City of Ryde

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ATTACHMENTS FOR: AGENDA NO. 15/24 COUNCIL MEETING

Meeting Date: Tuesday 10 December 2024
Location: Council Chambers, Level 1A, 1 Pope Street, Ryde and Online
Time: 6.00pm

ATTACHMENTS FOR COUNCIL MEETING

Item

9 DRAFT FLOOD RISK MANAGEMENT STUDY AND PLAN

Attachment 1 Draft Flood Risk Management Study and Plan

CITY OF RYDE COUNCIL

FLOOD HARMONISATION STUDY – FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

DRAFT

SEPTEMBER 2024

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FLOOD HARMONISATION STUDY – FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

DRAFT

SEPTEMBER 2024

Project Flood Harmonisation Study – Floodplain Risk Management Study and Plan	**Project Number** 120099
Client City of Ryde Council	**Client's Representative** Leila Faghihi
Project Manager Michael Reeves	

Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
1	Draft Report	City of Ryde Council	Michael Reeves, Allison Wong	Michael Reeves	Michael Reeves	June 2024
2	Draft Report	City of Ryde Council	Michael Reeves, Allison Wong	Michael Reeves	Michael Reeves	Sept 2024

FLOOD HARMONISATION STUDY – FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE OF CONTENTS

PAGE

APPENDICES

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF DIAGRAMS

LIST OF FIGURES

LIST OF ACRONYMS

1D	One-dimensional
2D	Two-dimensional
AAD	Average Annual Damage
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AMC	Antecedent Moisture Condition
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff (1987, 2016 and 2019 versions)
AVM	Average Variability Method
AWE	Average Weekly Earnings
BCA	Building Code of Australia
BoM	Bureau of Meteorology
CBA	Cost-Benefit Analysis
CBR	Cost-Benefit Ratio
CPI	Consumer Price Index
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DCP	Development Control Plan
DFE	Defined Flood Event
DPIE	Department of Planning, Industry and Environment (now DCCEEW)
DRAINS	Hydrologic and 1D hydraulic model for simulating urban stormwater
EP&A Act	Environmental Planning and Assessment Act 1979
EPBC	Environment Protection and Biodiversity Conservation
EY	Exceedances per Year
FDM	Floodplain Development Manual
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FRMS&P	Floodplain Risk Management Study and Plan
GIS	Geographic Information System
GPT	Gross Pollutant Trap
HPC	Heavily Parallelised Compute
IFD	Intensity, Frequency and Duration (Rainfall)
IPCC	Intergovernmental Panel on Climate Change
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (airborne survey method)
m	metres
m^3/s	cubic metres per second
mAHD	meters above Australian Height Datum
MCMA	Multi-Criteria Matrix Assessment
NPV	Net Present Value
OEH	Office of Environment and Heritage (now DCCEEW)

PMF	Probable Maximum Flood
PMP	Probably Maximum Precipitation
SES	State Emergency Service
SWC	Sydney Water Corporation
TSC	Threatened Species Conservation
TfNSW	Transport for NSW
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
VHR	Voluntary House Raising
VP	Voluntary Purchase

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) 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 2019 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. Therefore, the term Exceedances per Year (EY) is recommended. 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 (PMF) 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 has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % 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	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

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 assists Councils in the discharge of their floodplain management responsibilities.

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

1. Flood Study
- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management
- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan
- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

This study constitutes the second and third stages of the management process.

ACKNOWLEDGEMENTS

This study was undertaken by WMAwater Pty Ltd, on behalf of the City of Ryde Council. Council has prepared this document through its Floodplain Management Program.

A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- Residents of the study area
- City of Ryde Council
- NSW State Emergency Service (SES)
- Sydney Water Corporation (SWC)
- NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW)

EXECUTIVE SUMMARY

WMAwater was commissioned by the City of Ryde Council (Council) in May 2021 to undertake a flood harmonisation study across all 14 catchments within the Ryde Local Government Area (LGA). The study includes a comprehensive update to the previous Flood Studies (FS) and Floodplain Risk Management Study and Plans (FRMS&P) for the four catchment areas covered by the LGA. This report documents the FRMS&P component of the study. The study expands upon this information to further understand and plan for the nature and extent of flood risk throughout the study area. It seeks to investigate methods by which to manage existing, future and residual flood risk in the study area and to develop a Floodplain Risk Management Plan which documents the decisions for the management of flood risk into the future. This study provides an opportunity to revisit the existing Floodplain Risk Management Study and Plans (completed in 2008 to 2015), providing a consolidated flood risk management plan based on the latest information available. It has been undertaken in accordance with the NSW Government's Flood Prone Land Policy.

Study Area

The City of Ryde LGA is located between the Parramatta and Lane Cove rivers and has 16 suburbs within its boundaries, which are Chatswood West (part), Denistone, Denistone East, Denistone West, East Ryde, Eastwood (part), Gladesville (part), Macquarie Park, Marsfield, Meadowbank, Melrose Park (part), North Ryde, Putney, Ryde, Tennyson Point and West Ryde. The City of Ryde LGA is 40.7 km^2 in area and is located in northern Sydney between 8 and 15 km north-west of the Sydney CBD. It is bounded by Lower Parramatta River to the south and by Lane Cove River and Terrys Creek to the north, neighbouring the Peninsula of Hunters Hill to the east and the City of Parramatta to the west.

Available Data

This study aims to update the existing Floodplain Risk Management Studies and Plans for this area, including:

- Buffalo and Kittys Creek FS and FRMS&P (GHD, 2014),
- Eastwood and Terrys Creek FS (Bewsher, 2008) and FRMS&P (Bewsher, 2009),
- Macquarie Park FS (Bewsher, 2010) and FRMS&P (Bewsher, 2011),
- Parramatta River – Ryde Sub-Catchments FS (SKM, 2013) and FRMS&P (SKM, 2015).

These studies contain a technical description of the flood models and the calibration process undertaken. These flood models form the basis of the current study.

Design Flood Behaviour

Design flood behaviour was simulated with the updated models and is defined in the flood study (Reference 1). Results for peak flood depth, level, velocity, hydraulic hazard, hydraulic categories and flood emergency response classifications are mapped in the flood study. Additional flood assessments and comparisons were also undertaken, including tidal inundation, pipe capacity assessment, climate change sensitivity (both rainfall intensity and sea level rise considerations), and blockage sensitivity.

Economic Impacts of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the study area. A property database was compiled from surveyed and estimated floor levels, with over 5,900 properties identified. In each model area, there was typically a gradual increase in the number of properties affected with increasing flood magnitude, except for the PMF event in which the number of properties affected is substantially higher. Commercial and industrial properties account for approximately 10% of the affected properties, and up to 3% of the total flood damage cost, depending on the area and flood affectation of the commercial and industrial zones. The total damage cost is approximately $115M for the 1% AEP event, with the average annual damages of $38M. This represents the average cost of flooding each year and a summary can be found in the table below.

Catchment	Average Annual Damage ($)		
	Residential	Commercial and Industrial	Total[1]
Eastwood and Terrys Creek	$6.17M	$621,000	$10.59M
Macquarie Park	$4.16M	$174,000	$6.73M
Buffalo and Kittys Creeks	$4.88M	$0	$7.45M
Parramatta River	$8.29M	$87,000	$13.22M
Total	**$28.21M**	**$1.06M**	**$37.98M**

1. Includes vehicle damages, indirect tangible damages and social (intangible) damages

Floodplain Risk Management Measures

A variety of flood risk management measures were investigated as part of this study. These measures can be separated into three broad categories:

- Flood modification measures, which modify the physical behaviour of a flood including depth, velocity and direction of flow paths.
- Property modification measures, which modify the existing land use and development controls for future development.
- Response modification measures, which modify the response of the community to flood hazard by educating flood affected residents about the nature of flooding so that they can make better informed decisions.

Options were identified from the existing Floodplain Risk Management Studies and Plans as well as additional measures identified by WMAwater. This resulted in over 130 options to be investigated. A large number of these were considered not to be feasible based on a high-level assessment, hydraulic assessment or detailed assessment. The options that were considered viable were then assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on emergency responders among others. The outcomes of the analysis undertaken in this Floodplain Risk Management Study are presented in this report. The recommended options for implementation in the Floodplain Risk Management Plan are presented in the table and figure below.

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M027 5.2.4.7	First Avenue Drainage Upgrade	Upgrade existing stormwater line between First Avenue and Rowe Street together with demolition of 100-104 Rowe Street (partial rebuild possible).	• Reduces flood levels at the rear of Rowe Street by up to 600 mm. • Reduces flood damages. • Design already progressed.	• Primary benefit is to commercial properties only.	Council	Unlikely to be eligible for NSW Government funding as benefit is limited to commercial properties.	$3M	0.8	High
	M036 5.2.4.8	Jim Walsh Park Basin	Construct a basin by raising the existing bund and excavating a portion of Jim Walsh Park.	• Reduces flood levels residential downstream areas by up to 125 mm. • Reduces flood damages.	• Tree removal of listed species in TSC & EPBC Act required. • Social disruption as access to the park is reduced after a flood event. • Dam safety of a high embankment in close proximity to residential properties.	Council	May be eligible for NSW Government funding	$1.9M	4.6	High
	M102 5.2.5.1	Channel and Drainage Maintenance	Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels. Council should identify specific areas prone to blockage and periodically review and update these areas based on feedback from the community. Council should also inspect and record channels and drainage structures following flood events to assess debris build up and clear blockages.	• Removal of vegetation and debris blockage from structures will enable a more efficient conveyance of water.	• The major release of debris is during the storm event, and hence regular maintenance may not necessarily reduce blockage during a flood event. • Vegetation in open channels is not a significant constraint to the hydraulic capacity of the channel.	Council	Internal	N/A	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M073 5.2.4.12	Diversion Drain at Pittwater Road	Regrade road verge and construct a channel draining the low point.	• Improves flood hazard to H1 (generally safe)	• Tree removal for diversion drain	TfNSW	TfNSW / State Government	$260,000	N/A	Medium
	M084 5.2.4.13	Drainage Diversion to West Ryde Tunnel	Divert drainage from Gaza Rd into West Ryde Tunnel. This involves upgrading 15 existing pits and constructing 3 new pits	• Reduces flood levels in t% AEP and reduces flood damages	• Existing pipes run through existing properties and will require private property access	Council	May be eligible for NSW Government funding	$1.8M	0.8 to 1	Medium
	M051 5.2.4.9	Kotara Park Basin	Construct a 1.3 m maximum height embankment along the southern boundary of the Abuklea Road Tennis Courts and Kotara Park.	• Reduces flood levels in mainly frequent events and reduces flood damages.	• Minimal impacts in rare events. • Increases flood levels in some locations and will require mitigation strategies • Dam safety concerns due to proximity to residential properties • Social disruption from restricted access during and after food events.	Council	May be eligible for NSW Government funding	$156,000	13.3	Medium
	M061 5.2.4.11	North Ryde Golf Club Basin	Construct a basin in North Ryde Golf Club by raising a 1 m high bund along the eastern boundary.	• Reduces flood levels downstream over a large area	• Minor benefits to property impacts • Requires liaison with North Ryde Golf Club • Flood levels and extent increased in golf course directly upstream of the embankment	Council/North Ryde Golf Club	May be eligible for NSW Government funding	$97,000	12.7	Medium

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M003 Section 5.2.4.4	Gannan Park Basin	Construct a basin with a 1 m high bund running along the southwestern and southeastern boundary of Gannan Park.	• Reduces road inundation on Berripa Close. • Reduces property impacts for several properties on Berripa Close.	• Increases flood levels in Minga St properties • Social disturbance as the park may be inaccessible after flood events • Relocation or raising of park amenities may be required	Council	May be eligible for NSW Government funding	$4M	0.3	Low
	M057 5.2.4.10	Smalls Park Basin	Construct a basin in Smalls Park by raising a 1 m high bund along the northwestern and northeastern boundary.	• Reduces flood levels by 150 mm and reduces property impacts	• Access to park disrupted during and after flood events.	Council	May be eligible for NSW Government funding	$480,000	3.7	Low
	M094 5.2.4.15	Pickford Avenue and Lovell Road Intersection	Divert overland flows from properties into a reserve along Orange Street.	• Reduces flood levels in properties and property damages	• Requires mitigation options to management flooding within the reserve and along Orange St	Council	May be eligible for NSW Government funding	$190,000	10.8	Low
	M089 5.2.4.14	Lions Park Basin	Construct a basin by excavating the oval within Lions Park by 1 m. This option involves a drainage channel which directs water into the basin as well as a bund which prevents flows from entering adjacent residential properties.	• Reduce flood levels within residential properties and reduces property damages	• Available storage within the park is constrained by existing park amenities.	Council	May be eligible for NSW Government funding	$1.3M	0.4	Low
	M101 5.2.4.16	Boyce Street Drainage Upgrade	Upgrade 150 m length of pipes under and downstream of Boyce Street.	• Reduces flood levels by 0.4 m in properties along Boyce St	• Potential underground utilities that may need to be avoided or relocated, as well as tree roots. • Disruption to traffic and residents on Boyce St during construction. • Flood levels increases in properties downstream of the	Council	May be eligible for NSW Government funding	$2.3M	0.3	Low

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
					pipe upgrade will required mitigation					
Property Modification Measures	PM08 5.3.8	Climate Change Policy	A climate change policy guides Council's operations and policies at a high level. This would likely feed into other Council operations such as coastal management, asset design, flooding and planning controls. Climate change adaptation should also be considered at an LGA-wide scale.	• Ensures future climate and sea levels are incorporated into current planning controls and infrastructure design.	• Uncertainties in future climate and sea level predictions. The changes expected for future rainfalls and runoff response is largely unknown.	Council	Internal	N/A	N/A	High
	PM03 5.3.3	Flood Proofing	Flood proofing of non-residential buildings with temporary flood barriers (both existing and new structures, where floor levels are allowed to be lower). This could also be extended to existing residential development, but not recommended for new residential development – floor level controls should be applied instead.	• Reduce flood damages in the event of a flood	• Costs and implementation of flood proofing measures are the responsibility of the property owner / business.	Council (policy) and property owners (cost of flood proofing)	Internal (policy) Private (flood proofing)	Varies	N/A	High
	PM04 5.3.4	Flood Planning Levels	The current adopted FPL is considered appropriate. It is recommended to update flood levels based on the updated modelling developed as part of this FRMS&P and consider incorporating climate change projections into FPLs.	• Ensures new buildings are protected to an appropriate level.	• A freeboard of 500 mm in overland flow areas may be excessive given the scale in the range of flood events.	Council	Internal	N/A	N/A	High
	PM06 5.3.6	Flood Planning Policy	Flood planning policy is typically governed by the LEP and DCP, which outline flood-related development controls. Consideration	• Ensures adequate flood planning controls to reduce the flood damage and risk to life for	• Clarity in planning controls and their application to ensure adherence.	Council	Internal	N/A	N/A	High

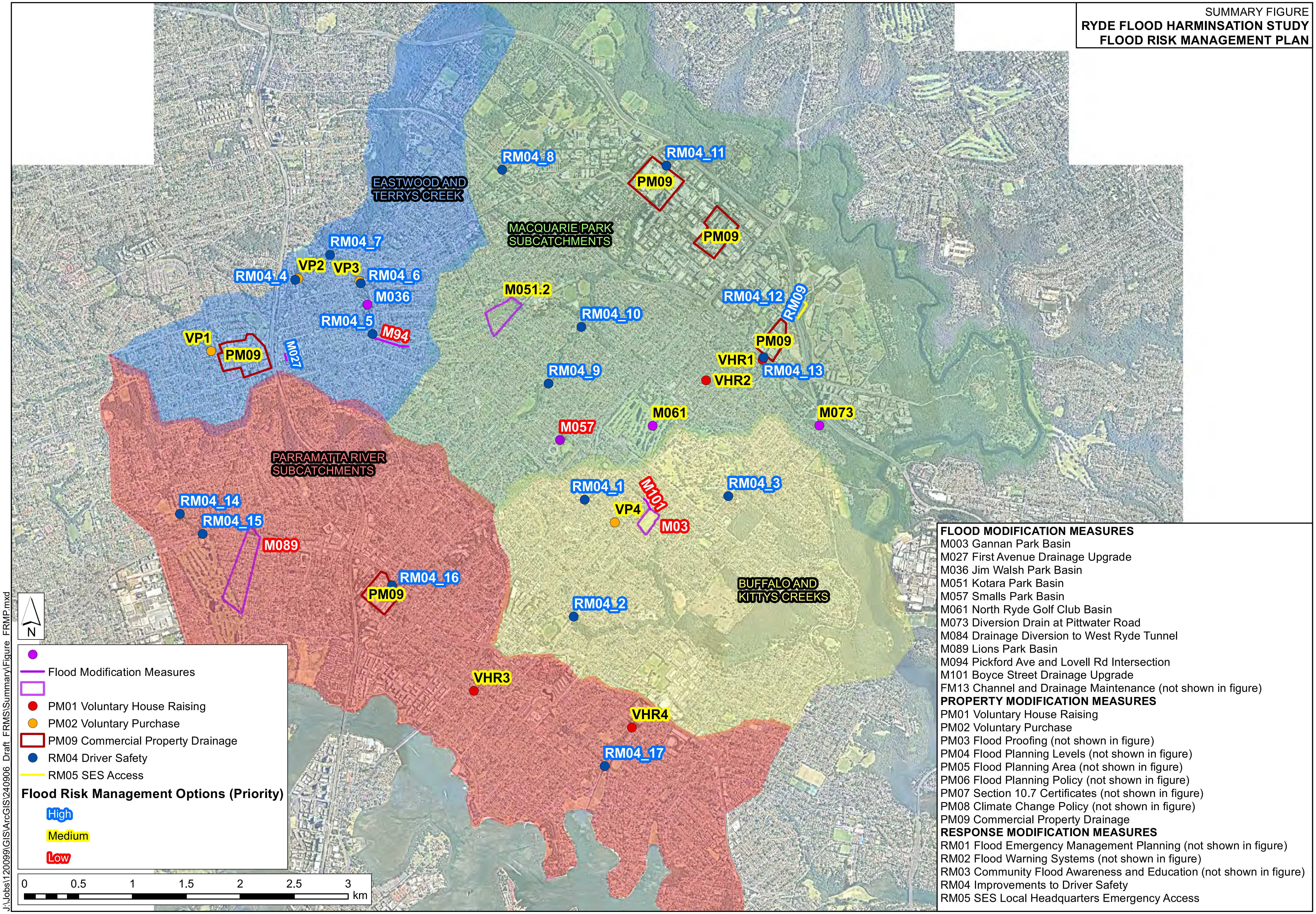
	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Property Modification Measures			should be given to the following: • Inclusion of climate change in the full range of flood related development controls. • Implementation of the draft DCP. • Provision of special flood considerations clause in the LEP.	new developments.						
	PM05 5.3.5	Flood Planning Area	It is recommended to retain the current lot-based tagging approach, and update the tagging status based on the updated modelling undertaken as part of this FRMS&P.	• Ensures that flood planning controls are applied to lots that are flood affected.	There are issues with the traditional approach of applying freeboard and 'stretching' the surface to identify the FPA, particularly with steep overland flow paths in urban areas.	Council	Internal	N/A	N/A	High
	PM07 5.3.7	Section 10.7 Certificates	Section 10.7 Certificates are required to show flood notation. This informs the land owner of flood risk and applicable development controls.	• Informs land owners of flood affectation of the lot and applicable flood planning controls.	• Typically only accessed for the purpose of redevelopment or in the sale/purchase of land.	Council	Internal	N/A	N/A	High
	PM09 5.3.9	Commercial Property Drainage	Identify commercial and industrial properties which may benefit from increased flood conveyance and flag these properties for further assessment when it is being redeveloped.	• Allows for opportunities of greater flood benefits for upstream drainage upgrades • Improves flow conveyance across the commercial property	• Commercial properties along the same watercourse are unlikely to be redeveloped at the same time and there may only be partial benefits until the entire length of conduit is upgraded.	Property Owner to consider upgrades. Council to compile register of identified properties.	Private – drainage upgrades) Internal – compilation of properties.	N/A	N/A	Medium
	PM02	Voluntary Purchase	Purchase existing properties to remove them from high hazard if	• Reduces exposure to flood damage	• High cost of properties in the current housing market	NSW State, Council and	NSW State	>$2M per property	>1	Medium

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
	5.3.2		they are eligible. Two properties recommended for feasibility study.	• Reduces exposure of residents and rescuers from high flood hazard	reduces economic viability, opposition from land owners and minimal properties in high hazard areas.	Owners				
	PM01 5.3.1	Voluntary House Raising	Physically raise existing dwelling structures above the FPL. Four properties recommended for feasibility study	• Reduces exposure to flood damage	• Construction type of housing stock in City of Ryde is typically brick/rendered, slab on ground or multi-storey buildings.	NSW State, Council and Owners	NSW State, Owner	$30,000 to $100,000	>1	Medium
Response Modification Measures	RM01 5.4.1	Flood Emergency Management Planning and Coordination	It is recommended that the SES: • Use the information and modelling developed as part of this FRMS to update their local flood plan for City of Ryde. • Consider providing an updated FloodSafe brochure or information on their website specific for the flood risk in City of Ryde. It is recommended that Council and SES: • Hold regular meetings of all responders and training exercises between flood events to identify roles and responsibilities in practice and build relationships between agencies and/or community groups.	• Flood emergency planning enables a more coordinated, timely and targeted response to flood events.	• As the interval between flood events increases, the coordination of flood response can lack attention.	Council and SES	Internal	N/A	N/A	High
	RM03 5.4.3	Community Flood Awareness	It is recommended to design and implement and ongoing community flood education program to maintain	• An informed community can better respond to	• Community education programs are typically well received by those interested in	Council	Internal with opportunities for State	Varies	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Response Modification Measures		and Education	a high level of flood awareness and understanding of the risk and appropriate response to flooding in the City of Ryde study catchments. At a minimum, this should include ongoing development of Council's website as a hub for flood information, development and distribution of a leaflet and continuing to provide flood information through Section 10.7 certificates and flood advice letters.	flood risks, including preparation for and making wise decisions during flood events.	and already aware of flood risk, and it is difficult to engage the wider community.		Government assistance.			
	RM04 5.4.4	Improvements to Drive Safety	Installation of flood signs and flood depth indicators can improve driver safety, in conjunction with community education about the risks of driving through floodwaters. It is recommended that a detailed study is undertaken to confirm the preferred locations, residual flood risk (i.e. need for road closure) and safe alternative routes and how traffic can be diverted in flood events. Following the detailed study, installation can proceed in accordance with the outcomes of that study.	• One of the primary risks for flash flooding in urban areas is motorists driving through floodwaters. This reduces that risk by warning motorists of flooded roads.	• There is the chance that these signs and warnings will be ignored by motorists.	Council and TfNSW where applicable.	Council and TfNSW, with opportunities for State Government funding.	Not Estimated	N/A	High
	RM05 5.4.1	SES Local Headquarters Emergency Access	Construction of an additional emergency access track from SES headquarters to the Delhi Rd off ramp of the M2	• Provides flood free access to and from SES headquarters. • Improved emergency access to parts of the LGA	• Access to the broader LGA remains constrained by local roads route access.	Council, SES, and TfNSW	Council, TfNSW	N/A	>1	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
	RM02 5.4.2	Flood Warning System	It is recommended that the severe weather and severe thunderstorm warnings issued by the BoM be used to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BoM, anticipating the impacts and preparing accordingly.	• Enable Council and SES to be on alert to potential flash flooding events. The community can also benefit by being aware of potential flash flooding as respond accordingly.	• Education about what these warnings means and actions that should be taken by residents in different locations is key.	Bureau of Meteorology, Council, SES.	Internal	N/A	N/A	Medium

SUMMARY FIGURE
RYDE FLOOD HARMINSATION STUDY
FLOOD RISK MANAGEMENT PLAN



FLOOD MODIFICATION MEASURES
M003 Gannan Park Basin
M027 First Avenue Drainage Upgrade
M036 Jim Walsh Park Basin
M051 Kotara Park Basin
M057 Smalls Park Basin
M061 North Ryde Golf Club Basin
M073 Diversion Drain at Pittwater Road
M084 Drainage Diversion to West Ryde Tunnel
M089 Lions Park Basin
M094 Pickford Ave and Lovell Rd Intersection
M101 Boyce Street Drainage Upgrade
FM13 Channel and Drainage Maintenance (not shown in figure)
PROPERTY MODIFICATION MEASURES
PM01 Voluntary House Raising
PM02 Voluntary Purchase
PM03 Flood Proofing (not shown in figure)
PM04 Flood Planning Levels (not shown in figure)
PM05 Flood Planning Area (not shown in figure)
PM06 Flood Planning Policy (not shown in figure)
PM07 Section 10.7 Certificates (not shown in figure)
PM08 Climate Change Policy (not shown in figure)
PM09 Commercial Property Drainage
RESPONSE MODIFICATION MEASURES
RM01 Flood Emergency Management Planning (not shown in figure)
RM02 Flood Warning Systems (not shown in figure)
RM03 Community Flood Awareness and Education (not shown in figure)
RM04 Improvements to Driver Safety
RM05 SES Local Headquarters Emergency Access

1. INTRODUCTION

1.1. Overview

WMAwater was commissioned by the City of Ryde Council (Council) in May 2021 to undertake a flood harmonisation study across all 14 catchments within the Ryde Local Government Area (LGA). The study includes a comprehensive update to the four Flood Studies (FS) and Floodplain Risk Management Study and Plans (FRMS&P) for each catchment across the LGA. The FRMS&P has been undertaken in accordance with the NSW Government's Flood Prone Land Policy and the "Floodplain Development Manual: the management of flood liable land", New South Wales Government, April 2005 (FDM) (Reference 2). This report documents the FRMS&P component of the study.

The primary aim of this FRMS&P is to provide a more informed understanding of flood risks and impacts across the study area and develop a long-term strategy to manage this risk. Updates to the existing flood studies was undertaken prior to this FRMS&P as part of Reference 1 to better define the existing flood behaviour and current flood risk. The FRMS&P expands upon this information to further understand and plan for the nature and extent of flood risk throughout the study area. This FRMS&P seeks to investigate methods by which to manage existing, future and residual flood risk in the study area and to develop a Floodplain Risk Management Plan (FRMP) which documents the decisions for the management of flood risk into the future. This study provides an opportunity to revisit the existing FRMS&P's (completed in 2001 to 2023) and re-evaluate flood risk mitigation measures with up-to-date flood modelling. This study provides a consolidated FRMP based on the latest information available.

1.2. Study Area

The City of Ryde LGA is located between the Parramatta and Lane Cove rivers and has 16 suburbs within its boundaries, which are Chatswood West (part), Denistone, Denistone East, Denistone West, East Ryde, Eastwood (part), Gladesville (part), Macquarie Park, Marsfield, Meadowbank, Melrose Park (part), North Ryde, Putney, Ryde, Tennyson Point and West Ryde.

The City of Ryde LGA is 40.7 km^2 in area, with an estimated population of around 129,000 in 2021 It is located in northern Sydney between 8 and 15 km north-west of the Sydney CBD. It is bounded by Lower Parramatta River to the south and by Lane Cove River and Terrys Creek to the north, neighbouring the Peninsula of Hunters Hill to the east and the City of Parramatta to the west. The city is serviced by the Northern railway line, along which Eastwood Station, Denistone Station, West Ryde Station and Meadowbank Station are within the study area, as well as a number of main roads including Victoria Road, Pittwater Road, Church Street, Devlin Street, Lane Cove Road, Blaxland Road, Epping Road, Marsden Road, and the M2 Motorway. The map for the study area with key features can be seen in Diagram 1, with further detail shown in Figure 1.

Diagram 1: Study Area

As shown in Diagram 2 (based on City of Ryde land zoning), the land area is largely occupied by residential dwellings with 56% of total land use. At the last census in 2021, detached dwellings make up less than half (40.8%) the dwelling types in Ryde. Medium to high density dwellings make up a significant proportion of the remainder (44.6%). Parklands and other lands including industrial, commercial, institutional areas and other special uses make up the remainder of the total area.’

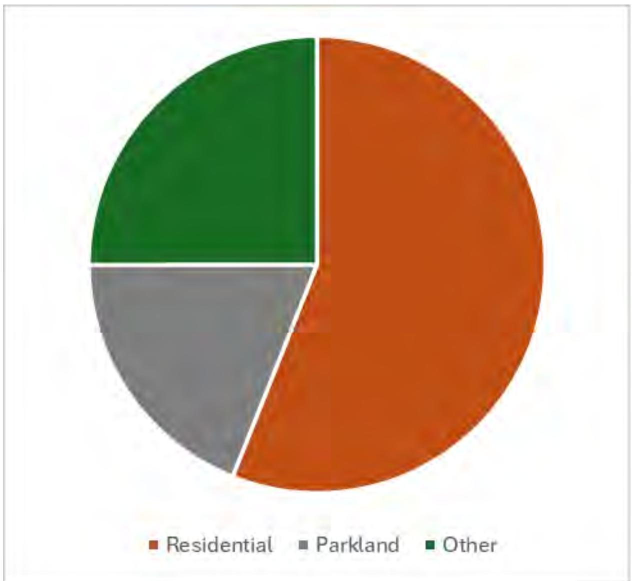


Diagram 2: City of Ryde Land Use

The study area was divided into several sub-catchments subject to individual flood study investigations in the past, as summarised in Table 1 and discussed below. These catchment areas are shown in Figure 2.

Table 1: Study Area Catchments

Catchment	**Area (km^2)**	**Flows to**
Eastwood Catchment[1]	1.69	Lane Cove River
Terrys Creek[1]	3.26	
Mars Creek (including University Creek)	3.27	
Shrimptons Creek	5.55	
Industrial Creek	1.48	
Porters Creek	2.25	
Lane Cover River Catchment[2]	3.03	
Kittys Creek	1.93	
Buffalo Creek	5.5	
Archer Creek	2.86	Parramatta River
Denistone Catchment	2.15	
Charity Creek	2.47	
Parramatta River[3]	1.58	
Gladesville Catchment	3.66	
TOTAL	40.68	

1 The total Terrys Creek catchment (including Terrys Creek and Eastwood drainage areas) is approximately 10.12 km^2, however, the upstream portion is located within the City of Parramatta LGA (approximately 1.60 km^2), and parts of the northern side of the catchment are located within the former Hornsby Shire Council LGA (now City of Parramatta LGA, approximately 3.57 km^2), and these areas outside the Ryde LGA have not been included in this table.

2 Area within the Ryde LGA that drain directly to the Lane Cove River

3 Area within the Ryde LGA that drain directly to the Parramatta River

1.3. Demographics

Understanding the social characteristics of the study area can help in ensuring appropriate risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. Information for the City of Ryde was obtained from the latest 2021 census data from the Australian Bureau of Statistics (ABS). A summary of the relevant information is contained in Table 2.

Table 2: Demographic Overview of the City of Ryde (Reference 3)

Census Category	Census Statistic	City of Ryde	NSW
Population	Total Population	129,123	8,072,163
	Male	48.8%	49.4%
	Female	51.2%	50.6%
Age	0-14 years	16.2%	18.2%
	15-64 years	68.8%	64.1%
	65-84 years	12.6%	15.4%
	> 85 years	2.4%	2.3%
Dwellings	Occupied dwellings	91%	90.6%
	Unoccupied dwellings	9%	9.4%
	Separate house	40.8%	65.6%
	Semi-detached	14.2%	11.7%
	Flat/Apartment	44.6%	21.7%
	Average people per dwelling	2.5	2.6
	No car at dwelling	12.5%	9.0%
Households	Family households (%)	69.1%	71.2%
	Lone person households (%)	26.5%	25.0%
	Group households (%)	4.4%	3.8%
Tenure	Owned (%)	55.6%	64.0%
	Rented (%)	41.5%	32.6%
Median Weekly Income	Personal	\$967	\$813
	Family	\$2,519	\$2,185
	Household	\$2,098	\$1,829
Cultural Diversity	Country of birth	Australia (47.5%)	Australia (65.4%)
	Top Non-Australian countries of birth	China (12.4%)	-
		India (4%)	-
		Korea (3.7 %)	-
		Hong Kong (2.8%)	-
	English only used at	46.3%	67.6%

	home		
	Non-English language used at home	55.3 %	29.5%
	Top Non-English languages	Mandarin, Cantonese, Korean, Italian, Arabic	-
Education	Year 12 and above (%)	78.9%	66.6%
Work	In Labour Force (%)	63.8%	58.7%
	Worked Full Time (%)	58.5%	55.2%
	Worked Part Time (%)	26.5%	29.7%

The characteristics noted above are considered in the community engagement strategy and when considering response modification options, such as flood education, warning or evacuation systems. Key characteristics include:

- Approximately 16% of the population are under the age of 15 and 15% are over the age of 65. These groups of people are more likely to be vulnerable and require assistance during flood events to evacuate and more likely to require assistance with recovery following a flood. The study area, however, typically has a slightly higher proportion of adults who are less likely to be vulnerable (in the 15 to 64 age bracket) than the state average.
- There is a high proportion (almost 50%, more than double the state average) of dwellings that are flats or apartments. This means that they are more likely to not be affected by above floor flooding and be safe during 'flash flooding' events that result in overland flow flooding. It may, however, contribute to evacuation difficulties if required, with many people trying to exit from a single building at once.
- Almost 13% of households do not have a car (50% higher than the state average), which may hinder the possibility of evacuation.
- Approximately a quarter of people live alone. These people may be at a greater risk of being unaware of flood warnings or evacuation orders.
- There is a higher proportion of people renting in City of Ryde than the state average. These households may be more likely to move around and be less aware of local flooding issues. Home ownership may also affect the willingness to participate in property modification measures.
- There is a higher proportion of people not born in Australia (over half) than the state average. There is also a very high proportion of households that speak a language other than English at home (over 50% more than the state average). This diversity of culture in City of Ryde means that flood signs, warnings, messages, brochures, etc. may need to cater for multiple languages. Interpretation services may also be required during emergencies and for effective public education strategies.
- The median weekly income for individuals, families and households is similar to or higher than the state average. This suggests that the value of house contents may be average or

above average (for flood damages), and the ability to recover from flooding events may also be average or above average.
- People are generally well educated (79% attaining year 12 or above). This suggests that there is a high capacity to understand technical information through education.
- A high proportion of people in the labour force were engaged in full-time or part-time work (85%). This means a large proportion of the population are in the workforce and may not be at their property during a flood event. This may limit their ability to minimise property damage.

1.4. Natural Environment

City of Ryde is around 40 km^2 in extent and highly urbanised with limited natural areas. The natural areas within the LGA total to approximately 205 ha and 130 ha of these areas are subject to active bush regeneration works (Reference 4). The natural areas that do remain, however, are of ecological significance and have high conservation value as they provide habitat for threatened flora and fauna in the LGA. There are 13 threatened flora and 75 threatened fauna species listed on NSW Wildlife Atlas under the Threatened Species Conservation (TSC) Act or Environment Protection and Biodiversity Conservation (EPBC) Act (or both) within City of Ryde. Priority areas that were identified in Reference 4 as very high biodiversity conservation priority include:
- Mars Reserve and areas along Buffalo Creek
- Kittys Creek Reserve
- Natural areas around near Kent Road and Wilson Road
- Natural areas at Marsfield Park
- Darvall Park
- Denistone Park
- Tyagarah Park

These areas typically align with natural or semi-natural waterways and wetlands, and hence these ecological communities should be considered when developing flood mitigation measures.

1.5. Heritage

In NSW, there are different types of statutory lists for local, state and national heritage items. Local heritage items are listed in the heritage schedule of a local council's Local Environmental Plan (LEP) or regional environmental plan. State heritage items are places and items of particular importance to the people of NSW, and are listed on the State Heritage Register. National heritage items are listed on the National Heritage List, established by the Australian Government to list places of outstanding heritage significance to Australia. In addition to these, there are other statutory listings such as the Aboriginal sites register. It is important in floodplain management and in the development of flood mitigation measures to be aware of these heritage items and where an additional heritage assessment may be required to ensure heritage items are preserved.

The State Heritage Inventory (Reference 5) is an online database containing heritage items in NSW including Aboriginal Places, State Heritage Register, Interim Heritage Orders, State Agency Heritage Registers and Local Environmental Plans. In City of Ryde there is approximately 209 local heritage items and 10 state heritage items. The state heritage items within the study area include:

- Willandra
- Ryde Pumping Station and site
- Riverview House, Outbuildings, etc
- Addington House
- Police Station (former)
- Hermitage and Garden
- Brush Farm
- Gladesville Drill Hall
- The Retreat
- Meadowbank rail bridge over Parramatta River

2. FLOOD STUDY

This flood harmonisation study is aimed to provide an integrated flood study across the whole LGA. As part of this flood harmonisation study an updated flood study was completed prior to this floodplain risk management study (FRMS). The updated flood study was prepared for Council and has been completed in February 2024 by WMAwater (Reference 1). An outline of the methodology and results of the flood study update is provided in this section. For further information on the flood study update, refer to Reference 1.

2.1. Previous Studies

Prior to the current flood harmonisation study, a number of previous studies have been completed within the City of Ryde area. These previous studies range from flood studies to floodplain risk management studies and plan as well as detailed studies of specific flood mitigation options.

Several Flood Studies (FS) and Floodplain Risk Management Studies and Plans (FRMS&P) have previously been completed within the City of Ryde catchments:

- Buffalo and Kittys Creek FS and FRMS&P (GHD, 2014), Reference 6 and Reference 7,
- Eastwood and Terrys Creek FS (Bewsher, 2008) and FRMS&P (Bewsher, 2009), Reference 8 and Reference 9,
- Macquarie Park FS (Bewsher, 2010) and FRMS&P (Bewsher, 2011), Reference 10 and Reference 11,
- Parramatta River – Ryde Sub-Catchments FS (SKM, 2013) and FRMS&P (SKM, 2015), Reference 12 and Reference 13.

Additionally, several studies which focus on flood behaviour and mitigation options in the Eastwood town centre area have been completed in the recent years:

- Eastwood Tunnel Investigation Stage 1 – Feasibility and Concept Report (Robinson GRC, 2001), Reference 14
- Eastwood Tunnel Investigation Stage 2 – Model Construction and Eastwood Flooding Assessment (Robinson GRC), Reference 15
- Eastwood Town Centre Drainage Study – Data and Model Review (Royal Haskoning DHV, 2019), Reference 16
- Eastwood Town Centre Flood Study and Stormwater Upgrades Design (Royal Haskoning DHV, 2019), Reference 17
- Eastwood CBD Flood Study – Glen Street Detention Tank – Detailed Concept Design (Royal Haskoning DHV, 2021), Reference 18
- Eastwood Drainage Tunnel Feasibility Study and Investigation (WMAwater, 2023), Reference 19

2.2. Methodology

2.2.1. Hydrologic and Hydraulic Modelling

Flood modelling of the LGA was undertaken with hydrologic modelling (which estimates the magnitude and timing of runoff for a given amount of rainfall) and hydraulic modelling (simulates how water moves across terrain). Hydrographs of flow versus time for each sub-catchment generated by the hydrologic modelling serve as input flows for the hydraulic modelling.

Hydrologic modelling was undertaken using DRAINS software and was based on the hydrologic models developed as part of previous studies. DRAINS software was selected as most previous studies had used this software and because it is capable of incorporating the most up to date Australian Rainfall and Runoff 2019 (ARR19) procedures. Version 2020.061 (64bit) of DRAINS was used in the study.

Two-dimensional (2D) hydraulic modelling was undertaken using TUFLOW (version 2020-10-AA-w64 using the finite volume HPC solver). The TUFLOW hydraulic models adopt a 2 m grid resolution with an embedded one-dimensional (1D) representation of concrete-lined channels in Eastwood and Parramatta River model. TUFLOW software was selected as it is widely used for a range of similar floodplain projects both internationally and within Australia and is capable of dynamically simulating complex overland flow regimes. A total of nine separate TUFLOW models (Table 3) were consolidated into four TUFLOW models as part of the updated flood study.

Table 3: Consolidation of TUFLOW Models

Existing models	Area (km^2)	Previous Model Resolution (m)	Consolidated Model ID
Eastwood and Terrys Creek	4.95	3	TC Model
Macquarie Park – Mars Creek	3.27	3	MQ Model
Macquarie Park – Shrimptons Creek	5.55	3	
Macquarie Park – Porters / Industrial / Lane Cove	6.76	3	
Kittys Creek	1.93	2	BK Model
Buffalo Creek	5.5	2	
Parramatta River – Archers / Denistone / Charity	7.48	3	PR Model
Parramatta River – Minor River Subcatchments	1.58	2	
Parramatta River – Gladesville	3.66	3	

2.2.2. Updates to Australian Rainfall and Runoff

Design flood modelling for this study was undertaken in accordance with the guidance for rainfall-runoff flood estimation techniques in the updated edition of ARR19 (Reference 20). Since the last major edition of ARR was published in 1987 (ARR87, Reference 21), numerous technological developments and a larger set of recorded rainfall data has been available for updating the guidelines on design rainfall depths and temporal patterns.

Compared to ARR87, ARR19 has three major updates to the rainfall-runoff design flood method:

1. The Intensity-Frequency-Duration (IFD) design rainfall data and the initial and continuing loss values across Australia have been updated using the additional 30 years of data;
2. There is information about the amount of rainfall likely to occur before the main storm burst and how to incorporate this into model estimates. This rainfall is commonly referred to as pre-burst;

3. The approach for assuming design temporal patterns and determining the critical duration has been significantly revised. ARR19 recommends that 10 temporal patterns should be analysed for each storm duration to determine the critical storm event. The critical storm event is not the event producing the maximum peak value for all the durations but the temporal pattern of the duration which produces the maximum average peak value from the 10 storms.

IFD rainfall data, initial loss and continual loss values were obtained from the ARR Datahub.

2.2.3. Critical Durations

The adoption of ARR19 has made a significant difference in critical duration analysis (the storm duration which produces the highest flood level at a given catchment location). Each AEP event may have a unique critical duration and critical storm on each catchment. The critical duration may vary throughout the catchment, with longer durations generally causing more severe flooding lower down in the catchment compared to the upper, as the total contributing catchment area size increases.

Critical duration and temporal pattern selection has been undertaken by running ensemble in the hydrologic and hydraulic model. Table 4 presents the critical duration and the selected temporal pattern for each AEP event for each model.

Table 4: Selected Representative Design Storm Temporal Patterns

Model Area	Frequent 50% and 20%	Intermediate 10% and 5%	Rare 2% and 1%	PMF
TC Model	45 min TP4547	45 min TP4478	45 min TP4525	45min, 90 min GSDM TP
MQ Model	45 min TP4550; Lane Cove River: 720 min TP4810	45 min TP4478; Lane Cove River: 720 min TP4794	45 min TP4362; Lane Cove River: 720 min TP4785	30 min, 60 min, 120 min GSDM TP
BK Model	45 min TP4552	45 min TP4478	45 min TP4496	15 min, 30 min, 45 min GSDM TP
PR Model	45 min TP4547	30 min TP4511	30 min TP4498	15 min, 45 min, 120 min GSDM TP

2.2.1. Rainfall Losses

The term “rainfall loss” refers to rain that falls but does not end up flowing across the catchment, either in pipes or as overland flow. The primary mechanism by which rainfall is “lost” and does not runoff in urban catchments is through infiltration into the ground. A small amount of rainfall is remains clinging to trees, buildings and other catchment features and eventually evaporates rather than contributing to runoff volumes.

Rainfall losses from a paved or impervious area are considered to consist of only an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions). Losses from grassed areas are comprised of an initial loss and a continuing loss. The continuing loss is calculated from an infiltration equation curve incorporated into the DRAINS hydrologic model and is based on the selected representative soil type and antecedent moisture condition. The adopted loss parameters are summarised in Table 5. These are generally consistent with the parameters adopted flood studies in similar catchments within the Sydney metropolitan area.

Table 5: Adopted rainfall loss Horton/ILSAX parameters

RAINFALL LOSSES	
Paved Area Depression Storage (Initial Loss)	1.0 mm
Grassed Area Depression Storage (Initial Loss)	5.0 mm
SOIL TYPE	3
Slow infiltration rates (may have layers that impede downward movement of water). This parameter, in conjunction with the AMC, determines the continuing loss	
ANTECEDENT MOISTURE CONDITONS (AMC)	3 (4 for extreme)events)
Description	Rather wet
Total Rainfall Preceding the Storm Burst	12.5 to 25 mm

For the DRAINS models in the Eastwood and Terrys Creek catchment, while sub-catchments within the City of Ryde were represented in the Horton/ILSAX model, sub-catchments within the City of Parramatta Council and the former Hornsby Shire Council were represented as RAFTS nodes. The rainfall losses in the RAFTS model were updated based on the ARR Data Hub, as shown in Table 6.

Table 6 Adopted rainfall loss RAFTS parameters

Rainfall Losses	2008 Eastwood and Terrys Creek FS	Harmonisation Study
Impervious Area Initial Loss (mm)	10	1
Impervious Area Continuing Loss (mm/h)	2.5	0
Pervious Area Initial Loss (mm)	10	Probability Neutral Burst Initial Loss according to the ARR Datahub
Pervious Area Continuing Loss (mm/h)	2.5	0.72

The impervious proportion of each sub-catchment were retained from the existing DRAINS models for each study area.

2.2.1. Debris Blockage

Design blockage for hydraulic structures was adopted in accordance with ARR19 (Reference 20).

The debris availability, debris mobility and debris transportability were deemed to be in the Low to Medium categories for each of the catchments. The overall debris potential was classified as Low. With this classification, an inlet headwall blockage of 50% was applied to culvert structures in the model with an opening size less than 1.2 m, and 20% blockage to culverts with a larger opening size. For bridges with relatively large spans across the waterway, 5% blockage was applied, or 0% blockage for clear-spanning structures with no piers.

2.3. Results

Flood modelling results were presented in Reference 1 and describe the flood behaviour in the LGA and included outputs such as flood hazard and flood function. Flood emergency response planning which included flood immunity of roads and emergency planning classification of communities were presented. Outputs such as flood risk precincts and flood planning areas, which guide development planning in the LGA were included as well.

Based on the flood modelling results in Reference 1, the pipe capacity across the entire LGA was assessed and locations with flood concern were identified in this study (see Sections 2.3.1 and 2.3.2 below).

2.3.1. Pipe Capacity Assessment

The design flood results were used to determine how frequently the stormwater pipe system capacity is likely to be exceeded throughout the catchment. Defining the capacity of a pipe is not straightforward, as it depends on multiple factors including shape, the flow regime (e.g. upstream or downstream controlled), inlet and outlet connection, pipe grade, and other factors.

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

The results of the pipe capacity assessment for the modelled range of design events are shown in Figure 5. There is a large proportion of pipes (46%) that are full in the 20% AEP event across the LGA.

2.3.2. Flood Hotspots

The design flood results were used to identify locations in the LGA which were exposed to a higher flood risk. These hotspots were generally locations which had high flood hazard over roads required for evacuation access or locations were many properties were flooded above floor. Flood mitigation options developed as part of this FRMS targeted these hotspots. This FRMS is not intended to address nuisance inundation or comprise a drainage study, but rather focussing on those areas where flood risk to people, vehicles and property is significant in a range of events including rare events such as the 1% AEP event.

2.3.2.1. Buffalo Road near Lane Cove Road, Ryde

This area is located in the upstream areas of the Buffalo Creek catchment and is impacted by a tributary of Buffalo Creek. This tributary crosses Lane Cove Road via culverts and flows through the rear of properties along Myra Avenue and Buffalo Road. A 1.8 m wide by 0.9 m high box culvert partially conveys this tributary under Lane Cove Road and expands to a 2.4 m wide and 1.45 m high box culvert downstream.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 6. The box culvert is at capacity in the 1% AEP event, with overland flow occurring though the properties. Flood depths above ground in these properties are typically 300 mm to 500 mm, however at its confluence with another tributary (near Bavin Avenue, Photo 1) flood depths are up to 800 mm in the 1% AEP. Hydraulic hazard is typically H1 (generally safe) and H2 (unsafe for vehicles) but reaches as high as H4 (unsafe for people and vehicles) in rear of the property near Bavin Avenue. In the 1% AEP, 8 properties are estimated to be inundated above floor level along the tributary.

Photo 1: Buffalo Road low point near Bavin Avenue (*Source: Google Street View*)

2.3.2.2. Terrys Creek, Eastwood

The main arm of Terrys Creek originates from Epping (outside of the City of Ryde LGA) and mostly flows overland along natural watercourses. The boundary of the City of Ryde LGA is at Terry Road and the main arm of Terrys Creek transitions to a concrete channel starting at Braemar Park. This channel runs through the rear of properties along Auld Avenue and Shaftsbury Road through to Glen Reserve (crossing under Shaftsbury Road via a 3 m wide by 1.7 m high box culvert, Photo 2). The channel transitions into a twin 2.6 m wide by 1.9 m high conduit under the Eastwood town centre at Progress Avenue (Photo 3), Eastwood Oval and the railway line. This conduit discharges into a concrete channel and runs through the rear of properties along May Street and Doomben Avenue. The channel transitions to a natural watercourse near Somerville Park. Terrys Creek upstream of Somerville Park is a Sydney Water Corporation (SWC) stormwater catchment (i.e. area that drains into SWC stormwater assets).

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 7. The main arm of Terrys Creek from Braemar Park to Somerville Park is a major flooding hotspot as a number of residential properties (along Auld Avenue, Shaftsbury Road, and Doomben Avenue) are flooded above floor and Eastwood town centre with many commercial properties are affected. Peak flood depth maps presented as part of the updated flood study (Reference 1) show that in the 50% AEP event flows are mostly contained within the concrete channel except near 190 to 194 Shaftsbury Road and at the eastern end of Glen Reserve. In the 1% AEP event, Terrys Creek overtops the concrete channel in most areas and inundates Progress Avenue and Eastwood Oval. Hydraulic hazard in the 1% AEP event is typically H6 within the concrete channel and on a number of roads (including Shaftsbury Road, Progress Avenue, Hillview Road, Doomben Avenue and Blaxland Road) reaches H5 (unsafe for vehicles and people and most buildings vulnerable to structural damage).

Photo 2: Terrys Creek upstream of Shaftsbury Road (*Source: Google Street View*)

Photo 3: Concrete channel transition to box culverts at Progress Avenue and Hillview Lane (*Source: Google Street View*)

2.3.2.3. Jupp Place and Jupp Reserve, Eastwood

A tributary of Terrys Creek flows from the south to the north through properties between Balaclava Road and Vimiera Road. This tributary is partially conveyed by a twin 1.8 m pipeline underneath these affected properties and expands to a twin 2.5 m wide by 2.2 m high box culvert prior to discharging to Terrys Creek. In the 1% AEP, this conduit is typically 60% to 80% full until it reaches Vimiera Road, where it is at full capacity. Upstream of Balaclava Road along the tributary is Jim Walsh Park (Photo 4), which has an existing embankment roughly parallel to Balaclava Road with a crest at approximately 65.3 m AHD. This embankment is overtopped in events as frequent as 50% AEP.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 8. A number of properties (more than 20) are estimated to be flooded above floor in the 1% AEP event between Balaclava Road and Vimiera Road. In the 1% AEP flood depths exceed 1 m in the rear of the properties along the tributary and hydraulic hazard reaches H4 (unsafe for people and vehicles). At the cul-de-sac of Jupp Place the hydraulic hazard also reaches H4. The tributary crossings at Balaclava Road and Vimiera Road have hydraulic hazards up to H3 (unsafe for vehicles, children and the elderly) in the 1% AEP event.

Section 2.3.1 presented the pipe capacity assessment undertaken in for the study area and Figure 5 shows the event at which the pipe is first at capacity. As shown in Figure 5, the majority of the pipeline running between Balaclava Road and Vimiera Road is only at capacity in the PMF event, except for the crossing underneath Vimiera Road (Photo 5) which is at capacity in the 50% AEP event.

Photo 4: Jim Walsh Park at Balaclava Road (*Source: Google Street View*)


Photo 5: Tributary crossing at Vimiera Road (*Source: Google Street View*)

2.3.2.4. Pickford Avenue, Eastwood

Near the intersection of Pickford Avenue and Lovell Road is the confluence of a tributary originating from the south (which runs through properties, adjacent to Russell Street and then adjacent to Pickford Avenue) and another tributary originating from the east. The eastern tributary partially flows through a grassed reserve, however, it begins to deviate away from the reserve upstream of Orange Street such that between Orange Street and Pickford Avenue, the flow path is entirely within private properties. The eastern tributary comprises a pipeline, which is 825 mm in diameter and gradually expands to 1050 mm in diameter, in addition to overland flow conveyance. The southern tributary is partially conveyed via a 600 mm diameter pipe in its upstream areas, which gradually expands to a 1.5 m diameter pipe. Downstream of this confluence, the pipes and overland flow discharge into a short channel within the reserve upstream of Graham Avenue (Photo 6). This channel is then connected Jim Walsh Park on the downstream side of Graham Avenue via a 1.35 m diameter pipe under the road.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 9. At the rear of the properties along Pickford Avenue, flood depths are 0.5 m to 1 m deep and flood hazards reach H3 (unsafe for vehicles, children and the elderly). In the 1% AEP event, a total of 10 properties are estimated to be inundated above floor.

Photo 6: Graham Avenue and Pickford Avenue intersection (*Source: Google Street View*)

2.3.2.5. Neville Street and Warren Street, Ryde

A flow path runs from east to west through Smalls Park, across Smalls Road (Photo 7), and diagonally through the properties between Warren Street and Neville Street. The flow path discharges into Shrimptons Creek at Santa Rosa Park. A single 1.05 m diameter pipe, which captures overland flows, runs under Neville Street and cuts through properties along Fawcett Street to discharge into Shrimptons Creek.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 10. Peak flood depths are up to 0.5 m through the properties between Neville Street and Warren Street. Hydraulic hazards in this area are generally low H1 (generally safe) and a total of 5 properties in are estimated to be inundated above floor level.

Photo 7: Smalls Road and Neville Street intersection (*Source: Google Street View*)

2.3.2.6. Danbury Close, Marsfield

Danbury Close is a cul-de-sac located near the confluence of several stormwater pipelines (Photo 8). A major conduit, which comprises a 2.1 m wide by 1.5 m high box culvert, runs from west to east crossing under Abuklea Road and along Crotoye Place. This pipeline joins with another 900 mm diameter stormwater pipe (originating from the north) at the rear of the properties at the ends of Crotoye Place and Danbury Close. This pipeline then runs under private property, through a reserve and then under properties along Herring Road. This pipeline then continues downstream through mostly commercial properties before discharging into Shrimptons Creek at ELS Hall Park.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 11. In the 1% AEP event, the cul-de-sac in Danbury Close has flood depths around 0.5 m to 1 m and most areas in the vicinity of the pipelines are inundated by up to 300 mm as pipes are at capacity. Danbury Close experiences greater flood depths than other locations because overland flow from Kotara Park in the north flows into Danbury Close as well and the southern (downstream) side of Danbury Close is developed with residential properties such that flow is partially blocked.

Photo 8: Danbury Close, looking southwest in the direction of Crotoye Place (*Source: Google Street View*)

2.3.2.7. Morshead Street, North Ryde

West of the M2 Motorway, the majority of Porters Creek has been urbanised and is now conveyed via pipes. The low point at Morshead Street is located along a tributary of Porters Creek at the intersection with Chisholm St (Photo 9) and just upstream of Epping Road. Flows are conveyed from the Morshead Street low point to Epping Road via a 2.1 m wide by 1.5 m high box culvert. As the conduit crosses Epping Road, it contracts to a 1.5 m diameter pipe and gradually expands again underneath the North Ryde Officeworks to up to a 5 m wide by 4.2 m high conduit. Immediately after the North Ryde Officeworks building, the pipeline contracts again to a 1.8 m diameter pipeline which gradually expands to 2.1 m diameter pipeline and crosses underneath Halifax Street via a twin 2.4 m wide by 2.1 m high box culvert prior to discharging into a channel at Halifax Street Park.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 12. In the 1% AEP event, flood depths are up to 0.5 m to 1 m deep above ground in the properties between Morshead Street and Epping Road. In this area, hydraulic hazards reach up to H4 (unsafe for people and vehicles) in some properties but are typically H3 (unsafe for vehicles, children and the elderly) and a number of properties along this tributary are estimated to be inundated above floor level. In the 1% AEP event, Epping Road at the crossing of this tributary is also significantly inundated (more than 0.5 m) and the hydraulic hazard is up to H5 in the eastbound lanes and H3 in the westbound lanes.

Photo 9: Intersection of Chisholm Street and Morshead Street (*Source: Google Street View*)

2.3.2.8. Hay Street, Bennett Street, Moss Street, and Darwin Street, West Ryde

A tributary of Archer Creek flows from north to south crossing Victoria Road (Photo 10), Hay Street, Bennett Street, Moss Street, Darwin Street, Huxley Street, and Deakin Street. The tributary is conveyed via a pipeline which is 0.75 m diameter near Lions Park and expands to a 2.2 m wide by 1.15 m high box culvert before it discharges to Ryde Parramatta Golf Club.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 13. In the 1% AEP event, flood depths in the properties are typically shallow (<0.5 m) and flood hazard is typically H1 (generally safe) with some properties reaching up to H3 (unsafe for vehicles, children and the elderly). However, a total of 9 properties are estimated to be inundated above floor level along the tributary in the 1% AEP event.

Photo 10: Victoria Road at Lions Park (*Source: Google Street View*)

2.3.2.9. Federal Road, Gaza Road and West Ryde Town Centre, West Ryde

A flow path flows from the north to south from West Ryde town centre, along Station Street and then along Federal Road (Photo 11) prior to discharging into a channel in Meadowbank Park. Downstream of West Ryde town centre this flow path is conveyed by a 2.76 m wide by 1.5 m high conduit and expands to 3 m wide by 1.8 m high conduit at Federal Road. The West Ryde Drainage Tunnel conveys a separate tributary which originates from Denistone Park. West Ryde Tunnel bypasses the main West Ryde commercial area and runs under Mons Avenue before discharging to Meadowbank Park.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 14. Properties between Station Street and Gaza Road have flood depths above ground up to 0.5 m although typically around 0.3 m. Flood depths are deepest at the intersection of Station Street and Dunmore Street, where the pipe network surcharges. This flow path cuts through several properties along Mons Ave and flows at the front of the properties along Federal Road. From Google Street View and ground elevation data, most properties along Federal Road have a dip in their driveway and front yard to accommodate this flow.

Photo 11: Federal Road, looking north (*Source: Google Street View*)

2.3.2.10. Victoria Road at Falconer Street, West Ryde

The intersection of Victoria Road and Falconer Street (Photo 12) is located at the confluence of two pipelines originating from the northeast and the southeast. This pipeline then passes under commercial and industrial properties on the west side of the intersection via a 3.3 m wide by 1.85 m high conduit and gradually expands to 4.3 m wide by 1.8 m high conduit and crosses under Marsden High School. This conduit discharges to a channel on the east side of the railway line prior to crossing the railway line via a 4.5 m wide by 1.8 m high box culvert. Downstream of the railway line, the flow path enters Charity Creek at Meadowbank Park.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 15. Upstream of the intersection of Victoria Road and Falconer Street, a number of properties are estimated to be inundated above floor in the 1% AEP event including along Bowden Street, Griffiths Avenue, Falconer Street and Herbert Street. Flood depths in the properties on the upstream side of the intersection are deep (more than 1 m) with hydraulic hazard up to H4 (unsafe for people and vehicles). While the conduits underneath the commercial properties downstream of the intersection are large, these conduits are at capacity in the 1% AEP event and pipe capacity assessment conducted as part of Section 2.3.1 show that these conduits only have 20% AEP or 50% AEP capacity.

Photo 12: Victoria Road at Falconers Street, looking southeast (*Source: Google Street View*)

2.3.2.11. Morrison Road, Putney

A tributary of Grove Creek, which flows from the northwest to the southeast, runs from Parry Park and through the rear of properties along Morrison Road prior to discharging into an open channel in Morrison Bay Park. This tributary is partially conveyed via a conduit, with flows in excess of the pipe capacity conveyed overland. This pipeline is 2.4 m wide by 1.2 m high upstream of Acacia Avenue, contracts to a 1.8 m diameter pipe as it crosses Acacia Avenue (Photo 13) and expands back to a 2.45 m wide by 1.3 m high conduit downstream. As this conduit crosses Morrison Road (Photo 14), it expands to a twin 3 m wide by 1.5 m high box culvert.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 16. In the 1% AEP event, the pipeline does not have enough capacity to fully convey the flow. Flood depths at the rear of the properties along Parry Street are deep and exceed 2 m in some locations. Along Morrison Road, flood depths are typically 0.5 m to 1 m across most areas in the 1% AEP event. Downstream of Parry Park, the pipeline is at capacity in the 1% AEP event (see Section 2.3.1). As shown in Figure 5, downstream of Parry Park the conduit has varying capacity from 2% AEP to 50% AEP. The crossings at Acacia Avenue and Morrison Road have the lowest capacity and are full at 50% AEP.

Photo 13: Tributary crossing at Acacia Avenue (*Source: Google Street View*)

Photo 14: Tributary crossing at Morrison Road and Gregory Street (*Source: Google Street View*)

3. ECONOMIC IMPACTS OF FLOODING

3.1. Background

The quantification of flood damages is an important part of the floodplain risk management process. It helps identify whether the benefits from various flood mitigation measures will outweigh the costs to implement those measures, and to prioritise which measures will be most cost-effective.

While flood damage assessment does not include all impacts or costs associated with flooding, it provides a basis for assessing the economic loss due to flooding, and a non-subjective means of assessing the merit of flood mitigation works such as detention basins, levees, drainage enhancements, etc. By quantifying flood damages for a range of design events, appropriate management measures can be evaluated in terms of their benefits (reduction in flood damage) versus the cost of implementation.

The cost of flood damage and disruption to a community depends on several factors which include:

- Flood magnitude (depth, velocity and duration).
- Type of structures at risk and their susceptibility to damage.
- Nature of the development at risk (residential, commercial, industrial).
- Physical factors such as failure of services (e.g. utilities), flood borne debris, sedimentation, etc.
- Awareness and readiness of the community to flooding.
- Effective warning times.
- Availability of evacuation plans.

The potential damage associated with a particular flood event can be divided into a number of components, which are grouped into two major categories;

- Tangible damages – financial costs of flooding quantified in monetary terms.
- Intangible damages – social costs of flooding reflected in increased levels of mental stress, loss of sentimental items, inconvenience to people, injury or loss of life, etc.

Intangible damages are difficult to measure and impossible to meaningfully quantify in dollar terms. For this reason, intangible damages were assumed to be proportional to the tangible damages. Tangible damages can be further sub-divided into two categories, direct and indirect damages, as illustrated in Diagram 3.

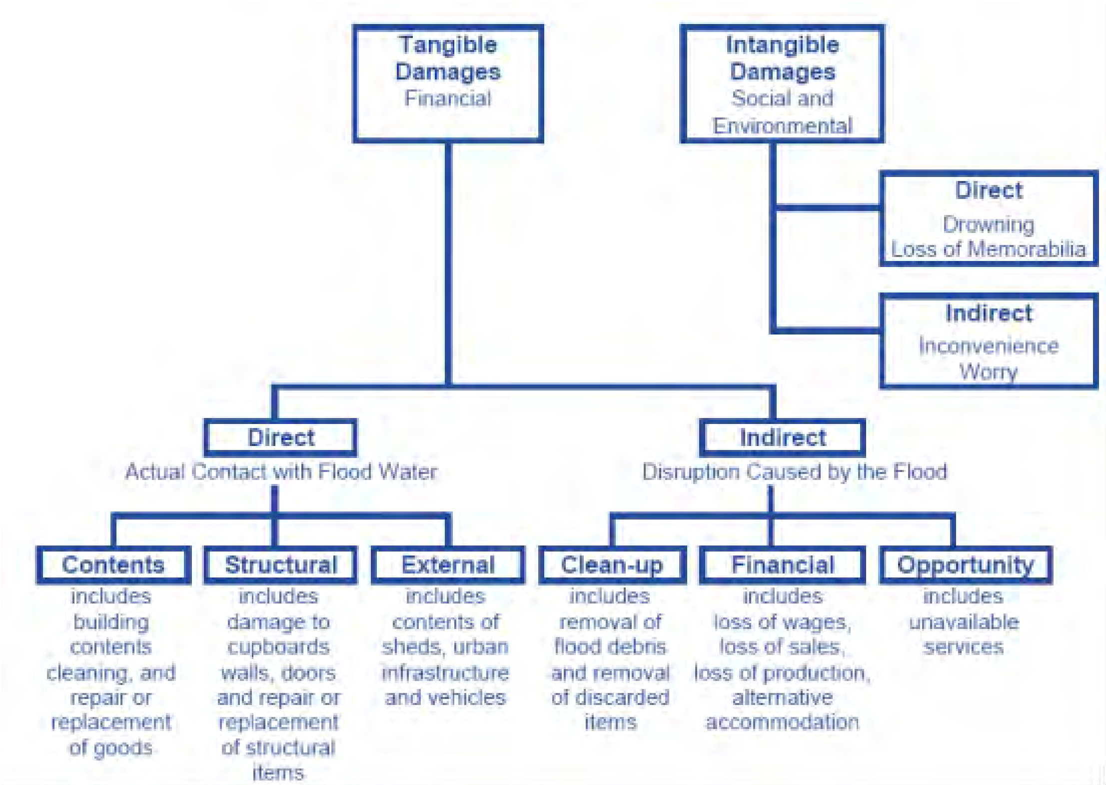


Diagram 3: Types of flood damages

The total likely damages in any given flood event is difficult to quantify precisely, given the variable nature of flooding and the property and content values of houses affected. Design flood damages are estimated to obtain an indication of the magnitude of the flood problem and compare the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of a mitigation option in relation to current damages, or to an alternative option, can assist in the decision-making process.

3.2. Approach

Estimation of flood damage has focussed on residential and community buildings in the study area using guidelines issued by the NSW Government (Reference 22) and recognised damage assessment methodologies. The most common approach to present flood damage data is in the form of flood-damage curves for a range of property types, i.e. residential, commercial, public property, public utilities etc. These relate flood damage to depth of flooding above a threshold level (usually floor level). The estimation of damage is based upon a flood level relative to the floor level of a property. In addition to the guidelines issued by the NSW Government (Reference 22), the approach from flood damages assessment undertaken as part of the Eastwood and Terrys Creek FRMS&P (Reference 9) and Eastwood Town Centre Flood Study and Stormwater Upgrades Design (Reference 17) was also adopted for this study.

The assumed parameters and flood damage curve assumptions are outlined in the following sections.

3.2.1. Property Database

A property database was assembled using the available data, since it is not cost-effective to undertake detailed topographic survey of all or even a portion of flood prone properties in the study area. Council provided the floor level database from the Eastwood Town Centre Flood Study (Reference 17), Macquarie Park FRMS&P (Reference 11), and the Buffalo and Kittys Creek FRMS&P (Reference 7). These property databases were consolidated into a single database of residential and commercial properties, and combined with floor level estimated from a desktop study.

WMAwater undertook the following updates to the property database:

1) Identify and compile a list of georeferenced points which represent properties in the LGA. These points were originated from:
    a) Previous databases completed as part of previous studies. Where required, locations of these points were updated and additional new points were infilled to ensure all properties within the PMF extent were included. Previous databases were adopted in the Terrys Creek catchments, areas in Macquarie Park, and catchments of Buffalo Creek and Kittys Creek.
    b) A new database completed as part of this FRMS. This was completed for properties within the Parramatta Model (i.e. catchments of Archer Creek, Charity Creek, Glades Creek, and Morrison Bay).
2) Floor levels were estimated using a 'desktop' or 'windscreen' survey, utilising Google Street View where available for properties within the 1% AEP flood extent. This task involved looking at features such as number of steps into the building, number of bricks to the floor level or other visible features which could be used to provide an estimate of the height of the floor above the adjacent ground. For properties where it was difficult to estimate the height above ground due to obstructions or inadequate Street View imagery, a lower level of confidence was noted in the database.
3) Estimates from consolidating property databases from previous studies were checked against the floor level estimates from Step 2 above. This was conducted as properties may have been demolished and rebuilt since the previous studies. Previous floor level estimates were which found to be no longer applicable were removed from the database.
4) Floor levels were estimated using the average floor height above ground between all surveyed and desktop surveyed properties. These estimates were made for properties which were not within the 1% AEP flood extent but within the PMF extent or properties which could not be estimated for floor level as visuals to the building were obstructed in Street View. These averages were:
    - Buffalo and Kittys Creek = 0.43 m
    - Eastwood and Terrys Creek = 0.42 m
    - Macquarie Park = 0.42m
    - Parramatta River = 0.39 m
5) The floor level was then estimated by taking the ground level from the available 2019 and 2020 LiDAR digital elevation model (DEM) and adding the average floor height above ground.
6) Estimate the floor level using, in order of preference:

- Surveyed floor level from previous studies (where these were considered to still be valid)
- Estimated floor level from ground level and Step 2 (typically those within the 1% AEP extent where floor levels were visible from Google Street View).
- Estimated floor level from ground level and Step 4 (typically those properties outside the 1% AEP extent but within the PMF extent).

The level of accuracy for the estimated floor heights is considered suitable for two reasons. Firstly, the estimation of property damage due to flooding is inherently difficult to estimate, given the large variation in building types, their contents, the duration of flooding and other factors, and so the accuracy of floor heights should be in line with the accuracy and applicability of the flood damage curves. Secondly, the economic damages assessment is only intended to be used as an estimate of the LGA-wide flood affectation and not on a per-property basis.

The property database that was developed consisted of 5,913 properties and these are shown in Figure 17. The database contained the following data:

- GIS point location at the building
- Property identification number and deposited plan number
- Address
- Lot area
- Type of development (residential, commercial or industrial)
- Number of dwellings.
- Model area
- Ground level
- Height of floor above ground
- Floor level
- Current flood tagging status

A summary of the floor levels within the property database is provided in Table 7.

Table 7: Summary of property floor levels for flood damage assessment

Catchment	Representative Height	Estimated with Street View	Surveyed	Total
Buffalo and Kittys Creek	389	98	359	846
Macquarie	946	285	452	1683
Parramatta River	1113	843	-	1956
Terrys Creek	981	187	260	1428
Total	3429	1413	1071	5913

Design flood levels were assigned to each property based on the modelled flood surface at the building or within 6 m of the building (3 TUFLOW grid cells). The database was used to determine the number and extent of properties inundated above protection level for the range of flood events modelled. No freeboard was included in these estimates.

3.2.2. Residential Damage

Flood damage of residential buildings was calculated using a residential damage spreadsheet developed by the NSW Government in 2007 (Reference 22). This was consistent with the approach adopted by both the Eastwood and Terrys Creek FRMS&P (Reference 9) and Eastwood Town Centre Flood Study and Stormwater Upgrades Design (Reference 17). This includes a representative stage-damage curve derived for a typical house on a floodplain to estimate structural, contents and external damage. The amount of damage is based on the flood inundation depth for a given flood event.

Several input parameters are required to determine which stage-damage curve will be adopted. The key parameters used in this assessment are shown in Table 8.

Table 8: Parameters adopted for Residential Damages Assessment

Parameter	Adopted Value	Comment
Regional Cost Variation Factor	1.0	Due to the location and proximity to major cities. Ryde is within close proximity to Sydney.
Post 2001 price adjustment	2.67	Costs adjusted to current day dollars using the change in Average Weekly Earnings (AWE) statistics from the Australian Bureau of Statistics.
Post flood inflation factor	1.0	Suggested range of 1.0 to 1.5 depending on the scale of impacts.
Typical duration of immersion (hours)	6	Building inundation would be of moderate duration
Building Damage Repair Limitation Factor	0.85	Suggested range of 0.85 to 1.00 (short to long duration events). Duration of flooding is expected to be relatively short.
Contents Damage Repair Limitation Factor	0.75	Suggested range of 0.75 to 0.90 (short to long duration events). Duration of flooding is expected to be relatively short.
Typical House Size (m2)	240	Typical house size of 240 m^2 adopted.
Level of Flood Awareness	Low	Guidelines suggest 'low' is adopted unless 'high' can be justified.
Effective Warning Time (hours)	0	It has been conservatively assumed that no warning time would be given for residents.
Average Contents (2001 $)	$60,000	Typical contents of $60,000 adopted.
External Damage (2001 $)	$6,700	Recommended external damages have been adopted.

Average Weekly Earnings (AWE) is used to update residential flood damage curves to current dollars rather than the inflation rate measured by the Consumer Price Index (CPI). The most recent AWE value from the Australian Bureau of Statistics (ABS) at the time of the assessment was November 2023, and a factor of 2.79 was applied to all ordinates in the residential stage-damage curves based on the increase from November 2001 (base value used by the spreadsheet). A regional cost variation factor of 1.00 was applied for the Sydney metropolitan region as per Rawlinson's Australian Construction Handbook (Reference 23).

For the purposes of the flood damage assessment, a PMF probability of 1 in 10^7 was adopted (primarily a function of catchment size). No damages were assumed to be incurred in the 1 Exceedance per Year (EY) event. Other default parameters and values within the spreadsheet were retained, including clean-up costs of $4,000 and accommodation costs of $220 per week for a period of 12 weeks (prior to adjustment factors). These parameters were applied to the residential damage curve for slab-on-ground house (dominant house type in the catchment), and high set homes (assumed to be high set if floor level was >1 m above ground). External damages were assumed to accumulate from 0.1 m below the habitable level of the house for slab-on-ground, and 1.5 m below floor level for high set homes. For apartment buildings with ground floor apartments, it was assumed that there were 4 ground floor apartments that could sustain flood damage.

3.2.3. Non-residential Damage

Industrial and commercial property damage curves were adopted from the study flood damages spreadsheet prepared by Royal Haskoning (Reference 17). It is understood that this spreadsheet was derived from the flood damage assessment prepared by Bewsher for the Eastwood and Terrys Creek FRMS&P (Reference 9). The cost of flood damage on non-residential properties varies greatly and is dependent on the type of business and duration of flooding.

Industrial and commercial properties in the spreadsheet prepared by Royal Haskoning (Reference 17) were further categorised into low, medium, and high valued properties. Each commercial property category had an associated damage curve. As the property database was collated from different sources (as described in Section 3.2.1), further classification of non-residential properties was only available for the Eastwood and Terrys Creek area. In other areas, non-residential properties were assumed to be of a medium value.

For both commercial and industrial properties, the flood damage curves provided by Royal Haskoning (Reference 17) were factored by 1.18 to account for inflation from 2018 (time of the Royal Haskoning Study) to 2023 (present day value). It was assumed that damages would begin only when water was above working floor level.

3.2.4. Vehicle Damage

Vehicle damages were included as per the methodology adopted in the study conducted by Royal Haskoning (Reference 17) and based on Bewsher (Reference 9). It is assumed that 1.3 vehicles are present (on average) per residential household at any one time. Flood damage begins to occur at a flood depth of 0.3 m above ground on the property, and the vehicle is written off at a flood depth of 0.6 m above ground on the property. Flood damages per vehicle (in 2018 value) range from $6,000 damage at 0.3 m depth to maximum of $12,000 damage at 0.6 m when the vehicle is considered written off. These flood damage values are then factored to by 1.18 to account for inflation from 2018 to the present day.

3.2.5. Indirect Damages

Indirect damages were included by assuming a rate of 20% of the total direct residential, industrial, and commercial damages for each affected property. The estimated residential stage-damage curves make allowance for clean-up costs and cost of time in alternative accommodation. However, the rate of 20% of the direct residential damages for indirect damages was still assumed to account other sources of indirect damage and to maintain consistency with previous studies.

3.2.6. 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 above, additional costs/damages are incurred by residents affected by flooding, such as stress, injury, loss of life, loss of sentimental items, etc. It is not possible to put monetary values on these intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to significantly more than tangible damages) and depend on a range of factors such as size of flood, the individuals affected and community preparedness. However, it is still important that the consideration of intangible damages is included when assessing the impacts of flooding on a community.

Post flood damage surveys have linked flooding to stress, ill-health and trauma for residents. For example, the loss of memorabilia, pets, important documents 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. The actual flood event, resulting property damage, risk to life for the individuals or their family and the clean-up process can also add to the stress. In addition to the stress caused during an event, many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage and loss. The extent of stress depends on the individual and although most flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event, these 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. However, there will always be localised areas of high risk where flows may be concentrated around buildings or other structures within low hazard areas. The intangible damages for the study area catchments may be substantial, due to the lack of warning time for a typical flood event.

Social damages (intangible damages) were included and were estimated at a rate of 25% of total direct residential or commercial damages for each affected property. This value was consistent with the previous FRMS&P completed for Terrys Creek (Reference 17), which was determined in accordance with advice from NSW State Government.

3.3. Estimated Flood Damages

An estimation of the number of properties impacted (flooding occurring on the property within 6 m of the dwelling/building), number of properties with above floor flooding and total damage costs for each modelled flood event was undertaken for each of the model areas.

A typical measure used to estimate flood damages over a range of flood events is the Annual Average Damage (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 over the long term. The AAD value is determined by multiplying the damages that can occur in a given flood by the probability of that flood actually occurring in a given year, and then summing across a range of floods. This method allows smaller floods, which occur more frequently to be given a greater weighting than the larger catastrophic floods that only occur rarely. The AAD for the existing case then provides a benchmark by which to assess the merit of flood management options.

A summary of the tangible flood damages is provided in Table 9. Residential, commercial/industrial and combined (both residential and commercial/industrial) damages are provided separately.

There is typically a gradual increase in the number of properties affected with increasing flood magnitude, except for the PMF event in which the number of properties affected is substantially higher. Commercial and industrial properties account for approximately 10% of the affected properties, and approximately 3% of the total flood damage cost, depending on the area and flood affectation of the commercial and industrial zones. The total damage cost for the entire Ryde LGA is approximately $115M for the 1% AEP event, with the AAD being approximately $38M.

Table 9: Summary of Estimated Flood Damages for City of Ryde LGA

Flood Event	No. Lots Affected[1]	No. Lots Flooded Above Floor Level[2]	Total Damages for Event[3]	Average Damage Per Flood Affected Property[3]	% of AAD
Residential					
50% AEP	318	166	$26,018,256	$81,818	23%
20% AEP	453	243	$38,348,914	$84,655	34%
10% AEP	571	332	$50,419,083	$88,300	16%
5% AEP	656	411	$61,681,248	$94,026	10%
2% AEP	717	462	$70,062,028	$97,716	7%
1% AEP	802	529	$80,945,124	$100,929	3%
PMF	2407	1998	$334,128,546	$138,815	7%
		Average Annual Damage	$28,205,026	$11,718	
Commercial and Industrial					
50% AEP	9	16	$334,513	$37,168	8%
20% AEP	44	49	$1,306,821	$29,700	23%
10% AEP	72	76	$2,526,887	$35,096	18%
5% AEP	95	99	$3,942,615	$41,501	15%
2% AEP	105	108	$5,249,046	$49,991	13%
1% AEP	123	126	$7,275,821	$59,153	6%
PMF	235	240	$27,706,111	$117,898	17%
		Average Annual Damage	$1,058,486	$4,410	
Total[4]					
50% AEP	327	182	$34,100,895	$104,284	22%
20% AEP	497	292	$51,343,401	$103,307	34%
10% AEP	643	408	$68,774,361	$106,959	16%
5% AEP	751	510	$85,475,258	$113,815	10%
2% AEP	822	570	$98,340,407	$119,636	7%
1% AEP	925	655	$115,298,332	$124,647	3%
PMF	2642	2238	$475,832,666	$180,103	8%
		Average Annual Damage	$37,982,125	$14,376	

1 - Floodwaters within 6 m of the building and are within 0.1 m of the floor level. This is the number of lots where external damage is estimated.
2 - Floodwater estimated to be above the building floor level for a lot.
3 - Rounded to the nearest $100.
4 - Includes vehicle damages, indirect tangible damages and social (intangible) damages

The estimation of tangible flood damages is a high-level exercise, intended to capture the catchment-scale flood damages. It can provide a good indication of the average flood damage across a catchment. The accuracy of the results at individual properties can be affected by vagaries such as the variability in the flood level across the property, the location of the sampled flood level for the property, whether the floor level is consistent or varies through the building. This variability tends to average out across the catchment, particularly if many properties are considered.

4. FLOODPLAIN MANAGEMENT POLICY

Council is responsible for local planning and land management in the City of Ryde LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by national and state planning legislation. It is important to understand the national and state context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of state and national legislation.

An overview of the national and state planning instruments is provided below to provide this background.

4.1. National Planning Provisions - Building Code of Australia

The Building Code of Australia (BCA) is part of the National Construction Code Series, an initiative of the Council of Australian Governments, developed to incorporate all on-site construction requirements into a single code. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian Government and each State and Territory Government.

The BCA is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia (Reference 24). The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the 'defined flood event' (DFE). The DFE is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority*". In NSW this is typically the 1% AEP event.

Flood hazard areas are identified by the relevant State/Territory or Local Government authority (such as via a FRMS). The BCA is produced and maintained by the Australian Building Codes Board and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Section 3.1.2.3 of the BCA refers specifically to drainage of surface water and finished slab heights, and contains the requirements shown below. Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

Building Code of Australia 3.1.3.3 Surface water drainage

Surface water must be diverted away from Class 1 buildings as follows:

(a) Slab-on-ground — finished ground level adjacent to buildings:
the external finished surface surrounding the slab must be drained to move surface water away from the building and graded to give a slope of not less than (see Figure 3.1.2.2):

- (i) 25 mm over the first 1 m from the building in low rainfall intensity areas for surfaces that are reasonably impermeable (such as concrete or clay paving); or
- (ii) 50 mm over the first 1 m from the building in any other case.

(b) Slab-on-ground — finished slab heights:
the height of the slab-on-ground above external finished surfaces must be not less than (see Figure 3.1.2.2):

- (i) 100 mm above the finished ground level in low rainfall intensity areas or sandy, well-drained areas; or
- (ii) 50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a); or
- (iii) 150 mm in any other case.

4.2. State Planning Provisions

4.2.1. State Provisions – 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 the impact of development. Pursuant to Section 9.1(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. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below.

Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

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.

4.2.2. 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 communities and individual owners and occupiers of flood prone property, and

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

In doing so, community resilience to flooding is improved. The NSW Flood Risk Management Manual: the policy and manual for the management of flood liable land (2023, Reference 25) and its toolkit support the implementation of the policy through the combined efforts of all levels of government. This document incorporates the NSW Flood Prone Land Policy and supersedes the 2005 Floodplain Development Manual (Reference 2) as the NSW Government's manual relating to the management of flood liable land in accordance with section 733 of the Local Government Act 1993.

The Flood Risk Management Manual recognises that flood prone land is a valuable resource and the development applications and proposals for rezoning of flood prone land should be the subject of careful assessment which incorporates consideration of local circumstances. The manual outlines 10 principles for flood risk management in NSW:

1. Establish sustainable governance arrangements
2. Think and plan strategically
3. Be consultative
4. Make flood information available
5. Understand flood behaviour and constraints

6. Understand flood risk and how it may change
7. Consider variability and uncertainty
8. Maintain natural flood functions
9. Manage flood risk effectively
10. Continually improve the management of flood risk

4.2.3. Section 733 – Local Government Act 1993

Section 733 of the Local Government Act relates to Exemption from liability – flood liable land, land subject to risk of bush fire and land in coastal zone. Section 733 provides councils with statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Flood Risk Management Manual). It states:

(1) A Council does not incur any liability in respect of:

(a) any advice furnished in good faith by the council relating to the likelihood of any land being flooded or the nature or extent of any such flooding, or

(b) anything done or omitted to be done in good faith by the council in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.

And;

(3) Without limiting subsections (1), (2) and (2A), those subsections apply to:

(a) the preparation or making of an environmental planning instrument, including a planning proposal for the proposed environmental planning instrument, or a development control plan, or the granting or refusal of consent to a development application, or the determination of an application for a complying development certificate, under the Environmental Planning and Assessment Act 1979 , and

(b) the preparation and adoption of a coastal management program under the Coastal Management Act 2016 (and the preparation and making of a coastal zone management plan under the Coastal Protection Act 1979 that is continued in effect by operation of clause 4 of Schedule 3 to the Coastal Management Act 2016), and

(c) the imposition of any condition in relation to an application referred to in paragraph (a), and

(d) advice furnished in a certificate under section 149 of the Environmental Planning and Assessment Act 1979 , and

(e) the carrying out of flood mitigation works, and

(f) the carrying out of coastal protection works, and

(f1) the carrying out of bush fire hazard reduction works, and

(f2) anything done or omitted to be done regarding beach erosion or shoreline recession on Crown land (including Crown managed land) or land owned or controlled by a council or a public authority, and

(f3) the failure to upgrade flood mitigation works or coastal protection works in response to projected or actual impacts of climate change, and

(f4) the failure to undertake action to enforce the removal of illegal or unauthorised structures that results in erosion of a beach or land adjacent to a beach, and

(f5) the provision of information relating to climate change or sea level rise, and

(g) any other thing done or omitted to be done in the exercise of a council's functions under this or any other Act.

(4) *Without limiting any other circumstances in which a council may have acted in good faith, a council is, unless the contrary is proved, taken to have acted in good faith for the purposes of this section if the advice was furnished, or the thing was done or omitted to be done—*
   (a) *substantially in accordance with the principles contained in the relevant manual most recently notified under subsection (5) at that time, or*
   (b) *substantially in accordance with the principles and mandatory requirements set out in the current coastal management manual under the Coastal Management Act 2016 , or*
   (c) *in accordance with a direction under section 14(2) of the Coastal Management Act 2016 .*

4.2.4. Flood Prone Land Package

On the 14th July 2021, the Department of Planning, Industry and Environment (DPIE, now DCCEEW) implemented updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation consideration in land use planning.

The changes include:

- A revised Ministerial Direction 4.1 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979,
- A revised planning circular on flooding
- A new guideline: Considering Flooding in Land Use Planning
- Revised Local Environmental Plan flood clauses,
- Amendments to Schedule 4, Section 7A of the Environmental Planning and Assessment Regulation 2000 (now Schedule 2, Section 9 of the Environmental Planning and Assessment Regulation 2021),
- State Environmental Planning Policy Amendment (Flood Planning) 2021.

The key changes and implications are outlined below:

- Amendments to Schedule 4 of EP&A Regulation including changes to Clause 7A(1), Clause 7A(2) (now Schedule 2, Clause 9(1) and 9(2), respectively). These amendments now require councils to note on Section 10.7 certificates if any flood related development controls apply to the land relating to either the FPA, hazardous materials / industry, sensitive, vulnerable or critical uses.
- The Ministerial Direction 4.3 has been amended to remove the requirement for councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (currently included in Clause 7 of Direction 4.3).
- Two proposed LEP clauses relating to the FPA, and Special Flood Consideration.
  - o The FPA clause (5.21) allows council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools. This was adopted as a standard clause on all NSW Council LEPs.
  - o The clause (5.22) relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive,

vulnerable or critical uses, or land with hazardous materials or industry. This is an optional clause that Councils are required to 'opt-in' to include on their LEP. City of Ryde has not adopted this clause.

4.2.5. Ministerial Direction 4.1

Direction 4.3 was one in a list of directions issued on the 1st July 2009, and updated on the 14th July 2021 and again on 20th February 2023 (now Direction 4.1). The directions were issued by the then Minister for Planning to relevant planning authorities under Section 9.1(2) (previously Section 117(2)) of the EP&A Act. Direction 4 pertains to "Resilience and Hazards", with Direction 4.1 relating specifically to Flooding. Direction 4.1 is provided below.

Objectives

(2) The objectives of this direction are to:

(a) 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) ensure that the provisions of an LEP that apply to flood prone land are commensurate with flood behaviour and include consideration of the potential flood impacts both on and off the subject land.

Application

This direction applies to all relevant planning authorities that are responsible for flood prone land when preparing a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Direction 4.1

(1) A planning proposal must include provisions that give effect to and are consistent with:

(a) the NSW Flood Prone Land Policy,
(b) the principles of the Floodplain Development Manual 2005,
(c) the Considering flooding in land use planning guideline 2021, and
(d) any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manual 2005 and adopted by the relevant council.

(2) A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront or Special Purpose Zones.

(3) A planning proposal must not contain provisions that apply to the flood planning area which:

(a) permit development in floodway areas,
(b) permit development that will result in significant flood impacts to other properties,
(c) permit development for the purposes of residential accommodation in high hazard areas,
(d) permit a significant increase in the development and/or dwelling density of that land,
(e) permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

(f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,
(g) are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or
(h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

(4) A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply 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 dwelling density of that land,
(d) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,
(e) are likely to affect the safe occupation of and efficient evacuation of the lot, or
(f) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

(5) For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

Consistency
A planning proposal may be inconsistent with this direction only if the planning proposal authority can satisfy the Planning Secretary (or their nominee) that:

(a) the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant council in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or
(b) where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the Floodplain Development Manual 2005 or
(c) the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements, or
(d) the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.

***Note**: In this direction:*
(a) "flood prone land" "flood storage" "floodway" and "high hazard" have the same meaning as in the Floodplain Development Manual 2005.
(b) "flood planning level" "flood behaviour" and "flood planning area" has the same meaning as in the Considering flooding in land use planning guideline 2021.

(c) Special flood considerations are outlined in the Considering flooding in land use planning guideline 2021 and an optional clause in the Standard Instrument (Local Environmental Plans) Order 2006.

(d) Under the floodplain risk management process outlined in the NSW Government's Floodplain Development Manual 2005, councils may produce a flood study followed by a floodplain risk management study and floodplain risk management plan.

Date commenced: 20 February 2023

4.2.6. Planning Circular PS 07-003 and PS 21-006

Planning Circular PS 07-003 (31st January 2007) provided 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. A revised planning circular '*Considering flooding in land use planning: guidance and statutory requirements'* PS 21-006 was released with the recent changes to the Flood Prone Land Package on 14th July 2021. The revised circular provides advice on a package of changes regarding how land use planning considers flooding and flood-related constraints, including Section 10.7 Planning Certificates, local planning direction 4.3, LEP clauses and associated guidelines.

In Planning Circular PS21-006 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual".*

4.2.7. Considering flooding in land use planning guideline

The guideline aims to provide councils with mechanisms to manage flood risk for the full range of flooding up to the PMF and give further consideration to evacuation constraints. Within the proposed Flood Prone Land package, there are two main categories council can use to address flooding impacts namely, FPAs or special considerations.

Historically, the focus has been on managing the 1% AEP flood event. The Flood Prone Land Package aims to provide councils the ability to apply development controls to areas outside the flood extent where the flood risk requires it. The FDM identifies either the 1% AEP flood event or an equivalent historic event as an appropriate starting point when selecting the DFE. However, it recommends considering selecting a more extreme flood event where there are significant economic, social, environmental or cultural risks associated with a larger event.

The Special Flood Considerations category provides council the ability to apply controls to land outside the FPA but within the PMF flood event where there is a significant risk to life or risk of hazardous material impacting the community or environment.

4.2.8. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the development controls applicable to that property. The Planning Certificate is issued under Section 10.7 of the EP&A Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.
(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).
(3) (Repealed)
(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.
(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.
(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.
(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The EP&A Regulation 2021, Schedule 2 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular, Schedule 2, Section 9 refers to flood related development control information and requires councils to provide the following information:

(1) If the land or part of the land is within the flood planning area and subject to flood related development controls.
(2) If the land or part of the land is between the flood planning area and the probable maximum flood and subject to flood related development controls.
(3) In this clause—
flood planning area has the same meaning as in the Flood Risk Management Manual.

Flood Risk Management Manual means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.
probable maximum flood has the same meaning as in the Flood Risk Management Manual.

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 2 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property, or *"advice on other such relevant matters affecting the land of which it may be aware" (EP&A Act, 10.7 (5)).*

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

The aims of the State Environmental Planning Policy (Exempt and Complying Development Codes) (SEPP) 2008 are presented below.

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and
(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and
(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and
(d) enabling the progressive extension of the types of development in this Policy, and
(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

Part 3 of the SEPP contains standards relating to development in flood control lots. This is described below.

4.2.10. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the *"Housing Code".* This section replaces the former *"General Housing Code",* which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots and is reproduced below.

3.5 *Complying development on flood control lots*

1) *Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, 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.*
2) *If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:*
    a) *if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*

b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,

c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),

d) the development must not result in increased flooding elsewhere in the floodplain,

e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,

f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,

g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

3) *The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*
4) *A word or expression used in this clause has the same meaning as it has in the* Floodplain Development Manual*, unless it is otherwise defined in this Policy.*
5) *In this clause:*

flood compatible material *means building materials and surface finishes capable of withstanding prolonged immersion in water.*

flood planning level *means:*
(a) the flood planning level adopted by a local environmental plan applying to the lot, or
(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

Floodplain Development Manual *means the* Floodplain Development Manual *(ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

flow path *means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the* Floodplain Development Manual.

high hazard area *means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the* Floodplain Development Manual.

high risk area *means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the* Floodplain Development Manual.

4.3. Local Planning Provisions

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce future flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use LEPs and Development Control Plans (DCPs) to govern control on development with regards to flooding.

4.3.1. Local Environmental Plan

Environmental Planning Instruments such as LEPs guide land use and development by zoning all land and identifying appropriate land uses allowed in each zone. LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

The Ryde LEP (Reference 26) was developed in 2014 and the most current version was last updated 4 March 2024. On the 14th July 2021, the NSW Government's Flood Prone Land Package commenced and a revised flood clause (Clause 5.21 Flood Planning) was introduced across all LEPs in NSW, including the City of Ryde LEP 2014. This clause allows for the FPA to include areas outside the 1% AEP event where the damages in more extreme flood events warrant additional development controls. The standard instrument clause is shown below.

(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 flood function and behaviour on the land, taking into account projected changes as a result of climate change,*
> *(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,*
> *(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.*

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

> *(a) is compatible with the flood function and behaviour on the land, and*
> *(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and*
> *(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and*
> *(d) incorporates appropriate measures to manage risk to life in the event of a flood, and*
> *(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.*

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

> *(a) the impact of the development on projected changes to flood behaviour as a result of climate change,*
> *(b) the intended design and scale of buildings resulting from the development,*
> *(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,*
> *(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.*
>
> *(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.*
>
> *(5) In this clause—*
>
> ***Considering Flooding in Land Use Planning Guideline** means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.*
> ***flood planning area** has the same meaning as it has in the Flood Risk Management Manual.*
> ***Floodplain Risk Management Manual** means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.*

The Flood Prone Land Package included a second optional clause '5.22 Special flood considerations' which provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry. The current LEP has not adopted this clause. The standard instrument clause is shown below.

> *Provides specific controls relating to risk to life, hazardous materials and sensitive, vulnerable or critical uses. It provides councils mechanisms to additional development controls where there is a risk to life. Key extracts included in this clause are:*
>
> *(1) The objectives of this clause are as follows—*
> *(a) to enable the safe occupation and evacuation of people subject to flooding,*
> *(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,*
> *(c) to avoid adverse or cumulative impacts on flood behaviour,*
> *(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,*
> *(e) to avoid adverse effects of hazardous development on the environment during flood events.*
>
> *(2) This clause applies to—*
> *(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and*
> *(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—*
> *(i) cause a particular risk to life, and*
> *(ii) require the evacuation of people or other safety considerations.*

(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) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause:

***Considering Flooding in Land Use Planning Guideline**—see clause 5.21(5).*

***flood planning area**—see clause 5.21(5).*

***Floodplain Risk Management Manual**—see clause 5.21(5).*

***probable maximum flood** has the same meaning as it has in the Flood Risk Management Manual.*

***sensitive and hazardous development** means development for the following purposes—*

(a) [list land uses]

***Direction—** Only the following land uses are permitted to be included in the list—*

(a) boarding houses,
(b) caravan parks,
(c) correctional centres,
(d) early education and care facilities,
(e) eco-tourist facilities,
(f) educational establishments,
(g) emergency services facilities,
(h) group homes,
(i) hazardous industries,
(j) hazardous storage establishments,
(k) hospitals,
(l) hostels,
(m) information and education facilities,
(n) respite day care centres,
(o) seniors housing,
(p) sewerage systems,
(q) tourist and visitor accommodation,
(r) water supply systems.

4.3.2. Development Control Plan

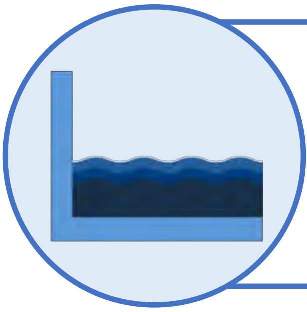
DCPs support the implementation of the objectives of the LEP, providing specific guidance for design and assessment of proposed developments. The City of Ryde LGA is covered by the City of Ryde Development Control Plan (Reference 27) which was adopted by council 28 May 2013 with some minor updates in 2017 and in 2021.

WMAwater was provided with the City of Ryde Development Control Plan (Reference 27), in particular Part 8.2 Stormwater and Floodplain Management as well as the Stormwater

Management Technical Manual. This covers items such as floor levels, car parking, building components, fencing, evacuation, and earthworks. Prescriptive controls are applied based on a matrix approach considering the land use category and flood risk of the development site.

5. FLOODPLAIN RISK MANAGEMENT MEASURES

The 2023 NSW Government's Flood Risk Management Manual (Reference 25) separates risk management measures into three broad categories, as shown below.



FLOOD MODIFICATION MEASURES
Modify the physical behaviour of a flood including depth, velocity and direction of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees, culvert or bridge modifications, flow path redirection and defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

PROPERTY MODIFICATION MEASURES
Modify the existing land use or development controls for future development. This is generally accomplished through means such as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls or voluntary purchase / voluntary house raising.

RESPONSE MODIFICATION MEASURES
Modify the response of the community to flood hazard by educating flood affected residents about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community, and the provision of flood insurance.

A summary of the typical floodplain risk management measures that have been assessed for the current study is shown in Table 10. These options are discussed in detail in the subsequent sections.

Table 10: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	Voluntary house raising	Flood warning
Temporary defences	Voluntary purchase	Flood emergency management
Channel construction	Flood proofing	Community awareness
Channel modification	Land use zoning	Improved evacuation access
Major structure modification	Flood planning levels	Flood plan / recovery plan
Drainage network modification	Flood planning area	
Drainage maintenance	Changes to planning policy	
Retarding basins	S10.7 Certificates	
	Flood Insurance	

5.1. Identification of Options and Assessment Methodology

This FRMS assessed a range of options for the management of flood risk within the City of Ryde LGA. The floodplain risk management option assessment process starts with identifying options that may be effective in mitigating flood risk. Consideration is given to areas where flood problems exist (either observed or modelled at properties and on roads) and areas with high property damages (either observed or using the flood damages assessment).

Options were identified from the existing FRMS&Ps that were available for the study area. WMAwater also identified some potential options in addition to those previously assessed. These were either new options or alternative options and variations of options previously investigated in the existing FRMS&P documents. WMAwater identified these options while undertaking a site visit of the study area and upon review of the design flood modelling results.

This identification process resulted in over 130 options to be investigated. Once these options were identified, an assessment process was undertaken, as outlined in Diagram 4. A high-level assessment was undertaken as a screening tool to eliminate options that would not be feasible or effective. Factors considered include:

- Physical and technical feasibility
- Support by the community and key decision-makers
- Compatibility with the management of other hazards and issues
- Effectiveness of reducing flood risk to the community
- Potential impacts on flooding to the existing community that cannot be offset
- Indicative costs and potential disbenefits
- Adaptability to address future risks

Property and response modification options that were not eliminated were progressed to the multi-criteria analysis stage. Flood modification options that were not eliminated were subject to two intermediate steps. Firstly, a hydraulic assessment was conducted by undertaking flood modelling for the option to determine the extent of impact on flood behaviour. The 1% AEP event was initially run for this assessment. Options that had a favourable outcome will subsequently be subject to a detailed assessment which will include modelling of all design flood events, calculation of the reduction in flood damages and an estimation of the capital and ongoing maintenance costs to conduct a cost-benefit analysis. Flood modification options that have a cost-benefit ratio close to or greater than 1 will be progressed to the multi-criteria analysis stage. The multi-criteria analysis will assess the relative benefits of options to inform the overall prioritisation of option implementation.

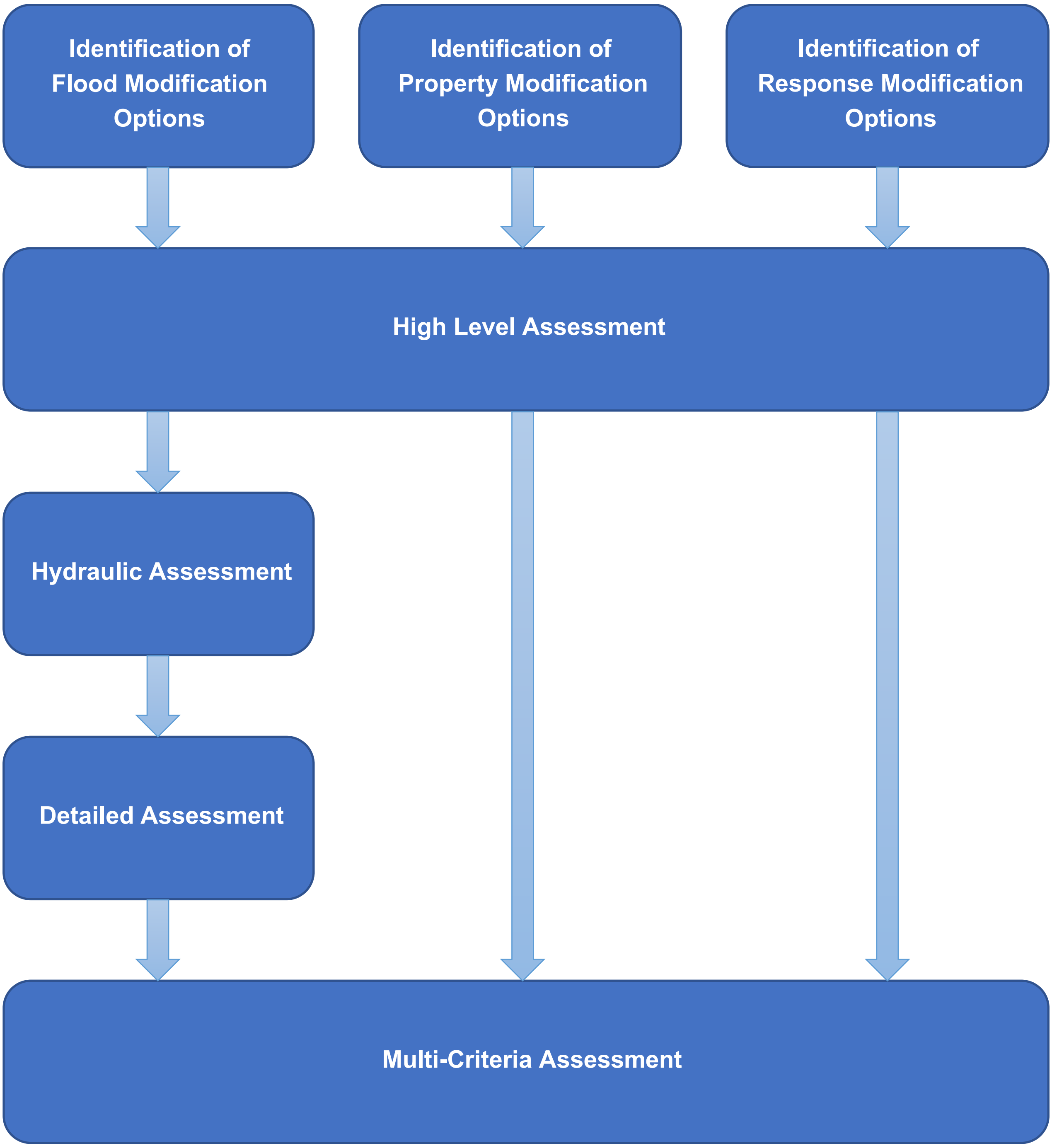


Diagram 4: Floodplain Risk Management Option Assessment Methodology

5.2. Flood modification Options

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities, or by excluding water from areas under threat. Typical measures involve structural works such as levee banks, retarding basins and drainage networks, and are generally installed to modify flood behaviour on a wider scale. Depending on the type of flood behaviour, spatial constraints and catchment conditions, different flood modification measures will be better suited to reducing flood risk than others. A key consideration when assessing potential flood modification options is ensuring that, in the pursuit of reducing flood risk in one area, the option (e.g. a basin or levee) does not adversely affect other areas.

A brief overview of some common types of flood modification measures appropriate for the study area is provided below. Other options, such as diversion channels, major channel modification, and dams are only relevant to larger riverine floodplains, and therefore have not been considered as part of this FRMS. Given the highly urbanised nature of the City of Ryde study area, there are significant limitations to the construction of flood modification measures. The measures are required to be compatible with the existing land use, considering aspects such as land availability, land ownership, existing assets and constructability. It was noted that some of the flood modification measures recommended in the previous FRMS/Ps were not feasible (for example, 'upgrade drainage infrastructure in this area' or 'formalise overland flow path through these properties'). It was the aim of this FRMS&P to develop solutions that are practical and feasible, giving Council the means to target options that are achievable and would provide tangible benefits to reducing flood risk in the City of Ryde area.

5.2.1. Flood Modification Option Types

5.2.1.1. Detention Basins

Detention basins work by storing floodwaters during an event and controlling the release of the water. They can be built above or below ground and can be installed either 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. Like the rest of the drainage system, detention basins have maintenance requirements.

The effectiveness of detention basins depends on their capacity, which for retrofitting options, can be significantly constrained by existing assets and development. However, they can also substantially 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 the basin to a variable rate, dependent on rainfall volumes and the water level in the detention basin. Depending on the outlet design and operation, however, they can increase the duration of flooding by prolonging the release of floodwaters.

Whilst detention 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 considered, including:

- 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.
- Specific flood benefits of basins can be difficult to quantify, as it depends on the basin and storm characteristics. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or 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 basin will be most effective when it is empty before the arrival of the storm burst, however, this is not always the case.

- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity;
- Basin costs can sometimes be difficult to quantify at early planning stages, since significant excavation is usually required and the presence of utilities, services, rock, hazardous fill, etc. can significantly increase costs.
- The intentional impounding of water can produce hazardous depths within the basin, and public safety measures such as limiting the basin depth, shallow batters or fencing may need to be considered. Basins with dual purposes (such as playing fields) can increase the utility of the land but can also pose safety risks. The risk of failure and release of water from the basin also needs to be considered.

All basins will provide some flow mitigation and water quality benefit. The benefit that can be achieved must be balanced against the loss of use of the land, the economic, social and environmental costs and concerns about liability if construction of a basin increases the flood hazard in the area.

5.2.1.2. Levees

Levees involve the construction of raised embankments between the watercourse 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 and rural areas and in overland flow situations where they usually take the form of smaller bunds. The levee needs to tie in with high ground in order to fully protect an area and the crest can also be used as an access path or road.

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. Flood gates, non-return valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. Management of the local drainage from behind a levee is a major design challenge for these structures. In addition, as the levee causes a displacement of water from one area of the floodplain to another, the design requires consideration of hydraulic modelling 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, wave action from passing vehicles or watercraft and effects of wind. Levees, however, can obstruct views of the waterway and provide those protected with a false sense of security, increasing flood risk in the event of overtopping or failure.

5.2.1.3. Temporary Flood Barriers

Temporary flood barriers include demountable defences, wall systems and sand bagging which are deployed prior to the onset of flooding and removed once the event has receded. Demountable defences can be used to protect large areas or specific buildings and are often used to assist current mitigation measures rather than sole protection measure (for example, fill gaps in levees or low points of road crossings, or to raise them as the risk of levee overtopping develops). The effectiveness of these measures relies on sufficient warning time, the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely used for mainstream fluvial flooding which have sufficient warning time and are not a suitable technically for smaller catchments with limited warning times. Temporary flood barriers may provide some benefit as a property-level protection measure, and this is discussed further in Section 5.3.3.

5.2.1.4. Road Raising

Depending on the topography of an area, floods can leave communities isolated by overtopping access routes. Raising roads to provide flood free access to such areas is commonly investigated in the floodplain risk management process as it can reduce evacuation time and improve accessibility as the flood progresses. Raised roads can also act like levees and increase flood levels unless culverts or overland bridge spans are upgraded as well (discussed below). Road raising may not only need to consider construction of the road, but also technical issues with existing services and infrastructure, as well as the possibility of diverting floodwaters into property or simply creating new flood paths across roadways.

5.2.1.5. Bridge and Culvert Modifications

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased (and vice versa). Generally, the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by increasing the size of a culvert, widening a bridge or raising the deck level. However, as flood levels are reduced upstream there is less temporary floodplain storage upstream and thus a slight increase in peak flow downstream. Reducing the structure capacity will increase flood level upstream and possibly reduce them downstream.

5.2.1.6. Channel Modifications

Channel modifications are undertaken to improve the conveyance and/or capacity of a creek or drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream, or that the works do not create ongoing difficulties and expense with maintenance and erosion. In City of Ryde, channels within urban areas are typically concrete lined and heavily constrained by existing development, with little opportunity for improvement.

5.2.1.7. Channel Construction

New channels or flow path diversions can sometimes be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration, particularly in overland flow areas. In City of Ryde, there is generally little scope to undertake this measure as there are existing development constraints, and where viable will often have already been undertaken. This measure may require additional land take, will generally involve significant costs and may have adverse environmental impacts.

5.2.1.8. Local Drainage Network Modification

The drainage network outside the creek and open channel system comprises Council's pit and pipe network. Local drainage systems typically reach capacity in an event equivalent to a 20% AEP event and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if of sufficient depth, properties. Increasing the size of pipes or installing more inlet capacity (possibly to compensate for blockage) will have some benefit, decreasing the quantity of overland flow and thus flood levels. Hydraulic restrictions in the system affect upstream flood levels due to backwatering effects. However, due to the relatively small percentage of flow carried by the pipe system in a large (eg. 1% AEP) event any improvements will have minimal benefit except in the smaller events (typically < 10% AEP). As such, these types of works will have minimal benefit in the large floods which generally are the cause of above floor inundation, however, may reduce the severity or frequency of nuisance inundation, particularly along roads, which could be beneficial to the community. It is noted that local drainage network modifications may fall into the purview of Council’s stormwater management rather than floodplain risk management, however they have still been investigated and modelled (where appropriate) as part of this study.

5.2.1.9. Drainage Network Maintenance

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. Blockage has the potential to increase peak flood levels as water is unable to efficiently drain away. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

A common issue with all residents in flood liable areas is the perceived lack of maintenance within the creek or piped drainage systems. This perception arises as residents see the build-up of debris either before, during or after the event and think that this is a major contributor to flooding. Whilst debris build-up does contribute to increased flood levels the issue is more complex than may be first assumed for the following reasons:

- Council already has a routine debris removal program for gross pollutant traps (GPTs);
- Council does undertake creek clearing and cleaning of pits and pipes if advised of major debris build up (fallen trees, blocked drains, etc.);
- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fall over or

water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources;

- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively, the implementation of trash racks or bollards upstream of structures could be considered by Council to keep structures free of debris (example shown in). The cost of trash racks or bollards varies greatly depending upon the nature of the structure.

Photo 15: Culvert under Constitution Road with trash rack

Some Councils have introduced silt and vegetation management plans to address this issue. However, it is acknowledged that these schemes are costly for Councils to operate and must be continued in perpetuity to be effective. These schemes are generally welcomed by the residents who appreciate that Council is listening and addressing their concerns.

5.2.2. Flood Modification Options Rejected with High Level Assessment

The high level assessment was undertaken as a screening tool to eliminate options that would not be feasible or effective. Based on the outcome of this assessment, the option was either not pursued further, or was subject to a hydraulic assessment. This section records those options that were not pursued further. These options fall into one of three categories:

1. Previous FRMS options that were reviewed as part of this study at a high level and assessed to be not viable
2. Previous FRMS options that were implemented
3. Additional or alternate options identified as part of this study that have been assessed to not be viable

Each of these are discussed in the following sections.

5.2.2.1. Previous FRMS Flood Modification Options Rejected

A number of flood risk mitigation options were investigated in the previous FRMS. WMAwater reviewed each of these at a high level to assess their viability. Options which were not found to be viable have been documented in this section for completeness and were not investigated further in the current study. These are listed in Table 11 and shown in Figure 19. A description as well as comments of the option based on the current flood of modelling is provided in Table 11. Further information about these options can be found in the previous FRMS Reports.

Table 11: Previous Flood Modification Measures that were rejected at the FRMS stage

ID	FRMS Name and Location	Description/Comment
Buffalo and Kittys Creek		
4	Basin in Holy Cross College (DB4 in Reference 7)	The proposed basin is in the upstream areas of the catchment and is unlikely to retain significant flows to reduce flooding or provide benefit to downstream properties. There are no inundated properties immediately downstream of this location. There are also safety concerns with a detention basin within a school facility.
6	Additional drainage network along Quarry Road (SI1 in Reference 7)	Existing flood depths are shallow across properties; therefore, it is unlikely to provide any significant benefit. There are only three properties inundated above floor level in the 1% AEP and the cost of additional pipes of this length will far outweigh the benefits in flood damages.
7	Drainage upgrade along Irvine Road (SI2 in Reference 7)	There is only one property inundated in the 1% AEP in the vicinity. Due to its distance from the proposed pipe, it is unlikely that there will be any flood level reduction at the property. Furthermore, diverting flows to a different stormwater line may increase flood levels in other properties.

Eastwood and Terrys Creek		
18	Glen Street Basin (Section 7.3 in Reference 9)	Investigated in Reference 9 and was found to reduce flood levels by less than 100 mm.
19	Mobbs Lane Basin (Section 7.4 in Reference 9)	Investigated and recommended in previous studies as it provides considerable flood level reduction. However, the basin is located outside of the City of Ryde LGA (within the Parramatta City Council LGA). Parramatta City Council were previously contacted and were not amenable to this option.
20	Enlargement of railway culvert (Section 7.5 in Reference 9)	High costs and worsens flood affectation for residents downstream.
21	Basin in Eastwood Park (Section 7.6 in Reference 9)	Investigation of basins in the upper and lower ovals of Eastwood Park was investigated in Reference 9. Basins act to retain water to lessen flood affectation downstream. Since these basins are located downstream of Eastwood CBD, they would not be effective in lower flood levels at Eastwood CBD.
22	Upgrade Terry Road culvert (Section 7.7 in Reference 9)	This option will only be effective if it is constructed with Mobbs Lane Basin (upstream) or further drainage upgrades downstream. This option constructed alone will only worsen flooding in properties downstream.
25	Wood Street drainage upgrade (Section 7.10 in Reference 9)	Since there is only one property with above floor inundation in 1% AEP event, upgrade to the pipe is unlikely to be financially feasible.
26	Diversion structure to Parramatta River (Section 7.11 in Reference 9)	High costs and high environmental impacts.
30	Lower Hillview Road crest (Option 10 in Reference 17)	Hillview Road is steep in this location and removal of the road crest will require substantial earthworks to be effective.
32	Detention basin at Somnerville Park (Section 5.3 in Reference 15)	Detention basins do not provide flood benefits upstream. Since there are only properties inundated above floor upstream (in the 1% AEP event) and none inundated downstream, a basin at this location will not materially improve flood risk.
34	Terry Creek widening (Section 3.3 in Reference 15)	Ground levels do not show that the creek is narrowed at this location. Widening works are unlikely to provide any substantial benefit.
Macquarie Park Catchments		
41	Marsfield Park detention basin (Section 6.1.1 in Reference 11)	Cannot be constructed due to environmental issues regarding habitat to endangered species.
44	Culloden Road (West) overland flow works (Section 6.2.1 in Reference 11)	This option does not address road sag point flooding on Epping Road. There are no buildings inundated above floor in 1% AEP at this location. Therefore, it is unlikely to provide significant benefits to flood damage.
45.1	Improve Epping Road	High costs and another lower cost option (MapID 45.2) at this

	drainage (near Culloden Road) (Section 6.2.2 in Reference 11)	location is being assessed.
48.1	Improve Epping Road drainage (at Sobraon Road) (Section 6.3.2 in Reference 11)	Only one property affected above floor level in PMF event (no properties in the 1% AEP). Intersection of Sobraon Road and Epping/ Waring Road is a low point (>1m depth in 1% AEP at Waring Road). Improvement would require upgrade across Epping Road and Waring Road as well as their downstream pipes (~270m of pipe to upgrade). Given that there is limited property damage and existing alternate routes available, this option is not considered viable.
49	Improve Talavera Road drainage (Section 6.3.3 in Reference 11)	The eastbound lane of Talavera Road is H1 in the 1% AEP and the westbound lane is H2. In the 1% AEP event, Talavera Road at this location is affected by runoff from the road only and is not overtopped by the basin upstream. Talavera Road is lower than its upstream (southern side) terrain such that there is no table drain or area available for runoff from the road to flow along, leading to 1 of 3 westbound lanes being untrafficable. Downstream properties are estimated to be flooded above floor in the PMF but not in the 1% AEP. Upgrading the cross drainage at this location will not be effective in reducing flood damages and improving road access.
50	Improve M2 drainage (Section 6.3.4 in Reference 11)	Westbound lanes of the M2 are modelled to be H1 in 1% AEP and eastbound is H3. This is because the TUFLOW model does not include pavement drainage structures for the M2. The drainage infrastructure on the M2 will likely cater for a portion of these flows.
93	Granny Smith Memorial Park detention basin (Section 6.4.1 in Reference 11)	There are no properties estimated to be inundated above floor in the 1% AEP immediately downstream of the site. Granny Smith Memorial Park is located in the upstream areas of the catchment and therefore a basin would not retain significant flow. Areas downstream of the park will still be affected by local catchment overland flows.
51.1	Pipe Upgrade from Danbury Close to Kent Road Public School (Section 6.4.2 in Reference 11)	This option involved pipe upgrade from Danbury Close to Kent Road Public School (320 m). High costs and another lower cost option (MapID 51.2) in this location is being assessed.
52.1	Mason Street Options (Section 6.4.3 in Reference 11)	This option involved installing additional drainage at Gallard Street and Mason Street. Only commercial properties are affected in the 1% AEP event and therefore are unlikely to receive funding for the works. Flood proofing options should be considered.
52.2		Option involves closing off Gallard Street from Jackson

		Crescent, which is unlikely to receive support from community.
55	Heath Street/Stephen Avenue works (Section 6.4.6 in Reference 11)	Along the flow path from Blaxland Road to Quarry Road, a total of 10 properties are inundated above floor level in the 1% AEP. The existing stormwater network runs through private properties. Additionally, as its downstream structures are also at capacity, upstream of a total of 900 m of pipes will be required. Upgrading these pipes is not considered feasible.
56.1	Santa Rosa Park overland flow path (Section 6.4.7 in Reference 11)	A total of 10 properties are currently inundated upstream of Quarry Road. A levee, which blocks flows from Quarry Road, will exacerbate flooding upstream.
58	Fawcett Street overland flow path (Section 6.4.9 in Reference 11)	This option involves formalising the overland flow path by acquiring properties where surface flows spill from Fawcett Street to Warren Street. There are no properties inundated above floor in the 1% AEP and Fawcett Street is mostly H1 hazard at its low point in the 1% AEP. Therefore, it is unlikely that this option will be cost effective or considered for route access improvement.
60	Ford Street overland flow path (Section 6.4.11 in Reference 11)	This option involves formalising the overland flow path, which spills from Ford Street to Shrimptons Creek, either by drainage upgrades or by acquiring properties and constructing a channel. There is one property with above floor flooding in the 1% AEP. Therefore, it is unlikely that this option will be cost effective. Recommendations for this residential property are flood proofing and development controls.
64	Peachtree Road overland flow path (Section 6.4.15 in Reference 11)	Google Street View shows that properties along Peach Tree Road are primarily units with garages at the ground level and most units have an existing fence at the rear of the property. Therefore, it is unlikely that this option will provide significant flood benefits.
65.1	Macquarie Shopping Centre options (Section 6.4.16 in Reference 11)	This option involves upgrading of pipes through an existing commercial property where no residential properties are inundated above floor in the 1% AEP immediately upstream of the options. It is highly unlikely that this option will receive state funding.
66.1	Epping Road flyover embankment options (Section 6.5.1 in Reference 11)	Four properties estimated to be inundated above floor level at this location in the 1% AEP with H3 hazard. Inundation is due to lack of drainage across Epping Road, which at this stage would be too costly to upgrade.
Parramatta River Catchments		
85	Regrade Wattle Lane and flood barrier (Section 7.2.4 in Reference 13)	This option involves regrading Wattle Lane to remove road sag and crest and constructing a low-level flood barrier which retains floodwaters in the road corridor. Three properties are estimated to be inundated above floor in the 1% AEP. A low-level barrier will increase flood levels in neighbouring properties.

87	Pipe upgrade in Gerrish Street, Cambridge Street and Pittwater Road (Section 7.2.6 in Reference 13)	This option involves upgrading the pipe network which runs through Gerrish Street, Cambridge Street, and Pittwater Road. There are two properties inundated above floor in the 1% AEP at the intersection of Gerrish Street and Cambridge Road. While the pipes are at capacity, this option is not feasible to construct as the pipe network runs through private properties.
91	Regrade Princes Street (from Morrison Road to Waterview Street) (Section 7.2.10 in Reference 13)	This option involves raising the median of Princes Street to retain floodwaters on the higher side of Princes Street. Raising the median would intercept an insignificant amount of flow and will have very low impacts downstream. Only one property is currently inundated along Princes Street in the 1% AEP event.
92	128 - 130 Cobham Avenue, Melrose Park Options (Section 7.2.11 in Reference 13)	Two options were investigated for this location. This first involved regrading the terrain at the rear of the properties to remove a berm. However, current ground levels do not show a berm in this location. The second option involved drainage upgrade in Cobham Avenue. However, there are no properties estimate to be inundated above floor level in 1% AEP and therefore is unlikely to provide significant flood damage benefits.

5.2.2.2. Previous FRMS Flood Modification Options Implemented

A number of flood risk mitigation measures recommended in the previous FRMP's have now been implemented. These are documented here for completeness and were not investigated further (with the exception of the First Avenue Drainage Upgrade). The structural measures implemented are listed in Table 12 and shown in Figure 20.

Table 12: Previous Flood Modification and Structural Measures that have been implemented

Map ID	Name	Description	Status
Buffalo and Kittys Creek			
9	Drainage upgrade along Monash Road (SI4 in Reference 7)	Drainage upgrade to pipes from Buffalo Road intersection to 76 Monash Road.	Completed
10	Upgrade to drainage from MacLeay Street to Gardener Avenue (SI5 in Reference 7)	Drainage upgrade to pipe diameter of 1500 mm along pipeline from MacLeay Street to Gardener Avenue.	Ongoing
Eastwood and Terry Creek			
23	Abuklea Road Drainage (Section 7.8 in Reference 9)	Additional twin 1500 mm pipes along Abuklea Road.	Partially completed.
24	Railway Culvert and Progress Avenue debris control structure (Section	Debris control measures to prevent blockage of the railway culvert and the Progress Avenue culverts were	Completed

	7.9 in Reference 9)	implemented	
27	First Avenue drainage works (Section 7.12 in Reference 9)	The final stages of the First Avenue Drainage Reconstruction Scheme involve the construction of an 1800 mm pipeline between First Avenue and Rowe Street.	Ongoing, subject to re-analysis in Section 5.2.4.7.
28	CBD Drainage Augmentation (Section 7.13 in Reference 9)	Onsite detention basin under Glen Street Carpark as it is redeveloped.	Subject to funding and Glen St Carpark redevelopment
37	Additional drainage pits at Brabyn Street (Section 8.2 in Reference 9)	Additional drainage inlets along Brabyn Street.	Completed
Macquarie Park Catchments			
42	Improve Waterloo Road Drainage (Section 6.1.2 in Reference 11)	Improve Waterloo Road drainage by lowering downslope ground levels.	Completed
43	Waterloo Park Detention Basin (Section 6.1.3 in Reference 11)	Construction of an earthen mound 1 m high and 120 m long at north-eastern end of Waterloo Park.	Completed
65.2	Consider upgrades during Macquarie Shopping Centre redevelopment (Section 6.4.16 in Reference 11)	Consider opportunities to increase conduit capacity through Macquarie Centre during redevelopment.	Implement as Macquarie Shopping Centre is redeveloped
70.3	Culvert inlet maintenance (Section 6.6.2 in Reference 11)	Remove shrubs from entrance to 'Officeworks' culvert inlet and maintain as short grass cover.	Ongoing
Parramatta River Catchments			
82	Earthworks at 79-81 Cobham Avenue (Section 7.2.1 in Reference 13)	Earthworks in existing floodway corridor (behind Cobham Avenue) and road verge to remove flow constriction and enhance capacity.	Completed
83	West Ryde Town Centre (Section 7.2.2 in Reference 13)	Construction of West Ryde Tunnel and associated upgrades.	Completed

5.2.2.3. Flood Modification Options Rejected with High Level Assessment

Additional or alternate options, which were not identified in a previous FRMS were assessed at a high level. Options which were assessed to be not viable were not investigated further but documented in this section for completeness. Options that were rejected at this stage are listed in Table 13 and shown in Figure 21.

Table 13: Options Rejected at High Level Assessment

Map ID	Name	Description/Comment
86.2	Regrade Meadowbank Park	Overtopping of Charity Creek banks only affects three properties above floor in the 1% AEP event along Meadow Crescent and is unlikely to be economically viable. However, this option should be reviewed if any developments affecting flood regime are undertaken upstream along Charity Creek in the future.
97	New culvert along flowpath in the rear of properties along the eastern side of Brush Road	There is a flow path which runs from Daryall Road to Brush Road through the rear of residential properties, which inundates three properties above floor in the 1% AEP event. The existing flow path is hydraulically efficient and no locations for improvement along this flow path were identified. A basin could be constructed to retain flows on the eastern side of intersection of Warrawong Street and Daryall Road, however, this has not been further investigated as it may worsen flooding in properties upstream of the basin, would likely have limited benefit, and has high capital costs.
98	Formalise flowpath at Hermoyne Street and Brush Road Playground	There is a flow path which runs from Brush Farm Park to Hermoyne Street Playground, which inundates three properties above floor in the 1% AEP event. The existing flow path is hydraulically efficient and no locations for improvement along this flow path were identified. A basin could be constructed to retain flows within Brush Farm Park, however, this has not been further investigated as it is located far upstream and is unlikely to alleviate flooding and has high capital costs.
96	Channel Upgrade in Terrys Creek upstream of Blaxland Road	Downstream of its crossing with the railway, Terrys Creek is conveyed via a channel. This option involves widening the channel to increase the conveyance. Terrys Creek between the Railway Culvert and Blaxland Road inundates 11 properties in the 1% AEP, however the majority of these are units which are typically not inhabited on the ground floor. Development controls will be more cost effective.
99	Hermoyne Street drainage upgrade	One property on Daphne Street (downstream of Hermoyne Street) is inundated above floor in the 1% AEP event. Pipe network upgrade is not economically feasible given the high costs and the likely minimal benefits.

5.2.3. Flood Modification Options Rejected with Hydraulic Assessment

The hydraulic assessment stage involved undertaking flood modelling for the option to determine the extent of impact on flood behaviour. The 1% AEP event was initially run for this assessment (10% AEP events were run the option was considered for emergency route access assessment only). The results of this assessment were used to determine if the option provided any substantial benefit to flooding. Based on the outcome of this assessment, the option was either not pursued further, or was subject to a detailed assessment. Options that were rejected at this stage are summarised in Table 14 below and shown in Figure 23. The following sections provide more detail of each of the options and the results of the hydraulic modelling.

Table 14: Flood Modification Options Rejected with Hydraulic Assessment

Option ID	Option Name	Modelling Outcomes (10% or 1% AEP Event)
1	Basin in Ryde Park (DB1 in Reference 7)	The basin is in the upstream areas of the catchment along a small tributary and does not retain enough flow to significantly improve flooding downstream. Areas downstream are still impacted by flooding from other tributaries and local rainfall runoff. In most areas, flood levels were reduced by less than 100 mm. There are no properties inundated above floor level in the 1% AEP immediately downstream of this basin. Reduction in flood damages is unlikely to be significant.
2	Basin in Ryde Public school (DB2 in Reference 7)	The basin is in the upstream areas of the catchment along a small tributary and does not retain enough flow to significantly improve flooding downstream. Areas downstream are still impacted by flooding from other tributaries and local rainfall runoff. In most areas, flood levels were reduced by less than 100 mm. There is only one property inundated above floor level in the 1% AEP downstream of this basin. Reduction in flood damages is unlikely to be significant.
45.2	Improve Epping Road Drainage (near Culloden Road) (Section 6.2.2 in Reference 11)	Investigated as a route access improvement option. This option involves lowering the median of Epping Road such that ponded water on the westbound lanes can flow downstream towards the northeast. This option did not provide any significant reduction in hazard on Epping Road in the 10% AEP event. Further drainage upgrades will be required to improve this location. However, this attracts high costs and does not improve flood damages.
46	Improve Talavera Road Drainage (Section 6.3.3 in Reference 11)	Investigated as a route access improvement option as there are no residential properties affected in the area. Only the 10% AEP event has been assessed as this low point in the road is completely inundated in the 1% AEP event. This option reduces hazards from H2 to H1 in 10% AEP. This option is not recommended as Talavera Road at this location does not significantly improve emergency access, as there are alternative routes available.
47	Dunbar Park Basin (Section 6.3.1 in Reference 11)	This option raises and extends the southeastern end of the basin embankment to prevent basin overtopping in the 1% AEP event. There is only one property inundated above floor in the 1% AEP event. This option reduces flood levels by 70 mm in the 1% AEP event near the property however it remains flooded above floor.
48.2	Improve Epping Road Drainage (Section 6.3.2 in	Existing hazards on Sobraon Road are H3 in 10% and Epping Road (westbound lanes) are H3 in the 1% AEP event. Inundation is more than 1 m deep along Sobraon Road and improvement is unlikely

	Reference 11)	without attracting high costs. Therefore, this option should only be considered for the access improvement of Epping Road only. This option has been modelled in the 10% AEP event by lowering the median strip to allow the ponding on the westbound lanes of Epping Road to drain east. This option is not recommended as hazards do not decrease in the 10% AEP event and there are no properties affected above floor.
59	Brendon Street sag point works (Section 6.4.10 in Reference 11)	There are no properties inundated above floor in the 1% AEP along Brendon St. A low level flood barrier, which runs along the front of 15 Brendon St, has been modelled for this option and it reduces the flood extent on the property. However, flood levels also increase by up to 28 mm on Brendon Street and there are newly flood areas along Flinders Road. Flood proofing options to be recommended to the resident instead.
65.3	Macquarie Shopping Centre Options (Section 6.4.16 in Reference 11)	This option involves installation of debris control structure upstream to the entrance to the existing culvert at Waterloo Road. The existing culvert is assumed to have a design blockage of 20% in the TUFLOW model. This option models the effect of the debris control structure by reducing the blockage of these culverts to 0% blocked. In the 1% AEP event, this option reduces flood levels on Waterloo Road by 150 mm, Talavera Road by 110 mm and through Macquarie Shopping Centre carpark by up to 330 mm. Given that no residential properties and only commercial properties were affected, it is unlikely that this option will improve flood damages or receive state funding.
69.1	Avon Road Stormwater Pipe Diversion	A pipeline which originates from the properties along Avon Road currently discharges to the pipeline along Beatrice Street, which is at capacity in the 1% AEP event. Whereas along Wicks Road, there is a pipeline which has capacity. This option involves re-routing the pipeline from Avon Road to discharge into the Wicks Road pipeline with capacity. This option was modelled in the 1% AEP event, however there were no changes (less than 10 mm reduction) to flood levels.
70	Improve drainage in the Morshead Street - Epping Road area (Section 6.6.2 in Reference 11)	There are nine properties inundated above floor at this location in the 1% AEP event. Cross drainage under Epping Road has less capacity than its downstream and upstream pipes. Since the pipe network in this area (both downstream and upstream) are at full capacity in 1% AEP, it is unlikely drainage upgrade will improve flood damages. However, it may improve route access in the 10% AEP. This option was further discussed as part of PM09 in Section 5.3.9.
72.2	Improve access to SES headquarters (Section 6.6.5 in Reference 11)	This option involves constructing a basin at Halifax Street Park to retain water from flooding Wicks Road. With this option there is no flood level increases to properties upstream of the basin and flood levels decrease by 280 mm in 1% AEP on Wicks Road. However, Wicks Road is still H3 hazard. This is because Wicks Road at this location is a low point and flow from surcharging pits along Wicks Road and Waterloo Road ponds there. Construction of another flood free

		emergency route for the SES headquarters should be considered instead (refer to Section 5.4.1).
84	Federal Road drainage (Section 7.2.3 in Reference 13)	Reference 13 investigated this option as it found that most properties along Federal Road had a defined floodway through them and driveways included a dip which accommodated the flow. The exception was 26 Federal Road, which did not accommodate this flow. Review of current ground levels from the LiDAR does not show blockage at 26 Federal Road. However, Google Street View (December 2023) shows that there may be a blockage as the driveway at 26 Federal Road is higher than 24 Federal Road. Street View also shows that many of these properties have fences which cross the flow path. The current Ryde Development Control Plan (DCP) includes controls on fencing crossing flow paths ensure the flow path is maintained. Two properties (32 and 34 Federal Road) along Federal Road and three properties near Gaza Road are estimated to be inundated above floor level. This option has been modelled with a lowered road verge to allow the flow path to cross onto road corridor and additional pits upstream near Gaza Road. Additional pits reduce flood levels along Station Street up to 100 mm. However, flood levels also increase downstream along Federal Road as pits surcharge. This pit upgrades are not recommended as it increases flooding on other properties. Lowering the road verge reduces flood levels by up to 50 mm. One property is no longer inundated above floor. However, flood levels also increase within the road corridor by 50 mm. Lowering the road verge is not recommended as only two properties are inundated above floor in the 1% AEP at this location and flood damages are unlikely to reduce significantly.
85.2	Falconers Road and Wattle Lane Pit Upgrade	This option involves upgrading the pits along Wattle Lane and at the intersection of Wattle Lane and Falconers Road to reduce inundation in the properties along Wattle Lane. This option is not recommended as it has minimal impact (typically less than 10 mm reduction) to the 1% AEP flood levels. Option ID 85 in Table 11 investigated low-level flood barriers at this location as well.
87	Gerrish Street, Cambridge Street and Pittwater Road (Section 7.2.6 in Reference 13)	This area was previously investigated in Reference 13 in effort to improve flooding along the flow path from Gerrish Street which cuts through residential properties on Cambridge Street and 48 Pittwater Road. Reference 13 and the current flood modelling shows that the apartments at 48 Pittwater Road are not inundated above inhabited floors and only the carpark is inundated. This option involves installing a low level flood barrier to prevent floodwaters from entering 48 Pittwater Road. This option removed flooding from 48 Pittwater Road in the 1% AEP event. However, flood levels increase by up to 0.3 m along Cambridge Road and flood level increases on the lawns of

		neighbouring properties. Structural options to prevent flooding in the car park is unlikely to gain state funding. Flood proofing options are recommended.
88 88.2	Morrison Road at Gregory Street Terrain Regrading (Section 7.2.7 in Reference 13)	More than 15 properties are inundated above floor level in the 1% AEP event upstream of Morrison Road. An existing 2.4 m x 1.6 m box culvert formalises the flow path at the rear of the properties along Morrison Road. Crossing Morrison Road, the structure expands to twin 3 m x 1.5 m box culverts. This option involves lowering Morrison Road and regrading Morrison Bay Park to smooth the transition into the creek downstream. This option did not have any significant reduction in flood levels (less than 50 mm reduction) in the properties. A secondary option was modelled which only involves regrading Morrison Bay Park. This option also did not have any significant reduction in flood levels.
88.3	Drainage Upgrade at rear of properties along Morrison Road	This option involves increasing the number of box culverts by 1 to the existing culvert at the rear of the Morrison Road properties (see Option ID 88 and 88.2 for existing conditions description). This option is not recommended as it only reduces flood levels by up to 25 mm in the 1% AEP event, and is therefore unlikely to economically viable.
90	Belmore Street to Shepherd Street (Section 7.2.9 in Reference 13)	This option involves raising low-level flood barriers along Belmore Street, Nicoll Avenue, Primrose Avenue and Addington Avenue, which retain water within the road corridors and reduce inundation in the properties. There are currently no properties inundated above floor level in the 1% AEP event. In the 1% AEP event, this option reduces flood extent in residential properties downstream of the low-level barriers without increasing flood levels in neighbouring properties. However, flood levels have increased in the road corridor. This option is not recommended because it is unlikely to provide benefits to flood damages.
95	Basin at TAFE NSW Ryde at Parkes St	A detention basin was simulated by implementing a high levee at the outlet of the TAFE NSW Ryde campus. Flood levels were reduced by up to 270 mm in properties along Griffiths Avenue and Bowden Street and several properties are no longer flooded above floor in the 1% AEP event. Flood levels were reduced by 50 mm to 100 mm over a large area downstream (including Meadowbank Park). The levee retained around 8,500 m^3 of floodwater in the 1% AEP event. This option is not feasible due to the volume of floodwater that needs to be retained. There are no suitable locations where a basin of this size can be constructed on the TAFE NSW campus.

5.2.3.1. Basin in Ryde Park (M001) and Basin in Ryde Public School (M002)

Option Description

The effectiveness of constructing basins in Ryde Park and Ryde Public School have been assessed together. These options were investigated in the previous studies (DB1 for Ryde Park and DB2 for Ryde Public School in Reference 7) and was not recommended as they had minimal impacts on flood hazard. For simplicity, these basins were implemented in the updated hydraulic model by raising a bund, which retains flows from upstream. The implementation of these basins is shown in Figure B1. An example of the location of the bund for Ryde Park is shown in Diagram 5.

The basins are in the upstream areas of the catchment along a tributary of Buffalo Creek such that areas downstream are still impacted by flooding from other tributaries and local rainfall runoff. There are no properties inundated above floor level in the 1% AEP immediately downstream of the basins.

Diagram 5: Bund in Ryde Park, photograph taken looking east from Argyle Avenue (*Source: Google Street View*)

Option Impacts

The basins in Ryde Park and Ryde Public School were modelled together in the same hydraulic model run. The modelled impacts of these basins in the 1% AEP event are shown in Figure B2. To fully retain the 1% AEP flows, the minimum crest level required for the basin embankments is 43.6 m AHD (maximum height of 1 m) at Ryde Park and 36.5 m AHD (maximum height of 1.7 m) at Ryde Public School. These are the minimum crest levels when both basins are constructed. If only Ryde Park basin (the downstream basin) were to be constructed, it would require an even higher embankment.

With both basins in place, flood levels between Ryde Public School and Ryde Park reduce by up to 110 mm (typically around 25 mm) in the 1% AEP event. Downstream of Ryde Park, flood levels decrease by up to 120 mm (typically around 50 mm). In current conditions there are no properties flooded above floor level. Therefore, it is unlikely that this option will provide significant flood benefits.

The basins are located community spaces and are likely to have some social impact. With the basins in place, flood levels and duration of inundation will increase within Ryde Park and Ryde Public School and restrict community access during and after flood events.

Conclusion

These basins are not recommended for the FRMP as it does not provide significant benefits to flood damages. In general, minimal flood damages are associated with this tributary of Buffalo Creek and the cost of capital works associated with the detention basins outweigh the benefits. The basins would have social impacts as community access to Ryde Park and Ryde Public School would be restricted during and after flood events. Therefore, these two basins were not considered a viable option to pursue further.

5.2.3.2. North Ryde Oval Basin (M005)

Option Description

North Ryde Oval is located in the upstream areas of Martins Creek (which is a tributary of Kittys Creek) in North Ryde. The oval has a relatively high elevation and only its southwestern corner is low-lying. In the current conditions, floodwaters in the 1% AEP flow overland around the oval and via a 1050 mm diameter pipe. Upstream of the oval, one property is inundated above floor level along Cressy Road and downstream of the oval two properties are inundated above floor level along Magdola Road.

This option involves construction of a basin at North Ryde Oval. This option was investigated in the previous study (Reference 7 as option DB3) and was not recommended as it had minimal impacts on flood hazard. This basin was implemented in the hydraulic model by raising a bund around the oval on its downstream side, which retains flows from upstream as well as re-routing an existing stormwater pipe to discharge into the formed basin. The implementation of the basin is shown in Figure B3.

Option Impacts

A detention basin in North Ryde Oval was modelled with a bund at the downstream end with a crest elevation of 47.1 m AHD (approximately 2.5 m high). The modelled peak flood level impacts for the 1% AEP event are shown in Figure B4. With the bund in place, the newly flooded extent in the Oval is restricted to the southwestern corner as the remainder of the oval is raised in comparison. It is expected that a detention basin in this location could be constructed by partially excavating the oval and the provision of a lower bund, which would have the same hydraulic performance of the modelled bund.

The decreases in downstream flood levels in the 1% AEP event were typically around 50 mm. One of the two properties become no longer flooded above floor level. However, the other experiences minimal reduction (<50mm) in above floor flooding. Upstream of the basin along Cressy Road, flood levels are increased by up to 65 mm (typically around 35 mm). Further assessment to reduce this flood level increase is required if this option were to be progressed.

Conclusion

The reduction in flood levels (up to 50 mm) and the extent benefited is not considered to be greater than the construction cost of this basin. There would be substantial works required to construct the basin, including augmentation of the existing stormwater network and potential difficulties with landscaping and dam safety (if constructed above ground). Additionally, the basin is constrained by the space available as the oval is raised in comparison to the road and the basin embankment would be required to be built in close proximity to the road corridor. Thus, this basin was not considered a viable option to pursue further.

5.2.3.3. Additional Drainage Along Monash Road (M009.1)

Option Description

This option involves installation of a twin 900 mm diameter pipe, which connects the existing stormwater network at the intersection of Higginbotham Road and Monash Road and discharges to directly to Buffalo Creek. The pipe would be installed within the road corridor of Monash Road, where existing underground services may need to be relocated or avoided. The implementation of these basins is shown in Figure B5. Approximate locations of the additional pipe alignment are shown in Diagram 6. This option aims to relieve the flood affectation in properties downstream of Higginbotham Road by directing flows from stormwater pipes which are at capacity directly into Buffalo Creek. This option was investigated in the previous study (Reference 7 as option SI4) and was not recommended as it had minimal impacts on flood hazard.

Diagram 6: Additional pipe along Monash Road (*Source: Google Street View*)

Option Impacts

The modelled impacts of the new pipe for the 1% AEP event are shown in Figure B6. With the additional pipe along Monash Road, flood levels in properties downstream of Higginbotham Road reduce by up to 100 mm (typically around 25 mm). Flood levels increase by up to 100 mm at the outlet of the new pipe as it enters Buffalo Creek. These areas of increased flood level are constrained to Field of Mars Reserve and do not impact any existing private properties. In current conditions, the stormwater network at the intersection of Higginbotham Road and Monash Road are at capacity in the 1% AEP event. With the new pipe in place, the existing stormwater network at this location is 80% to 90% full in the 1% AEP event.

As the new pipe is located along the road corridor, there should be minimal environmental impacts. There are minimal social impacts, with only disruption occurring during the installation of the pipe.

Conclusion

This option is not recommended as it in unlikely to be economically viable. The option has minimal flood benefits (typically only 25 mm to 50 mm) and high costs, which may be increased if existing services are present. Therefore, this option was not considered a viable option to be pursued further.

5.2.3.4. Lower Epping Road Median at Mars Creek (M045.2)

Option Description

This option involves lowering of the median along Epping Road at the crossing of Mars Creek (downstream of Pioneer Park). This option was investigated in the previous study (Section 6.2.2

in Reference 11) and was recommended due to its low cost. An alternative option (MapID 45) at this location was suggested in Reference 11, which involved upgrading to the stormwater network at this location. This alternative option was rejected in the high level assessment in Section 5.2.2. This option involves lowering the median along Epping Road to match the elevation of the eastbound lanes such that ponding does not occur along the westbound lanes. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B7. The approximate location of the lowered median is shown in Diagram 7.

Diagram 7: Epping Road at Mars Creek looking west (*Source: Google Street View*)

Option Impacts

The modelled impacts of the lowered median are shown in Figure B8 for the 10% AEP event. With the lowered median, the peak flood levels reduce by 100 mm to 200 m in the westbound lanes, however, in the eastbound lanes flood levels increase by approximately 50 mm to 100 mm. The lowered median only has localised impacts, which are within the road corridor. There are minimal impacts to downstream areas.

In current conditions in the 10% AEP event, hydraulic hazard along the westbound lane reaches H3 (unsafe for vehicles, children and the elderly). With the lowered median, the hydraulic hazards remain at H3.

Conclusion

While this option is relatively affordable, it does not reduce hydraulic hazard on the road. Therefore, this option was not considered a viable option to be pursued further.

5.2.3.5. Talavera Road Drainage Upgrade at Mars Creek (M046)

Option Description

This option involves upgrading the cross drainage culverts across Talavera Road at Mars Creek. This option was investigated in the previous study (Section 6.3.3 in Reference 11) and was recommended at a low priority as Talavera Road may have increased usage as Macquarie Park grows.

The current cross drainage for Talavera Road is a 1.8 m diameter culvert. Downstream of this culvert is a 2.4 m wide by 1.8 m height box culvert which crosses under the M2 Motorway. Road drainage pipes also feed into the crossing drainage. This option involves upgrading the Talavera Road cross drainage to a twin 1.8 m diameter pipe as well as upgrading the road surface drainage on the eastbound lane to a twin 375 mm diameter pipe. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B9. Diagram 8 shows the approximate location of the existing cross drainage culvert under Talavera Road.

Diagram 8: Location of Talavera Road cross drainage, photograph taking looking southeast (*Source: Google Street View*)

There are no residential properties in the vicinity of this culvert. Therefore, it is unlikely that there will be any significant benefits to flood damages. This option has only been assessed as a emergency access option due to this.

Option Impacts

The modelled impacts of upgraded drainage under Talavera Road for the 10% AEP event are shown in Figure B10. Flood levels are reduced locally upstream of the upgraded culvert by up to 100 mm. Within the road corridor, flood levels are reduced by 25 mm to 50 mm. In current conditions in the 10% AEP event, the hydraulic hazard on Talavera Road reaches H2 (unsafe for small vehicles) in the 10% AEP event, whereas with the upgraded drainage, hydraulic hazards are at most H1 (generally safe).

At this crossing Talavera Road is inundated in events 20% AEP and rarer. The road crest at the sag of Talavera Road is at approximately 42.7 m AHD. While the road is overtopped in the 10% AEP event, there is still hydraulic gradient across the road (i.e. flood levels on the upstream side of the road higher than the downstream side) and increase capacity crossing the road will result in lowered flood levels upstream. However, in the 1% AEP event, there is virtually no hydraulic gradient across the road. This indicates that this area is affected by backwater from the crossing drainage under the M2 Motorway. While drainage upgrades across Talavera Road may be effective in frequent events when there is some hydraulic gradient, in rare events there are no benefits.

Conclusion

It is not recommended that this option be pursued further. While there are some reductions in flood hazard in frequent events, this option does not provide any improvements to emergency access rare events. Furthermore, there are no existing residential properties in the area and in the current conditions there are alternative routes which can be taken. While it is understood that Macquarie Park is a growing suburb and route usage may increase, increasing flood immunity to Talavera Road to rarer events (such as the 1% AEP event) are constrained by downstream conditions. Without drainage upgrades under M2 Motorway as well, it is unlikely that greater flood immunity can be readily achieved.

5.2.3.6. Dunbar Park Basin Upgrade (M047)

Option Description

This option involves the raising and extending the southeastern embankment of the existing Dunbar Park Basin. This option was investigated in the previous study (Section 6.3.1 in Reference 11) and was not recommended as it was unlikely to be economically viable.

In the current conditions in the 1% AEP event, the basin spills at the southern eastern end of its embankment. This option involves raising the existing embankment to a minimum crest level of 75.3 m AHD (maximum height of raising of 0.5 m). The implementation of this option in the TUFLOW hydraulic model is shown in Figure B11.

Option Impacts

The modelled impacts of basin upgrade in the 1% AEP event are shown in Figure B12. Flood levels are reduced locally downstream of the upgraded basin by up to 70 mm in the 1% AEP event. In current conditions there is only one property inundated above floor level in the 1% AEP event. While the upgrade basin reduces the above floor flood depth in the 1% AEP event, it remains flooded above floor.

Conclusion

It is not recommended that this option be pursued further as it is unlikely to be economically viable. This option has limited flood benefits as there are few flood affect properties downstream of the basin and the upgrade is likely to be costly.

5.2.3.7. Lower Epping Road Median at Sobraon Road (M048)

Option Description

This option involves lowering of the median along Epping Road at its sag near the intersection with Sobraon Road. This option was investigated in the previous study (Section 6.3.2 in Reference 11) and was recommended due to its low cost. An alternative option (MapID 48.1) at this location was suggested in Reference 11, which involved upgrading to the stormwater network at this location. This alternative option was rejected in the high level assessment in Section 5.2.2.

This option involves lowering the median along Epping Road to match the elevation of the eastbound lanes such that ponding in the westbound lanes can drain over the eastbound lanes. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B13.

Option Impacts

The modelled impacts of the lowered median in the 10% AEP event are shown in Figure B14. The lowered median has minimal impacts road corridor and flood hazards were not reduced.

In current conditions, there is a low point along Sobraon Road approximately 30 m from the intersection. In the 1% AEP event, inundation at this low point is more than 1 m deep and flood depths in the westbound lanes of Epping Road are more than 0.5 m deep. As the Sobraon Road low point is significantly lower than Epping Road, any modifications to the median is unlikely to be able to drain floodwaters away from this low point.

Conclusion

While this option is relatively cost effective, it does not reduce hydraulic hazards. Therefore, this option was not considered a viable option to be pursued further.

5.2.3.8. Cecil Street and Macquarie Place Drainage Upgrade (M053)

Option Description

A tributary of Shrimptons Creek flows east through properties along Cecil Street, crosses Quarry Road, and then flows through Rocca Street to discharge into Shrimptons Creek at Santa Rosa Park. This tributary is partially conveyed via the pipe network, however, the remaining flows run overland land through low points in the terrain, which are typically in existing properties along Cecil Street and Macquarie Place. In this tributary, downstream of Cecil Street and Cecil Park, the pipe network splits into two pipelines – one 1.05 m (expanding to 1.35 m) diameter pipeline, which runs through the properties along Cecil Street and North Road, and another 1.5 m diameter (expanding to 2.1 m wide by 1.2 m high) pipeline, which runs within the road corridors of Cecil Street and Quarry Road. While the first pipeline through the properties is at capacity in the 1% AEP event, the second pipeline is not at capacity along Cecil St but is at capacity at Quarry Road. This indicates that the second, larger pipeline may be able to carry more flow. A review of the existing pipe network indicated that the bottleneck is caused by the second 1.5 m diameter pipeline contracting to 1.2 m diameter prior to expanding to 2.1 m wide by 1.2 m high.

This option involves drainage upgrade to the second pipeline to remove the bottleneck and diverting upstream flows to the second pipeline only in order to maximise flow in the pipe. The implementation of this option in the TUFLOW model is shown in Figure B15. This option was implemented in TUFLOW by:

- Doubling pit and pipe capacity along Richmond Street and through Cecil Park
- Doubling the 1.5 m diameter pipe along Cecil Street
- Upgrading the 1.2 m diameter pipe to a 2.1 m wide by 1.2 m high conduit along Cecil Street and Quarry Road
- Disconnecting the first pipeline such that pipes from Cecil Park are only connected to the second 1.5 m diameter pipeline within the road corridor of Cecil Street.

This location was considered in the previous study (Section 6.4.4 in Reference 11), however no structural options were pursued as options in this location were unlikely to be economically viable.

Option Impacts

The modelled impacts of the drainage upgrades are shown in Figure B16. Flood levels in properties along Richmond Street reduce by up to 100 mm. Along the overland flow path between Cecil Street and Macquarie Place, flood levels reduce by 100 mm to 200 mm. Additionally, flood levels are reduced along Rocca Street by up to 110 mm.

While this option provides some flood level reduction, in the current conditions, there are eight properties are inundated above floor in the 1% AEP event. With the option in place the number of properties inundated above floor are reduced by four. Therefore, there will only be minor reductions in flood damages. The drainage upgrade for this option is extensive and comprises 570 m of pipe upgrade and 7 pit upgrades. This option is costly and is unlikely that it will not be economically viable.

Conclusion

It is not recommended that this option be pursued further as it is not economically viable (benefit to cost ratio is <1).

5.2.3.9. Rocca Street (M054) and Santa Rosa Park (M056) Overland Flow

Option Description

A tributary Shrimptons Creek flows east through properties along Rocca Street and discharges into the creek at Santa Rosa Park. This option involves regrading the terrain to improve capacity for overland flow to be directed into Shrimptons Creek. Rocca Street is a cul-de-sac and properties at the end of the street are directly adjacent to Santa Rosa Park. Ground levels at the properties at the end Rocca Street are higher than the road such that waters pond at the end of Rocca Street and the properties are blocking this area from draining to Santa Rosa Park. There is a pipe network (twin 1.35 m diameter), which provides some connection from the low point to Santa Rosa Park. However, in the 1% AEP event, ponding at the end of Rocca Street spills through the properties and into Santa Rosa Park.

This option involves regrading the terrain to improve overland flow capacity between the Rocca Street low point and Santa Rosa Park, as well as terrain changes within Santa Rosa Park itself. The implementation of this option is shown in Figure B17. This option was implemented in the TUFLOW model by:

- Constructing a 2 m wide drain, which runs between two properties, from the Rocca Street low point to Santa Rosa Park (M054)
- Convert three pipes within Santa Rosa Park to an open channel (M056).
- Installation of an additional conduit (1.55 m wide by 1.1 m high), which connects the pipe network from Fawcett Street to the headwall of the proposed Santa Rosa Park open channel.

Options for this location have been investigated in the previous study (Reference 11 Section 6.4.5 for M054 and Section 6.4.7 for M056). The previous study investigated a similar option to M054 except it included a shallower overland flow path and required property acquisition. The previous study investigated three alternative options within Santa Rosa Park for M056. The first was a levee along Fawcett Street to exclude waters from Quarry Road. This was not recommended as it prevented overland flows from the south-east. The second option was to remove the trunk conduit and restore an open channel. The third option was to construct a bund cutting through the park divert flows towards the northwestern side of the park. While the third option was recommended in the previous study it has not been modelled as part of the current study. This is because the southwestern corner of Santa Rosa Park is where the carpark is located as well as a community centre. Construction of the proposed bund would affect these structures.

Option Impacts

The modelled impacts of both the drain from Rocca Street to Santa Rosa Park as well as Santa Rosa Park regrading is shown in Figure B18 for the 1% AEP event. Flood levels in Rocca Street and its properties are reduced by more than 300 mm in the 1% AEP event. Within Santa Rosa Park outside of the proposed open channel, flood levels are reduced by typically 100 mm to 200 mm. While there are some flood level increases of around 100 mm, they are constrained to small areas within Santa Rosa Park.

In current conditions, there are three properties inundated above floor level in the 1% AEP event. While this option lowers flood levels in the area, given that there are only a few affect properties in this location, it is unlikely that extensive works like this option would be economically viable. Furthermore, construction of a drain between two existing properties will likely require partial property acquisition (or at a minimum an easement) and community consultation.

Conclusion

It is not recommended that these options be pursued further as they are unlikely to be economically viable.

5.2.3.10. Brendon Street Low Point Flood Barrier (M059)

Option Description

This option involves installation of a low level flood barrier along the front of 15 Brendon Street, which prevents water from entering the property. This option was investigated in the previous study (Section 6.3.2 in Reference 11) and was recommended due to its low cost. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B19.

Option Impacts

The modelled impacts of the flood barrier in the 1% AEP event are shown in Figure B20. While 15 Brendon St is no longer flooded, flood levels increase by 25 mm to 50 mm in the road corridor of Brendon St and there are newly flooded areas along Flinders Road.

In current conditions, this property is not inundated above floor in the 1% AEP event. Therefore, it is unlikely that this option will provide significant flood benefits.

Conclusion

It is not recommended that this option be pursued further. While this option is coat-effective, it only benefits one property and is unlikely to provide any significant flood benefits to the wider community. It is recommended that Council promotes flood proofing to the community, as detailed in Section 5.3.3.

5.2.3.11. Halifax Street Park Basin (M072.2)

Option Description

This option involves construction of a basin at Halifax Street Park to retain floodwater which would enter Wicks Road. This option was investigated in the previous study (Section 6.6.5 in Reference 11) and was not recommended as it would not economically viable, given the significant pipework required upstream. This option was explored as part of improving access to the SES headquarters, which is located along Wicks Road, east of the M2 Motorway. Further discussion for improving access to the SES headquarters are provided in Section 5.4.1 where another option is presented.

This option was implemented by raising an embankment to a minimum crest level of 34.45 m AHD along Wicks Road. No upgrades to upstream stormwater network have been modelled as part of this option. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B21.

Option Impacts

The modelled impacts of the basin in the 1% AEP event are shown in Figure B22. While the basin does not overtop, Wicks Road downstream of the basin remains inundated. This is because flow from the stormwater network and other overland flow paths, which are not captured by the basin, still drain towards the low point on Wicks Road. Flood levels at the low point of Wicks Road reduce by 200 mm to 300 mm. While this is a significant reduction, flood hazards remain too high (H3, unsafe for all vehicles, children and the elderly) for access to the SES headquarters.

Conclusion

It is not recommended that this option be pursued further. There are no residential properties near Halifax Street Park. Therefore, benefits to flood damage are likely insignificant and the only benefit provided by this basin is access to the SES headquarters. However, even with the basin in place, access has not improved significantly during rare events.

5.2.3.12. Federal Road and Gaza Road Drainage Upgrade (M084)

Option Description

A flow path which runs towards the south flows through properties along Gaza Road, crossing through Mons Avenue and Station Street, and flows along the front of properties on Federal Road. Further details of this flow path have been discussed in Section 2.3.2.9.

This option has two components. The first involves drainage upgrades of the stormwater network on Gaza Road and Station Street. The second involves regrading the road verge along Federal Road such that the flow path can be diverted onto the road and be conveyed within the road corridor rather than through the properties. This option has been investigated in the previous study (Section 7.2.3 in Reference 13). The implementation of this option is shown in Figure B23.

Option Impacts

The modelled impacts of the road verge regrading and drainage upgrades are shown in Figure B24. With the option in place, flood levels reduce along Station Street by up to 100 mm. However, flood levels also increase in properties downstream along Federal Road. This is because the pipe network is capturing floodwaters more efficiently with the pit upgrades and with more flow in the network, the pits downstream begin to surcharge.

With the road verge regraded, flood levels in the properties along Federal Road reduce by up to 50 mm and one property becomes no longer flooded above floor. However, flood levels also increase within the road corridor by 50 mm.

Conclusion

These pit upgrades are not recommended as it increases flooding on other properties. Lowering the road verge is not recommended as only two properties are inundated above floor in the 1% AEP at this location and flood damages are unlikely to reduce significantly.

5.2.3.13. Wattle Lane Pit Upgrade (M085.2)

Option Description

A flow path runs from the northeast along Wattle Lane and cuts through the properties along Falconers Street. This flow path is partially conveyed by a 1.26 m wide by 1.06 m high conduit, however there is still significant flow overland in the 1% AEP event with flood depths more than 0.7 m in some properties. In the 1% AEP event, this conduit is not at capacity. This option involves upgrades to the pits along this conduit such that more overland flows can be more effectively captured and conveyed by the conduit. The implementation of this option in the TUFLOW model is shown in Figure B25. This pit upgrade is implemented in the TUFLOW hydraulic model by:

- Quadrupling the capacity of the existing pits along Wattle Lane and at the intersection of Wattle Lane and Parkes Street
- Adding a new pit in Wattle Lane
- Doubling pipe capacity by including an additional pipe for two road surface drainage pipes along Parkes Street

An alternative option to mitigate flood affectation at this location was investigated in previous studies (Section 7.2.4 in Reference 13). This option (ID 85) was rejected as part of the high level assessment conducted in Table 11.

Option Impacts

The modelled impacts from the pit upgrades are presented in Figure B26 for the 1% AEP event. Upgrades to the pit have minimal impacts on flood levels in the 1% AEP event.

Conclusion

This option is not recommended to be pursued further as it does not provide significant flood benefits.

5.2.3.14. Gerrish Street, Cambridge Street, and Pittwater Road (M087)

Option Description

This option involves installation of a low level flood barrier along Cambridge Street, which prevents water from entering a property at the intersection of Cambridge Street and Pittwater Road (Diagram 9). This option was investigated in the previous study (Section 7.2.6 in Reference 13) and was recommended due to its low cost. In addition to this option, the previous study (Reference 13) also investigated drainage upgrades to the stormwater network, which crosses

Gerrish Street and Cambridge Street. This was option was rejected in the high level assessment (Map ID 87 Table 11).

This flood barrier was modelled at a minimum level of 26.4 m AHD (approximately 0.4 m high). The implementation of this option in the TUFLOW hydraulic model is shown in Figure B27. The flood barrier would need to be tied into the existing terrain such that water does not flow around the flood barrier.

Diagram 9: Property at intersection of Cambridge Street and Pittwater Road (*Source: Google Street View*)

Option Impacts

In current conditions, in the 1% AEP event, the property at the intersection is not inundated above floor level. The property is a residential multi-storey unit which has a carpark on its lower ground floor. The modelled impacts of the flood barrier in the 1% AEP event are shown in Figure B28. With the flood barrier in place, the property is no longer flooded along its perimeter at Cambridge Street and flood levels are reduced by 100 mm to 200 mm along Pittwater Road. However, flood levels increase by up to 0.3 m along Cambridge Road and flood level increases on the lawns of neighbouring properties.

Conclusion

It is not recommended that this option be pursued further. While this option does reduce flood affectation to the property at the intersection of Cambridge Street and Pittwater Road, it also increases flood levels within the road corridor of Cambridge Street. Additionally, in the current condition this property is not inundated above habitable floor level and only the car park is affected. Structural options to prevent flooding of a residential car park is unlikely to gain state funding. It is recommended that Council promotes flood proofing methods to the community as detailed in Section 5.3.3.

5.2.3.15. Morrison Road Drainage Upgrade (M088)

Option Description

The intersection of Morrison Road and Gregory Street is flood affected and has flood depths approximately 300 mm to 500 mm in the 1% AEP event. More than 15 properties along Morrison Road are inundated above floor level in the 1% AEP event. The flow path along the rear of the properties is considered a flood hotspot and its flood behaviour was described in Section 2.3.2.11. Several options have been considered for this location. Some of these options were investigated in previous studies as well (Section 7.2.7 in Reference 13). These options included:

- M088.1 – Remove existing fig tree and regrade raised areas to improve outflow from Morrison Road sag point into the concrete channel (Reference 13).
- M088.2 – In addition to M088.1 also regrade the road surface of Morrison Road and Gregory Street roundabout (Reference 13).
- M088.3 – Upgrade the pipe network at the rear of the properties along Morrison Road. Pit and pipe upgrades start from the upstream side of the flow path crossing Acacia Avenue downstream to its outlet at Morrison Bay Park. The upgrade to the pipe network was implemented in the TUFLOW model by including an additional pipe of the same size as the existing. Existing pits along the upgraded area were quadrupled in capacity.

The implementation of these options in the TUFLOW hydraulic model are shown in Figure B29 and Figure B31 for M088.2 and M088.3, respectively. While the option M088.1 was modelled, the set up and impacts for this option have not been presented as this option is similar to M088.2 and provides similar results, although less flood benefits.

Option Impacts

The modelled impacts for regrading Morrison Road and Morrison Bay Park (i.e. M088.2) is shown in Figure B30. With the option in place, flood levels in Morrison Road are reduce by up to 100 mm and flood levels are reduced the most in Morrison Bay Park by more than 100 mm in the 1% AEP event. However, there are minimal impacts (<25 mm) to the flood levels along the flow path at the rear of the properties along Morrison Road. While this option provides some improvement to road access, it is unlikely to provide any benefit to flood damages as there are minimal impacts to properties.

The modelled impacts for drainage upgrade to the flow path at the rear of the properties along Morrison Rd (i.e. M088.3) are shown in Figure B32. With the option in place, flood levels in the rear of properties typically reduce by 75 mm to 100 mm in the 1% AEP event. At the intersection of Morrison Road and Gregory Street, flood levels are reduced by 50 mm to 75 mm. In current conditions, the are inundation on these properties ranges from 0.1 m to 0.6 m in the 1% AEP event. Therefore, while this option does reduce flood levels in properties, it does not reduce flood levels enough such that properties are no longer flooded above floor. This option requires private property access as the pipe upgrades are located at the rear of existing properties.

Conclusion

Neither regrading of Morrison Road and Morrison Bay Park, nor drainage upgrades are recommended to be pursued further. Regrading of the road and park area does not provide significant flood benefits to residential properties in the area. While drainage upgrades do provide flood benefits, it is constrained by the high construction cost and requires access to private property.

5.2.3.16. Belmore Street and Addington Avenue Flood Barrier (M090)

Option Description

This option involves constructing low level flood barriers along Belmore Street and Addington Avenue at their crossings with minor flow paths. These flood barriers can be constructed along the downstream road verge such that floodwaters are retained within the road corridors and are captured by the local stormwater network. These flood barriers were implemented in the TUFLOW hydraulic model by raising a high level bund to investigate the minimum height required to retain the 1% AEP event flows. This is shown in Figure B33. This option was investigated in previous studies (Section 7.2.9 in Reference 13) and was recommended due to its low cost.

Option Impacts

The modelled impacts of the flood barriers are shown in Figure B34. Along Addington Avenue, the flood barriers required a maximum barrier height of 0.4 m to adequately retain the 1% AEP event flows within the road corridor. With the barriers in place flow paths are diverted from running through to the property to running along Sewell Street. Properties on the downstream side of Addington Avenue become no longer flooded however flood levels increase by approximately 200 mm to 300 mm within the road corridor.

Along Nicoll Avenue, the flood barriers require a maximum height of 0.1 m to adequately retain the 1% AEP event. However, while some properties along Nicoll Avenue are no longer flooded in the 1% AEP event, there are also other properties along Nicoll Avenue which have increased flood levels (by up to 100 mm).

Along Belmore Street, the flood barrier near Allan Avenue requires a maximum height of 0.7 m and near Primrose Avenue requires 0.1 m. At Belmore Street near Allan Avenue flood levels increase significantly (more than 300 mm) in the 1% AEP event and affect the properties on the upstream side.

Conclusion

It is not recommended that this option be pursued further. In the current conditions there are no properties flooded above floor level in the 1% AEP at this location and therefore it is at lower flood risk and unlikely to provide any significant flood benefits. While most of the flood barriers proposed are low-level and feasible to construct, this option will be moderately disruptive to the community as it would require the driveway of a number of properties to be regraded. Furthermore, while the roads at this location are not considered high priority for emergency access, these flood barriers increase flood levels within the road corridor.

5.2.3.17. Basin at TAFE NSW Ryde (M095)

Option Description

This option involves construction of a basin in the green space of TAFE NSW at Ryde (along Parkes Street). In current conditions, the intersection of Parkes Street and Bowden Street is the confluence of two minor flow paths. One flow path originates from the northeast within the TAFE NSW campus and the other originates from the east via the existing stormwater network. This option was investigated by implementing a high level bund along the southwestern perimeter of the TAFE NSW site which retains the 1% AEP event flows from the northeast flow path. The implementation of this option in the TUFLOW hydraulic model is shown in Figure B35.

Option Impacts

The modelled impacts of the bunding are shown in Figure B36. Downstream of the basin in properties along Bowden Street and Griffiths Avenue, flood levels are reduced by up to 300 mm but are typically reduced less than 100 mm. Immediately downstream of the basin, some properties along Parkes Street become no longer flooded. While flood levels are reduced downstream, flood levels also increase upstream in properties along Hinkler Avenue.

To retain the 1% AEP event flows, the basin embankment requires a minimum crest level of 27.4 m AHD (i.e. maximum height of 2.2 m). Even within this embankment in place, water flows around the ends of the embankment raised. This is because the basin is located directly adjacent residential properties along Hinkler Avenue, which are situated at a lower elevation than the embankment crest.

This option has many constraints regarding its feasibility for construction. Firstly, the required embankment height exceeds 2 m. This would reduce access to the rest of the TAFE NSW site and dam safety would be a concern given the proximity to densely populated areas. Secondly, the basin location is currently a car park which will be required to be relocated. Thirdly, as mentioned above, the adjacent properties are lower than the required embankment crest. Therefore, to create a continuous embankment which is tied into the existing terrain, voluntary purchase of these properties would be required. Lastly, the proposed basin location is currently densely vegetated with large trees and construction of the basin will have associated environmental impacts. Alternatively, embankment height could be reduced if the basin area is excavated to provide more storage. However, this would involve removal of many trees and have environmental impacts. Furthermore, there is limited space available to excavate and the storage provided is unlikely to be sufficient in retaining all the flows.

Conclusion

It is not recommended that this option be pursued further. While some flood benefits downstream are provided, this option has many constraints which make it unfeasible to progress.

5.2.4. Flood Modification Options Subject to Detailed Assessment

Options that provided reasonable benefits to flooding at the hydraulic assessment stage were subject to a detailed assessment. This included modelling of all design flood events, calculation of the reduction in flood damages and an estimation of the capital and ongoing maintenance costs to conduct a cost-benefit analysis. Based on the outcome of this assessment, the option was either not pursued further, or was included in the multi-criteria assessment.

5.2.4.1. Flood Modification Option Costs

A preliminary cost estimate was undertaken for options which progressed to the detailed assessment stage. Costs were estimated first compiling a schedule of rates for tasks and materials required. The source of these rates was primarily from Rawlinsons Australian Construction Handbook (Reference 23). The rates published for Sydney (the upper rate if a range was supplied) was used for this investigation. It will be assumed that the regional cost factor for the City of Ryde was 1.0 (i.e. the same as Sydney Metropolitan Area). There are several factors which affect construction costs and the estimates provided here are preliminary estimates for the purpose of determining a cost-benefit ratio. The schedule of rates is contained in Appendix D.

A set of standard costs included for each option related to direct costs incurred by Council, pre-construction costs and construction contingencies. These are outlined in Table 15.

Table 15: Additional costs factored into costing

Item	Cost / Rate
Pre-construction Costs	
Design (including survey, investigation design, geotechnical investigations, REF, detailed design, etc.)	15% of construction cost
Project Management of Design	15% of design costs
Pre-construction contingency	40% of total pre-construction costs
Construction Costs	
Establishment (project inception, management and coordination)	$10,000
Preparation and implementation of preliminaries (CEMP, SMP, TCP, QMP, etc)	$20,000
Construction management / supervision	15%
Construction contingency	40% of total construction costs

The following assumptions were also made:

- No major tree clearing is necessary.
- All excavations are in 'light soil'. Costs will be higher in soils with high clay content or

through rock.

- No service relocation costs were included, which can be a significant cost if required.
- No land acquisition costs were included.

A breakdown of the cost estimates for each option is also contained in Appendix D.

5.2.4.2. Flood Modification Option Benefits

The benefits to flooding for most options were mapped for the 5% AEP and 1% AEP flood events. These maps show the change in peak flood level and indicate the magnitude and extent of flood benefits. The economic benefits of the options were quantified by estimating the reduction in AAD. AAD was estimated using the same methodology outlined in Section 3. It is likely that options may also provide additional benefits that were not quantified in this assessment (for example, increased access during floods for emergency services, evacuation and reduced travel disruptions in general for those options that improve flooding on roads).

5.2.4.3. Flood Modification Option Cost-Benefit Analysis

A cost-benefit analysis (CBA) was undertaken to determine a cost-benefit ratio (CBR). This was done by comparing the Net Present Value (NPV) of the reduction in AAD (benefit) with the capital cost of the works. To calculate NPV, an asset life of 25 years with a discount rate of 7% was applied (in accordance with NSW Treasury Guidelines, Reference 30). It is assumed that capital works costs are the only costs, with no additional annual costs (such as maintenance of the stormwater system) incurred to Council beyond current expenditure.

5.2.4.4. Option M003 Gannan Park Basin

Description of Flooding

Gannan Park is located in the upstream areas of a tributary of Buffalo Creek in Ryde. The park currently has two outlets. One outlet is at the southern corner (at the car park) and flows through pipes and overland towards Minga Street. One property along Minga Street is estimated to be inundated above floor in the 1% AEP event. The other outlet is along the northeastern corner and flows via pipes and overland through residential properties to Berripa Close. Flood depths in the 1% AEP event exceed 0.5 m within the road corridor of Berripa Close as there is only one 825 mm diameter pipe draining this location. Three properties are estimated to be inundated above floor in the 1% AEP event along Berripa Close.

Option Description

This option involves construction of a basin within Gannan Park to retain flows which would have inundated Berripa Close and Minga Street. This option was investigated in the previous studies (Reference 7) and was recommended for further assessment. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C1 and the approximately locations of works are shown in Diagram 10. The basin was implemented within the TUFLOW hydraulic model as:

- A bund with a minimum crest level of 50 m AHD (up to 1 m high) running along the southwestern and southeastern boundary of the park.
- Removal (or capping and decommissioning) of the existing 1050 mm diameter pipe through the park.
- A channel (maximum depth of 0.6 m) along the bund which drains the flow path in the northeastern corner to the southern corner.
- Basin outlet (1050 mm diameter pipe) at the southern corner of the basin, which discharges into the existing stormwater network.

Diagram 10: Gannan Park Proposed Works (photograph taken facing northeast)

This option is feasible to construct and involves earthworks to form the embankment and channel, as well as removal of an existing pipe (or capping and decommissioning) and installation of a new pipe at the basin outlet. The basin embankment should be tied into the existing terrain at the ends to ensure that retained water does not flow around the embankment. Given that the embankment is typically less than 1 m high, the space available to construct the embankment is sufficient. Trees along the perimeter of the park will either need to be removed or the embankment alignment will need to cater for the tree.

The channel would be relatively easy to construct involving earthworks for excavation as well as some regrading and landscaping. The channel needs to be installed to ensure flow from the flow path along the northeastern boundary is efficiently conveyed to the southern corner of the park where the basin outlet is located. Given that the channel is at most only 600 mm deep and is located within the park, it is unlikely that there are any services that need to be relocated.

Southern corner of the park is the proposed location for the basin outlet and is where the basin embankment is the highest (1 m). Most of the park amenities are in the southern corner and at this location the embankment divides the carpark from the main area of the park. Access to the park from the carpark may need to be amended and park amenities may need to be relocated or raised to prevent damages.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C2 and Figure C3 for the 5% AEP event and 1% AEP event, respectively. With the minimum crest level of 50 m AHD, the basin retains flows up to the 20% AEP event and overtops in the southern corner (at the basin outlet) in the 10% AEP event and rarer. The embankment also overtops at the eastern corner, where the outlet of the existing flow path along the northeastern boundary is, in the PMF event. In the 1% AEP event, this location is not overtopped.

With the basin, peak flood depth is up to 0.9 m directly upstream of the embankment. As the playing field is sloped from the north to the south (towards the embankment), most of the field is inundated by less than 0.5 m, with the exception of the southern corner. There are newly flood areas on the southern side of the park which inundate the amenities building by around 0.5 m in the 1% AEP event.

The main benefit of the basin is that it redirects the flow path along the northeastern boundary of the park towards the southern corner. This redirection prevents flow from discharging into residential properties along Berripa Close. In the 1% AEP event, the basin lowers flood levels on Berripa Close by 300 mm. While the embankment is overtopped in the PMF at this location, flood levels are still reduced in Berripa Close by 100 to 200 mm. In the watercourse at Quarry Road, flood levels are reduced by more than 1 m.

As the basin embankment overtops in events 10% AEP and rarer, flood levels downstream of the basin outlet are also increased. In events up to the 5% AEP, the flood level increases are constrained to the Gannan Park carpark. However, in rarer events (up to the 1% AEP), flood level increases in residential properties by up to 100 mm. Flood level increases are the worst in the PMF event and range from 100 mm to 200 mm in the residential properties. These impacts could be managed by drainage upgrades downstream of the basin outlet. However, this may significantly increase the cost of this option. It is recommended that these options to mitigate adverse impacts are investigated in future feasibility studies.

The proposed basin reduces flood levels downstream in Berripa Close and is most effective in the intermediate to rare events. In frequent events (50% AEP and 20% AEP), flood affectation in the area is generally minor as above floor flooding only begins to occur in the current 5% AEP event. In the 1% AEP event, there are some benefits to flood damages at properties. Along Berripa Close two properties are no longer inundated above floor and one property has above floor flood depths reduced by 300 mm.

Some social impacts are associated with this option as it disrupts usage of the Gannan Park during construction as well as during flood events. While the main sporting field has increased peak flood levels and prolonged the duration of inundation, the affected locations are constrained to the southern corner and it is expected that the sporting field would generally not be in use during flood events. The park amenities buildings are also located in the southern corner where flood depths are greater. The park amenities may be required to be relocated or raised to prevent flood damages. However, as Gannan Park has only recently been upgraded (with a new amenities building), it is unlikely that community will support continued park access disruption or relocation of the new amenities building.

There are a number of trees along the perimeter of Gannan Park. There may be some tree removal required as part of embankment construction. However, given that there is enough space for the embankment to be realigned it is expected that tree removal will not be extensive.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $4M, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $83,000. The NPV of this benefit was estimated to be approximately $1M. A summary of the benefits to flood damages is provided in Table 16. For the change in the number of properties affected, a negative number indicates a decrease in the number of properties affected and a positive number indicates an increase in the number of properties affected.

Table 16: Summary of flood damage benefits for M003

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages
50% AEP	0	0	-$52,291	0	0	-$67,987
20% AEP	-2	0	-$60,937	-2	0	-$74,335
10% AEP	-3	-1	-$111,261	-3	-1	-$149,061
5% AEP	-3	-2	-$313,024	-3	-2	-$386,618
2% AEP	-3	-2	-$322,644	-3	-2	-$406,502
1% AEP	-2	-2	-$314,990	-2	-2	-$396,274
PMF	-1	-2	-$419,675	-1	-2	-$517,690
Average Annual Damages			-$54,722	Average Annual Damages		-$83,383

The CBR of this option was therefore estimated to be approximately 0.3. While the type of works required for this option are considered feasible, the low benefit to cost ratio for this option is unlikely to attain state funding.

Summary and Recommendation

	M003 Gannan Park Detention Basin
Description	• Construct a 1 m high bund running along the southwestern and southeastern boundary of the park. • Construct a wide channel with connects the flow path in the northeastern boundary to the southern corner
Benefits	• Reduces road inundation on Berripa Close • Reduces property impacts for several properties on Berripa Close
Concerns	• Increases flood levels in properties along Minga Street will require mitigation • May cause social disturbance as the sporting field may be inaccessible after flood events • Relocation or raising of park amenities may be required
Approximate Cost	$4M
CBR	0.3
Responsibility	Council
Outcome	Low CBR, but recommended for further investigation.
Priority	Low

5.2.4.5. Option M008 Drainage Upgrade Along Buffalo Road

Description of Flooding

A tributary of Buffalo Creek crosses Lane Cove Road via culverts and flows through properties along Myra Avenue and Buffalo Road. A 1.8 m wide by 0.9 m high box culvert partially conveys this tributary under Lane Cove Road and these properties, however, this culvert is at capacity in the 1% AEP event, with overland flow occurring though the properties. In the 1% AEP, 8 properties are estimated to be inundated above floor level along the tributary.

Option Description

This option involves installation of a new culvert, which commences at the existing box culvert location on Lane Cove Road and runs southwest along Lane Cove Road and then southeast along Buffalo Road. This pipeline connects with the existing culvert as it crosses Buffalo Road. This option was investigated in the previous study (Reference 7) and was not recommended as it had minimal to no impact on flood hazard. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C4 and the approximate location of the proposed works are shown in Diagram 11. This option was implemented in the TUFLOW hydraulic model by:

- A new 1050 mm diameter pipe along Lane Cove Road and Buffalo Road
- A new pit on the eastbound lane of Lane Cove Road
- Pit upgrades to 1 existing pit (on the westbound lane of Lane Cove Road)
- Pit upgrade to 4 existing pits (along the existing conduit at the rear of properties along Buffalo Road)

Diagram 11: Intersection of Lane Cove Road and Buffalo Road (*Source: Google Street View*)

This option would be difficult to construct as it is constrained by the invert levels of the existing stormwater network as well as the terrain that it traverses. The intersection of Lane Cove Road and Buffalo Road is at high point where ground levels are approximately 5 m higher than the ground levels at the inlet and outlet of the new pipeline. Therefore, trench excavation will likely be very deep. In addition to this as the new pipeline is aligned along the road, there may be several services that would need to be avoided or relocated. This may pose a significant constraint and increases costs significantly. During installation of this new pipeline partial road closures to Lane Cove Road, which is an arterial road, and a Buffalo Road will be required.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C5 and Figure C6 for the 5% AEP event and 1% AEP event. In the 1% AEP event, this option lowers the flood levels in the tributary from downstream of Lane Cove Road to Watt Avenue by up to 135 mm (typically 70 mm). In the 1% AEP event, there are minor benefits to property impacts where eight properties have reduced above floor flooding (seven of which have reduced flood levels by less than 100 mm).

In frequent (50% AEP) to intermediate events (5% AEP), flood levels are reduced along the properties at the rear of Buffalo Rd and Lane Cove Road by more than 100 mm. However, flood levels increase along the tributary downstream of Buffalo Road and Pratten Avenue. Flood levels increase by up to 75 mm to 100 mm in the rear of Crescent Avenue. This flood level increase occurs because the option only increases drainage capacity in one intermediary segment of the overall tributary (from Lane Cove Road to Buffalo Road). While flooding in the area with upgraded drainage improves, downstream conduits which were not upgraded become the bottleneck. Further drainage upgrades which extend downstream to the outlet could mitigate these flood level increases. However, the length of pipelines to upgrade would almost double the original length of added pipeline and access to the pipeline is constrained as it is located at the rear of private properties. Further drainage upgrades have not been explored due to these constraints.

The option has some property flood benefits and overall reduces above floor flooding in two properties in the 2% AEP event.

There are likely to be minimal social impacts as only some disruption during the installation of the pipe is expected. There are likely to be minimal environmental impacts as the pipe is installed under the existing road and no land clearing is required.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $4.1M, with no ongoing maintenance costs directly associated with this option. It is assumed that the additional pipeline can be maintained as part of Council's existing stormwater maintenance program. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $102,000. The NPV of this benefit was estimated to be approximately $1.3M. A summary of the benefits to flood damages is provided in Table 17.

Table 17: Summary of flood damage benefits for M008

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages
50% AEP	-1	0	-$22,451	-1	0	-$27,190
20% AEP	-1	-1	-$176,366	-1	-1	-$213,109
10% AEP	0	-2	-$232,843	0	-2	-$303,253
5% AEP	-2	0	-$246,665	-2	0	-$352,622
2% AEP	-2	-2	-$224,472	-2	-2	-$317,701
1% AEP	-3	0	-$366,552	-3	0	-$494,152
PMF	0	0	-$79,008	0	0	-$96,936
Average Annual Damages			-$66,776	Average Annual Damages		-$102,124

The CBR of this option was therefore estimated to be approximately 0.3.

Summary and Recommendation

	M008 Drainage Upgrade Along Buffalo Road
Description	• Installation of 1050 mm diameter pipe from Lane Cove Road to Buffalo Road
Benefits	• Reduced flood levels in the rear of properties • Minor benefits to property impacts
Concerns	• Deep trench excavation required • Existing underground services may need to be avoided or relocated • Installation of pipes require closure of Lane Cove Road • Flood level increases downstream in frequent and intermediate events
Approximate Cost	$4M
CBR	0.3
Responsibility	Council
Outcome	Not recommended.
Priority	N/A

5.2.4.6. Option M016 and M017 Eastwood Drainage Tunnel

Description of Flooding

The main source of flooding in the Eastwood CBD is the Terrys Creek channel, which begins as an open, concrete-lined channel west of the CBD then enters a culvert at the southern end of Progress Avenue. During flood events. When flow exceeds the culvert capacity and an overland flow path forms along Progress Avenue and Hillview Lane – impacting the Eastwood CBD. In the 1% AEP event, upstream of the CBD, water also escapes the Terrys Creek channel, impacting residential dwellings along both Shaftsbury Road and Auld Avenue. Downstream of the railway culvert, water also escapes the channel during rare events, inundating properties along Doomben Avenue and Ball Avenue.

Option Description

This option involves the installation of a drainage tunnel with collects water upstream and discharges water directly into Terrys Creek downstream such that Eastwood CBD is bypassed. Multiple studies in the past have investigated the viability of this option (Reference 9, Reference 14, Reference 15, Reference 17, and Reference 19). The most recently completed study (Reference 19) was commissioned by Council and undertaken by WMAwater using the most up to date flood modelling results. A summary of the outcomes of this study has been provided in this section and the full report is provided in Appendix E.

At a fundamental level, these options consist of three variables: tunnel inlet location, tunnel outlet location and tunnel size. In Reference 19, two potential inlet locations and three potential outlet locations were investigated. It was also found that a size of 3.5 m to 3.9 m diameter the most suitable to convey the 1% AEP flows and provide the highest benefit to the CBD in the 1% AEP event. In Reference 19, five main options and four alternate routes were assessed:

- TO1a – Tunnel from David Hamilton Reserve to Forrester Park (direct route)
  - TO1b – alternative route
- TO2a – Tunnel from David Hamilton Reserve to Eastwood Park (direct route)
  - TO2b – alternative route
- TO3_GRC – Tunnel from David Hamilton Reserve to Somerville Park
- TO4a – Tunnel from Glen Reserve to Forrester Park (direct route)
  - TO4b – alternative route
- TO5a – Tunnel from Glen Reserve to Somerville Park
  - TO5b – alternative route

As mentioned in Section 2.3.2.2, most of the catchment of Terrys Creek up to Somerville Park is a SWC stormwater catchment. Any alterations to the existing conditions would require consultation with SWC.

Option Impacts

For all routes assessed, in the 1% AEP event, flood levels were reduced by approximately 0.6 m to 1.1 m in Eastwood CBD. For options where the tunnel inlet was at David Hamilton Reserve (i.e. TO1a, TO1b, TO2a, TO2b, and TO3_GRC), flood levels were reduced by up to 1.3 m to 2.3 m in the residential area between Terrys Road and Richards Avenue (upstream of Eastwood CBD). There were no flood level reductions at this residential area for options where the tunnel inlet was at Glen Reserve, as Glen Reserve is downstream of the residential area. Downstream of the railway line, flood levels were reduced by up to 0.6 m for the options with tunnel inlet at David Hamilton Reserve. For the routes with the tunnel inlet at Glen Reserve, flood levels reduced by up to 1.5 m when the tunnel outlet was located in Forrester Park and by up to 0.9 m when the tunnel outlet was located at Somerville Park.

Cost Benefit Analysis

A detailed cost benefit analysis is provided in Reference 19 and a summary of the analysis is provided in this section. The total cost of the options ranged from $42.4M (Option TO2a – direct route from David Hamilton Reserve to Eastwood Park) to $91.5M (Option TO1b – alternative route from David Hamilton Route to Forrester Park). Total flood benefits of the options ranged from $5M (Option TO2 – direct or alternative route from David Hamilton Reserve to Eastwood Park) to $11.3M (Option TO1 – direct or alternative route from David Hamilton Route to Forrester Park). The benefit to cost ratio were assessed for all options and ranged from 0.11 to 0.13.

Summary and Recommendation

	Option M016 and M017 Eastwood Drainage Tunnel
Description	• Installation of a drainage tunnel which bypasses Eastwood CBD
Benefits	• Flood levels reduced by 0.6 m to 1.1 m in Eastwood CBD • Flood levels reduced by up to 1.3 m to 2.3 m in residential areas been Terrys Road and Richards Avenue (for selected routes) • Flood levels reduced by up to 0.6 m to 1.5 m downstream of the railway line. • Flood benefits ranging from $5M to $11.3M dependent on the route
Concerns	• Land acquisition may be required • Relocation of existing services may be required • Construction (tunnelling) under existing properties may be required • Approval from City of Parramatta Council may be required as some routes are beyond City of Ryde LGA
Approximate Cost	$42.4M to $91.5M
CBR	0.11 to 0.13
Responsibility	Council
Outcome	Not recommended. The alternative solution of a detention tank was found to be more feasible (Reference 17), with a detailed concept design existing (Reference 18). The detention tank is currently the planned flood mitigation measure for the Eastwood CBD (item 28 in Table 12).
Priority	N/A

5.2.4.7. Option M027 First Avenue Drainage Upgrade

Description of Flooding

A tributary flow path of Terrys Creek commences at Fourth Avenue and flows through private property and over roads in the 1% AEP event before reaching First Avenue, between East Parade and Ryedale Road in Eastwood. It then flows down a driveway between properties (Photo 16) that opens up to rear yards for shops fronting Rowe Street (Photo 17). At this location, peak flood depths reach up to 0.9 m deep in the 1% AEP event. In the November 2018 event, ponding was noted in this area, with water flowing through the commercial properties at 100-104 Rowe Street. The model was calibrated with an allowance for this flow. Other than flow through the buildings, the water would be trapped in this location. If no flow is assumed through the buildings, the 1% AEP peak flood level is approximately 0.5 m higher. There is an existing stormwater line along this flow path consisting of a 1.05 m to 1.35 m diameter pipe from First Avenue to Rowe Street that is at capacity in the 50% AEP event.

Photo 16: Location of the flow path from the First Avenue sag point to the rear of properties on Rowe Street (*Source: Google Street View*)

Photo 17: Area at the rear of 100-104 Rowe Street where signfiicant ponding occurs (*Source: Google Street View*)

Option Description

The Eastwood Town Centre Flood Study and Stormwater Upgrades Design (Reference 17) was undertaken by Royal Haskoning in 2019. The study identified a number of flood mitigation options for the Eastwood CBD. One of these options was the First Avenue drainage upgrade, to alleviate flooding downstream of First Avenue. The recommended concept design involved the following:

- Demolition of 100-104 Rowe Street
- Construct a new 1.8 m diameter pipe in place of the existing stormwater line
- Partial rebuild of the site, allowing for a 4 m wide overland flow path between First Avenue and Rowe Street.

This reduced 1% AEP flood levels between Rowe Street and First Avenue by 600 mm to 800 mm, and reduced the number of flood-liable properties by 8 in the 1% AEP event. The total reduction in flood damages in the Eastwood CBD east area was estimated to be approximately 33%, with the total cost of works estimated to be $1.86 M.

This progressed to a concept and detailed design (Reference 28). The detailed design option reduced the proposed pipe to a 1.5 m diameter pipe. Updated flood modelling indicated that the reduction in flood depths between Rowe Street and First Avenue was in the range of 400 mm to 800 mm, with increases on Rowe Street up to 100 mm. The cost estimate of the works was revised to $2.5M.

This option was re-assessed with the updated flood model as part of the current study. The 1.5 m diameter pipe was implemented in addition to a 4 m overland flow path allowance at 100-104 Rowe Street. The set up for this option is shown in Figure C7. This option has been subject to several investigations in the past to determine constraints and feasibility.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C8 and Figure C9 for the 5% AEP event and 1% AEP event, respectively. With the proposed upgrade, there is a reduction in 1% AEP flood levels of 500 mm to 600 mm at the rear of the properties on Rowe Street. There are also reductions downstream on Rowe Avenue of 100 mm to 200 mm, and on Railway Parade of up to 400 mm. There were minor reductions in the Terrys Creek channel downstream of the railway line in the order of 10 mm to 20 mm and minor increases downstream of Davis Avenue to the confluence with the Lane Cove River of the same magnitude.

This option removes flooding at 100-104 Rowe Street (with the demolition of the building) and assuming that two shops are re-instated, however, with floor levels at the 1% AEP flood level (minimum requirement). There are further benefits to downstream properties on Rowe Street and Railway Parade. It results in benefits of up to 16 commercial properties being no longer affected in the 1% AEP event, with 15 of these being no longer flooded above floor. There are minor benefits to residential properties further downstream on Terrys Creek.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $2.5M at the time of the previous report (Reference 28), with no ongoing maintenance costs directly associated with this option. The costs associated with resale of the property (as Council owns this land) was not included. These costs were assumed to still be valid, however, were uplifted to account for inflation (approximately 18% since 2020). Therefore, the total cost of this option was estimated to be approximately $3M.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $191,100. The NPV of this benefit was estimated to be approximately $2.4M. A summary of the benefits to flood damages is provided in Table 27.

Table 18: Summary of flood damage benefits for First Avenue Drainage Upgrade

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	0	0	-$3,207	-2	-3	-$52,243
20% AEP	0	0	-$26,789	-7	-7	-$384,746
10% AEP	0	0	-$14,583	-8	-8	-$498,334
5% AEP	0	0	-$19,545	-9	-8	-$489,251
2% AEP	0	0	-$90,456	-9	-10	-$877,518
1% AEP	-1	0	-$37,705	-17	-15	-$1,262,741
PMF	-1	-2	-$317,673	-3	-4	-$1,224,498
		Average Annual Damages	-$10,241	Average Annual Damages		-$191,079

The CBR of this option was therefore estimated to be approximately 0.8.

Summary and Recommendation

	First Avenue Drainage Upgrade
Description	• Demolition of 100-104 Rowe Street • Construct a new 1.5 m diameter pipe in place of the existing stormwater line • Allowance for an overland flow path 4 m wide from First Avenue to Rowe Street
Benefits	• Reduces flood levels at the rear of Rowe Street by up to 600 mm in the 1% AEP event, with further reductions on Rowe Street and Railway Parade • Reduction in flood damages • Design already progressed
Concerns	• Primary benefit is to commercial properties only
Approximate Cost	$3M
CBR	0.8
Responsibility	Council
Outcome	Recommended to continue with current design proposal
Priority	High

As this option has already been progressed, it is recommended to continue the implementation of this option.

5.2.4.8. Option M036 Jim Walsh Park Basin

Description of Flooding

A tributary of Terrys Creek flows from south to north through Jim Walsh Park. This tributary enters a 1.8 m diameter pipe at Jim Walsh Park, which then transitions to a 3 m wide by 2 m high box culvert under Balaclava Road and continues through a twin 1.8 m diameter pipe underneath residential properties. At Vimiera Road, the pipeline expands to twin 2.5 m wide by 2.2 m high box culverts prior to discharging to Terrys Creek. In the 1% AEP, the 1.8 m diameter pipe at the inlet at Jim Walsh Park is at capacity and is the bottleneck of the conduit. The conduit downstream of this is typically 60% to 80% full until it reaches Vimiera Road where it is at full capacity.

Jim Walsh Park has an existing embankment roughly parallel to Balaclava Road with a crest at approximately 65.3 m AHD. This embankment retains some floodwaters within the park but is overtopped in events as frequent as the 50% AEP.

In the 1% AEP event, this tributary flows overland as the 1.8 m diameter pipe at Jim Walsh Park is at capacity and the embankment overtops. This inundates more than 20 properties downstream of Balaclava Road above floor. Peak flood depths along this tributary through the properties are typically 1 m to 1.5 m.

Balaclava Road is a classified regional road under the Roads Act 1993 and due to its network significance and Transport for NSW (TfNSW) may provide financial assistance to Council for the management of the road. Both Vimiera Road and Balaclava Road are inundated by more than 0.5 m in the 1% AEP event and have H4 hazard. In the 10% AEP, hazards on these roads are H3 (unsafe for vehicles, children, and the elderly).

Option Description

This option involves the construction of a basin in Jim Walsh Park. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C7: M027 First Avenue Drainage Upgrade – Option
Figure C8: M027 First Avenue Drainage Upgrade – Peak Flood Level Impact – 5% AEP
Figure C9: M027 First Avenue Drainage Upgrade – Peak Flood Level Impact – 1% AEP
Figure C10. The approximate location of the proposed basin embankment is shown in Diagram 12. The works comprise:

- Raising and extending the existing embankment to a minimum crest level of 66 m AHD (increase of 0.7 m)
- Excavation of parts Jim Walsh Park to 65 m AHD (such that the natural flow path is maintained) to increase storage
- Upgrade to the pipe within the basin at Jim Walsh Park from 1.8 m diameter pipe to 3 m wide by 2 m high box culvert (to match the pipe capacity downstream)
- Removal of trees and site clearance within the basin area.

To fully retain the 1% AEP event flows within Jim Walsh Park without excavation, the existing embankment needs to be raised by more 2 m. This is not considered feasible due to its proximity to residential properties and because the flood behaviour is likely to change such that flood affectation in properties to the east of Jim Walsh Park are made worse.

Diagram 12: Jim Walsh Park at Balaclava Road (*Source: Google Street View*)

The option is considered feasible to construct, however it may be constrained by the removal of trees and proximity to nearby residential properties. Jim Walsh Park is currently vegetated with many trees and excavation of the basin may require removal of more than 15 of these trees. Tree removal will likely have some environmental impacts as well as reduce community support for this option. In addition to this, the City of Ryde Biodiversity Plan (Reference 4) states that threaten flora (Blue Gum High Forest) which is listed under the TSC Act and EPBC Act has been mapped within Jim Walsh Park. The embankment of the basin is in close proximity to the road and adjacent residential properties and may not gain support from the community. A portion of the park would need to be closed during construction.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C12 and Figure C13 for the 5% AEP event and 1% AEP event, respectively. With the basin in place, the raised embankment at Jim Walsh Park stores all water in the 50% AEP event. However, it remains overtopped in the 20% AEP event and rarer. During the 1% AEP event, flood levels in the basin are at 66.2 m AHD with peak flood depths reaching 3.3 m directly upstream of the embankment in the natural flow path. In the excavated areas, peak flood depths are approximately 1.25 m.

In the 1% AEP event, the basin lowers flood levels in the properties from Balaclava Road to Vimiera Road by up to 125 mm (typically around 100 mm). Downstream of the tributary, Terrys

Creek has minor flood level reductions of up to 35 mm.

This option reduces the depth of above floor flooding by more than 100 mm at more than 10 properties between Balaclava Road and Vimiera Road in the 1% AEP event. Three properties become no longer flooded above floor level in the 1% AEP event with the basin. This option provides the greatest property benefits in the frequent to intermediate events as shown in Table 19.

The option offers minor improvements to road access. In frequent events (50% AEP), hydraulic hazard across Balaclava Road and Vimiera Road reduce from H2 (unsafe for small vehicles) to H1 (generally safe). In rarer events, there are no reductions in hydraulic hazard across the roads, however the length of road subject to high hazards is reduced.

There will likely be some social impacts as community access to the park is restricted because the basin increases flood depths within the park and prolongs duration of inundation. The property directly adjacent to the west of Jim Walsh Park along Balaclava Road has flood level increases by more than 200 mm in the 5% AEP and 1% AEP event. Consultation with the landowner will be required in the feasibility studies for this option and voluntary purchase may be required. Significant environmental impacts are expected as excavation of a basin will require removal of trees, which are currently listed under the TSC Act and EPBC Act. Critically endangered Blue Gum High Forest exists on the site which will require specialist ecologist input at the feasibility stage to determine whether a basin configuration can be designed that avoids impacts to the ecological community.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $1.9M with no ongoing maintenance costs directly associated with this option. The cost associated with acquiring the impacted property west of the park has not been included. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $701,800. The NPV of this benefit was estimated to be approximately $8.8M. A summary of the benefits to flood damages is provided in Table 19.

Table 19: Summary of flood damage benefits for M036

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	-6	-6	-$763,941	-6	-6	-$985,679
20% AEP	-3	-5	-$817,227	-3	-5	-$1,039,237
10% AEP	-4	-3	-$583,253	-4	-3	-$828,015
5% AEP	-3	-3	-$496,671	-3	-3	-$703,746
2% AEP	1	-2	-$224,633	1	-2	-$349,954
1% AEP	-3	-2	-$209,807	-3	-2	-$322,707
PMF	1	0	$109,803	1	0	$149,381
	Average Annual Damages		-$448,895	Average Annual Damages		-$701,848

The CBR of this option was therefore estimated to be approximately 4.6.

Summary and Recommendation

	M036 Jim Walsh Park Basin
Description	• Raise existing embankment to minimum crest level of 66 m AHD • Excavate basin to 65 m AHD
Benefits	• Reduces flood levels residential downstream areas by up to 125 mm. • Reduces flood damages
Concerns	• Excavation of the basin will require tree removal and has associated social and environmental impacts. • Excavation of the basin may change how Jim Walsh Park is utilised • Safety and social perception of a high embankment in close proximity to residential properties
Approximate Cost	$1.9M
CBR	4.6
Responsibility	Council
Outcome	Recommended for further investigation.
Priority	High

5.2.4.9. Option M051 Kotara Park Basin

Description of Flooding

The 1% AEP flood depth at Abuklea Road (near Alison Street) and on the western side of Danbury Close exceeds 0.5 m in the 1% AEP event. Multiple minor flow paths converge and stormwater pipelines run through properties along Crotoye Place and Danbury Close. Properties on the southern side of Crotoye Place and Danbury Close are higher than the roads by more than 0.5 m in most areas and higher than the properties on the northern side in some areas. This forms a barrier which prevents runoff from flowing downstream towards a reserve located south of those properties. Two properties are inundated above floor on Danbury Close and three properties on Herring Road in the 1% AEP event.

Abuklea Road Tennis Courts and Kotara Park are located north (upstream) of the properties along Crotoye Place and Danbury Close. Abuklea Road Tennis Courts have shallow inundation in the 1% AEP (<100 mm), with the car park being the most affected. Kotara Park is also inundated to shallow depths (<100 mm).

Option Description

Several options were considered for this location:

1. Drainage upgrade from Danbury Close to Kent Road Public School.
2. Construction of a wall around Kotara Park (and Abuklea Road Tennis Courts), raising of driveways along Danbury Close, acquisition of one residential property for repurposing to an overland flow path, and regrading of land in the reserve to direct it away from Herring Road properties.
3. Construction of wall around Kotara Park (and Abuklea Road Tennis Courts) only.
4. Construction of a basin at Kotara Park only.

The first two options were suggested by previous studies (Section 6.4.2 of Reference 9). The first option was not recommended by the previous study as it was costly and therefore it was not investigated further in this study. The second option was tested in the TUFLOW hydraulic model, however it was found that construction of the wall around Kotara Park (and Abuklea Rd Tennis Courts) only, i.e. the third option, produced similar impacts and there was no material benefit to providing the overland flow path.

The third option involves construction of an embankment (approximately 210 m long) with a minimum crest level of 67.5 m AHD along the southern boundary of the carpark of Abuklea Rd Tennis Court and Kotara Park. This embankment will have a maximum height of 1.3 m at the eastern end of the carpark at Abuklea Rd Tennis Courts. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C14. The approximate locations of the embankments are shown in Diagram 13 and Diagram 14. It is considered feasible to construct this option as the embankment height is generally low.

An alternative embankment height of the third option with a minimum crest level of 68.1 m AHD (i.e. maximum 1.9 m in height) was also tested. This option is constrained by the space available for an embankment of this height. It is likely that construction of this wall will reduce the available spaces within the tennis court car park.

Diagram 13: Basin embankment at Abuklea Road Tennis Court Carpark (*Source: Google Street View*)

Diagram 14: Basin embankment in Kotara Park (*Source: Google Street View*)

The last option involves construction of an embankment wall around Kotara Park only to a minimum crest level of 68 m AHD (maximum height of 1.1 m) and a 1 m deep excavation over a portion of the park. This option, however, only retains flows entering the park from Wilga Place.

Option Impacts

The embankment along both Abuklea Road Tennis Court and Kotara Park with minimum crest levels of 67.5 m AHD and 68.1 m AHD were tested in the TUFLOW hydraulic model. Flood modelling results are presented for the 67.5 m AHD crest level only for the 5% AEP and 1% AEP events in Figure C15 and Figure C16, respectively. The higher minimum crest level has not been graphically presented as it is likely that construction of a 1.9 m high embankment is likely unfeasible at this location.

When raised to 68.1 m AHD, the embankment is not overtopped in the 1% AEP event. The flood levels downstream on Shrimptons Creek reduce by more than 25 mm to the M2 in the 1% AEP event. On Danbury Close, the flood levels reduce by up to 250 mm and properties immediately downstream of the embankment (at both Danbury Close and Crotoye Place) are no longer flooded. Flood levels on properties along Herring Road are reduced by 170 mm. Within the basin, flood levels are increased by up to 1.2 m and two of the tennis courts in Abuklea Road Tennis Courts are newly flooded. However, flood levels are also increased along Crotoye Place by up to 55 mm and on Abuklea Road by 90 mm, such that two properties are impacted. Feasibility studies of this option will need to mitigate the flood level increases due to this option.

When raised to the lower height of 67.5 m AHD, the embankment has flood immunity up to the 50% AEP event and begins to overtop in the 20% AEP event. As the embankment is overtopped, flood levels downstream of the embankment in the 1% AEP event are minimally impacted (<50 mm reduction). In the 1% AEP event, there are no newly flooded areas upstream of the embankment and areas with flood level increases mostly remain within the Abuklea Road Tennis Court and Kotara Park areas. While the basin has minimal benefits in the rarer events, it reduces flood levels in the frequent events. In the 50% AEP event, properties along Danbury Close are no longer flooded and properties along the watercourse between Herring Road and Kent Road have flood level reductions up to 100 mm to 200 mm. Although the embankment is overtopped in the 20% AEP and 10% AEP events, the impact the basin has on flood levels follow similar patterns to the 50% AEP event. In the PMF event flood levels increase on properties along Crotoye Place. Therefore, feasibility studies for this option will need to mitigate flood level increases due to the proposed works.

In the alternative option where the basin is only constructed at Kotara Park, the basin does not overtop in the 1% AEP event and peak flood levels are 67.9 m AHD in the basin. Flood levels in Danbury Close reduce by up to 150 mm and properties along Herring Road reduced by up to 120 mm. Flood levels downstream along Shrimptons Creek reduce by 30 mm to Epping Road in the 1% AEP event.

There will likely be some social impacts as community access to the tennis courts and the park are restricted because the basin increases flood depths within the park and prolongs duration of inundation. There will likely be minimal environmental impacts as the works are located within an existing cleared park and car park.

Cost-Benefit Analysis

Cost benefit analysis has been conducted for the third option with minimum crest level of 67.5 m AHD. The cost of implementing this option was estimated to be approximately $156,000 with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D. A cost benefit analysis was conducted for the fourth option (basin at

Kotara Park), however this option can be investigated further in a feasibility study if the third option is not feasible.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $60,000. The NPV of this benefit was estimated to be approximately $2.1M. A summary of the benefits to flood damages is provided in Table 20.

Table 20: Summary of flood damage benefits for M051

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	**Change in # Properties Flooded Above Floor**	**Reduction in Damages**	**Change in # Properties Affected**	**Change in # Properties Flooded Above Floor**	**Reduction in Damages**
50% AEP	0	0	$-	0	0	$-
20% AEP	-1	-1	-$59,945	-1	-1	-$72,434
10% AEP	-2	-3	-$354,703	-2	-3	-$438,418
5% AEP	-1	-1	-$168,311	-1	-1	-$207,505
2% AEP	-1	0	-$90,116	-1	0	-$121,737
1% AEP	-4	0	-$181,560	-4	0	-$232,078
PMF	1	-1	$68,329	1	-1	$80,820
		Average Annual Damages	-$40,500	Average Annual Damages		-$60,019

The CBR of this option was therefore estimated to be approximately 4.8.

Summary and Recommendation

	M051 Kotara Park Basin
Description	• Construction of wall along Kotara Park and Abuklea Road Tennis Courts
Benefits	• Reduces flood levels over a large area, particularly in the frequent events
Concerns	• Minimal reductions of flood levels in rare events • Increase in flood levels will require mitigation strategies • Embankment constructed in close proximity to the rear of residential properties • Social disruption from restricted access during and after flood events
Approximate Cost	$156,000
CBR	4.8
Responsibility	Council
Outcome	Recommended for further investigation.
Priority	Medium

5.2.4.10. Option M057 Smalls Park Basin

Description of Flooding

Smalls Park is located in the upstream areas of a tributary of Shrimptons Creek. A pipeline (ranging from 450 mm to 600 mm in diameter) runs along the northeastern boundary of the park. This pipeline continues along Neville Street, expanding to a 1050 mm diameter pipe. The pipe continues under properties at the end of Neville Street and discharges to Shrimptons Creek. This pipe is insufficient to carry the full capacity of this tributary in the 1% AEP event. At the intersection of Smalls Road and Neville Street, overland flows run through properties towards the intersection diagonally opposite (at Fawcett Street and Warren Street). In the 1% AEP, 5 properties are estimated to be inundated above floor level along the tributary.

Option Description

This option involves the construction of a detention basin within Smalls Park, comprising:

- Construction of an embankment along the northwestern and northeastern boundary of the park
- Realignment of the existing pipeline to ensure pits are moved to be within the basin.

This option was implemented in the TUFLOW hydraulic model by raising an embankment at the downstream boundary of Smalls Park to a minimum crest level of 68.7 m AHD. This embankment would be around a 1 m high in most areas. At the eastern end of the park, the embankment should be 0.2 m high to reduce overland flows from entering the residential properties to the north. Excavation of Smalls Park can be explored to ensure that the basin provides to same storage if a lower embankment is desired. This may also be controlled by the levels of the underground stormwater system. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C17. The approximate location of the basin embankment is shown in Diagram 15.

Diagram 15: Smalls Park at Smalls Road (*Source: Google Street View*)

This option is considered feasible to construct, with no major issues identified at this stage. The main concern is that the embankment is close to the lot boundary with properties along Christine Avenue and existing stormwater pipelines will need to be relocated to be within the basin. It is expected that there would be minimal interference to services and the park would be closed during construction.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C15 and Figure C16 for the 5% AEP event and 1% AEP event, respectively. The basin embankment achieves flood storage up to the 1% AEP event without overtopping. Peak flood depths are greatest at the northern corner of the park where ground levels are lower in comparison. In the 1% AEP event, peak flood depths reach up to 1.4 m at the northern corner of the park and other areas are mostly less than 0.5 m. There are newly flooded areas within the park (mainly on the northwestern side).

In the 1% AEP event, there are minor reductions in flood level downstream, however, these reductions are over a large area. In the 1% AEP event, this option lowers the flood levels on properties along Neville Street and Warren Street by approximately 150 mm. In Shrimptons Creek, flood levels are reduced by less than 50 mm until it crosses Epping Road. In more frequent events (50% AEP and 20% AEP), the properties between Neville Street and Warren Street are no longer flooded. In the 1% AEP event, there are some benefits to property impacts.

There will likely be some social impacts as community access to the park are restricted because the basin increases flood depths within the park and prolongs duration of inundation. It is understood that the land is owned by the Department of Education and as such, liaison with the department will be required. There will likely be minimal environmental impacts as the works are located within an existing cleared park.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $480,000, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $30,000. The NPV of this benefit was estimated to be approximately $1.8M. A summary of the benefits to flood damages is provided in Table 21.

Table 21: Summary of flood damage benefits for M057

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	0	0	$-	0	0	$-
20% AEP	0	-1	-$42,671	0	-1	-$51,622
10% AEP	0	0	-$86,403	0	0	-$115,446
5% AEP	0	0	-$49,084	0	0	-$62,950
2% AEP	-2	-1	-$182,535	-2	-1	-$236,805
1% AEP	0	-1	-$217,797	0	-1	-$279,566
PMF	0	-2	-$142,227	0	-2	-$189,996
	Average Annual Damages		-$19,596	Average Annual Damages		-$29,980

The CBR of this option was therefore estimated to be approximately 0.8.

Summary and Recommendation

	M057 Smalls Park Detention Basin
Description	• Construct an embankment along the boundary of Smalls Park • Realign existing pipeline at the boundary of Smalls Park as required.
Benefits	• Reduces flood levels by 150 mm • Reduces property impacts
Concerns	• Social disruption as access to Smalls Park may become restricted during and after a flood event.
Approximate Cost	$480,000
CBR	0.8
Responsibility	Council
Outcome	Low CBR, however, recommended for further investigation.
Priority	Low

5.2.4.11. Option M061 North Ryde Golf Club Basin

Description of Flooding

North Ryde Golf Club is located in the upstream areas of a tributary of Shrimptons Creek. Flows from the golf club cross under Lane Cove Road via a 1.8 m by 0.75 m high box culvert. These flows continue through a culvert with sizes ranging from a 1.2 m diameter pipe to 3.3 m wide by 1.18 m high box culvert (at the outlet) and discharge to Shrimptons Creek at Greenwood Park. The conduit has insufficient capacity in the 1% AEP event and the pits surcharge such that floodwaters flow overland through the rear of properties along Eastview Avenue, Ada Street, and Ford Street. In the 1% AEP, 5 properties are estimated to be inundated above floor level along the tributary.

Option Description

This option was implemented in the TUFLOW model by raising an embankment at the boundary of the golf club to a minimum crest level of 61.5m AHD. This embankment would have a maximum height of 1.0 m and be approximately 52 m long. The embankment is aligned in between an existing golf course pond and the inlet of the stormwater network (as shown in Diagram 16). Implementation of this option in the TUFLOW hydraulic model is presented in Figure C20. Excavation of the golf club can be explored to ensure that the basin provides to same storage if a lower embankment is desired. This may also be controlled by the invert level of the culvert under Lane Cove Road (as the primary drainage from the basin) and the configuration of the golf course fairways.

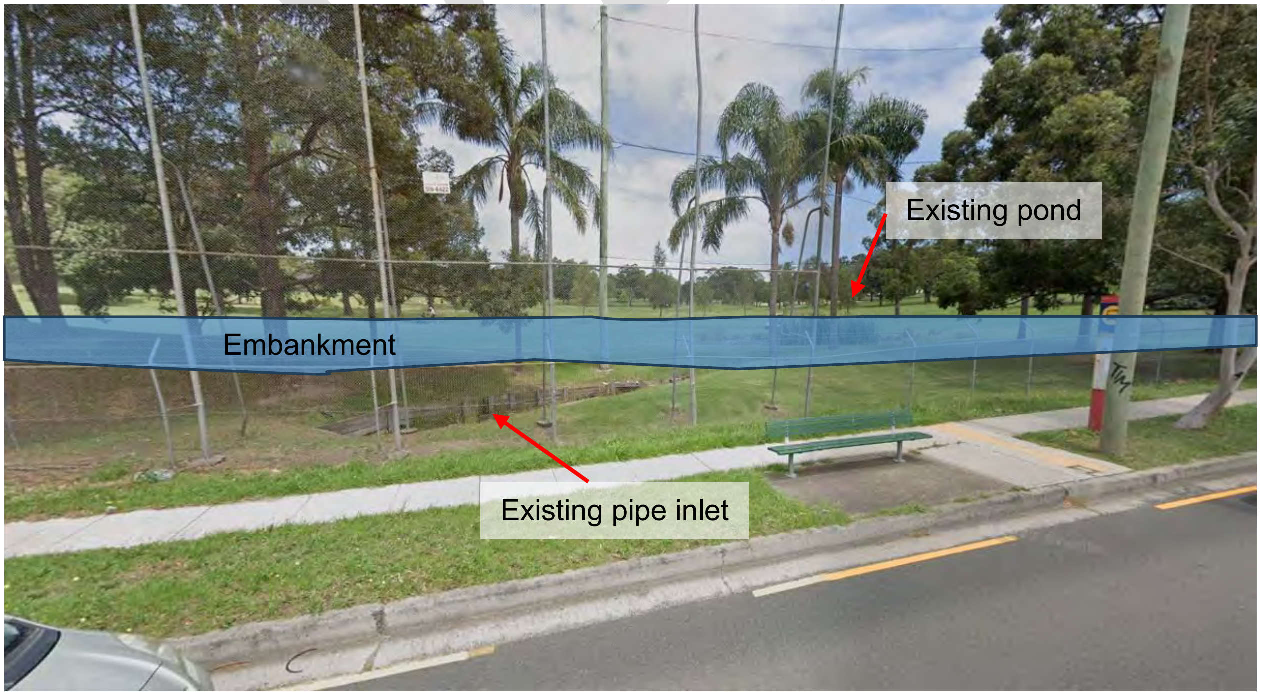


Diagram 16: Option M061 – North Ryde Golf Club Basin (*Source: Google Street View*)

This option would be relatively easy to construct, involving earthworks to construct the embankment and some rehabilitation of the area such as new turf. The basin embankment should be tied into the existing terrain at the ends of the embankment to ensure that retained water does not spill around the embankment. Some tree clearing may be required. Consultation of the golf course would be required for this option.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C21 and Figure C22 for the 5% AEP event and 1% AEP event, respectively. With the minimum embankment crest level of 61.5 m AHD, the proposed basin is overtopped in events as frequent as 50% AEP event. Within the golf course, flood levels increase by up to 1.05 m in the 1% AEP event. However, the area where flood level increases is mostly constrained to the pond directly upstream of the proposed embankment. The remainder of the golf course is largely unaffected.

As the embankment has a low crest level and is overtopped even in frequent events, there are minimal flood level reductions in rare events (for example the 1% AEP event and PMF event). In the 1% AEP event, flood levels in properties (near the intersection of Ada Street and Kent Road) are lowered by less than 10 mm. The location with greatest flood level reduction is in the watercourse at the rear of properties along Kent Road. However, flood levels are also only reduced by less than 50 mm. This option has the greatest effect on flood levels in frequent to intermediate events (20% AEP and 10% AEP), where flood levels are reduced by more than 100 mm in the properties near the intersection of Ada Street and Kent Road.

In the PMF event, peak flood level increases along the Lane Cove Road corridor directly downstream of the embankment. These impacts could be managed by grading in the embankment crest such that overtopping occurs in a controlled location to prevent flood level increases. It is recommended that these options to mitigate adverse impacts are investigated in future feasibility studies.

As this option only provides minor reductions to flood levels, there are only minor changes to the number of properties inundated above floor, as shown in Table 22. Along the road corridor, there are minor flood level reduction on Lane Cove Road, Ada Street and Kent Road in frequent events (<100 mm) and minimal impacts in rarer events.

There are likely to be minimal negative social impacts, with only slight disruption to the golf course while regrading works are taking place. There are likely to be minimal negative environmental impacts, with cleared land able to be re-landscaped.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $97,000, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to tangible AAD was estimated to be $99,000. The NPV of this benefit was estimated to be approximately $1.2M. A summary of the benefits to flood damages is provided in Table 22.

Table 22: Summary of flood damage benefits for M061

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	0	-1	-$116,421	0	-1	-$146,732
20% AEP	-1	0	-$78,150	-1	0	-$112,764
10% AEP	-1	-1	-$108,854	-1	-1	-$166,463
5% AEP	0	0	-$86,578	0	0	-$112,782
2% AEP	0	0	-$3,207	0	0	-$15,743
1% AEP	0	0	-$45,877	0	0	-$56,842
PMF	0	0	-$16,034	0	0	-$21,852
	Average Annual Damages		-$62,024	Average Annual Damages		-$99,234

The CBR of this option was therefore estimated to be approximately 12.7.

Summary and Recommendation

	M061 North Ryde Golf Club Detention Basin
Description	• Construct embankment in North Ryde Golf Club
Benefits	• Reduces flood levels downstream over a large area • Minor benefits to property impacts downstream
Concerns	• Requires consultation with North Ryde Golf Club • Only minor flood benefits provided
Approximate Cost	$97,000
CBR	12.7
Responsibility	Council / North Ryde Golf Club
Outcome	Recommended for further investigation.
Priority	Medium

5.2.4.12. Option M073 Diversion Drain at Pittwater Road

Description of Flooding

There is a low point on Pittwater Road near its intersection with Clarence Street. There is an existing stormwater network in this location with a pit at the low point, which then discharges into Pages Creek. Water in excess of the stormwater network capacity ponds at the low point until it overtops the eastern road verge and flows into Pages Creek. The flood hazard is H3 at this location in both the 10% AEP and the 1% AEP events due to the flood depth. It is noted that closure of this road has occurred in the past due to flooding, including during the November 2018 event (southbound lane closed).

Option Description

This option involves the construction of a diversion drain at Pittwater Road, comprising the following elements:

- Regrading of the eastern road verge which blocks water from flowing to Pages Creek
- Construction of a wide shallow channel which formalises the path down to Pages Creek.
- Removal of trees and vegetation as required during construction of the drain.

This option was implemented in the TUFLOW hydraulic model by lowering the terrain of the eastern verge to match the level of the low point in the road. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C23. This option is considered feasible, with some earthworks for regrading the road verge and channel excavation.

Note that review of Google Street View images shows that some works involving the road verge were undertaken between February 2020 and September 2020. These changes have not been reflected in this study. It is understood that the shared path was upgraded and tree planting took place on the land, which is owned by TfNSW.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C24 and Figure C25 for the 5% AEP event and 1% AEP event. In the 1% AEP event, the flood levels at the Pittwater Road low point reduce by approximately 0.6 m and flood hazards reduce from H3 to H1. Flood levels in Pages Creek increase by 30 mm, however, it does not affect any properties as it flows through bushland before discharging into the Lane Cove River.

While there are other routes available with a higher flood immunity, Pittwater Road is considered an arterial road which provides access to East Ryde. In addition, the low point of Pittwater Road is located near its intersection with Epping Road such that most traffic heading towards or coming from Epping Road will be bottlenecked if this low point is overtopped. Therefore, any improvements to flood immunity at this low point are likely to provide significant benefits to emergency access.

There are no long-term social disruptions associated with this option and mainly effects Pittwater Road only. As the road verge is regraded and a channel is constructed, the pedestrian footpath across the regraded area may have minor changes, which was only recently upgraded. Social disruptions during construction are likely minor as the road corridor itself is not subject to regrading.

There will be some environmental impacts as the regrading will require minor landscaping and removal of trees, which may have only been recently planted.

Cost-Benefit Analysis

Cost benefit analysis has not been conducted for this option. This is because this option aims to improve road access during flood events rather than reducing flood damages. Changes to peak flood levels due to this option do not affect any nearby properties and in turn there is no reduction in AAD to properties. The method used to assess option benefits outlined in Section 5.2.4.12 is not suited to account for benefits from improving road access. The benefits of this option have been assessed qualitatively as part of the multi criteria matrix analysis in Section 6.

Costing for this option has been provided in Appendix D for a general indication of the cost. The cost of implementing this option was estimated to be approximately $260,000, with no ongoing maintenance costs directly associated with this option.

Summary and Recommendation

	M073 Diversion Drain at Pittwater Road
Description	• Road verge regrading • Drain from Pittwater Road low point to Pages Creek
Benefits	• Reduced flood hazard in 1% AEP to H1
Concerns	• Environmental impact issues relating to removal of trees for diversion drain
Approximate Cost	$260,000
CBR	Cannot be assessed with property damages
Responsibility	Council / Roads and Maritime Services
Outcome	Recommended for further investigation.
Priority	Medium

5.2.4.13. Option M084 Drainage Diversion to West Ryde Tunnel

Description of Flooding

A flow path originating from the north (near Darvall Park) runs through West Ryde and inundates properties at the rear of Gaza Road. This flow path runs south along Station Street and continues to flow along Federal Road until it reaches an open channel at Meadowbank Park. This flow path is partially conveyed via conduits (typically 2.6 m to 3 m in width by 1.5 m in height). The culverts are around 60% to 80% full in the 1% AEP event except where they are at capacity near the Station Street and Dunmore Road intersection, along Federal Road where two pipelines join, and also in a small section along Gaza Road. In the 1% AEP event, 3 properties along the rear of Gaza Road and another 4 properties along Federal Road are estimated to be inundated above floor.

The West Ryde Drainage Tunnel conveys a separate tributary which originates from Denistone Park. West Ryde Tunnel bypasses the main West Ryde commercial area and runs under Mons Avenue before discharging to Meadowbank Park. The tunnel comprises a large conduit that is typically 40% to 60% full in the 1% AEP event.

Option Description

This option involves the diversion of the culvert along Gaza Road to the West Ryde Tunnel. This option comprises:

- Re-routing of the conduit at the intersection of Station Street and Dunmore Road to the discharge into West Ryde Tunnel at Mons Avenue
- Conversion of an inlet pit to a junction pit where the conduit is re-routed (to avoid surcharging)
- Upgrade of 15 Pits (7 downstream of Station Street and 8 upstream)
- Construction of 3 additional pits (2 along Federal Road and 1 at Station Street)

Implementation of this option in the TUFLOW hydraulic model is presented in Figure C26. This option is considered feasible to construct, however it does have several technical constraints. The modelled alignment of the diversion conduit runs through an existing property in order to connect existing pits in the model. It is envisaged, however, that the actual diversion would be constructed under the Dunmore Avenue road corridor. This path and the technical feasibility of the diversion as a whole, depends on the actual invert levels of the two conduits and whether a diversion could drain under gravity. The estimated invert levels of the conduits in the TUFLOW model indicate that this diversion is feasible. There may be several services that would need to be avoided or relocated on Station Street, Dunmore Road and Mons Avenue. This may pose a significant constraint and increases costs significantly. The West Ryde Tunnel invert level is estimated to be at approximately at 8.7 m AHD where the diversion conduit discharges, whereas the ground elevation is approximately at 13 m AHD. Open trench construction of this option will require a deep trench excavation, which increases the construction complexity.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C27 and Figure C28 for the 5% AEP event and 1% AEP event. In frequent events (20% AEP and 50% AEP), the option has minimal impact on peak flood levels as the existing pipe network has sufficient capacity to carry these flows. In intermediate events (10% AEP to 5% AEP), this option reduces the flood extent in the properties at the intersection of Dunmore Road and Mons Avenue and there are some flood level reductions in the properties along Gaza Road, Station Street and Federal Road.

In the 1% AEP event, flood levels in rear of the properties along Gaza Road are reduced by up to 120 mm. With this option, the three properties currently inundated at this location remain flooded above floor in the 1% AEP, however at the peak flood depth above floor was reduced. At the intersection of Dunmore Road and Station Street, peak flood levels reduce by up to 300 mm.

Along Mons Ave, most properties become no longer flooded and along Federal Road peak flood levels typically reduce by 300 mm such that 3 of 4 of the currently inundated properties are no longer inundated above floor. With this reduction in properties flooded above floor, this option provides minor reduction in demand on emergency services.

This option provides some improvement to road access. In the 1% AEP event, peak hydraulic hazard at the intersection of Federal Road and Constitution Road reduces from H3 (unsafe for vehicles, children, and the elderly) to H2 (unsafe for small vehicles). Near the intersection of Dunmore Road and Station Street, flood hazards are reduced from H2 to H1 (generally safe). In addition to this, flood hazards in the flow path at the front of properties along Federal Road are reduced from H3 to H1 in most areas. This reduction significantly improves the access to the buildings on the properties. At the rear of Gaza Road and Station Street, flood hazards have minor reductions from H2 to H1.

There are minimal longer term social disruptions associated with this option. There are some minor flood levels increases in Meadowbank Park. However, these increased levels have minimal impact on the duration of inundation of the park and are unlikely to prolong restricted access to community facilities. The extent of social impacts during construction of this option is likely to be minimal, with the closure (or partial closure) of Dunmore Road required in addition to Station Street and Mons Avenue. However, alternate routes are available and traffic around the intersections can be diverted.

There are minimal environmental impacts associated with this option as the alignment is within the road corridor.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $1.8M, with no ongoing maintenance costs directly associated with this option as it is assumed that this option can be incorporated into Council's existing maintenance plan. Costing was based on the modelled alignment with an open trench construction method. The cost of implementing the alternate alignment, which runs within road corridors only, was estimated to be approximately $2.3M. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $149,000. The NPV of this benefit was estimated to be approximately $1.9M. A summary of the benefits to flood damages is provided in Table 23.

Table 23: Summary of flood damage benefits for M084

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	0	-4	-$116,421	0	-4	-$140,951
20% AEP	-8	-4	-$167,737	-8	-4	-$246,913
10% AEP	-4	-4	-$181,543	-5	-4	-$277,302
5% AEP	0	0	-$89,785	0	0	-$120,817
2% AEP	-1	-5	-$182,780	-1	-5	-$365,629
1% AEP	-2	-3	-$333,243	-2	-3	-$544,758
PMF	-5	-5	-$783,289	-5	-6	-$1,025,237
Average Annual Damages			-$90,185	Average Annual Damages		-$149,272

The CBR of this option with the modelled alignment was therefore estimated to be approximately 1.0. With the alternate alignment, the CBR for this option was estimated to be approximately 0.8.

Summary and Recommendation

	M084 Drainage Diversion to West Ryde Tunnel
Description	• Re-routing pipeline from Gaza Road to West Ryde Tunnel • Upgrade 15 existing pits and construct 3 additional pits
Benefits	• Reduced flood levels in 1% AEP • Reduces flood damages
Concerns	• Re-routed pipe and some additional and upgraded pits run through existing properties and will require access.
Approximate Cost	$1.75M
CBR	0.8 to 1 (dependent on alignment)
Responsibility	Council
Outcome	Recommended for further investigation.
Priority	Medium

5.2.4.14. Option M089 Lions Park Detention Basin

Description of Flooding

A tributary of Archer Creek runs through (and adjacent to) Lions Park, crosses Victoria Road and flows through properties until it reaches Ryde Paramatta Golf Club and joins Archer Creek. This tributary is conveyed overland and through stormwater pipes ranging from 750 mm diameter pipes to 2.2 m wide by 1.15 m high box culverts (towards the golf club). Peak flood depths are the largest for the properties along Hay Street, Bennetts Street and Moss Street, with a total of 10 properties estimated to be inundated above floor in the 1% AEP event.

Option Description

This option involves the construction of a basin within Lions Park. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C29. This option comprises:

- Excavation of the basin by 1 m within the oval of Lions Park
- Construction of a diversion drain which directs overland flow into the basin and prevents flows from entering the low point on the boundary of Lions Park
- Installation of a flood barrier which prevents basin flows from entering adjacent properties to the east

The construction of a basin in Lions Park is constrained by its small size, layout of its structures, and the terrain. The depth of excavation is constrained by the existing topography of the park, which is quite steep. The maximum excavation depth is likely around 1 m in order to adequately tie in with surrounding ground levels.

Lions Park has a small oval at its centre and a car park at the rear of the lot, with a long driveway along the eastern boundary of the lot lined with trees. East of the driveway is a natural low point where floodwaters pond during an event (the adjacent residential properties form part of this low point). Feasibility studies of this options will need to ensure that overland flows from the upstream catchment are captured and directed into the basin instead of toward the adjacent natural low point. If a larger basin is required, relocation of the existing park facilities will need to be considered.

The existing stormwater network runs through Lions Park, with a stormwater pit located within the proposed excavation area. The stormwater pipes are estimated to be located well below the ground surface and not expected to require relocation to accommodate the excavation. However, the existing stormwater pit will need to be removed during excavation and reinstalled. This stormwater pit can then provide drainage to the basin.

Drainage upgrades to the pit and pipes downstream of Victoria Road were investigated by previous studies (Section 7.2.4 Reference 13). These options were replicated in the TUFLOW hydraulic model but were found to have insignificant benefits.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C30 and Figure C31 for the 5% AEP event and 1% AEP event, respectively. In frequent events (50% AEP and 20% AEP), this option has minimal impact on flood levels (<10 mm) in properties south of Victoria Road and flood levels are reduced locally near Lions Park. The basin has capacity to store flows from the 50% AEP event, however in events 20% AEP and rarer, the basin overtops along the southeastern boundary. In intermediate events (10% AEP and 5% AEP), this option lowers flood levels by 50 mm to 100 mm south of Victoria Road.

In the 1% AEP event, peak flood levels are 29.4 m AHD within the basin in the oval at Lions Park. The basin overtops along the eastern boundary by up to 300 mm. This option reduces flood levels by around 80 mm in properties downstream of Victoria Road. A total of five properties become no longer inundated above floor level in the 1% AEP and other properties have flood levels reduced by around 50 mm. In the 1% AEP event, peak flood levels are increased in the adjacent properties to the east as flow from the east ponds against the embankment. Feasibility studies of this option should include strategies to mitigate these adverse impacts.

There will likely be some social impacts as community access to the park is restricted because the basin increases flood depths within the park and prolongs duration of inundation. The perimeter of the park is lined by a number of trees. The flood barrier along the eastern boundary suggested as part of this option may pose some environmental impacts depending on the type of flood barrier constructed. An earth embankment requires more space and may require removal of trees.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $1.3M, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $40,000. The NPV of this benefit was estimated to be approximately $499,000. A summary of the benefits to flood damages is provided in Table 24.

Table 24: Summary of flood damage benefits for M089

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	0	0	$-	0	0	$-
20% AEP	-1	0	-$23,513	-1	0	-$28,411
10% AEP	0	-1	-$80,142	-1	-1	-$104,471
5% AEP	-3	-2	-$229,455	-3	-2	-$277,258
2% AEP	-2	-2	-$281,258	-2	-2	-$339,795
1% AEP	-3	-5	-$481,229	-3	-6	-$584,957
PMF	0	-2	-$34,112	0	-2	-$35,201
		Average Annual Damages	-$25,414	Average Annual Damages		-$37,426

The CBR of this option was therefore estimated to be approximately 0.4.

Summary and Recommendation

	M089 Lions Park Detention Basin
Description	• Excavation of basin within oval at Lions Park • Diversion drain to ensure overland flows enter the basin
Benefits	• Reduces flood level by 50 mm to 130 mm • Reduces property damages
Concerns	• May not be economically viable • Constraints due to the size and layout of the existing park
Approximate Cost	$1.3M
CBR	0.4
Responsibility	Council
Outcome	Low CBR, however, this is recommended for further investigation.
Priority	Low

5.2.4.15. Option M094 Pickford Avenue and Lovell Road Intersection

Description of Flooding

A total of ten properties bounded by Pickford Avenue, Lovell Road and Orange Street are estimated to be inundated above floor in the 1% AEP event. This location is the confluence of a tributary originating from the south (which runs through properties, adjacent to Russell Street and then adjacent to Pickford Avenue) and another tributary (which originates from the east). The eastern tributary partially flows through a grassed reserve, however, it begins to move away from the reserve upstream of Orange Street such that between Orange Street and Pickford Avenue, the flow path is entirely within private properties. Along Pickford Avenue, a pipeline, which comprises a 600 mm diameter pipe in its upstream areas and gradually expands to a 1.5 m diameter pipe, conveys a portion of the flow. The eastern tributary comprises a pipeline, which is 825 mm in diameter and gradually expands to 1050 mm in diameter, in addition to overland flow conveyance. Downstream of this confluence, the pipes and overland flow discharge into a short channel within a reserve upstream of Graham Avenue. This channel is then connected downstream to Jim Walsh Park via a 1.35 m diameter pipe under Graham Avenue.

Option Description

For this location both a bund along the reserve and drainage upgrade were investigated.

The first option involves constructing a bund (up to 1 m height) which prevents overland floodwaters in the eastern tributary from flowing out of the reserve into the residential properties. As part of the first option, a culvert will need to be installed under Orange Street to convey the flow within the reserve. Continuity of the bund across Orange Street is a constraint of this option. This option was implemented in the TUFLOW hydraulic model by raising a bund along the southern boundary of the reserve, which crosses over Orange Street. Implementation of this option in the TUFLOW hydraulic model is presented in Figure C32.

This option is considered feasible to implement and would require earthworks to construct the embankment. The embankment should be tied into the existing terrain at the ends of the embankment to ensure water does spill around the embankment. Regrading and landscaping of the embankment area would be required. It is understood that this reserve is part of the Green Links Masterplan (Reference 29). The current design consists of an off-road shared path between Grove Street and Pickford Avenue (crossing Orange Street). The path is located on the northern side of the reserve, with landscaping and planting on the southern side. This masterplan could accommodate the proposed option easily, creating a flow path adjacent to the shared path.

Diagram 17: Reserve looking west from Orange Street (*Source: Google Street View*)

The second option involves drainage upgrade of the pipeline which connects the channel in the reserve to Jim Walsh Park, under Graham Avenue. In this option, the existing pipeline (1.35 m in diameter) is upgraded to twin 1.35 m diameter pipes. There are no existing buildings along this pipeline route.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C33 and Figure C34 for the 5% AEP event and 1% AEP event, respectively. With a bund constructed in the reserve, the flood levels on the properties along Pickford Avenue reduce by up to 100 mm and along Orange Street up to 260 mm. Several properties downstream of the bund become no longer flooded. Within the reserve there are newly flooded areas as the waters are diverted to the reserve. This newly flooded area extends to the boundaries of some properties along Graham Street. These impacts can potentially be mitigated by formalising the new flow path in the reserve by shaping a channel. Orange Street near the reserve also become newly flooded, however it is expected that these impacts can be mitigated by installation of a culvert under the road and/or by raising the road.

With the culvert upgrade to twin 1.35 m diameter pipes, flood levels along Graham Avenue and within the channel at the reserve are reduced by up to 80 mm in the 1% AEP event. Within Jim Walsh Park, flood levels are reduced by less than 50 mm. The drainage upgrade has minimal impact on the inundated properties along Pickford Avenue in the 1% AEP and is unlikely to provide any significant flood damage benefits. The recommended option for this location is the bund alone.

This option likely has minimal social impacts. While flood levels and duration of inundation within the reserve increases, the reserve only serves as an accessway for foot traffic. There are likely minimal environmental impacts as the embankment is constructed within the cleared reserve, with minimal tree removal.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $199,000, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D. No costs associated with road works on Orange Street were included in this cost, as it would depend on how the flow path across the road is managed.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $172,000. The NPV of this benefit was estimated to be approximately $2.1M. A summary of the benefits to flood damages is provided in Table 25.

Table 25: Summary of flood damage benefits for M094

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Reduction in Damages
50% AEP	-2	0	-$141,279	-2	0	-$183,100
20% AEP	-2	-2	-$266,413	-2	-2	-$329,746
10% AEP	-2	-3	-$269,937	-2	-2	-$216,022
5% AEP	-1	-2	-$173,195	-1	-2	-$233,656
2% AEP	0	-1	-$90,802	0	-1	-$108,220
1% AEP	-2	0	-$305,654	-2	0	-$418,670
PMF	0	0	-$139,190	0	0	-$254,323
	Average Annual Damages		-$118,778	Average Annual Damages		-$172,357

The CBR of this option was therefore estimated to be approximately 10.8.

Summary and Recommendation

	M094 Pickford Avenue and Lovell Road Intersection
Description	• Construct a bund along the reserve
Benefits	• Reduces flood levels in properties • Reduces property damages
Concerns	• Requires mitigation options including management of flooding within the reserve to avoid impacts to properties in the vicinity of Graham Avenue, and consideration of how to avoid inundation of the natural low point of Orange Street.
Approximate Cost	$199,000
CBR	10.8
Responsibility	Council
Outcome	Recommended for further investigation.
Priority	Low

5.2.4.16. Option M101 Boyce Street Drainage Upgrade

Description of Flooding

The road corridor of Boyce Street near McCauley Park is raised such that there is low point on the upstream side where waters pond (around 1.5 m deep in the 1% AEP) during an event. Three properties are estimated to be inundated above floor in the 1% AEP event upstream of Boyce Street. An existing 900 mm stormwater pipe carries flows under Boyce Street, through McCauley Park and Gannan Park. Pipe capacity assessment for the stormwater network was completed in Section 2.3.1. As shown in Figure 5, the pipe under Boyce Street to McCauley Park is at capacity in events as frequent as the 50% AEP. Under Gannan Park, the network has some more capacity in comparison to its upstream areas, however is still at capacity in the 20% AEP event.

Option Description

This option involves drainage upgrade of the pipes under and downstream of Boyce Street, approximately 150 m in length. This option has been implemented in the TUFLOW hydraulic model by upgrading the pipeline to twin 900 mm pipes as well as upgrading four pits within the area of ponding. The set up for this option is shown in Figure C35. The approximate location of the proposed pipe upgrade across Boyce Street is shown in Diagram 18.

Diagram 18: Option M101 – Boyce St Drainage Upgrade (*Source: Google Street View*)

This option is feasible to construct. The ponding area is located within residential property and works for pit upgrade will require access to the property and agreement with the owners. As the proposed additional pipe is the same size as the existing pipeline and follows the same alignment, there is likely to be sufficient cover and space for the pipe to be installed.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C36 and Figure C37 for the 5% AEP event and 1% AEP event, respectively. With the drainage upgrade from Boyce Street to

McCauley Park, the flood level in the rear of the properties upstream of Boyce Street lowers by approximately 0.4 m in the 1% AEP event. This magnitude of flood level reduction is consistent from events ranging from 20% AEP to 1% AEP (due to the nature of ponding), whereas the PMF event has minor flood level reductions (<50 mm). Flood level reduction in McCauley and Gannan Park are minor in comparison and are typically less than 100 mm across all events. With the drainage upgrade, the pipeline is no longer at capacity in the 50% AEP event, however it remains at capacity in the 20% AEP event.

This option only upgrades the pipeline from Boyce Street to McCauley Park. Areas downstream of McCauley Park are not upgraded and downstream pipe capacity becomes the bottleneck. This causes flood level increases downstream along Berripa Close (<100 mm in the 1% AEP event) and in the water course at the rear of Minga Street and Burke Street (200 mm to 300 mm in the 1% AEP event). These impacts would need to be mitigated if this option is to be implemented. Impacts at Berripa Close could be managed by upgrading drainage further downstream all the way to the watercourse at the rear of Minga Street and Burke Street. However, this exacerbates the impacts in this watercourse. Alternatively, these impacts could also be mitigated by implementing this option with the Gannan Park Basin (M003, Section 5.2.4.4). However, this may require the basin embankment to be raised further. It is recommended that these options be investigated in future feasibility studies to mitigate adverse impacts.

This option provides some benefits to private properties. However, it is mostly constrained to the properties near the low point on the upstream side of Boyce Street. These properties are mostly not significantly flood affected in the current conditions as the low point is in the rear of their properties. As shown in Table 26, the number of properties flooded above floor is reduced by 1 in the 1% AEP event.

At the pipe crossing, while there is some ponding on the upstream side of the road, within the road corridor, Boyce Street currently has hydraulic hazards of H1 (generally safe) to H2 (unsafe for small vehicles). Therefore, the proposed option has minimal benefits for improving road access.

There may be some social disruption as Boyce Street will need to be closed and access to McCauley Park may be restricted. However, this disruption will likely be only for a short period of time during construction. There are likely minimal negative environment impacts as the proposed added pipeline is parallel to the existing network. Only some land clearing and re-landscaping will be required. There may be potential impacts to trees depending on the alignment of the pipe.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $1.6M, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be $104,000. The NPV of this benefit was estimated to be approximately $1.2M. A summary of the benefits to flood damages is provided in Table 26.

Table 26: Summary of flood damage benefits for M101

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages
50% AEP	-1	0	-$19,244	-1	0	-$35,366
20% AEP	-2	-1	-$167,737	-2	-1	-$211,370
10% AEP	-2	-2	-$185,009	-2	-2	-$254,293
5% AEP	-2	-2	-$319,434	-2	-2	-$423,667
2% AEP	-3	-2	-$276,518	-3	-2	-$372,392
1% AEP	-2	-2	-$289,591	-2	-2	-$385,374
PMF	0	0	-$48,391	0	0	-$59,787
	Average Annual Damages		-$63,804	Average Annual Damages		-$104,037

The CBR of this option was therefore estimated to be approximately 0.8.

Summary and Recommendation

	M101 Boyce Street Drainage Upgrade
Description	• Upgrade 150 m of pipeline under and downstream of Boyce Street
Benefits	• Reduces flood levels at the low point by 0.4 m in the 1% AEP • Reduction in flood damages
Concerns	• Flood levels increase along Berripa Close and in downstream watercourse will require mitigation, which further reduces the benefit to cost ratio.
Approximate Cost	$1.6M
CBR	0.8
Responsibility	Council
Outcome	Recommended for further investigation.
Priority	Low

5.2.5. Catchment-Wide Flood Modification Options Investigated

A number of additional flood modification options were investigated that are not site-specific, but rather are catchment-wide strategies. These are discussed in the following sections.

5.2.5.1. M102: Channel and Drainage Maintenance

Option Description

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels.

Blockage has the potential to increase peak flood levels as water is unable to efficiently drain away. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

Discussion

Whilst debris buildup does contribute to increased flood levels, the issue is more complex than may be first assumed for the following reasons:

- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fallen over or water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources;
- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

Vegetation within channels is also a form of blockage. It is often community perception that an open channel full of vegetation has significantly less capacity and exacerbates overbank flooding. The real benefits to 'clearing out the creek', however, are minimal and there are numerous environmental limitations. A test was completed in the TUFLOW hydraulic model, where all typical vegetated open channels, modelled with Manning's 'n' of 0.045, were reduced to 0.02 (essentially concrete lined). The change in 1% AEP peak flood levels due to reducing Manning's 'n' in the channels are shown in Figure C38. General comments on the results include:

- Insignificant changes (<10 mm difference) to areas outside of open channels
- Sensitive areas near residential properties where decreases are significant have been assessed by other flood mitigation options in section 5.2.3.2.
- Channel clearing to reduces flood levels within the open channel however when an open channel transitions into a pipe network there are minor flood level increases within the downstream pipe network.

This test resulted in insignificant changes to areas outside of the open channels and therefore it is not recommended to completely clear out vegetated creeks as a form of flood mitigation.

City of Ryde Council has a drainage maintenance program which includes regular clearance of GPTs in the LGA either every two months or every quarter. However, currently there is no proactive maintenance schedule for stormwater pipes and Council operates on a reactive maintenance for stormwater pipes. It is recommended that Council establishes a proactive maintenance schedule for the stormwater network.

This proactive maintenance schedule can be compiled by creating a register of specific areas prone to blockage based on community experience, flood hotspot zones and outcomes of the flood study (Reference 1). Council should periodically review and update this register based on feedback from the community. Council staff can also use the blockage sensitivity maps presented in Figure H4 to H5 of the current flood study (Reference 1) to determine which locations are sensitive to blockage that may require additional attention. Flood hotspot zones are described in Section 2.3.2.

Summary and Recommendation

	Channel and Drainage Maintenance
Description	• Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels.
Benefits	• Removal of vegetation and debris blockage from structures will enable a more efficient conveyance of water.
Concerns	• Environmental concerns including water quality, erosion, habitat removal, etc. • The major release of debris is during the storm event, and hence regular maintenance may not necessarily reduce blockage during a flood event. • Vegetation in open channels is not a significant constraint to the hydraulic capacity of the channel.
Responsibility	Council
Outcome	Council already has an appropriate creek and drainage maintenance program, and it is recommended to continue this program. Council should identify specific areas prone to blockage and periodically review and update these areas based on feedback from the community. Council should also inspect and record channels and drainage structures following flood events to assess debris build up and clear blockages.
Priority	High

5.2.5.2. M103: Drainage Capacity Upgrades

Option Description

This option investigates catchment-wide drainage upgrades for the pit and pipe network, with the view to reduce flooding and improve access on roads across the City of Ryde study area. City of Ryde currently requires road pavement drainage to be designed for at least the 5% AEP event. Arterial roads or access to Emergency Facilities are required to be design for the 1% AEP event. Given the age of many of the pipes across the LGA, however, it is likely that the pit and pipe network may not even cater for the 20% AEP event in some cases. Even in these frequent events, there is still inundation on roads (as water makes its way into pits, bypasses pits or in areas where capacity is exceeded). This option was originally envisaged as implementing a pit and pipe system capable of conveying the 5% AEP design flows. It is difficult to specify a pipe size for a specific design standard in an area such as City of Ryde, as the pipe capacity depends on the catchment to the pipe, the pipe capacity upstream and downstream, and the 'feeder' network – that is, the pit and pipe system that is designed to collect local runoff and convey it into trunk drainage lines.

Discussion

As shown in various other options to upgrade the pipe network, there is often very little difference to overland flood levels. The pit and pipe network typically carries only a very small proportion of flows, and hence increasing capacity does not tend to reduce the magnitude of inundation of roads. Upgrade of these stormwater systems is also difficult in fully developed urban areas such as City of Ryde. It would require digging up the road, kerb and gutter, existing pits and pipes, and laying new pipes and potentially new pits, pit inlets, gutters, road surfaces and verges. This can be complicated by things such as trees alongside roads, utilities and services, and sections of the pipe network that may cross through private property or even under buildings in some cases. This option is not realistic to achieve across the entire LGA.

Section 2.3.1 presents the pipe capacity assessment for the entire LGA. It was found that 46% of the pipes within the LGA are full in the 20% AEP. In some cases, there are downstream pipes which appear to not be at capacity in larger flood events, however, this may just be a function of the upstream pipes throttling flows. If upstream pipes were enlarged to allow a greater flow, then it may be that this pipe would also be at capacity in smaller events such as the 20% AEP event. The actual ‘capacity’ of urban stormwater networks is difficult to quantify and specifying a certain AEP capacity at a catchment-wide scale is difficult to implement with piece-meal upgrades.

As an example, all stormwater pipes were doubled in each of the models to observe the change in peak flood levels. The change in 5% AEP and 1% AEP peak flood levels with duplicating the stormwater network for each of the study areas is shown in Figure C39 and Figure C40. General comments on the results include:

- There are minor flood level changes (<100 mm) when increasing stormwater pipe capacity in the Terrys Creek, Kittys Creek, and Archer Creek catchments.
- Flood levels decrease typically up to 300 mm in the upstream areas of Shrimptons Creek, however, increase (by 100 mm to 200 mm) in downstream open channel reaches.
- Flood levels reduce significantly (more than 300 mm) in some locations in the commercial precinct at Macquarie Park and at Victoria Road and Falconers Street. Options for these areas have been explored in Section 5.3.9.
- Flood levels in upstream areas of Buffalo Creek are sensitive to increased drainage capacity, however, alternative options in this area have already been explored in Section 5.2.4.5.

Summary and Recommendation

	Drainage Network Upgrades
Description	• Increase pit and pipe network capacity to cater for the 5% AEP event (nominally)
Benefits	• Reduced flooding on roads
Concerns	• Very difficult to achieve on a catchment-wide basis.
Approximate Cost	Very High
CBR	<<1
Responsibility	Council, TfNSW (Roads and Maritime Services and Sydney Trains)
Outcome	This option is not feasible, however, Council should encourage the upgrading of pipelines in areas of redevelopment to increase the existing capacity of the stormwater network where this is feasible.
Priority	Not recommended as a catchment-wide flood mitigation option.

5.2.5.3. M104: Channel Upgrades

Option Description

This option investigates catchment-wide channel upgrades, typically for the concrete lined channels within the study area, but also for the vegetated channels. Channel modifications are undertaken to improve the conveyance and/or capacity if a creek or drainage system. This includes measures such as straightening, concrete lining, removal/augmentation of structures, dredging or widening.

Discussion

Channel upgrades are constrained by urban development, and channel widening is not feasible in most locations. Structures over the channels are also typically single-spans that do not significantly restrict the channel capacity. Several locations where channel upgrades were investigated in this study were rejected as they were found not to be feasible or provide significant flood benefit, such as Option ID 34 (Table 11), Option ID 86.2 (Table 13), Option ID 98 (Table 13), and Option ID 96 (Table 13). Even simple options such as covering open channels or providing walls for the channel will likely have significant constraints for implementation and not causing adverse impacts elsewhere. The only option to avoid this is large-scale upgrades of the whole channel, which is not realistic. As a catchment-wide option, this was not pursued further.

Summary and Recommendation

	Channel Upgrades
Description	• Increase the conveyance or capacity of channels in the study area.
Benefits	• Reduced overbank flooding on roads and through properties
Concerns	• Very difficult to achieve on a catchment-wide basis, particularly with existing constraints.
Approximate Cost	Very High
CBR	<1
Responsibility	Council and Sydney Water
Outcome	Not recommended as a catchment-wide flood mitigation option.

5.2.6. Summary of Flood Modification Options

A summary of the flood modification options subject to detailed assessment is provided in Table 27 below, along with the CBR and outcome.

Table 27: Summary of flood modification options subject to detailed assessment.

ID	Option	CBR	Outcome
M003	Gannan Park Detention Basin	0.3	Low priority
M008	Drainage Upgrade along Buffalo Road	0.3	Not recommended
M016 M017	Eastwood Drainage Tunnel	~0.13	Not recommended
M027	First Avenue Drainage Upgrade	0.8	High priority
M036	Jim Walsh Park Basin	4.6	High priority
M051	Kotara Park Basin	4.8	Medium priority
M057	Smalls Park Basin	0.8	Low priority
M061	North Ryde Golf Club Detention Basin	12.7	Medium priority
M073	Diversion Drain at Pittwater Road	N/A	Medium priority
M084	Drainage Diversion to West Ryde Tunnel	0.8 – 1.0	Medium priority
M089	Lions Park Basin	0.4	Low priority
M094	Pickford Avenue and Lovell Road Intersection	10.8	Low priority
M101	Boyce Street Drainage Upgrade	0.8	Low priority
M102	Channel and Drainage Maintenance	N/A	High priority
M103	Drainage Capacity Upgrade	<<1	Not recommended
M104	Channel Upgrade	<1	Not recommended

5.3. Property Modification Options

Property modification measures aim to reduce flood risk to existing and future developments. Options to modify the existing land use include voluntary house raising and flood proofing that can be implemented to reduce damage to existing properties, while voluntary purchase schemes can be implemented to remove dwellings from areas of high flood hazard, thereby reducing the number of residents at risk and potentially improving flood conveyance. Flood risk to future developments can be managed via land use planning and flood related development controls which regulate where and how various types of developments are constructed based on the flood affectation of the land. The key tools Council uses to regulate development are the LEP and the DCP. This section discusses each of the property modification options investigated and assesses their suitability for implementation in the study area.

5.3.1. PM01: Voluntary House Raising

Description

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to properties being isolated by floodwaters.

VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes* (Reference 31). In accordance with these guidelines, VHR is generally excluded for properties located within floodways; is limited to low hazard areas; and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers, and is typically not feasible for slab-on-ground constructions. However, advances in construction techniques and other alternatives may make house raising a viable option for slab-on-ground properties, and therefore individual assessments are required. Repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable uses may also be a possibility. The VHR guideline states that "*VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomical"* (Reference 31).

An indicative cost to raise a house is between $30,000 and $100,000 (Reference 32) though this can vary considerably depending on the specific details of the house (such as topography, structural integrity of the house, services to reconnect, access stairs, laying of a slab underneath, etc). Additionally, the type of construction of a house can make raising unfeasible, either technically or economically. There can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to a house, etc). Additional costs relate to temporary relocation costs during construction and unwillingness of the homeowner to pay the unfunded portion of the raising costs.

Discussion

Voluntary house raising as a mitigation measure has been successful in the past in areas where regular mainstream flooding occurs frequently. However, as these older houses are nearing the end of their useful life, re-building has become comparatively much cheaper than in the past and landowners want modern features in their houses (en-suite, air conditioning, several bathrooms, new kitchen, etc) there are few opportunities for house raising to be a viable measure. This trend has been further increased with developers and landowners seeing the opportunity to re-develop an old house as a dual occupancy.

Most houses within the study area are a brick construction, and there were very few flood prone properties that were identified that met the criteria for house raising. Four properties were identified as potentially eligible for VHR, as outlined in Table 28.

Table 28: Properties potentially eligible for VHR

Property	10% AEP Event		1% AEP Event	
	Depth above floor (m)	Hazard	Depth above floor (m)	Hazard
Epping Road, North Ryde	0.43	3	0.57	3
Avon Road, North Ryde	0.19	1	0.22	1
Potts Street, Ryde	0.26	2	0.35	2
Simpson Street, Putney	0.23	1	0.26	1

Council should review the year of construction of these properties to confirm whether they are eligible for the voluntary house raising scheme. A VHR feasibility study could be conducted including discussions with property owners to assess the full viability of this option. It is noted that the previous studies did not identify any properties that were eligible for VHR.

Experience has also shown that many owners of houses that potentially could be raised are not interested for reasons such as:

- they do not want an elevated entry to their house,
- the house is old without modern facilities and will be re-developed in the near future,
- owners will have to live elsewhere during the construction phase (possibly 2 months),
- owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace),
- whilst it is possible to raise most single storey non brick houses many owners consider the inconvenience too much of a burden,
- flood insurance is available,
- the owners of any low lying building that has experienced frequent above floor inundation over the past 30+ years will generally have addressed the issue by modifying the entrance to the building (constructing minor walls or landscaping) as the above ground water depths are typically shallow (less than 0.5m) and thus a local measure can eliminate or significantly reduce the problem.

Summary and Recommendation

	PM01: Voluntary House Raising
Description	• Physically raise existing dwelling structures above the FPL
Benefits	• Reduce exposure to flood damage
Concerns	• Construction type of housing stock in City of Ryde is typically brick/rendered, slab on ground or multi-storey buildings.
Approximate Cost	$30,000 to $100,000
CBR	>1
Responsibility	NSW State Government, Council, and Owner
Outcome	Feasibility of voluntary house raising for four properties recommended
Priority	Low

5.3.2. PM02: Voluntary Purchase

Description

Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard. VP is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers,
- A property is located within a floodway and its removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway, or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements or levee construction).

In the NSW Government *Guidelines for Voluntary Purchase Schemes* (Reference 33), the eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property, and that subsidised funding is generally only available for residential properties. Once a house is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development.

The NSW Government Guideline sets out the way in which a VP scheme should be undertaken and how properties should be valued. Valuations are to assume there are no flood related development constraints applied to the property. The aim of this is to allow those who take up voluntary purchase to be able to buy a similar property in a location not subject to flood risk, acknowledging that flood impacted properties often have lower value.

Discussion

VP is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. The median house price in the study area is between $2M and $2.7M, depending on the suburb. Based on the median house price, discount rate of 7% and flood benefits expected to last for 25 years, the current average annual damage for the property considered for VP must be approximately $160,000 to $200,000 or more for VP to be economically viable. Although there are several properties which have high flood hazard within the LGA, most of these were found to be not economically viable. Three properties were identified as part of this study which may be economically viable for VP and these are outlined in Table 29.

Table 29: Properties potentially eligible for VP

Property	10% AEP Event		1% AEP Event	
	Depth above floor (m)	Hazard	Depth above floor (m)	Hazard
Shaftsbury Road, Eastwood	1.19	5	1.65	5
Blaxland Road, Eastwood	1.16	5	1.70	5
Balaclava Road, Eastwood	0.92	4	1.27	5

The properties on Shaftsbury Road and Blaxland Road are recommended for further investigation in a subsequent feasibility study, however, the property on Balaclava Road is not recommended as it was likely constructed after 1986.

Properties identified in previous studies for VP are summarised in Table 30. These properties have been reviewed for their suitability for VP based on the updated flood study. Most of these properties were found to be not economically viable for VP or not located in areas of high hazard.

Table 30: Voluntary purchase from previous studies

Address	Recommended for VP
Quarry Road, Ryde	**NO.** Not in high hazard area (H4)
Buffalo Road, Ryde	**NO.** Not economically viable
Epping Road, North Ryde	**NO.** Not economically viable
Epping Road, North Ryde	**NO.** Not economically viable
Morshead Street, North Ryde	**NO.** Not economically viable
Morshead Street, North Ryde	**NO.** Not economically viable
Epping Road, North Ryde	**NO.** Not economically viable
Epping Road, North Ryde	**NO.** Not economically viable

Summary and Recommendation

	PM02: Voluntary Purchase
Description	• Purchase existing properties to remove them from high hazard.
Benefits	• Reduce exposure to flood damage • Reduce exposure of residents and rescuers from high flood hazard
Concerns	• High cost of properties in the current housing market reduces economic viability, opposition from land owners and minimal properties in high hazard areas.
Approximate Cost	>$2M per property
CBR	>1
Responsibility	NSW State Government, Council and Owner
Outcome	Feasibility of voluntary purchase for two properties recommended
Priority	Low

5.3.3. PM03: Flood Proofing

Description

Flood proofing is a strategy that is often applied to non-residential buildings and is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times through use of water-resistant materials, locating electricals above the FPL, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building and is typically best incorporated into a structure at the construction phase, though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered. Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction and allowed under development controls, although this should not replace or be used instead of minimum floor level controls. As such, flood proofing can be suggested within Council's DCP for structures to improve flood resilience above the standard for minimum floor levels. For example, for commercial property, controls may allow floor levels at a lower level (1% AEP) with flood proofing up to the 1% AEP + 0.5 m.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding. Temporary flood barriers such as sandbagging and floodgates can be a cost-effective option for existing properties and can be useful where there is frequent shallow flooding. However, it relies on someone being available to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

Discussion

Given the limited warning time available in the study area, dry flood proofing measures such as doorframe-mounted barriers would be an effective alternative to sandbags as they can be stored on the premises and quickly installed in the event of a flood, or alternatively, permanent flood barriers could be retrofitted to existing doorframes. Existing basement driveways which are impacted by flooding can be retrofitted with automatic hydraulic flood barriers which do not rely on electricity to operate.

When installed properly, such barriers could be expected to have the following benefits:

- Can be implemented by business owners (with little or no SES or Council assistance).
- Reduce time needed to prepare the building, particularly if proactive measures are adopted (e,g, relocating stock etc), allowing more time for staff to evacuate safely.
- Reduce or eliminate need for sandbagging.
- Reduce property damages.
- Allow premises to reopen as soon as safe access and services are restored.
- Reduction of days of lost business during recovery period.
- Greatly reduce clean up required.
- Range of products available from $1,000 - $10,000.
- Create regular staff training and drills, providing opportunity for community activity and flood education to be implemented.
- Increased continuity of work (and hence wages) for employees of affected businesses.
- Improved social amenity of being able to access and use key facilities and shops.

There have been considerable advances in the principles and approaches to flood proofing properties, both in the retrofitting and construction phases, to commercial and residential properties. Two guidelines of particular note are:

- *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas* (2006), Hawkesbury-Nepean Valley Floodplain Management Steering Committee.
- *Flood Resilient Building Guidance for Queensland Homes* (2019), State of Queensland (Queensland Reconstruction Authority).

Many councils support flood proofing principles for existing development and new structures which are below the FPL to reduce flood damages. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, and maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Access to community facilities, shops, healthcare services, sporting facilities and pubs are key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event. It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks or stock yards). Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the immediate recovery period.

Flood proofing can also be an option for sensitive and hazardous land uses, where controls could require aspects to the essential operation, such as generators to be located above the FPL, while allowing a lower floor level. The risks and consequences of a lower floor level would need to be assessed.

The Floodplain Development Manual (Reference 2) allows for greater flexibility for business to manage and recover from flooding. Specifically, referencing that FPLs could be based upon more frequent flood events than required for residential purposes. By allowing FPLs for floor levels to be lower, but still requiring or allowing flood proofing to a higher FPL, damages can be minimised and the acceptable level of risk becomes a business decision, trading off potential damages with lower initial set up costs.

New commercial buildings can be required to be flood proofed to the FPL when constructed which would include consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in the DCP, by stipulating an FPL for flood proofing. It is recommended that planning controls allow some flexibility in the type of proofing adopted. Flood policy is further discussed in Section 5.3.6.

The previous FRMS reports identified flood proofing as a management option for several commercial and industrial properties and areas. The areas within City of Ryde that would benefit from flood proofing include the Eastwood town centre, West Ryde town centre, residential properties along Morrison Road and Gregory Street.

Flood proofing is the responsibility of the property owner or business, and as such there is no Government funding for flood proofing of commercial and industrial buildings.

Summary and Recommendation

	PM03: Flood Proofing
Description	• Flood proofing of non-residential buildings with temporary flood barriers (both existing and new structures, where floor levels are allowed to be lower). This could also be extended to existing residential development, but not recommended for new residential development where floor level controls should be applied instead.
Benefits	• Reduce exposure to internal flood damage
Concerns	• Costs and implementation of flood proofing measures are the responsibility of the property owner / business.
Outcome	Flood proofing to be promoted for existing buildings, particularly industrial and commercial premises. Include options for the use of flood proofing to the FPL for non-residential land uses within Council's DCP (in addition to, not replacing minimum floor level requirements). This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.
Priority	High

5.3.4. PM04: Flood Planning Levels

FPLs are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is derived from a combination of a flood event and a freeboard and provides a development control measure for managing future flood risk (e.g. by elevating floors above a particular flood level), reducing potential damage and setting minimum levels for floodplain mitigation works. Typically, this level would be the 1% AEP flood level plus a freeboard of 500 mm for residential development.

The FPL for planning purposes is generally the height at which new (or redeveloped) building floor levels should be built to minimise the frequency of inundation and associated damage. It may also refer to the height to which flood proofing could be applied to reduce damages to commercial properties, required levels for evacuation or height of storage for hazardous goods. FPLs can vary for different types of land use categories depending on the level of risk, consequences of inoperability or vulnerability of occupants. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, acknowledging that businesses may be better placed to recover from flood related damages or implement flood protection/mitigation measures compared to residents. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. This allows a decision around the acceptable level of risk to be a business decision, allowing a trade-off of responsibility between Council and present and future business owners. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

Until recently the NSW Government planning framework allowed for the FPL to be initially defined within the LEP and supported through subsequent controls in the DCP. Recent changes to the NSW Government planning framework in relation to flooding came into effect on the 14th July 2021 (discussed in Section 4.2.4). These changes removed the definition of the FPL from the LEP. Flood planning controls for the City of Ryde are defined via the DCP, which is consistent with the changes that came into effect on 14th July 2021. Flood policy is further discussed in Section 5.3.6. A summary of flood planning levels according to the City of Ryde DCP (Reference 26) is contained in Table 33 below.

Table 31: Summary of flood planning levels for City of Ryde

Type of Development	Type of Flooding	Design Event + Freeboard
Residential – non-habitable	Low Risk	1% AEP + 150 mm
	Medium/High Risk	1% AEP + 300 mm
Residential – habitable	Low Risk	1% AEP + 300 mm
	Medium/High Risk	1% AEP + 500 mm
Industrial / Commercial	Low Risk	1% AEP + 300 mm
	Medium/High Risk	Not specified
Carpark – open	All	1% AEP
Carpark – enclosed	All	1% AEP + 150 mm
Carpark – basement	All	PMF

Discussion of Design Event

FPLs for typical residential development would generally be based on the 1% AEP event plus an appropriate freeboard. Assuming the average lifetime or the design life of a structure is 70 years, the likelihood of at least one 1% AEP flood event occurring is 50%. Given this potential, it is considered reasonable from a risk management perspective to adopt the 1% AEP flood as the design flood event for residential development. Consideration of more or less frequent events can be appropriate for different land uses, with considerations around level of risk, consequences of inoperability or vulnerability of occupants. In the case of sensitive and hazardous uses and the available land within this zone, it is appropriate for the PMF to be considered. This aligns with the FPLs in City of Ryde's DCP (discussed further in Section 5.3.6).

It is also considered reasonable to include climate change projections for the design flood event. FPLs will be used for setting floor levels of buildings that will have a certain design life, typically in the order of 50 to 100 years. In this circumstance, it is reasonable to assume that these buildings will be subject to a future climate and should be protected considering potential future design flood levels. This is discussed further in Section 5.3.8.

Discussion of Freeboard

As noted above, the FPL is typically derived from a design flood event (usually the 1% AEP) plus a freeboard allowance. The freeboard can be considered as a compulsory 'safety factor' used to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of an FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels,
- Differences in water level because of local factors,
- Increases due to wave action,
- The cumulative effect of subsequent infill development.

The Floodplain Development Manual (Reference 2) states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 0.5 m. This FRMS offers an opportunity to consider if a 0.5 m freeboard is appropriate. The current DCP already specifies minimum freeboard requirements based on the flood risk and type of development.

A key aspect to consider is the scale of flood behaviour that occurs within the catchment. Typically, overland flooding is shallower in nature, in most circumstances, and flood levels are generally not sensitive to factors such as wave action, wind setup or local obstructions. Importantly, the modelled flood behaviour in overland areas does not scale as significantly with event size, i.e., flood behaviour in the 0.5% AEP is generally not significantly greater than that of the 1% AEP, meaning that even if design rainfall estimates were to vary significantly (e.g. due to climate change), the overland flood behaviour would remain relatively consistent. In the study area within the main creeks, flood levels generally vary up to around 2 m between the 50% AEP and the 1% AEP events. Beyond the main creeks, flood levels are relatively consistent and vary between 0.1 m to 0.8 m. These aspects suggest that in some circumstances a freeboard less than 0.5 m may be appropriate to provide reasonable certainty that the flood risk in the 1% AEP is accounted for. While consideration could be given for very low risk overland flow areas (for example, where flood depths are less than 150 mm), it is assumed that these areas would be removed from the FPA due to the lot-based selection process (see Section 5.3.5).

Discussion of Critical and Sensitive Uses

The FPL may also be raised depending on the vulnerability of the building/development to flooding. The vulnerability of a building may arise from its use (e.g. power supply, sewerage treatment plant) or from its occupants (e.g. children or the elderly). The Floodplain Development Manual (Reference 2) lists the following as examples of critical facilities: fire, ambulance and police stations, hospitals and nursing homes, schools, water and electricity supply installations, interstate highways, bus stations and chemical plants. For such facilities, the consequences of flooding are significantly more severe, and so the avoidance (or limitation) of flood damage is particularly important. In addition, the changes to the NSW Government planning framework in relation to flooding that came into effect on the 14th July 2021, allows councils to opt-in to a second LEP clause to allow controls to be applied to these more vulnerable land uses, particularly in the area between the FPA and the PMF extent or land that is subject to non-direct evacuation constraints. City of Ryde has currently not adopted this clause.

Due to the flood behaviour in the study area, the floodplain is relatively constrained, and it is likely to be possible to avoid developing critical utilities or vulnerable facilities within the FPA or even floodplain (i.e. PMF extent) altogether. In some Councils, the PMF is used as the FPL for critical utilities and vulnerable facilities, as it allows developers to design new utilities or facilities with consideration of the full range of flood risk that may occur. It is therefore recommended that critical utilities and vulnerable facilities, if possible, are located outside of the PMF extent. If this is not possible, and the use is considered suitable, it is recommended that the PMF level be set as the FPL.

As for commercial development, the FPLs for critical utilities may refer to the minimum level to which flood proofing is applied, if it is impractical to elevate floor levels to the FPL. However, the risk to the lives of occupants of vulnerable facilities must be appreciated when considering the application of the FPL requirement. If the lowest habitable floor level cannot practically be raised to the FPL, the suitability of the vulnerable facility (such as residential aged care or childcare) in the proposed location must be carefully considered.

The current DCP differentiates development controls for sensitive and critical uses, where sensitive uses are developments such as community facilities, educational establishments and public utility and critical uses are developments such as emergency services facilities, public administration buildings and hospitals. Developments categorised as sensitive uses and facilities are not permitted in medium and high flood risk areas and all floor levels must be above the PMF level. Developments categorised as critical uses and facilities are not permitted on land subject to major overland flow and floodwaters.

Summary and Recommendation

	PM04: Flood Planning Levels
Description	• FPLs are typically based on a design flood event plus freeboard. It is used to determine the FPA and set minimum floor levels.
Considerations	• Minimum floor levels in the current DCP are mostly based on the 1% AEP event with some clauses based on the PMF event. Consideration should also be given to potential future climate scenarios appropriate for the design life of the structure. • The current flood planning levels for residential properties is considered appropriate. Minimum habitable floor levels for residential properties vary based on the type of flow experienced such that properties affected by medium and high risk flooding have freeboard of 500 mm, whereas properties affected by overland flow or are low risk have freeboard of 300 mm. • Similar to residential properties, minimum floor levels for commercial properties are specified based on type of flow experienced at the site. Within overland and low flood risk precincts, minimum floor levels are required to be 300 mm. The DCP should be updated to include a minimum floor level for commercial properties in medium and high risk flood precincts. • The current DCP requires sensitive uses to have habitable floors at the PMF level. This is considered appropriate for this land use type. The

	application of development controls outside the FPA is discussed further in Section 5.3.7. • The minimum finished levels of car parks required are considered appropriate with open parking areas set at the 1% AEP level, enclosed areas at 1% AEP with 150 mm freeboard, and basement parking entrances set at the PMF. • Minimum floor level requirements for recreational and non-urban uses are based on the type of flow experienced at the site. However, the current DCP does not explicitly state freeboard requirements for this type of development. The current DCP should be updated to include this.
Outcome	The current DCP, in terms of setting FPLs, is considered appropriate for most developments. It adopts a matrix approach which depends on the type of development, and the type of flow experienced at the site. The DCP should be updated to further clarify freeboard requirements for commercial developments, recreational and non-urban uses. Consideration should also be given to adopting the PMF level as the FPL for critical uses and facilities.
Priority	High

5.3.5. PM05: Flood Planning Area

Description

The FPA is the area of land at or below the FPL. It identifies the area to which flood planning controls apply.

Discussion

City of Ryde Flood Harmonisation Study (Reference 1) recommended a lot-based tagging process to identify land within the FPA and flood-prone land. This avoids the complications of the traditional approach of selecting a flood level, adding freeboard (typically 0.5 m), and 'stretching' this FPL surface to identify additional land that is above the flood level but below the FPL. This process is difficult to apply in steeper areas of overland flow where the land adjacent to the flow path does not rise more than 0.5 m above the flood surface. Adding the freeboard and stretching this surface leads to erroneous identification of areas that may not even be flood prone. Additional issues also arise from detailed 2D modelling now available. Minor watercourses and overland flow can be mapped at a refined scale such that shallow flows are also included. To ensure that 'flooded' areas are mapped appropriately, filter of flood depths is required. However, there can often be isolated areas of ponding that may not be 'flooding' and do not warrant a lot to be tagged.

City of Ryde Council engaged WMAwater to undertake the lot-based tagging process as part of the Flood Study Update (Reference 1). This involved a two-step process shown in Diagram 19.

Step 1.
GIS Algorithm
Automated spatial analysis identifying the properties subject to flooding from the modelling results of the flood study

- 1% AEP flood extent identified using hydraulic modelling.
- Filtering applied to results to remove areas of local drainage, and identify mainstream and significant overland flow areas.
- 0.5m freeboard added for mainstream areas and stretched across nearby terrain.
- Affected lots identified.

Step 2.
Desktop Assessment -
Flood Behaviour Review
Reviewing flow paths and flood behaviour to confirm the magnitude and distinguish between overland flow / local drainage

- Review of flood behaviour undertaken to broadly classify the flow path
- Modification of tagging status to ensure consistent outcomes along flow paths and among neighbouring properties, based on the flow path review.

Diagram 19: Two-Step Flood Tagging Process

This tagging process adopts a clear and defensible methodology for identifying flood affected properties under Section 10.7 of the *Environmental Planning and Assessment Act*. The tagging identified lots affected by the 1% AEP (plus a consideration of freeboard, i.e. the FPA) and the PMF (flood-prone land). These can be directly correlated with tagging for Clause 9 of Schedule 2 of the new *Environmental Planning and Assessment Amendment (Flood Planning) Regulations 2021*.

Summary and Recommendation

	PM05: Flood Planning Area
Description	• The FPA is area of land at or below the FPL to which flood planning controls apply.
Considerations	• There are issues with the traditional approach of applying freeboard and 'stretching' the surface to identify the FPA, particularly with steep overland flow paths in urban areas. • Lot based tagging provides a clear and defensible methodology for identifying flood affected properties.
Outcome	It is recommended to retain the current lot-based tagging approach, and update the tagging status based on the Ryde Flood Harmonisation Study (Reference 1).
Priority	Low

5.3.6. PM06: Flood Planning Policy

Description

Appropriate planning instruments ensure that development can be undertaken considering compatibility with the flood risk. Effective planning instruments can reduce residual flood risk over time as redevelopment occurs. Planning instruments can be used as tools to:

- Reduce risk to life,
- Reduce damage to the proposed development itself, and
- Reduce damage to the broader floodplain and existing development.

The types of controls (this list is not exhaustive) that achieve each of the objectives listed above are shown in Table 32.

Table 32: Planning Instrument Objectives – Control Type

Objective	Type of Control
Reduce Risk to Life	Evacuation considerations, vulnerable land use and occupant considerations, flood awareness and education (Section 10.7 certificates), prevention of ingress of water to car parks.
Flood Damage to New Development	FPLs, location considerations including, hydraulic hazard and category considerations, structural requirements.
Flood Damage to Existing Development	Flood impact consideration, design considerations, location considerations including, hydraulic hazard and category considerations.

The primary planning instruments used by local Councils are the LEP and DCP. The LEP is a legal planning instrument that guides planning decisions for Council through zoning and development controls. They provide a framework for the way land can be developed and used. The DCP support the objectives of the LEP and are used by Council to define and articulate the specific standards needed for different types of developments. Flood related development controls are a key aspect for development that occurs on flood prone land.

Discussion

Examination of existing risk throughout the study area indicates that managing this risk is problematic due to the very short warning times available. However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long-term management of these areas and how this can be facilitated by planning tools. Rezoning and redevelopment reduce flood risk through the application of planning controls such as setting minimum floor levels and ensure safe flood refuge is available.

Development in the City of Ryde LGA is currently governed by the Ryde LEP 2014 (Reference 26) and City of Ryde DCP 2014 (Reference 27). In general, Section 5.21 of the Ryde LEP 2014 (Reference 26) contains the overall objectives and guidance for development on flood prone land, while Part 8.2 (Stormwater and Floodplain Management) of the City of Ryde DCP 2014 (Reference 27) and contain specific flood-related development controls. A supplementary technical manual is provided as part of Part 8.2 of the City of Ryde DCP 2014. This document provides further guidance on the flood assessment process to produce compliant developments. The LEP and DCP are comprehensive and cover a range of flood aspects. Key considerations and whether they are included in the documents are provided in Table 33.

Table 33: Flood-related Development Control Considerations

Aspect/Control	Contained in LEP/DCP	Comment
Terminology	Yes	Uses consistent terminology in line with the Floodplain Development Manual 2005 and ARR 2019. Potential for updating to the new Flood Risk Management Manual 2023. ARI terminology recommended to be changed to AEP. Flood risk category definition recommended to be updated in utilising H1-H6 hazard categories to differentiate between high and medium flood risk.
Flood Planning Level	Yes	Discussed in Section 5.3.4.
Flood Planning Area	Yes	Discussed in Section 5.3.5. Ensure map is available on Council's website if separate from the DCP, since changes to the NSW Government planning framework in relation to flooding has removed the FPA overlay from the LEP.
Consideration of flood affectation and land use	Yes	Development controls consider the flood risk (low to high) of the site and land use, although this primarily extends only to freeboard. The DCP allows for varying degrees of complexity in preparing a flood impact statement. Consideration could be given to implementing an actual matrix approach, with differing requirements specified depending on the flood risk and type of development.
Minimum Floor Level	Yes	Minimum floor levels are specified, typically being the 1% AEP level plus a freeboard, ranging from 0.1 m to 0.5 m depending on the type of development and type of flooding it is exposed to.
Minimum Carpark Level	Yes	Minimum carpark levels, including basement carparks, are specified in the DCP at appropriate levels (1% AEP level, 1% AEP level plus 150 mm or PMF level for entrance to basement car parks).
Flood Proofing	Yes	Consideration of flood compatible building materials and structural soundness are included in the DCP. There is no consideration of electrical components or storage of hazardous materials.
Flood Impacts	Yes	The DCP requires all flood affected developments to submit a flood impact statement which includes flood effects. DCP stipulates that the proposed development does not result in increased flooding elsewhere in the floodplain and outlines requirements of a flood impact assessment. The DCP allows for a simplified approach to be undertaken. This should be reviewed since detailed overland flow flood modelling is available.
Evacuation	Partial	Evacuation requirements in the DCP are broad. In flood impact statements, developments are required to consider escape from flood waters to ensure the development does not

Aspect/Control	Contained in LEP/DCP	Comment
		jeopardise public safety. The site must have access to a safe refuge above the PMF event. It is recommended evacuation requirements in the DCP should be updated to require consideration of a formalised Emergency Response Flood Plan and specify requirements for evacuation or shelter in place.
Fencing and Landform	Yes	Fencing and landform requirements are prescribed in the DCP, including requirements for fencing to be permeable in nature across overland flow paths. The requirements are suitable, however, there are differences between the requirements specified in the DCP (Section 4.4.3) and the Stormwater Management Technical Manual (Section 2.4).
Special Flood Considerations	Partial	The LEP currently does not include the *Special Flood Considerations* clause. Changes to the NSW Government planning framework in relation to flooding allows Council the opportunity to include a second clause within their LEPs which applies to land between the FPA and the PMF extent and considers sensitive and hazardous uses in addition to those uses which may have evacuation constraints. This inclusion empowers Council to apply controls that ensure the developers of such facilities appropriately consider and plan for the full range of flood risk at the site, so as to reduce potential property damages and minimise the risk to life in future flood events. There are controls in the DCP to this effect, which should be applied by including the *Special Flood Considerations* clause in the LEP. This would also require a map of the area to which this clause applies to be available in Council's DCP.
Future Climate	No	The DCP does not consider climate change. The DCP should be updated to incorporate climate change in two ways. Firstly, the climate change should be considered in as part of flood impact assessment, where climate change impacts should be modelled to manage risk of future climate change. Secondly, development controls should be integrated with consideration of climate change. As discussed in Section 5.3.4 in regard to FPLs, it is recommended that Council includes climate change in flood-related development controls considering best available climate change data to combat future sea level rise and increased rainfall intensity. Climate change policy is discussed further in Section 5.3.8.

Summary and Recommendation

	PM06: Flood Planning Policy
Description	• Flood planning policy is typically governed by the LEP and DCP, which outline flood-related development controls.
Benefits	• Appropriate flood development controls ensure future developments have reduced flood risk.
Concerns	• Only provides benefits to at risk properties during redevelopment.
Outcome	Consideration should be given to the following: • Updating of the DCP to be clearer and more concise, including implementation of a matrix approach to flood risk considering hazard and development type. The DCP should align with current terminology and best practice. • Inclusion of climate change in flood related development controls. • Provision of special flood considerations clause in the LEP.
Priority	High

5.3.7. PM07: Section 10.7 Certificates

Description

Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the *Environmental Planning & Assessment Act 1979*. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about their own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the *Conveyancing Act 1919* requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Schedule 4 of the *Environmental Planning and Assessment Regulations 2000* gives requirements for inclusion on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. Schedule 4, Clause 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls. Schedule 4 of the *Environmental Planning and Assessment Regulations 2000* has since been updated to Schedule 2 of the *Environmental Planning and Assessment Regulations 2021*. Clause 9 of Schedule 2 of the new regulation requires the planning certificate to include whether the land or part of the land is within the FPA and subject to flood related development controls as well as if the land or part of the land is between the FPA and PMF and is subject to flood related development controls.

Discussion

City of Ryde currently provides flood information on Section 10.7 certificates in terms of land that is subject to flooding in the 1% AEP (Clause 7A(1) or Clause 9) and the PMF (Clause 7A(2) or Clause 9). Landowners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5)

Planning Certificates. Landowners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be considered when developing a consultation strategy for notification of any changes related to S10.7 Planning Certificates.

The more informed a homeowner is, the greater the understanding of their flood risk. During a flood event, having this understanding helps prepare residents for evacuation, and improves the ability of residents to recover following an event. Improved flood risk awareness may also reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated. Residents can also request flood information for their property, which includes more detailed information such as:

- Flood levels (1% AEP and PMF) at various locations around the property,
- Flood extent mapping (1% AEP and PMF),
- Flood risk precinct mapping,
- Applicable minimum floor levels,
- DRAINS model peak flow rates for the 1% AEP event, and
- Other relevant information such as the presence of stormwater pipes.

Summary and Recommendation

	PM07: Section 10.7 Certificates
Description	Section 10.7 Certificates are required to show flood notation. This informs the landowner of flood risk and applicable development controls.
Outcome	The current provision of information (Section 10.7 notification) to landowners is considered adequate. Section 10.7 Certificate information should be updated with information from this FRMS&P.
Priority	High

5.3.8. PM08: Climate Change Policy

Description

The City of Ryde had passed a resolution in May 2019 acknowledging the Climate Emergency (Reference 34) and as part of this had developed a Net Zero Emissions Pathway (Reference 35) and Resilience Plan (Reference 36). These plans are centred around achieving net zero emissions and outline adaption and resilience strategies across the LGA. While flood risk and coastal management are key considerations in the plans, they are typically broad in nature and do not have specific outcomes for flood risk management. Specific climate change policies should be drafted and adopted. These policies would be guided by a climate change action/adaptation plan which would sit under the policy and may also contain a number of individual plans or strategies, such as a ‘sea level rise policy’.

Sutherland Shire Council, for example, adopted a sea level rise policy in May 2016, which outlines sea level rise projections that are to be applied to all planning instruments, policies, flood and coastal studies. This provides for a predicted 0.72 m increase in sea level for the year 2100 horizon. The same projection has been used in Eurobodalla Shire Council's Interim Coastal Hazard Adaptation Code that applies planning controls to proposed developments in the coastal zone. Several other Councils have also chosen to adopt sea level rise projections in flood planning levels or certain aspects of their DCP requirements (such as Georges River Council, Northern Beaches Council, Shoalhaven City Council and Port Stephens Council). Other Councils, however, have recently rescinded their climate change response policy (Port Macquarie Hastings Council).

Discussion

The results of the impact of climate change (both rainfall intensity increases and sea level rise projections) were documented in Reference 1. These results indicate that there are parts of the City of Ryde study area that are at risk from climate change. In particular, rainfall increases have significant effect on Terrys Creek upstream of the railway line, Shrimptons Creek upstream of Epping Road, Buffalo Creek near Minga Street and Charity Creek in the commercial precinct at Victoria Road and Falconer Street. Sea level rise would affect foreshore areas such as the outlet of Archer Creek, Charity Creek and Morrison Bay. An assessment of climate change impacts was included in the flood study component of the Flood Harmonisation Study (Reference 1).

A policy (or sub-policy) that outlines Council's adoption of an IPCC AR6 (Reference 37) emissions scenario, planning horizon and hence projected sea level rise is recommended for future planning for these areas. An overarching climate change policy and sub-policies would ensure consistency in Council's approach to climate change, and sea level rise in particular, across a range of asset design and maintenance sectors as well as coastal and floodplain management. This would ultimately feed into flood policy (Section 5.3.6), FPAs (Section 5.3.5) and FPLs (Section 5.3.4).

New development, such as buildings, have a typical design life in the order of 50 to 100 years. Given this, Council should consider a planning horizon and account for future climate change based on best available climate projections for both increases in rainfall intensity and sea level rise. Council should consider a year 2100 planning horizon for the potential effects of climate change on developments. Major infrastructure works may have a design life over 100 years, in which case a longer planning horizon, such as the year 2150, should be considered. For example, depending on the proposed development life, a sea level rise projection could be incorporated into the FPL to ensure the flood risk of the site is maintained into the future.

It is noted that across the previous Flood Studies for City of Ryde a range of tailwater levels and sea level rise levels were adopted. The Flood Harmonisation Study – Flood Study Update (Reference 1) addresses this by adopted a unified set of sea level rise and rainfall increase scenario across the entire LGA. A climate change policy will guide any future coastal management, asset design and flooding and planning controls.

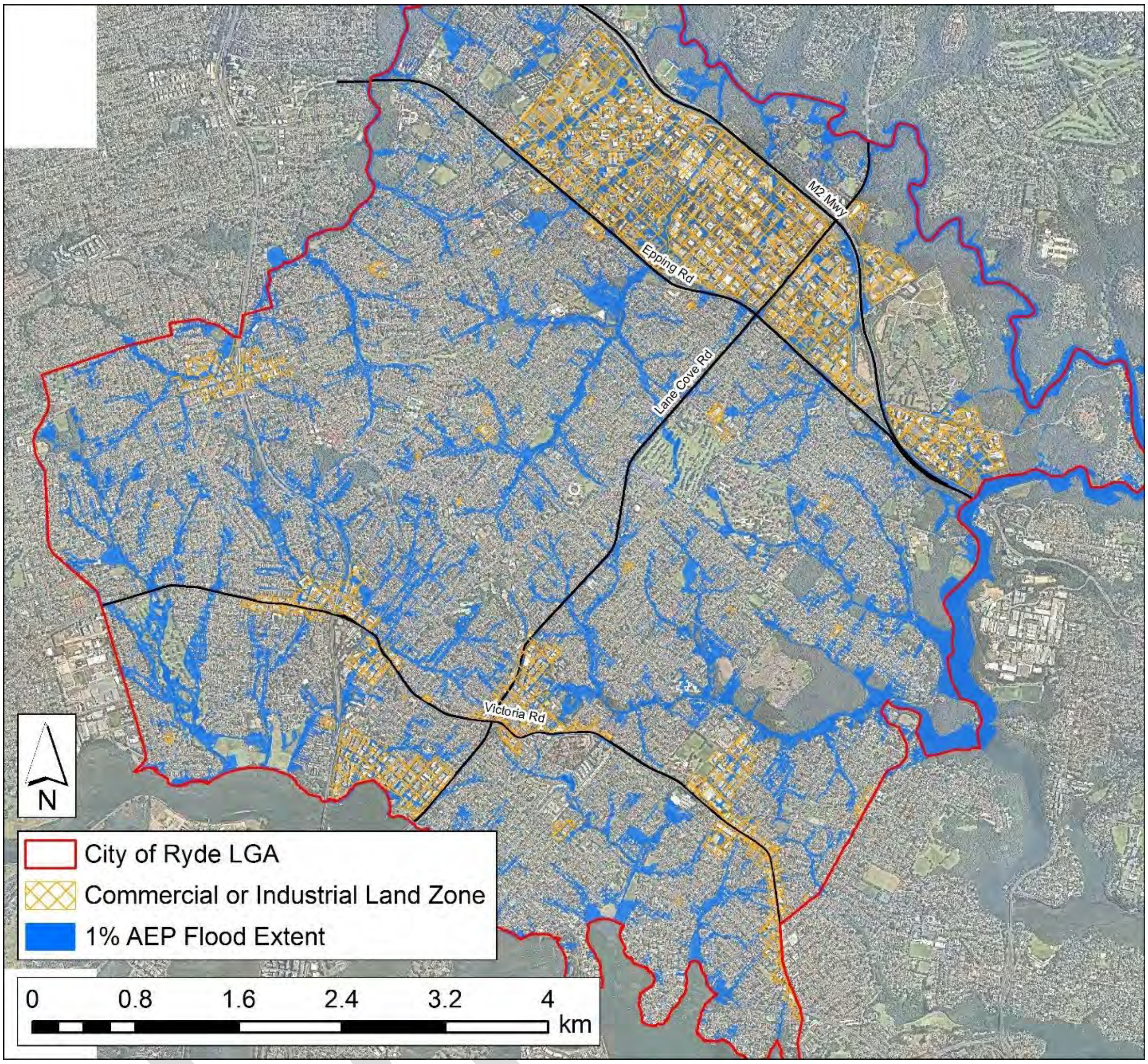
Summary and Recommendation

	PM08: Climate Change Policy
Description	• A climate change policy guides Council's operations and policies at a high level. This would likely feed into other Council operations such as coastal management, asset design, flooding and planning controls. Climate change adaptation should also be considered at an LGA-wide scale.
Benefits	• Allows for uniform approach to climate change adaption across the entire LGA. • Improves Council's climate change adaptability. • Ensures future climate and sea levels are incorporated into current planning controls and infrastructure design.
Concerns	• Uncertainties in future climate and sea level predictions. The changes expected for future rainfalls and runoff response is largely unknown.
Outcome	It is recommended that City of Ryde pursues a climate change policy, particularly as there are several areas that will be impacted by future sea level rise and rainfall increase. This requires a holistic approach from City of Ryde, as climate change and sea level rise does not just affect flooding, but a range of Council assets, plans and policies. It is recommended that the policy outlines the scientific basis for climate change, adopts a planning horizon (or different planning horizons for different applications) and specify rainfall increase and sea level rise parameters, and outline its application to Council's operations, planning instruments, policies and floodplain management strategy.
Priority	High

5.3.9. PM09: Commercial Property Redevelopment

Description

The flood behaviour across the LGA was reviewed with consideration of commercial and industrial areas in the LGA. Commercial or industrial land zones are typically located in the downstream areas of watercourses in the LGA such that major watercourses run through or adjacent to the properties. In several of these precincts, natural watercourses have been formalised to large underground conduits to allow watercourses to be conveyed underneath the built structures. While these conduits provide some conveyance, most are at capacity in the 1% AEP event and waters flow overland without a defined flow path causing flood damages. Retrofitting larger underground conduits and overland flow paths to existing commercial/ industrial developments are difficult to construct and are unlikely to be economically viable. These upgrades are unlikely to gain state funding as the main beneficiaries are commercial properties. However, during redevelopment of these buildings, Council may be able to include upgrades to the underground network and improve overland flow paths as part of the development assessment process. Upgrades can be completed as part of the redevelopment and be funded primarily by the developer. Council should identify commercial and industrial areas, which would likely benefit from improved flood conveyance, and flag them for consideration for future redevelopment assessment processes.



Discussion

Review of the flood behaviour show that commercial properties have been built on top of Shrimptons Creek, Industrial Creek, Porters Creek and Charity Creek with natural watercourses converted to underground conduits. These areas include:

- Shrimptons Creek is conveyed via a 3 cell 2.6 m wide by 2.7 m high conduit under Macquarie Shopping Centre.
- Industrial Creek is conveyed via a 1.8 m conduit from Waterloo Road between Talavera Road and runs under four commercial properties.
- Porters Creek is conveyed via a 5 m wide by 4.2 m high conduit underneath Officeworks North Ryde and several other commercial properties.
- Charity Creek is conveyed via a 4.3 m wide by 1.8 m high conduit underneath the industrial park at Victoria Road and Falconer Road as well as underneath Marsden High School.

The effect of upgrades to conduits along Shrimpton Creek and Porters Creek were investigated as part of this study. Figure 25 presents the peak flood level impact from increasing pipe capacity by 25% under Macquarie Shopping Centre. In the 1% AEP event, flood levels reduce by up to 300 mm in the shopping centre and reduce by 100 mm to 200 mm upstream. Downstream of Officeworks North Ryde, the conduit conveying Porters Creek contracts from 5 m wide by 4.2 m high to 1.8 m in diameter. Figure 26 presents the peak flood level impact from increasing pipe capacity downstream of Officeworks North Ryde to match the 5 m wide by 4.2 m high conduit capacity as well as increase in capacity underneath Epping Road. In the 1% AEP event, flood levels reduce by more than 300 mm in the downstream of Officeworks and areas adjacent to the Officeworks are also no longer within the flood extent.

While upgrade to conduits underneath commercial zones primarily benefit the commercial properties, there are flow on effects to residential properties and the wider community. Large commercial and industrial properties tend to be located in the downstream areas of the catchment. Upgrades to stormwater network in upstream areas would generally require upgrades to its downstream counterparts. This is generally to prevent adverse impacts downstream as upgrades in upstream areas would only move the bottleneck in the pipe network downstream. Therefore, upgrades to these conduits underneath commercial zones may allow future upstream drainage upgrades to be more effective.

Council should identify and flag commercial/ industrial properties along portions of creeks which have been converted into underground conduits and may benefit from increased capacity. Redevelopments typically occur lot-by-lot such that only portions of the conduit can be upgraded at a time. A register of identified properties will allow Council to consistently monitor the drainage upgrade. This register would be prioritised in terms of flood benefit and feasibility as well as include its likely redevelopment time. For example, while Eastwood CBD is heavily flood affected, there are a number of affected commercial lots and redevelopment of each lot within a similar time frame is unlikely. On the other hand, Macquarie Shopping Centre is the only lot along Shrimptons Creek in that area with underground conduits. Therefore, it would be prioritised higher as redevelopment of the shopping centre would lead to immediate improvements to flow conveyance.

During redevelopment of identified properties, Council should include the requirement for the property owner to consider both conduit upgrades and reinstatement of an overland flow path. While an overland flow path solely may not provide enough capacity to convey the watercourses, it allows for any surcharge from the underground conduit system to flow in a defined flow path.

Summary and Recommendation

	PM09: Commercial Property Redevelopment
Description	• Identify commercial and industrial properties which may benefit from increased flood conveyance and flag these properties for further assessment when it is being redeveloped.
Benefits	• Improves flow conveyance across the commercial property • Allows for opportunities of greater flood benefits for upstream drainage upgrades
Concerns	• Commercial properties along the same watercourse are unlikely to be redeveloped at the same time and there may only be partial benefits until the entire length of conduit is upgraded.
Responsibility	Property Owner to consider upgrades to drainage and overland flow during redevelopment. Council to compile a register of identified properties.
Outcome	Recommended
Priority	Medium

5.4. Response Modification Options

The measures described in this section relate to how the City of Ryde community receives information about floods, responds to and recovers from flood emergencies. Response modification options aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities, evacuation and planning, and supporting greater community flood awareness and preparedness.

5.4.1. RM01: Flood Emergency Management Planning and Coordination

Description

The SES is the legislated combat agency for flood, storm and tsunami response, responsible for the control of operations. The SES prepares a range of documents that cover preparedness, response and coordination measures that are essential to the management of storm and flood risk. These documents include information brochures about storms and flooding, Local Flood Plans, regionally based information webpages (Northern Sydney region), unit based webpages (Ryde Unit) in addition to information and brochures on preparedness strategies for urban areas. The SES website (www.ses.nsw.gov.au) also contains an array of information that residents can access.

During a flood event in the study area, the two main response agencies are the SES and Council. Each have defined roles and responsibilities, as outlined in the Ryde Hunters Hill Flood Emergency Sub Plan (Reference 38). Council plays a significant role in ensuring the safety of its community in times of emergency, including preparedness of the organisation in the lead up to an event such as a flood, its response, integration with other emergency services and recovery from the event. During a local storm or flash flood event, Council is responsible for responding to issues relating to public areas and infrastructure, for example, road closures, cleaning out drains, and pumps, and debris removal within road reserves or riparian corridors.

The SES is responsible for the control of flood operations, including the coordination of evacuation, undertaking flood rescues, assisting with flood damage and welfare of affected communities. The SES can respond to calls regarding private property, including storm damage, evacuations (if appropriate) and rescues (e.g. motorists or pedestrians who have entered floodwaters). It is important to share information about the typical roles of each agency with community members, to allow them to contact the appropriate agency in the event of a flood related emergency, to ensure their call is responded to without unnecessary delay, and not place additional burden on agencies that cannot assist directly.

Discussion

Flood emergency planning and coordination is an important aspect of reducing flood risk in the study area. In terms of planning, dissemination of information to the community is an integral aspect. An information brochure containing flood information, emergency contact information, and guidance on preparation and response can be distributed to the community. Although the information may be general, it provides information to residents on flood risks, how to prepare and what to do during a flood. This brochure could be updated and included as part of an ongoing flood education and awareness program.

A Local Flood Plan is also available for the City of Ryde LGA, published in June 2021 (Reference 38). The document contains an overview of the flood hazard and risk in the area (Volume 2, not publicly available), prevention and mitigation measures, as well as preparation before a flood, response during a flood, and recovery following a flood. This is a high-level document, with most of the information not being specific to the City of Ryde LGA. It is assumed that Volume 2 of the plan, which is not publicly available, would provide more detailed information about flood risk. It is recommended that this be updated to include the modelling and results available as part of this FRMS.

Coordination between responsible agencies (primarily Council and SES) is critical to providing an adequate level of service during flood events. It is recommended that regular meetings and exercises be held to improve plans at the strategic level. There would be significant benefit in including a broader range of representatives from each agency in these meetings. In particular, the inclusion of Council engineering and outdoor staff, and SES volunteers and volunteer coordinators, would ensure that the individuals who are most likely to be active during the event would benefit from the training exercises, and could add input from their own experience. Not only will this help more responders prepare for flood events but increase familiarity between representatives of each agency.

Difficulties in achieving the above objectives stem from the logistics of gathering the relevant parties at a mutually convenient time, staff changeover within agencies, and location and availability of out-of-area volunteers. It may be more feasible to have regular, smaller meetings, where representatives from each agency can attend and report back to their teams, and perhaps aim to hold a larger scale gathering and training day on an annual basis to ensure individuals can plan their attendance well in advance.

Summary and Recommendation

	RM01: Flood Emergency Management Planning and Coordination
Description	• The NSW SES is the legislated combat agency for floods, including the preparation, response and recovery phases. The SES provides information to residents and assists during flood events. Council also has responsibilities and works with the SES to achieve these goals.
Responsibility	SES and Council
Outcome	It is recommended that the SES: • Use the information and modelling developed as part of this FRMS to update their local flood plan for City of Ryde. • Consider creating and distributing brochures or information on their website specific for the flood risk in City of Ryde. • Provide guidance to City of Ryde Council with regard to evacuation and shelter in place as floodplain management strategies. It is recommended that City of Ryde Council and SES hold regular meetings of all responders to identify roles and responsibilities in practice and build relationships between agencies and/or community groups.
Priority	High

5.4.2. RM02: Flood Warning Systems

Description

The purpose of a flood warning is 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.

A wide range of prediction tools are available, from basic flash flood information systems that use real-time rainfall triggers, to complex flash flood warning systems that run real-time hydrodynamic models informed by radar rainfall estimates. There is a need to find the appropriate balance between the risk presented by the flooding, model complexity (and cost), available warning time, and accuracy of prediction. The flood prediction then needs to be interpreted in terms of what area, people and infrastructure are at risk. This is then required to be disseminated to the appropriate people and areas for them to take appropriate action. Providing sufficient warning time is necessary for people to prepare and act (for example, moving goods to a higher level and evacuating to higher ground) has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Discussion

The BoM is responsible for monitoring and predicting flood events. Flood Watches and Flood Warnings, however, are only provided for large river systems where it is possible to predict flooding more than 6 hours in advance. There are no Flood Watches or Flood Warnings within the LGA. Typical critical durations across the study area range from 30 minutes to 90 minutes for major overland flow paths and creeks. This would be categorised as ‘flash flooding’, that is typically the result of intense local rainfall and characterised by rapid rises in water levels, occurring within 6 hours. Due to the nature of overland flow in the study area, flood warnings are difficult to prepare and disseminate. The quick catchment response time does not allow time to interpret recorded rainfall data, construct and disseminate a flash flood warning, with enough time for the community to be able to take meaningful action to prepare.

While the BoM does not provide warnings for flash flood catchments, it does provide forecasts and warnings for severe weather conditions that can potentially cause flash flooding. Flash flood warnings themselves are provided by State and local government where gauges and warning systems are available. While these can be developed, maintained and monitored for a cost, its usefulness is dictated by how well rainfall predictions or rainfall observations can be translated into accurate flash flood warnings that provide adequate warning time without triggering false alarms. This balance is difficult in areas such as City of Ryde. It is also difficult to justify based on a cost-benefit analysis, as the reduction in tangible damages is limited and it is the reduction of intangible damages that a flood warning system generally benefits. Additional issues include vandalism, maintenance and the ability or willingness of residents to respond accordingly.

As an alternative to a flash flood warning system in the study area, severe weather warnings issued by the BoM can be used as a warning of the potential onset of flooding in overland flow areas coupled with education and awareness. Severe weather warnings are issued when severe weather or thunderstorms are expected – these are the types of storms that can cause flash flooding in the study area. The warning may also note the hazards associated with the storm including damaging wind gusts, large hail and flash flooding. These alerts are available through the BoM website, BoM weather app, the SES website and a variety of other platforms (such as news outlets and social media). Recently, the BoM updated its app so that users can receive push notifications for severe weather warnings. A flood awareness campaign can assist in providing guidance to residents on how to interpret BoM weather warnings and how to manage flooding.

Summary and Recommendation

	RM02: Flood Warning System
Description	• A flood warning system is designed to provide advice on impending flooding so people can take action to minimise its negative impacts.
Outcome	A dedicated flash flood warning system for the City of Ryde is not viable. It is recommended that the severe weather and severe thunderstorm warnings issued by the BoM be used to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BoM, anticipating the impacts and preparing accordingly.
Priority	Medium

5.4.3. RM03: Community Flood Awareness and Education

Description

A key step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain. Flood awareness is a vital component of flood risk management for people residing and working in the floodplain, as well as for those reliant on services operated from within flood prone areas. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, responds to, and recovers from flooding.

Key messages to be communicated to the community include:

- General information about how overland flow in the City of Ryde LGA is generated, where it is conveyed and typical durations of inundation.
- Specific information about flow paths and associated flood behaviour (for key areas at risk.
- Guidance on the roles and responsibilities of the SES and Council, and contact details of each agency.
- What to do when BoM issues a severe weather warning for the study area.
- General information regarding personal safety during a flash flood event, particularly, the risks of driving across flooded roads, even if flow is shallow.

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 only consisting 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 experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, videos, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs).
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and flooding.
- Are ongoing programs rather than one-off, unintegrated ‘campaigns’, with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program, but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

Ongoing flood awareness campaigns can be costly and can become ineffective over time with residents becoming bored or dismissive of messaging, particularly in periods of little rainfall. The community’s perception of flooding may be more driven by flood risk occurring in large river systems, and overland flow flood risk may be perceived as less important or hazardous in comparison. Overland flow events do occur, and bring with them their own risks, particularly relating to flash flooding of roads, and driver safety. It is key to keep overland flow flood awareness current, as flash floods can occur frequently and quickly.

Table 34 provides a list of commonly applied methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 34: Methods to Increase Flood Awareness and Preparedness

Method	Comment
Council website	 Council already provides flood information on their website, via the “Floodplain Risk Management Studies and Plan” section, which provides the adopted flood studies and FRMS&P reports in full as is. There is also a section “Flooding” which provides a list of frequently asked questions and Section 10.7 Certificate Information. While these sections are useful to the community, an additional

Method	Comment
	section which provides an overview of the flood behaviour in the LGA and the floodplain risk management process is recommended. This section would give the community a general understanding of the type of flooding expected. Council already provides flood preparation information on their website via the “Prepare for Heavy Rainfall and Floods” section. However, Council should consider continuing to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. Information about what to do in the event of a flood, and how to stay safe, could also be provided. This could include, for example, links to SES FloodSafe Materials and campaigns such as “15 to Float”, “If it’s flooded forget it” and “Turn Around Don’t Drown”, which aim to improve driver safety during flood events. It is recommended that Council’s website continue to be updated as and when required.
Community Champions Program	There could be an opportunity for the SES and Council to liaise with these trusted community members to trial a community champion program. This would also provide a valuable two way conduit between the local residents and Council. The SES Community Action Team Volunteers is an SES program where community members volunteer to help prepare and protect their community during severe weather events. There may be members of the local community well suited for involvement in an SES Community Action Team group and this team should be more widely promoted to encourage involvement.
Community Working Group	Council could initiate a Community Working Group framework (undertaken in other catchments elsewhere) and this would provide a valuable two-way conduit between the local residents and Council.
Letter/pamphlet from Council	A leaflet containing specific information about flood behaviour, and what to do in the event of a flash flood is an effective way of providing information without necessarily requiring active participation from residents. A leaflet/pamphlet from Council may be sent (annually or biannually) with the rate notice (electronically or by mail). A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of on-going implementation of actions identified in the FRMS&P, changes to flood levels or development controls, reinforce the differences between sources of flooding, provide information on the actions Council is taking to reduce the flood risk in their area and direct residents to further information. It could also be combined with other general council information, reducing the potential fatigue from repeated messages. 
School engagement	Engagement with school students can be a successful means of not only informing the younger generation about flooding but can also lead to infiltration to parents. This can be implemented through various techniques including: • adopting messaging about not playing in or driving in floodwaters into

Method	Comment
	appropriate lessons, • school projects where students can learn about historical floods by interviewing older residents and documenting what happened, • and hosting "flood awareness" days where members of the local SES visit schools and participate in flood safety activities. While this FRMS focuses on flood risk only, this approach can be combined to include other topics relating to water quality, drainage management, etc.
S10.7 certificate notifications	This option is discussed in detail in Section 5.3.7, and is a useful tool as a 'point in time' awareness exercise, but has limited use as a method to maintain flood awareness in the community, as generally the certificates will only be requested when a property is to be redeveloped or sold. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
A range of media	A range of media and community engagement methods should be used to publish interest pieces on flooding, and to promote flood awareness activities. Communication means include council newsletters, social media, local newspapers and the radio. Ongoing pieces in newsletters or the local paper will ensure that flood issues are not forgotten.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages and tips for responding to future flood events. This could also be set up at any number of other sites, such as shopping centres.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate time and visible location. The event would be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out. These materials are used to engage with people and make them aware of 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 property owners to develop self-help networks and particularly people checking on neighbours if a flood is imminent. Longer-term residents with flood experience could be used to help provide other residents with an understanding of previous floods and how to prepare for future flooding.
Flood Information Signage	Flood information signs could be implemented in locations known to flood to inform residents of the risk, and appropriate responses. Like the SWC 'flood zone' that are currently around the Terrys Creek concrete open channel areas that are fenced.  This can also take the form of historical flood markers, where signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are

Method	Comment
	inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. This might also include establishment of peak water level marker poles and which house floors are inundated. For example, a page on the Council website could be added, where residents can drop a pin on a map and upload photos and information about flooding.

Discussion

These options for community education include both passive (pamphlet, flood signage, library displays, etc) and interactive methods of engagement (community champions, SES Breakfast, Meet the Street events and school engagement, etc), and target various sectors of the community (businesses, residents etc), and can be implemented by various organisations (Council, SES, schools, community groups). It is therefore recommended that a program which utilises a variety of approaches and looks to engage a wide cross section of the community is developed, for implementation ongoing implementation over the coming 5-10 years. Learnings from other recent engagement activities can be used to formulate a program most suited to the City of Ryde LGA and its community.

At a minimum, it is recommended that the following three community education methods are enacted for the City of Ryde LGA:

1. Council website: Council should continue to develop and expand the flood section of their website. It currently comprises of information specific to each catchment and includes links to flood studies as well as general information about preparing for floods. This could be expanded to include a general overview of flood behaviour in the LGA as well as links to emergency contacts during flood events It is also recommended that Council develops an additional page, which allows residents to upload photographs and flood information.
2. Leaflet: It is recommended that a FloodSafe leaflet is published by the SES be updated with the latest information and include specific information related to flooding in the LGA. Development of the leaflets would need to be undertaken outside of the FRMS project, as a collaborative exercise between Council and the SES, ensuring use of appropriate branding and approvals and licencing obtained where necessary. Due consideration of the sensitivity of the information is also needed, as the use of specific street names when describing affected areas may be off-putting to residents who may perceive property values are negatively affected. The leaflet could be distributed to residents via mail or at a minimum uploaded on SES and Council websites and promoted through social media and other Council announcement mediums. This could also take the form of a more modern digital format (for example, suitable for viewing on mobile phones).
3. Section 10.7 Certificates: Section 10.7 Certificates are described in detail (Section 5.3.7) and are issued by Council in accordance with the *Environmental Planning & Assessment Act 1979*. A person may request a Section 10.7 Planning Certificate at

any time to obtain information about his or her own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the *Conveyancing Act 1919* requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale. Provision of flood information to residents via Section 10.7(2) and (5) Planning Certificates can be an effective method of providing site-specific flood information to residents. Council should continue to provide the lot-specific flood information service in addition to this, where residents can request more detailed flood information specific to their property.

	RM03: Community Flood Awareness and Education
Description	• Flood awareness is a vital component of flood risk management for people residing and working in the floodplain. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, responds to, and recovers from flooding.
Responsibility	Council and SES
Outcome	It is recommended to design and implement an ongoing community flood education program to maintain a high level of flood awareness and understanding of the risk and appropriate response to flooding in the LGA. At a minimum, this should include ongoing development of Council's website as a hub for flood information, development and distribution of a leaflet and continuing to provide flood information through Section 10.7 certificates and flood advice letters.
Priority	High

5.4.4. RM04: Improvements to Driver Safety

Description

One of the key hazards associated with flooding in the study area is inundation of roads. In urban areas such as City of Ryde, the risk to life is generally low if people stay indoors. Usually, the riskiest thing to do in a flood event is drive a vehicle. It can be difficult to estimate the depth of water and velocity of flow over a road, and many people attempt to cross flooded roads, believing that the vehicle is safe to do so. Research has shown that a small car can begin to lose traction in just 15 cm of water. In urban areas, the duration of inundation is typically short, and alternative routes are often available. Flood signage can be an effective measure to inform drivers of road inundation and deter them from attempting to drive through flood waters.

Discussion

This section contains a discussion of the practical considerations that are involved when installing new flood signage on roads that are subject to inundation, in addition to suggested locations. It is recommended that an investigation be undertaken by Council to confirm the most appropriate locations for and types of flood signage, and complementary education programs to reduce flood risk most effectively to motorists and consequences to flood behaviour in surrounding areas (such as wave action and flow diversion). Flood depth signage may also act as a passive reminder to residents of the potential for flooding on local streets.

Due to the flash flooding nature of the catchments within the City of Ryde LGA, water can rise to dangerous depths and velocities before a formal road closure can be implemented and traffic rerouted safely. Flooding in the study area can cause several roadways to become overtopped, depending on the location and intensity of rainfall. In most cases, alternative safe routes can be taken, however, unless residents are aware of them, some may attempt to cross through flood waters, putting themselves and others at risk. This is particularly likely if visibility is poor during heavy rain, as water over the road is either not noticed, or the risk of driving through it is not appreciated.

A recent campaign by the Victorian Sate Government (15tofloat.com.au) highlighted that “a small car can be moved by water only 15 cm deep”. Driving through even shallow floodwater can put the driver at risk and increase the demand on SES resources (and risk to their lives) if rescue is required. It is noted that deeper water at lower velocities is also hazardous to vehicles, as identified in Reference 39, which has been used to categorise the design flood behaviour in the study area into 6 hazard categories, from H1 to H6. The hazard over roads in both the 20% AEP (representing frequent flooding) and in the 1% AEP (representing a large flood event) was checked across the entire study area. In general roads which had high hazards in the 1% AEP were identified. Consideration was also given to the nature of the road (for example, a main road compared to a cul-de-sac) and length of inundation to assess an indicative risk. A total of 17 locations were identified across the City of Ryde LGA that were considered a flood risk to road users. These are listed in Table 35 and shown in Figure 27.

Table 35: Potential Locations for Flood Warning Signage and/or Depth Markers

ID	Location	Hazard Classification in 20% AEP event	Hazard Classification in 1% AEP event
1	Lane Cove Road at Quarry Road	H1	H3
2	Princes Street near Argyle Avenue	H1	H5
3	Badajoz Road near Norfolk Way	H1	H5
4	Blaxland Road	Not Flooded (inundated in 2% AEP)	H5
5	Graham Avenue	H2	H4
6	Balaclava Road	H2	H4
7	Vimiera Road	H2	H4
8	Epping Road near Culloden Road	H3	H3
9	Bridge Road	Not Flooded (inundated in 2% AEP)	H5
10	Kent Road	H2	H5
11	Talavera Road	H1	H5
12	Wicks Road	H2	H4
13	Epping Road near Wicks Road	H3	H5
14	Brush Road	H5	H5
15	Victoria Road at Archer Creek	H1	H4
16	Victoria Road at Falconer Street	Not Flooded (inundated in 5% AEP)	H3
17	Morrison Road	H1	H4

To communicate potential flood risk to drivers, it is recommended that appropriate signage is installed at key locations. Such signage might include depth indicators, warning signs, hinged flood signs, or signs fitted with flashing lights.

Flood signs must be installed in accordance with AS1742.2-2009 *Manual of Uniform Traffic Control Devices* (Reference 40*) Part 2: Traffic Control Devices for General Use*, which stipulates that *"The 'ROAD SUBJECT TO FLOODING, INDICATORS SHOW DEPTH' sign shall be erected on the left side of the road on which Depth Indicators are used, to advise drivers that the road ahead may be covered by floodwaters…the NEXT x km sign may be used in conjunction with this sign when there are two or more floodways ahead, not more than 2km apart." (Clause 4.10.6.9)*

Where flood depths are more than 1.5 m, the G9-22-1 depth indicator sign is to be used (refer to Diagram 20).

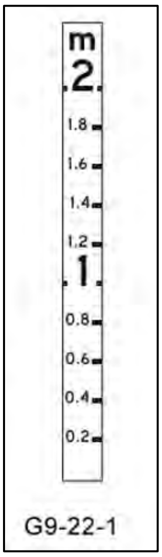


Diagram 20: G9-22-1 Flood Depth Indicators (Reference 40)

Where special attention is required due to the “extreme severity of the hazard to which they refer, or lack of adequate sight distance to the hazard, or a combination of the two”, flashing lights can be set up alongside the warning signs. The flashing lights must comply with the requirements of AS2144 and consist of 200 mm diameter traffic signal lanterns flashing at a rate of 40 to 60 flashes per minute with the light on for 40 to 60% of the time (Reference 40). An example is provided in Diagram 21.

Diagram 21: Examples of Warnings Signs with Flashing Lights (Reference 40)

With the potential for Council resources to be focused on storm-related responses (e.g. debris removal from roads), it is recommended that where possible, flood signs that require manual activation are not installed. Instead, warning signs and/or depth indicators (with or without automated flashing lights), that can give information to or warn drivers, without increasing the burden on Council’s staff are likely to be preferable. Depending on the location and size of the event, installation of depth indicators or warning signs will not replace the need for Council to formally close roads, though they may assist in dissuading drivers to enter flood waters before the road is officially closed.

Placement of depth markers in an overland flow area requires careful consideration. If depth markers are placed where flooding is short-lived or shallow, they may be dismissed, which may lead to drivers ignoring depth markers at roads overtopped by fast flowing water. In addition, residents may be concerned that installation of depth markers or other flood warning signs may detract from the amenity of their area, and/or perceived to affect property values. Conversely, if road closure signs are left out for hours or days after water has drained away, drivers are likely to ignore the signs and drive through. This may lead to future complacency or dismissiveness when the road is flooded.

Installation of depth markers or other flood signs should be undertaken in conjunction with extensive community education, for three key reasons:

- to ensure drivers understand what the depth marker shows (i.e. depth of water over road),
- to educate the community about the potential flood risk associated with water at that depth, and the danger of driving through even shallow water, as velocity can be hard to judge, and
- to educate the community regarding the potential consequences to flood behaviour such as wave generation, flow diversion and impacts on property.

Recommendations relating to community flood education and awareness are provided in Section 5.4.3.

Summary and Recommendation

	RM04: Improvements to Driver Safety
Description	Installation of flood signs and flood depth indicators can improve driver safety, in conjunction with community education about the risks of driving through floodwaters.
Responsibility	Council
Outcome	Specific locations have been identified as potential flood sign locations. Further consideration of the factors discussed above is needed to identify the most appropriate type of sign, specific placements and accompanying community education needed to convey flood risk most effectively to motorists. It is recommended that a detailed study is undertaken to confirm the preferred locations, residual flood risk (i.e. need for road closure) and safe alternative routes and how traffic can be diverted in flood events. Following the detailed study, installation can proceed in accordance with the outcomes of that study.
Priority	High

5.4.1. RM05: SES Local Headquarters Emergency Access

Description

The NSW SES is the designated combat agency for floods, storms and tsunami and controls response operations. The SES is the main responder during a flood event and executes evacuation and rescue operations. The SES local headquarters for City of Ryde is located at 137 Wicks Road, Macquarie Park, which is on the eastern side of the M2. While the SES headquarters itself if flood free in the 1% AEP event, it is inundated by more than 3 m in the PMF event. As events between the 1% AEP and the PMF event has not been model as part of this study, it is not clear at which flood event will the SES headquarter begin to be flood affected.

As the SES is the main responder during flood events, access to the headquarters should have a high level of flood immunity. Currently, the SES headquarters is only accessible to the rest of the City of Ryde LGA via Wicks Road. However, there is a low point at Wicks Road (at the M2 underpass) which is inundated even in frequent events and prevents access to the rest of the LGA. In the 10% AEP event, the hydraulic hazard at the Wicks Road low point is H2 (unsafe for small vehicles) to H3 (unsafe for vehicles, children and the elderly) and in the 1% AEP, the hydraulic hazard is H4 (unsafe for people and vehicles).

Discussion

The emergency access to SES local headquarters has been discussed in previous studies (Reference 11) and a number of options to improve access were considered. These options were:

1. Drainage upgrade along Wicks Road over 520 m of pipeline to twin 2.4 m width by 1.8 m height box culverts.
2. Construct a detention basin at the southwestern corner of Wicks Road at the M2 underpass. This option involves significant pipework to direct flows to the basin.
3. Debris control structures at the M2 culvert inlet to reduce the potential for overflow to the Wicks Road low point.
4. Alternative gated emergency access track from the SES headquarters to the M2

Option 1 above was rejected in high level assessment as it was difficult to justify economically and unlikely to provide sufficient capacity across a range of events. The low point at Wicks Road is located away from most properties and there are few properties which would benefit from drainage upgrade along Wicks Road. Therefore, it has insignificant flood benefits and has a near zero cost benefit ratio (when assessing tangible flood damages). Furthermore, the effectiveness of drainage upgrades is dependent on the capture of overland flow into the pipe network. Unless the pipeline has capacity to capture and convey all runoff up to the PMF event, remaining overland flow will eventually flow into the Wicks Road low point and still restrict emergency access to the SES local headquarters.

Option 2 was tested in the TUFLOW hydraulic model (summarised in Option 72.2 in Table 14) and was found to be ineffective in reducing flood hazards at the low point. Option 3 was rejected in the high level assessment as it is unlikely to provide sufficient capacity across a range of events.

Of the above, Option 4 presents the most reliable alternative for improving emergency access to the SES local headquarters and was recommended as a high priority measure in the previous study (Reference 11). Construction of an alternative emergency access track from the SES local headquarters to the M2, which is above the PMF flood extent, will improve the flood response during rare flood events. Google Street View and aerial imagery show that approximately 500 m north of the Wicks Road underpass along the southbound lane is an existing gated access onto the M2. This was likely to provide access from 160 Wicks Road, which was previously a material stockpiling and storage yard for the City of Ryde and now converted to an additional construction support site for the Warringah Freeway Upgrade Project. Aerial imagery and ground elevation data show that there is a local depression in the terrain just near this gate, such that flood hazards in the 1% AEP in the depression is H4. While this gate is accessible in the 1% AEP event (with some vegetation clearing), the gate is inaccessible in the PMF event, as flood hazards reach are H3 and higher across most areas. Therefore, an alternative emergency access, which connects the SES to the southbound lanes of the M2 on the south side of Wicks Road and allows SES vehicles to take the off ramp at Delhi Road, is recommended. The road alignment is depicted in Diagram 22 and is approximately 160 m long and passes through the western boundary of the Macquarie Park Cemetery. From the off-ramp, Delhi Road to the east, Pittwater Road to the south, Epping Road to the west and the M2 to the north are accessible. This emergency access track should be gated with restricted access for SES only. Access to the broader City of Ryde LGA remains constrained by the route access of local roads.

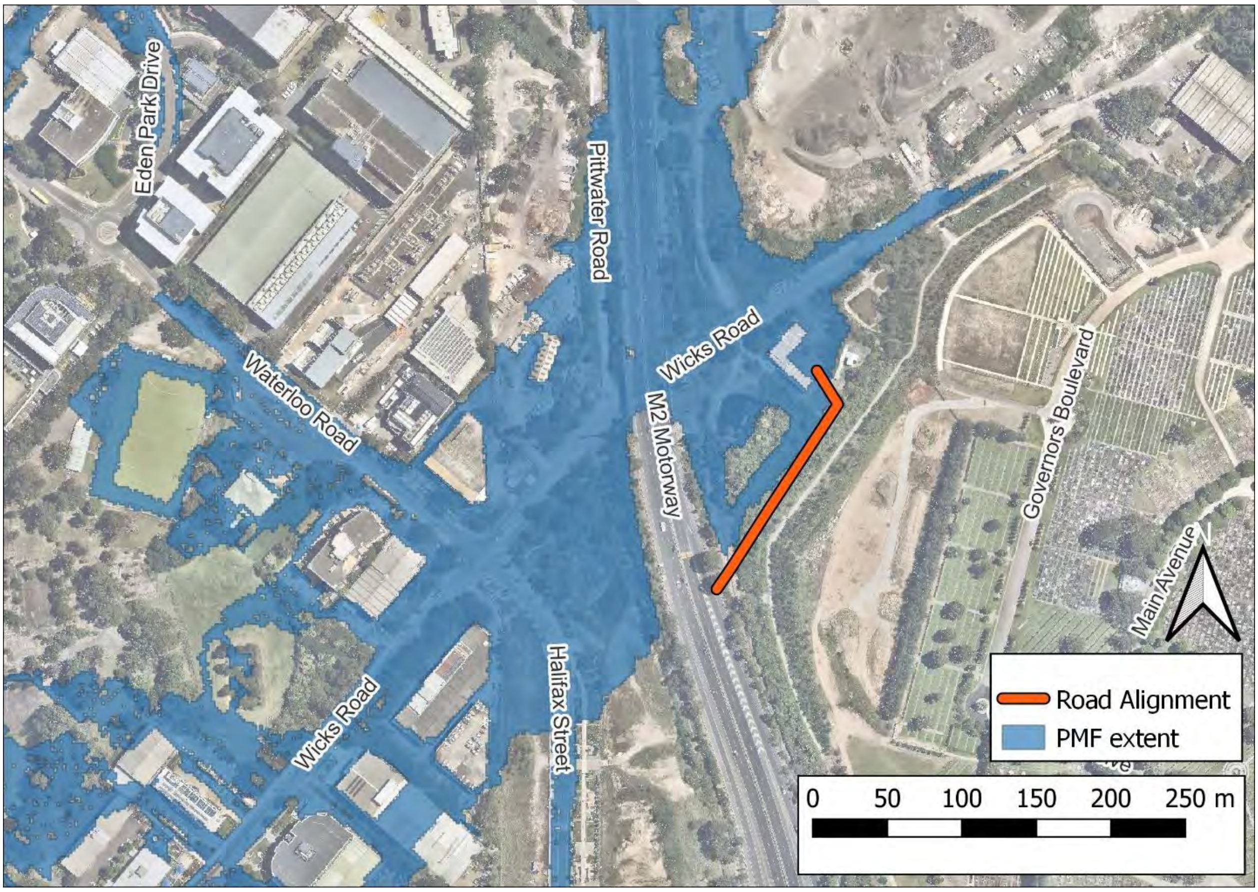


Diagram 22: Emergency Access Route from SES Headquarters to M2 Motorway.

Summary and Recommendation

	RM05: SES Local Headquarters Emergency Access
Description	Construction of an additional emergency access track from SES headquarters to the Delhi Rd off ramp of the M2
Responsibility	SES and TfNSW
Outcome	While access to the broader LGA remains constrained by the route access of local roads, emergency access to the SES is greatly improved.
Priority	High

6. MULTI-CRITERIA MATRIX ASSESSMENT

The Floodplain Development Manual (Reference 2) recommends the use of multi-criteria matrix assessment (MCMA) when comparing flood risk mitigation measures. An MCMA provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a cost-benefit analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCMA will not give a definitive ‘right’ answer. Rather, it provides a tool to debate the relative merits of each option.

6.1. Scoring System

A scoring system has been devised to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into key areas such as flood behaviour, economic, social and environmental considerations. Scores for each criterion are to be 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 positive and negative aspects. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in several criteria and should not be considered further. The scoring system is provided in Table 36, and the outcomes of the assessment shown in Table 37. Discussion of the results is provided in Section 6.3.

Table 36: Multi-criteria Matrix Assessment – Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	Comparison of the economic benefits against the capital and ongoing costs (BC may be estimated)	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 Feasibility	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	Long term performance	Maintenance burden, design life	Significant increase requiring additional resources and / or <10 year design life	Moderate increase in maintenance requirements, <20 year design	Minor increase in maintenace requirements	No change	Can be incorporated in current planned maintenance	Some reduction to current maintenance requirements, > 30 year design life	Some reduction to current maintenance requirements, > 30 year design life
Economic	Staging of works	Ability to stage 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	Road 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	Climate Change Adaptability	Performance under future climate change conditions, contribution to mitigation of or adaptation to changing climate	Increases risk	Benefits entirely eroded in future	Benefits partially eroded in future	Neutral	Provides some mitigation to changing climate	Provides moderate mitigation to changing climate	Entirely mitigates changing climate
Social	Social disruption	Closure of or restricted access to community facilities (including recreation)	Normal access significantly reduced or facilities disrupted for > 1 day	Normal access routes moderately reduced or facilities disrupted for 6-24 hours	No change to access but facilities disrupted for up to 6 hours	No Change	Reduces duration of access disruption or facility disruption by up to 6 hours	Reduces duration of access disruptioin or facility disruption by 6-24 hours	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	Environmental and Ecological Impacts	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/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
Environmental	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
Other Aspects	Compatibility with existing Council plans, policies or projects	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

Notes:
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 37: Multi-criteria Matrix Assessment – Results

			Economic				Social									Environmental			Other			
Category	ID	Detailed Assessment Options	Economic Merit	Technical Feasibility	Long Term Performance	Staging of Works	Impact On Emergency Services	Road Access	Impact On Critical and/or Vulnerable Facilities	Impact On Properties	Impact On Flood Hazard	Community Flood Awareness	Climate Change Adaptability	Social Disruption	Community and Stakeholder Support	Impacts On Flora and Fauna	Heritage Conservation Areas and Heritage Items	Acid Sulfate Soils and Contaminated Land	Financial Feasibility and Funding Availability	Compatibility With Existing Council Plans, Policies, or Projects	Total Score	Overall Rank
Flood Modification Measures	M003	Gannan Park Basin	-2	1	1	0	1	1	0	2	1	0	1	-2	0	-1	0	0	1	1	5	22
	M008	Drainage Upgrade Along Buffalo Rd	NOT RECOMMENDED																		NA	NA
	M016 & M017	Eastwood Drainage Tunnel	NOT RECOMMENDED																		NA	NA
	M027	First Avenue Drainage Upgrade	-1	1	1	0	1	1	0	3	1	1	1	-1	0	0	0	0	1	2	11	12
	M036	Jim Walsh Park Basin	3	-1	1	0	2	2	0	3	1	0	1	-2	0	-2	0	0	1	1	10	13
	M051	Kotara Park Basin	3	-1	1	0	1	0	0	1	1	0	1	-2	0	0	0	0	1	1	7	20
	M057	Smalls Park Basin	-1	-1	1	0	1	1	0	2	0	0	1	-2	0	-1	0	0	2	1	4	23
	M061	North Ryde Golf Club Basin	3	-2	1	0	1	1	0	1	0	0	1	-2	0	0	0	0	2	1	7	20
	M073	Diversion Drain at Pittwater Rd	0	1	1	0	2	1	0	0	2	0	1	1	0	-1	0	0	1	1	10	13
	M084	Drainage Diversion to West Ryde Tunnel	2	-2	1	0	1	1	0	2	1	0	1	0	0	0	0	0	1	1	9	18
	M089	Lions Park Basin	-2	-2	1	0	1	1	0	3	0	0	1	-2	0	-1	0	0	1	1	2	25
	M094	Pickford Ave and Lovell Rd Intersection	3	-2	-1	0	0	0	0	2	0	0	1	0	0	-1	0	0	1	1	4	23
	M101	Boyce St Drainage Upgrade	-1	-2	-1	0	0	1	0	1	0	0	0	0	0	-1	0	0	1	1	-1	26
	M102	Channel and Drainage Maintenance	1	2	0	0	0	1	0	0	1	1	1	0	0	0	0	0	1	2	10	13
	M103	Drainage Capacity Upgrade	NOT RECOMMENDED																		NA	NA
	M104	Channel Upgrade	NOT RECOMMENDED																		NA	NA
Property Modification Measures	PM01	Voluntary House Raising	0	-1	0	0	1	0	0	3	0	1	3	0	0	0	0	0	1	1	9	18
	PM02	Voluntary Purchase	-3	-1	3	0	2	0	0	3	0	1	3	0	0	1	-1	0	1	1	10	13
	PM03	Flood Proofing	3	1	0	3	2	0	2	3	1	1	0	2	0	0	0	0	3	2	23	2
	PM04	Flood Planning Levels	3	3	1	0	1	0	3	3	1	1	2	0	0	0	0	0	2	3	23	2
	PM05	Flood Planning Area	3	3	1	0	1	0	1	3	0	1	2	0	0	0	0	0	2	3	20	5
	PM06	Flood Planning Policy	3	3	1	0	0	0	3	3	1	1	2	0	0	0	0	0	2	3	22	4
	PM07	Section 10.7 Certificates	3	3	1	0	0	0	0	3	0	2	2	0	0	0	0	0	2	3	19	8
	PM08	Climate Change Policy	3	3	2	0	1	1	2	3	1	2	3	0	0	0	0	0	2	1	24	1
	PM09	Commercial property drainage	3	2	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	10	13
Response Modification Measures	RM01	Flood Emergency Management Planning	3	3	1	3	3	0	0	0	0	1	2	0	0	0	0	0	2	2	20	5
	RM02	Flood Warning Systems	2	3	0	1	1	0	0	0	0	2	2	0	0	0	0	0	1	2	14	11
	RM03	Community Flood Awareness and Education	2	3	0	3	3	0	0	0	0	3	2	0	0	0	0	0	1	3	20	5
	RM04	Improvements to Driver Safety	1	2	0	2	3	0	0	0	1	2	2	0	0	0	0	0	1	2	16	9
	RM05	SES Local Headquarters Emergency Access	3	1	1	0	3	0	3	0	0	0	3	0	0	-1	0	0	2	0	15	10

Note: Community and stakeholder support scores will be completed following Public Exhibition

6.2. MCMA Results

The results of the multicriteria assessment are provided in Table 37, with each of the assessed management measures scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis, which stakeholders can then use to make a decision.

For the same reason, the total score given to each option, is only an indicator to be used for general comparison. Options with positive scores indicate that the benefits of the option outweigh negative aspects. These options have been recommended for inclusion in the Floodplain Risk Management Plan.

6.3. Discussion of MCMA Results

The multi-criteria matrix assessment results, presented in Table 37, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Property Modification Measures related to policy changes or updates ranked the highest, as they are cost effective methods to reduce property damages in the study area, and have additional benefits relating to improvements to community flood awareness.
- Response Modification Measures also rank higher than Flood Modification Measures, as they also are relatively cost-effective to implement and can have substantial impact on the preparedness for floods, as well as changes to the actions and attitudes of the community.
- Flood Modification Measures rank the lowest, with varying degrees of benefits and disbenefits across the range of criteria assessed.

The results of the MCMA have been used to identify a priority list of options, shown in Table 38.

Table 38: Rank of Flood Risk Mitigation Measures

Rank	Option	Priority
1	PM08 Climate Change Policy	High
2	PM03 Flood Proofing	High
2	PM04 Flood Planning Levels	High
4	PM06 Flood Planning Policy	High
5	PM05 Flood Planning Area	High
5	RM01 Flood Emergency Management Planning	High
5	RM03 Community Flood Awareness and Education	High
8	PM07 Section 10.7 Certificates	High
9	RM04 Improvements to Driver Safety	High
10	RM05 SES Local Headquarters Emergency Access	High
11	RM02 Flood Warning Systems	Medium
12	M027 First Avenue Drainage Upgrade	High
13	M036 Jim Walsh Park Basin	High
13	M102 Channel and Drainage Maintenance	High
13	M073 Diversion Drain at Pittwater Road	Medium
13	PM09 Commercial Property Drainage	Medium
13	PM02 Voluntary Purchase	Medium
18	PM01 Voluntary House Raising	Medium
18	M084 Drainage Diversion to West	Medium

Rank	Option	Priority
	Ryde Tunnel	
20	M051 Kotara Park Basin	Medium
20	M061 North Ryde Golf Club Basin	Medium
22	M003 Gannan Park Basin	Low
23	M057 Smalls Park Basin	Low
23	M094 Pickford Ave and Lovell Rd Intersection	Low
25	M089 Lions Park Basin	Low
26	M101 Boyce Street Drainage Upgrade	Low
NA	M008 Drainage Upgrade Along Buffalo Rd	Not Recommended
NA	M016 & M017 Eastwood Drainage Tunnel	
NA	M103 Drainage Capacity Upgrade	
NA	M104 Channel Upgrade	

This will form the basis of the Floodplain Risk Management Plan (Section 7).

7. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

The Floodplain Risk Management Plan (FRMP, Table 39) summarises the recommended measures that have been investigated as part of the FRMS. The recommended flood modification options that have a specific location are shown in Figure 24. Measures have been assessed for effectiveness against a range of criteria. The assessment criteria included how the option affected property damages, community flood awareness, impact on the SES, and economic merits, and a range of other factors. Recommended options are prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority.

The FRMP was prepared in accordance with the NSW Floodplain Development Manual (Reference 2).

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

The FRMP provides input into the strategic and statutory planning roles of Council and provides a plan for Council to effectively manage flood liable land. It lists the mitigation measures that have been recommended in the FRMS for implementation and describes the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 5 of the Study.

7.1. Funding and Implementation

There are several sources of funding for the investigation and implementation of the recommended flood risk mitigation measures. The DCCEEW offers support to local Councils through Floodplain Management Grants. Assistance under this program is usually provided at a ratio of 2:1 State Government funding to local council funding. There are also schemes such as Resilience NSW's Get Ready Program which distributes practical resource kits and supports local councils to build resilient communities and help prepare for disasters such as flooding. There are also schemes supported by the Federal Government as well that are typically channelled through the State Government.

In addition to government funding, Council could also approach other organisations (such as TfNSW and SES) or private owners (such as property developers where appropriate) to assist with funding of measures.

Implementation of the Plan should be overseen by a Floodplain Risk Management Committee. The local community should continue to be informed of progress through regular updates.

7.2. Ongoing Review of the Plan

This FRMP should be reviewed and amended as required over time. It is recommended that this occurs every 10 years at a minimum. This ensures the Plan remains relevant to the requirements of the area. Reviews can also be undertaken following flood events, or where new information becomes available that may be relevant. Changes in State or Local Government legislation or alterations to funding availability may also trigger the need for a review.

Table 39: City of Ryde Floodplain Risk Management Plan

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M027 5.2.4.7	First Avenue Drainage Upgrade	Upgrade existing stormwater line between First Avenue and Rowe Street together with demolition of 100-104 Rowe Street (partial rebuild possible).	• Reduces flood levels at the rear of Rowe Street by up to 600 mm. • Reduces flood damages. • Design already progressed.	• Primary benefit is to commercial properties only.	Council	Unlikely to be eligible for NSW Government funding as benefit is limited to commercial properties.	$3M	0.8	High
	M036 5.2.4.8	Jim Walsh Park Basin	Construct a basin by raising the existing bund and excavating a portion of Jim Walsh Park.	• Reduces flood levels residential downstream areas by up to 125 mm. • Reduces flood damages.	• Tree removal of listed species in TSC & EPBC Act required. • Social disruption as access to the park is reduced after a flood event. • Dam safety of a high embankment in close proximity to residential properties.	Council	May be eligible for NSW Government funding	$1.9M	4.6	High
	M102 5.2.5.1	Channel and Drainage Maintenance	Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels. Council should identify specific areas prone to blockage and periodically review and update these areas based on feedback from the community. Council should also inspect and record channels and drainage structures following flood events to assess debris build up and clear blockages.	• Removal of vegetation and debris blockage from structures will enable a more efficient conveyance of water.	• The major release of debris is during the storm event, and hence regular maintenance may not necessarily reduce blockage during a flood event. • Vegetation in open channels is not a significant constraint to the hydraulic capacity of the channel.	Council	Internal	N/A	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M073 5.2.4.12	Diversion Drain at Pittwater Road	Regrade road verge and construct a channel draining the low point.	• Improves flood hazard to H1 (generally safe)	• Tree removal for diversion drain	TfNSW	TfNSW / State Government	$260,000	N/A	Medium
	M084 5.2.4.13	Drainage Diversion to West Ryde Tunnel	Divert drainage from Gaza Rd into West Ryde Tunnel. This involves upgrading 15 existing pits and constructing 3 new pits	• Reduces flood levels in t% AEP and reduces flood damages	• Existing pipes run through existing properties and will require private property access	Council	May be eligible for NSW Government funding	$1.8M	0.8 to 1	Medium
	M051 5.2.4.9	Kotara Park Basin	Construct a 1.3 m maximum height embankment along the southern boundary of the Abuklea Road Tennis Courts and Kotara Park.	• Reduces flood levels in mainly frequent events and reduces flood damages.	• Minimal impacts in rare events. • Increases flood levels in some locations and will require mitigation strategies • Dam safety concerns due to proximity to residential properties • Social disruption from restricted access during and after food events.	Council	May be eligible for NSW Government funding	$156,000	13.3	Medium
	M061 5.2.4.11	North Ryde Golf Club Basin	Construct a basin in North Ryde Golf Club by raising a 1 m high bund along the eastern boundary.	• Reduces flood levels downstream over a large area	• Minor benefits to property impacts • Requires liaison with North Ryde Golf Club • Flood levels and extent increased in golf course directly upstream of the embankment	Council/North Ryde Golf Club	May be eligible for NSW Government funding	$97,000	12.7	Medium

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	M003 Section 5.2.4.4	Gannan Park Basin	Construct a basin with a 1 m high bund running along the southwestern and southeastern boundary of Gannan Park.	• Reduces road inundation on Berripa Close. • Reduces property impacts for several properties on Berripa Close.	• Increases flood levels in Minga St properties • Social disturbance as the park may be inaccessible after flood events • Relocation or raising of park amenities may be required	Council	May be eligible for NSW Government funding	$4M	0.3	Low
	M057 5.2.4.10	Smalls Park Basin	Construct a basin in Smalls Park by raising a 1 m high bund along the northwestern and northeastern boundary.	• Reduces flood levels by 150 mm and reduces property impacts	• Access to park disrupted during and after flood events.	Council	May be eligible for NSW Government funding	$480,000	3.7	Low
	M094 5.2.4.15	Pickford Avenue and Lovell Road Intersection	Divert overland flows from properties into a reserve along Orange Street.	• Reduces flood levels in properties and property damages	• Requires mitigation options to management flooding within the reserve and along Orange St	Council	May be eligible for NSW Government funding	$190,000	10.8	Low
	M089 5.2.4.14	Lions Park Basin	Construct a basin by excavating the oval within Lions Park by 1 m. This option involves a drainage channel which directs water into the basin as well as a bund which prevents flows from entering adjacent residential properties.	• Reduce flood levels within residential properties and reduces property damages	• Available storage within the park is constrained by existing park amenities.	Council	May be eligible for NSW Government funding	$1.3M	0.4	Low
	M101 5.2.4.16	Boyce Street Drainage Upgrade	Upgrade 150 m length of pipes under and downstream of Boyce Street.	• Reduces flood levels by 0.4 m in properties along Boyce St	• Potential underground utilities that may need to be avoided or relocated, as well as tree roots. • Disruption to traffic and residents on Boyce St during construction. • Flood levels increases in properties downstream of the	Council	May be eligible for NSW Government funding	$2.3M	0.3	Low

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
					pipe upgrade will required mitigation					
Property Modification Measures	PM08 5.3.8	Climate Change Policy	A climate change policy guides Council's operations and policies at a high level. This would likely feed into other Council operations such as coastal management, asset design, flooding and planning controls. Climate change adaptation should also be considered at an LGA-wide scale.	• Ensures future climate and sea levels are incorporated into current planning controls and infrastructure design.	• Uncertainties in future climate and sea level predictions. The changes expected for future rainfalls and runoff response is largely unknown.	Council	Internal	N/A	N/A	High
	PM03 5.3.3	Flood Proofing	Flood proofing of non-residential buildings with temporary flood barriers (both existing and new structures, where floor levels are allowed to be lower). This could also be extended to existing residential development, but not recommended for new residential development – floor level controls should be applied instead.	• Reduce flood damages in the event of a flood	• Costs and implementation of flood proofing measures are the responsibility of the property owner / business.	Council (policy) and property owners (cost of flood proofing)	Internal (policy) Private (flood proofing)	Varies	N/A	High
	PM04 5.3.4	Flood Planning Levels	The current adopted FPL is considered appropriate. It is recommended to update flood levels based on the updated modelling developed as part of this FRMS&P and consider incorporating climate change projections into FPLs.	• Ensures new buildings are protected to an appropriate level.	• A freeboard of 500 mm in overland flow areas may be excessive given the scale in the range of flood events.	Council	Internal	N/A	N/A	High
	PM06 5.3.6	Flood Planning Policy	Flood planning policy is typically governed by the LEP and DCP, which outline flood-related development controls. Consideration	• Ensures adequate flood planning controls to reduce the flood damage and risk to life for	• Clarity in planning controls and their application to ensure adherence.	Council	Internal	N/A	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Property Modification Measures			should be given to the following: • Inclusion of climate change in the full range of flood related development controls. • Implementation of the draft DCP. • Provision of special flood considerations clause in the LEP.	new developments.						
	PM05 5.3.5	Flood Planning Area	It is recommended to retain the current lot-based tagging approach, and update the tagging status based on the updated modelling undertaken as part of this FRMS&P.	• Ensures that flood planning controls are applied to lots that are flood affected.	There are issues with the traditional approach of applying freeboard and 'stretching' the surface to identify the FPA, particularly with steep overland flow paths in urban areas.	Council	Internal	N/A	N/A	High
	PM07 5.3.7	Section 10.7 Certificates	Section 10.7 Certificates are required to show flood notation. This informs the land owner of flood risk and applicable development controls.	• Informs land owners of flood affectation of the lot and applicable flood planning controls.	• Typically only accessed for the purpose of redevelopment or in the sale/purchase of land.	Council	Internal	N/A	N/A	High
	PM09 5.3.9	Commercial Property Drainage	Identify commercial and industrial properties which may benefit from increased flood conveyance and flag these properties for further assessment when it is being redeveloped.	• Allows for opportunities of greater flood benefits for upstream drainage upgrades • Improves flow conveyance across the commercial property	• Commercial properties along the same watercourse are unlikely to be redeveloped at the same time and there may only be partial benefits until the entire length of conduit is upgraded.	Property Owner to consider upgrades. Council to compile register of identified properties.	Private – drainage upgrades) Internal – compilation of properties.	N/A	N/A	Medium
	PM02	Voluntary Purchase	Purchase existing properties to remove them from high hazard if	• Reduces exposure to flood damage	• High cost of properties in the current housing market	NSW State, Council and	NSW State	>$2M per property	>1	Medium

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
	5.3.2		they are eligible. Two properties recommended for feasibility study.	• Reduces exposure of residents and rescuers from high flood hazard	reduces economic viability, opposition from land owners and minimal properties in high hazard areas.	Owners				
	PM01 5.3.1	Voluntary House Raising	Physically raise existing dwelling structures above the FPL. Four properties recommended for feasibility study	• Reduces exposure to flood damage	• Construction type of housing stock in City of Ryde is typically brick/rendered, slab on ground or multi-storey buildings.	NSW State, Council and Owners	NSW State, Owner	$30,000 to $100,000	>1	Medium
Response Modification Measures	RM01 5.4.1	Flood Emergency Management Planning and Coordination	It is recommended that the SES: • Use the information and modelling developed as part of this FRMS to update their local flood plan for City of Ryde. • Consider providing an updated FloodSafe brochure or information on their website specific for the flood risk in City of Ryde. It is recommended that Council and SES: • Hold regular meetings of all responders and training exercises between flood events to identify roles and responsibilities in practice and build relationships between agencies and/or community groups.	• Flood emergency planning enables a more coordinated, timely and targeted response to flood events.	• As the interval between flood events increases, the coordination of flood response can lack attention.	Council and SES	Internal	N/A	N/A	High
	RM03 5.4.3	Community Flood Awareness	It is recommended to design and implement and ongoing community flood education program to maintain	• An informed community can better respond to	• Community education programs are typically well received by those interested in	Council	Internal with opportunities for State	Varies	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Response Modification Measures		and Education	a high level of flood awareness and understanding of the risk and appropriate response to flooding in the City of Ryde study catchments. At a minimum, this should include ongoing development of Council's website as a hub for flood information, development and distribution of a leaflet and continuing to provide flood information through Section 10.7 certificates and flood advice letters.	flood risks, including preparation for and making wise decisions during flood events.	and already aware of flood risk, and it is difficult to engage the wider community.		Government assistance.			
	RM04 5.4.4	Improvements to Drive Safety	Installation of flood signs and flood depth indicators can improve driver safety, in conjunction with community education about the risks of driving through floodwaters. It is recommended that a detailed study is undertaken to confirm the preferred locations, residual flood risk (i.e. need for road closure) and safe alternative routes and how traffic can be diverted in flood events. Following the detailed study, installation can proceed in accordance with the outcomes of that study.	• One of the primary risks for flash flooding in urban areas is motorists driving through floodwaters. This reduces that risk by warning motorists of flooded roads.	• There is the chance that these signs and warnings will be ignored by motorists.	Council and TfNSW where applicable.	Council and TfNSW, with opportunities for State Government funding.	Not Estimated	N/A	High
	RM05 5.4.1	SES Local Headquarters Emergency Access	Construction of an additional emergency access track from SES headquarters to the Delhi Rd off ramp of the M2	• Provides flood free access to and from SES headquarters. • Improved emergency access to parts of the LGA	• Access to the broader LGA remains constrained by local roads route access.	Council, SES, and TfNSW	Council, TfNSW	N/A	>1	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
	RM02 5.4.2	Flood Warning System	It is recommended that the severe weather and severe thunderstorm warnings issued by the BoM be used to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BoM, anticipating the impacts and preparing accordingly.	• Enable Council and SES to be on alert to potential flash flooding events. The community can also benefit by being aware of potential flash flooding as respond accordingly.	• Education about what these warnings means and actions that should be taken by residents in different locations is key.	Bureau of Meteorology, Council, SES.	Internal	N/A	N/A	Medium

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FIGURES

Figures

FIGURE 1
CITY OF RYDE STUDY AREA

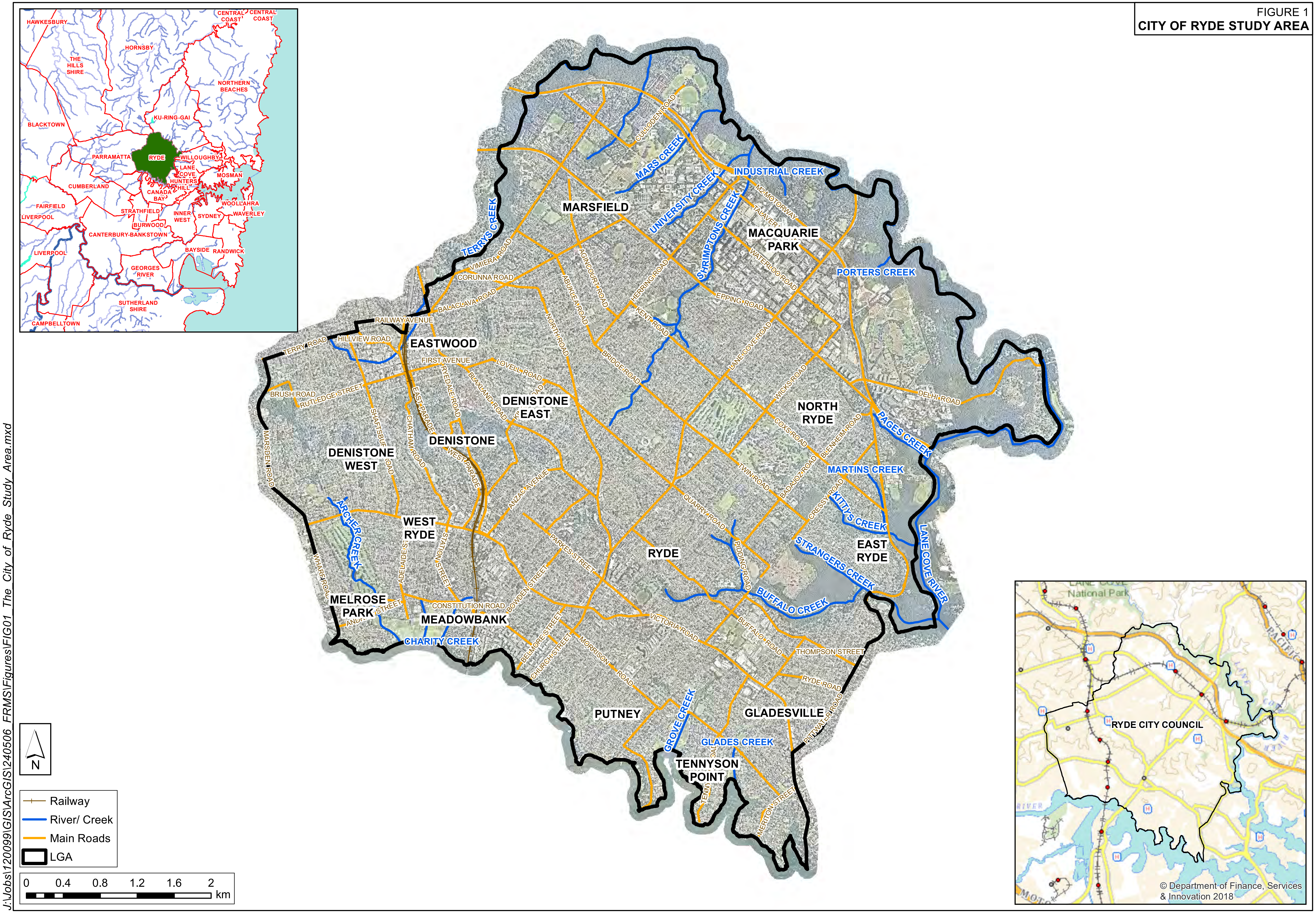
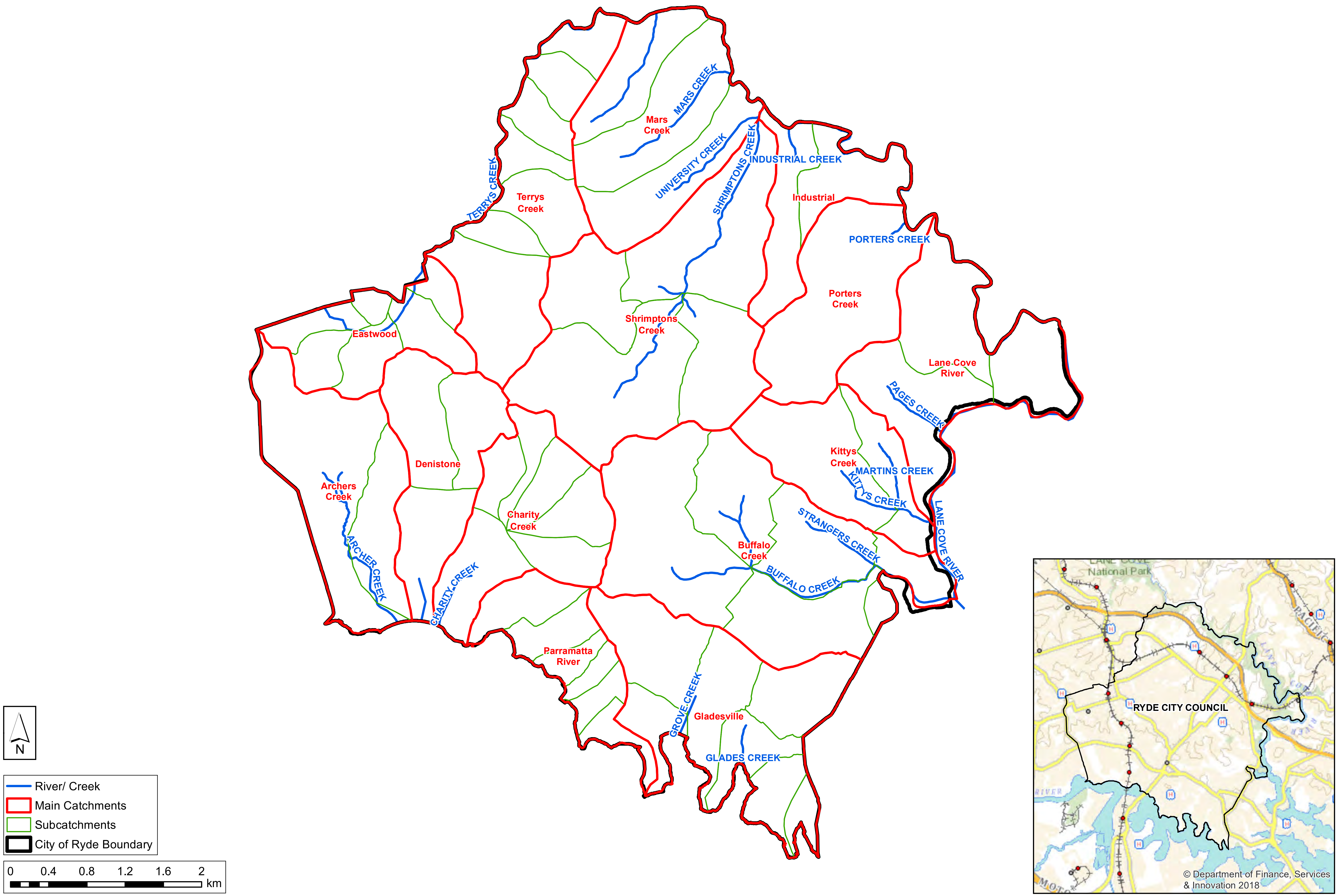


FIGURE 2
STUDY AREA CATCHMENTS



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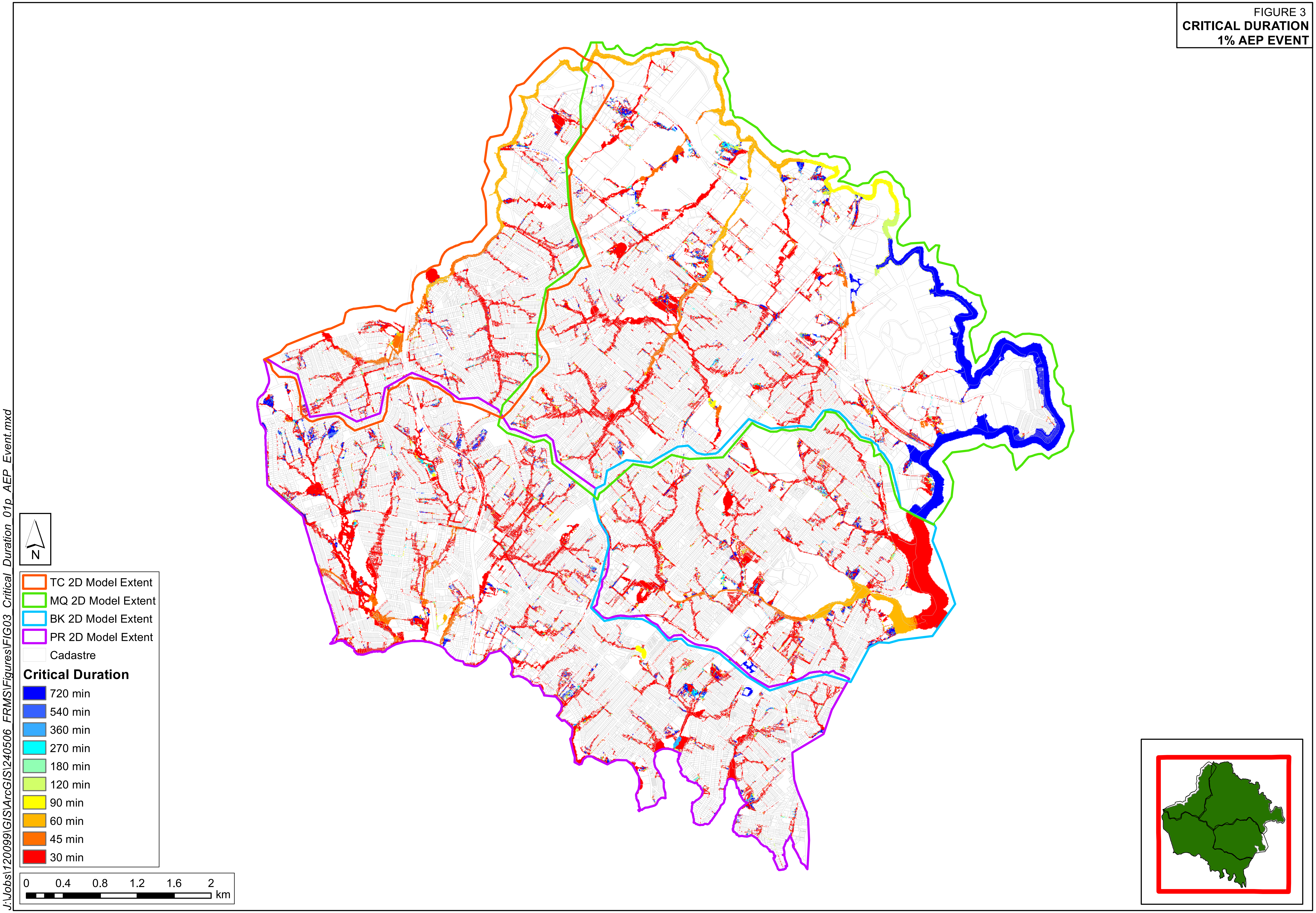

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FIGURE 3a
CRITICAL DURATION
1% AEP EVENT

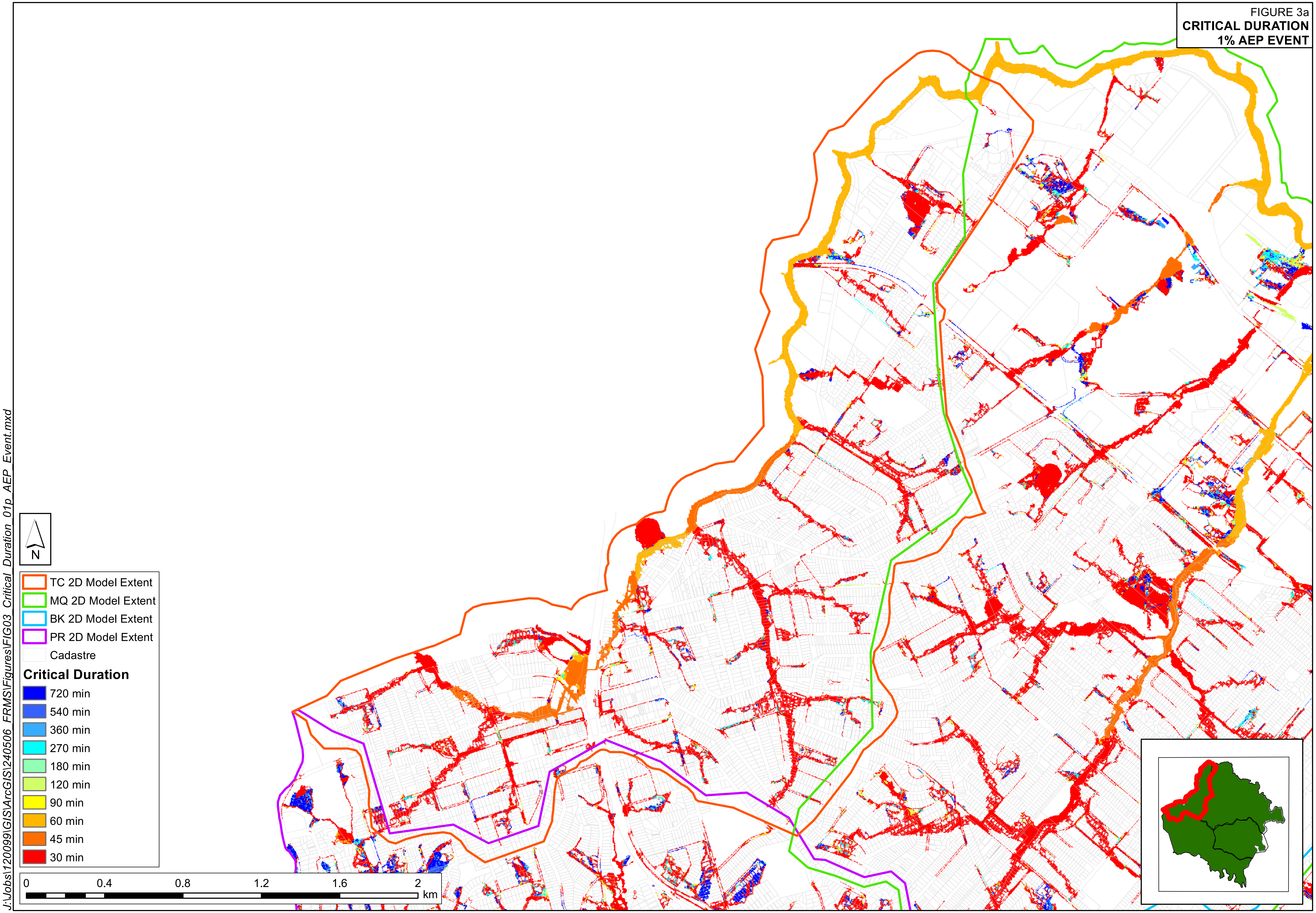

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FIGURE 3b
CRITICAL DURATION
1% AEP EVENT

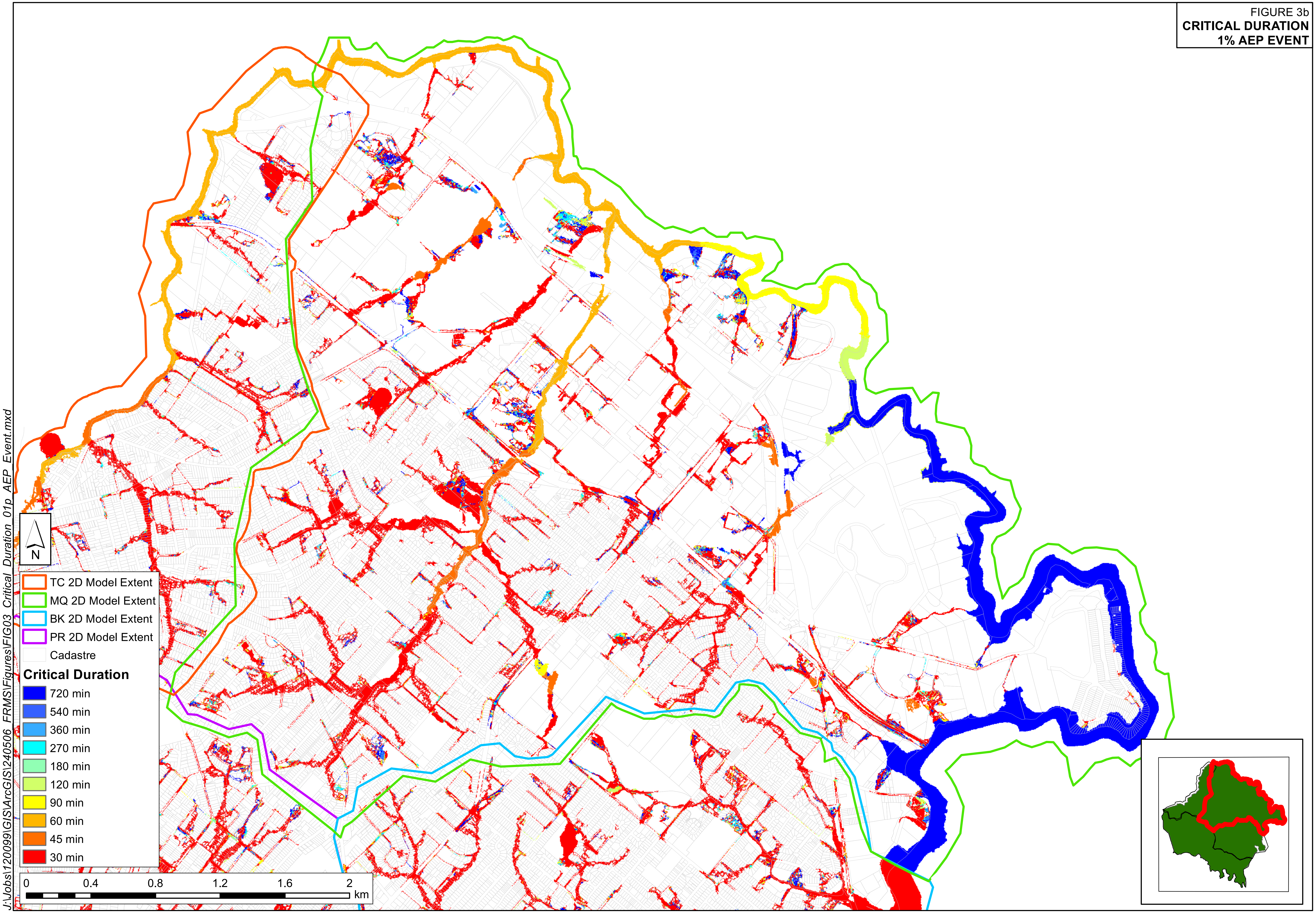

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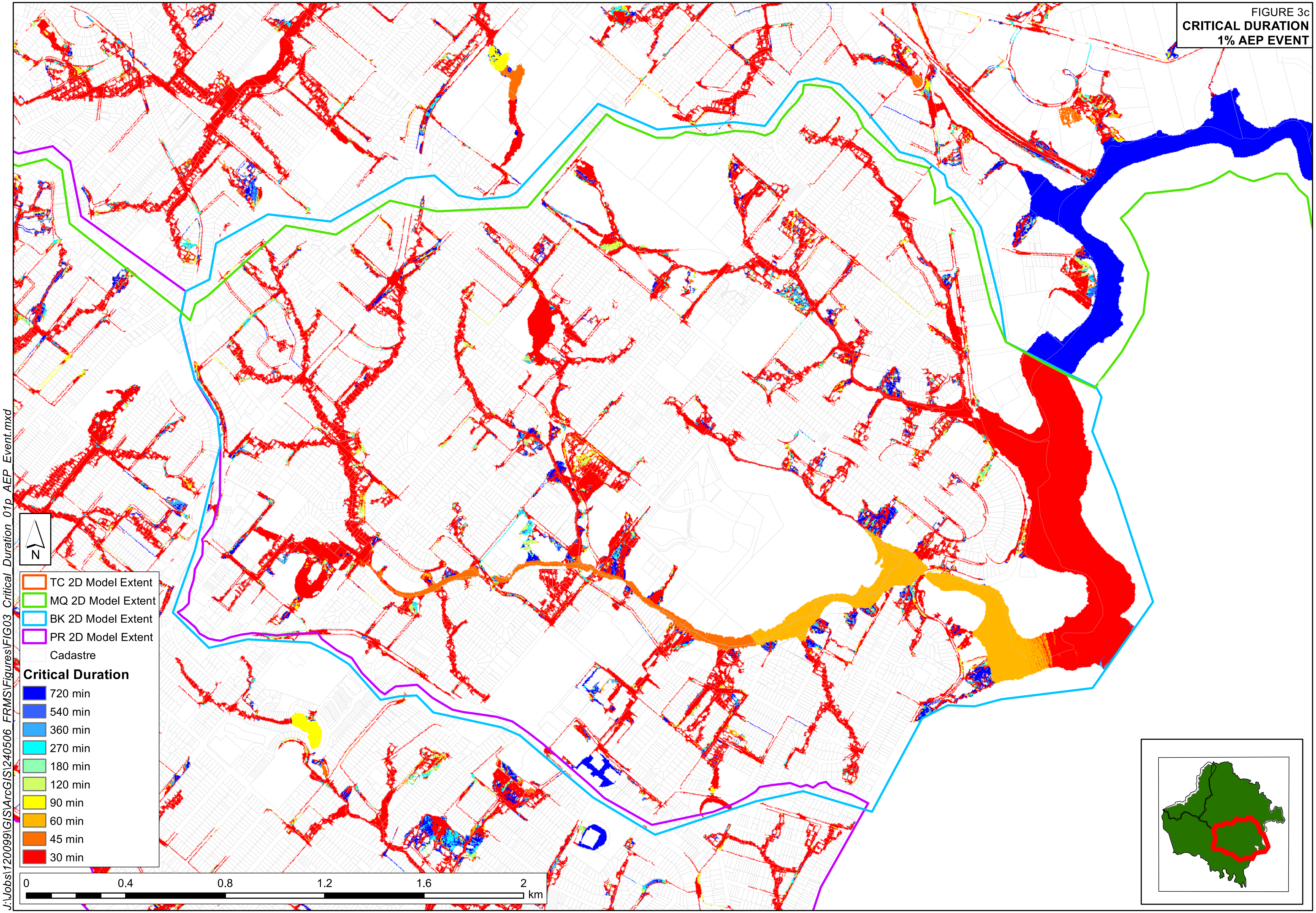
FIGURE 3c
CRITICAL DURATION
1% AEP EVENT



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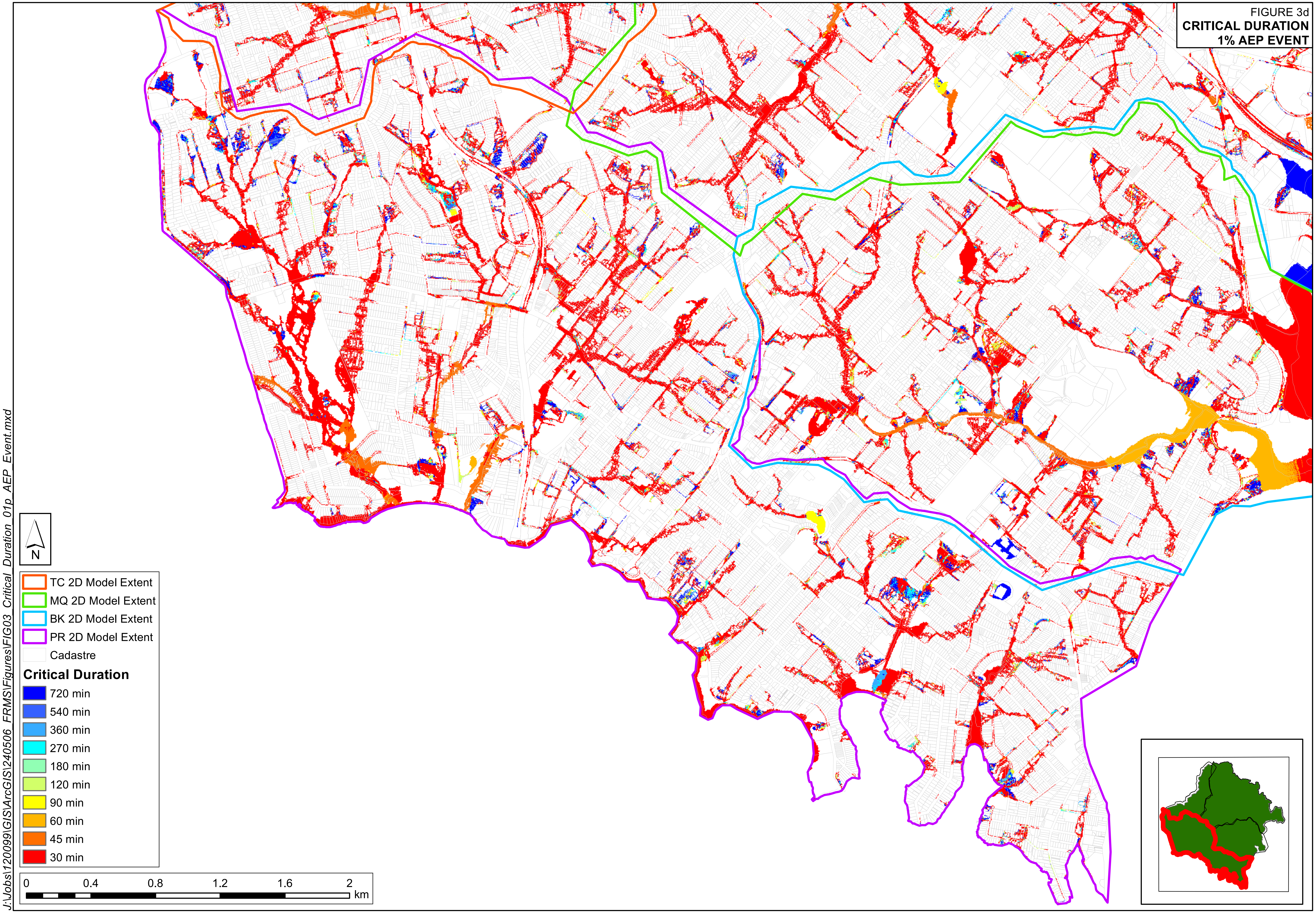

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FIGURE 4
LEVEL IN DIFFERENCE - SELECTED EVENTS VS ENVELOPED MEAN
1% AEP EVENT

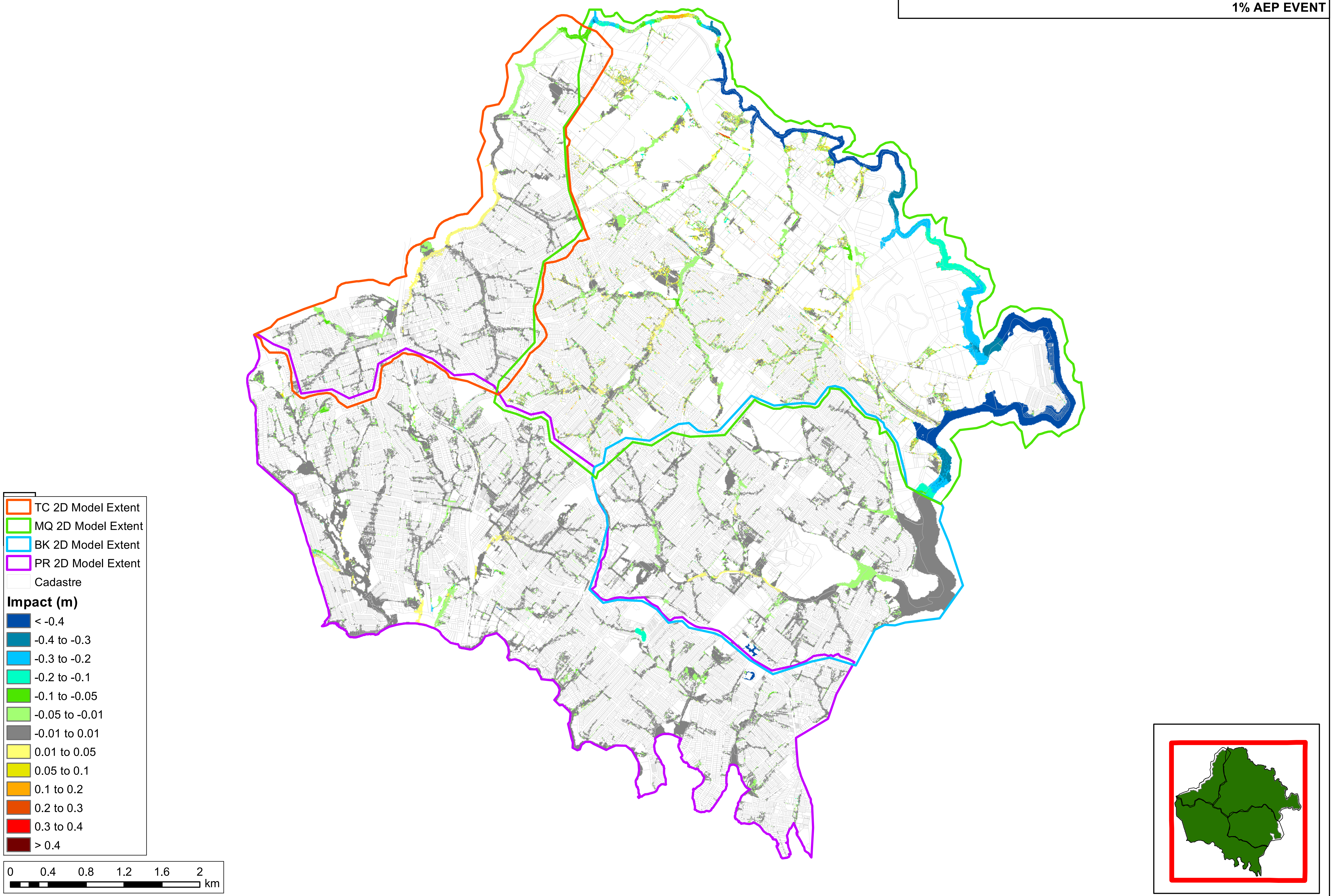

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FIGURE 4a
LEVEL IN DIFFERENCE - SELECTED EVENTS VS ENVELOPED MEAN 1% AEP EVENT

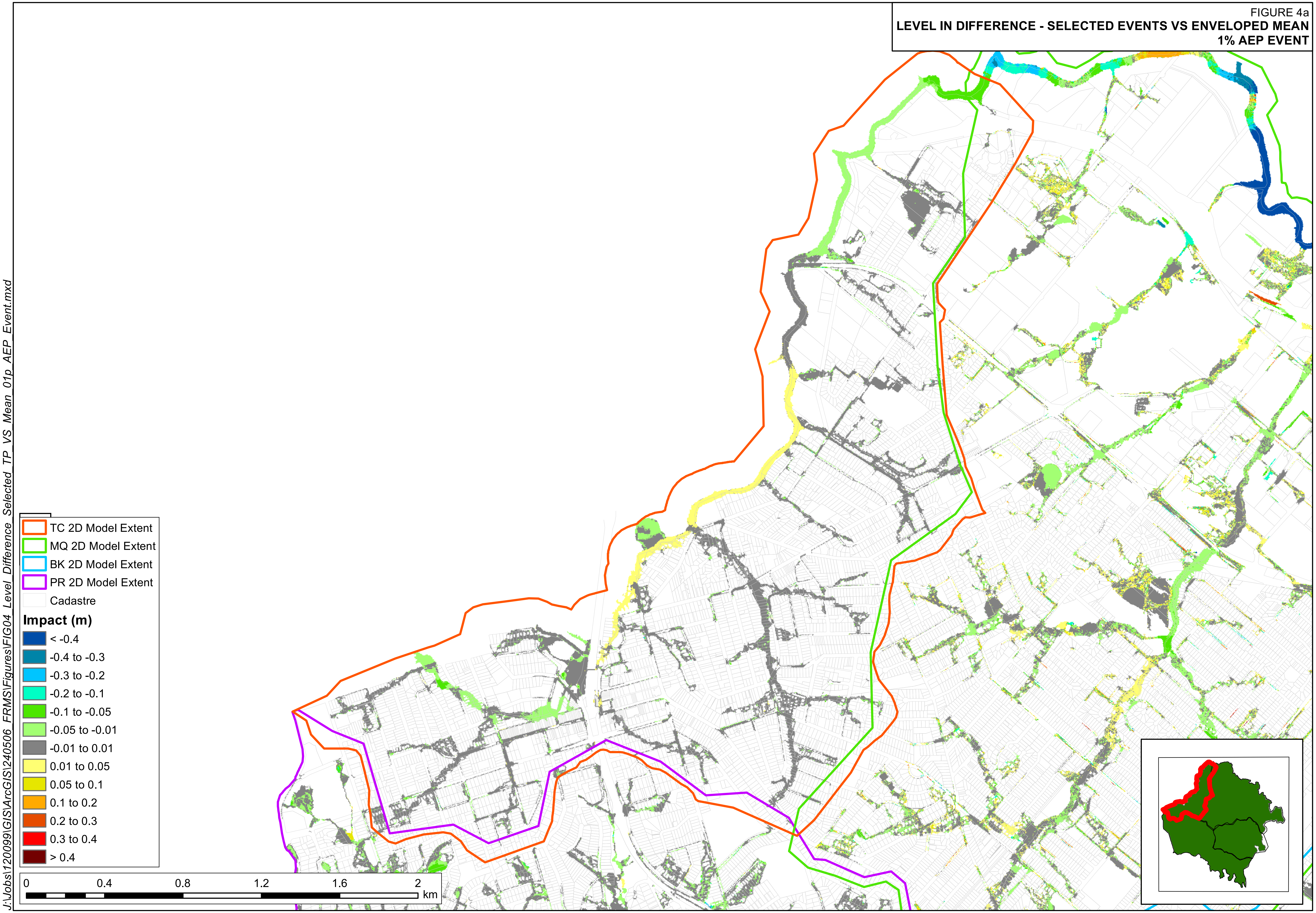

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FIGURE 4b
LEVEL IN DIFFERENCE - SELECTED EVENTS VS ENVELOPED MEAN
1% AEP EVENT

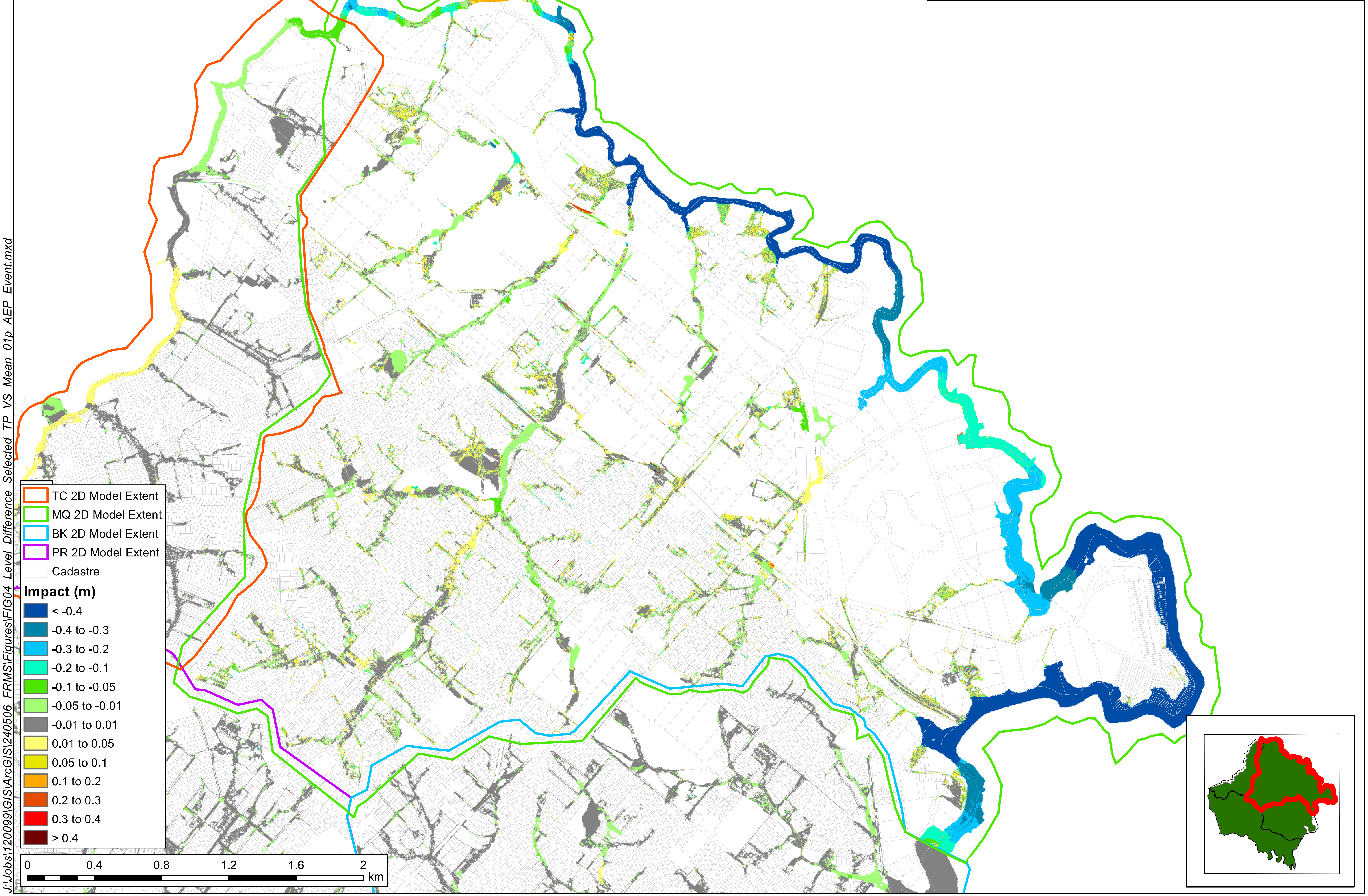

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FIGURE 4c

LEVEL IN DIFFERENCE - SELECTED EVENTS VS ENVELOPED MEAN

1% AEP EVENT

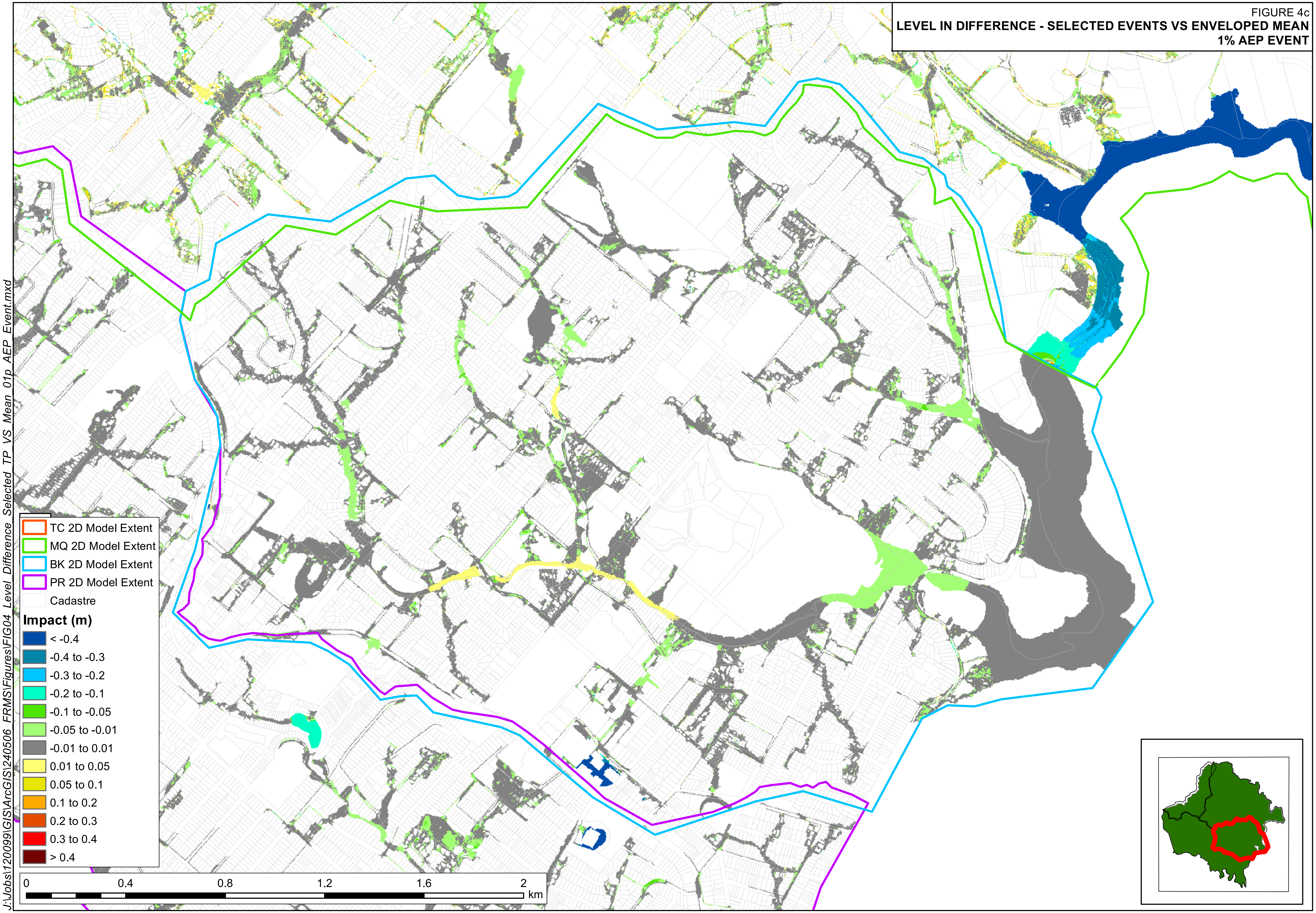
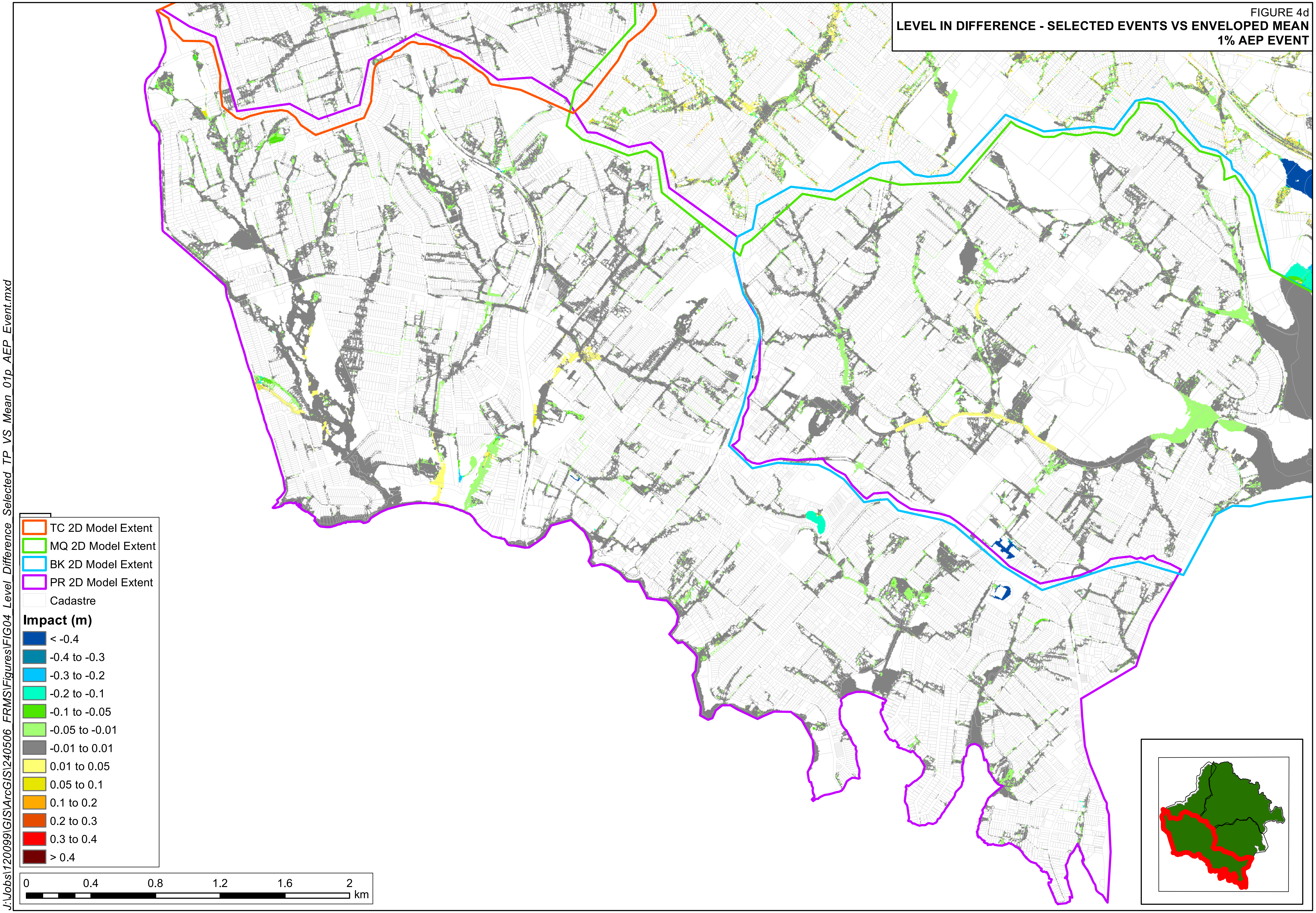


FIGURE 4d
LEVEL IN DIFFERENCE - SELECTED EVENTS VS ENVELOPED MEAN
1% AEP EVENT



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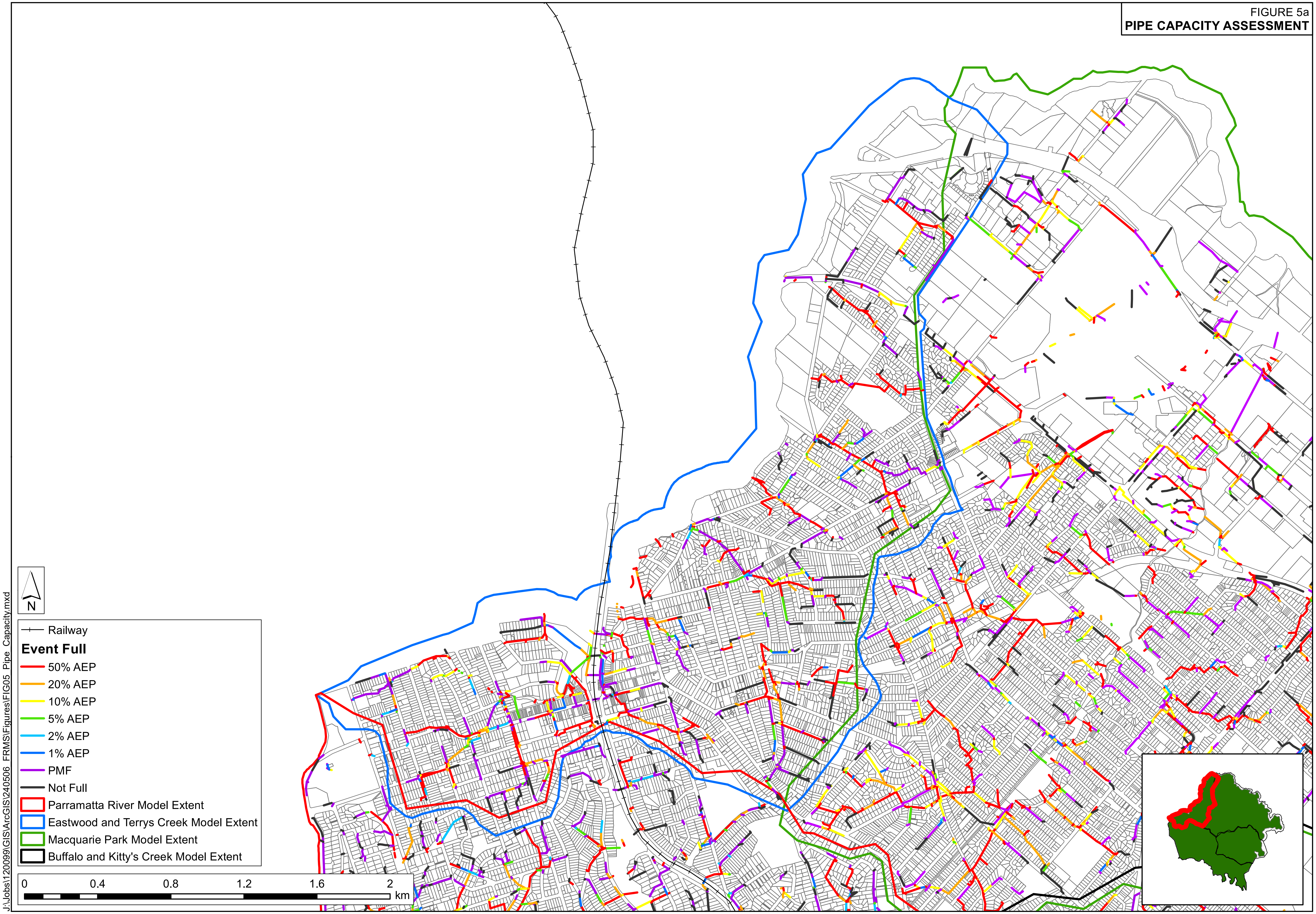

FIGURE 5a
PIPE CAPACITY ASSESSMENT
N
Railway
Event Full
50% AEP
20% AEP
10% AEP
5% AEP
2% AEP
1% AEP
PMF
Not Full
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0
0.4
0.8
1.2
1.6
2
km
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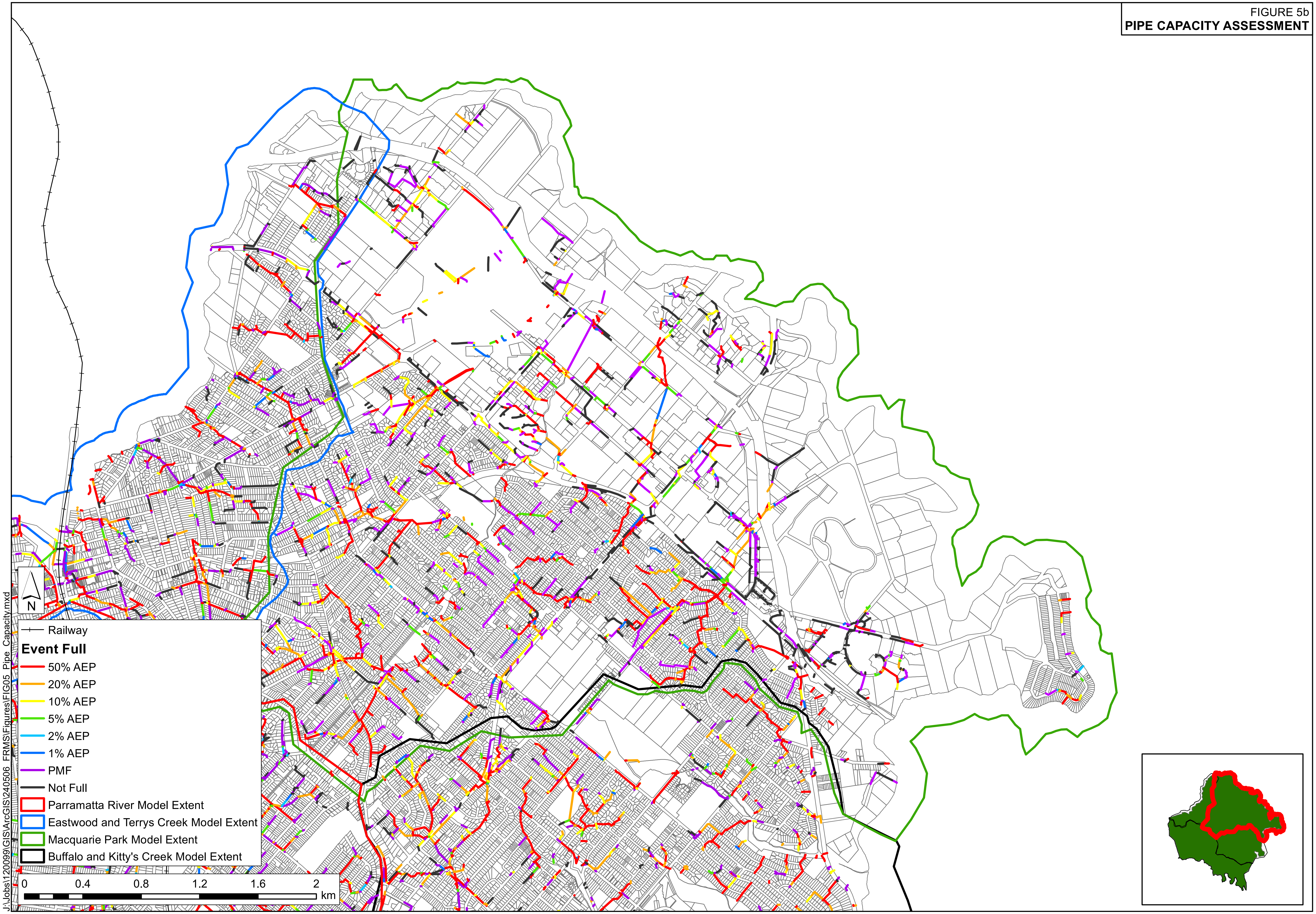

FIGURE 5b
PIPE CAPACITY ASSESSMENT

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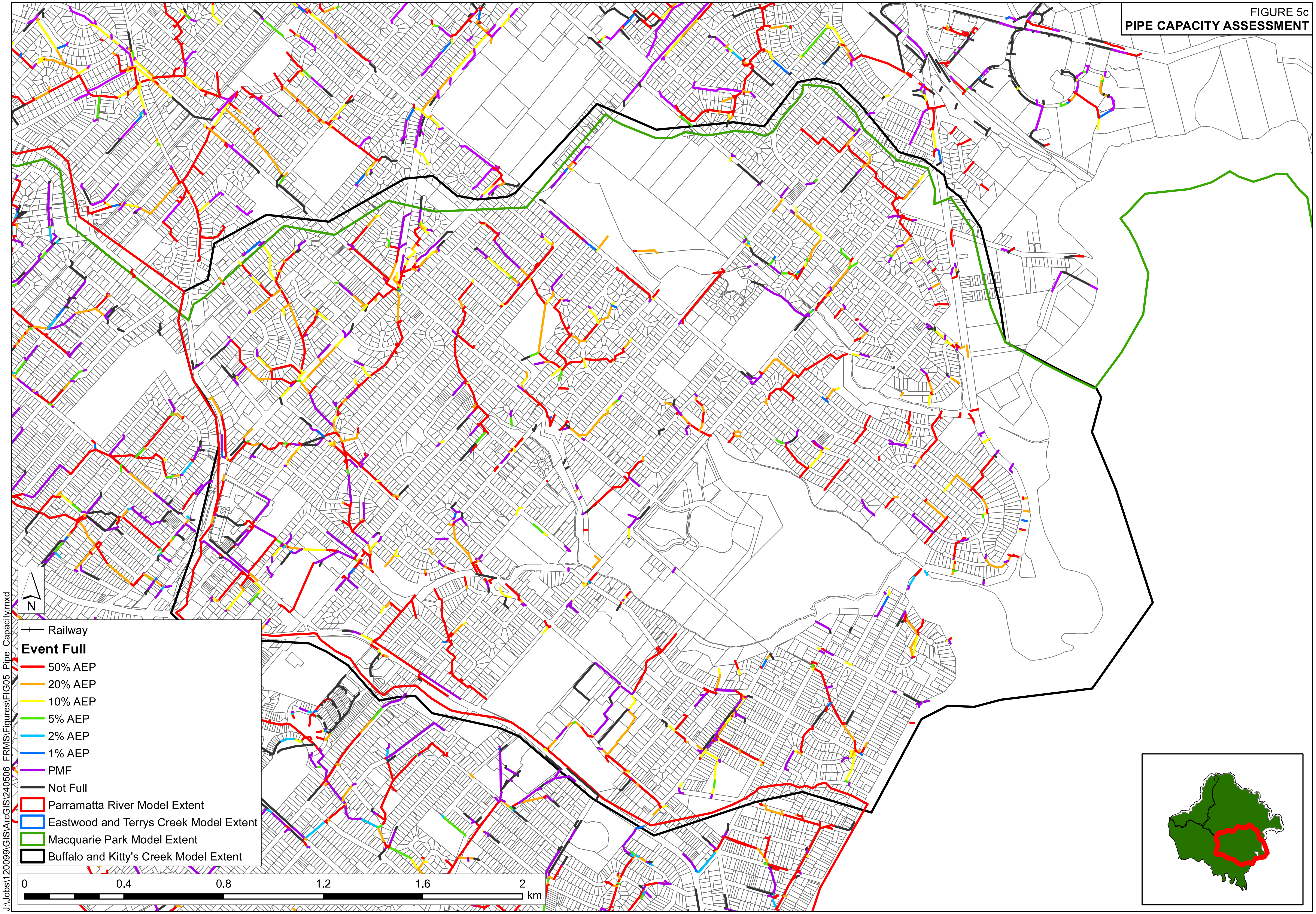

FIGURE 5c
PIPE CAPACITY ASSESSMENT
N
Railway
Event Full
50% AEP
20% AEP
10% AEP
5% AEP
2% AEP
1% AEP
PMF
Not Full
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0
0.4
0.8
1.2
1.6
2
km
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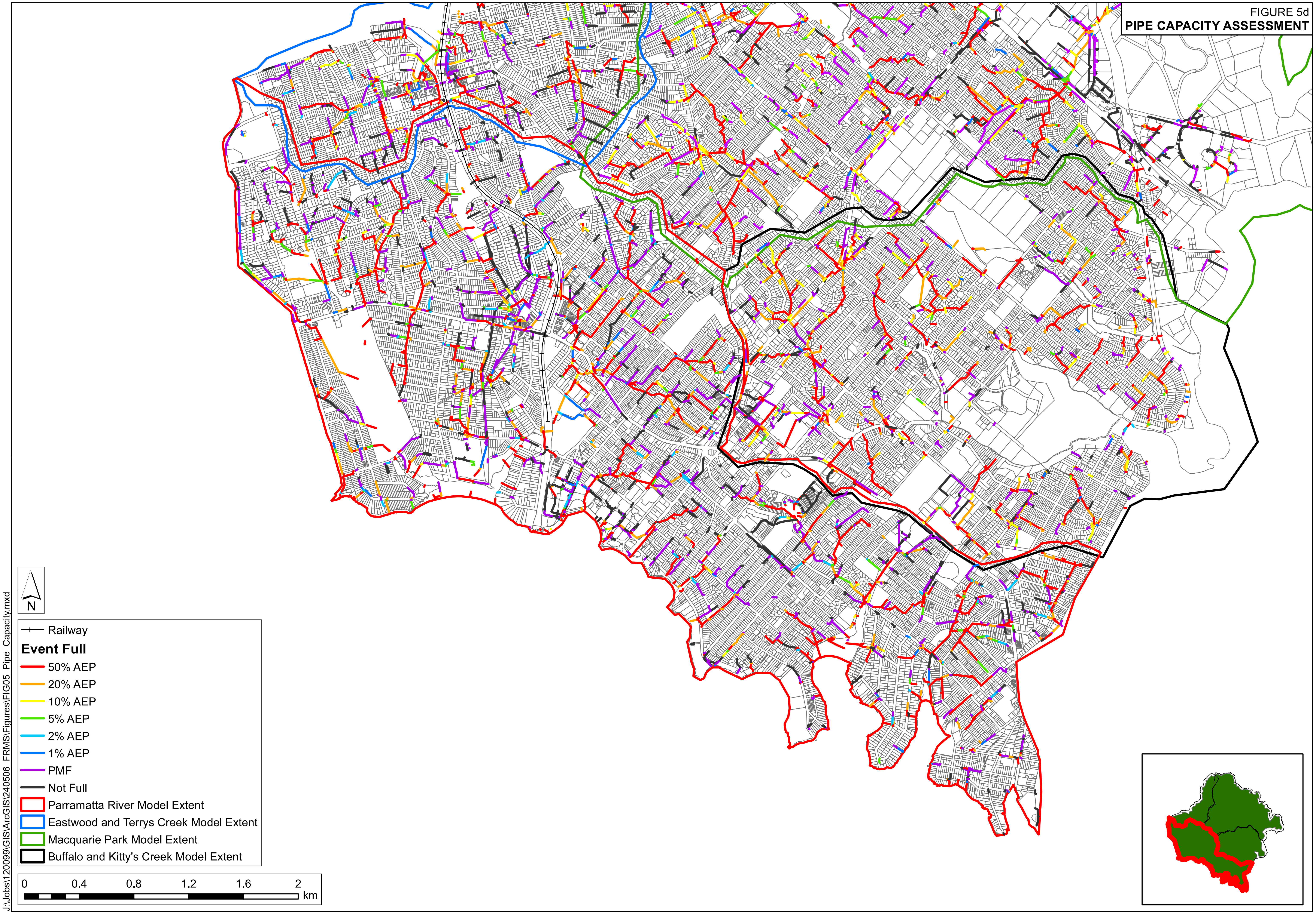
FIGURE 5d
PIPE CAPACITY ASSESSMENT



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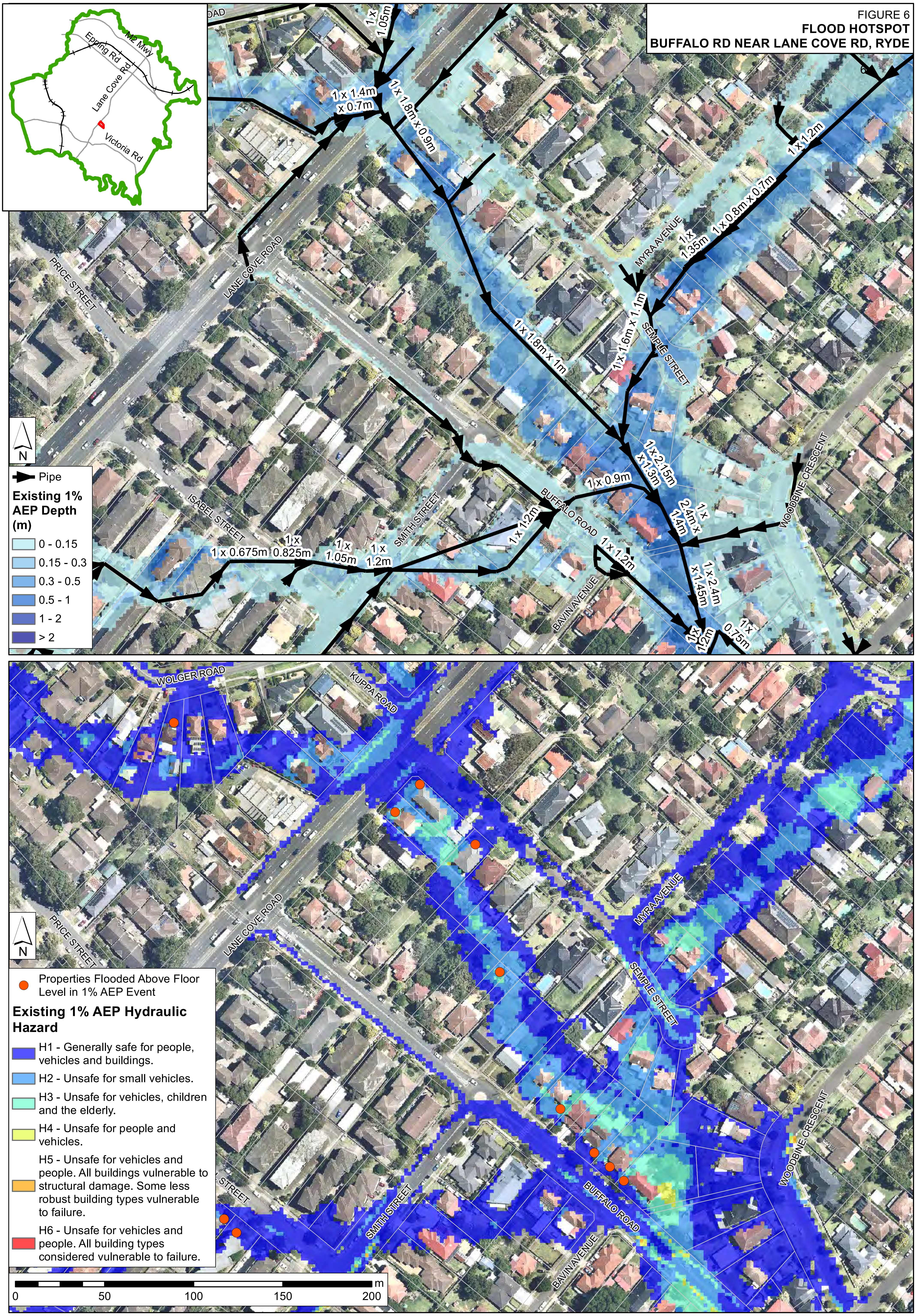

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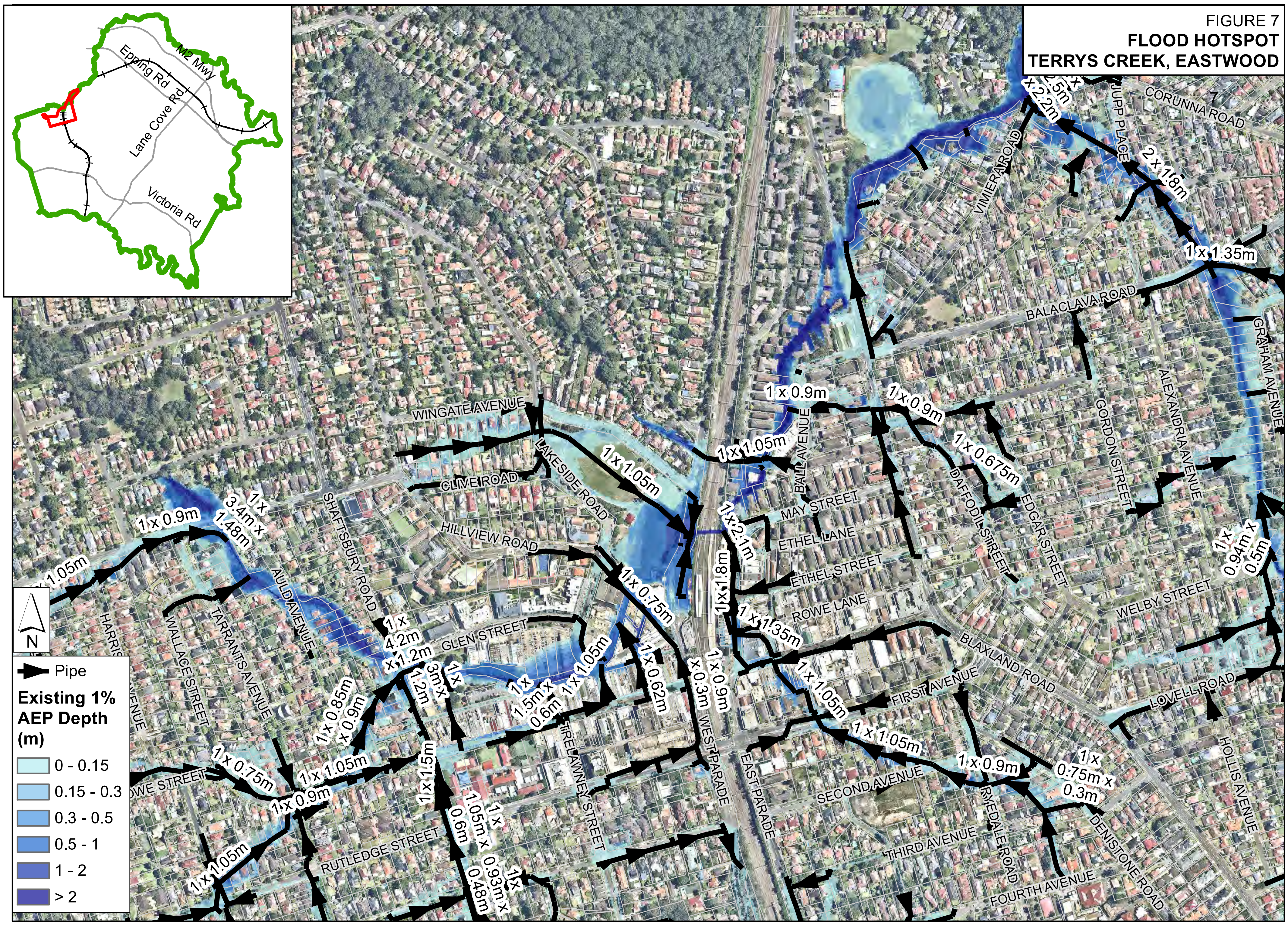
FIGURE 7
FLOOD HOTSPOT
TERRYS CREEK, EASTWOOD



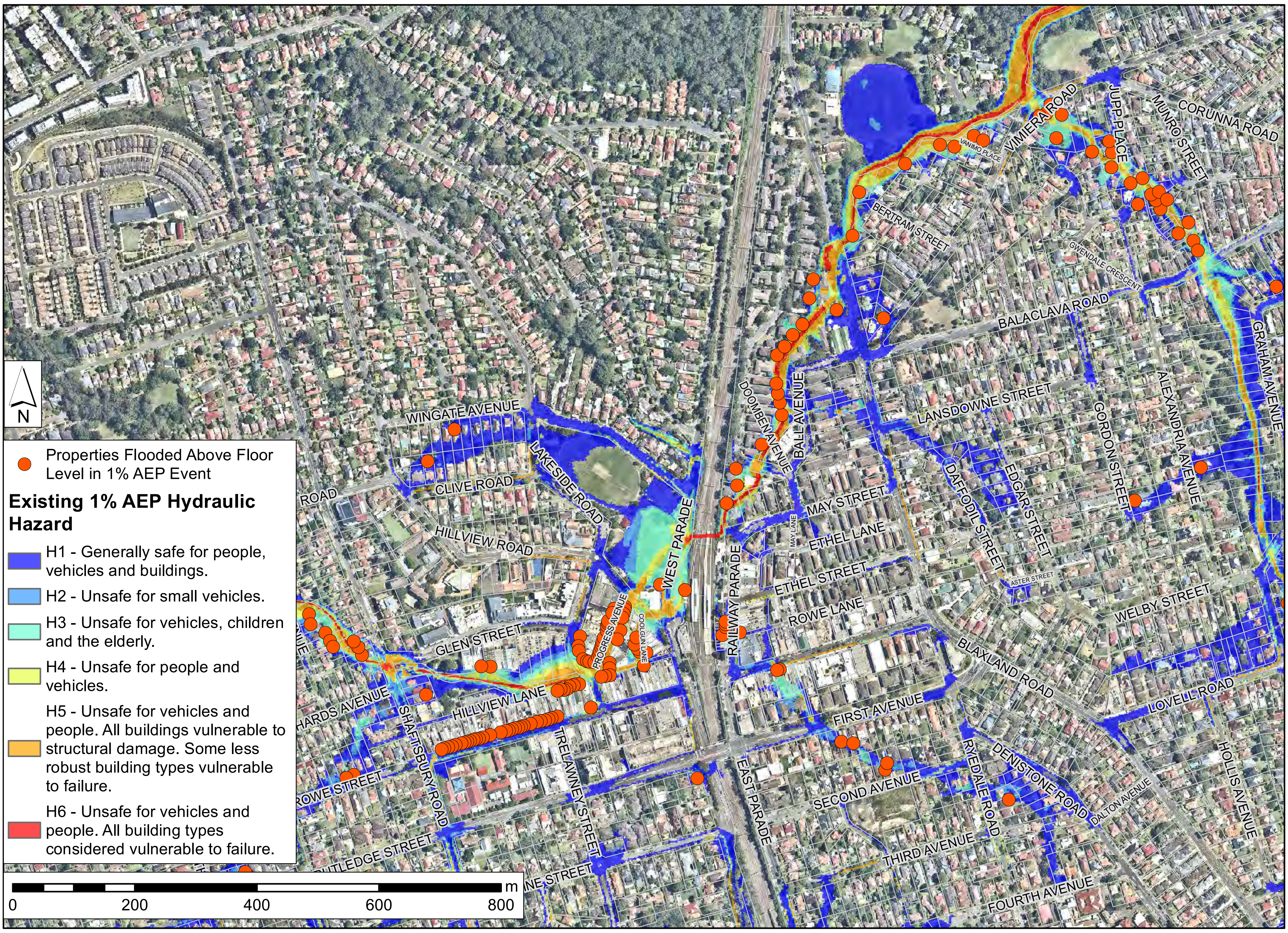
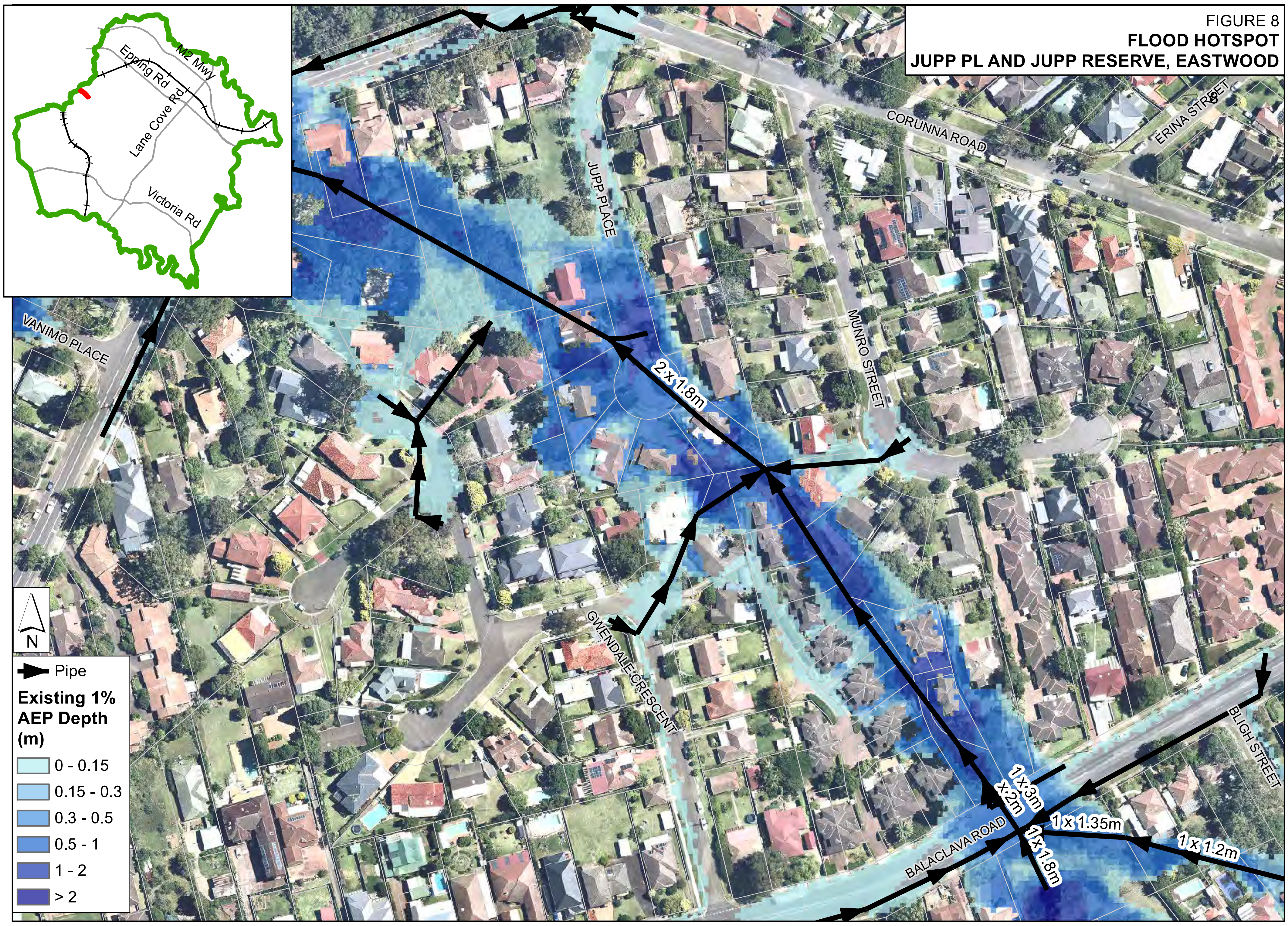


FIGURE 8
FLOOD HOTSPOT
JUPP PL AND JUPP RESERVE, EASTWOOD



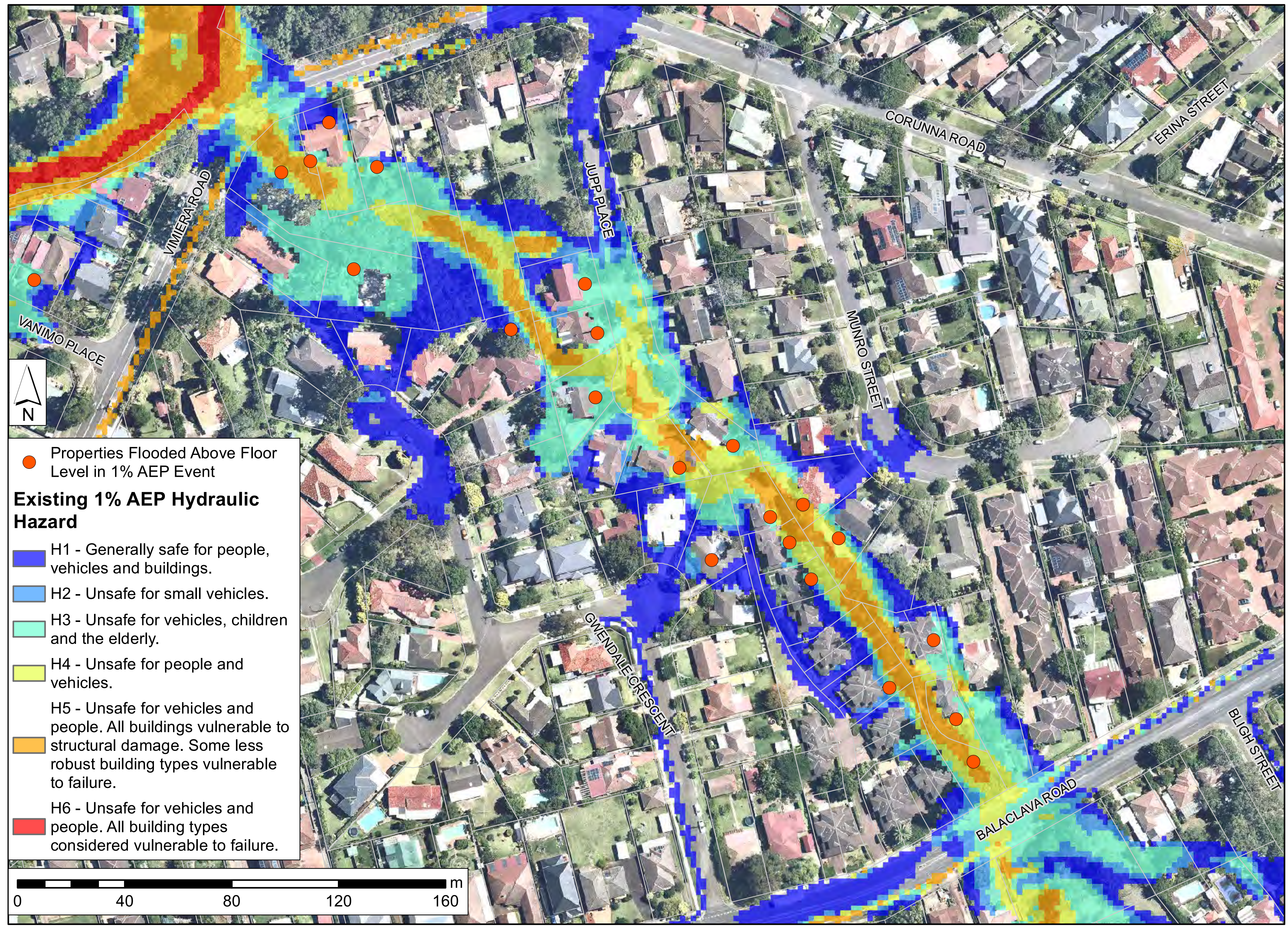


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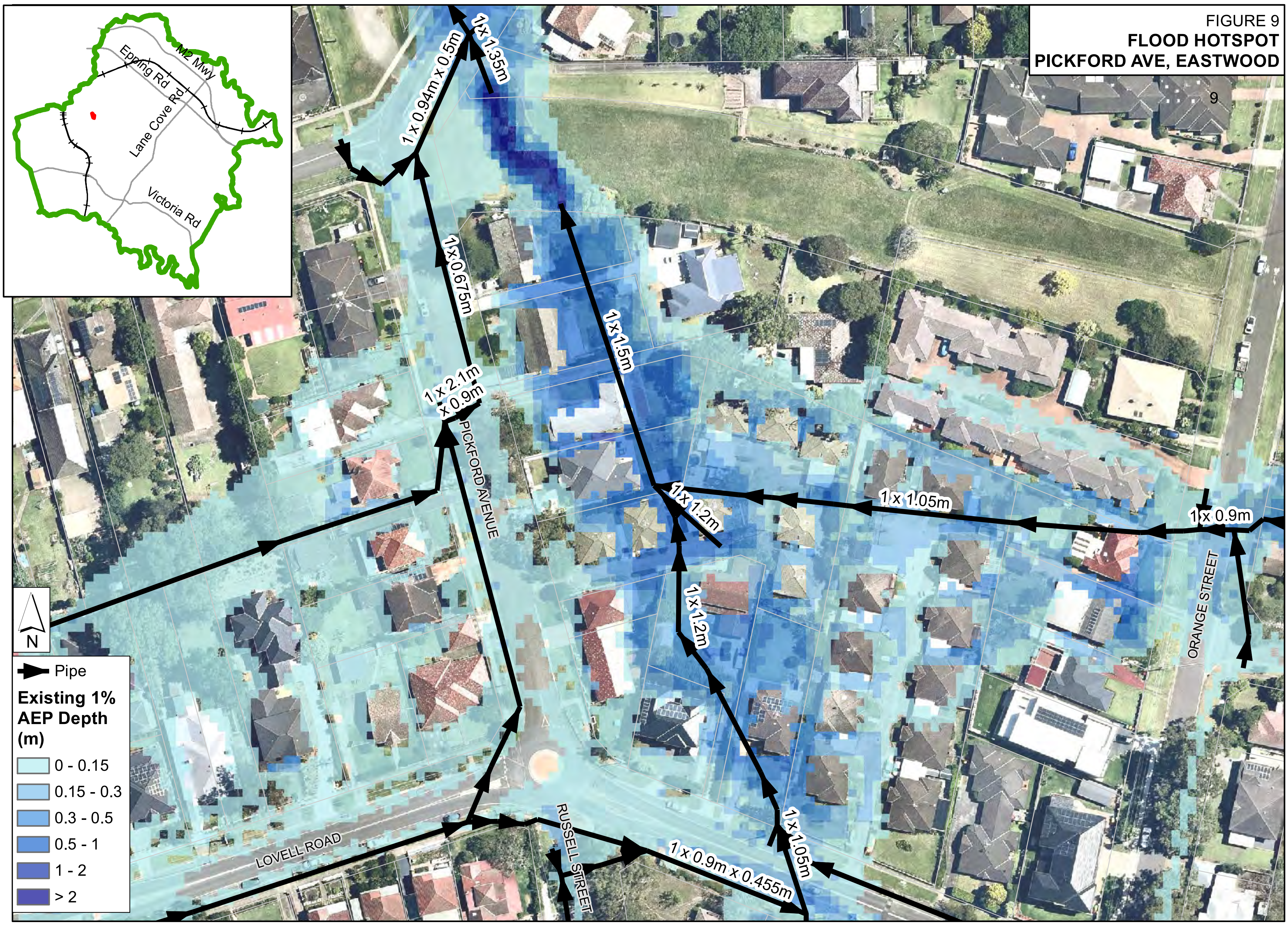
FIGURE 9
FLOOD HOTSPOT
PICKFORD AVE, EASTWOOD



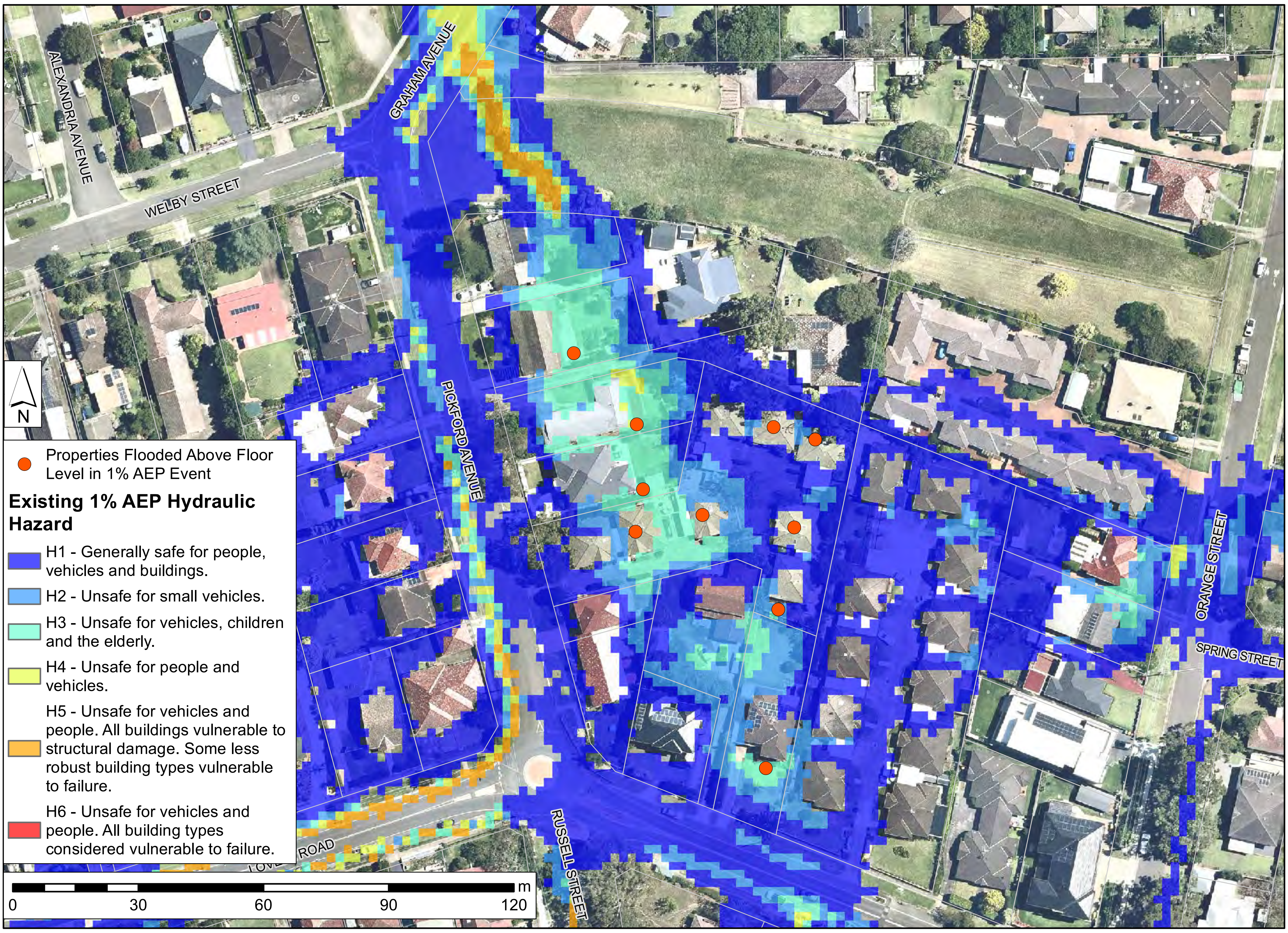


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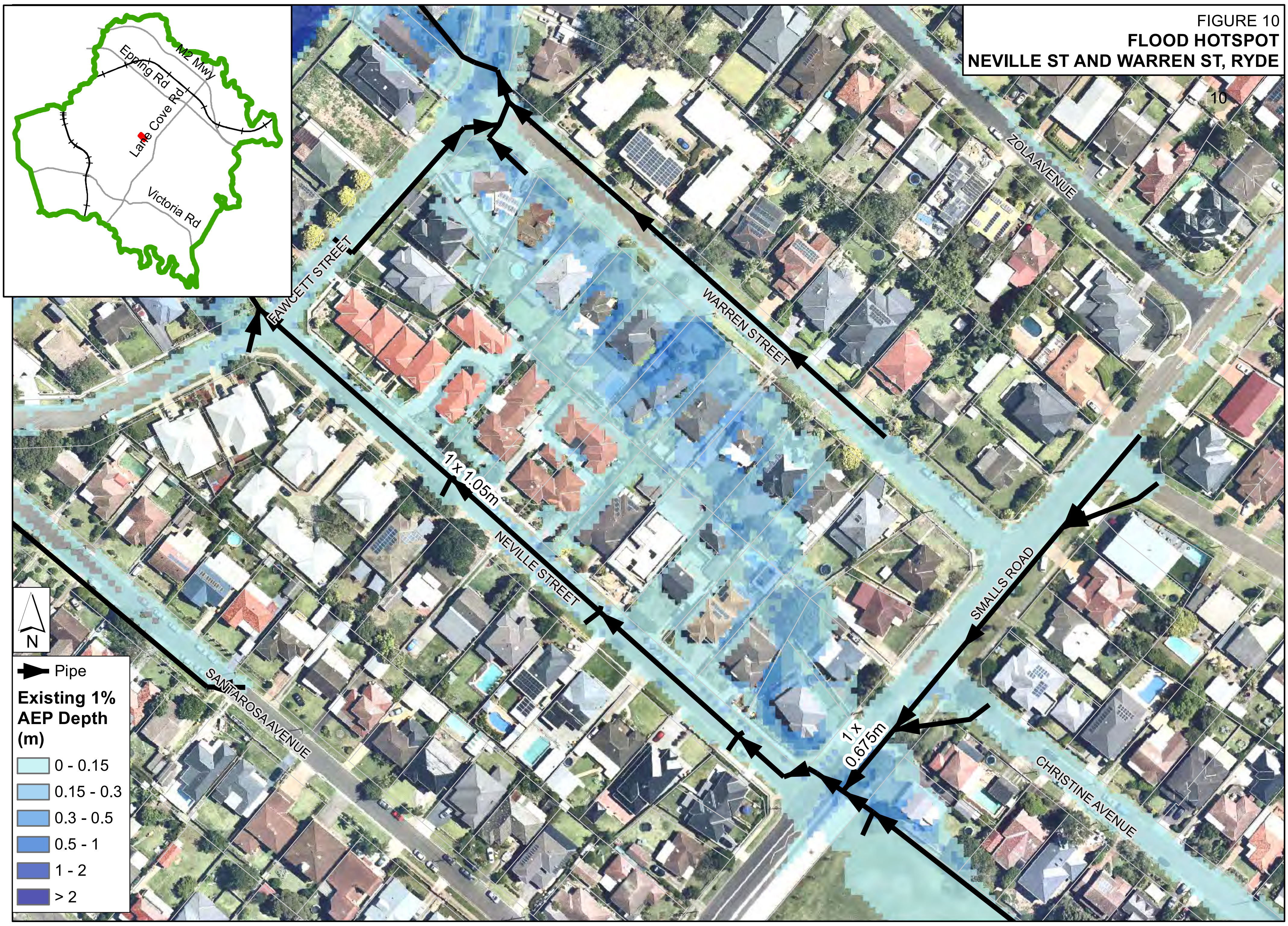
FIGURE 10
FLOOD HOTSPOT
NEVILLE ST AND WARREN ST, RYDE



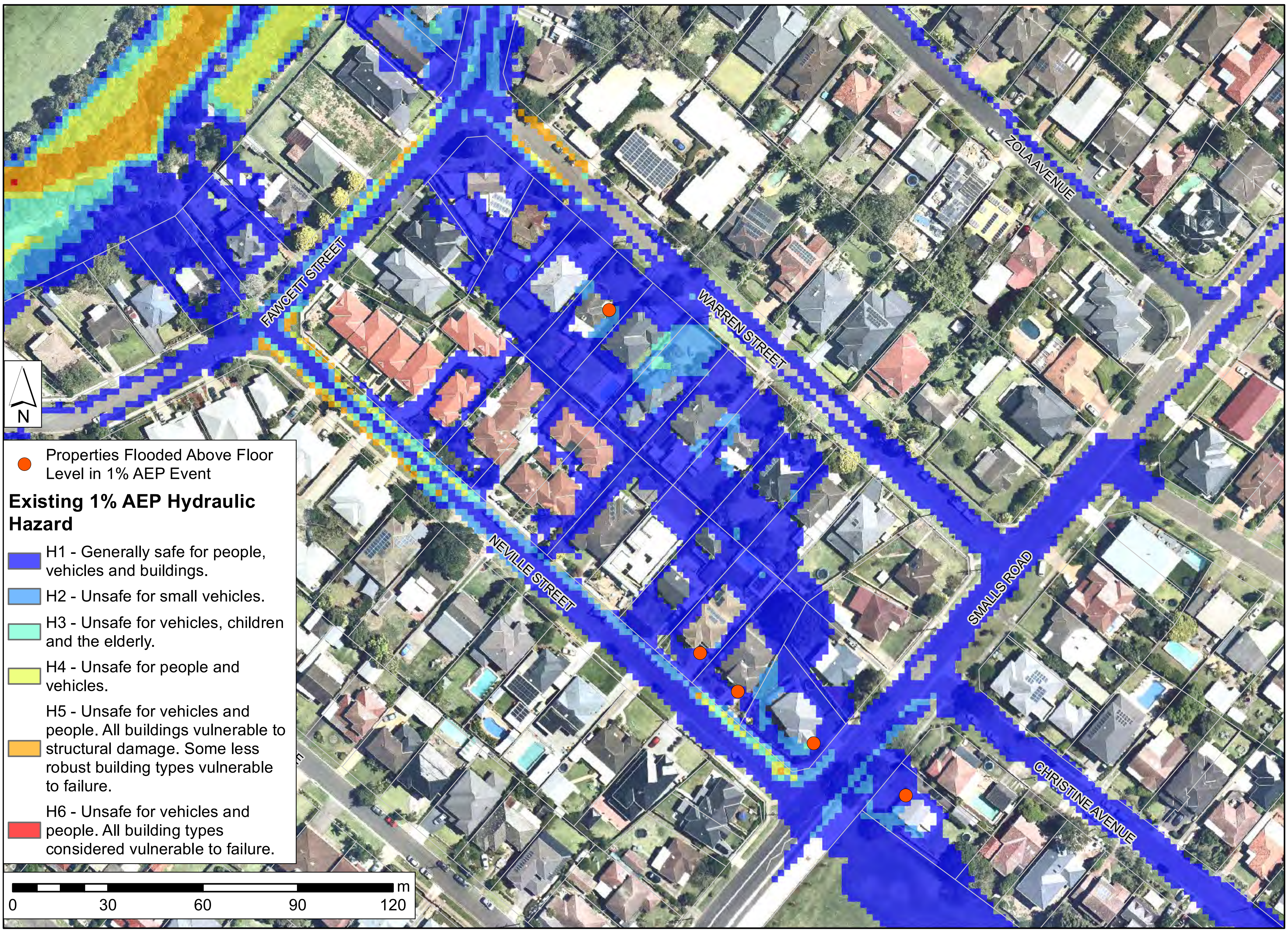
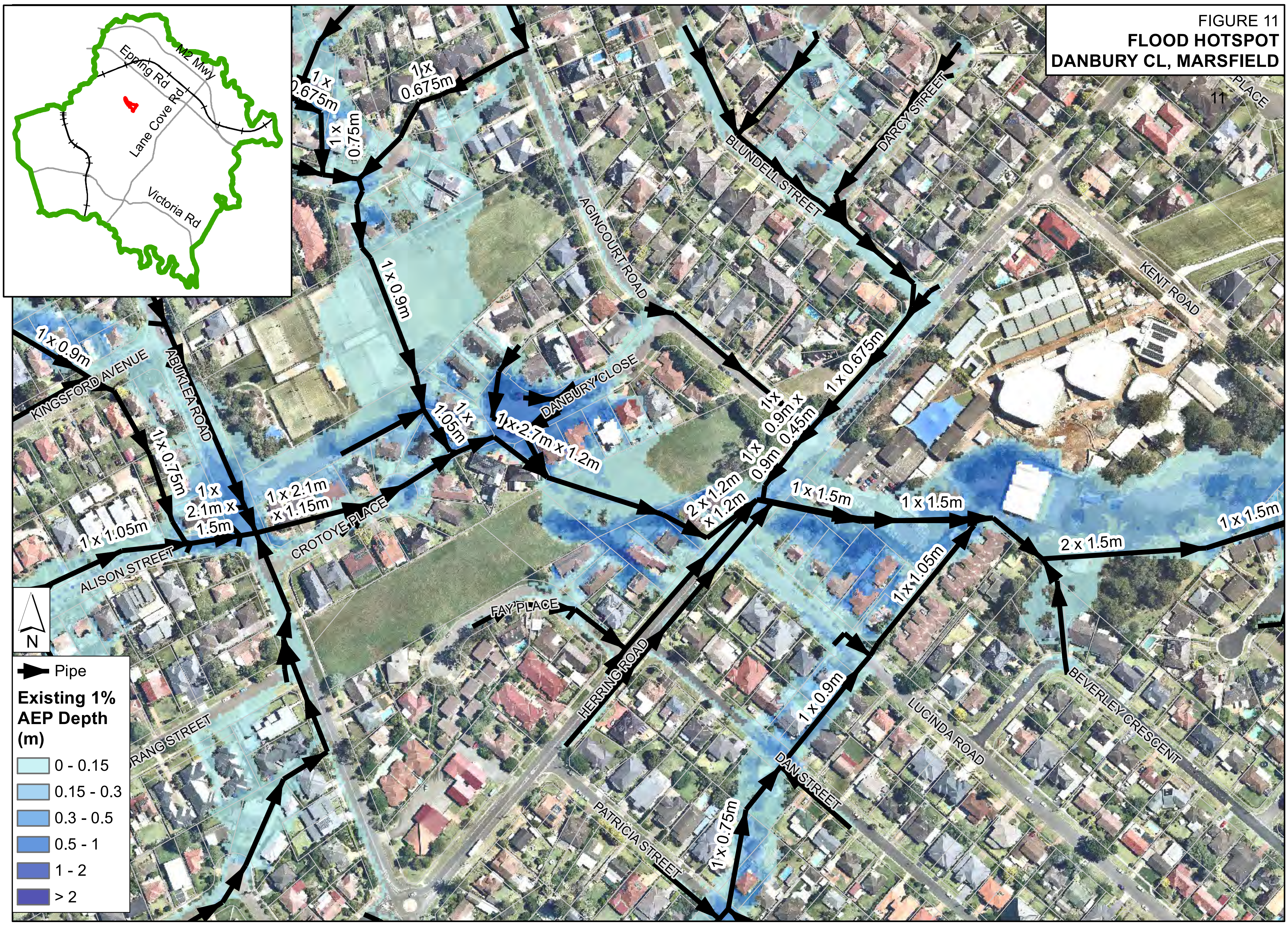


FIGURE 11
FLOOD HOTSPOT
DANBURY CL, MARSFIELD



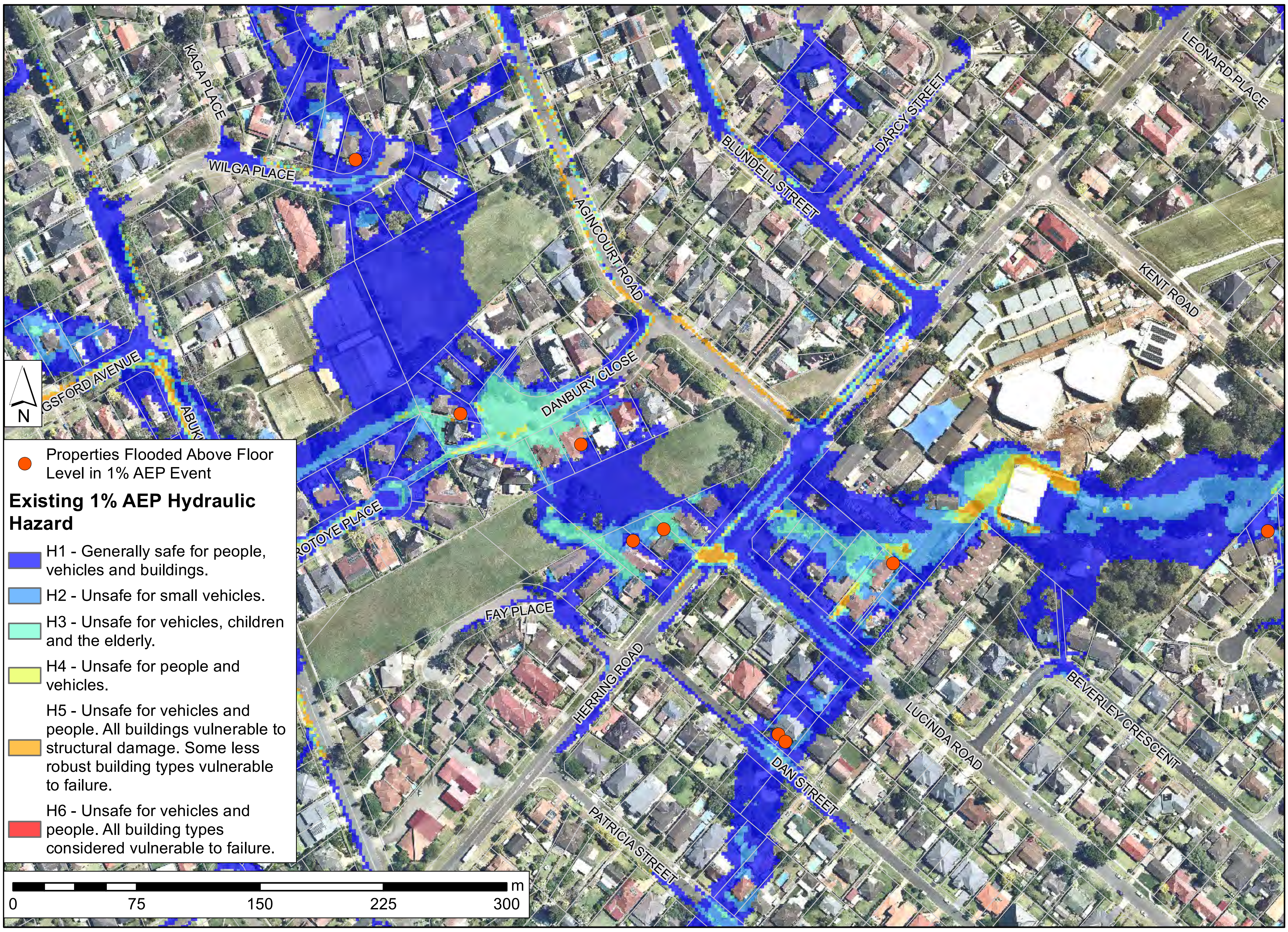
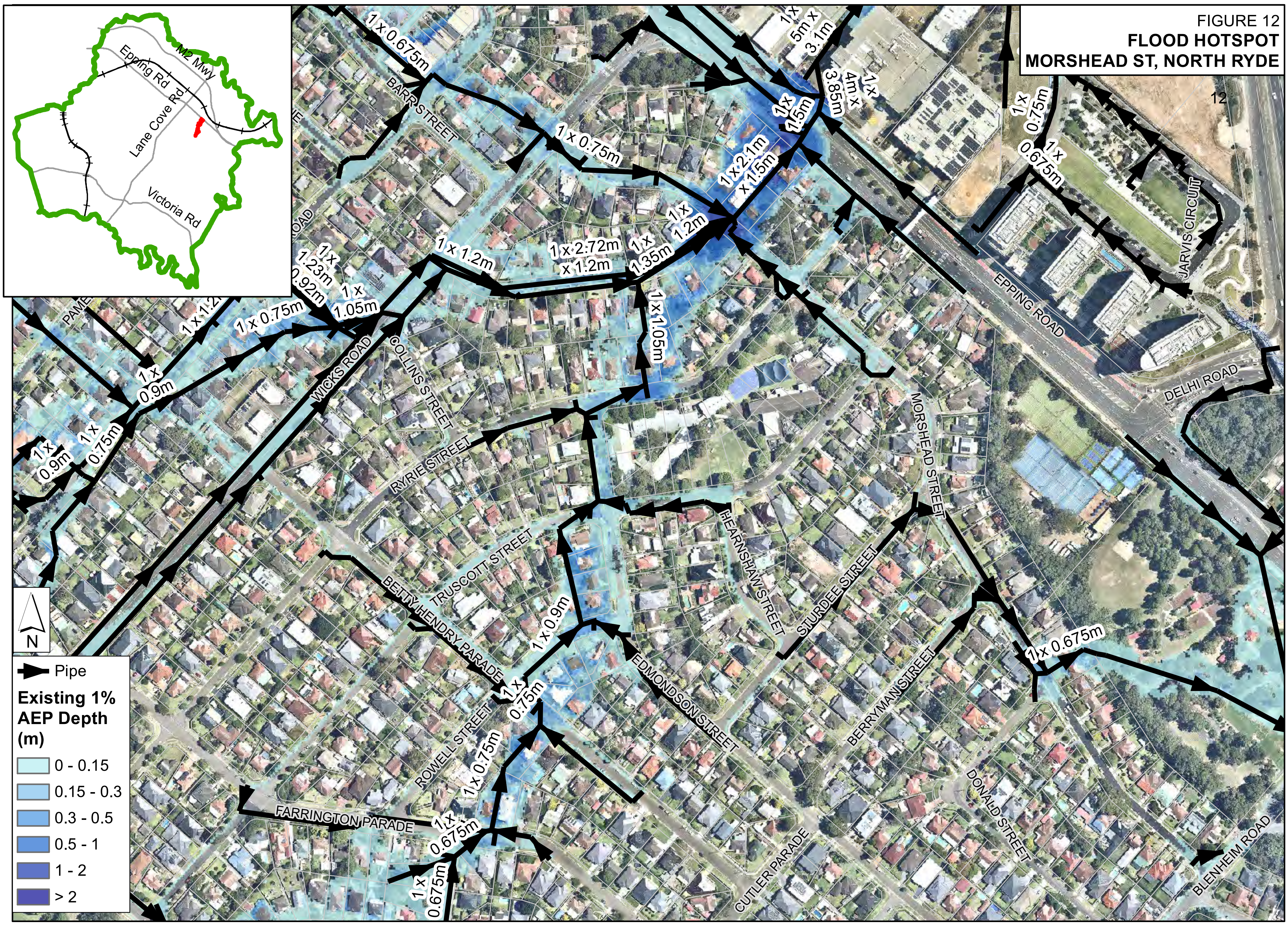


FIGURE 12
FLOOD HOTSPOT
MORSHEAD ST, NORTH RYDE



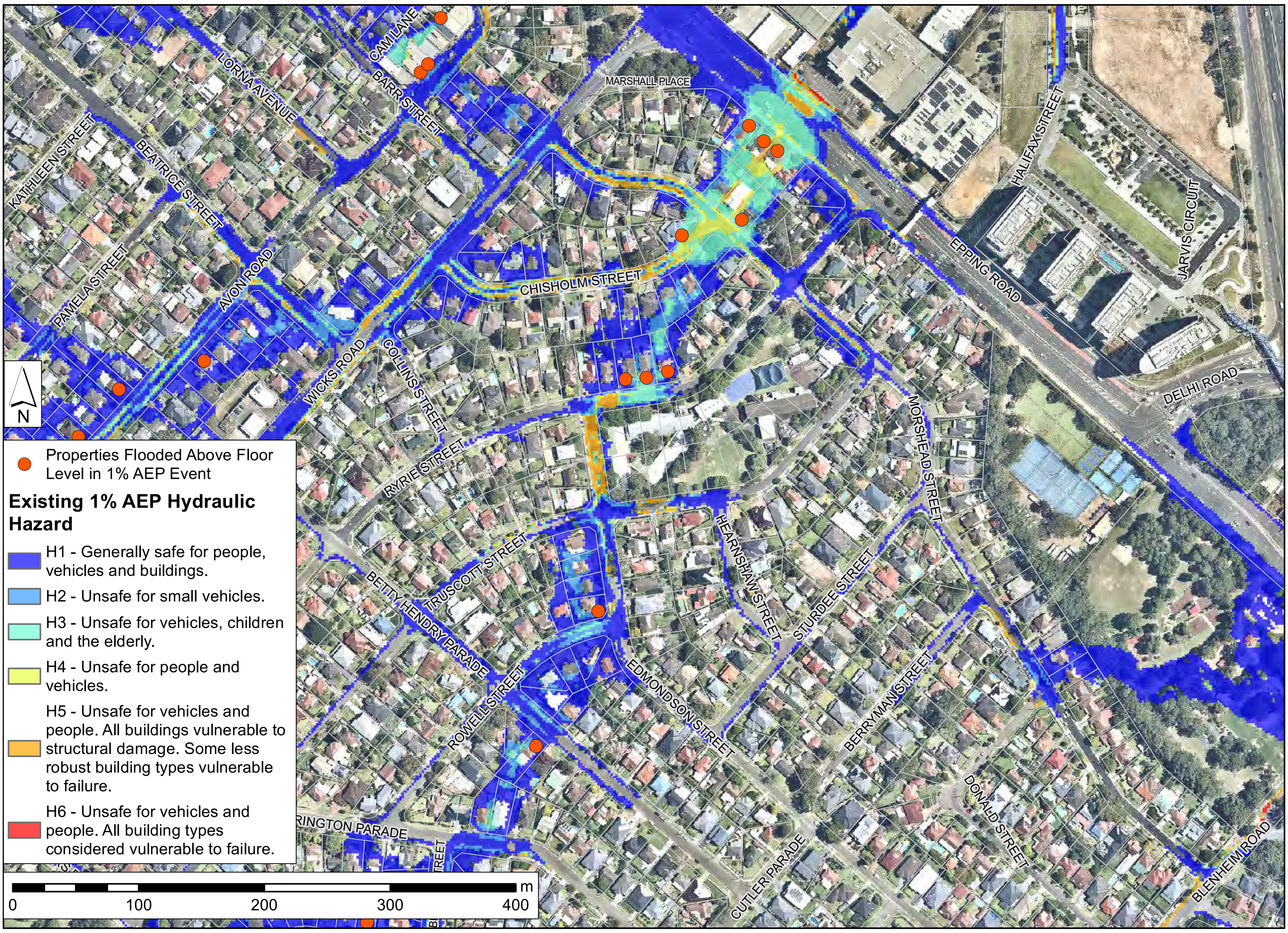


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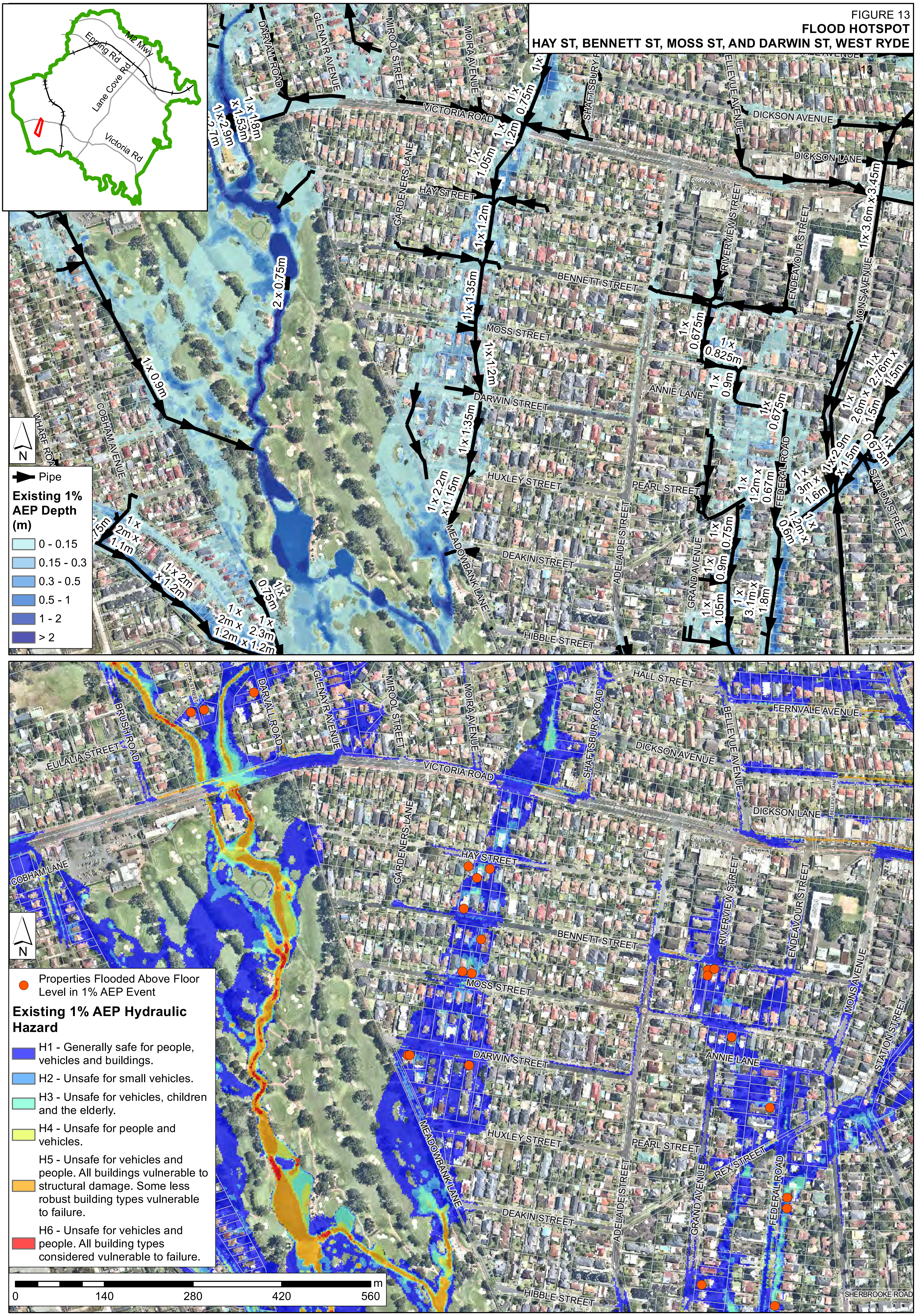
FIGURE 13
FLOOD HOTSPOT
HAY ST, BENNETT ST, MOSS ST, AND DARWIN ST, WEST RYDE



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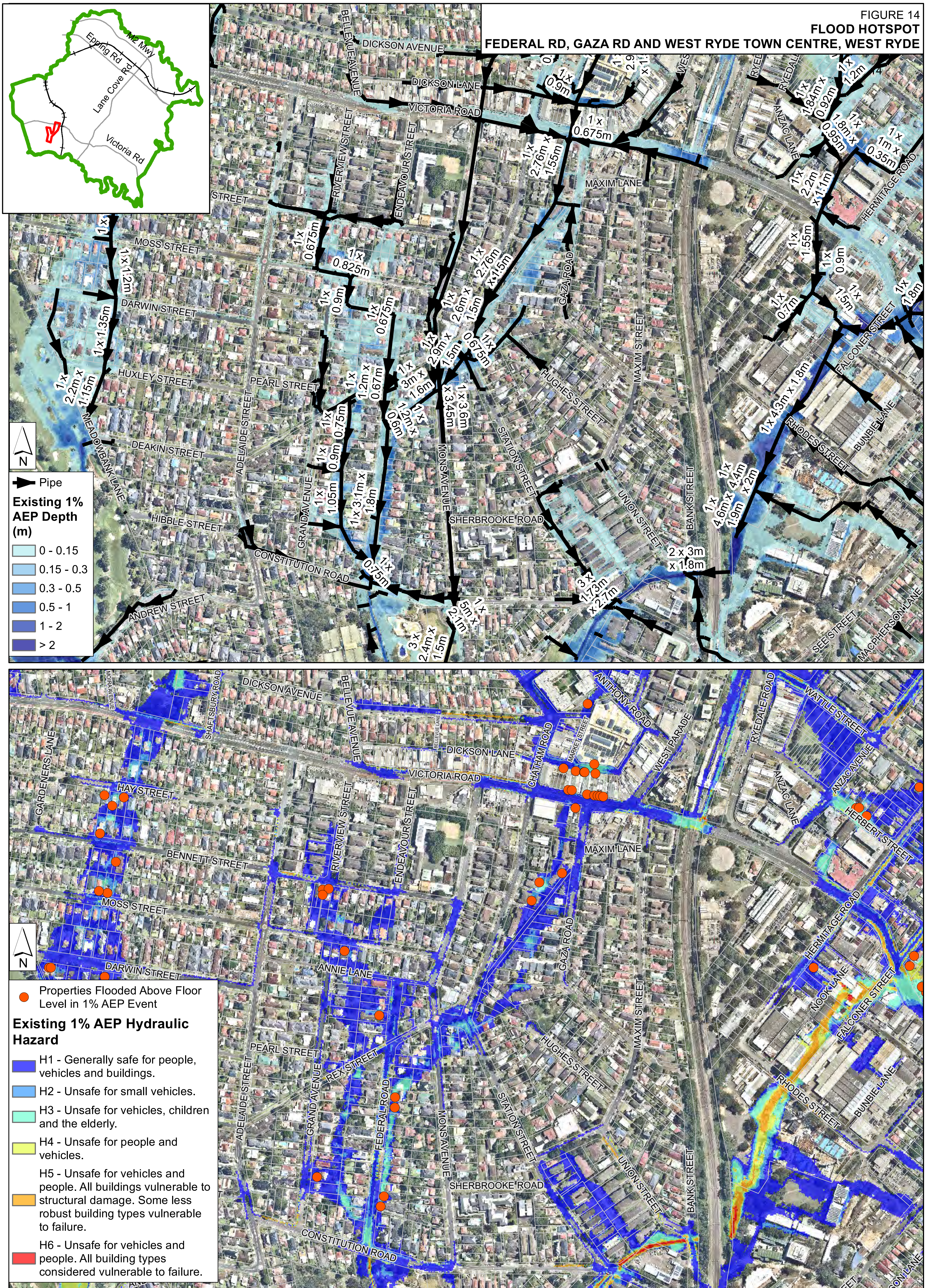

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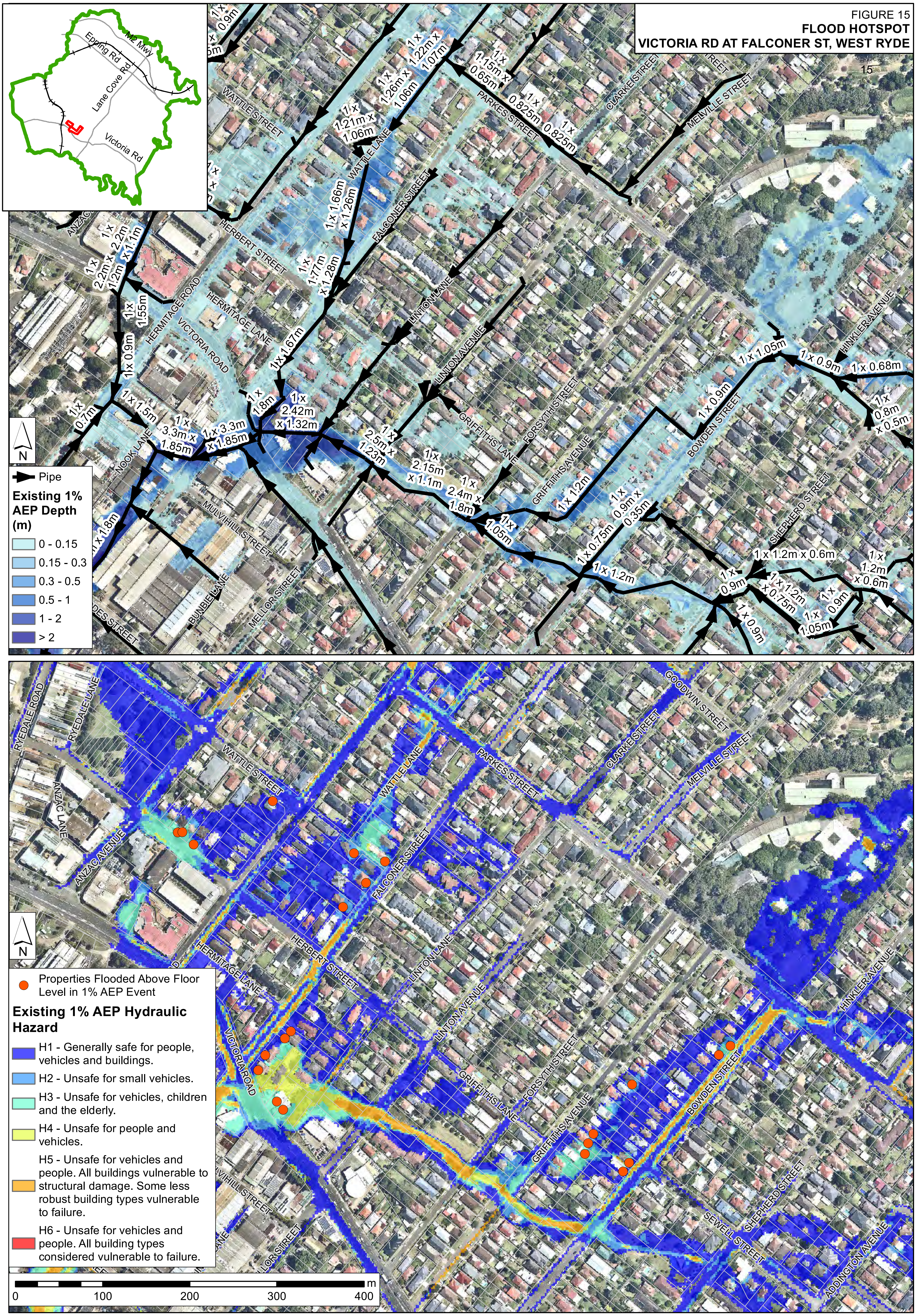

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FIGURE 16
FLOOD HOTSPOT
MORRISON RD, PUTNEY

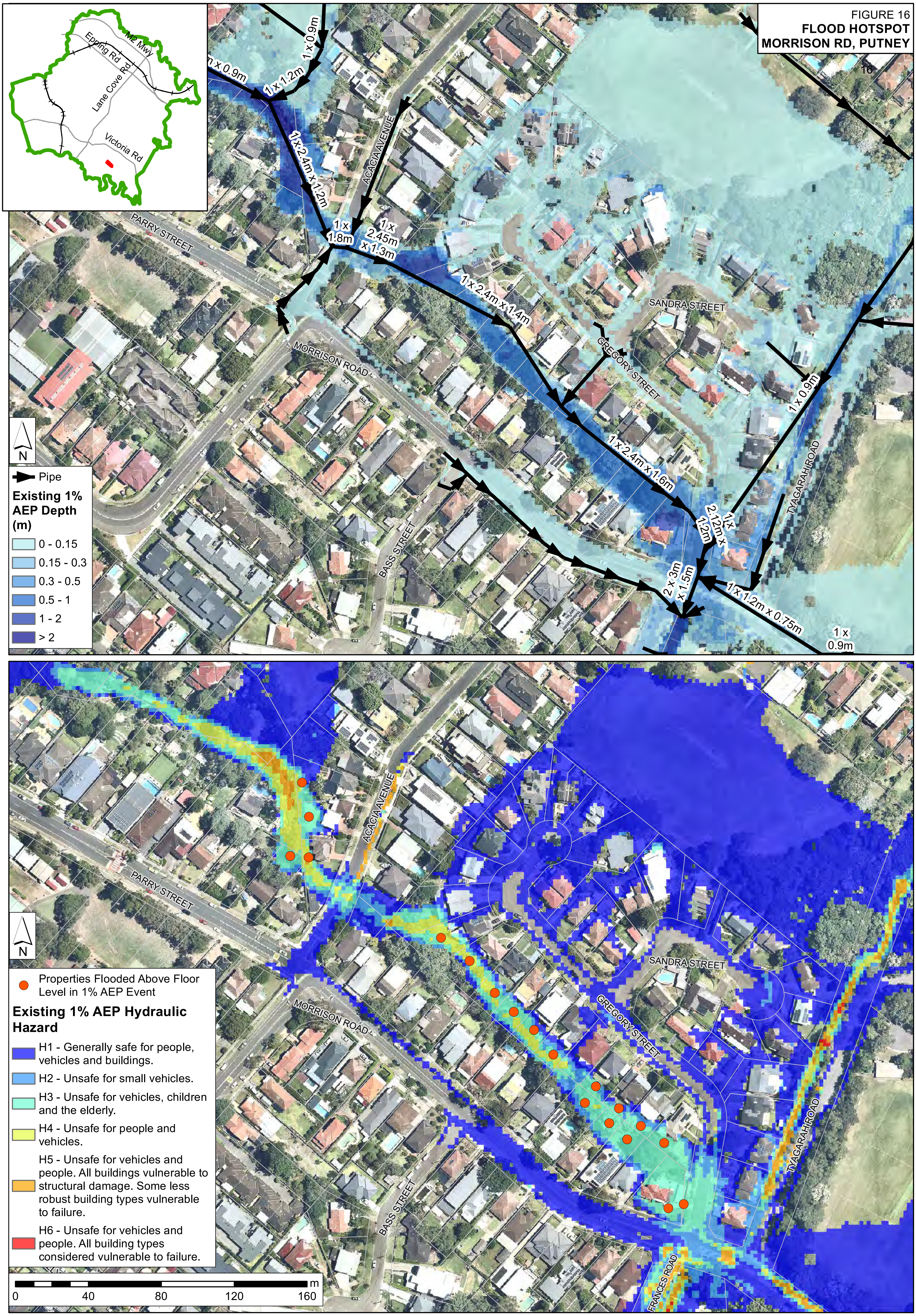

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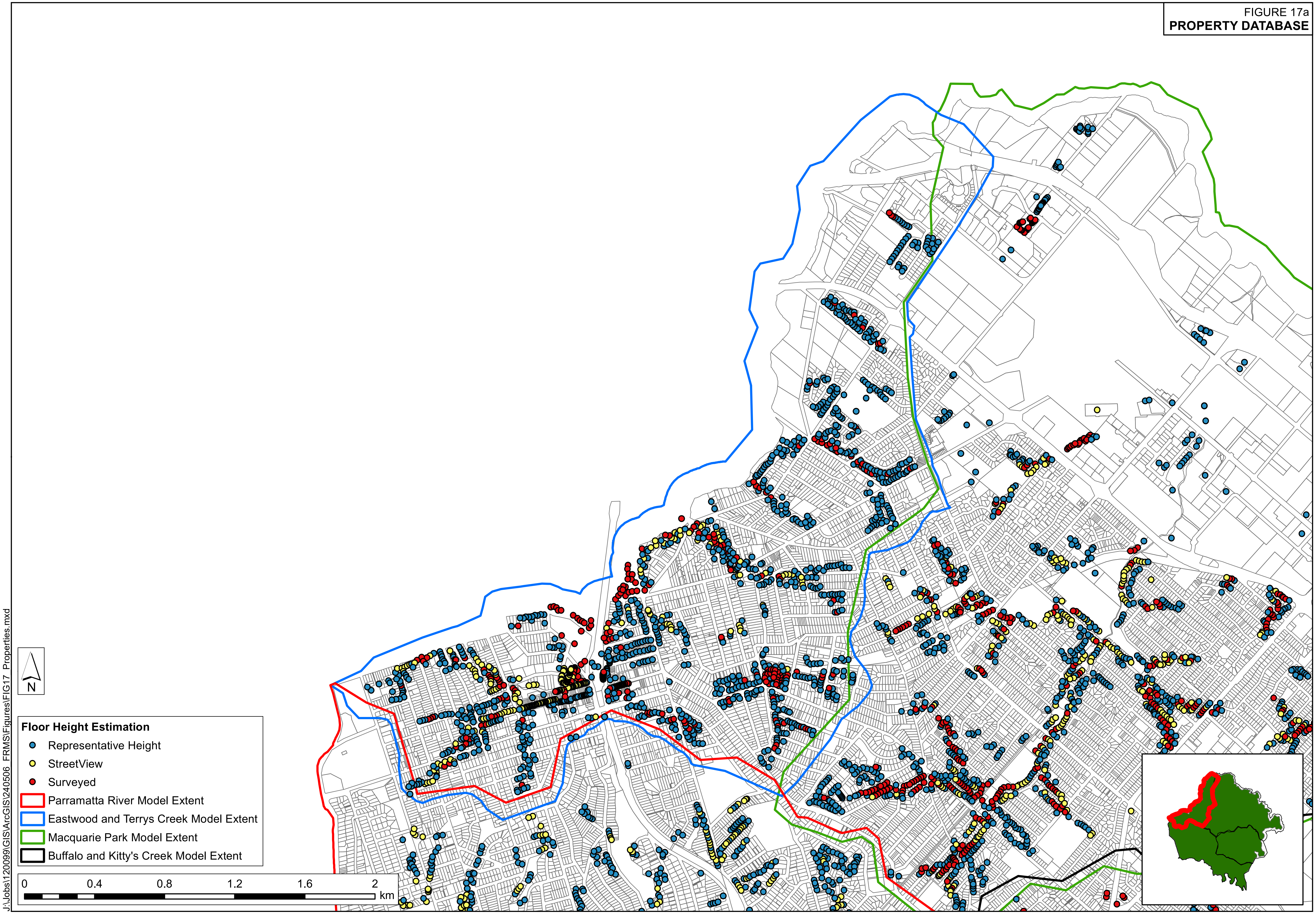
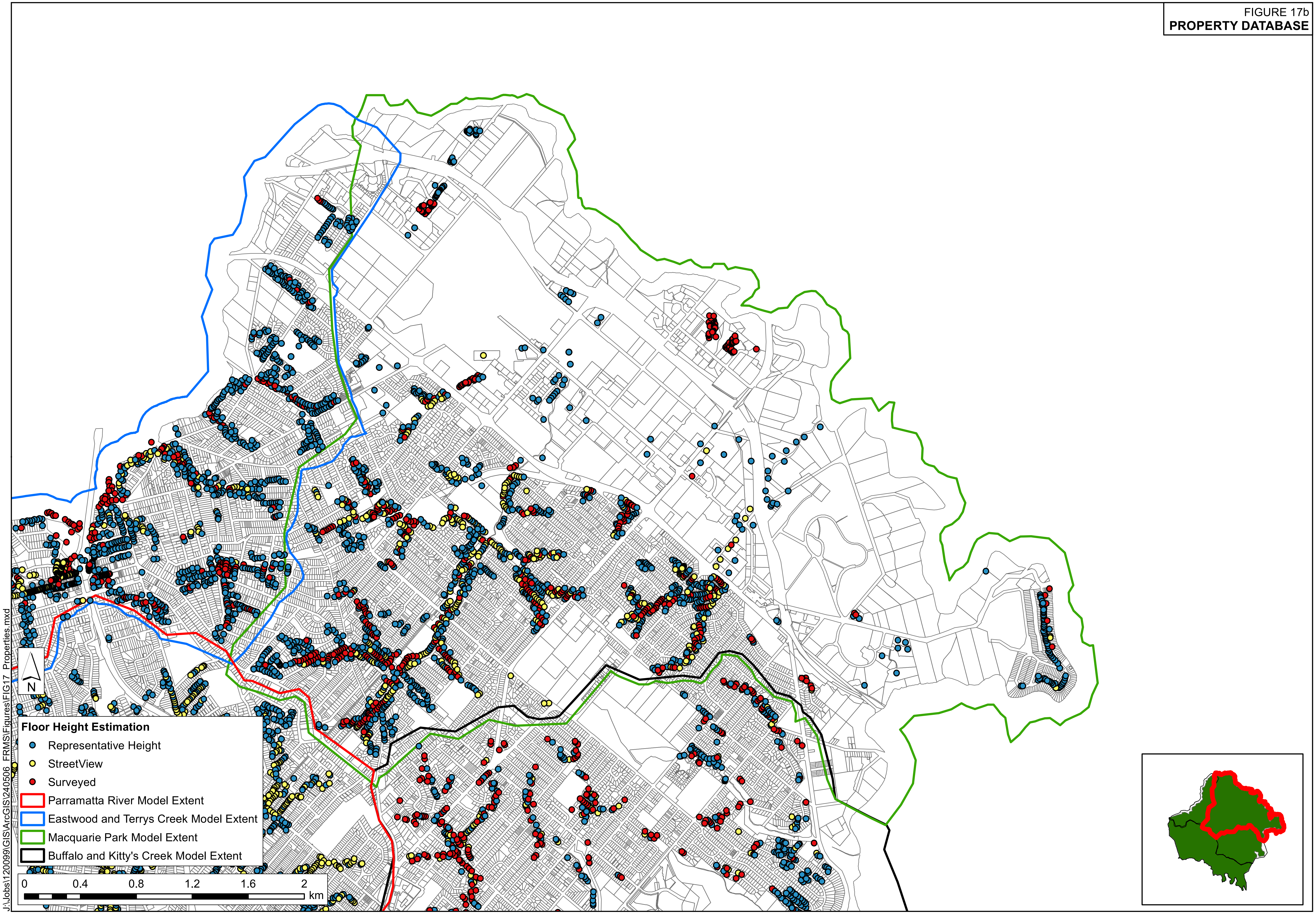
FIGURE 17a
PROPERTY DATABASE



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG17_Properties.mxd

FIGURE 17b
PROPERTY DATABASE



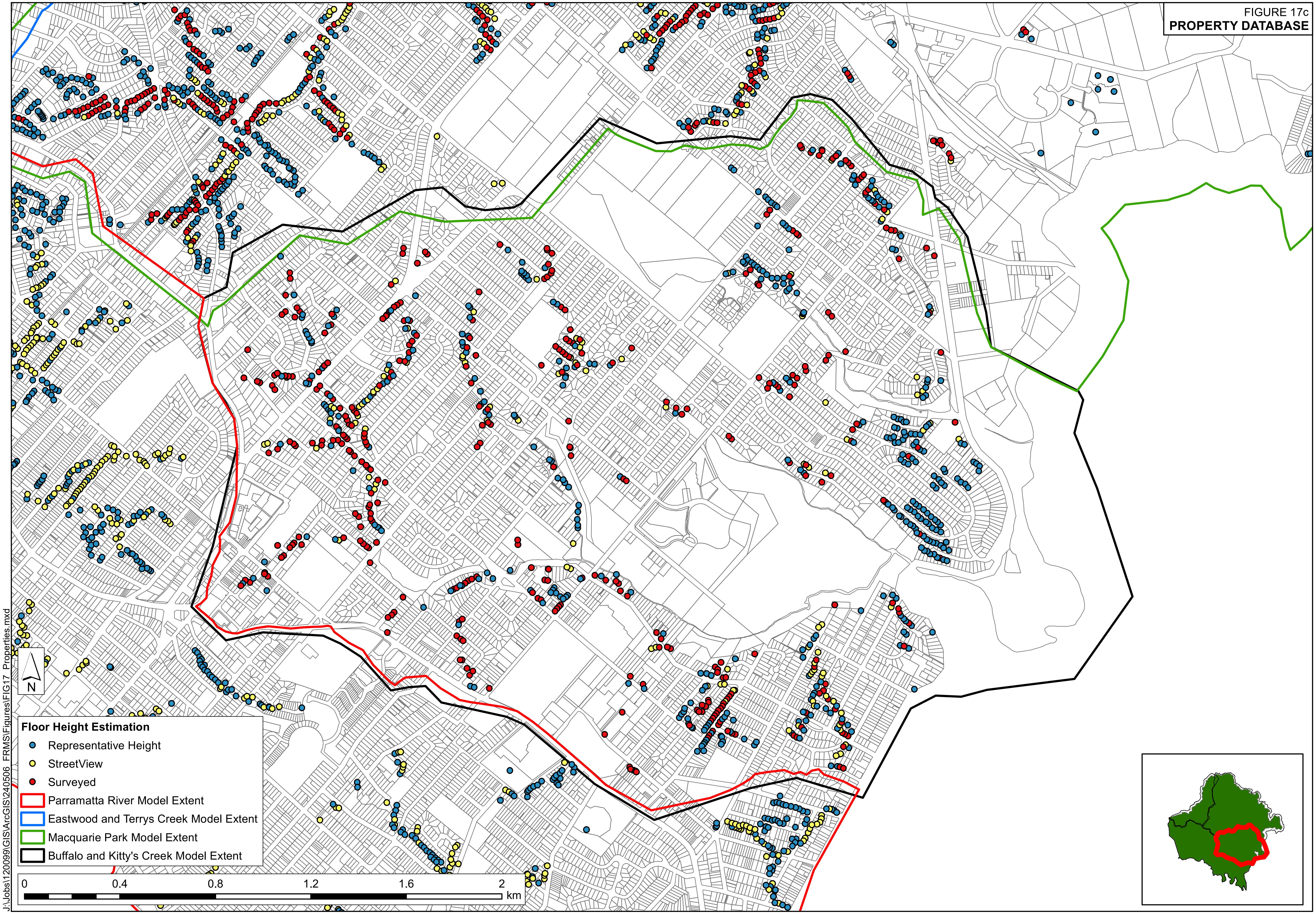


FIGURE 17c
PROPERTY DATABASE
Floor Height Estimation
Representative Height
StreetView
Surveyed
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
N
0
0.4
0.8
1.2
1.6
2
km
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG17_Properties.mxd

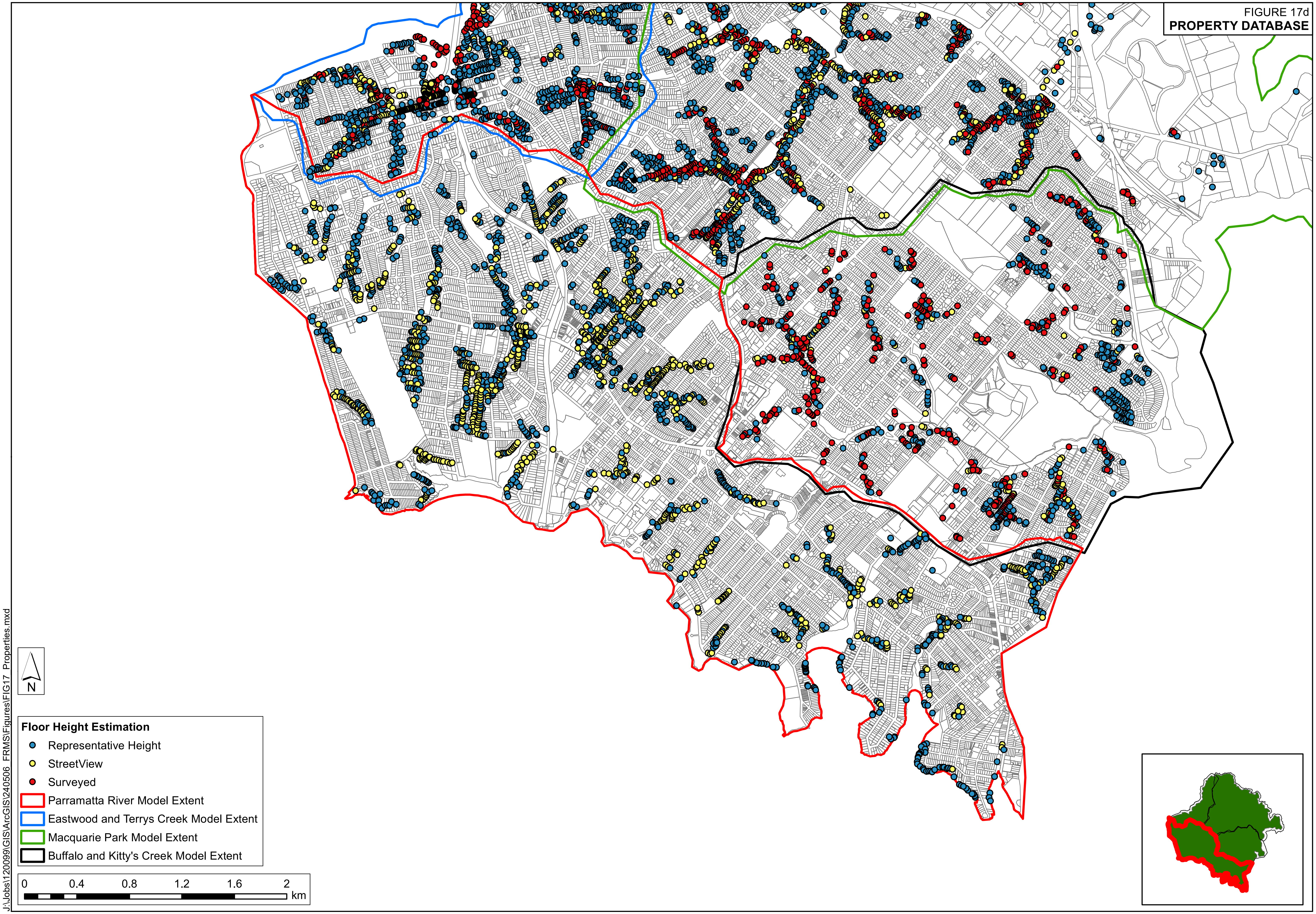
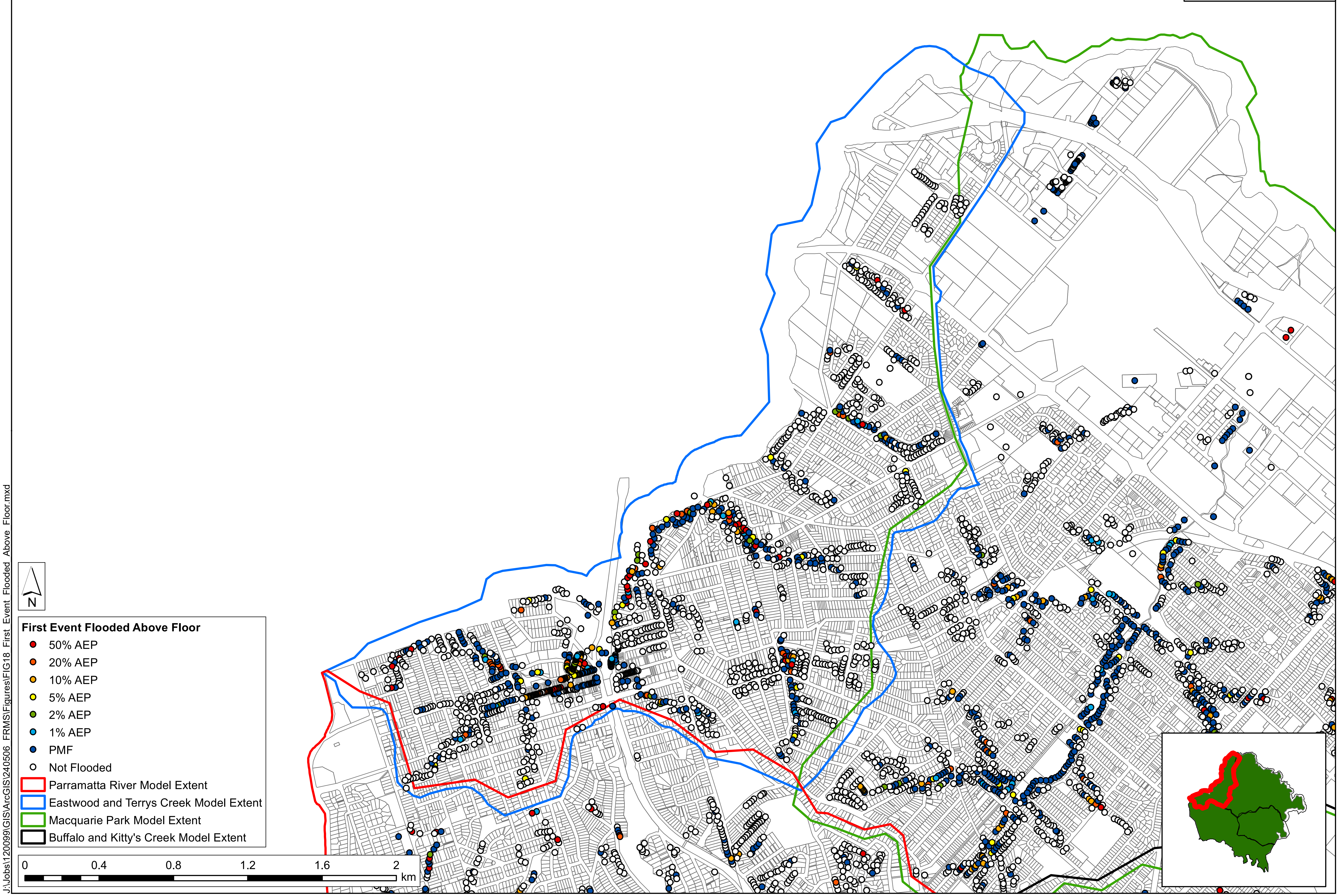


FIGURE 17d
PROPERTY DATABASE
N
Floor Height Estimation
Representative Height
StreetView
Surveyed
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0 0.4 0.8 1.2 1.6 2
km
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG17_Properties.mxd

FIGURE 18a
PROPERTY DATABASE



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG18_First_Event_Flooded_Above_Floor.mxd

FIGURE 18b
PROPERTY DATABASE

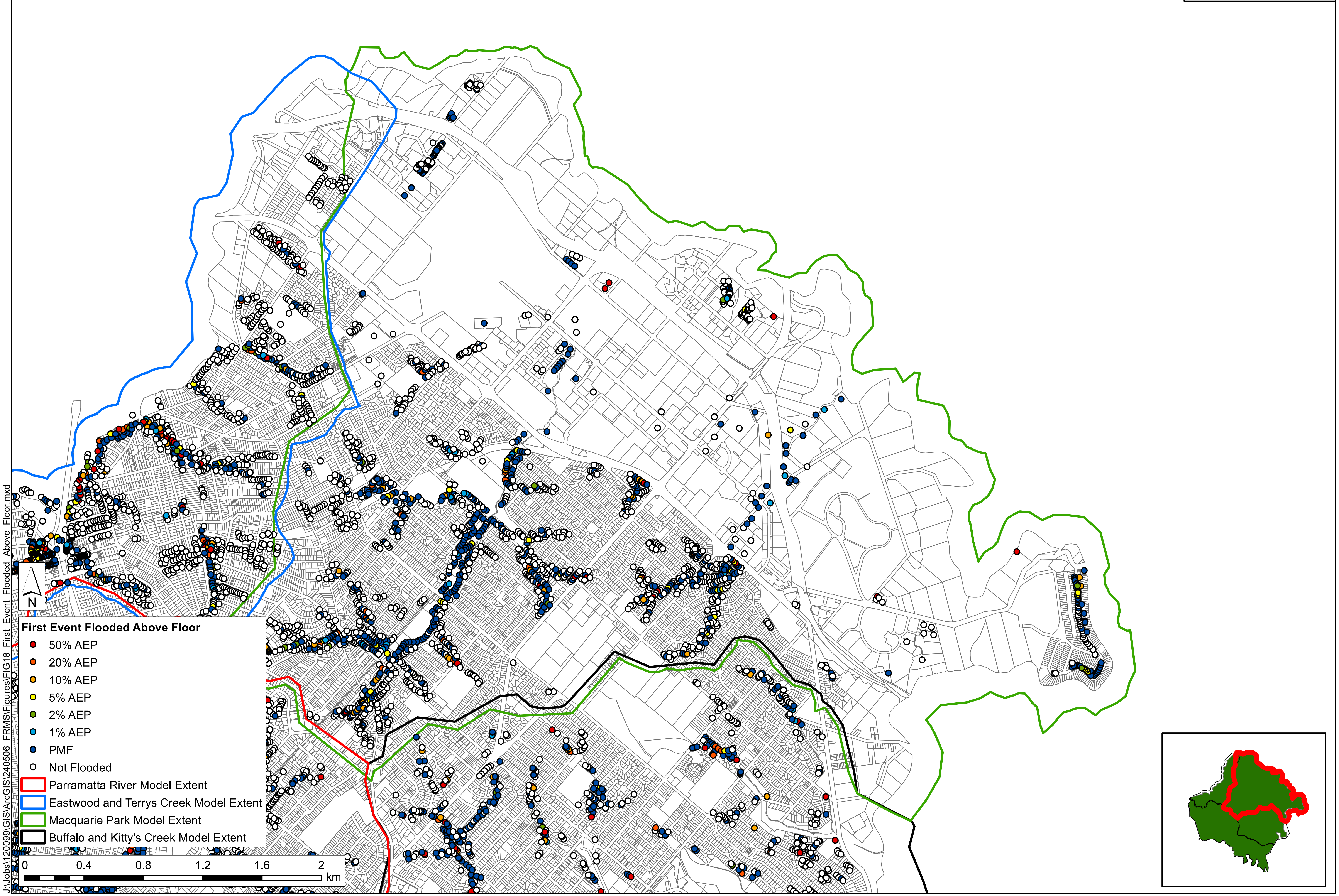
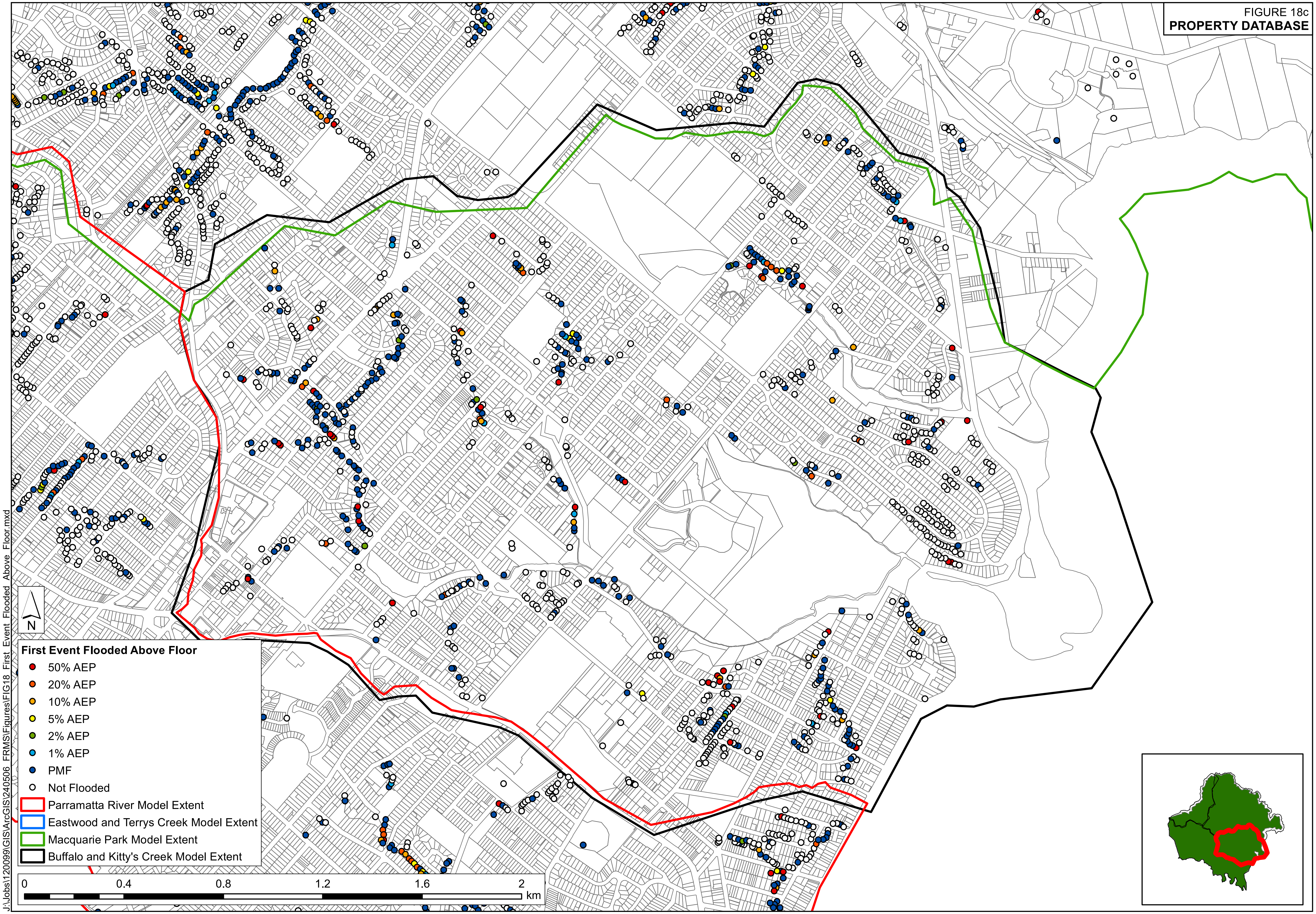
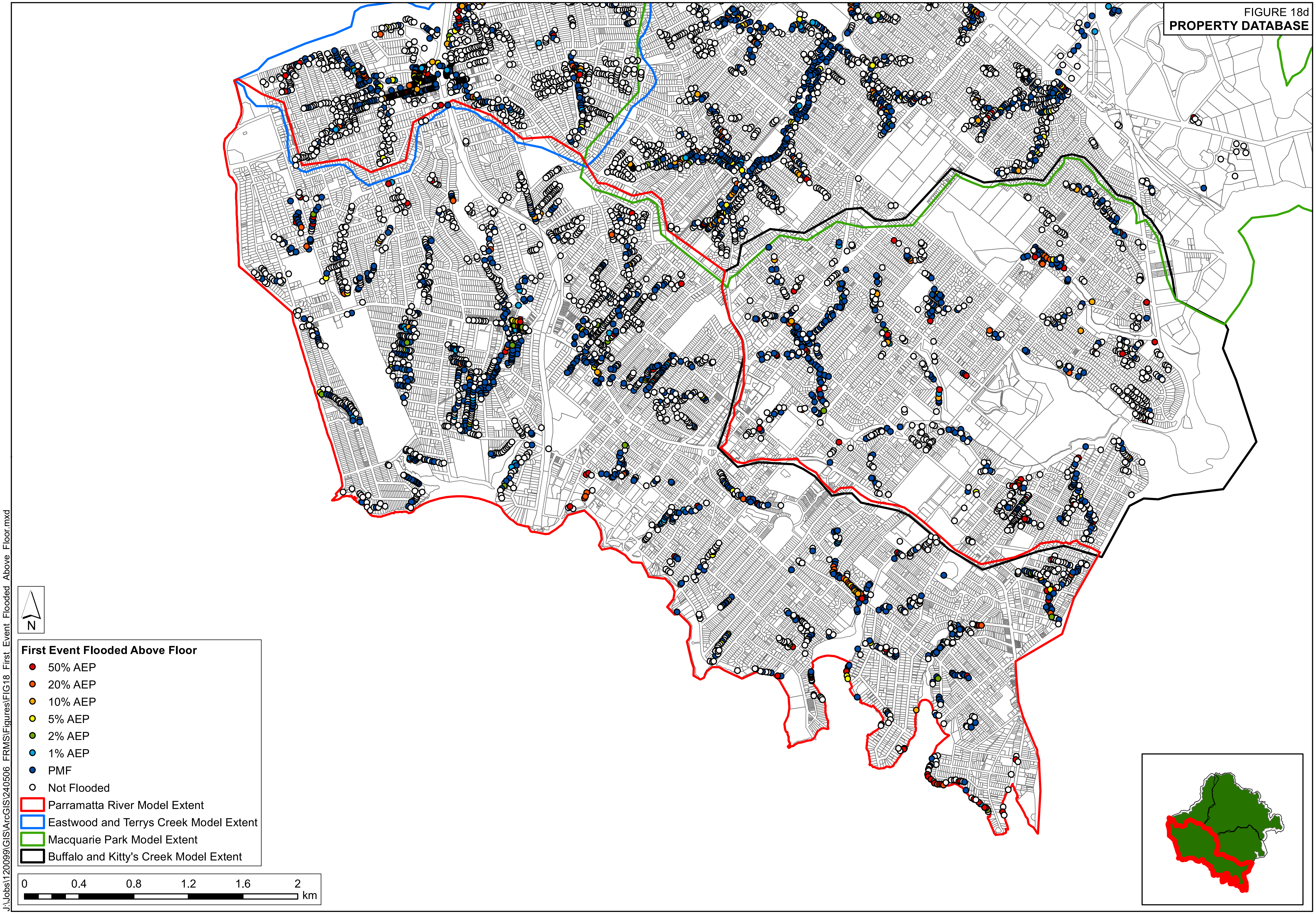


FIGURE 18c
PROPERTY DATABASE



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG18_First_Event_Flooded_Above_Floor.mxd



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG18_First_Event_Flooded_Above_Floor.mxd

FIGURE 19a
PREVIOUS FLOOD MITIGATION OPTIONS REJECTED

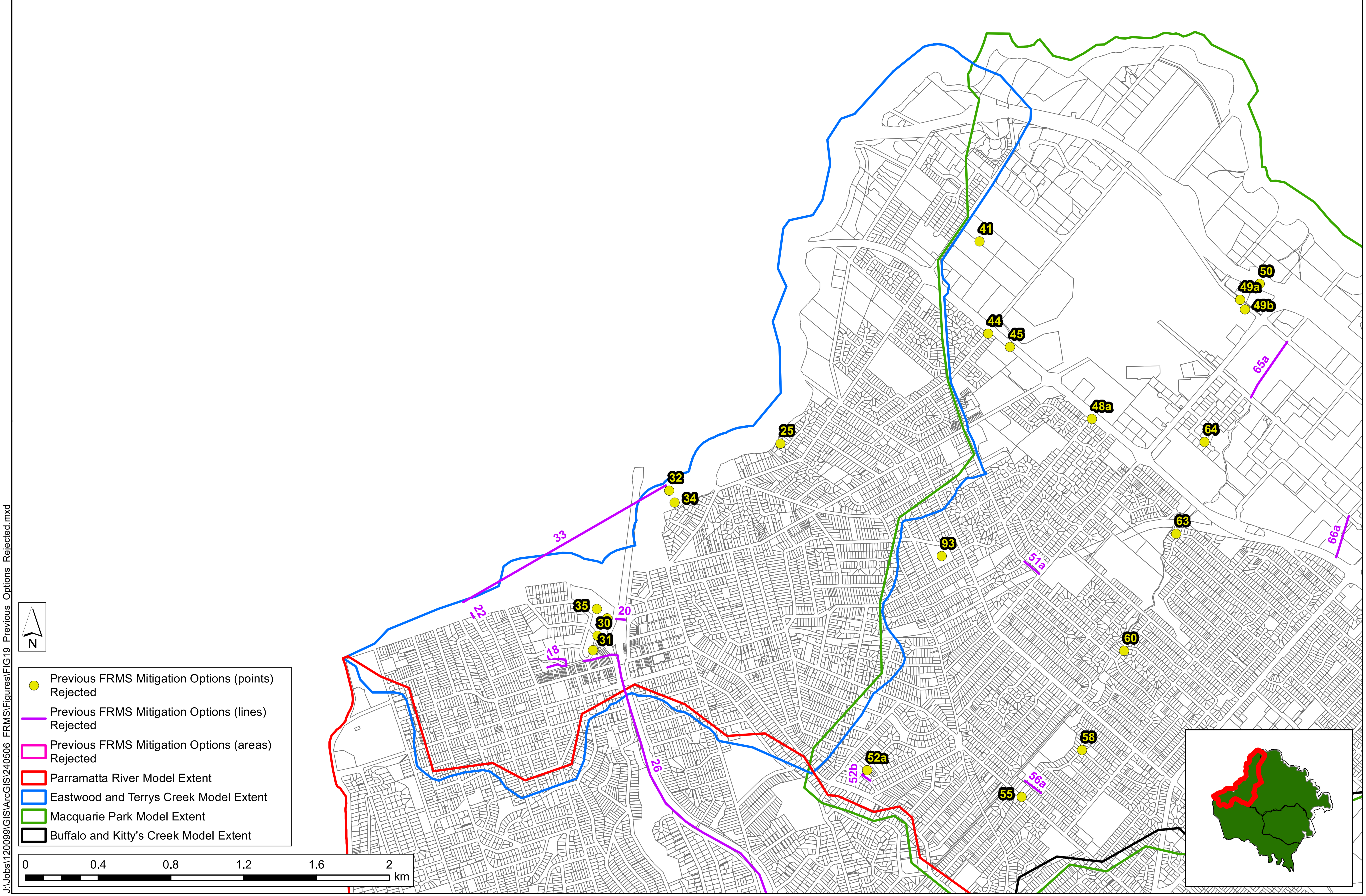


FIGURE 19b
PREVIOUS FLOOD MITIGATION OPTIONS REJECTED

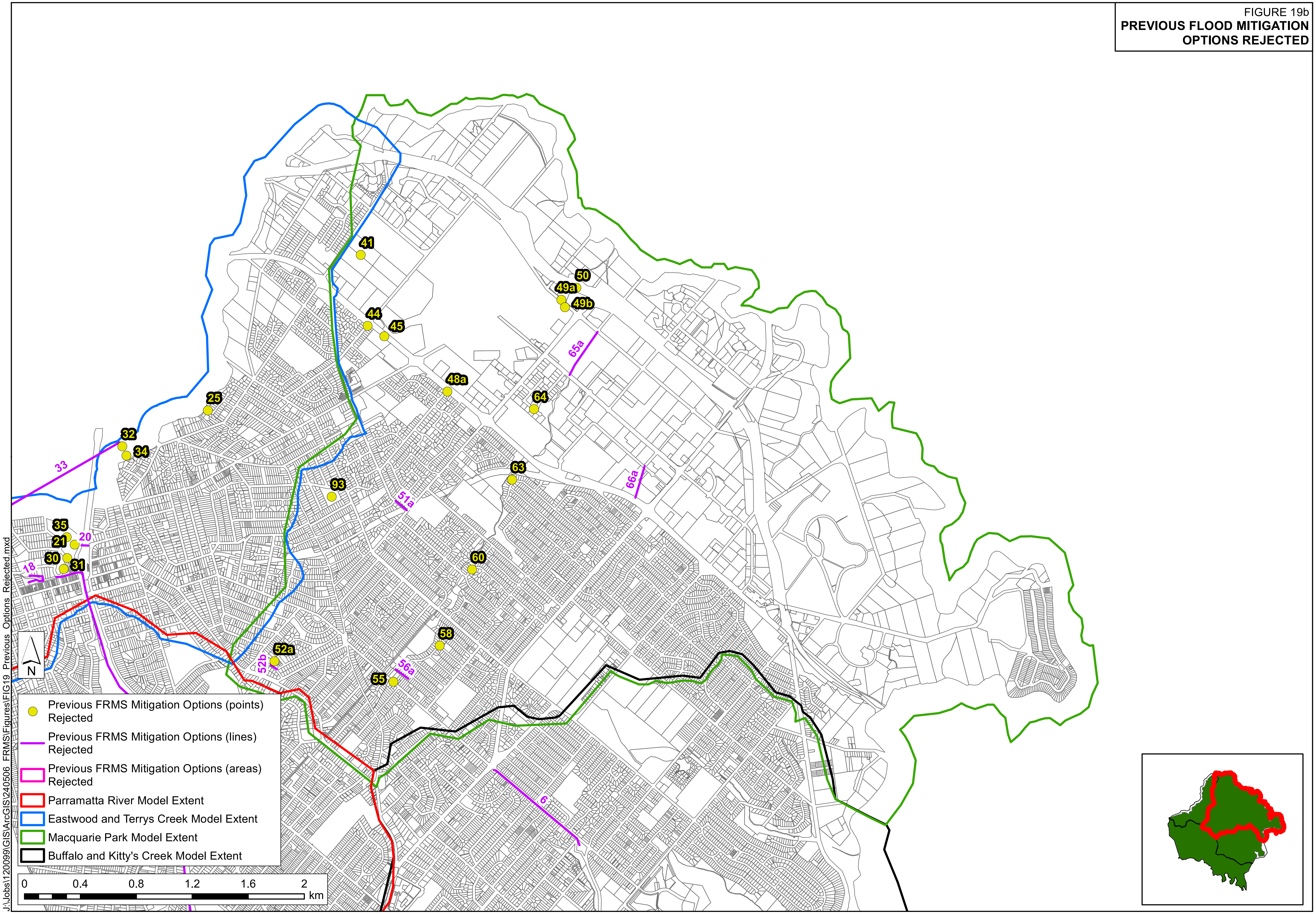
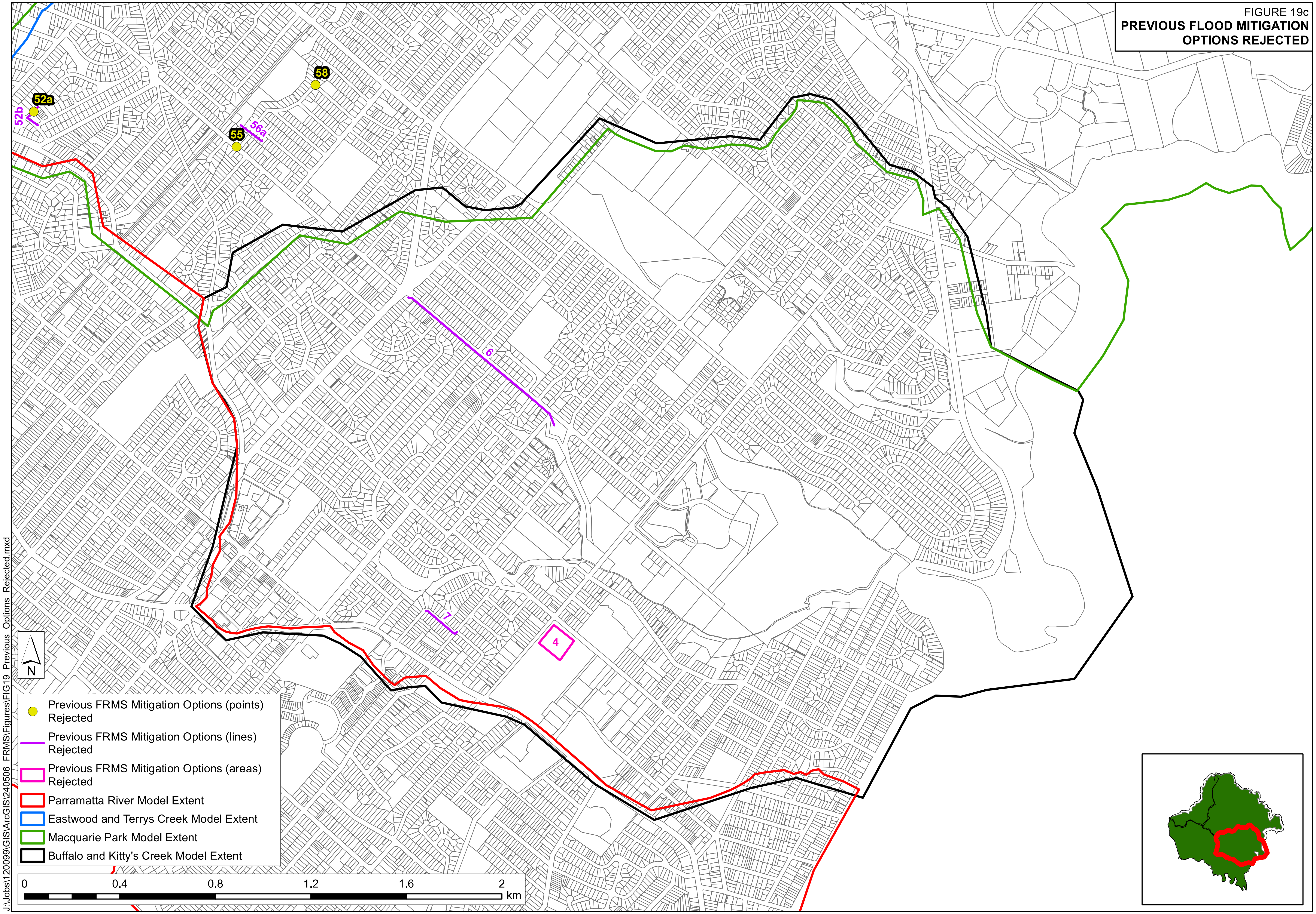
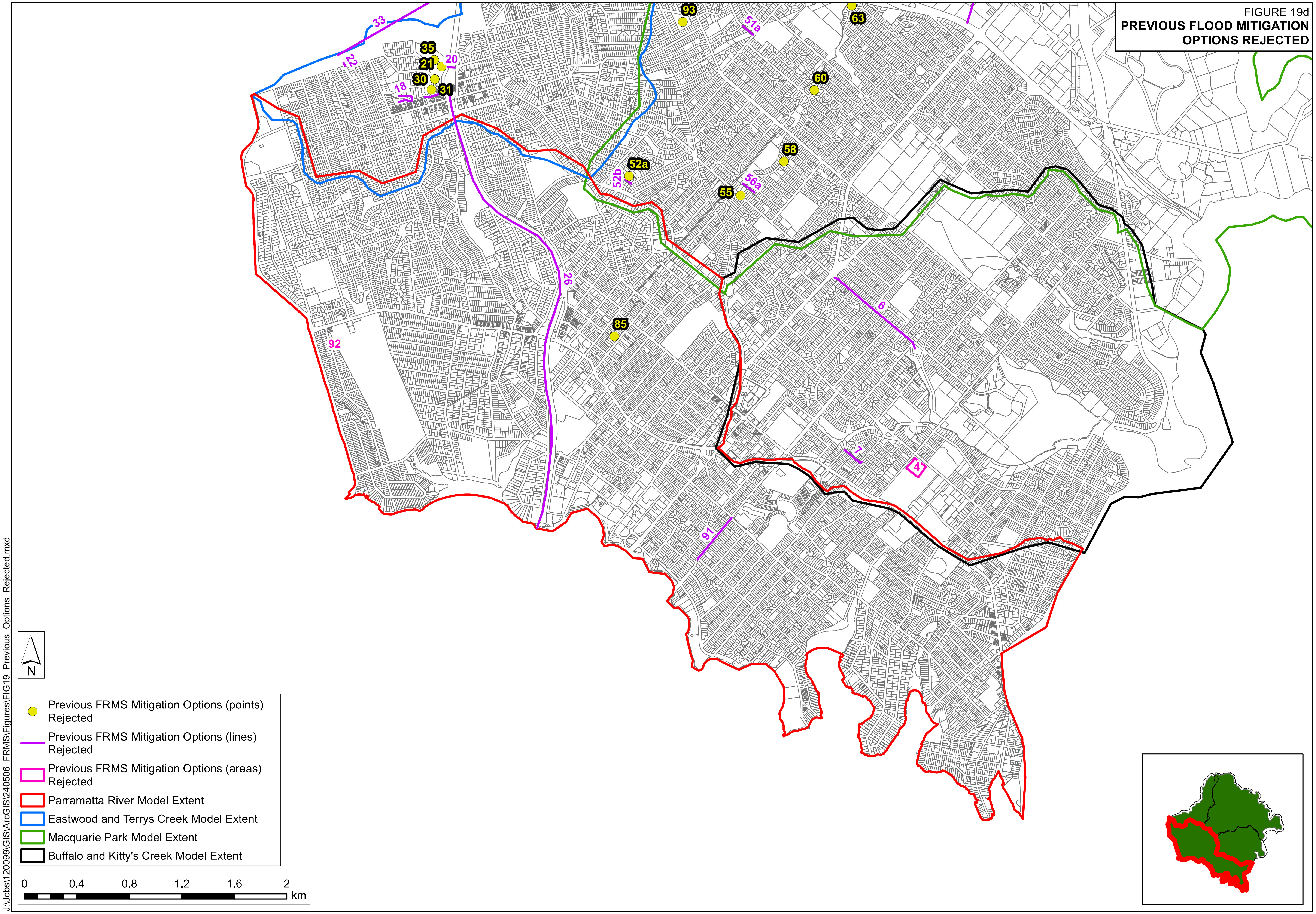


FIGURE 19c
PREVIOUS FLOOD MITIGATION OPTIONS REJECTED



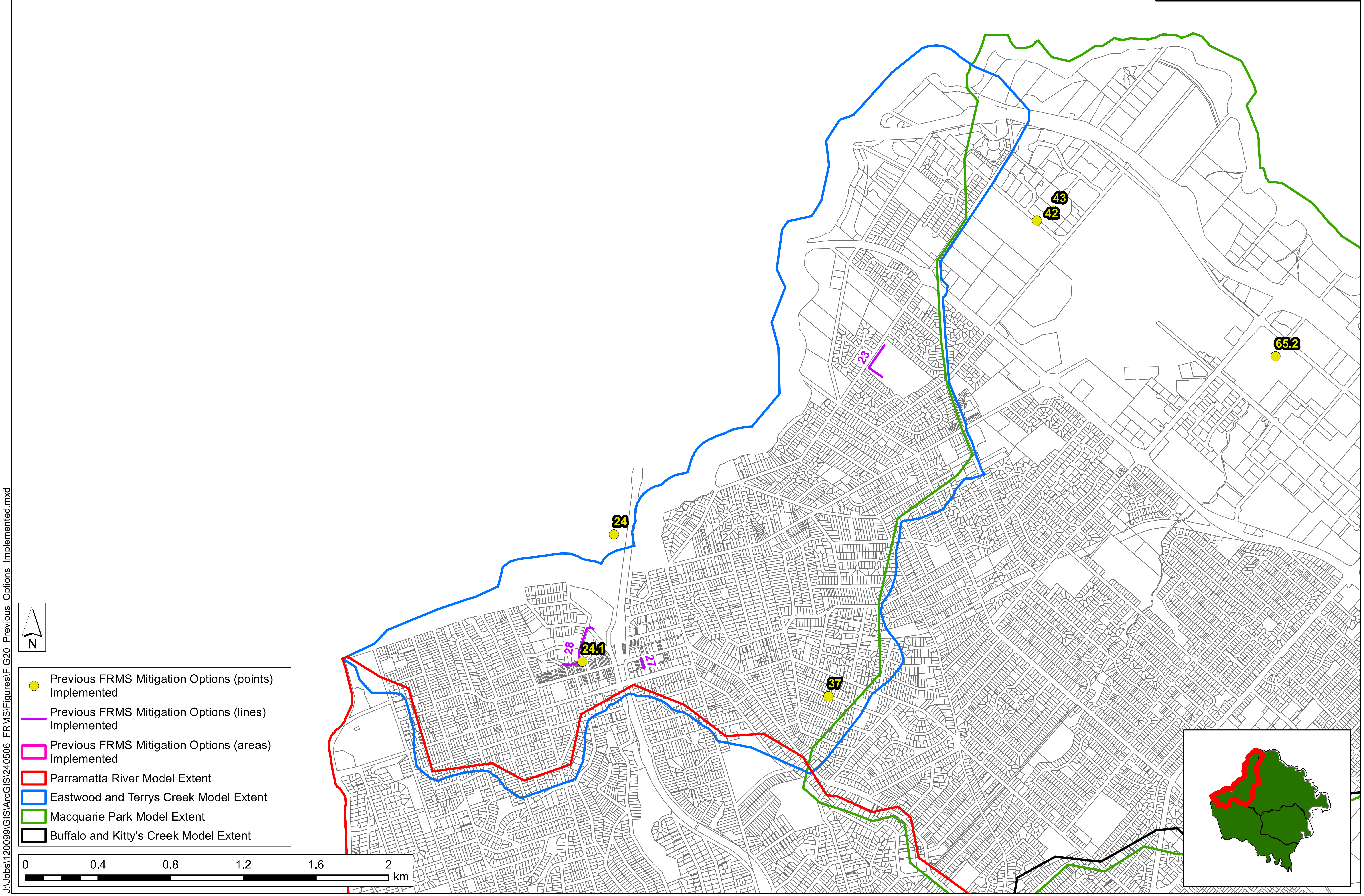
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG19_Previous_Options_Rejected.mxd

FIGURE 19d
PREVIOUS FLOOD MITIGATION OPTIONS REJECTED



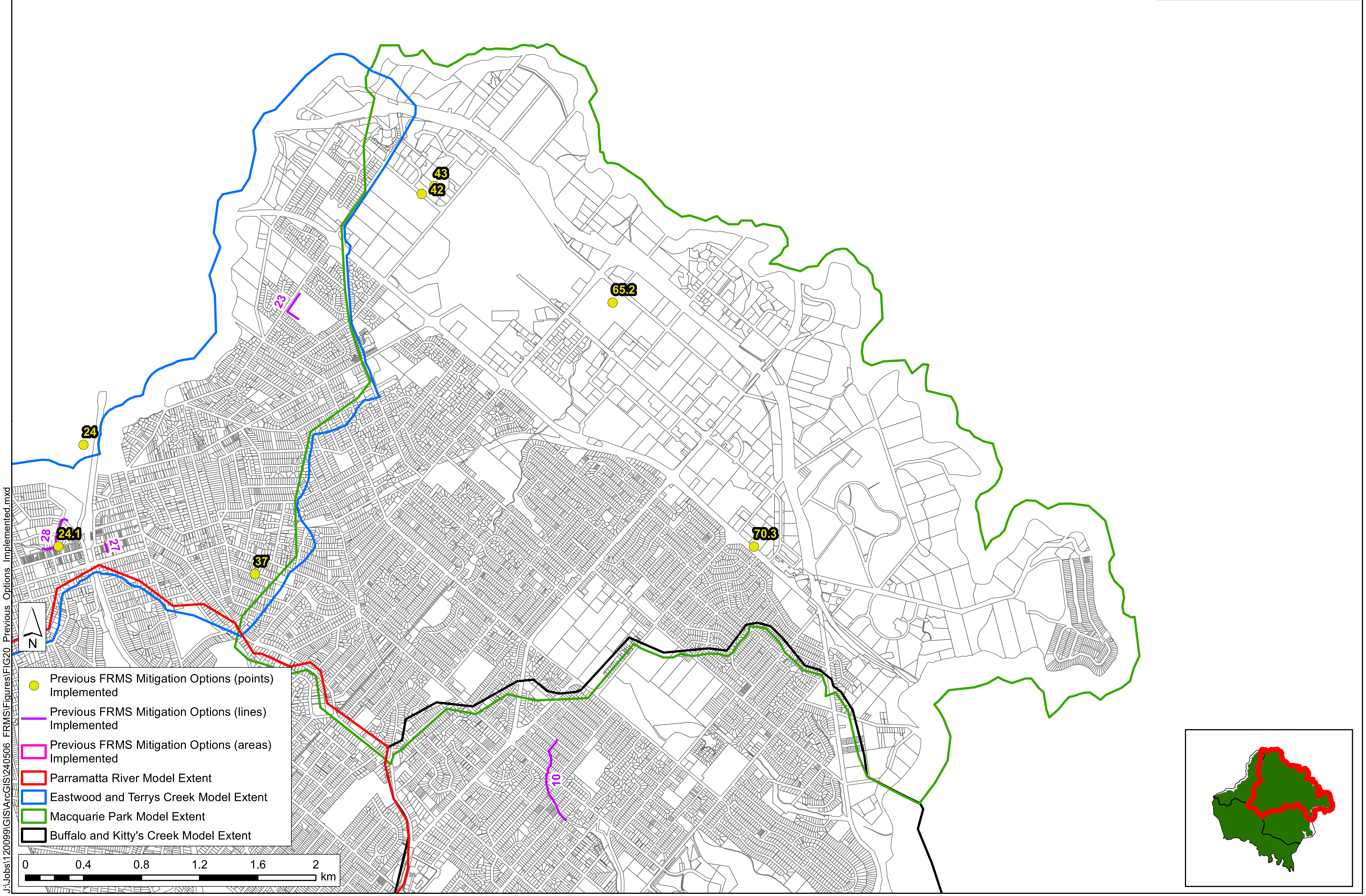
J:\Jobs\120099\GIS\ArcGIS\240506 FRMS\Figures\FIG19 Previous Options Rejected.mxd

FIGURE 20a
PREVIOUS FLOOD MITIGATION OPTIONS IMPLEMENTED



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG20_Previous_Options_Implemented.mxd

FIGURE 20b
PREVIOUS FLOOD MITIGATION OPTIONS IMPLEMENTED



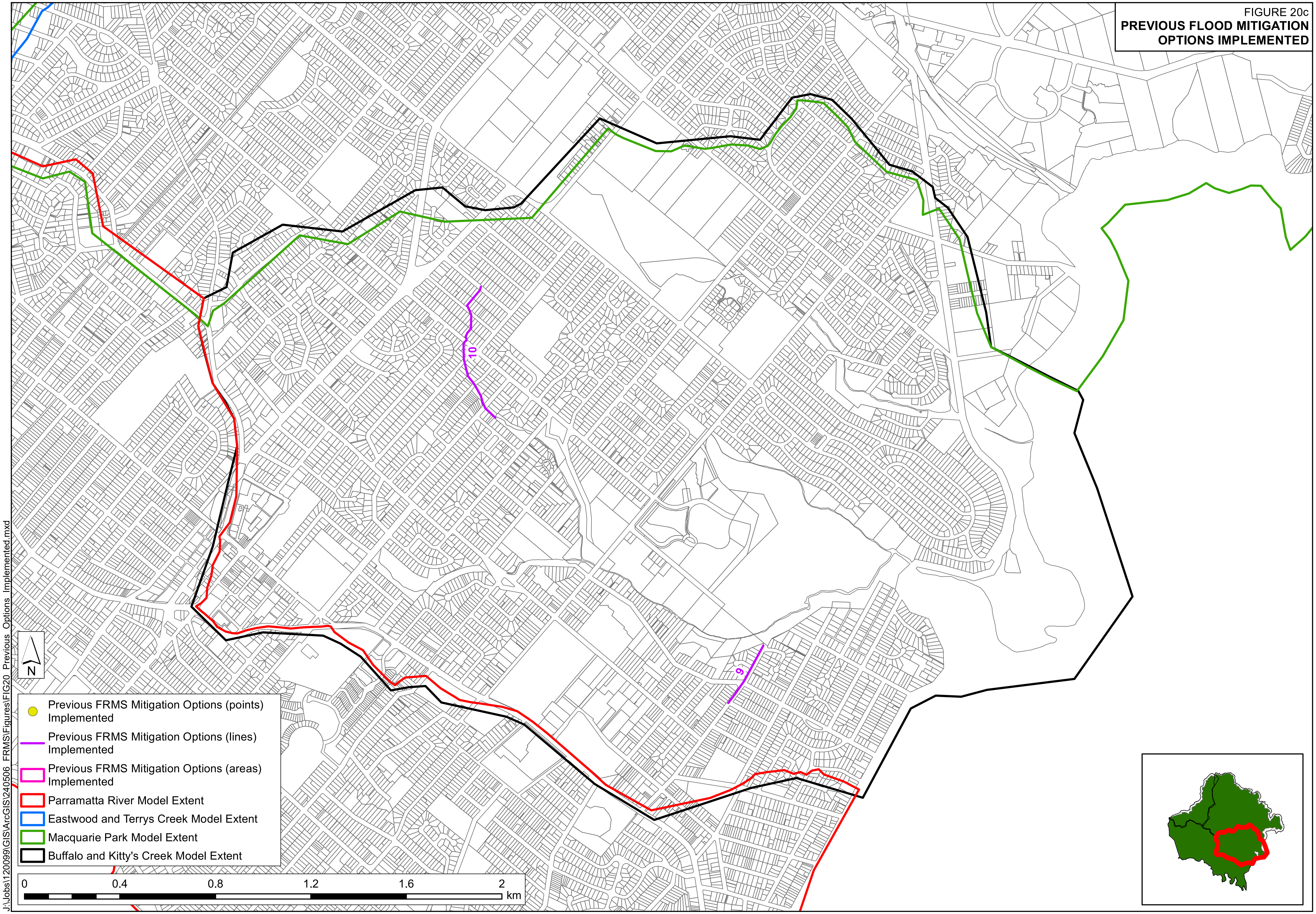
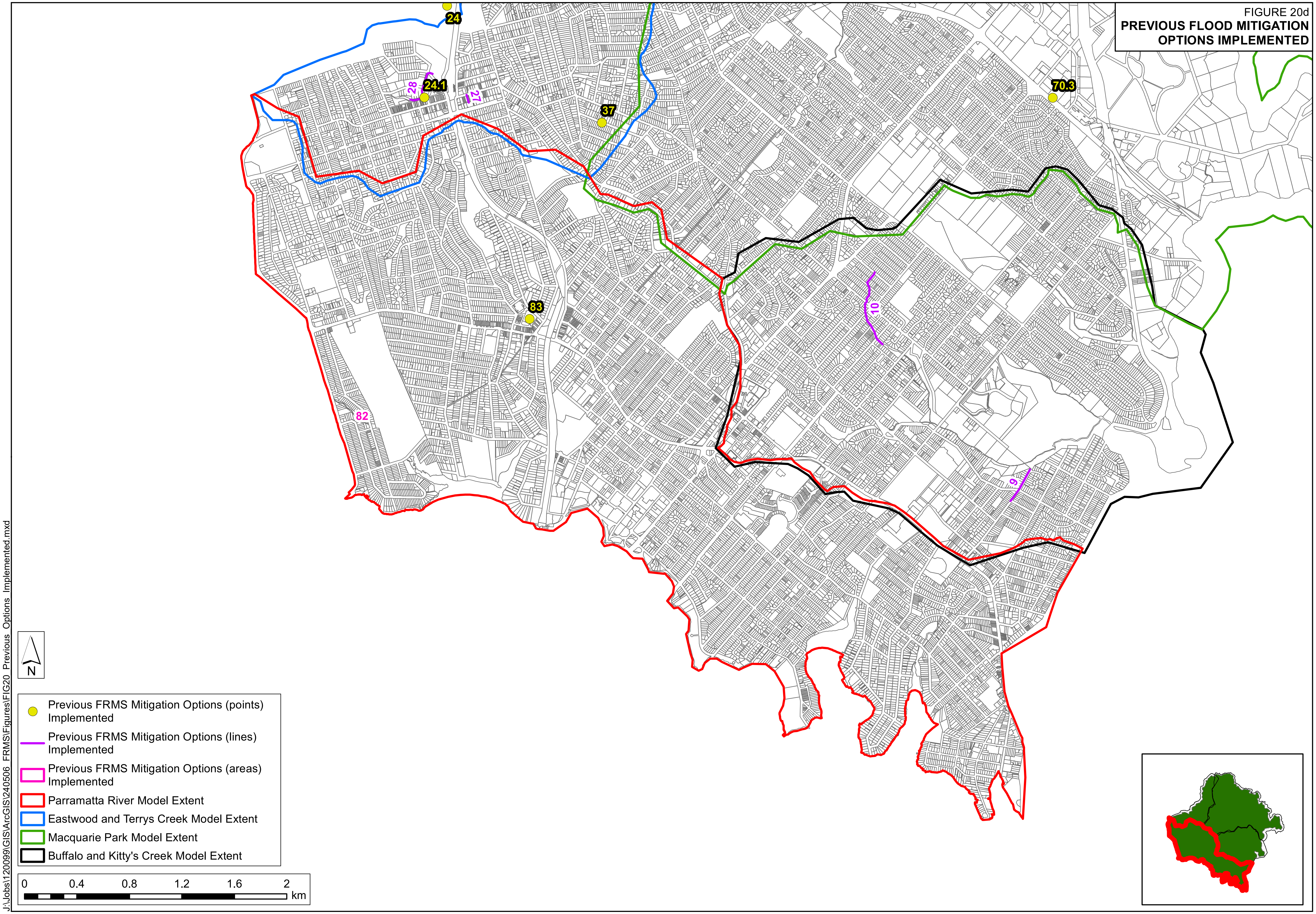


FIGURE 20c
PREVIOUS FLOOD MITIGATION OPTIONS IMPLEMENTED
10
9
N
Previous FRMS Mitigation Options (points) Implemented
Previous FRMS Mitigation Options (lines) Implemented
Previous FRMS Mitigation Options (areas) Implemented
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0
0.4
0.8
1.2
1.6
2
km
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG20_Previous_Options_Implemented.mxd

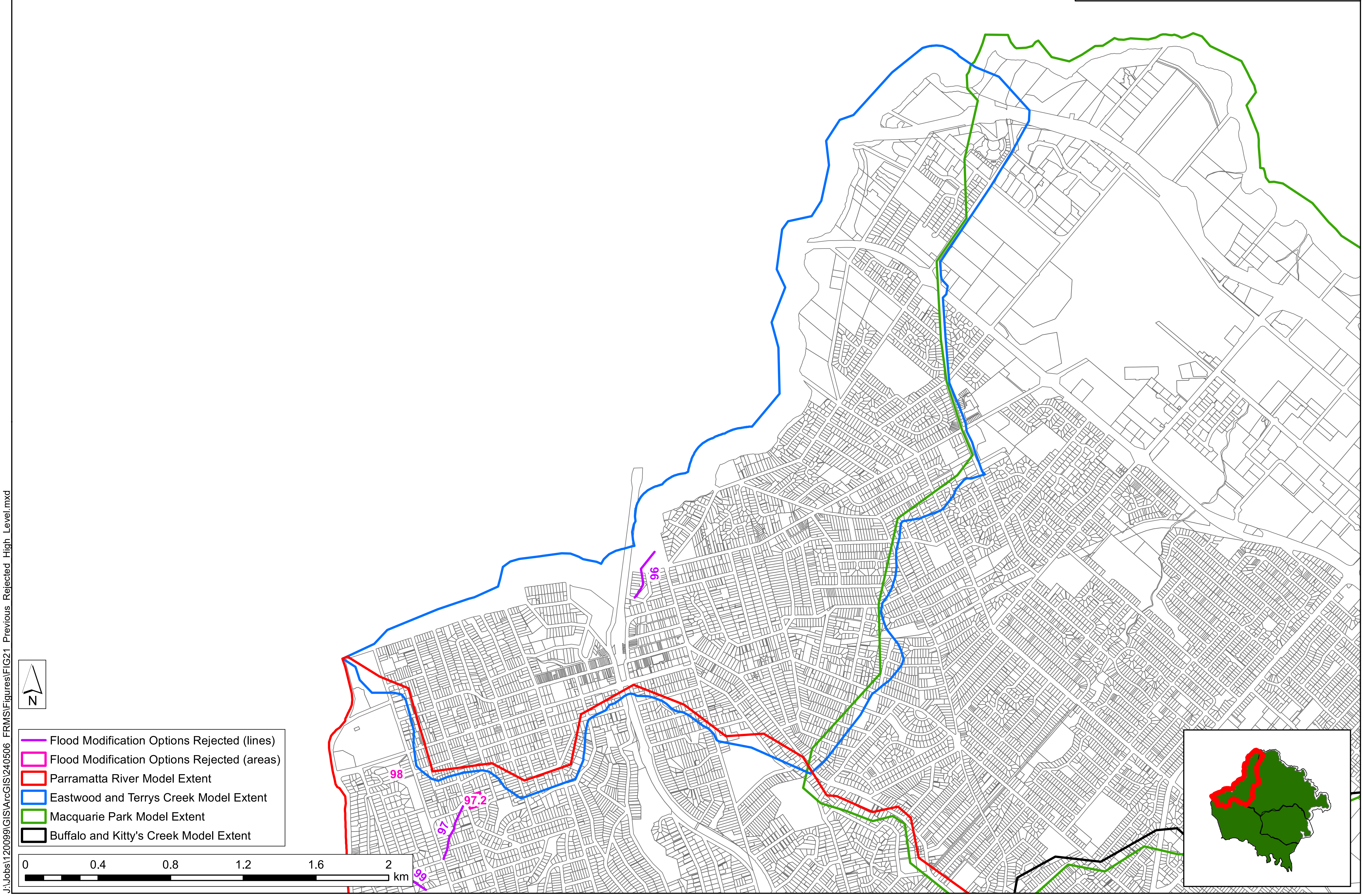
FIGURE 20d
PREVIOUS FLOOD MITIGATION OPTIONS IMPLEMENTED



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG20_Previous_Options_Implemented.mxd

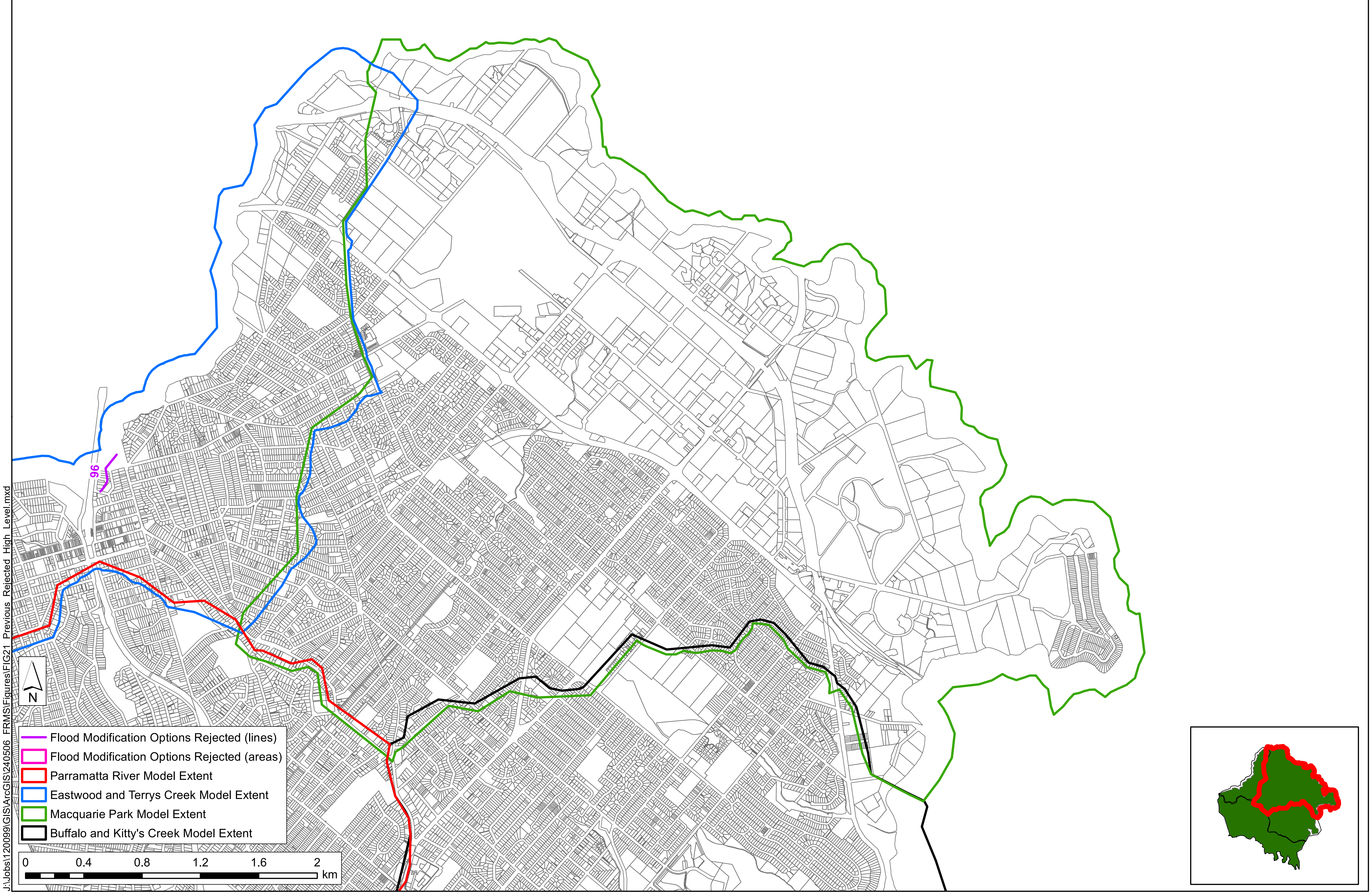
FIGURE 21a

FLOOD MODIFICATION OPTIONS REJECTED AT HIGH LEVEL ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG21_Previous_Rejected_High_Level.mxd

FIGURE 21b
FLOOD MODIFICATION OPTIONS REJECTED AT HIGH LEVEL ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG21_Previous_Rejected_High_Level.mxd

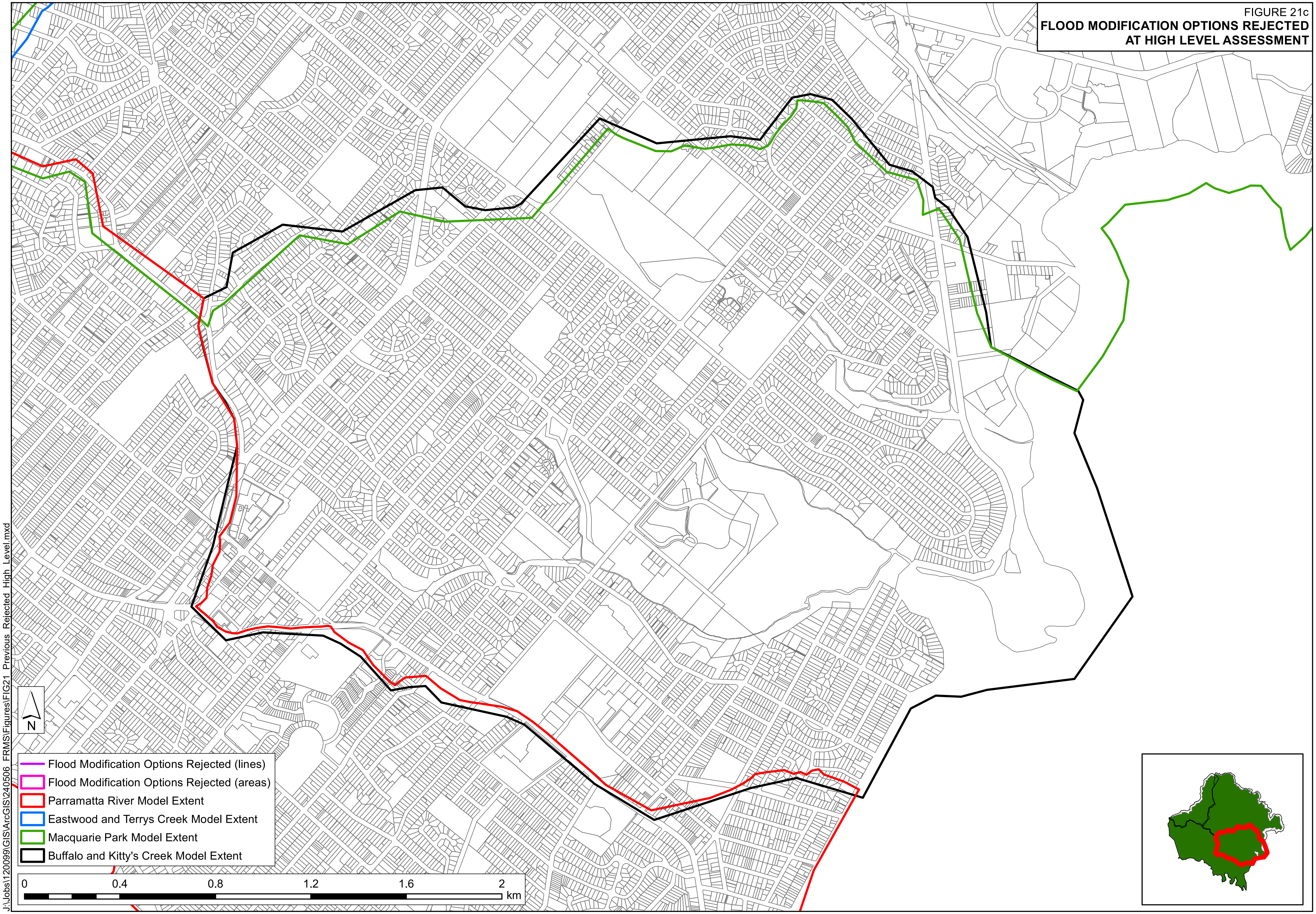
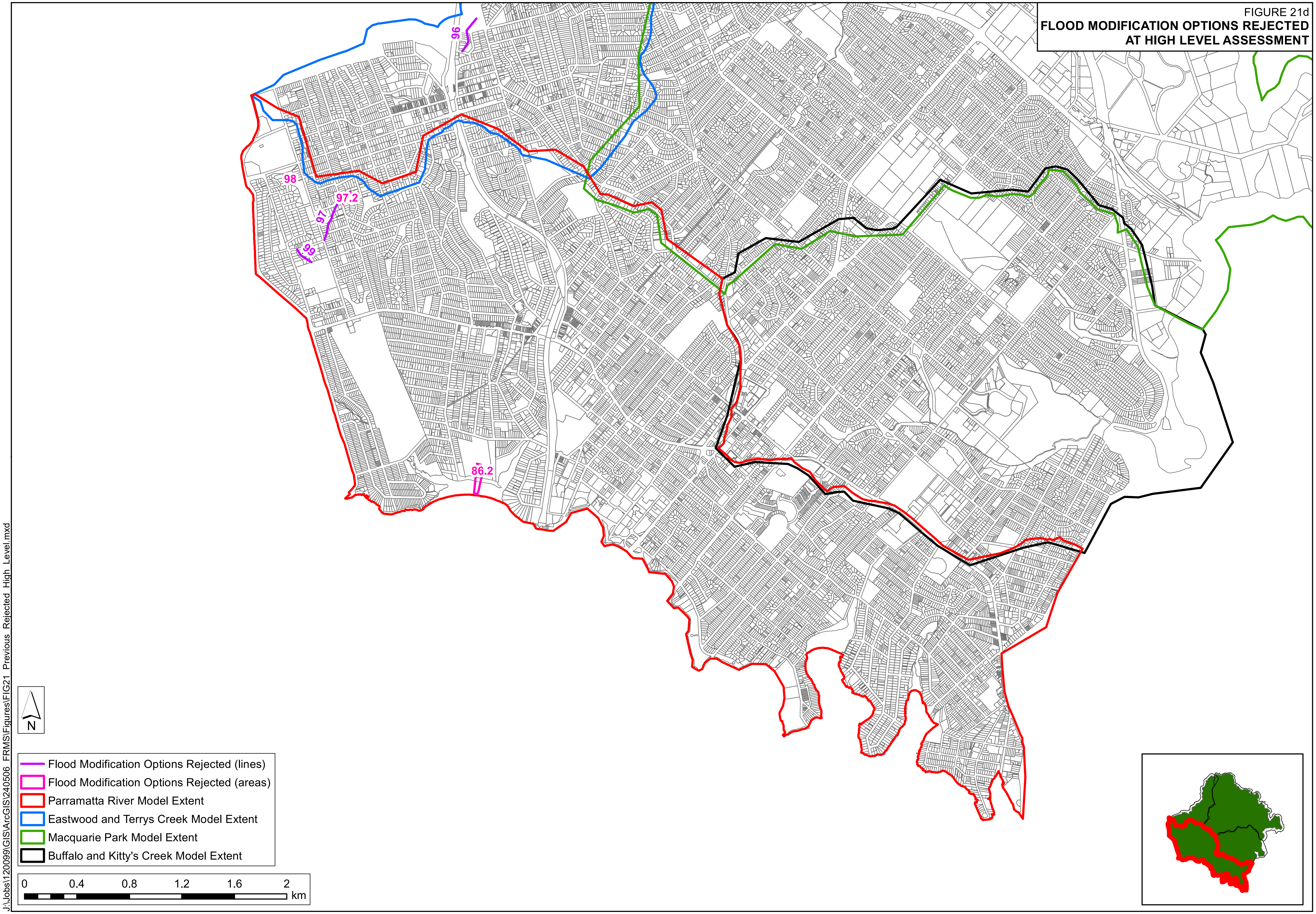


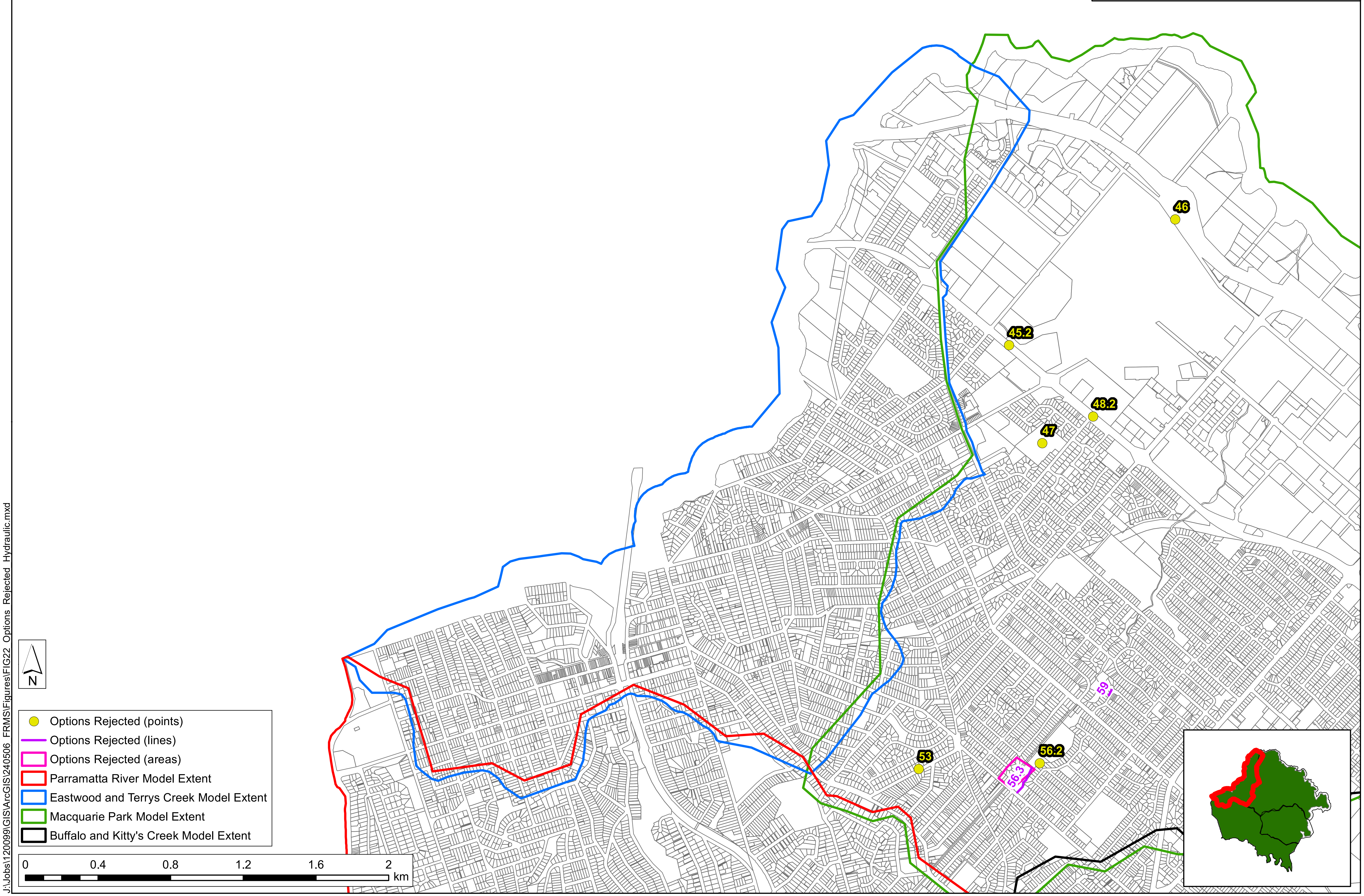
FIGURE 21c
FLOOD MODIFICATION OPTIONS REJECTED AT HIGH LEVEL ASSESSMENT
N
Flood Modification Options Rejected (lines)
Flood Modification Options Rejected (areas)
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0
0.4
0.8
1.2
1.6
2
km
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG21_Previous_Rejected_High_Level.mxd

FIGURE 21d
FLOOD MODIFICATION OPTIONS REJECTED AT HIGH LEVEL ASSESSMENT



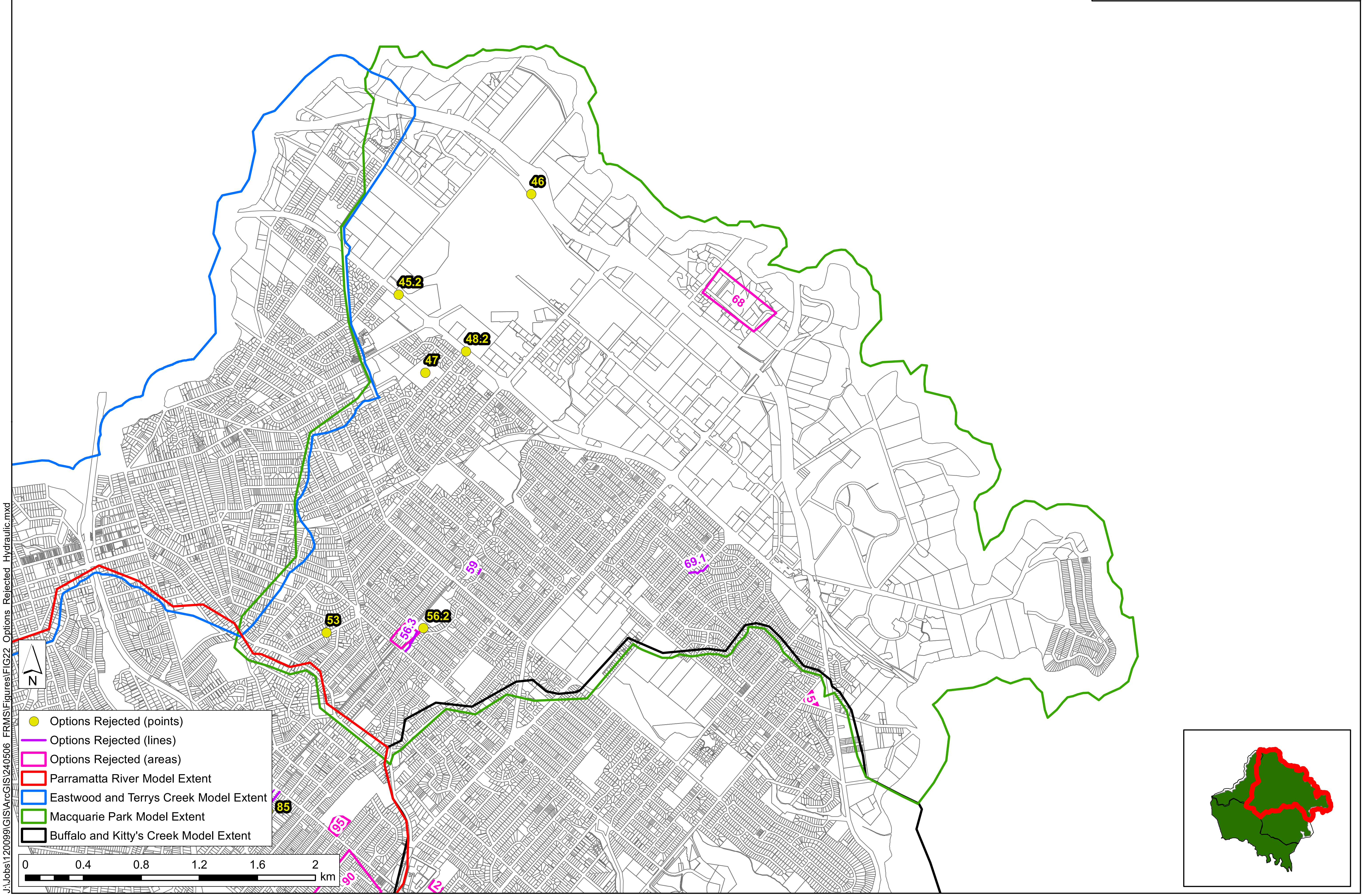
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG21_Previous_Rejected_High_Level.mxd

FIGURE 22a
FLOOD MITIGATION OPTIONS REJECTED AT HYDRAULIC ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240506 FRMS\Figures\FIG22 Options Rejected Hydraulic.mxd

FIGURE 22b
FLOOD MITIGATION OPTIONS REJECTED AT HYDRAULIC ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG22_Options_Rejected_Hydraulic.mxd

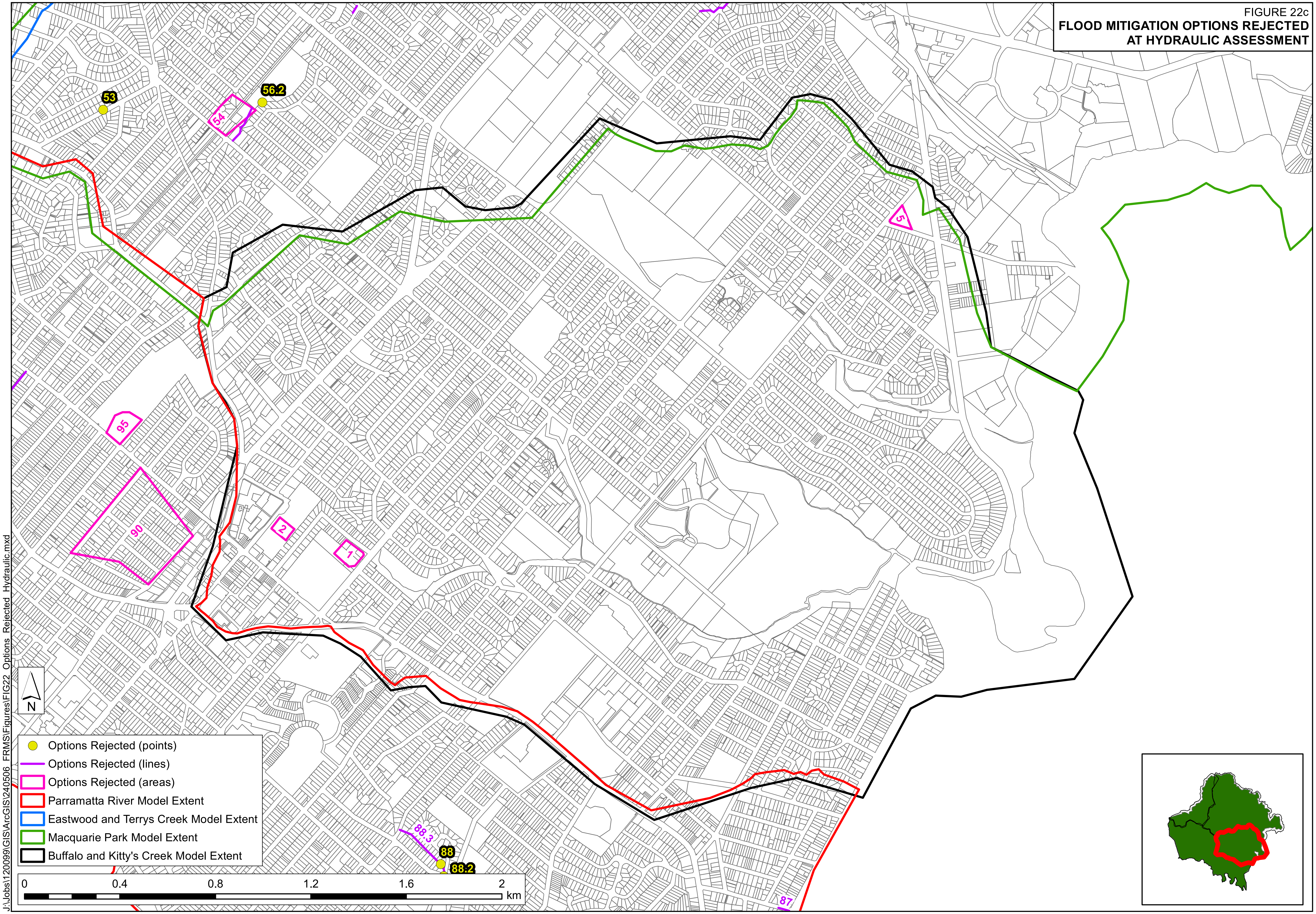
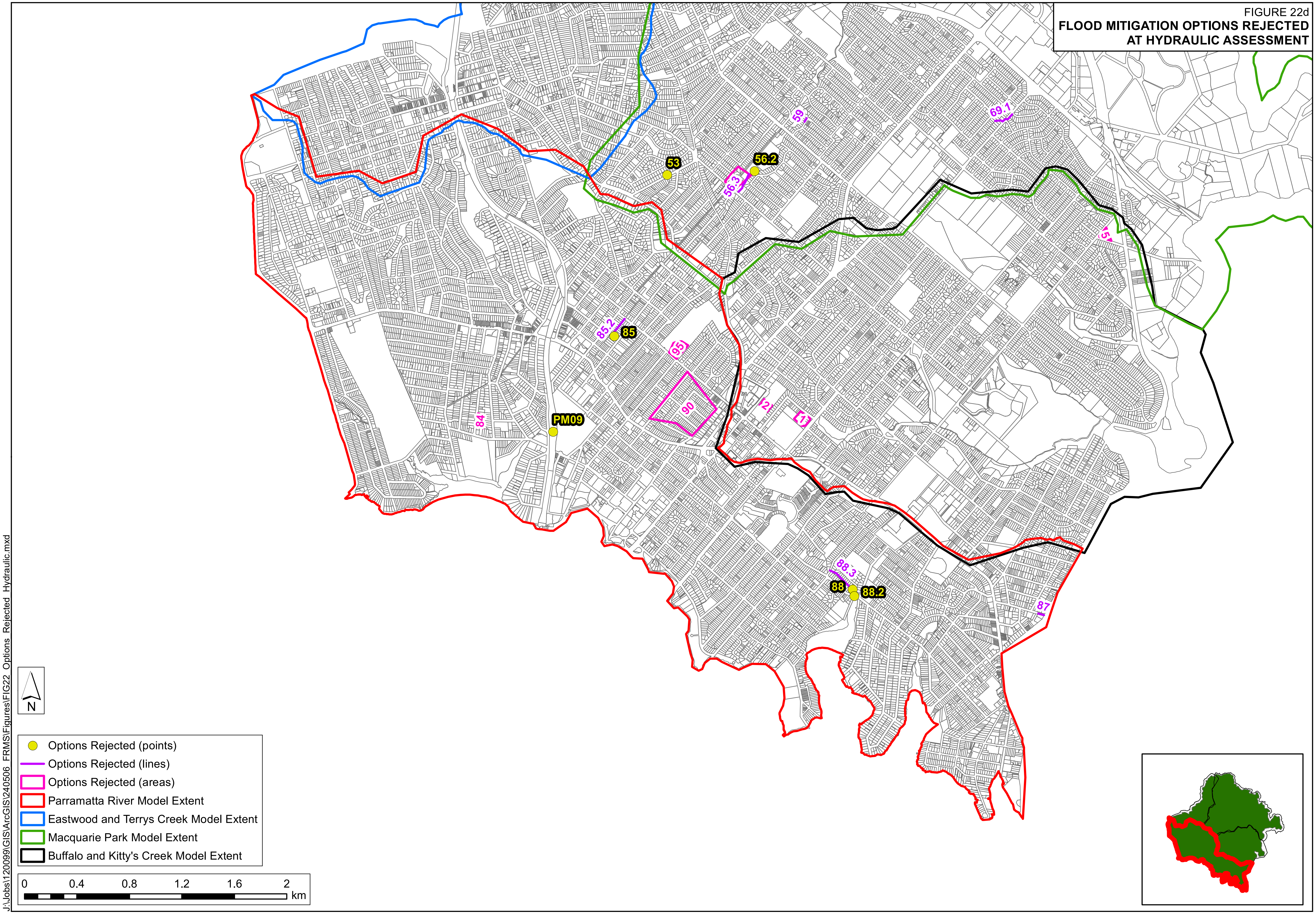


FIGURE 22c
FLOOD MITIGATION OPTIONS REJECTED AT HYDRAULIC ASSESSMENT

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG22_Options_Rejected_Hydraulic.mxd

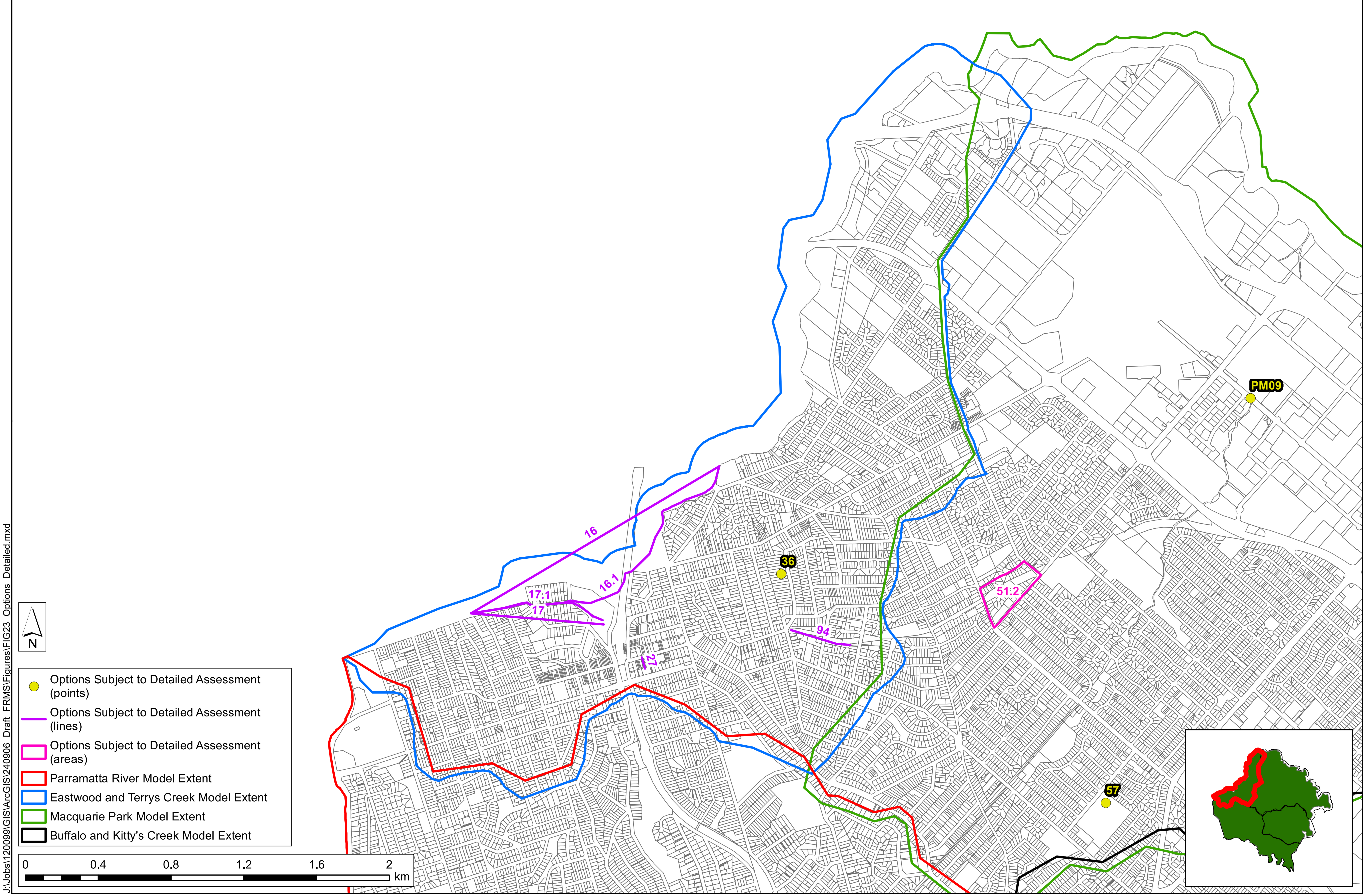
FIGURE 22d

FLOOD MITIGATION OPTIONS REJECTED AT HYDRAULIC ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG22_Options_Rejected_Hydraulic.mxd

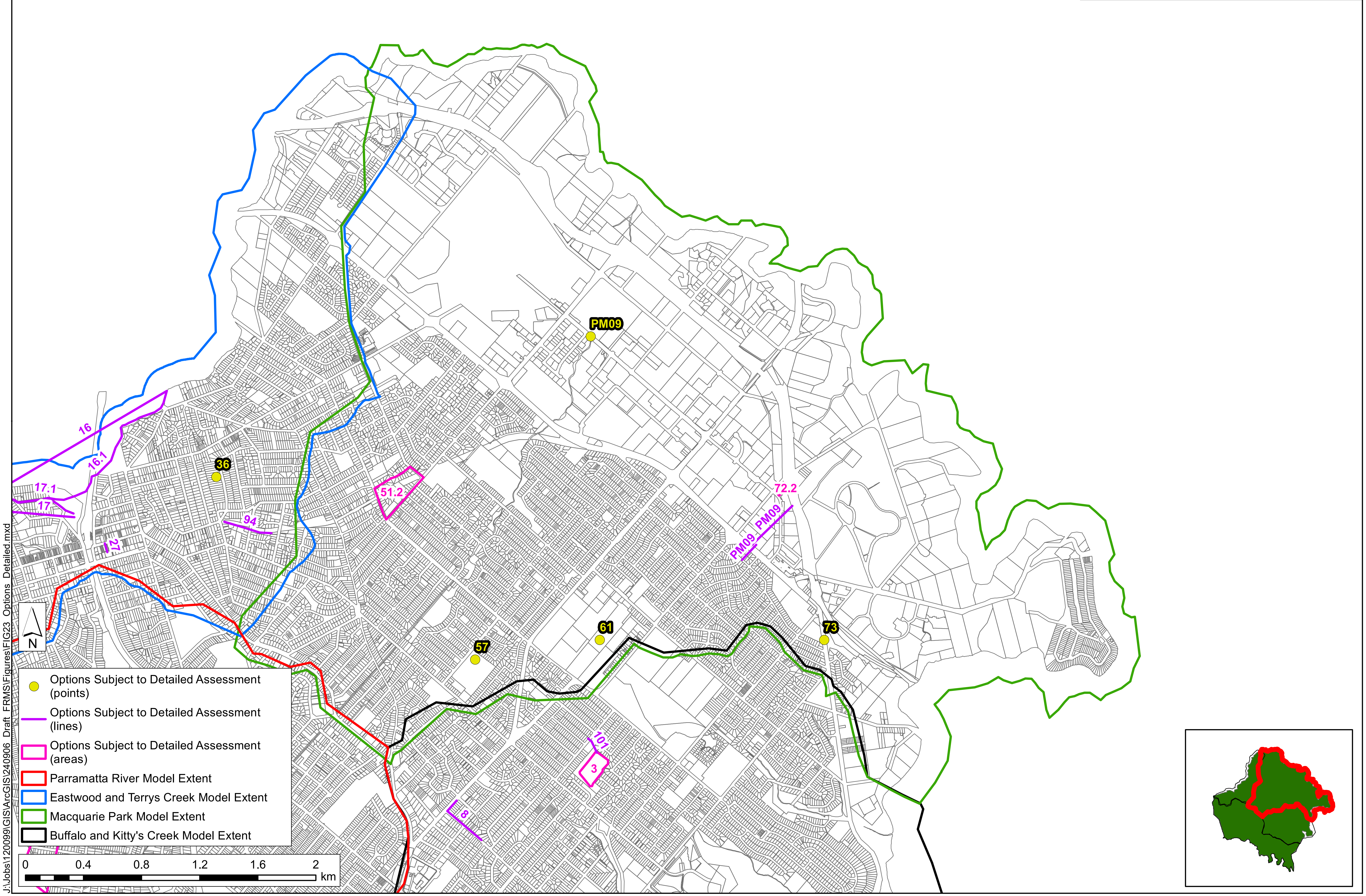
FIGURE 23a
FLOOD MITIGATION OPTIONS SUBJECT TO DETAILED ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\Figures\FIG23_Options_Detailed.mxd

FIGURE 23b

FLOOD MITIGATION OPTIONS SUBJECT TO DETAILED ASSESSMENT



J:\Jobs\120099\GIS\ArcGIS\240906 Draft FRMS\Figures\FIG23 Options Detailed.mxd

FIGURE 23c
FLOOD MITIGATION OPTIONS SUBJECT TO DETAILED ASSESSMENT

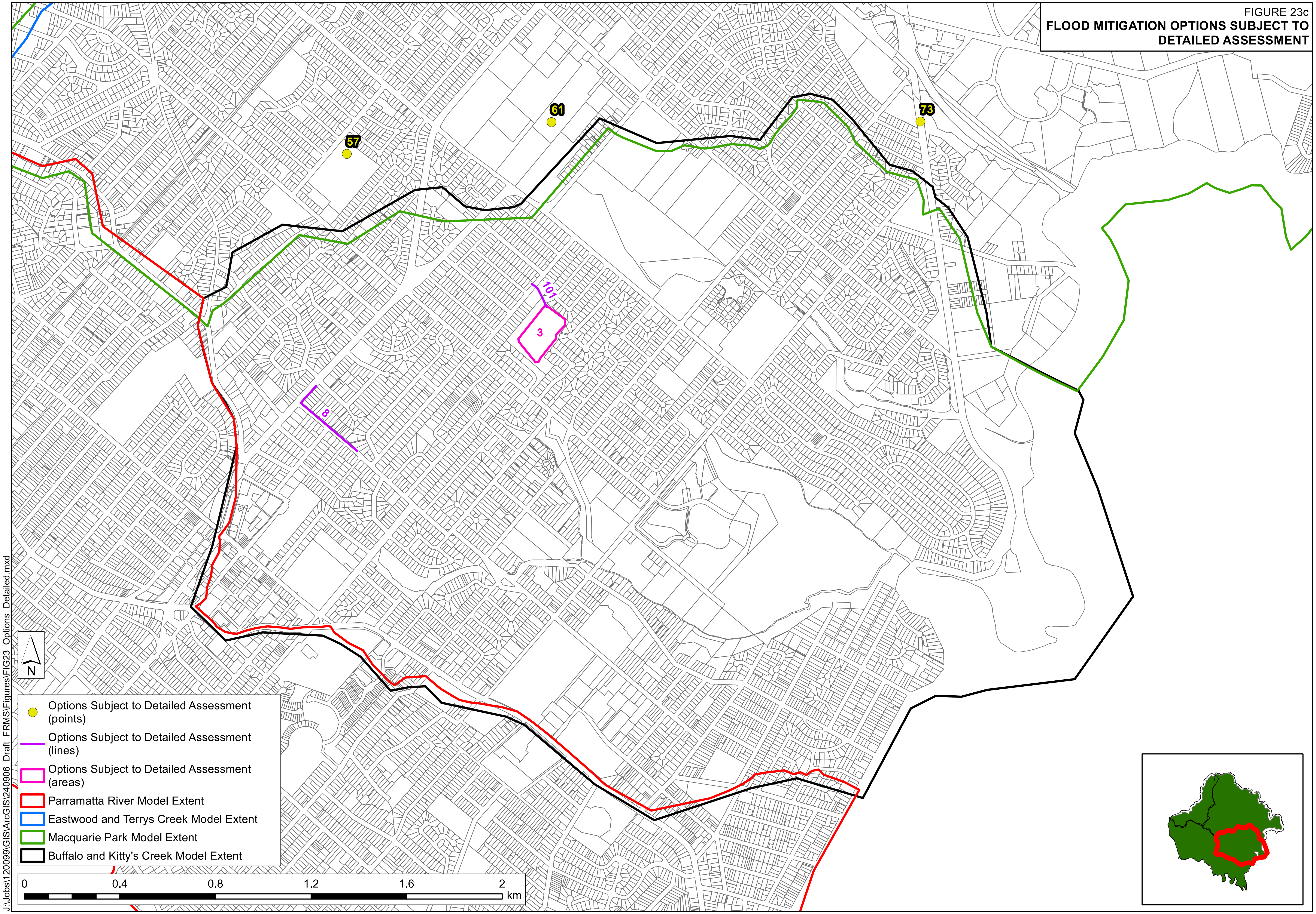
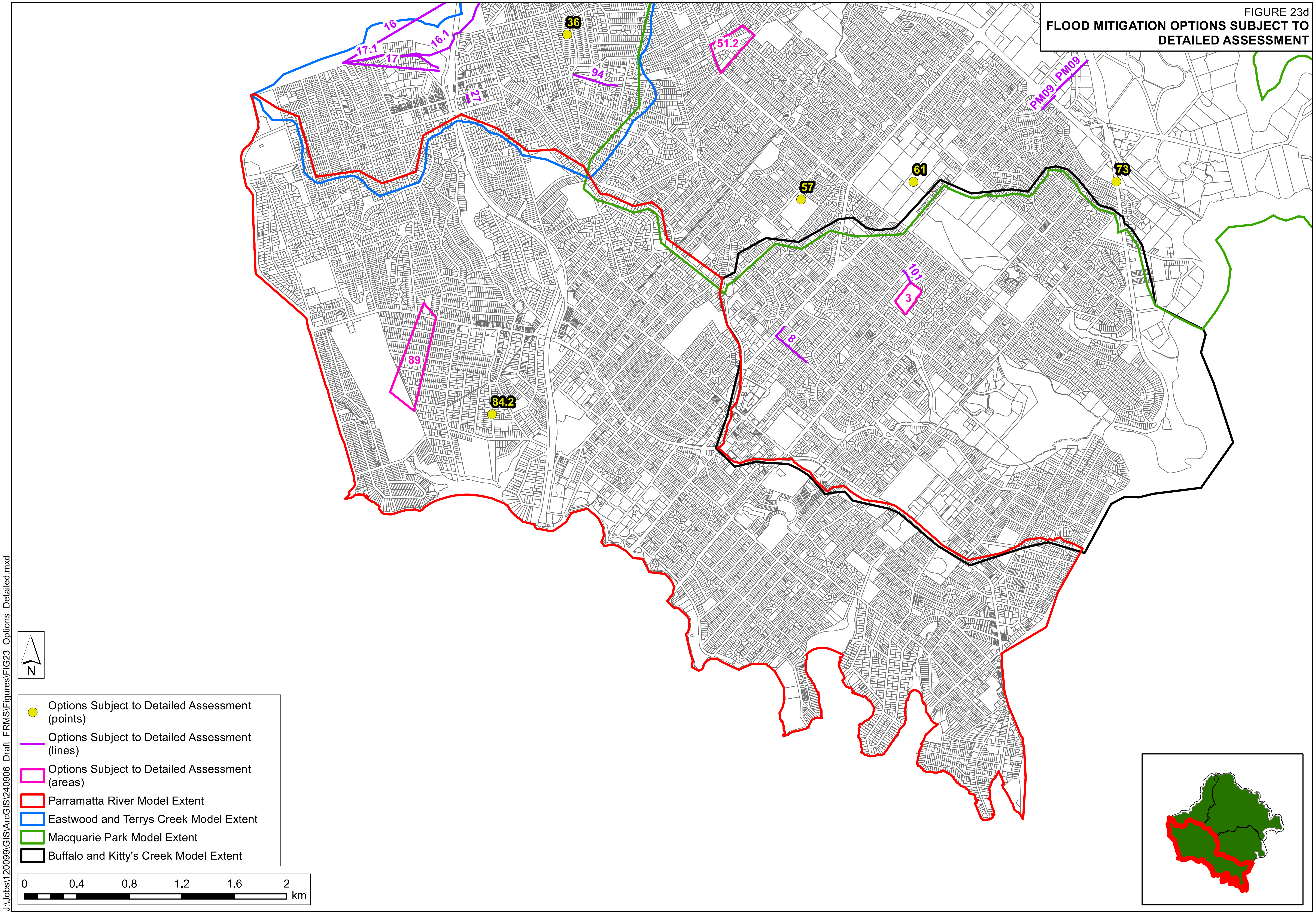
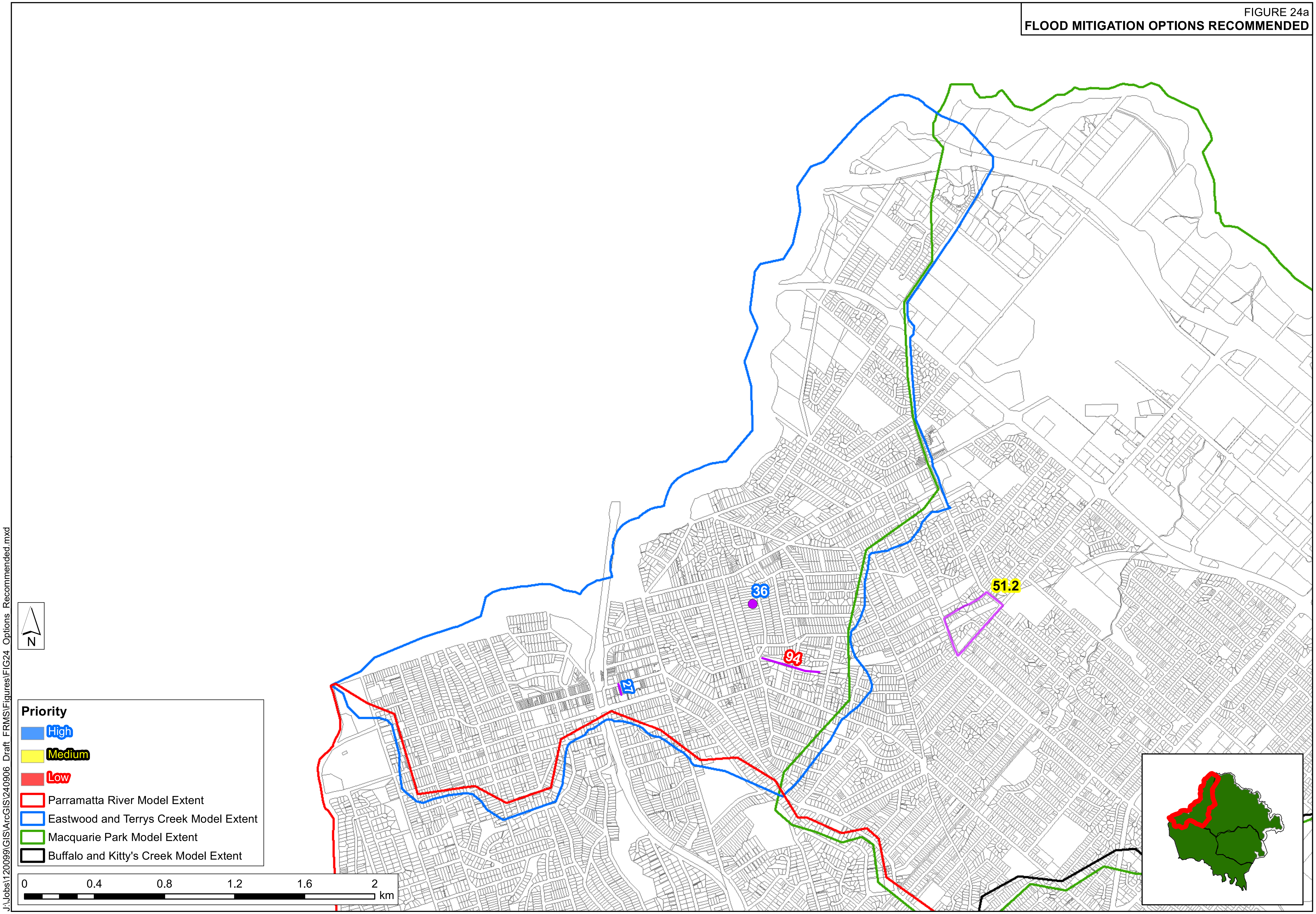


FIGURE 23d
FLOOD MITIGATION OPTIONS SUBJECT TO DETAILED ASSESSMENT



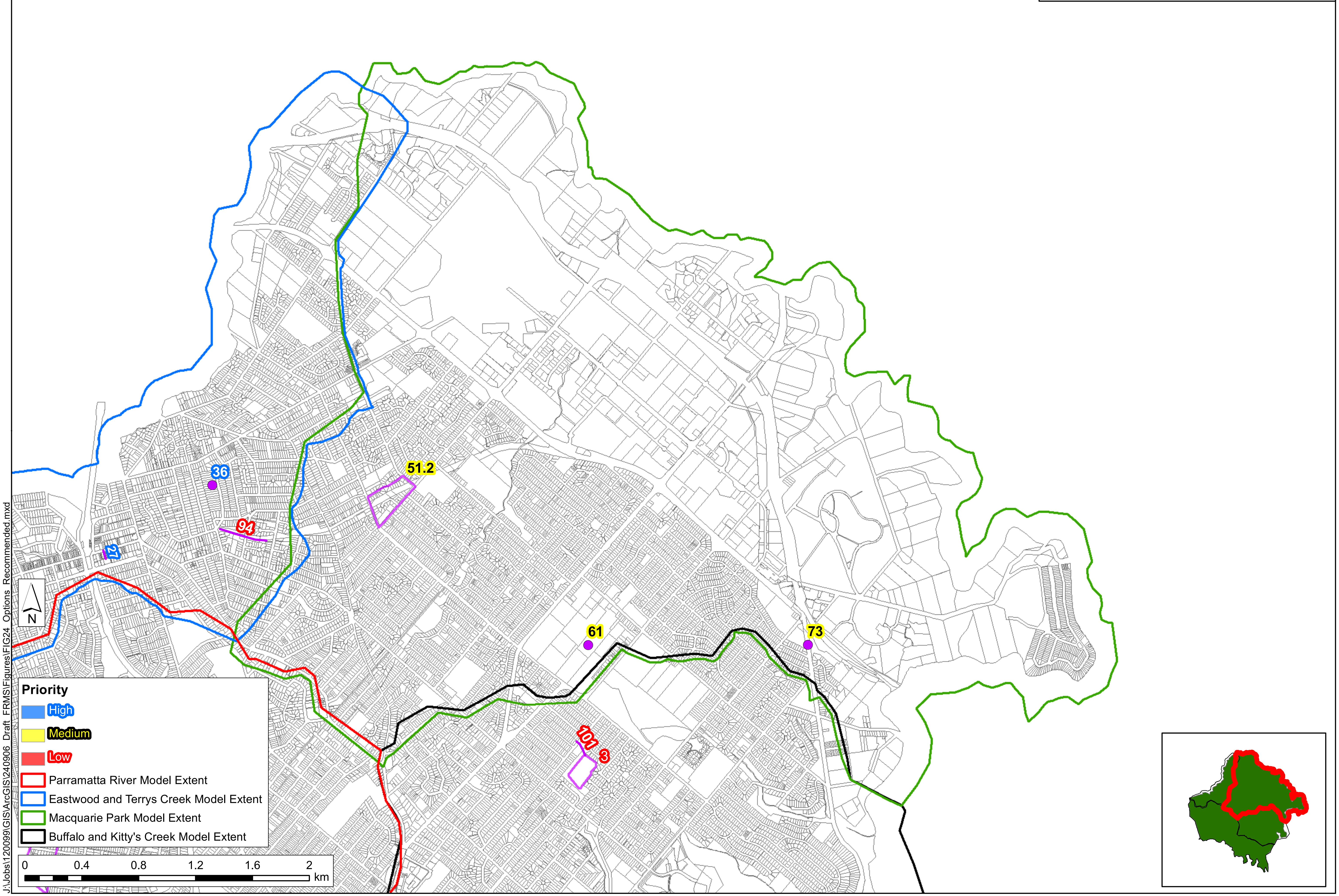
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\Figures\FIG23_Options_Detailed.mxd

FIGURE 24a
FLOOD MITIGATION OPTIONS RECOMMENDED



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\Figures\FIG24_Options_Recommended.mxd

FIGURE 24b
FLOOD MITIGATION OPTIONS RECOMMENDED



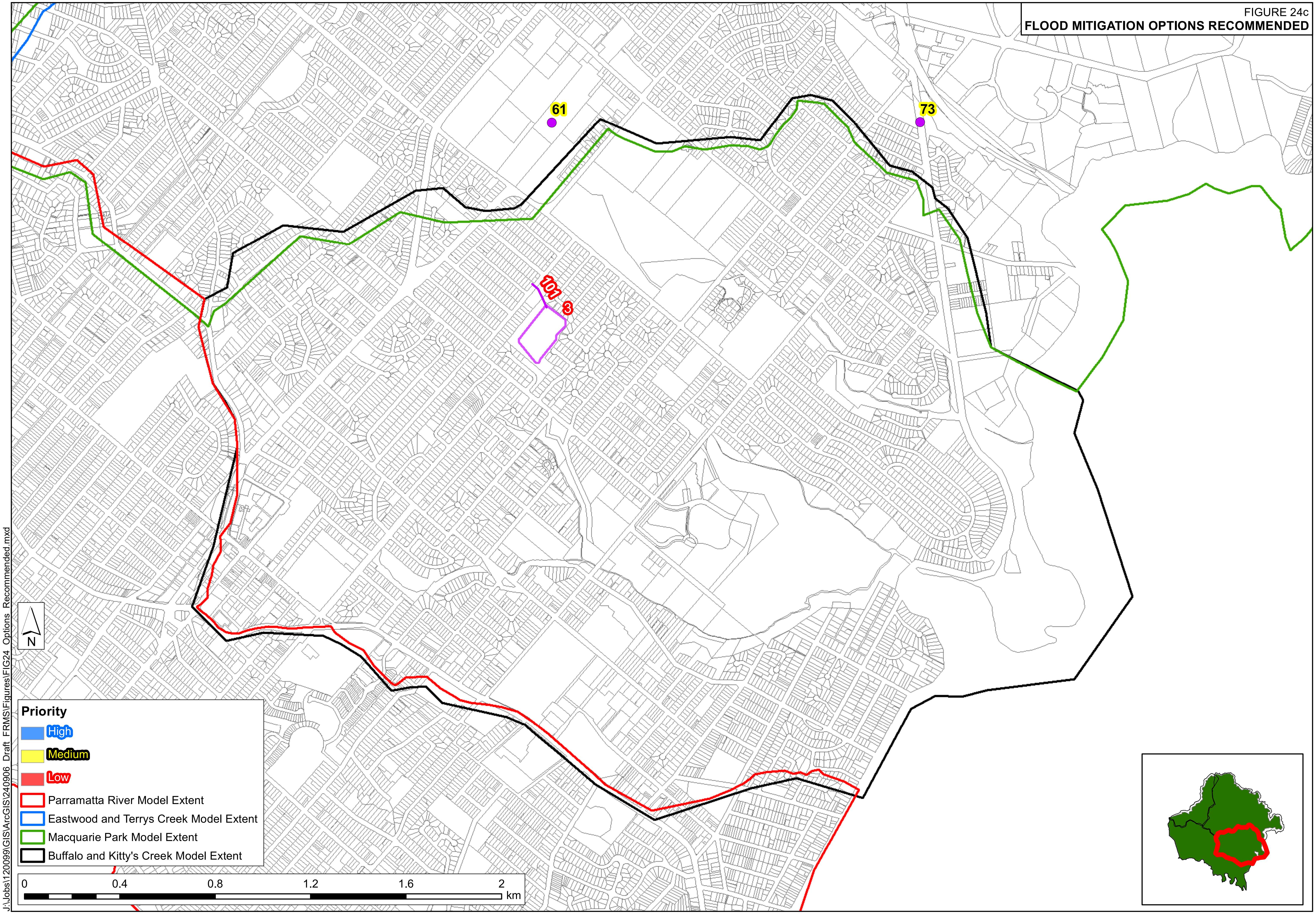
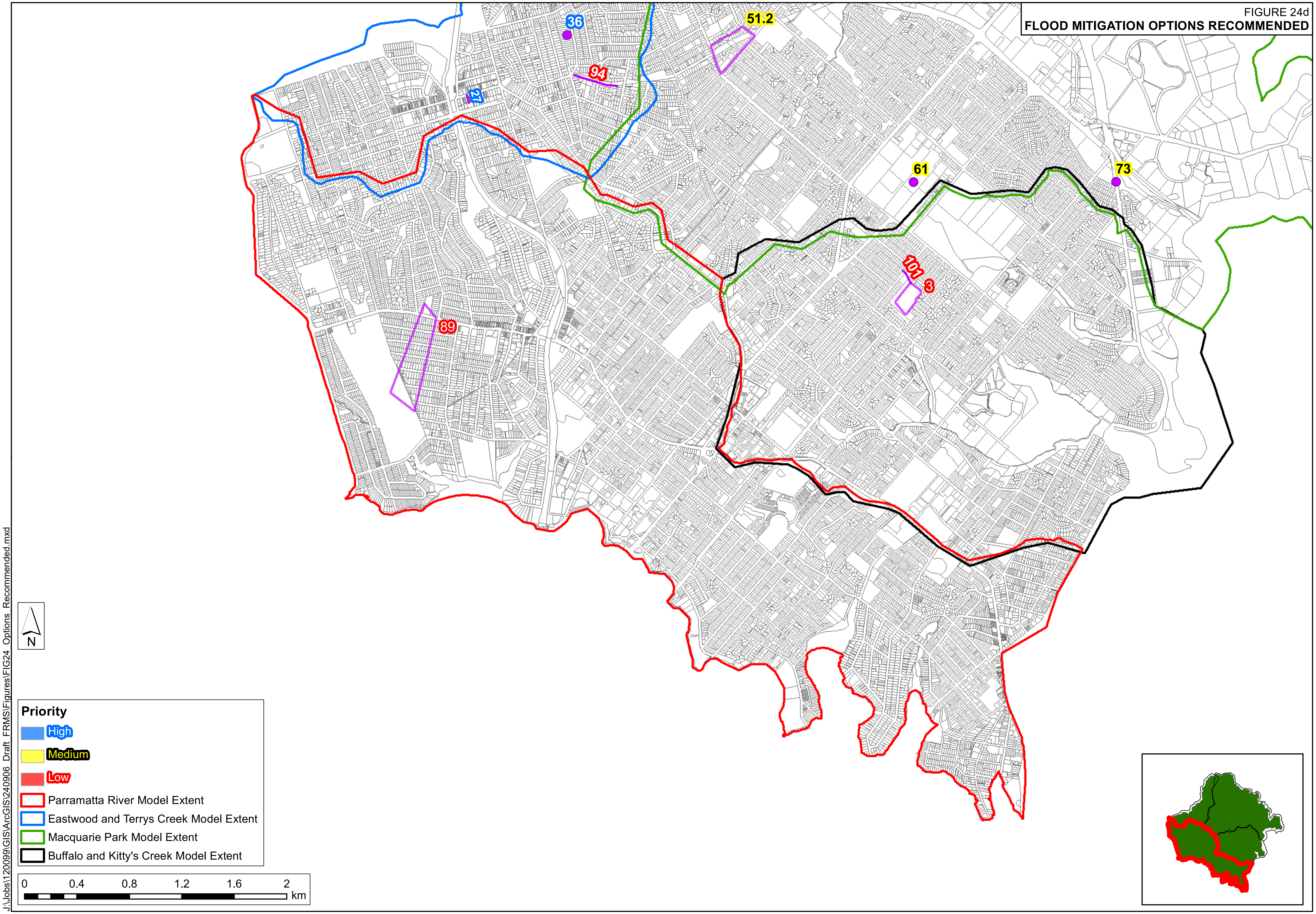


FIGURE 24c
FLOOD MITIGATION OPTIONS RECOMMENDED
61
73
101
3
N
Priority
High
Medium
Low
Parramatta River Model Extent
Eastwood and Terrys Creek Model Extent
Macquarie Park Model Extent
Buffalo and Kitty's Creek Model Extent
0
0.4
0.8
1.2
1.6
2
km
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\Figures\FIG24_Options_Recommended.mxd

FIGURE 24d
FLOOD MITIGATION OPTIONS RECOMMENDED



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\Figures\FIG24_Options_Recommended.mxd

FIGURE 25
MACQUARIE SHOPPING CENTRE OPTIONS M065C
PEAK FLOOD LEVEL IMPACT
1% AEP

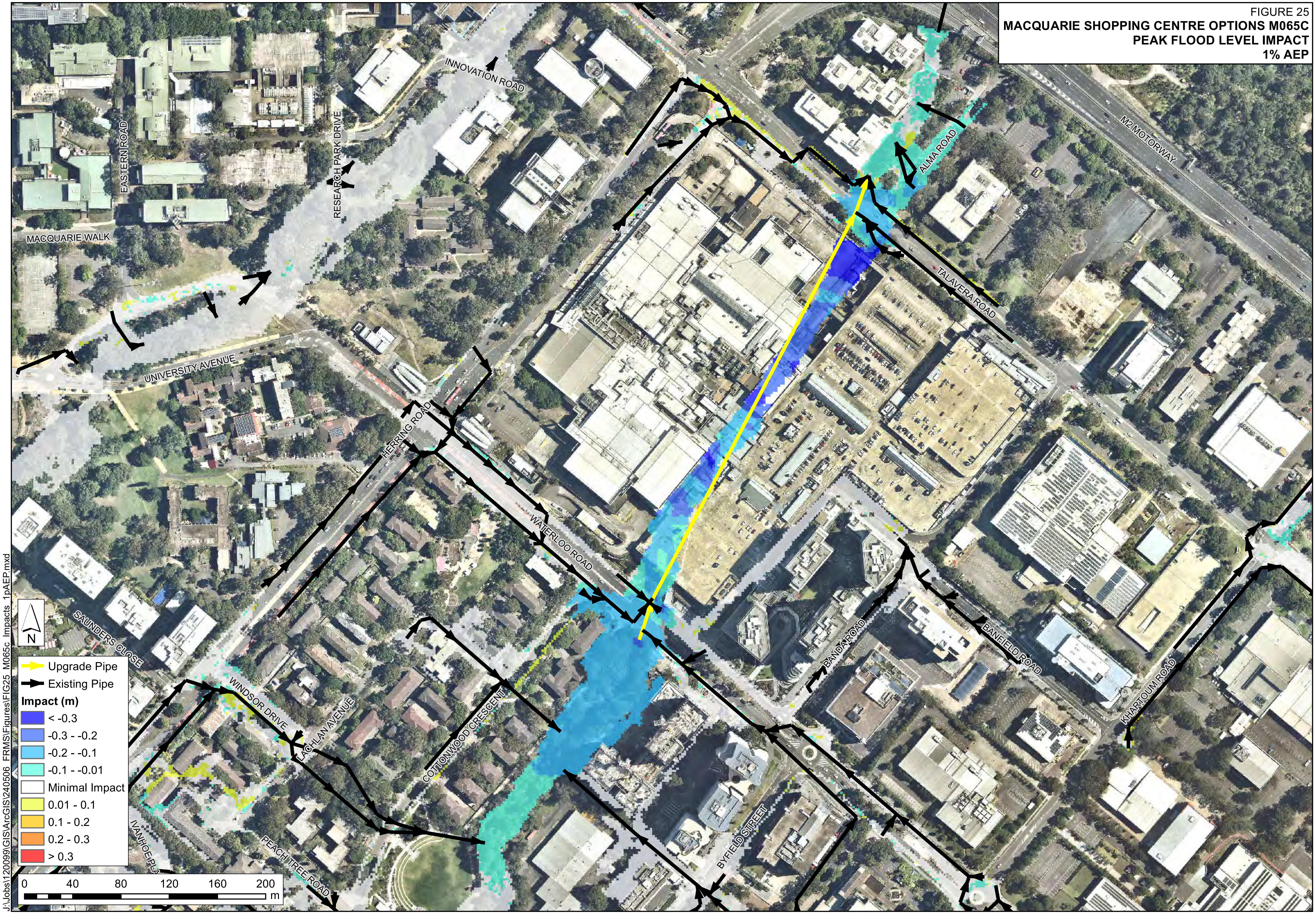
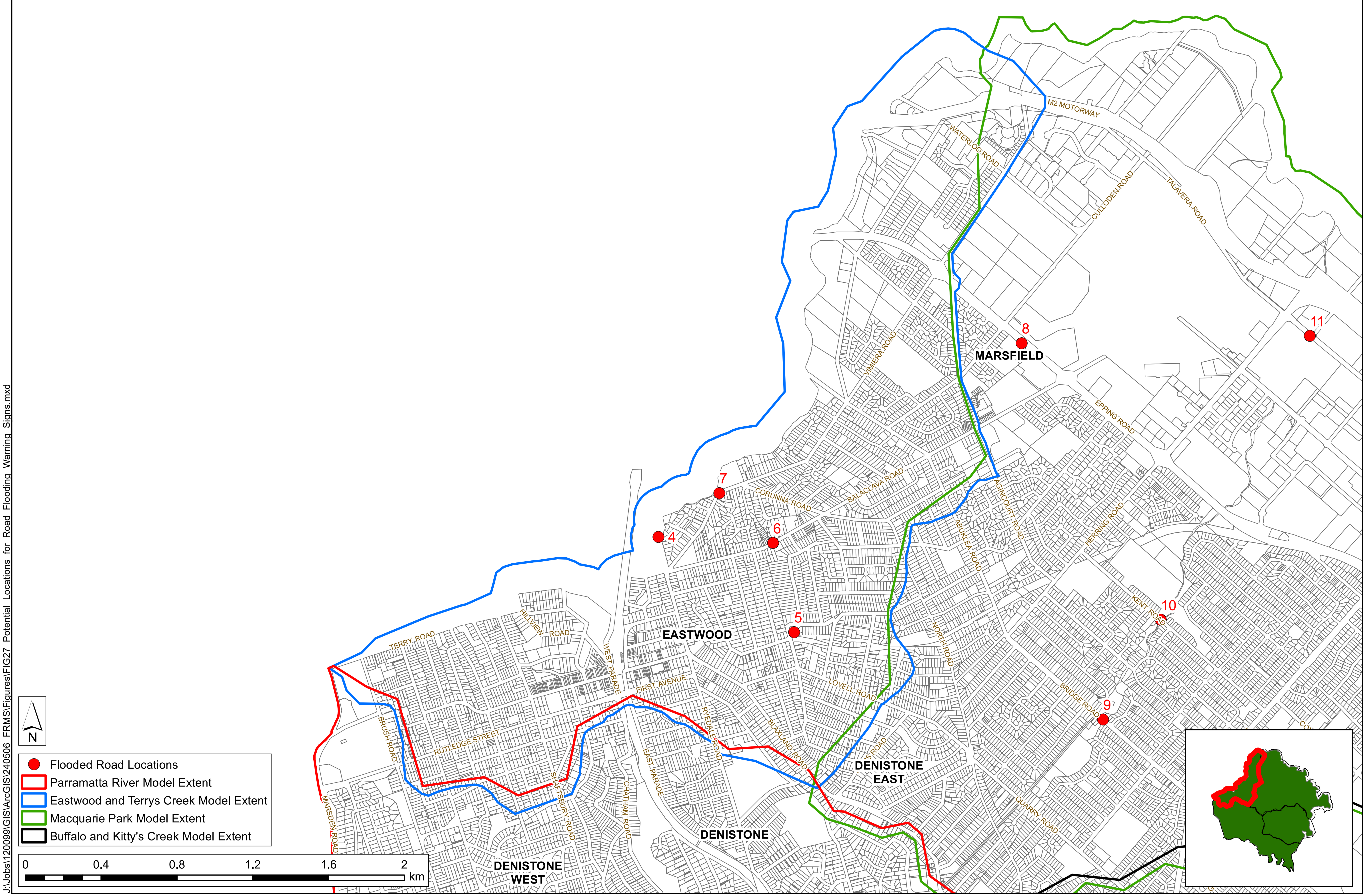


FIGURE 26
DRAINAGE UPGRADE AT PORTERS CREEKS M071B PEAK FLOOD LEVEL IMPACT 1% AEP

FIGURE 27a
POTENTIAL LOCATIONS FOR FLOOD WARNING SIGNS



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG27_Potential_Locations_for_Road_Flooding_Warning_Signs.mxd

FIGURE 27b
POTENTIAL LOCATIONS FOR FLOOD WARNING SIGNS

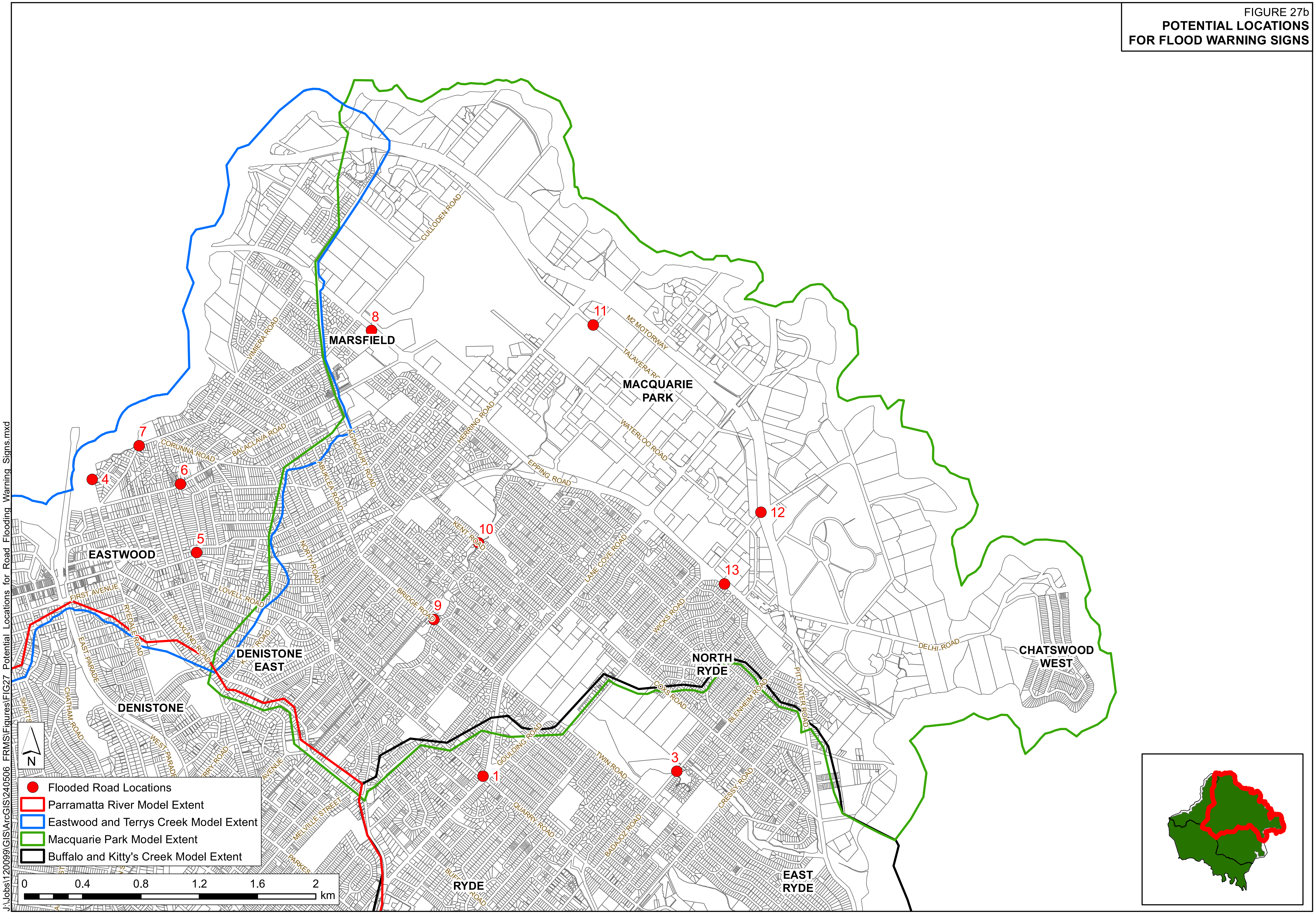


FIGURE 27c
POTENTIAL LOCATIONS FOR FLOOD WARNING SIGNS

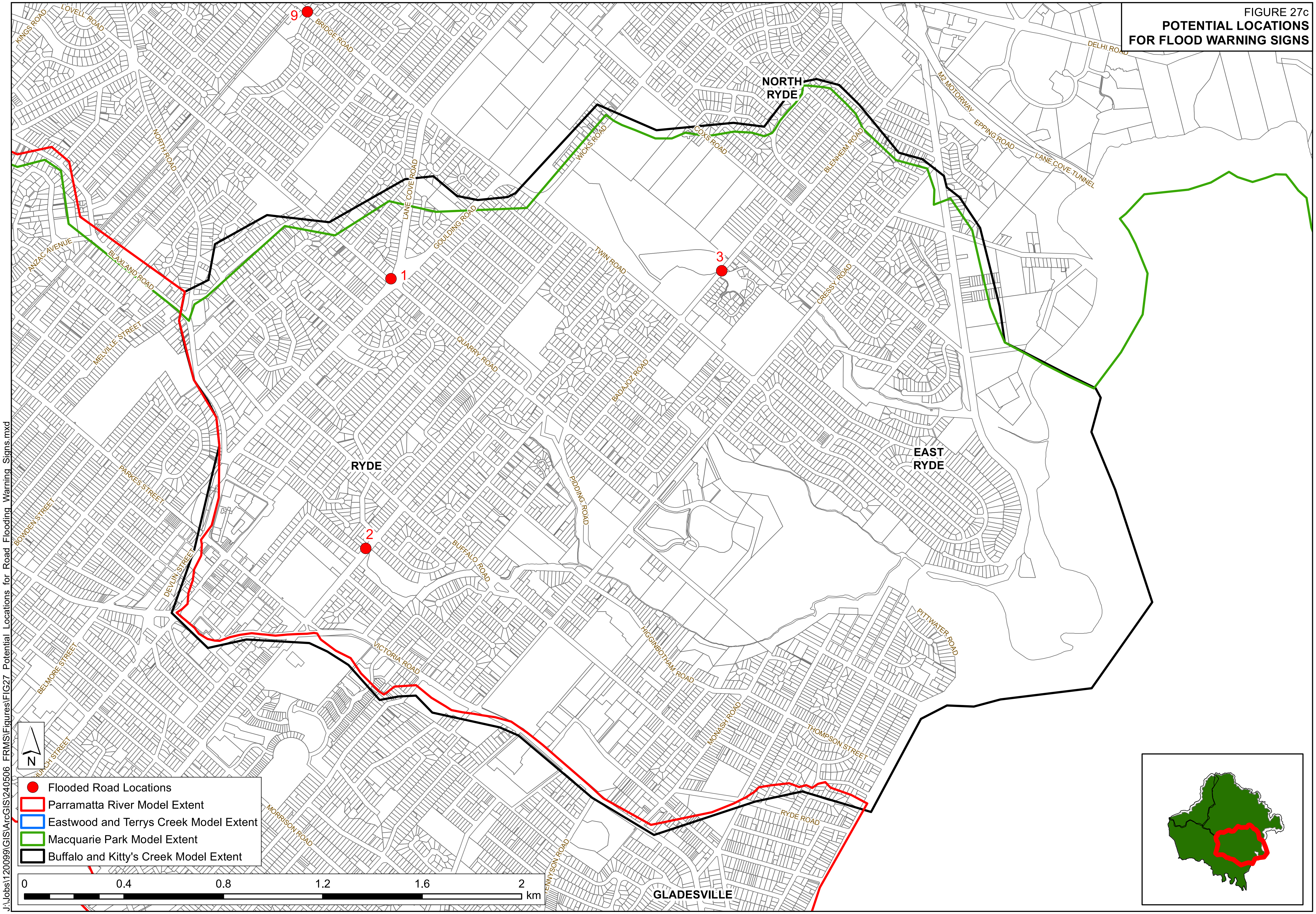
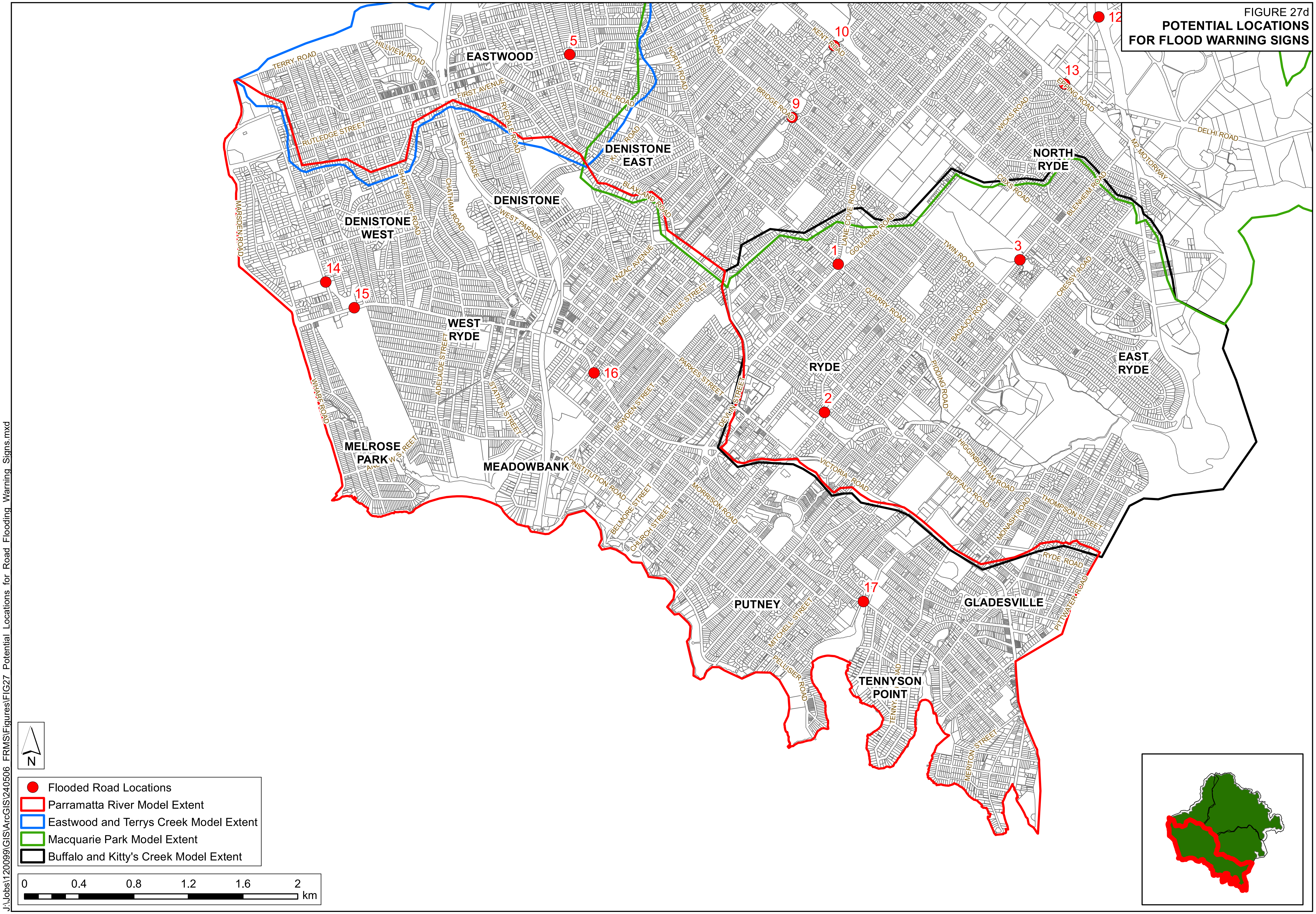


FIGURE 27d
POTENTIAL LOCATIONS FOR FLOOD WARNING SIGNS



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\Figures\FIG27_Potential_Locations_for_Road_Flooding_Warning_Signs.mxd

ATTACHMENT A: ARR 2019 Datahub Metadata

Attachment A

APPENDIX A. GLOSSARY OF TERMS

Appendix A

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large

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

floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic 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 Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard 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.

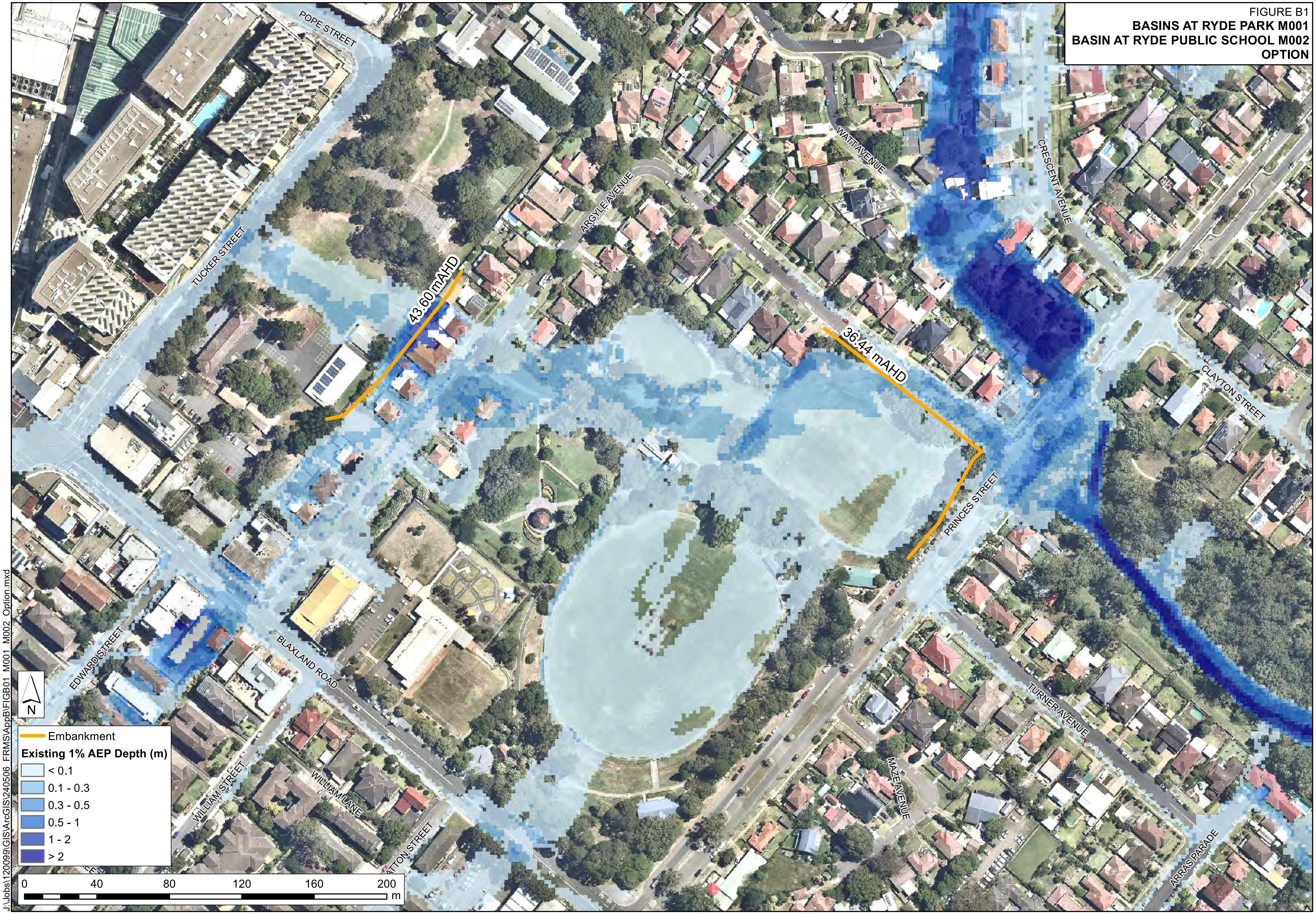
Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 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 Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

APPENDIX B. FLOOD MODIFICATION OPTIONS REJECTED WITH HYDRAULIC ASSESSMENT

Appendix B

FIGURE B1
BASINS AT RYDE PARK M001
BASIN AT RYDE PUBLIC SCHOOL M002
OPTION



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB01_M001_M002_Option.mxd

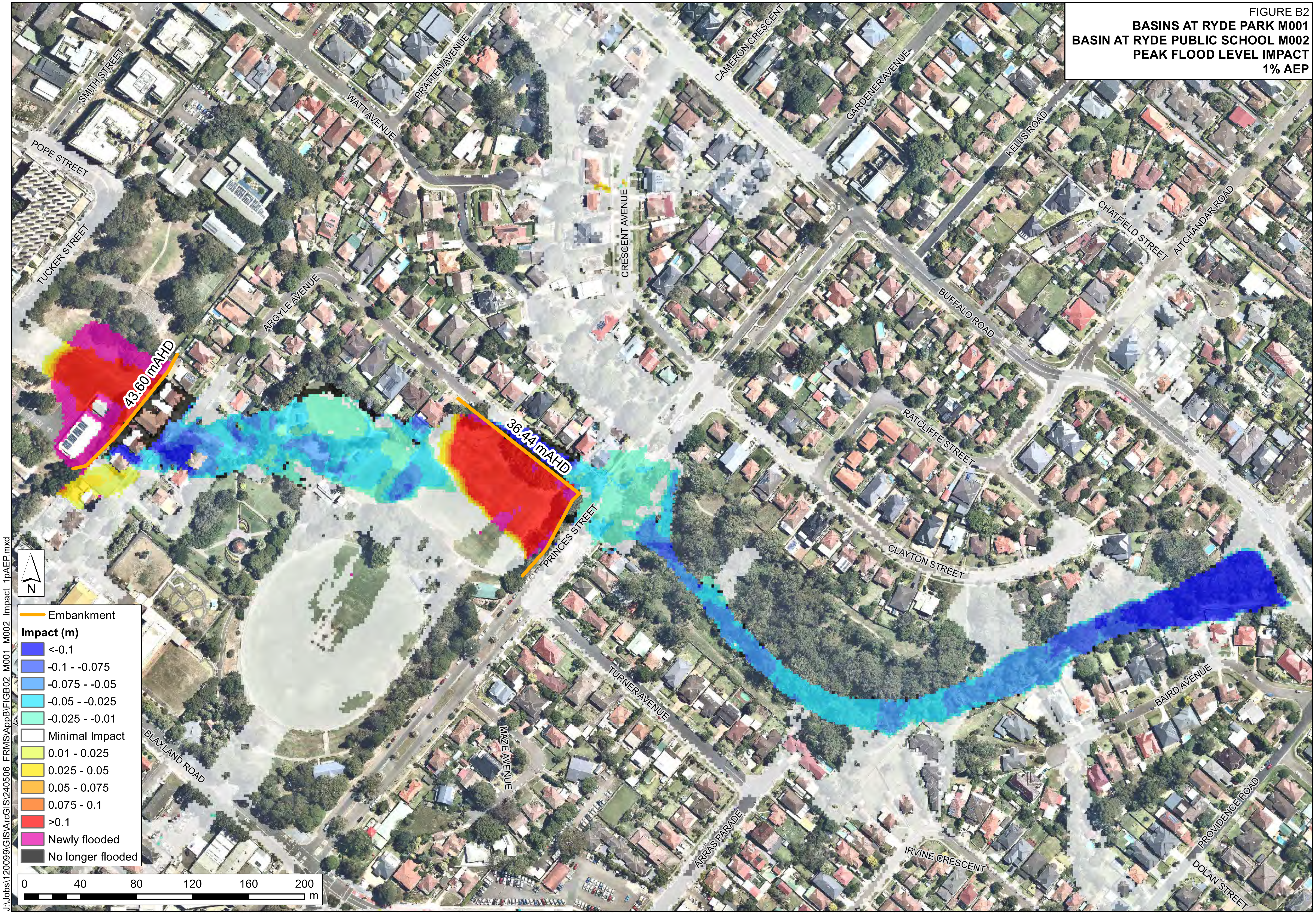
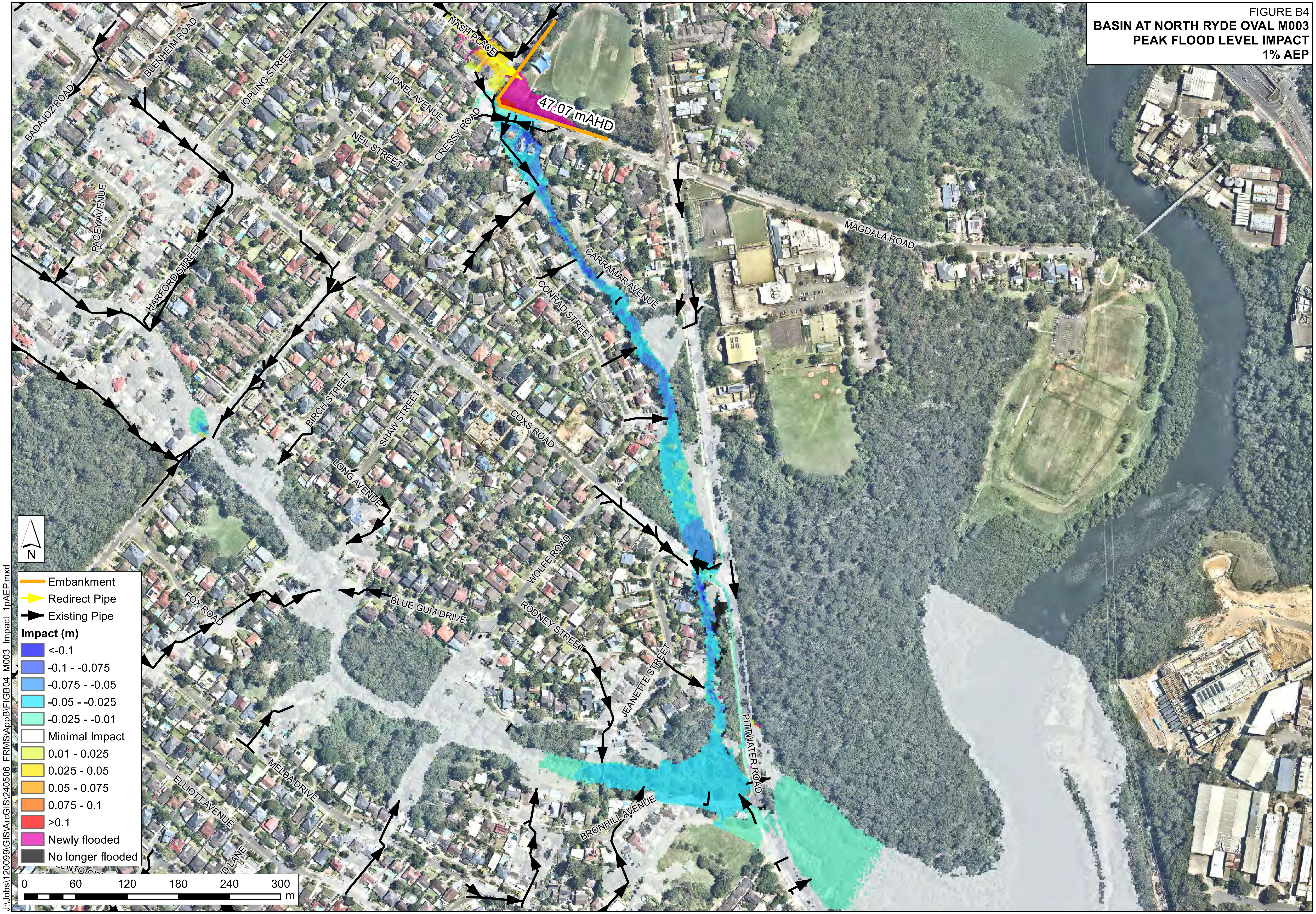


FIGURE B2
BASINS AT RYDE PARK M001
BASIN AT RYDE PUBLIC SCHOOL M002
PEAK FLOOD LEVEL IMPACT
1% AEP
43.60 mAHD
36.44 mAHD
SMITH STREET
POPE STREET
TUCKER STREET
WATT AVENUE
PRATTEN AVENUE
CAMERON CRESCENT
GARDENER AVENUE
KELLS ROAD
CHATFIELD STREET
AITCHANDAR ROAD
CRESCENT AVENUE
ARGYLE AVENUE
BUFFALO ROAD
RATCLIFFE STREET
CLAYTON STREET
PRINCES STREET
TURNER AVENUE
MAZE AVENUE
BLAXLAND ROAD
ARRAS PARADE
IRVINE CRESCENT
BAIRD AVENUE
PROVIDENCE ROAD
DOLAN STREET
N
Embankment
Impact (m)
<-0.1
-0.1 - -0.075
-0.075 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.025
0.025 - 0.05
0.05 - 0.075
0.075 - 0.1
>0.1
Newly flooded
No longer flooded
0
40
80
120
160
200
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB02_M001_M002_Impact_1pAEP.mxd

FIGURE B3
BASIN AT NORTH RYDE OVAL M003 OPTION

FIGURE B4

BASIN AT NORTH RYDE OVAL M003 PEAK FLOOD LEVEL IMPACT 1% AEP



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB04_M003_Impact_1pAEP.mxd

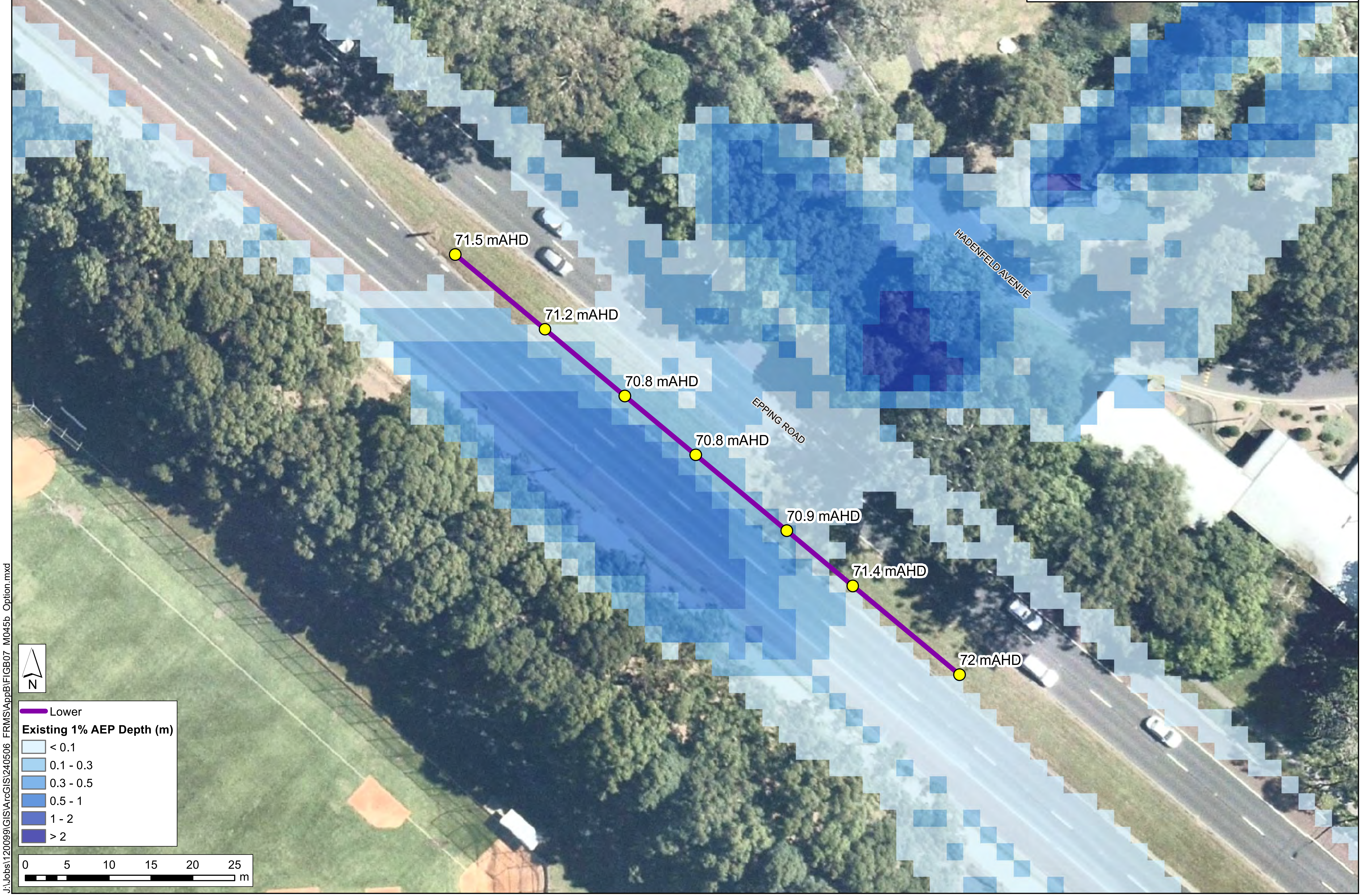
FIGURE B5
ADDITIONAL DRAINAGE ALONG MONASH ROAD M009.1 OPTION

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB05_M009a_Option.mxd

FIGURE B6
ADDITIONAL DRAINAGE ALONG MONASH ROAD M009.1
PEAK FLOOD LEVEL IMPACT
1% AEP

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB06_M009a_Impact_1pAEP.mxd

FIGURE B7
EPPING ROAD DRAINAGE AT MARS CREEK M045.2 OPTION



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB07_M045b_Option.mxd

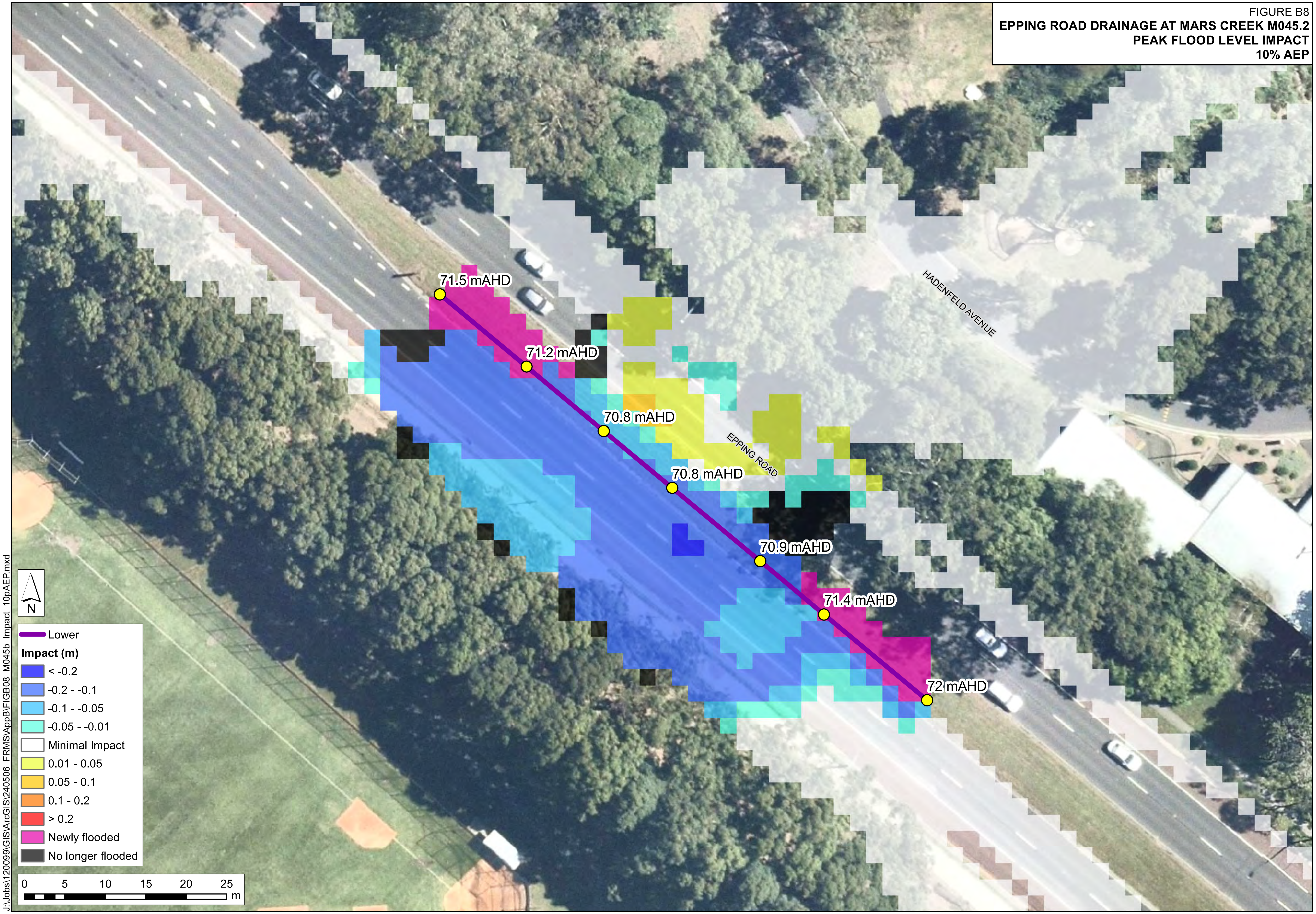


FIGURE B8
EPPING ROAD DRAINAGE AT MARS CREEK M045.2
PEAK FLOOD LEVEL IMPACT
10% AEP
71.5 mAHD
71.2 mAHD
70.8 mAHD
70.8 mAHD
70.9 mAHD
71.4 mAHD
72 mAHD
HADENFELD AVENUE
EPPING ROAD
N
Lower
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 5 10 15 20 25
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB08_M045b_Impact_10pAEP.mxd

FIGURE B9
TALAVERA ROAD DRAINAGE M046.2 OPTION

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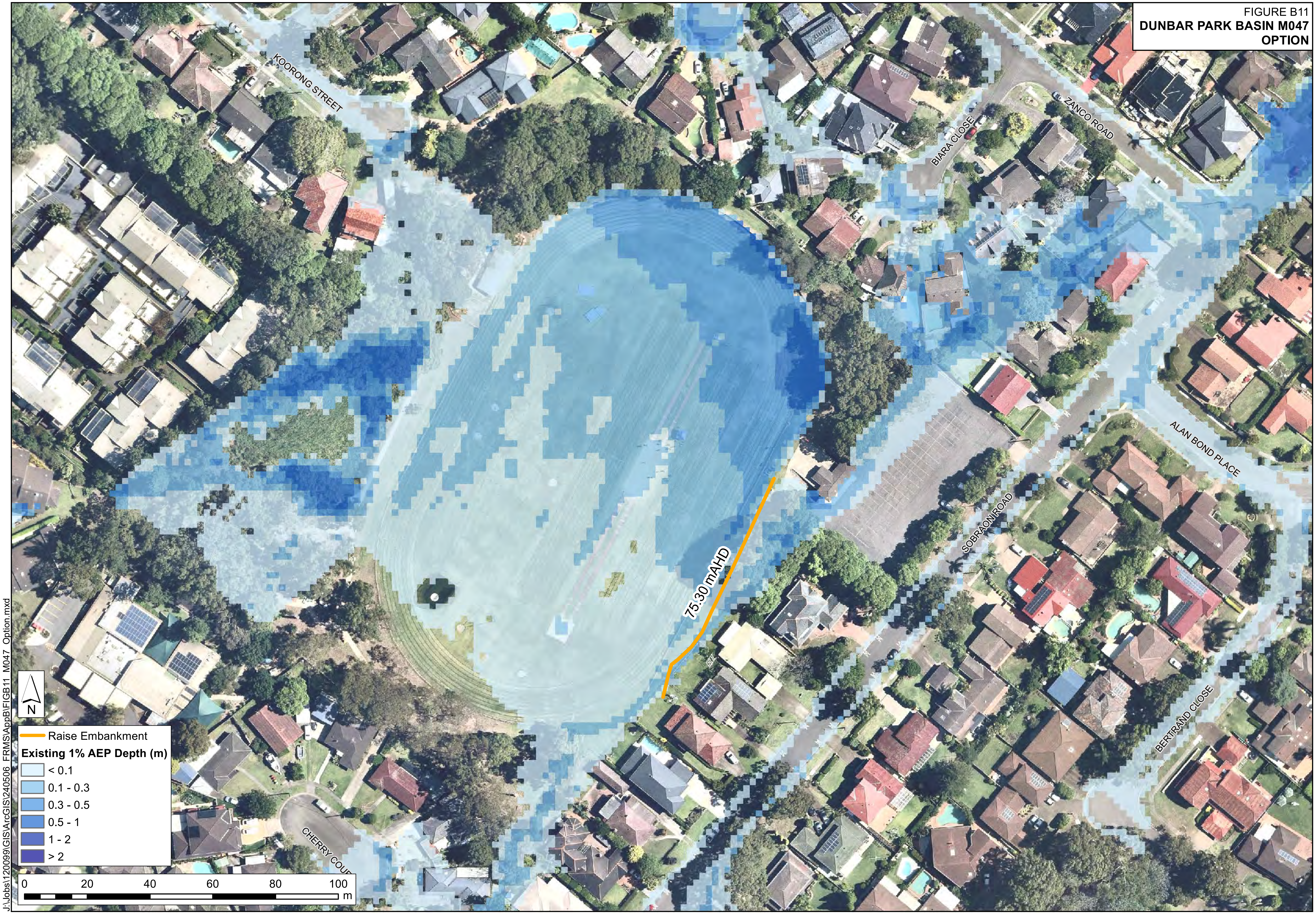
FIGURE B10
TALAVERA ROAD DRAINAGE M046.2
PEAK FLOOD LEVEL IMPACT
10% AEP

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\App B\FIGB10_M046b_Impact_10pAEP.mxd

FIGURE B11
DUNBAR PARK BASIN M047 OPTION



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB11_M047_Option.mxd

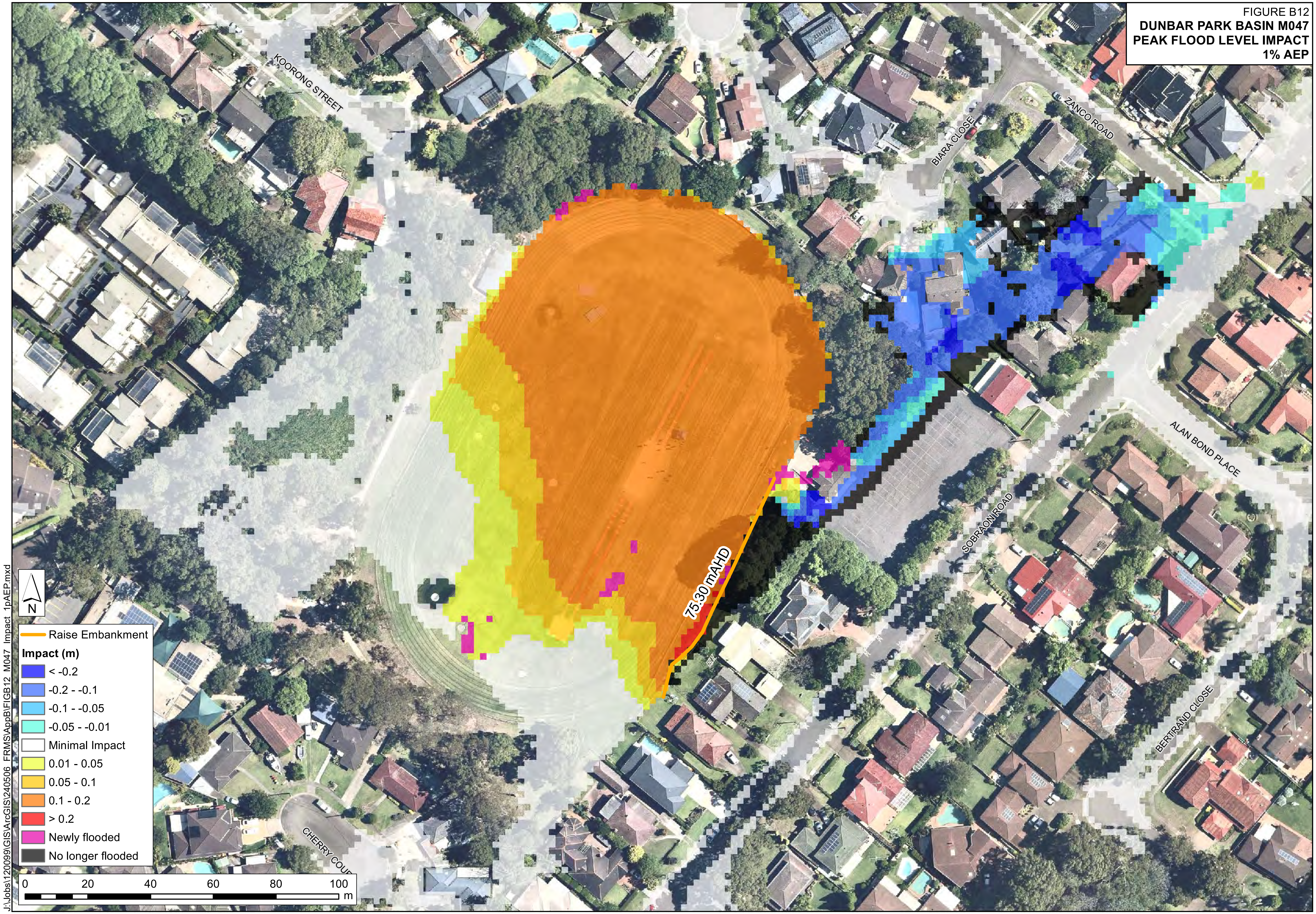
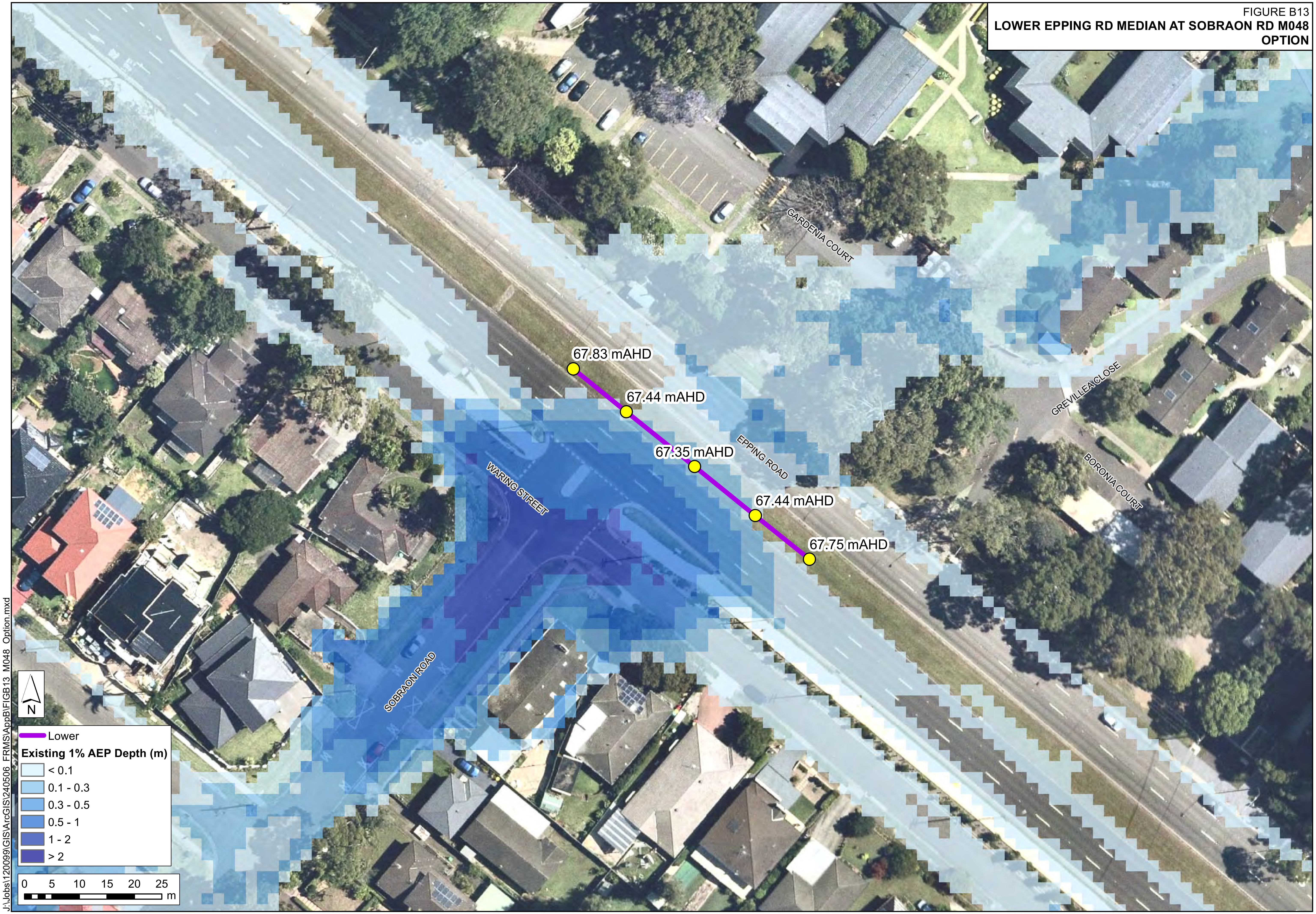


FIGURE B12
DUNBAR PARK BASIN M047
PEAK FLOOD LEVEL IMPACT
1% AEP
KOORONG STREET
BIARA CLOSE
ZANCO ROAD
ALAN BOND PLACE
SOBRAON ROAD
BERTRAND CLOSE
CHERRY COURT
75.30 mAHD
N
Raise Embankment
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 20 40 60 80 100 m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB12_M047_Impact_1pAEP.mxd

FIGURE B13
LOWER EPPING RD MEDIAN AT SOBRAON RD M048 OPTION



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB13_M048_Option.mxd

FIGURE B14
LOWER EPPING RD MEDIAN AT SOBRAON RD M048
PEAK FLOOD LEVEL IMPACT
10% AEP
67.83 mAHD
67.44 mAHD
67.35 mAHD
67.44 mAHD
67.75 mAHD
GARDENIA COURT
GREVILLEACLOSE
EPPING ROAD
BORONIA COURT
WARING STREET
SOBRAON ROAD
N
Lower
Impact (m)
<-0.1
-0.1 - -0.075
-0.075 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.025
0.025 - 0.05
0.05 - 0.075
0.075 - 0.1
>0.1
Newly flooded
No longer flooded
0 5 10 15 20 25
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB14_M048_Impact_10pAEP.mxd

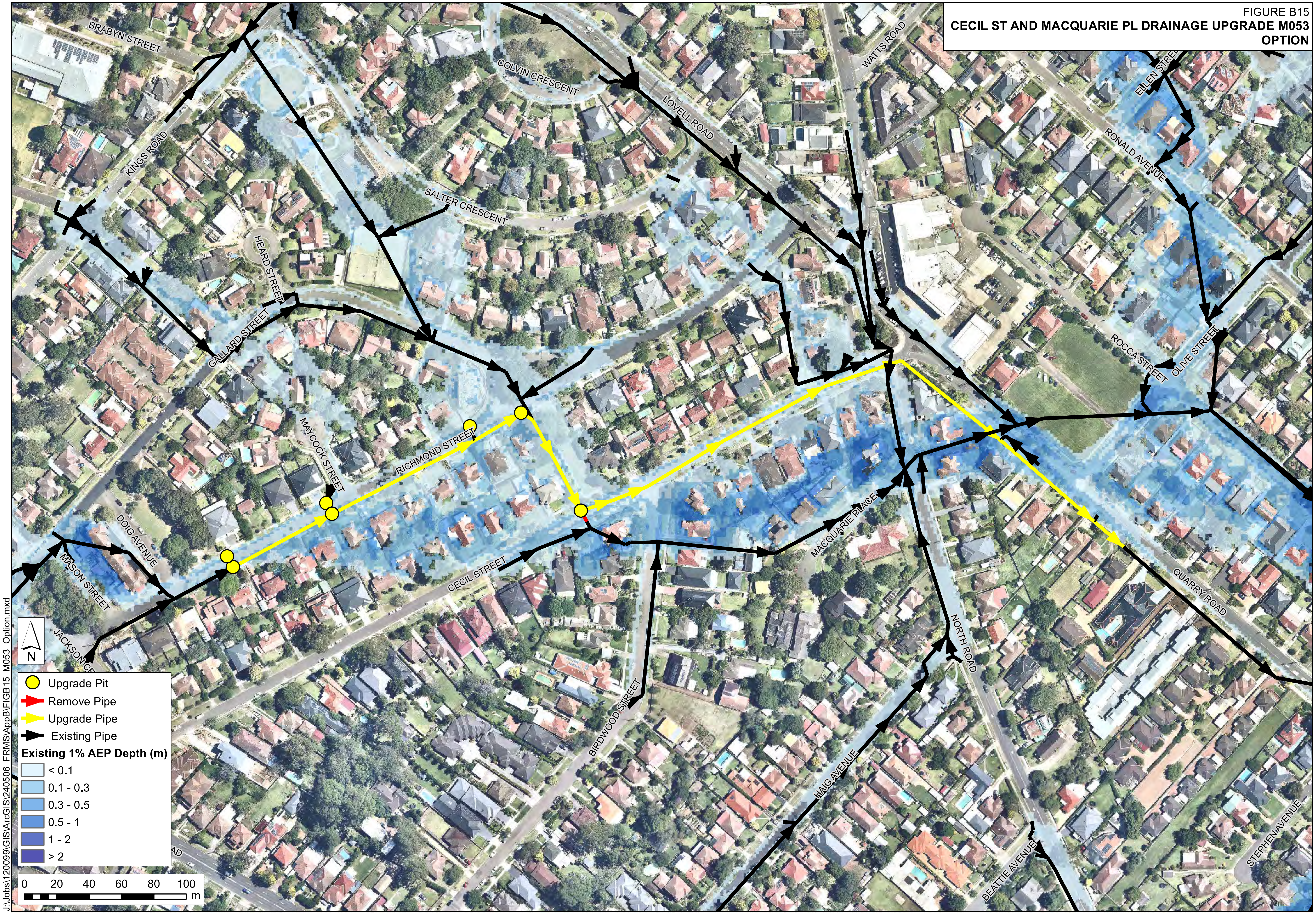


FIGURE B15
CECIL ST AND MACQUARIE PL DRAINAGE UPGRADE M053
OPTION
BRABYN STREET
COLVIN CRESCENT
WATTS ROAD
LOVELL ROAD
ELLEN STREET
RONALD AVENUE
KINGS ROAD
SALTER CRESCENT
HEARD STREET
GALLARD STREET
ROCCA STREET
OLIVE STREET
MAYCOCK STREET
RICHMOND STREET
DOIG AVENUE
MASON STREET
MACQUARIE PLACE
CECIL STREET
QUARRY ROAD
NORTH ROAD
JACKSON CRES
BIRDWOOD STREET
HAIG AVENUE
BEATTIE AVENUE
STEPHEN AVENUE
N
Upgrade Pit
Remove Pipe
Upgrade Pipe
Existing Pipe
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 20 40 60 80 100
m
J:Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB15_M053_Option.mxd

FIGURE B16
CECIL ST AND MACQUARIE PL DRAINAGE UPGRADE M053
PEAK FLOOD LEVEL IMPACT
1% AEP

FIGURE B17
ROCCA ST M054 AND SANTA ROSA PART M056 OVERLAND FLOW OPTION

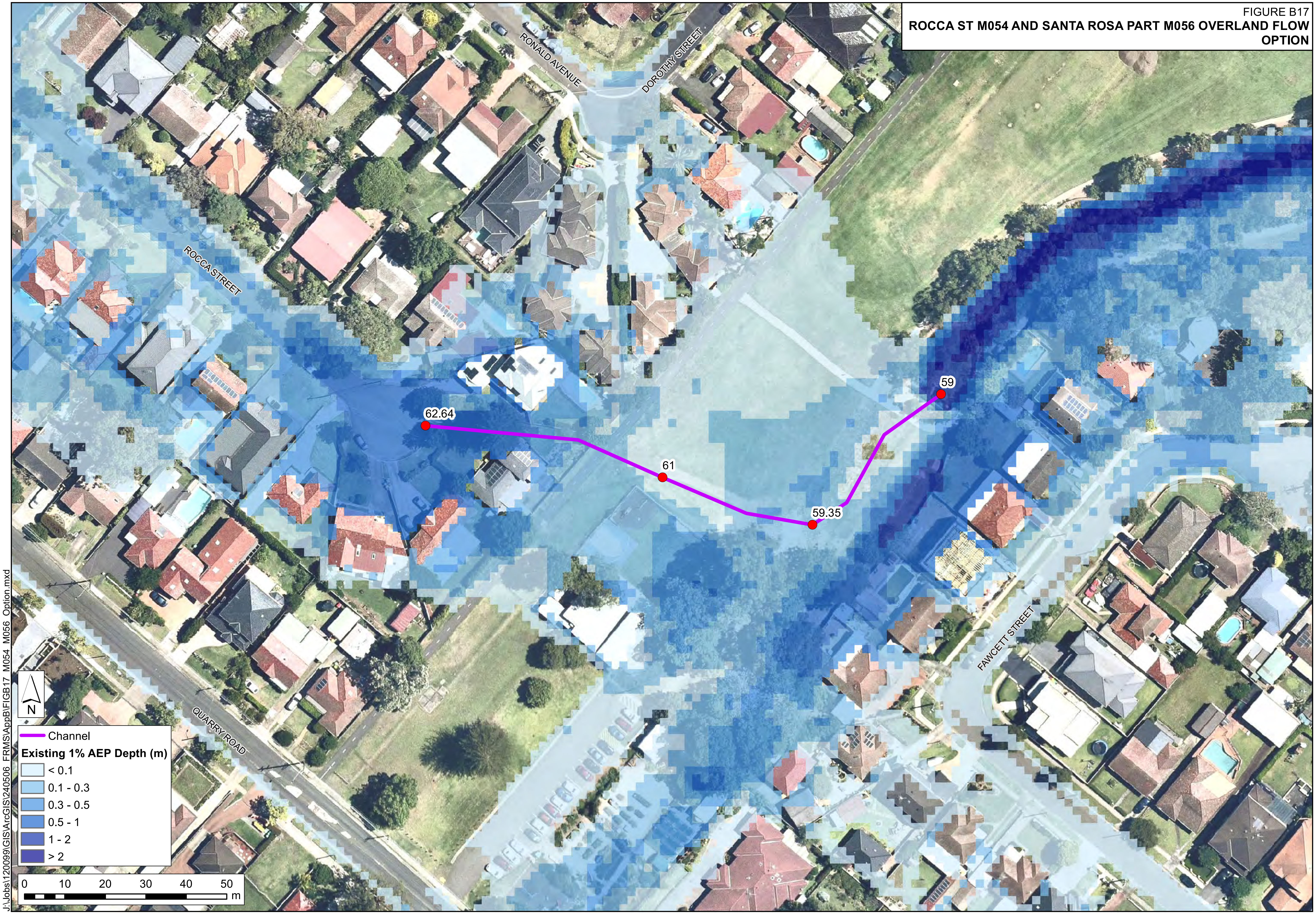


FIGURE B18
ROCCA ST M054 AND SANTA ROSA PART M056 OVERLAND FLOW PEAK FLOOD LEVEL IMPACT 1% AEP

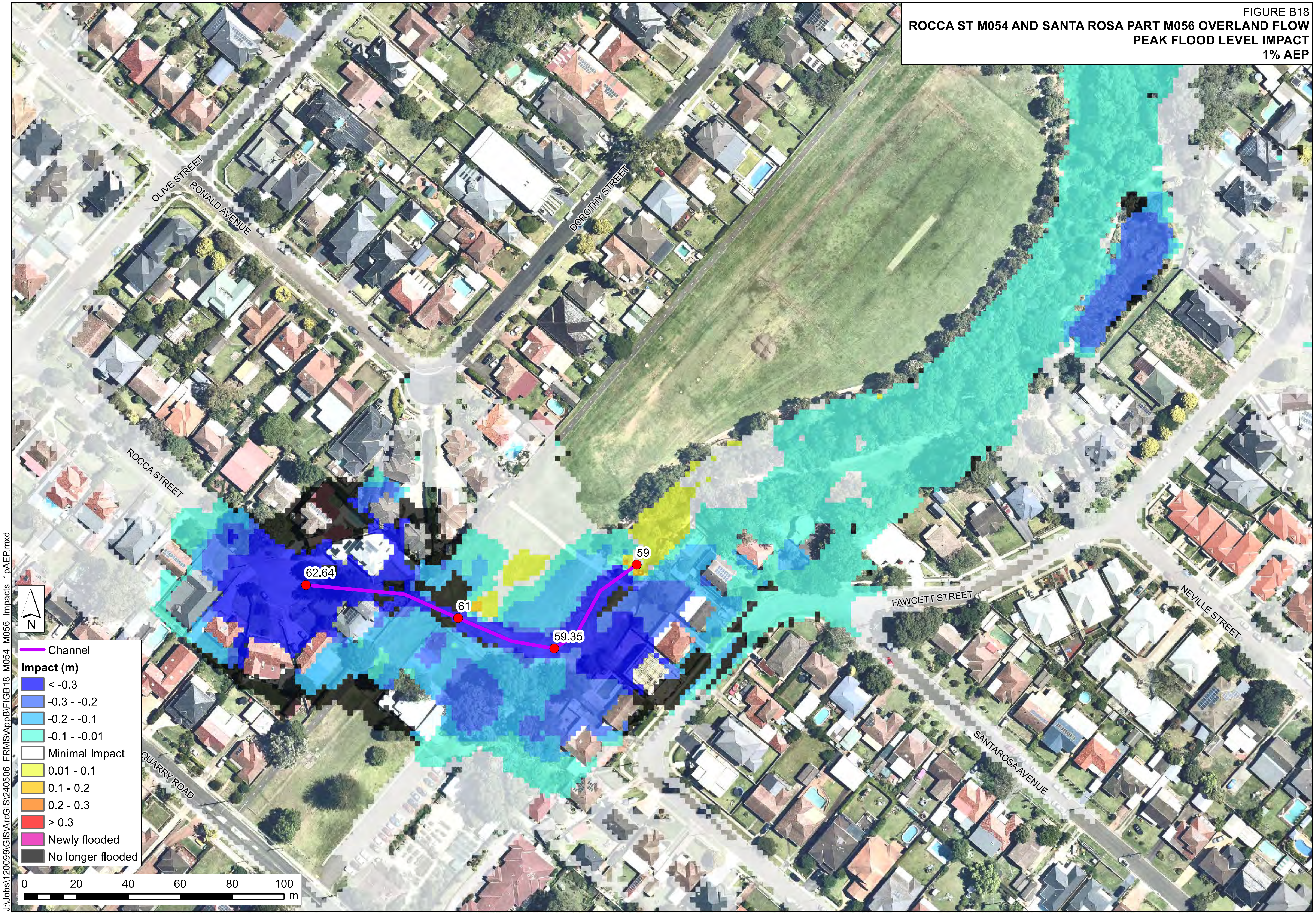


FIGURE B19
BRENDON ST LOW POINT FLOOD BARRIER M059 OPTION

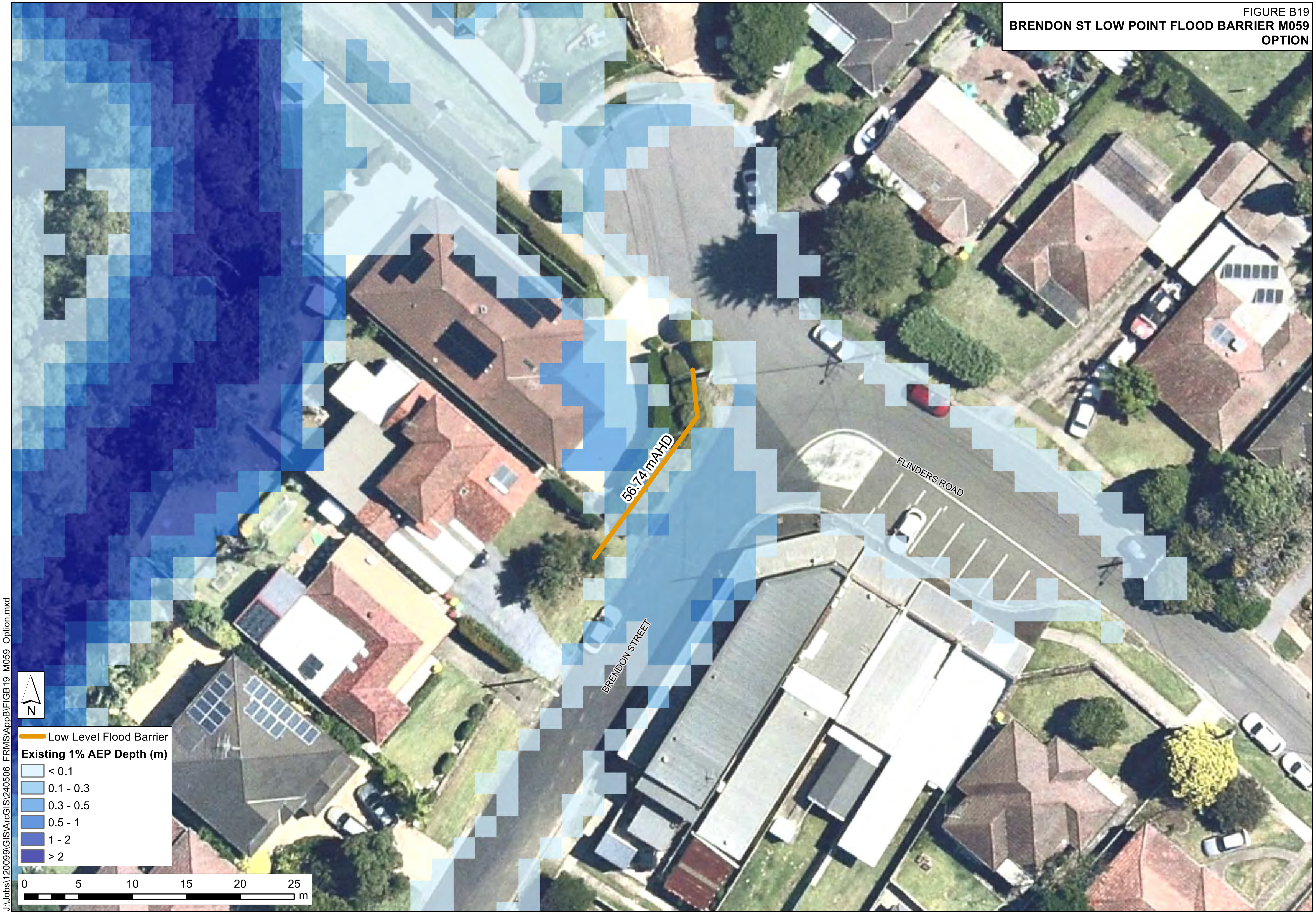


FIGURE B20
BRENDON ST LOW POINT FLOOD BARRIER M059
PEAK FLOOD LEVEL IMPACT
1% AEP

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB20_M059_Impact_1pAEP.mxd

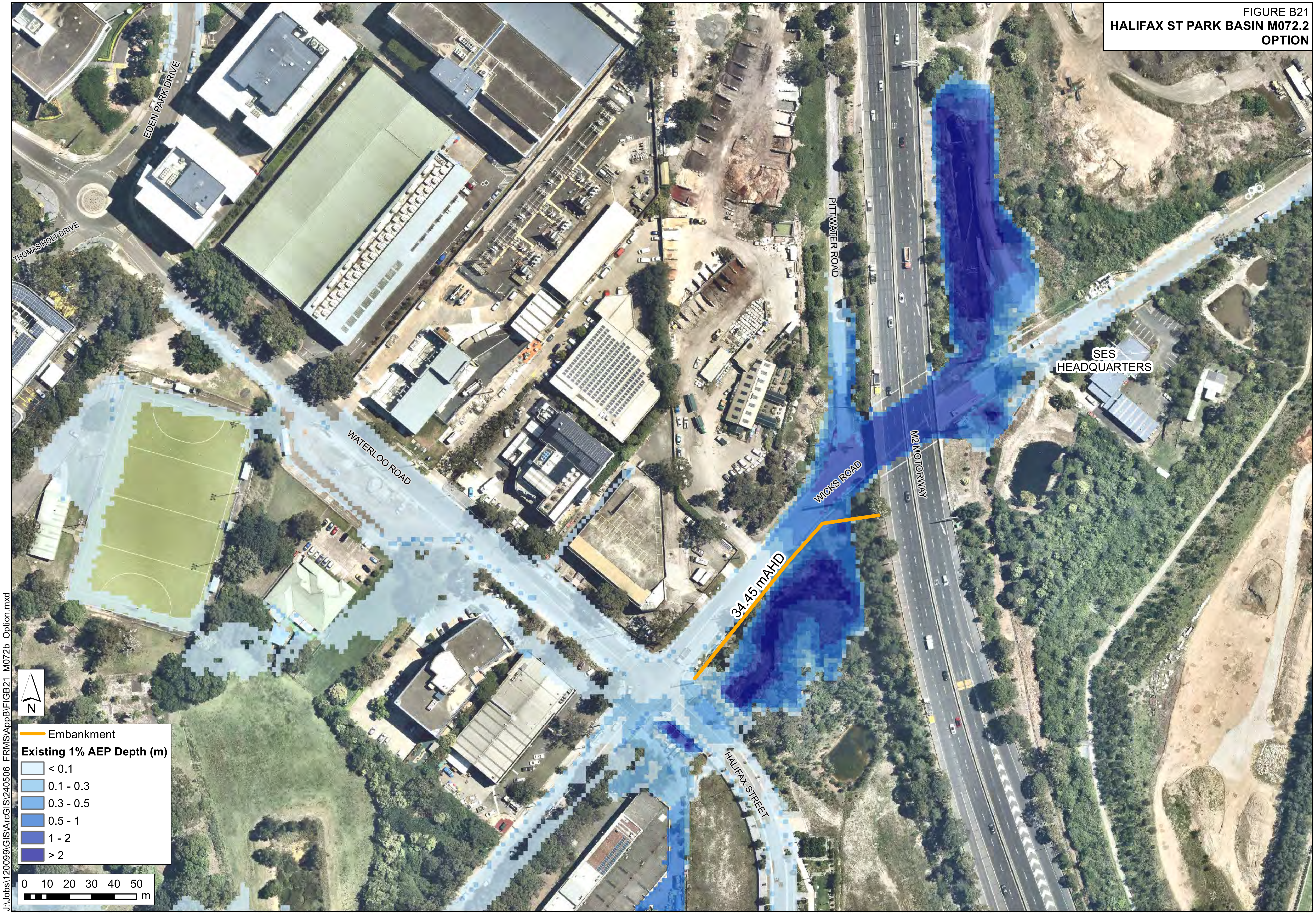


FIGURE B21
HALIFAX ST PARK BASIN M072.2
OPTION
EDEN PARK DRIVE
THOMAS HOLT DRIVE
WATERLOO ROAD
PITTWATER ROAD
M2 MOTORWAY
WICKS ROAD
SES
HEADQUARTERS
34.45 mAHD
HALIFAX STREET
N
Embankment
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 10 20 30 40 50
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB21_M072b_Option.mxd


FIGURE B22
HALIFAX ST PARK BASIN M072.2
PEAK FLOOD LEVEL IMPACT
1% AEP
EDEN PARK DRIVE
THOMAS HOLT DRIVE
WATERLOO ROAD
PITTWATER ROAD
WICKS ROAD
M2 MOTORWAY
SES
HEADQUARTERS
34.45 mAHD
HALIFAX STREET
N
Embankment
Impact (m)
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.01
Minimal Impact
0.01- 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
Newly flooded
No longer flooded
0
20
40
60
80
100
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB22_M072b_Impact_1pAEP.mxd

FIGURE B23
FEDERAL RD AND GAZA RD DRAINAGE UPGRADE M084 OPTION

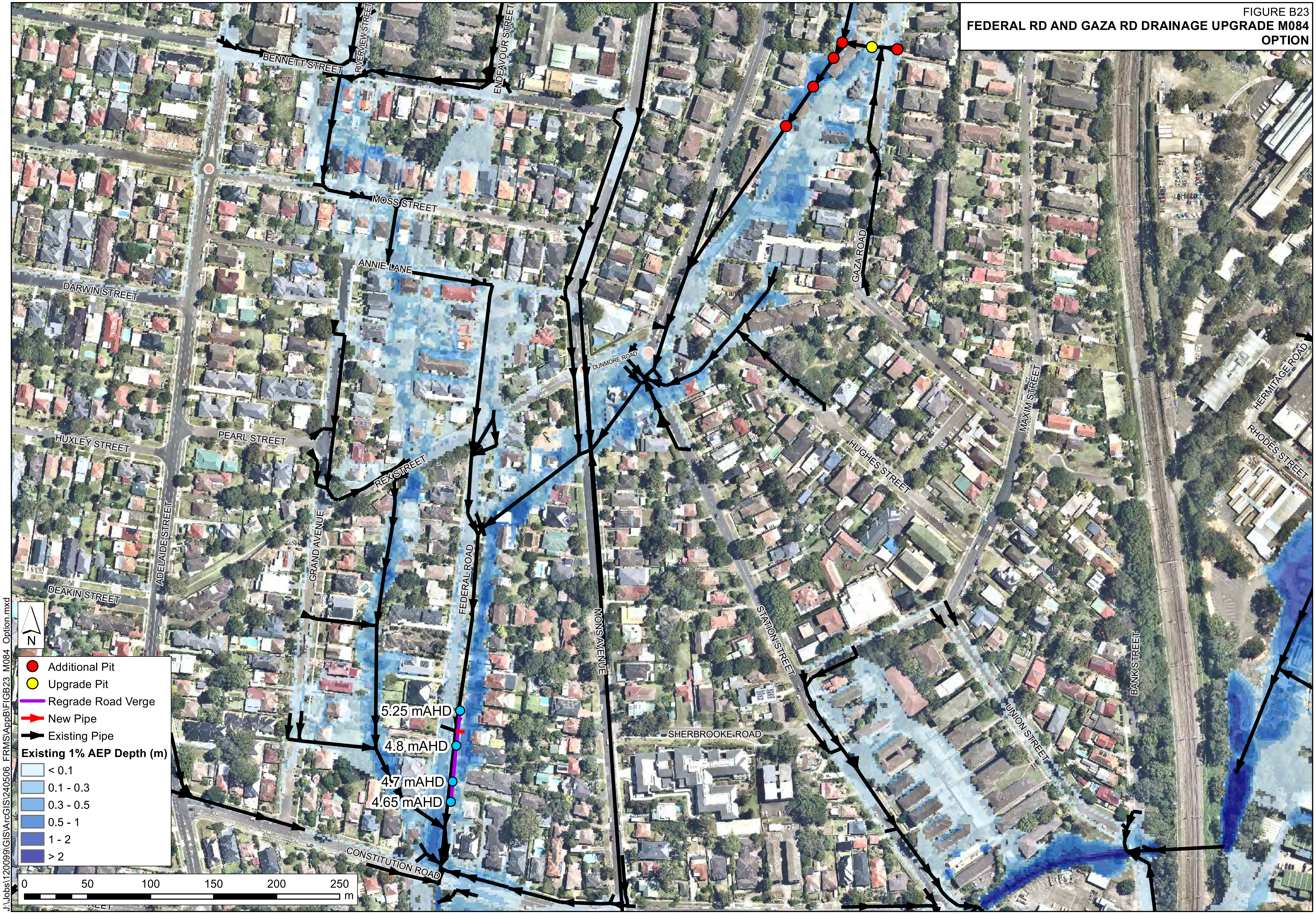


FIGURE B24
FEDERAL RD AND GAZA RD DRAINAGE UPGRADE M084
PEAK FLOOD LEVEL IMPACT
1% AEP

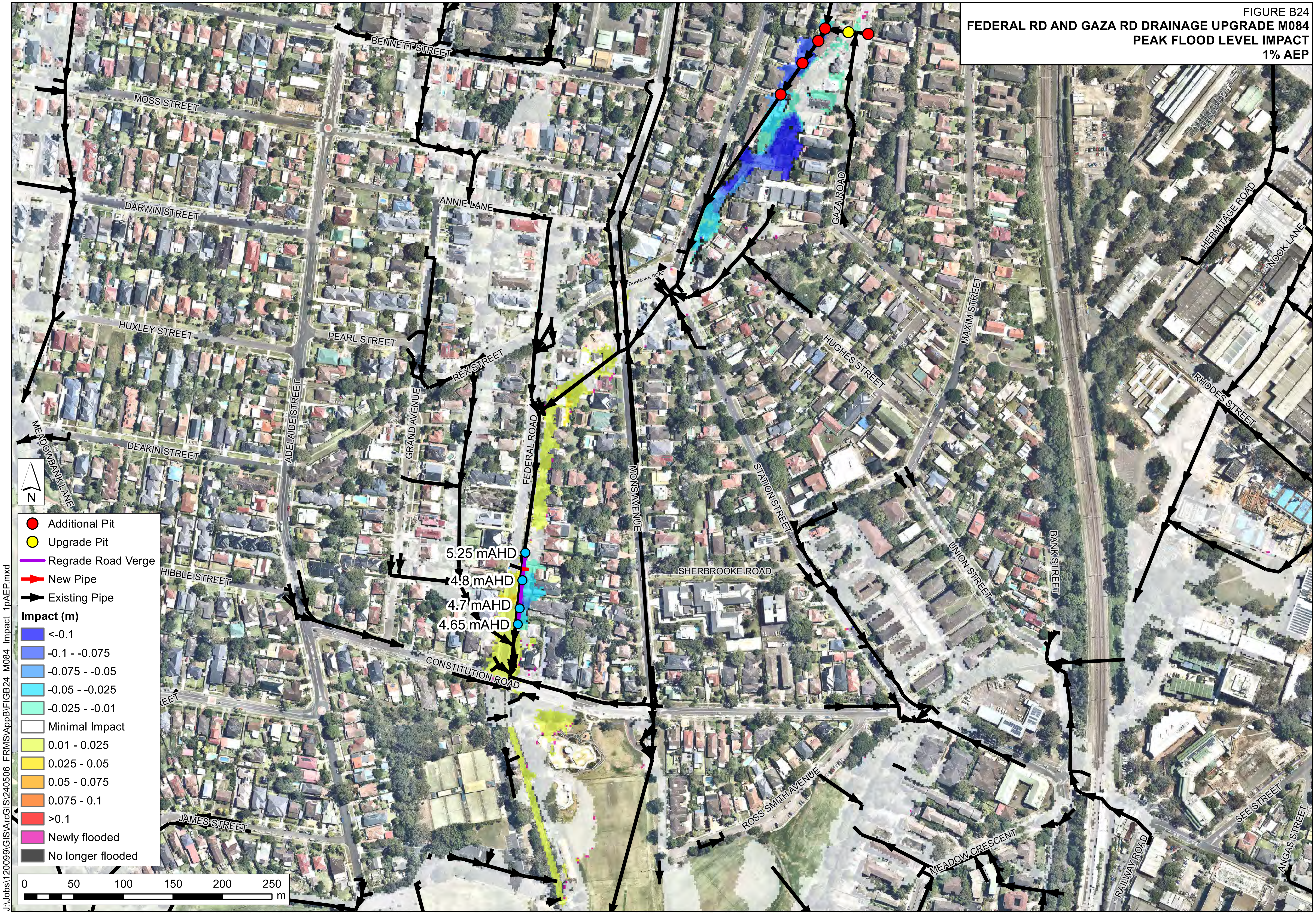
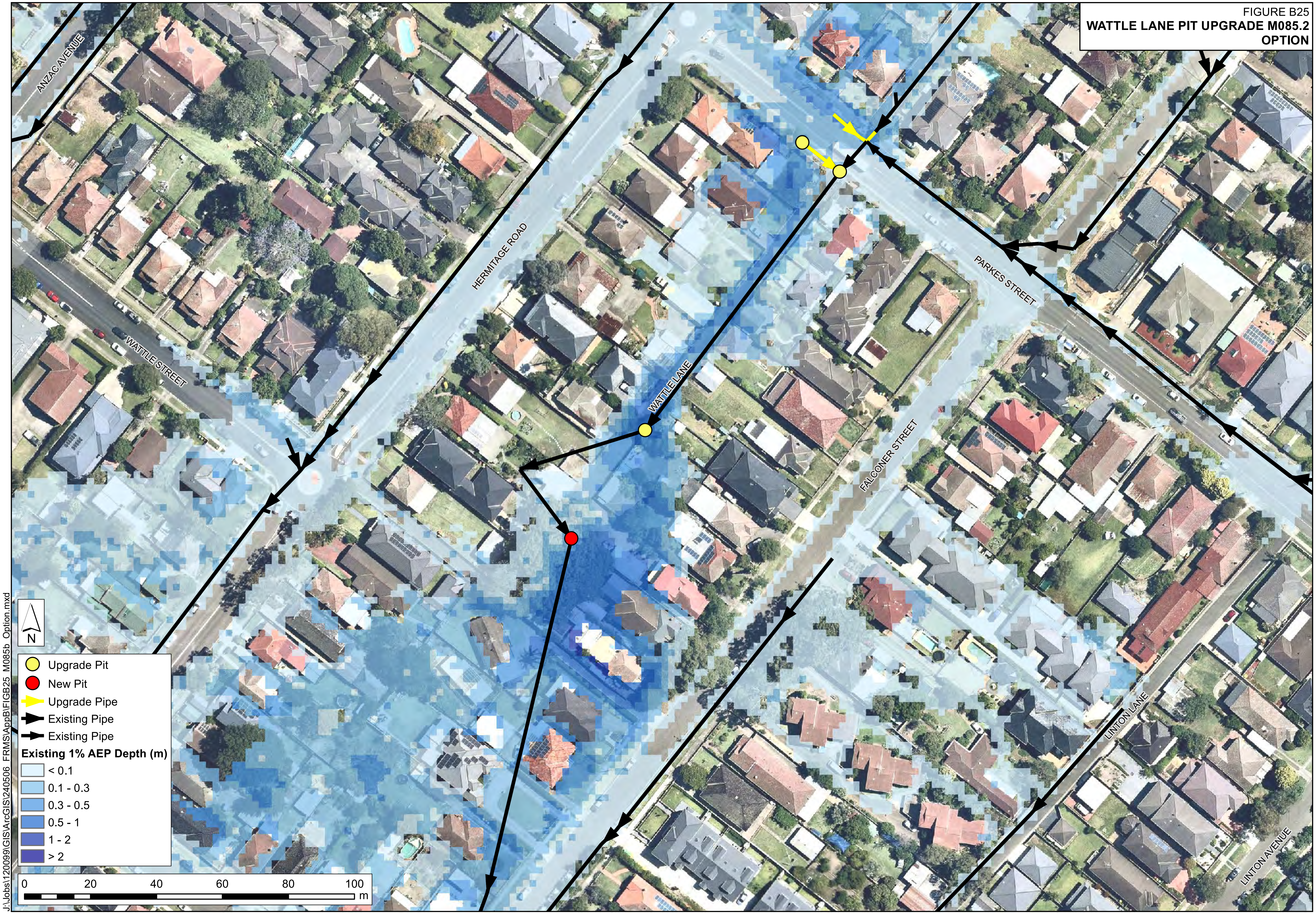


FIGURE B25
WATTLE LANE PIT UPGRADE M085.2 OPTION



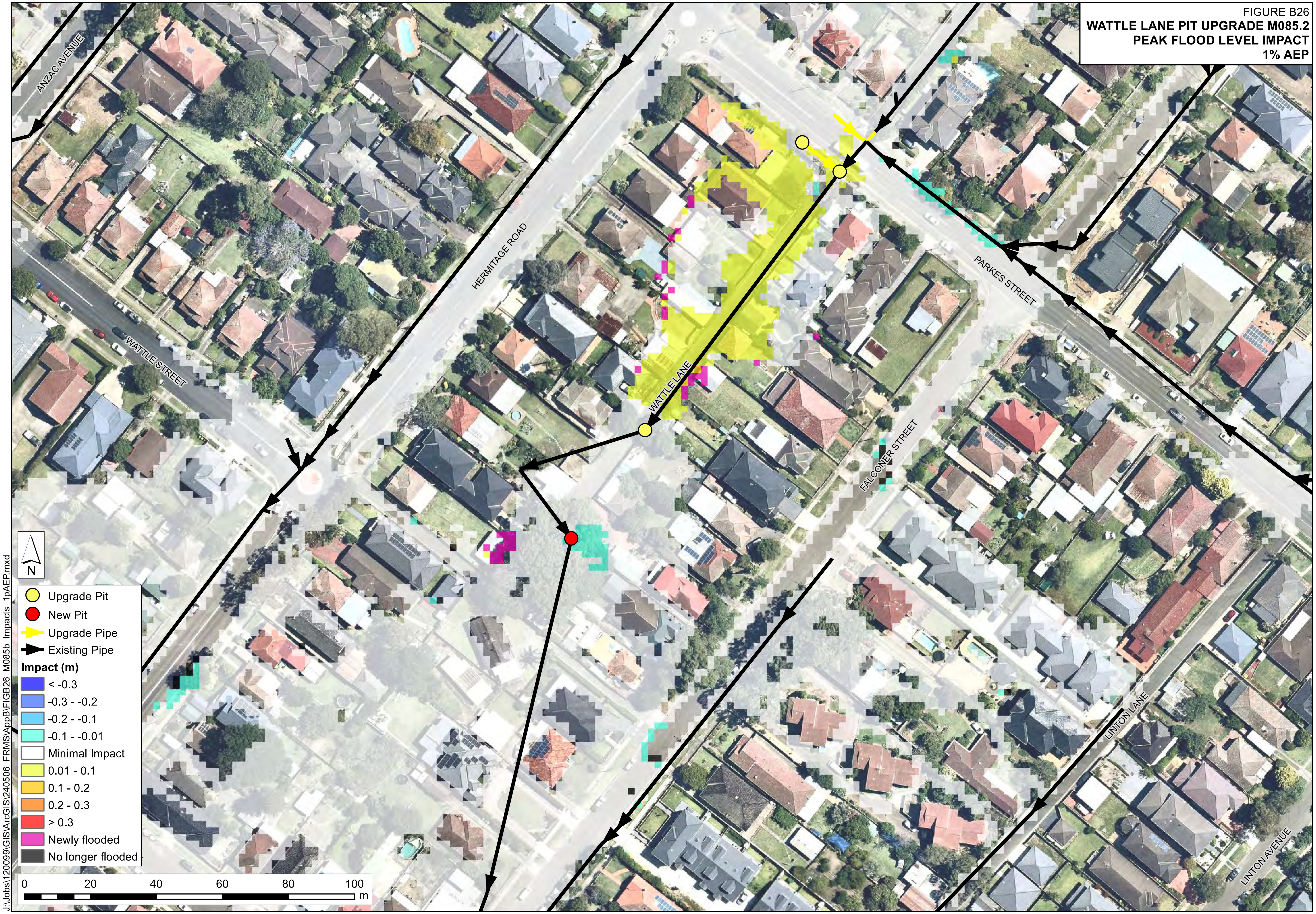


FIGURE B26
WATTLE LANE PIT UPGRADE M085.2
PEAK FLOOD LEVEL IMPACT
1% AEP
ANZAC AVENUE
HERMITAGE ROAD
WATTLE STREET
WATTLE LANE
PARKES STREET
FALCONER STREET
LINTON LANE
LINTON AVENUE
N
Upgrade Pit
New Pit
Upgrade Pipe
Existing Pipe
Impact (m)
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
Newly flooded
No longer flooded
0
20
40
60
80
100
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB26_M085b_Impacts_1pAEP.mxd

FIGURE B27
GERRISH ST, CAMBRIDGE ST AND PITTWATER RD M087 OPTION

FIGURE B28
GERRISH ST, CAMBRIDGE ST AND PITTWATER RD M087
PEAK FLOOD LEVEL IMPACT
1% AEP
PERCY STREET
GERRISH STREET
CAMBRIDGE STREET
PITTWATER ROAD
HARVARD
26.4 mAHD
N
Flood Barrier
Impact (m)
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
Newly flooded
No longer flooded
0 10 20 30 40 50
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB28_M087_Impact_1pAEP.mxd

FIGURE B29
MORRISON ROAD TERRAIN REGRADE M088.2 OPTION

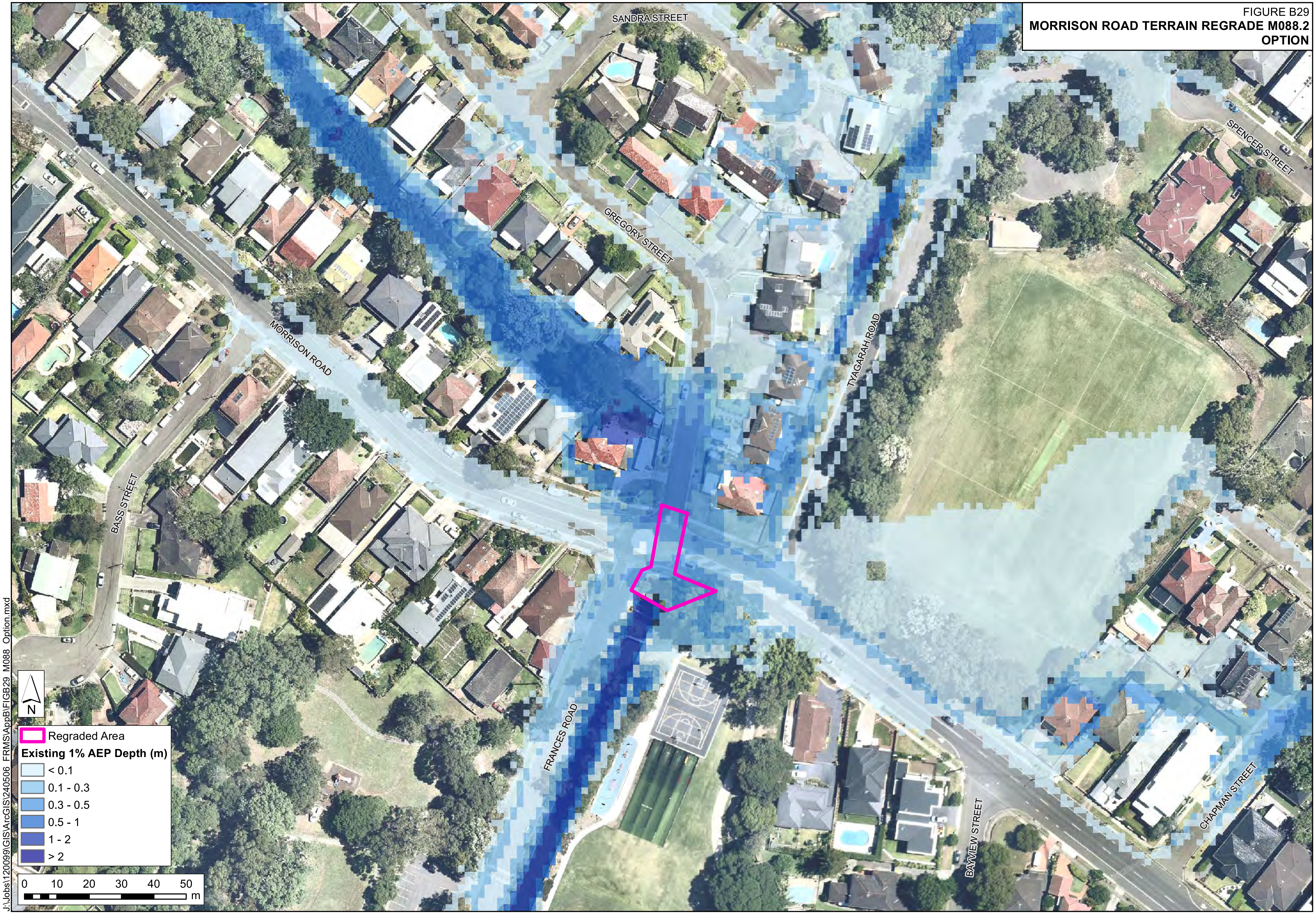


FIGURE B30
MORRISON ROAD TERRAIN REGRADE M088.2
PEAK FLOOD LEVEL IMPACT
1% AEP

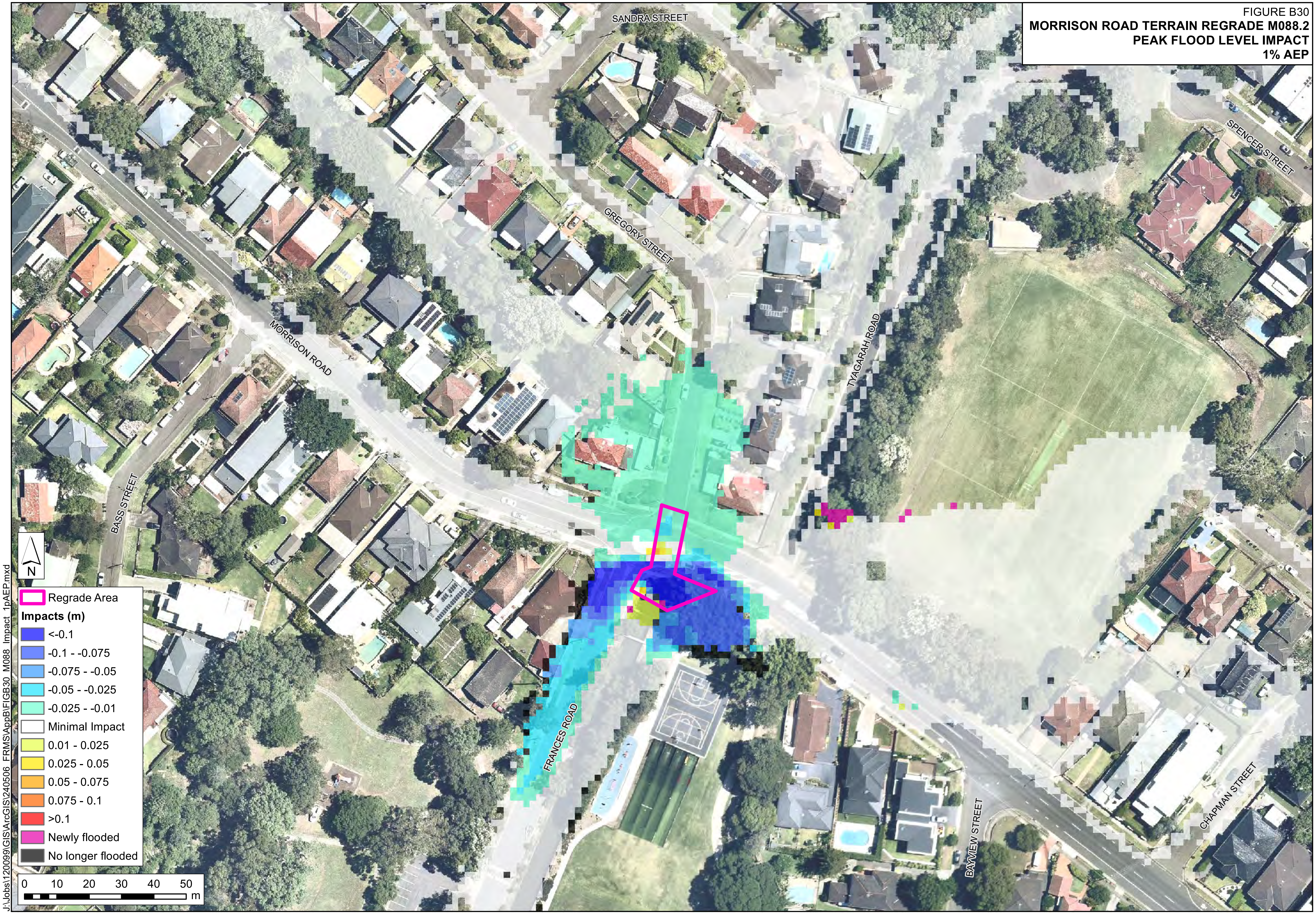


FIGURE B31
MORRISON RD DRAINAGE UPGRADE M088.3 OPTION

FIGURE B32
MORRISON RD DRAINAGE UPGRADE M088.3
PEAK FLOOD LEVEL IMPACT
1% AEP

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB32_M088c_Impacts_1pAEP.mxd

FIGURE B33
BELMORE ST AND ADDINGTON AVE FLOOD BARRIER M090 OPTION

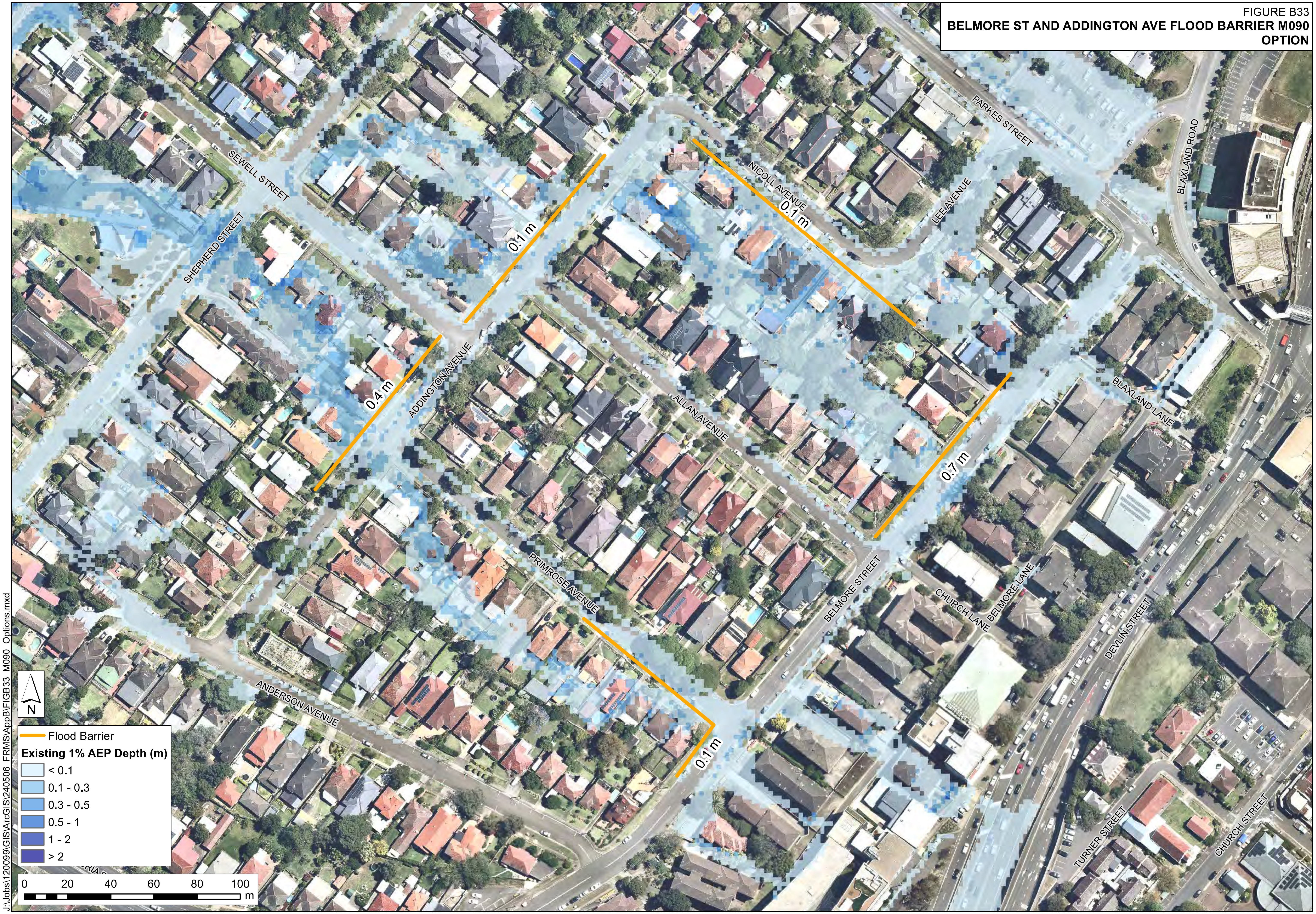
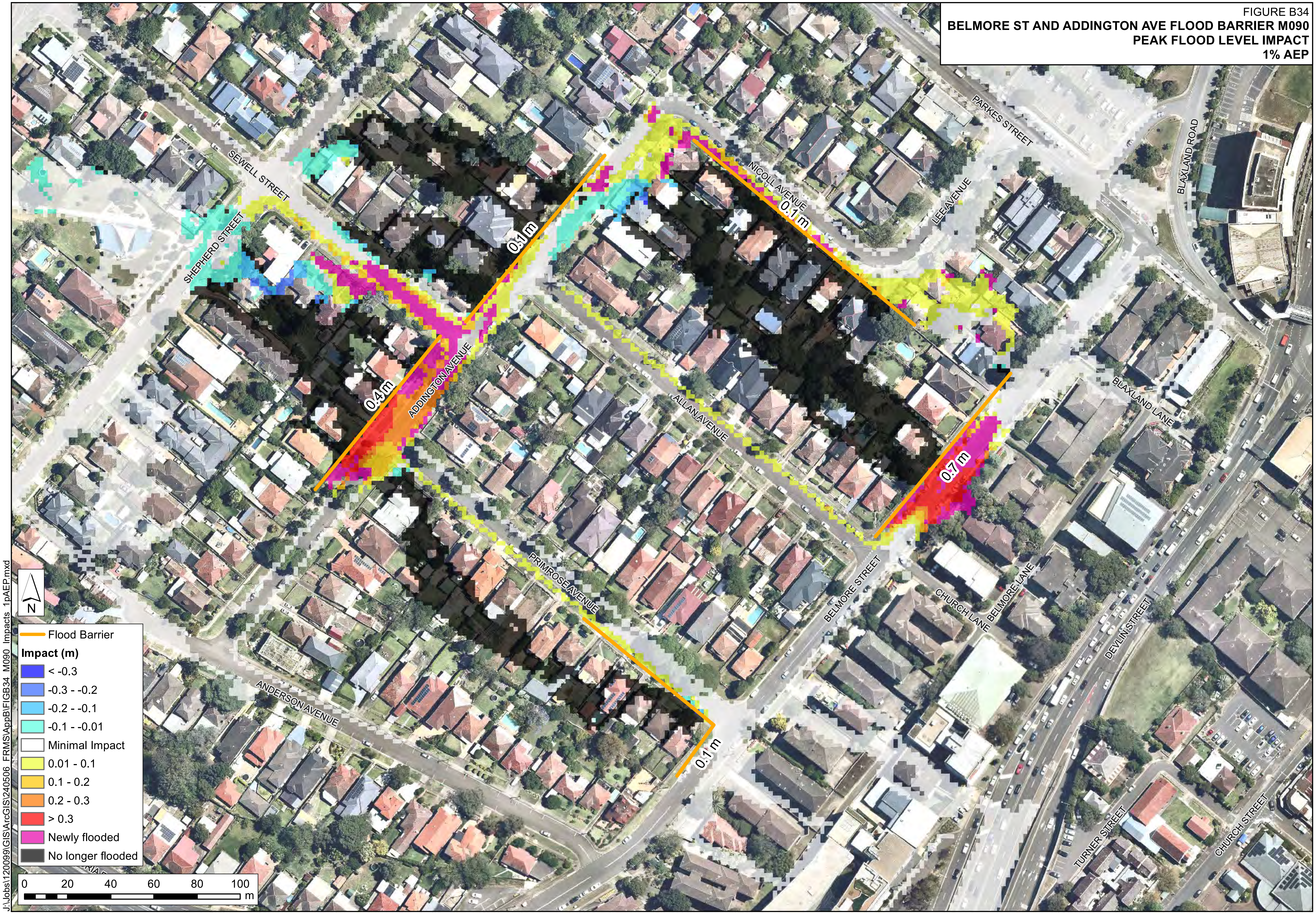


FIGURE B34
BELMORE ST AND ADDINGTON AVE FLOOD BARRIER M090
PEAK FLOOD LEVEL IMPACT
1% AEP



J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppB\FIGB34_M090_Impacts_1pAEP.mxd

FIGURE B35
BASIN AT PARKES ST M095 OPTION

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FIGURE B36
BASIN AT PARKES ST M095
PEAK FLOOD LEVEL IMPACT
1% AEP
WATTLE LANE
MELVILLE STREET
HERMITAGE ROAD
FALCONER STREET
HERBERT LANE
HERBERT STREET
HERMITAGE LANE
LINTON LANE
LINTON AVENUE
PARKES STREET
27.42 mAHD
HINKLER AVENUE
COLSTON STREET
BOWDEN STREET
GRIFFITHS LANE
FORSYTH STREET
GRIFFITHS AVENUE
VICTORIA ROAD
SHEPHERD STREET
SEWELL STREET
ADDINGTON AVENUE
STREET
N
Embankment
Impact (m)
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
Newly flooded
No longer flooded
0
40
80
120
160
200
m
J:\Jobs\120098\GIS\ArcGIS\240506_FRMS\AppB\FIGB36_M095_Impact_1pAEP.mxd

APPENDIX C. FLOOD MODIFICATION OPTIONS SUBJECT TO DETAILED ASSESSMENT

Appendix C

FIGURE C1
M003B GANNAN PARK BASIN OPTION

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\App C\FIGC01_M003b_Option.mxd

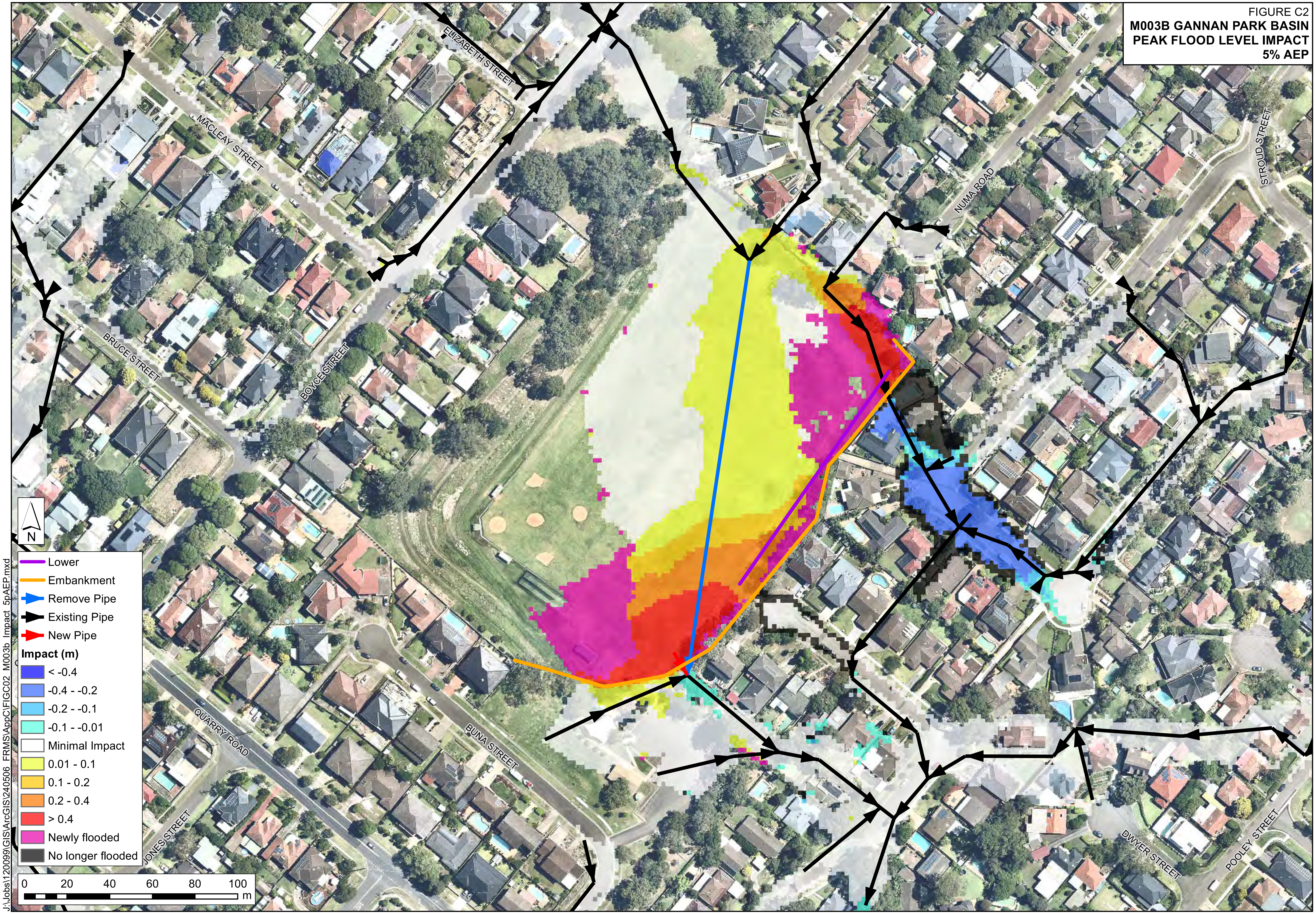


FIGURE C2
M003B GANNAN PARK BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP
ELIZABETH STREET
MACLEAY STREET
NUMA ROAD
STROUD STREET
BRUCE STREET
BOYCE STREET
QUARRY ROAD
BUNA STREET
JONES STREET
DWYER STREET
POOLEY STREET
N
Lower
Embankment
Remove Pipe
Existing Pipe
New Pipe
Impact (m)
< -0.4
-0.4 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.4
> 0.4
Newly flooded
No longer flooded
0 20 40 60 80 100
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppC\FIGC02_M003b_Impact_5pAEP.mxd

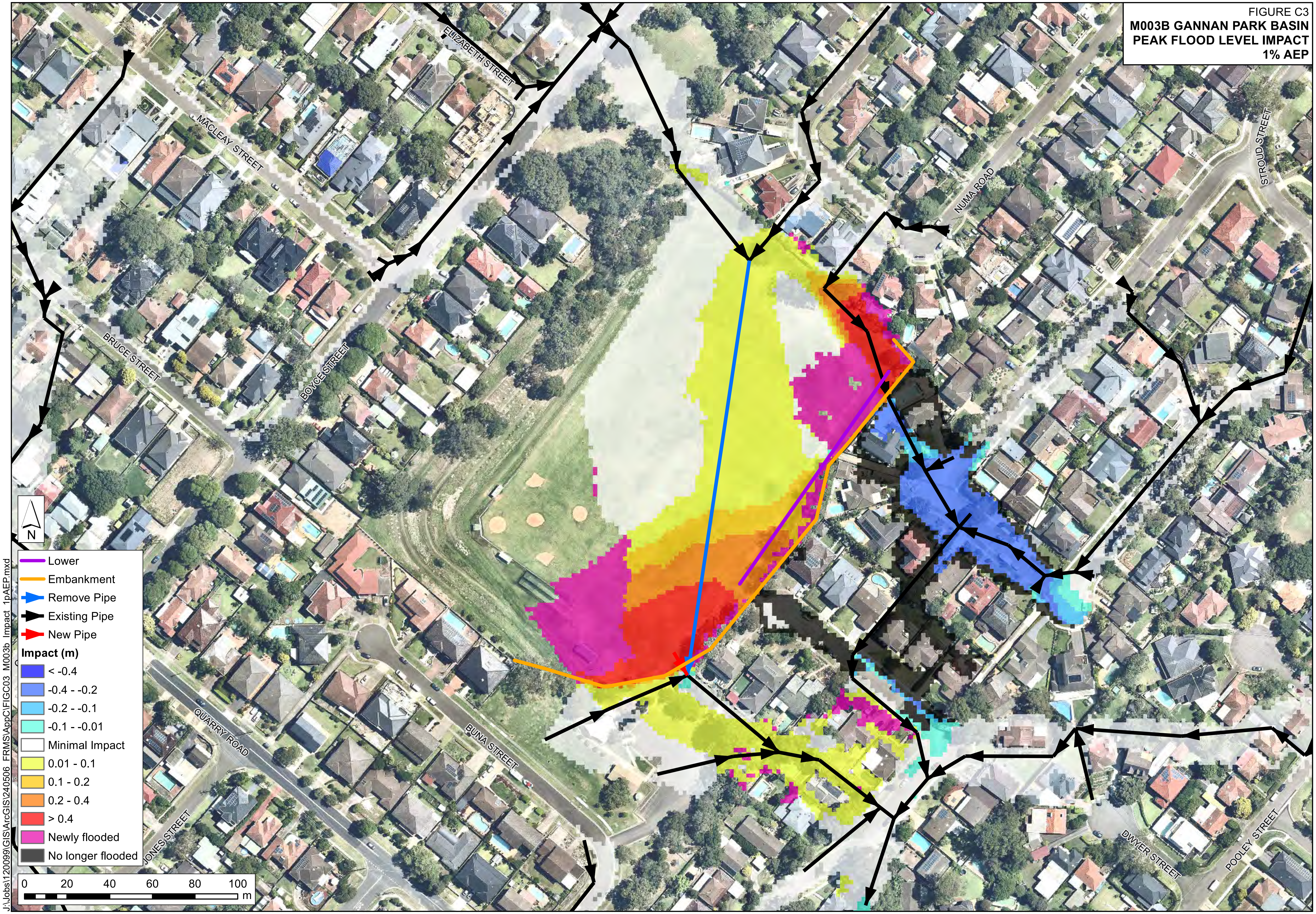


FIGURE C3
M003B GANNAN PARK BASIN
PEAK FLOOD LEVEL IMPACT
1% AEP
ELIZABETH STREET
MACLEAY STREET
NUMA ROAD
STROUD STREET
BRUCE STREET
BOYCE STREET
QUARRY ROAD
BUNA STREET
JONES STREET
DWYER STREET
POOLEY STREET
N
Lower
Embankment
Remove Pipe
Existing Pipe
New Pipe
Impact (m)
< -0.4
-0.4 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.4
> 0.4
Newly flooded
No longer flooded
0 20 40 60 80 100
m
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppC\FIGC03_M003b_Impact_1pAEP.mxd

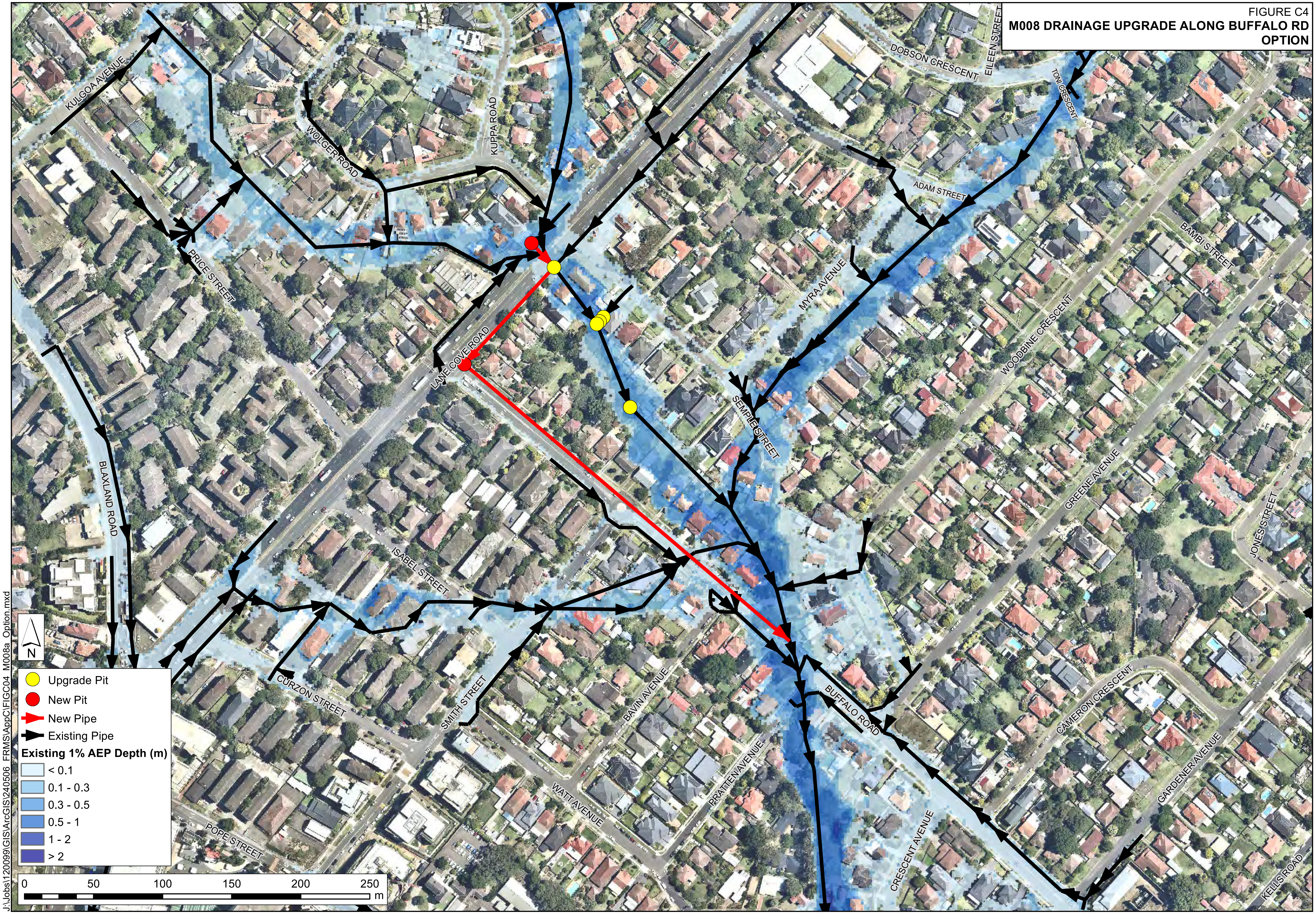


FIGURE C4
M008 DRAINAGE UPGRADE ALONG BUFFALO RD OPTION
Upgrade Pit
New Pit
New Pipe
Existing Pipe
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 50 100 150 200 250 m
KULGOA AVENUE
WOLGER ROAD
KUPPA ROAD
PRICE STREET
LANE COVE ROAD
DOBSON CRESCENT
EILEEN STREET
TONI CRESCENT
ADAM STREET
MYRA AVENUE
SEMPLE STREET
BAMBI STREET
WOODBINE CRESCENT
GREENE AVENUE
JONES STREET
BLAXLAND ROAD
ISABEL STREET
CURZON STREET
SMITH STREET
BAVIN AVENUE
PRATTEN AVENUE
BUFFALO ROAD
CAMERON CRESCENT
GARDENER AVENUE
WATT AVENUE
POPE STREET
CRESCENT AVENUE
KELLS ROAD
J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppC\FIGC04_M008a_Option.mxd

FIGURE C5

M008 DRAINAGE UPGRADE ALONG BUFFALO RD
PEAK FLOOD LEVEL IMPACT
5% AEP

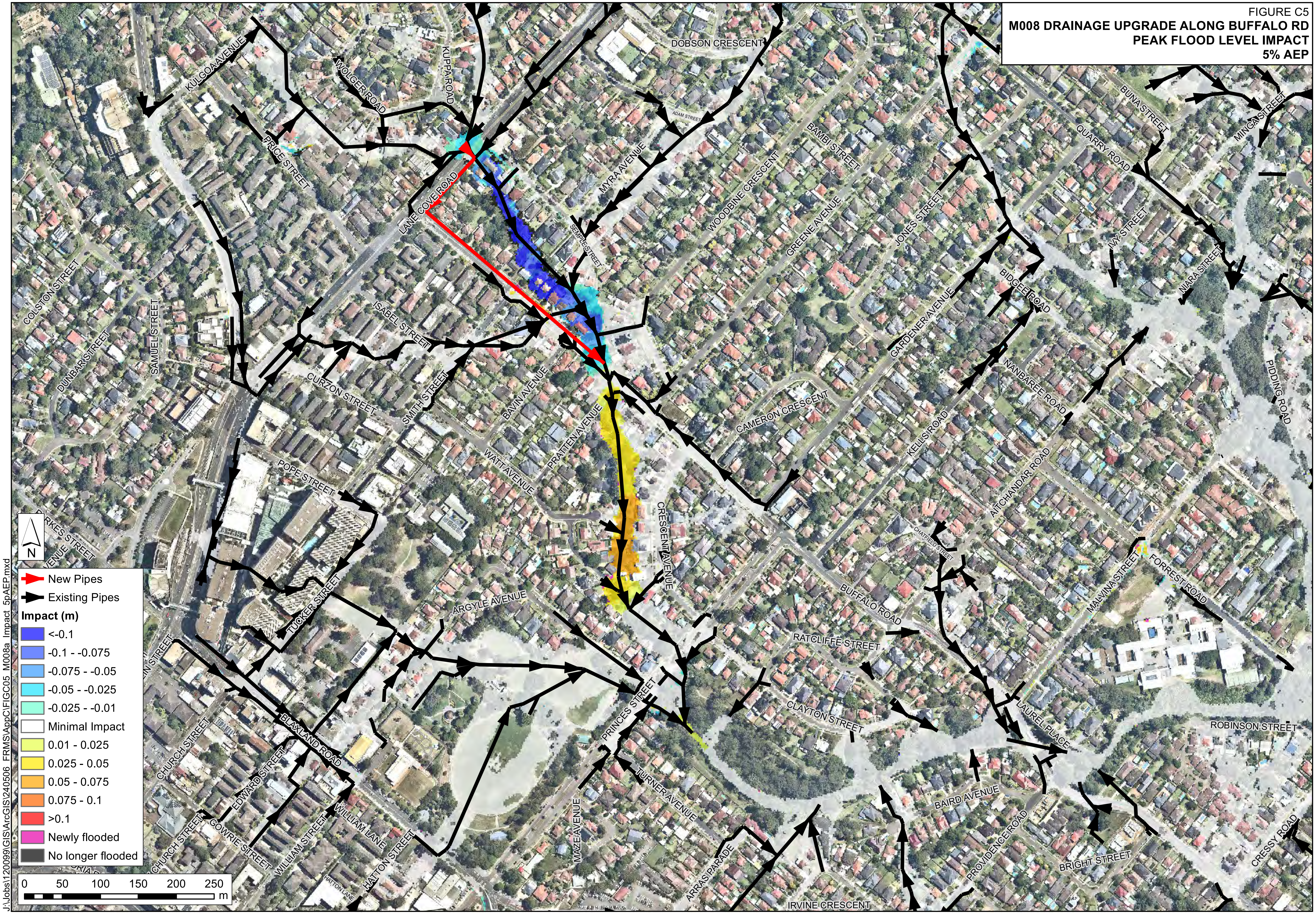


FIGURE C6

M008 DRAINAGE UPGRADE ALONG BUFFALO RD
PEAK FLOOD LEVEL IMPACT
1% AEP

J:\Jobs\120099\GIS\ArcGIS\240506_FRMS\AppC\FIGC06_M008a_Impact_1pAEP.mxd

FIGURE C7
M027 DRAINAGE UPGRADE FIRST AVENUE OPTION


FIGURE C8
M027 DRAINAGE UPGRADE FIRST AVENUE
PEAK FLOOD LEVEL IMPACT
5% AEP
STATION LANE
ROWE LANE
RAILWAY PARADE
ROWE STREET
EAST PARADE
FIRST AVENUE
N
Upgraded Pit
Existing Pipe
Upgraded Pipe
Demolished Building
Impact (m)
<-0.1
-0.1 - -0.075
-0.075 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.025
0.025 - 0.05
0.05 - 0.075
0.075 - 0.1
>0.1
Newly flooded
No longer flooded
0 10 20 30 40 50
m
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC08_M027_Impact_5pAEP.mxd

FIGURE C9
M027 DRAINAGE UPGRADE FIRST AVENUE
PEAK FLOOD LEVEL IMPACT
1% AEP

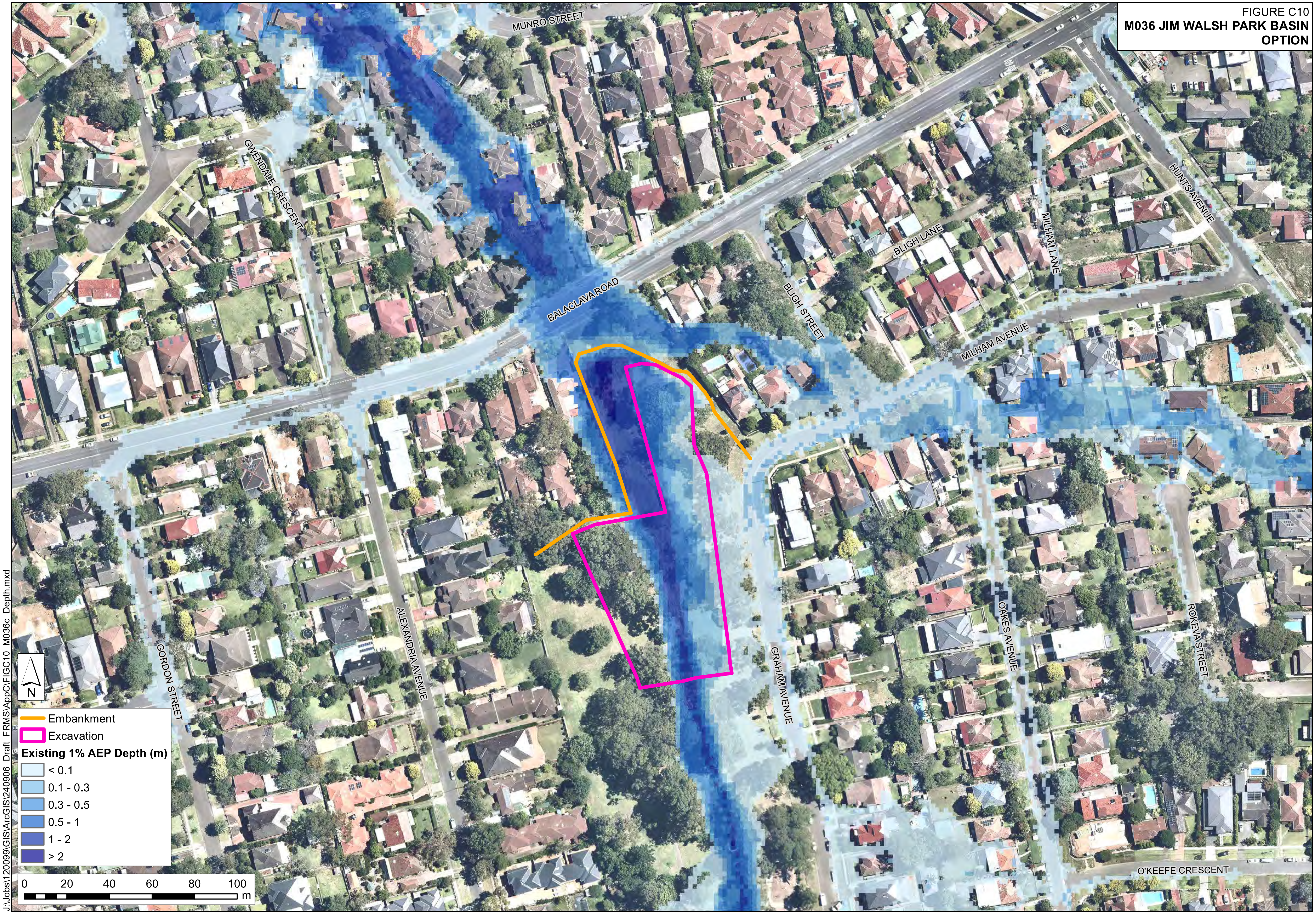


FIGURE C10
M036 JIM WALSH PARK BASIN OPTION
MUNRO STREET
GWENDALE CRESCENT
BALACLAVA ROAD
BLIGH STREET
BLIGH LANE
MILHAM LANE
HUNTS AVENUE
MILHAM AVENUE
GORDON STREET
ALEXANDRIA AVENUE
GRAHAM AVENUE
OAKES AVENUE
ROKEVA STREET
O'KEEFE CRESCENT
N
Embankment
Excavation
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
20
40
60
80
100
m
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\App C\FIG C10_M036c_Depth.mxd

FIGURE C11

M036 JIM WALSH PARK BASIN OPTION TERRAIN CHANGES

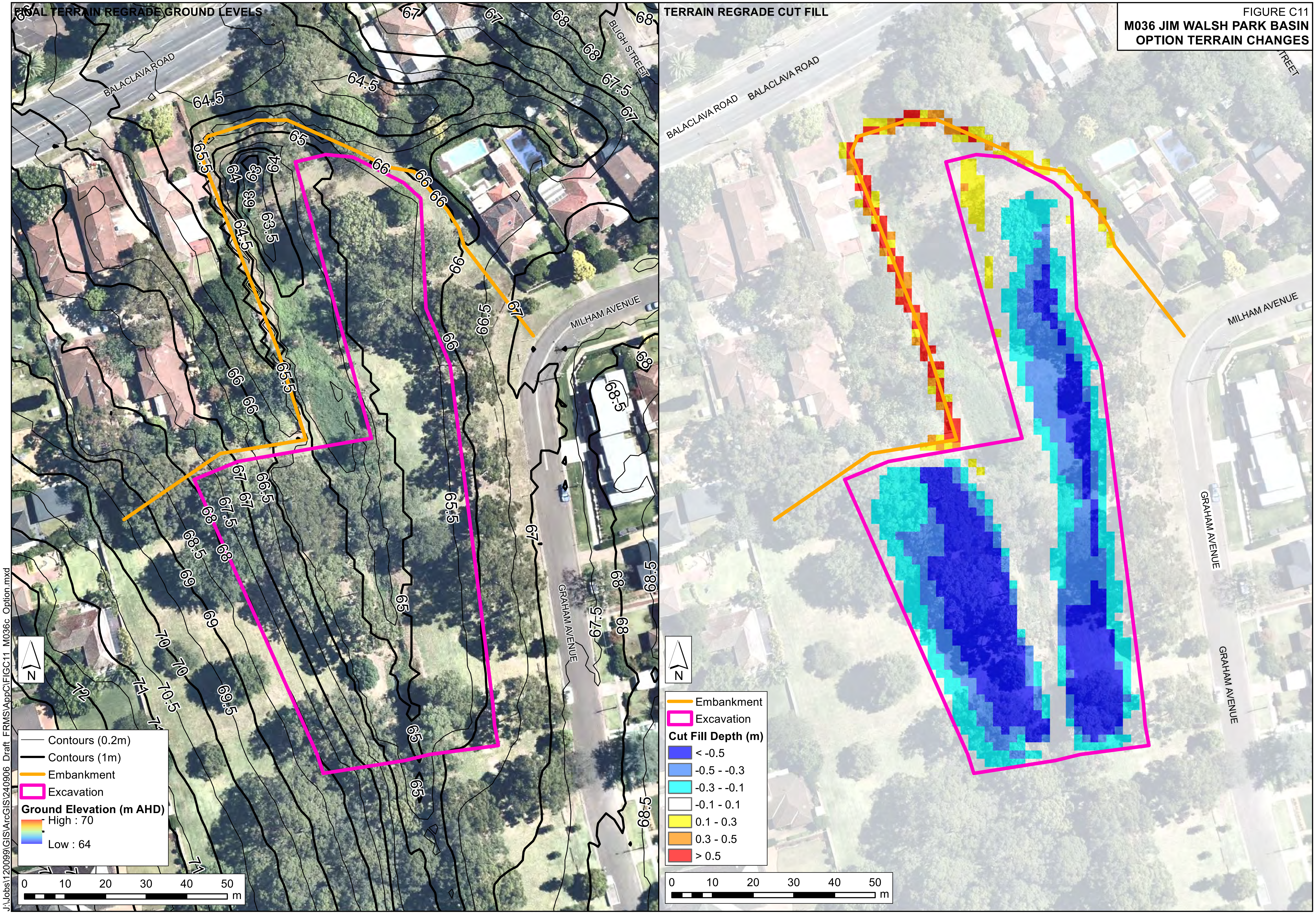
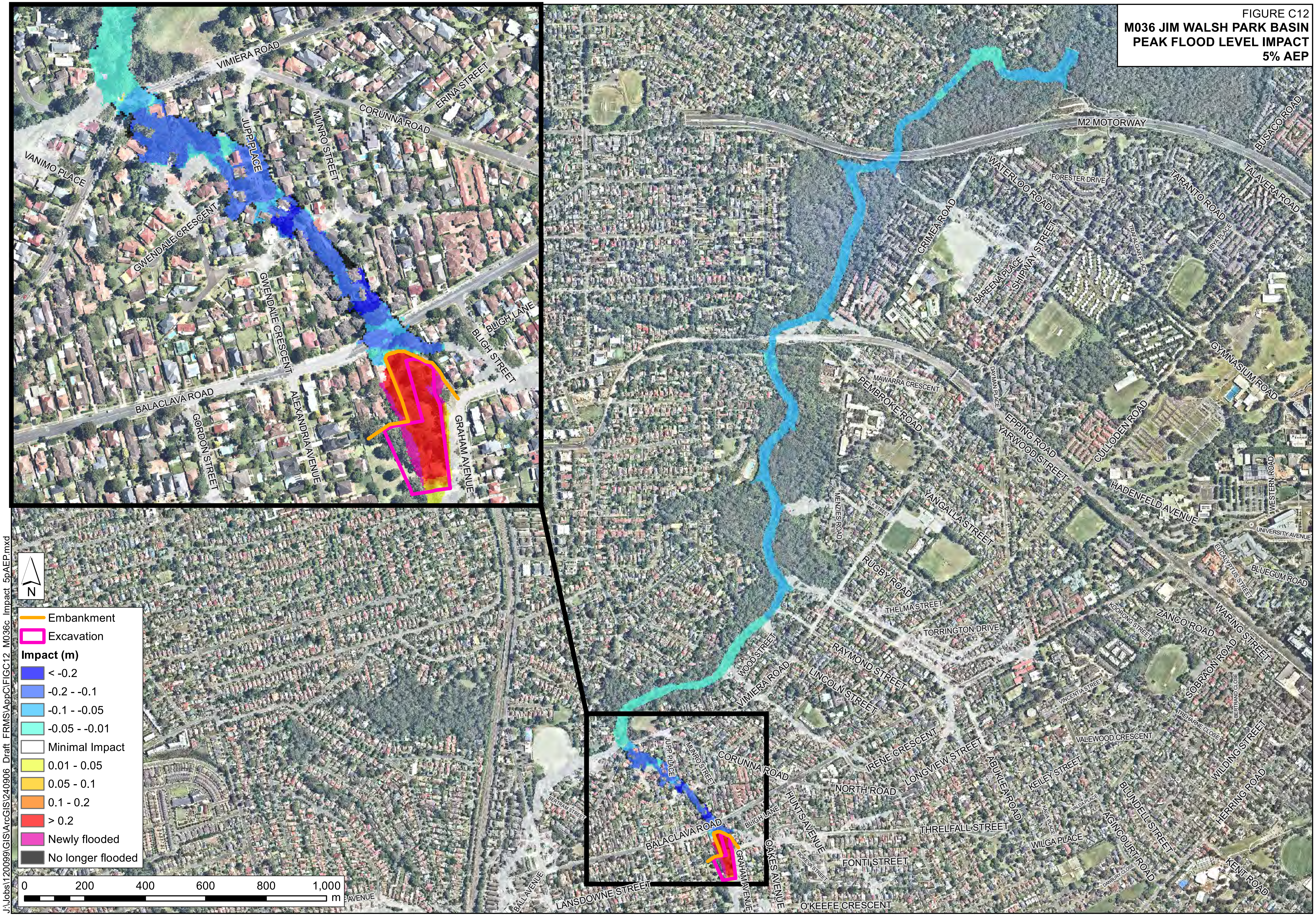


FIGURE C12
M036 JIM WALSH PARK BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC12_M036c_Impact_5pAEP.mxd

FIGURE C13
M036 JIM WALSH PARK BASIN
PEAK FLOOD LEVEL IMPACT
1% AEP

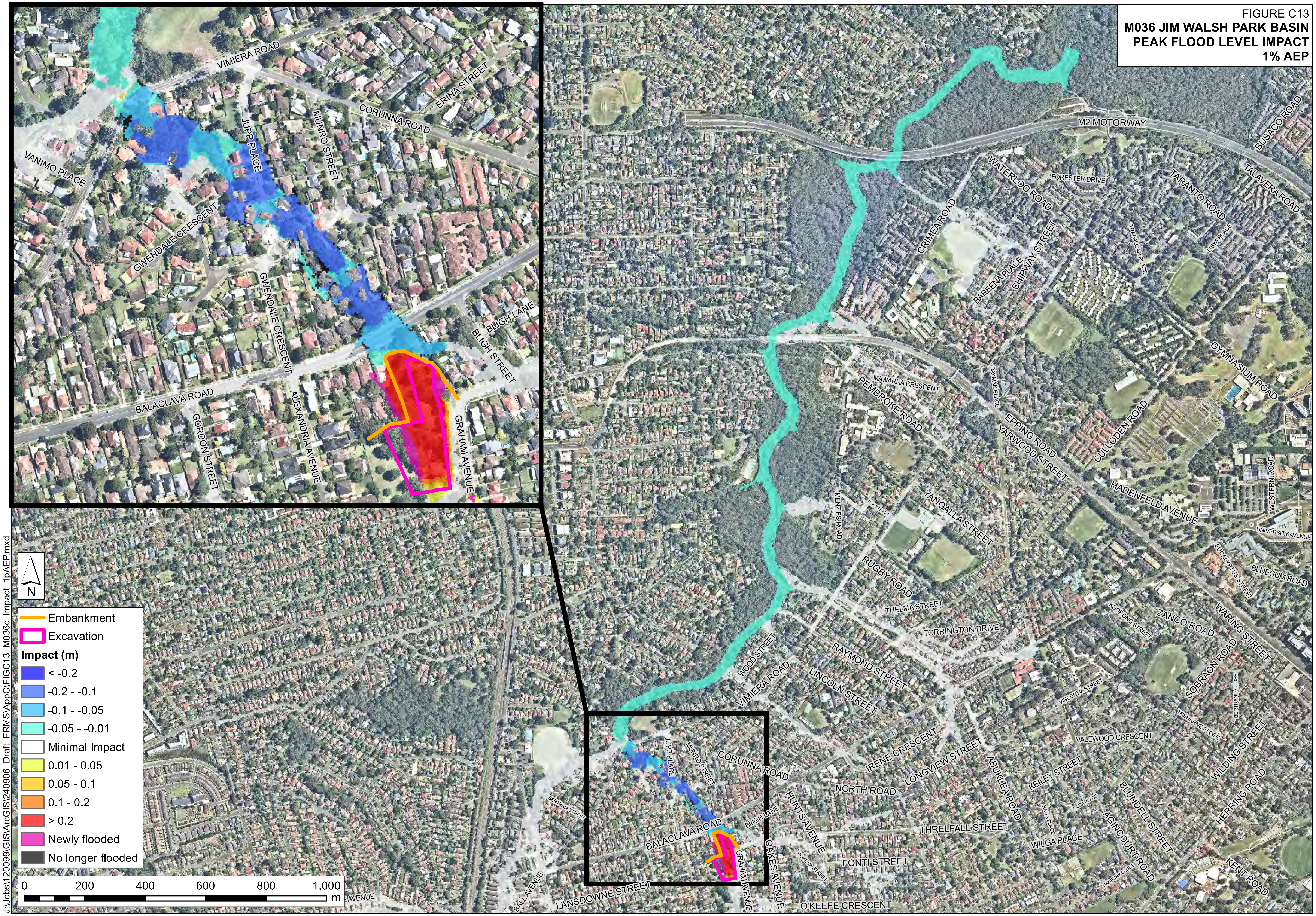
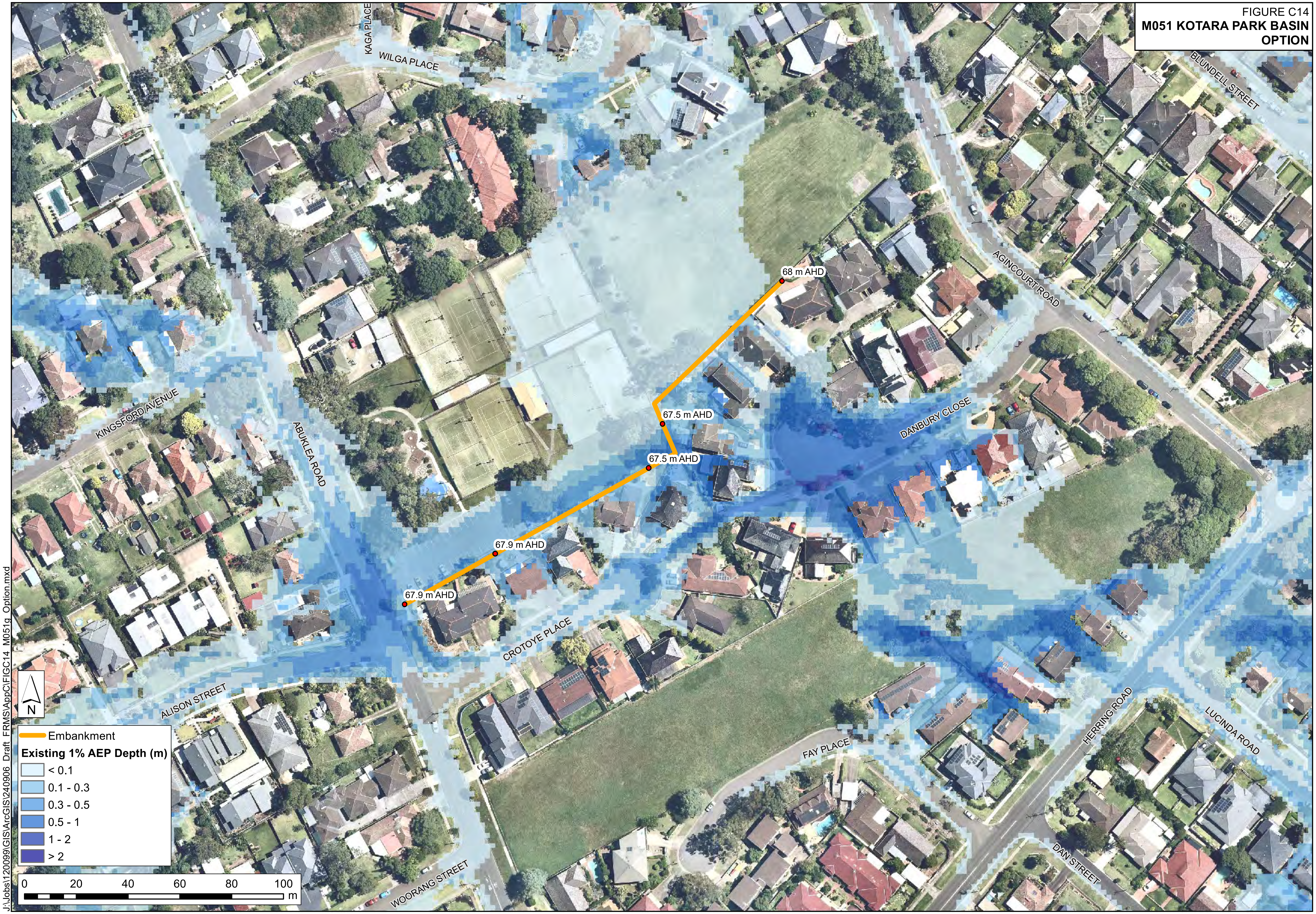


FIGURE C14
M051 KOTARA PARK BASIN OPTION



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC14_M051g_Option.mxd

FIGURE C15
M051.4 KOTARA PARK BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP

FIGURE C16
M051.4 KOTARA PARK BASIN PEAK FLOOD LEVEL IMPACT 1% AEP

J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC16_M051g_Impact_1pAEP.mxd

FIGURE C17
M057 SMALLS PARK BASIN OPTION

J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC17_M057c_Option.mxd

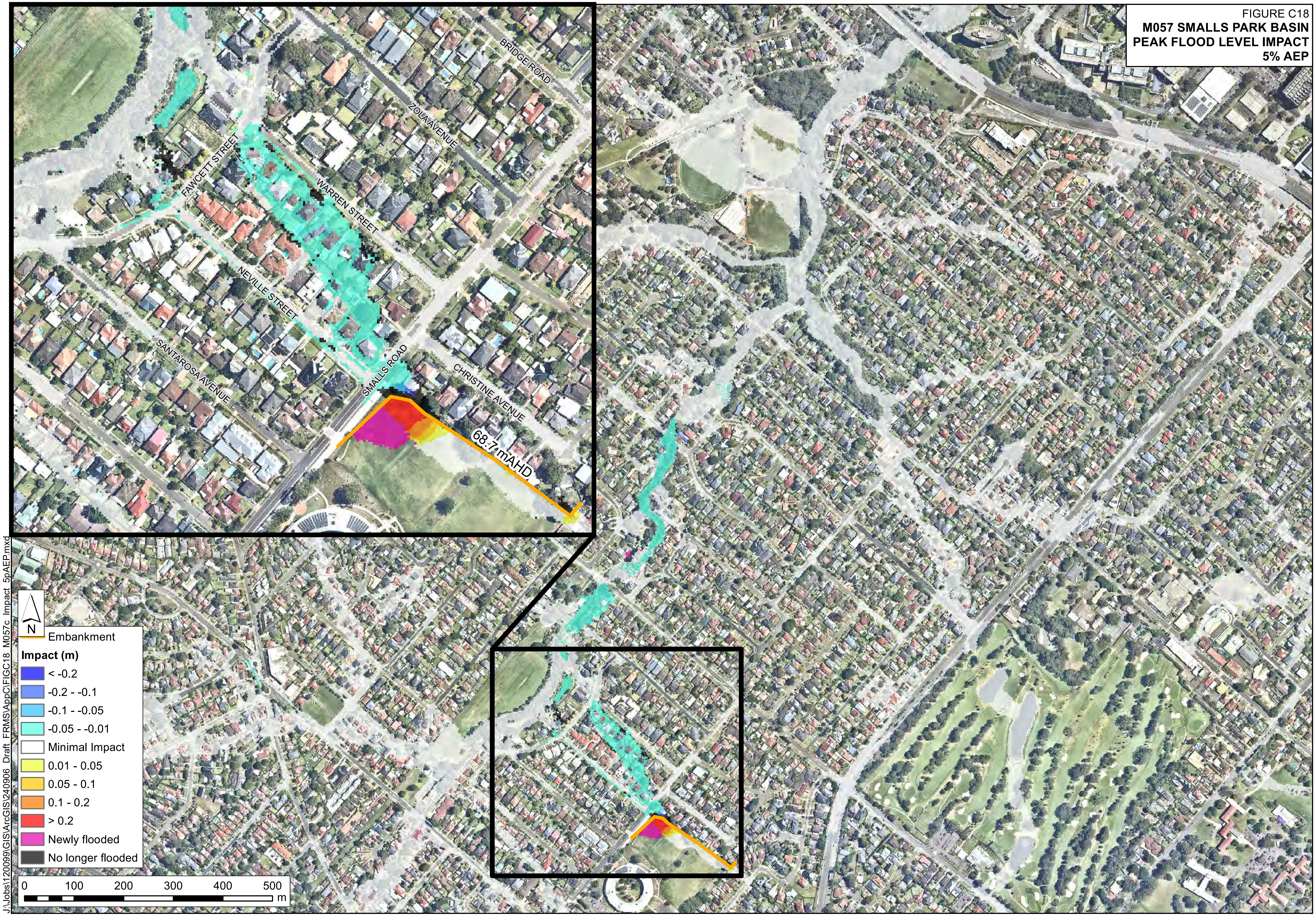


FIGURE C18
M057 SMALLS PARK BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP

J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC18_M057c_Impact_5pAEP.mxd

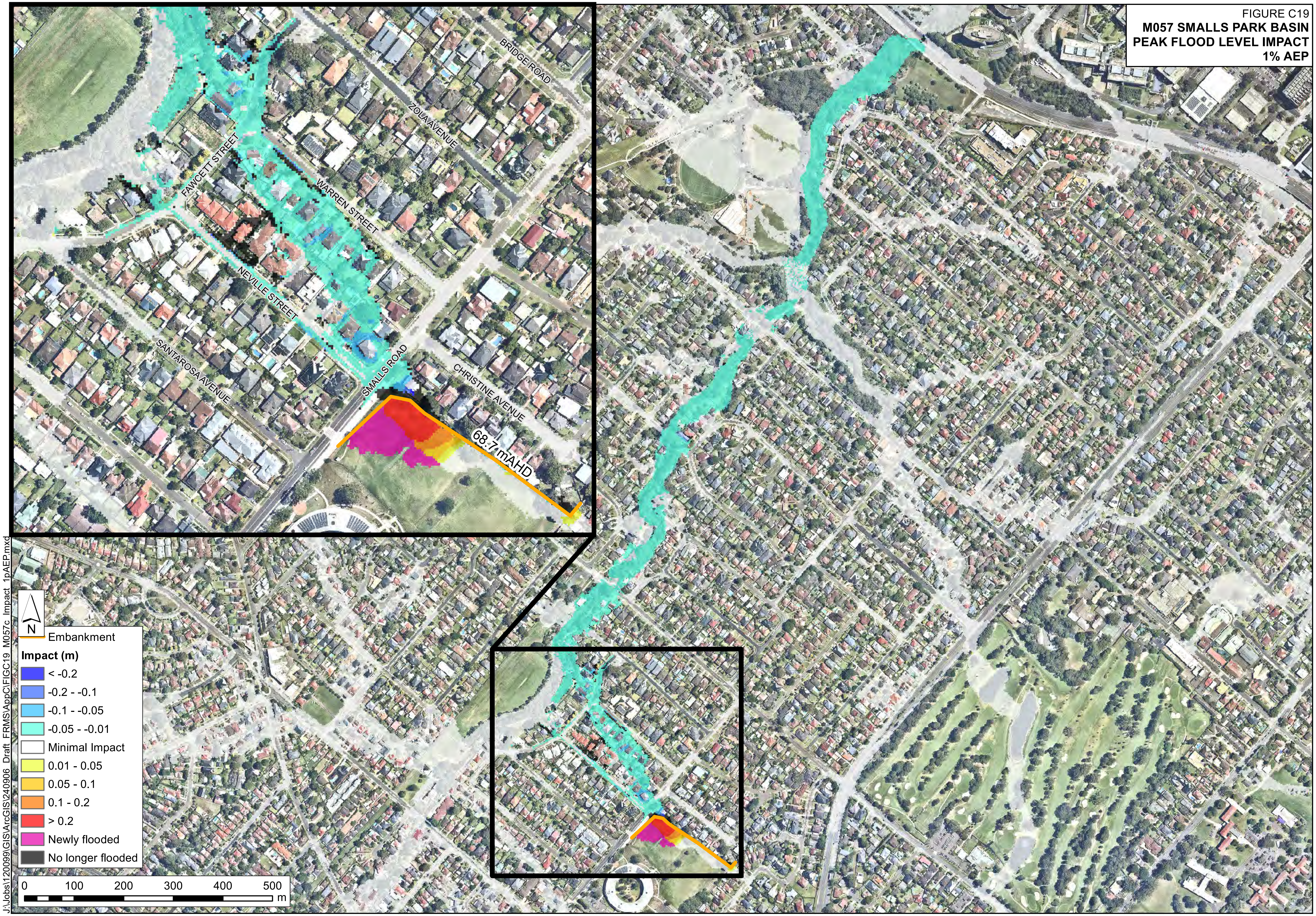
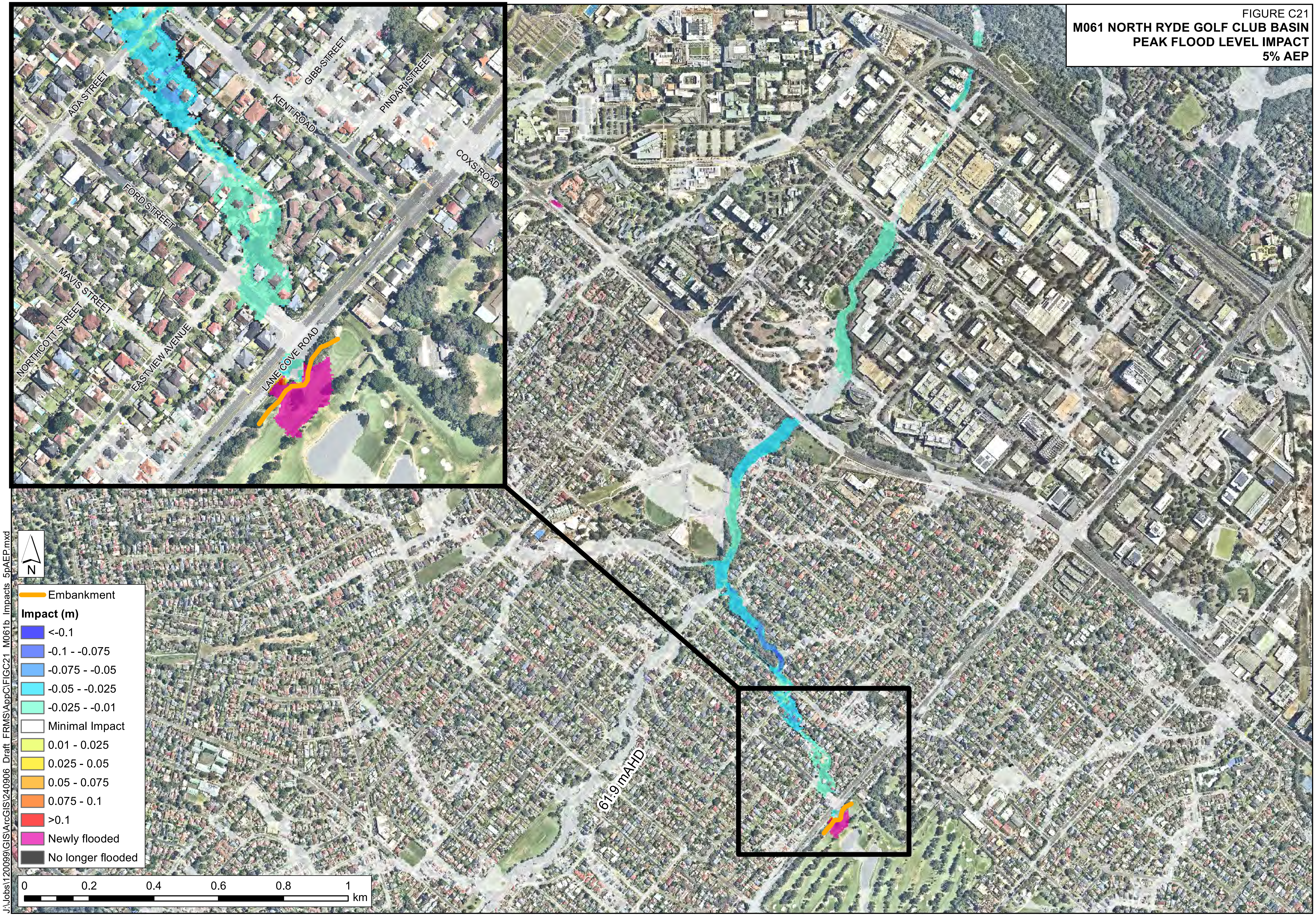


FIGURE C19
M057 SMALLS PARK BASIN
PEAK FLOOD LEVEL IMPACT
1% AEP
BRIDGE ROAD
ZOLA AVENUE
FAWCETT STREET
WARREN STREET
NEVILLE STREET
SANTAROSA AVENUE
SMALLS ROAD
CHRISTINE AVENUE
68.7mAHD
N
Embankment
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 100 200 300 400 500
m
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC19_M057c_Impact_1pAEP.mxd

FIGURE C20
M061 NORTH RYDE GOLF CLUB BASIN OPTION

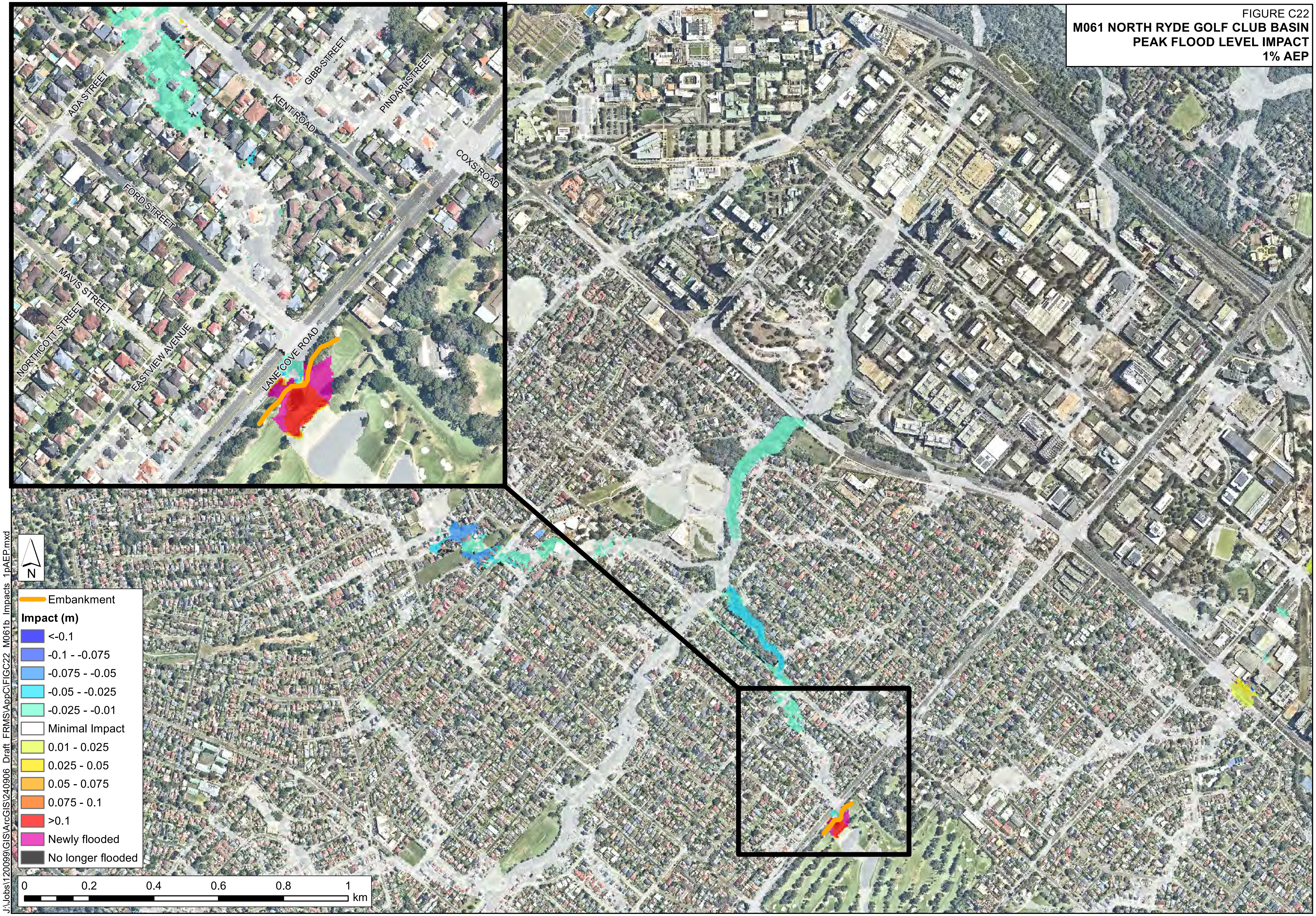
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC20_M061b_Option.mxd

FIGURE C21
M061 NORTH RYDE GOLF CLUB BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC21_M061b_Impacts_5pAEP.mxd

FIGURE C22
M061 NORTH RYDE GOLF CLUB BASIN
PEAK FLOOD LEVEL IMPACT
1% AEP



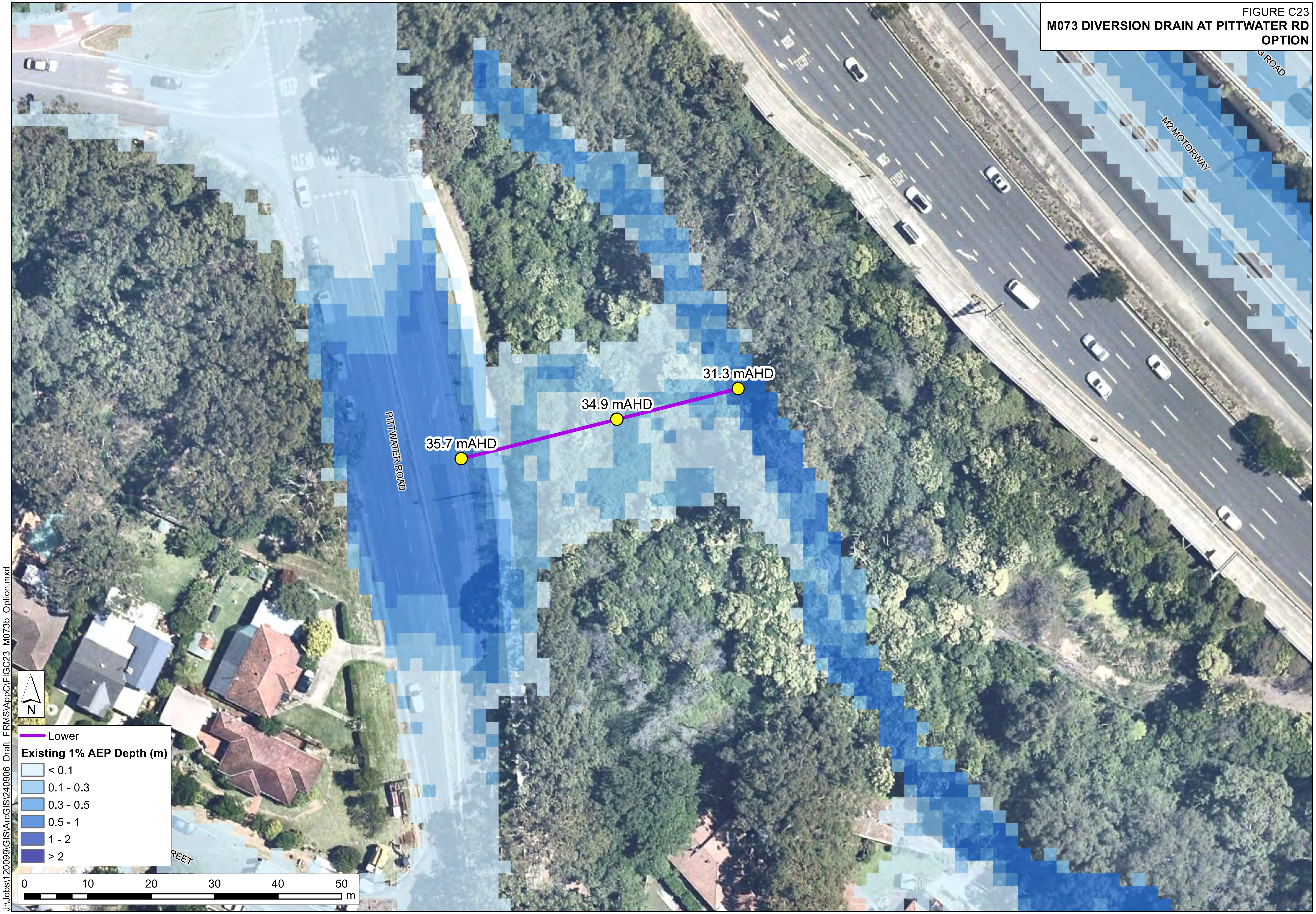


FIGURE C23
M073 DIVERSION DRAIN AT PITTWATER RD OPTION
M2 MOTORWAY
PITTWATER ROAD
31.3 mAHD
34.9 mAHD
35.7 mAHD
N
Lower
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 10 20 30 40 50
m
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC23_M073b_Option.mxd

FIGURE C24
M073 DIVERSION DRAIN AT PITTWATER RD
PEAK FLOOD LEVEL IMPACT
5% AEP

J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC24_M073b_Impact_5pAEP.mxd

FIGURE C25
M073 DIVERSION DRAIN AT PITTWATER RD PEAK FLOOD LEVEL IMPACT 1% AEP

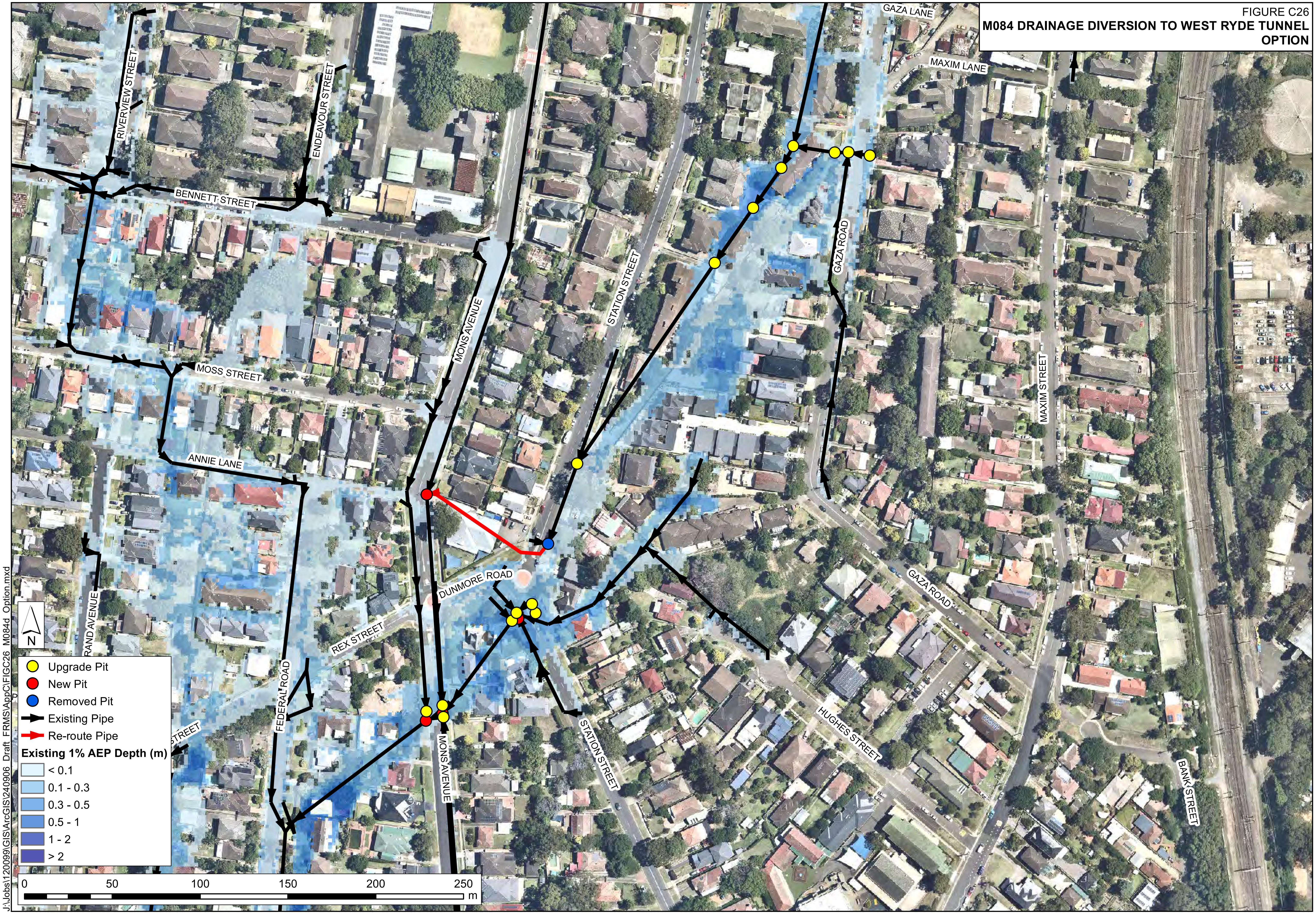
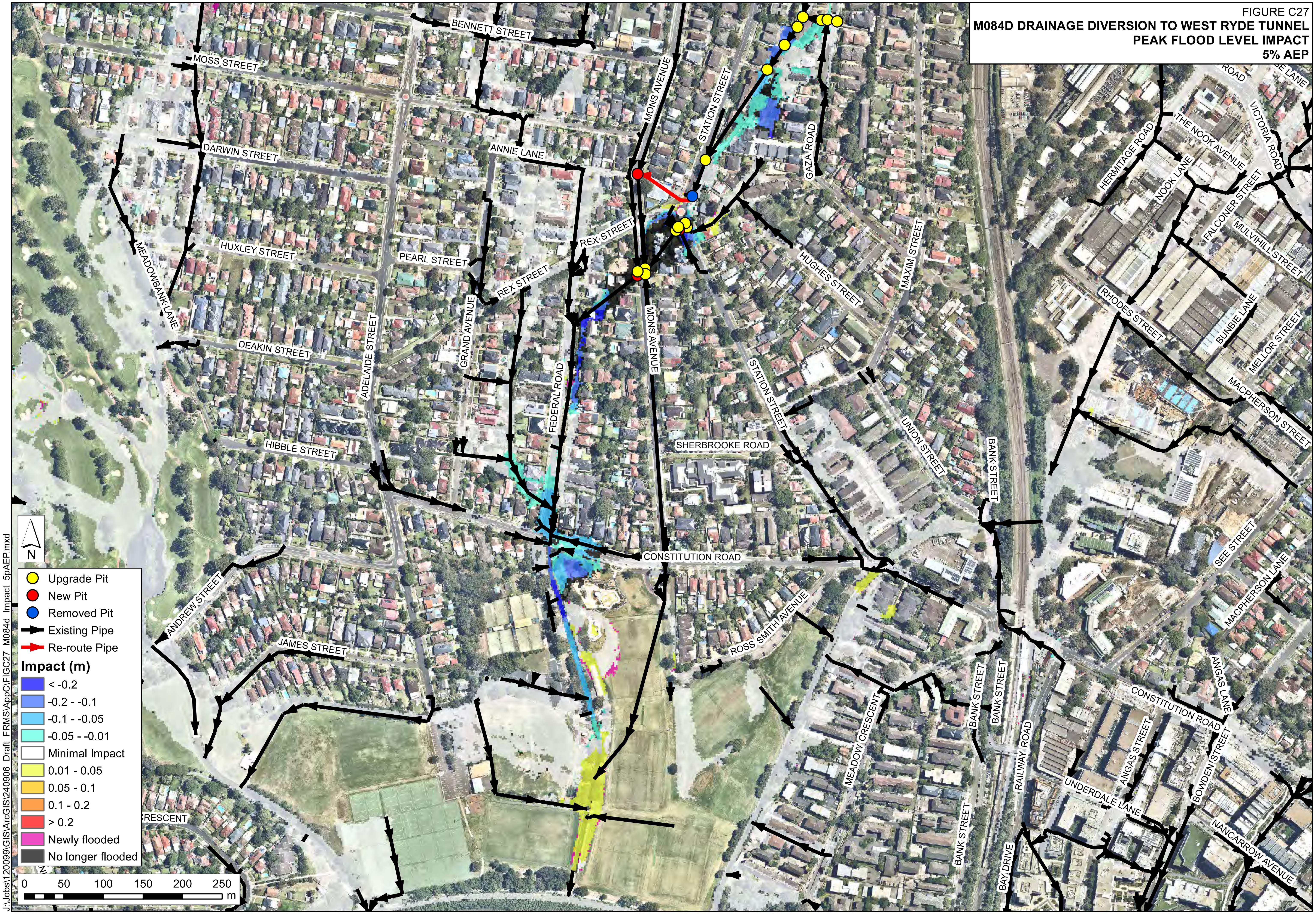
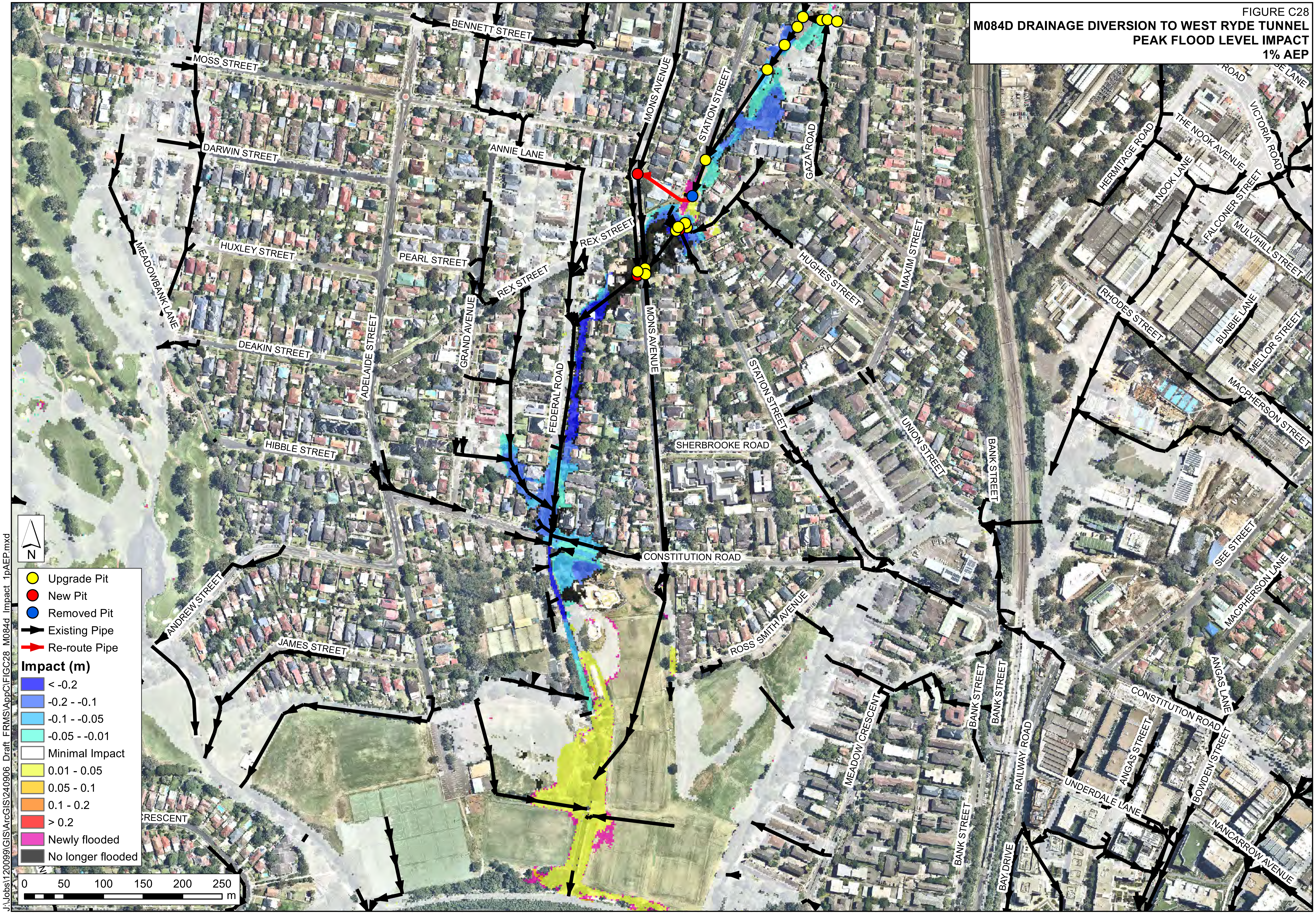


FIGURE C26
M084 DRAINAGE DIVERSION TO WEST RYDE TUNNEL OPTION
GAZA LANE
MAXIM LANE
RIVERVIEW STREET
ENDEAVOUR STREET
BENNETT STREET
MONS AVENUE
STATION STREET
GAZA ROAD
MOSS STREET
MAXIM STREET
ANNIE LANE
DUNMORE ROAD
REX STREET
GRAND AVENUE
FEDERAL ROAD
HUGHES STREET
BANK STREET
Upgrade Pit
New Pit
Removed Pit
Existing Pipe
Re-route Pipe
Existing 1% AEP Depth (m)
< 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
50
100
150
200
250
m
N
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC26_M084d_Option.mxd

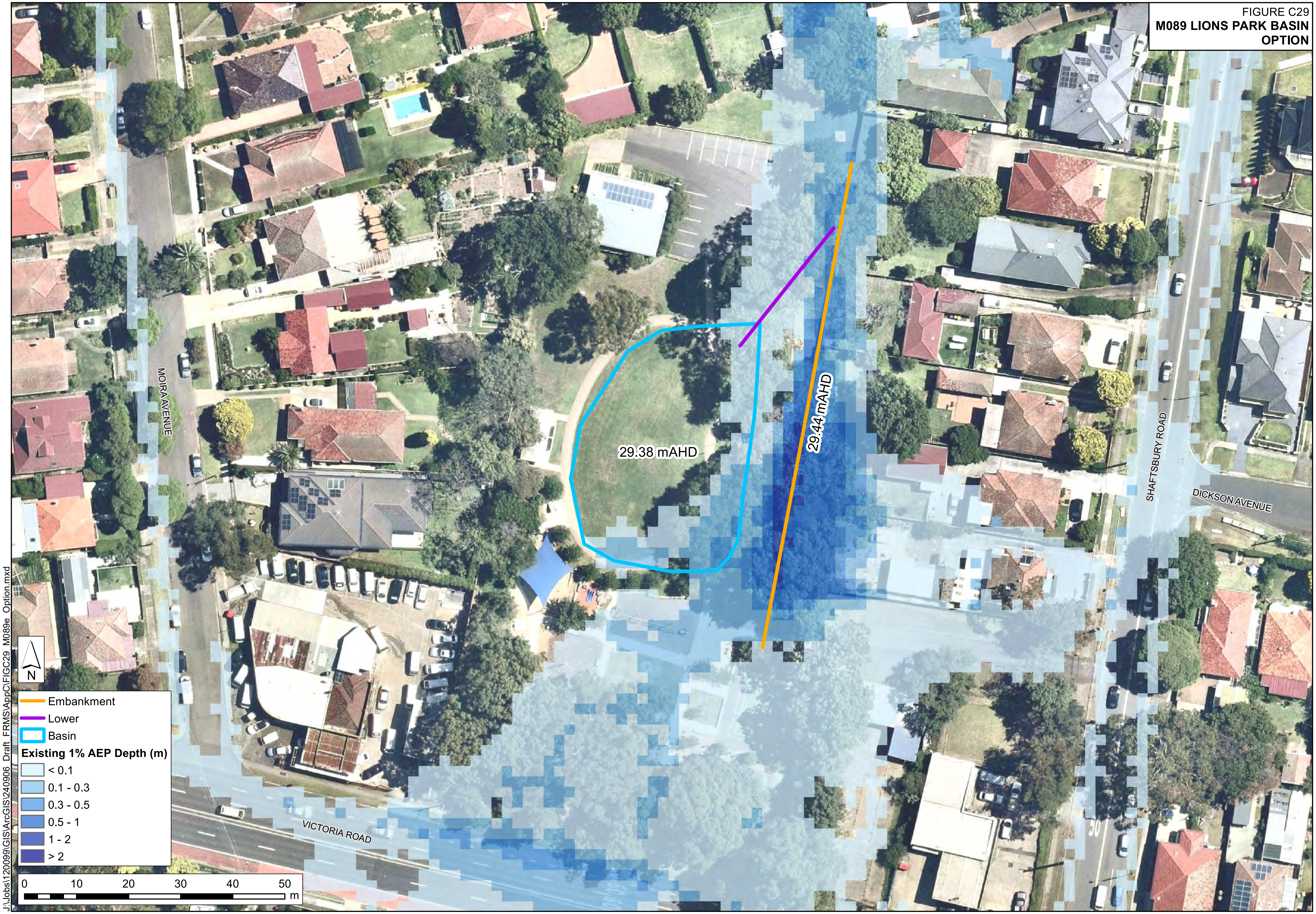
FIGURE C27
M084D DRAINAGE DIVERSION TO WEST RYDE TUNNEL
PEAK FLOOD LEVEL IMPACT
5% AEP





J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC28_M084d_Impact_1pAEP.mxd

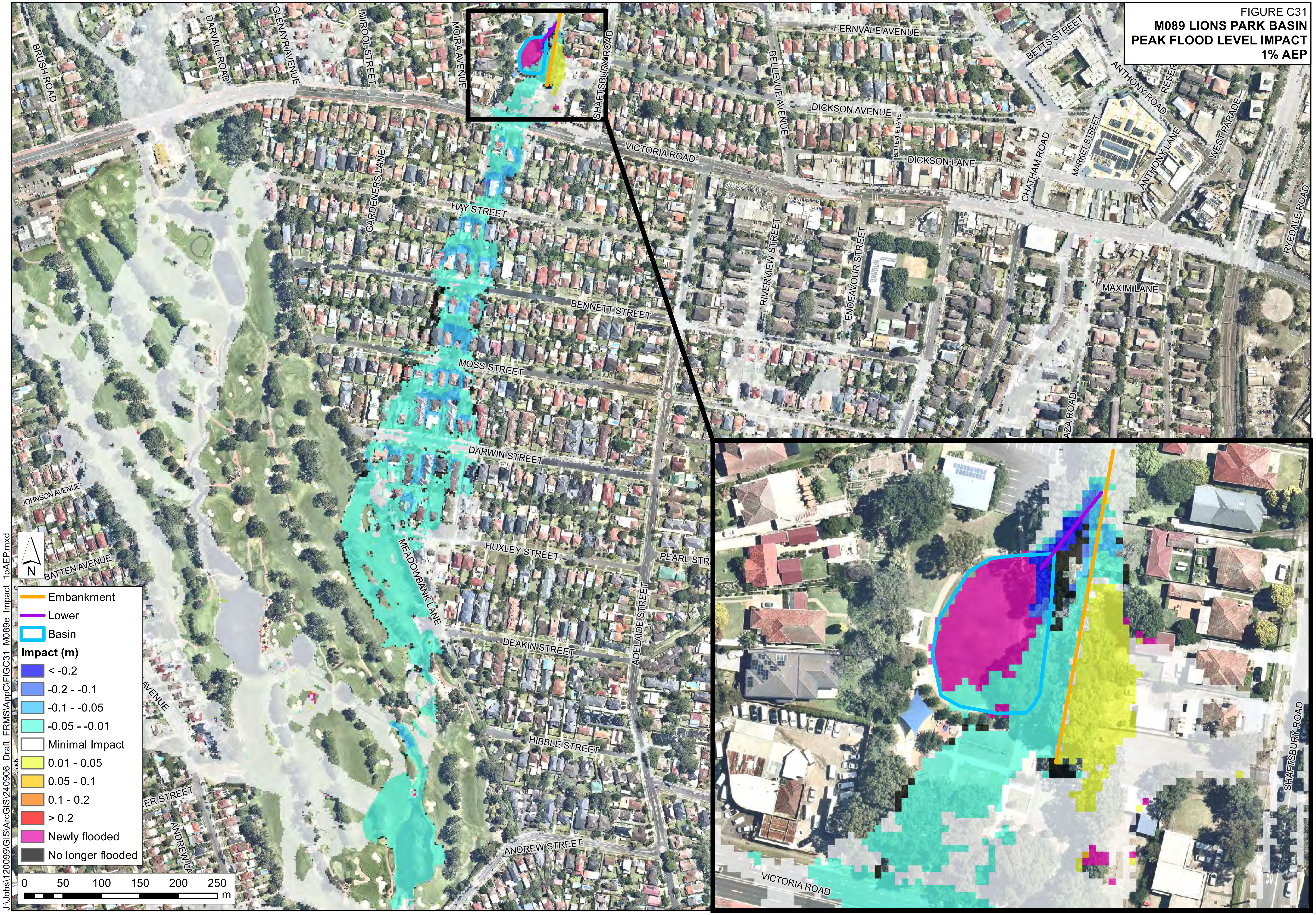
FIGURE C29
M089 LIONS PARK BASIN OPTION



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC29_M089e_Option.mxd

FIGURE C30
M089 LIONS PARK BASIN
PEAK FLOOD LEVEL IMPACT
5% AEP

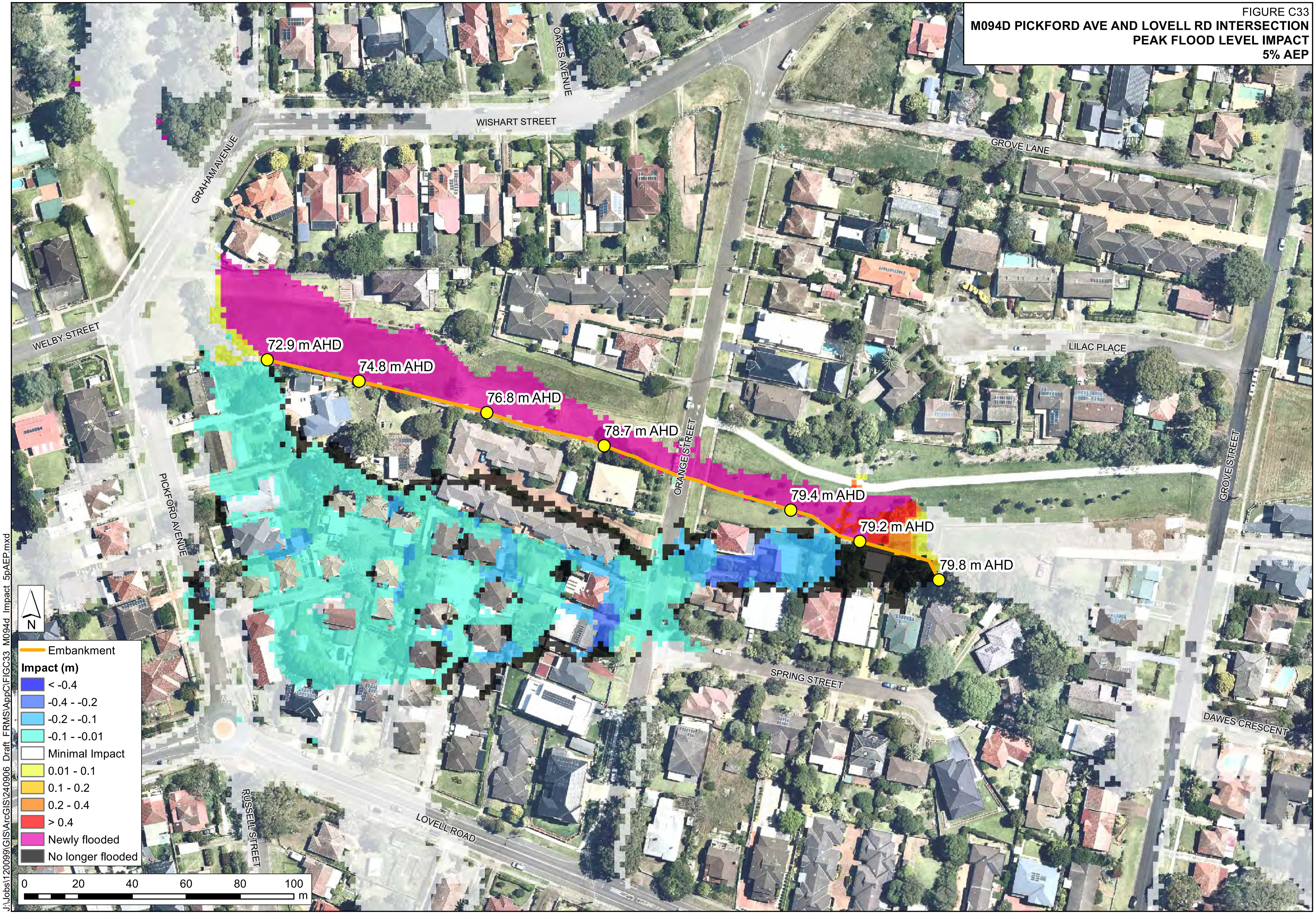
FIGURE C31
M089 LIONS PARK BASIN PEAK FLOOD LEVEL IMPACT 1% AEP



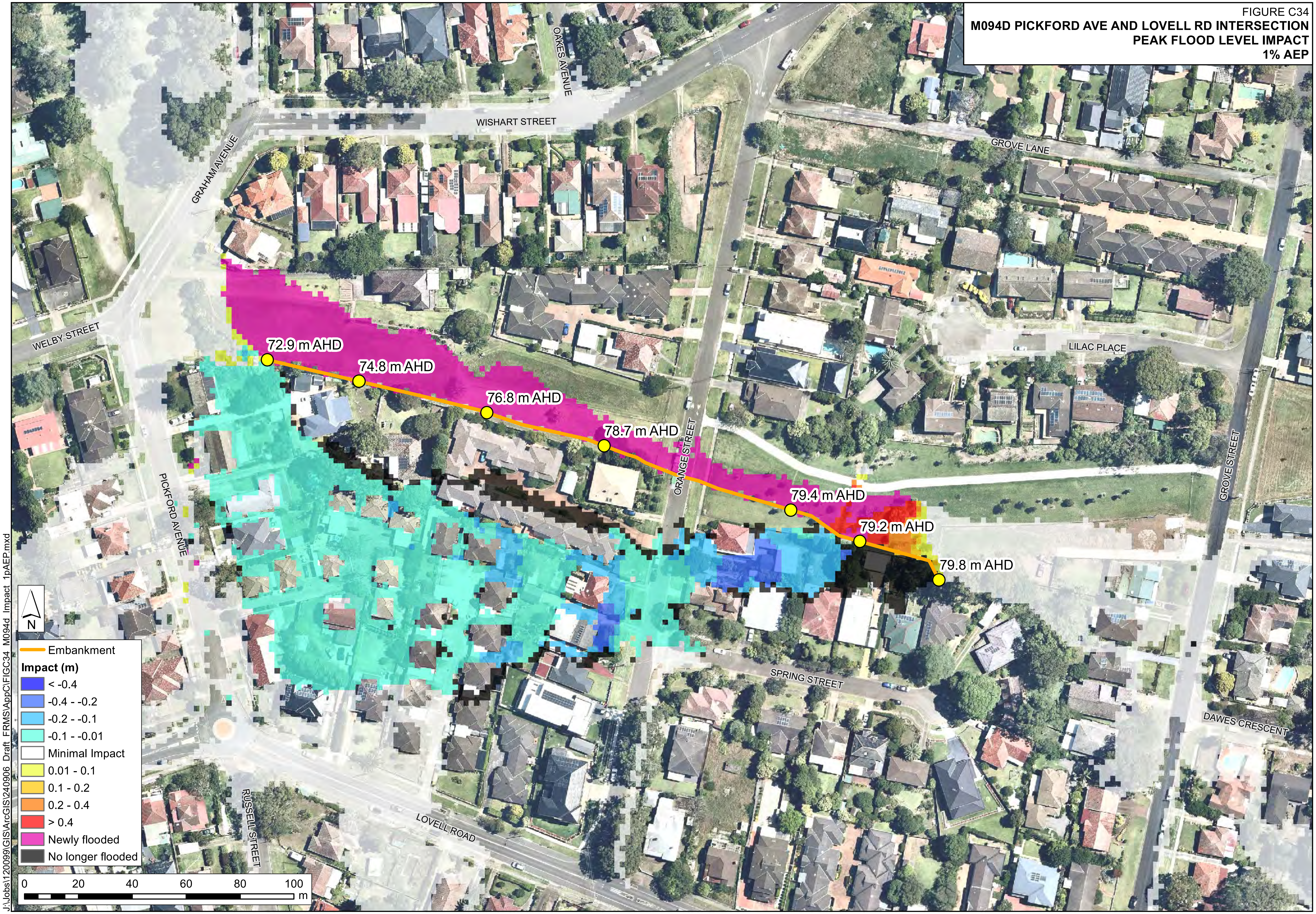
J:\Jobs\120099\GIS\ArcGIS\240906 Draft FRMS\AppC\FIGC31 M089e Impact 1pAEP.mxd

FIGURE C32
M094D PICKFORD AVE AND LOVELL RD INTERSECTION OPTION

FIGURE C33
**M094D PICKFORD AVE AND LOVELL RD INTERSECTION
PEAK FLOOD LEVEL IMPACT
5% AEP**



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC33_M094d_Impact_5pAEP.mxd



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC34_M094d_Impact_1pAEP.mxd

FIGURE C35
M101B BOYCE ST DRAINAGE UPGRADE OPTION

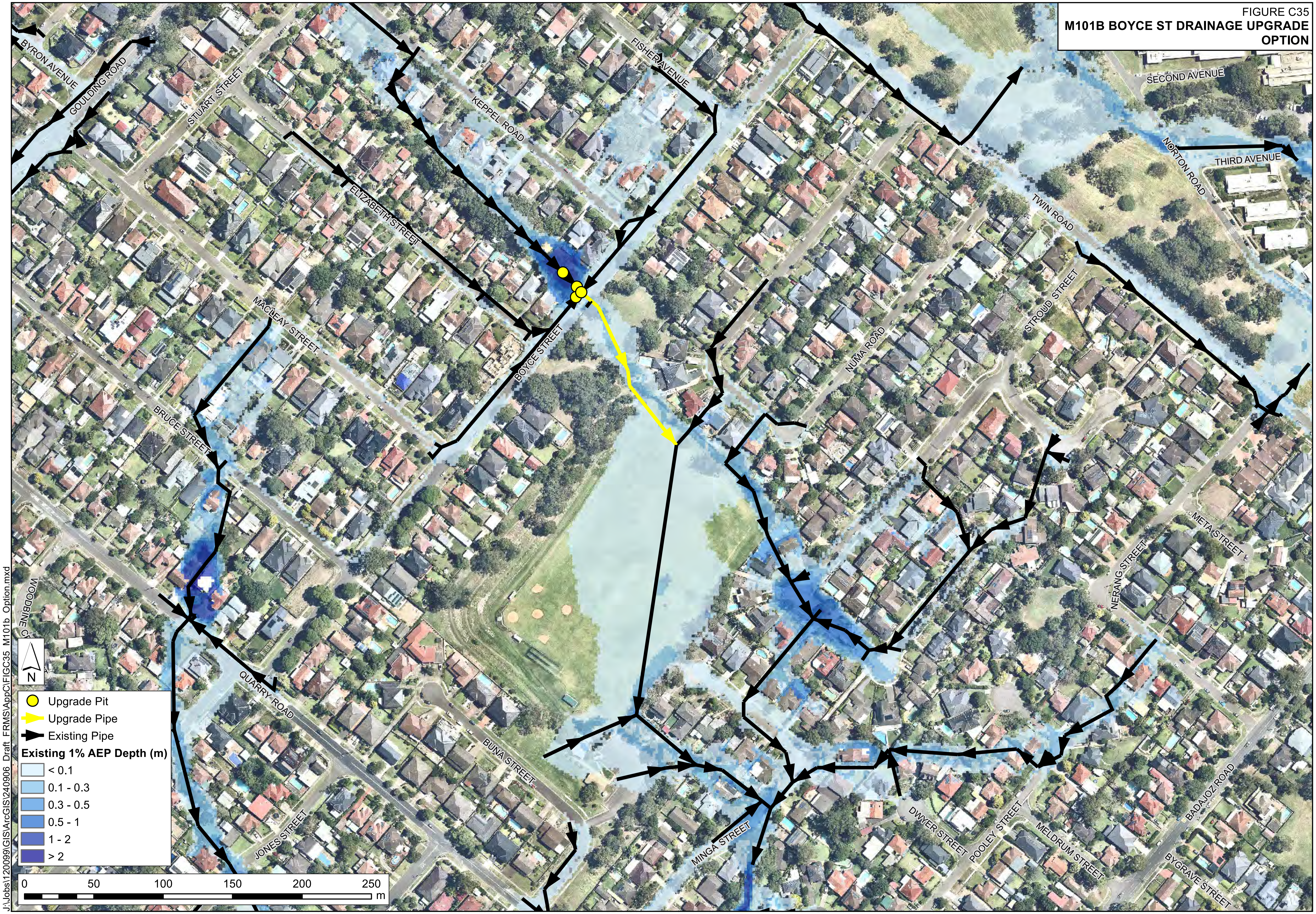
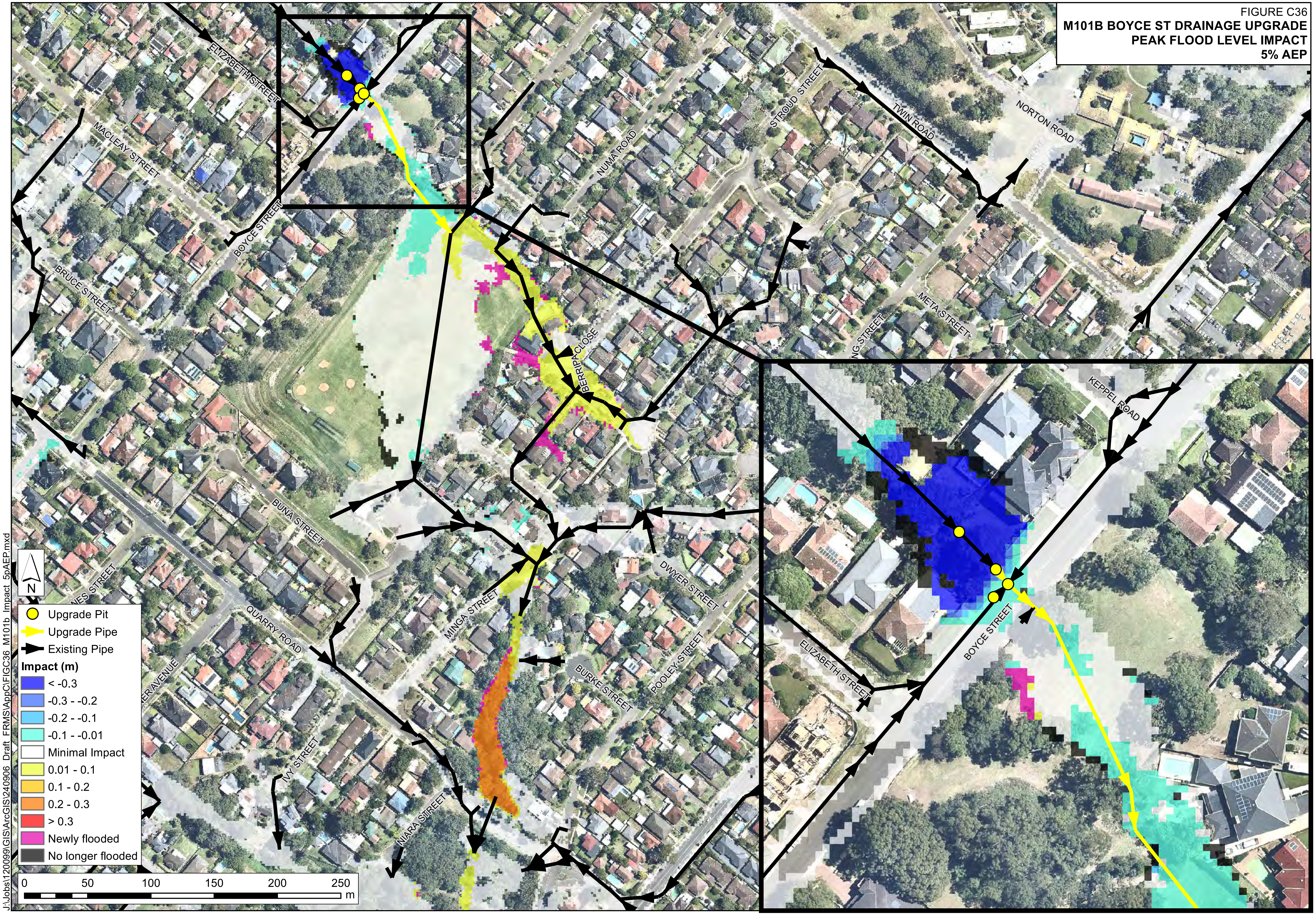


FIGURE C36
M101B BOYCE ST DRAINAGE UPGRADE
PEAK FLOOD LEVEL IMPACT
5% AEP



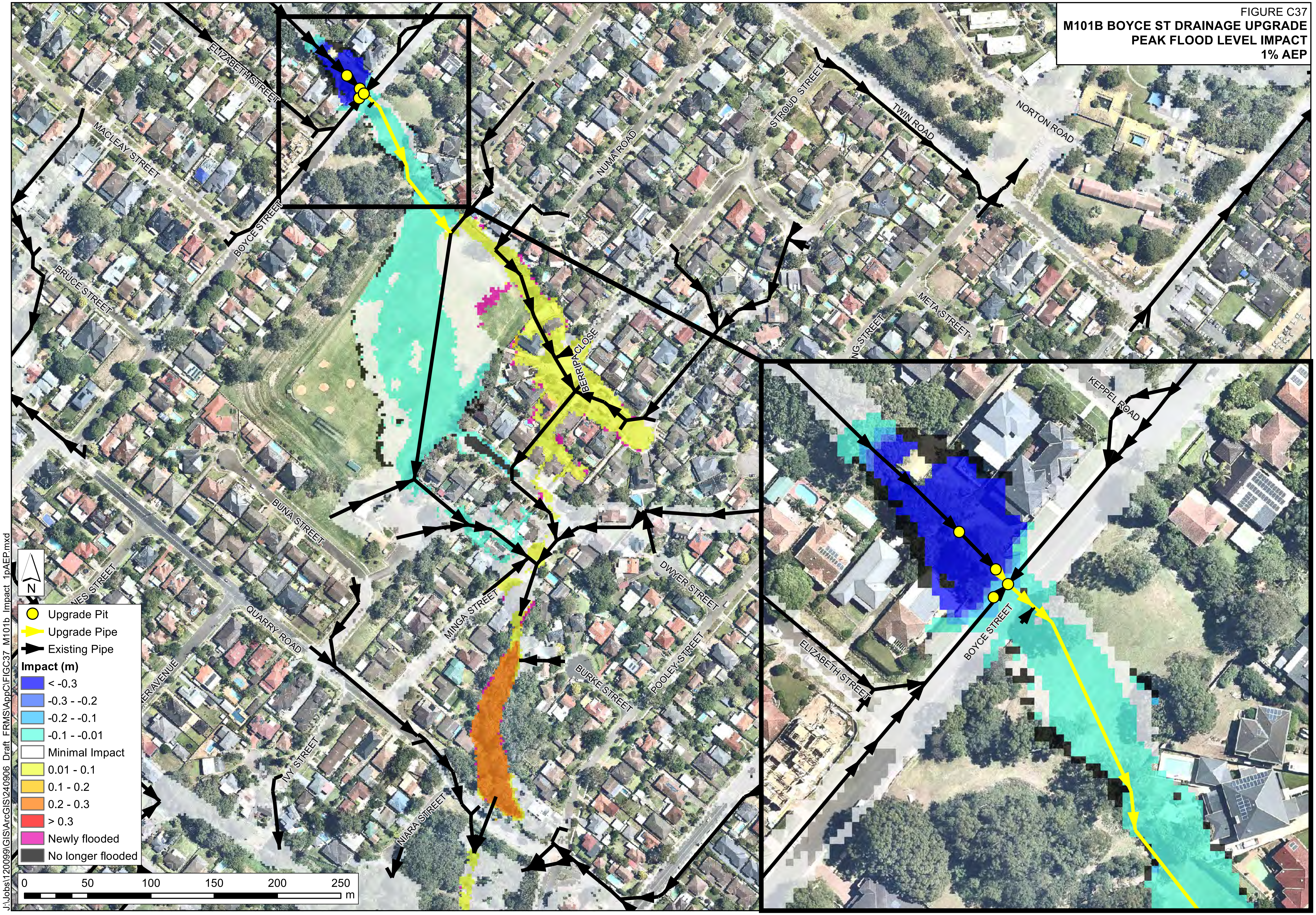
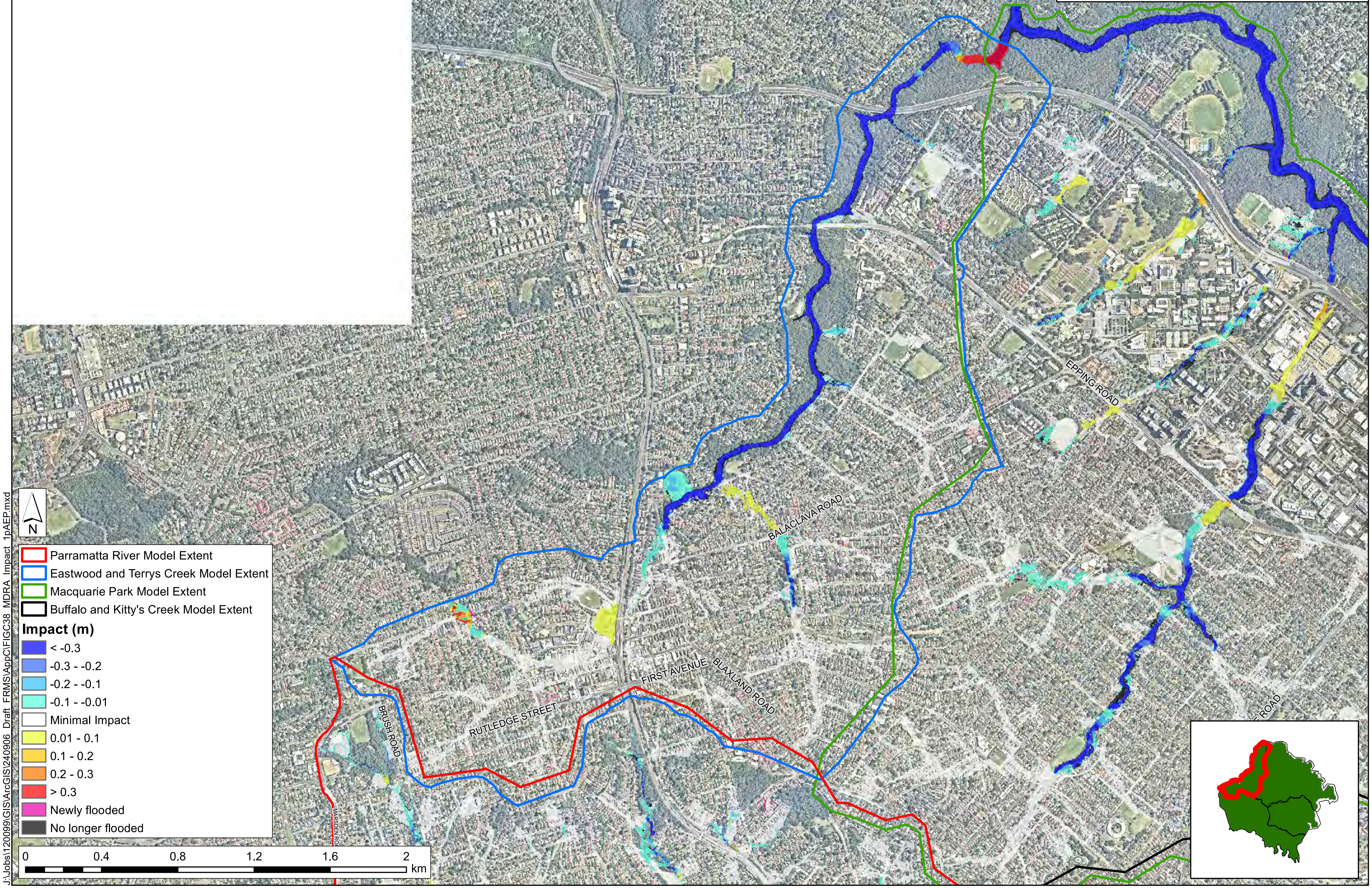


FIGURE C37
M101B BOYCE ST DRAINAGE UPGRADE
PEAK FLOOD LEVEL IMPACT
1% AEP
ELIZABETH STREET
MACLEAY STREET
BOYCE STREET
BRUCE STREET
NUMA ROAD
STROUD STREET
TWIN ROAD
NORTON ROAD
META STREET
BERRIPA CLOSE
KEPPEL ROAD
BUNA STREET
DWYER STREET
MINGA STREET
QUARRY ROAD
BURKE STREET
POOLEY STREET
IVY STREET
NIARA STREET
N
Upgrade Pit
Upgrade Pipe
Existing Pipe
Impact (m)
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.01
Minimal Impact
0.01 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
Newly flooded
No longer flooded
0
50
100
150
200
250
m
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\App C\FIG C37_M101b_Impact_1pAEP.mxd

FIGURE C38a
FM13 CATCHMENT WIDE CHANNEL CLEARING
PEAK FLOOD LEVEL IMPACT
1% AEP



J:\Jobs\120099\GIS\ArcGIS\240906 Draft FRMS\AppC\FIGC38 MDRA Impact 1pAEP.mxd

FIGURE C38b

FM13 CATCHMENT WIDE CHANNEL CLEARING
PEAK FLOOD LEVEL IMPACT
1% AEP

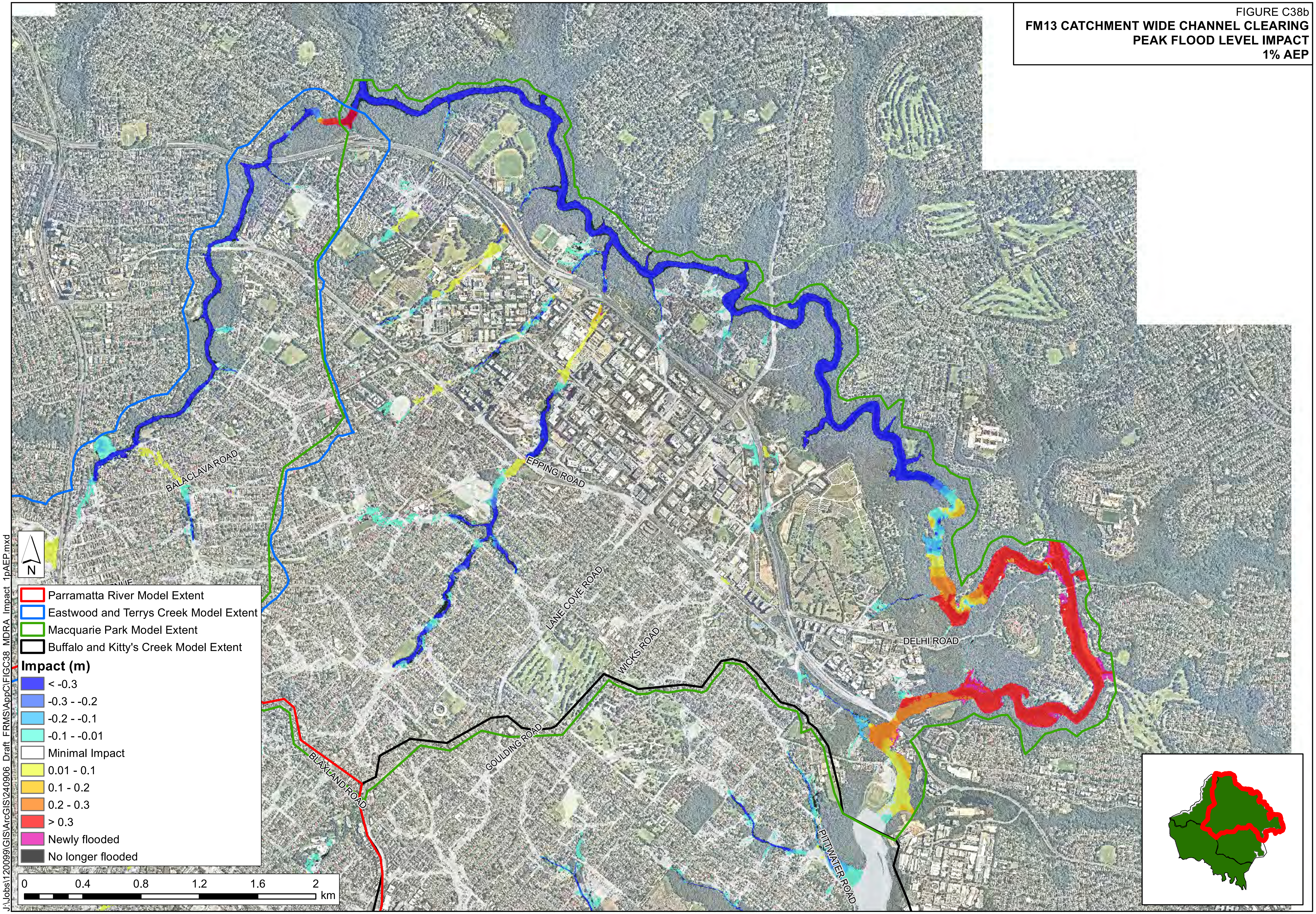


FIGURE C38c
FM13 CATCHMENT WIDE CHANNEL CLEARING
PEAK FLOOD LEVEL IMPACT
1% AEP

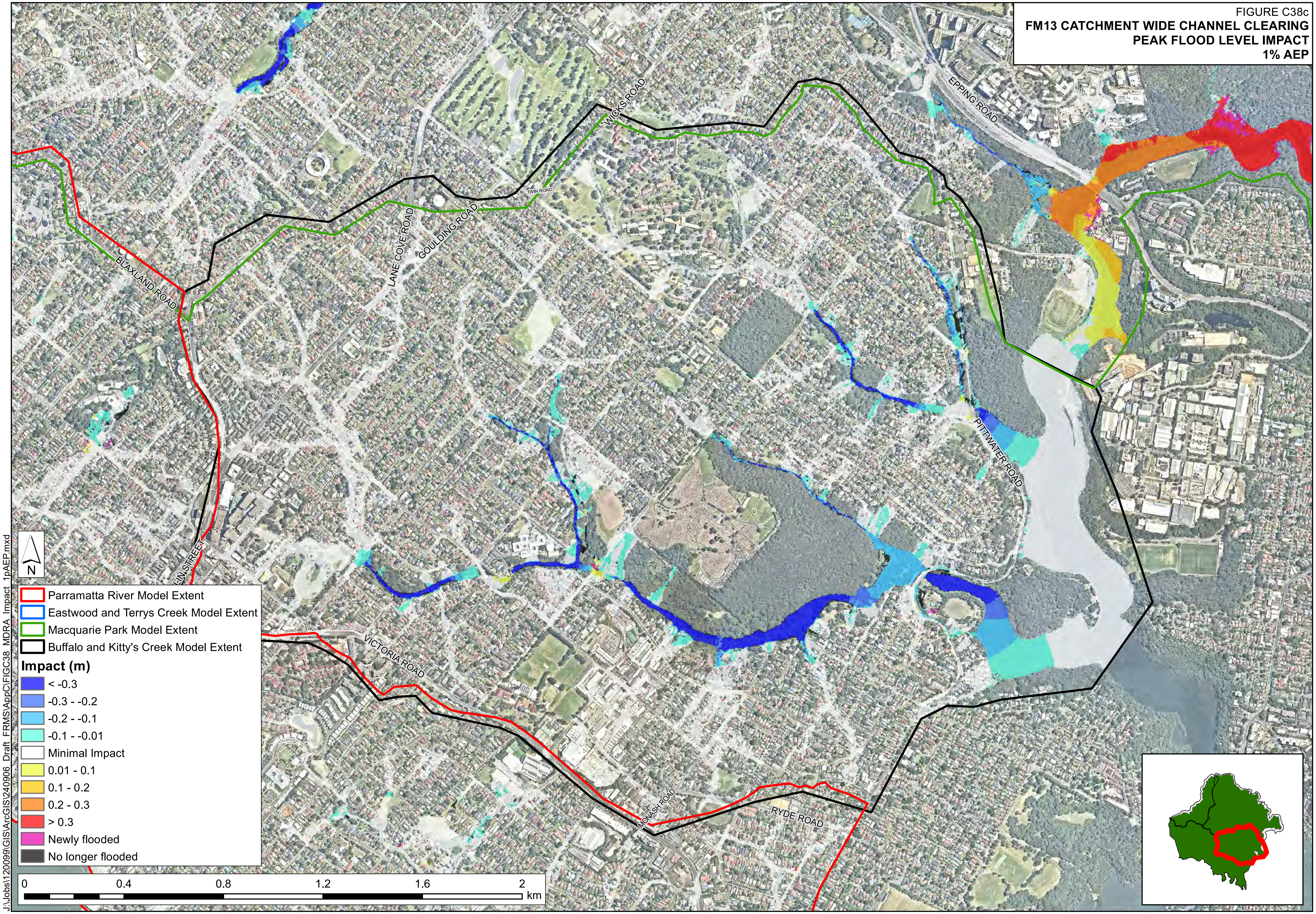
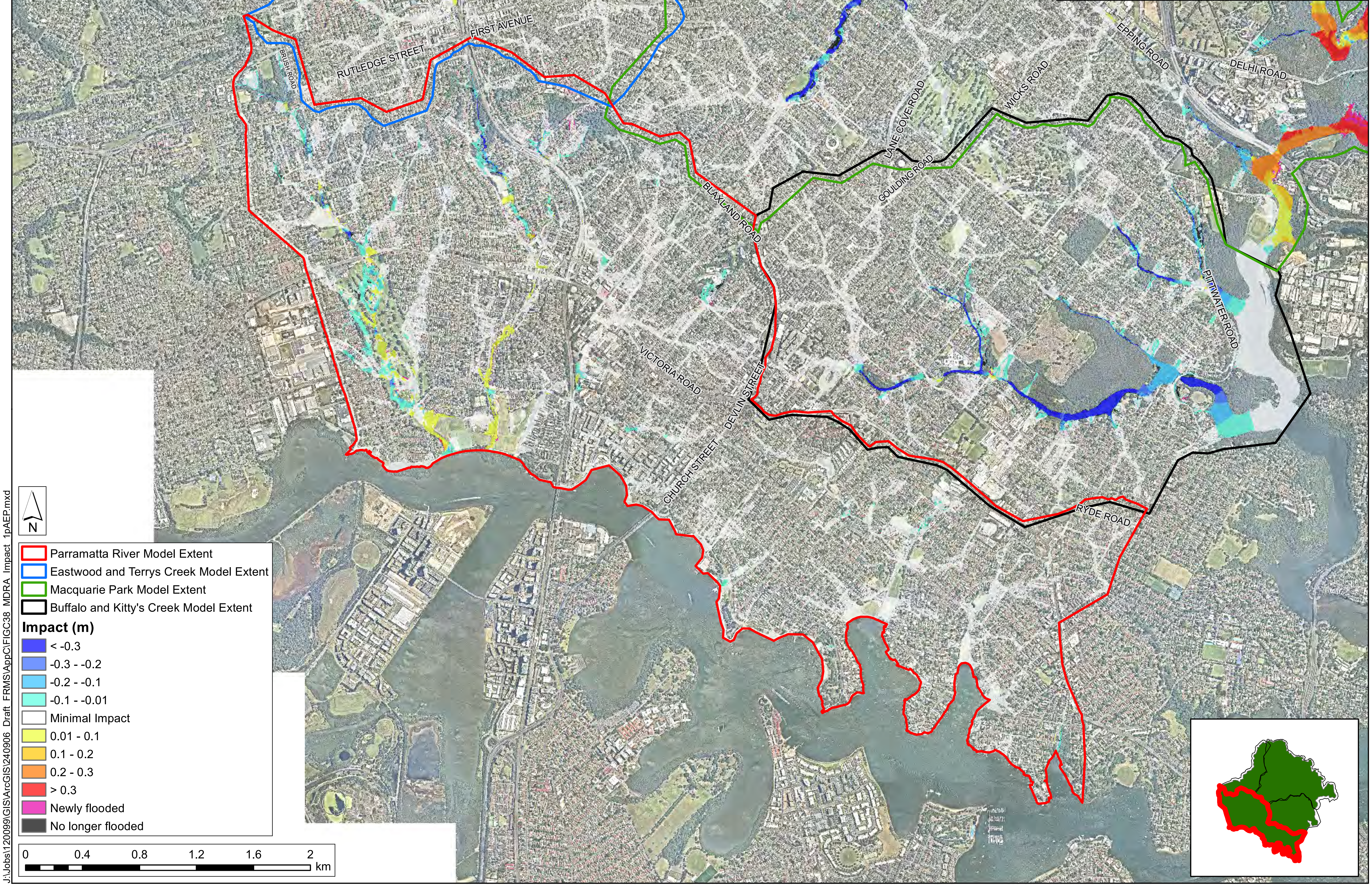
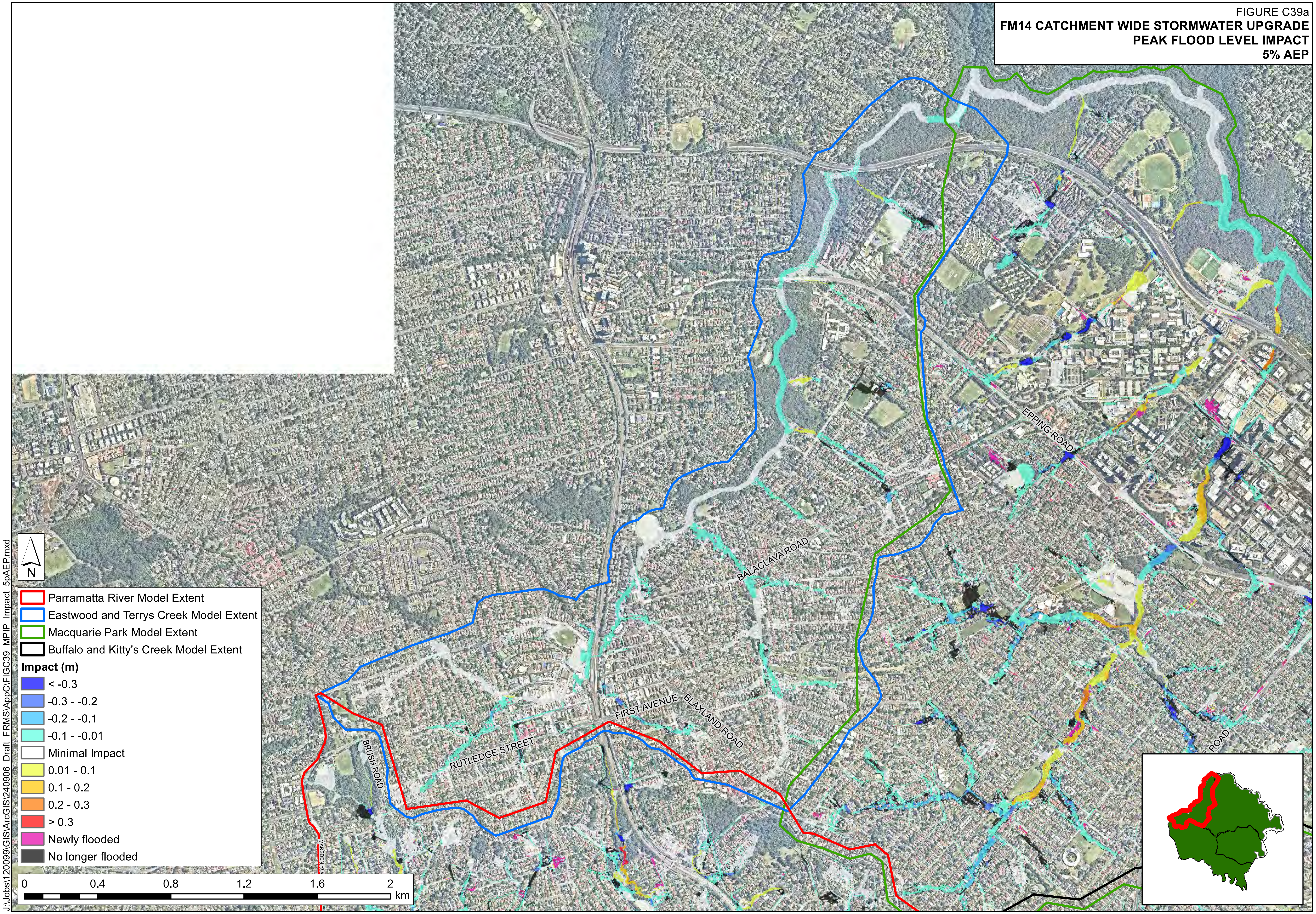


FIGURE C38d
FM13 CATCHMENT WIDE CHANNEL CLEARING PEAK FLOOD LEVEL IMPACT 1% AEP



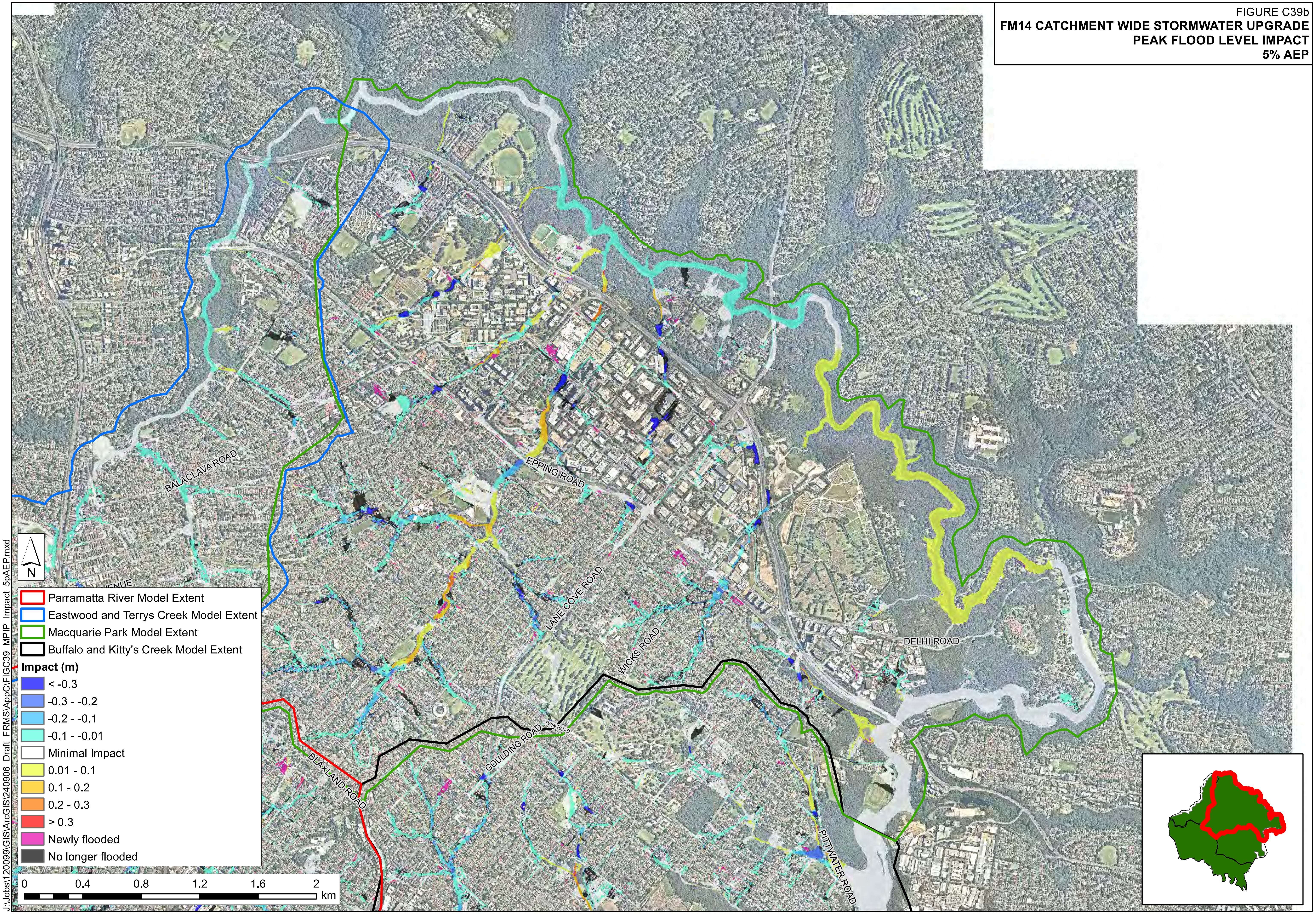
J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC38_MDRA_Impact_1pAEP.mxd

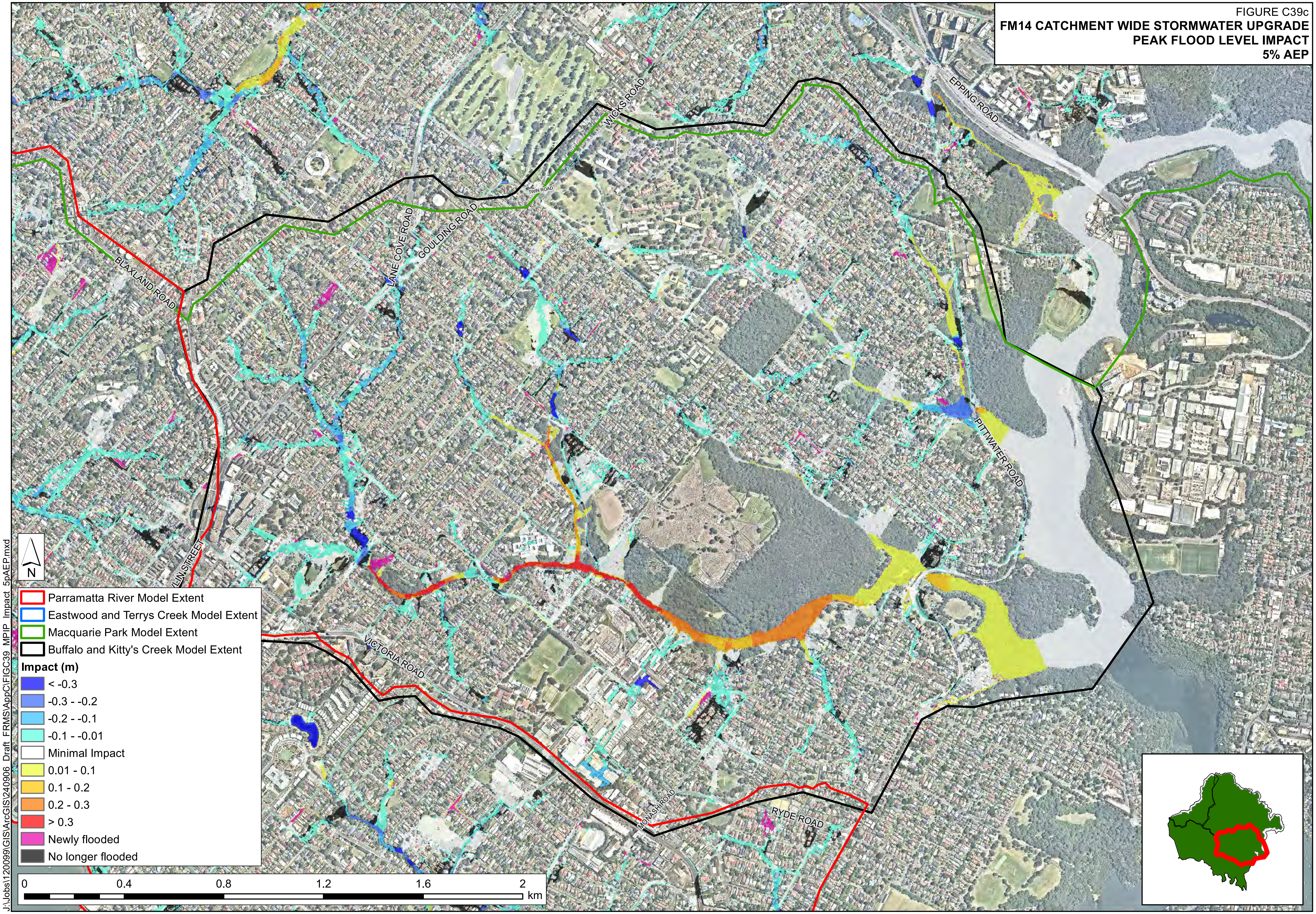


J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC39_MPIP_Impact_5pAEP.mxd

FIGURE C39b

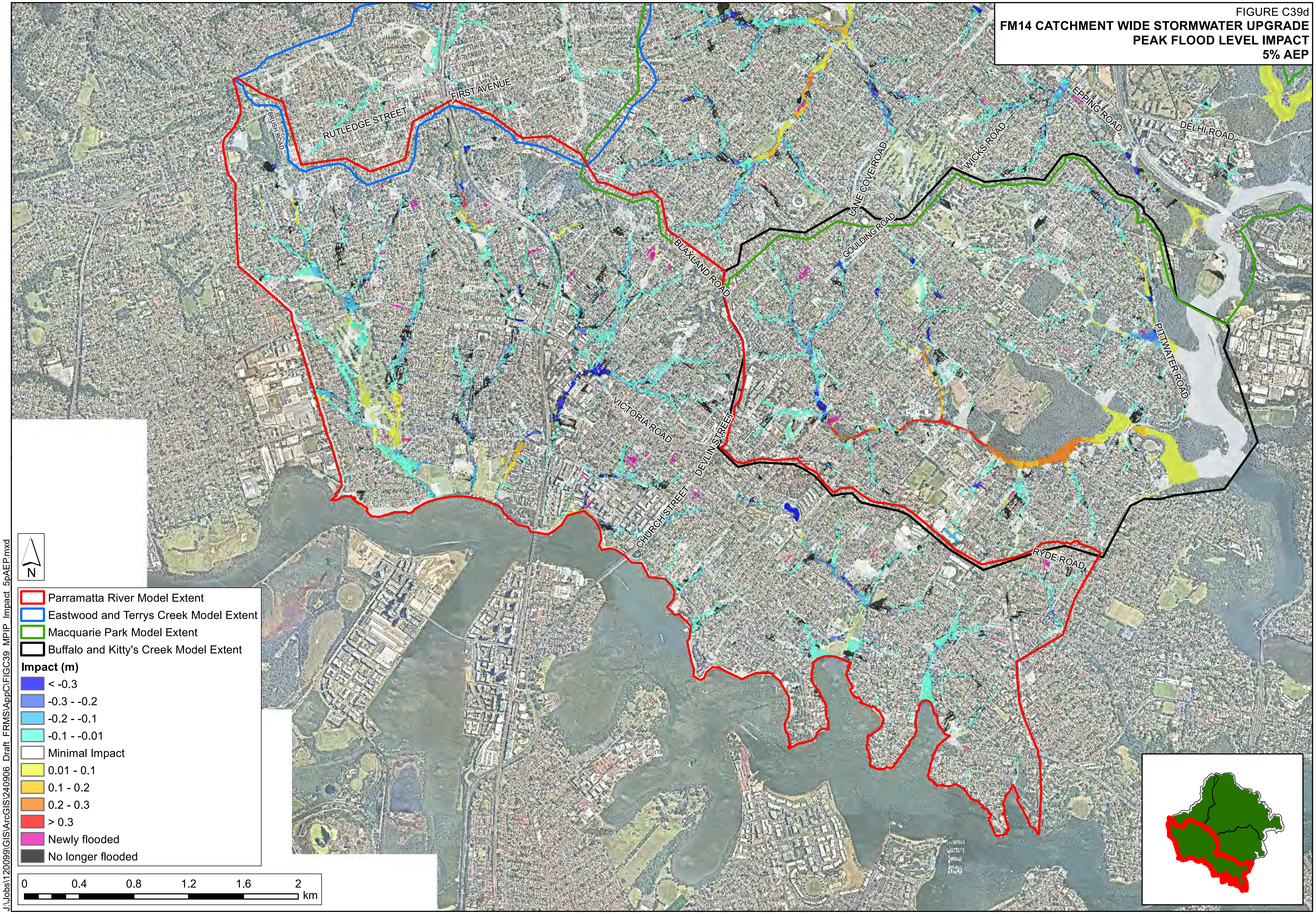
FM14 CATCHMENT WIDE STORMWATER UPGRADE PEAK FLOOD LEVEL IMPACT 5% AEP





J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC39_MPIP_Impact_5pAEP.mxd

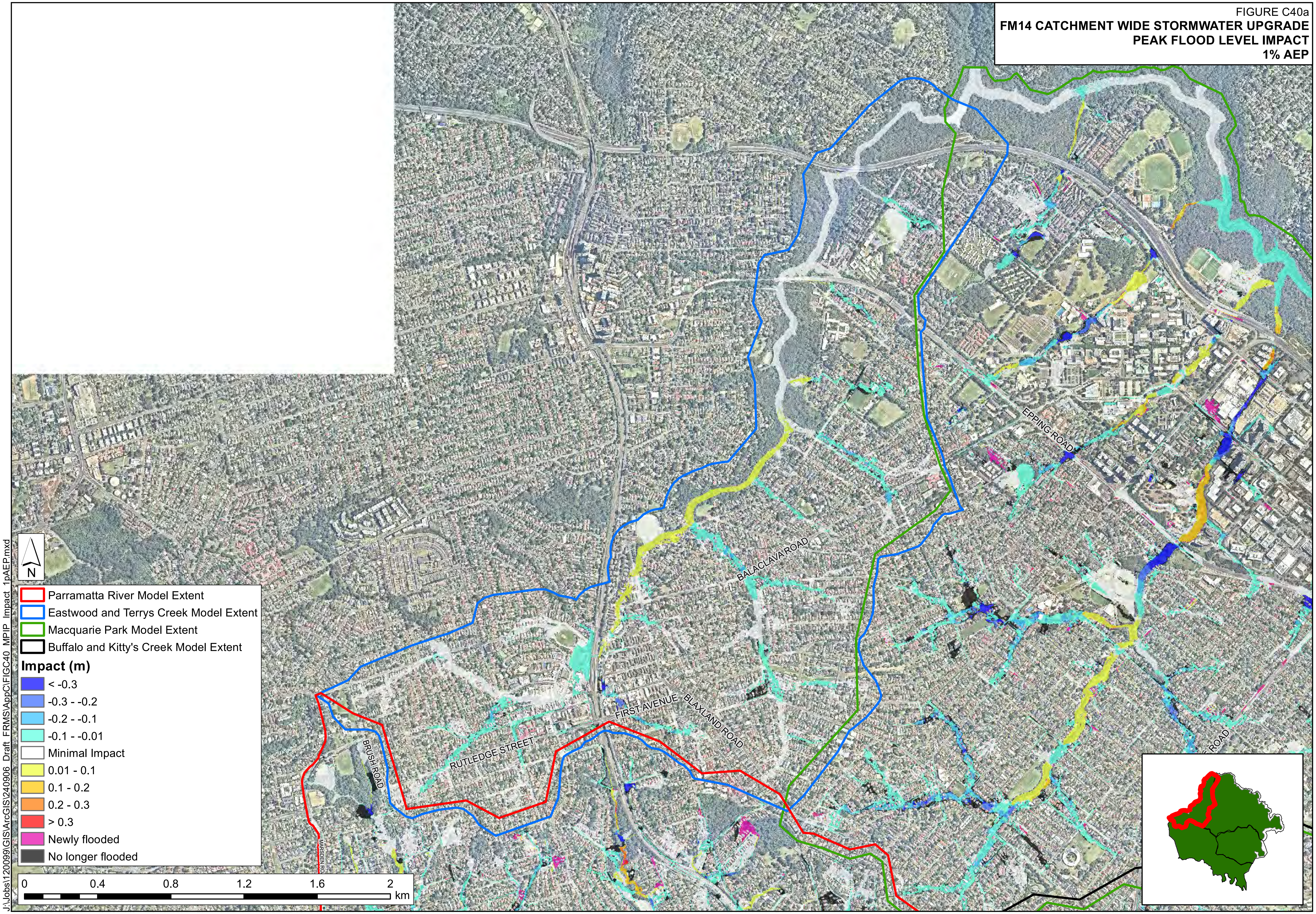
FIGURE C39d
FM14 CATCHMENT WIDE STORMWATER UPGRADE
PEAK FLOOD LEVEL IMPACT
5% AEP



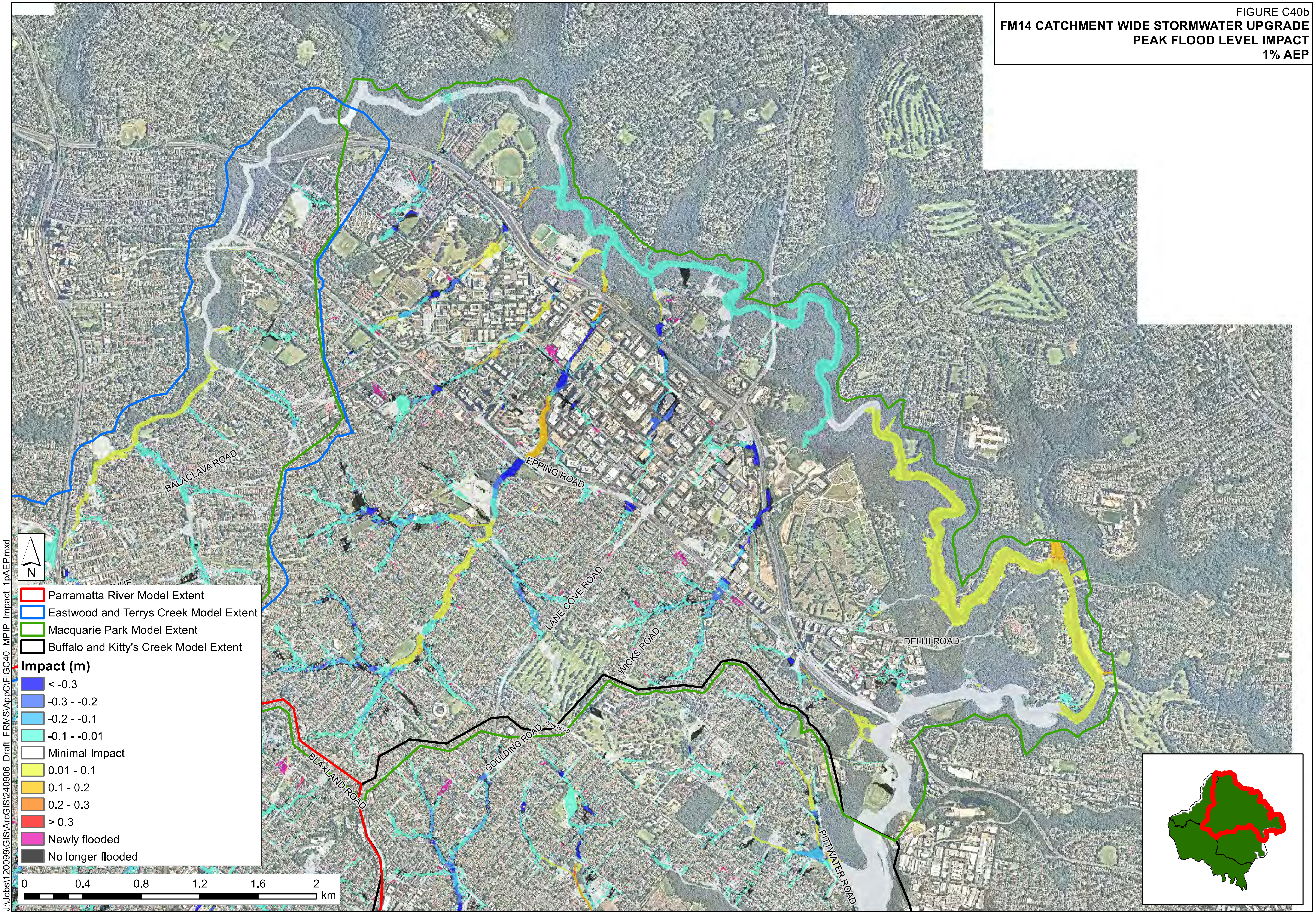
J:\Jobs\120099\GIS\ArcGIS\240906 Draft FRMS\AppC\FigC39 MPIP Impact 5pAEP.mxd

FIGURE C40a

FM14 CATCHMENT WIDE STORMWATER UPGRADE PEAK FLOOD LEVEL IMPACT 1% AEP



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC40_MPIP_Impact_1pAEP.mxd



J:\Jobs\120099\GIS\ArcGIS\240906_Draft_FRMS\AppC\FIGC40_MPIP_Impact_1pAEP.mxd

FIGURE C40c

FM14 CATCHMENT WIDE STORMWATER UPGRADE
PEAK FLOOD LEVEL IMPACT
1% AEP

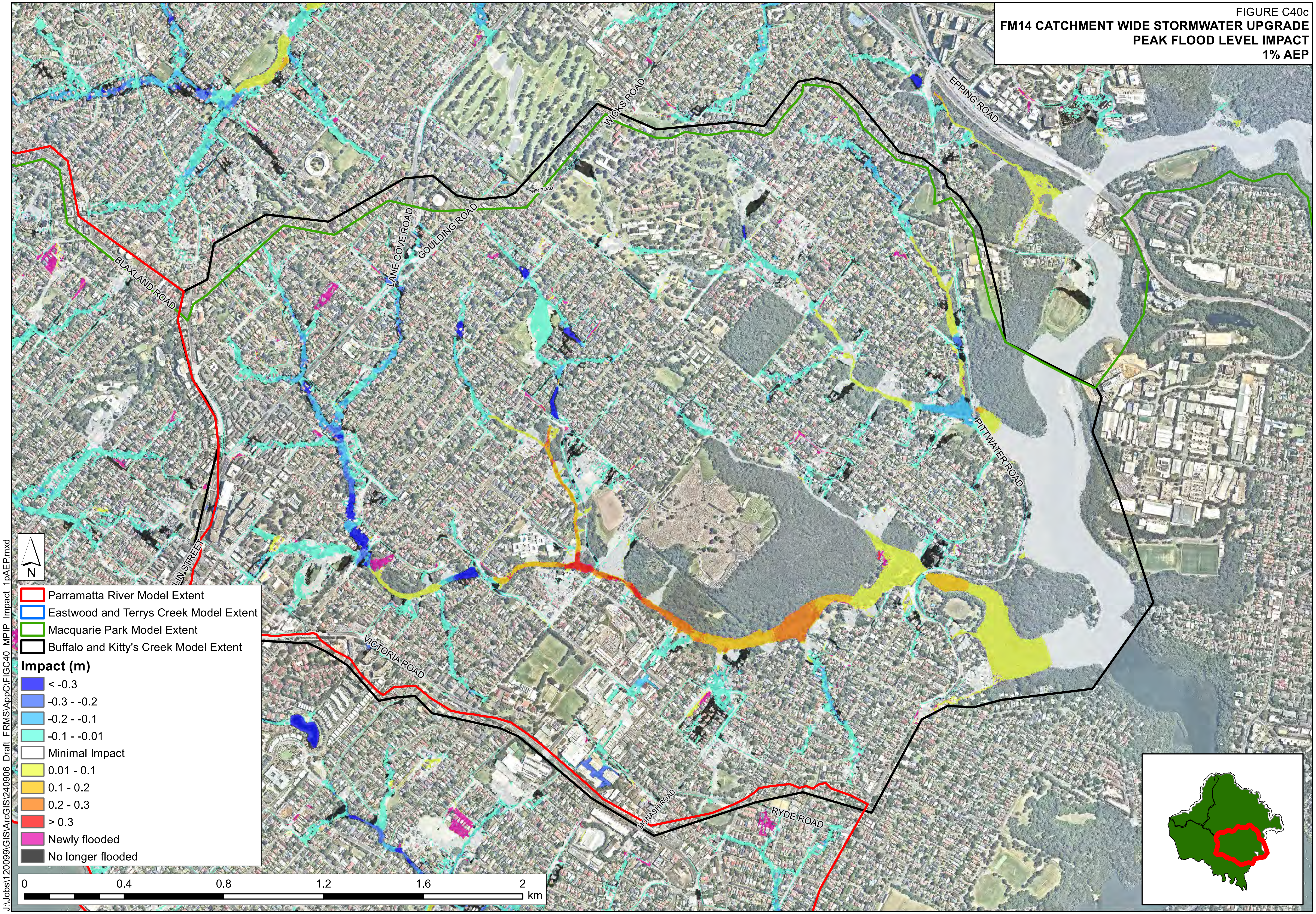


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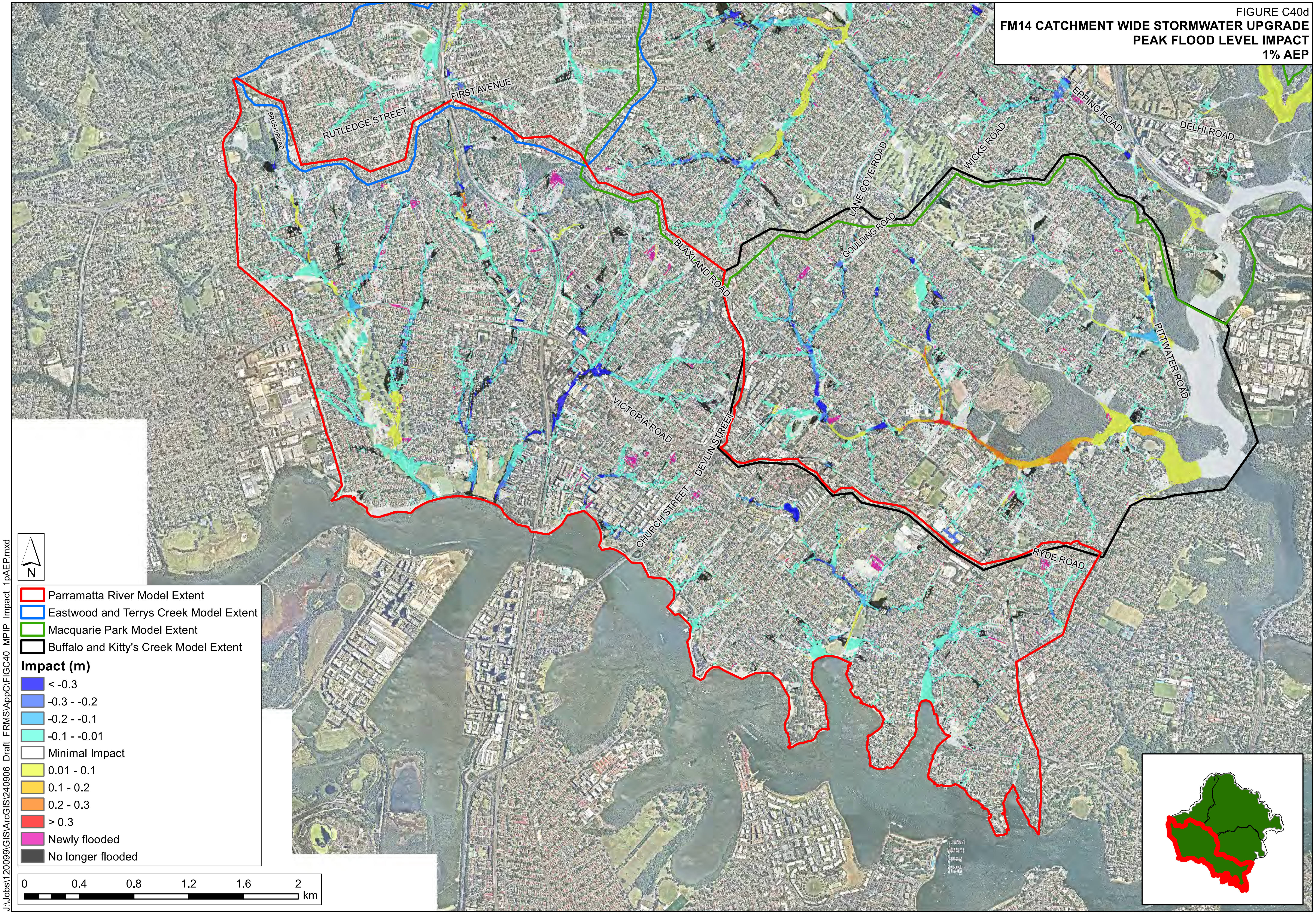
FIGURE C40d

FM14 CATCHMENT WIDE STORMWATER UPGRADE
PEAK FLOOD LEVEL IMPACT
1% AEP



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APPENDIX D. FLOOD MODIFICATION OPTIONS COSTS

Cost Database

Description	Unit	Raw Rate	Factored Rate	Source	Page
Establishment (Project Inception, Management and Coordination)	ea		$ 10,000.00	Estimation of Council Costs	
Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, Q	ea		$ 20,000.00	Estimation	
Survey and set out works	day	$ 1,200.00	$ 1,200.00	Estimation $150/h	
Temporary Access Track	m	$ 100.00	$ 100.00	Estimation	
Temporary Fencing (light duty site mesh)	m	$ 15.00	$ 15.00	Rawlinsons 2024 Australian Construction Handbook	178
Temporary Fencing (chainwire)	m	$ 38.00	$ 38.00	Rawlinsons 2024 Australian Construction Handbook	176
Temporary Signage	ea	$ 500.00	$ 500.00	Estimation	
Portable Toilet	week	$ 70.00	$ 76.97	Rawlinsons 2018 Australian Construction Handbook	179
Single chemical pan toilet including pumping out and cleaning	week	$ 65.00	$ 65.00	Rawlinsons 2024 Australian Construction Handbook	177
Silt fence	m	$ 20.60	$ 20.60	Estimate based on costing from other Councils	713
Silt sausage	m	$ 19.35	$ 19.35	Rawlinsons 2024 Australian Construction Handbook	713
Geotech during construction	day	$ 1,200.00	$ 1,200.00	Estimation $150/h	
Traffic Control - Road closure	day	$ 300.00	$ 300.00	Estimation with signage of closure (VMS) and detours in place	
Traffic Control	day	$ 1,776.00	$ 1,776.00	Estimation with 2 controllers, 2 VMS, plus management	
Land clearing (medium vegetation)	m^2	$ 0.64	$ 0.64	Rawlinsons 2024 Australian Construction Handbook	211
Cut down tree, grub up stump, roots and cart away or burn on site (1000/	ea	$ 564.00	$ 564.00	Rawlinsons 2024 Australian Construction Handbook	211
Breakup and remove reinforced concrete in open excavations	m^3	$ 338.00	$ 338.00	Rawlinsons 2024 Australian Construction Handbook	211
Breakup and remove reinforced concrete in trenches	m^3	$ 418.00	$ 418.00	Rawlinsons 2024 Australian Construction Handbook	211
Break up and remove bitumen paving with basecourse under	m^2	$ 4.20	$ 4.20	Rawlinsons 2024 Australian Construction Handbook	211
Remove kerbs	m	$ 34.00	$ 34.00	Estimate based on costing from other Councils	
Remove Pipes	m	$ 120.00	$ 120.00	Estimate based on costing from other Councils	
Remove Pits	ea	$ 566.00	$ 566.00	Estimate based on costing from other Councils	
Take down and remove timber fence	m	$ 8.50	$ 8.50	Rawlinsons 2024 Australian Construction Handbook	211
Take down and remove chain link fence	m	$ 8.50	$ 8.50	Rawlinsons 2024 Australian Construction Handbook	211
Take down and remove spear head security fence	m	$ 20.00	$ 20.00	Estimate based on costing from other Councils	
Remove retaining wall	m	$ 55.00	$ 55.00	Estimate based on costing from other Councils	
Remove signage	ea	$ 36.00	$ 36.00	Estimate based on costing from other Councils	
Dismantle large sign	ea	$ 2,000.00	$ 2,000.00	Estimation	
Excavate over site to reduce levels in light soil	m^3	$ 26.90	$ 26.90	Rawlinsons 2024 Australian Construction Handbook	212
Excavate trenches (up to 1m deep in light soil, incl backfilling)	m^3	$ 60.00	$ 60.00	Rawlinsons 2024 Australian Construction Handbook	212
Excavate trenches (up to 2m deep in light soil, incl backfilling)	m^3	$ 68.50	$ 68.50	Rawlinsons 2024 Australian Construction Handbook	212
Excavate trenches (beyond 2m deep in light soil, incl backfilling)	m^3	$ 65.00	$ 83.40	Estimation	
Detailed excavation around pits	m^3	$ 155.00	$ 155.00	Estimate based on costing from other Councils	
Dewatering deep system with 150mm header pipe, 1500mm well point ce	m^2	$ 72.60	$ 72.60	Rawlinsons 2024 Australian Construction Handbook	212
Balance cut and fill (0.5/1m deep) in light soil	m^3	$ 18.30	$ 18.30	Rawlinsons 2024 Australian Construction Handbook	214
Remove surplus excavated materail from site to tip not exceeding 10km d	m^3	$ 27.50		Rawlinsons 2024 Australian Construction Handbook	235
Cart excavated material	per 5km per m^3	$ 30.00	$ 30.00	Rawlinsons 2024 Australian Construction Handbook	213
Dispose of demolition material - mixed	t	$ 428.00	$ 428.00	Rawlinsons 2024 Australian Construction Handbook	213
Dispose of clean fill	t	$ 351.00	$ 351.00	Rawlinsons 2024 Australian Construction Handbook	213
Dispose of contaminated soil (low level, assumed ASS)	t	$ 397.50	$ 397.50	Rawlinsons 2024 Australian Construction Handbook	213
Dispose of contaminated soil (high level)	t	$ 912.50	$ 912.50	Rawlinsons 2024 Australian Construction Handbook	213
				Rawlinsons 2024 Australian Construction Handbook	
Concrete pipe to AS 4058-1992 Class 4 600mm dia	m	$ 540.00	$ 540.00	Rawlinsons 2024 Australian Construction Handbook	491
Concrete pipe to AS 4058-1992 Class 4 750mm dia	m	$ 490.00	$ 538.78	Estimation - Interpolation	
Concrete pipe to AS 4058-1992 Class 4 900mm dia	m	$ 1,050.00	$ 1,050.00	Rawlinsons 2024 Australian Construction Handbook	491
Concrete pipe to AS 4058-1992 Class 4 1050mm dia	m	$ 850.00	$ 934.62	Estimation - Interpolation	
Concrete pipe to AS 4058-1992 Class 4 1200mm dia	m	$ 1,750.00	$ 1,750.00	Rawlinsons 2024 Australian Construction Handbook	491
Concrete pipe to AS 4058-1992 Class 4 1500mm dia	m	$ 2,500.00	$ 2,500.00	Rawlinsons 2024 Australian Construction Handbook	491
Precast headwall for 600mm diameter culvert	ea	$ 1,380.00	$ 1,380.00	Rawlinsons 2024 Australian Construction Handbook	685
Precast headwall for 900mm diameter culvert	ea	$ 1,500.00	$ 1,500.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast headwall for 1050mm diameter culvert	ea	$ 2,000.00	$ 2,000.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast headwall for 1200mm diameter culvert	ea	$ 3,000.00	$ 3,000.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast headwall for 1500mm diameter culvert	ea	$ 5,000.00	$ 5,000.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast Concrete Box Culvert (375 x 225)	m	$ 389.00	$ 389.00	Rawlinsons 2024 Australian Construction Handbook	224
Precast Concrete Box Culvert (450 x 600)	m	$ 546.00	$ 546.00	Rawlinsons 2024 Australian Construction Handbook	224
Precast Concrete Box Culvert (750 x 600)	m	$ 709.00	$ 709.00	Rawlinsons 2024 Australian Construction Handbook	224
Precast Concrete Box Culvert (1200 x 1200)	m	$ 2,000.00	$ 2,000.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast Concrete Box Culvert (1800 x 1800)	m	$ 3,000.00	$ 3,000.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
Precast Concrete Box Culvert (2700 x 900)	m	$ 1,120.00	$ 1,120.00	Estimate based on costing from other Councils	718
Precast Concrete Box Culvert (4000 x 3115)	m	$ 5,760.00	$ 5,760.00	Rawlinsons 2024 Australian Construction Handbook	
Cast in-situ concrete culvert	m	$ 6,675.00	$ 6,675.00	Estimate based on costing from other Councils	
Cast in-situ concrete pit (900 x 900 x 900)	ea	$ 2,650.00	$ 2,650.00	Rawlinsons 2024 Australian Construction Handbook	488
Additional pit depth beyond 900mm	per 100mm	$ 250.00	$ 250.00	Rawlinsons 2024 Australian Construction Handbook	488
Precast concrete pit (1200 x 1200 x 1200)	ea	$ 2,200.00	$ 2,200.00	Estimation (Bayside Stormwater Risers = $2,300)	
Precast concrete pit (2400 x 2400 x 2400)	ea	$ 4,000.00	$ 4,000.00	Estimation	
Concrete covers (900 x 900 trafficable)	ea	$ 410.00	$ 410.00	Rawlinsons 2024 Australian Construction Handbook	503
Grate (762 x 762 class D sump grate)	ea	$ 1,700.00	$ 1,700.00	Rawlinsons 2024 Australian Construction Handbook	299
Grate (2m x 2m)	ea	$ 2,000.00	$ 2,000.00	Estimation	
2.4m lintel and grate	ea	$ 1,600.00	$ 1,600.00	Estimation, checked with Holcim/Humes/Rocla Quotes	
4.2m lintel and grate	ea	$ 3,500.00	$ 3,500.00	Estimation	
HumeGard GPT 600mm	ea	$ 39,000.00	$ 39,000.00	Rawlinsons 2024 Australian Construction Handbook	504
HumeGard GPT 900mm	ea	$ 80,000.00	$ 80,000.00	Rawlinsons 2024 Australian Construction Handbook	504
HumeGard GPT 1200mm	ea	$ 125,000.00	$ 125,000.00	Rawlinsons 2024 Australian Construction Handbook	504
50mm sand bed laid in trenches	m^2	$ 4.30	$ 4.30	Rawlinsons 2024 Australian Construction Handbook	214
Compaction of foundation trenches	m^2	$ 4.00	$ 4.00	Rawlinsons 2024 Australian Construction Handbook	214
Preparation of culvert base	m^2	$ 385.00	$ 385.00	Estimate based on costing from other Councils	Big increas
Backfill of culvert	m^3	$ 221.00	$ 221.00	Estimate based on costing from other Councils	Excavation
Break into existing pit	ea	$ 600.00	$ 600.00	Estimation	
Bridge (2 lane conventional, reinforced concrete spans, safety rails, excl al	m^2	$ 2,260.00	$ 2,260.00	Rawlinsons 2024 Australian Construction Handbook	723
Pipe Jacking Excavations (2)	ea	$ 19,500.00	$ 19,500.00	Gold Coast Water 2008, factored by 1.3 for current price	
Pipe Jacking 1050mm/1200mm dia	m	$ 6,555.00	$ 6,555.00	Estimation based on Gold Coast Water 2008, incl pipe cost, facto	RMS provid
Reinforced Concrete 25 MPa in slabs thickening on fill (NE 150mm thick)	m^3	$ 420.00	$ 420.00	Rawlinsons 2024 Australian Construction Handbook	238
Reinforced Concrete 25 MPa in slabs thickening on fill (150/300mm thick)	m^3	$ 415.00	$ 415.00	Rawlinsons 2024 Australian Construction Handbook	238
Outlet scour protection - reno mattress	m^2	$ 500.00	$ 500.00	Estimation	
Land Acquisition/Easement Costs	m^2				
200mm crushed rock base	m^2	$ 24.00	$ 24.00	Rawlinsons 2024 Australian Construction Handbook	716
Hot bituminous concrete 25mm thick	m^2	$ 30.35	$ 30.35	Rawlinsons 2024 Australian Construction Handbook	1038
Cast in-situ 250mm x 150mm kerb	m	$ 115.00	$ 115.00	Rawlinsons 2024 Australian Construction Handbook	224
Kerb and gutter	m	$ 1,294.50	$ 1,294.50	Estimate based on costing from other Councils	202
Pavement	m^2	$ 300.00	$ 300.00	Estimate based on costing from other Councils	
Composite Road 8m suburban with kerb	m	$ 1,040.00	$ 1,040.00	Rawlinsons 2024 Australian Construction Handbook	720
Footpath 1500mm wide	m	$ 260.00	$ 260.00	Rawlinsons 2024 Australian Construction Handbook	721
Footpath	m^2	$ 304.00	$ 304.00	Estimate based on costing from other Councils	
Line marking (100mm wide)	m	$ 2.10	$ 2.10	Rawlinsons 2024 Australian Construction Handbook	224
Guard Rail	m	$ 166.00	$ 166.00	Rawlinsons 2024 Australian Construction Handbook	304
F-Type concrete barrier 970mm high	m	$ 425.00	$ 425.00	Rawlinsons 2024 Australian Construction Handbook	717
Prepare ground - rotary hoe	m^2	$ 0.60	$ 0.60	Rawlinsons 2024 Australian Construction Handbook	228
Top soil spread and levelled 300mm thick	m^2	$ 23.00	$ 23.00	Rawlinsons 2024 Australian Construction Handbook	228
Turf laid, rolled and watered - couch	m^2	$ 12.00	$ 12.00	Rawlinsons 2024 Australian Construction Handbook	228
Level, seed, fertilise and water playing field	ha	$ 9,660.00	$ 9,660.00	Rawlinsons 2024 Australian Construction Handbook	228
Pine bark chips	m^3	$ 164.00	$ 164.00	Rawlinsons 2024 Australian Construction Handbook	229
Ground cover and planting	m^2	$ 31.50	$ 31.50	Rawlinsons 2024 Australian Construction Handbook	229
Sign 450mm x 600mm	ea	$ 460.00	$ 460.00	Rawlinsons 2024 Australian Construction Handbook	720
Reconstruct large sign	ea	$ 10,000.00	$ 10,000.00	Estimation	
Bollard removal and reinstatement	ea	$ 212.00	$ 212.00	Estimate based on costing from other Councils	
Keystone retaining wall	m	$ 1,086.00	$ 1,086.00	Estimate based on costing from other Councils	
Blockwork retaining wall (composite, reinforced)	m^2	$ 355.00	$ 355.00	Rawlinsons 2024 Australian Construction Handbook	168
Install timber fence 1.8m high	m	$ 116.00	$ 116.00	Rawlinsons 2024 Australian Construction Handbook	225
Install metal pool type fence 1.4m round top	m	$ 168.00	$ 168.00	Rawlinsons 2024 Australian Construction Handbook	227
Install metal security fence 2m spear head	m	$ 165.00	$ 165.00	Rawlinsons 2024 Australian Construction Handbook	228
Install metal chain mesh fence 1.8m high	m	$ 87.00	$ 87.00	Rawlinsons 2024 Australian Construction Handbook	226

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M003: Gannan Park Basin **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Formation of bund (max 1.5m, typically 1m)
- Excavation of channel
- Removal of 1050mm pipe in park

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.4	Temporary Fencing (light duty site mesh)	460	m	$ 15.00	$ 6,900
1.5	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.6	Portable Toilet	26	week	$ 76.97	$ 2,001
1.7	Silt sausage	20	m	$ 19.35	$ 387
2	**Site Clearance**				
2.1	Land clearing (medium vegetation)	3,049	m2	$ 0.64	$ 1,951
2.2	Excavate over site to reduce levels in light soil	3,356	m3	$ 26.90	$ 90,269
2.3	Balance cut and fill (0.5/1m deep) in light soil	118	m3	$ 18.30	$ 2,151
2.4	Cart excavated material	3,238	per 5km per m3	$ 30.00	$ 97,146
2.5	Dispose of clean fill	5,181	t	$ 351.00	$ 1,818,568
2.6	Remove Pipes	200	m	$ 120.00	$ 24,000
3	**Stormwater Management**				
3.1	Cast in-situ concrete pit (900 x 900 x 900)	1	ea	$ 2,650.00	$ 2,650
3.2	Grate (2m x 2m)	1	ea	$ 2,000.00	$ 2,000
3.3	Concrete pipe to AS 4058-1992 Class 4 1050mm dia	1	m	$ 934.62	$ 935
4	**Rehabilitation**				
4.1	Turf laid, rolled and watered - couch	3,049	m2	$ 12.00	$ 36,590
4.2	Ground cover and planting	305	m2	$ 31.50	$ 9,605
4.3	Pine bark chips	30	m3	$ 164.00	$ 5,001
4.4	Sign 450mm x 600mm	2	ea	$ 460.00	$ 920
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 2,138,572**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 320,786
	Project Management of Design			15%	$ 48,118
	Pre-construction sub-total				$ 368,904
	Pre-construction contingency			40%	$ 147,561
	TOTAL PRE-CONSTRUCTION COSTS				**$ 516,465**
6	**Additional construction costs**				
	Preliminary construction cost				$ 2,138,572
	Construction management/supervision			15%	$ 320,786
	Construction sub-total				$ 2,459,358
	Construction contingency			40%	$ 983,743
	TOTAL CONSTRUCTION COSTS				**$ 3,443,101**
	TOTAL PROJECT ESTIMATE				**$ 3,959,567**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M008: Drainage Upgrade Along Buffalo Rd **Date of Estimate: Jun-24**

Involves the following construction works:
- New 1050mm diameter pipe down Buffalo Rd

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Traffic Control	80	day	$ 1,776.00	$ 142,080
1.4	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.5	Temporary Fencing (light duty site mesh)	425	m	$ 15.00	$ 6,375
1.6	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.7	Portable Toilet	26	week	$ 76.97	$ 2,001
1.8	Silt sausage	50	m	$ 19.35	$ 968
2	**Site Clearance**				
2.1	Break up and remove bitumen paving with basecourse under	659	m2	$ 4.20	$ 2,767
2.2	Remove kerbs	425	m	$ 34.00	$ 14,450
2.3	Excavate trenches (up to 2m deep in light soil, incl backfilling)	1,416	m3	$ 68.50	$ 97,017
2.4	Cart excavated material	708	per 5km per m3	$ 30.00	$ 21,245
2.5	Dispose of demolition material - mixed	1,133	t	$ 428.00	$ 484,945
3	**Stormwater Management**				
3.1	Concrete pipe to AS 4058-1992 Class 4 1050mm dia	425	m	$ 934.62	$ 397,214
3.2	Preparation of culvert base	659	m2	$ 385.00	$ 253,619
3.3	Precast concrete pit (1200 x 1200 x 1200)	6	ea	$ 2,200.00	$ 13,200
3.43	Break into existing pit	2	ea	$ 600.00	$ 1,200
4	**Rehabilitation**				
4.1	Pavement	659	m2	$ 300.00	$ 197,625
4.2	Kerb and gutter	425	m	$ 1,294.50	$ 550,163
4.3	Line marking (100mm wide)	425	m	$ 2.10	$ 893
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 2,223,261**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 333,489
	Project Management of Design			15%	$ 50,023
	Pre-construction sub-total				$ 383,513
	Pre-construction contingency			40%	$ 153,405
	TOTAL PRE-CONSTRUCTION COSTS				**$ 536,918**
6	**Additional construction costs**				
	Preliminary construction cost				$ 2,223,261
	Construction management/supervision			15%	$ 333,489
	Construction sub-total				$ 2,556,750
	Construction contingency			40%	$ 1,022,700
	TOTAL CONSTRUCTION COSTS				**$ 3,579,450**
	TOTAL PROJECT ESTIMATE				**$ 4,116,368**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M036 Jim Walsh Park Basin **Date of Estimate: Jun-24**

Involves the following construction works:
- Raising bund
- Excavation of basin
- Upgrade of cross drainage across Balaclava Rd

ITEM	DESCRIPTION	QTY	UNIT		RATE		SUB-TOTAL
1	**Construction Preliminaries**						
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$	10,000.00	$	10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$	20,000.00	$	20,000
1.3	Survey and set out works	5	day	$	1,200.00	$	6,000
1.4	Temporary Fencing (light duty site mesh)	331	m	$	15.00	$	4,965
1.5	Temporary Signage	3	ea	$	500.00	$	1,500
1.6	Portable Toilet	26	week	$	76.97	$	2,001
1.7	Silt sausage	20	m	$	19.35	$	387
2	**Site Clearance**						
2.1	Land clearing (medium vegetation)	6,850	m2	$	0.64	$	4,384
2.2	Excavate over site to reduce levels in light soil	1,962	m3	$	26.90	$	52,778
2.3	Balance cut and fill (0.5/1m deep) in light soil	627	m3	$	18.30	$	11,472
2.4	Cart excavated material	1,335	per 5km per m3	$	30.00	$	40,054
2.5	Dispose of clean fill	2,136	t	$	351.00	$	749,808
2.6	Remove Pipes	200	m	$	120.00	$	24,000
2.7	Cut down tree, grub up stump, roots and cart away or burn on site (1000/2000mm girth 10 off)	20	ea	$	564.00	$	11,280
3	**Stormwater Management**						
3.1	Precast headwall for 900mm diameter culvert	2	ea	$	1,500.00	$	3,000
3.2	Grate (2m x 2m)	1	ea	$	2,000.00	$	2,000
3.3	Precast Concrete Box Culvert (4000 x 3115)	1	m	$	5,760.00	$	5,760
4	**Rehabilitation**						
4.1	Turf laid, rolled and watered - couch	4,636	m2	$	12.00	$	55,638
4.2	Ground cover and planting	464	m2	$	31.50	$	14,605
4.3	Pine bark chips	46	m3	$	164.00	$	7,604
4.4	Sign 450mm x 600mm	2	ea	$	460.00	$	920
	TOTAL PRELIMINARY CONSTRUCTION COSTS					**$**	**1,028,155**
5	**Pre-construction costs**						
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)				15%	$	154,223
	Project Management of Design				15%	$	23,133
	Pre-construction sub-total					$	177,357
	Pre-construction contingency				40%	$	70,943
	TOTAL PRE-CONSTRUCTION COSTS					**$**	**248,299**
6	**Additional construction costs**						
	Preliminary construction cost					$	1,028,155
	Construction management/supervision				15%	$	154,223
	Construction sub-total					$	1,182,378
	Construction contingency				40%	$	472,951
	TOTAL CONSTRUCTION COSTS					**$**	**1,655,330**
	TOTAL PROJECT ESTIMATE					**$**	**1,903,629**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M051 Kotara Park Basin **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Formation of bund (max 1.3m, typically 0.6m)
- Realignment of stormwater pipeline along the northeastern boundary of the park

ITEM	DESCRIPTION	QTY	UNIT	RATE		SUB-TOTAL	
1	**Construction Preliminaries**						
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$	10,000.00	$	10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$	20,000.00	$	20,000
1.3	Survey and set out works	5	day	$	1,200.00	$	6,000
1.4	Temporary Fencing (light duty site mesh)	650	m	$	15.00	$	9,750
1.5	Temporary Signage	3	ea	$	500.00	$	1,500
1.6	Portable Toilet	26	week	$	76.97	$	2,001
1.7	Silt sausage	20	m	$	19.35	$	387
2	**Site Clearance**						
2.1	Land clearing (medium vegetation)	1,621	m2	$	0.64	$	1,037
2.2	Balance cut and fill (0.5/1m deep) in light soil	296	m3	$	18.30	$	5,414
3	**Rehabilitation**						
3.1	Turf laid, rolled and watered - couch	1,621	m2	$	12.00	$	19,446
3.2	Ground cover and planting	162	m2	$	31.50	$	5,105
3.3	Pine bark chips	16	m3	$	164.00	$	2,658
3.4	Sign 450mm x 600mm	2	ea	$	460.00	$	920
	TOTAL PRELIMINARY CONSTRUCTION COSTS					**$**	**84,218**
4	**Pre-construction costs**						
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%		$	12,633
	Project Management of Design			15%		$	1,895
	Pre-construction sub-total					$	14,528
	Pre-construction contingency			40%		$	5,811
	TOTAL PRE-CONSTRUCTION COSTS					**$**	**20,339**
5	**Additional construction costs**						
	Preliminary construction cost					$	84,218
	Construction management/supervision			15%		$	12,633
	Construction sub-total					$	96,851
	Construction contingency			40%		$	38,740
	TOTAL CONSTRUCTION COSTS					**$**	**135,591**
	TOTAL PROJECT ESTIMATE					**$**	**155,930**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

City of Ryde

M057 Smalls Park Basin	**Date of Estimate:**	**Jun-24**

Involves the following construction works:
- Formation of bund (max 1.7m, typically 1m)
- Realignment of stormwater pipeline along the northeastern boundary of the park

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.4	Temporary Fencing (light duty site mesh)	330	m	$ 15.00	$ 4,950
1.5	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.6	Portable Toilet	26	week	$ 76.97	$ 2,001
1.7	Silt sausage	20	m	$ 19.35	$ 387
2	**Site Clearance**				
2.1	Land clearing (medium vegetation)	2,778	m2	$ 0.64	$ 1,778
2.2	Balance cut and fill (0.5/1m deep) in light soil	714	m3	$ 18.30	$ 13,074
2.3	Remove Pipes	225	m	$ 120.00	$ 27,000
2.4	Remove Pits	3	ea	$ 566.00	$ 1,698
3	**Stormwater Management**				
3.1	Grate (2m x 2m)	1	ea	$ 2,000.00	$ 2,000
3.2	Concrete pipe to AS 4058-1992 Class 4 600mm dia	225	m	$ 540.00	$ 121,500
4	**Rehabilitation**				
4.1	Turf laid, rolled and watered - couch	2,778	m2	$ 12.00	$ 33,333
4.2	Ground cover and planting	278	m2	$ 31.50	$ 8,750
4.3	Pine bark chips	28	m3	$ 164.00	$ 4,555
4.4	Sign 450mm x 600mm	2	ea	$ 460.00	$ 920
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 259,446**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 38,917
	Project Management of Design			15%	$ 5,838
	Pre-construction sub-total				$ 44,754
	Pre-construction contingency			40%	$ 17,902
	TOTAL PRE-CONSTRUCTION COSTS				**$ 62,656**
6	**Additional construction costs**				
	Preliminary construction cost				$ 259,446
	Construction management/supervision			15%	$ 38,917
	Construction sub-total				$ 298,363
	Construction contingency			40%	$ 119,345
	TOTAL CONSTRUCTION COSTS				**$ 417,708**
	TOTAL PROJECT ESTIMATE				**$ 480,364**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M061 North Ryde Golf Club Basin **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Formation of bund
- Tree removal

ITEM	DESCRIPTION	QTY	UNIT	RATE		SUB-TOTAL	
1	**Construction Preliminaries**						
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$	10,000.00	$	10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$	20,000.00	$	20,000
1.3	Survey and set out works	5	day	$	1,200.00	$	6,000
1.4	Temporary Fencing (light duty site mesh)	104	m	$	15.00	$	1,560
1.5	Temporary Signage	3	ea	$	500.00	$	1,500
1.6	Portable Toilet	26	week	$	76.97	$	2,001
1.7	Silt sausage	20	m	$	19.35	$	387
2	**Site Clearance**						
2.1	Land clearing (medium vegetation)	326	m2	$	0.64	$	208
2.2	Balance cut and fill (0.5/1m deep) in light soil	93	m3	$	18.30	$	1,702
2.3	Cut down tree, grub up stump, roots and cart away or burn on site (1000/2000mm girth 10 off)	5	ea	$	564.00	$	2,820
3	**Rehabilitation**						
3.1	Turf laid, rolled and watered - couch	326	m2	$	12.00	$	3,909
3.2	Ground cover and planting	33	m2	$	31.50	$	1,026
3.3	Pine bark chips	3	m3	$	164.00	$	534
3.4	Sign 450mm x 600mm	2	ea	$	460.00	$	920
	TOTAL PRELIMINARY CONSTRUCTION COSTS					**$**	**52,568**
4	**Pre-construction costs**						
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)				15%	$	7,885
	Project Management of Design				15%	$	1,183
	Pre-construction sub-total					$	9,068
	Pre-construction contingency				40%	$	3,627
	TOTAL PRE-CONSTRUCTION COSTS					**$**	**12,695**
5	**Additional construction costs**						
	Preliminary construction cost					$	52,568
	Construction management/supervision				15%	$	7,885
	Construction sub-total					$	60,453
	Construction contingency				40%	$	24,181
	TOTAL CONSTRUCTION COSTS					**$**	**84,634**
	TOTAL PROJECT ESTIMATE					**$**	**97,329**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M073 Diversion Drain at Pittwater Rd **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Regrading eastern road verge from blocking flow into Pages Creek
- Constructing a wide shallow channel which formalises the path down to Pages Creek

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Traffic Control	20	day	$ 1,776.00	$ 35,520
1.4	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.5	Temporary Fencing (light duty site mesh)	50	m	$ 15.00	$ 750
1.6	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.7	Portable Toilet	26	week	$ 76.97	$ 2,001
1.8	Silt sausage	10	m	$ 19.35	$ 194
2	**Site Clearance**				
2.1	Cut down tree, grub up stump, roots and cart away or burn on site (1000/2000mm girth 10 off)	15	ea	$ 564.00	$ 8,460
2.2	Land clearing (medium vegetation)	264	m2	$ 0.64	$ 169
2.3	Remove kerbs	8	m	$ 34.00	$ 272
2.4	Breakup and remove reinforced concrete in open excavations	3	m3	$ 338.00	$ 1,055
2.5	Excavate trenches (up to 2m deep in light soil, incl backfilling)	89	m3	$ 68.50	$ 6,076
2.6	Cart excavated material	44	per 5km per m3	$ 30.00	$ 1,331
2.7	Dispose of demolition material - mixed	71	t	$ 428.00	$ 30,372
3	**Rehabilitation**				
3.1	Footpath	21	m2	$ 304.00	$ 6,323
3.2	Kerb and gutter	8	m	$ 1,294.50	$ 10,356
3.3	Line marking (100mm wide)	8	m	$ 2.10	$ 17
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 140,395**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 21,059
	Project Management of Design			15%	$ 3,159
	Pre-construction sub-total				$ 24,218
	Pre-construction contingency			40%	$ 9,687
	TOTAL PRE-CONSTRUCTION COSTS				**$ 33,905**
6	**Additional construction costs**				
	Preliminary construction cost				$ 140,395
	Construction management/supervision			15%	$ 21,059
	Construction sub-total				$ 161,455
	Construction contingency			40%	$ 64,582
	TOTAL CONSTRUCTION COSTS				**$ 226,036**
	TOTAL PROJECT ESTIMATE				**$ 259,942**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M084.2: Diversion to West Ryde Tunnel **Date of Estimate: Jun-24**

Involves the following construction works:
- 80m of trench construction
- 2.9 x 1.5m box culvert
- removal of pits and installtion of new pits

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Traffic Control	80	day	$ 1,776.00	$ 142,080
1.4	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.5	Temporary Fencing (light duty site mesh)	80	m	$ 15.00	$ 1,200
1.6	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.7	Portable Toilet	26	week	$ 76.97	$ 2,001
1.8	Silt sausage	50	m	$ 19.35	$ 968
2	**Site Clearance**				
2.1	Break up and remove bitumen paving with basecourse under	272	m2	$ 4.20	$ 1,142
2.2	Remove kerbs	80	m	$ 34.00	$ 2,720
2.3	Remove Pits	16	ea	$ 566.00	$ 9,056
2.4	Excavate trenches (up to 2m deep in light soil, incl backfilling)	788	m3	$ 68.50	$ 54,008
2.5	Cart excavated material	394	per 5km per m3	$ 30.00	$ 11,826
2.6	Dispose of demolition material - mixed	631	t	$ 428.00	$ 269,959
3	**Stormwater Management**				
3.1	Precast Concrete Box Culvert (2700 x 900)	80	m	$ 1,120.00	$ 89,600
3.2	Preparation of culvert base	272	m2	$ 385.00	$ 104,720
3.3	Precast concrete pit (1200 x 1200 x 1200)	18	ea	$ 2,200.00	$ 39,600
3.4	2.4m lintel and grate	18	ea	$ 1,600.00	$ 28,800
3.5	Break into existing pit	2	ea	$ 600.00	$ 1,200
4	**Rehabilitation**				
4.1	Pavement	272	m2	$ 300.00	$ 81,600
4.2	Kerb and gutter	80	m	$ 1,294.50	$ 103,560
4.3	Line marking (100mm wide)	80	m	$ 2.10	$ 168
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 981,709**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 147,256
	Project Management of Design			15%	$ 22,088
	Pre-construction sub-total				$ 169,345
	Pre-construction contingency			40%	$ 67,738
	TOTAL PRE-CONSTRUCTION COSTS				**$ 237,083**
6	**Additional construction costs**				
	Preliminary construction cost				$ 981,709
	Construction management/supervision			15%	$ 147,256
	Construction sub-total				$ 1,128,965
	Construction contingency			40%	$ 451,586
	TOTAL CONSTRUCTION COSTS				**$ 1,580,551**
	TOTAL PROJECT ESTIMATE				**$ 1,817,634**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M089 Lions Park Basin | **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Raising bund
- Excavation of basin
- Excavation channel

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.4	Temporary Fencing (light duty site mesh)	331	m	$ 15.00	$ 4,965
1.5	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.6	Portable Toilet	26	week	$ 76.97	$ 2,001
1.7	Silt sausage	20	m	$ 19.35	$ 387
2	**Site Clearance**				
2.1	Land clearing (medium vegetation)	2,563	m2	$ 0.64	$ 1,640
2.2	Excavate over site to reduce levels in light soil	1,400	m3	$ 26.90	$ 37,660
2.3	Balance cut and fill (0.5/1m deep) in light soil	411	m3	$ 18.30	$ 7,514
2.4	Cart excavated material	989	per 5km per m3	$ 30.00	$ 29,682
2.5	Dispose of clean fill	1,583	t	$ 351.00	$ 555,651
3	**Rehabilitation**				
3.1	Turf laid, rolled and watered - couch	2,563	m2	$ 12.00	$ 30,759
3.2	Ground cover and planting	256	m2	$ 31.50	$ 8,074
3.3	Pine bark chips	26	m3	$ 164.00	$ 4,204
3.4	Sign 450mm x 600mm	2	ea	$ 460.00	$ 920
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 720,958**
4	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 108,144
	Project Management of Design			15%	$ 16,222
	Pre-construction sub-total				$ 124,365
	Pre-construction contingency			40%	$ 49,746
	TOTAL PRE-CONSTRUCTION COSTS				**$ 174,111**
6	**Additional construction costs**				
	Preliminary construction cost				$ 720,958
	Construction management/supervision			15%	$ 108,144
	Construction sub-total				$ 829,102
	Construction contingency			40%	$ 331,641
	TOTAL CONSTRUCTION COSTS				**$ 1,160,743**
	TOTAL PROJECT ESTIMATE				**$ 1,334,854**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

City of Ryde

M094 Pickford Ave and Lovell Rd Intersection **Date of Estimate:** **Jun-24**

Involves the following construction works:
- Raising bund

ITEM	DESCRIPTION	QTY	UNIT		RATE		SUB-TOTAL
1	**Construction Preliminaries**						
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$	10,000.00	$	10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$	20,000.00	$	20,000
1.3	Survey and set out works	5	day	$	1,200.00	$	6,000
1.4	Temporary Fencing (light duty site mesh)	528	m	$	15.00	$	7,920
1.5	Temporary Signage	3	ea	$	500.00	$	1,500
1.6	Portable Toilet	26	week	$	76.97	$	2,001
1.7	Silt sausage	20	m	$	19.35	$	387
2	**Site Clearance**						
2.1	Land clearing (medium vegetation)	2,675	m2	$	0.64	$	1,712
2.2	Excavate over site to reduce levels in light soil	100	m3	$	26.90	$	2,690
2.3	Balance cut and fill (0.5/1m deep) in light soil	521	m3	$	18.30	$	9,536
3	**Rehabilitation**						
3.1	Turf laid, rolled and watered - couch	2,675	m2	$	12.00	$	32,095
3.2	Ground cover and planting	267	m2	$	31.50	$	8,425
3.3	Pine bark chips	27	m3	$	164.00	$	4,386
3.4	Sign 450mm x 600mm	2	ea	$	460.00	$	920
	TOTAL PRELIMINARY CONSTRUCTION COSTS					**$**	**107,572**
4	**Pre-construction costs**						
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)				15%	$	16,136
	Project Management of Design				15%	$	2,420
	Pre-construction sub-total					$	18,556
	Pre-construction contingency				40%	$	7,422
	TOTAL PRE-CONSTRUCTION COSTS					**$**	**25,979**
6	**Additional construction costs**						
	Preliminary construction cost					$	107,572
	Construction management/supervision				15%	$	16,136
	Construction sub-total					$	123,708
	Construction contingency				40%	$	49,483
	TOTAL CONSTRUCTION COSTS					**$**	**173,191**
	TOTAL PROJECT ESTIMATE					**$**	**199,169**

City of Ryde FRMS - Option Costs

PRELIMINARY PROJECT COST ESTIMATE FOR FLOOD MITIGATION WORKS

M101 Boyce St Drainage Upgrade **Date of Estimate: Jun-24**

Involves the following construction works:
- Pit upgrades to four pits on upstream side of Boyce St
- Additional 900mm pipe along existing pipeline from Boyce St to Gannan Park

ITEM	DESCRIPTION	QTY	UNIT	RATE	SUB-TOTAL
1	**Construction Preliminaries**				
1.1	Establishment (Project Inception, Management and Coordination)	1	ea	$ 10,000.00	$ 10,000
1.2	Preparation and implementation of preliminaries (e.g. CEMP, SMP, TCP, QMP)	1	ea	$ 20,000.00	$ 20,000
1.3	Traffic Control	80	day	$ 1,776.00	$ 142,080
1.4	Survey and set out works	5	day	$ 1,200.00	$ 6,000
1.5	Temporary Fencing (light duty site mesh)	150	m	$ 15.00	$ 2,250
1.6	Temporary Signage	3	ea	$ 500.00	$ 1,500
1.7	Portable Toilet	26	week	$ 76.97	$ 2,001
1.8	Silt sausage	50	m	$ 19.35	$ 968
2	**Site Clearance**				
2.1	Break up and remove bitumen paving with basecourse under	210	m2	$ 4.20	$ 882
2.2	Remove kerbs	150	m	$ 34.00	$ 5,100
2.3	Excavate trenches (up to 2m deep in light soil, incl backfilling)	420	m3	$ 68.50	$ 28,770
2.4	Cart excavated material	210	per 5km per m3	$ 30.00	$ 6,300
2.5	Dispose of demolition material - mixed	336	t	$ 428.00	$ 143,808
3	**Stormwater Management**				
3.1	Concrete pipe to AS 4058-1992 Class 4 1050mm dia	150	m	$ 934.62	$ 140,193
3.2	Preparation of culvert base	210	m2	$ 385.00	$ 80,850
3.3	Precast concrete pit (1200 x 1200 x 1200)	6	ea	$ 2,200.00	$ 13,200
3.4	2.4m lintel and grate	4	ea	$ 1,600.00	$ 6,400
3.5	Break into existing pit	2	ea	$ 600.00	$ 1,200
4	**Rehabilitation**				
4.1	Pavement	210	m2	$ 300.00	$ 63,000
4.2	Kerb and gutter	150	m	$ 1,294.50	$ 194,175
4.3	Line marking (100mm wide)	150	m	$ 2.10	$ 315
	TOTAL PRELIMINARY CONSTRUCTION COSTS				**$ 868,992**
5	**Pre-construction costs**				
	Design (includes Survey, Investigation Design, Geotech, REF, Concept & Detail Design)			15%	$ 130,349
	Project Management of Design			15%	$ 19,552
	Pre-construction sub-total				$ 149,901
	Pre-construction contingency			40%	$ 59,960
	TOTAL PRE-CONSTRUCTION COSTS				**$ 209,862**
6	**Additional construction costs**				
	Preliminary construction cost				$ 868,992
	Construction management/supervision			15%	$ 130,349
	Construction sub-total				$ 999,341
	Construction contingency			40%	$ 399,736
	TOTAL CONSTRUCTION COSTS				**$ 1,399,077**
	TOTAL PROJECT ESTIMATE				**$ 1,608,939**