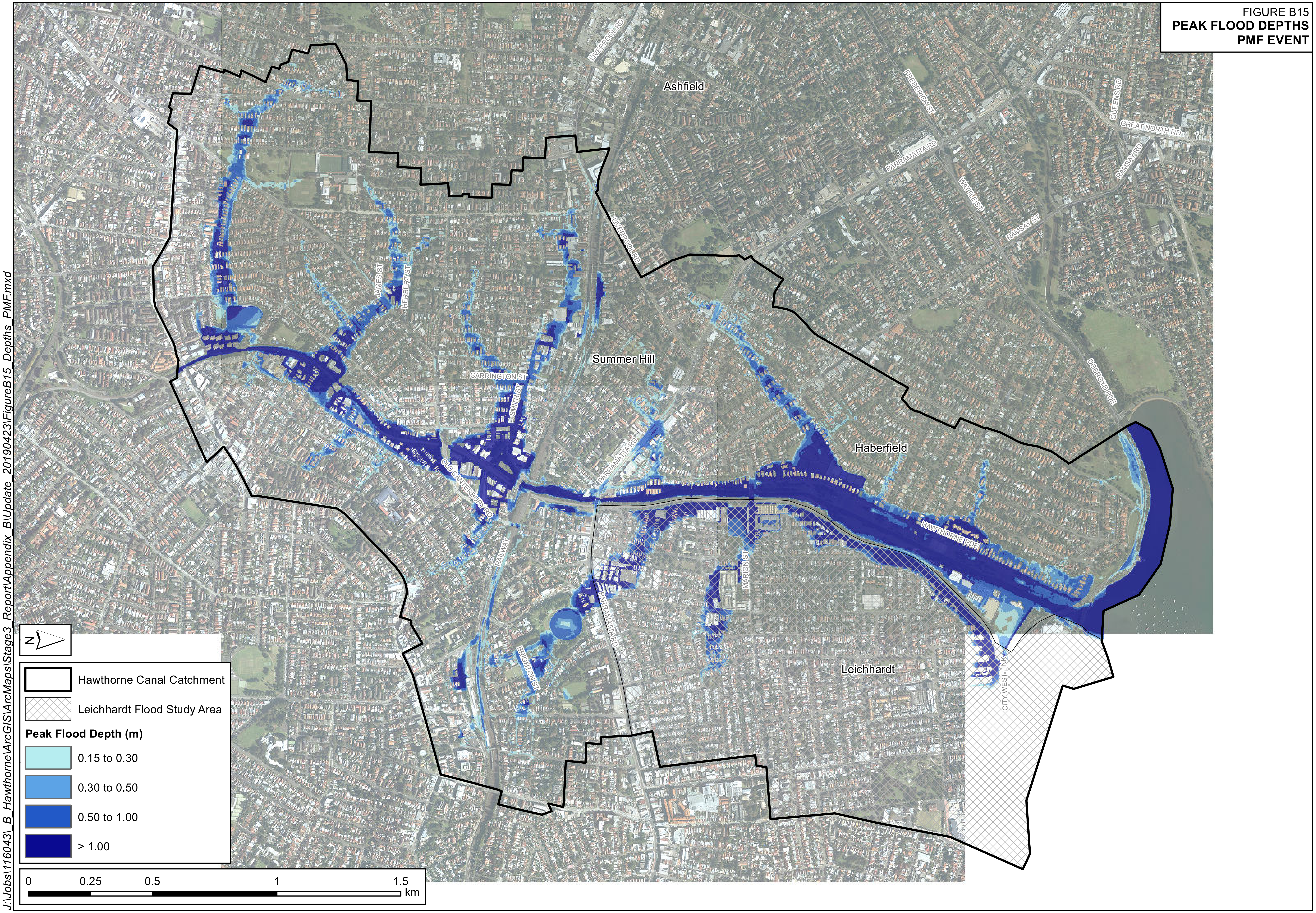


FIGURE B15
PEAK FLOOD DEPTHS
PMF EVENT

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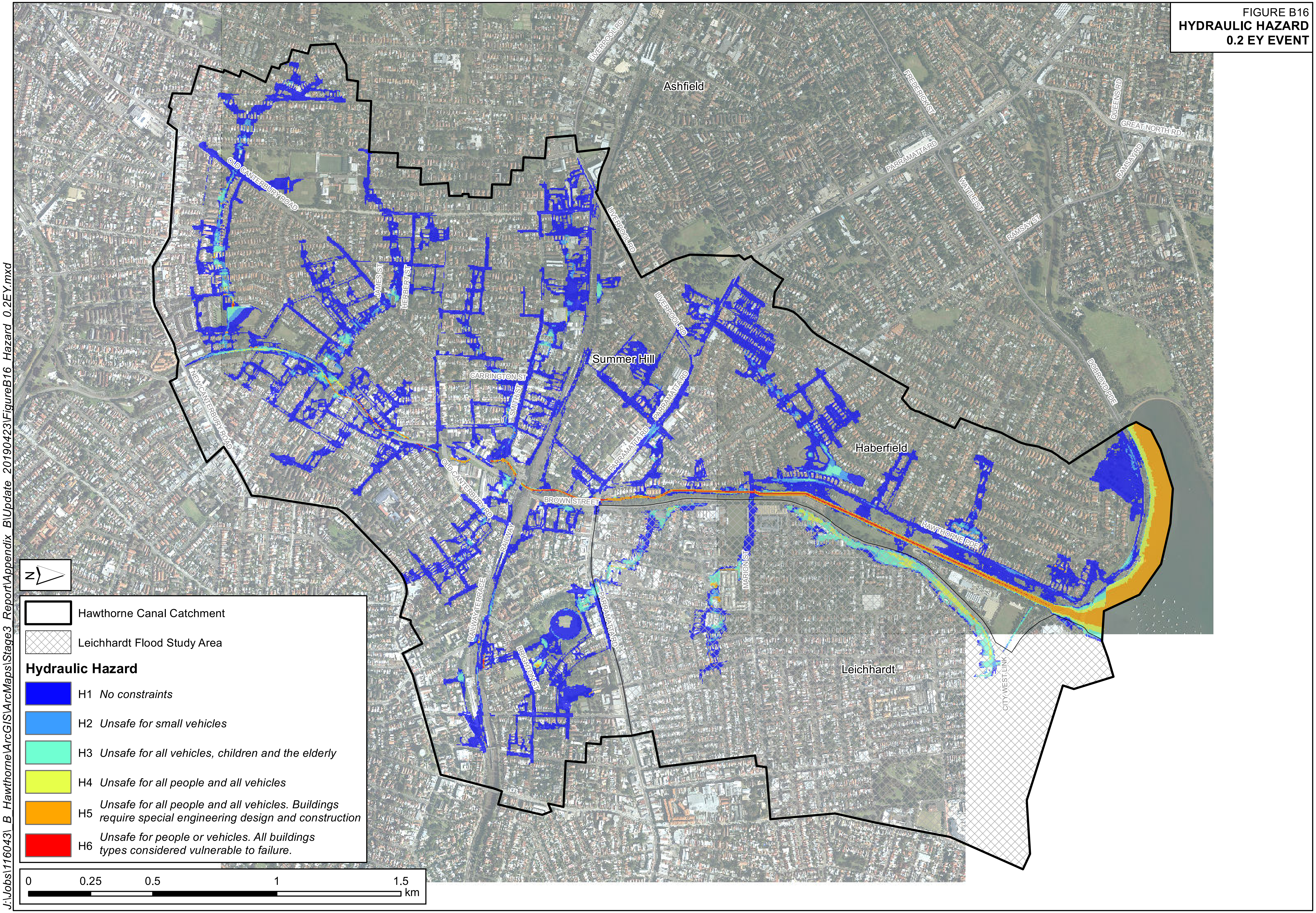

FIGURE B16
HYDRAULIC HAZARD
0.2 EY EVENT
Ashfield
Summer Hill
Haberfield
Leichhardt
OLD CANTERBURY ROAD
NEW CANTERBURY ROAD
LIVERPOOL RD
PARRAMATTA RD
JAMES ST
HERBERT ST
CARRINGTON ST
SMITH ST
BROWN STREET
HAWTHORNE PDE
MARION ST
RAILWAY TERRACE
CITY WEST LINK
GREAT NORTH RD
QUEENS RD
RAMSAY RD
RAMSAY ST
FREDERICK ST
WATTLE ST
DOBROYD PDE
N
Hawthorne Canal Catchment
Leichhardt Flood Study Area
Hydraulic Hazard
H1 No constraints
H2 Unsafe for small vehicles
H3 Unsafe for all vehicles, children and the elderly
H4 Unsafe for all people and all vehicles
H5 Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 Unsafe for people or vehicles. All buildings types considered vulnerable to failure.
0
0.25
0.5
1
1.5
km
J:\Jobs\116043\ B_Hawthorne\ArcGIS\ArcMaps\Stage3_Report\Appendix_B\Update_20190423\FigureB16_Hazard_0.2EY.mxd

FIGURE B17
HYDRAULIC HAZARD
1% AEP EVENT

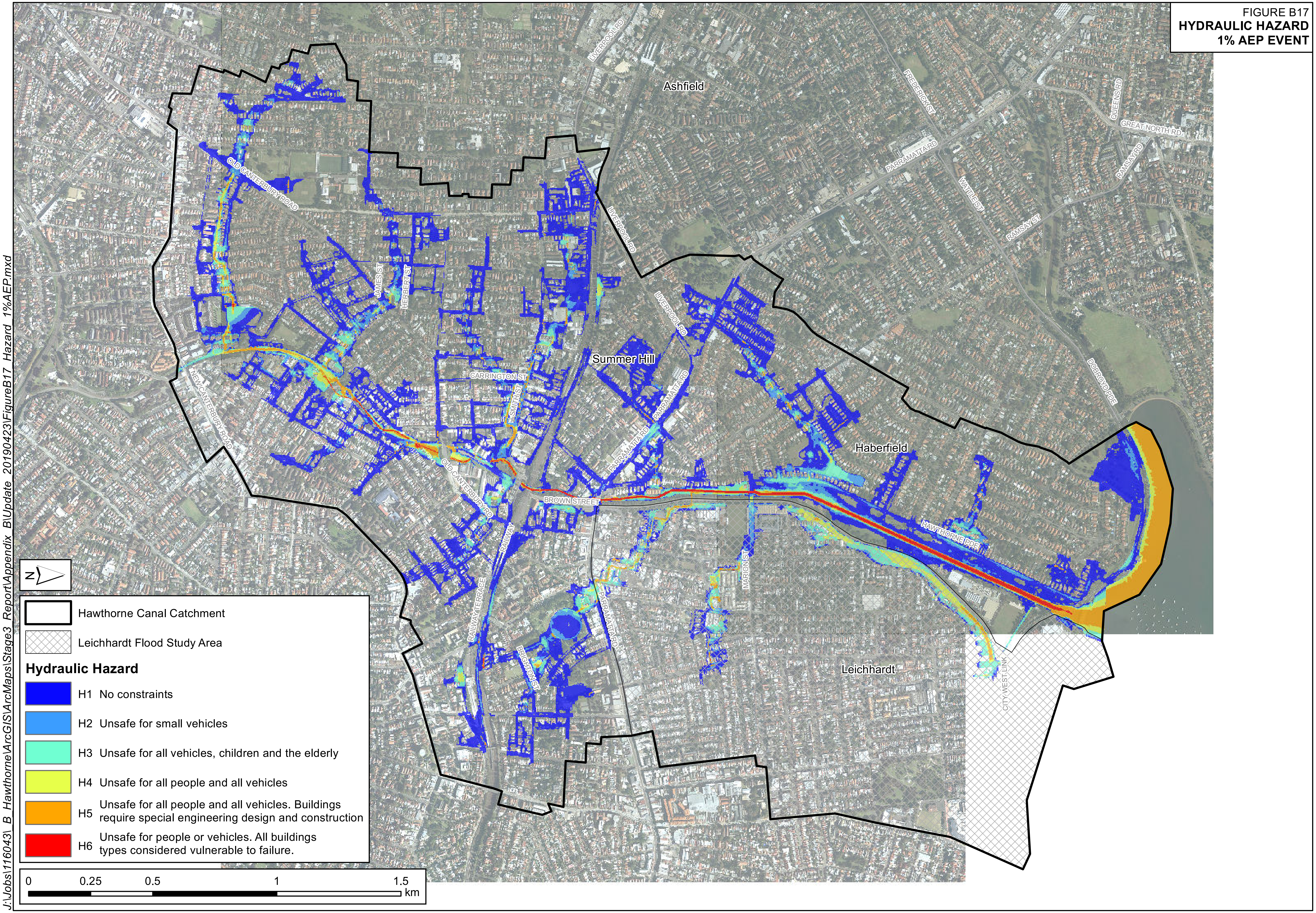

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FIGURE B18
HYDRAULIC HAZARD
PMF EVENT

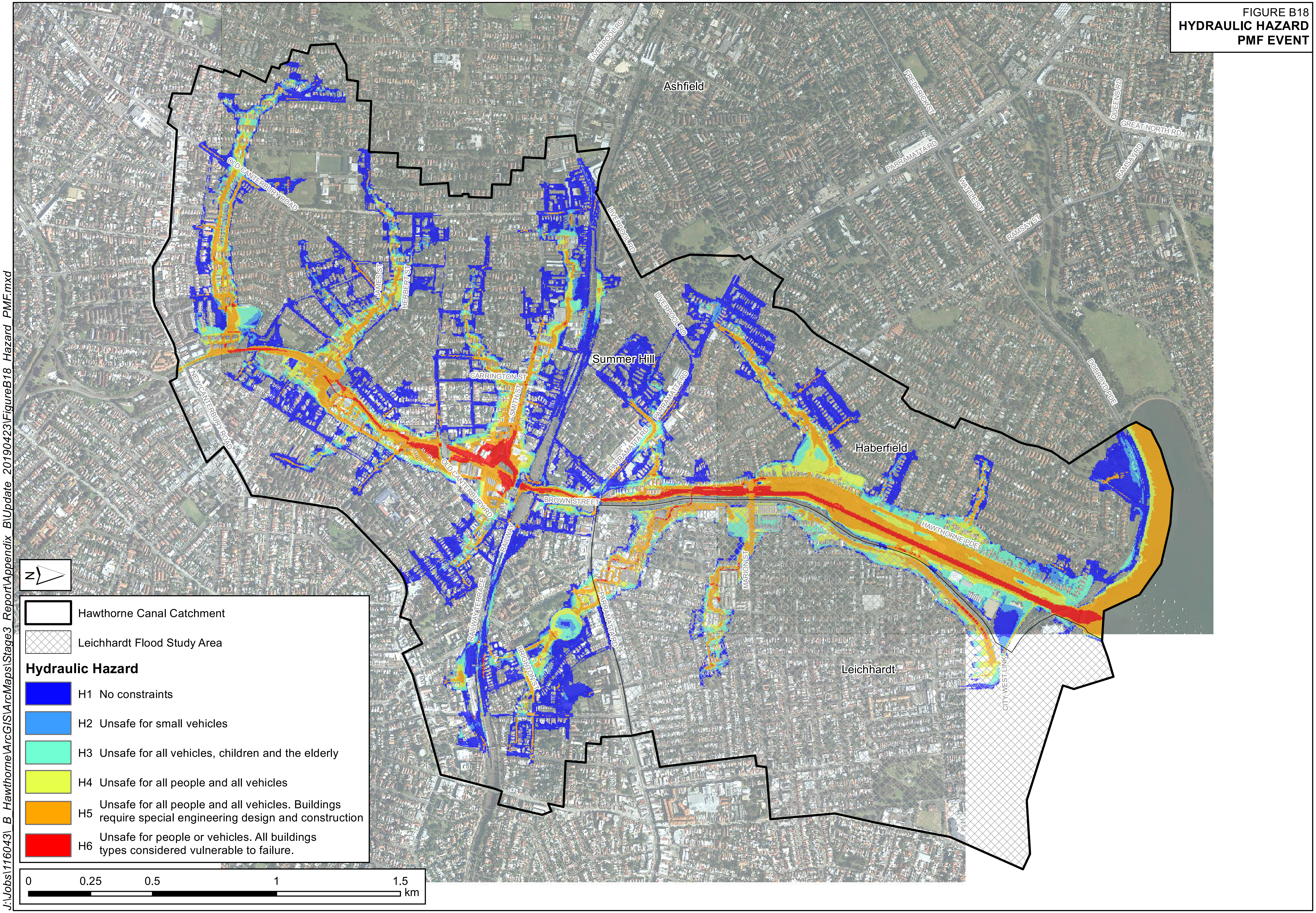

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FIGURE B19
HYDRAULIC CATEGORIES
0.2 EY EVENT

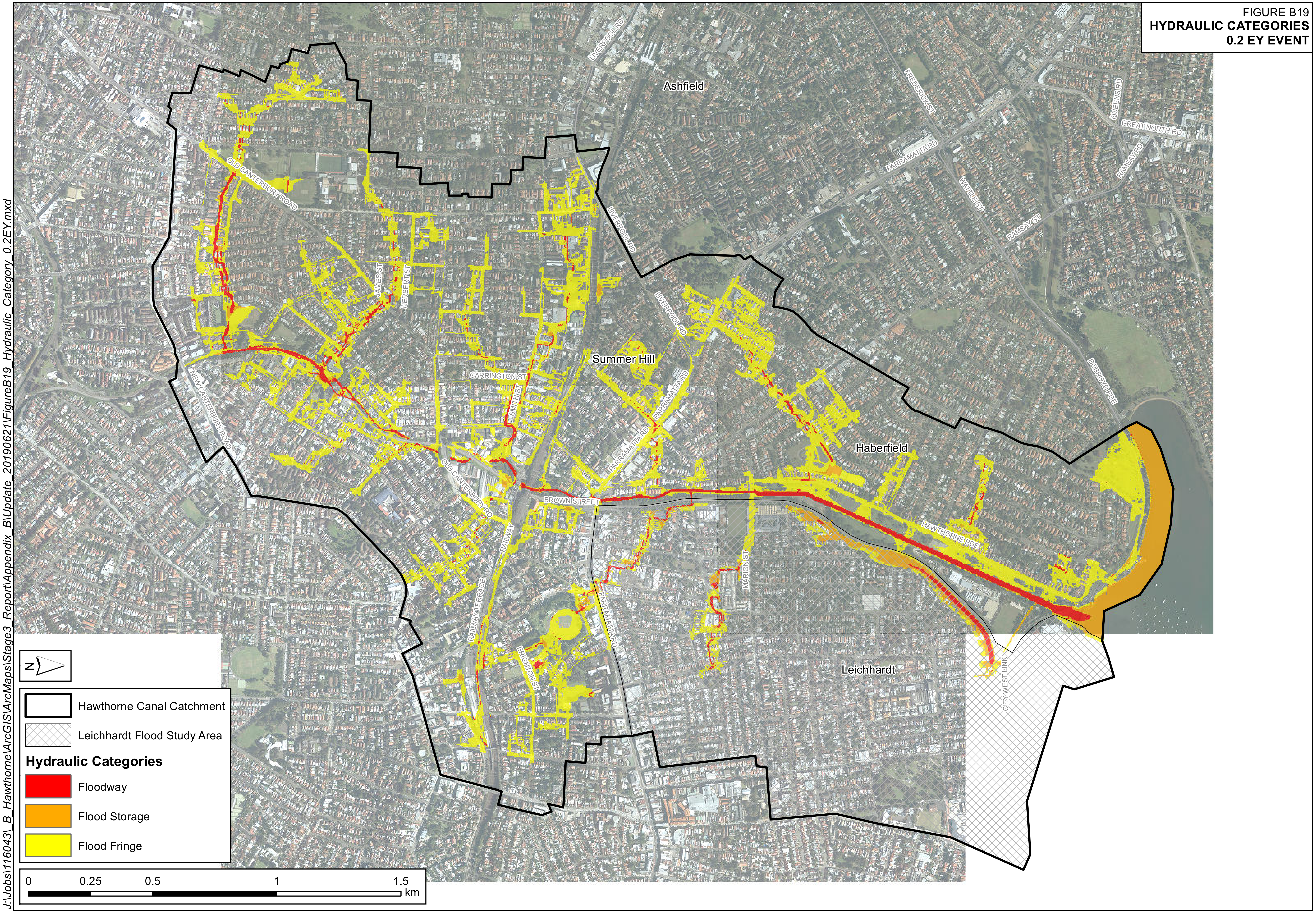

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FIGURE B20
HYDRAULIC CATEGORIES
1% AEP EVENT

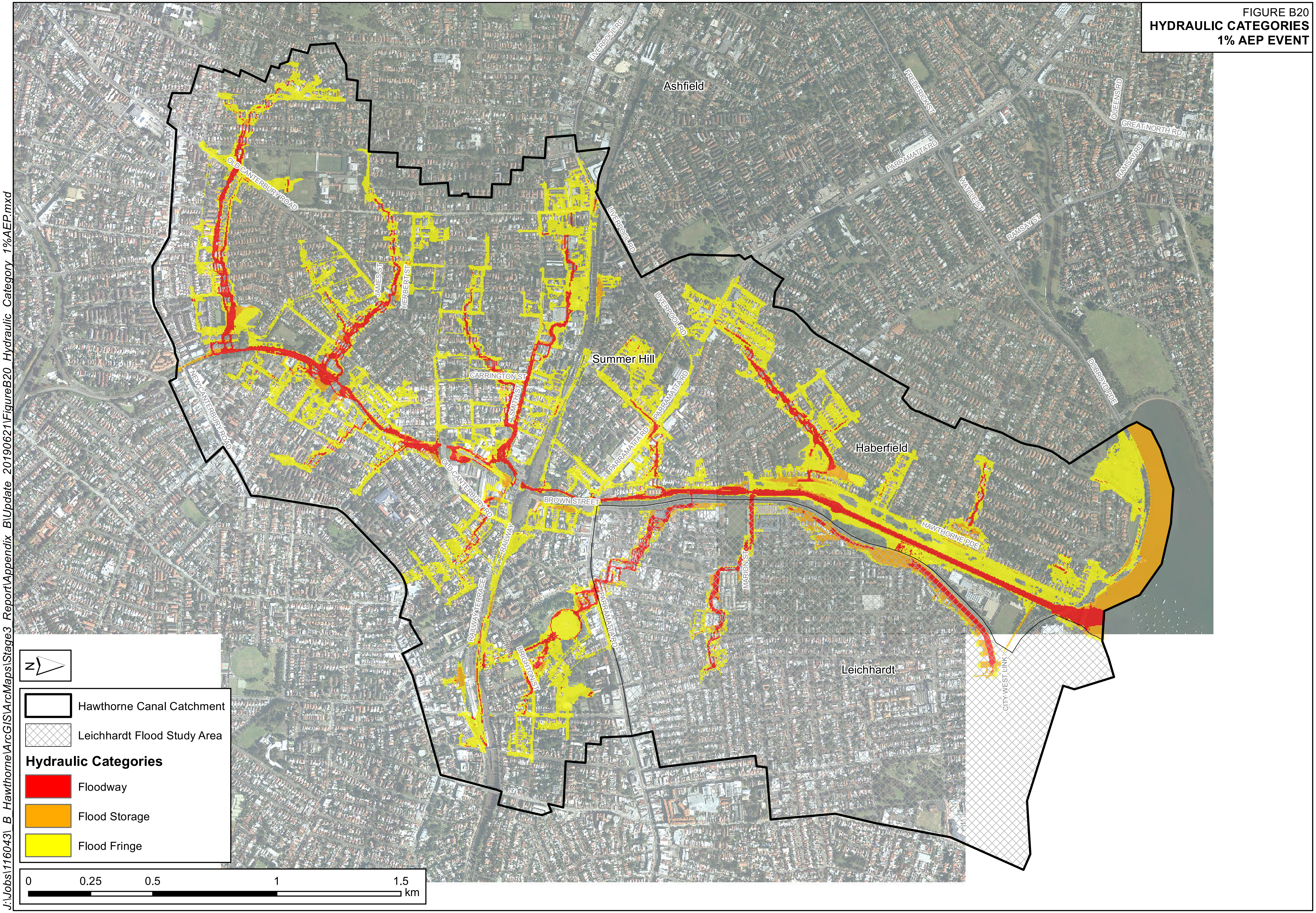

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FIGURE B21
HYDRAULIC CATEGORIES
PMF EVENT

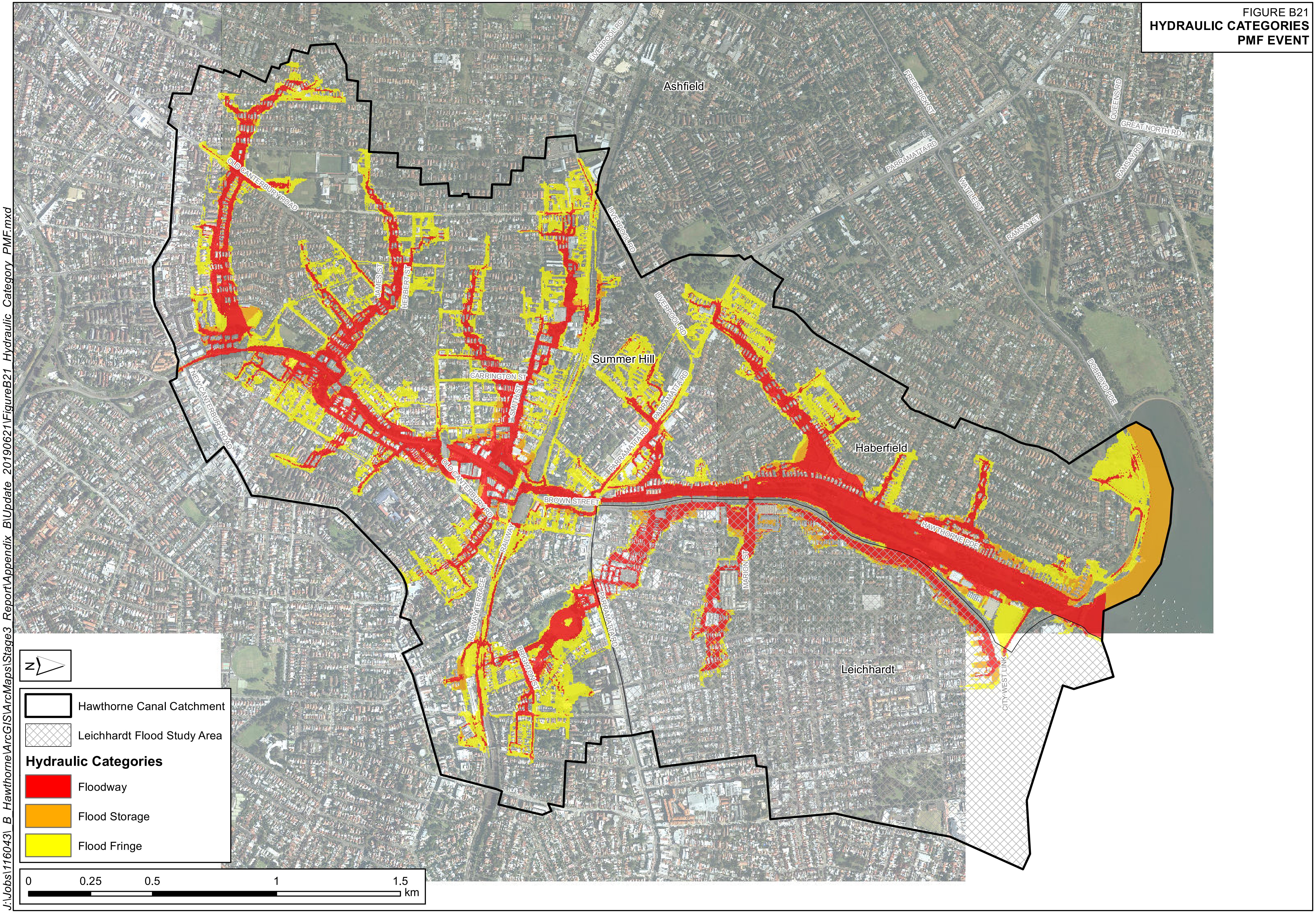

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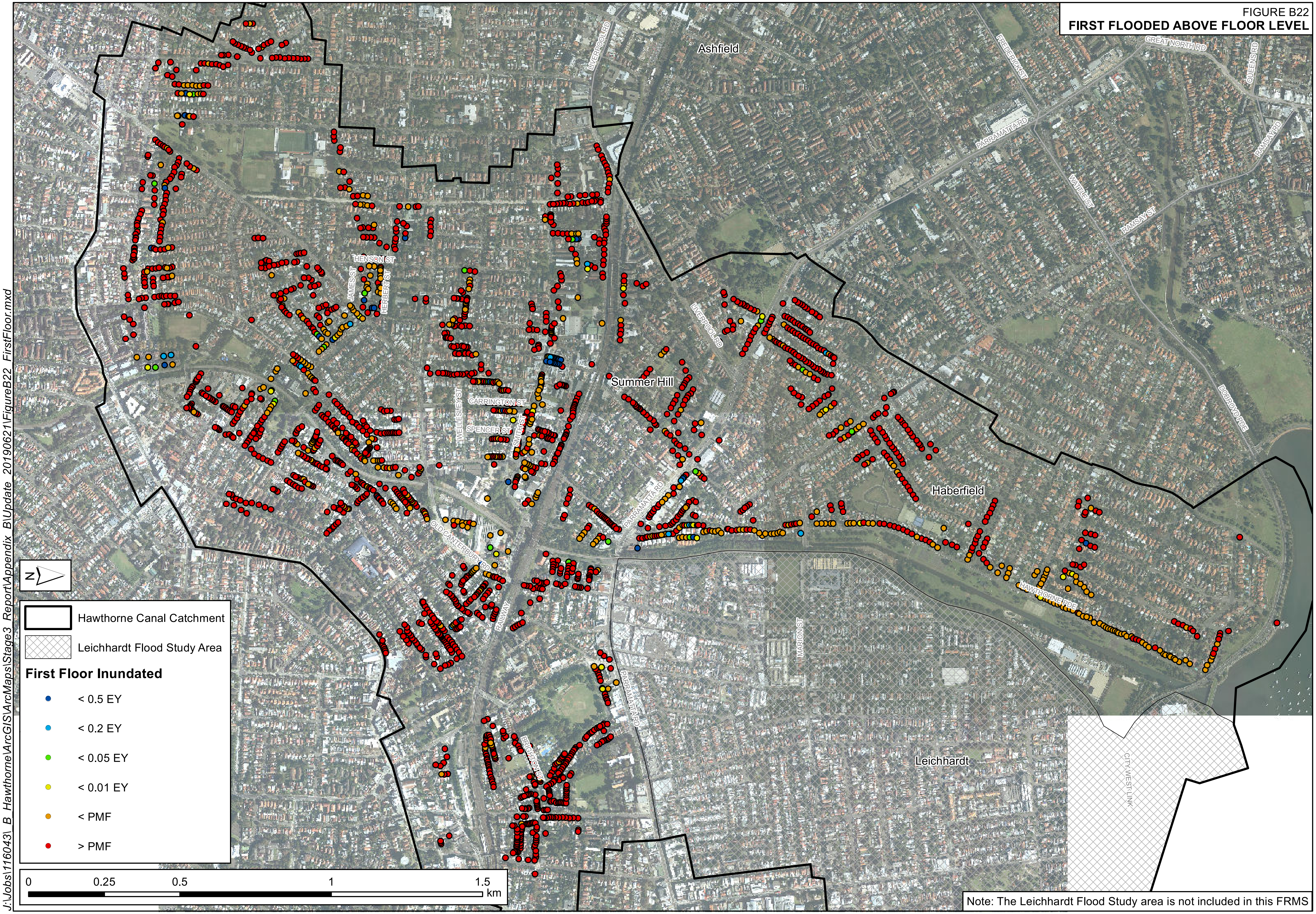
FIGURE B22
FIRST FLOODED ABOVE FLOOR LEVEL



Note: The Leichhardt Flood Study area is not included in this FRMS

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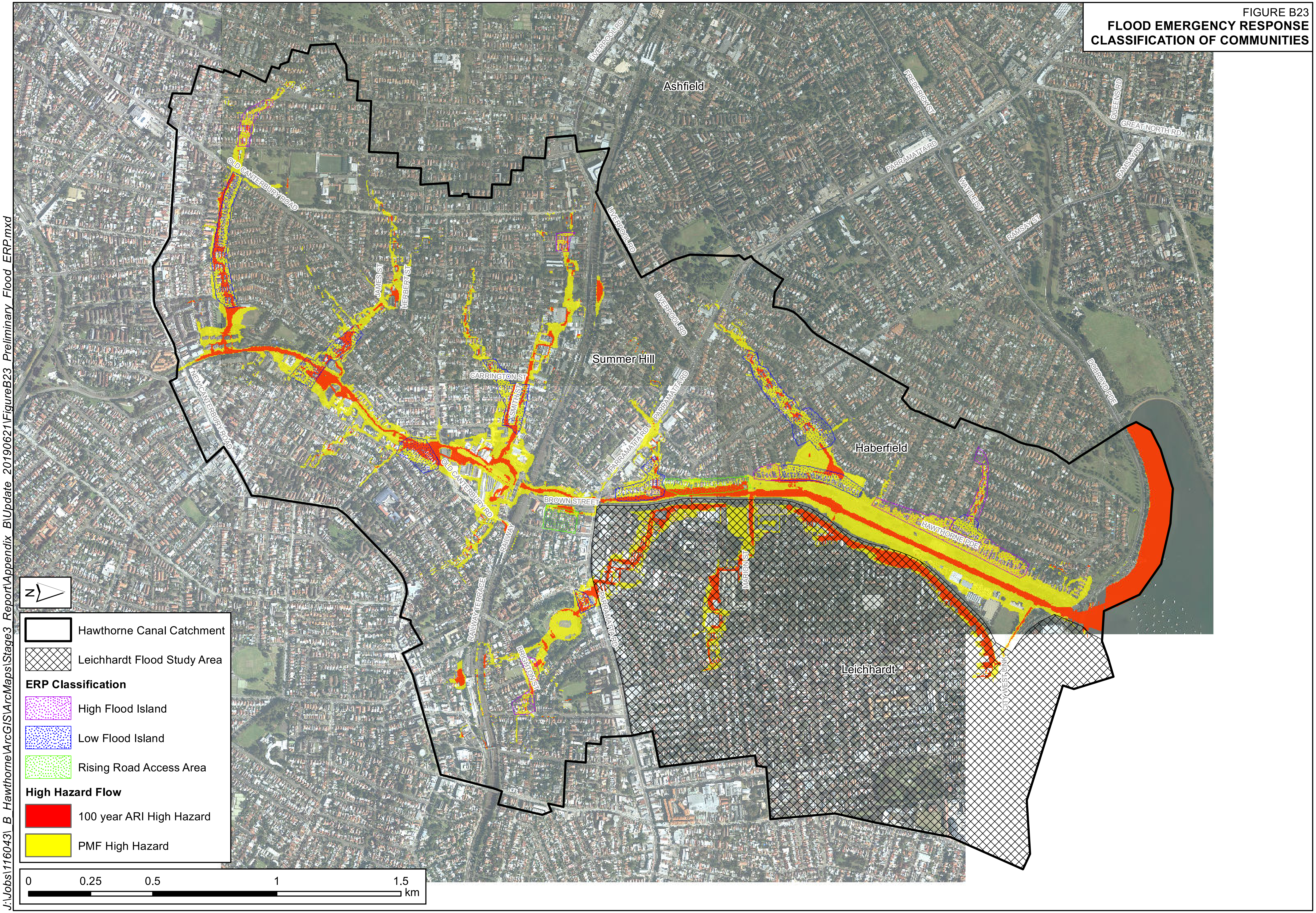
FIGURE B23
FLOOD EMERGENCY RESPONSE CLASSIFICATION OF COMMUNITIES



J:\Jobs\116043\ B_Hawthorne\ArcGIS\ArcMaps\Stage3 Report\Appendix B\Update 20190621\FigureB23 Preliminary Flood ERP.mxd

FIGURE B24
FLOOD PLANNING AREA

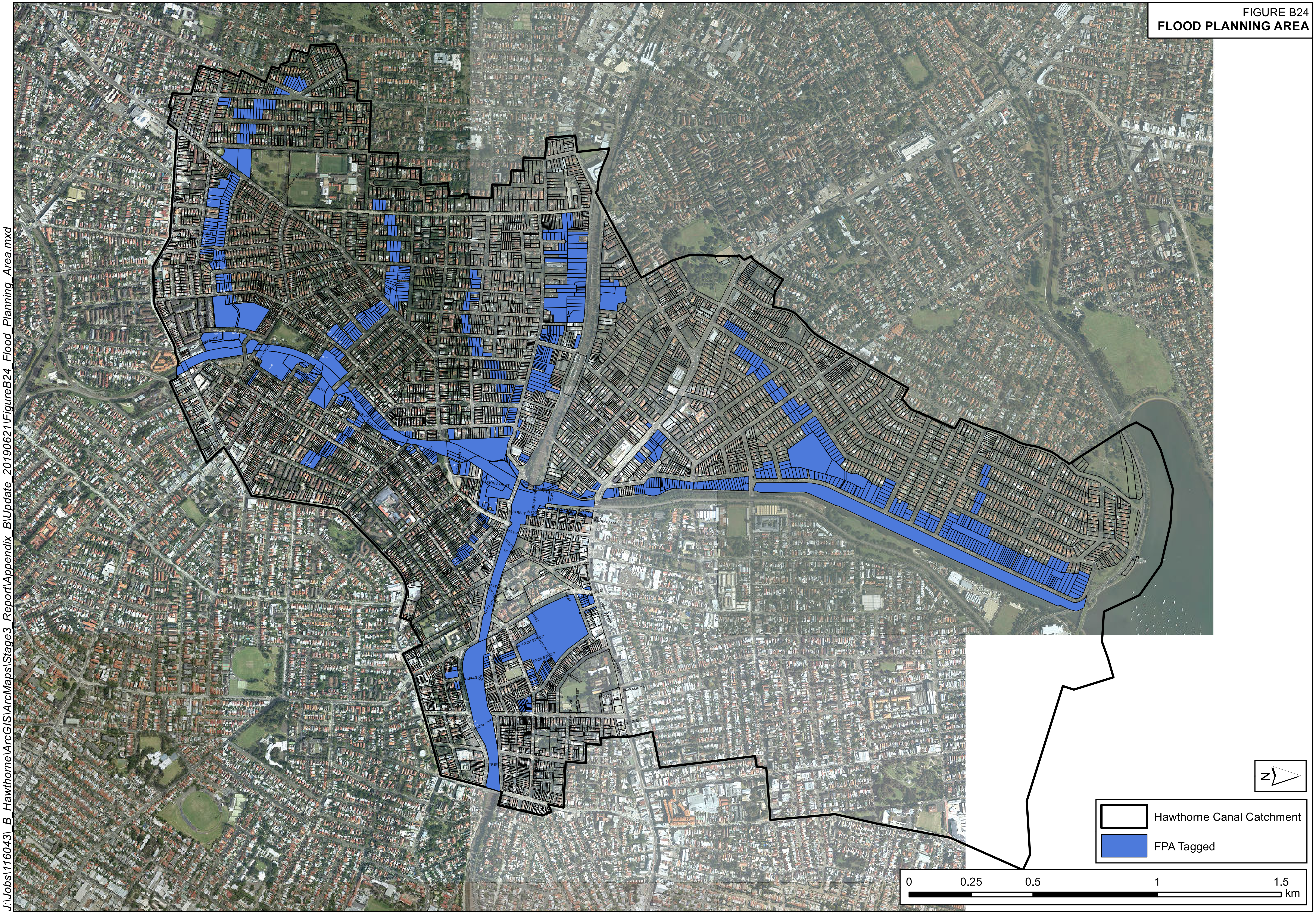


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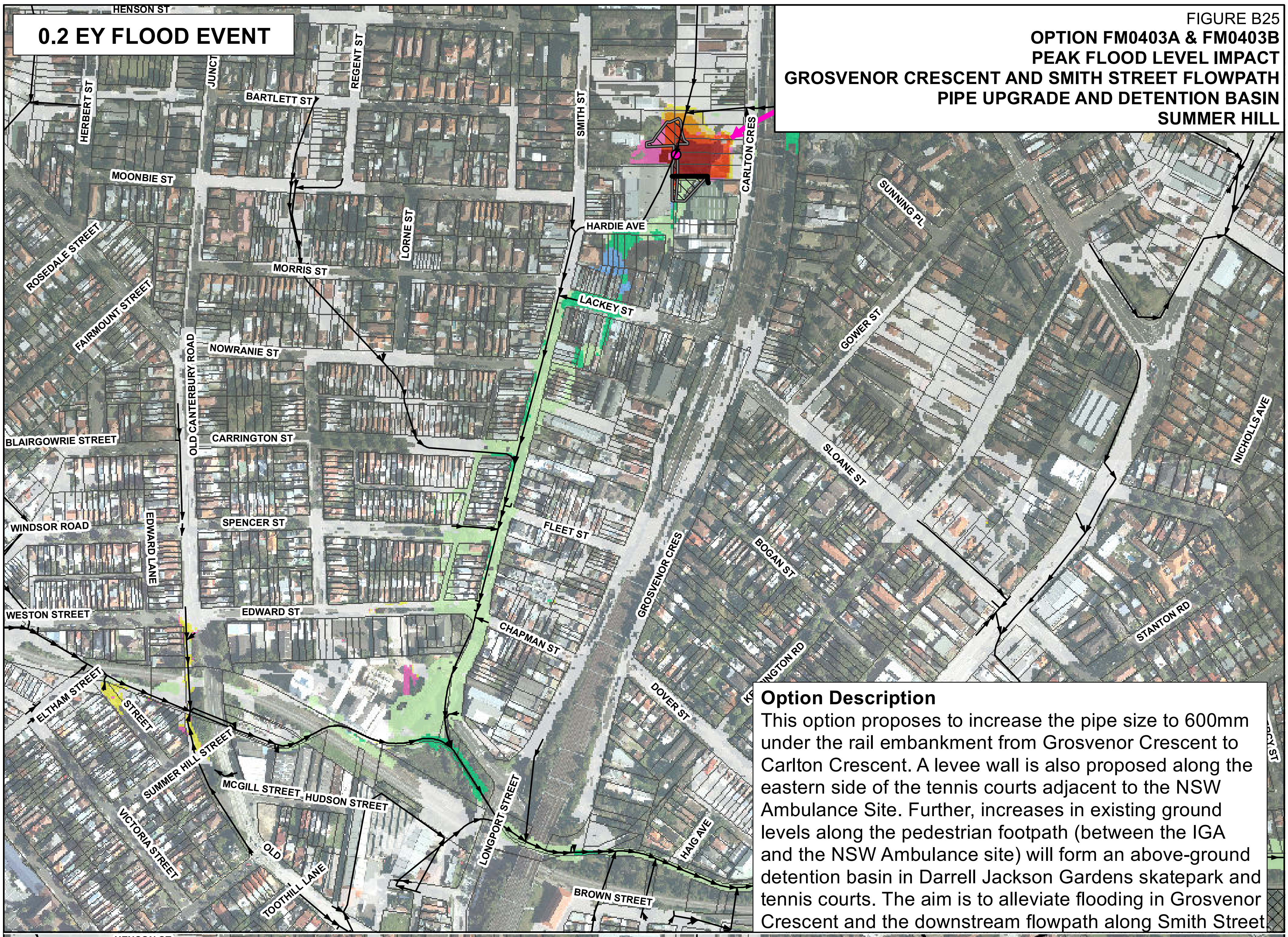
FIGURE B25

OPTION FM0403A & FM0403B
PEAK FLOOD LEVEL IMPACT
GROSVENOR CRESCENT AND SMITH STREET FLOWPATH
PIPE UPGRADE AND DETENTION BASIN
SUMMER HILL

0.2 EY FLOOD EVENT



Option Description

This option proposes to increase the pipe size to 600mm under the rail embankment from Grosvenor Crescent to Carlton Crescent. A levee wall is also proposed along the eastern side of the tennis courts adjacent to the NSW Ambulance Site. Further, increases in existing ground levels along the pedestrian footpath (between the IGA and the NSW Ambulance site) will form an above-ground detention basin in Darrell Jackson Gardens skatepark and tennis courts. The aim is to alleviate flooding in Grosvenor Crescent and the downstream flowpath along Smith Street

1% AEP FLOOD EVENT

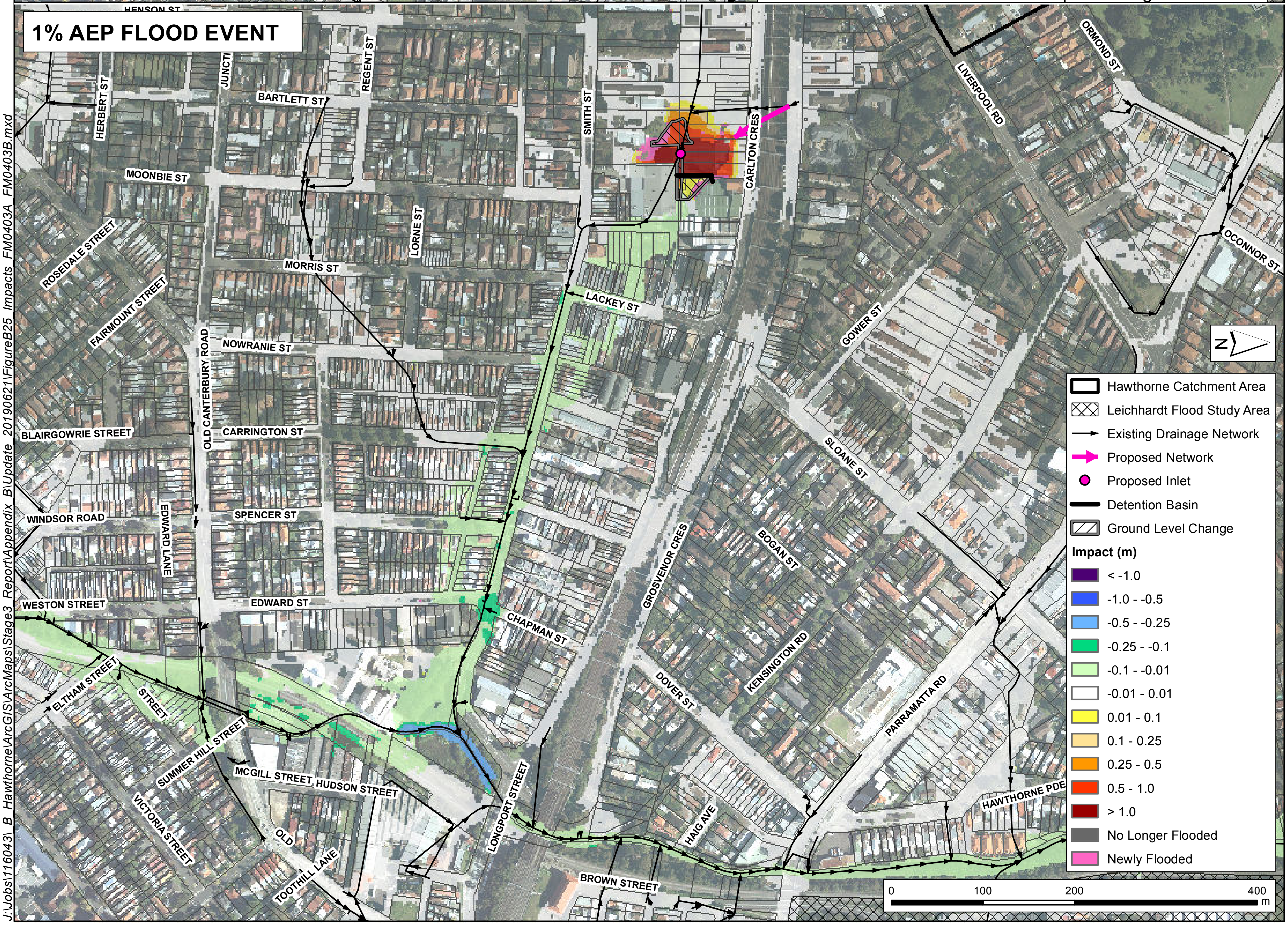


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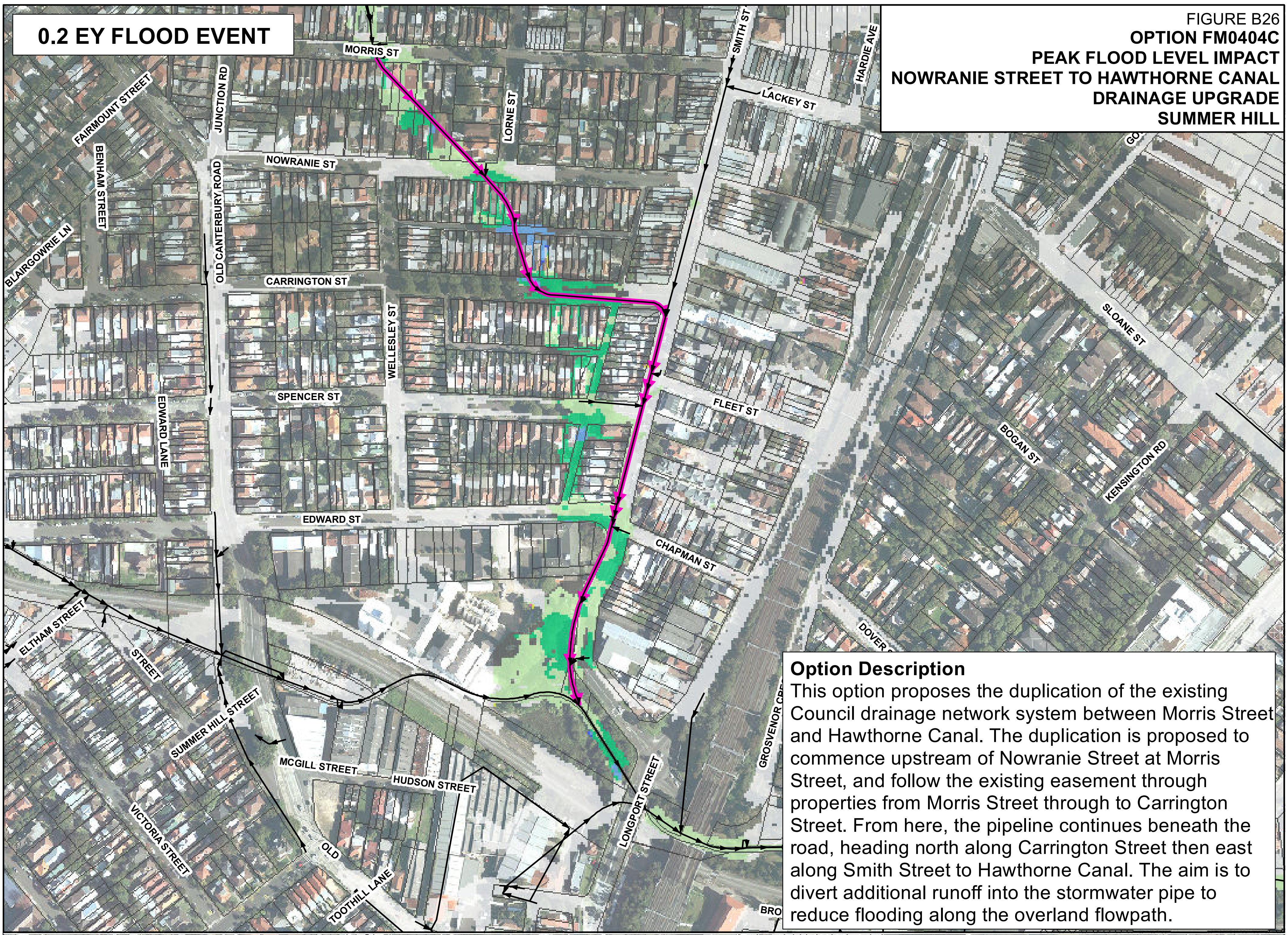
FIGURE B26
OPTION FM0404C
PEAK FLOOD LEVEL IMPACT
NOWRANIE STREET TO HAWTHORNE CANAL
DRAINAGE UPGRADE
SUMMER HILL



Option Description

This option proposes the duplication of the existing Council drainage network system between Morris Street and Hawthorne Canal. The duplication is proposed to commence upstream of Nowranie Street at Morris Street, and follow the existing easement through properties from Morris Street through to Carrington Street. From here, the pipeline continues beneath the road, heading north along Carrington Street then east along Smith Street to Hawthorne Canal. The aim is to divert additional runoff into the stormwater pipe to reduce flooding along the overland flowpath.

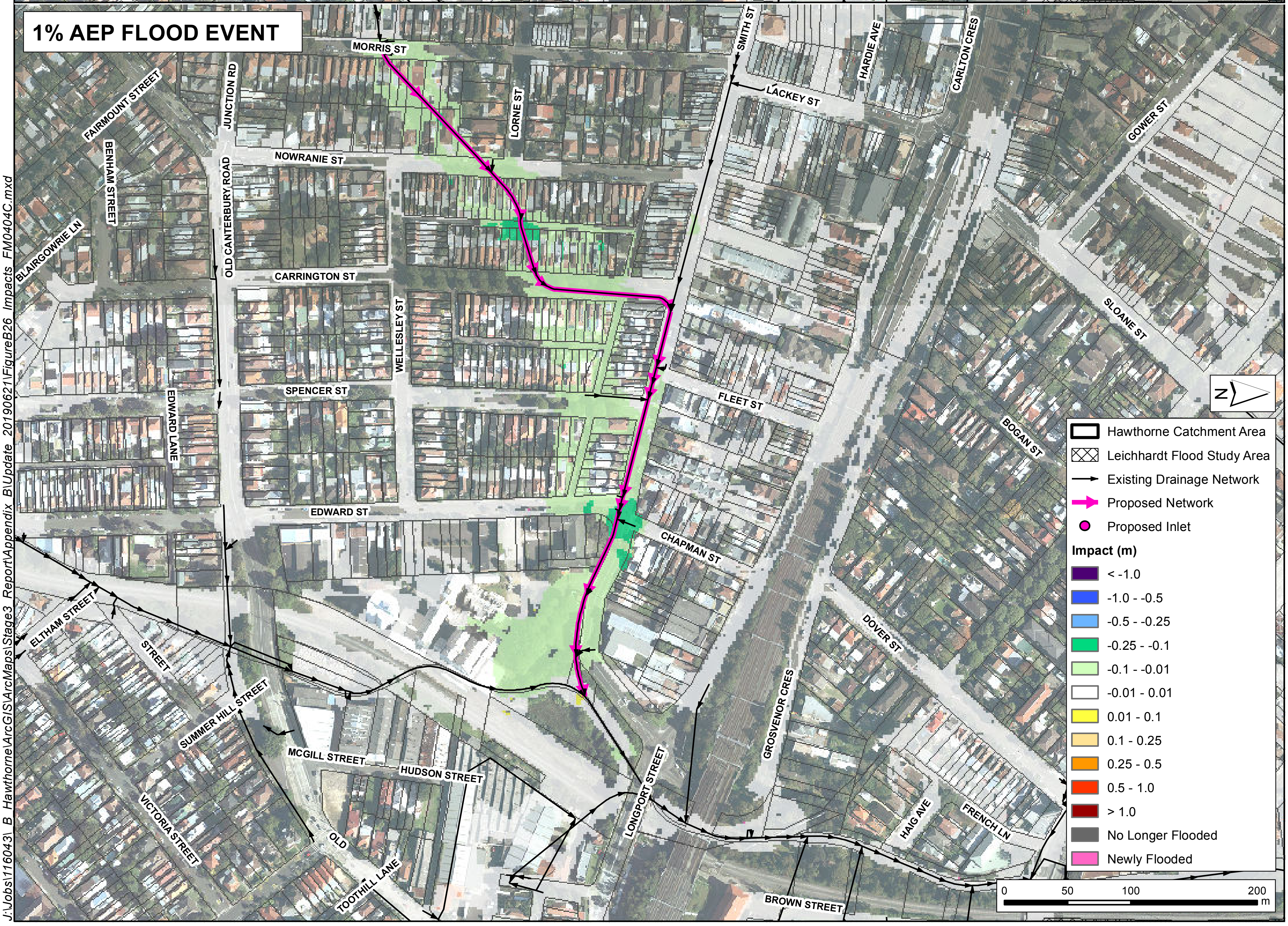


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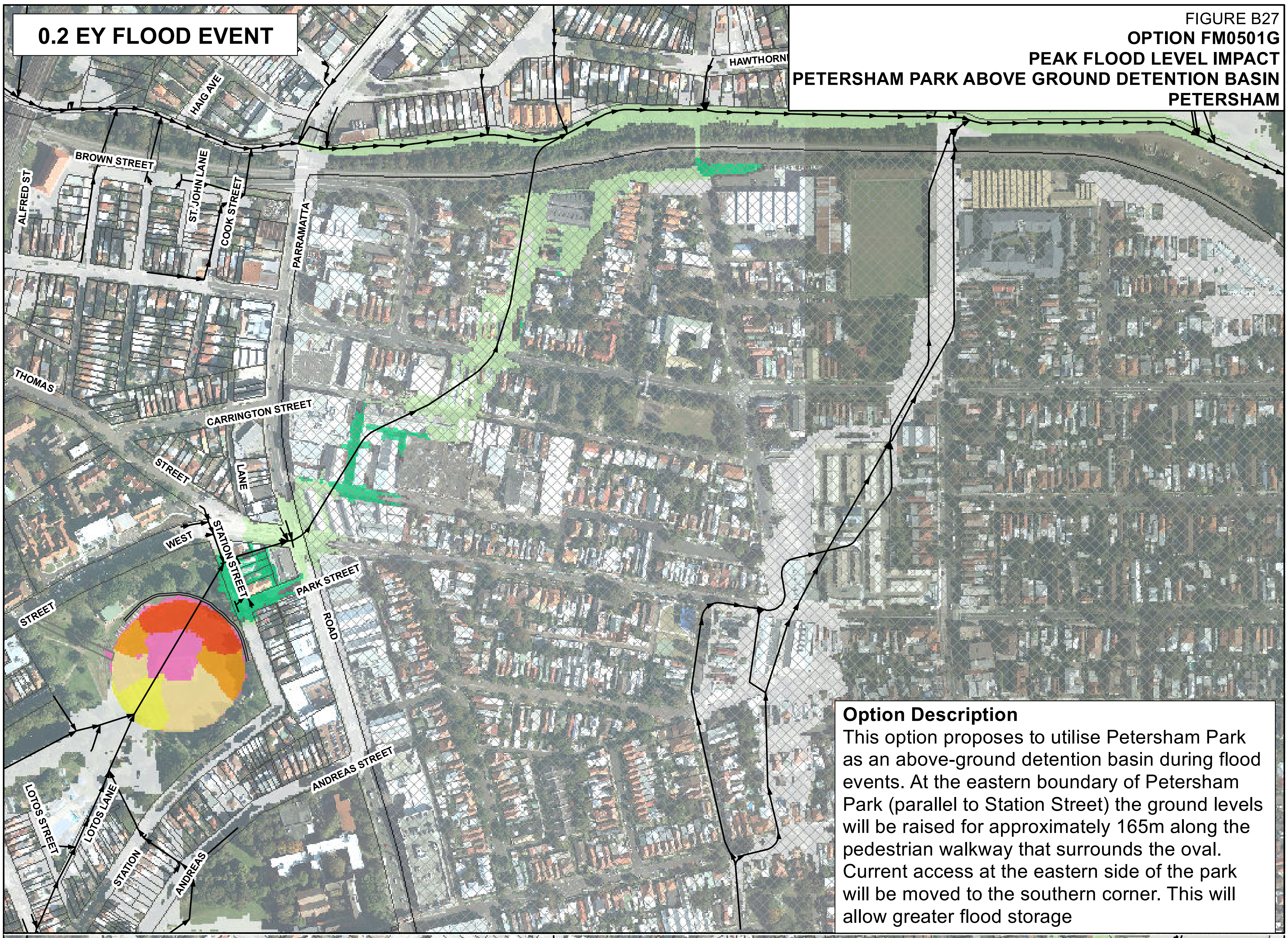
FIGURE B27
OPTION FM0501G
PEAK FLOOD LEVEL IMPACT
PETERSHAM PARK ABOVE GROUND DETENTION BASIN
PETERSHAM



Option Description
This option proposes to utilise Petersham Park as an above-ground detention basin during flood events. At the eastern boundary of Petersham Park (parallel to Station Street) the ground levels will be raised for approximately 165m along the pedestrian walkway that surrounds the oval. Current access at the eastern side of the park will be moved to the southern corner. This will allow greater flood storage

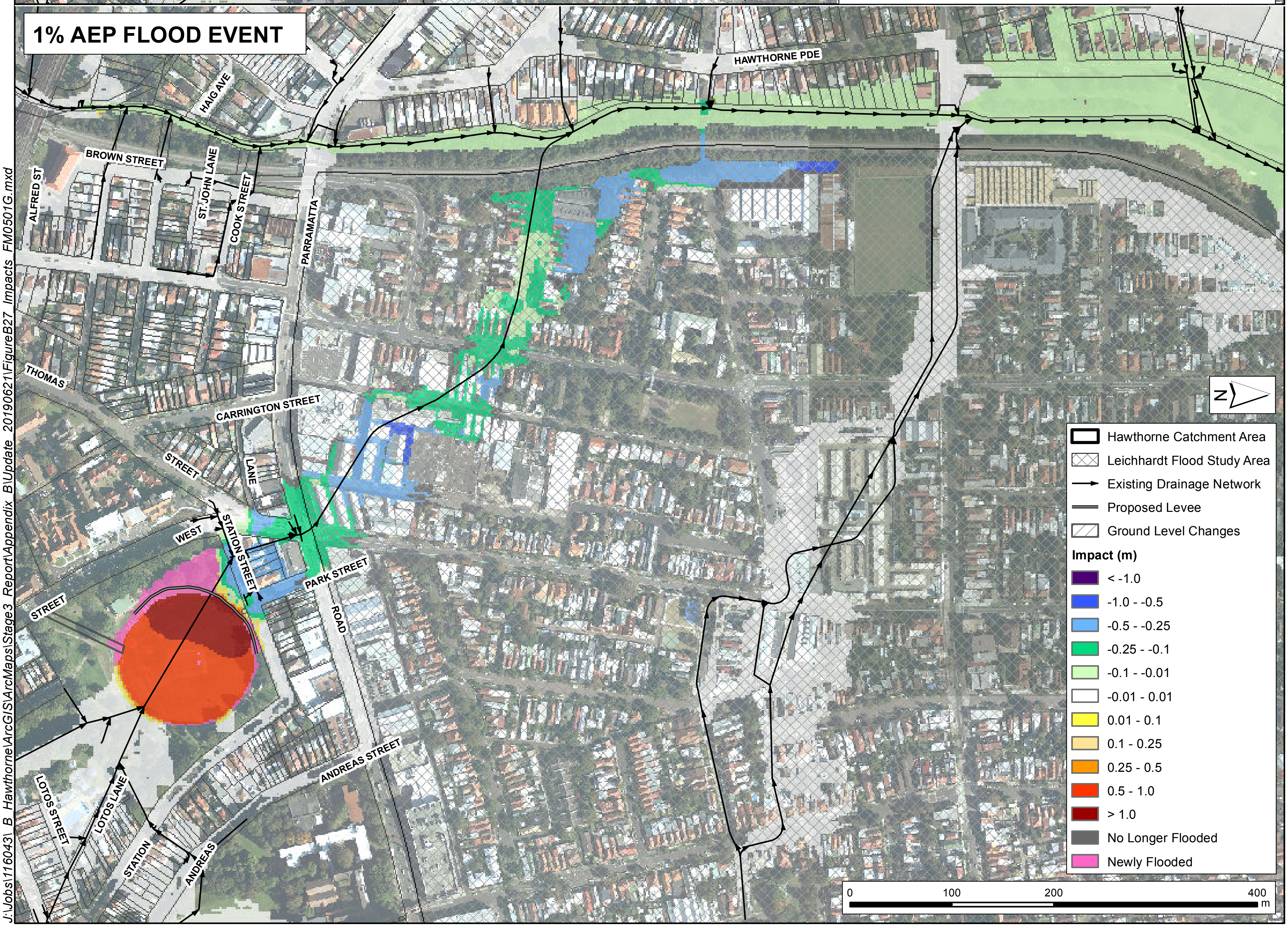


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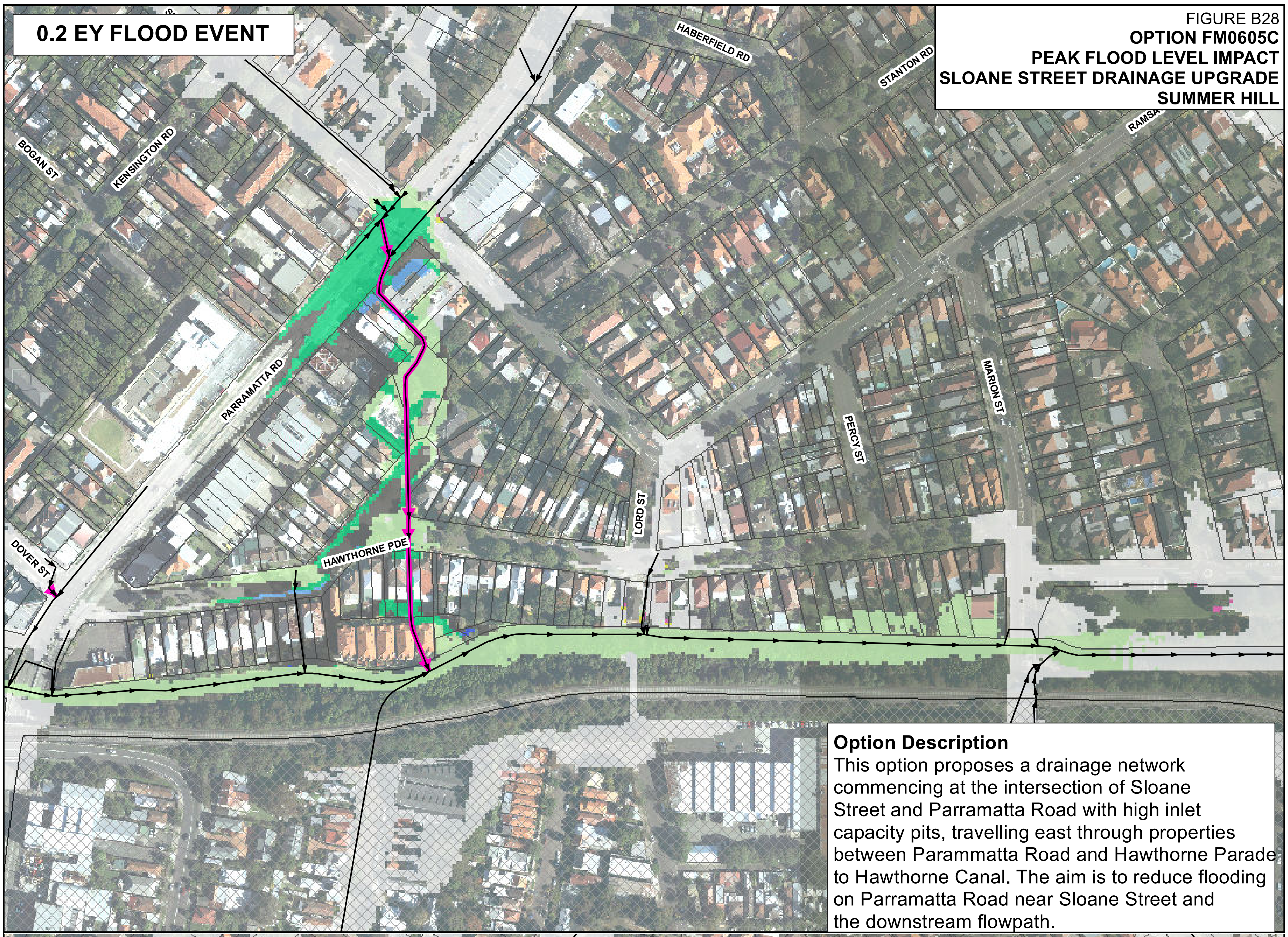
FIGURE B28
OPTION FM0605C
PEAK FLOOD LEVEL IMPACT
SLOANE STREET DRAINAGE UPGRADE
SUMMER HILL



Option Description

This option proposes a drainage network commencing at the intersection of Sloane Street and Parramatta Road with high inlet capacity pits, travelling east through properties between Parammatta Road and Hawthorne Parade to Hawthorne Canal. The aim is to reduce flooding on Parramatta Road near Sloane Street and the downstream flowpath.

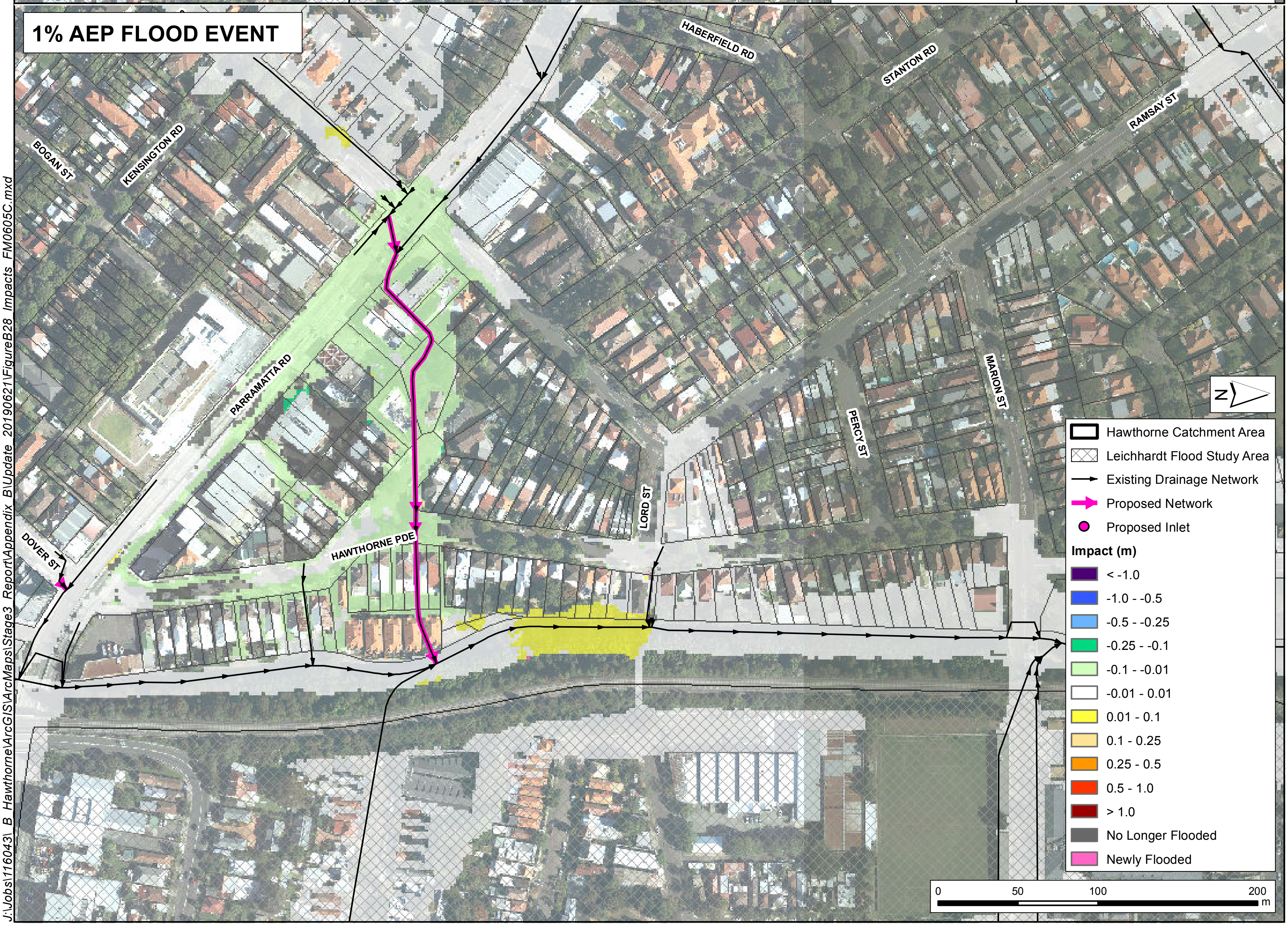


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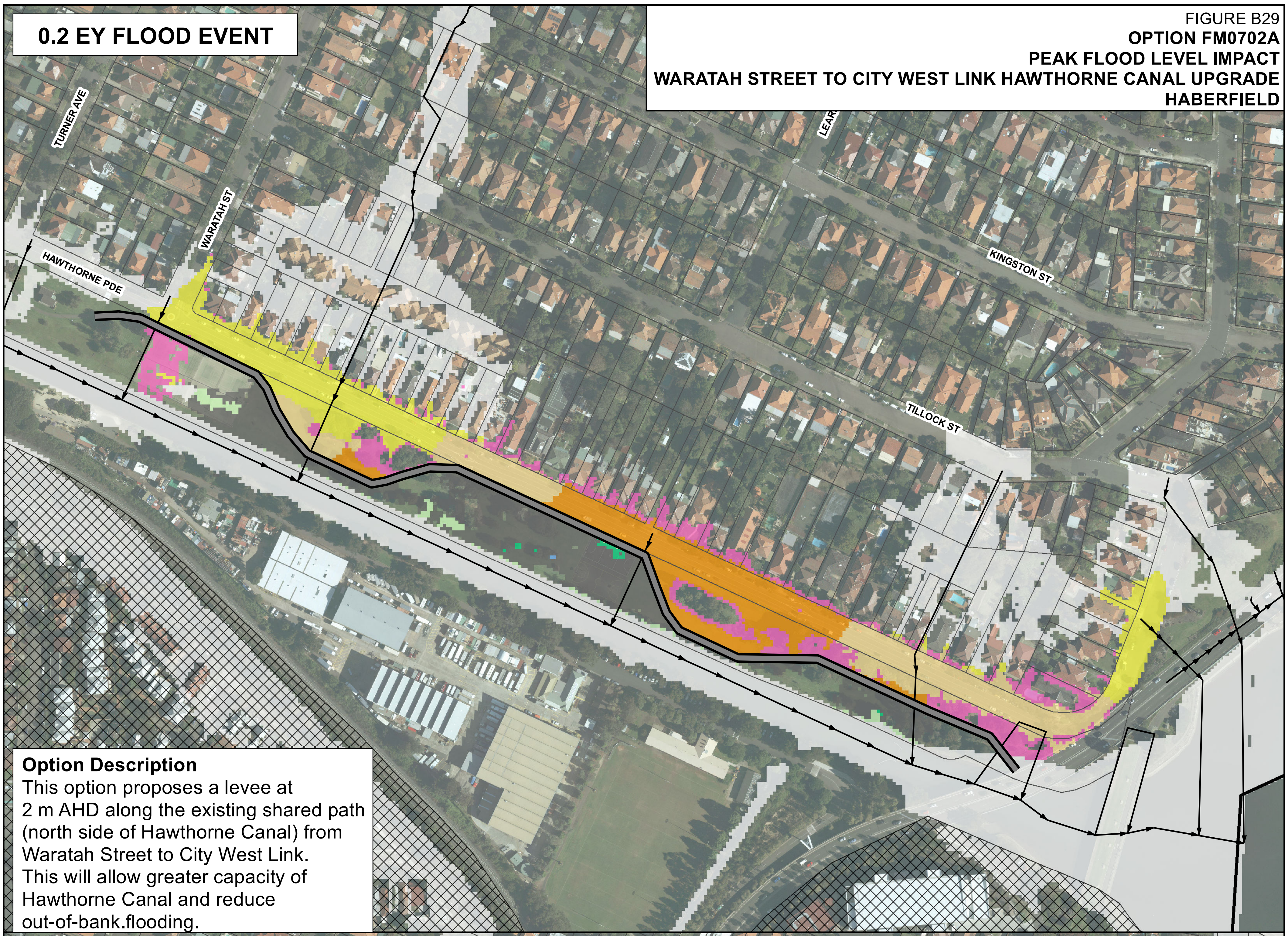
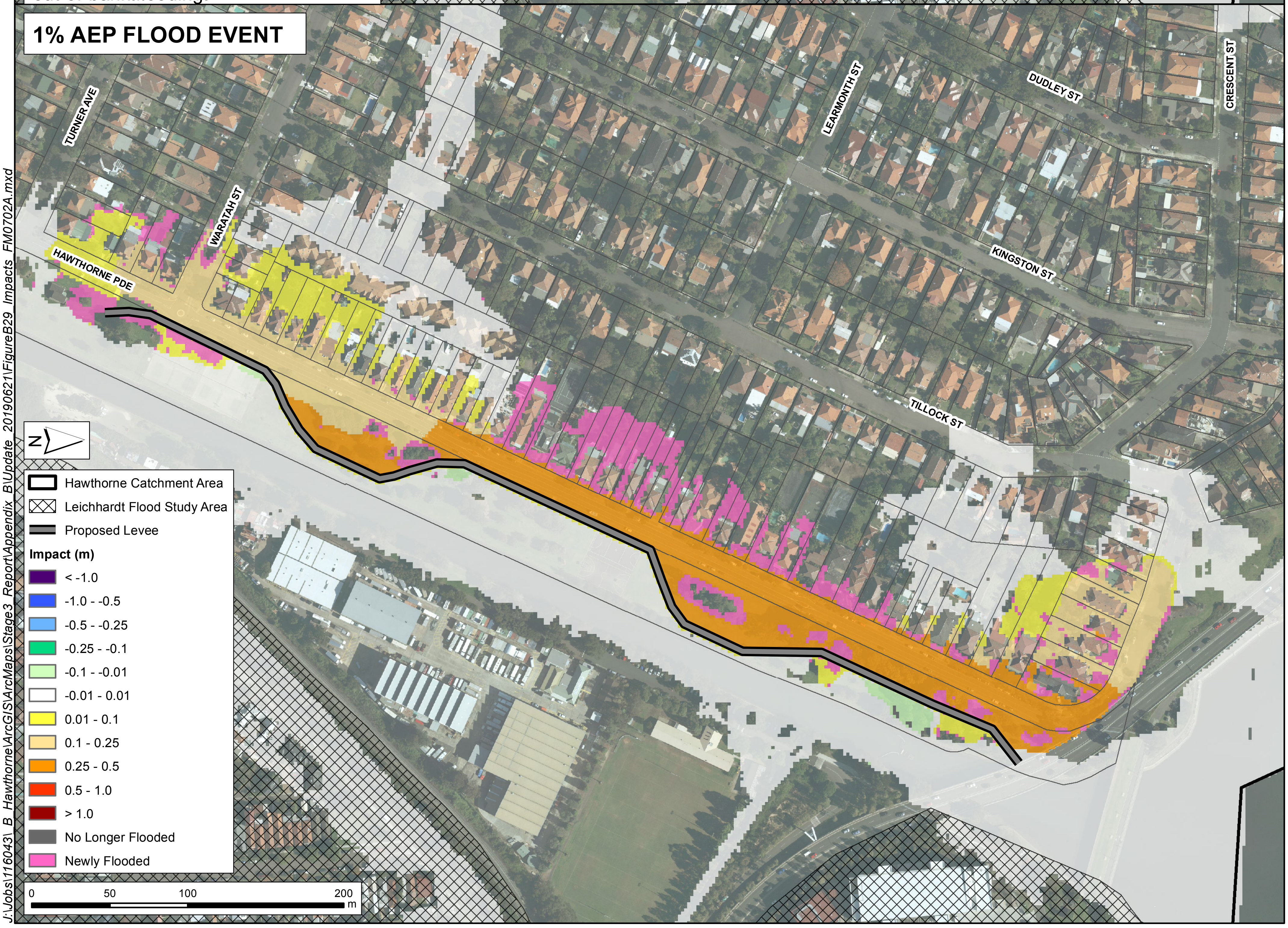
FIGURE B29
OPTION FM0702A
PEAK FLOOD LEVEL IMPACT
WARATAH STREET TO CITY WEST LINK HAWTHORNE CANAL UPGRADE
HABERFIELD



Option Description
This option proposes a levee at 2 m AHD along the existing shared path (north side of Hawthorne Canal) from Waratah Street to City West Link. This will allow greater capacity of Hawthorne Canal and reduce out-of-bank.flooding.



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Appendix B

Appendix C

LIST OF DIAGRAMS Part A

LIST OF DIAGRAMS Part B

LIST OF PHOTOS

Part A: DOBROYD CANAL PRELIMINARY OPTION ASSESSMENT

A.1. Hotspot D01 – Heighway Avenue, Croydon

A.1.1. Option FM0102: Underground Detention Basin, Heighway Avenue

This option proposes an under-road detention basin in Heighway Avenue. Its purpose is to temporarily store water during frequent rainfall events, and discharge the flow at a later time where the outflow is regulated through flow-control structures.

The option involves a 2.4 m diameter pipe installed at Frederick Street, where water is diverted from the existing pipe network into the new pipe and discharges flow into a detention basin (dimensions L 80 m x W 4.7 m x H 1.5 m) beneath Heighway Avenue, between Frederick Street and just east of Dobroyd Canal. A small 150 mm diameter pipe at the detention basin outlet passes water back into the existing pipe network where it travels a small distance before joining with Dobroyd Canal.

Diagram A1 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, the option is shown to decrease peak flood levels on Heighway Avenue itself by up to 0.1 m in comparison to existing depths in excess of 0.5m. There are however increased flood levels in the canal by 0.1 m. In the 1% AEP event the option has only minor localised benefits at the upstream end of the upgraded Frederick Street pipe, and negligible impacts on Heighway Avenue. Existing depths in the 1% AEP exceed 1.5m. As a result the option has no discernible impact on flood hazard in either event.

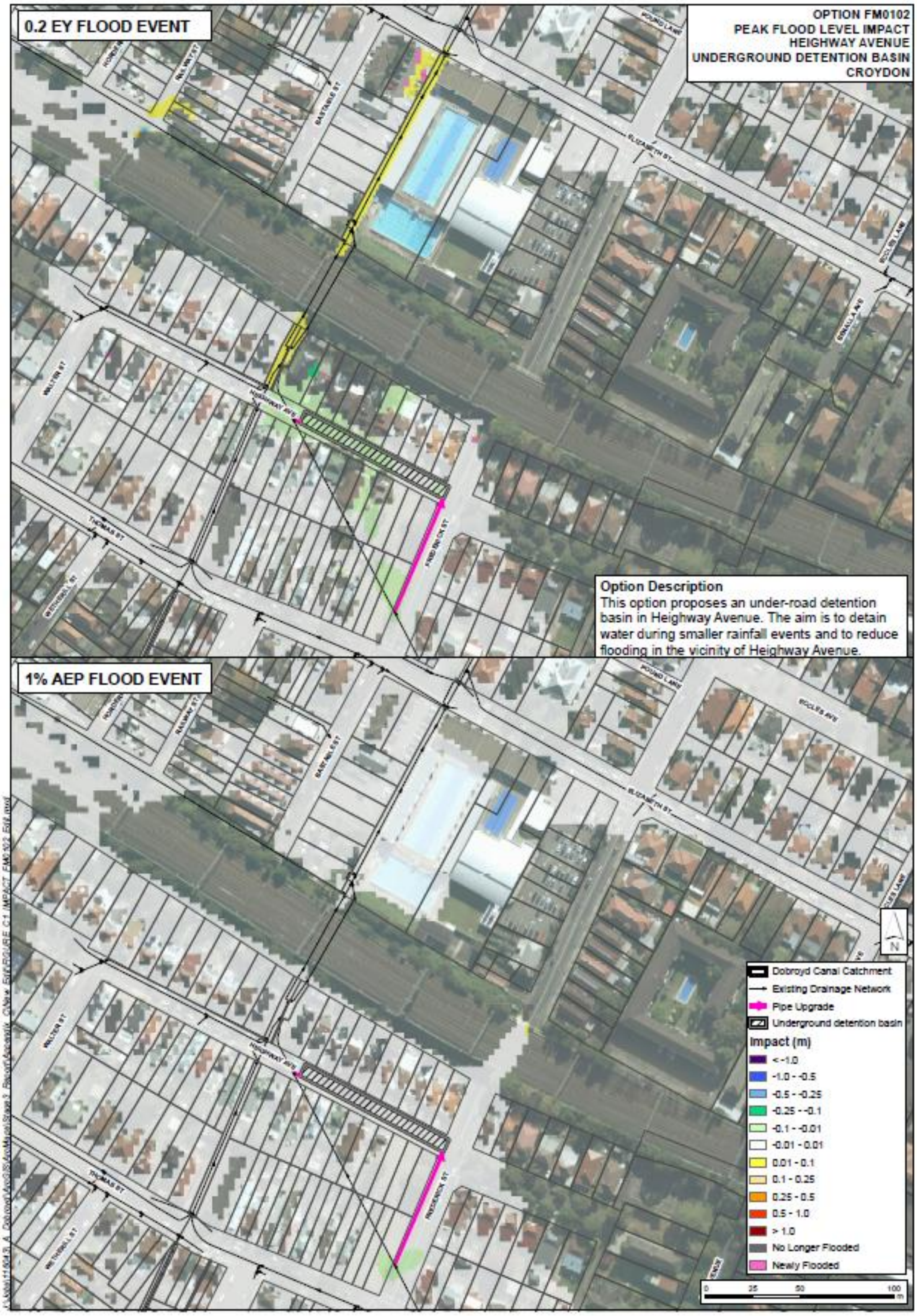
Table 1 – Over floor Property Affectation FM0102

Event	Properties Flooded Overfloor		
	Current	With Option (FM0102)	Change
0.5EY	23	23	0
0.2EY	66	66	0
10% AEP	132	132	0
5% AEP	209	209	0
2% AEP	301	301	0
1% AEP	399	399	0
PMF	1339	1339	0

The marginal flood impacts are a result of the detention basin reaching full capacity in the 0.5 EY event (the most frequent event modelled). Once the detention basin reaches capacity, its effectiveness diminishes and the same downstream flow as the existing case occurs. This indicates that the detention basin is too small for the incoming volume of flood waters, however it is not physically feasible to increase the size of the basin.

The limited impact on peak flood levels would result in no change to property over floor affectation in the Dobroyd Canal catchment (Table 1). As a result of the negligible impact on flood behaviour this option is not recommended for further consideration.

Diagram A1: Option FM0102 Schematisation and Impacts 0.2 EY and 1% AEP Events



A.1.2. Option FM0102B: Drainage Upgrade, Heighway Avenue

This option proposes the pipe duplication of the Sydney Water drainage network between the intersection of Thomas Street and Frederick Street and Heighway Avenue where flow is discharged into Dobroyd Canal. The drainage upgrade includes the duplication of the existing irregular shaped culvert (1 m diameter semicircle pipe) and a 1.83 m diameter pipe between Heighway Avenue and Dobroyd Canal.

Diagram A2 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

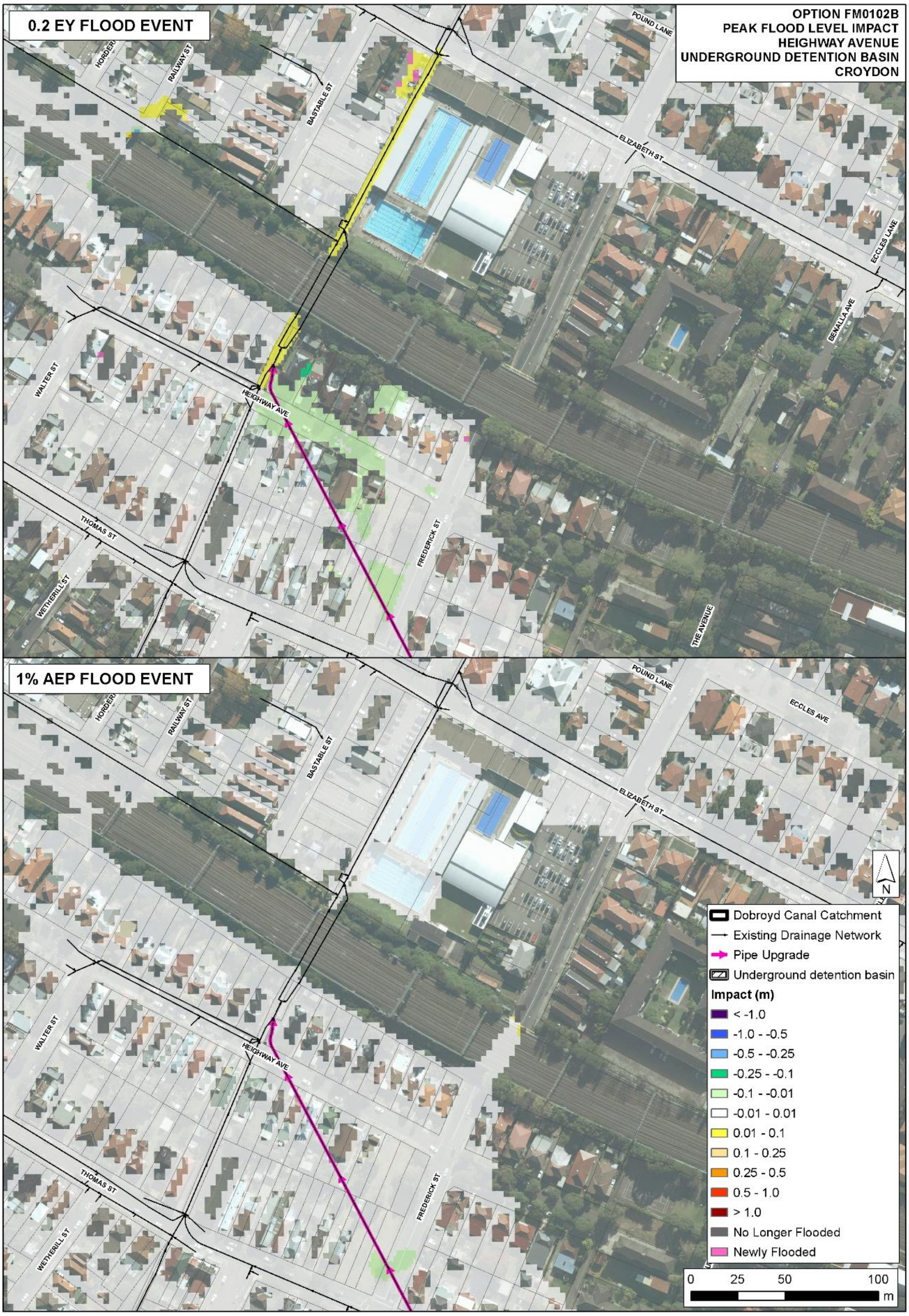
In the 0.2 EY event, the option is shown to decrease peak flood levels on Heighway Avenue by up to 0.1 m, in comparison to existing depths in excess of 0.5m. There are however increased flood levels in the canal by 0.1 m. In the 1% AEP event the option has only minor localised benefits at the upstream end of the upgraded Frederick Street pipe, and negligible impacts on Heighway Avenue. Existing depths in the 1% AEP exceed 1.5m.

Table 2 – Over floor Property Affectation FM0102B

	Properties Flooded Overfloor		
Event	Current	With Option (FM0102B)	Change
0.5EY	23	23	0
0.2EY	66	66	0
10% AEP	132	132	0
5% AEP	209	209	0
2% AEP	301	301	0
1% AEP	399	399	0
PMF	1339	1339	0

The limited impact on peak flood levels would result in no change to property over floor affectation in the Dobroyd Canal catchment (Table 2). As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram A2: Option FM0102B Schematisation and Impacts 0.2 EY and 1% AEP Events



A.1.3. Option FM0103: Underground Detention Basin, Milton Street

This option proposes an under-road detention basin in Milton Street North. The detention basin is designed to store overland flow originating from Liverpool Road to the south. The detention was designed with a 0.9 m diameter pipe installed at Liverpool Road (at a topographical low point between Dobroyd Canal and Milton Street North). The pipe is aligned to follow the road corridor to Milton Street North where several inlet pits collect water from the road corridor. The pipe then discharges into the under-road detention basin at the northern end of Milton Street North (dimensions L 100 m x W 10 m x H 1.5 m). A small 150 mm diameter pipe at the detention basin outlet passes water back into the existing pipe network (1 m diameter pipe) where it travels a small distance before joining with Dobroyd Canal.

Diagram A3 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, there is a reduction in peak flood levels up to 0.1 m observed in Milton Street North, Thomas Street, Dobroyd Canal (between Liverpool Road and Thomas Street). In the 1% AEP event, a reduction of peak flood levels up to 0.1 m are primarily observed along Liverpool Road and Milton Street North and adjacent properties. Existing depths on Milton Street North are 0.5m and 0.8m in the 0.2EY and 1% AEP events, respectively. In both of these flood events, the flood depths within Milton Street and Thomas Street still remain in excess of 0.3 m from a 0.2 EY and 1% AEP event, which is considered unsafe for traffic.

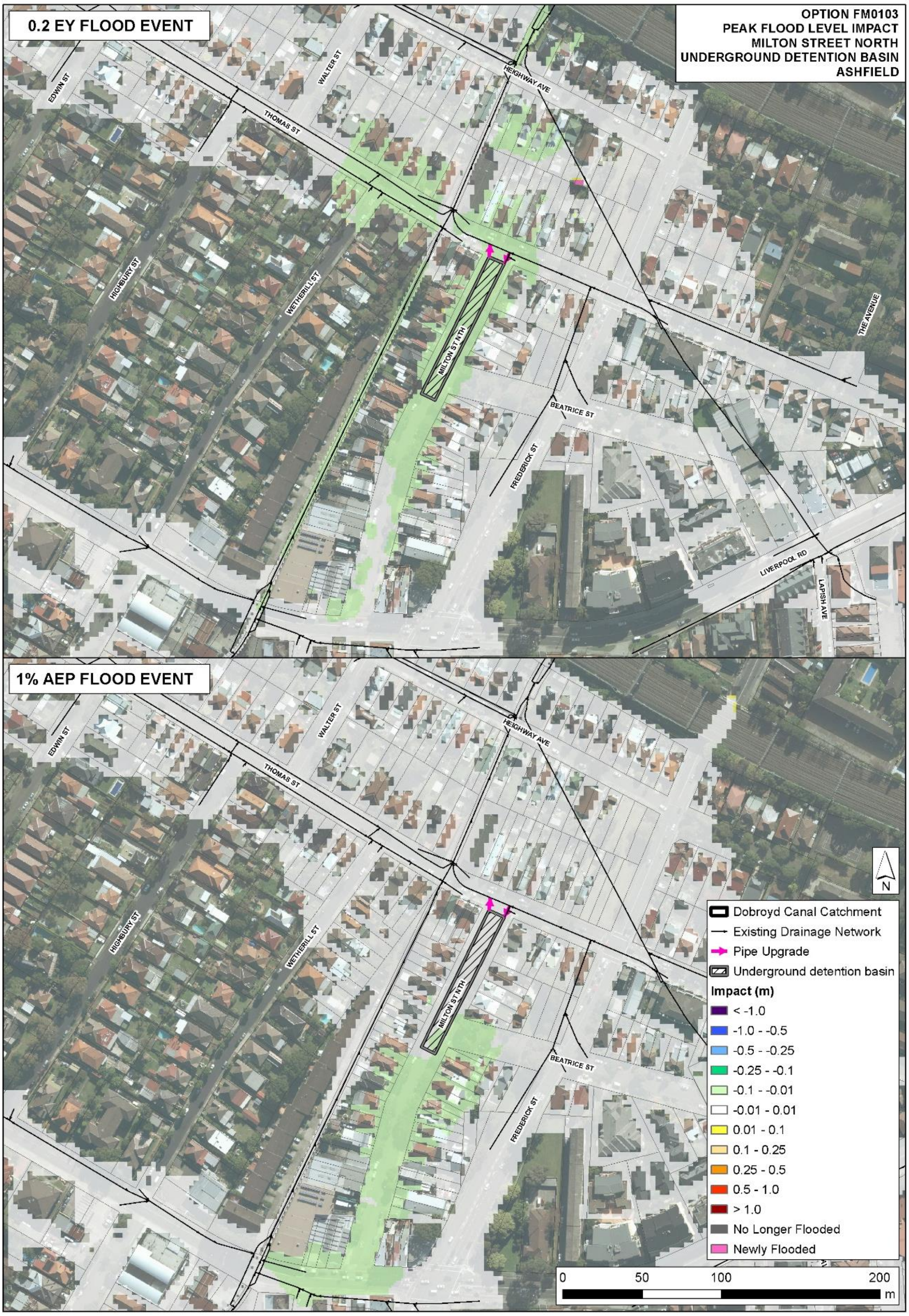
The detention basin reaches full capacity during the 0.5 EY event (the most frequent event modelled). It was also found that there was minimal change to the peak flow or time of peak flow within the existing Council owned pipe that the detention basin discharges into during the 0.5 EY event. This indicates that the detention basin is too small for the incoming volume flood waters, however it is not physically feasible to increase the size of the basin.

The limited impact on peak flood levels result in limited change to property over floor affectation in the Dobroyd Canal catchment as shown below in Table 3. The option results in an additional two properties being flooded over floor in the 2% AEP. As a result of the negligible benefits on flood behaviour this option is <u>not recommended</u> for further consideration.

Table 3 – Over floor Property Affectation FM0103

Event	Properties Flooded Overfloor		Change
	Current	With Option (FM0103)	
0.5EY	23	23	0
0.2EY	66	65	-1
10% AEP	132	131	-1
5% AEP	209	210	1
2% AEP	301	303	2
1% AEP	399	397	-2
PMF	1339	1338	-1

Diagram A3: Option FM0103 Schematisation and Impacts 0.2 EY and 1% AEP Events



A.1.4. Option FM0104: Underground Detention Basin, Heighway Avenue and Milton Street

This option proposes to combine the two under-road detention basins assessed in FM0102 (Heighway Avenue) and FM0103 (Milton Street North). The aim is to increase the available storage of flood water during smaller rainfall events, and reduce flooding between Liverpool Road and the downstream flowpath. The same configuration is assumed as discussed in Sections A.1.1 and A.1.3.

Diagram A4 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

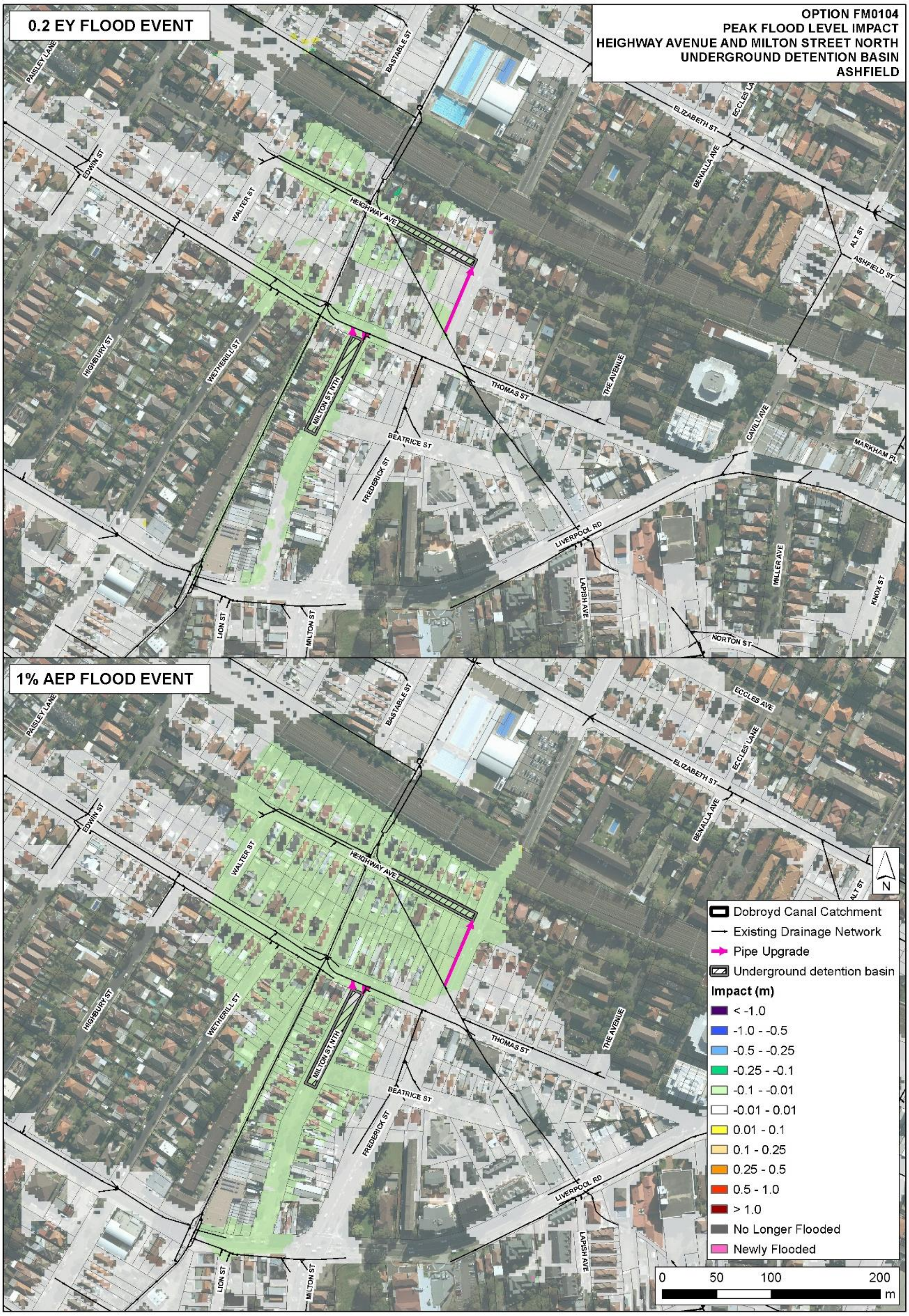
In the 0.2 EY event, there is a reduction in peak flood levels up to 0.1 m observed in Milton Street North, Thomas Street, Dobroyd Canal (between Liverpool Road and Thomas Street). In the 1% AEP event, a reduction of peak flood levels up to 0.1 m extends to include Walter Street and Wetherhill Street. In a 0.2 EY event, the flood depths remain in excess of 0.3 m which is considered unsafe for traffic. Depths in the 1% AEP are in the order of 0.8m.

There would be some, albeit limited, benefit to property over floor affection in the area (Table 4), however this would be marginal, especially when considering the significant construction and maintenance costs. In order to achieve a BCR of between 0.5 – 1.0, this option would need to be costed at between $1.15 and $2.23 Million. As a result of the minor impact on flood behaviour and the likely costs, this option is <u>not recommended</u> for further consideration.

Table 4 – Over floor Property Affectation FM0104

	Properties Flooded Over floor		
Event	**Current**	**With Option (FM0104)**	**Change**
0.5EY	23	23	0
0.2EY	66	65	-1
10% AEP	132	131	-1
5% AEP	209	208	-1
2% AEP	301	301	0
1% AEP	399	397	-2
PMF	1339	1338	-1

Diagram A4: Option FM0104 Schematisation and Impacts 0.2 EY and 1% AEP Events



A.1.5. Option FM0106A: Duplication of Dobroyd Canal

This option proposes the duplication of the Dobroyd Canal trunk drainage system from upstream at Norton Street through to the confluence with Iron Cove. The aim is to increase the capacity of Dobroyd Canal minimising the downstream constraint to convey larger amounts of flow from the upper catchment, especially upstream of the railway embankment at Heighway Avenue to reduce the flooding. As part of the duplication, 5.4 km of Dobroyd Canal would be upgraded, including 6 bridges. This option would require a number of property acquisitions to be feasible.

Diagram A5 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, there is a minimal change to peak flood levels across the study area. The open channel does not reach 100% capacity during this flood event and thus does not present a constraint to drainage. As such, the duplication of the open channel does not alleviate flooding behaviour across the study area in this event. In frequent flood events, overland flooding is primarily driven by local drainage networks exceeding capacity. In the existing 1% AEP event, the open channel reaches capacity and causes overbank flooding in many locations. The duplication results in small decreases of up to 0.1 m around Thomas Street and adjacent properties as well as some localised pockets in other locations. Depths remain in excess of 0.3m for this event. Increases in flood levels are observed within the trunk system downstream of Parramatta Road and within Queen Street.

In the 1% AEP event, there is a large area between the railway embankment at Heighway Avenue (existing depth 1.5m) and Thomas Street (existing depth 0.8m) where flood levels have reduced by up to 0.5 to 1.0 m. Further to this, there is a decrease in flood levels of up to 0.25 m along Milton Street North (existing depth 0.8m) and a small section along Liverpool Road near Dobroyd Canal. The decreases observed upstream of the railway are assumed to mostly be controlled by the culvert under the railway.

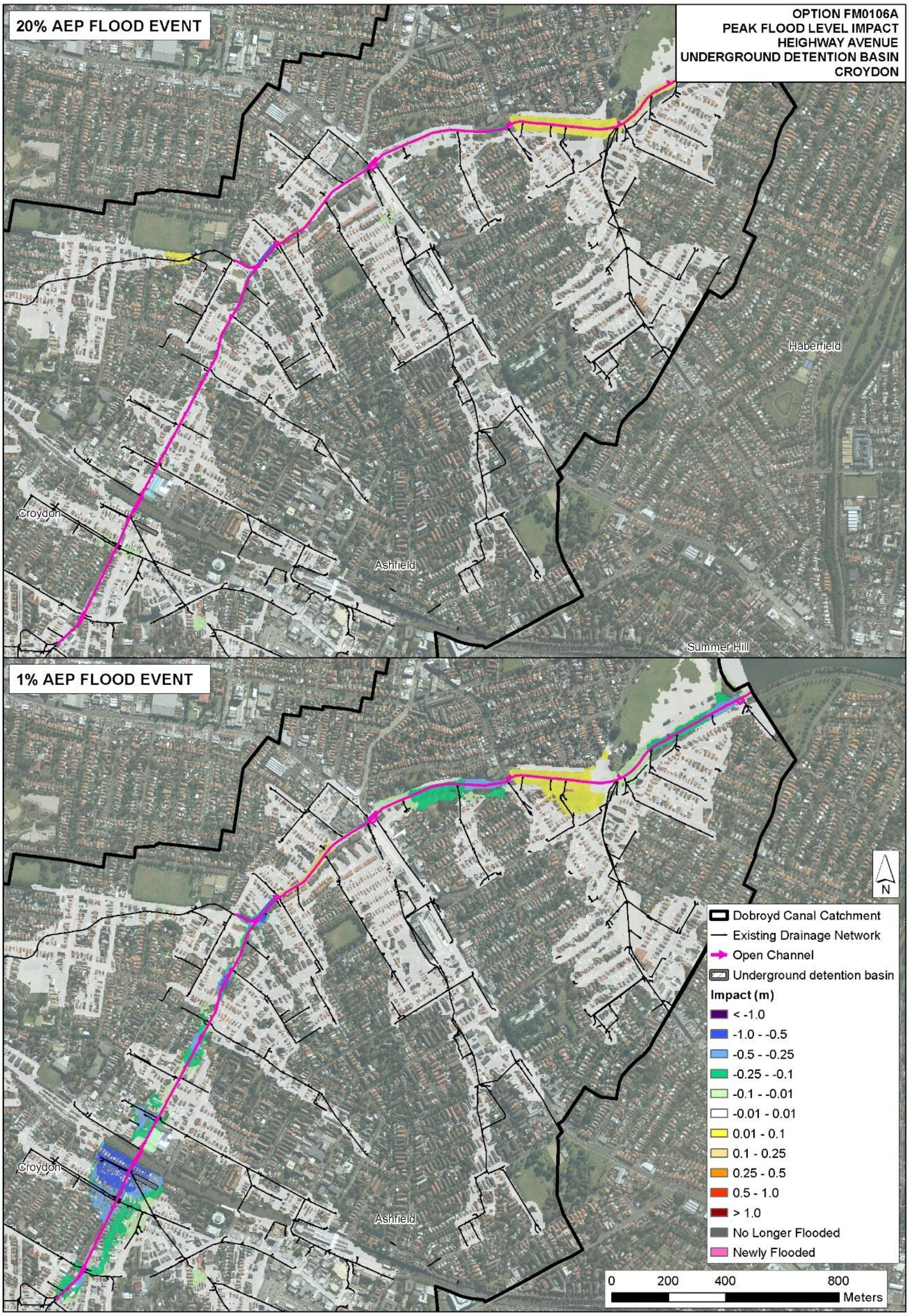
A previous option, FM0105 proposed a secondary box culvert (3.3 m W x 3.3 m H) to pass under the railway. The impacts for the 0.2 EY showed no discernible impacts whilst the 1% AEP event was observed to decrease flood levels by 0.6 m upstream, whilst increasing flood levels in the order of 0.01 and 0.2 m downstream of the railway to the confluence of Iron Cove, affecting a large number of properties adjacent to the canal.

Table 5 – Over floor Property Affectation FM0106A

Properties Flooded Overfloor			
Event	**Current**	**With Option (FM0106A)**	**Change**
0.5EY	23	23	0
0.2EY	66	66	0
10% AEP	132	132	0
5% AEP	209	209	0
2% AEP	301	301	0
1% AEP	399	399	0
PMF	1339	1339	0

As a result of the minimal overall improvement to property over floor affectation (Table 5) or large reductions in flood impacts, significant costs and technical challenges associated with the construction, this option is not recommended for further consideration.

Diagram A5: Option FM0106A Schematisation and Impacts 0.2 EY and 1% AEP Events



A.2. Hotspot D02 – Queen Street, Croydon

A.2.1. Option FM0201, FM0202, FM0203 and FM0206A: Queen Street and Centenary Park Detention Basin

These three options proposed various extents of lowering the ground levels in Centenary Park to increase the temporary storage area available during flood events, as described below. Diagram A6, Diagram A7and Diagram A8 show a schematisation of the options and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

Option	Configuration
FM0201	Located at the cricket nets with a gradient sloping from 8.8 m AHD at the north-east corner of the basin to 7.7 m AHD at the south-east corner. The levels along the eastern side on the basin are the same level as the basketball courts (part of Centenary Park). The approximate capacity of the basin is 3,500m^3.
FM0202	Lowering of ground levels across the eastern portion of the playing fields to a uniform 7 m AHD to enable the soccer fields to be still used, whilst also being approximately 0.2 m lower than the road level along Queen Street to divert flow from the street during rainfall events. The approximate capacity of the basin is 89,000m^3.
FM0203	Lowering of ground levels across the entire playing fields to a uniform 7 m AHD to enable the soccer fields to be still used, whilst also being approximately 0.2 m lower that the road level along Queen Street to divert flow from the street during rainfall events. The approximate capacity of the basin is 177,000m^3.

In the 0.2 EY event for Option FM0201, there is a minor reduction in flood levels along Queen Street and adjacent properties of up to 0.1 m, in comparison to existing depths in excess of 1m. The maximum flood depth for this option within Queen Street remains around 1.4 m. In the 1% AEP event, there are little changes to peak flood levels. Subsequently, this option results the removal of over floor flooding at one property only in the 0.2 EY. There is also an increase in over floor affectation in the 2% and 5% AEP events (3 and 2 properties, respectively).

In the 0.2 EY event for Option FM0202, there is some very localised reduction in flood levels along Queen Street of up to 1 m (in comparison to depths over 1m in the existing case), and a minor reduction in flood levels of up to 0.1 m within Iron Cove Creek. In the 1% AEP event, there are localised reductions in flood levels of up to 0.5 m along Queen Street (in comparison to depths in excess of 1.5m in the existing case), and a reduction in flood levels of up to 0.25 m within Iron Cove Creek. While the option results in an overall improvement in over floor property affectation, there is both an increase and decrease in the number of properties affected in the 5% and 2% AEP events. The overall change in over floor flood affectation is shown in Table 6.

Table 6 – Over floor Property Affectation FM0202

Event	Properties Flooded Overfloor		
	Current	With Option (FM0202)	Change
0.5EY	23	23	0
0.2EY	66	64	-2
10% AEP	132	130	-2
5% AEP	209	207	-2 (2)
2% AEP	301	300	-1 (4)
1% AEP	399	394	-5
PMF	1339	1330	-9

Note: Values in brackets are the number of additional properties inundated over floor during that event.

In the 0.2 EY event for Option FM0203, there is some localised reduction in flood levels along Queen Street of over 1m, and a minor reduction in flood levels of up to 0.1 m within Iron Cove Creek. In the 1% AEP event, there are localised reductions in flood levels of over 1 m along Queen Street, and a reduction in flood levels up to 0.25 m within Iron Cove Creek. While the option results in a greater overall improvement in over floor property affectation, there is both an increase and decrease in the number of properties affected again in the 5% and 2% AEP events. The overall change in over floor flood affectation is shown in Table 7.

Table 7 – Over floor Property Affectation FM0203

Event	Properties Flooded Overfloor		
	Current	With Option (FM0203)	Change
0.5EY	23	23	0
0.2EY	66	64	-2
10% AEP	132	130	-2
5% AEP	209	207	-2 (2)
2% AEP	301	299	-2 (4)
1% AEP	399	392	-7
PMF	1339	1322	-17

Note: Values in brackets are the number of additional properties inundated over floor during that event.

Diagram A6: Option FM0201 Schematisation and Impacts 0.2 EY and 1% AEP Events

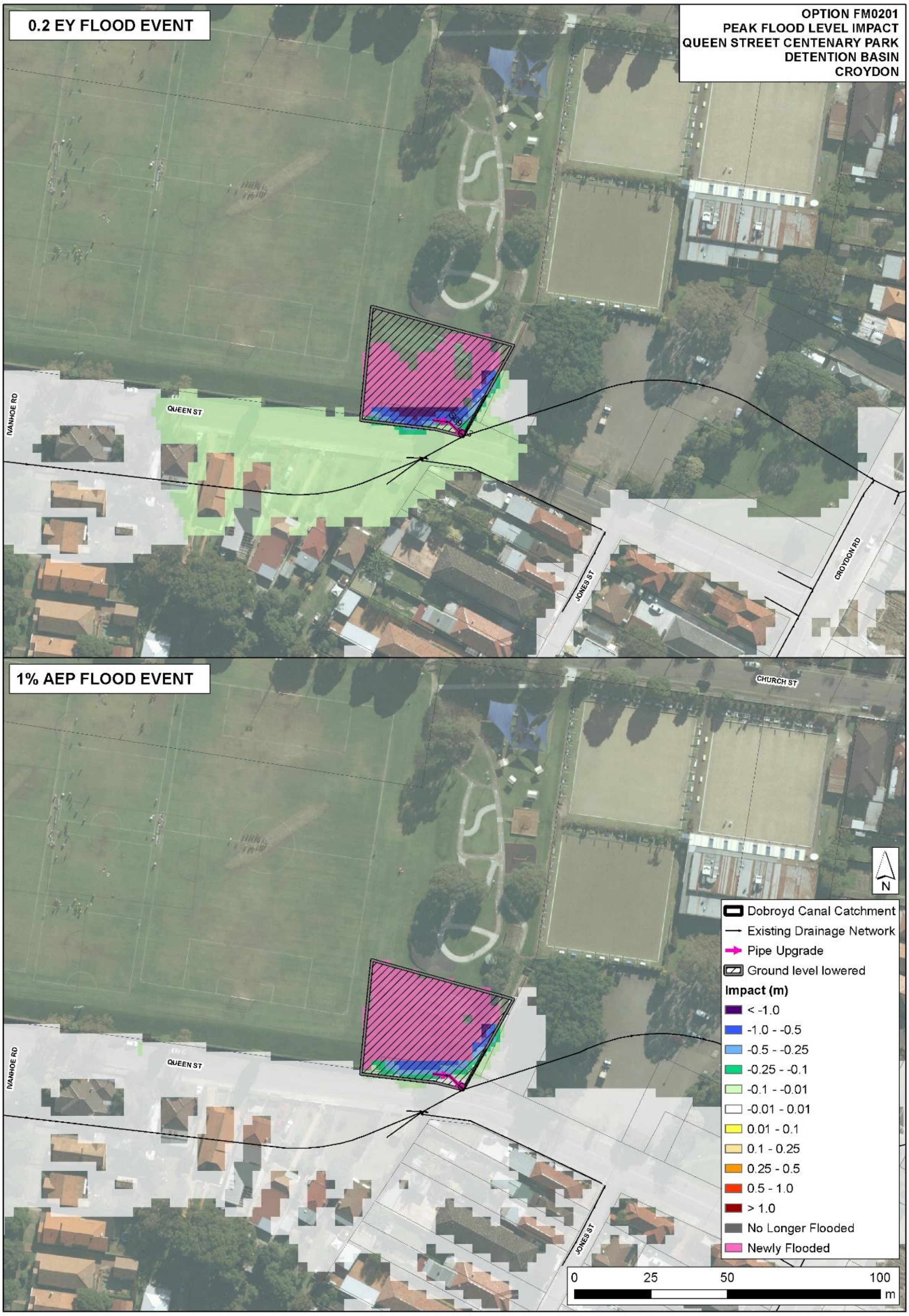


Diagram A7: Option FM0202 Schematisation and Impacts 0.2 EY and 1% AEP Events

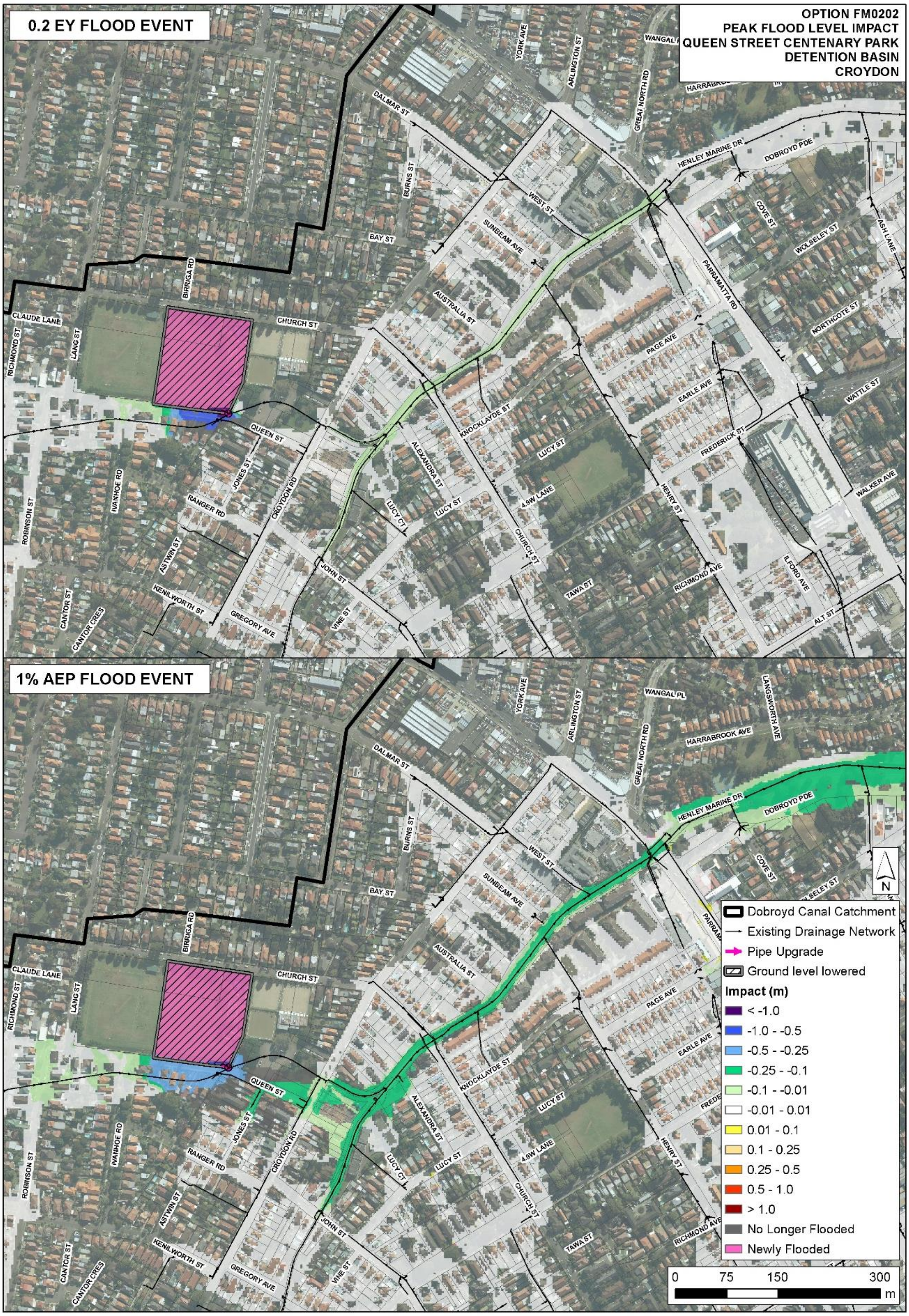
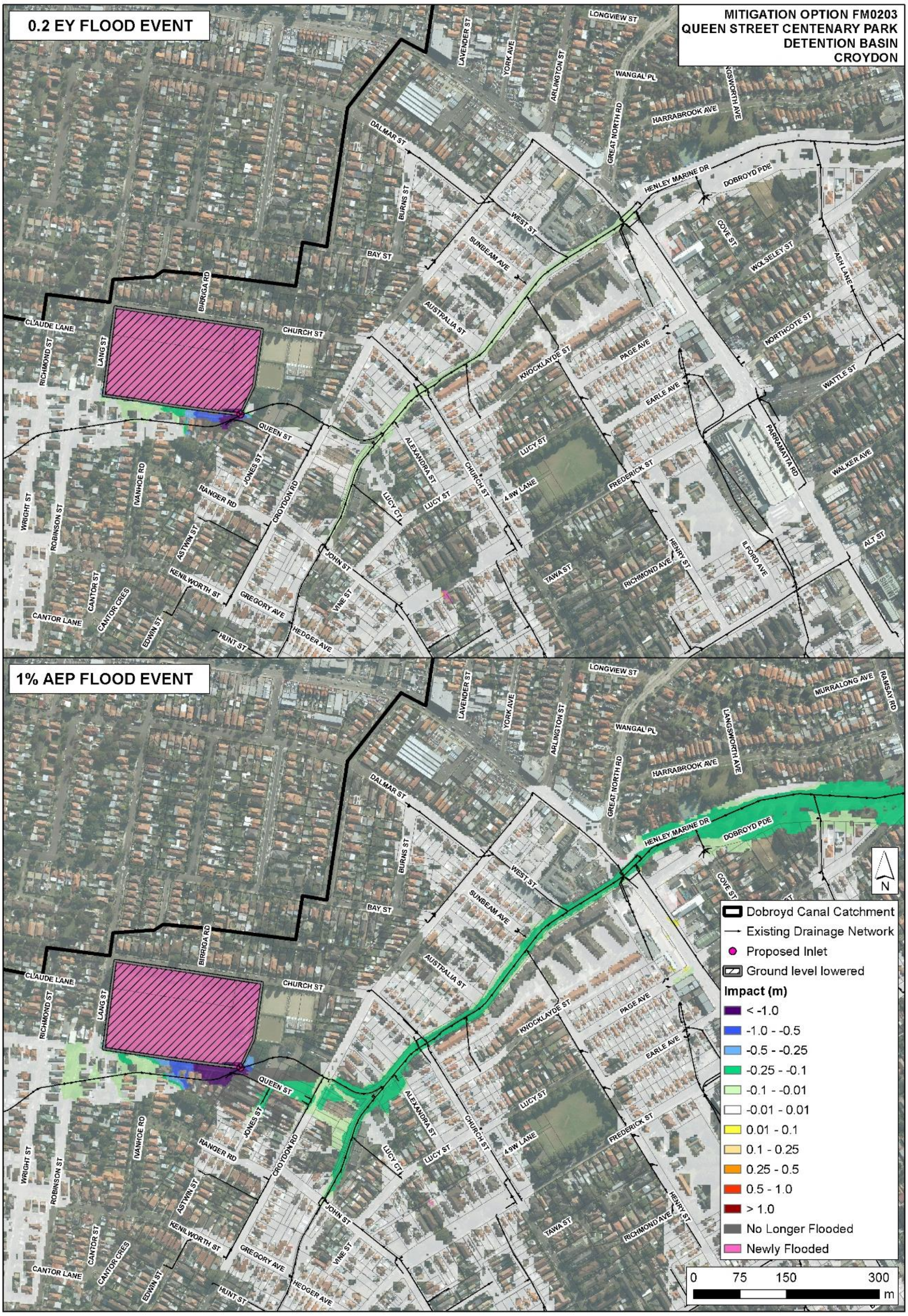


Diagram A8: Option FM0203 Schematisation and Impacts 0.2 EY and 1% AEP Events



The limited extent of reduced peak flood levels for FM0201 results in no change to property over floor affectation in the Dobroyd Canal catchment. FM0202 and FM0203 result in broader reductions in peak flood levels and subsequently show an overall decrease in the number of properties flooded over floor, however both options also result in an increase in the number of properties affected over floor in the 2% and 5% AEP events.

As a result of the minor impact on flood behaviour (FM0201) and the increases in property affectation (FM0202 and FM0203) these options are not recommended for further consideration.

A.2.2. Option FM0205: Queen Street Centenary Park Underground Detention Basin

This option proposes an under-ground detention basin running along the south-west boundary of Centenary Park, beneath the cricket nets and sports fields. The detention basin is designed to store overland flow from Queen Street. The aim is to allow greater capacity within the Council owned pipes for flow from overland flow paths and so reduce flooding. The proposed detention basin has the following dimensions - L 140 m x W 35 m x H 3 m. The inlet to the detention basin is located along southern boundary over a 140 m length. A small 150 mm diameter pipe at the detention basin outlet passes water back into the existing SWC owned pipe where it travels a small distance before joining with Dobroyd Canal.

Diagram A9 shows the schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, there is a minor reduction in flood levels running along Queen Street and adjacent properties of up to 0.5 m, in comparison to existing depths of over 1 m. In the 1% AEP event, there is little change in the peak flood levels. In the vicinity of the Queen Street, flood levels decrease by up to 0.1 m, with depths in excess of 1.5 m remaining. This decrease is also observed further downstream in Dobroyd Canal. There are both increases and decreases in the overall property affectation. The change to over floor flood affectation is shown in Table 8.

Diagram A9: Option FM0205 Schematisation and Impacts 0.2 EY and 1% AEP Events

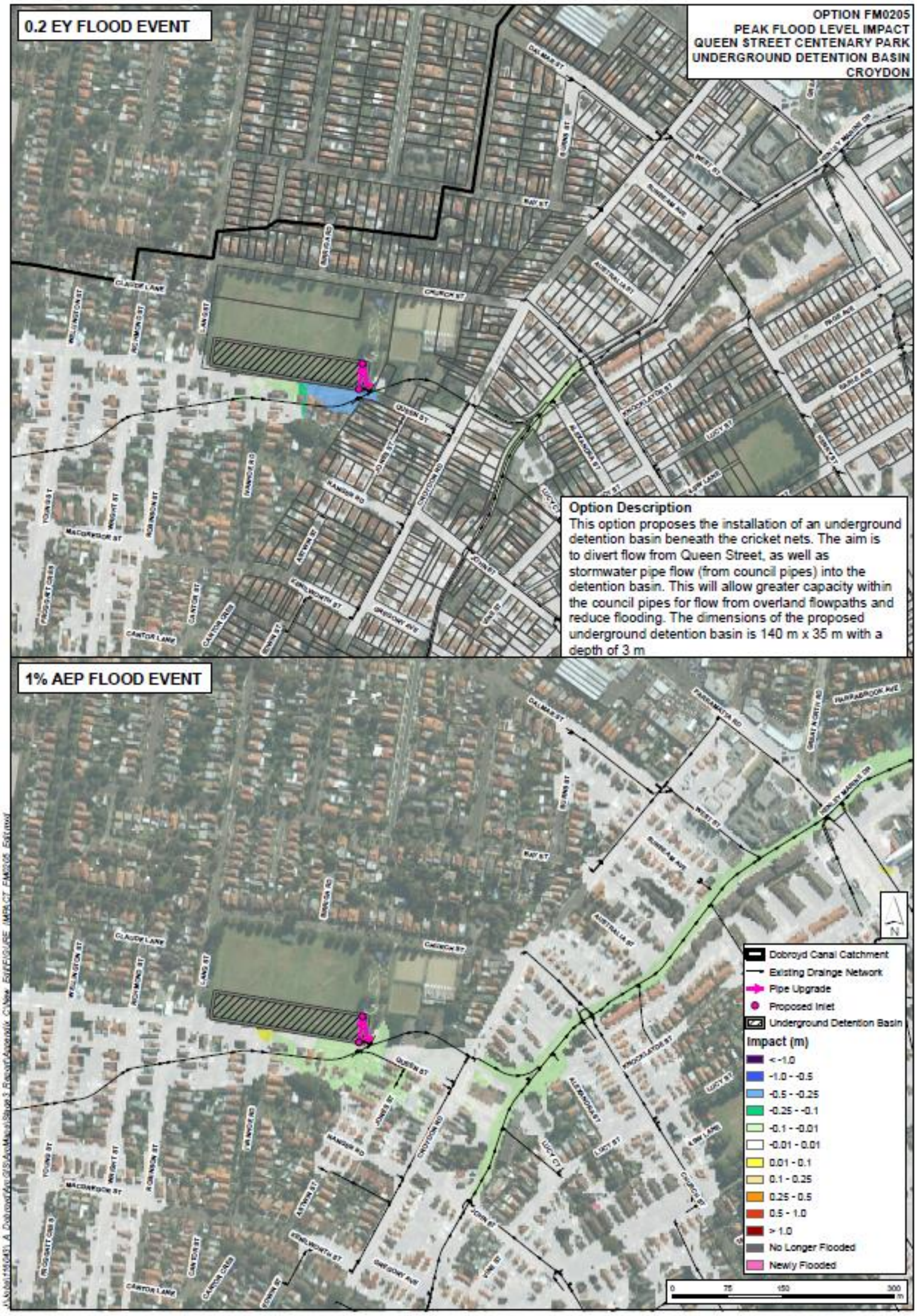


Table 8 – Over floor Property Affectation FM0205

	Properties Flooded Over floor		
Event	**Current**	**With Option (FM0205)**	**Change**
0.5EY	23	23	0
0.2EY	66	64	-2
10% AEP	132	137	5
5% AEP	209	209	0 (2)
2% AEP	301	306	5
1% AEP	399	398	-1
PMF	1339	1313	-26

Note: Values in brackets are the number of additional properties inundated over floor during that event.

The limited extent of reduced peak flood levels results in a mixture of increases and decreases in the number of properties inundated over floor in the Dobroyd Canal catchment. As a result, this option is not recommended for further consideration.

A.3. Hotspot D03 – Brown Street, Ashfield

Four options were considered for this location, an underground detention basin and three drainage upgrades.

A.3.1. Option FM0301B, FM0302B: Brown Street Drainage Upgrade

These three options proposed various combinations of drainage upgrade in Brown Street and Elizabeth Street, as described below. Earlier iterations of FM0301B and FM0302B, FM0301 and FM0302 were also assessed and discarded.

Option	Configuration
FM0301B	Increase the feeder pipes in Brown Street to 0.3 m
FM0302B	Upgrade of the existing Council pipes (from 1.2 m x 0.9 m box culverts) to 2.4 m x 0.9 m box culverts from Bland Street (beneath the railway), along Elizabeth Street to Dobroyd Canal. The aim is to allow overland flow to escape more readily.

Diagram A10 and Diagram A11 show the schematisation of the options and their impact on peak flood levels for the 0.2 EY and 1% AEP events for Option FM0301B and Option FM0302B

Diagram A10: Option FM0301B Schematisation and Impacts 0.2 EY and 1% AEP Events

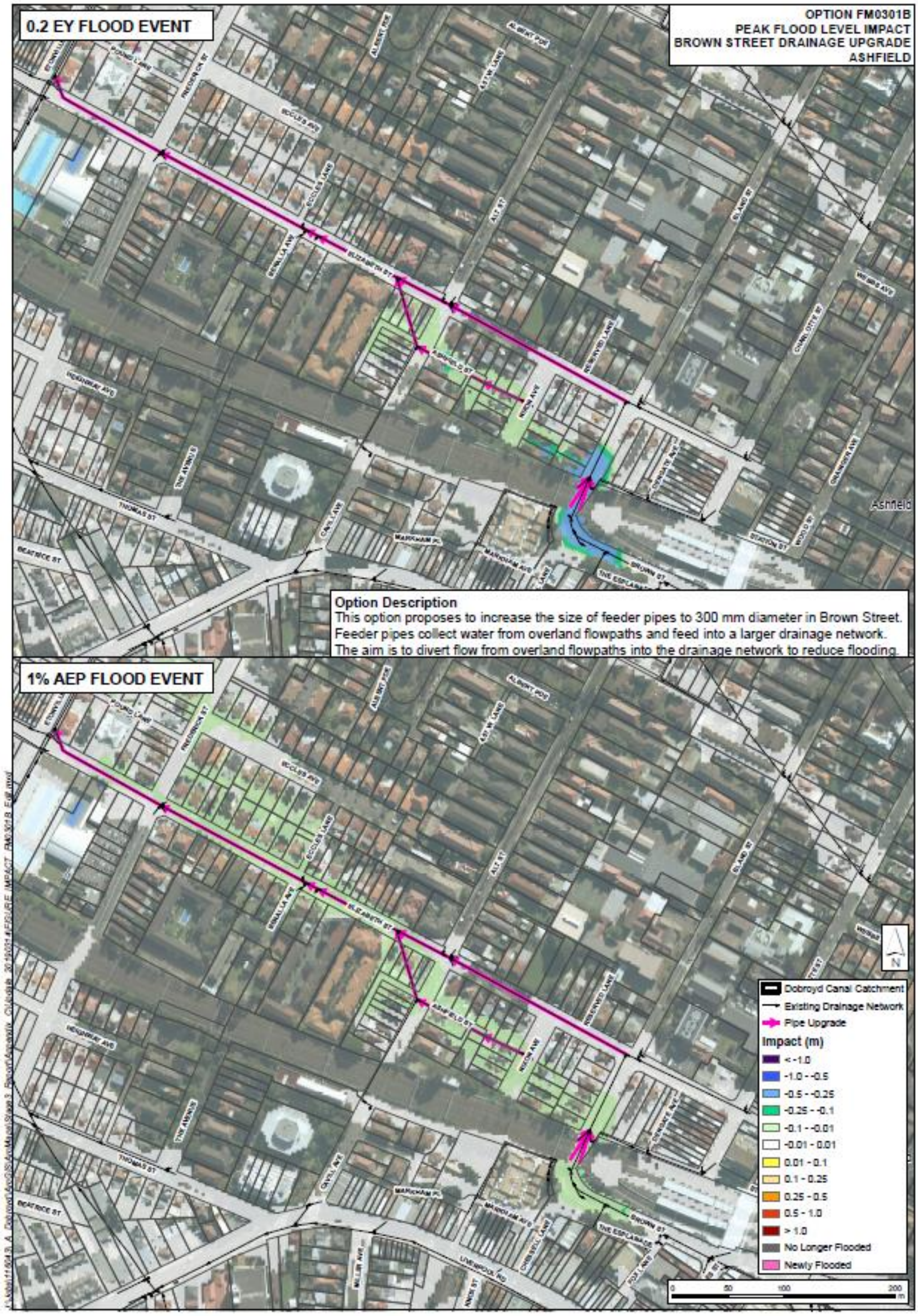
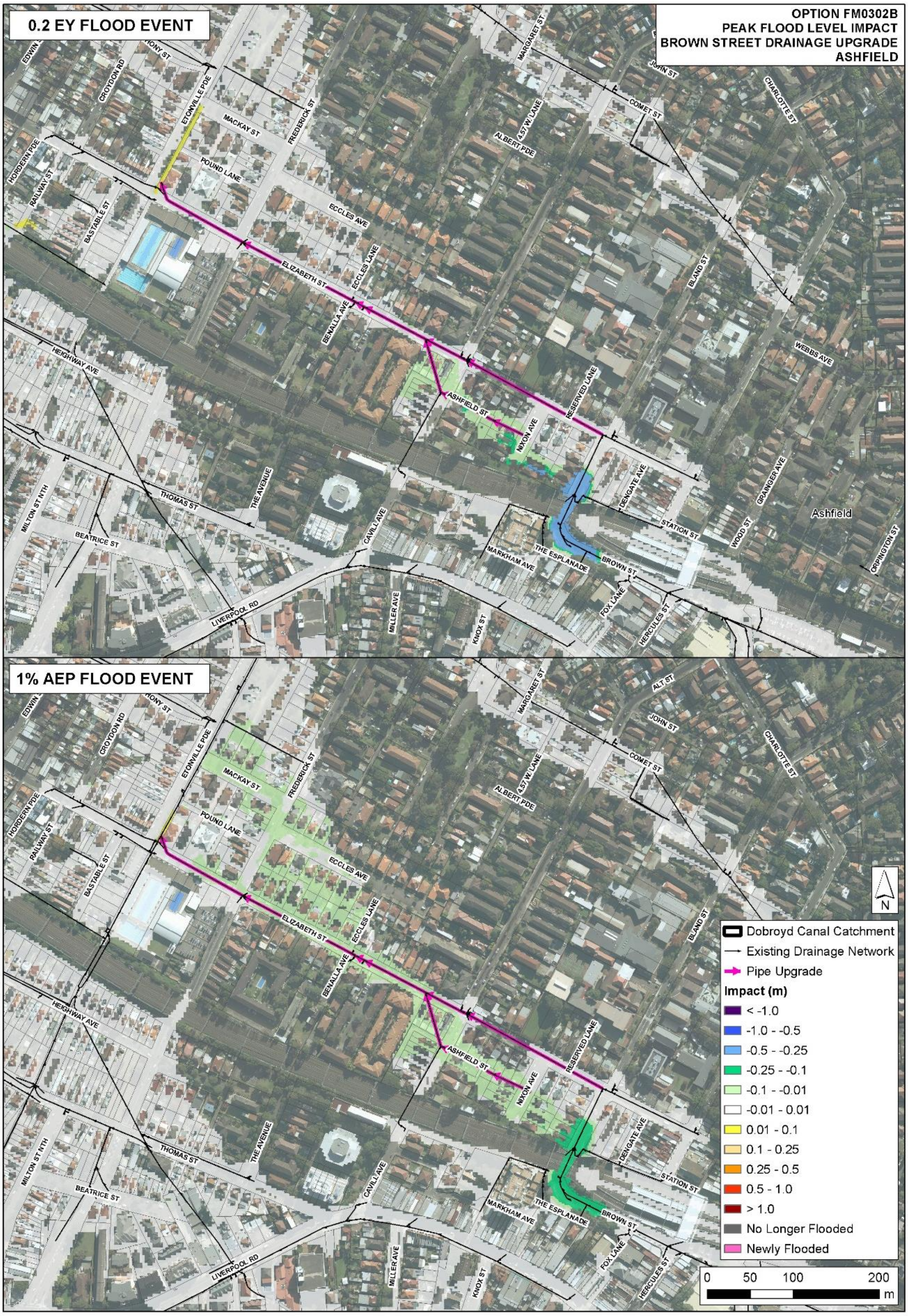


Diagram A11: Option FM0302B Schematisation and Impacts 0.2 EY and 1% AEP Events



In the 0.2 EY event for FM0301B, peak flood levels decrease by up to 0.5 m along Brown Street, under the railway as well as decreasing by up to 0.1 m along the flowpath between Brown Street and Ashfield Street. Existing depths in Brown Street are in excess of 1.5 m and 2.0 m in the 0.2EY and 1% AEP, respectively. In the 1% AEP event, reduction in peak levels of up to 0.1 m are shown along Brown Street and Elizabeth Street, in comparison to an existing depth of around 0.3 m. The option results in a minor overall decrease to property affectation, with additional properties inundated over floor in the 2% and 5% AEP events (Table 9).

Table 9 – Over floor Property Affectation FM0301B

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0301B)**	**Change**
0.5EY	23	22	-1
0.2EY	66	65	-1
10% AEP	132	130	-2
5% AEP	209	208	-1 (2)
2% AEP	301	300	-1 (3)
1% AEP	399	399	0
PMF	1339	1339	0

Note: Values in brackets are the number of additional properties inundated over floor during that event.

In the 0.2 EY event for FM0302B, the peak flood levels decrease by up to 0.5m along Brown Street, under the railway. Decreases in flood levels of 0.1 m are also observed along the flowpath between Brown Street and Ashfield Street. In the 1% AEP event, there is a smaller change in peak flood levels with flood levels decreasing by up to 0.25 m along Brown Street and up to 0.1 m downstream of Brown Street towards Dobroyd Canal. The option results in a minor overall decrease to property affectation, with additional properties inundated over floor in the 2% and 5% AEP events (Table 10).

Table 10 – Over floor Property Affectation FM0302B

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0302B)**	**Change**
0.5EY	23	22	-1
0.2EY	66	65	-1
10% AEP	132	130	-2
5% AEP	209	208	-1 (2)
2% AEP	301	302	1 (3)
1% AEP	399	398	-1
PMF	1339	1339	0

Note: Values in brackets are the number of additional properties inundated over floor during that event.

The limited extent of reduced peak flood levels for both options results in a mixture of increases and decreases in the number of properties inundated over floor in the Dobroyd Canal catchment. As a result of the minor impact on flood behaviour these options are <u>not recommended</u> for further consideration.

A.3.2. Option FM0303: Brown Street Underground Detention Basin

This option comprises of an under-road detention basin in Brown Street. The aim is to detain water during smaller rainfall events and reduce flood levels in the vicinity of Bland Street and the downstream flow path along Elizabeth Street. Its purpose is to temporarily store water during frequent rainfall events and discharge the flow at a later time where the outflow is regulated through flow-control structures.

The option includes directing water from an existing Council owned box culvert (1.2 m x 0.9 m) along Brown Street (under the railway line) into a detention basin (dimensions L 75 m x W 10 m x H 1.8 m) beneath Brown Street, just north of the railway line to the intersection of Elizabeth Street. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing pipe network where it travels along Elizabeth Street before joining with Dobroyd Canal.

Diagram A12 shows the schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, there is a reduction in peak flood levels of up to 0.25 m along Brown Street, under the railway, and decreases of up to 0.1 m along the flowpath between Brown Street and Ashfield Street. Existing depths in Brown Street are in excess of 1.5 m and 2.0 m in the 0.2EY and 1% AEP, respectively. In the 1% AEP event, there is a smaller change in peak flood levels, decreasing by up to 0.1 m from Brown Street downstream to Dobroyd Canal. The option results in a minor overall decrease to property affectation, with additional properties inundated over floor in the 2% and 5% AEP events (Table 11).

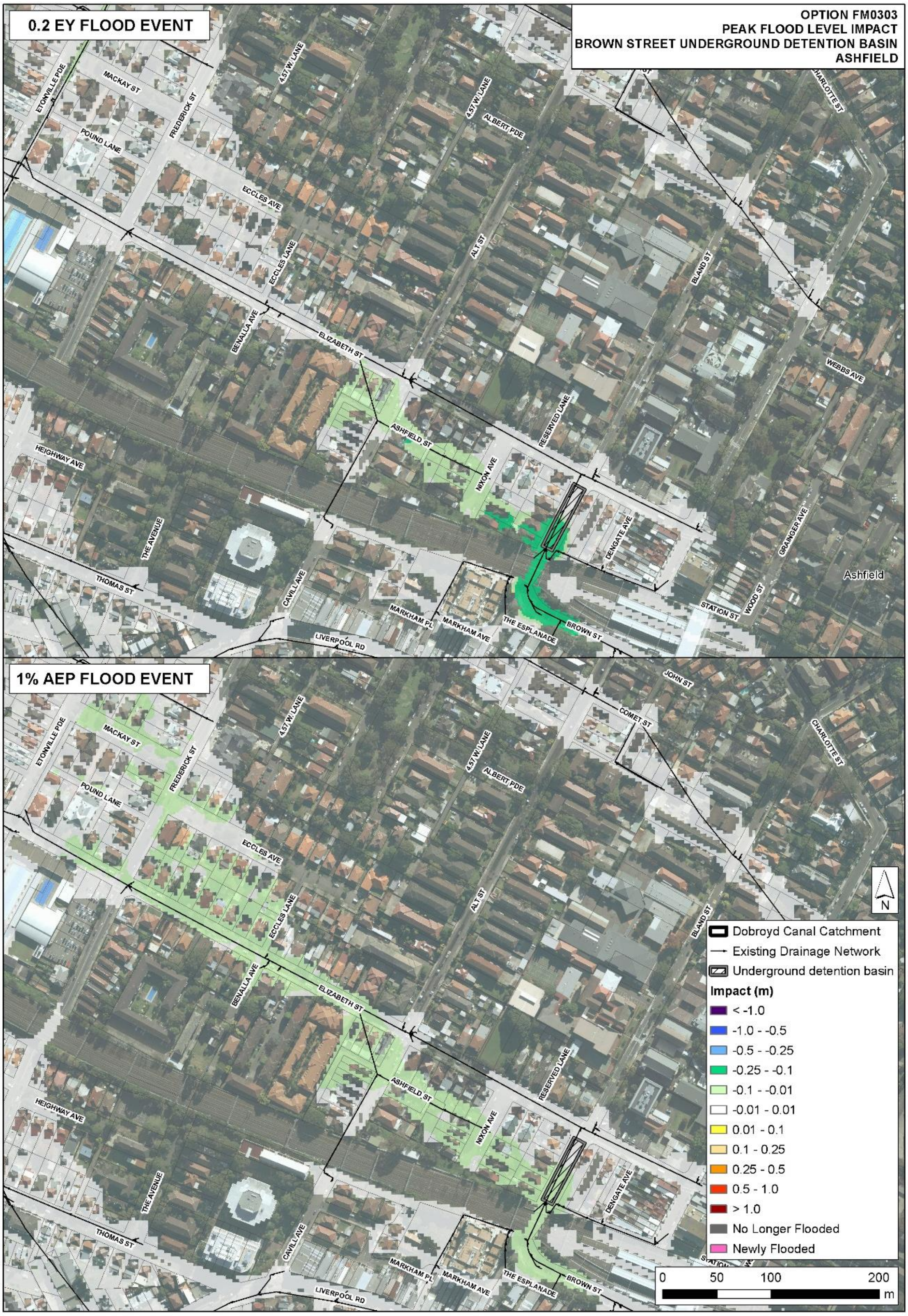
Table 11 – Over floor Property Affectation FM0303

Event	Properties Flooded Overfloor		Change
	Current	With Option (FM0303)	
0.5EY	23	23	0
0.2EY	66	65	-1
10% AEP	132	131	-1
5% AEP	209	209	0 (2)
2% AEP	301	303	2 (3)
1% AEP	399	399	0
PMF	1339	1339	0

Note: Values in brackets are the number of additional properties inundated over floor during that event.

The limited extent of reduced peak flood levels would result in limited change to property affectation in the Dobroyd Canal catchment. As a result of the minor impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram A12: Option FM0303 Schematisation and Impacts 0.2 EY and 1% AEP Events



A.4. Hotspot D06 – Algie Park, Haberfield

A.4.1. Option FM0601B: Algie Park Detention Basin, Levee and Drainage Upgrade

This option proposes the extension of an existing concrete levee in Algie Park, running along the western boundary of the park, to increase storage capacity of an existing above-ground detention basin. The aim is to reduce excess flow from properties on Ramsay Street and Alt Street. The proposed design for the extended concrete levee includes the installation of a 1 m high concrete levee for a length of 53 m along the east boundary of 197 Ramsay Street. This will join with the existing levee. The majority of Algie Park has ground levels (around 5.25 m AHD) lower than the surrounding residential properties (at around 7 m AHD). The extension of the levee wall allows a larger portion of the park to be used as an above-ground detention basin.

An earlier iteration of FM0601B, FM0601 was also assessed and discarded. As an alternative an underground detention basin was also considered, FM0602, however was found to result in no change in flood behaviour and was discarded.

Diagram A13 shows the schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

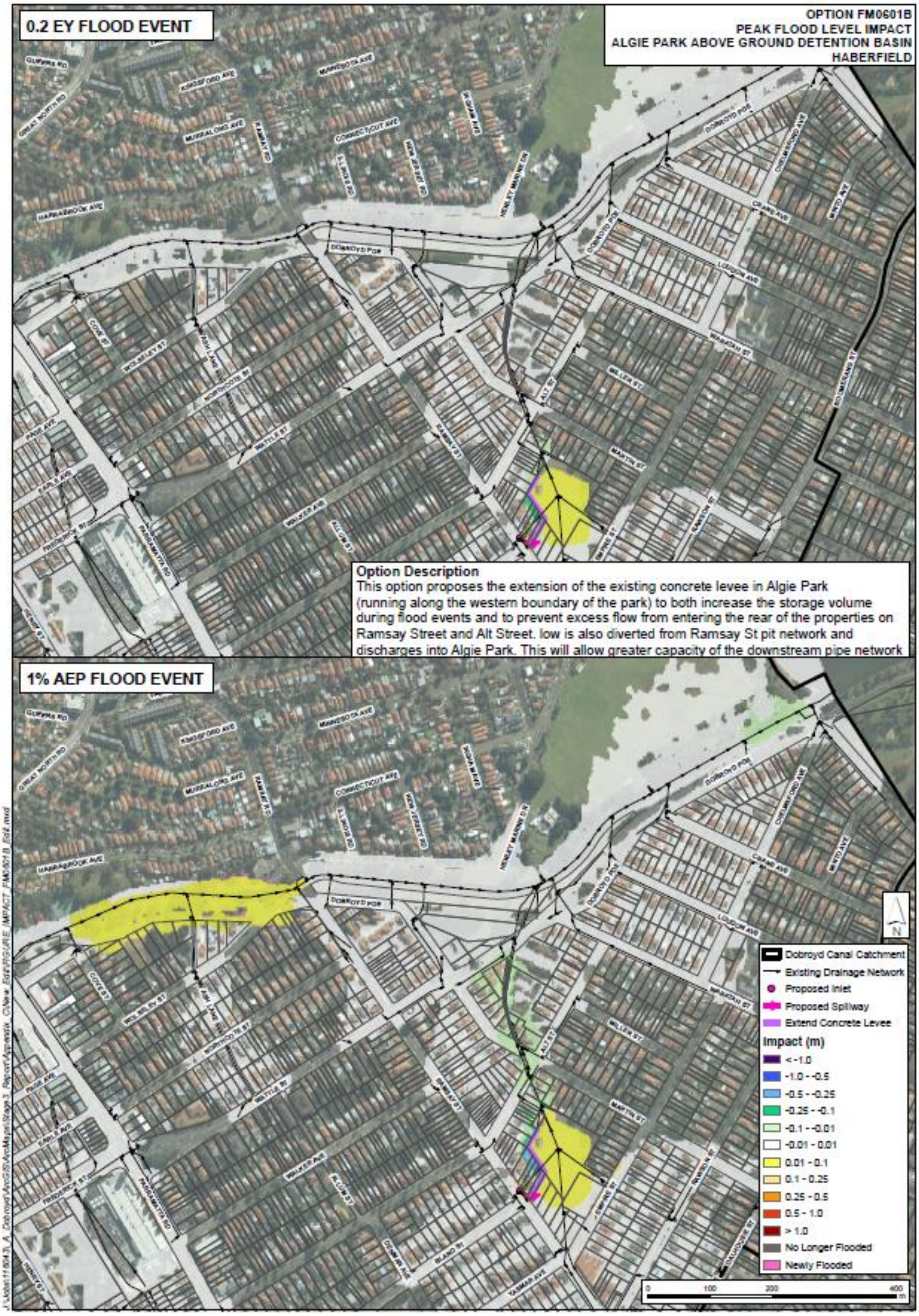
In the 0.2 EY event, there is a minor reduction in peak flood levels up to 0.2 m (in comparison to existing depths of 0.4 m) within the rear backyards of properties along Ramsay Street that back onto the proposed levee. Minor decreases up to 0.1 m are observed directly downstream. In the 1% AEP event, similar decreases to the 0.2 EY event are observed, however, the decrease in flood levels extends to Dobroyd Canal and existing depths through the backyards are up to 0.8 m under existing conditions . In addition during the 1% AEP event the change to flow timing as a result of the option causes an increase in flood levels through the Dobroyd Parade branch and subsequently increases property affection (Table 12).

Table 12 – Over floor Property Affectation FM0601

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0601)**	**Change**
0.5EY	23	23	0
0.2EY	66	66	0
10% AEP	132	132	0
5% AEP	209	211	2
2% AEP	301	304	3
1% AEP	399	399	0
PMF	1339	1341	2

The limited, and in some locations, increase in peak flood levels would result worsening of property affectation in the Dobroyd Canal catchment. As a result this option is not recommended for further consideration.

Diagram A13: Option FM0601B Schematisation and Impacts 0.2 EY and 1% AEP Events



A.5. Dobroyd Canal - Other

Three options were considered, an above and an underground detention basin at Pratten Park, and an underground detention basin on Arthur Street.

A.5.1. Option FM0701, FM0701B: Pratten Park Detention Basins

These options are based on detention basins in Pratten Park. FM0701 proposes an above ground basin and FM0701B an underground basin.

Option	Configuration
FM0701	The aim is to divert overland flow as well as stormwater pipe flow from the existing Council owned pipes (0.9 m diameter) at the southern boundary of Pratten Park into a detention basin (dimensions L130 m x W 80 m x H 1.2 m) beneath Pratten Park. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing pipe (0.75 m diameter). This option also includes removing an existing 0.9 m pipe under Pratten Park.
FM0701B	Installation of an above ground detention basin in Pratten Park. The aim is to divert flow during rainfall events to the detention basin. This allows greater capacity for flow from overland flowpaths to enter the pipe network and to reduce flooding down to Dobroyd Canal.

Diagram A14 and Diagram A15 show the schematisation of the options and their impact on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY and 1% AEP events for FM0701, the peak flood levels decrease by up to 0.1 m between the proposed detention basin and Dobroyd Canal, in comparison to existing depths between 0.4 m and 0.7 m and 0.7 m and 1.5m, in the 0.2EY and 1% AEP respectively. In the 0.2 EY and 1% AEP event, 9 and 18 properties respectively are no longer flooded above floor level and there is a broad reduction in properties impacted (Table 13).

Table 13 – Over floor Property Affectation FM0701

Event	Properties Flooded Overfloor		
	Current	With Option (FM0701)	Change
0.5EY	23	22	-1
0.2EY	66	57	-9
10% AEP	132	112	-20
5% AEP	209	192	-17
2% AEP	301	289	-12
1% AEP	399	381	-18
PMF	1339	1332	-7

In the 0.2 EY and 1% AEP events for FM0701B, the peak flood levels decrease by up to 0.1 m between the proposed detention basin and Dobroyd Canal.

Whilst there is an improvement to flooding behaviour with a number of properties no longer being flooded above floor level, there are large costs associated with the construction as well as the social disruption (the park would be out of commission for a long period of time), this option is not recommended for further consideration. An option combining a basin in Pratten Park and addition storage in Arthur Street (FM0703 – Section 10.2.9.6) was found to offer greater benefits and is assessed further.

Diagram A14: Option FM0701 Schematisation and Impacts 0.2 EY and 1% AEP Events

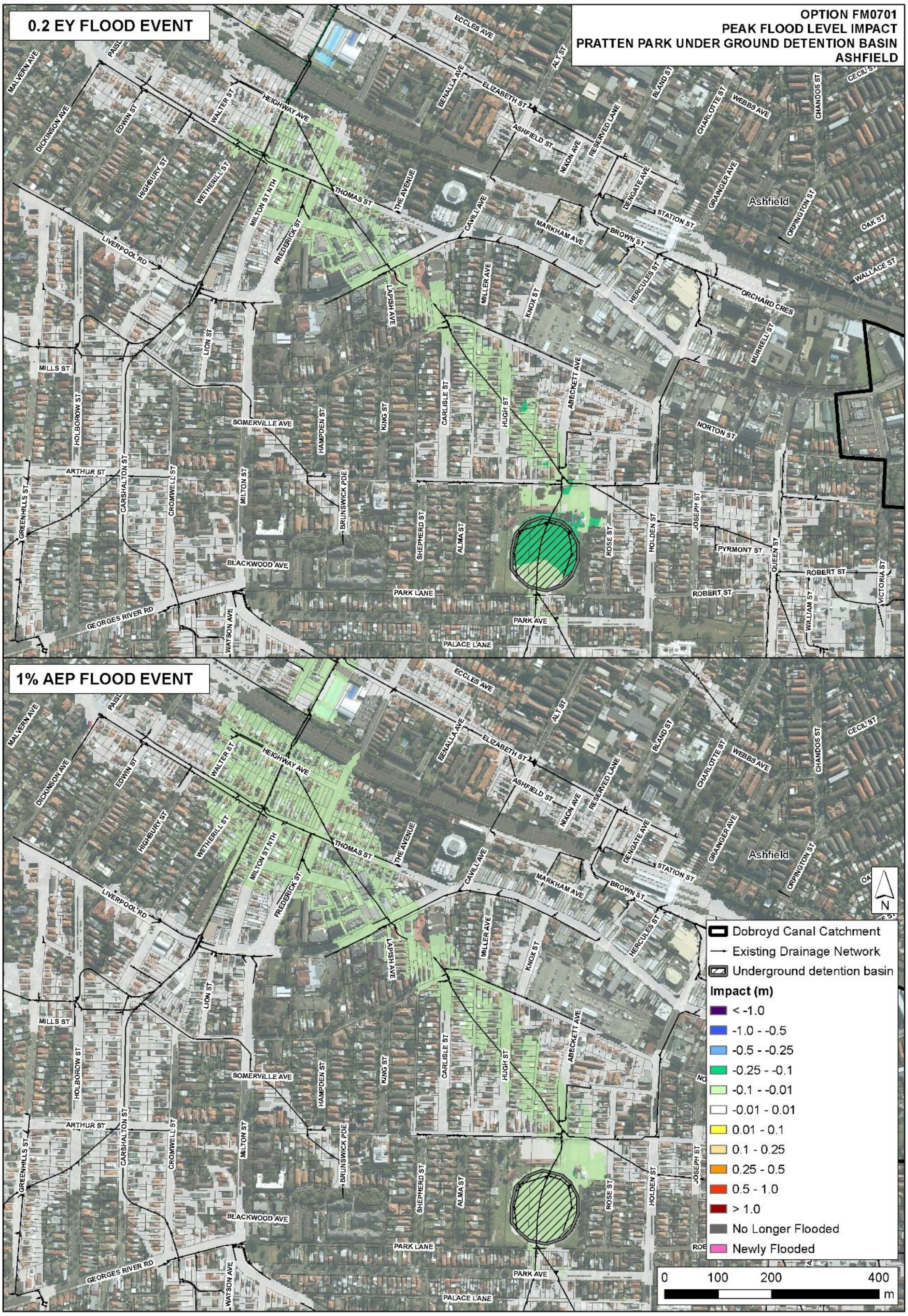
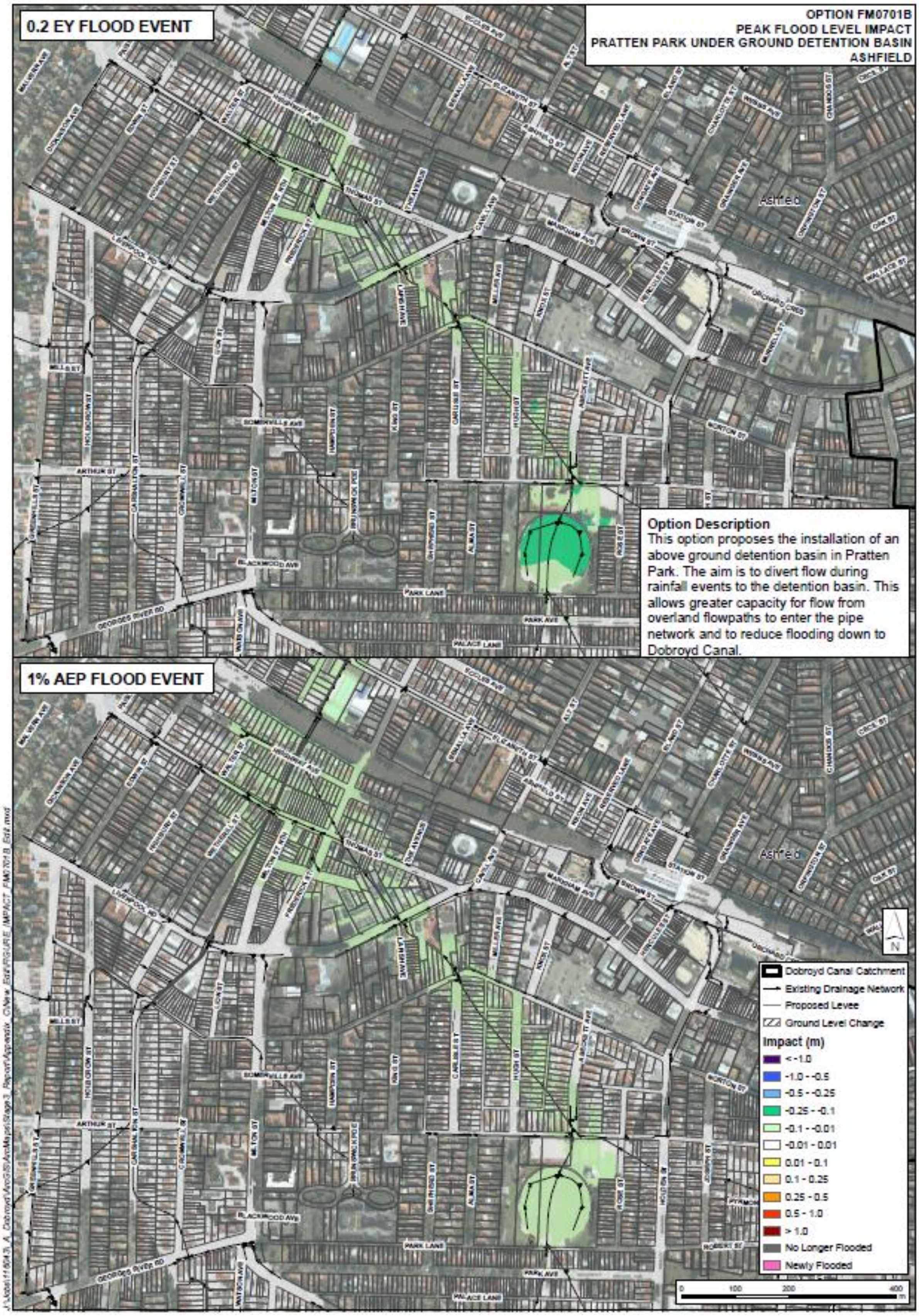


Diagram A15: Option FM0701B Schematisation and Impacts 0.2 EY and 1% AEP Events



A.5.2. Option FM0702: Arthur Street Underground Detention Basin

This option proposes the installation of a detention basin beneath the tennis courts along Arthur Street. The aim is to divert overland flow as well as stormwater pipe flow into the basin. This allows greater capacity for flow from overland flow paths to enter the pipe network to reduce overland flooding down to Dobroyd Canal.

The option includes directing water from an existing SWC owned pipe (1 m diameter) at the eastern boundary of the tennis courts into a 1.2 m diameter pipe before discharging into a detention basin (dimensions L 70 m x W 40 m x H 3 m) beneath the tennis courts. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing pipe (1 m diameter pipe).

Diagram A16 shows the schematisation of the option and the impact on peak flood levels for the 0.2 EY and 1% AEP events.

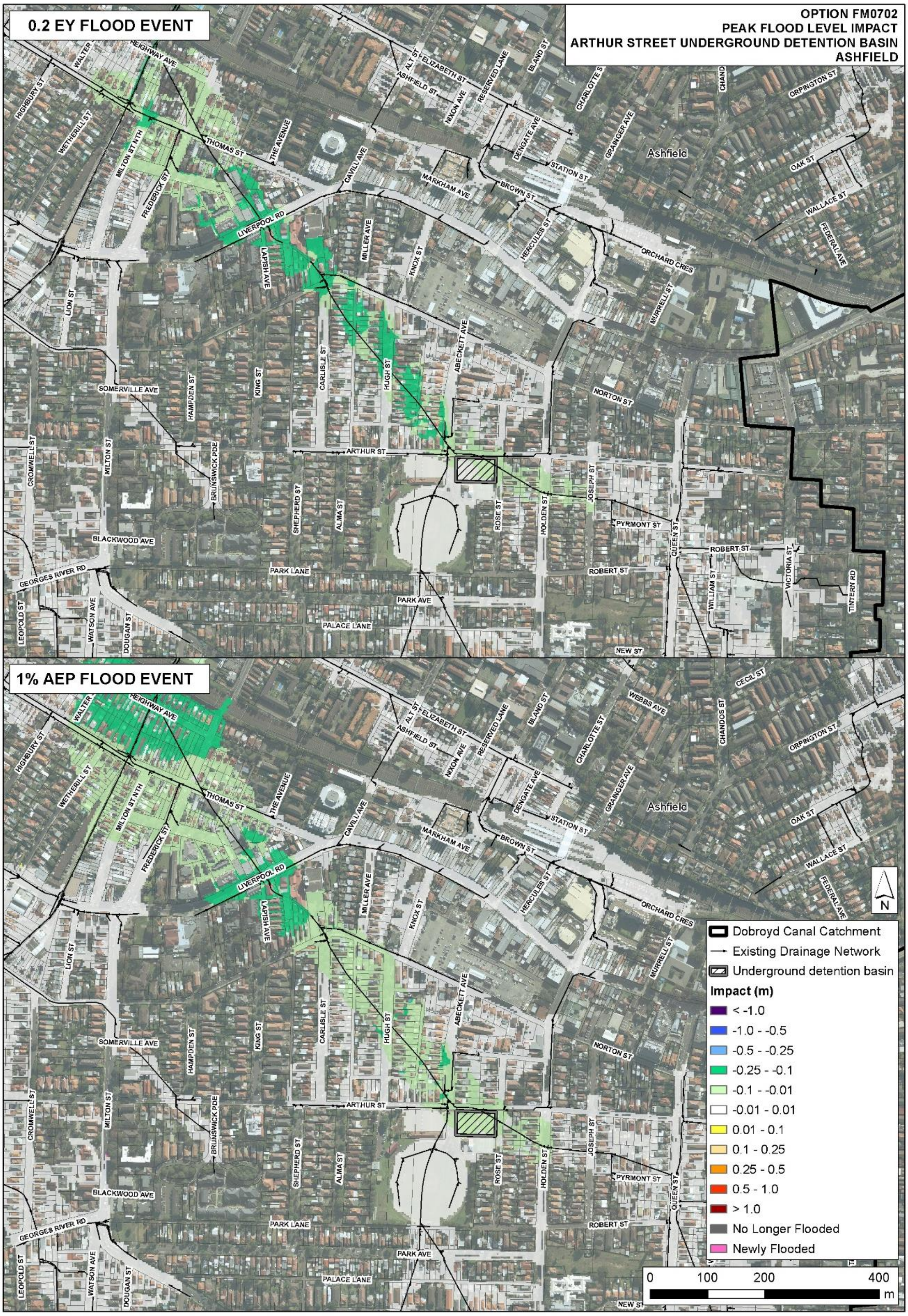
In the 0.2 EY event, the peak flood levels typically decrease by 0.15 m downstream of the proposed detention basin to Dobroyd Canal. In the 1% AEP event, the peak flood levels decrease by up to 0.1 m along the flowpath downstream. In comparison the existing depths along this flowpath are between 0.4 m and 0.7 m and 0.7 m and 1.5m, in the 0.2EY and 1% AEP respectively. At Liverpool Road and Heighway Avenue, the decreases in flood levels are in the order of 0.15 m in comparison to 0.5m and 1.5m existing depth. In the 0.2 EY event and 1% AEP event, 17 and 24 properties respectively are no longer flooded above floor and there is a broad reduction in properties impacted (Table 14).

Table 14 – Over floor Property Affectation FM0702

	Properties Flooded Overfloor		
Event	Current	With Option (FM0702)	Change
0.5EY	23	19	-4
0.2EY	66	49	-17
10% AEP	132	102	-30
5% AEP	209	179	-30
2% AEP	301	277	-24
1% AEP	399	375	-24
PMF	1339	1328	-11

Whilst there is an improvement to flooding behaviour with a number of properties no longer being flooded above floor level, there are large costs associated with the construction, acquisition of the site as it is currently not a Council owned asset as well as the social disruption (road closures), this option is not recommended for further consideration. An option combining addition storage in Arthur Street with a basin in Pratten Park (FM0703 – Section 10.2.9.6) was found to offer greater benefits and is assessed further.

Diagram A16: Option FM0702 Schematisation and Impacts 0.2 EY and 1% AEP Events



Part B: HAWTHORNE CANAL PRELIMINARY OPTION ASSESSMENT

B.1. Hotspot H01 – Queen Street to Hawthorne Canal (Ashfield)

B.1.1. FM0101A Yeo Park (North of Primary School) Detention Basin

This option proposes a new 750 mm diameter pipe beginning in Queen Street where water from an existing Council owned pipe is diverted into the new pipe that travels along Harland Avenue and across Victoria Street to the north-east corner of Yeo Park. Water is then diverted to a detention basin (dimensions L 80 m x W 80 m x H 4.0 m) beneath Yeo Park running parallel to Victoria Street. A small 150 mm diameter pipe at the detention basin outlet transfers flow from the detention basin into an existing 450 mm Council owned pipe network located at the south-east of the memorial in Yeo Park.

The aim of diverting flow into the detention basin is to increase the capacity of the existing drainage network to enable more surface flow and reduce the flood levels.

Diagram B1 shows the schematisation of the option and their impacts on peak flood levels for the 0.2 EY and 1% AEP events.

The required invert levels along Harland Street (a minimum pipe invert of 40.5 m AHD) for the proposed pipe along Harland Street would require approximately a 6 m deep trench to be dug for construction.

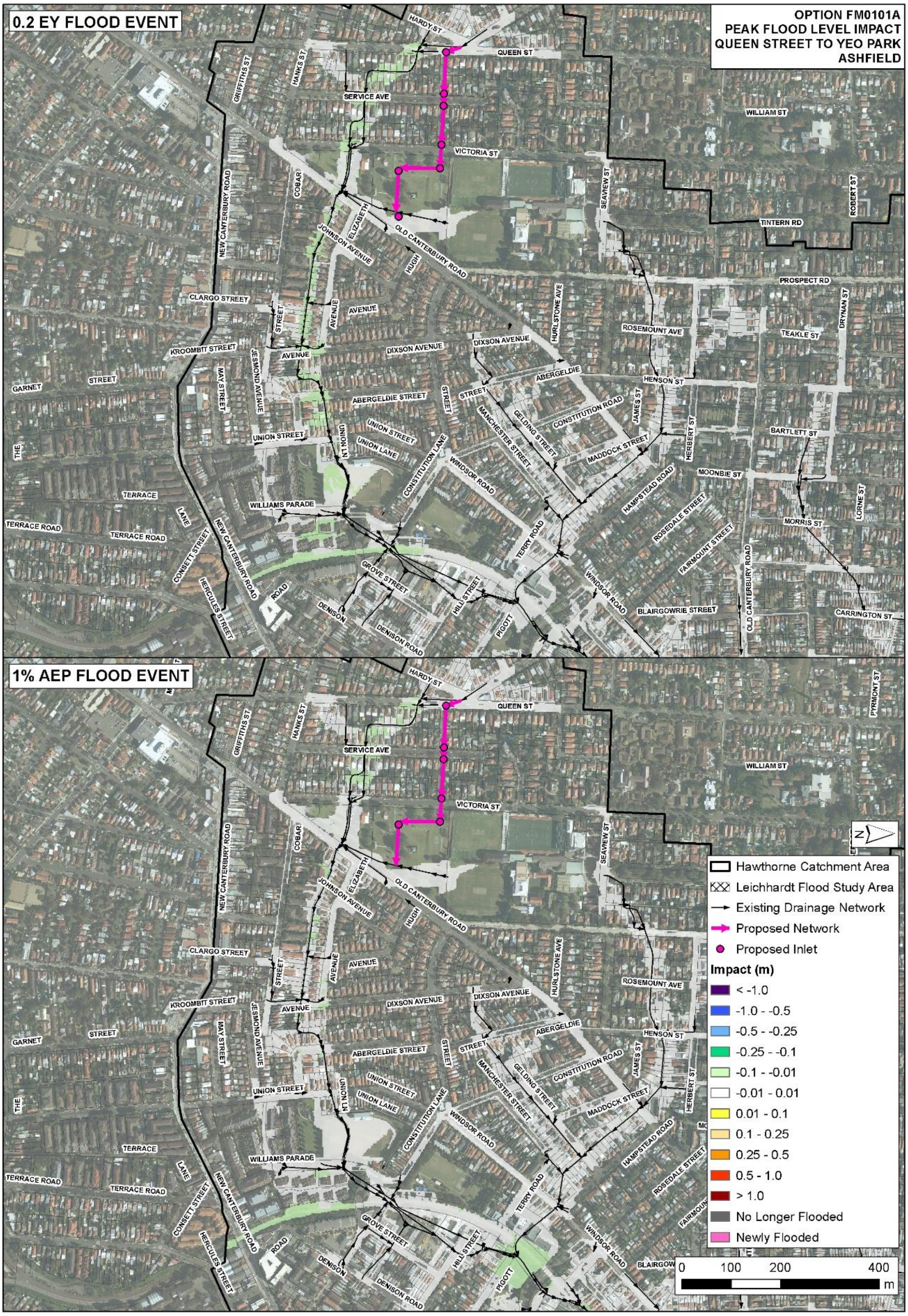
In the 0.2 EY event, there is a reduction in flood levels along the flowpath from between Queen Street and Hawthorne Canal of up to 0.1 m, in comparison to existing depths of between 0.2 m and 0.6 m. There is no change to the number of properties affected by flooding during this event. In the 1% AEP event, peak flood levels decrease by up to 0.1 m between Queen Street and Victoria Street with small pockets of minor decreases located along the downstream flowpath. Existing depths in the 1% AEP event are between 0.5 m and 0.8 m.

There would be some, albeit limited, benefit to property over floor affection in the area (Table 15) however this would be marginal (and thus limited changes to the estimated AAD), especially when considering the significant construction associated with deep trenching. In order to achieve a BCR of less than 1.0, this option would need to be costed at less than $400,000. As a result of the minor impact on flood behaviour and the likely costs, this option is not recommended for further consideration.

Table 15 – Over floor Property Affectation FM0101A

Properties Flooded Overfloor			
Event	**Current**	**With Option (FM0101A)**	**Change**
0.5EY	12	12	0
0.2EY	37	37	0
10% AEP	53	52	-1
5% AEP	75	75	0
2% AEP	100	99	-1
1% AEP	120	119	-1
PMF	537	512	-25

Diagram B1: Option FM0101A Schematisation and Impacts 0.2 EY and 1% AEP Events



B.1.2. FM0101B Drainage Upgrade Queen Street to Yeo Park

This option proposes a new 750 mm diameter pipe beginning in Queen Street where water from an existing Council owned pipe is diverted into the new pipe that travels along Harland Avenue and discharges into Yeo Park (north west corner) where an above-ground detention basin would temporarily stores flood water. The above ground-detention basin is formed by raising the ground levels along the current pedestrian walkway running parallel to Victoria Street and then turning east running from Victoria Street to Old Canterbury Road and then travelling north parallel to Old Canterbury Road. The total length of the raised ground is 330 m. A small 150 mm pipe would slowly discharge flood waters from the detention basin into an existing 450 mm Council owned pipe network located at the south east of the memorial in Yeo Park.

The required invert levels along Harland Street (a minimum pipe invert of 40.5 m AHD) for the proposed pipe along Harland Street would require approximately a 6 m of trench to be dug for construction which is not feasible.

Diagram B2 shows the schematisation of the option and their impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, there is a decrease in flood levels of up to 0.1 m from Queen Street extending down to Old Canterbury Road, in comparison to existing depths of between 0.2 m and 0.6 m. Small areas of increased flood levels (up to 0.05 m) and newly flooded areas are observed downstream within the road corridor of Fred Street and adjacent areas (enters properties). In the 1% AEP event, the majority of flood levels between Queen Street and Old Canterbury Road decrease by up to 0.1 m, in comparison to existing depths up to 0.8 m. Decreases in flood levels of up to 0.2 m are observed between Fred Street and Old Canterbury Road including on a number of properties.

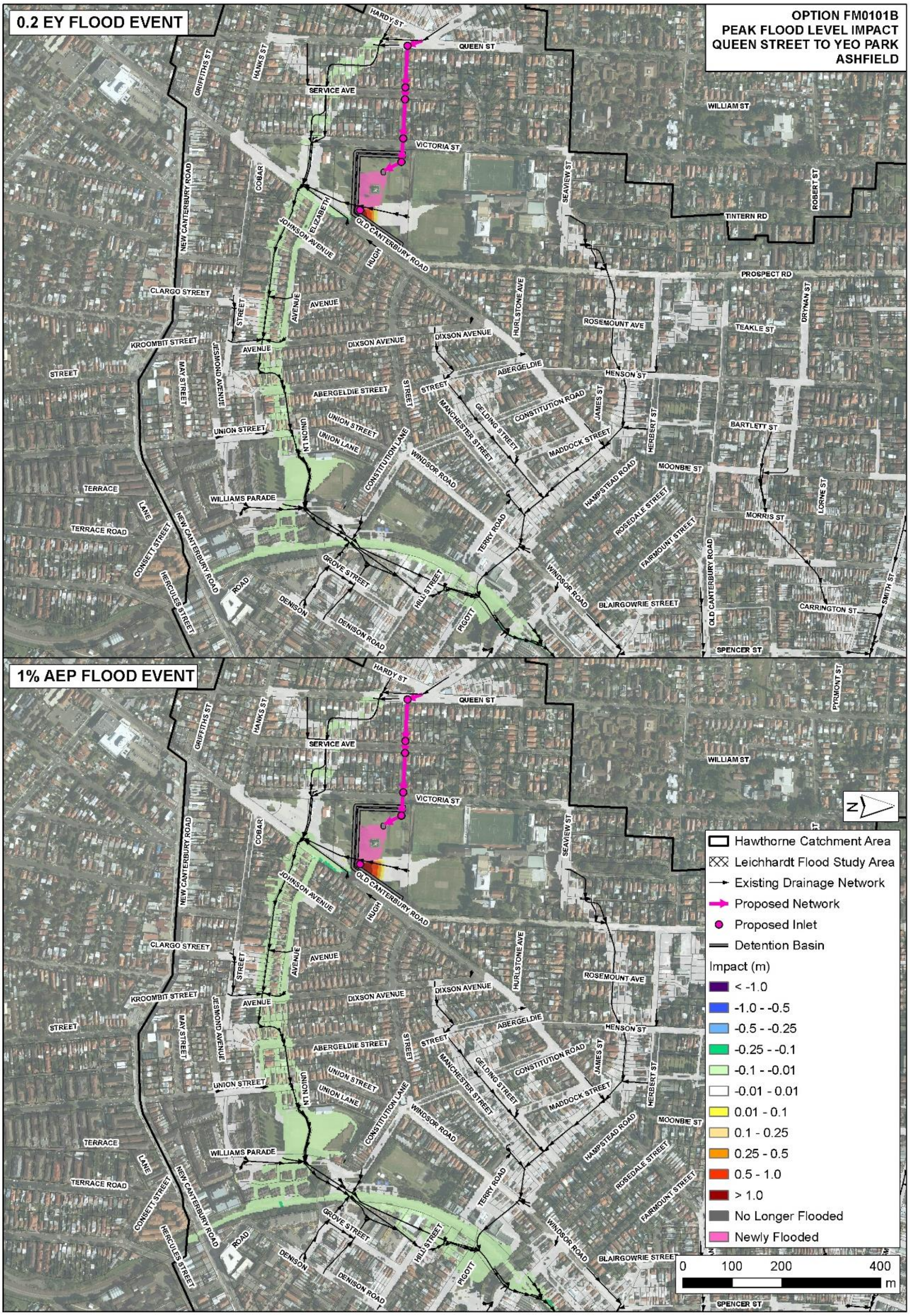
The numbers of properties that become no longer flood affected are 1 and 2 for the 0.2 EY and 1% AEP events respectively (Table 16).

Table 16 – Over floor Property Affectation FM0101B

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0101B)**	**Change**
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	52	-1
5% AEP	75	73	-2
2% AEP	100	99	-1
1% AEP	120	118	-2
PMF	537	531	-6

There would be some, albeit limited, benefit to property over floor affection in the area (Table 16) however this would be marginal (and thus limited changes to the estimated AAD), especially when considering the significant construction associated with deep trenching. In order to achieve a BCR of less than 1.0, this option would need to be costed at less than $490,000. As a result of the minor impact on flood behaviour and the likely costs, this option is <u>not recommended</u> for further consideration.

Diagram B2: Option FM0101B Schematisation and Impacts 0.2 EY and 1% AEP Events



B.1.3. FM0102A Yeo Park (South of Primary School) Detention Basin

This option proposes to utilise Yeo Park (south of the primary school) as an above-ground detention basin. The aim is to reduce flow along the downstream flowpath. The proposed design is to excavate an area of 275 m^2 to a ground level of 34.75 m AHD. The current ground levels are approximately 35.2 m AHD (just to the south of the primary school) and slope up to approximately 38 m AHD at the southern side of the proposed basin. Overland flow from Victoria Street is directed into the basin at the north-west corner of the basin where a 150 mm outlet pipe would slowly discharge water into the existing 1 m pipe.

Diagram B3 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

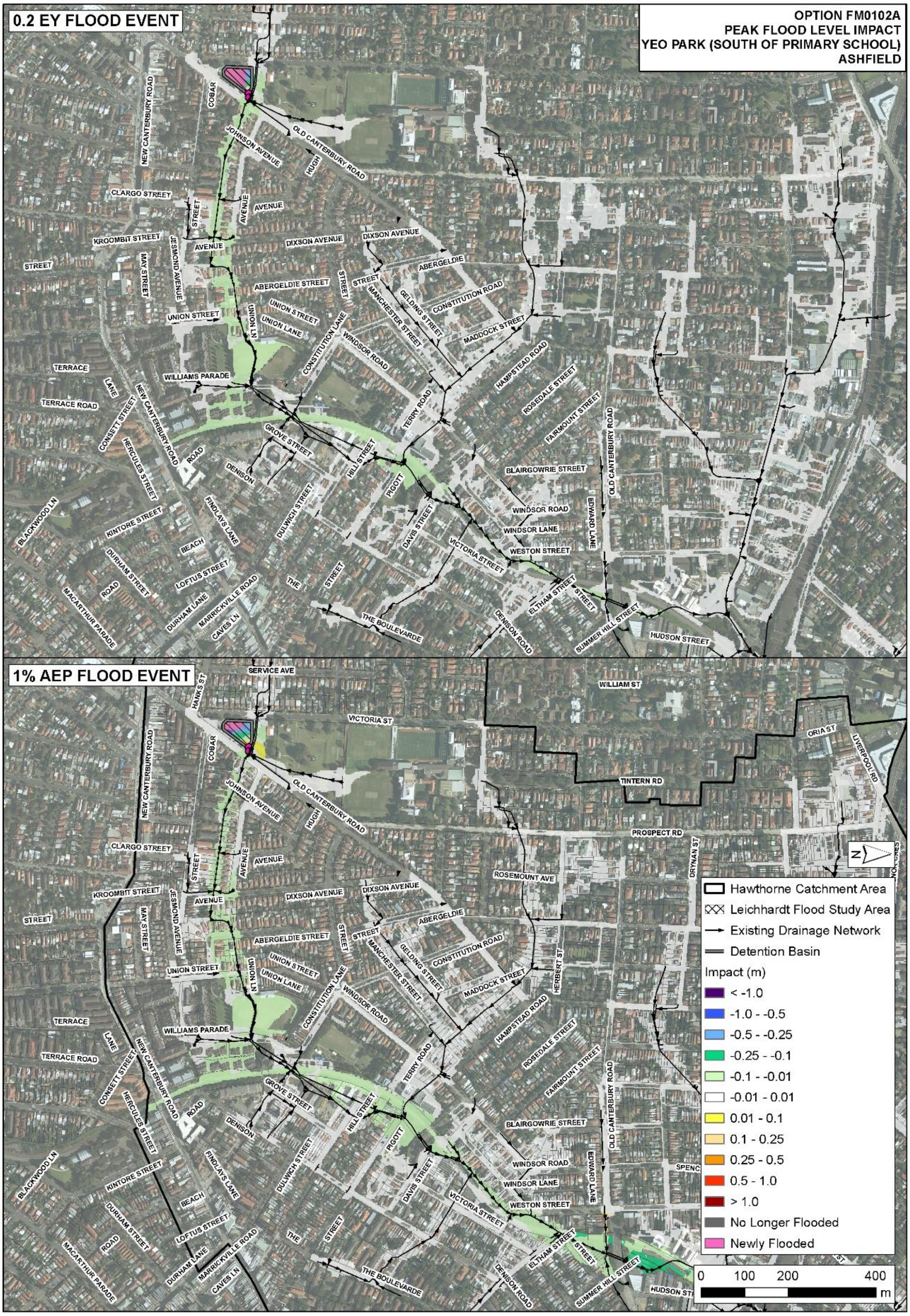
In the 0.2 EY and 1% AEP event, the peak flood levels decrease by up to 0.1 m for the flowpath extending downstream to Old Canterbury Road affecting a number of properties including adjacent to the Canal. This reduction is in comparison to existing depths of between 0.2 m and 0.6 m. One property is no longer affected above floor level for the 0.2 EY event, and two properties in the 1% AEP (Table 17). There is no adverse impact to Yeo Park Infants school. However, in the 1% AEP event, there is an increase in flood levels east of the school (between the school and Old Canterbury Road). This presents an increased risk adjacent to the school.

Table 17 – Over floor Property Affectation FM0102A

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0102A)**	**Change**
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	52	-1
5% AEP	75	74	-1
2% AEP	100	99	-1
1% AEP	120	118	-2
PMF	537	513	-24

There would be some, albeit limited, benefit to property over floor affection in the area however this would be marginal (and thus limited changes to the estimated AAD), especially when considering the additional risks due to flood depths in an area adjacent to an infants school. As a result of the minor impact on flood behaviour, this option is <u>not recommended</u> for further consideration.

Diagram B3: Option FM0102A Schematisation and Impacts 0.2 EY and 1% AEP Events



B.1.4. FM0103A: Elizabeth Avenue Drainage Upgrade

This option proposes a pipe upgrade beginning at Old Canterbury Road. The proposed 1200 mm diameter pipe would travel north along Old Canterbury Road, before travelling along Elizabeth Avenue, Dixson Avenue and between properties (same location as existing SWC system). The aim is to increase pipe capacity and reduce flooding along the existing overland flowpaths.

Diagram B4 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

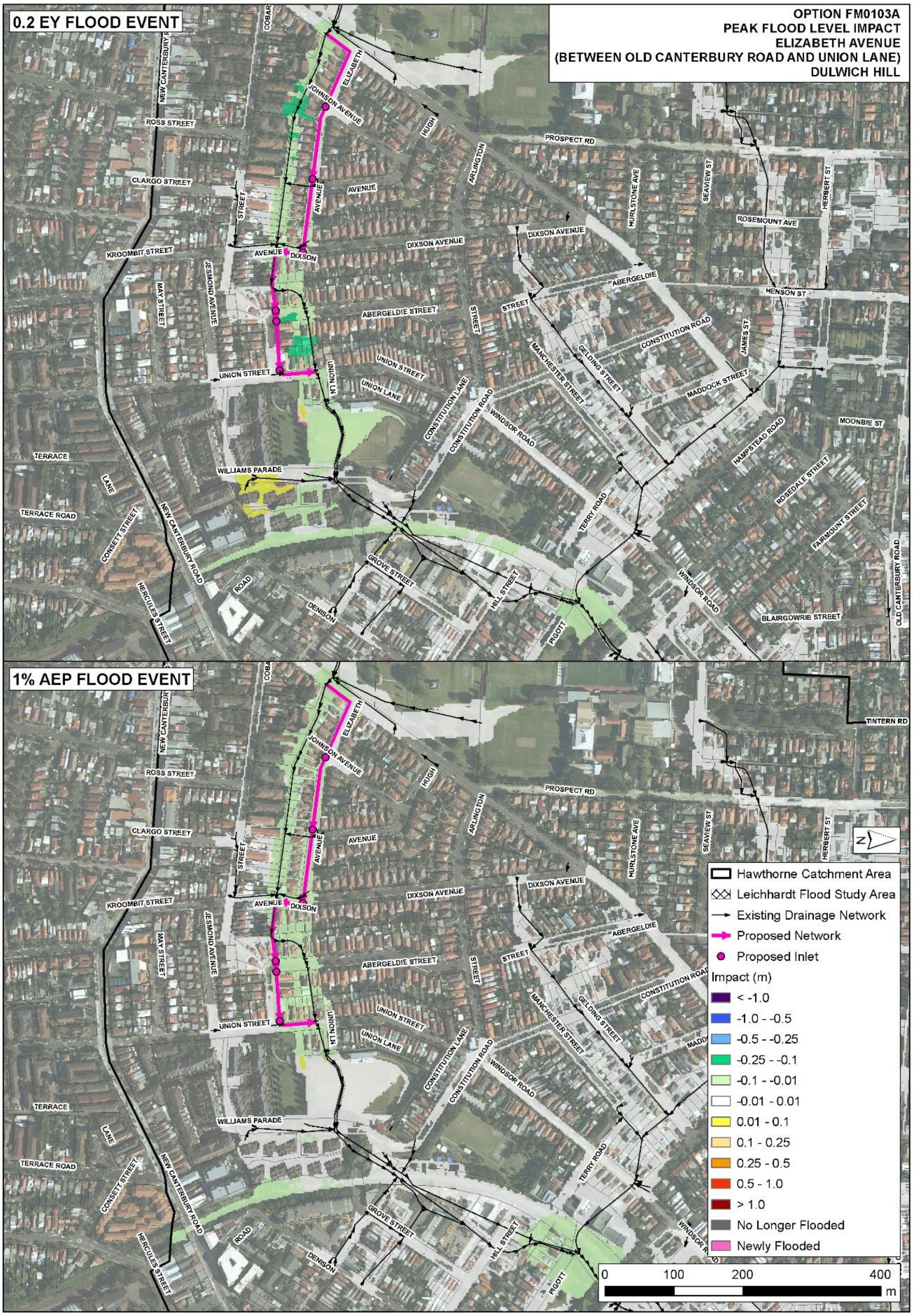
In the 0.2 EY event, the peak flood levels typically decrease by 0.01 to 0.1 m between Old Canterbury Road and Hawthorne Canal, in comparison to existing depths of between 0.2 m and 0.6 m. Several locations are observed to have decreases in flood levels up to 0.25 m including Abergeldie Street and properties between Elizabeth Avenue and Cobar Street. An increase in flood level is observed in the area surrounding Williams Parade (downstream). This is due to stormwater network reaching capacity earlier upstream due to the proposed pipe network preventing flow around Williams Parade entering the stormwater system. In the 1% AEP event, peak flood levels typically decrease by up to 0.1 m between Old Canterbury Road and Union Lane, in comparison to existing depths of up to 0.8m. One property becomes not flood affected above floor in both the 0.2EY and 1% AEP event (Table 18).

Table 18 – Over floor Property Affectation FM0103A

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0103A)**	**Change**
0.5EY	12	11	0
0.2EY	37	36	-1
10% AEP	53	52	-1
5% AEP	75	74	-1
2% AEP	100	99	-1
1% AEP	120	119	-1
PMF	537	535	-2

As a result of the negligible impact on flood behaviour and substantial costs this option is <u>not recommended</u> for further consideration.

Diagram B4: Option FM0103A Schematisation and Impacts 0.2 EY and 1% AEP Events



B.1.5. FM0104C & FM0104D: Arlington Recreation Grounds Detention Basin

These two options are based on utilising Arlington Recreation Grounds as an above-ground detention basin during flood events. For both options, the proposed design includes replacing the existing metal fence that is along the eastern boundary (parallel to Williams Parade) with a 0.6 m high impermeable wall. The wall would extend from the club house at the north-east corner of the site (as seen in Photo 1) and continue along the eastern boundary and approximately 25 m along the southern boundary. A wall height of 0.6 m would ensure that the club house is not affected above floor by inundation.

Photo 1 – Arlington Recreational Grounds - existing fence and club house along the eastern boundary

A ramp for roadway access to the grounds would be located at the current location (south east boundary of the site). Option FM0104C would have a permanent ramp, extending from Williams Parade up to 0.6 m above ground level to line up with the impermeable wall. Two other ramp heights of 0.15 m and 0.3 m were also assessed which produced no benefit mainly due to reduced storage and were not further considered. In option FM0104D a flood gate is also considered at the same location as the roadway. The floodgate would be triggered, and the fence would close, during events greater than the 5% AEP event. In both of these scenarios, the total storage available is approximately 8,300m^3. A floodgate has the potential for failure in floods due to poor maintenance or an unforseen issue arising during the event.

Diagram B5 and Diagram B6 show the schematisation of the options and their impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event for FM0104C, peak flood levels decrease by up to 0.1 m downstream of the proposed detention basin in comparison to existing depths of up to 0.5 m. In the 1% AEP event, the decrease in flood levels is more significant, with flood levels within Hawthorne Canal and adjacent properties decreasing in the order of 0.01 to 0.5 m, in comparison to existing depths of between 0.7 m and 0.9 m. The number of properties no longer affected above floor level is 1 and 2 for the 0.2 EY and 1% AEP events respectively.

In the 0.2 EY event for FM0104D, peak flood levels decrease up to 0.1 m downstream of the proposed detention basin. In the 1% AEP event, the decrease in flood levels is more significant, with flood levels within Hawthorne Canal and adjacent properties decreasing in the order of 0.01 to 0.5 m. The number of properties no longer affected above floor level is 1 and 2 for the 0.2 EY and 1% AEP events respectively (Table 19).

In order to achieve a BCR of less than 1.0, both options would need to be costed at less than $500,000.

Table 19 – Over floor Property Affectation FM0104C and FM0104D

Event	Properties Flooded Overfloor		Change
	Current	With Option (FM0104C and FM00104D)	
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	51	-2
5% AEP	75	74	-1
2% AEP	100	99	-1
1% AEP	120	118	-2
PMF	537	533	-4

As a result of the negligible impact on flood behaviour, and potential high costs associated with flooding and damaging the turf, this option is not recommended for further consideration.

Diagram B5: Option FM0104C Schematisation and Impacts 0.2 EY and 1% AEP Events

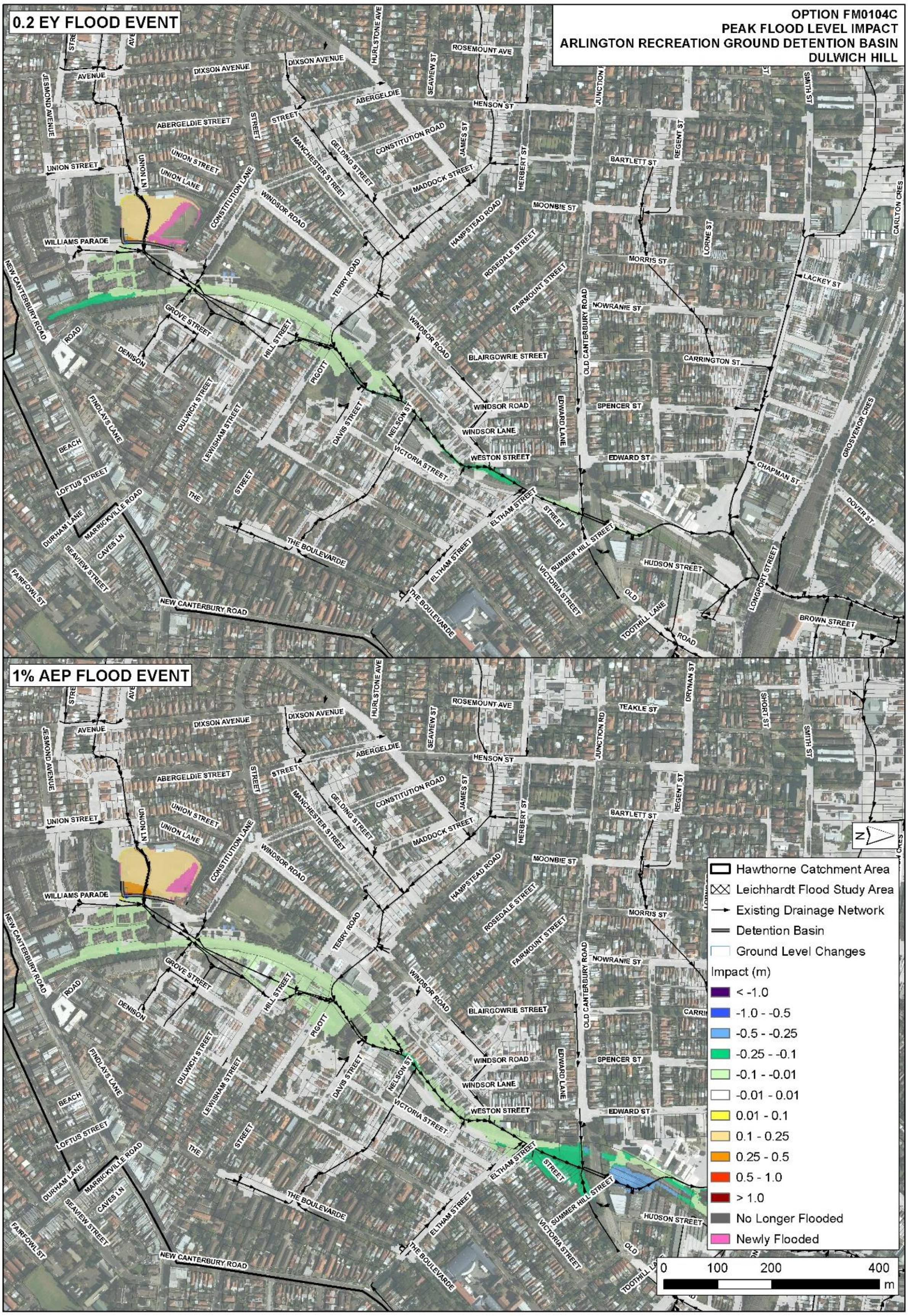
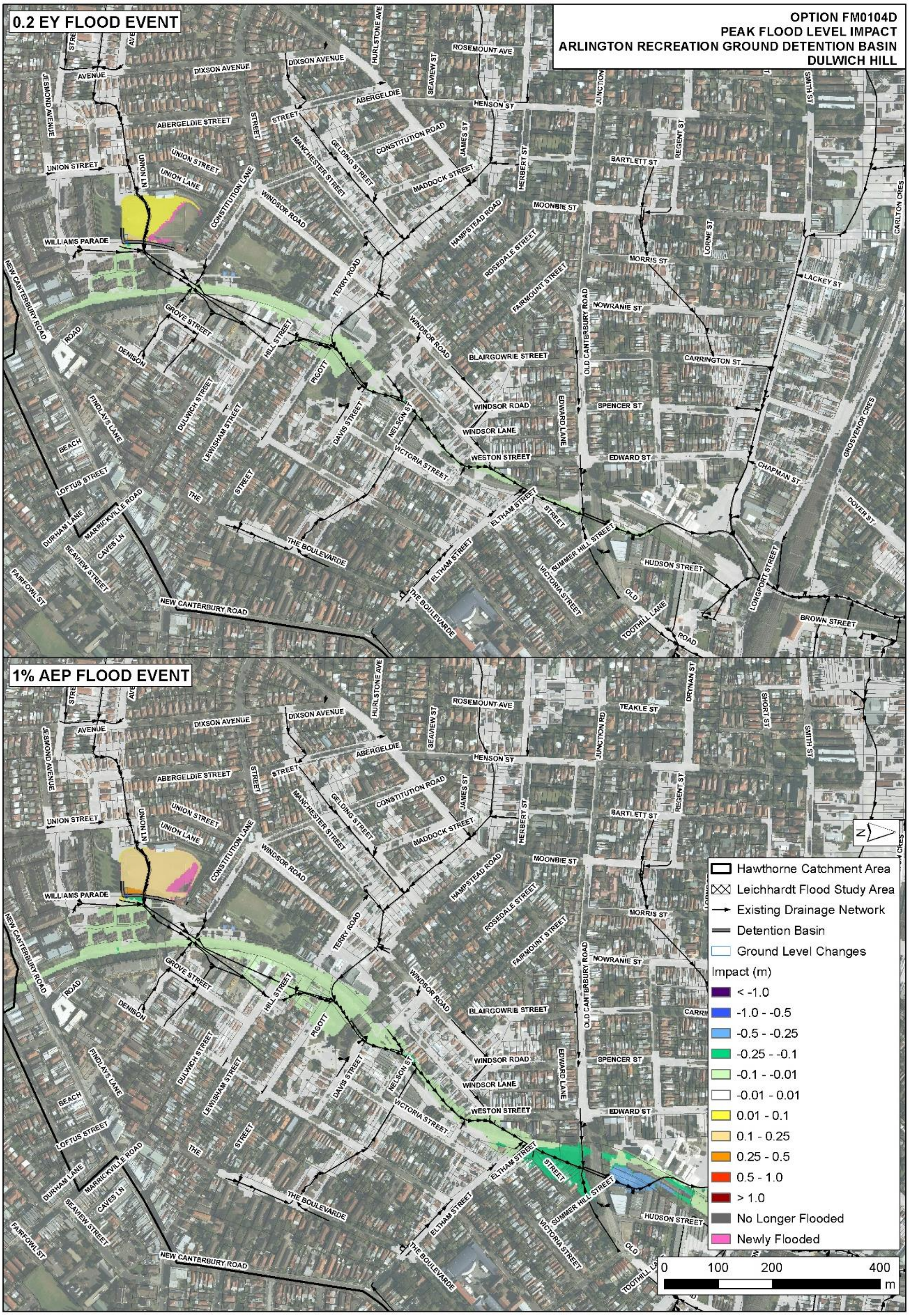


Diagram B6: Option FM0104D Schematisation and Impacts 0.2 EY and 1% AEP Events



B.2. Hotspot H03 – Light Rail Track

B.2.1. FM0301B: The Boulevarde to Hawthorne Canal Drainage Upgrade

This option proposes a pipe duplication of an existing 750 mm diameter pipe extending from The Boulevarde, through Dennis Road and Victoria Street, then into Hawthorne Canal. This option includes modification to the pipe network under the light rail track. The aim is to reduce flooding along The Boulevarde flowpath.

An earlier iteration of option FM0301B, FM0301A was also considered and discarded.

Diagram B7 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, the peak flood levels decrease by up to 0.1 m between The Boulevarde and Hawthorne Canal, in comparison to existing depths up to 0.4 m. Minor decreases are also within Hawthorne Canal. In the 1% AEP event, peak flood levels decrease by up to 0.1 m between The Boulevarde and Hawthorne Canal, in comparison to existing depths up to 0.6 m.

Table 20 – Over floor Property Affectation FM0301B

	Properties Flooded Overfloor		
Event	Current	With Option (FM0301B)	Change
0.5EY	12	12	0
0.2EY	37	37	0
10% AEP	53	53	0
5% AEP	75	75	0
2% AEP	100	100	0
1% AEP	120	120	0
PMF	537	537	0

The limited impact on peak flood levels would result in no change to property affectation (Table 20) in the Hawthorne Canal catchment. As a result of the negligible impact on flood behaviour and high likely costs this option is not recommended for further consideration.

Diagram B7: Option FM0301B Schematisation and Impacts 0.2 EY and 1% AEP Events

B.2.2. FM0302A: The Boulevarde to Hawthorne Canal Underground Detention Basin

This option proposes an under-road detention basin and rain-garden on the road and verge of The Boulevarde. The aim is to detain water within the detention basin, alleviating flooding along The Boulevarde flowpath. The option involves two existing 0.3 m diameter pipes along The Boulevarde discharging flow into a detention basin (dimensions L 42 m x W 10 m x H 1.5 m) beneath the road. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing 0.75 m diameter pipe where it continues downstream and eventually discharging into Hawthorne Canal.

Diagram B8 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, the peak flood levels decrease by up to 0.1 m between The Boulevarde and Hawthorne Canal, in comparison to existing depths up to 0.4 m. However, an increase in flood levels is observed within Hawthorne Canal. This is due to flow being discharged into Hawthorne Canal at a later time where it converges with the peak flow from upstream. In the 1% AEP event, there are no discernible impacts on flood levels. This is likely due to the detention basin not having enough capacity.

Table 21 – Over floor Property Affectation FM0302A

	Properties Flooded Overfloor		
Event	Current	With Option (FM0302A)	Change
0.5EY	12	12	0
0.2EY	37	37	0
10% AEP	53	53	0
5% AEP	75	75	0
2% AEP	100	100	0
1% AEP	120	120	0
PMF	537	533	-4

The limited impact on peak flood levels would result in no change to property affectation in the Hawthorne Canal catchment (Table 21). As a result of the negligible impact on flood behaviour this option is not recommended for further consideration.

Diagram B8: Option FM0302A Schematisation and Impacts 0.2 EY and 1% AEP Events

B.2.3. FM0303A: Denison Road to Old Canterbury Road Drainage Upgrade

This option includes a 900 mm diameter pipe beginning at the intersection of Hunter Street and Denison Road, which travels along Dension Road, Hobbs Street and Jubilee Street before connecting to the existing drainage network on Old Canterbury Road. The aim is to divert flow from the surface into the stormwater pipe so flooding is reduced along the overland flowpath between Denison Road and Old Canterbury Road.

Diagram B9 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

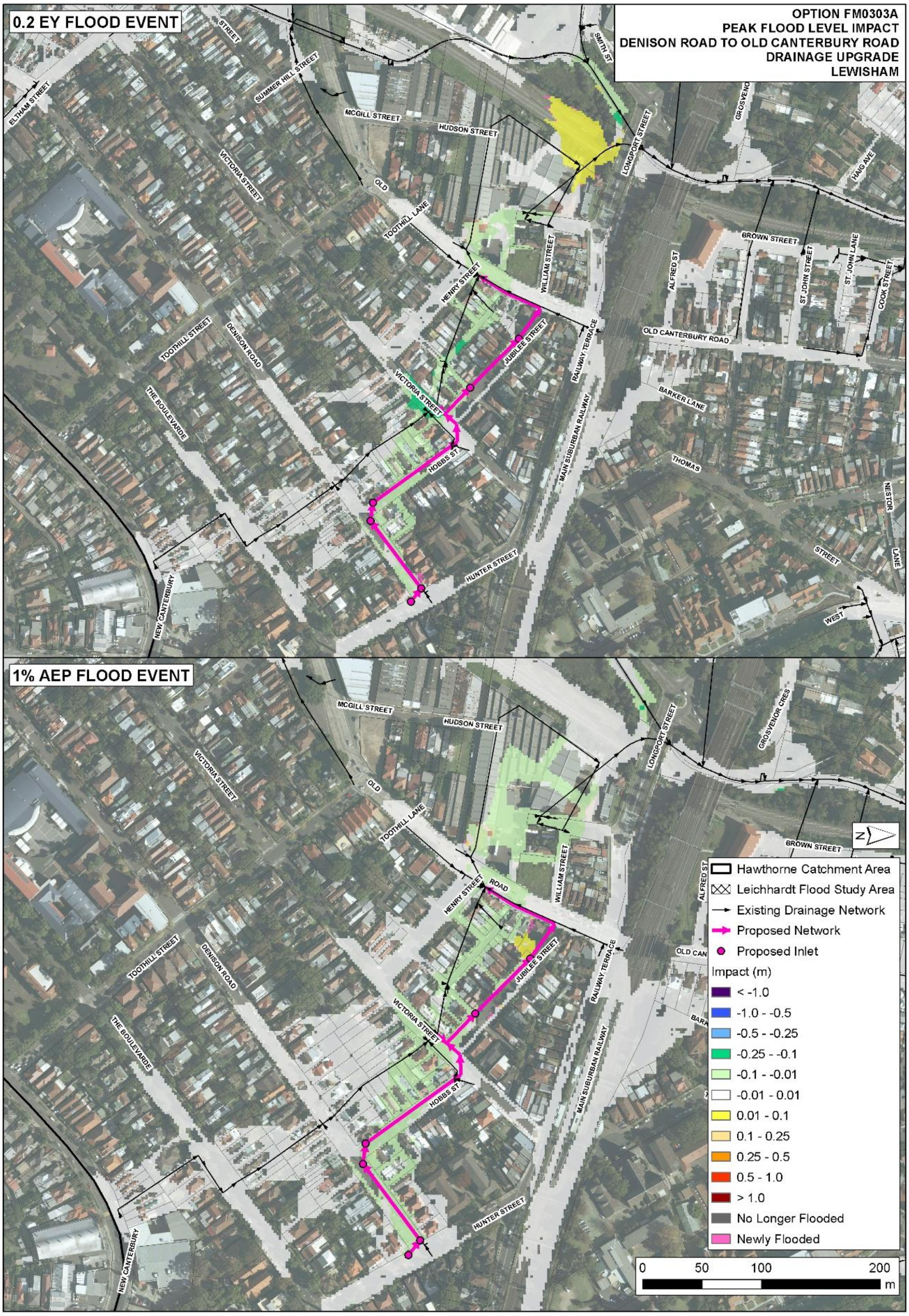
In the 0.2 EY event, the peak flood levels typically decrease by up to 0.1 m between the intersection of Hunter Street and Denison Road and William Street, in comparison to existing depths up to 0.4 m. However, an increase in flood levels is observed within Hawthorne Canal. This is due more flow discharging into Hawthorne Canal. In the 1% AEP event, the peak flood levels typically decrease by up to 0.1 m between the intersection of Hunter Street and Denison Road and William Street, in comparison to existing depths up to 0.7 m. An increase in flood levels is observed in properties along Jubilee Street due to the proposed pipe reaching capacity and the pit surcharging.

Table 22 – Over floor Property Affectation FM0303A

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0303A)**	**Change**
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	51	-2
5% AEP	75	75	0
2% AEP	100	100	0
1% AEP	120	120	0
PMF	537	518	-19

The limited impact on peak flood levels would result in limited to property affectation in the Hawthorne Canal catchment (Table 22). As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram B9: Option FM0303A Schematisation and Impacts 0.2 EY and 1% AEP Events



B.2.4. FM0303B: Denison Road to Old Canterbury Road Drainage

This option proposes a new drainage network starting at the intersection of Hunter Street and Denison Road. A 900 mm diameter pipe is proposed that travels along Denison Road, Hobbs Street and Jubilee Street before connecting to the existing box culvert (1 m W x 0.9 m H) at Old Canterbury Road.

Diagram B10 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

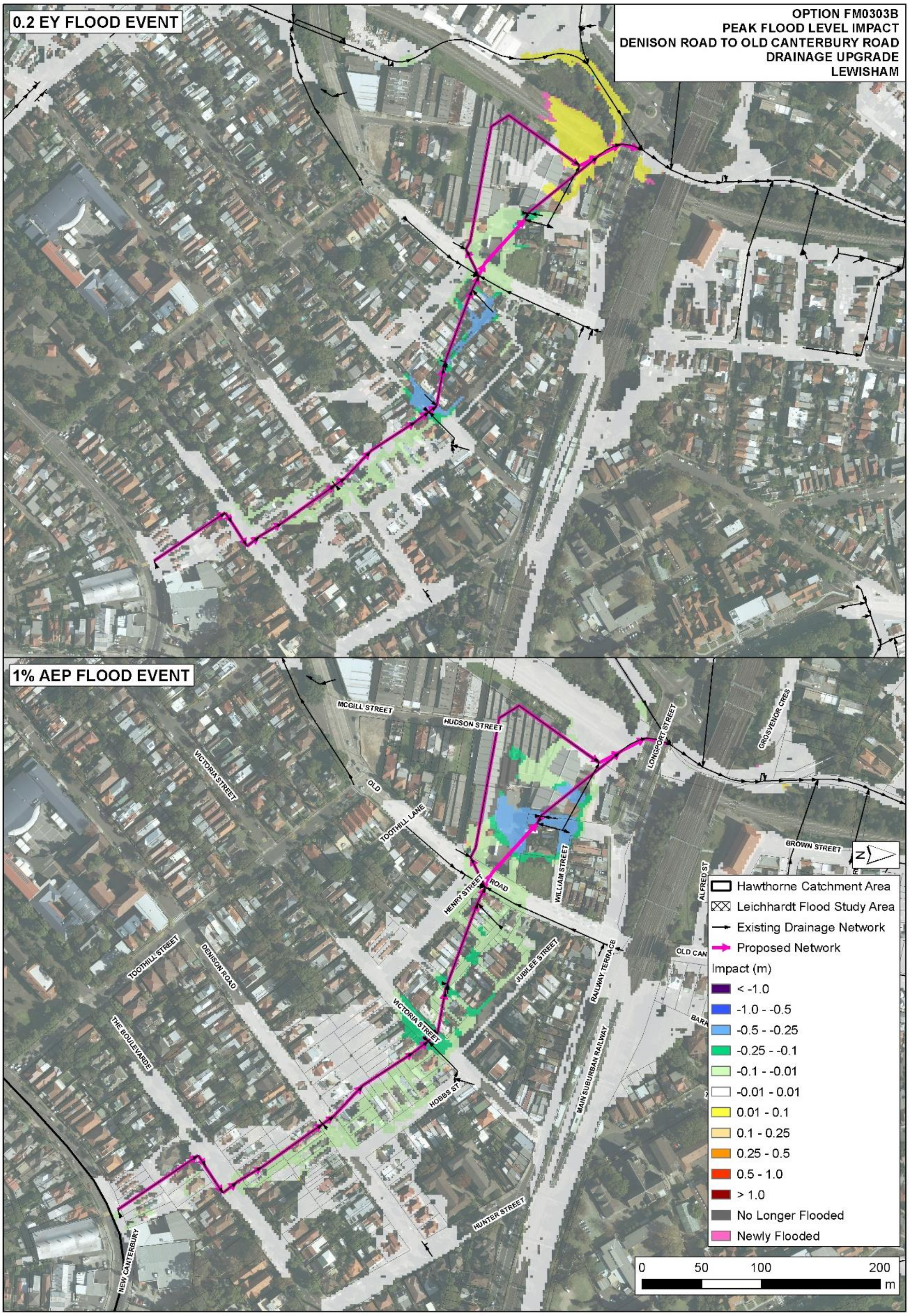
In the 0.2 EY event, decreases in flood levels are observed along the flowpath between Denison Road and Hawthorne Canal. Between Victoria Street and Old Canterbury Road, the decreases are between 0.01 and 0.4 m, in comparison to existing depths up to 0.5 m. However, there is an increase in flood levels of up to 0.1 m where the proposed drainage network discharges into Hawthorne Canal. In the 1% AEP event, the decreases are similar to that in the 0.2 EY event, however, there are no increases in flood levels. Considering existing depths in the order of 0.7 m, up to 0.2 m depths remain.

Table 23 – Over floor Property Affectation FM0303B

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0303B)**	**Change**
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	51	-2
5% AEP	75	75	0
2% AEP	100	100	0
1% AEP	120	120	0
PMF	537	518	-19

The limited impact on peak flood levels would result in limited change to property affectation in the Hawthorne Canal catchment (Table 23). As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram B10: Option FM0303B Schematisation and Impacts 0.2 EY and 1% AEP Events



B.3. Hotspot H02 – Grosvenor Crescent, Summer Hill

B.3.1. FM0401A: Grosvenor Crescent Underground Detention Basin

This option proposes an under-road detention basin in Grosvenor Crescent. Its purpose is to temporarily store water during frequent rainfall events, and discharge the flow at a later time where the outflow is regulated through flow-control structures.

The option involves an inlet pit at a topographical low point in Grosvenor Crescent where overland flow is diverted into a detention basin (dimensions L 47 m x W 8.0 m x H 0.6 m) beneath the road. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing 550 mm diameter pipe where it travels underneath the railway embankment.

Diagram B11 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

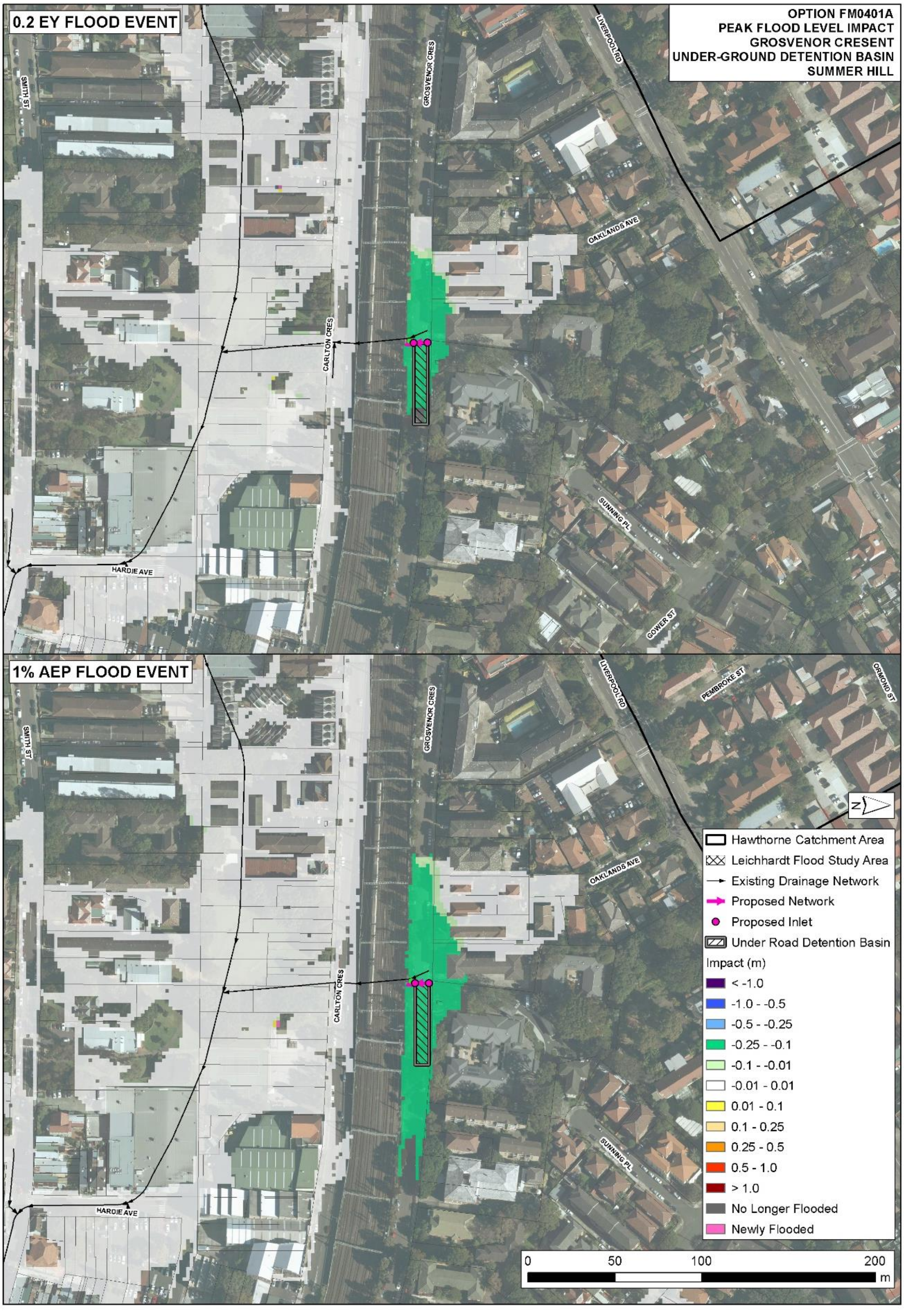
In both the 0.2 EY and 1% AEP events, the peak flood levels in Grosvenor Crescent decrease by 0.2 m and 0.1 m respectively. This is in comparison to existing depths of 0.9 m and 1.5 m for the same two events. The road would still be considered cut-off during all flood events. There is no change to the flood behaviour downstream of the railway embankment. The aim of this option is to improve road trafficability and as such has limited impact on over floor inundation (Table 24).

Table 24 – Over floor Property Affectation FM0401A

	Properties Flooded Overfloor		
Event	Current	With Option (FM0401A)	Change
0.5EY	12	12	0
0.2EY	37	37	0
10% AEP	53	53	0
5% AEP	75	75	0
2% AEP	100	99	-1
1% AEP	120	120	0
PMF	537	535	-2

As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram B11: Option FM0401A Schematisation and Impacts 0.2 EY and 1% AEP Events



B.3.2. FM0404B: Nowranie Street to Hawthorne Canal Drainage Upgrade

This option proposes a 1.2 m diameter pipe beginning within a drainage easement between Morris Street and Nowranie Street diverting flow from an existing Council pipe. The proposed pipe will travel east along Wellesley Street, between properties along Edward Street before spilling into Hawthorne Canal. The aim is to divert water from the existing stormwater pipe to allow a greater capacity for overland flow and reduce flooding between Nowranie Street and Smith Street through to Hawthorne Canal.

An earlier iteration of option FM0404B, FM0404A was also considered and discarded.

Diagram B12 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY and 1% AEP event, the peak flood levels typically decrease by up to 0.1 m between Morris Street and Edward Street, in comparison to existing depths of up to 0.7 m. However, in both events, an increase in flood levels is observed in Hawthorne Canal and adjacent properties upstream of where the proposed pipe discharges. This is likely due to the area where the proposed pipe discharges into being highly sensitive to flow change as it is located between two hydraulic structures.

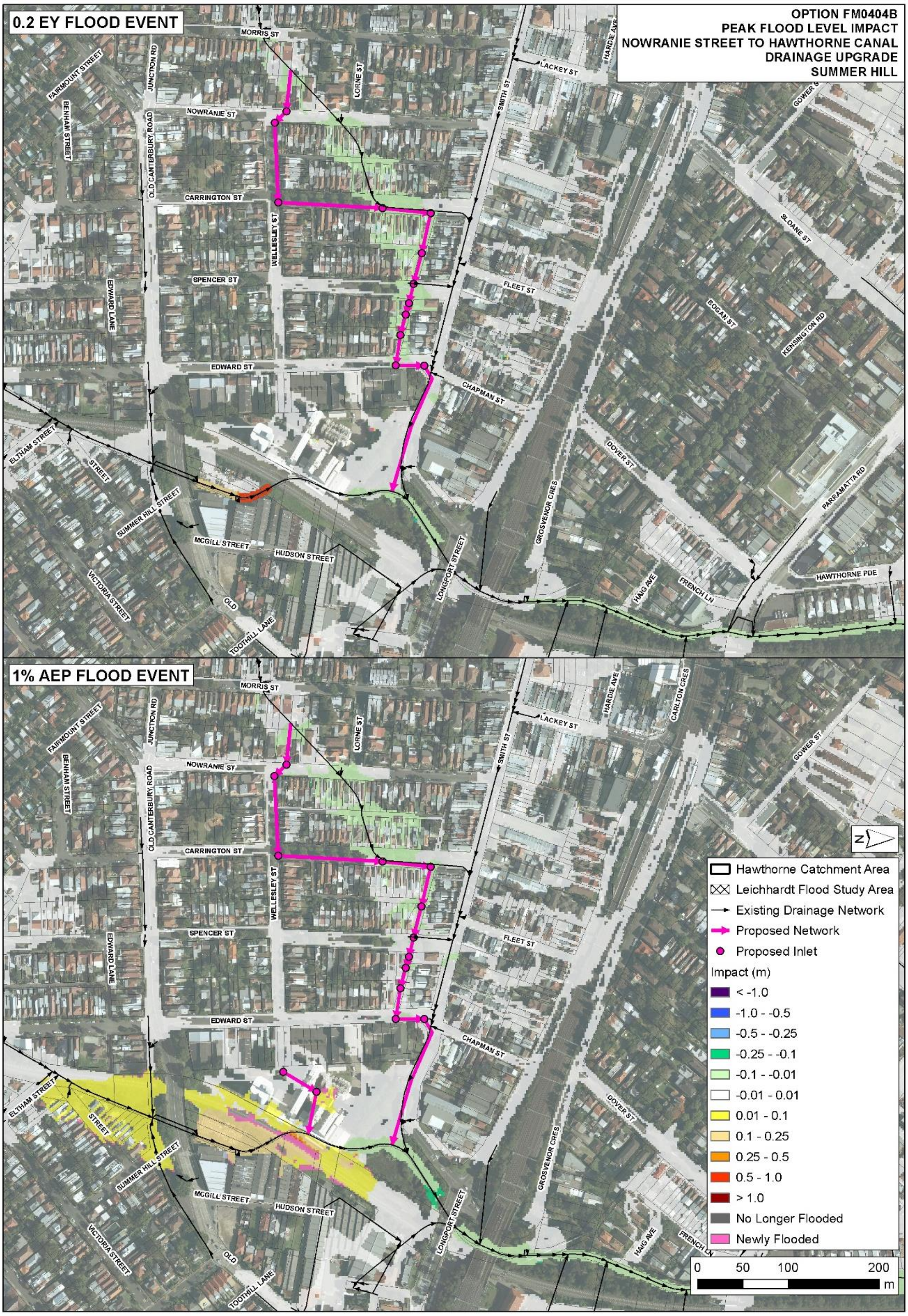
Table 25 – Over floor Property Affectation FM0404B

	Properties Flooded Overfloor		
Event	Current	With Option (FM0404B)	Change
0.5EY	12	12	0
0.2EY	37	35	-2
10% AEP	53	53	0
5% AEP	75	72	-3
2% AEP	100	100	0
1% AEP	120	121	1
PMF	537	532	-5

The limited impact on peak flood levels would result in limited change to property affectation in the Hawthorne Canal catchment (Table 25). As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

FM0404C also considered a pipe upgraded through this area, was shown to provide greater benefit and is assessed further in Section 10.2.9.2.

Diagram B12: Option FM0404B Schematisation and Impacts 0.2 EY and 1% AEP Events



B.4. Hawthorne Canal - Other

B.4.1. FM0501C, FM0501D, FM0501E, FM0501F Petersham Park Above Ground Detention Basin

This option proposes to utilise Petersham Park as an above-ground detention basin during flood events. Various configurations were modelled to assess the impacts on peak flood levels and these are discussed below.

FM0501C: At the northern boundary of Petersham Park (parallel to Station Street) the ground levels would be raised to 14.4 m AHD (0.5 m to 2 m higher than current ground levels) for approximately 130 m along the pedestrian walkway that surrounds the oval. A spillway, at a level of 14.15 m AHD would be installed at the current vehicle access point (currently at approximately 12.5 m AHD). The approximate storage of the proposed basin would be 2,350,000 m^3. Vehicle access would still be available. That is, the entry and exit grade from ground level to the top of the spillway would still allow for access to the Park.

Diagram B13 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, peak flood levels between Petersham Park and Hawthorne Canal typically decrease by up to 0.1 m, whilst some areas (particularly properties along Station Street) decrease by up to 0.2 m. The proposed detention basin does not spill during this event. In the 1% AEP event, flood levels decrease by between 0.1 m – 0.5m along the downstream flowpath. The capacity of the detention basin is exceeded, and flow overtops predominately around the western side of the cricket field, newly flooding the north western portion of Petersham Park. In the 1% AEP event, 4 properties are no longer flooded above floor level. There is no change to property affectation in the 0.2EY.

FM0501D: Ground levels at the current vehicle access along the north boundary of Petersham Park (in Station Street) would be increased from 12.5 m AHD to 12.9 m AHD. This will increase the amount of flood storage of the park whilst reducing the amount of construction. The approximate storage of the proposed basin is 570,000 m^3. Vehicle access will be maintained for this option.

Diagram B14 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, isolated areas along the downstream flowpath have a decrease in peak flood levels up to 0.1 m. For the 1% AEP event, there is an increase in flood levels where the detention basin overtops at the vehicle access and pedestrian pathway just to the east. This results in a number of properties along Station Street being affected with an increase of 0.2 m of flooding. In the 1% AEP event, only one property is no longer flooded above floor level. There is no change to property affectation in the 0.2EY.

FM0501E & FM0501F: At the northern boundary of Petersham Park (parallel to Station Street) the current pedestrian walkway would be redesigned to increase the ground levels to create a large storage basin. The current vehicle access point would be increased from 12.5 m AHD to 13.2 m AHD and would act as the spillway. Vehicle access to the park will be maintained with a ramp installed. On the western side of the vehicle access, the pedestrian walkway will ramp from 13.2 m AHD to 14.2 m AHD and tie in with existing ground levels approximately 40 m away. On the eastern side of the vehicle access, the pedestrian walkway will ramp from 13.2 m AHD to 13.9 m AHD and also tie in with existing ground levels approximately 20 m away.

As the proposed design alters ground levels to the west of the vehicle access point, an existing heritage stone wall extending along the pedestrian walkway will need to be reinstalled.

Diagram B15 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, peak flood levels between Petersham Park and Hawthorne Canal typically decrease by up to 0.1 m, this is in comparison to existing depths between 0.6 m and 0.9 m. The proposed detention basin does not spill during this event. In the 1% AEP event, flood levels decrease by between 0.1 m – 0.5m along the downstream flowpath, in comparison to existing depths of 0.8 m and 1.5 m. The capacity of the detention basin is exceeded, where flow overtops predominately around the eastern side of the cricket field, inundating the north eastern portion of Petersham Park. In the 1% AEP event, only one property is no longer flooded above floor level. There is no change to property affectation in the 0.2EY.

The boundary of the Marrickville Council LGA is located at Parramatta Road, approximately 90 m downstream of Petersham Park. As such, only a small number of properties between Station Street and Parramatta Road are included in the floor level assessment. As a result, the full monetary benefit of this option has not been evaluated.

The limited impact on peak flood levels would result in limited or no change to property affectation in the Hawthorne Canal catchment. As a result of the negligible impact on flood behaviour these options are <u>not recommended</u> for further consideration.

An option considering an alternative arrangement (FM0404C – Section 10.2.9.2) was found to offer greater benefits and is assessed further.

Diagram B13: Option FM0501C Schematisation and Impacts 0.2 EY and 1% AEP Events

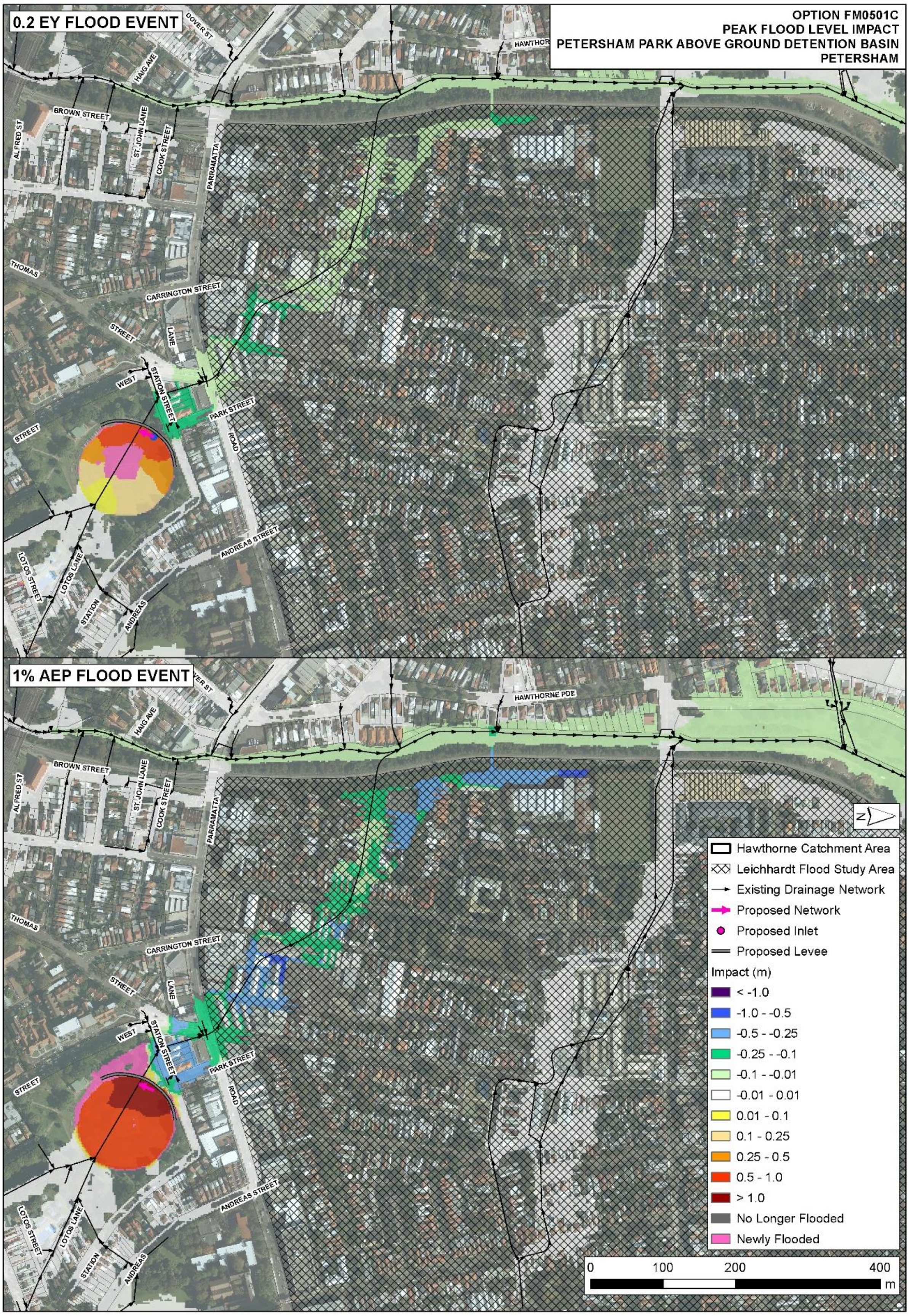


Diagram B14: Option FM0501D Schematisation and Impacts 0.2 EY and 1% AEP Events

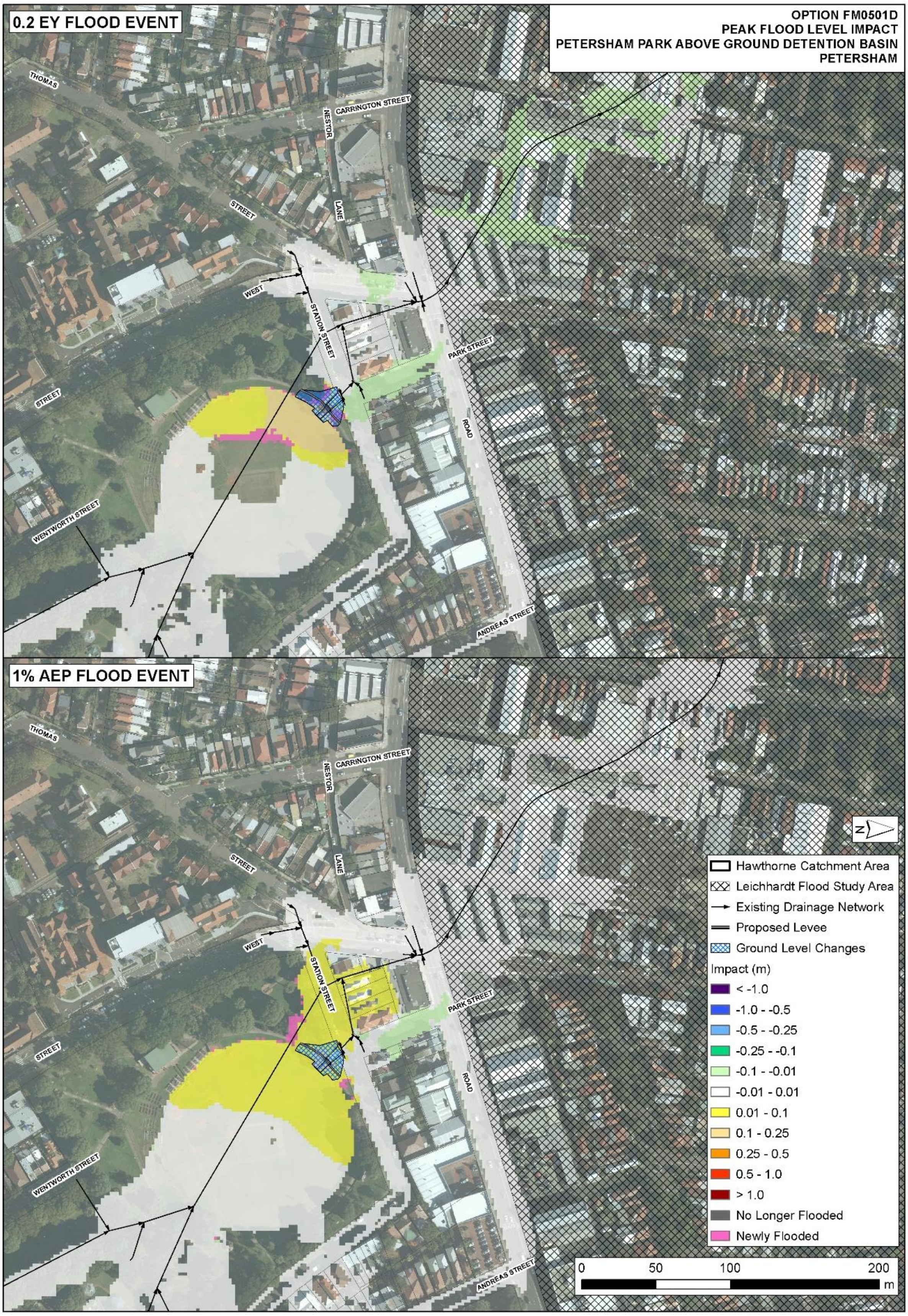
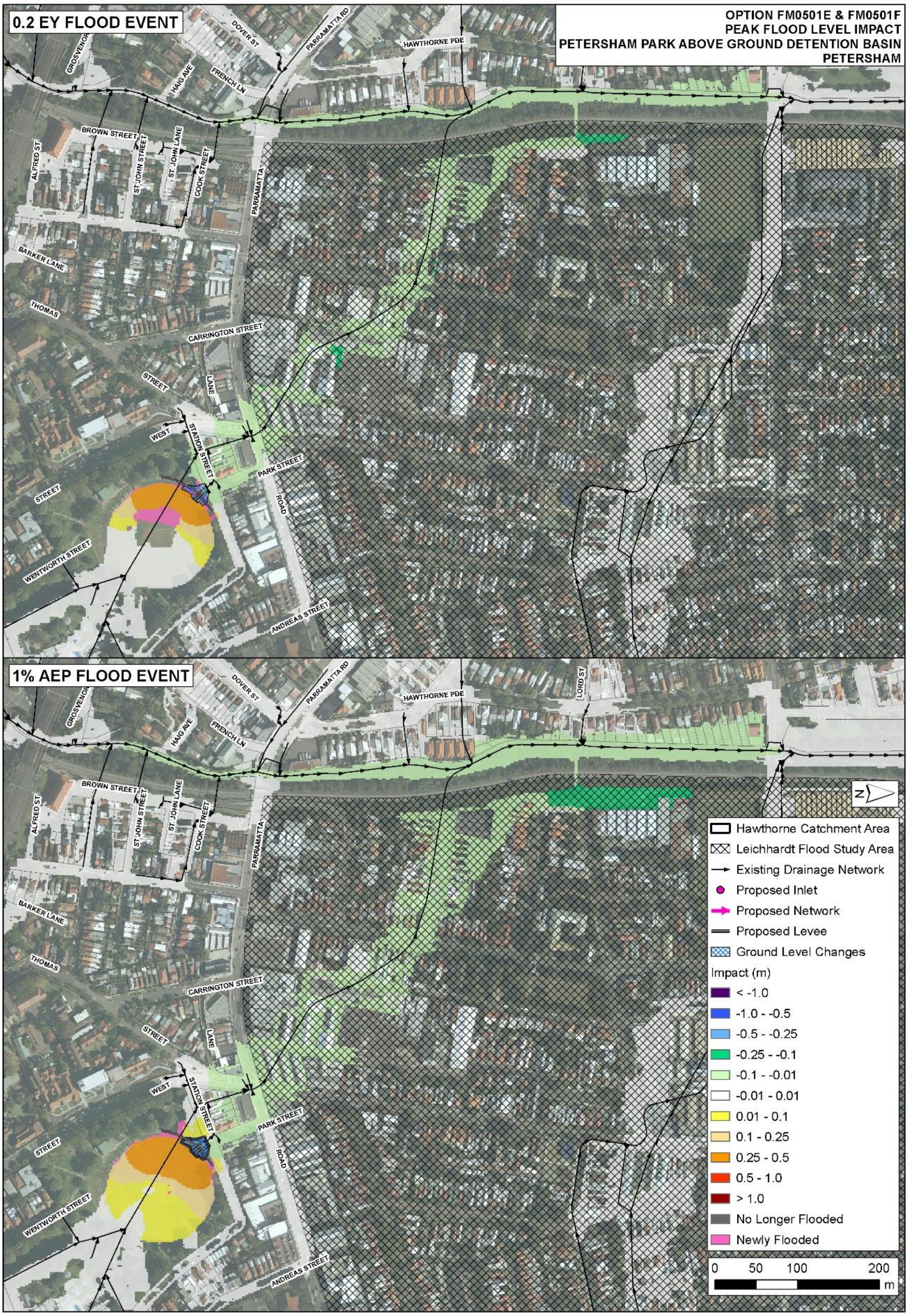


Diagram B15: Option FM0501E & FM0501F Schematisation and Impacts 0.2 EY and 1% AEP Events



B.5. Hotspot H04 – Sloane Street, Summer Hill/Haberfield

B.5.1. FM0601B: Ashfield Park to Hawthorne Canal Drainage Upgrade

This option proposes a new 0.9 m diameter drainage network extending from Ashfield Park, travelling along St Davids Road and through Daragh Lane where it connects into the existing Council owned drainage network. The aim is to reduce flooding in the O'Connor Street flowpath.

Other iterations of option FM0601B, FM0601A and FM0601C were also considered and discarded.

Diagram B16 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

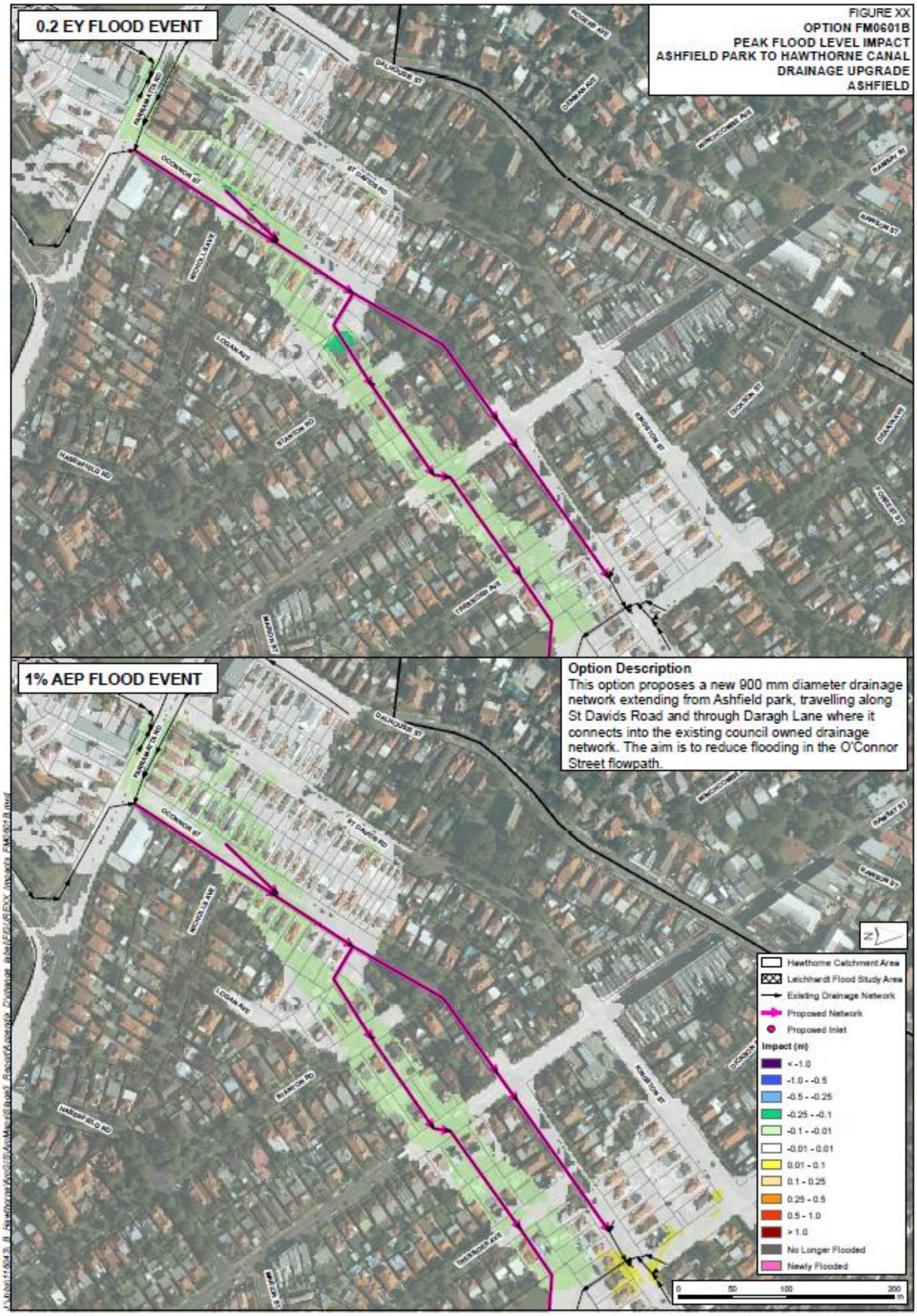
In the 0.2 EY event, the peak flood levels have decreased by up to 0.1 m between Parramatta Road and Tressider Avenue, in comparison to existing depths of 0.4 m. Similar decreases are observed in the 1% AEP event, in comparison to existing depths of 0.7 m. There are increases in flood levels of 0.03 m along Deaks Avenue, O'Connor Street as well as several properties on the downstream side of O'Connor Street adjacent to the drainage reserve. These increases are due to flow surcharging from the pits in this location.

Table 26 – Over floor Property Affectation FM0601B

	Properties Flooded Overfloor		
Event	**Current**	**With Option (FM0601B)**	**Change**
0.5EY	12	12	0
0.2EY	37	37	0
10% AEP	53	52	-1
5% AEP	75	73	-2
2% AEP	100	97	-3
1% AEP	120	118	-2
PMF	537	536	-1

The limited impact on peak flood levels would result in limited change to property affectation in the Hawthorne Canal catchment (Table 26). As a result of the negligible impact on flood behaviour this option is not recommended for further consideration.

Diagram B16: Option FM0601B Schematisation and Impacts 0.2 EY and 1% AEP Events



B.5.2. FM0605A, FM0605B: Sloane Street Drainage Upgrade

These options propose to alleviate overland flooding from Sloane Street through to Hawthorne Canal by providing drainage upgrades. Various configurations were modelled to assess the impacts on peak flood levels. These are discussed below.

Option FM0605A proposes a drainage network commencing at the intersection of Sloane Street and Parramatta Road where flow within two existing pipes (0.6 m and 0.45 m diameter) are diverted into a 1.2 m diameter pipe travelling under Parramatta Road, along Sloane Street and Lord Street where it then discharges into Hawthorne Canal. This option includes maintaining the existing drainage network. The aim is to reduce flooding on Parramatta Road near Sloane Street and the downstream flowpath.

Diagram B17 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

Option FM0605B proposes a drainage network commencing at the intersection of Sloane Street and Parramatta Road. Flow within an existing 0.6 diameter pipe travelling under Parramatta Road would be diverted into a new 1.2 m diameter pipe that travels a short distance along Parramatta Road, then along Sloane Street, Lord Street and then discharges into Hawthorne Canal. This option includes maintaining the existing drainage network. The aim is to reduce flooding on Parramatta Road near Sloane Street and the downstream flowpath.

Diagram B18 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event for Option FM0605A, peak flood levels decrease within Paramatta Road by 0.15 m, however the road is still cut-off due to the flood depths up to 0.25 m. Downstream of this location, flood levels decrease by 0.3 m within 4 properties whilst the majority of the flowpath decreases by 0.1 m. This continues down to Hawthorne Canal with a small section of Hawthorne Canal also decreasing by around 0.1 m. Two properties are no longer affected above floor level. In the 1% AEP event, peak flood levels decrease by up to 0.1 m for the majority of the flowpath, in comparison to existing depths of up to 0.7 m. Increases in flood levels of approximately 0.01 m are observed within Hawthorne Canal and a number of adjacent properties. Five properties are no longer affected above floor level in the 1% AEP event (Table 27).

Table 27 – Over floor Property Affectation FM0605A

Event	Properties Flooded Overfloor		
	Current	With Option (FM0605A)	Change
0.5EY	12	12	0
0.2EY	37	35	-2
10% AEP	53	46	-7
5% AEP	75	68	-7
2% AEP	100	94	-6
1% AEP	120	115	-5
PMF	537	534	-3

In the 0.2 EY event for Option FM0605B, peak flood levels decrease by 0.1 m from Parramatta Road through to Hawthorne Canal. The flood levels for approximately six properties decrease by 0.2 m. Two properties are no longer affected above floor level. In the 1% AEP event, peak flood levels decrease by up to 0.1 m between Parramatta Road to Hawthorne Parade. Increases in flood levels of approximately 0.01 m are observed within Hawthorne Canal and a number of adjacent properties. Four properties are no longer affected above floor level (Table 28).

Table 28 – Over floor Property Affectation FM0605B

Event	Properties Flooded Overfloor		
	Current	With Option (FM0605B)	Change
0.5EY	12	12	0
0.2EY	37	35	-2
10% AEP	53	47	-6
5% AEP	75	71	-4
2% AEP	100	97	-3
1% AEP	120	116	-4
PMF	537	524	-13

There would be some, albeit limited, benefit to property over floor affection in the area, however this would be marginal, especially when considering the significant construction costs. As a result of the minor impact on flood behaviour and the likely costs, this option is not recommended for further consideration.

Diagram B17: Option FM0605A Schematisation and Impacts 0.2 EY and 1% AEP Events

Diagram B18: Option FM0605B Schematisation and Impacts 0.2 EY and 1% AEP Events

B.5.3. FM0606A: Sloane Street Underground Detention Basin

This option proposes an under-road detention basin in Sloane Street near the intersection of Parramatta Road. Its purpose is to temporarily store water during frequent rainfall events, and discharge the flow at a later time where the outflow is regulated through flow-control structures.

The option involves high inlet pits across Sloane Street to capture overflow flow travelling towards Parramatta Road. Flow is diverted into a detention basin (dimensions L 60 m x W 7.05 m x H 1.2 m) beneath the road. A small 150 mm diameter pipe at the detention basin outlet would pass water back into the existing 0.6 m diameter pipe where it travels underneath Parramatta Road and continues downstream to Hawthorne Canal.

Diagram B19 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In the 0.2 EY event, reductions of peak flood levels are observed only within the road corridor at the intersection of Sloane Street and Parramatta Road and several properties on the downstream side of Parramatta Road, flood depths of 0.25 m remain. In the 1% AEP event, there is no reduction in peak flood levels. From the 0.2 EY event, the flood depths within Parramatta Road exceed 0.3 m, which is considered not accessible.

Table 29 – Over floor Property Affectation FM0606A

	Properties Flooded Ove floor		
Event	**Current**	**With Option (FM0606A)**	**Change**
0.5EY	12	12	0
0.2EY	37	35	0
10% AEP	53	51	-2
5% AEP	75	75	0
2% AEP	100	99	-1
1% AEP	120	118	-2
PMF	537	536	-1

The limited impact on peak flood levels would result in limited change to property affectation in the Hawthorne Canal catchment (Table 29). As a result of the negligible impact on flood behaviour this option is <u>not recommended</u> for further consideration.

Diagram B19: Option FM0606A Schematisation and Impacts 0.2 EY and 1% AEP Events

B.6. Hotspot H06 – Hawthorne Canal

B.6.1. FM0701A: Dudley Street to Hawthorne Canal Upgrade

This option proposes a 0.6 m diameter pipe beginning in Dudley Street, running along Waratah Street and spilling into Hawthorne Canal. Inlet pits in Dudley Street would capture water from the upstream catchment, diverting water from entering the existing drainage network. The aim is to allow greater pipe capacity and reduced flooding between Dudley Street and Kingston Street.

Diagram B20 shows a schematisation of the option and the impacts on peak flood levels for the 0.2 EY and 1% AEP events.

In both the 0.2 EY event and 1% AEP events, there is a decrease in flood levels between Dudley Street and Hawthorne Parade by around 0.1 m. Existing flood depths are up to 0.4 m and 0.6 m for both events. For both flood events, one property no longer becomes flood affected (Table 30).

Table 30 – Over floor Property Affectation FM0701A

	Properties Flooded Overfloor		
Event	Current	With Option (FM0701A)	Change
0.5EY	12	12	0
0.2EY	37	36	-1
10% AEP	53	52	-1
5% AEP	75	75	0
2% AEP	100	98	-2
1% AEP	120	119	-1
PMF	537	523	-14

The limited impact on peak flood levels would result in limited change to property affectation in the Hawthorne Canal catchment. As a result of the negligible impact on flood behaviour this option is not recommended for further consideration.

Diagram B20: Option FM0701A Schematisation and Impacts 0.2 EY and 1% AEP Events

Appendix D

13 October 2016

WRL Ref: L20161013_WRL2016029_gps

Mr Stephen Gray
Director
WMAwater
Level 2
160 Clarence St
Sydney NSW 2000

By email: gray@wmawater.com.au

UNSW AUSTRALIA

Water Research Laboratory

Dear Stephen,

RE: Peer Review of Dobroyd and Hawthorne Canal Flood Studies: Summation

Thank you for your response (your ref: 116043/L160926) to my letter dated 25 May 2016 (our ref: L20160525) in which I sought additional information and clarifications to the WMAwater flood study reports for Dobroyd and Hawthorne Canals. Your response has generally answered my concerns with original reporting of these flood studies. I have appended both these documents to this letter for ease of reference.

Your response provided additional information regarding the flood study data analysis and numerical modelling for the sixteen (16) specific queries that I had raised. I understand that, predominantly, you had the information for your response at-hand, but had not fully documented it in the study reports. I am of the strong opinion that this additional information is important for Council's and the community's understanding of the methods used and assumptions made in the flood studies. I recommend that this additional information and analysis be included in the floodplain management study report as it provides important baseline information for floodplain management decision makers.

I understand that the amalgamation of the former Ashfield, Leichardt and Marrickville Councils to form the Inner West Council has provided the opportunity for the Hawthorne Canal Flood Study to be expanded to include the former Leichardt Council area and the model recalibrated. This will provide an excellent opportunity for WMAwater to update the study with information similar to that provided in your letter of 25 May, 2016.

Based on the combined information from the flood studies, supplemented by the information from your letter, I am of the opinion that the methodology WMAwater applied to audit and review the data available to the studies is sound. Using this available data, the approach applied to configure and interface the hydrologic and hydraulic models is also sound.

The quality of the hydrologic and hydraulic model outputs is highly dependent on the quality of the input datasets. While the topographic data including survey of hydraulic structures used to configure the models is of a generally high quality, the model 'calibration' datasets for historical floods are of lower quality. While indicative of locations that have been flooded in the past, the recorded flood levels are of little use to confirm actual peak flood levels during the events. The ARI of the two historical events available for model calibration/validation are no greater than 10 years ARI. This means that a significant extrapolation of the modelled flood behaviour is required to generate flood planning levels at the 100 year ARI. While the models as configured are suitable for predicting 100 year ARI flood behaviour, careful quantification of the uncertainty bounds on the model results by suitable model sensitivity analysis is recommended so that planning decisions can adequately take this into account.

The modelled design flood behaviour is also characterised by floodwaters ponding behind elevated road and railway embankments (my query xv). While the methods used to configure these hydraulic structures in the model (as described) are generally sound, the predicted flood levels behind these structures are likely to be very sensitive to the adopted model head loss coefficients. Unfortunately, the historical flood events do not provide the opportunity to adequately calibrate the headlosses for design flood planning levels. This being the case, I recommend that the uncertainties associated with the headlosses be similarly quantified by sensitivity analysis.

Yours sincerely,

Grantley Smith
Manager

Attachments:
L20165625_2016029gps_signed.pdf
L161007_ReviewResponse_compressed.pdf

25 May 2016

WRL Ref: L20160525_WRL2016029_gps

Mr Stephen Gray
Director
WMAwater
Level 2, 160 Clarence St
Sydney, NSW, 2000

By email: gray@wmawater.com.au

UNSW AUSTRALIA

Water Research Laboratory

Dear Stephen,

RE: Peer Review of Dobroyd and Hawthorne Canal Flood Studies

I have completed a first pass review of the WMAwater report "Hawthorne Canal Flood Study" dated 28 October, 2014 and noted as Revision 5.

I have a series of questions and clarifications on the report content that are listed below. I'd request that you provide a response to each of these items below, so that I can progress my peer review of the report. I have similar issues with the Dobroyd Canal Flood Study. Since the studies use the same methodology and modelling approach, many of the answers provided below will likely be the same for both studies. Please indicate in your response if this is the case. However, I expect that queries xiii), xiv), xv) and xvi) as a minimum will require a separate response for each study.

i. Data checking. Please describe how the following datasets were audited/checked for suitability (accuracy) of use in the model. If the model datasets were updated/modified from their raw form, please describe the process for modifying the data.
    a) ALS/Lidar for model DEM;
    b) Pit and pipe data;
    c) Rainfall;
ii. Overall model approach / model development. While I understand the broad modelling approach of combining a DRAINS model of the upper catchment, primarily for generating catchment runoff, and a TUFLOW model to represent the floodplain flow paths, it's not clear to me from the report how the two models interface and which catchment/floodplain elements are included in each model. Please clearly describe how the models interface i.e. which catchment/floodplain components are in the DRAINS model and which are in the TUFLOW model, and how they connect to each other in the model. Please specifically describe how the components of the pit and pipe stormwater system interface with the catchment runoff hydrographs and surface water flow paths. A conceptual model diagram(s) might assist in this regard;
iii. Please describe how the upstream limits of the piped stormwater system in the model were decided.
iv. Please describe the method used to ensure all the potential overland flow paths have been identified for design events greater than the flood of record / most recent flood in the community's 'living memory'?
v. Please demonstrate how it was determined that the model simulations had converged to a 'stable' solution e.g. mass balance checks etc.

vi. **Section 2.5 Pit and Pipe Data** notes "*Lack of this data* (i.e. missing pit and pipe data) *will only impact results to a very small degree and impacts will be less significant for larger events such as the 100 year ARI*". This based on what assessment? Please justify by quantitative analysis e.g. comparison of serviced catchment inflow volume vs. flow capacity of piped system vs. overland flow volume;

vii. **Section 2.6.2 Community Consultation** provides a series of photographs of local flooding and reports of property/floor inundation. The model validation would benefit from a qualitative comparison these data with inundation mapping. Please provide local area mapping comparing photo location / property inundation reports with modelled inundation area for the respective historical flood event;

viii. **Section 2.7 Historic Rainfall Data.** Further information on the spatial variability of rainfall would assist in the interpretation of the model calibration outcomes. Suggest that a graphical representation of rainfall e.g. rainfall isohyets for historical events in the local area, and perhaps also in the wider Sydney area compared to design rainfalls would help put the model calibration in better context;

ix. **Section 2.8 Design Rainfall Data** – were catchment reduction factors applied? If not, why not?

x. **Section 4 Hydrologic Model, 4.1 Sub catchment definition.** There are many sub-catchments. How was the catchment boundary and outlet location of each sub-catchment defined? E.g. area contributing to a stormwater pit?

xi. **Section 5 Hydraulic Model, 5.1 Digital Elevation Model.** The DEM resolution for the Tuflow model was defined as a 3mx3m grid. This is at the upper limit of what I would consider suitable for defining overland flow paths in an urban environment. My knowledge of the catchment is that there are some locations where important overland flow paths, particularly between buildings, would be less than 3m wide. How were these included in the model? Please provide an example.

xii. **Section 6.3.3 Model Calibration**. The model calibration levels are consistently low. Commentary in this section implies this is because there was significant blockage of the stormwater system in the catchment. In my view there are numerous other reasons why the model calibration levels might be consistently low. I think you have two options, either you decide that there are numerous reasons why the calibration is low and test each of these reasons in the model sensitivity testing, or re-calibrate the model with blockage included to demonstrate that levels can be successfully matched and include blockage in the design runs.

xiii. **Section 7.2 Critical Duration** Please provide more information on the critical duration assessment e.g. map showing areas dominated by each duration and/or longitudinal profile showing adopted envelope approach;

xiv. **Section 7.3. Downstream Boundary Conditions** Please provide an explanation of why 1.38 m AHD and 1 m AHD were adopted as design boundary conditions for the Hawthorne Canal Study. Similarly Please explain the logic for selecting the various design boundary conditions outlines in Table 23 of the Dobroyd Canal Flood Study which differ from the Hawthorne Canal study.

xv. **Section 8 Sensitivity Analysis.** Quantification of the accuracy and uncertainty of the design model outputs is important for floodplain management decision making. In this catchment, where there is little calibration data, sensitivity analysis is the primary source of information for uncertainty. Figures 26a and 26b demonstrate that headloss at hydraulic structures is an important consideration since floodwaters backing up behind these structures are a dominant feature controlling inundation in the catchment. Please demonstrate how the adopted model headloss coefficients were checked. Understanding sensitivity of model outputs to culvert headlosses is important. This has been partially covered off in the blockage analysis. Please demonstrate the model sensitivity to head loss changes.

xvi. Council has noted several locations where either the Council or the local community has concern with the model results. Could you please name these locations, summarise the Council/community concerns, and for each floodplain location provide a detailed description of the model configuration, model calibration/validation results and design model results.

Yours sincerely,

Grantley Smith
Manager

Water Research Laboratory
110 King Street
Manly Vale NSW 2093

116043/L161007_ReviewResponse.docx

7 October 2016

Attention: Mr G Smith

Dear Grantley,

Re: Response to Letter "Peer Review of Dobroyd and Hawthorne Canal Flood Studies" dated 25 May 2016

Please see below for response to questions tendered in the above referenced letter.

Item i)

As part of the Flood Study work, WMAwater commissioned Chase Burke & Harvey (CBH) Surveyors to collect levels and cross-section data in the open channel and at bridges over the open channel. This data was used to create the 1D open channel network within the hydraulic model. Where the 1D domain (using the surveyed levels) intersected with the 2D domain (using the ALS data), such as the bridge deck levels and the top of bank/channel levels, the surveyed levels were compared to the ALS to assess the suitability of the ALS for defining the topography in the 2D domain.

The DEM used in the 2D domain was also updated/modified in the following ways:

- TUFLOW breaklines were used to assign the elevations in the road gutters as 0.15 m below the ALS levels, as the gutter widths are smaller than the ALS resolution and hence outside the capacity of the ALS to precisely represent.
- Bridges over roadways, where the roadway acted as a flowpath (such as the railway bridge over Frederick Street and the railway bridge over Brown Street) had the DEM modified locally as the ALS data could not penetrate the bridges. In these situations the DEM on the roadway underneath the bridge was assigned the elevation of the roadway at locations on either side of the bridge. A 2D bridge structure was then schematised over the roadway in the hydraulic model.

Invert data was determined / estimated using a number of methods:

- Along the open channel, inverts were interpolated from cross-section and hydraulic structure survey locations;
- Along Sydney Water Corporation (SWC) drainage infrastructure, the inverts were estimated using the pipe slopes reported in the SWC Capacity Assessment Reports (SWC, 1998);
- Along Council drainage infrastructure, the inverts were provided by Council; and

- Where invert data was not available, the inverts were estimated from the ALS level and an assumed depth.

The invert data was then checked to ensure that the entire connected drainage infrastructure had a positive grade from downstream to upstream.

The observed rainfall data was sourced from the Bureau of Meteorology (BOM) and Sydney Water Corporation (SWC). Both agencies quality control check and verify the data that they collect, with the BOM publishing details of the Quality Assurance (QA) process undertaken at:
http://www.bom.gov.au/climate/data-services/content/quality-control.html

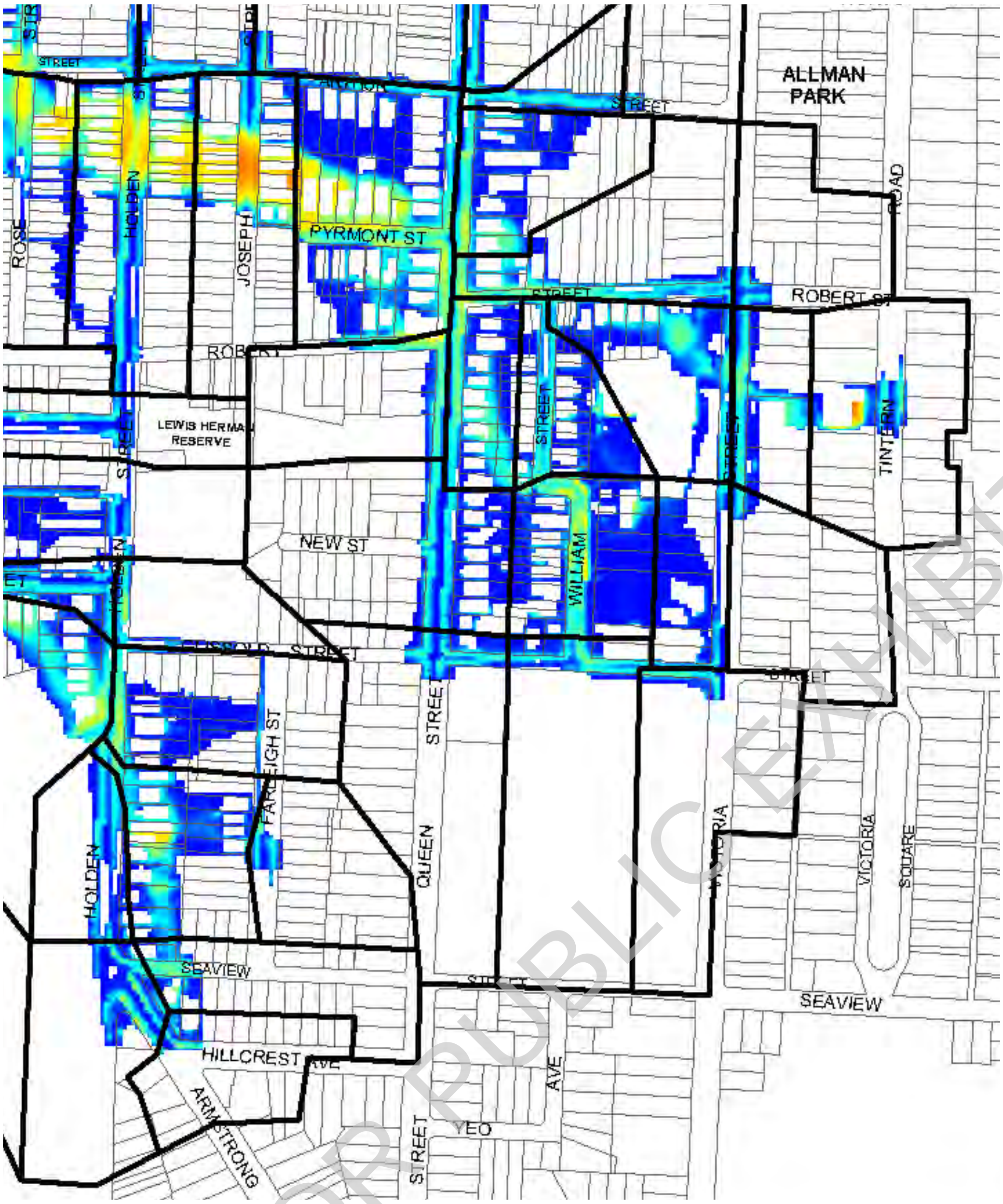
Item ii)
DRAINS was used for the hydrologic model for the conversion of rainfall into flow. The catchment/floodplain elements included in the DRAINS model were: sub-catchment area, sub-catchment slope, impervious percentage, and rainfall losses. No routing of flows between sub-catchments was undertaken in DRAINS (instead this was undertaken in the TUFLOW hydraulic model), and hence no pipe dimensions or overland flow path dimensions were defined in the DRAINS model.

The flows from each individual sub-catchment from the DRAINS model were input into the 2D TUFLOW hydraulic model as point inflows. These point inflows were located at the downstream boundary to each sub-catchment and corresponded to the kerb and gutter system. This emulates the way most properties are designed to drain intralot flow and roof flow into the street gutters.

Within TUFLOW, flow applied to the gutter system (modelled in the 2D domain) travels based on elevation and roughness (Manning's value) and enters the pit and pipe system (modelled in the 1D domain) via 1D-2D connections.

Item iii)
The upstream limits of the piped stormwater system were based upon pipe elements that were equal to or greater than 450 mm in diameter in the Council drainage database.

Item iv)
The highest upstream inflows were located as far upstream as the stormwater drainage network extended. The average sub-catchment size of 0.015 km^2 ensured that where overland flow paths existed, these were represented in the hydraulic model (as shown below).



Item v)

The model simulations were determined to be 'stable' based upon assessment of:

- the mass balance outputs (in the order of 0.1% in the 1% AEP event). This assures that globally, the hydraulic model is not generating or losing significant mass;
- the peak velocity outputs, as a high velocity may be indicative of stability issues; and
- the hydrograph outputs generated across the hydraulic model.

Item vi)

The pipes servicing Parramatta Road (where pipe dimensions were unavailable) spanned relatively short lengths (less than 300 m in length) and drained relative small local catchments (in the order of 0.06 km^2). The SWC stormwater pipes that the pipes along Parramatta Road discharged into were found to be operating at capacity in events as small as the 2 year ARI (in which event, the pipes were full for approximately 1.3 hrs over the course of a 1 hr storm duration).

Additionally, the sensitivity of the model to the size of these unknown pipes were assessed for the 1% AEP event by doubling the assumed size of the unknown pipes. This resulted in a peak flood level increase of 0.016 m.

Item vii)
The Hawthorne Canal Flood Study (community consultation phase) received 10 photos of flooding spanning 2009 to 2012. The Flood Study extracted 8 approximate water levels for the 2012 event. The modelled March 2012 peak flood depth compared to the approximate water levels is shown on Figure 17.

Please see Item xii) for further information in this regard.

Item viii)
The spatial distribution of the rainfall depths and IFD ranges is shown on “Item 8A” and “Item 8B” for the February 1993 6 hour storm burst and “Item 8C” and “Item 8D” for the March 2012 6 hour storm burst.

Item ix)
Aerial reduction factors (as per Australian Rainfall and Runoff 1987 (AR&R 1987)) predominantly affect large catchment areas, as shown in Diagram 1 extracted from AR&R 1987. The Dobroyd Canal and Hawthorne Canal catchment areas were less than 10 km^2, and as such the Depth-Area Ratio was converging on 1 (from Diagram 1). Therefore, no catchment reduction factors were applied to the design rainfall data.

Diagram 1: Extract from Australian Rainfall and Runoff (1987)

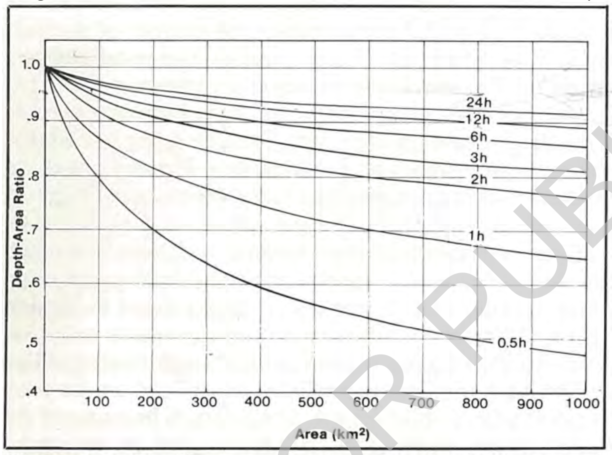
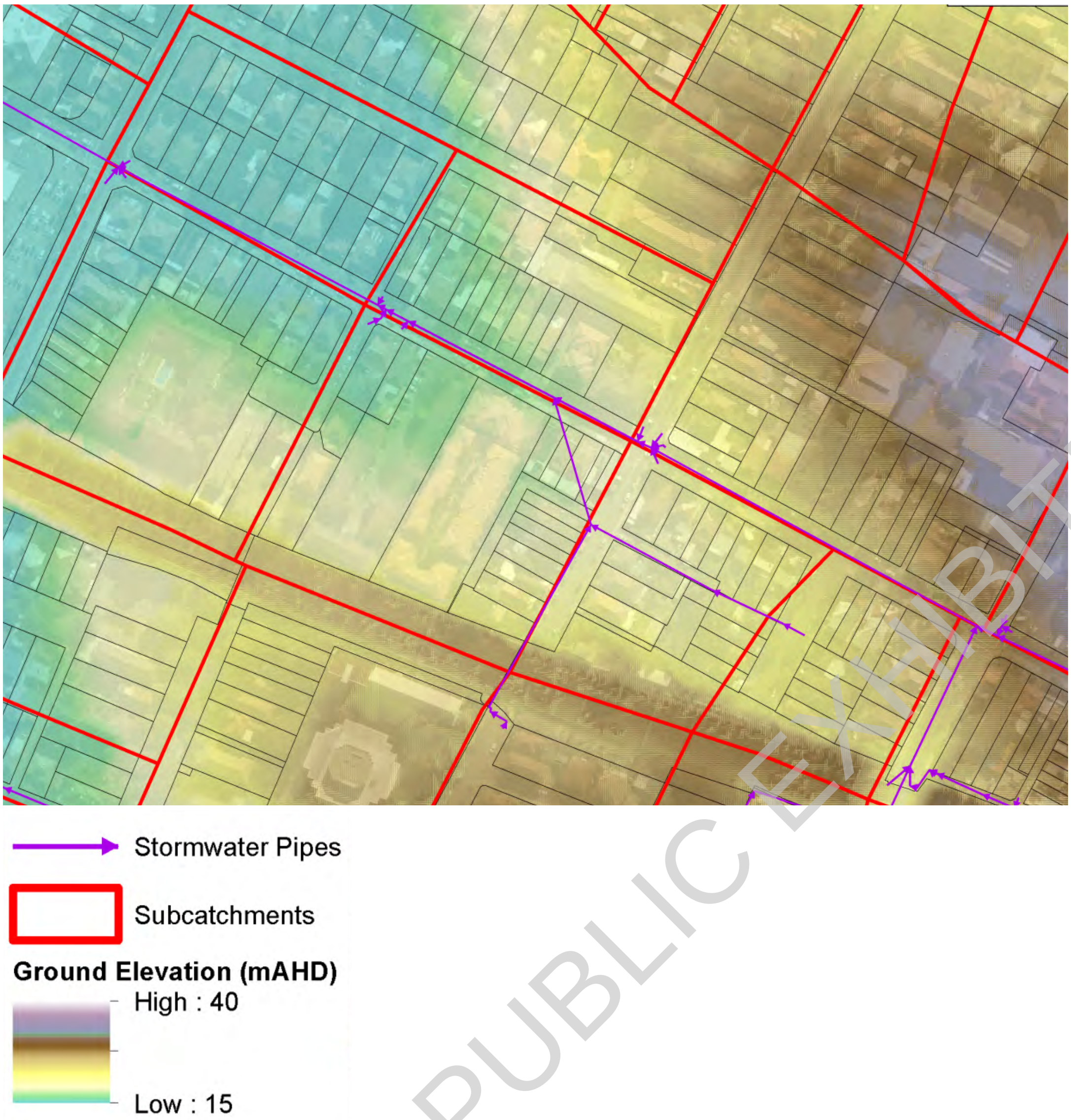


Figure 2.6 – Depth-area ratios for use in Australia (except Zone 5 of Figure 3.2, Chapter 3). (From U.S. NOAA Tech. Report, NWS 24, 1980)

Item x)
Sub-catchments were defined such that each area drained to a stormwater pit. The elevation and major features like roads or crests of hills were used to delineate the boundary for each sub-catchment.



Item xi)

Following initial establishment of the modelling, and during the calibration/validation phase of the work, the model results were subject to review. Locations where flood water was being detained upstream of buildings were identified and assessed. Site visits were undertaken. Where the assessment found the upstream detention of flood water to be artificial, the model schematisation of building extents was altered in order to ensure that where in reality flow could travel downstream, the same could also occur in the hydraulic model.

Item xii)

Given review comments in regard to calibration, WMAwater have examined the flood mark set. It is apparent that the flood observations are suitable for describing areas impacted by flooding but not appropriate for use in exact flood level comparisons. This conclusion is based on the fact that the flood level estimates (which are in turn based on observations of flooding submitted by the community) are clearly approximate in nature. Some in fact, based on review of design flood level estimates, would appear to be difficult to achieve even given the occurrence of a PMF event. As such, WMAwater submit that rather than a level comparison exercise, these points are best used as an indication of which areas are subject to some degree of flooding, for a given event.

In May 2016, the former Ashfield Council, Leichhardt Council and Marrickville Council were amalgamated to form the Inner West Council. As a result of the amalgamation, a variation is pending for WMAwater to expand the current Hawthorne Canal Study area to include former Leichhardt Council area (both hydrologic and hydraulic models) and re-calibrate the model.

Item xiii)

The spatial variation of the critical duration for the 1% AEP event in the Dobroyd Canal catchment is shown in "Item 13A". As per the report, further analysis of the difference between the 1 hour and 2 hour (durations critical along the major drainage lines) was undertaken and shown in "Item 13B".

The spatial variation of the critical duration for the 1% AEP event in the Hawthorne Canal catchment is shown in "Item 13C". The difference between the 25 minute and 1 hour (durations critical along the major drainage lines) was undertaken and shown in "Item 13D".

Item xiv)

The ocean levels used in the Flood Studies were taken from *Fort Denison Sea Level Rise Vulnerability Study* (Department of Environment and Climate Change NSW, October 2008).

However, subsequent to the completion of the Flood Studies further guidance has been released, namely the *Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (NSW Government and Office of Environment and Heritage, November 2015). The Floodplain Risk Management Study will adopt the ocean levels specified in this document (shown in Table 1).

Table 1: Combinations of Catchment Flooding and Oceanic Inundation Scenarios

Design AEP for peak flood levels	Catchment Flood Scenario	Ocean Water Level Boundary
50% AEP	50% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
20% AEP	20% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
10% AEP	10% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
5% AEP	5% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
2% AEP	2% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
1% AEP (Enveloped)	5% AEP Rainfall	1% AEP Ocean Level 1.45 m AHD
	1% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
PMF	PMF Rainfall	1% AEP Ocean Level 1.45 m AHD

Item xv)

There is sensitivity to culvert headlosses. This relates to the fact that many areas rely significantly on drainage via hydraulic structures. Default losses have been used for these structures as, in the absence of any data/observations to suggest that otherwise, this was considered the best approach to use. As the reviewer suggests, blockage sensitivity runs then become a proxy for varying headloss values, and hence such runs indicate the sensitivity of flood levels to varying head loss values.

Additional work undertaken in the Hawthorne Canal Catchment area investigated the afflux across hydraulic structures in the vicinity of Longport Street, Lewisham. The investigation was undertaken using a HEC-RAS hydraulic model. From the HEC-RAS model the afflux across Longport Street was found to be 2.33 m, which is a close match to the 2.36 m afflux found in the TUFLOW model used in the Flood Study.

Item xvi)

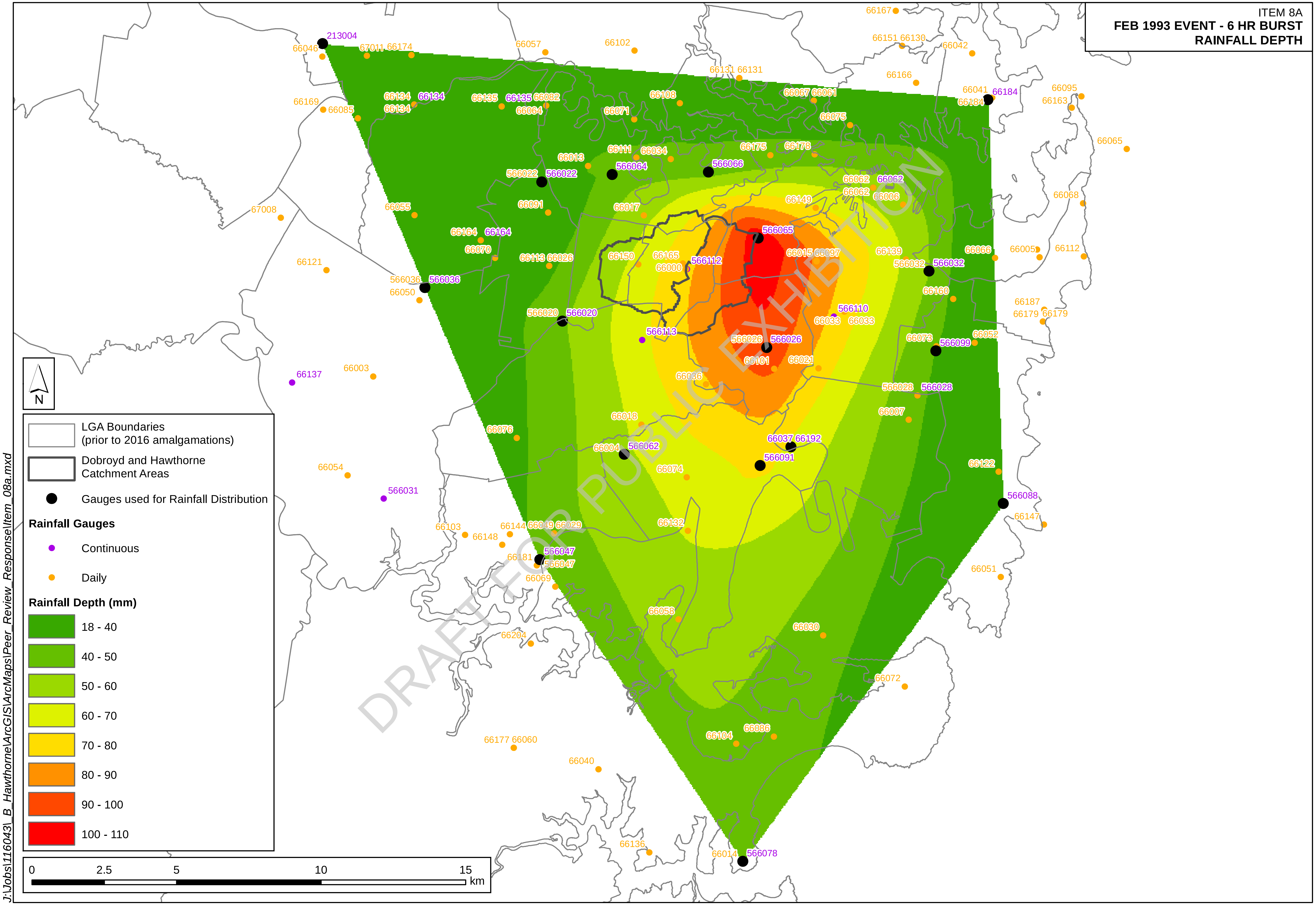
Community concerns were less centred on specific locations and were more centred on the whole model process. The Railway Embankment over Dobroyd Canal and the Parramatta Road Bridge over Hawthorne Canal is representative of the hydraulic model configuration across the catchments. At these locations, the open channel is represented as a 1D element, carved into the 2D domain. This is shown in the attached figures.

Should you require any further clarification, please do not hesitate to contact the undersigned.

Yours Sincerely,
WMAwater

Stephen Gray
Director

ITEM 8A
FEB 1993 EVENT - 6 HR BURST RAINFALL DEPTH



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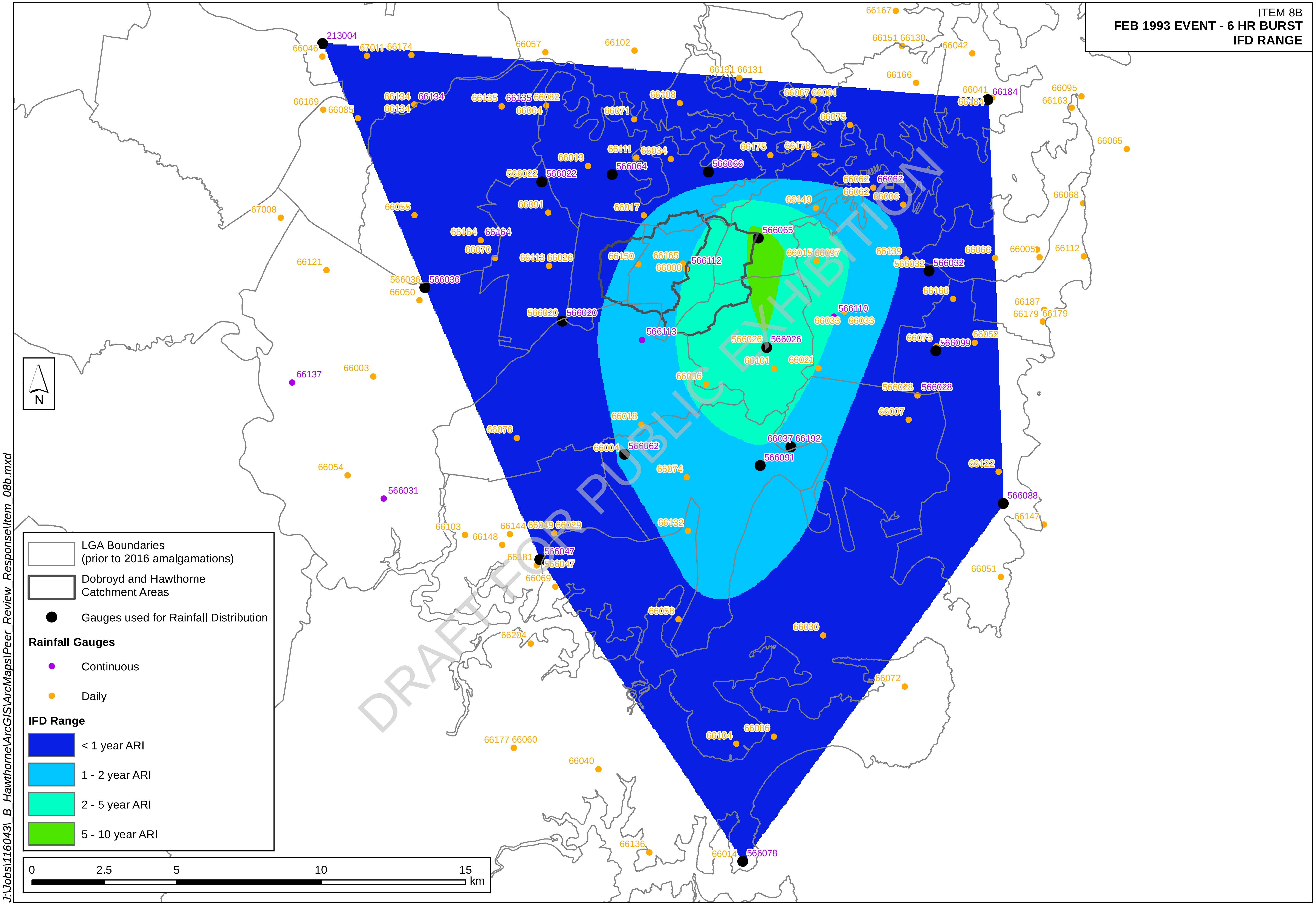

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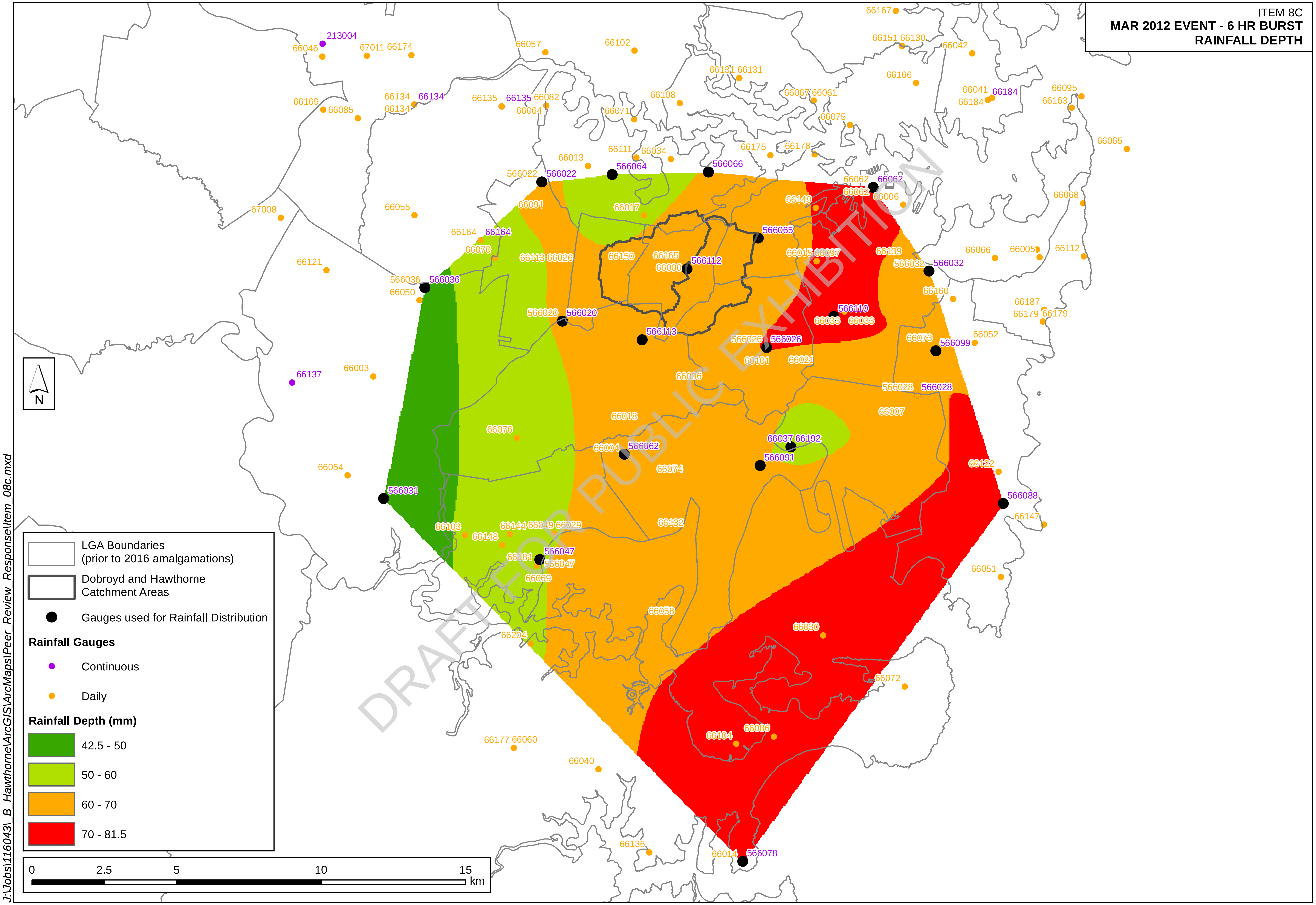

ITEM 8C
MAR 2012 EVENT - 6 HR BURST RAINFALL DEPTH
LGA Boundaries (prior to 2016 amalgamations)
Dobroyd and Hawthorne Catchment Areas
Gauges used for Rainfall Distribution
Rainfall Gauges
Continuous
Daily
Rainfall Depth (mm)
42.5 - 50
50 - 60
60 - 70
70 - 81.5
0 2.5 5 10 15 km
N
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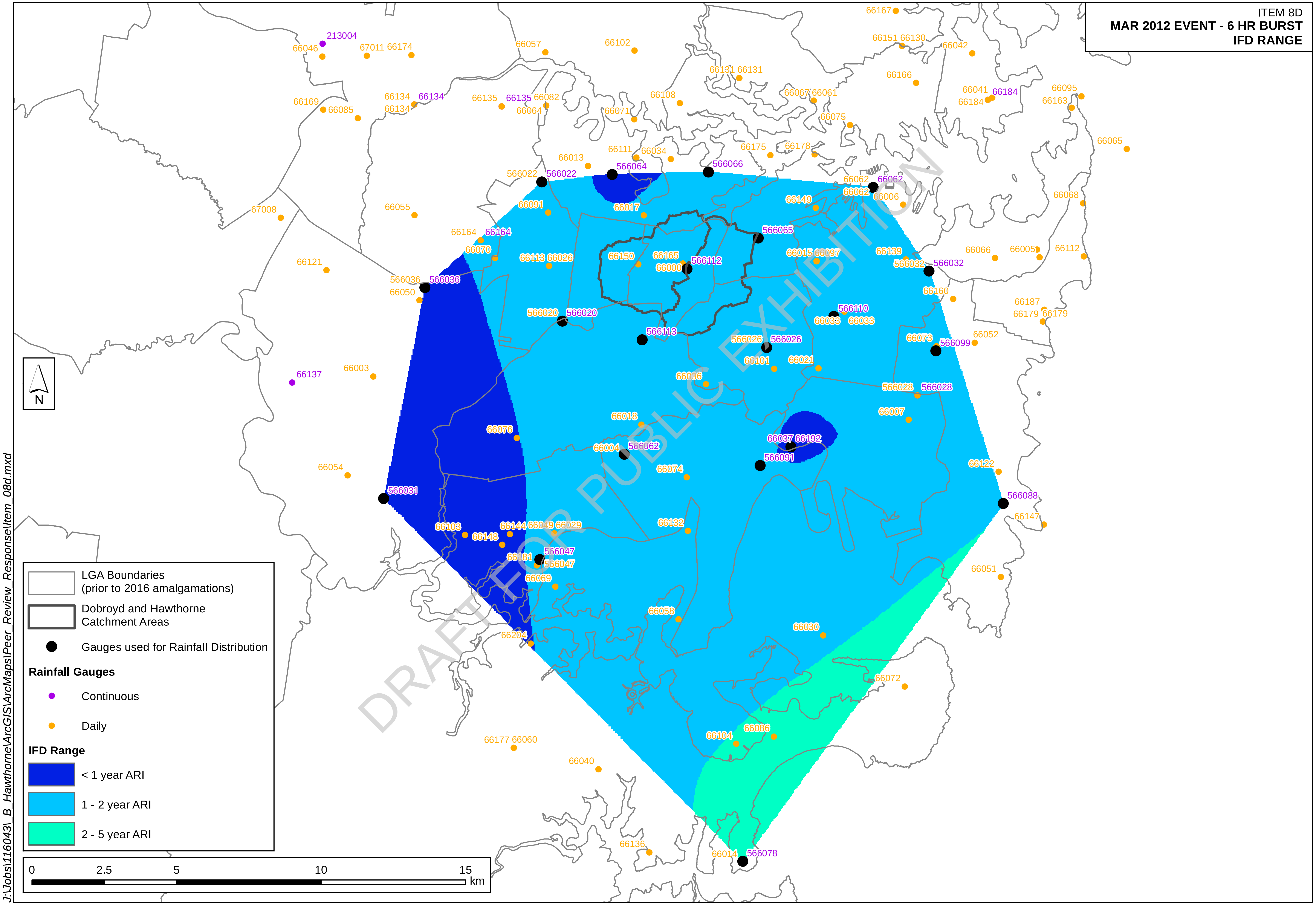
ITEM 8D
MAR 2012 EVENT - 6 HR BURST IFD RANGE



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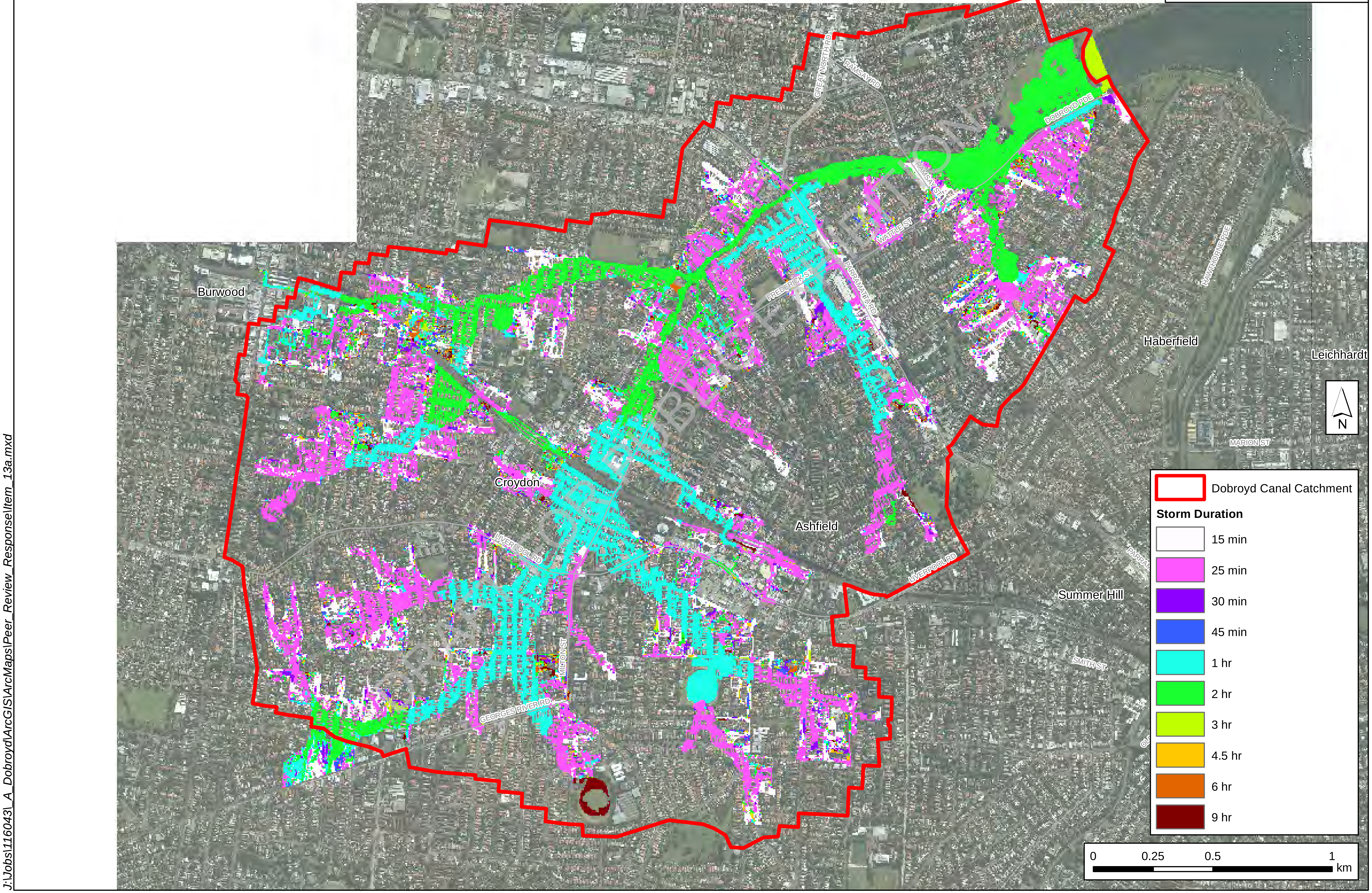
ITEM 13A
1% AEP CRITICAL DURATION EVENTS



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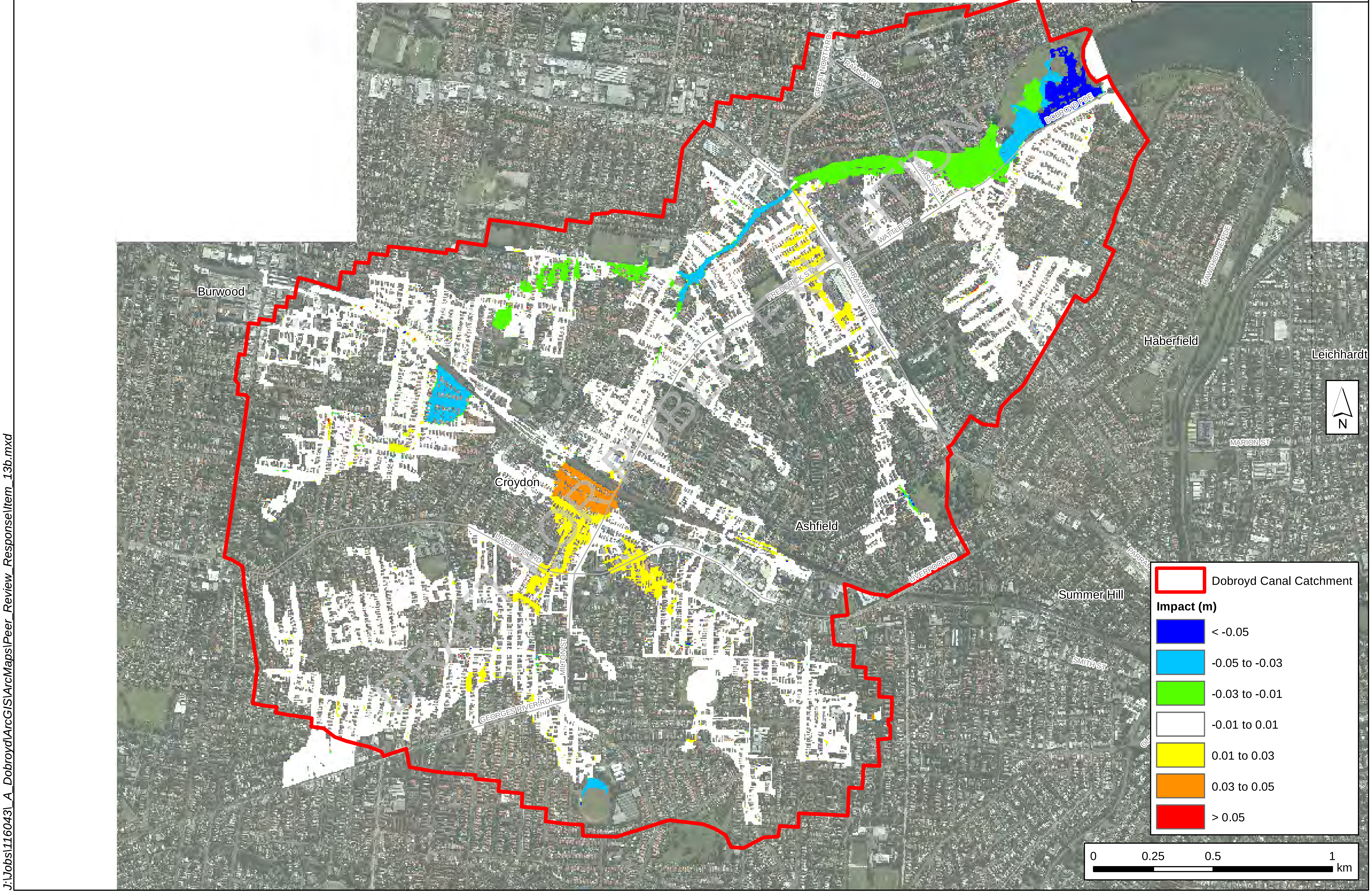
ITEM 13B

1% AEP CRITICAL DURATION

IMPACT BETWEEN 1HR AND 2HR



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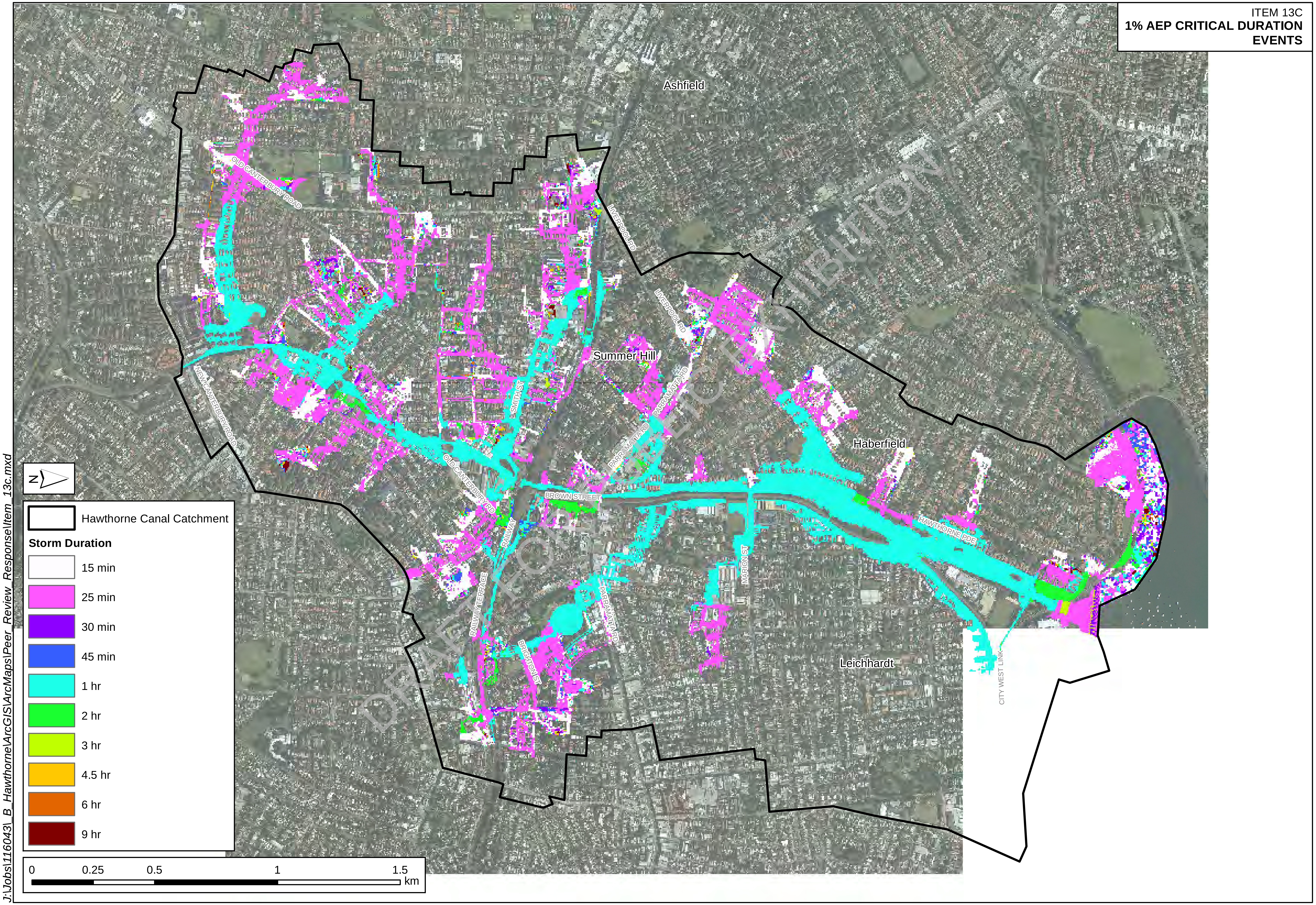
ITEM 13C
1% AEP CRITICAL DURATION EVENTS



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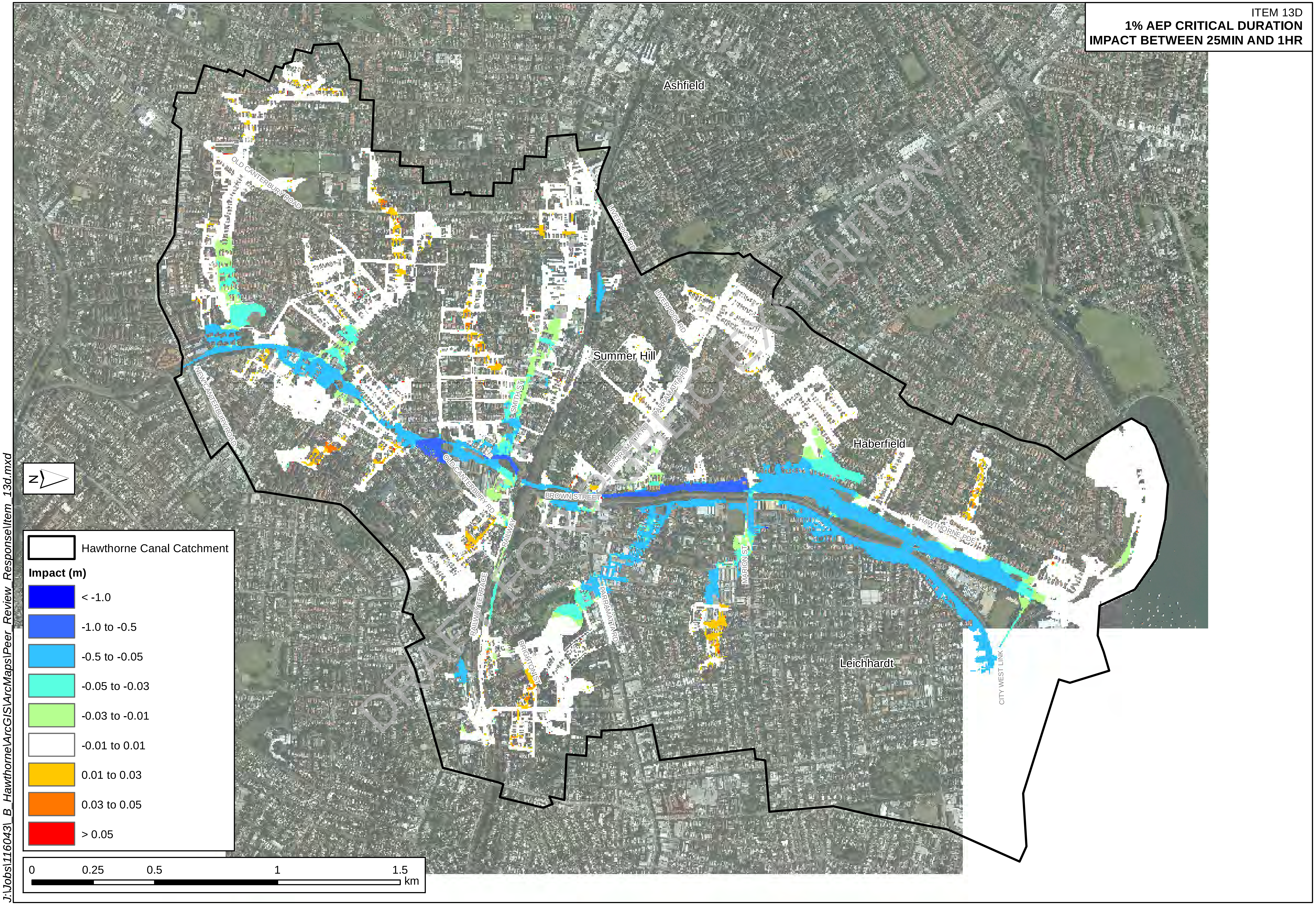
ITEM 13D

1% AEP CRITICAL DURATION IMPACT BETWEEN 25MIN AND 1HR



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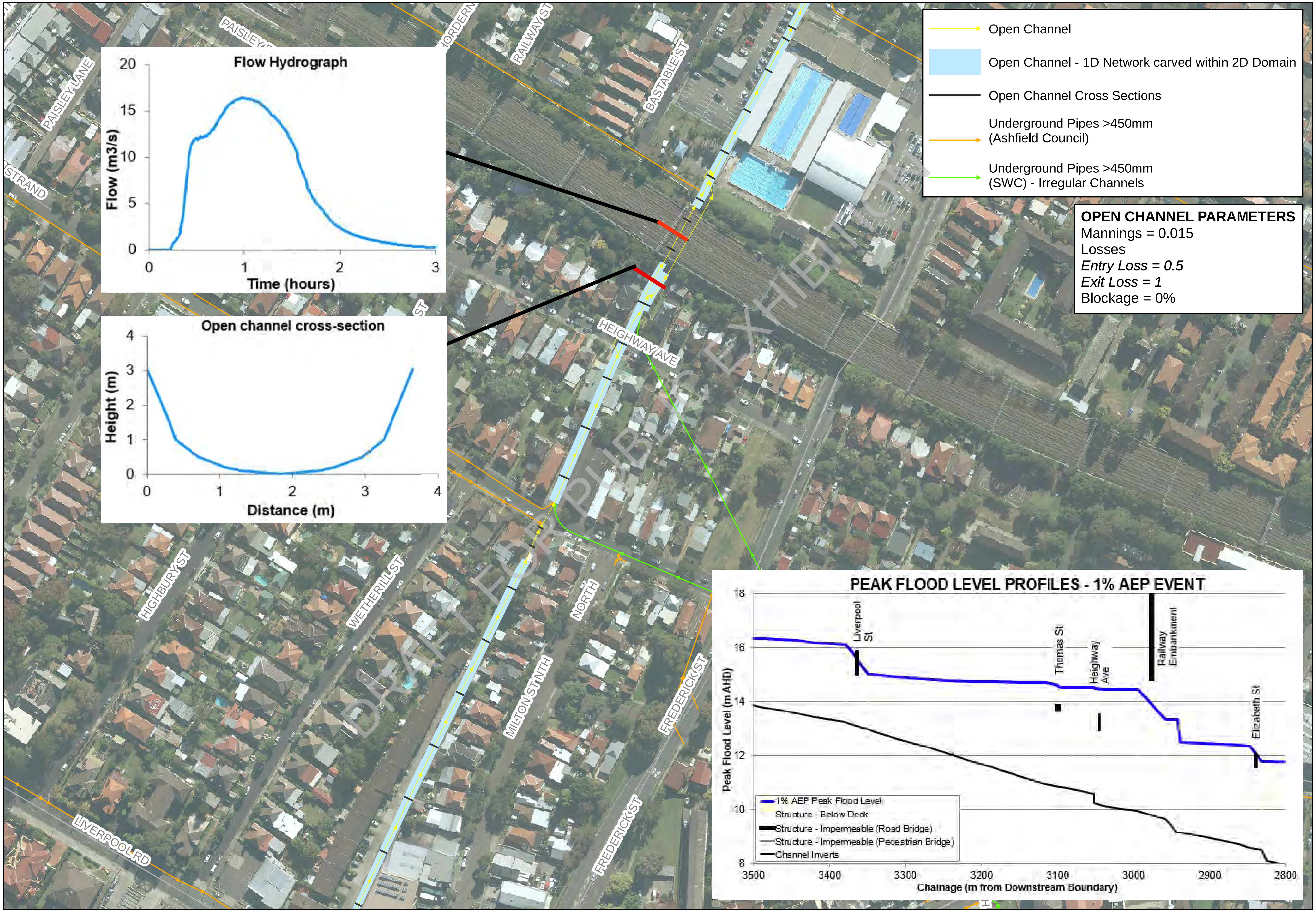
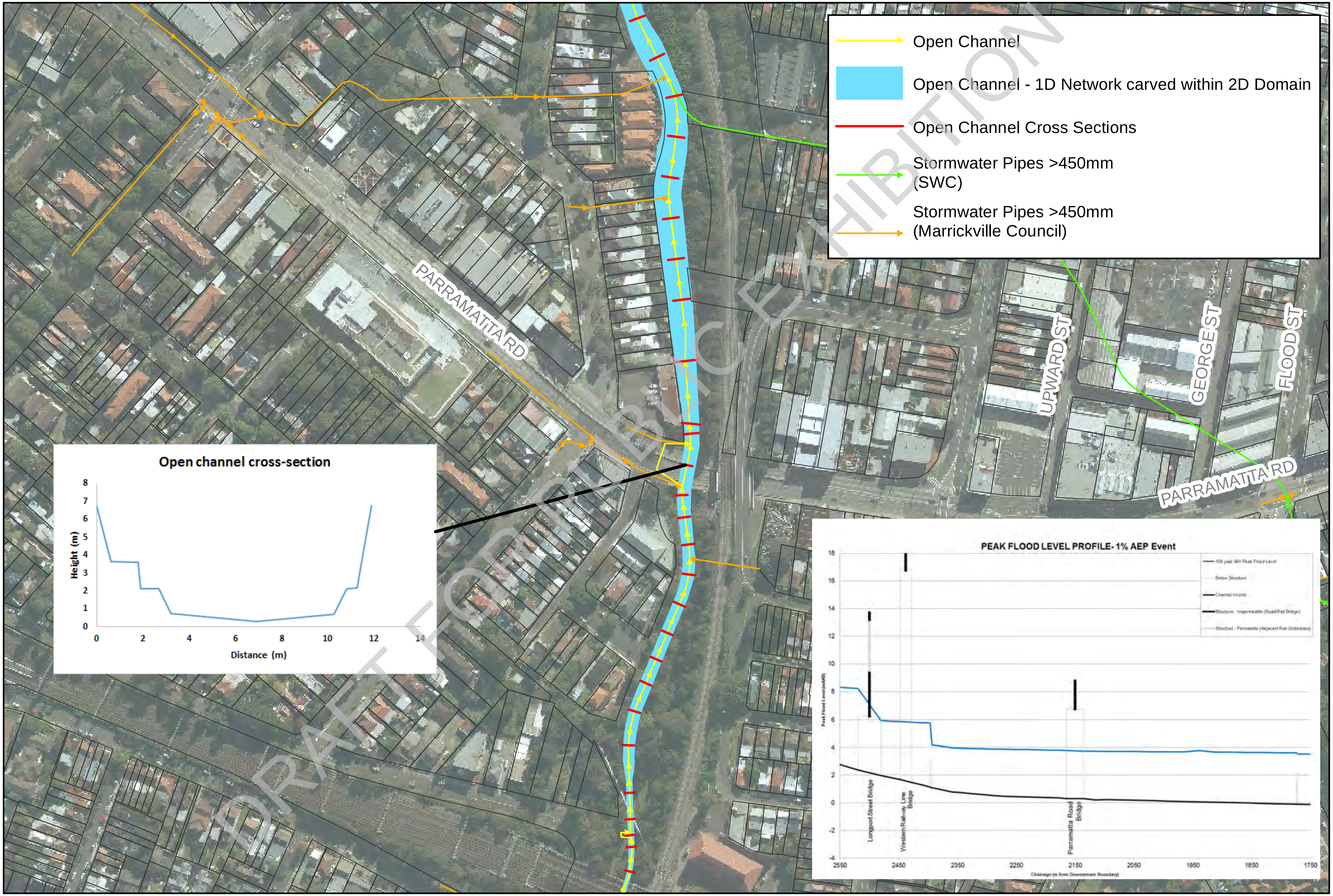
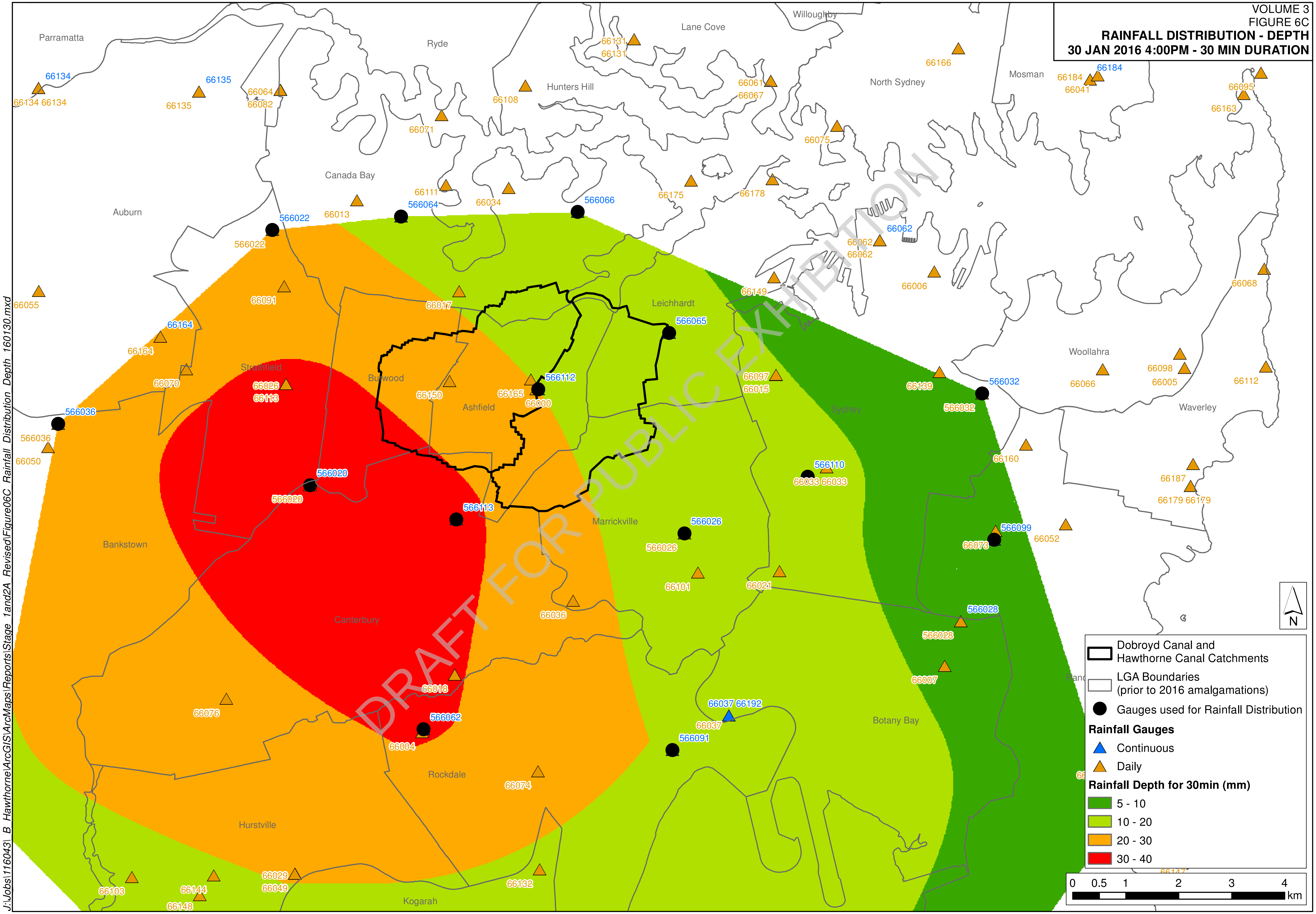

Open Channel
Open Channel - 1D Network carved within 2D Domain
Open Channel Cross Sections
Underground Pipes >450mm
(Ashfield Council)
Underground Pipes >450mm
(SWC) - Irregular Channels
OPEN CHANNEL PARAMETERS
Mannings = 0.015
Losses
Entry Loss = 0.5
Exit Loss = 1
Blockage = 0%
Flow Hydrograph
Flow (m3/s)
Time (hours)
Open channel cross-section
Height (m)
Distance (m)
PEAK FLOOD LEVEL PROFILES - 1% AEP EVENT
Peak Flood Level (m AHD)
Chainage (m from Downstream Boundary)
Liverpool St
Thomas St
Heighway Ave
Railway Embankment
Elizabeth St
1% AEP Peak Flood Level
Structure - Below Deck
Structure - Impermeable (Road Bridge)
Structure - Impermeable (Pedestrian Bridge)
Channel Inverts
PAISLEY LANE
STRAND
BASTABLE ST
RAILWAY ST
HEIGHWAY AVE
HIGHBURY ST
WETHERILL ST
NORTH
MILTON ST NTH
FREDERICK ST
LIVERPOOL RD
DRAFT FOR PUBLIC EXHIBITION

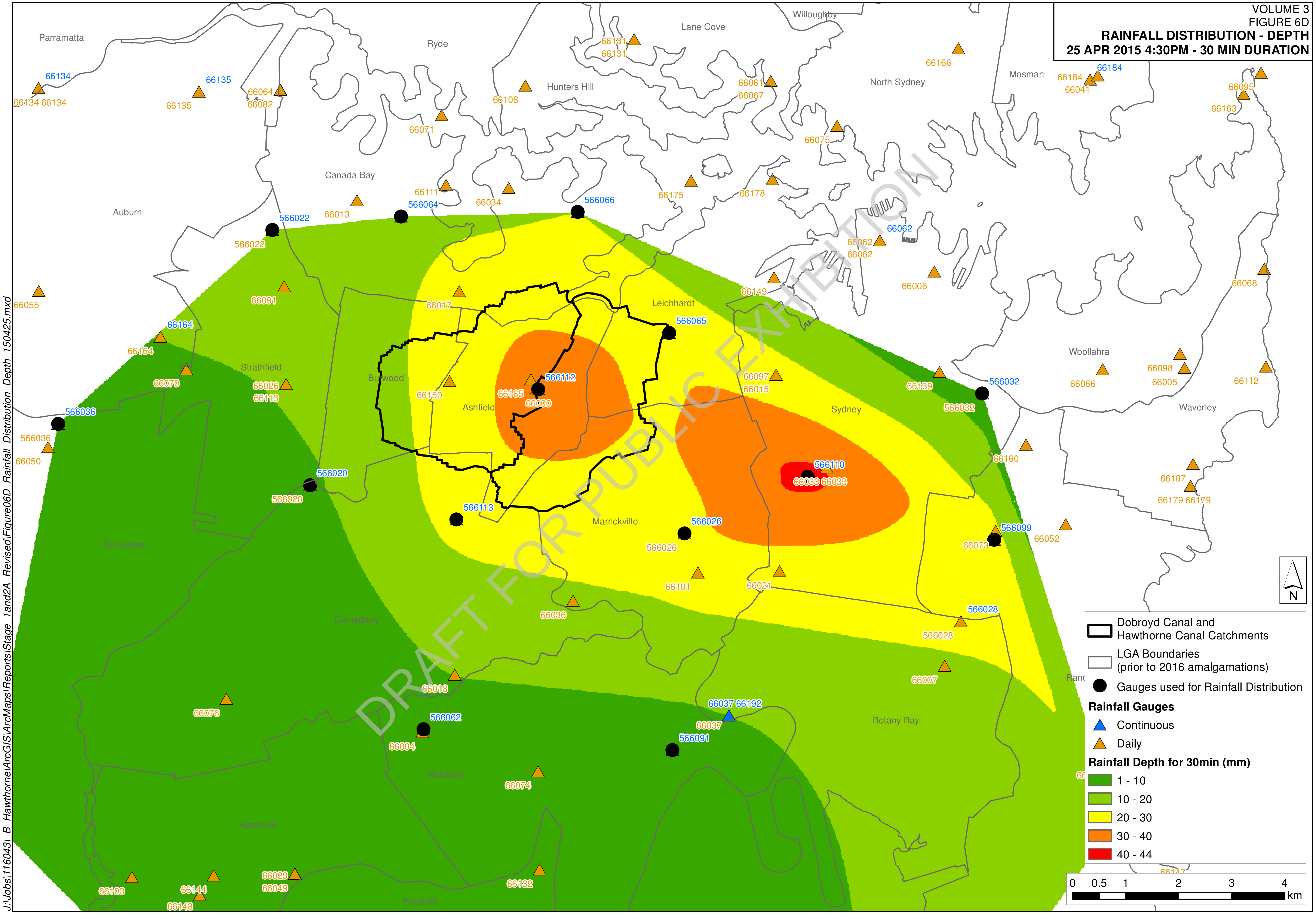


Open Channel
Open Channel - 1D Network carved within 2D Domain
Open Channel Cross Sections
Stormwater Pipes >450mm (SWC)
Stormwater Pipes >450mm (Marrickville Council)
PARRAMATTA RD
UPWARD ST
GEORGE ST
FLOOD ST
PARRAMATTA RD
Open channel cross-section
Height (m)
Distance (m)
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12
14
PEAK FLOOD LEVEL PROFILE- 1% AEP Event
Peak Flood Level (mAHD)
18
16
14
12
10
8
6
4
2
0
-2
-4
Longport Street Bridge
Western Railway Line Bridge
Parramatta Road Bridge
2550
2450
2350
2250
2150
2050
1950
1850
1750
Chainage (m from Downstream Boundary)
DRAFT FOR PUBLIC EXHIBITION

Appendix E

VOLUME 3
FIGURE 6C
RAINFALL DISTRIBUTION - DEPTH
30 JAN 2016 4:00PM - 30 MIN DURATION





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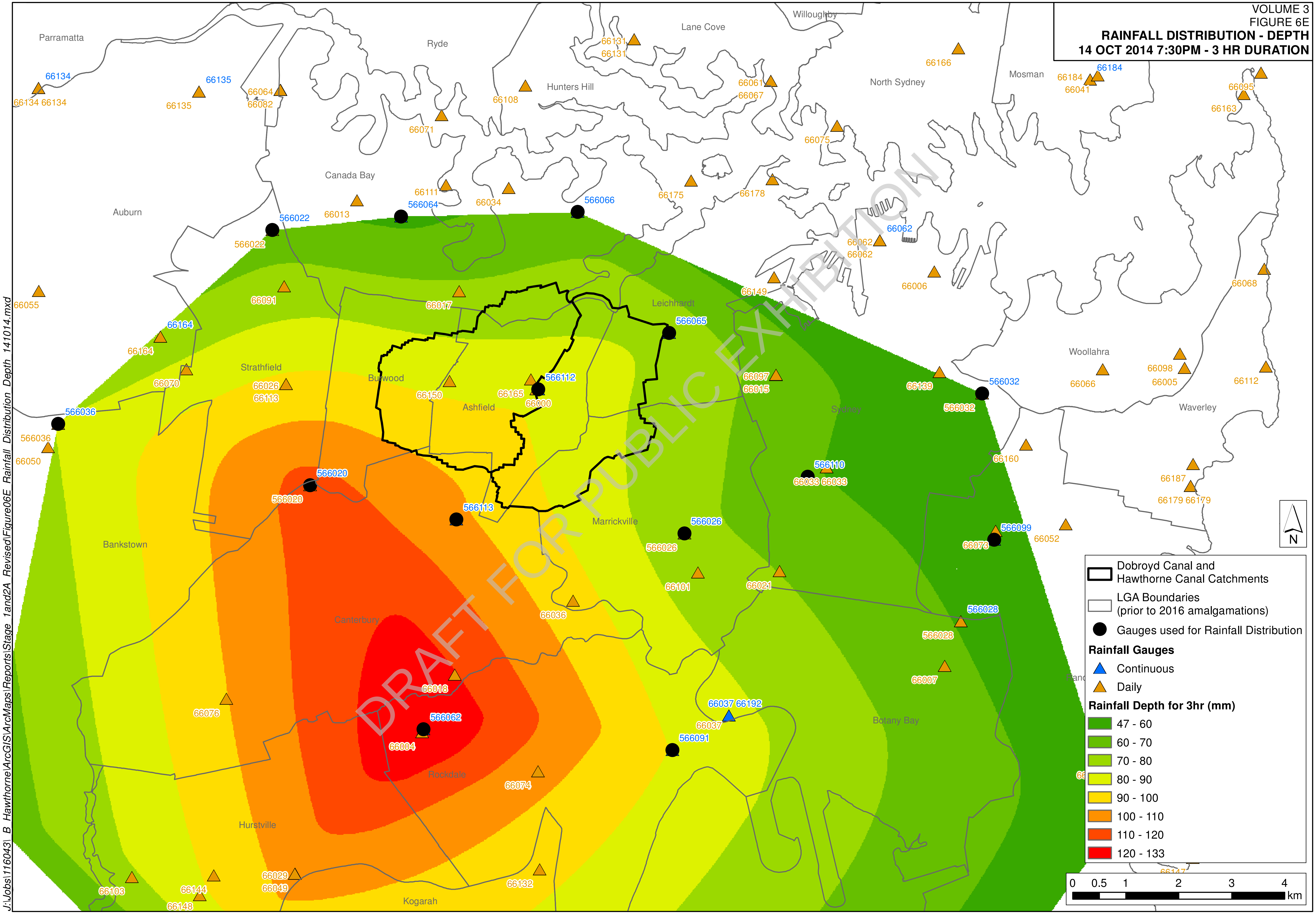
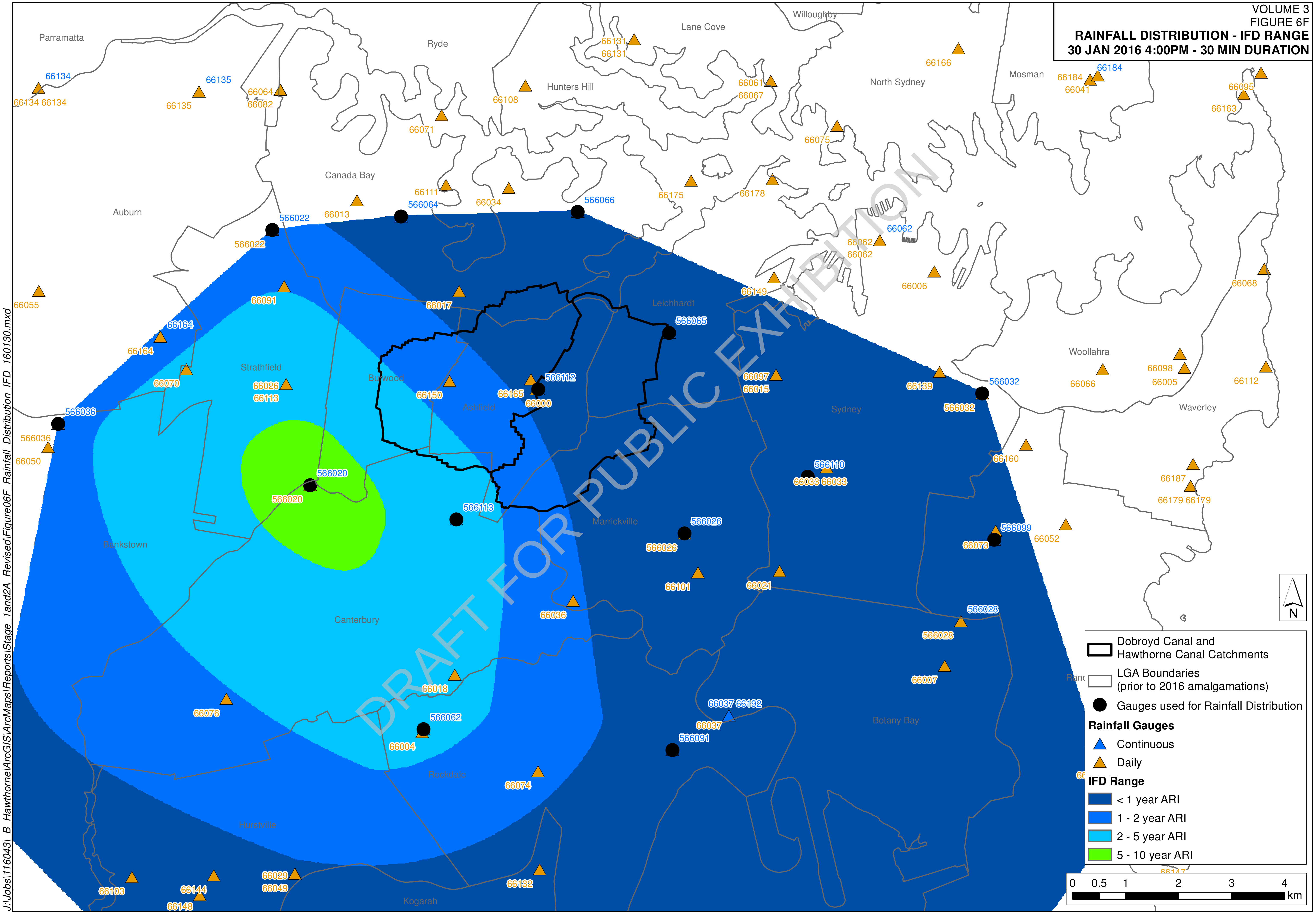
RAINFALL DISTRIBUTION - DEPTH
14 OCT 2014 7:30PM - 3 HR DURATION



VOLUME 3
FIGURE 6F
RAINFALL DISTRIBUTION - IFD RANGE
30 JAN 2016 4:00PM - 30 MIN DURATION



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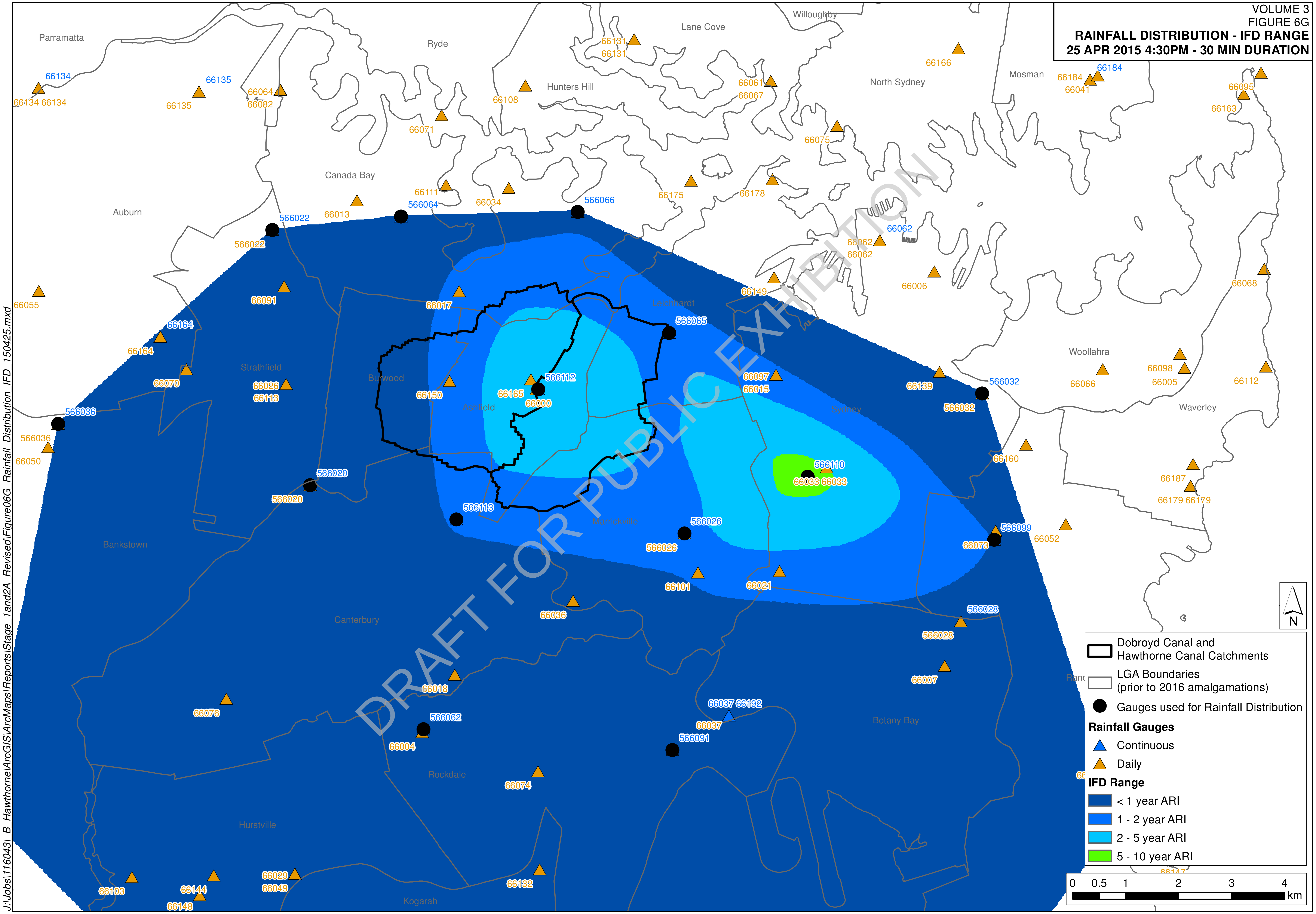
VOLUME 3
FIGURE 6G
RAINFALL DISTRIBUTION - IFD RANGE
25 APR 2015 4:30PM - 30 MIN DURATION



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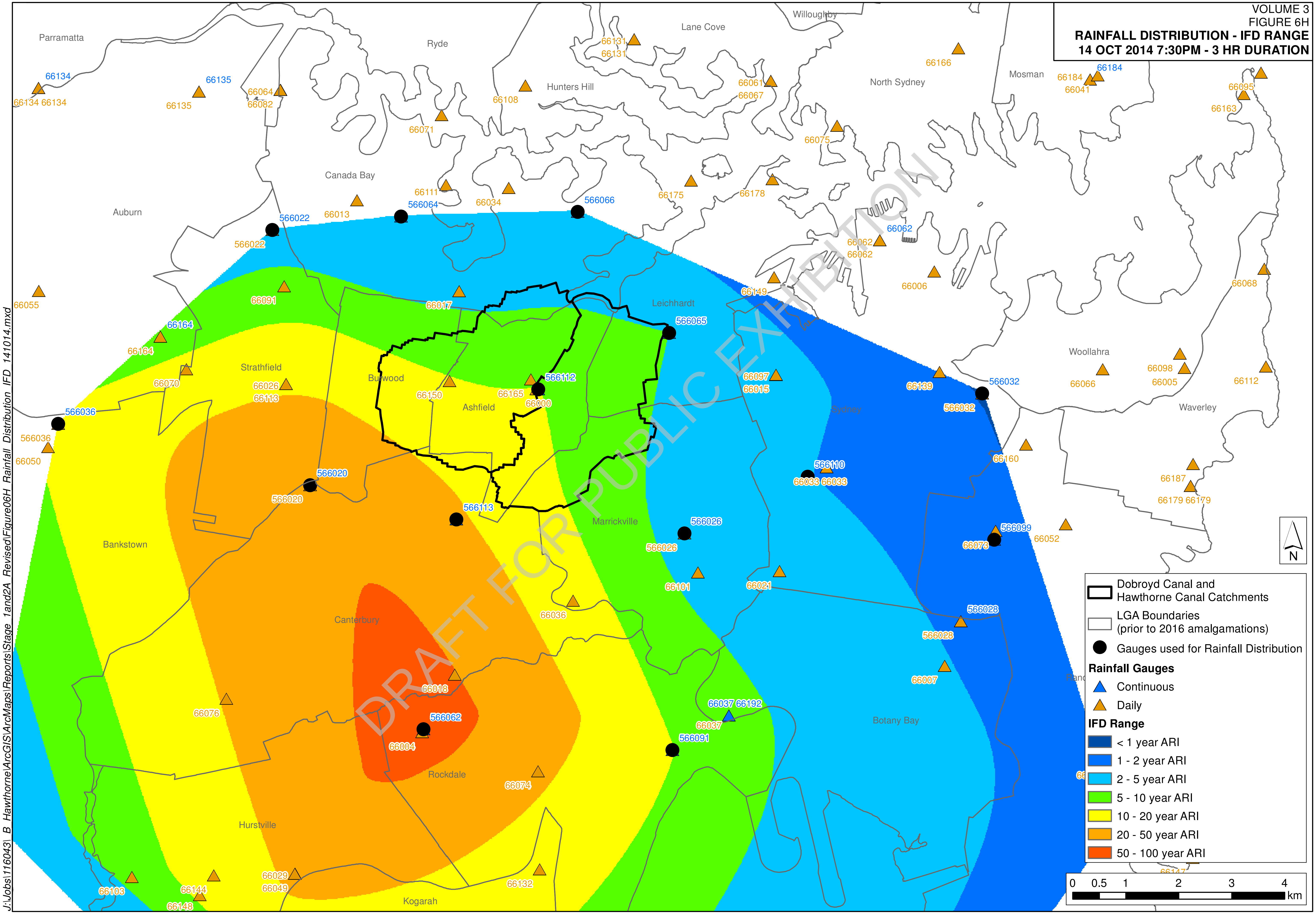
VOLUME 3
FIGURE 6H
RAINFALL DISTRIBUTION - IFD RANGE
14 OCT 2014 7:30PM - 3 HR DURATION



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Appendix F

Hotspot	Option ID	Location	Description	Assessment Stage [1]
Hawthorne Canal **Hotspot 01 – Queen Street, Ashfield**	FM0101A	Queen Street to Yeo Park	Pipe drainage upgrade	2 (App C Section B1.1)
	FM0101B	Queen Street To Yeo Park	Pipe drainage upgrade and above ground retention	2 (App C Section B1.2)
	FM0102A	Yeo Park (South Of Primary School)	Above ground detention basin	2 (App C Section B1.3)
	FM0103A	Elizabeth Avenue (Between Old Canterbury Road And Union Lane)	Pipe drainage upgrade	2 (App C Section B1.4)
	FM0104C	Arlington Recreation Ground Detention Basin	Above ground detention basin, with ramp for roadway access	2 (combined with 104D) (App C Section B1.5)
	FM0104D	Arlington Recreation Ground Detention Basin	Above ground detention basin, with ramp and floodgate for roadway access	2 (combined with 104C) (App C Section B1.5)
Hawthorne Canal **Hotspot 02 – Grosvenor Crescent, Summer Hill**	FM0401A	Grosvenor Cresent Under-Ground Detention Basin	Under-road detention basin	2 (App C Section B3.1)
	FM0403A & FM0403B	Grosvenor Cresent And Smith Street Flowpath Pipe Upgrade And Detention Basin	Pipe drainage upgrade, above ground detention basin and levee wall	3 (Section 10.2.9.1)
	FM0404A	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0404B	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B3.2)
	FM0404C	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	3 (Section 10.2.9.2)
Hawthorne Canal **Hotspot 03 – Light Rail Track**	FM0201E	Gelding Street To Constitution Road Drainage Upgrade, Johnsons Park Detention Basin	Pipe drainage upgrade and above ground detention basin	1
	FM0301A	The Boulevarde To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0301B	The Boulevarde To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.1)
	FM0302A	The Boulevarde To Hawthorne Canal Underground Detention Basin	Under-ground detention basin and raingarden	2 (App C Section B2.2)
	FM0303A	Denison Road To Old Canterbury Road Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.3)
	FM0303B	Denison Road To Old Canterbury Road Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.4)
	FM0503A	Gordon Street, Trafalgar Street And Audley Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0504A	Light Rail Training Centre Carpark Under Ground Detention Basin	Underground detention basin	1
Hawthorne Canal **Hotspot 04 – Sloane Street, Summer Hill/Haberfie ld**	FM0601A	Ashfield Park To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0601B	Ashfield Park To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.1)
	FM0601C	Ashfield Park to Daragh Lane drainage upgrade	Pipe drainage upgrade	1
	FM0602A	O'connor Avenue To Daragh Lane Drainage Upgrade	Pipe drainage upgrade	1
	FM0605A	Sloane Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.2)
	FM0605B	Sloane Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.2)
	FM0605C	Sloane Street drainage upgrade	Pipe drainage upgrade	3 (Section 10.2.9.4)

Hotspot	Option ID	Location	Description	Assessment Stage (1)
	FM0606A	Sloane Street Under-road Detention Basin	Under-road detention basin	2 (App C Section B5.3)
Hawthorne Canal **Hotspot 06 – Hawthorne Canal**	FM0701A	Dudley Street Down To Hawthorne Canal Upgrade	Pipe drainage upgrade	2 (App C Section B6.1)
	FM0702A	Waratah Street To City West Link Hawthorne Canal Upgrade	Levee	3 Combined with FM0702B (Section 10.2.9.5)
	FM0702B	Hawthrone Canal levee, Waratah St to City West Link	Levee	3 Combined with FM0702A (Section 10.2.9.5)
Hawthorne Canal **Other**	FM0501C	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with spillway for larger events	2 (App C Section B4.1)
	FM0501D	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with vehicle access maintained	2 (App C Section B4.1)
	FM0501E & FM0501F	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with vehicle access ramp	2 (App C Section B4.1)
	FM0501G	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with access moved to southern corner	3 (Section 10.2.9.3)
Dobroyd Canal **Hotspot 01 – Heighway Avenue, Croydon**	FM0102	Heighway Avenue Underground Detention Basin	Under-road detention basin	2 (App C Section A1.1)
	FM0102B	Heighway Avenue Underground Detention Basin	Under-road detention basin	2 (App C Section A1.2)
	FM0103	Milton Street North Underground Detention Basin	Under-road detention basin	2 (App C Section A1.3)
	FM0104	Heighway Avenue And Milton Street North Underground Detention Basin	Under-road detention basins	2 (App C Section A1.4)
	FM0106A	Duplication of Dobroyd Canal	Canal upgrade	2 (App C Section A1.5)
Dobroyd Canal **Hotspot 02 – Queen Street, Croydon**	FM0201	Queen Street Centenary Par Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0202	Queen Street Centenary Park Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0203	Queen Street Centenary Park Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0205	Queen Street Centenary Park Underground Detention Basin	Underground detention basin	2 (App C Section A2.2)
	FM0206A	Queen Street Centenary Park Underground Detention Basin	Above ground detention basin	2 (App C Section A2.1)
Dobroyd Canal **Hotspot 03 – Brown Street, Ashfield**	FM0301	Brown Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0301B	Brown Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section A3.1)
	FM0302	Brown Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0302B	Brown Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section A3.1)
	FM0303	Brown Street Underground Detention Basin	Under-road detention basin	2 (App C Section A3.2)
Dobroyd Canal **Hotspot 06 – Algie Park, Haberfield**	FM0601	Algie Park Above Ground Detention Basin	Detention basin upgrade	1
	FM0601B	Algie Park Above Ground Detention Basin	Detention basin upgrade with levee and drainage system	2 (App C Section A4.1)
	FM0602	Algie Park Under Ground Detention Basin	Underground detention basin	1

Hotspot	Option ID	Location	Description	Assessment Stage [1]
Dobroyd Canal **Other**	FM0701	Pratten Park Under Ground Detention Basin	Underground detention basin	2 (App C Section A5.1)
	FM0701B	Pratten Park Above Ground Detention Basin	Above ground detention basin	2 (App C Section A5.1)
	FM0702	Arthur Street Underground Detention Basin	Underground detention basin	2 (App C Section A5.2)
	FM0703	Pratten Park And Arthur Street Under Ground Detention Basin	Underground detention basin	3 (Section 10.2.9.6)

(2) Assessment Stages

1 – High Level

2 – Detailed Assessment

3 – Full Cost Benefit Assessment