South Creek Floodplain Risk Management Study

February 2020

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North Sydney NSW 2060
Australia

Revision E

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List of Acronyms and Initialisations

AAD	Average Annual Damages
ABS	Australian Bureau of Statistics
AEP	Average Exceedance Probability
AHD	Australian Height Datum
ALS	Aerial Laser Survey
ARR	Australian Rainfall and Runoff
BCR	Benefit Cost Ratio
BOM	Bureau of Meteorology
DCP	Development Control Plan
DPE	Department of Planning and Environment
DTM	Digital Terrain Model
EMP	Estuary Management Plan
FDM	Floodplain Development Manual
FERP	Flood Emergency Response Plan
FIA	Flood Impact Assessment
FPCC	Flood Planning Constraints Categories
FPA	Flood Planning Area
FPL	Flood Planning Level
HAT	Highest Astronomical Tide
ICOLL	Intermittently Closed and Open Lake or Lagoon
IFD	Intensity Frequency Duration
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
NSW	New South Wales
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PV	Present Value
RCP	Representative Concentration Pathway
SEPP	State Environment Planning Policies
SES	State Emergency Service
VHR	Voluntary House Raising
VHP	Voluntary House Purchase

Acknowledgements

The following report was prepared by Advisian (*part of the WorleyParsons Group*) on behalf of the South Creek Floodplain Risk Management Committee acting in association with Penrith City Council and the Office of Environment & Heritage (*OEH*).

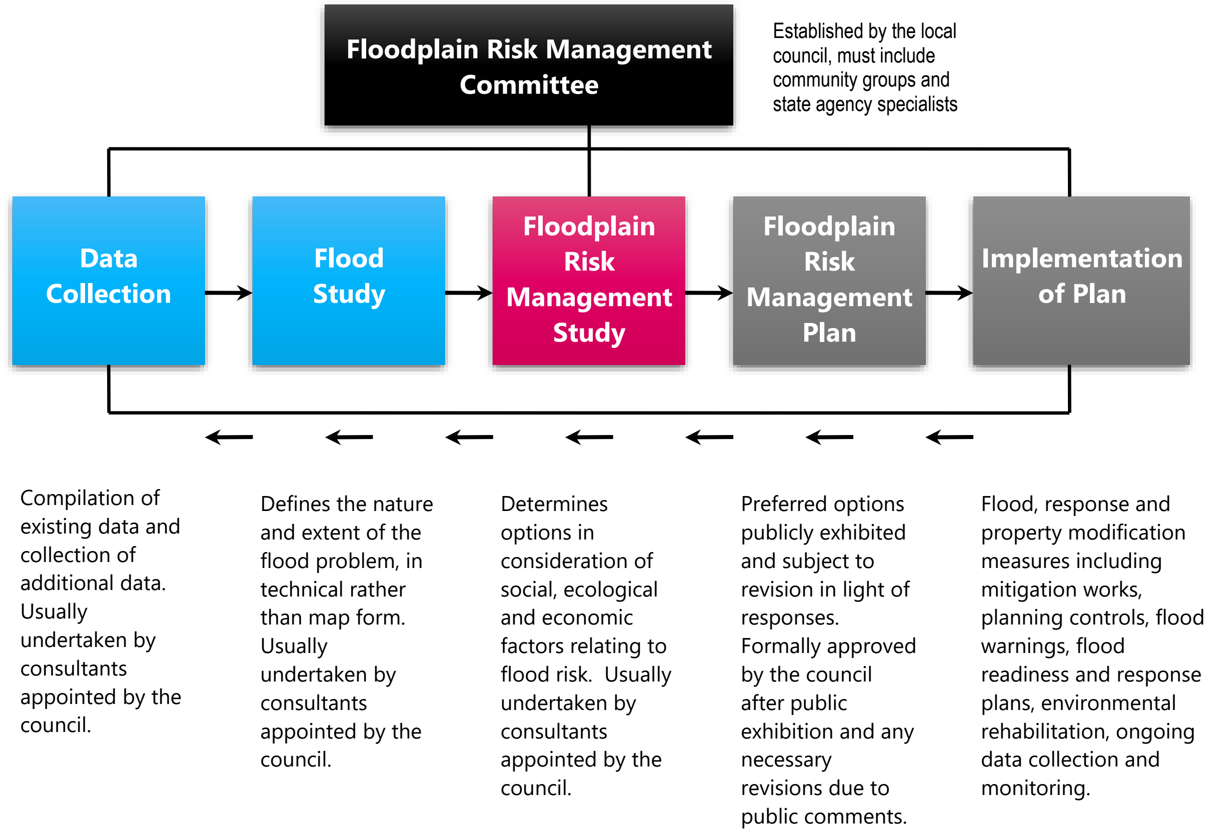
The study is the culmination of many months of investigation, analysis and flood modelling, which has been supported by valuable contributions from representatives of the community of Penrith and Penrith City Council.

It has been prepared by incorporating contributions from individuals from the local community and key stakeholders. Contributions from members of the Floodplain Risk Management Committee have been essential to the formation of management strategies that have been considered as part of the Study and are greatly appreciated.

The collegial manner in which input has been provided to the project from representatives from the Penrith City Council has been critical to its success.

Foreword

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (*2005*).



Source: 'Floodplain Development Manual' (2005)

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

Penrith City Council commenced this process in 2005, when WorleyParsons (*then Patterson Britton and Partners*) was engaged to undertake the Flood Study for South Creek and its tributaries. Penrith City Council has now proceeded further with the floodplain management process by engaging Advisian (*part of WorleyParsons Group*) to continue the process by undertaking the Floodplain Risk Management Study and Plan for South Creek. These have been prepared to assist Council in identifying and assessing management options to reduce the existing flood problem for the South Creek catchment and to manage flooding into the future.

S1. Executive Summary

Setting

South Creek is a tributary of the Hawkesbury River that drains a 414 km^2 catchment in western Sydney extending from its headwaters near Narellan in the south, to its confluence with the Hawkesbury River near Windsor.

South Creek generally flows from south to north through the catchment with the commercial centres of Penrith and Blacktown located to the west and east, respectively. Ropes Creek is a major tributary of South Creek that falls within the Penrith City Council LGA. Minor tributaries that also fall within the Penrith LGA include Werrington, Claremont, Blaxland, Cosgroves and Badgerys Creeks.

Large areas of the catchment have been urbanised, particularly in the vicinity of these commercial centres. The major urban centres located along South Creek and its tributaries and at risk of flooding are St Clair (*population 19,837*), Erskine Park (*population 6,436*), Claremont Meadows (*population 4,776*), St Marys (*population 12,195*), Werrington and Werrington County (*population 7,702*). The semi-rural suburbs of Llandilo and Berkshire Park are located to the north of the study area and downstream of the Ropes Creek confluence.

Flooding of South Creek typically occurs as a result of local catchment runoff breaking out of the main channel and spilling across the adjoining floodplain. However, the lower reaches of South Creek also serve as a large flood storage area during major flooding of the Hawkesbury-Nepean River system.

The largest two floods to have occurred in the South Creek catchment in the last 50 years occurred in the 1980s. The August 1986 flood and the April 1988 flood are two of the largest floods to have occurred in the catchment since European settlement. The 1988 flood is considered to be in the order of a 1% Annual Exceedance Probability (AEP) flood along the lower half of South Creek and the 1986 flood is considered to be in the order of the 1% AEP flood for Ropes Creek. Other significant floods occurred in 1867, 1956, 1961, 1978 and 2017.

Project Objectives

The primary objective of the floodplain risk management process is to reduce the risk to life and property from flooding.

The objective of the South Creek Floodplain Risk Management Study is to develop a set of cost-effective floodplain risk management actions that can be progressively implemented by Council, SES and others to reduce flood risk for the benefit of flood-affected property owners as well as the wider community.

The Flooding Problem

Advisian (*formerly WorleyParsons*) completed a Flood Study for the South Creek catchment in 2015 for Penrith, Blacktown, Liverpool and Fairfield City Councils. The Flood Study involved hydrologic modelling using the runoff-routing software XP-RAFTS. The flow hydrographs determined from this modelling were fed into a two-dimensional RMA-2 hydrodynamic model.

The RMA-2 flood model was validated against flood marks collected for the 1968 and 1988 historic floods and used to simulate flood behavior for the 5%, 2%, 1%, 0.5% and 0.2% AEP floods and the Probable Maximum Flood (*PMF*). Key outputs from the modelling included in the *Updated South Creek Flood Study* (*2015*) include mapping of peak flood levels and extents, depths and velocities, provisional flood hazard and hydraulic categories; i.e., mapping of floodway, flood fringe and flood storage areas.

Predicted lag times for the 1% AEP flood at critical locations was extracted from the flood modelling results to provide an indication of the flood warning times that could be available to the community. As shown in **Table S-1**, the flood wave for a 1% AEP flood would take approximately 5½ hours to traverse South Creek from Elizabeth Drive to Richmond Road.

Table S-1 Predicted Lag Times for the 1% AEP Flood

	DESCRIPTION OF LOCATION	TIME OF PEAK FLOOD LEVEL (*hours after start of design storm*)*
South Creek	Elizabeth Drive Crossing	22.5
	Warragamba Pipeline	23.5
	Luddenham Road, St Clair	24.0
	Western Motorway (*M4*)	25.0
	Great Western Highway	26.0
	Main Western Railway	26.0
	Dunheved Road, Dunheved	26.5
	Munitions Road	27.0
	Ropes Creek Confluence	27.5
	Eighth Avenue, Shanes Park	27.5
	Stony Creek Road	27.5
	Richmond Road	28.0
Ropes Creek	Capitol Hill Drive Crossing	19.0
	Warragamba Pipeline	20.0
	M4 Motorway	21.0
	Great Western Highway	21.5
	Main Western Railway	22.0
	Debrincat Ave, Tregear	22.0
	Forrester Road, Dunheved	22.5
Kemps Creek	Elizabeth Drive Bridge Crossing	21.0
	Kemps Creek Dam	22.5

The Flood Study (*2015*) also identified numerous roadways and railway lines throughout the study area at risk of overtopping. The major crossings assessed and identified to be at risk of overtopping are listed in **Table S-2**.

Of the roads identified, many were major roads such as the Great Western Highway, the Western Motorway (*M4*) and Elizabeth Drive which would be overtopped during events more frequent than the 1% AEP flood. The Western Railway was predicted to remain flood free during events up to and including the 0.2% AEP flood.

Table S-2 Predicted Flood Immunity of the Major Crossings within the Study Area

Road Crossing	Event (AEP) and Depth at which Overtopping is first Predicted	Severity of Overtopping
Elizabeth Drive crossing of Badgerys Creek	100 mm at peak of 5% AEP flood	High
Elizabeth Drive crossing of South Creek	80 mm at peak of 2% AEP flood	High
Elizabeth Drive crossing of Kemps Creek	300 mm at peak of 5% AEP flood	High
Western Motorway (M4) crossing of South Creek	305 mm at peak of 1% AEP flood	Moderate
Western Motorway (M4) crossing of Ropes Creek	1.0 metre at peak of the PMF	Low
Great Western Highway crossing of South Creek	100 mm at peak of 5% AEP flood	High
Great Western Highway crossing of Ropes Creek	300 mm at peak of the PMF	Low
Railway Line crossing of South Creek	1.25 metres at peak of the PMF	Low
Railway Line crossing of Ropes Creek	100 mm at peak of the PMF	Low
Dunheved Road crossing of South Creek	900 mm at peak of 5% AEP flood	High
Debrincat Ave crossing of Ropes Creek	150 mm at peak of 1% AEP flood	Moderate

Source: Appendix J of the Updated South Creek Flood Study (2015)

The results from the *Updated South Creek Flood Study* (*2015*) were adopted as the basis for the floodplain risk management study for the calculation of flood damages and the assessment of existing flood mitigation, emergency response and flood modification measures.

Flood Hazard, Hydraulic Categories and Flood Planning Constraints Categories

The provisional flood hazard mapping was updated to reflect the hazard categories and criteria recommended within *Australian Rainfall and Runoff 2019* (*ARR19*). This led to the flood hazard across the South Creek floodplain being categorised as H1 to H6 in lieu of the former Low, Medium, High, Very High and Extreme hazard categories previously adopted. The hazard mapping was further updated to reflect 'true' hazards by taking into consideration other factors such as access and evacuation constraints, warning times and the rate of rise of floodwaters. True hazard mapping was prepared for the 5%, 2%, 1%, 0.5% and 0.2% AEP floods and the PMF.

The 1% AEP true hazard mapping demonstrates that the populated areas within the floodplain upstream of Dunheved Road would generally be exposed to hazards of up to H3. The hazard generally increases downstream of the Ropes Creek confluence with hazards ranging between H4 to H5 across Llandilo and H5 to H6 across Berkshire Park.

Updated hydraulic category mapping was prepared as part of the FRMS to reflect changes to the extent of flood storages and the flood fringe following mapping of the 1% AEP flood to 2011 LiDAR. The re-mapping of the flood study results led to localised changes to flood extents and depths that were largely limited to the peripheries of the floodplain and accordingly within areas designated as flood storage or fringe. No changes to the floodway corridor were required reflecting the rigorous methodology applied as part of the Flood Study (*2015*).

Flood Planning Constraints Category (*FPCC)* mapping was also prepared for the study area in accordance with the *Australian Institute of Disaster Resilience (ADR) Guideline 7-5 Flood Information to Support Land Use Planning Activities*. The preparation of FPCC mapping allows the relative severity of flood risks to be compared throughout the floodplain based consideration of floods of varying size, the variation in flood hazards across the floodplain, hydraulic categories and potential constraints to emergency response and evacuation. This leads to the floodplain being categorised as FPCC1 through to FPCC4, with FPCC1 representing locations with the greatest flood risk.

Flood Damages Analysis

Flood damages are adverse impacts that private and public property owners experience as a consequence of flooding. They can be both tangible and intangible, direct and indirect, and are usually measured in terms of a dollar cost.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (*e.g., the cost of replacing carpets*). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. Intangible damages include impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. It is more difficult to quantify intangible damages, but it is possible they could be as high or higher than the total tangible damage cost.

Flood damages have been calculated according to the flood model results for the PMF, 0.2%, 0.5%, 1%, 2% and 5% AEP events. The adopted methodology for South Creek is in accordance with the Floodplain Risk Management Guideline (*and accompanying spreadsheet*) prepared by OEH in 2007. The level of flooding is compared to the floor level of the dwelling/structure to extract a flood depth relative to floor level. This depth is applied to the relevant depth vs damage curve to determine the dollar value of damage, according to the property type (*residential, commercial, industrial, recreational or 'other'*) and the construction type (*slab on ground vs high set vs two-storey*).

The relative cost of the potential flood damages is typically expressed in terms of the Average Annual Damage (AAD). The AAD is equivalent to the total damage caused by all floods over a long period of time divided by the number of years in that period. The AAD for South Creek was calculated to be **$985,000**. That is, funds in the order of $985,000 would need to be put aside each year on average, in order to cover the damage bills that could be incurred as a consequence of flooding.

The findings from the damages assessment are summarised in the following.

- **Table S-3** for total number of properties inundated above floor level for a range of design events;
- **Table S-4** for total Average Annual Damages (AAD) for the study area; and
- **Chart S-1** for the total number of properties inundated above floor level by suburb.

Table S-3 Number of Properties Inundated Above Floor Level for a Range of Design Events

Property Type	Number of Properties					
	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Residential	30	66	125	202	516	2338
Commercial	5	6	10	13	26	77
Industrial	1	1	15	15	22	191
Recreation	4	5	8	10	14	22
Other	3	3	4	5	9	11
TOTAL	**43**	**81**	**162**	**245**	**587**	**2639**

Table S-4 Total Flood Damages Predicted for the South Creek Study Area

Property Type	Total flood damage for event ($1000s)						Total AAD ($1000s)
	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF	
Residential	2,203	5,191	9,899	17,237	41,772	267,037	***$ 817***
Commercial	213	294	466	620	1,238	5,831	***$ 40***
Industrial	112	226	1,057	1,533	3,009	44,754	***$ 81***
Recreation	58	108	168	240	384	788	***$ 11***
Other	224	279	449	537	1,089	2,550	***$ 37***
TOTAL	**2,811**	**6,097**	**12,038**	**20,168**	**47,492**	**320,960**	***$ 985***

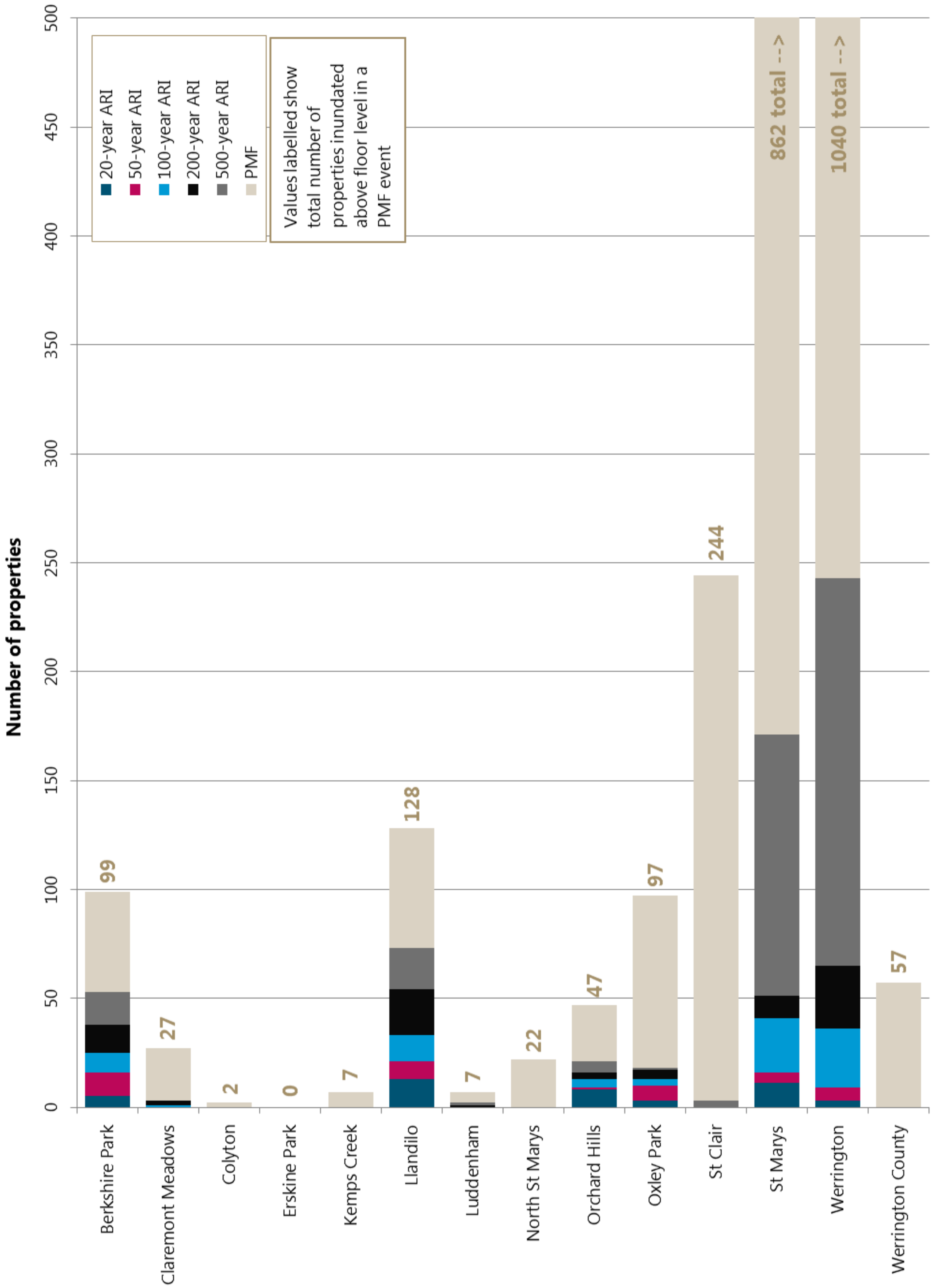


Chart S-1 Total Number of Properties Inundated Above Floor Level by Suburb

Floodplain Risk Management

Options to address the flood risks and potential flood damages are typically separated into the following categories:

- **Flood modification measures**. These are typically structural works, such as flood protection levees, flood detention basins or bypass floodways, which act to reduce flood damages.
- **Property modification measures**. These measures include flood planning controls for future development to ensure that land uses are compatible with flood risk. They can also include voluntary house raising and purchase, or flood-proofing of buildings, which can act to reduce flood damages.
- **Response modification measures**. These typically include emergency response management measures, flood predictions and warnings and community flood awareness and preparedness.

To address the existing, future and residual flooding problem a combination of mitigation types is often required. For example, a flood modification measure such as a levee may be proposed to reduce flood damages that could occur to existing properties. Property modification measures such as planning controls are then required to control development behind the levee to ensure the risks of overtopping and/or failure are taken into consideration. This could include freeboard requirements and limitations on intensifying development.

At the commencement of the floodplain risk management study, Council's Floodplain Risk Management Committee (*FRMC*) identified a range of potential flood related issues across the study area for which structural, planning and emergency response measures may be introduced to reduce the flood damages and ameliorate associated flood risk to individuals. A total of 38 specific issues were identified by the FRMC and listed in the FRMS&P brief for consideration.

A triple-bottom-line assessment was undertaken to evaluate the 38 issues with the following identified as high priority for further investigation:

- Kemps Creek farm dams - effectiveness and impacts of failure
- Flooding of Mamre Road and adjacent St Claire residential properties
- Flooding of properties near Mandalong Close, Orchard Hills
- Adequacy and integrity of the St Marys Levee
- Overtopping of the Kingsway and feasibility of road access
- Flood protection to properties upstream of the Great Western Highway at Claremont Meadows
- Flood risks to the special needs Kurrambee School in Werrington
- Flood protection to residential properties along Rance Road, Werrington
- Adequacy and integrity of the Werrington Road Levee
- Werrington evacuation constraints due to overtopping of Burton Street, Victoria Street and John Oxley Avenue crossings of Werrington Creek
- Flooding of properties at Llandilo and Berkshire Park
- Ropes Creek flooding of properties upstream of the Railway Line at Oxley Park

The key findings from the levee adequacy and integrity review conducted for the St Marys Earthen and Concrete Levee are:

- Three locations are identified where crest elevations either fall below the predicted 1% AEP flood level or do not meet the 0.5 metre freeboard design criteria.
- The crest of the concrete levee at the tie-in to the Great Western Highway is approximately 0.8 metres above the road surface creating a scenario where floodwaters overtopping the road could flow around the concrete levee despite the levee crest not overtopping.
- Visual inspection of the levee highlighted locations of extensive overgrowth that may create issues with intrusive root growth and could harbour burrowing animals and snakes.
- Considering the above findings, a crest level survey and external audit is recommended for the St Marys Levee. Following confirmation of crest elevations, a design review for the three locations identified and the downstream end of the concrete leave at the tie in to the Great Western Highway is recommended.

The key findings from the levee adequacy and integrity review conducted for the Werrington Road Levee are:

- Three locations spanning a total length of 470 metres have been identified where crest elevations do not meet the 0.5 metre freeboard design criteria.
- The earthen levee appears to be routinely maintained with grass mowed and no unwanted growth of trees and shrubs.

A crest level survey is recommended to confirm the freeboard available at the three locations identified. Once crest elevations are confirmed it is recommended an audit take place to assess the levee structure and the flood operating level.

Proposed Flood Modification Measures

Flood modification measures are physical works that aim to reduce the existing flood risk and damages. The assessment of flood modification measures was completed using the following approach:

- Hydraulic modelling using the two-dimensional RMA-2 model developed as part of the *Updated South Creek Flood Study* (*2015*).
- Assessment of the cost of options, including upfront capital costs and ongoing maintenance costs. Note that all cost estimates represent a total present value of costs over a 30 year design life assuming a real discount rate of 7%. All cost estimates also include an allowance for further design and approvals.
- Calculation of the Benefit Cost Ratio (*BCR*), and
- Triple-Bottom-Line (*TBL*) assessment to consider additional factors, such as social and environmental impacts/benefits.

The flood modification options considered and the BCR determined are documented in **Table S-5**. Based on the BCR alone, Measures F-2, F-7B and F-1A were determined to return the highest benefit relative to the cost of the works.

The TBL assessment for each measure is documented in **Table S-6**. It shows that the three measures that returned the highest BCR ratios are still ranked highest however, Measure F-1A moved from 2nd to 1st place following consideration of other economical, environmental and social factors.

It is recommended that Measures F-1A, F2 and F-7B be included in the South Creek Floodplain Risk Management Plan for further investigation, design and implementation.

Table S-5 Benefit/Cost Ratio for Proposed Flood Modification Measures

Mitigation Measure	Cost of Works (*PV*)	Reduction in AAD	Present Value of Damage Reduction	Benefit-Cost Ratio
F-1A - Oxley Park Low Cut	**$356,600**	**$20,000**	**$268,100**	**0.75**
F-1B - Oxley Park High Cut	**$914,400**	**$28,000**	**$375,400**	**0.41**
F-2 - Oxley Park Levee	**$694,000**	**$45,000**	**$603,000**	**0.87**
F-3 - Railway Bridge Widening	**$1M to $1.5M**	Measure did not progress beyond modelling to benefit-cost analysis based on low benefit compared to F-1A		
F-4 - Additional Storage Upstream of the Railway Crossing	Measure did not progress beyond modelling based on low benefits compared to F-1A			
F-5 - Raise Werrington and Rance Road	**$1,086,000**	**$35,000**	**$470,000**	**0.43**
F-6 - Raise Mamre Road	Measure focused on improving emergency response with minimal reduction in flood damages			
F-7A – Upgrades to St Marys Levee	**$634,000**	**$13,000**	**$174,000**	**0.27**
F-7B – F-7A plus Installation of Flap Gate	**$744,000**	**$42,000**	**$563,000**	**0.76**
P-1 - Voluntary House Raising	**$988,000**	**$32,000**	**$425,800**	**0.43**
P-2 - Voluntary House Purchase	**$8,569,000**	**$125,000**	**$1,660,000**	**0.19**

Table S-6 Triple-Bottom-Line Assessment (Flood Modification Measures)

Evaluation Criteria	Weighting	Raw Scores												Weighted Scores										
		F-1A Floodplain Excavation downstream of the Railway Line (Low Cut)	F-1B Floodplain Excavation downstream of the Railway Line (High Cut)	F-2 Flood Protection Levee (Oxley Park)	F-3 Ropes Creek Railway Bridge Widening	F-4 Additional Storage Upstream of the Ropes Creek Railway Crossing	F-5 Raise Werrington & Rance Road	F-6 Raise Mamre Road at Low-Points	F-7A Upgrade St Marys Levee	F-7B Upgrade St Marys Levee & Install Flap Gate	P-1 Voluntary House Raising	P-2 Voluntary House Purchase		F-1A Floodplain Excavation downstream of the Railway Line (Low Cut)	F-1B Floodplain Excavation downstream of the Railway Line (High Cut)	F-2 Flood Protection Levee (Oxley Park)	F-3 Ropes Creek Railway Bridge Widening	F-4 Additional Storage Upstream of the Ropes Creek Railway Crossing	F-5 Raise Werrington & Rance Road	F-6 Raise Mamre Road at Low-Points	F-7A Upgrade St Marys Levee	F-7B Upgrade St Marys Levee & Install Flap Gate	P-1 Voluntary House Raising	P-2 Voluntary House Purchase
Flood Impacts																								
Impact on hydraulic behaviour	**5**	4	5	4	3	4	3	2.5	4	5	2.5	2.5		20	25	20	15	20	15	12.5	20	25	12.5	12.5
Reduction in flood damages	**4**	1	1	3	1	0	2	0	0	2	2	4		4	4	12	4	0	8	0	0	8	8	16
Economic																								
Benefit / Cost Ratio	**4**	3	2	3	0	0	2	0	1	3	2	0		12	8	12	0	0	8	0	4	12	8	0
Life cycle cost of option	**4**	4	2	3	1	3	1	1	2	2	2	1		16	8	12	4	12	4	4	8	8	8	4
Social																								
Impact on local community	**4**	3.5	3	3	3.5	3	3	3	3	3.5	3	3		14	12	12	14	12	12	12	12	14	12	12
Likely community acceptance	**3**	4	4	3	4	4	3.5	3	3	4	2.5	2		12	12	9	12	12	10.5	9	9	12	7.5	6
Environmental																								
Disruption to the natural character of the area	**3**	2.5	2	1	2.5	2.5	2.5	2.5	2.5	2	2.5	2.5		7.5	6	3	7.5	7.5	7.5	7.5	7.5	6	7.5	7.5
Ecological impacts	**4**	2	1.5	2	1.5	2	2	2.5	2	1.5	2.5	2.5		8	6	8	6	8	8	10	8	6	10	10
TOTAL SCORE														**93.5**	**81**	**88**	**62.5**	**71.5**	**73.0**	**55**	**70.5**	**91**	**73.5**	**68**
RANK														**1**	**4**	**3**	**10**	**7**	**6**	**11**	**8**	**2**	**5**	**9**

Flood Emergency Response Management

A review of the existing *Local Flood Plan* for Penrith prepared by SES (*2014*) identified that all references to the monitoring of flooding is focused on gauges located along the Hawkesbury-Nepean River. This is despite three (3) gauges existing along South Creek, at Elizabeth Drive, the Great Western Highway and Richmond Road, and one (1) along Ropes Creek at Debrincat Avenue.

It is recommended that the Local Flood Plan for the South Creek catchment be updated to include:

(i) Reference to all existing gauges within the study area which can be used to monitor the progression of a local flood event.

(ii) Nominate minor, moderate and major gauge heights so that reference markers are available against which warning times and known problem locations can be monitored.

(iii) Prepare flood intelligence cards for the existing gauges that shows the predicted stage-hydrograph for a range of design events plus indicators of times when roads, regions and critical facilities (*such as nursing homes, childcare centres, schools*) would start to be flooded or are at risk of isolation.

It is also recommended that the Local Flood Plan (*2014*) be updated to take into consideration the information prepared as part of the FRMS and documented in Community Data Sheets. The sheets have been prepared for each suburb within the study area and generally comprise the following information:

- Flood Management Community name and extent;
- Assessment of the population at risk;
- A description of flood characteristics for major floods such as the 1% AEP flood and PMF events;
- Identification of critical/vulnerable areas within the Community;
- Identification of evacuation routes, including the elevation of low points along each route;
- The magnitude of flooding that would cause local roads to be overtopped (*presented as maps*);
- The available flood warning time relative to upstream gauge levels if available; and
- The location of potential refuge centres; and
- Mapping of Emergency Response Management Communities (ERMC) in accordance with SES Guidelines.

To gain as much reliable flood warning time as possible it is recommended that a continuous river level gauge be installed along South Creek near the Warragamba Pipeline; i.e., near the confluence with Cosgroves Creek. This location was selected as it could provide over 1 hour of additional warning time to communities downstream (*such as St Clair, Orchard Hills, St Marys, Werrington, Llandilo and Berkshire Park)* compared to monitoring at the existing Great Western Highway Gauge, whilst still capturing approximately 50% of catchment runoff.

To reduce the risk associated with frequent overtopping of the Eighth Avenue bridge crossing at Llandilo, it is recommended that flood boom gates be installed on either side of the crossing. To reduce the frequency to which floodwaters overtop the crossing, and to reduce potential impact loads against the crossing, it is recommended that a vegetation management plan be implemented for the crossing.

Flood Planning

Council's existing planning controls, instruments and policies have been reviewed in the context of floodplain management and flood related development controls, with the primary objective of identifying ways in which the development preparation and assessment process can be improved across the Penrith LGA, with South Creek as an example catchment/floodplain.

Existing land use zonings throughout the study area were reviewed against the predicted flood related constraints, including the floodway corridor, variations in flood hazard, the Flood Planning Area (FPA) and Probable Maximum Flood (*PMF*) extent. The review determined that existing land use zonings where generally appropriate with the exception of several properties located within the floodway corridor such as at Werrington and Llandilo or where flood risks and potential for damages were high such as at Werrington along Rance Road.

A review of the Penrith Development Control Plan (*DCP*) 2014 led to the following recommendations:

- Updateable annexures be added to the DCP to include 'True Flood Hazard Mapping' and 'Hydraulic Category Mapping' prepared as part of the FRMS;
- Future Floodplain Risk Management Studies for watercourses within the Penrith LGA be required to prepare Flood Planning Constraints Category (FPCC) mapping similar to the FPCC prepared for South Creek and included as Appendix D. Once FPCC mapping is available for the LGA, it is recommended that DCP controls be updated to ensure development is guided by the FPCC mapping.
- Amendments to the DCP be made to update development controls relating to:
  - Extensions to existing development,
  - Change of use, and
  - Rural Development
- Development controls be revised relating to the assessment of flood impacts; and
- Additional clauses be added to the DCP relating to:
  - Critical facilities (e.g. schools, hospitals, aged care facilities, etc),
  - Requirements for flood impact assessments and flood risk assessments commensurate to the development size, type and flood risk, and
  - Climate change
- The format of the DCP be revised to set out different development types and flood risk into a matrix approach.

1. Introduction

South Creek is a tributary of the Hawkesbury River that drains a 414 km2 catchment in western Sydney. As shown in Figure 1.1, the South Creek catchment extends from its headwaters near Narellan in the south, to its confluence with the Hawkesbury River near Windsor.

South Creek generally flows from south to north through the catchment with the commercial centres of Penrith and Blacktown located to the west and east, respectively. Large areas of the catchment have been urbanised particularly in the vicinity of these commercial centres.

Ropes Creek is a major tributary of South Creek that falls within the Penrith City Council Local Government Area (LGA). Minor tributaries that also fall within the Penrith LGA include Werrington, Claremont, Blaxland, Cosgroves and Badgerys Creeks.

Flooding of South Creek typically occurs as a result of local catchment runoff breaking out of the main channel and spilling across the adjoining floodplain. However, the lower reaches of South Creek also serve as a large flood storage area during major flooding of the Hawkesbury-Nepean River system. As a result, floodwaters can 'back-up' along South Creek from its confluence with the Hawkesbury River, leading to inundation of areas of the South Creek floodplain to beyond the area that would typically be flooded in local catchment events.

The largest two floods to have occurred in the South Creek catchment in the last 50 years occurred in the 1980s. The August 1986 flood and the April 1988 flood are two of the largest floods to have occurred in the catchment since European settlement. The 1988 flood is considered to be in the order of a 1% Annual Exceedance Probability (AEP) flood along the lower half of South Creek; that is, it was a flood which has one chance in 100 of occurring in a given year. The 1986 flood is considered to be in the order of the 1% AEP flood for Ropes Creek. Other significant floods occurred in 1867, 1956, 1961, 1978 and 2017.

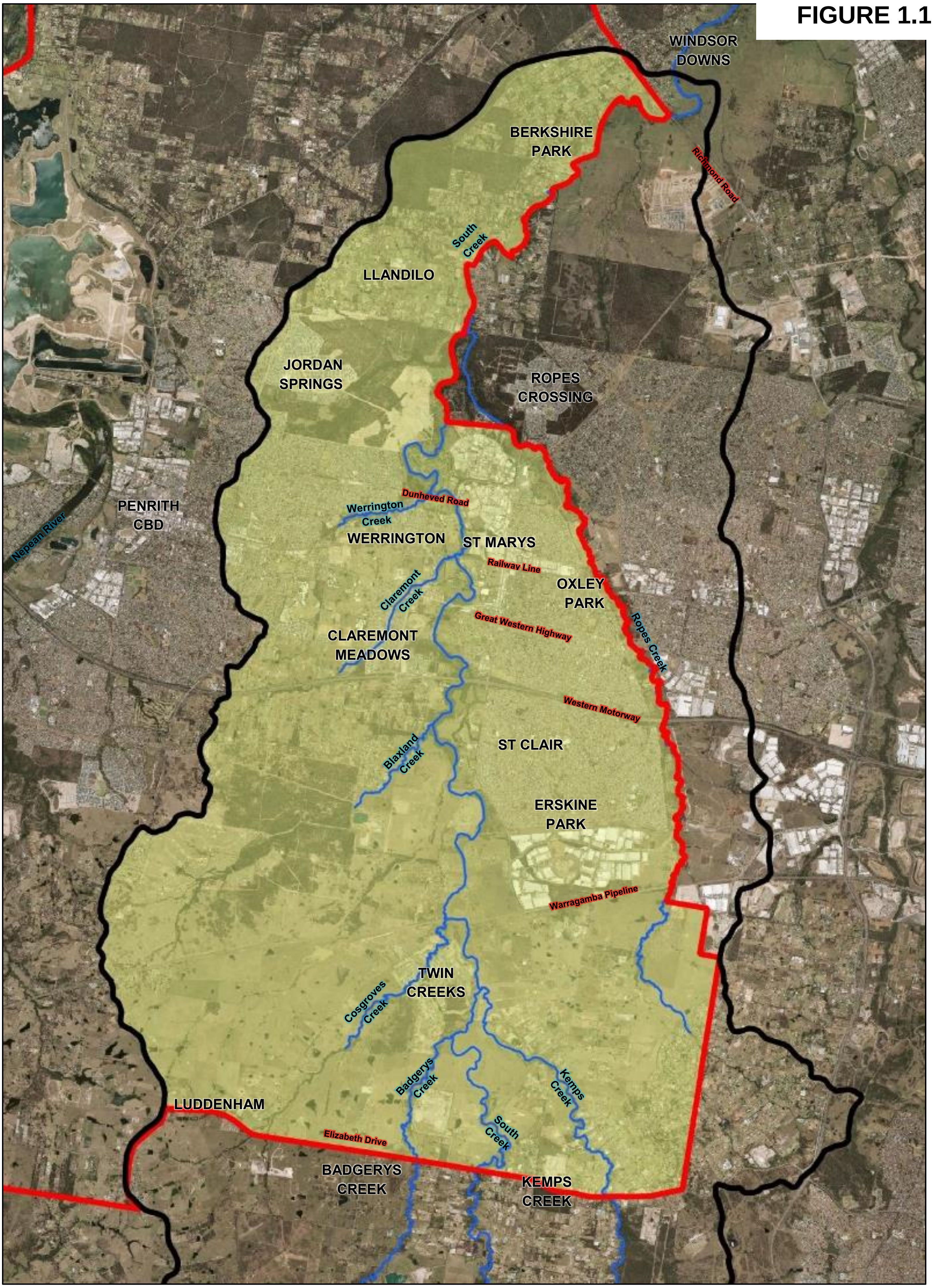
The primary objective of the floodplain risk management process is for Council to formulate a Floodplain Risk Management Plan for the study area (refer **Figure 1.1**).

The Plan is to be based on a range of strategies and mitigation measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. The primary objective of the Government's Flood Prone Land Policy is to reduce the impact of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding. In this regard, the Policy recognises:

- that flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development; and,
- that if all applications for development on flood prone land are assessed according to rigid and prescriptive criteria, some proposals may be unjustifiably disallowed or restricted, and equally, quite inappropriate proposals could be approved (*NSW Government, 2005*).

Accordingly, it is appropriate, under the NSW Government's Floodplain Management Program, to consider options for reducing the flood damages that could be experienced by residents along South Creek and to reduce the risk for loss of life. Suitable options can serve to mitigate the existing, future and continuing flood risk.

FIGURE 1.1



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301310-08772 South Creek FRMS
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STUDY AREA FOR THE SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY

The associated assessment first involves consideration of the flood damages that residents and the broader community may experience as a consequence of the existing flood problem. These damages are a measure of the cost of flooding under existing conditions. As outlined above, the NSW Government's *Floodplain Management Program* is targeted toward determining measures that can be cost effectively implemented to reduce existing flood damages.

Typically, the community is engaged to comment on a range of potential flood damage reduction measures (*structural measures*) and potential planning controls (*non-structural measures*) that could reduce the impact of floods. These are tested to establish their relative <u>benefit</u>, which is usually measured in terms of the potential reduction in flood damages, or the potential for additional future development that can occur at no increased risk to the community. The measures are also <u>costed</u> and their respective costs compared to their net benefit, thereby allowing a benefit-cost ratio to be determined for each measure.

Measures with a high benefit-cost ratio are typically recommended for inclusion within a Floodplain Risk Management Plan, which is the fourth phase in the floodplain management process (*refer to flow chart in Foreword*).

Therefore, this Floodplain Risk Management Study sets out to:

- identify and evaluate management options for the floodplain in terms of their capacity to reduce existing and potential future flooding problems;
- provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed on a consistent basis;
- provide recommendations for emergency response management during local catchment flooding; and,
- provide a framework for revisions to planning instruments such as Local Environmental Plans (*LEPs*), so that land use controls are consistent with flood risk and flood hazard.

2. Background

2.1 Catchment Description

South Creek is a tributary of the Hawkesbury River that drains a 414 km^2 catchment in western Sydney. As shown in **Figure 1.2**, the South Creek catchment is generally bound by Windsor in the north, Narellan in the south, Penrith in the west and Blacktown in the east. South Creek generally flows from south to north through the catchment.

The catchment falls within four Local Government Areas (*LGA*) which in order of coverage are Penrith, Liverpool, Blacktown and Fairfield City Councils. Major tributaries of South Creek are Ropes and Kemps Creeks. Minor tributaries include Werrington, Claremont, Blaxland, Cosgroves, Badgerys and Thompsons Creeks (*refer* **Figure 1.1**).

Within the Penrith LGA, major centres of development are generally located downstream and to the north of the Warragamba Pipeline. This includes the suburbs of Erskine Park, St Clair, St Marys, Claremont Meadows, Werrington and Oxley Park. Development is much less concentrated downstream and to the north of Dunheved Road at Llandilo and Berkshire Park.

2.2 Previous Investigations

A number of previous studies have been undertaken that relate to flooding within the study area. A synopsis of those investigations considered relevant to this study is provided in the following. These include the following reports:

- *'Flood Study Report, South Creek' (Department of Water Resources, 1990*)
- *'South Creek Floodplain Management Study'* (*Willing and Partners Pty Ltd, 1991*)
- *'ADI St Mary's Water Cycle & Soil Management Study - Final Study Report'* (*Sinclair Knight Merz, 1998*)
- *'Austral Floodplain Risk Management Study and Plan'* (*Perrens Consultants, 2003*)
- *'South Creek Floodplain Risk Management Study and Plan'* (*Bewsher Consulting, 2004*)
- *'Updated South Creek Flood Study' (WorleyParsons, 2015)*

A brief synopsis of each is presented in the following sections.

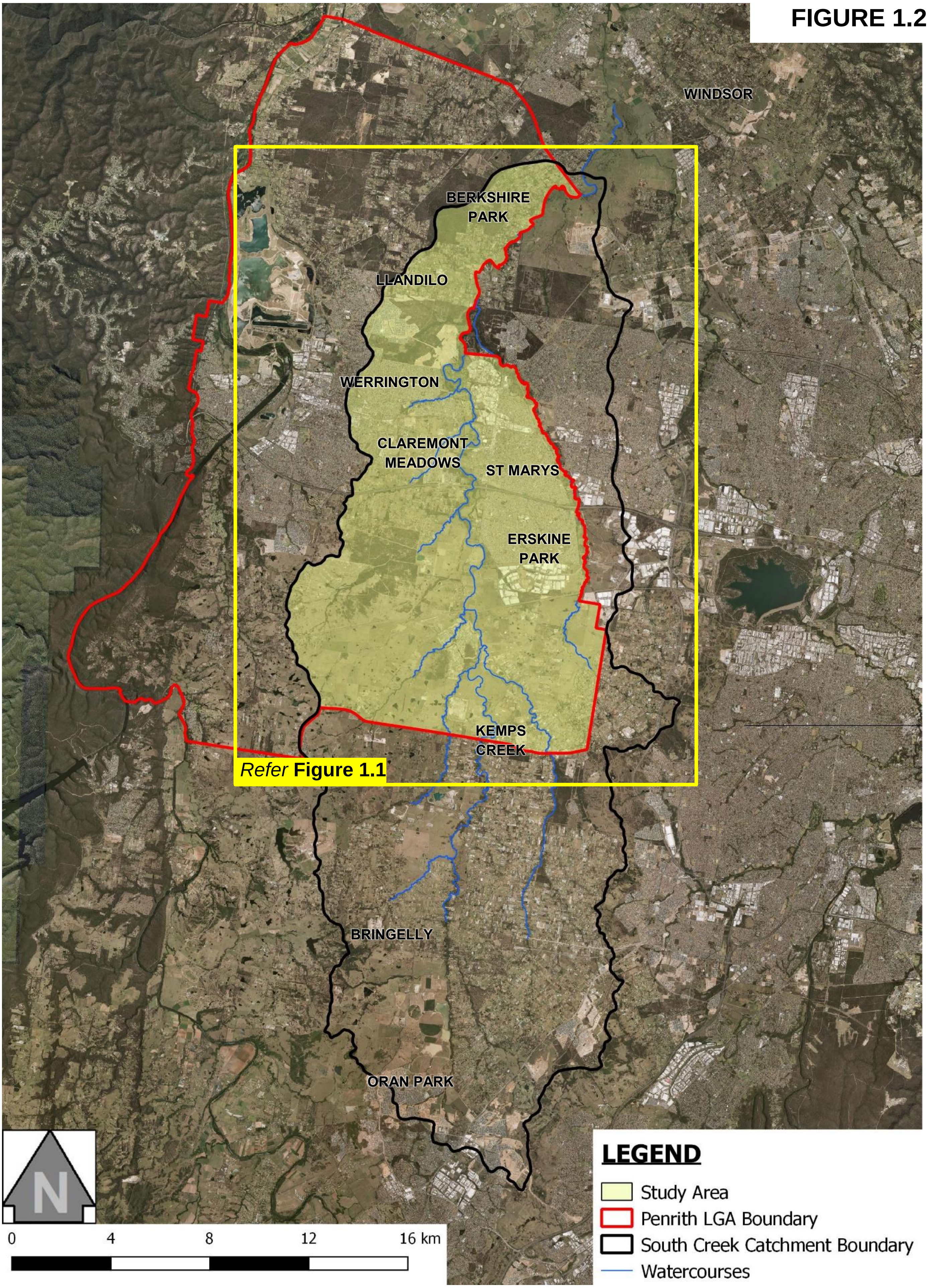
2.2.1 Flood Study Report South Creek (NSW Department of Water Resources, July 1990)

This report (*referred to hereafter as the "1990 Flood Study"*) was prepared by the NSW Department of Water Resources for the South Creek catchment. The primary objective of the study was to revise the earlier South Creek Flood Study based on data from severe flooding in August 1986 and April 1988. In addition, plans to undertake large scale development in western Sydney resulted in the need for the hydrologic and hydraulic modelling for South Creek to be updated.

The report details the historic flood behaviour within the catchment and specifies historic flood levels at key locations in the area. These historic flood levels are listed in **Table 2-1**.

Flood discharges throughout the South Creek catchment were determined through the development of a RAFTS hydrologic model. The RAFTS model was calibrated and validated against the August 1986 and April 1988 events. The model was simulated for the 1% AEP flood event only.

FIGURE 1.2



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SOUTH CREEK CATCHMENT RELATIVE TO THE PENRITH LOCAL GOVERNMENT AREA

Table 2-1 Historic Flood Levels from the 1990 South Creek Flood Study

LOCATION	PEAK FLOOD LEVEL (*mAHD*)					
	1867	1956	1961	1978	1986	1988
Elizabeth Drive	-	43.0	-	42.0	42.7	43.3
Mandalong Stud	-	32.9	-	32.0	-	32.5
F4 Freeway	-	-	-	-	-	26.9
Great Western Highway	24.5	-	24.0	24.4	24.4	24.7
Richmond Road	-	13.5	14.8	14.5	11.2	12.7
Windsor	19.7	13.8	15.0	14.5	11.4	12.8

Flood characteristics for South Creek and its floodplain was defined using MIKE 11 and HEC-2 software. A MIKE 11 one-dimensional unsteady flow model was developed to model South Creek and the lower reaches of the primary tributaries including Ropes, Badgerys and Kemps Creeks. A HEC-2 steady-state model was created to model the upper reaches of the primary tributaries and other tributaries of South Creek such as Werrington, Claremont, Blaxland, Cosgroves, and Rileys Creeks. The hydraulic models were calibrated to the 1986 and 1988 flood events.

The hydraulic models were only simulated for the 1% AEP flood event. The 1% AEP flow hydrographs were defined using results generated from the RAFTS hydrologic model of the South Creek catchment. A Hawkesbury River water level of 17 mAHD was used as the tailwater condition in the MIKE 11 model.

The report outlines the design flood behaviour for the 1% AEP flood event. This data includes peak flood levels, flow velocities and flows at each of the cross-sections within the hydraulic models. The peak 1% AEP flood levels determined as part of the study are shown in **Table 2-2** for key locations within the study area.

2.2.2 South Creek Floodplain Management Study (*Willing & Partners, 1991*)

This report documents the Floodplain Management Study carried out by Willing and Partners Pty Ltd for the South Creek catchment. The study quantifies the extent and impacts of flooding in the study area and determines the effects of proposed urban development on flood behaviour. Works and measures aimed at reducing the impact of flooding and water quality issues within the catchment have also been assessed as part of the study.

Hydrologic and hydraulic analyses were undertaken using the RAFTS, MIKE 11 and HEC-2 models developed by the DWR as part of the 1990 Flood Study (*refer* **Section 2.2.1**). The hydraulic analysis was extended to include the 5% and 2% AEP flood events and the PMF (*based on Bulletin 51 and Nepean Catchment PMP*). The Hawkesbury River water levels used as the tailwater levels for the modelling are shown in **Table 2-3**.

Table 2-2 Design 1% AEP Flood Levels for South Creek from the 1990 South Creek Flood Study

LOCATION	PEAK FLOOD LEVEL (*mAHD*)
Upstream of Richmond Road	17.0
Stony Creek Road	17.0
Ropes Creek Confluence	18.9
Downstream Main Western Railway	23.5
Upstream Great Western Highway	25.4
Upstream F4 Freeway	28.5
Upstream Elizabeth Drive	43.2
Upstream Bringelly Road	59.3
Downstream Camden Valley Way	90.5

Table 2-3 Hawkesbury River Tailwater Levels from the 'South Creek Floodplain Management Study'

AVERAGE RECURRENCE INTERVAL (*YEARS*)	TAILWATER LEVEL (*mAHD*)
20	13.8
50	15.9
100	17.5
PMF	22.2

Investigations undertaken as part of the study also involved the estimation of the hydraulic categories for South Creek and its tributaries for the 1% AEP event. The extent of the floodway was determined based on the results of the hydraulic modelling and using the encroachment approach.

Flood damages were assessed by the Centre for Resource and Environmental Studies (*CRES*) at the Australian National University (*ANU*) using ANUFLOOD software. This software was used to assess direct and indirect tangible damages. The total damage within the study area as a result of the 1% AEP flood was estimated to be $6.6M at 1990 prices.

A range of flood mitigation works and measures were investigated for the catchment and evaluated in terms of their relative benefits and costs. A number of measures were recommended as a result of the analyses. These included a levee at Overett Avenue, with channel enlargement and a bypass floodway, bridge waterway enlargements at Bringelly Road and Elizabeth Drive and a levee at Victor Avenue with a compensating bypass floodway, which have all been implemented.

Water quality analyses were also carried out to establish the water quality conditions in the South Creek catchment and the likely impacts of urban development on water quality within the study area. A number of water quality measures were proposed as part of the study.

2.2.3 ADI St Mary's Water Cycle & Soil Management Study (Sinclair knight Merz, August 1998)

Sinclair Knight Merz undertook this study to address matters relating to water cycle and soil management to support the Regional Environmental Plan for the ADI St Marys site. The site is located at the downstream end of the South Creek catchment, with approximately 3 river kilometres of the creek passing through the site between the northern and southern site boundaries. The site ultimately discharges to South Creek and Stony Creek. The study addresses both site specific and mainstream flooding issues for South Creek.

A RAFTS model was developed for the site to determine the peak flow rates for three scenarios, including existing conditions, proposed conditions without flow mitigation and proposed conditions with flow mitigation. Peak site discharges were determined for the 50%, 20%, 10%, 5%, 2% and 1% AEP events. Twelve (*12*) detention basins were proposed to ensure no net increase in the peak discharges for the design events due to the development.

A hydraulic assessment of flood behaviour in South Creek was conducted in 1997 to determine the impact of the proposed development within the ADI site. The assessment was undertaken using the MIKE11 model developed for the 'Flood Study Report South Creek' (*DWR, 1990*).

However, additional cross sections were incorporated within the model in order to provide a more reliable assessment of the flood behaviour across the site and the impacts associated with proposed filling for the site development.

The flood behaviour along South Creek was assessed for a range of design flood events, including the 5%, 2% and 1% AEP events and the PMF. The flood event 20% greater than 1% AEP event was also investigated. The 1% AEP event for the study corresponds to the 1% AEP catchment event for South Creek and the 20% AEP in the Hawkesbury River.

The results of this assessment are documented in the document 'ADI St Marys Redevelopment – Flood Levels Assessment for Filling within the Floodplain of South Creek' (Sinclair Knight Merz, April 1997). The peak flood levels determined in the study are shown in **Tables 2-4** and **2-5** for key locations along South Creek and Ropes Creek, respectively.

Table 2-4 Simulated Flood Levels for South Creek from the 'ADI St Mary's Watercycle & Soil Management Study, Final Study Report' (1998)

LOCATION	PEAK FLOOD LEVEL (*mAHD*)	
	PMF	1% AEP Event
Dunheved Road	25.97	22.56
Upstream Extent of the ADI Site	24.59	20.63
30 metres Upstream of Munitions Road Bridge	23.95	19.76
50 metres Downstream of Munitions Road Bridge	23.68	19.60
Downstream Extent of the ADI Site	23.21	18.09

Table 2-5 Simulated 100 Year ARI Flood Levels for Ropes Creek from The *'ADI St Mary's Water Cycle & Soil Management Study'* (1998)

LOCATION	PEAK 1% AEP FLOOD LEVEL (*mAHD*)
Upstream of St Marys STP	20.26
Downstream of St Marys STP	19.79
30 metres Upstream of Munitions Road Bridge	19.70
50 metres Downstream of Munitions Road Bridge	19.27
Confluence with South Creek	18.92

The MIKE 11 model was used to simulate flood levels and response times on the floodplain with the proposed development (filling plus replacement of Munitions Road Bridge). The Munitions Road Bridge has been removed since 1991 Study however, the approach embankments remain in place.

2.2.4 Austral Floodplain Risk Management Study and Plan, Review and Finalisation (*Perrens Consultants, September 2003*)

This study covers the Kemps Creek catchment within the Liverpool LGA and was carried out by Perrens Consultants as part of the '*South Creek Floodplain Risk Management Study and Plan for the Liverpool Local Government Area*' (*Bewsher Consulting Pty Ltd, 2004*).

The study area includes the Austral-Kemps Creek area between Elizabeth Drive and Bringelly Road and a small portion of the Bonds Creek catchment upstream of the Hume Highway which lies within Liverpool LGA.

A RAFTS model was developed for Kemps and Bonds Creeks and used to estimate flows under existing conditions for the 20%, 5% and 1% AEP events and the PMF (*based on Bulletin 51*).

A HEC-2 steady-state hydraulic model was developed to define the flood behaviour along Kemps and Bonds Creeks. Cross-sections for the model were extracted from photogrammetric survey of the study area and major hydraulic controls were defined by field survey. The results from the 1990 and 1991 studies were used to define boundary conditions. Peak flood levels from the simulation of the HEC-2 model are shown in **Tables 2-6** and **2-7** for Kemps and Bonds Creeks, respectively.

Provisional hydraulic and hazard categories were determined based on the 1% AEP event. Flood damages were also estimated for the Austral area, with the damage costs resulting from a 1% AEP flood determined to be $8.37M and the AAD estimated to be $1.8M.

Table 2-6 Simulated Flood Levels for Kemps Creek from the 'Austral Floodplain Risk Management Study and Plan, Review And Finalisation'

LOCATION	PEAK FLOOD LEVEL (mAHD)			
	PMF	1% AEP Event	5% AEP Event	20% AEP Event
Elizabeth Drive	47.5	46.5	46.1	45.9
Gurner Avenue	56.1	55.2	55.0	54.9
Fifteenth Avenue	57.8	56.9	56.7	56.6
Twelfth Avenue	60.6	60.1	60.1	60.1
Bringelly Road	74.3	74.0	73.9	73.9

Table 2-7 Simulated Flood Levels for Bonds Creek from the 'Austral Floodplain Risk Management Study and Plan, Review and Finalisation'

LOCATION	PEAK FLOOD LEVEL (mAHD)			
	PMF	1% AEP Event	5% AEP Event	20% AEP Event
Confluence with Kemps Creek	59.0	58.1	58.0	57.7
Tenth Avenue	63.1	62.4	62.2	61.7
Ninth Avenue	64.6	64.0	63.9	63.7
Fourth Avenue	66.0	65.1	64.4	64.1
Eighth Avenue	66.8	66.1	65.9	65.2
Seventh Avenue	67.9	67.1	66.9	66.5
Confluence with Scalabrini Creek	68.6	67.8	67.7	67.3
Edmondson Avenue	69.1	68.5	68.3	67.7
Sixth Avenue	69.9	69.2	69.0	68.8
Fifth Avenue	72.0	71.3	71.2	71.2
Bringelly Road	74.4	73.8	73.3	73.3
Cowpasture Road	78.7	78.4	78.0	77.5
Hume Highway	79.7	79.4	79.0	78.9
Denham Court Road	86.7	86.2	86.1	86.1

2.2.5 South Creek Floodplain Risk Management Study and Plan for the Liverpool Local Government Area (*Bewsher Consulting Pty Ltd, December 2004*)

This report details the floodplain risk management study and plan undertaken by Bewsher Consulting, in association with Don Fox Planning. The study covers the South Creek and Thompsons Creek floodplains that lie within the Liverpool LGA.

As part of this study, Bewsher Consulting Pty Ltd made modifications to a MIKE 11 sub-model developed in the mid 1990's. This sub-model extends from 2.5 kilometres downstream of Elizabeth Drive to just downstream of Bringelly Road.

The MIKE 11 sub-model was originally developed for a number of studies that were undertaken in 1994 to 1997 to examine the flood mitigation options for the Overett and Victor Avenue areas in more detail. The hydrologic and hydraulic analyses undertaken as part of these studies were based on the RAFTS and MIKE 11 models from the '*South Creek Floodplain Management Study*' (*1991*). The sub-model of South Creek was created from the 1991 MIKE 11 model and incorporates greater topographic detail through the addition of cross-sections in the Overett and Victor Avenue areas.

The flood mitigation works that were completed in the late 1990's in response to the 1986 and 1988 floods, as recommended in '*South Creek Floodplain Management Study*' (*1991*) were also incorporated within the sub-model, including:

- a new bridge under Elizabeth Drive about 150m east of the main South Creek crossing; and,
- about 500m of floodway channel between Overett Avenue and north of Elizabeth Drive.

As part of this study, the model was updated to include the new two-lane road bridge was built by the Roads and Traffic Authority (RTA) over the main South Creek crossing of Elizabeth Drive. These works were completed in 1996 as part of the RTA's proposed future upgrade of Elizabeth Drive.

The model was also modified to incorporate Thompsons Creek and extend the upstream extent of the model to about 800 metres upstream of Bringelly Road. The model developed for this floodplain management study is referred to as the '*2003 MIKE 11 model*' and represented the best available information for the South Creek and Thompsons Creek floodplains within the Liverpool LGA.

The '*2003 MIKE 11 model*' was used to simulate the 20%, 5%, 2% and 1% AEP events and the PMF. The simulated flood levels at key locations along South Creek and Thompsons Creek are presented in **Tables 2-8** and **2-9**, respectively.

The study involved the definition of flood hazards and hydraulic categories within the study area. The hydraulic floodway limit was determined based on the encroachment approach.

The impacts and the costs of flooding in the study were also determined using the results of the MIKE 11 model. The flood damages resulting from a 1% AEP event in the study area were estimated to be $3.1M and the Average Annual Damages (*AAD*) were calculated as $420,000 (*in 2004 dollars*).

Table 2-8 Simulated Flood Levels for South Creek from the *'South Creek Floodplain Risk Management Study'*

LOCATION	PEAK FLOOD LEVEL (mAHD)				
	PMF	1% AEP Event	2% AEP Event	5% AEP Event	20% AEP Event
Upstream of Bringelly Road	60.28	59.30	59.01	58.55	57.96
Downstream of Bringelly Road	59.60	58.27	58.18	58.04	57.80
Confluence with Thompsons Creek	54.79	53.31	53.20	53.03	52.75
Upstream of Elizabeth Drive	44.42	42.64	42.49	42.21	41.80
Downstream of Elizabeth Drive	44.16	42.61	42.47	42.20	41.79
South Creek Dam	39.89	38.61	38.51	38.31	37.84

Table 2-9 Simulated Flood Levels for Thompsons Creek from the *'South Creek Floodplain Risk Management Study'*

LOCATION	PEAK FLOOD LEVEL (mAHD)				
	PMF	1% AEP Event	2% AEP Event	5% AEP Event	20% AEP Event
Downstream of The Northern Road	70.43	69.77	69.68	69.58	-
Just upstream of The Retreat	59.41	58.9	58.87	58.81	-
250m upstream of Confluence with South Creek	54.25	52.88	52.78	52.65	-

2.2.6 Updated South Creek Flood Study (WorleyParsons, *January 2015*)

Advisian/WorleyParsons completed a Flood Study of the South Creek catchment between Bringelly Road to the south and Richmond Road to the north. The study was joint funded by Penrith, Blacktown, Fairfield and Liverpool City Councils.

The study involved the first development of a two-dimensional hydrodynamic model of the South Creek floodplain using the RMA-2 software package. In addition to modelling South Creek, the RMA-2 model included the floodplains of Kemps, Ropes, Badgerys, Cosgroves, Blaxland, Claremont and Werrington Creeks.

The XP-RAFTS hydrologic model that was originally developed as part of the original *South Creek Flood Study* (1990) was adopted as a base for this study. The sub-catchment delineation was updated to reflect more recent topographic data in the form of 2002 Aerial Laser Survey, and impervious/pervious percentages were also reviewed against recent aerial photography.

The outputs form the hydrologic model were then applied to the RMA-2 model as continuity line and local element inflows. The RMA-2 model was validated based on modelling of the 1986 and 1988 historic floods. Simulated flood levels were compared to recorded flood levels to assess the performance of the hydraulic model and to check its reliability.

The hydrodynamic model results were used to prepare flood level, depth and velocity mapping for the 5%, 2%, 1%, 0.5% and 0.2% Annual Exceedance Probability (*AEP*) floods and the Probable Maximum Flood (*PMF*). Provisional flood hazard and hydraulic category mapping was prepared for the 1% AEP flood.

Other extracts form the flood study modelling included Flood Planning Area (*FPA*) mapping, an assessment of the flood immunity at key road crossings and information on the timing / rate of rise of flood levels throughout the study area.

3. Community Consultation

In preparing the Floodplain Risk Management Study it is important to understand the views of the local community at risk or affected by flooding. In this regard, a community consultation program formed part of the process to develop the study, including newsletters, a questionnaire, and a workshop to obtain community feedback.

The Draft Floodplain Risk Management Study (this report) will also be placed on Public Exhibition. The community will be invited to an information session where the findings of the study will be presented.

3.1 Newsletter and Questionnaire

A community newsletter and questionnaire were mailed to all households and businesses in the Penrith LGA that were identified as being flood prone; that is, potentially at risk of flooding up to the PMF. The area of flood prone land was based on the PMF extent that was mapped for the *'Updated South Creek Flood Study'* (*2015*). The purpose of the questionnaire and newsletter was twofold:

(i) to inform the community of the findings of the Flood Study and the ongoing Floodplain Risk Management Study; and,

(ii) to allow Advisian and Council to better understand the perceptions of the local community with regard to flooding and the potential flood mitigation options.

The main purpose of the questionnaire was to:

- understand people's perception of flood risk;
- identify whether or not their local area or current address had experienced flooding, and if so, when and under what circumstances it flooded;
- identify areas where priority should be placed for any future flood management work; and,
- ask community members for their opinions on potential mitigation measures and whether they would support them.

A copy of the newsletter and questionnaire is provided in **Appendix A**.

3.2 Questionnaire Findings

The findings of the Questionnaire, based on each of the thirteen open and closed questions asked, are discussed in the following sections.

3.2.1 Response Rate

The questionnaire was mailed to approximately 4,000 addresses within the South Creek catchment. A total of 76 responses were received online, a further 182 by mail and two by email. The total number of responses was 260 which represents a 6.5% response rate. This is considered to be a reasonable response rate given the majority of the 4,000 properties invited to participate are located on land with a low-risk of flooding; that is, located on land above the 1% AEP flood.

The majority of responses were from residential and rural residential property owners and tenants with 87% of the responses received. Industrial and commercial premises made up another 4% each and "other" accounted for 6% of responses.

As the survey mail out was targeted to those people within flood prone areas it should be expected that a reasonably high percentage of respondents have opinions regarding flood related issues. People who feel affected by the subject of a questionnaire are more likely to respond than those who do not believe the issue affects them. The response analysis suffers from a non-response rate of over 90%. This non-response leads to the survey results to have bias toward those who have some flood awareness, are likely to be most at risk (*i.e., lower lying properties*) and also to residential properties.

3.2.2 Who Responded

Identifying where respondents live can indicate areas where flooding is of greater concern to residents, as those in more flood prone areas are often more inclined to respond. Understanding how long residents have lived in an area is useful in gauging the level of flood awareness in the community; i.e., those residents who have lived in the area for longest may have experienced flooding and are more likely to have an awareness.

Where do Respondents Live

The location of respondents across the Study Area and is summarised in **Table 3-1Error! Reference source not found.**. Where respondents contact address differed to the actual property address, the property address location has been counted if known.

Table 3-1 Number of Respondents per Suburb

SUBURB	RESPONSES		SUBURB	RESPONSES	
Berkshire Park	13	(5.5%)	Mulgoa	1	(0.4%)
Bringelly	1	(0.4%)	North St Marys	1	(0.4%)
Claremont Meadows	18	(7.7%) [4]	Orchard Hills	12	(5.1%)
Colyton	3	(1.3%)	Oxley Park	6	(2.6%)
Cranebrook	1	(0.4%)	Penrith	2	(0.9%)
Eastern Creek	2	(0.9%)	St Clair	14	(6.0%)
Erskine Park	1	(0.4%)	St Marys	39	(16.6%) [2]
Glenmore Park	1	(0.4%)	Werrington	57	(24.3%) [1]
Kemps Creek	9	(3.8%)	Werrington County	12	(5.1%)
Llandilo	23	(9.8%) [3]			
Londonderry	1	(0.4%)	Other / Not Known	16	(6.8%)
Luddenham	2	(0.9%)			

[1] Indicates an overall ranking for four suburbs that received the most responses

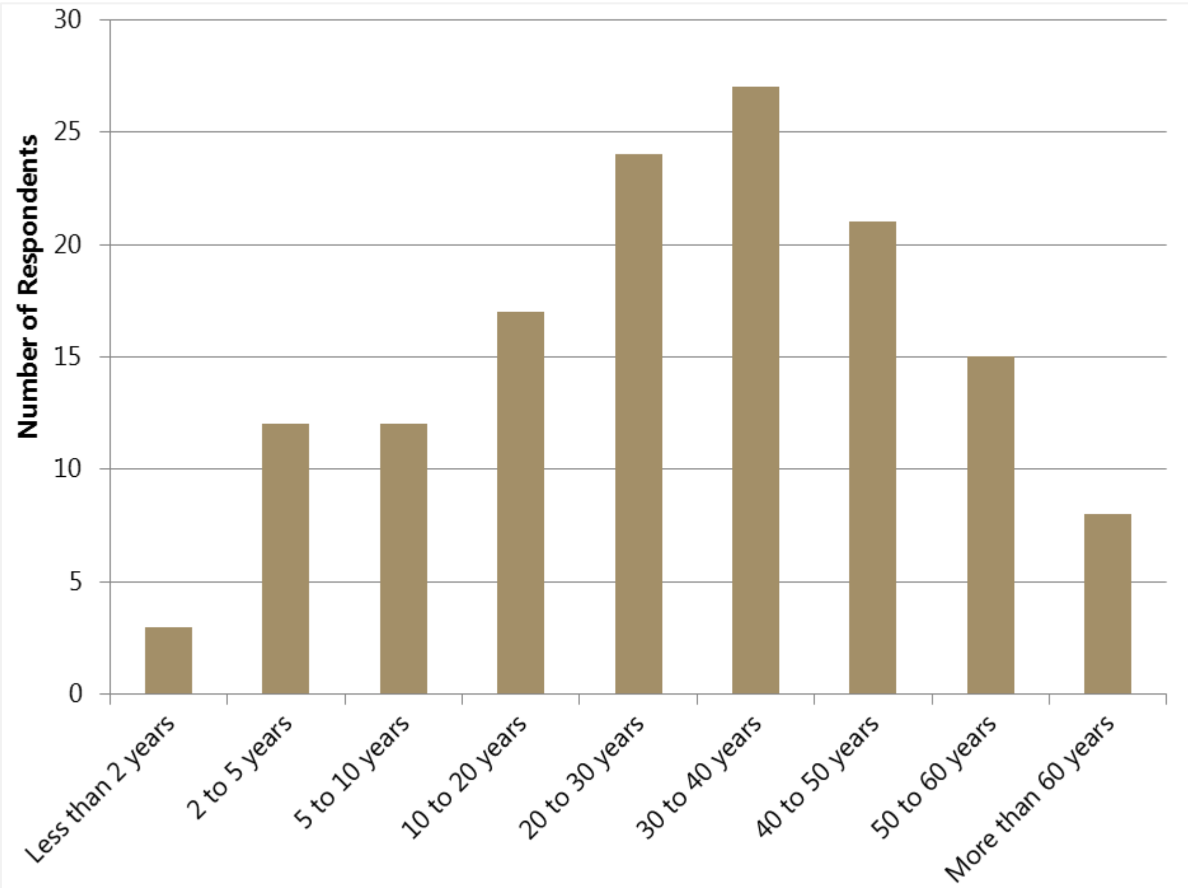
The areas with greatest percentage of responses came from Werrington (24.3%), St Marys (16.6%), Llandilo (9.8%) and Claremont Meadows (7.7%). Interestingly these areas coincide with high priority areas raised by Council and the Floodplain Risk Management Committee toward the start of the Floodplain Risk Management Study.

The four highest responding areas are some of the most flood prone within the South Creek catchment study area. This may have prompted a higher rate of responses due to a general higher level of public interest in flooding issues. Both Werrington and St Marys have flood protection levees and such visual reminders of the potential of flooding can mean the general public maintain a level of interest in the issue.

How Long Have Respondents Lived in the Area

Graph 3-1 shows the period in which respondents have lived within the area. Over 50% of the respondents have lived in the area for over 30 years and therefore may remember the larger flood events of the 1980s. This indicates that some residents would be likely to have an awareness of flooding issues and furthermore some residents living in the more flood prone areas may be aware of the risk to their own property through having experienced flooding to personal property.

Over 10% of respondents have moved into the area in the last 5 years. These people are least likely to be aware of the existing flood risk or be aware if their own property could be subject to inundation, particularly those people living in rented accommodation.

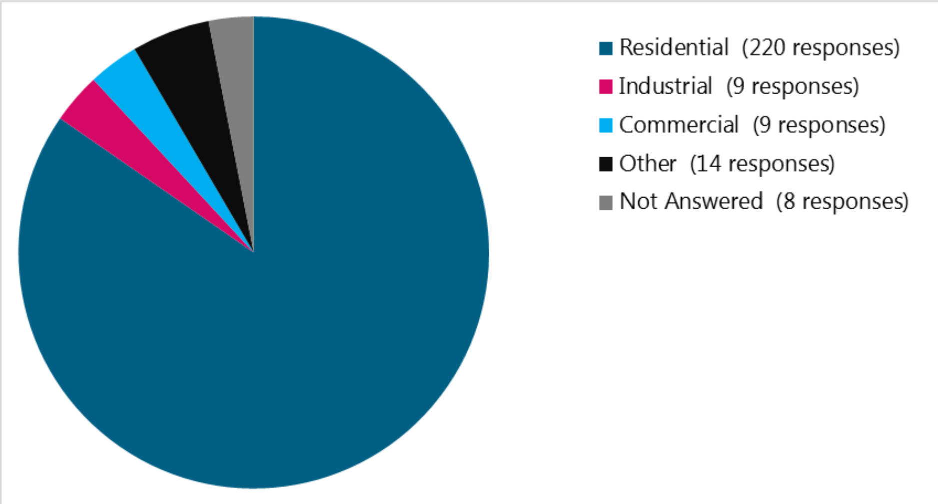


Graph 3-1 Period of Time Respondents Have Lived in the Area

What Type of Properties do the Respondents Own

As shown in **Graph 3-2**, the majority of responses received were from residential properties. A small number of people selected 'residential' as a response but also commented that their property was 'rural residential'. Other responses where comments suggested the property was rural residential are counted in the residential category. Non-residential responses ranged from small businesses to child care and primary production and are shown in **Table 3-2**.

The responses to this question show that it is home owners and occupiers who may feel more affected by the flooding issue than non-residential owners and occupiers. However, this result can be skewed by a tendency for residential occupants to be more likely to respond to the questionnaire than businesses and other uses.



Graph 3-2 Responses by Building Use Type

Table 3-2 Non-Residential Property Types and Their Uses

PROPERTY TYPE	PROPERTY USE
Industrial	- warehouse and factory - proposed development (x2) - bus depot
Commercial	- child care (x2) - quarry and resource recovery - motor repair centre - primary production - business - shopping centre
Other	- grazing / rural (x3) - farm / primary production (x4) - business - Warragamba Pipe line crossing west of Mamre Road - animal shelter and vet - vacant

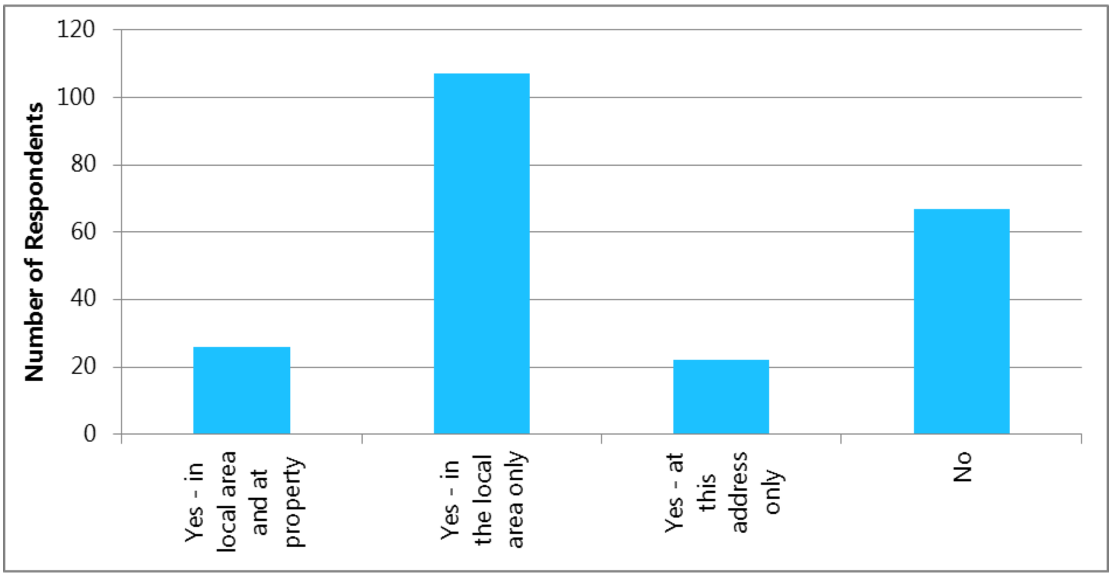
3.2.3 Flood Experiences of Respondents

The perceptions of respondents with regard to previous flood experiences, or lack thereof, and preferred flood prevention or reduction measures are discussed in the following.

Flood Affectation

The questionnaire asked the number of respondents who had been affected by flooding in the past. Often this type of question can be skewed towards a positive "yes" response by the nature of the survey being sent to only people within flood prone areas and being answered by those most interested in the issue. Therefore, the percentage of yes and no responses should not be taken as representative of the community as a whole.

As shown in **Graph 3-3**, 70% of respondents to this question reported having been affected by some form of flooding, either in the local area, at their property or both. It is not uncommon that Flood Study surveys show a high incidence of people reporting flooding as these are the people interested in the topic of the questionnaire. People who have not experienced flooding have a tendency to not respond to a questionnaire as they feel it does not affect them.



Graph 3-3 Number of Respondents Affected By Flooding in the Past

A total of 133 people stated that they been affected by flooding in the local area, with 26 of these also being affected by flooding at their property. A further 22 people reported flooding only at their property but not in the local area. Streets where people reported some degree of flooding to their property are show in **Table 3-3**. From this, particularly flood prone areas can be identified for consideration in the FRMS.

Table 3-3 shows that the suburbs of Werrington, St Marys and Llandilo are particularly affected by flooding. The most reports of flooding were on Pages Road, St Marys (*4 properties),* Luddenham Road, Orchard Hill (*3 properties*) and Josquin Way, Claremont Meadows (*3 properties*).

Table 3-3 Residential Streets Where Residents Have Reported Flooding to Their Property

AREA	STREET	NUMBER OF PROPERTIES
Llandilo / Berkshire park	▪ Mayo Road (2) ▪ 7th Avenue (2) ▪ 8th Avenue (2) ▪ Sirius Place (1)	7
St Marys	▪ Saddington Street (1) ▪ Pages Road (4) ▪ Cole Place (1) ▪ Schleicher Street (1) ▪ Charles Street (1) ▪ Smith Street (1)	9
Colyton	▪ Patricia Street (1)	1
St Clair	▪ Jari Close (1)	1
Claremont Meadows	▪ Henze Crescent (1) ▪ Josquin Way (3)	4
Orchard Hill	▪ Luddenham Road (3)	3
Werrington	▪ Albert Street (1) ▪ Lack Place (1) ▪ Landers Street (2) ▪ Chapman Street (1) ▪ Victoria Street (2) ▪ Heavey Street (2) ▪ Kazanis Court (1) ▪ Isabella Street (1) ▪ Gibson Avenue (1) ▪ Semaan Street (1)	13
Werrington County	▪ Hume Crescent (1)	1
Bringelly	▪ Jersey Road (1)	1
Address not given		5

People were also asked to provide comments on the time and place where they had been affected by flooding. Where dates and locations were provided these are summarised in **Table 3-4** below. It is of note that a number of the events are as a result of stormwater rather than mainstream flooding from South Creek and its tributaries.

The responses indicate that the most significant period of flooding occurred during the 1980s with 19 people referencing instances of flooding from 1980 to 1989. Seven people commented on flooding during the 1990s while there was only one comment regard flooding in the first decade of 2000. Twenty-six people have reported flooding since 2010.

Although more people have reported flooding in the last six years than previous decades, this does not necessarily mean that incidences of flooding are increasing. This value can be influenced by being in the more recent memory of people and the time people have lived in the area.

Table 3-4 "Flooding" Events Noted by Respondents (*Continues Over 3 Pages*)

DATE	LOCATION / COMMENTS	NUMBER OF COMMENTS
1947 to 1965	▪ Putland Street, St Marys	1
1965 to 1980	▪ Heath Street, Kingswood	1
1960s	▪ Gibson Avenue and Princess Street	1
1970s	▪ Minor inundation of parkland at the eastern end of Erwin Street, Werrington (late 1970s) ▪ Heavey Street made impassable by flows from Werrington Creek ▪ Gibson Avenue and Princess Street	3
(about 20-years ago) 1980's or 1990's - unsure	▪ Victoria Street, Werrington near the shops and bridge over Werrington Creek	1
1980s	▪ From Auburn to Penrith, Werrington Station Shop and football field (early 1980s) ▪ Minor inundation of parkland at the eastern end of Erwin Street, Werrington ▪ Most flooding occurred in the 1980s but was mainly on Eastern Creek. ▪ Creek at back of property has flooded, Luddenham Road, Erskine Park ▪ Forrestor Road, North St Marys ▪ Gibson Avenue and Princess Street	6
March 1983	▪ Princess Street and Gibson Street	1
1985	▪ Heavey Street made impassable by flows from Werrington Creek	2
1986 - 1989	▪ Llandilo - Flooded about 3 times during this period	1
1986	▪ Werrington area ▪ Hobbart Street was under deep water between Glossop to Sydney Streets ▪ Cole Place, St Marys (resident's backyard only) (August)	3
1987	▪ Werrington Shops ▪ Rance Oval ▪ Parkland along Charles Stuart Drive	1
1988	▪ Werrington Area ▪ Entire property on Pages Road flooded ▪ Two residential properties on Pages Road, St Marys, flooded (30 April 1988) ▪ Cole Place, St Marys (resident's backyard only) (April 1988)	4
1989	▪ Water reach three steps high at property on Pages Road, St Marys	1

DATE	LOCATION / COMMENTS	NUMBER OF COMMENTS
1990s	▪ Pool Street collapsed due to flooding of Dunheved Golf Course and Greenway ▪ Creek at back of property has flooded, Luddenham Road, Erskine Park ▪ Flooding at the intersection of Solander Drive and Mamre Road (1991) through heavy weeks of rain ▪ Werrington area – twice between 1990 and 1995	4
1990	▪ Heavey Street made impassable by flows from Werrington Creek	1
1994	▪ The bridge on 8th Avenue, Llandilo	1
1995	▪ "Near park and Creeks" No specific location given	1
2007/2008	▪ Area in and around Werrington Golf Course flooded due to abnormal amount of rainfall	1
2010	▪ Heavey Street made impassable by flows from Werrington Creek	1
2011	▪ Caddens Road and the Claremont Meadows Reserve - Water entered back yards and houses of a few properties on Josquin Way that back onto Caddens Road. Roads in and out of Claremont Meadows were flooded and closed. (date could be 2010 to 2012)	1
2012	▪ 30cm of water from the south side of Semaan Street flooded garages and yards.	1
February 2012	▪ Heavey Street flooded at Burton Street and Lethbridge Street, Werrington, preventing vehicle access (9th Feb 2012) ▪ Eastern and western ends of Heavey Street, Werrington ▪ Corner of Solander Drive and Mamre Road, St Clair – flooding happened 4 times in 3 weeks	3
2014	▪ Extensive flooding brought on by several hours of Heavy rain – Josquin Way and surrounds, Claremont Meadows (unsure of date, thinks 2014) ▪ Units on Short Street, Carlton, flooded during heavy rain, Flooding to the yard, laundry area to as deep as middle of washing machine, Left mud in the room when water was gone. (unsure of date, thinks "about 2 years ago")	2
2015	▪ Melbourne Street at the bottom end of Hobart Street (during summer) ▪ Heavey Street, Werrington ▪ Heavey Street made impassable by flows from Werrington Creek ▪ Burton Street, Werrington ▪ Victoria Street, Werrington ▪ Luddenham Road closed at Mamre Road due to flooding over the bridge and roadway ▪ Mistletoe Avenue, Claremont Meadows – water went 500 mm over the property boundary	6

DATE	LOCATION / COMMENTS	NUMBER OF COMMENTS
March 2015	▪ Saddington Street and Putland Street due to the insufficient stormwater drain capacity that runs along the front of property and parallel streets and blockage of drainage.	1
April 2015	▪ Corner of 7th and 2nd Avenue, Llandilo	2
December 2015	▪ Flooding from creek at back of property – no location given	1
2015 / 2016	▪ Within the past 2 years West and North of Mandalong Close were subject to partial flooding	1
Early 2016	▪ No details given	3
23rd January 2016	▪ Kingsway and Werrington Road roundabout	1
24th January 2016	▪ The Kingsway towards Charles Hackett Drive before the bridge, St Marys,	1
February 2016	▪ Worst flooding in memory (location not given) ▪ Corner of Solander Drive and Mamre Road, St Clair	2

In addition to the events listed in **Table 3-4**, respondents identified a number of areas where they have noted flooding. These are summarised in **Table 3-5**. Key themes across the question responses are flooding in the Werrington, Llandilo and the St Marys areas. The streets mentioned by respondents varied significantly with most streets only being mentioned by one person. It is likely that a number of these areas have been subject to local stormwater flooding and are not subject to mainstream flooding from one of the watercourses.

The streets mentioned most are:

- The Kingsway (St Marys / Werrington)
- Victoria Street, Werrington
- Albert Street, Werrington
- Mamre Road, St Marys and St Clair
- St Marys Road / Stoney Creek Road and the causeway, Llandilo.

Table 3-5 Flooding Hot Spots (*Continues Over 3 Pages*)

AREA	STREET	NUMBER OF COMMENTS

Llandilo / Berkshire park	▪ Roads in the Llandilo area (4)
	▪ Roads in the Berkshire Park Area (1)
	▪ 2nd Avenue between 7th and 8th Avenue (2)
	    ○ Almost yearly
	    ○ When drains overflow
	▪ 6th Avenue (1)
	    ○ Flash flooding due to an overflow channel running south to north
	▪ 8th Avenue (4)
	▪ 9th Avenue between 3rd Avenue and Northern Road (1)
		26

AREA	STREET	NUMBER OF COMMENTS
	▪ St Marys Road and Stoney Creek Road (4) ▪ South Creek Causeway, St Marys Road (5) – 3 or 4 times a year ▪ Spence Road (1) ▪ Richmond Road (1) ▪ Palymra Road (1) ▪ Llandilo Bridge (1) ▪ Bisht Avenue to Llandilo Road (1) ▪ Localised flooding at the back of personal property (1)	
St Marys	▪ St Marys area (1) ▪ Forrester Road (1) ▪ Pages Road - during heavy rain (1) ▪ Charles Hackett Drive (1) ▪ Charles Street (1) ▪ St Marys Quarry site – flood during heavy rain as drains back up (1) ▪ Anne Street (2) ▪ Wilson Street (before levee was constructed) (1) ▪ Schleicher Street (2) – regular occurrence when there is significant rainfall – in yard ▪ Golf Course near links Road (1) ▪ Village Shopping Centre (1) ▪ Parklands and sporting fields near Ripples Leisure Centre (1) – Creek overflows and roads are closed ▪ The Kingsway (5) (see also Werrington) – Near Ripples Leisure Centre after heavy rain – Numerous times – Road closures	21
Oxley Park	▪ Braddon Street and Munmora Place (1) ▪ Durham Street crossing at Ropes Creek (1)	2
St Clair	▪ Corner of Solander Drive and Mamre Road (2) – Every time there is heavy rain ▪ Rotorua Road, St Clair (1) – Water came in from drain at back of property	3
Claremont Meadows	▪ Dolphin Close (1) ▪ Claremont Creek (1) ▪ Sports Oval (1) ▪ Gips Street (1)	4
Orchard Hills	▪ Mamre Road (2) – Between Kerrs Road and Mount Vernon	3

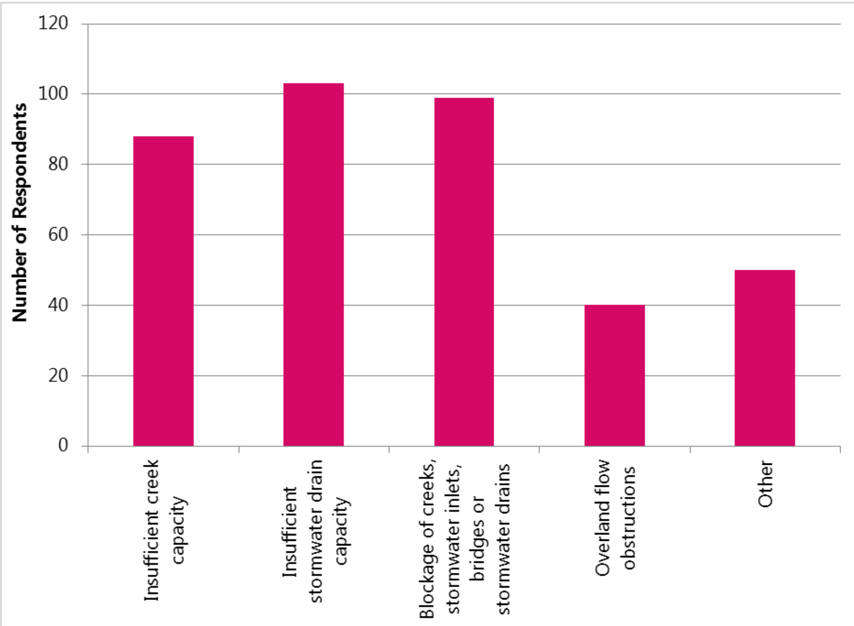
AREA	STREET	NUMBER OF COMMENTS
	▪ Samuel Marsden Road – heavy rain ponds in backyard and shed (1) ▪ Mandalong Close (1) ▪ Wentworth Road – floods during heavy rain (1) ▪ Luddenham Road (2) – Problems with creek crossing access	
Werrington	▪ Local street flooding (1) ▪ Albert Street (3) – Stormwater got into sewerage system – Near the cricket ground and becomes impassable during prolonged rains ▪ Victoria Street (5) – underground carpark of units always flooded – yards of houses – end of road towards railway station – Kazanis Court ▪ Heavey Street – flooding by Werrington Creek (1) ▪ Burton Street and Lethbridge Street bridges over Werrington Creek cut (1) ▪ Corner of Burton Street and Henry Street (1) ▪ Lack Place (1) ▪ Landers Street (1) ▪ Hume Crescent (1) – Water builds up at low side of property during rain ▪ Rance Oval (1) ▪ Werrington shops (2) – Flooding through shops about 400 mm deep ▪ Railway Station (2) ▪ Werrington Road (2) – And Parkland Golf course ▪ Parklands (3) ▪ The Kingsway (3) (See also St Marys) – Occurs about once a year – Detours to get to local shops needed	29
Area unknown	▪ Kemps Creek – overflows during heavy rain ▪ The Driftway ▪ Roads and sports fields ▪ Baseball fields	4

What Does the Community Believe the Cause of the Flooding Was?

This question explored the community's perception to the main causes of flooding and the problems they would expect to see resolved in a Floodplain Risk Management Study. Where the perceived cause of flooding is not fully aligned with the true cause of flooding, this can highlight the need for community education of the flood risks in their area.

Respondents were allowed to select more than one response for this question. 50% of responders identified insufficient creek or stormwater capacity as the cause of flooding and 26% of responders also identified blockage being an issue.

50 "other" responses were also provided. Questionnaire responses to this question are summarised in **Graph 3-4** and comments are summarised in **Table 3-6**.



Graph 3-4 Perceived Reasons for Flooding

Table 3-6 "Other" Perceived Reasons for Flooding

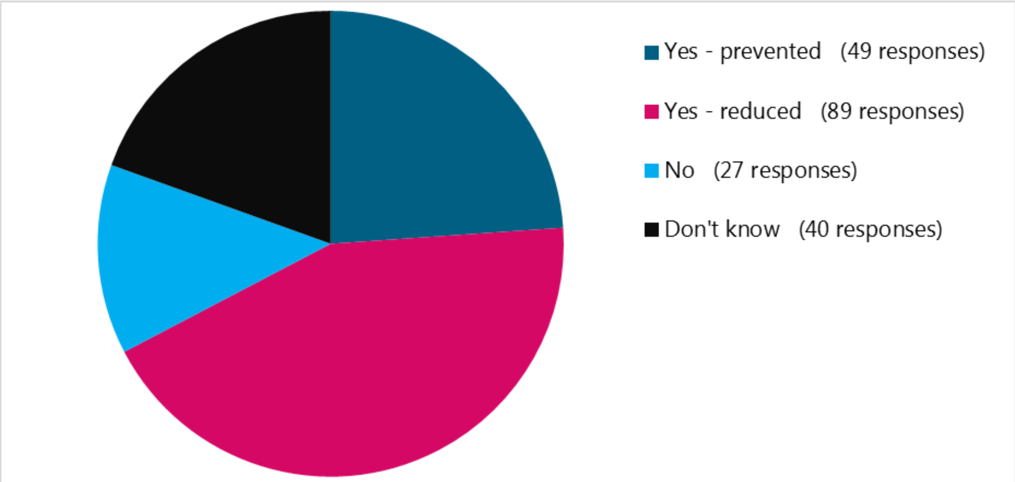
COMMENT	NUMBER OF COMMENTS
Development in the floodplain / new development	9
Above normal rainfall	8
Build-up of weeds / vegetation / debris and lack of cleaning	6
Flooding on the Hawkesbury Nepean / Releases from Warragamba Dam	5
Poor drainage design	5
Low points in roads or low level watercourse crossings	4
Other	4
Modification of drainage channels / creeks by others	1

COMMENT	NUMBER OF COMMENTS
Modification of land by others	1
Clearing trees and vegetation has caused flooding	1
Backup behind railway embankment	1
Stormwater runoff	1

Does the Community Believe This Flooding Could Have Been Reduced or Prevented?

As shown in **Graph 3-5**, 67% percent of people were of the opinion that flooding could have been prevented or reduced. 43% of people believe that flooding could have been reduced and a further 24% of people believe that flooding could have been prevented.

Some residents provided additional comments and details about actual events they have been affected by.



Graph 3-5 Perception on Prevention and Reducing Flooding – Do you think the flooding that you experienced could have been reduced or prevented?

3.2.4 Managing Existing Flood Problems

This section of the Questionnaire asked for additional opinions from residents on their feelings towards floodplain risk management. Often the opinions expressed by residents in regard to flood management reflect on their personal experiences with flooding and the area in which they live.

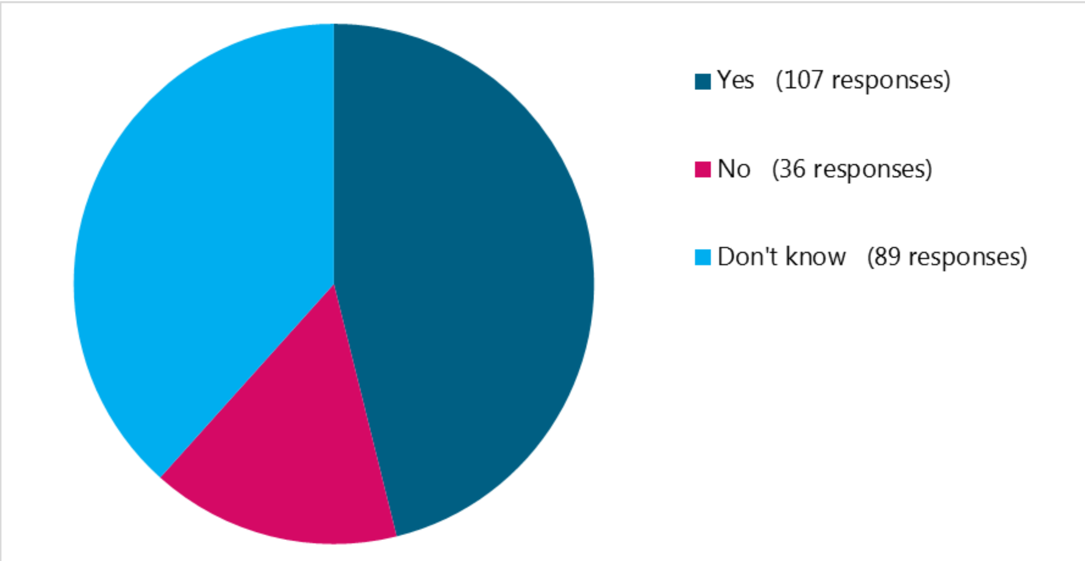
High Priority Areas

Respondents were asked if there were any areas where they believed resolving the flooding issue should be a high priority. As shown in **Graph 3-6**, 46% of respondents to this question identified areas where they believed flood management should be a priority. These are summarised in **Table 3-7**. Only areas where two or more respondents identified the area as a high priority area are shown.

Respondents to the questionnaire favoured protecting existing residential property. Seven people made comments on the causeway across South Creek at Stoney Creek Road. A number of these people would like to see a bridge in this area so that access can be maintained during times of flood on South Creek.

The Kingsway was also identified as a priority area for the community, in keeping with the responses from previous questions (*see* **Table 3-5**). The Werrington area was also considered high priority with respondents suggesting that flooding from Werrington Creek and flooding at Albert and Victoria Streets should be high priority.

In this section a number of people also made comments about maintaining the waterways and drainage within the area. Several people made comments on needing to clear vegetation and debris and rubbish from the creeks.



Graph 3-6 Perception High priority Areas – Are There Any Areas Within the Study Area which You Think Should be a Priority for Floodplain Management?

Table 3-7 Perceived High Priority Areas

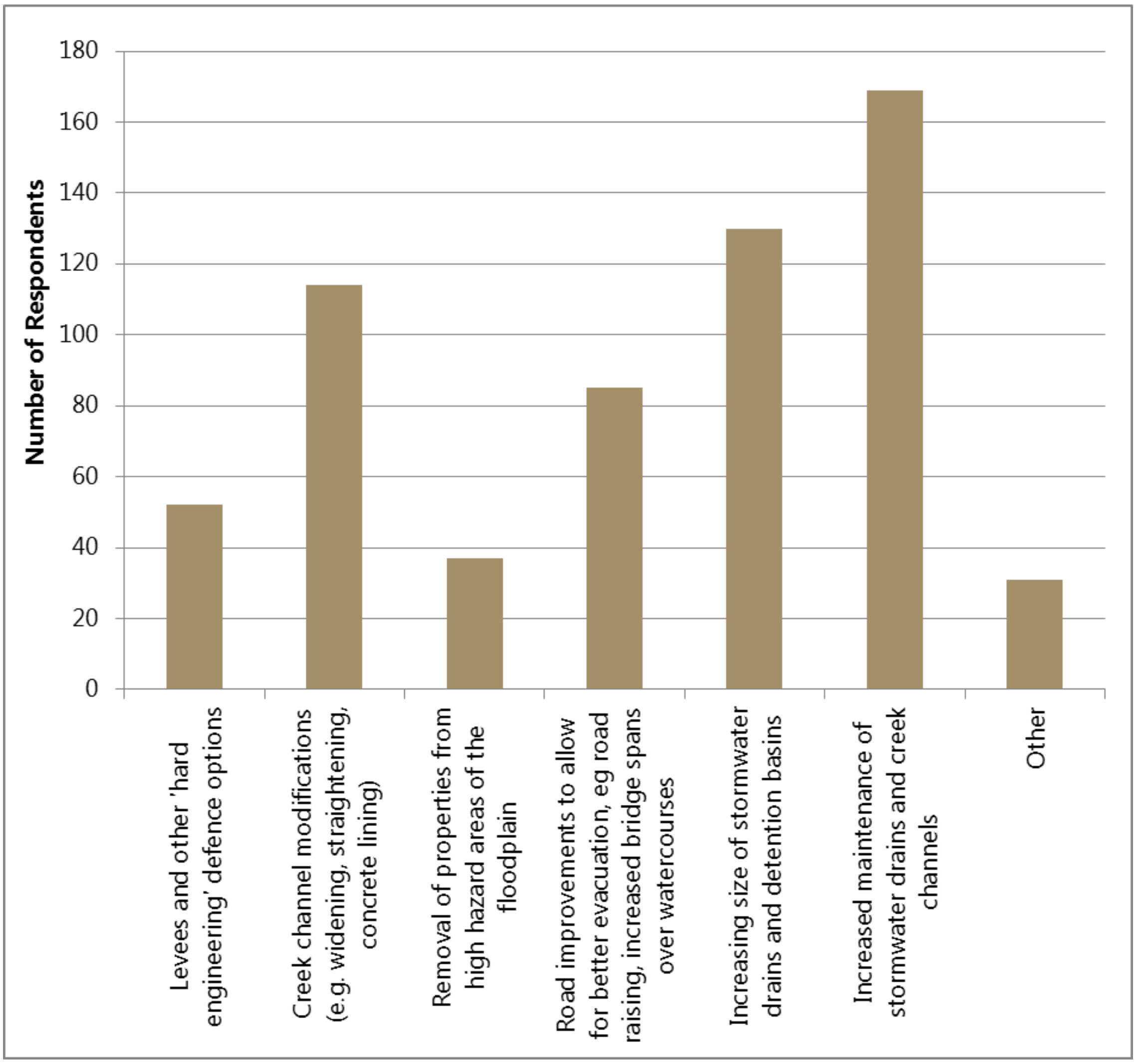
COMMENT	NUMBER OF COMMENTS
All of the Study Area	7
All existing residential property	7
The Causeway between St Marys Road and Stoney Creek Road	7
The Kingsway - including Werrington Road roundabout and surrounding area	6
Respondents personal property	5
Werrington - behind the levee, the ovals, and railway station	5
Werrington - Albert and Victoria Streets	4
Werrington Creek - John Oxley Avenue area, Prince Street, Hume Crescent, Malcolm Avenue, Burton Street Bridge	4

COMMENT	NUMBER OF COMMENTS
All current developed areas	3
Roads, especially main arteries	3
Llandilo – 2nd Avenue, 8th Avenue, Llandilo Road	3
Hospitals, Schools	2
Mamre Road	2
St Marys	2
St Marys (Byrnes Creek) Saddington Street and Putland Street commercial properties	2
Werrington Road – including Caddens Road	2

What Approach Would You Like to See Used in Managing Existing Flood Problems?

People were asked to select all the measures they would like to see to reduce the existing flood problem. As shown in **Graph 3-7**, the majority of people selected increased maintenance as a preferred option. Modification to watercourses and increasing the capacity of stormwater drainage systems also ranked highly. '*Hard engineering*' measures (*such as levees, diversion banks etc*) were ranked low on the preference list with only 47 respondents selecting this as a preferred option. 37 people would like to see properties removed from high hazard areas of the floodplain.

Other comments included improving evacuation, raising low bridge crossings, maintaining vegetative zones and new levees.



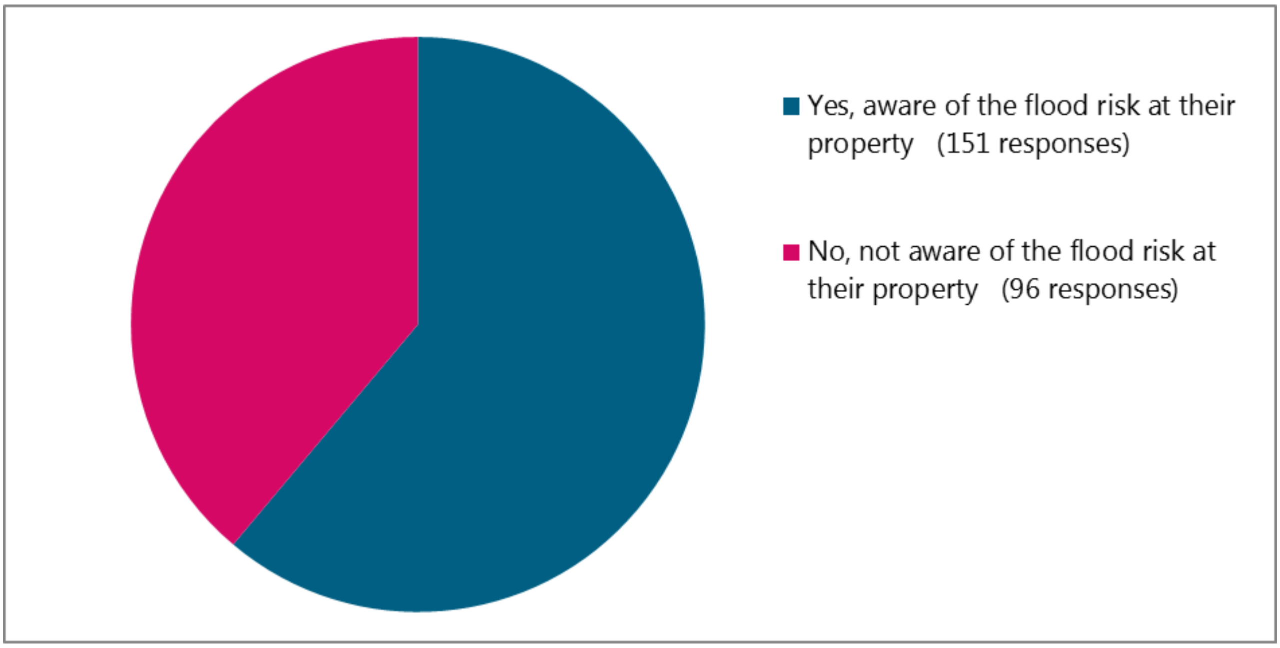
Graph 3-7 Respondents Opinions on Managing Existing Flood Risk

3.2.5 Flood Awareness

Questions asked within this section of the Questionnaire were designed to understand the level of flood awareness of the community. Answers to previous questions have indicated a good awareness of flooding, particularly in the areas of Llandilo, Werrington and St Marys.

Awareness of Flood at Personal Property

As shown in **Graph 3-8**, 61% of respondents to this question believe that they are aware of the flood risk to their property. Although this represents a high rate of awareness the response to this question can be skewed in that those aware or interested in flooding are more likely to respond to the questionnaire.



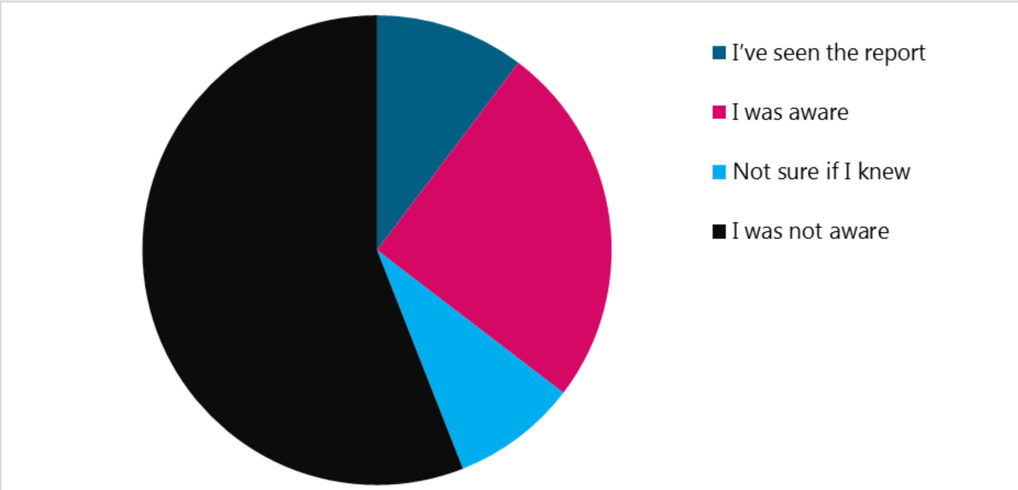
Graph 3-8 Respondents Awareness of Flooding at Their Property

Awareness of the South Creek Flood Study and its Findings

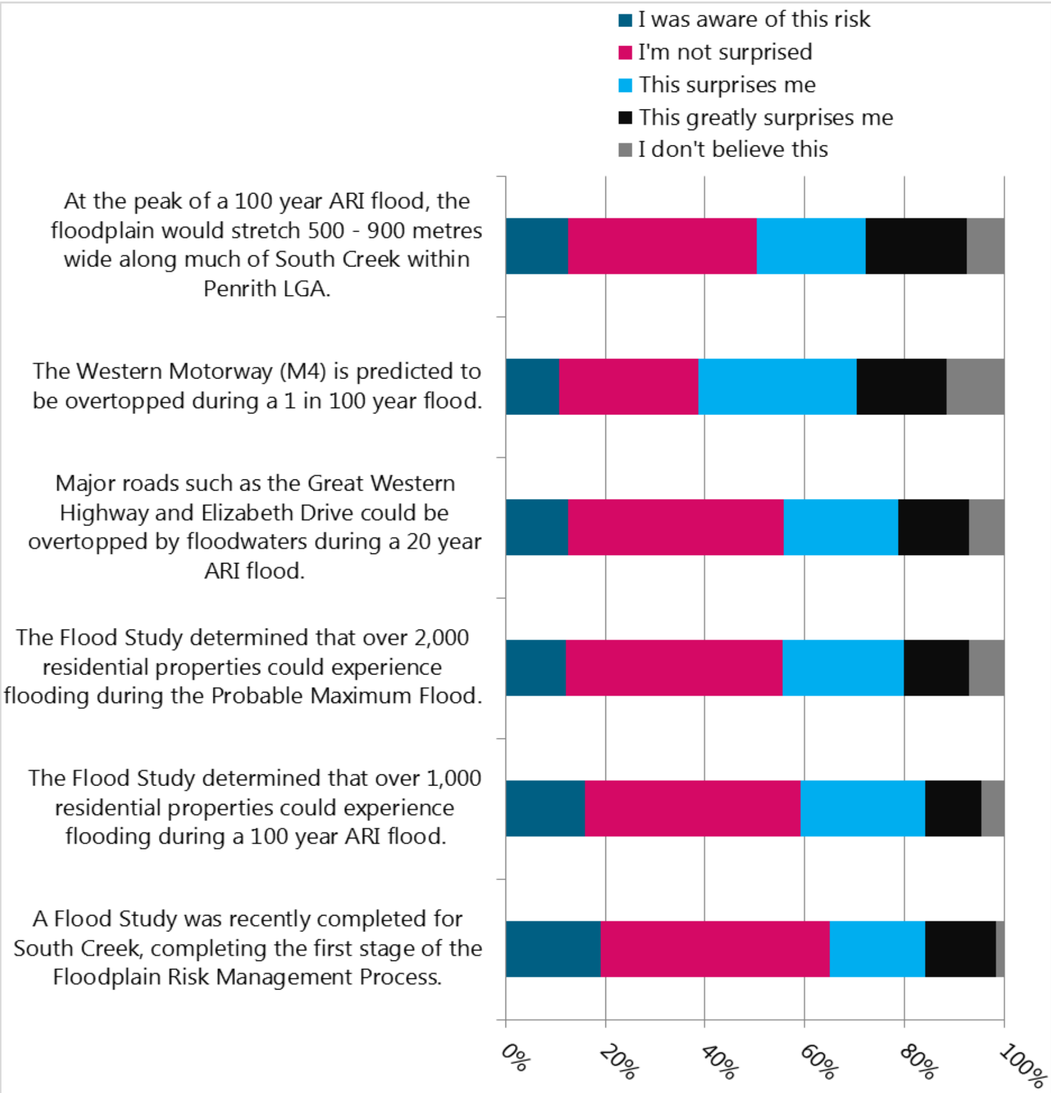
Residents were asked about the South Creek Flood Study. The purpose of these questions were two-fold; one to gain an understanding of current flood awareness in the community and secondly to provide some information to residents on the findings of the Flood Study.

Over half of the respondents were unaware of the South Creek Flood Study while 35% were aware of it or had even seen the report (*refer* **Graph 3-9**). While the 35% of people who are aware of the report is good, the large percentage of people who were not aware that the study had been completed indicated that there is potential to improve community awareness of flooding.

Graph 3-10 shows the perceptions of the community in regard to the findings of the Flood Study. Worrying is the number of "non-believers" and people who are surprised by the findings. While it would appear that the community is generally flood aware, the high percentage of people who are "surprised" indicates that people may be only aware of the small scale "nuisance" type flooding that they have been affected by in the past and are not aware of the implications of a major flood such as a 1% AEP event that last occurred in the mid 80's. This indicates that raising community awareness of the implications of flooding is important. In particular this should focus on major evacuation routes.



Graph 3-9 Awareness of the South Creek Flood Study



Graph 3-10 Awareness of Findings of the Flood Study

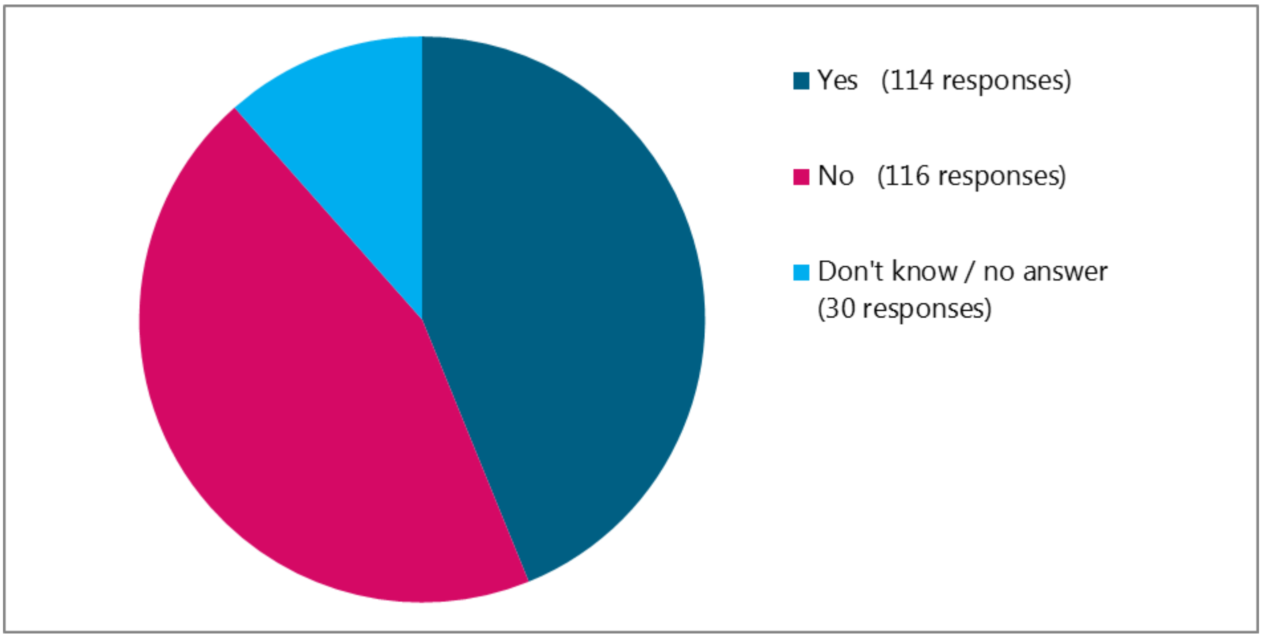
3.2.6 Future Flood Problems

Questions asked within this section were designed to understand how the community feel about climate change and the acceptable level of flood risk.

Perception of Climate Change

The community were asked if they believe climate change would impact on flooding in the future. Where there is a high percentage of "non-believers" in climate change this can make it more difficult for Council to gain community support when planning for the future.

Opinion on climate change is divided equally with about half of respondents believing and disagreeing that climate change will impact flooding in the future (*see* **Graph 3-11**). This indicates the need for community awareness regarding the potential impacts of climate change on flooding and how this would affect them.

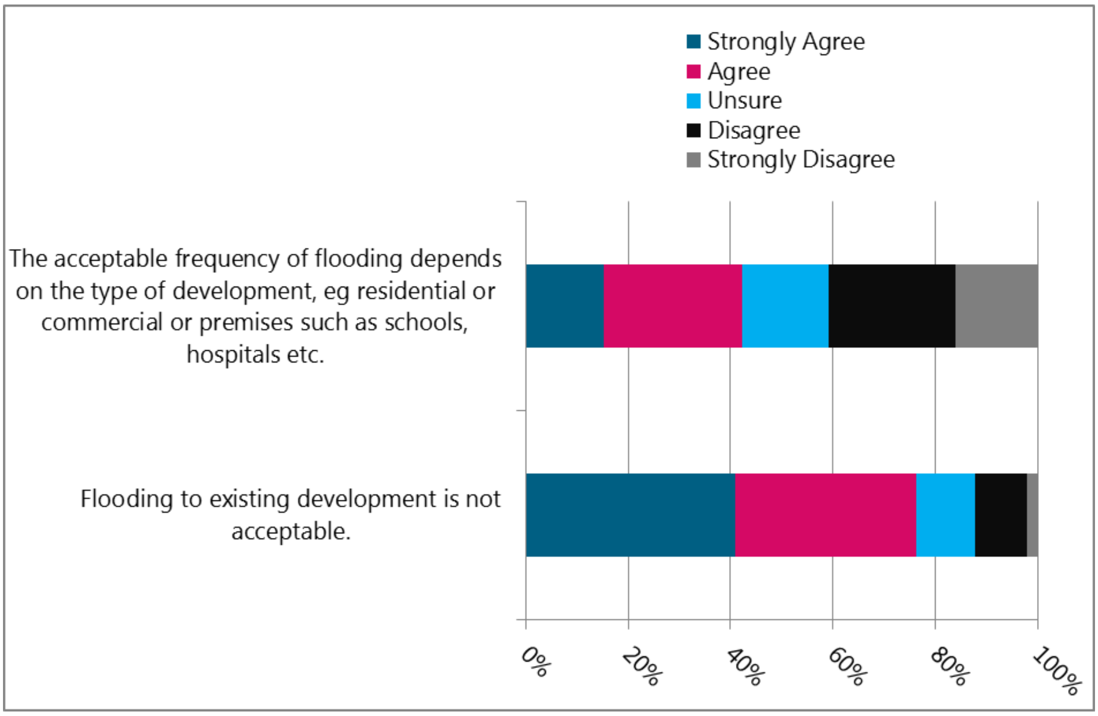


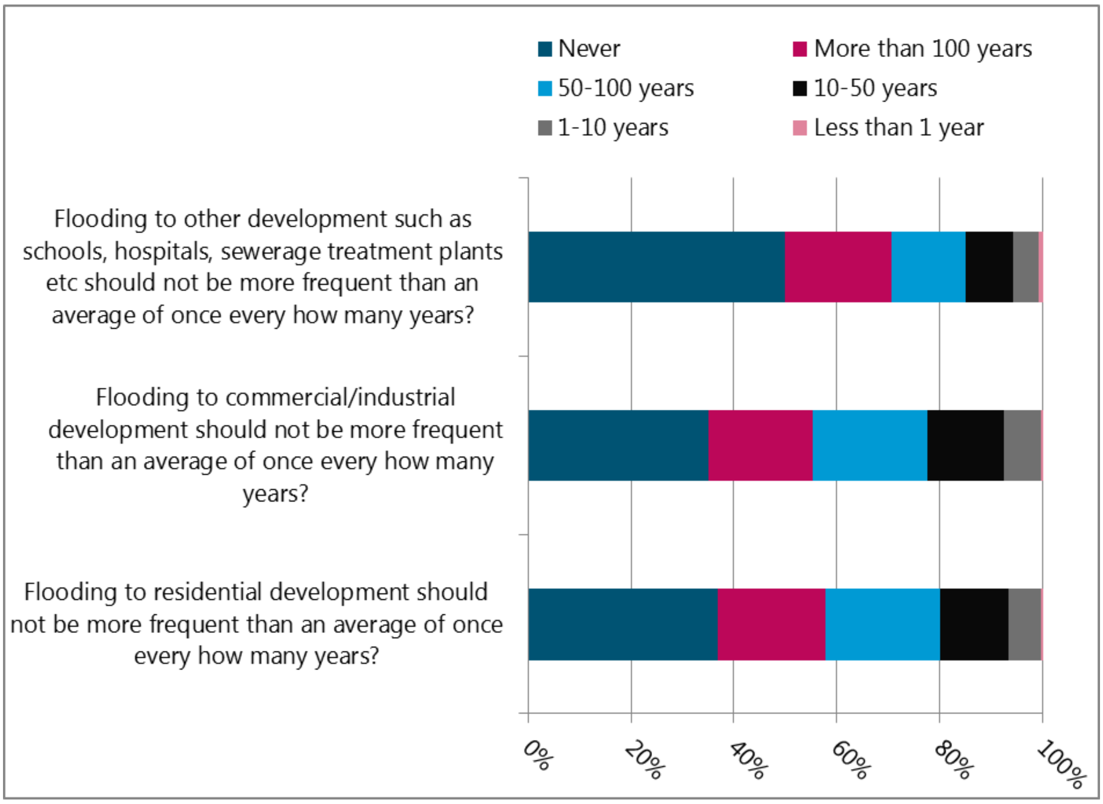
Graph 3-11 Number of Respondents who Think Climate Change will Impact on Flooding in the Future

Perception of Acceptable Flood Risk

Understanding how people feel towards flooding, and how accepting people are of the risk is useful in flood planning. While flood planning is governed by NSW legislation and the NSW Floodplain Development Manual, Council needs to be able to inform the public of their risk and also to try to gain the support of the community in their planning decisions. These questions also show how much the community expects their flooding problems to be resolved and whether or not they will accept measures that reduce the risk of flooding, whilst not eliminating it entirely.

The findings of these questions are summarised in **Graph 3-12**.





Graph 3-12 Opinions of the Acceptable Frequency of Flooding

The majority of the respondents (76%) believed that flooding to existing developments was not acceptable (**Graph 3-12**). However, opinions were fairly equally spit in regard to the acceptable frequency of flooding for different development types. This shows that a high percentage of the population expects that their current flood problems should be resolved. However, by the nature of flooding this is not always possible. Therefore, while efforts should be made to improve the flooding situation, raising community awareness on why all flooding cannot be prevented is important.

This trend is also shown to questions regarding the acceptable flood frequency to different development types. There is a slight tendency for people consider flooding to be less acceptable for more vulnerable development and critical infrastructure.

The question also identified that one third of people believe that flooding should never be acceptable, no matter the type of development.

3.2.7 Conclusions

A summary of key findings is presented below. The responses also identified that while the community is generally flood aware, this may be skewed closer to smaller 'nuisance' flooding and not to the potential larger flood events. In that regard, community awareness campaigns are still important.

Flood Awareness

The population of the South Creek study area are generally flood aware. However, it would appear that flood awareness of small more frequent flood events is high but awareness of the potential effects of a major flood or of the potential implications of climate change is low. This is understandable given the absence of any substantial flood events since the mid 1980s.

Flooding Hotspots

The community have identified a number of areas where flooding occurs frequently. One area, the Causeway, is not in the original 40 flood issue areas listed by the FRMC. As this area has been raised by a significant number of people, it is recommended for consideration in the FRMS.

The highlighted flood "hotspots" are:

- The Kingsway
- The Causeway (St Marys Road / Stoney Creek Road crossing of South Creek)
- Werrington including Victoria and Albert Streets, Werrington Road and the area affected by Werrington Creek
- St Marys
- Llandilo, mainly the area between 2nd, 7th and 8th Streets

Perceived Cause of Flooding and Floodplain Risk Management Measures

A large percentage of the population believe poorly maintained drainage and waterways to be the cause of the flooding that they have experienced in the past. As a result of this, many comments were made in regard to clearing blockages of vegetation and debris from watercourses.

New development was also raised as a concern and perceived as having the potential to increase the severity and risk of flooding due to increased runoff.

Priority Areas

The following priority areas were identified by the community. They are generally in keeping with the thoughts of the FRMC with the addition of the Causeway.

- Existing residential properties
- The Kingsway
- The Causeway
- Werrington area

Other Issues Raised

Through comments made by respondents, one of the major issues appeared to be inundation from stormwater ponding rather than from mainstream flooding. Residents rarely see stormwater and mainstream flooding as two separate issues. Therefore, there can be an element of community expectation that the FRMS would solve some of these stormwater problems. While this is not the case, stormwater issues in the catchment should be considered separately.

A number of people raised concerns in regard to the new developments at Ropes Crossing and Jordan Springs. A number of residents believe that such large scale new development has caused an increased risk of flooding.

3.3 Public Exhibition of Draft Reports and Community Information Session

The Draft Floodplain Risk Management Study and Draft Floodplain Management Plan are to be placed on Public Exhibition at the same time. A community information session will be held prior to public exhibition in order to discuss the study and the recommendations. During the public exhibition period the community will be invited to make submissions on the study.

4. The Flooding Problem

The contemporary flooding problem in the South Creek floodplain can be broken up into three major components, namely:

- the existing flooding problem;
- the potential future flooding problem; and,
- the residual, or continuing flooding problem.

Measures to address these components are complicated by the social consequences of removing people from flood affected areas and the political and economic attractiveness of the floodplain lands due to their accessibility to existing infrastructure and their lower cost per hectare. Each component of the flooding problem is discussed in the following sections.

4.1 Existing Flooding Problem

The existing flooding problem relates to those areas where flood damages are likely to arise as a consequence of flooding. It concerns existing dwellings, industrial complexes and commercial premises that would be inundated during a flood, as well as all associated infrastructure within the floodplain, including roads, railways and utility services. In this context, the existing flooding problem is usually addressed by structural measures which aim to modify flood behaviour and thereby reduce flood damages.

Investigations undertaken as part of the '*Updated South Creek Flood Study*' (2015), involved detailed flood modelling of these processes to define the existing behaviour of flooding along South Creek and its tributaries. Key outputs from the Flood Study included mapping of peak flood extents, flood levels, depths and velocities, and provisional hazard and hydraulic category mapping.

Preliminary analysis of the Flood Study (*2015*) results identified approximately 2,500 properties as being flood affected during events up to and including the Probable Maximum Flood (*PMF*). Approximately 600 of those properties were at risk of flooding during more frequent events such as the 1% AEP flood.

The Flood Study (*2015*) also identified numerous roadways and railway lines throughout the study area at risk of overtopping. The major crossings assessed and identified to be at risk of overtopping are listed in **Table 5.1**.

Of the roads identified, many were major roads such as the Great Western Highway, the Western Motorway (*M4*) and Elizabeth Drive which would be overtopped during events more frequent than the 1% AEP flood. The Western Railway was predicted to remain flood free during events up to and including the 0.2% AEP flood.

1. Predicted lag times for the 1% AEP flood at critical locations was also extracted from the flood modelling results to provide an indication of the flood warning times that could be available to the community. As shown in **Table 5.2**, the flood wave for a 1% AEP flood would take approximately 6½ hours to traverse South Creek from Elizabeth Drive to Richmond Road.

Table 5.1 Predicted Flood Immunity of the Major Crossings within the Study Area

Road Crossing	Event (AEP) and Depth at which Overtopping is first Predicted	Severity of Overtopping
Elizabeth Drive crossing of Badgerys Creek	100 mm at peak of 5% AEP flood	High
Elizabeth Drive crossing of South Creek	80 mm at peak of 2% AEP flood	High
Elizabeth Drive crossing of Kemps Creek	300 mm at peak of 5% AEP flood	High
Western Motorway (M4) crossing of South Creek	305 mm at peak of 1% AEP flood	Moderate
Western Motorway (M4) crossing of Ropes Creek	1.0 metre at peak of the PMF	Low
Great Western Highway crossing of South Creek	100 mm at peak of 5% AEP flood	High
Great Western Highway crossing of Ropes Creek	300 mm at peak of the PMF	Low
Railway Line crossing of South Creek	1.25 metres at peak of the PMF	Low
Railway Line crossing of Ropes Creek	100 mm at peak of the PMF	Low
Dunheved Road crossing of South Creek	900 mm at peak of 5% AEP flood	High
Debrincat Ave crossing of Ropes Creek	150 mm at peak of 1% AEP flood	Moderate

Source: Appendix J of the Updated South Creek Flood Study (2015)

The Flood Study (*2015*) also assessed the performance and level of protection provided by structural mitigation measures currently constructed in the Penrith LGA. These included the St Marys Levee and Werrington Road and earthen levees. The modelling indicated that the St Marys Levee would not overtop until a 0.5% AEP flood whilst the Werrington Road levee would provide protection during events up to the 0.2% AEP flood.

The development and assessment of options for mitigating the impact of flooding are outlined in **Section 9**.

Table 5.2 Predicted Lag Times for the 1% AEP Flood

	DESCRIPTION OF LOCATION	TIME OF PEAK FLOOD LEVEL (*hours after start of design storm*)*
South Creek	Elizabeth Drive Crossing	22.5
	Warragamba Pipeline	23.5
	Luddenham Road, St Clair	24.0
	Western Motorway (*M4*)	25.0
	Great Western Highway	26.0
	Main Western Railway	26.0
	Dunheved Road, Dunheved	26.5
	Munitions Road	27.0
	Ropes Creek Confluence	27.5
	Eighth Avenue, Shanes Park	27.5
	Stony Creek Road	27.5
	Richmond Road	28.0
Ropes Creek	Capitol Hill Drive Crossing	19.0
	Warragamba Pipeline	20.0
	M4 Motorway	21.0
	Great Western Highway	21.5
	Main Western Railway	22.0
	Debrincat Ave, Tregear	22.0
	Forrester Road, Dunheved	22.5
Kemps Creek	Elizabeth Drive Bridge Crossing	21.0
	Kemps Creek Dam	22.5

Source: Updated South Creek Flood Study (2015)

4.2 Future Flooding Problem

The potential future flooding problem refers to those areas of the floodplain that are likely to be proposed for future development or to be the subject of rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise be avoided. The future flooding problem has a significant potential to cause large scale flood damages within the study area and presents the greatest potential risk to loss of life.

Council has a duty of care to ensure that its current planning instruments recognise the potential flood risk. Council also has a responsibility to ensure that a Floodplain Management Plan is in place and that this Plan, or an associated Flood Policy, can be used to support decisions to approve or reject development proposals on flood affected sections of the LGA.

Future development of the Badgerys Creek airport is expected to increase development pressure on the floodplain and in particular across areas upstream of the Western Motorway. Proper and strategic planning of development in these areas should be a priority in order to ensure safe and environmentally friendly development occurs and that the land is appropriately utilised where possible. Future development in this area would also include the Western Sydney Employment Area for which development is already being proposed within the floodplain.

Other areas of future development include the proposed development of the former ADI site downstream of Werrington and St Marys, development of the Western Sydney Employment lands near Erskine Park and future development pressure along Cosgroves and Claremont Creek.

There is also potential for increased risks of flooding to existing development and infrastructure due to future development within the catchment and the associated reduction in pervious land and/or reductions in available flood storage. Climate change poses further risks with potential changes to rainfall patterns and intensities which are predicted to lead to an increase in the severity and frequency of flooding.

The role of planning controls to manage the future problem is covered in **Section 11** of this report.

4.3 Residual Flooding Problem

Unless the PMF is adopted as the basis for determining structural and planning measures aimed at reducing flood damages, there will always be a residual or continuing flooding problem.

However, the adoption of the PMF as the '*planning flood*' is not realistic or practical because it would sterilise a large area of land, thereby forcing development to areas of higher ground which may not historically be serviced or which could introduce unrealistically high infrastructure costs.

Hence, a lesser flood standard is adopted. Most Councils in NSW, including Penrith City Council, have adopted the 1% AEP flood as the flood standard (100-year average recurrence interval (ARI)). As a result, measures that are put in place to control flood damage will ultimately be overwhelmed by a flood that is larger than that adopted as the threshold for the planning control of land use, or as the limiting flood for the design of structural measures.

Accordingly, it is incumbent upon Council to consider the implications of floods greater than the adopted planning flood and to work with the State Emergency Service (SES) to develop a contingency plan for such events.

Emergency response management is covered in **Section 10** of this report.

5. Existing Hydrology and Hydraulic Modelling

As a part of preparing the South Creek Floodplain Risk Management Study, Advisian reviewed the hydrologic and hydrodynamic modelling that was completed for the Updated South Creek Flood Study (*2015*). The review determined that the hydrologic and hydrodynamic models were suitable to adopt for the Floodplain Risk Management Study investigations, primarily for determining flood damages, flood risk and for assessing structural mitigation measures.

An overview of the findings of the hydrologic and hydrodynamic modelling review are provided in the following sections.

5.1 Hydrology

The hydrologic modelling for the Updated South Creek Flood Study (*2015*) was based on the use of a XP-RAFTS (*Runoff Analysis and Flow Training Simulation*) hydrologic model that was first developed by the Department of Water Resources in 1990 as part of the original South Creek Flood Study (*1990*). The XP-RAFTS model was updated for the 2015 flood study by reviewing sub-catchment delineations, roughness parameters and pervious/impervious percentages. The Updated South Creek Flood Study (2015) states that these parameters were reviewed and updated to match catchment conditions up to the year 2007.

Although new development has occurred across the catchment since 2007, primarily as a function of the Twin Creeks and Ropes Crossing developments amongst other smaller scale development, the relative change in pervious area is considered to be low and unlikely to manifest as a change to peak flow rates and volumes greater than 1% of current predictions. This reflects the small scale of all new development relative to the total catchment area. Furthermore, the increased requirement for Onsite Stormwater Detention (OSD) and rainwater tanks to offset any increases to runoff as a function of increased impervious area.

Updated temporal patterns and Intensity-Frequency-Duration (IFD) data available in Australian Rainfall and Runoff (2016) (ARR16) could lead to changes in catchment hydrology in terms of peak flows and hydrograph shapes estimated as part of the 2015 updated flood study. The decision not to update the hydrology to reflect ARR16 was reflected within the floodplain risk management study brief and was confirmed during early meetings with the South Creek Technical Working Group.

5.2 Hydraulics

5.2.1 Two-Dimensional RMA-2 Model and Results

Hydraulic modelling for the *Updated South Creek Flood Study* (*2015*) was based on the use of a two-dimensional RMA-2 model covering South Creek and its tributaries. RMA-2 is a fully two-dimensional finite element model developed by Resource Management Associates and Prof. Ian King from the University of New South Wales.

Elevations within the RMA-2 model are based on a combination of Aerial Laser Survey (*ALS*) flow in 2002 for the Penrith LGA, ALS for Liverpool, Blacktown and Fairfield LGAs flown in 2006, creek cross-sections extracted from old MIKE-11 and HEC-2 models and localised Work-As-Executed (*WAE*) survey. Roughness values for the floodplain and creek channels was based on a combination of aerial photography and site inspections.

All RMA-2 modelling results were mapped to a Digital Terrain Model (*DTM*) made up of a combination of each of the above topographic data sources. The process of 'mapping' results enabled an improvement to flood extents and flood depth estimates by increasing the resolution of the flood model outputs. Mapped results were used for all figures presented in the 2015 updated flood study.

5.2.2 Availability of 2011 LiDAR

At the commencement of the floodplain risk management study, Advisian was provided with Light Detection and Ranging (*LiDAR*) survey covering the Penrith LGA.

A comparison of topographic elevations between the 2011 LiDAR and 2002 ALS is presented in **Figure 5.1** as a topographic difference map. The map shows via varying shades of red and blue the magnitude of topographic differences between the two data sets. The darker the shade of blue or red indicates locations where the 2011 LiDAR captured surface elevations that were either lower or higher than those captured by the 2002 ALS, respectively. White shading indicates locations where surface elevations were captured by both the 2011 LiDAR and 2002 ALS that were within +/- 0.2 metres of each other.

As shown in **Figure 5.1**, topographic differences between the 2011 LiDAR and 2002 ALS are generally between +/- 0.2 metres falling within the adopted range for white shading. Areas of larger differences are generally aligned with locations of development that is known to have occurred since the 2002 ALS was collected. This includes:

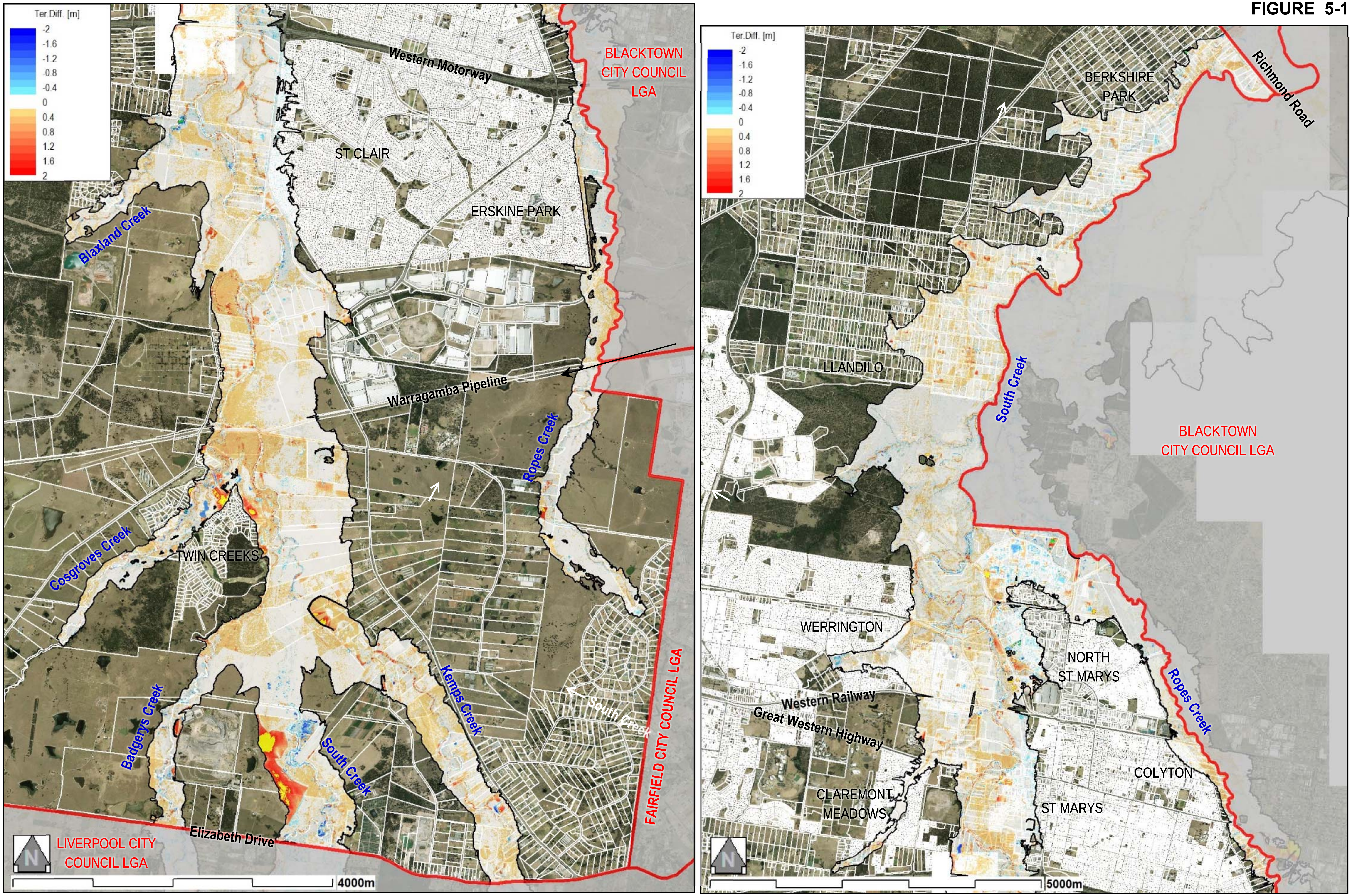
- Lenore Drive bridge crossing of Ropes Creek (to the south-east of Erskine Park)
- Raised road surface for Ropes Crossing Boulevard, Ropes Crossing/North St Marys
- Development on and in the vicinity of the St Marys Leagues Club, North St Marys
- Filling downstream of Elizabeth Drive to the west of South Creek
- Fill pad construction on the Mamre West Precinct site, and
- Cut and Fill earthworks associated with the Marsden Park 'Elara' development.

Although the RMA-2 model was not updated to reflect the above changes in floodplain topography, the implications on decision making was taken into consideration through preparation of updated flood extent mapping and consideration of topographic elevations as defined by the 2011 LiDAR. For example, emergency response procedures, including the community data sheets, take into consideration the constructed Lenore Drive and upgraded Ropes Crossing Boulevard as well as road elevations as defined by the 2011 LiDAR for the assessment of available warning times and the frequency of flooding leading to road closures.

5.2.3 Representation of the St Marys and Werrington Road Levees

The RMA-2 Flood Study model includes the existing levees constructed at St Marys and Werrington. A review of the levee extents and crest elevations adopted within the RMA-2 model compared to elevations defined by the 2011 LiDAR and more recent survey is presented below.

FIGURE 5-1



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 5.1_Comparison of 2011 LiDAR to 2002 ALS

NOTES:
1. Extent of terrain comparison has been clipped to match the predicted flood extent for the Probable Maximum Flood.
2. Terrain differences greater than + 2 metres are shaded YELLOW.
3. Terrain differences of less than – 2 metres are shaded green
4. White shading indicates differences that are within +/- 0.2 metres.

COMPARISON OF TOPOGRAPHIC ELEVATIONS CAPTURED BY 2011 LiDAR AND 2002 ALS
[2011 LiDAR less 2002 ALS]

St Marys Earthen and Concrete Levee

The St Marys levee was constructed along the western floodplain of South Creek to protect both residential and commercial/industrial properties upstream of the Great Western Highway at St Marys. The combined earthen and concrete levee is approximately 1,7000 metres in length. The concrete component is minimal spanning approximately 60 metres of the northern most section of the levee where it 'meets' the upstream embankment of the Great Western Highway.

Crest elevations along the earthen and concrete levee components are shown in **Figure 5.2** based on elevations adopted in the RMA-2 Flood Study model and by the 2011 LiDAR and surveyed spot elevations. Also superimposed on **Figure 5.2** are peak flood levels predicted for the 1% AEP flood with and without 0.5 metres freeboard added.

The comparison indicates some substantial differences in crest elevations between those adopted in the RMA-2 model and those picked-up by recent survey and the 2011 LiDAR. Two locations are highlighted on **Figure 5.2** where the differences in crest elevations are significant as they will have an influence on flood behaviour during the design 1% AEP flood. All other locations where crest elevations differ, levee crests are above the peak 1% AEP flood level with and without 0.5 metres freeboard allowance for both data sets.

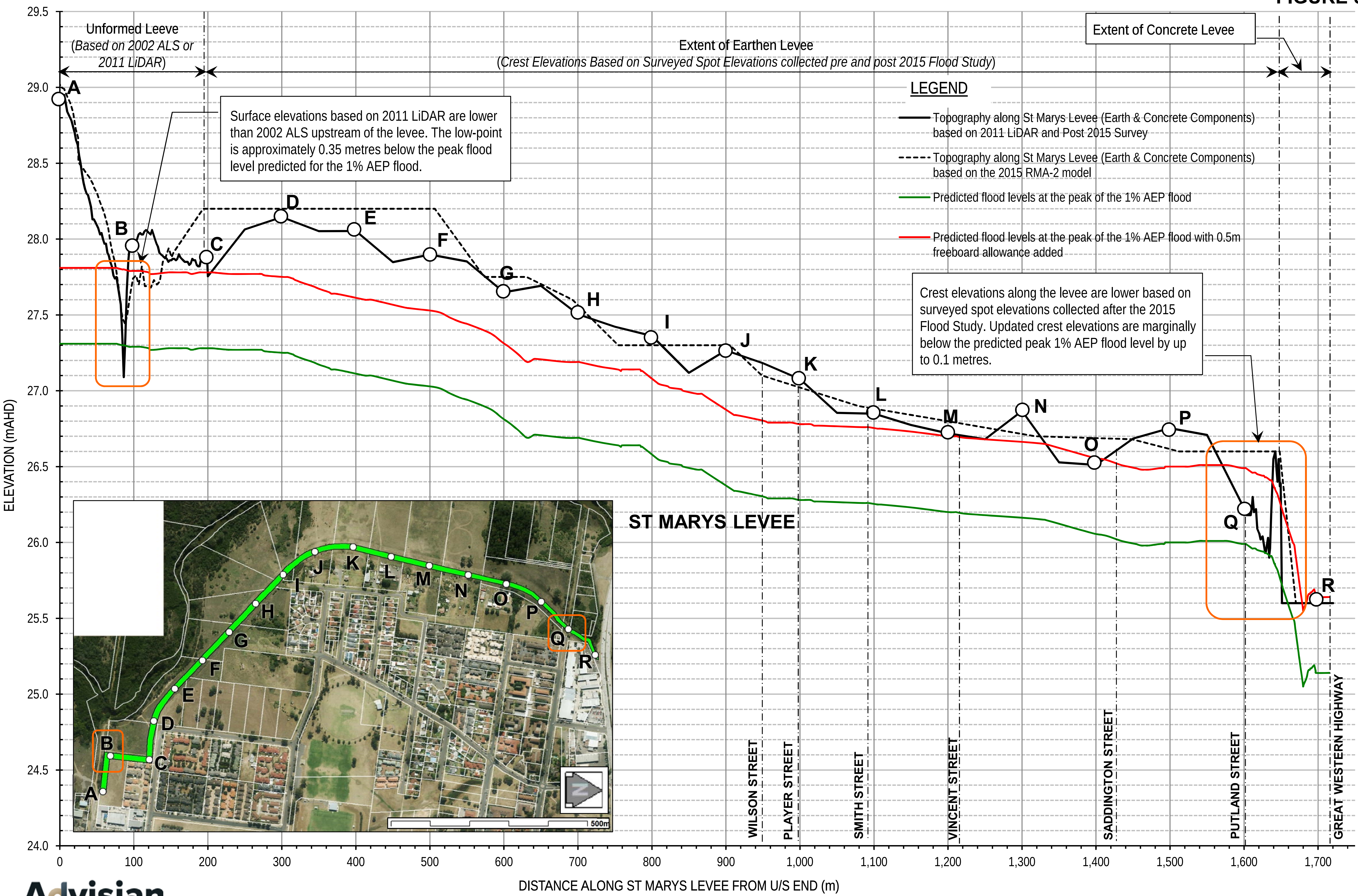
In addition to identifying lower than previously adopted levee crest elevations, a site inspection of the concrete component of the levee raised concerns with the '*tie-in*' at the downstream end to the Great Western Highway. As shown in **Plate 5.1**, the downstream end of the concrete levee finishes against the culvert crossing with crest elevations approximately 0.8 metres above the crossing surface. The consequence of this is that floodwaters could flow around the concrete levee when flood levels are less than 0.8 metres below the levee crest. During this scenario, floodwaters would flow south to north over the Great Western Highway before flowing east and around the levee.

Based on the findings above, the RMA-2 Flood Study model and the results generated would have over-predicted the protection provided by the St Marys levee to properties to the east and within St Marys. The level of protection modelled is representative of the original design criteria for the levee which was to provide protection to properties in St Marys during floods up to and including the 1% AEP flood event.

For the existing levee to provide flood protection during events up to and including the 1% AEP flood in accordance with the modelling documented in the *Updated South Creek Flood Study* (*2015*), the following will need to be undertaken:

- Sandbagging or flood barriers to a height of at least 0.8 metres across the Great Western Highway to prevent floodwaters flowing around the northern end of the concrete levee (*refer* **Plate 5-1**).
- Raising of the northern end of the earthen levee near the beginning of the Concrete Levee component (*refer* **Figure 5.2**), and
- Extension to the Southern end of the earthen levee where the topography falls below the predicted 1% AEP flood level (*refer* **Figure 5.2**).

A benefit/cost analysis of the above required changes is included in **Section 9**. Further discussion on the condition and operational level of the St Marys Levee, and recommendations for the immediate and future management are included in **Section 8.4.1**.



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South Creek Flood Study
fg301311-09772rg200220_Profiles along St Marys Levee

COMPARISON OF CREST ELEVATIONS ADOPTED ALONG THE ST MARYS CONCRETE AND EARTHEN LEVEE [2015 Flood Study to Latest Topographic Data]

Plate 5-1 Photograph Taken of the Downstream End of the St Marys Concrete Levee facing North-West

Note: Arrows indicate direction of flow that would occur if flood levels reached an elevation 0.8 metres below the levee crest.

Werrington Road and Earthen Levee

The Werrington Road and Earthen levee is designed to protect the suburb of Werrington from South Creek flooding to the west. The levee consists of two parts with the elevated Werrington Road initially acting as the levee followed by a raised earthen embankment which runs parallel to, and along the eastern side of Werrington Road.

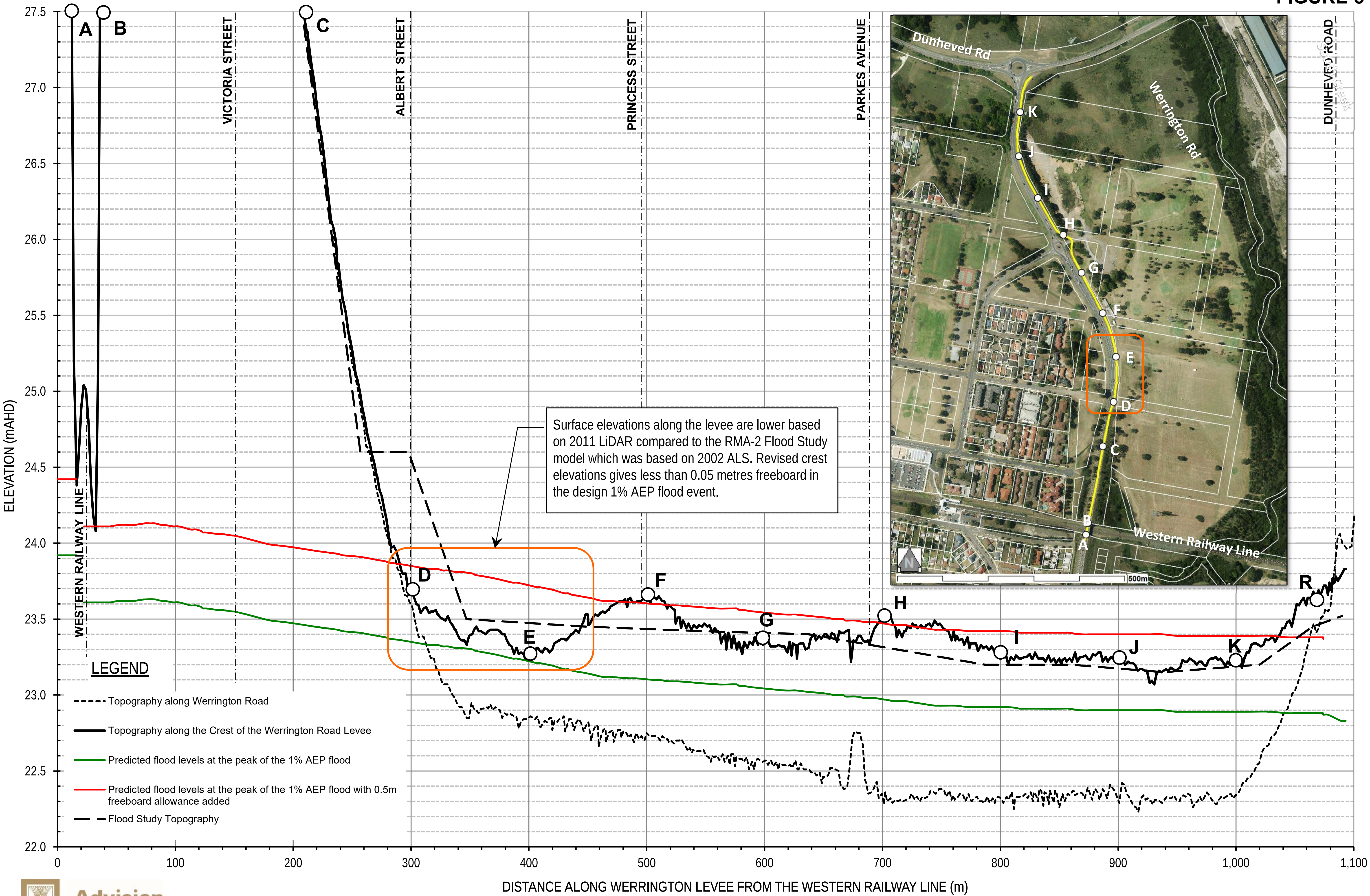
The alignment of both components of the Werrington Road levee are shown in **Plate 5.2** against aerial photography and the 2011 LiDAR topography.

Crest elevations along the Werrington Road and earthen levee are shown in **Figure 5.3** based on elevations adopted in the RMA-2 Flood Study model (*which were extracted from the 2002 ALS*) and the 2011 LiDAR. Also superimposed on **Figure 5.3** are peak flood levels predicted for the 1% AEP flood with and without 0.5 metres freeboard added.

The comparison indicates that the 2011 LiDAR has captured crest elevations that are comparable to the 2002 ALS along most of the levee length. In that regard, crest elevations are typically within +/- 0.2 metres between the two data sets (*refer* **Figure 5.3**).

One location is highlighted on **Figure 5.3** where the difference in crest elevations are greatest and leads to a significant reduction in the freeboard available to the design 1% AEP flood. As shown, the updated crest elevations are only 0.05 metres above the predicted peak 1% AEP flood level, compared to 0.25 metres based on the 2002 ALS.

- For both data sets the crest elevations are above the predicted peak 1% AEP flood levels and therefore the 2011 LiDAR will not lead to any changes flood levels predicted for the 1% AEP flood as part of the *Updated South Creek Flood Study* (*2015*).
- Further discussion on the condition and operational level of the Werrington Road, and recommendations for the immediate and future management are included in **Section 8.4.2**.



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South Creek Flood Study
6033rg131115_Profiles along Levees.xls

COMPARISON OF CREST ELEVATIONS ADOPTED ALONG THE WERRINGTON ROAD AND EARTHEN LEVEE [2015 Flood Study to Latest Topographic Data]

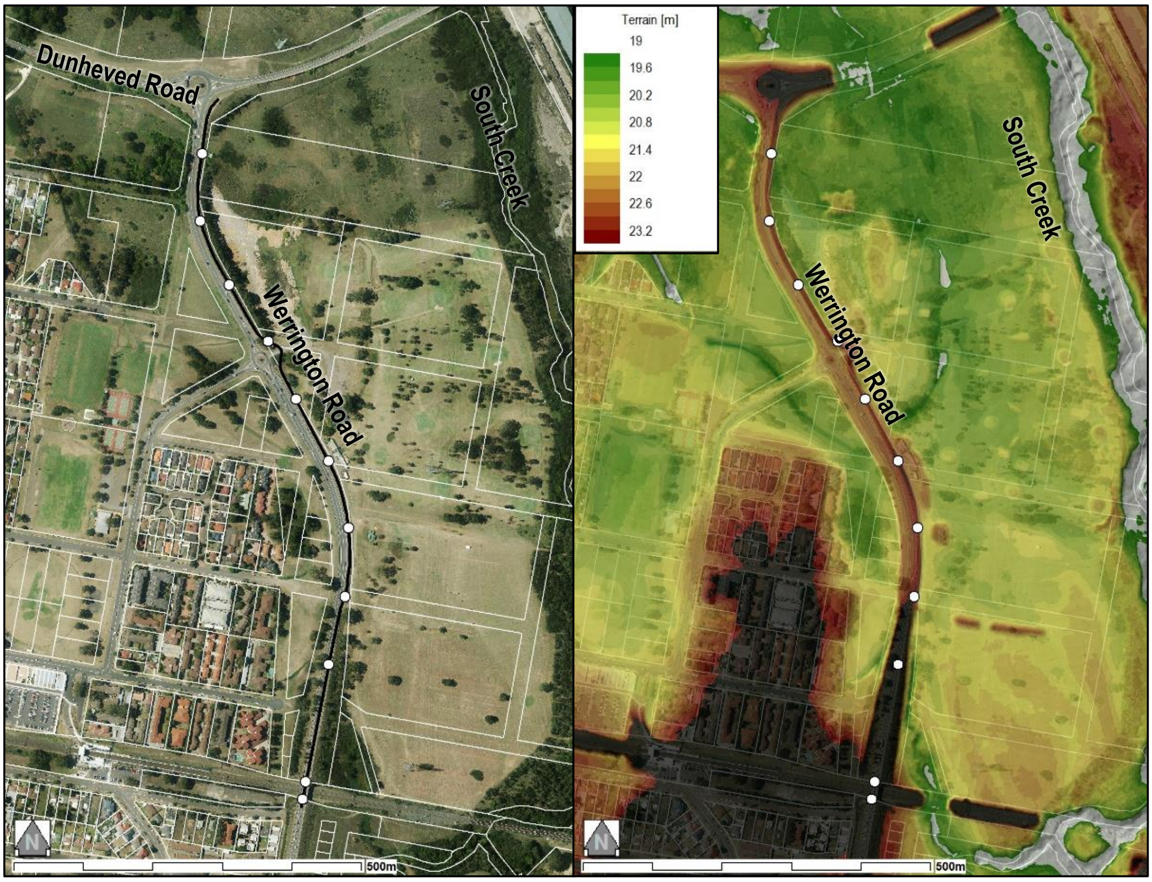


Plate 5-2 Alignment of the Werrington Road Levee against an Aerial Photograph and the 2011 LiDAR

6. Flood Hazard, Hydraulic Categories and Planning Constraints Categories

6.1 Background

Provisional flood hazard mapping was prepared as part of the *Updated South Creek Flood Study* (*2015*) for the 1% Annual Exceedance Probability (*AEP*) flood event. The hazard criteria adopted was initially based on the categorisation displayed in Figure L1 and Figure L2 of the *NSW Floodplain Development Manual* (*2005*); that is, delineating the floodplain as either Low, Transition or High Hazard.

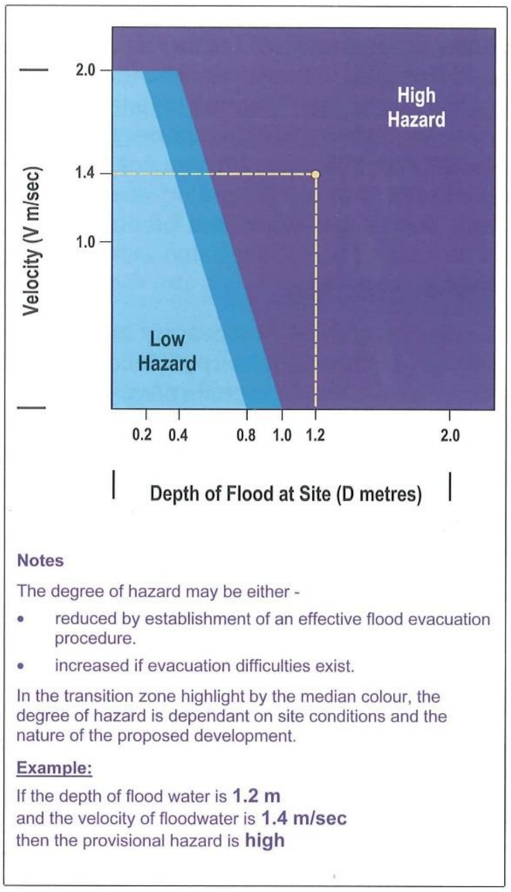


FIGURE L2 - Provisional Hydraulic Hazard Categories

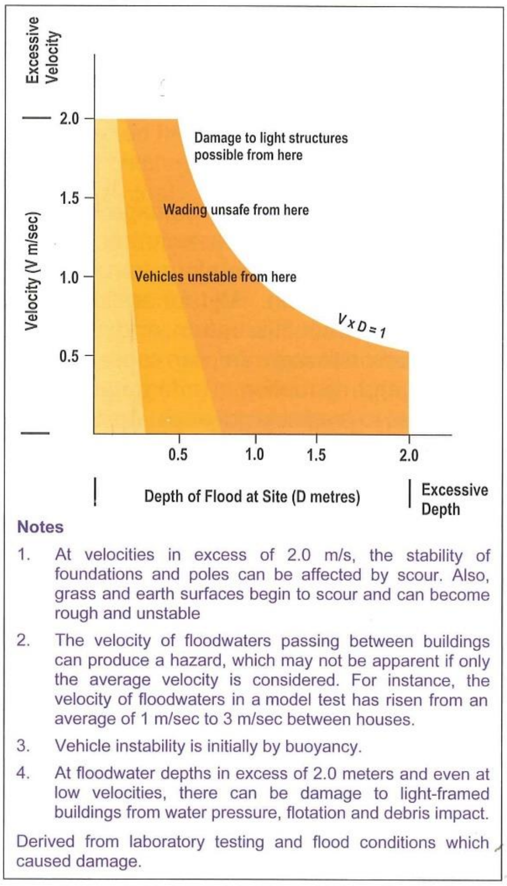


FIGURE L1 - Velocity & Depth Relationships

The initial mapping adopting the hazard categories defined within the FDM 2005 indicated that for large events such as the 1% AEP flood, the majority of flooded land would fall within the High Hazard category. To better understand those parts of the floodplain most at risk of flooding the high hazard category was further divided to High, Very High and Extreme. The Low and Transition/Medium categories were retained.

The final criteria adopted for each hazard category is listed in **Table 6-1** and presented in the coloured hazard chart shown as **Plate 6-1**.

Table 6-1 Adopted Hazard Criteria

HAZARD CATEGORY	CRITERIA
Low	Depth (*d*) < 0.4 m & velocity (*v*) < 0.5 m/s
Medium	exceeding Low criteria, and $d \leq 0.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 0.5$
High	exceeding Medium criteria, and $d \leq 1.8$ m, $v \leq 3.0$ m/s, and $v \times d \leq 1.5$
Very High	exceeding High criteria, and 0.5 m/s < velocity < 4 m/s & $v \times d \leq 2.5$
Extreme	exceeding Very High criteria and v > 4 m/s

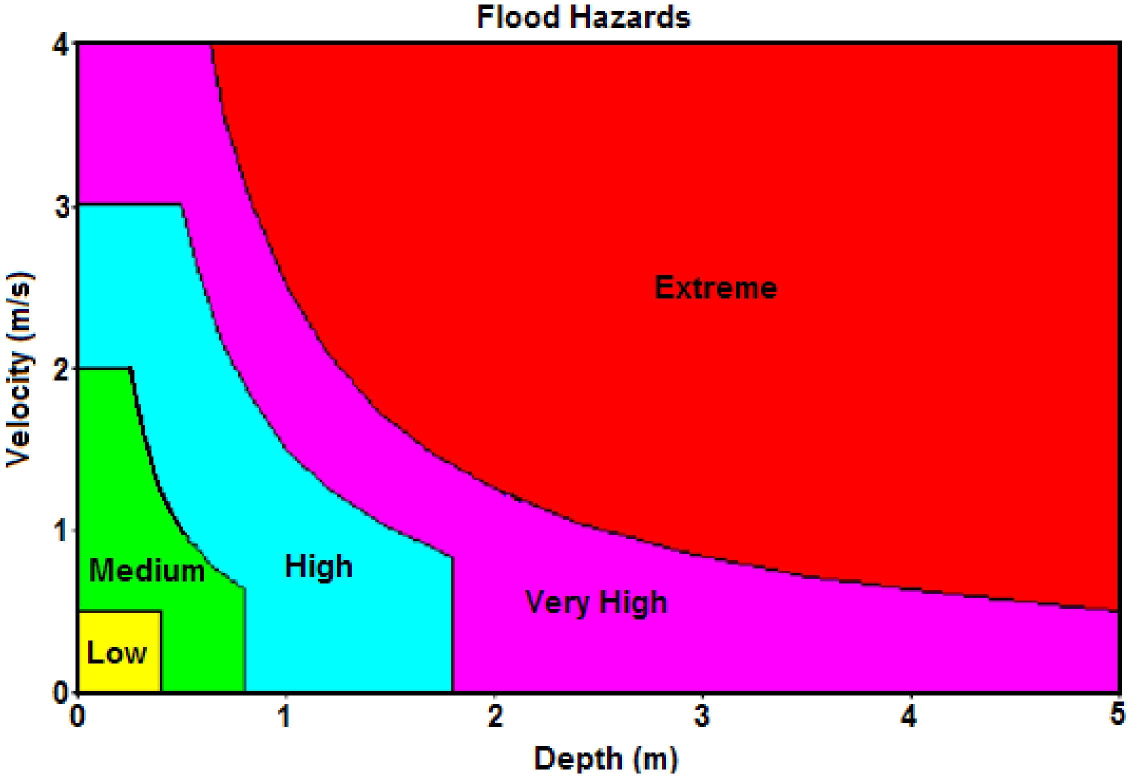


Plate 6-1 Adopted Hazard Criteria

6.2 Updated Hazard Criteria

An updated set of hydraulic criteria and hazard classifications are presented in the following publications:

- Australian Rainfall & Runoff 2019 (Book 6, Section 7.2.7)
- Australian Institute for Disaster Resilience Council's "Handbook 7" (2017)

The updated hazard classifications separate hazards into six categories starting at H1 for the lowest hazards and H6 for extreme flood conditions. The hazard classifications assess the vulnerability of people, vehicles and buildings to flooding based on the velocity and depth of flood flows. The ARR 2016 hazard curves are shown in **Plate 6-2**.

A comparison between the hazard classifications adopted as part of the *Updated South Creek Flood Study* (*2015*) and ARR 2019 is shown in **Plate 6-2**. The comparison shows that the ARR 2019 classification system allows for further breakdown of hazard conditions particularly for hazards of H5 and lower. The previously adopted criteria for '*Medium*' and '*Extreme*' flood hazards aligns well with the ARR 2019 H3 and H5 classifications, respectively. The previous '*Low*' criteria varies substantially to the new H1 and H2 based on a large difference in velocity values that fall within each criteria. In that regard, '*Low*' hazards were previously defined by velocities of up to 0.5 m/sec compared to 2.0 m/sec for H1 and H2 (*refer* **Plate 6-2**)

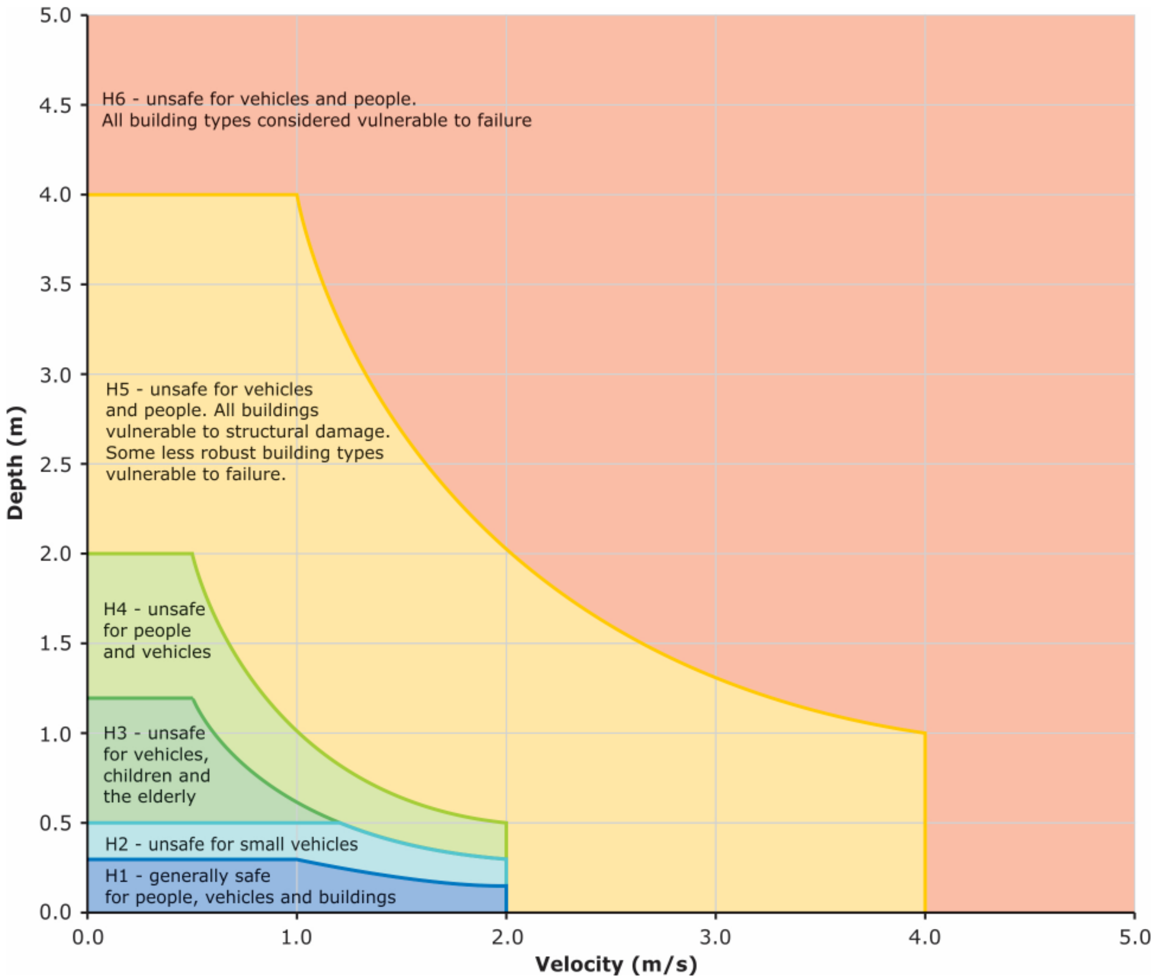


Plate 6-2 ARR 2019 Flood Hazard Vulnerability curves

The greater discretisation of hazards in the ARR 2019 guidelines allows conditions to be distinguished between when floodwaters become unsafe for a fit able-bodied adult versus children or the elderly or small vehicles in shallow water. It also aims to recognise when flood conditions may begin to impact on the structural integrity of buildings (*H5 and higher*).

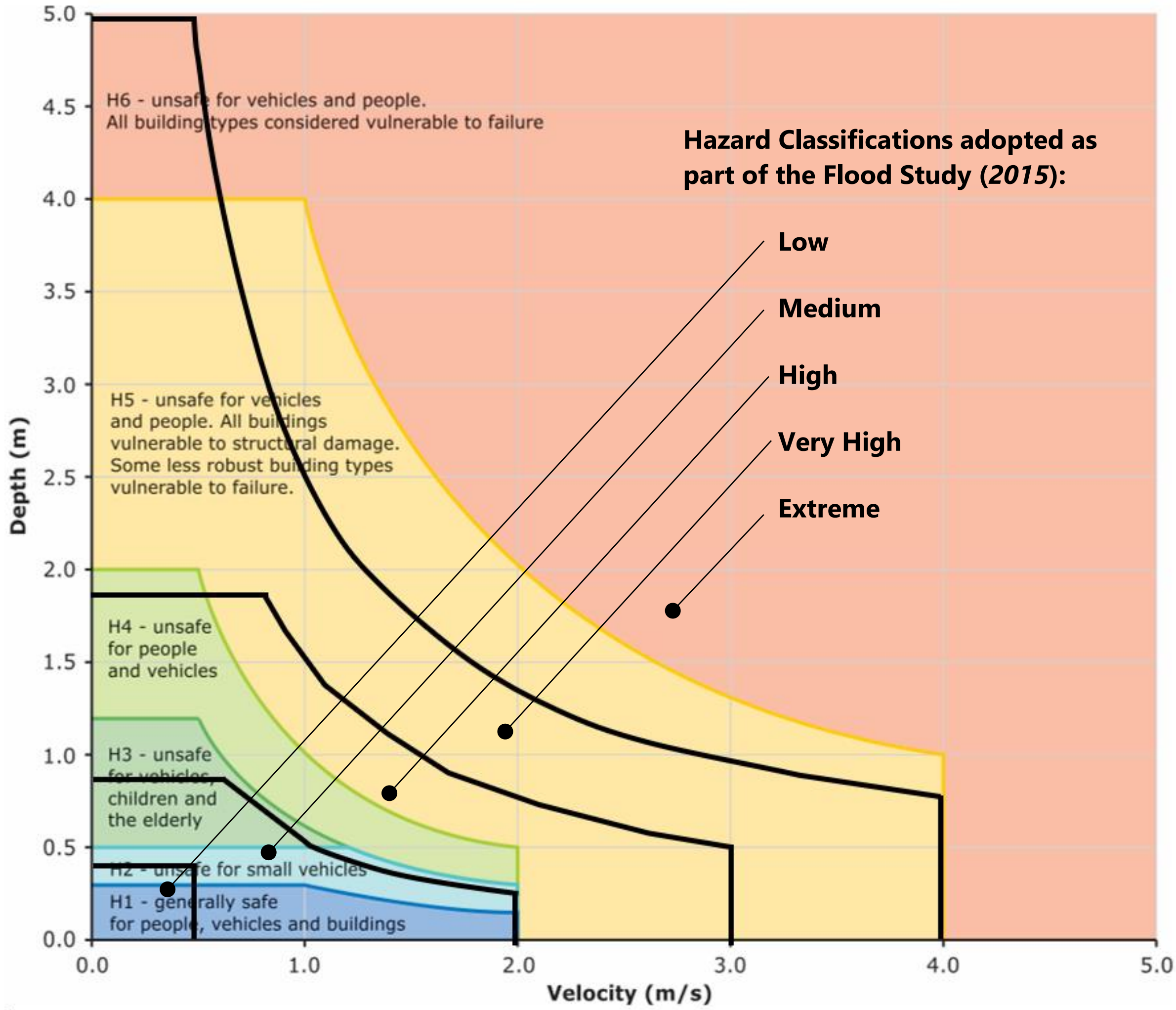


Plate 6-3 Comparison of ARR 2019 Flood Hazard Vulnerability curves to those adopted for the Updated South Creek Flood Study (2015)

6.3 True Flood Hazard Mapping

Provisional flood hazard mapping considers only the hydraulic characteristics of flooding at any given location. According to the NSW Floodplain Development Manual (*2005*) the preparation of mapping for the true flood hazard also needs to consider other factors, including:

- the size of the flood;
- effective warning time;
- flood readiness of the community;
- the rate of rise of the flood waters;
- duration of the flooding;
- any evacuation problems that may be encountered;
- effective flood access; and,
- the type of development present.

Flood hazard across the floodplain of South Creek and its tributaries is complicated by the relatively rapid rise in the level of floodwaters. The rate-of-rise is greatest along Werrington Creek and Claremont Creek where a shorter critical duration of 2 hours and 9 hours applies compared to 36 hours for the remainder of the catchment. Accordingly, properties and evacuation routes along Werrington and Claremont Creek may receive initial inundation within 0.5 hours and 3.0 hours after the initial rise in floodwaters, respectively.

Along South Creek and the other tributaries the rate-of-rise is slower but still considered 'rapid' in the context of the large river systems such as the Hawkesbury-Nepean River. In that regard, properties and low-lying roads could start to experience inundation within 8 to 10 hours of floodwaters initially breaking the banks of the respective watercourse. The peak flood level is generally reached within 8 to 10 hours along most tributaries and locations.

Depending on the magnitude of the event, many properties and evacuation routes, including major roads such as the Great Western Highway and the Western Motorway (M4), could experience initial inundation well before the peak of the event. As a result, there is little time to for people to prepare for flooding and evacuation. Evacuation out of the floodplain is not a problem for most residents. However, some properties in Oxley Park, Werrington and Claremont Meadows could become trapped prior to any inundation of properties occurring.

The duration of flooding is relatively short with floodwaters receding from most properties or roadways approximately 5-10 hours after the commencement of flooding. As a result, any trapped residents will not be isolated for extended periods of time, and therefore will not need to be supplied with food or other provisions.

An exception to the above is properties located north of Dunheved Road (*such as at Llandilo and Berkshire Park*) which can be inundated by backwater flooding from the Hawkesbury-Nepean River concurrently or independently. The rate of rise is slower and the duration of inundation longer for Hawkesbury-Nepean River flooding.

The mapping for true flood hazards was in most locations derived from the provisional flood hazard maps by removing islands of lower hazard or other areas which have become substantially surrounded by high hazard floodwaters.

Additionally, there are a few properties for which evacuation could be potentially hindered by rising floodwaters. These areas were assigned a hazard corresponding to the highest hazard encountered along the most likely evacuation route. For example, properties at the eastern end of Dolphin Close at Claremont Meadows are at risk of isolation with the evacuation route inundated prior to property flooding. At this location the hazard across the properties was manually changed to match the hazard across the evacuation route.

The true flood hazard has been determined for the 5%, 2%, 1%. 0.5% and 0.2% AEP flood events and the PMF based on the ARR 2019 hazard classifications discussed in **Section 6.2** and shown in **Plate 6.2**. Although the mapping is available to Council for the full range of events, only figures have been prepared for the 5% and 1% AEP events and the PMF and are presented in **Figures B1** to **B36** in **Appendix B**.

All flood hazard maps are based on results generated as part of the *Updated South Creek Flood Study* (*2015*) mapped to the 2011 LiDAR.

6.4 Hydraulic Category Mapping

A rigorous assessment of hydraulic categories along South Creek and its tributaries was completed as part of the *Updated South Creek Flood Study* (*2015*). The methodology adopted to determine the floodway corridor was based on the iterative and multi staged approach developed by Thomas & Golaszewski (*2012*). This approach has been applied with success to similar floodplains in NSW and has been shown to provide a robust procedure for defining floodway extent.

An overview of the methodology adopted for delineation of the existing floodway corridor that is in accordance with the methodology developed by Thomas et al (*2012*) is as follows.

- Stage 1 - Initial estimate of the floodway corridor based on a review of existing modelling results to determine:
  - The location of flood storages that are readily identifiable from aerial photography;
  - The location and potential impact of hydraulic controls and geomorphic features that could influence floodwater movement and flood characteristics (e.g., velocity);
  - The distribution of flows across the floodplain to identify the floodplain width that conveys approximately 80% of the total flow;
  - Mapping of contours of 'velocity-depth' product (V×D); and,
  - Mapping of the variation in peak flow velocity.
- Stage 2 – Encroachment modelling to test the magnitude of flood level increase predicted to occur as a result of blocking all areas outside of the initial floodway corridor (refer Stage 1). Where flood level increases are predicted to be lower or higher than the target range of 100 mm, Stage 1 was reviewed and the floodway corridor adjusted accordingly.

Based on the rigorous methodology that was applied as part of the flood study assessment and because the modelling has not changed as part of floodplain risk management study, a review of the floodway was not undertaken as part of the floodplain risk management study.

Mapping of flood fringe and flood storage has been updated as a function of the RMA-2 flood study results being mapped to the 2011 LiDAR. The updated hydraulic category mapping for the 1% AEP flood is included in **Appendix C** as **Figure C1** to **Figure C12**.

6.5 Flood Planning Constraints Categories

Flood Planning Constraints Categories (*FPCC*) is a holistic approach to assessing the relative severity of flood risks and constraints to development across the floodplain. The approach is recommended within the *Australian Institute of Disaster Resilience (ADR) Guideline 7-5 Flood Information to Support Land Use Planning Activities* as a tool to assist land use planners with strategic decision making. FPCC mapping simplifies the process of assessing flood risks and hazard across the floodplain by considering the following key flood related factors:

- frequency of exposure to flooding;
- hydraulic categories; i.e., floodway, flood storage and flood fringe;
- flood hazard; and,
- evacuation constraints in accordance with the SES mapping of Emergency Response Planning Communities (*ERPC*).

In accordance with *ADR Guideline 7-5*, FPCC mapping has been prepared for the South Creek floodplain based on the delineation of four (*4*) FPC Categories. The relative severity of the flood constraint is highest for FPCC1 reducing through to the lowest constraint for FPCC4.

The criteria adopted for defining each FPC Category is listed in **Table 6-2**. Each FPC Category is made-up of one or more flood criteria that are based on the key flood related factors outlined above. There is overlap between many of the criteria due to them not being mutually exclusive. For example, for FPCC1 the criteria for areas falling within the floodway corridor and areas defined as H6 hazard in the 1% AEP flood leads to the delineation of very similar extents. This recognises that the floodway generally encapsulates those areas with hazardous flow conditions.

Mapping of Flood Planning Constraints Categories for South Creek and its tributaries is included in **Appendix D** as **Figure D1** to **Figure D12**.

Table 6-2 Criteria Adopted for Flood Planning Constraint Category (FPCC) Mapping

FPCC	Suggested Constraint Criteria Source: *ADR Guideline 7-5*	Adopted for FPCC Mapping in South Creek	Comment
1	Areas falling within the Floodway Corridor	Yes	Floodway delineation determined as part of the Updated South Creek Flood Study (*2015*) was adopted
	Areas defined as flood storage in 1% AEP flood	No	The criteria was not adopted as it led to FPCC1 covering almost the entire 1% AEP flood extent; with the exception of locations flooded to depths of less than 0.3 metres (*i.e., the flood fringe*)
	Flood Hazard H6 in the 1% AEP flood	Yes	Adopted based on hazard mapping shown in **Appendix B** and discussed in **Section 6.3**.
2	Important flow corridor events larger than the 1% AEP flood	Yes	The criteria was adopted and investigated however, no locations where identified.
	Flood Hazard H5 in the 1% AEP flood	Yes	Adopted based on hazard mapping shown in **Appendix B** and discussed in **Section 6.3**.
	Emergency response – Isolated but elevated areas	Yes	Adopted based on the Emergency Response Planning Communities (*ERPC*) discussed in **Section 11**.
3	Flood affected areas outside FPCC2 and within the Flood Planning Area (*FPA*)	Yes	Adopted as the design 1% AEP flood with 0.5 metres freeboard
4	Flood affected areas outside FPCC3 and within the Probable Maximum Flood (*PMF*) Extent	Yes	Defined as all remaining flood liable lands.

7. Flood Damages Analysis

7.1 What are Flood Damages?

Flood damages are adverse impacts that private and public property owners experience as a consequence of flooding. They can be both tangible and intangible, direct and indirect, and are usually measured in terms of a dollar cost.

Residential, commercial and industrial damages can be separated into direct and indirect damages. Direct damages are the result of the physical contact of floodwaters with the structure and may include the costs associated with repair, replacement or the loss in value of inundated items. Indirect damages represent all other costs not associated with physical damage to property and typically include the loss of income incurred by residents affected by flooding, as well as flood recovery items such as clean-up costs.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (*e.g., the cost of replacing carpets*). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. These costs can usually be measured and data has been gathered over many years to provide a reliable indication of the likely damage costs that can be incurred by residential, commercial and industrial property owners.

It is more difficult to quantify intangible damages. Intangible damages include impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. Only limited data is available, but it has been stated that intangible damages could be as much or more than the tangible damage cost.

As part of a Floodplain Risk Management Study, it is necessary to determine the total damages that could be incurred as a consequence of flooding. If the total damage cost is significant, it can be argued that works or planning measures to reduce the cost can be justified. The justification process involves determining an estimate of the flood damage that could be expected to occur over the design life of the works. This damage cost is then compared to the damage cost if no works were undertaken. The difference defines the reduction in flood damage cost, or the net benefit. The net benefit of the works is compared against the cost of the works, thereby generating a benefit-cost ratio for the works.

If the benefit-cost ratio is sufficiently high (*i.e., ideally greater than 1*), it is likely that the works will be eligible for State Government funding and could proceed.

7.2 Adopted Methodology for Calculating Flood Damages

It is reasonable to assume that flood damages increase as the depth of inundation increases. Increased depths translates to a higher potential for over-floor flooding whilst also triggering a higher potential for external property damages due to the resulting increases in flood extents. In that regard, flood damages are calculated by comparing modelled flood level data with ground elevation and floor level data.

7.2.1 Developing a Floor Level Database

Floor level data was collated for 3,652 properties within the study area. For those properties predicted to be within the 1% Annual Exceedance Probability (AEP) flood extent, surveyors ChaseBurkeHarvey (CBH) were appointed to conduct a floor level survey of approximately 550 buildings. For properties unlikely to be flooded until events greater than the 1% AEP event but up to the 0.2% AEP event a driveby survey was undertaken during which the floor height above ground was estimated by visual inspection. Advisian staff conducted a driveby survey of over 1,000 properties in total.

For properties less at risk of flooding (*i.e. less than a 0.2% AEP event*) an average floor height method was used. Using data from the survey and driveby the average height of building floors above ground was established for properties along each of the roads in the study area. This was then applied to the remaining buildings identified from aerial maps. For streets where no survey or driveby data was available, a floor height of 100 mm above ground level was assumed.

The survey and driveby also noted if a residential property was single or multiple story and for apartment blocks, estimated the number of apartments on the ground floor so that damages for these lots could be multiplied accordingly.

Council provided design plans for floor level data at three other properties which were of a commercial and industrial nature.

Table 7-1 summarises the number of properties used in the damages assessment.

Table 7-1 Number of Floor Level Survey Points Used in the Damages Database

Survey Method	Residential	Commercial	Industrial	Recreation	Other^	*Total*
Survey undertaken by CBH surveyors[1]	622	35	70	15	4	*730*
Drive by undertaken by Advisian	960	43	34	4	2	*1,021*
Average floor height for street applied	1,687	38	126	3	6	*1,861*
Council supplied floor level data	0	2	1	0	0	*3*
TOTAL	***3,269***	***118***	***231***	***22***	***12***	***3,652***

[1] *note that the surveyor's total numbers also include the multipliers to allow for multiple ground floor units in apartment blocks or where there were multiple properties due to subdivision*

^ *Surveyors were not able to gain access to St Marys Sewerage Treatment Plant but provided a previous survey of some of the area. This was used along with LiDAR data to determine ground and floor levels for this site.*

The following assumptions were made when classifying property use:

- "Residential" was defined by surveyor comments, drive-by or by the land use zone defined in Penrith City Council LEP.
- "Recreation" was used to represent sports fields with changing rooms or small clubhouses while larger recreation facilities such as Ripples Centre on the Kingsway and Dunheved Golf Course were considered "commercial" for the purposes of flood damages.
- "Commercial" and "Industrial" were defined either by the surveyor's comments, through the drive-by or by the land use zone defined in Penrith City Council LEP.
- Schools and other educational facilities, churches and similar uses were considered as "Commercial" for the purpose of determining flood damages.
- Critical infrastructure such as the St Mary's Sewerage Treatment Plant was considered as "Other".

7.2.2 Developing a Flood Stage-Damage Curve

Stage-damage curves are utilised in order to calculate flood damages. These curves reflect the potential flood damage as a function of the depth of over-floor flooding of a building. Therefore, stage-damage curves represent the dollar value of damage in relation to the flood depth above or below the floor level of the building.

Stage-damage curves are based on real-life flood damage data and have been developed from records of damages gathered from data gathered after flood events in Australia. The development of stage-damage curves for residential and non-residential property are discussed below.

Residential Flood Damage Curves

DECC's (now OEH) Floodplain Risk Management Guideline on Residential Flood Damages (2007), outlines the method for determining stage-damage curves for residential dwellings. This procedure and accompanying spreadsheet is recommended by OEH as the basis for deriving AAD for residential properties and net present values of damages to enable the comparison of flood management options.

Different stage-damages curves are derived for three residential property types as each is likely to suffer damages in a different way. For the purpose of residential damages, dwellings are classified as one of three types:

- Single storey low set (floor level is less than 0.5 m above the ground level);
- Single storey high set (floor level is 0.5 m or more above ground level); and
- Two or more storey.

For apartment blocks each ground floor unit was considered as one single storey low set dwelling.

The Guidelines incorporate allowance for indirect damages in the stage-damage curves as well as external contents and structural damage. External and indirect damage costs are assumed the same for all residential property types. Stage-damage curves were updated to 2016 dollar value using Average Weekly Earnings (AWE).

The adopted stage-damages curves for residential dwellings are shown in **Chart 7-1**.

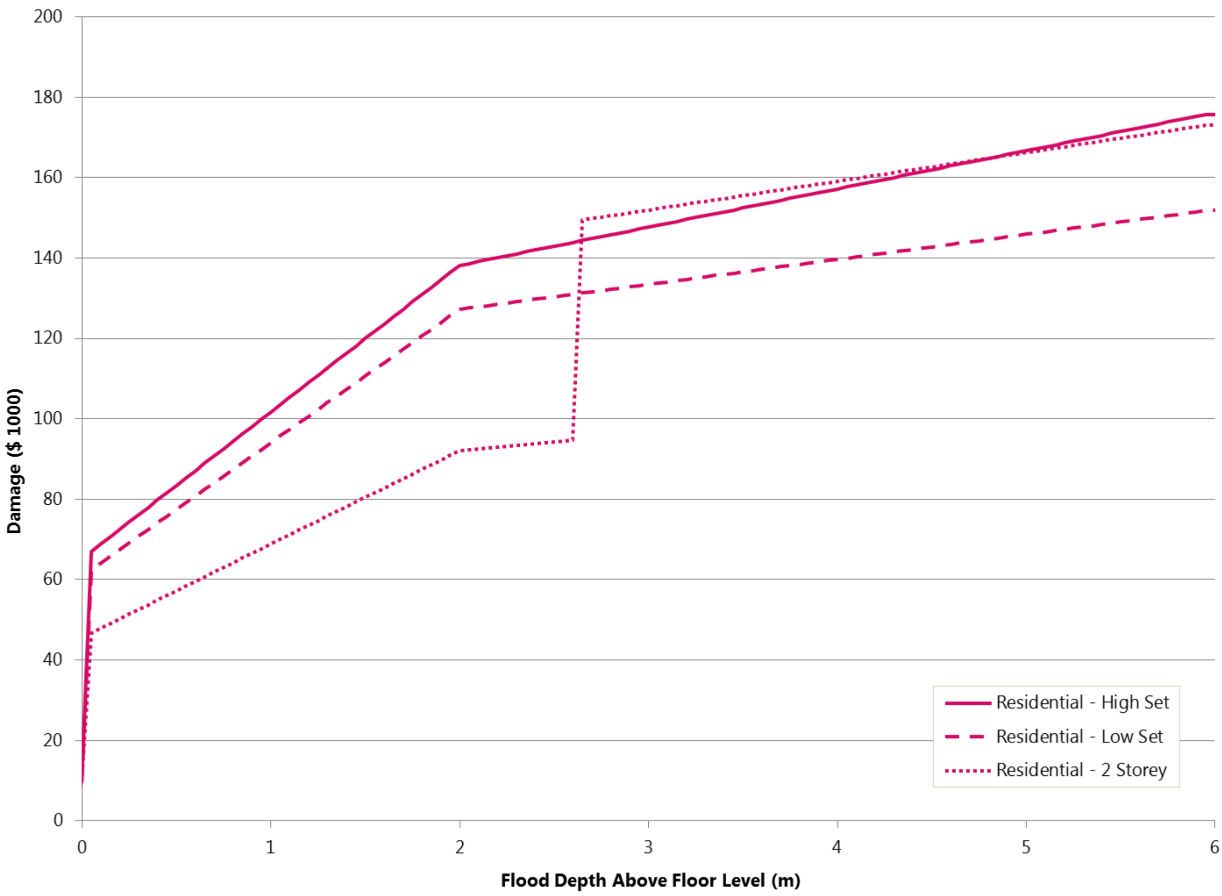


Chart 7-1 Residential Stage-Damage Curves used for South Creek FRMS

The stage-damage curves do not take into account damages from flooding below floor level. Therefore, for below floor flooding a damage value of up to $10,000 was applied depending on the depth of flooding above ground level. This value is the recommended external damage value from the Guidelines factored to a 2016 dollar value.

Non-Residential Flood Damage Curves

As outlined in the 2007 Guideline, the data available on flood damages only applies to residential properties. Therefore, an alternative stage-damage curve is required for non-residential properties.

Flood damages for non-residential properties have a considerably larger variability making the derivation of the stage-damage curve more difficult. Direct damage depends on the property size and its use. Indirect damages can depend on the ability of a business or service provider to continue to operate during and following flooding. Furthermore, a small local business is likely to have very different damages to an electric goods store for example. In order to account for some of this variability, non-residential damages have been separated into commercial, industrial, recreational and other uses.

An estimate of the flood damages associated with the inundation of non-residential properties was based on recorded damage costs for similar properties reported in the literature including the events which have occurred at Nyngan (1990), Inverell (1991), Forbes (1990) and others. In addition, data from a range of previous floodplain management studies and recorded data presented in intergovernmental reports was used. Damage values used to develop the stage-damage curves were updated to 2016 dollar values using the consumer price index (*CPI*). OEH has advised that this approach is suitable (*pers.com. the South Creek FRMS Technical Committee meeting on 3rd September 2016*).

The adopted stage-damage curves for non-residential properties are shown in **Chart 7-2**. Low, medium and high damage curves were assigned to properties based on the footprint area of the building which occupies the lot. For properties only flooded below floor level, the same approach to establishing a damage value was taken as for residential properties.

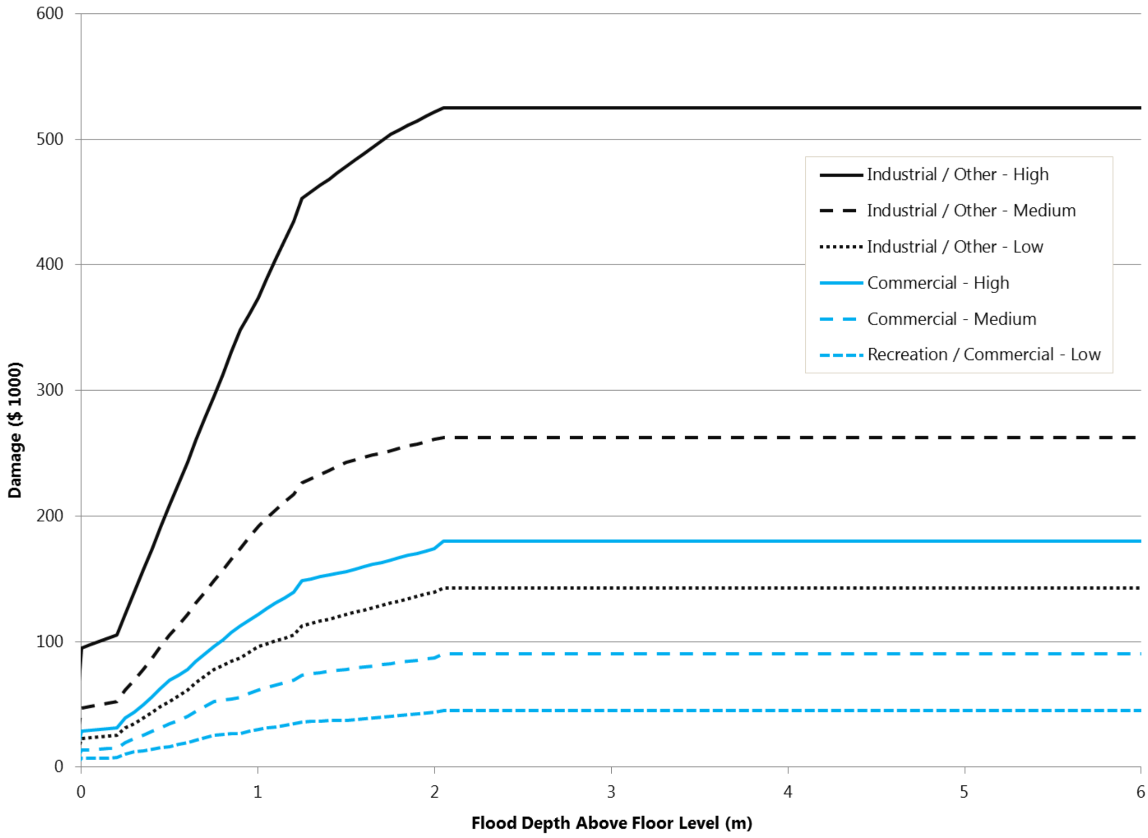


Chart 7-2 Non-Residential Stage Damage Curves used for South Creek FRMS

All properties classified as "Recreation" use the "Commercial – Low" damage curve. These buildings are often located in the floodplain and are often simple brick structures such as changing rooms which can usually be washed down and therefore would be unlikely to suffer from high damage costs.

A total of seven schools were included in the floor level database (*note for two of these the school premises are flood prone but the school buildings are not*). The commercial flood damage curves were applied for each building at the school (*i.e. multiple curves may be used for one school with multiple flood prone buildings*).

A similar approach of applying damage curves to multiple buildings was applied to "Other" uses. However, for these uses the "Industrial" curves were used. "Other" uses include:

- St Marys Sewerage Treatment Works (*6 floor levels available*)
- Mount Druitt Sub-Station, Kurrajong Road, North St Marys
- Sub-Station at Parkes Avenue, Werrington
- Erskine Rural Fire Brigade at Mamre Road, Orchard Hills
- Sydney Water Utilities at 121 Links Road, St Marys (*3 floor levels available*)

Damage to infrastructure as a result of flooding includes losses associated with damage caused by inundation of roads, water supply and sewerage services, and damage to utilities such as electricity, gas and telecommunications systems. While some of this is partially reflected in the damages to "Other" uses, damage to infrastructure is not included in this assessment.

7.2.3 Estimating Average Annual Damages (AAD)

For each of the design flood events modelled in the Flood Study, the estimate total damage likely to occur as a result of each design event was estimated by use of the damage curves described above. From this AAD was calculated by summing the total damages weighted for their probability of occurrence; i.e., total damage divided by period of time in which the damage is likely to occur.

In calculating AAD it was assumed that there would be zero damage in a 20% AEP event. This assumption is considered appropriate for the study area based on review of the recent flood that occurred in June 2016, during which damage to property was minimal despite the event being estimated to be between a 20% and 10% AEP frequency.

7.3 Assessment of Flood Affected Properties

Table 7-2 presents the number of properties that have been identified to be inundated above floor in each design flood event by property type. A breakdown of properties inundated above floor level by suburb is shown in **Chart 7-3**.

By the peak of a PMF event, 2639 properties are expected to be subject to above floor flooding with many more subject to inundation below floor level. Residential properties make up for 90% of properties which are inundated above floor level in a PMF.

Table 7-2 Number of Properties Inundated Above Floor Level for a Range of Design Events

	Number of Properties					
	PMF	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP
Residential	2338	516	202	125	66	30
Commercial	77	26	13	10	6	5
Industrial	191	22	15	15	1	1
Recreation	22	14	10	8	5	4
Other	11	9	5	4	3	3
TOTAL	**2639**	**587**	**245**	**162**	**81**	**43**

The suburbs of St Marys and Werrington have the greatest number of flood prone properties. However, the majority of properties in these suburbs are not inundated above floor level until events greater than the 0.5% AEP event. The effect of the levees at St Marys and Werrington can be seen in **Chart 7-3** as the number of flooded properties increases significantly in a 0.2% AEP event as the levees are overtopped. Llandilo, Berkshire Park, Orchard Hills and St Marys have the greatest number of properties inundated above floor level in smaller design events *(< 2% AEP flood events*).

Chart 7-4 presents the design event in which buildings are first inundated above floor level. Areas where there is high risk of above-floor flood affection are noted as:

- Berkshire Park and Llandilo
- Rance Road, Werrington
- West of Mamre Road, Orchard Hills
- Melbourne Street, Oxley Park

Interestingly this compares well with the responses received to the Community Questionnaire (*refer* **Section 3**) from which the suburbs of Llandilo, Berkshire Park, St Marys and Werrington were highlighted as flooding hot-spots.

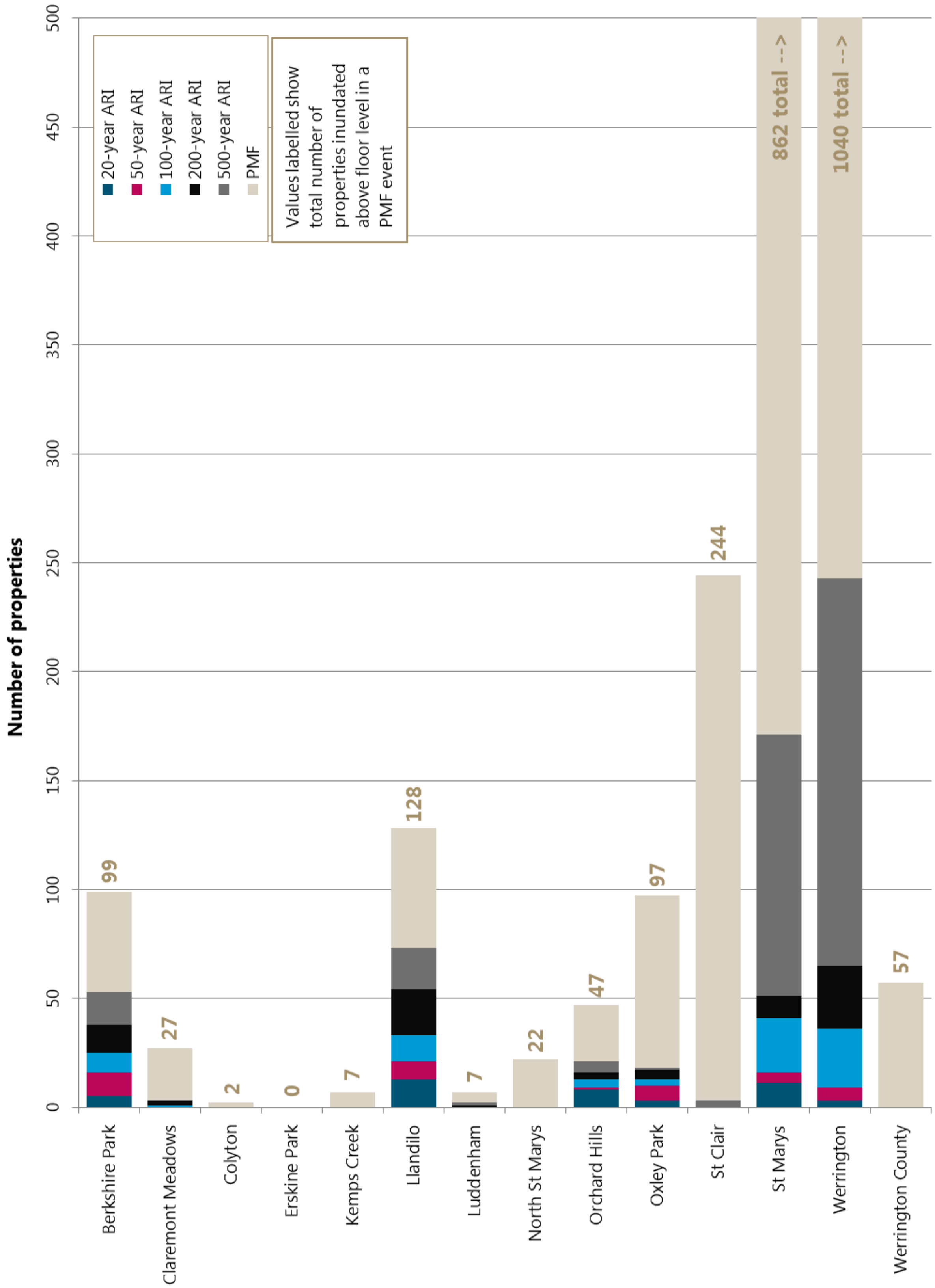


Chart 7-4 Total Number of Properties Inundated Above Floor Level by Suburb

7.4 Calculated Flood Damages

A summary of the total potential flood damage calculated for each of the design events modelled is presented in **Table 7-3** below. The total AAD for the study area is estimated to be $0.98 million.

A breakdown of AAD by suburb and property type is presented in **Chart 7-5**.

Table 7-3 Total Flood Damages Predicted for the South Creek Study Area

	Total flood damage for event ($1000s)						*Total AAD ($1000s)*
	PMF	**0.2% AEP**	**0.5% AEP**	**1% AEP**	**2% AEP**	**5% AEP**	
Residential	267,037	41,772	17,237	9,899	5,191	2,203	***$ 817***
Commercial	5,831	1,238	620	466	294	213	***$ 40***
Industrial	44,754	3,009	1,533	1,057	226	112	***$ 81***
Recreation	788	384	240	168	108	58	***$ 11***
Other	2,550	1,089	537	449	279	224	***$ 37***
TOTAL	**320,960**	**47,492**	**20,168**	**12,038**	**6,097**	**2,811**	***$ 985***

From **Chart 7-5**, the areas particularly susceptible to high AAD are identified as:

- Berkshire Park
- Llandilo
- Orchard Hills (mainly due to rural properties located between South Creek and Mamre Road)
- Oxley Park (mainly due to properties located on Melbourne Street)
- St Marys
- Werrington (mainly due to properties located on Rance Road).

A comparison of **Chart 7-4** and **Chart 7-5** shows that AAD is not necessarily highest in areas with the greatest number of inundated properties. Breaking **Chart 7-5** down further into AAD on a per property basis shows that residential properties in Berkshire Park, Llandilo and Orchard Hills have a particularly high AAD. AAD per property is greatest in suburbs where property and above floor inundation is predicted to occur more frequently; i.e., during events of a lesser AEP.

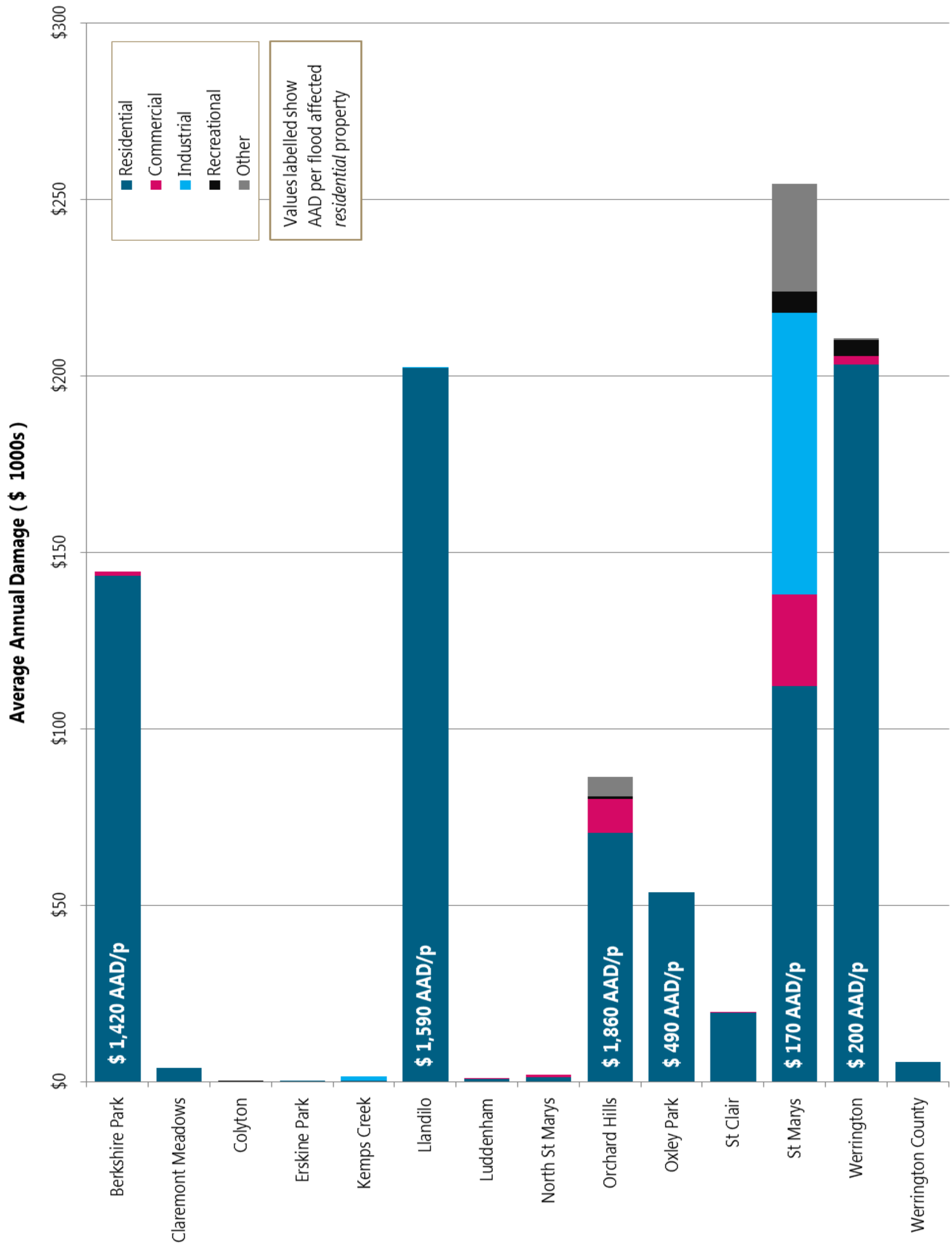


Chart 7-5 Average Annual Damages by Suburb and Property Type

7.4.1 Residential Damages

Residential AAD accounts for 83% of the total study area AAD.

Residential flood damages in the Llandilo and Berkshire Park suburbs make up for 35% of the total residential AAD for the study area with 57 dwellings affected by above floor flooding by the peak of the 1% AEP event.

As shown in **Chart 7-5**, the AAD per flood prone residential property in Llandilo and Berkshire Park is significantly higher than it is in many other suburbs. This is directly due to the number of properties inundated in the smaller design flood events (*<1% AEP*).

AAD per flood prone residential property is highest in Orchard Hills where the average AAD per flood prone residential property is predicted to be $1,860. The higher average AAD per property in Orchard Hills is a result of the proportionally larger percentage of dwellings inundated by smaller magnitude design flood events. This is largely attributed to those properties located on land between South Creek and Mamre Road.

Although the Werrington area has a significant number of flood prone dwellings (*1012 dwellings in Werrington could be subject to above floor flooding in a PMF event compared to 125 dwellings in Llandilo*) the AAD on a per property basis is considerably lower in Werrington due to the presence of the levee system. Most residential dwellings are only susceptible to flooding when the levee is overtopped by the peak of the 0.2% AEP flood event or in events of greater magnitude. Nonetheless, the potential risks associated with the levee should not be overlooked. Should the levee fail, the residential damages in Werrington would increase significantly and would exceed that of other suburbs including Llandilo and Berkshire Park.

7.4.2 Non- Residential Damages

Non-residential damages comprise damages to commercial, industrial, recreation and other property types. Combined, non-residential AAD makes up for 17% of the total study area AAD.

St Marys has the highest total AAD for non-residential damages given the greater number of commercial and industrial properties in this area. When taking St Marys Sewerage Treatment Plant into account (*classified as "other" for the purpose of flood damages*) the potential damages increases significantly (*refer* **Chart 7-5**). The indirect damages as a result of failure of the treatment plant during a flood can be high and the effects would spread to the entire serviceable are of the plant.

7.5 Intangible Flood Damages

Intangible flood damages are those that are unable to be quantified in monetary terms. These damages are related to the physical and mental health of individuals, environmental concerns, the ability to undertake necessary evacuation measures and disruption to essential community services and operations.

Notwithstanding this, emotional stress and mental illness can stem from a number of experiences associated with damage to family homes and businesses. These include:

- destruction of memorabilia (i.e., family photos);
- death of pets;
- financing the replacement of damaged property;
- living in temporary accommodation;

- children attending a different school;
- loss of business income and potential clients;
- loss of wages; and,
- anxiety experienced by young children.

This type of intangible damage to the well-being of residents could be significant in the event of a major flood. Accordingly, it is possible that the intangible damage cost could be as high or higher than the total tangible damage cost.

8. Floodplain Risk Management

8.1 Types of Floodplain Risk Management Measures

According to the *Floodplain Development Manual (2005)*, floodplain risk management options are separated into the following categories:

- **Flood modification measures**. These are typically structural works, such as flood protection levees, flood detention basins or bypass floodways, which act to reduce flood damages.
- **Property modification measures**. These measures include flood planning controls for future development to ensure that land uses are compatible with flood risk. They can also include voluntary house raising and purchase, or flood-proofing of buildings, which can act to reduce flood damages.
- **Response modification measures**. These typically include emergency response management measures, flood predictions and warnings and community flood awareness and preparedness.
- A **Risk Assessment** measure is also proposed to address issues for which the risks are unknown and have not previously been assessed. It is possible that once the risks are understood, and if they are significant, that Flood, Property or Response modification measures may be identified and proposed to mitigate the risks.

8.2 Approach to Addressing the Flood Problem

The flooding problem in the South Creek floodplain can be broken up into three major components, namely:

- the existing flooding problem;
- the potential future flooding problem; and,
- the residual, or continuing flooding problem.

Measures to address these components are complicated by the social consequences of removing people from flood affected areas and the political and economic attractiveness of the floodplain lands due to their accessibility to existing infrastructure and their lower cost per hectare. Each component of the flooding problem is discussed in the following sections.

8.2.1 Existing Flooding Problem

The existing flooding problem relates to those areas where flood damages are likely to arise as a consequence of flooding. It concerns existing dwellings, industrial complexes and commercial premises that would be inundated during a flood, as well as all associated infrastructure within the floodplain, including roads, railways and utility services. In this context, the existing flooding problem is usually addressed by structural measures which aim to modify flood behaviour and thereby reduce flood damages.

Investigations undertaken as part of the '*Updated South Creek Flood Study*' (2015), involved detailed flood modelling of these processes to define the existing behaviour of flooding along South Creek and its tributaries. Key outputs from the Flood Study included mapping of peak flood extents, flood levels, depths and velocities, and provisional hazard and hydraulic category mapping.

Preliminary analysis of the Flood Study (*2015*) results identified approximately 2,500 properties as being flood affected during events up to and including the Probable Maximum Flood (*PMF*).

Approximately 600 of those properties were at risk of flooding during more frequent events such as the 1% AEP flood.

The Flood Study (*2015*) also identified numerous roadways and railway lines throughout the study area at risk of overtopping. Of the roads identified, many were major roads such as the Great Western Highway, the Western Motorway (M4) and Elizabeth Drive which would be overtopped during events more frequent than the 1% AEP flood. The Western Railway was predicted to remain flood free during events up to and including the 0.2% AEP flood.

The Flood Study (*2015*) also assessed the performance and level of protection provided by structural mitigation measures currently constructed in the Penrith LGA. These included the St Marys Levee and Werrington Road and earthen levees. The modelling indicated that the St Marys Levee would not overtop until a 0.5% AEP flood whilst the Werrington Road levee would provide protection during events up to the 0.2% AEP flood.

The key flood problem areas within the study area are identified based on the findings of the flood damages analysis are outlined within **Section 7**. These problem areas, and those locations identified as part of the Flood Study (*2015*), were considered in selecting the flood modification measures for assessment using the RMA-2 model (*refer* **Section 9**).

8.2.2 Future Flooding Problem

The potential future flooding problem refers to those areas of the floodplain that are likely to be proposed for future development or to be the subject of rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise be avoided. The future flooding problem has a significant potential to cause large scale flood damages within the study area and presents the greatest potential risk to loss of life.

Council has a duty of care to ensure that its current planning instruments recognise the potential flood risk. Council also has a responsibility to ensure that a Floodplain Management Plan is in place and that this Plan, or an associated Flood Policy, can be used to support decisions to approve or reject development proposals on flood affected sections of the LGA.

Future development of the Badgerys Creek airport is expected to increase development pressure on the floodplain and in particular across areas upstream of the Western Motorway. Proper and strategic planning of development in these areas should be a priority in order to ensure safe and environmentally friendly development occurs and that the land is appropriately utilised where possible. Future development in this area would also include the Western Sydney Employment Area for which development is already being proposed within the floodplain.

Other areas of future development include the proposed development of the former ADI site downstream of Werrington and St Marys, development of the Western Sydney Employment lands near Erskine Park and future development pressure along Cosgroves and Claremont Creek.

There is also potential for increased risks of flooding to existing development and infrastructure due to future development within the catchment and the associated reduction in pervious land and/or reductions in available flood storage. Climate change poses further risks with potential changes to rainfall patterns and intensities which are predicted to lead to an increase in the severity and frequency of flooding.

The role of planning controls to manage the future problem is covered in **Section 11** of this report.

8.2.3 Residual Flooding Problem

Unless the Probable Maximum Flood (*PMF*) is adopted as the basis for determining structural and planning measures aimed at reducing flood damages, there will always be a residual or continuing flooding problem.

However, the adoption of the PMF as the '*planning flood*' is not realistic or practical because it would sterilise a large area of land, thereby forcing development to areas of higher ground which may not historically be serviced or which could introduce unrealistically high infrastructure costs.

Hence, a lesser flood standard is adopted. Most Councils in NSW, including Penrith City Council, have adopted the 1% AEP flood as the flood standard (*100-year average recurrence interval*). As a result, measures that are put in place to control flood damage will ultimately be overwhelmed by a flood that is larger than that adopted as the threshold for the planning control of land use, or as the limiting flood for the design of structural measures.

Accordingly, it is incumbent upon Council to consider the implications of floods greater than the adopted planning flood and to work with the State Emergency Service (SES) to develop a contingency plan for such events.

Emergency response management is covered in **Section 10** of this report.

8.3 Preliminary Review of Potential Floodplain Risk Management Measures

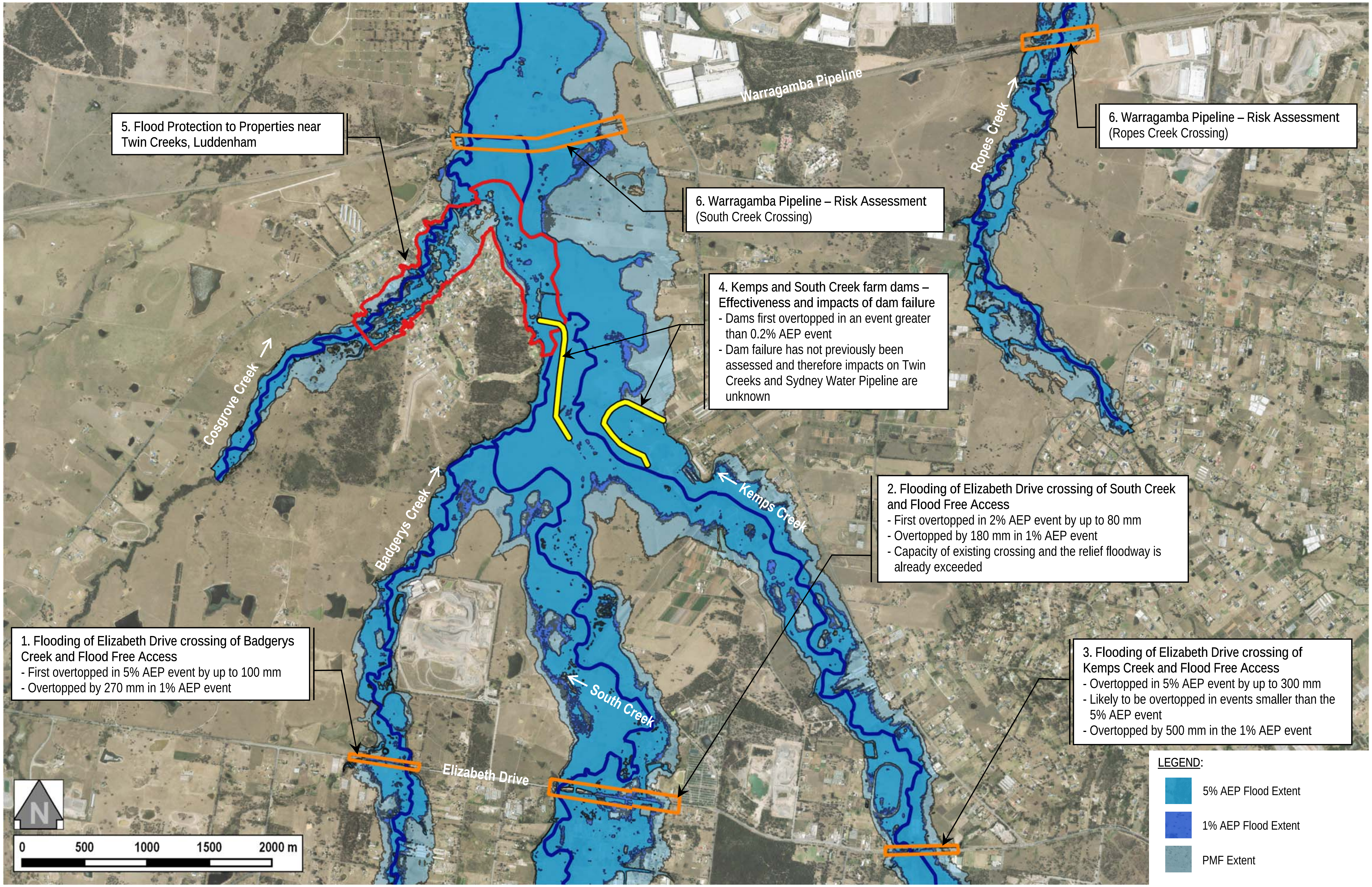
Council's Floodplain Risk Management Committee (*FRMC*) identified a range of potential flood related issues across the study area for which structural, planning, emergency response and risk assessment measures may be introduced to reduce the flood damages and ameliorate associated flood risk to individuals. A total of 38 specific issues were identified by the FRMC and listed in the FRMS&P brief for consideration.

An assessment of the 38 issues was initially documented in a Discussion Paper. The paper identified a range of structural, planning, emergency response or risk assessment options that could reduce the associated flood risk. Where multiple mitigation options were identified for a single issue, one was recommended and progressed to a high-level triple bottom line assessment. A priority ranking was then assigned to each option of Low, Medium and High based on consideration of the economic, social and environmental benefits or disbenefits of each option. Those options identified with a High priority ranking were generally recommended for further and more detailed investigation as part of the FRMS.

The Discussion Paper was submitted and presented to the FRMC to discuss and confirm the final list of issues and options to be included within the FRMS. **Table E.1** in **Appendix E** provides an overview of the findings of the assessment. The table lists the flood, property and response modification measures that were identified for each preliminary issue as well as the outcome of the triple-bottom-line assessment.

The location of each of the 38 issues identified by the FRMC and considered for inclusion within the FRMS are shown in **Figures 8.1** to **8.8**. The sub-area that relates to each figure is listed below.

- **Sub Area 1** - Floodplain between Elizabeth Drive and the Warragamba Pipeline (*refer* **Figure 8.1**)
- **Sub Area 2** - South Creek Floodplain between the Warragamba Pipeline and the Western Motorway (*refer* **Figure 8.2**)
- **Sub Area 3** - St Marys upstream of the South Creek Railway Line Crossing (*refer* **Figure 8.3**)



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.1_Preliminary Issues for Sub Area 1

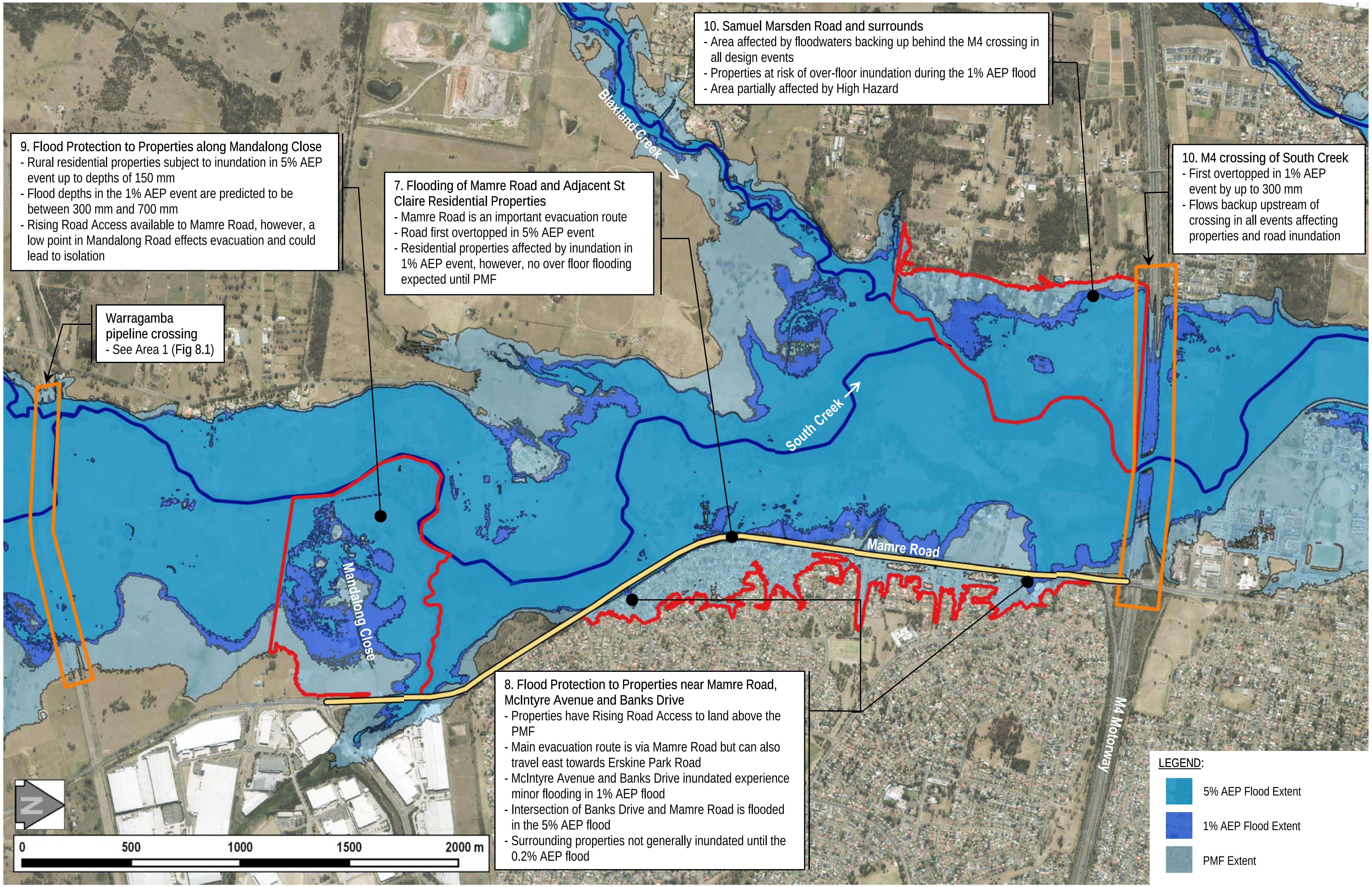
NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 1 – FLOODPLAIN BETWEEN ELIZABETH DRIVE AND THE SYDNEY WATER PIPELINE

FIGURE 8-2



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.2_Preliminary Issues for Sub Area 2

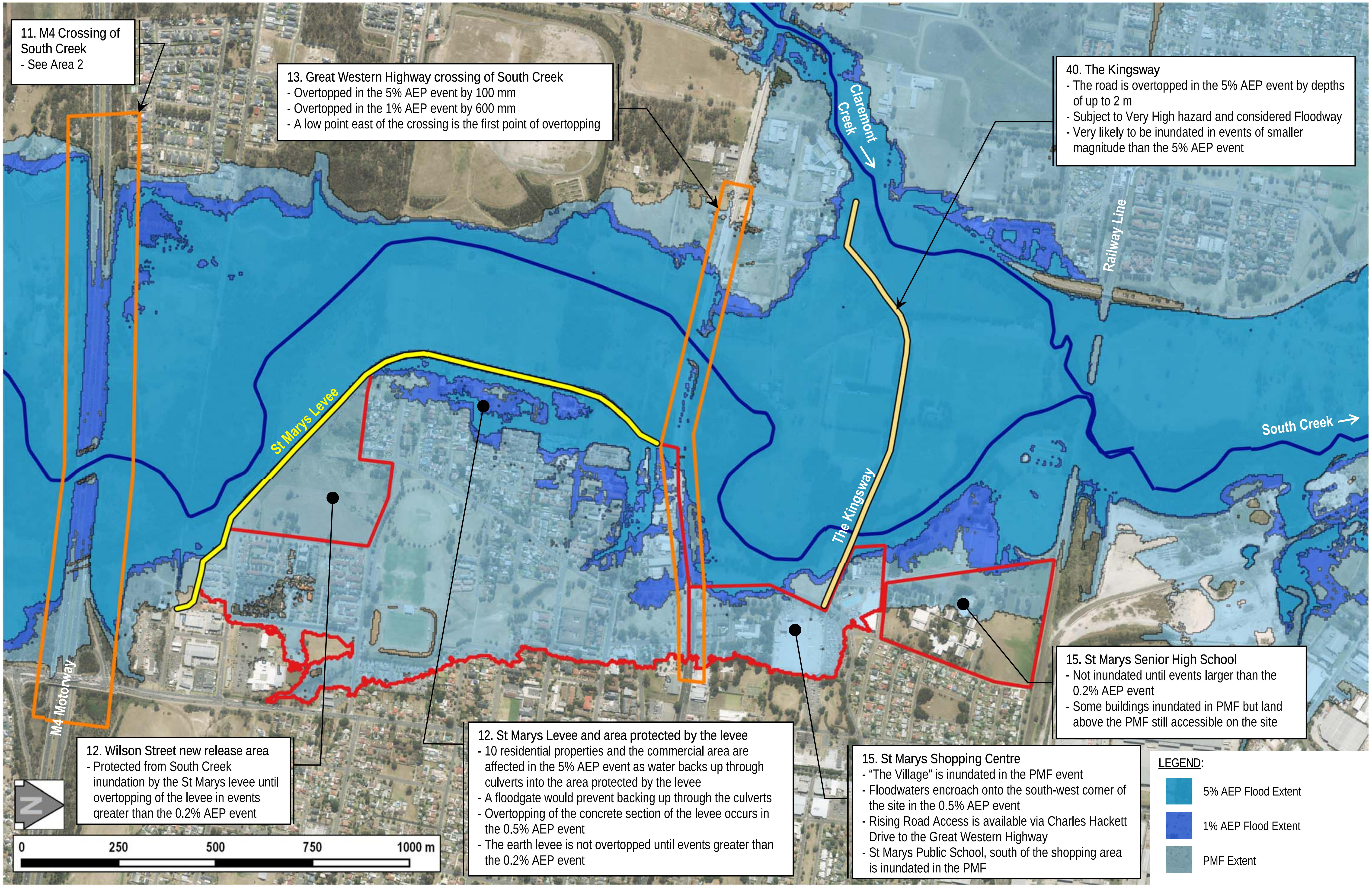
NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 2 – FLOODPLAIN BETWEEN THE SYDNEY WATER PIPELINE AND THE WESTERN MOTORWAY (M4) CROSSINGS OF SOUTH CREEK

FIGURE 8-3



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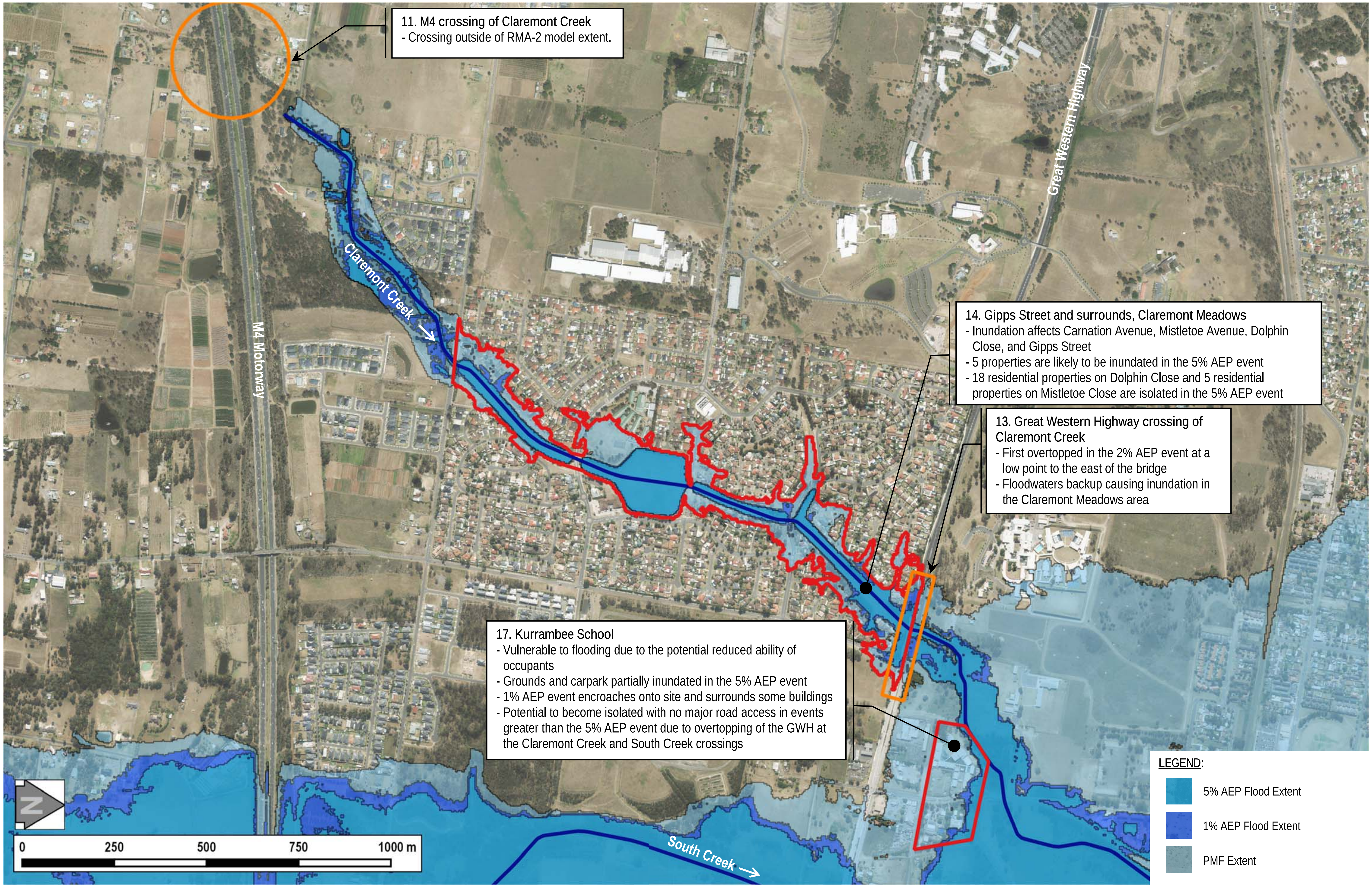
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.3_Preliminary Issues for Sub Area 3

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 3 – ST MARYS UPSTREAM OF THE SOUTH CREEK RAILWAY LINE CROSSING



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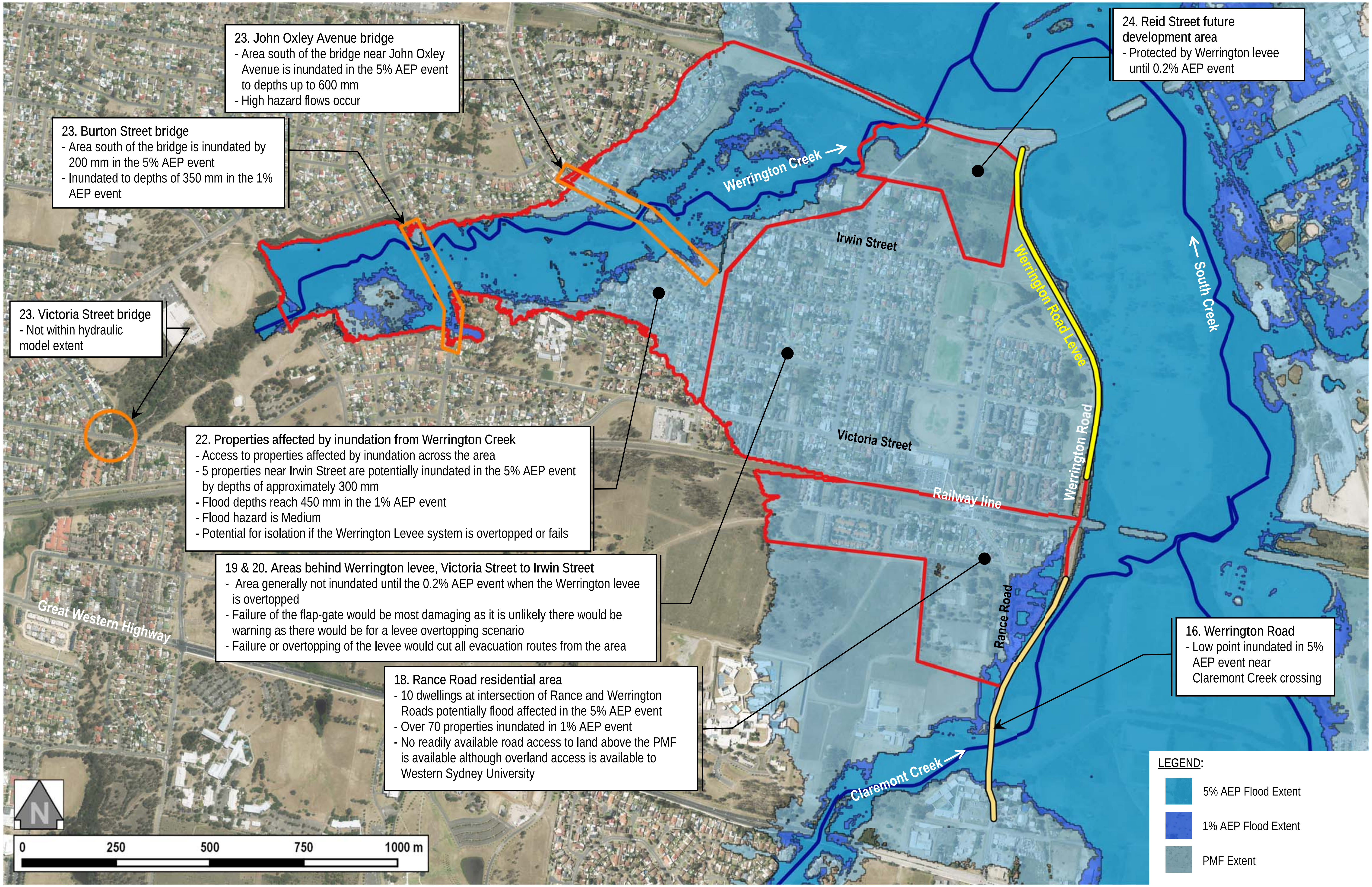
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.4_Preliminary Issues for Sub Area 4

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 4 – CLAREMONT MEADOWS AND PROPERTIES AFFECTED BY CLAREMONT CREEK



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.5_Preliminary Issues for Sub Area 5

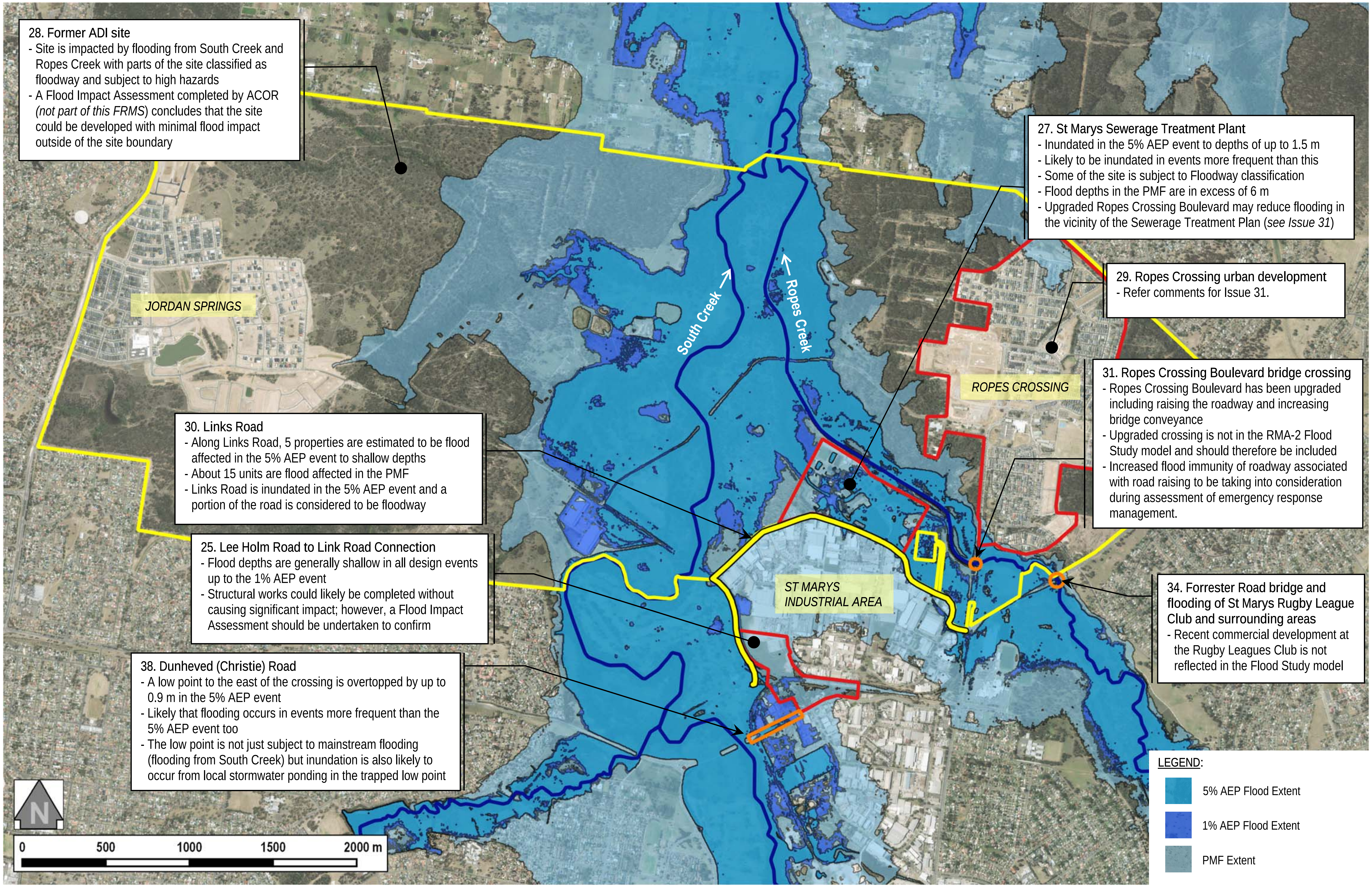
NOTES:

1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale*

2. *Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.*

FLOODPLAIN MANAGEMENT AREAS
AREA 5 - WERRINGTON ROAD AND RANCE ROAD RESIDENTIAL AREAS

FIGURE 8-6



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.6_Preliminary Issues for Sub Area 6

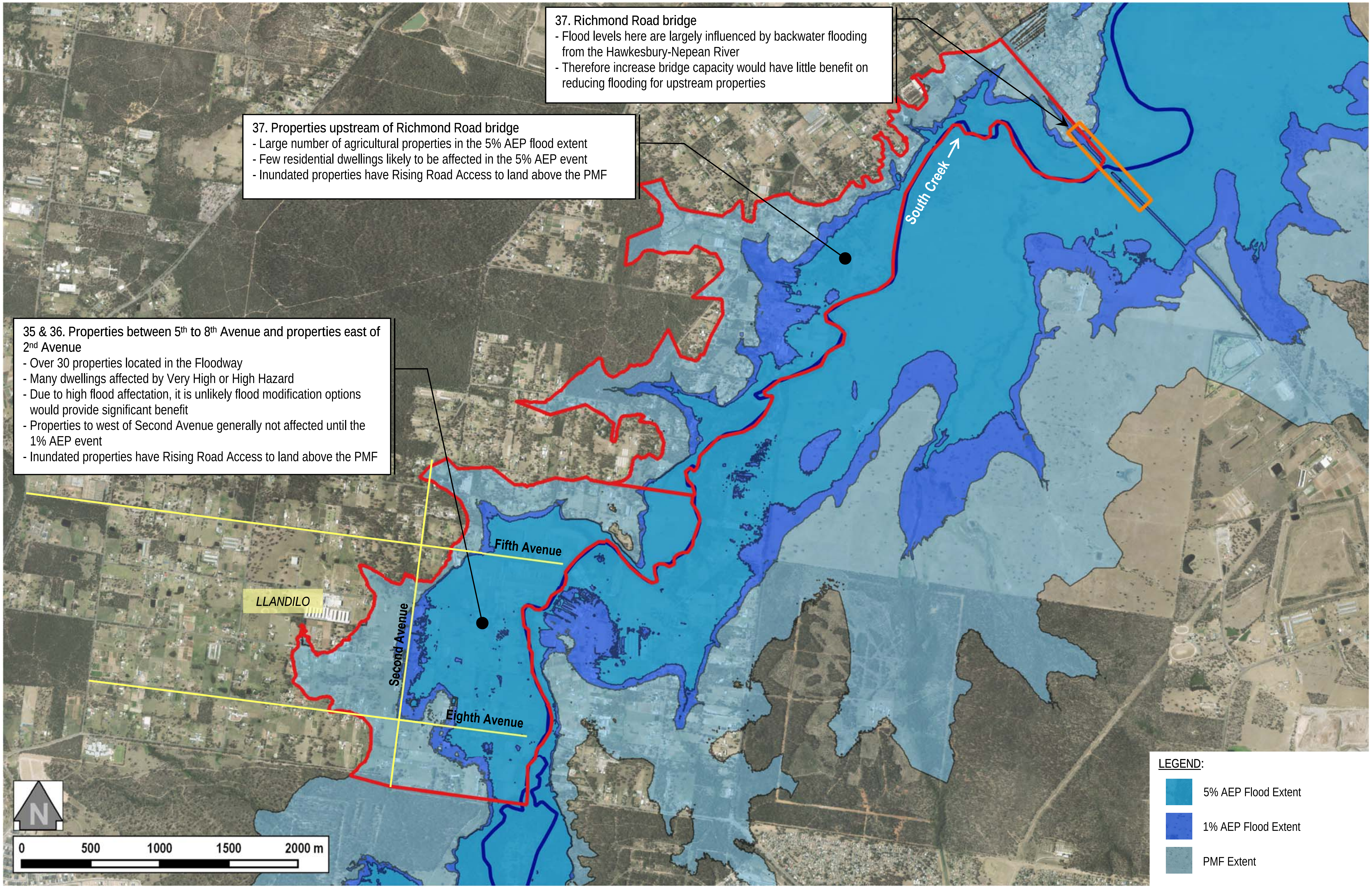
NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 6 – NORTH ST MARYS INCLUDING THE FORMER ADI SITE AND ROPES CROSSING URBAN DEVELOPMENT

FIGURE 8-7



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.7_Preliminary Issues for Sub Area 7

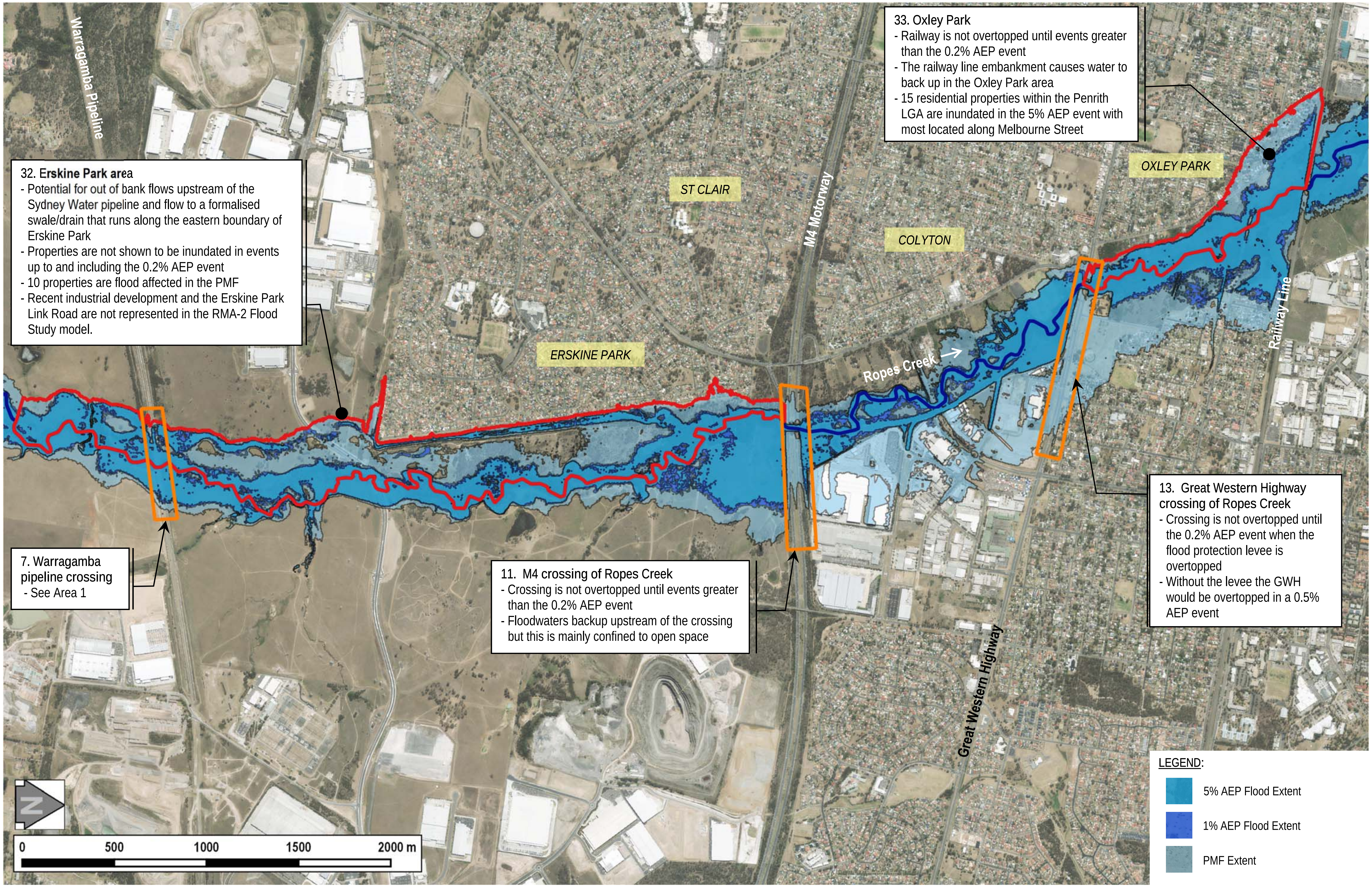
NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 7 – LLANDILO AND AREA UPSTREAM OF RICHMOND ROAD BRIDGE

FIGURE 8-8



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 8.8_Preliminary Issues for Sub Area 8

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale

2. Flood extents are based on a catchment flood event occurring concurrently with a Hawkesbury-Nepean River flood of the same magnitude; i.e., 1% AEP South Creek flood concurrently with a 1% AEP Hawkesbury-Nepean River flood.

FLOODPLAIN MANAGEMENT AREAS
AREA 8 – ROPES CREEK FLOODPLAIN
UPSTREAM OF RAILWAY LINE CROSSING

- **Sub Area 4** - Claremont Meadows and properties/infrastructure affected by Claremont Creek (*refer* **Figure 8.4**)
- **Sub Area 5** - Werrington and Rance Road residential areas (*refer* **Figure 8.5**)
- **Sub Area 6** – North St Marys including the former ADI site (*refer* **Figure 8.6**)
- **Sub Area 7** – South Creek floodplain downstream of the ADI site (*refer* **Figure 8.7**)
- **Sub Area 8** – Ropes Creek floodplain upstream of the Railway Line (*refer* **Figure 8.8**)
- In accordance with the findings of the initial assessment presented in **Appendix E**, flood modification measures designed to protect properties and infrastructure in Llandilo and Berkshire Park were not recommended for detailed assessment as part of the FRMS. Flood modification measures considered include channel clearing along South Creek and construction of flood protection levees.
- Based on the proportionally high flood damages predicted for Llandilo and Berkshire Park (*refer* **Section 7.4**), further justification for the omission of flood modification measures is merited and provided in the following.

8.3.1 Review of Potential Flood Modification Measures for Llandilo and Berkshire Park

Flood Protection Levee/s

The potential for a flood protection levee or a series of levees at Llandilo and Berkshire Park was considered as part of the preliminary issues assessment. The aim of the levee/s would be to reduce the risk and frequency of inundation during floods up to and including the 1% AEP event. At Llandilo and Berkshire Park, this corresponds to a peak flood level of approximately 17.7 to 18.5 mAHD and 17.3 to 17.4 mAHD, respectively.

Construction of a flood protection levee to protect properties at Llandilo and Berkshire Park is not considered feasible for the following reasons:

- High land acquisition, construction and maintenance costs required due to the significant levee length, footprint and crest heights that would be required to deliver a level of flood immunity that would materially reduce flood risk and flood damages to existing development. The required levee length is directly influenced by the large size and spatial distribution of properties that would need to be protected and the wide inundation extents. A levee at Llandilo would likely require:
  - levee length of between 1.0 to 2.0 kilometres pending the number of properties to be protected;
  - typical levee heights of 2.0 to 4.0 metres (*including 0.5 metre freeboard allowance*); and,
  - typical levee footprint (*base width*) spanning 18 to 34 metres; assuming 2 metre crest width and 1(V):4(H) batter slopes.
- Potential flood level increases elsewhere due to the resulting reduction in flood storage volume and the constriction imposed by the levee on the floodplain.
- Remaining flood risks to properties during Hawkesbury River flood events exceeding the South Creek 1% AEP flood design criteria.

Channel Clearing

The potential for vegetation management or channel clearing along South Creek was considered as a potential flood modification. Vegetation management can be an effective measure for reducing peak flood levels especially where a significant portion of the flow is conveyed within the bounds of the creek channel and overbank areas. Reductions in vegetation density therefore allow the channel to convey floodwaters more efficiently allowing the flood to pass through the area at lower peak flood levels.

For the section of South Creek to the east of Llandilo, the creek channel is relatively incised with the creek bed sitting approximately 7 to 8 metres below overbank elevations. Although overbank vegetation is overgrown and dense upstream and downstream of Eighth and Sixth Avenue, respectively, aerial photos show it to be less overgrown in the areas in between.

Any proposal to reduce the density of vegetation upstream of Eighth Avenue would be expected to lead to increased hazards and levels downstream at Llandilo. This would occur as floodwaters would reach Llandilo quicker and at higher velocities.

Removal of vegetation at and downstream of Sixth Avenue could benefit Llandilo at the expense of areas downstream including Berkshire Park. Although some benefit in terms of level reductions could occur as a result of the vegetation removal, the magnitude of these reductions would be low and likely mirrored as increases further downstream.

The effectiveness of channel clearing is reduced further where flooding along South Creek occurs concurrently with flooding along the Hawkesbury River. In this scenario, backwater flooding is the dominant mechanism that governs peak flood levels at Llandilo and Berkshire Park.

The benefits of vegetation management at the Eighth Avenue bridge crossing as an emergency response measure are discussed in **Section 10.5.1**.

8.4 Existing Levee Assessment

The following levees are located within the catchment providing protection to residential and commercial/industrial properties from damage due to flooding:

- St Marys Earthen and Concrete Levee; and the
- Werrington Road and Earthen Levee

The levee assessment has been undertaken with the objective to review the current level of protection provided by each levee and to make recommendations for the future management of the levees. Levee crest elevations have been determined based on the best available topographic data, which includes surveyed spot elevations and 2011 LiDAR (*see* **Section 5.2**).

8.4.1 St Marys Earthen and Concrete Levee

Levee Details

The St Marys levee was constructed along the western floodplain of South Creek to protect residential and commercial/industrial properties to the east of South Creek and upstream of the Great Western Highway at St Marys. The combined earthen and concrete levee is approximately 1,7000 metres in length. The concrete levee is the smaller component spanning approximately 60 metres of the northern most section. Byrnes Creek flows along the eastern side of the concrete levee.

Council has indicated that the levee was designed to provide 1% AEP flood immunity with a freeboard allowance of 0.5 metres. At the time, crest elevations would have been set based on a review of one-dimensional flood modelling completed using the HEC-2 and MIKE-11 models developed as part of the original *South Creek Flood Study* (*1990*).

Review of Levee Crest Elevations

Crest elevations along the earthen and concrete levee components are shown in **Figure 8.9** based on elevations extracted from the 2011 LiDAR and surveyed spot elevations. Also superimposed are peak flood levels predicted for the 1% AEP flood with and without 0.5 metres freeboard included.

Figure 8.9 shows that crest elevations along the St Marys Levee are above the predicted 1% AEP flood levels with and without 0.5 metres freeboard for most of the levee length. The formed section of the earthen levee satisfies the design elevations most with additional freeboard of up to 0.5 metres (*i.e., total freeboard of 1.0 metres to the 1% AEP flood*) predicted along much of its length.

Three locations are identified where crest elevations either fall below the predicted 1% AEP flood level and/or do not meet the 0.5 metre freeboard design criteria. These locations are highlighted in the surface water profile on **Figure 8.9** and as a plan on **Figure 8.10**.

It is worth noting that the upstream most location is within the extent where the levee is unformed and may not have been included within the original levee design. Original design drawings should be reviewed, and/or a levee extension should be considered. Alternatively, sandbagging of the low-point could be a cost-effective and less intrusive option. This recognises that a residential complex borders the eastern edge of the unformed levee alignment (*refer* **Plate 8.1**).

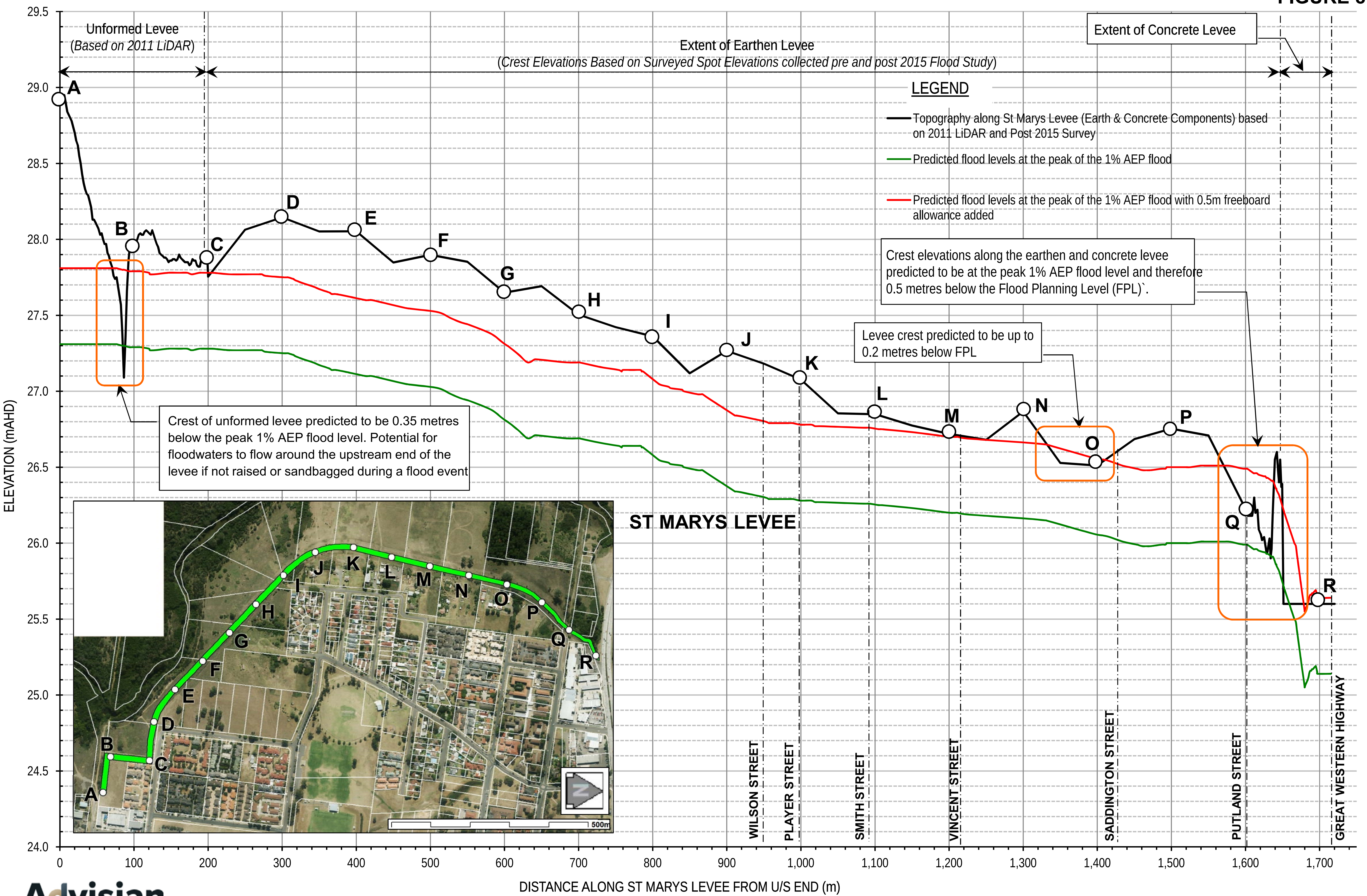
Plate 8-1 Photograph Taken Facing North (Upstream) showing the Unformed Section of the St Marys Levee

Note: Photograph taken from Point C as shown on Figure 8.9 or 8.10

Review of the Downstream Levee Tie-in to the Great Western Highway

The concrete component of the levee ties in to the Great Western Highway at the northern and downstream end. As shown in **Plate 8.2**, the concrete levee is bounded to the east by Byrnes Creek

FIGURE 8.9



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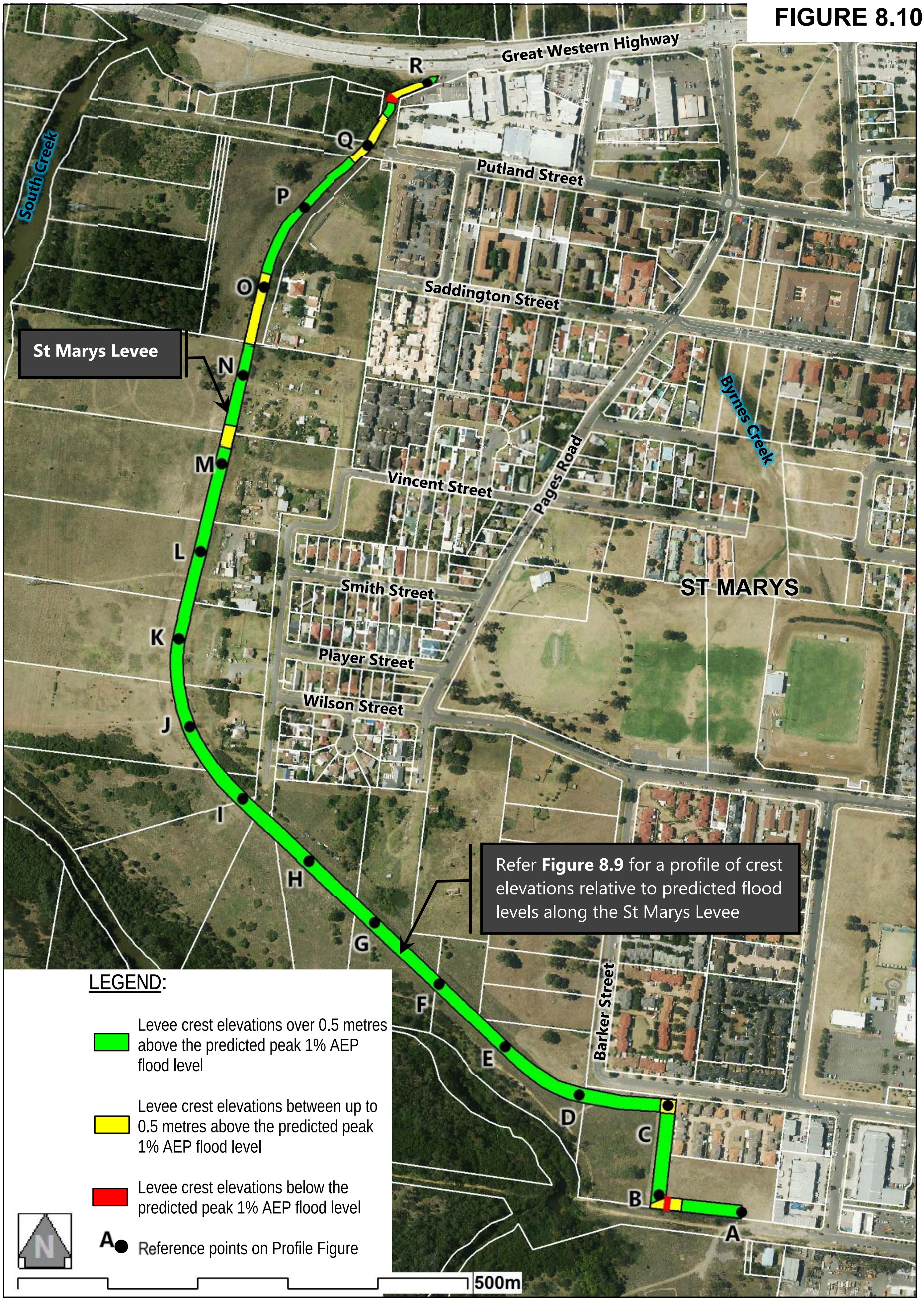
South Creek Flood Study
fg301311-09772rg200220_Profiles along St Marys Levee

REVIEW OF THE FREEBOARD AVAILABLE ALONG THE ST MARYS LEVEE

FIGURE 8.10



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301310-08772 South Creek FRMS
fg301310-08772rg200220-Fig 8.10-St Marys Levee Freeboard Review.docx

AVAILABLE FREEBOARD BETWEEN CREST ELEVATIONS ALONG THE ST MARYS LEVEE AND PEAK 1% AEP FLOOD LEVELS

and west by a side channel that breaks away from South Creek (*located further to the west*). Floodwaters flowing along Byrnes Creek towards the south discharge through a 3.5 metre wide and 3.7 metre high culvert. Three culverts of the same dimensions convey South Creek flows on the opposite side of the levee.

Although the concrete levee ties into the culvert group described above, the levee crest extends above the culverts and the road surface by approximately 0.8 metres (*refer* **Plate 8-2**). The levee crest is understood to be at an elevation of 25.6 mAHD compared 24.8 mAHD along the road corridor.

The difference in levee crest elevation compared to the adjoining road corridor creates a scenario where floodwaters could flow around the concrete levee if the road surface is overtopped.

Plate 8-2 Photograph Taken of the Concrete Levee Facing North (Upstream)

General Observations

Site inspections of the earthen levee embankment identified extensive vegetation including long grass, dense shrub cover and trees. This is a concern as it may create issues with intrusive root growth, could harbour burrowing animals and snakes and may cause difficulties for a levee inspector to adequately assess the condition of the levee.

The section of the earthen levee near the tie-in to the concrete levee was particularly overgrown and poorly maintained. A photograph of the vegetation with the earthen levee obstructed is shown in **Plate 8-3**.

Conclusions and Recommended Actions

The following conclusions are drawn from the assessment of the St Marys Levee:

Three locations are identified where crest elevations either fall below the predicted 1% AEP flood level or do not meet the 0.5 metre freeboard design criteria. These locations are highlighted in the surface water profile on **Figure 8.9** and as a plan on **Figure 8.10**.

The crest of the concrete levee at the tie-in to the Great Western Highway is approximately 0.8 metres above the road surface (*refer* **Plate 8-2**). This creates a scenario where floodwaters overtopping the road could flow around the concrete levee despite the levee crest not overtopping.

Visual inspection of the levee highlighted locations of extensive overgrowth that may create issues with intrusive root growth and could harbour burrowing animals and snakes.

In light of the above findings it is recommended that a crest level survey and external audit be completed. Once the findings are available and crest elevations confirmed it is recommended that a design review be commenced focusing on the three locations identified in **Figure 8.9** and the downstream end of the concrete leave at the tie in to the Great Western Highway.

Plate 8-3 Photograph Taken Facing West of the St Marys Levee showing the overgrowth along the Earthen Levee at the Join with the Concrete Levee

8.4.2 Werrington Road and Earthen Levee

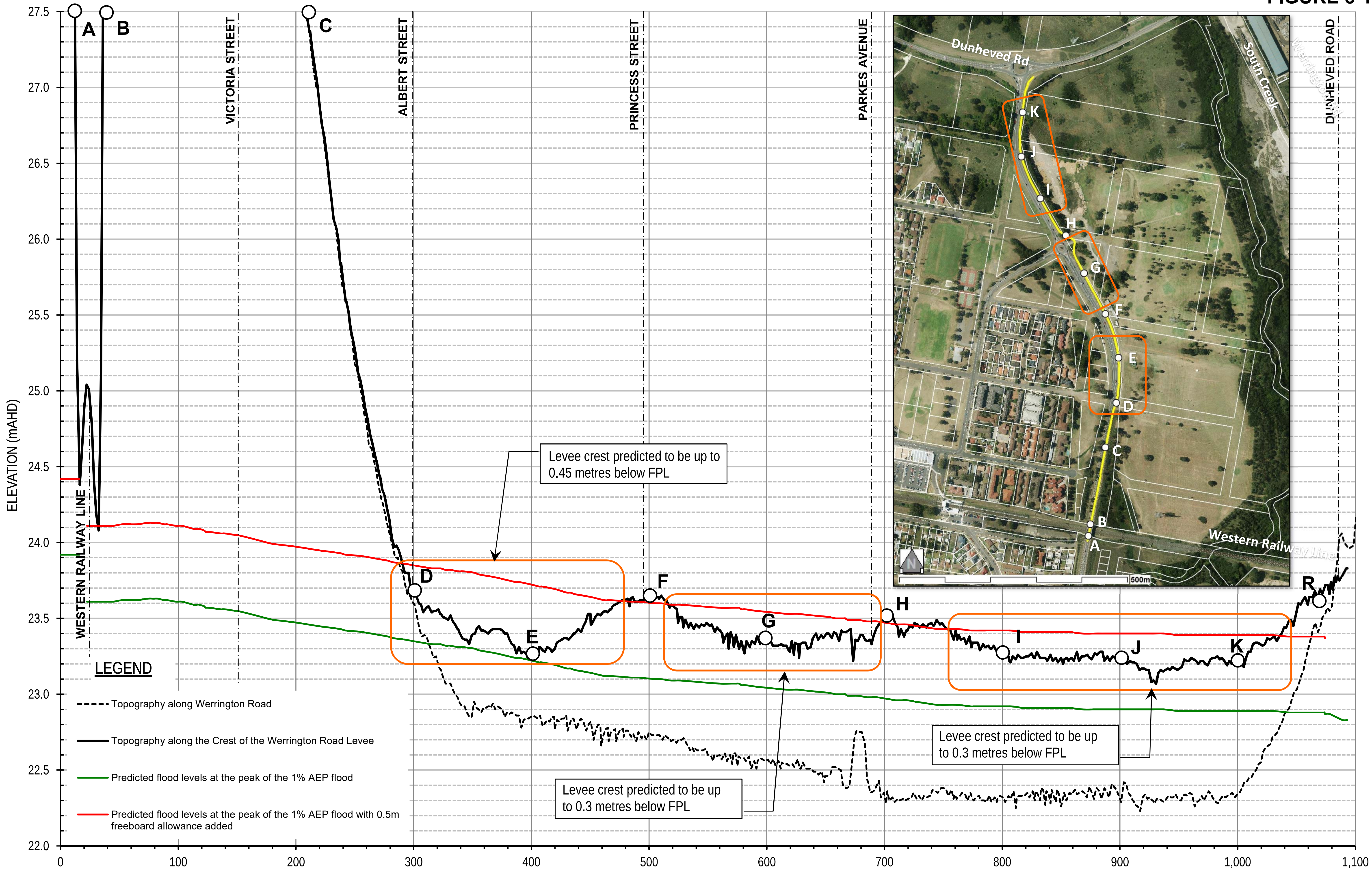
Levee Details

The Werrington Road and Earthen levee is designed to protect the suburb of Werrington from South Creek flooding to the west. The levee spans a total length of 800 metres and consists of two parts starting upstream with the elevated Werrington Road followed by a transition to a raised earthen embankment which runs parallel to, and along the eastern side of Werrington Road.

Council has indicated that the levee was designed to provide 1% AEP flood immunity with a freeboard allowance of 0.5 metres. It is understood that crest elevations would have been based on the one-dimensional flood modelling completed using the HEC-2 and MIKE-11 models developed as part of the original *South Creek Flood Study* (*1990*).

Review of Levee Crest Elevations

Crest elevations along the Werrington Road levee are shown in **Figure 8.11** based on elevations extracted from the 2011 LiDAR. Also superimposed are peak flood levels predicted for the 1% AEP flood with and without 0.5 metres freeboard included.



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South Creek Flood Study
fg301311-08772rg200220_Profiles along Werrington Levee

COMPARISON OF CREST ELEVATIONS ADOPTED ALONG THE WERRINGTON ROAD AND EARTHEN LEVEE [2015 Flood Study to Latest Topographic Data]

Crest elevations along the Werrington Road levee are predicted to be above peak flood levels for the 1% AEP flood. The freeboard available is lowest between Albert Street and Princess Street where the levee crest is only 0.05 metres above peak 1% AEP flood levels (*refer* **Figure 8-11**).

Three locations spanning a total length of approximately 470 metres (*almost 60% of the total levee length*) have been identified where the levee crest does not meet the 0.5 metre freeboard design criteria. These locations are highlighted in the surface water profile on **Figure 8.11** and as a plan on **Figure 8.12**.

General Observations

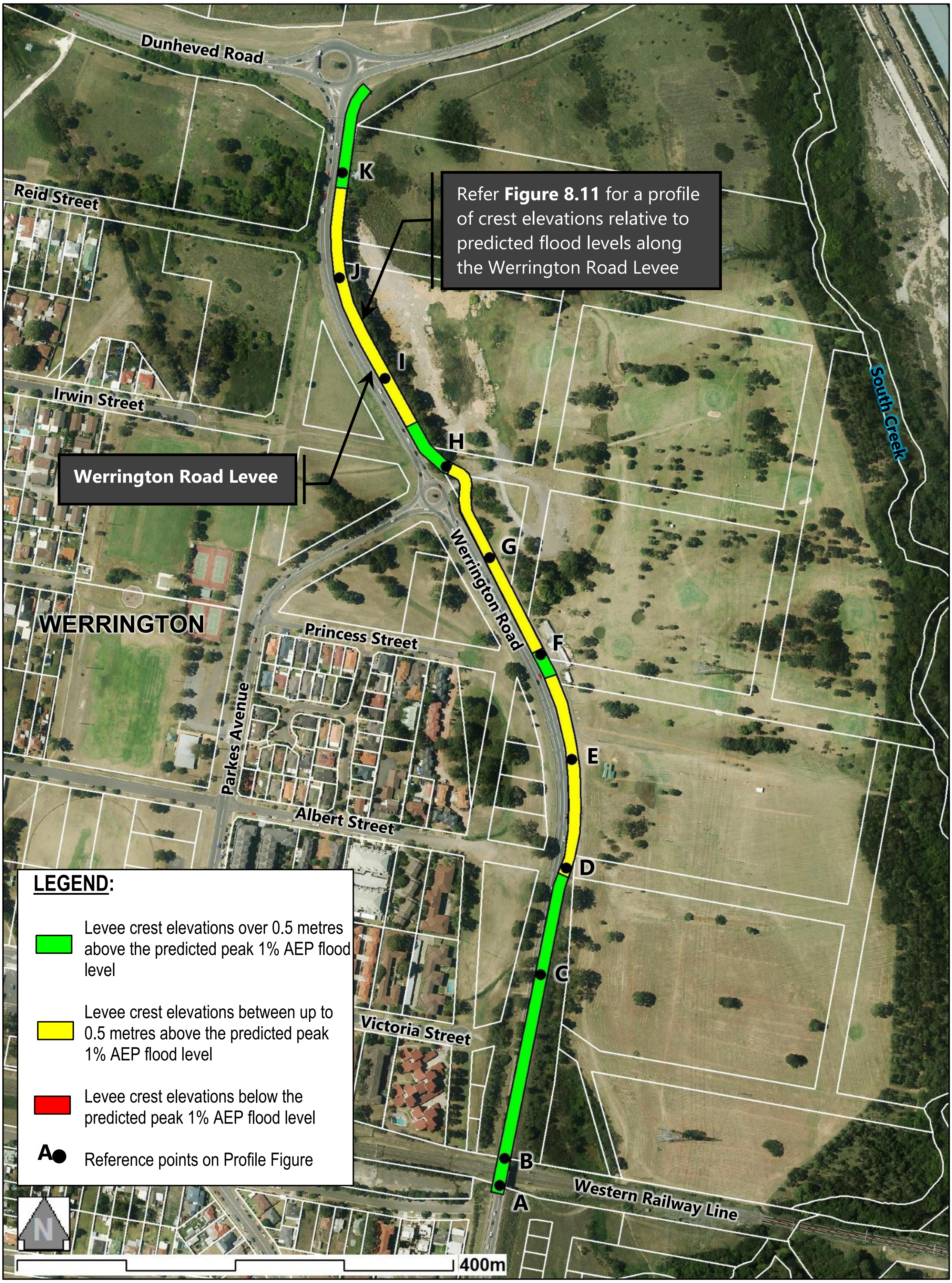
The earthen levee appears to be well maintained with grass routinely mowed and no uncontrolled shrub and tree growth.

Conclusions and Recommended Actions

The following conclusions are drawn from the assessment of the Werrington Road levee:

- Three locations spanning a total length of 470 metres have been identified where crest elevations do not meet the 0.5 metre freeboard design criteria. These locations are highlighted in the surface water profile on Figure 8.11 and as a plan on Figure 8.12.
- The earthen levee appears to be routinely maintained with grass mowed and no unwanted growth of trees and shrubs.

A crest level survey is recommended to confirm the freeboard available at the three locations identified. Once crest elevations are confirmed it is recommended an audit take place to assess the levee structure and the flood operating level. Where the operating level is below the original design criteria it is recommended a design review be commenced to determine options for raising the levee.



AVAILABLE FREEBOARD BETWEEN CREST ELEVATIONS ALONG THE WERRINGTON ROAD LEVEE AND PEAK 1% AEP FLOOD LEVELS

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301310-08772 South Creek FRMS
fg301310-08772rg200220-Fig 8.10-St Marys Levee Freeboard Review.docx

9. Assessment of Flood Modification Measures

A key objective of this Floodplain Risk Management Study is to identify and assess opportunities for reducing the impact of floods on the community.

The damages assessment for the study area documented in **Section 7** established that the single occurrence of the design 1% AEP flood would lead to damages amounting to $12M. This damage cost does not account for intangibles, which have the potential to be as much again. The results of the analysis also indicate that the Average Annual Damages (*AAD*) for all events is in the order of $980,000. That is, funds in the order of $980,000 would need to be put aside each year on average, to cover the damage bills that could be incurred as a consequence of flooding.

In response to current flood damages and based on the findings of the preliminary options assessment (*refer* **Section 8.3** *and* **Appendix G**), a range of potential flood management measures have been identified to reduce the flood damages and ameliorate associated flood risk to individuals. Options were selected for further investigation and modelling based on consideration of their expected hydraulic impact, cost of construction, social impacts, and environmental impacts.

The detailed assessment of the adopted flood modification measures is provided in the following sections.

9.1 Flood Modification Measures

The flood modification measures that have been selected following the preliminary options assessment are listed in **Table 9.1**. The location of each measure and a description of the works involved are included.

The measures listed in **Table 9-1** are generally located in those parts of the floodplain that have been identified to experience a high flood risk and/or high value of damages. Two locations that match these criteria include properties along Melbourne Avenue in Oxley Park (*along Ropes Creek*) and properties to the north of Rance Road at Werrington (*impacted by Claremont Creek and South Creek flooding*).

No flood modification measures are proposed for Llandilo and Berkshire Park based on flooding being dominated at these locations by backwater flooding from the Hawkesbury-Nepean River. As a result, peak flood levels are a direct function of the volume of available flood storage upstream of the Sackville Gorge as well as the hydraulics through the gorge itself. Localised structural measures such a channel modifications or levees therefore result in little, to no measurable, change to flood behaviour and benefit to properties. Extreme excavation of the floodplain would be required to cause any substantial reduction to peak flood levels. Due to the large spatial area required such a proposal would not be possible.

In lieu of this, property modification measures such as voluntary purchase or voluntary raising are preferred and have been investigated for Llandilo and Berkshire Park.

Table 9-1 Potential Flood Mitigation Options

Measure^	Location	Description
F-1A	Oxley Park	Floodplain excavation downstream of the railway bridge (*low cut scenario*)
F-1B	Oxley Park	Floodplain excavation downstream of the railway bridge (*high cut scenario*)
F-2	Oxley Park	Flood Protection Levee
F-3	Oxley Park	Railway Bridge Widening
F-4	Oxley Park	Additional Storage Upstream of the Railway Crossing
F-5	Werrington	Raise Werrington and Rance Road
F-6	St Clair Erskine Park	Raise low-points along Mamre Road
F-7A	St Marys	Upgrades to the St Marys Levee
F-7B	St Marys	Option F-7A plus installation of a Flap Gate
P-1	Llandilo Berkshire Park Orchard Hills	Voluntary House Raising
P-2	Llandilo Berkshire Park	Voluntary House Purchase

^ Measures starting with 'F' are structural measures with a focus on Flood Modification and 'P' on Property Modification.

9.2 Assessment Methodology

The assessment of flood modification measures was completed using the approach outlined below:

- Hydraulic modelling using the two-dimensional RMA-2 model developed as part of the *Updated South Creek Flood Study* (*2015*).
  - Initially modelling completed for the 5% and 1% AEP floods only and reviewed to determine whether the hydraulic benefit expected was predicted to occur and whether impacts on adjoining properties was within an acceptable range.
  - Where results were favourable further modelling for the entire range of design events; i.e., 2%, 0.5% and 0.2% AEP floods.
  - Flood behaviour at the peak of the Probable Maximum Flood (*PMF*) was assumed to be unchanged between pre and post-mitigation conditions.
- Assessment of the cost of options, including upfront capital costs and ongoing maintenance costs. Note that all cost estimates represent a total present value of costs over a 30 year design life assuming a real discount rate of 7%. All cost estimates also include an allowance for further design and approvals.

- Calculation of the Benefit Cost Ratio (BCR), and
- Triple-Bottom-Line (TBL) assessment to consider additional factors, such as social and environmental impacts/benefits.

9.3 Assessment of Flood Modification Measures

The flood modification measures listed in Table 9-1 were assessed to determine their impact on flood hydraulics, flood damages and the cost to construct and maintain. A Benefit Cost Analysis (BCA) was also prepared to assess the economic viability of implementing the proposed measures. This is completed by comparing the estimated cost of construction/implementation to the predicted monetary benefit in terms of the predicted reduction in flood damages.

Where proposed measures were found to generate a lower than expected hydraulic benefit for the 5% and 1% AEP floods, modelling of the remaining design events was not undertaken and a benefit/cost analysis was not prepared.

9.3.1 Measure F-1A: Floodplain Excavation Downstream of the Railway Crossing (*Low Cut Scenario*)

Description of Proposed Works

Measure F-1A involves excavation of the floodplain immediately downstream of the Western Railway bridge crossing of Ropes Creek at Oxley Park. The excavation is proposed to increase the hydraulic efficiency of the existing bridge crossing by reducing the hydraulic impediment to floodwaters caused by Ropes Creek meandering sharply immediately of the crossing combined with elevated surface elevations overbank.

Inset 1 on **Figure 9-1** shows the location and extent of the proposed excavation relative to existing topographic elevations. Inset 1 shows the creek meander and high overbank elevations that cause the reduced hydraulic efficiency of the crossing.

Inset 2 and Inset 3 of **Figure 9-1** show the depths of the proposed excavation and the finished surface elevations with the proposed cut completed, respectively. As shown in Inset 2, Measure F-1A involves excavation to depths of up to 1.45 metres across an area covering 1.2 hectares (*ha*). Finished surface elevations across the excavated area are in the order of 31.10 mAHD.

Once excavated, areas disturbed would be revegetated to reinstate the area to reflect conditions pre-excavation. A controlled works application would be required given that excavation is proposed within close proximity to Ropes Creek and within the riparian corridor.

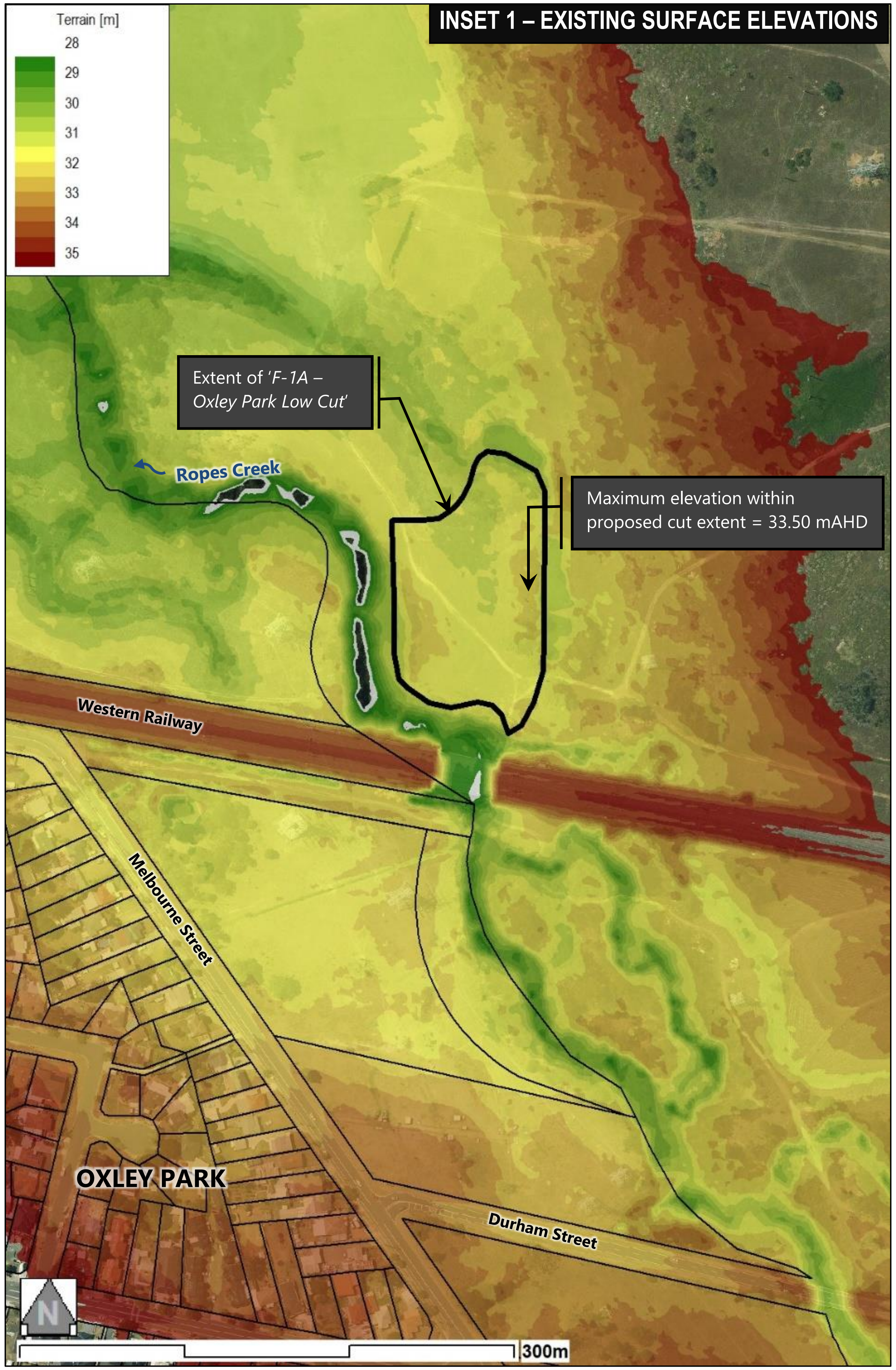
Hydraulic Assessment

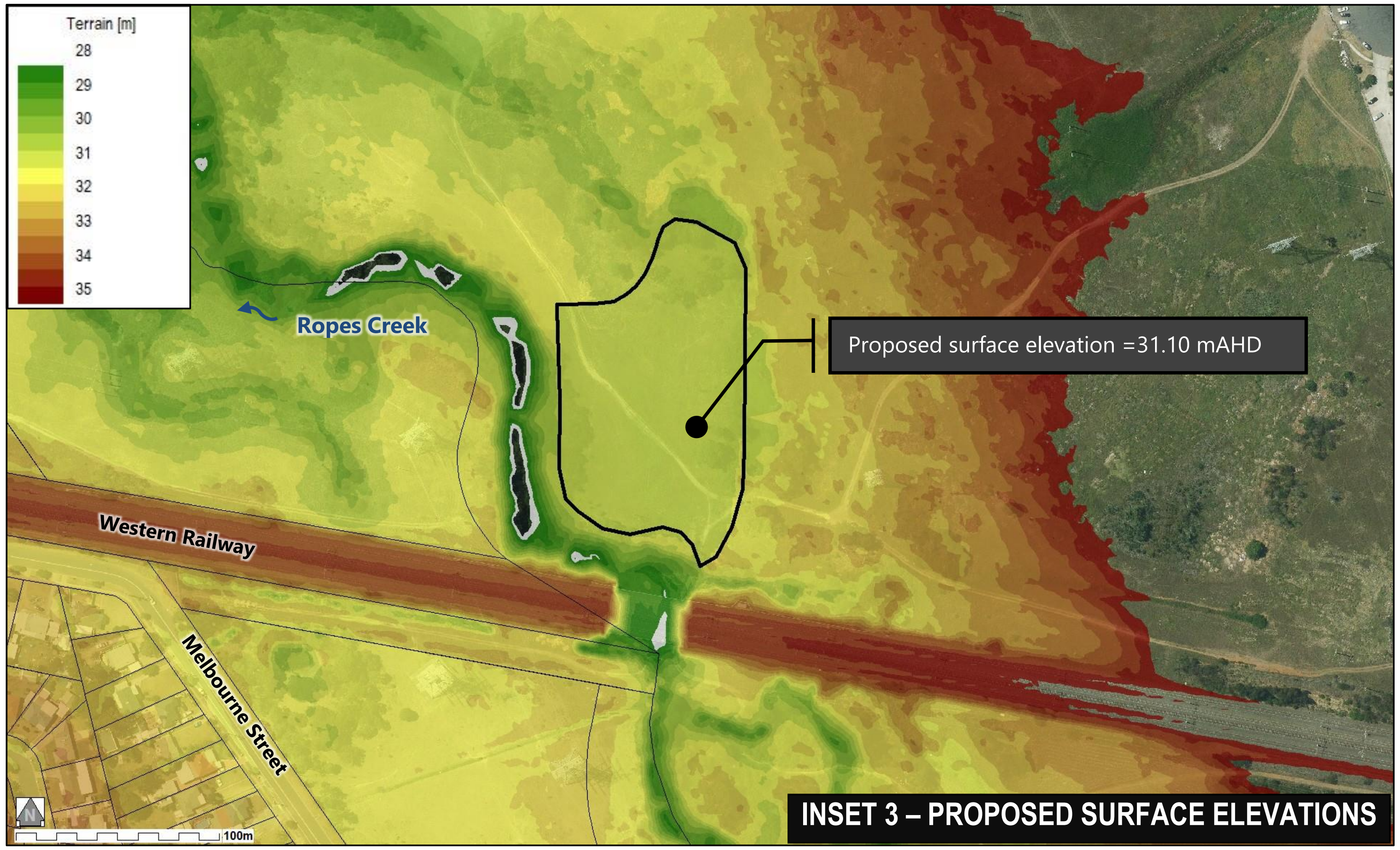
Changes in peak 1% AEP flood levels due to mitigation Measure F-1A are shown in **Figure 9-2**. During the 1% AEP event, the proposed excavation is predicted to result in a maximum reduction in peak flood levels of up to 0.26 metres.

Along properties that front Melbourne Street (where the damages have been identified as highest) the reduction in peak 1% AEP flood levels are predicted to be 0.12 metres. As shown in **Table 9-2**, the reduction in levels for all other design events is similar in magnitude.

Reductions to flood levels are also predicted to the east of Ropes Creek at Colyton within the Blacktown City Council LGA. As shown in **Figure 9-2**, reductions in flood levels of between 0.03 to 0.06 metres are predicted for all design events simulated.

FIGURE 9.1





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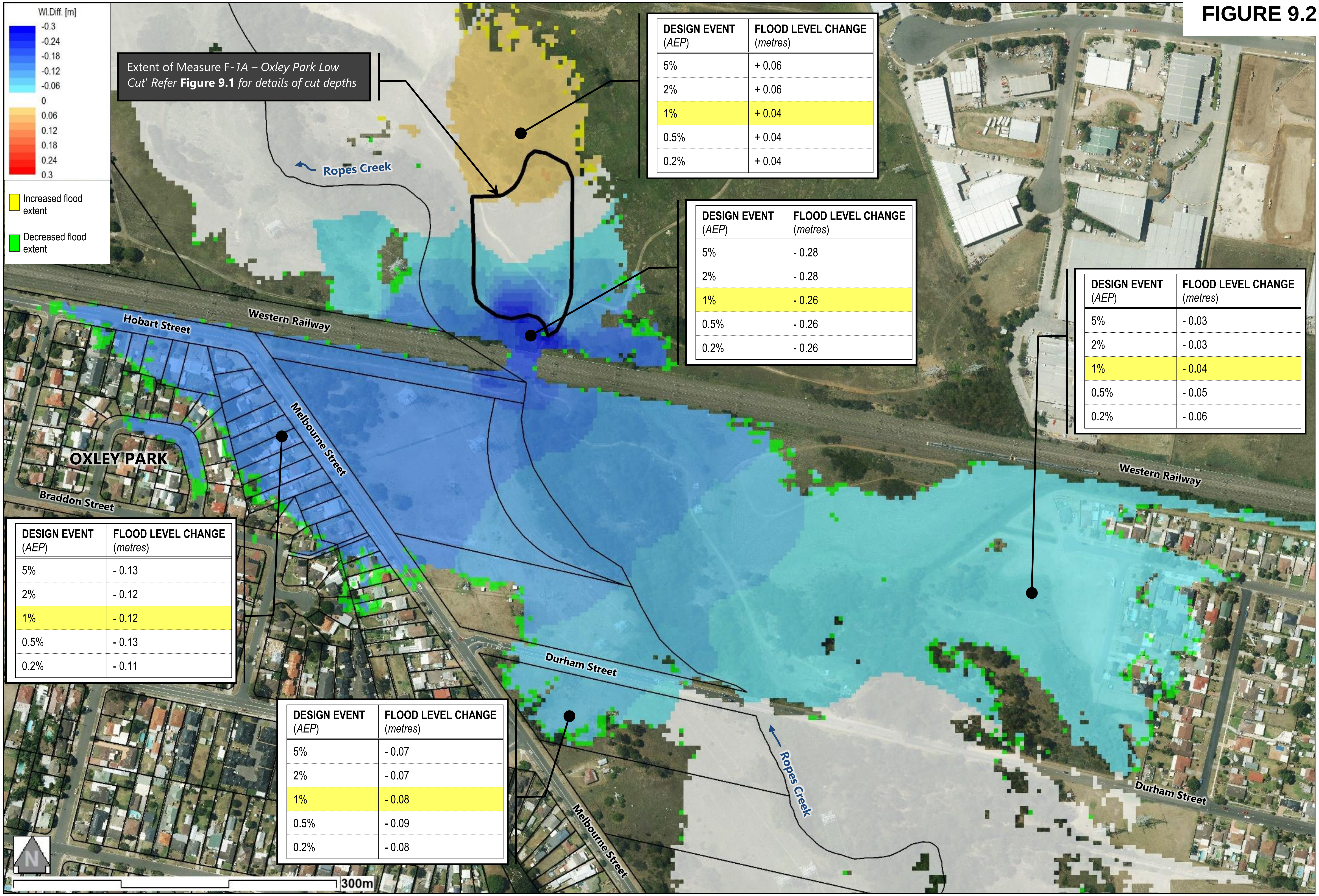
301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.1_DRM Oxley Park Cut (Low) Overview

OVERVIEW OF PROPSOED MEASURE F-1A – OXLEY PARK LOW CUT' SCENARIO'

FIGURE 9.2



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.06
2%	+ 0.06
1%	+ 0.04
0.5%	+ 0.04
0.2%	+ 0.04

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.28
2%	- 0.28
1%	- 0.26
0.5%	- 0.26
0.2%	- 0.26

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.03
2%	- 0.03
1%	- 0.04
0.5%	- 0.05
0.2%	- 0.06

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.13
2%	- 0.12
1%	- 0.12
0.5%	- 0.13
0.2%	- 0.11

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.07
2%	- 0.07
1%	- 0.08
0.5%	- 0.09
0.2%	- 0.08

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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.2_DRM Oxley Park Cut (Low) Impacts (100yr)

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-1A – OXLEY PARK LOW CUT' SCENARIO

[CHANGES FOR THE 1% AEP FLOOD SHOWN]

Increases in flood levels of up to 0.06 metres are predicted to occur downstream of the Railway Crossing and the proposed excavation area (refer Figure 9-1). The affected area is within the Blacktown LGA. Although shown as undeveloped it is understood that the area will be turned into playing/sporting fields.

Table 9-2 Predicted Change in Flood Levels to Properties along Melbourne Street, Oxley Park, as a Result of Flood Modification Measure F-1A

Design Event (*AEP*)	**Predicted Flood Level Change** (*metres*)
5%	- 0.13
2%	- 0.12
1%	- 0.12
0.5%	- 0.13
0.2%	- 0.11

The benefit of the predicted flood extent and level reductions on the affectation of properties in the local area is shown in **Table 9-3**. The benefit is measured based on the total number of properties predicted to be flooded below and above floor levels with and without the mitigation measure in place.

As shown in **Table 9-3**, Measure F-1A is predicted to result in three (3) less residential properties experiencing over floor flooding during floods up to and including the 1% AEP flood; i.e., during the 5%, 2% and 1% AEP events. Where an increase in the number of properties experiencing below floor flooding occurs this is due to properties previously experiencing above floor flooding shifting to below floor flooding. Accordingly, no new properties are predicted to be inundated.

Table 9-3 Predicted Change in Flood Affectation of Properties in Local Area (Below and Above Floor Flooding)

Design Event (*AEP*)	**Below Floor Flooding**		**Above Floor Flooding**	
	Existing	**Post Mitigation**	**Existing**	**Post Mitigation**
5%	12	12 *(- 0)*	3	0 *(- 3)*
2%	8	9 *(+ 1)*	10	7 *(- 3)*
1%	7	9 *(+ 2)*	13	10 *(- 3)*
0.5%	8	5 *(- 3)*	17	15 *(- 2)*
0.2%	12	10 *(- 2)*	18	17 *(- 1)*
PMF	14	14 *(- 0)*	97	88 *(- 9)*

Cost Estimate

The cost of implementing Measure F-1A is estimated to be $408,000 (*refer* **Appendix F**), which represents the total present value of upfront costs and maintenance costs with a 20% contingency.

The capital cost includes an allowance for excavation of the area, levelling, revegetation and the ongoing maintenance of the area; particularly those areas disturbed within the Riparian Corridor.

Environmental Factors

The proposed works would require excavation within close proximity to Ropes Creek and within the riparian corridor. Removal of trees and low-lying vegetation from the creek bank would be required over a distance of approximately 150 metres.

The vegetation across the floodplain to the north-east of Ropes Creek is generally grassed with scattered trees. Removal of trees and grass followed by revegetation is not expected to pose any environmental issues.

If the sporting fields proposed by Blacktown City Council are completed at the time of the works commencing there would be an impact on the amenity of the area during construction works.

Benefit / Cost Analysis

As shown in **Table 9-4**, Measure F-1A has been determined to result in a reduction in the NPV of damages for Oxley Park of $268,100. Based on an estimated construction cost for the measure of $356,600 this translates to a benefit/cost ratio of 0.75.

Table 9-4 Benefit/Cost Ratio for Measure F-1A

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Oxley Park Existing	30	**$54,000**	**$724,000**	-	-	-
Oxley Park Low Cut	30	**$34,000**	**$455,900**	$356,600	$268,100	**0.75**

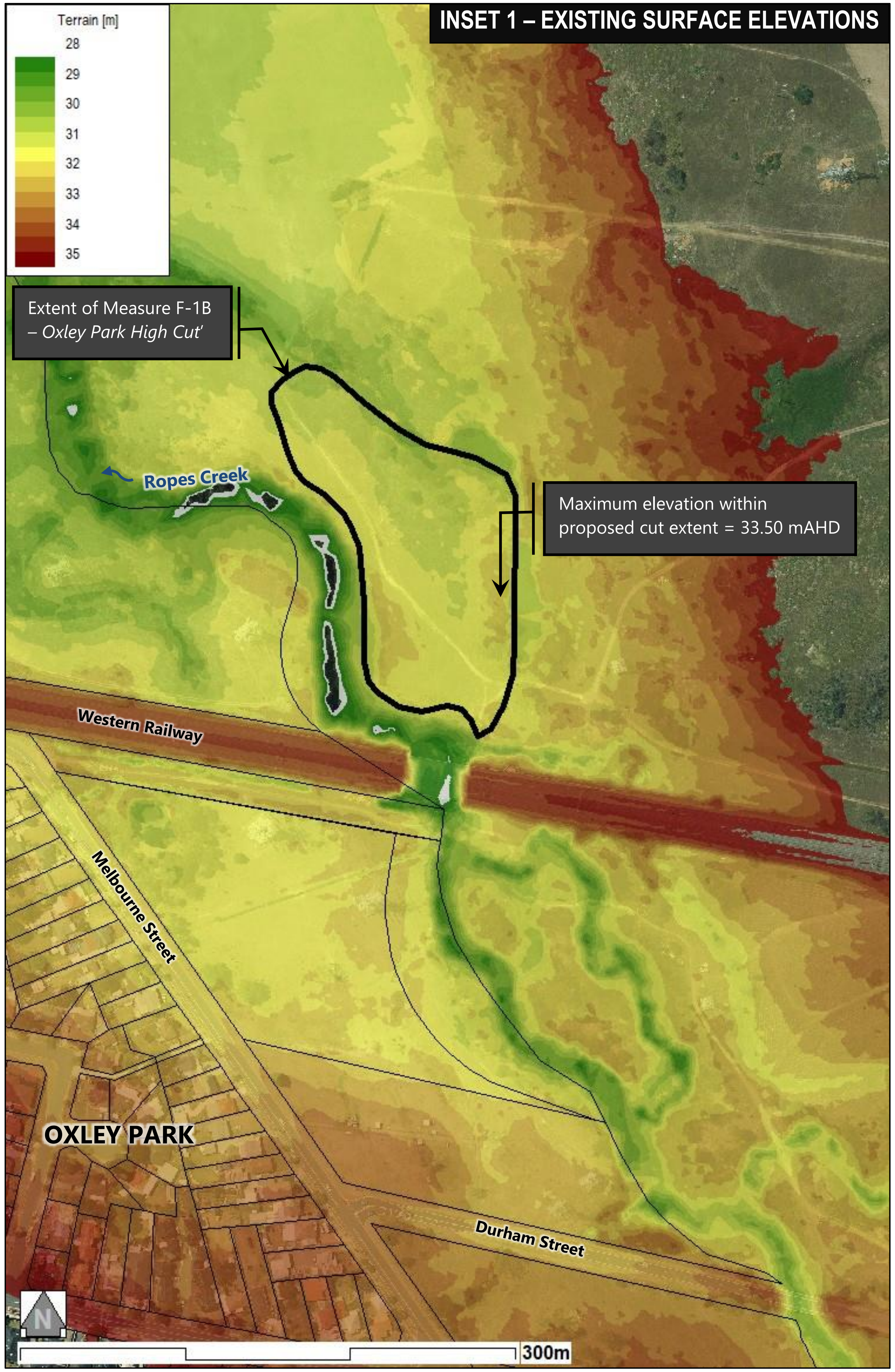
9.3.2 Measure F-1B: Floodplain Excavation Downstream of the Railway Crossing (*High Cut Scenario*)

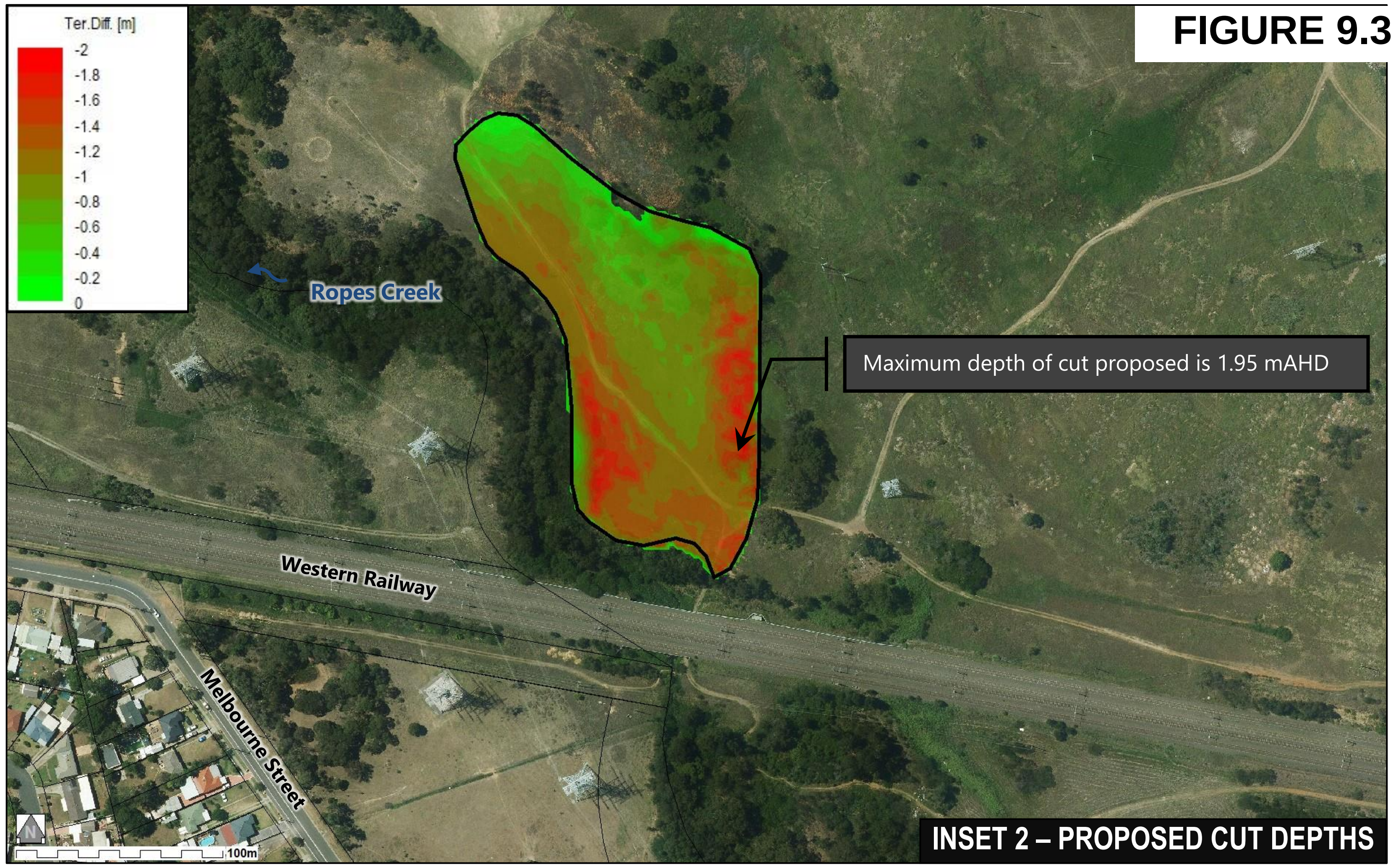
Description of Proposed Works

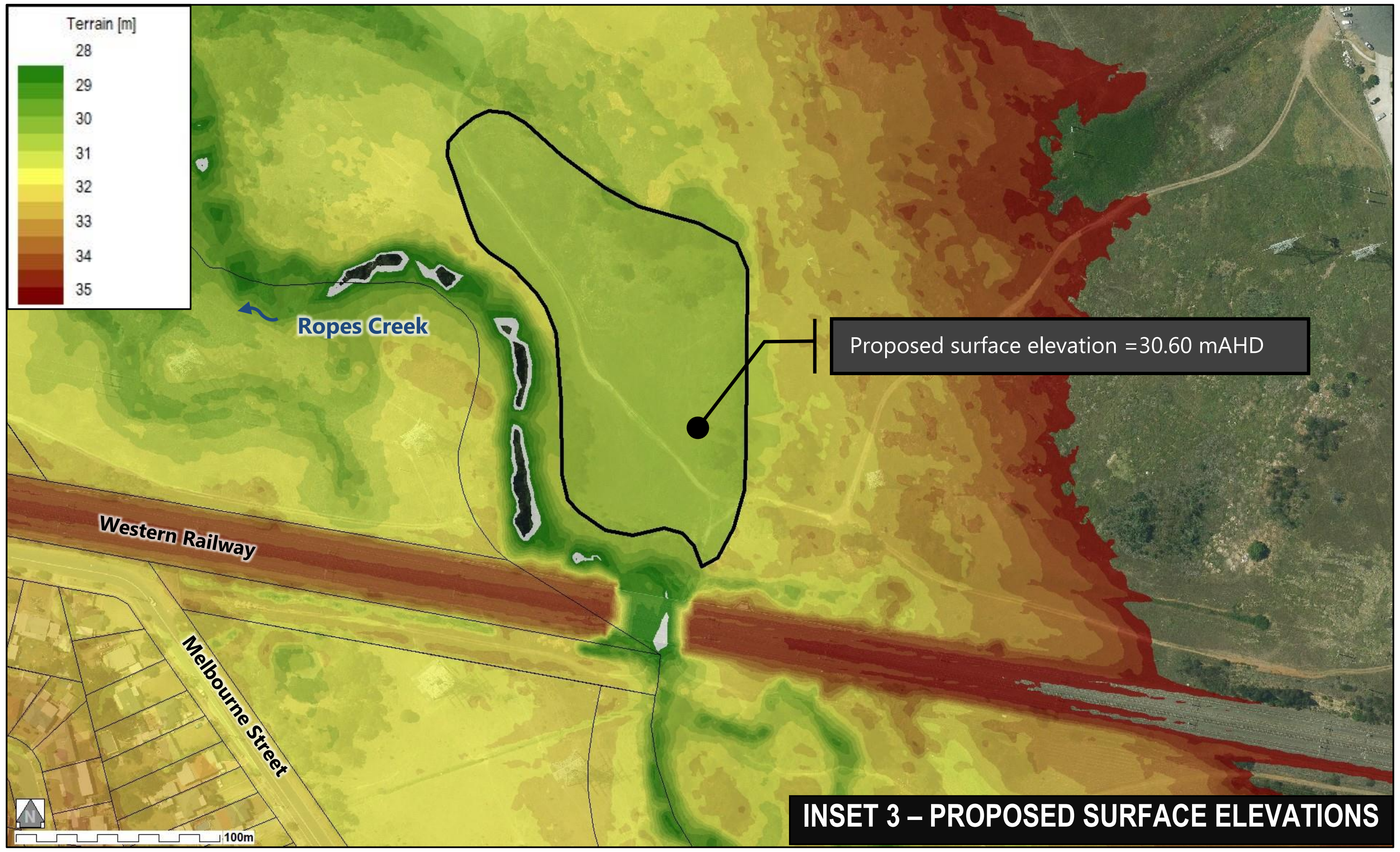
Measure F-1B proposes more aggressive excavation than Measure F-1A for increasing the hydraulic efficiency of the existing Railway Crossing. As shown in **Figure 9.3**, the extent of proposed excavation is extended to the north beyond what was proposed for Measure F-1A resulting in a total excavation area of 1.8 ha; compared to 1.2 hectares for Measure F-1A.

The depths of excavation are also increased with a maximum depth of 1.95 metres proposed; compared to 1.45 metres for Measure F-1A. This represents an additional 0.5 metres of cut to create finished surface elevations of approximately 30.6 mAHD (*refer Inset 3*, **Figure 9.3**).

FIGURE 9.3







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**OVERVIEW OF PROPSOED MEASURE F-1B
– OXLEY PARK HIGH CUT' SCENARIO'**

Hydraulic Assessment

Changes in flood level due to Measure F-1B are shown in **Figure 9.4** for the 1% AEP flood. The predicted changes to peak flood levels for the 5%, 2%, 0.5% and 0.2% AEP floods are shown in tables on **Figure 9.4** for key locations.

During the A% AEP event, the proposed excavation is predicted to result in a maximum reduction in peak flood levels immediately downstream of the crossing of up to 0.45 metres. Along properties that front Melbourne Street (*where the damages have been identified as highest*) the reduction in peak 100 year ARI flood levels is predicted to be 0.21 metres.

The reduction in levels for all other design events is similar in magnitude as shown in **Table 9.5**.

Reductions to flood levels to the east of Ropes Creek at Colyton (*within the Blacktown City Council LGA*) are predicted to range between 0.04 to 0.08 metres for all design events. Increases in flood levels of between 0.06 and 0.10 metres are predicted to occur downstream of the Railway Crossing and the proposed excavation area (*refer* **Figure 9.4**). The affected area is within the Blacktown LGA.

Cost Estimate

The cost of implementing Measure F-1B is estimated to be $996,000 (*refer* **Appendix F**), which incorporates similar allowances to that provided for Measure F-1A plus the cost of additional excavation and re-vegetation.

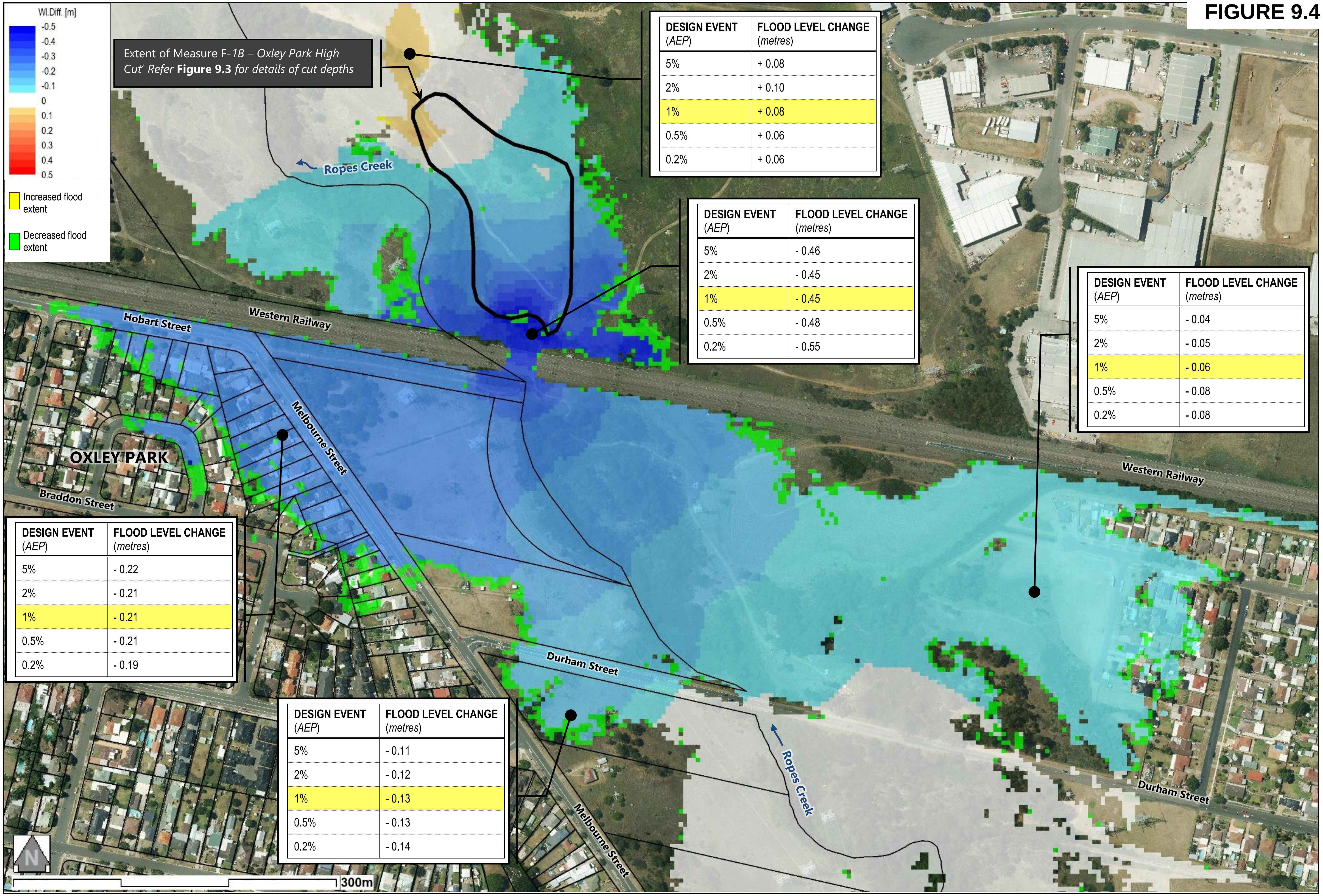
Table 9-5 Predicted Change in Flood Levels to Properties along Melbourne Street, Oxley Park, as a Result of Measure F-1B

Design Event (AEP)	**Predicted Flood Level Change** (*metres*)
5%	- 0.22
2%	- 0.21
1%	- 0.21
0.5%	- 0.21
0.2%	- 0.19

The benefit of the predicted flood extent and level reductions on the affectation of properties in the local area is shown in **Table 9-6**. The benefit is measured based on the total number of properties predicted to be flooded below and above floor levels with and without the mitigation measure in place.

As shown in **Table 9-6**, Measure F-1B is predicted to result in a reduction in dwellings being flood above floor by up to nine (9) depending on the design event. Where an increase in the number of properties experiencing below floor flooding occurs this is due to properties previously experiencing above floor flooding shifting to below floor flooding. Accordingly, no new properties are predicted to be inundated.

FIGURE 9.4



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.08
2%	+ 0.10
1%	+ 0.08
0.5%	+ 0.06
0.2%	+ 0.06

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.46
2%	- 0.45
1%	- 0.45
0.5%	- 0.48
0.2%	- 0.55

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.04
2%	- 0.05
1%	- 0.06
0.5%	- 0.08
0.2%	- 0.08

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.22
2%	- 0.21
1%	- 0.21
0.5%	- 0.21
0.2%	- 0.19

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.11
2%	- 0.12
1%	- 0.13
0.5%	- 0.13
0.2%	- 0.14

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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.4_DRM Oxley Park Cut (High) Impacts (100yr)

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-1B – OXLEY PARK HIGH CUT' SCENARIO
[CHANGES FOR THE 1% AEP FLOOD SHOWN]

Table 9-6 Predicted Change in Flood Affectation of Properties in Local Area (Below and Above Floor Flooding)

Design Event (*AEP*)	Below Floor Flooding		Above Floor Flooding	
	Existing	Post Mitigation	Existing	Post Mitigation
5%	12	12 *(- 0)*	3	0 *(- 3)*
2%	8	12 *(+ 4)*	10	1 *(- 9)*
1%	7	7 *(- 0)*	13	10 *(- 3)*
0.5%	8	10 *(+ 2)*	17	10 *(- 7)*
0.2%	12	8 *(- 4)*	18	17 *(- 1)*
PMF	14	11 *(- 3)*	97	88 *(- 9)*

Environment Factors

The potential impact on the environment would be similar to that for Measure F-1A, with potentially increased impacts due the increased extent and magnitude of proposed excavation.

Benefit / Cost Analysis

As shown in **Table 9-7**, Measure F-1B has been determined to result in a reduction in the NPV of damages for Oxley Park of $375,400. Based on an estimated construction cost for the measure of $914,000 this translates to a benefit/cost ratio of 0.41.

Table 9-7 Benefit/Cost Ratio for Measure F-1B

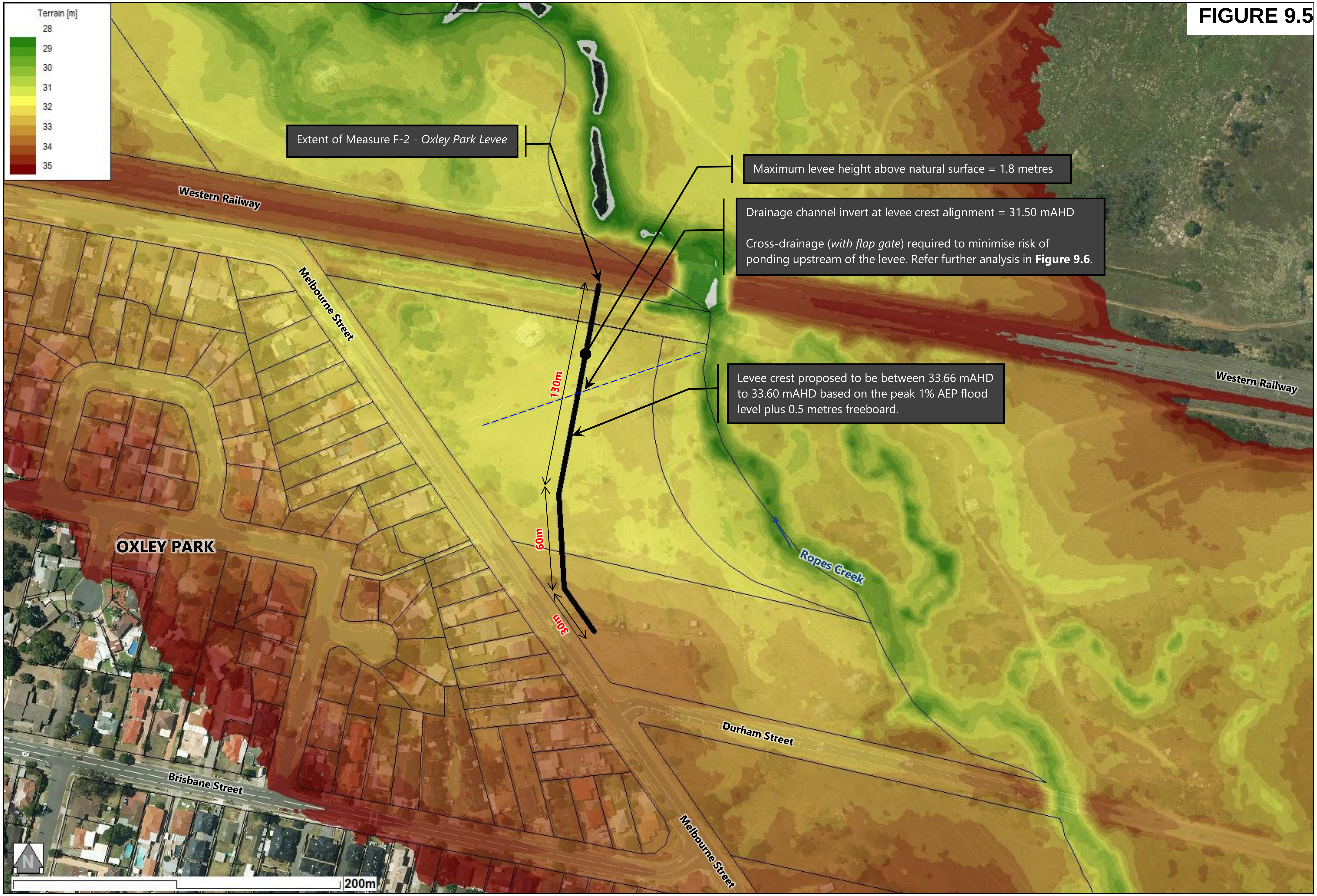
Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Oxley Park Existing	30	**$54,000**	**$724,000**	-	-	-
Oxley Park High Cut	30	**$26,000**	**$348,600**	$914,000	$375,400	**0.41**

9.3.3 Measure F-2: Oxley Park Flood Protection Levee

Description of Proposed Works

Measure F-2 consists of a flood protection levee designed to prevent flooding of properties along Melbourne Street, Oxley Park, during Ropes Creek flood events up to and including the 1% AEP flood.

The proposed alignment and extent of the flood protection levee is shown in **Figure 9.5**.



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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.5_DRM Oxley Park Levee Overview

OVERVIEW OF PROPOSED MEASURE F-2 – OXLEY PARK LEVEE

To provide flood protection during events up to and including the 1% AEP flood, the levee will need to be constructed with crest elevations of between 33.60 and 33.66 mAHD and a total length of approximately 220 metres. The minimum crest elevations have been determined based on the predicted 1% AEP flood levels plus 0.5 metres freeboard. The levee crest would be a maximum 1.8 metres above the natural surface.

A review of the topography west of the proposed levee indicates that a 27 ha catchment could capture and convey runoff towards the levee (*refer* **Figure 9.6**). Hydrologic modelling of the catchment using XP-RAFTS indicates that the runoff volume could be sufficient for long duration events to lead to ponding behind the levee to ponding depths sufficient to cause damage to properties along Melbourne Street.

The proposed levee would therefore require cross-drainage to allow any local build-up of overland runoff behind the levee to be conveyed onwards to Ropes Creek. The proposed location for this cross-drainage structure would be along the existing drainage channel that conveys runoff east-to-west to Ropes Creek (*refer* **Figure 9.5**). A flap gate would be required to prevent floodwaters east of the levee from backing up through the culverts.

A detailed assessment of the cross-drainage component of the flood protection levee will be required if this measure is to be progressed.

Hydraulic Assessment

Changes in peak 100 year ARI flood levels due to mitigation Measure F-2 are shown in **Figure 9.7**. The predicted changes to peak flood levels for the 5%, 2%, 0.5% and 0.2% AEP floods are shown in tables on **Figure 9.7** for key locations.

The flood protection levee is predicted to cause only minor increases in flood levels of up to 0.02 metres that are concentrated against the eastern face of the levee. The flood level increases are not predicted to extend to properties at Colyton to the east of Ropes Creek until a 0.2% AEP flood or rarer (*refer* **Figure 9.7**).

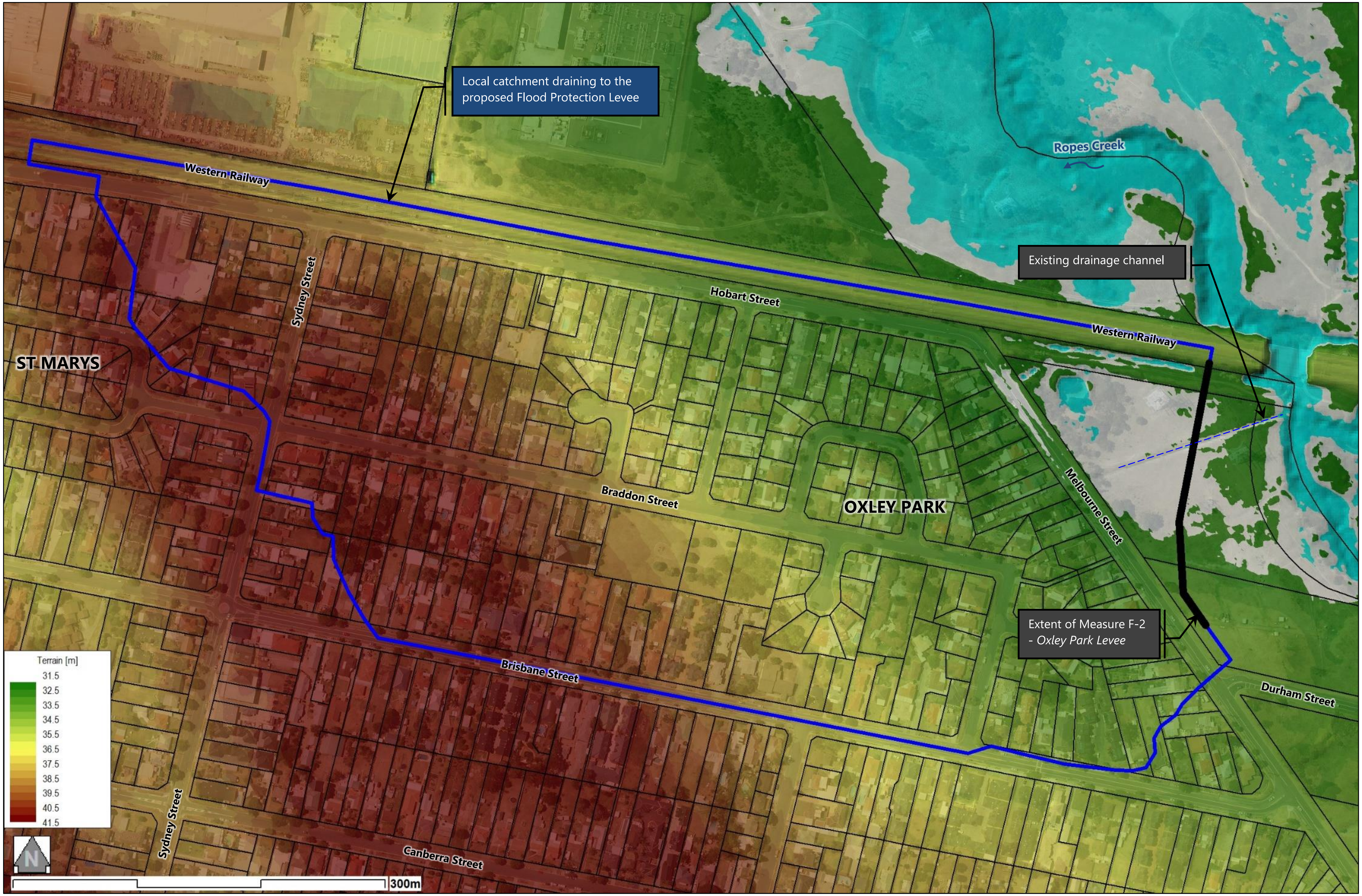
The reduction in peak 1% AEP flood extents is shown in **Figure 9.7** by the green mapping to the west of the levee. This indicates that those properties along Melbourne Street previously inundated during a 1% AEP Ropes Creek flood would be flood free with the flood protection levee constructed.

Based on the proposed crest elevations of 33.60 to 33.66 mAHD (*1% AEP flood levels plus 0.5 metres freeboard*) the levee could also provide protection to those properties along Melbourne Street during floods up to and included the 0.2% AEP flood with up to 0.12 metres of freeboard remaining. As the levee is not designed to provide protection during events up to and including the 0.2% AEP flood, and no allowance is made for other factors such as wave action, it is assumed for the purposes of calculating damages that the levee is overtopped for floods exceeding the design 1% AEP flood.

The benefit of the predicted reduction in flood extents on the affectation of properties in the local area is shown in **Table 9-8**. The benefit is measured based on the total number of properties predicted to be flooded below and above floor levels with and without the mitigation measure in place.

As shown in **Table 9-8**, Measure F-2 is predicted to prevent flooding of all properties along Melbourne Street during events up to and including the 1% AEP flood; i.e., the design event. No change to flood affectation is predicted for larger events. This allows for potential failure mechanisms which could lead to inundation behind the levee for occurrences where the design flood has been exceeded.

FIGURE 9.6



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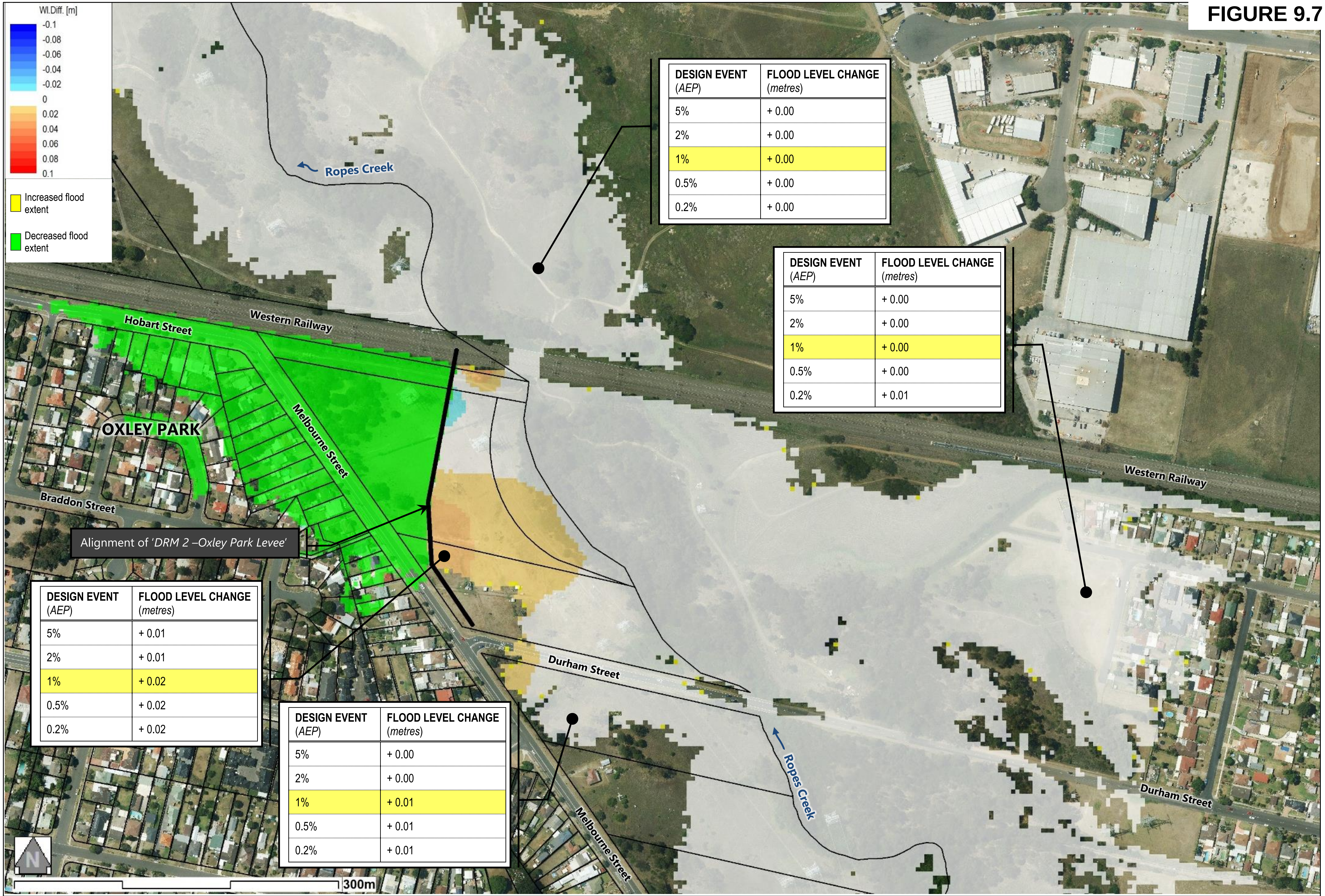
301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.6_DRM Oxley Park Levee (Local Catchment)

LOCAL CATCHMENT THAT CAPTURES AND CONVEYS LOCAL RUNOFF TO THE FLOOD PROTECTION LEVEE

FIGURE 9.7



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.00
0.2%	+ 0.00

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.00
0.2%	+ 0.01

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.01
2%	+ 0.01
1%	+ 0.02
0.5%	+ 0.02
0.2%	+ 0.02

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.01
0.5%	+ 0.01
0.2%	+ 0.01

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301015-03955 – Beechwood Road Bridge Waterway Hydraulics
fg301310-08772rg200220_Fig 9.7_DRM Oxley Park Levee Impacts (100yr)

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-2 – OXLEY PARK LEVEE'
[CHANGES FOR THE 1% AEP FLOOD SHOWN]

Table 9-8 Predicted Change in Flood Affectation of Properties in Local Area (Below and Above Floor Flooding)

Design Event (*AEP*)	Below Floor Flooding		Above Floor Flooding	
	Existing	Post Mitigation	Existing	Post Mitigation
5%	12	0 *(- 12)*	3	0 *(- 3)*
2%	8	0 *(- 8)*	10	0 *(- 10)*
1%	7	0 *(- 7)*	13	0 *(- 13)*
0.5%	8	10 *(- 0)*	17	17 *(- 0)*
0.2%	12	12 *(- 0)*	18	18 *(- 0)*
PMF	14	14 *(- 0)*	97	97 *(- 0)*

Cost Estimate

The cost of implementing Measure F-2 is estimated to be $694,000 (*refer* **Appendix F**), which represents the total present value of upfront costs and maintenance costs with a 20% contingency.

The capital cost includes an allowance for site preparation, construction of the levee and levee core, batter shaping, surface treatment post construction and the ongoing maintenance of the levee. A $50,000 allowance is included for analysis and construction of cross-drainage plus a 20% contingency on the final cost estimate.

Environmental Factors

Measure F-2 would require earthworks across areas covering approximately 1,200 m^2. All earthworks would be located at least 60 metres away from Ropes Creek and would occur across an area that is mostly covered by grass with few trees which could be avoided.

The levee is proposed to be located within close proximity to a transmission line corridor and therefore precautions will be required to ensure safety whilst excavating and operating heavy machinery. The proposed levee alignment would be over 10-20 metres clear of the nearest transmission towers.

The levee may impact the amenity of the area and could obstruct the views towards Ropes Creek available to properties along Melbourne Street. Based on the dense vegetation between Melbourne Street and the proposed levee it is expected the levee will not cause any significant change to the views of residents towards Ropes Creek.

Benefit / Cost Analysis

As shown in **Table 9-9**, Mitigation Measure F-2 has been determined to result in a reduction in the NPV of damages for Oxley Park of $603,300. Based on an estimated construction cost for the measure of $694,000 this translates to a benefit/cost ratio of 0.87.

Table 9-9 Benefit/Cost Ratio for Mitigation Measure F-2

Damages Scenario	Design Life *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Oxley Park Existing	30	**$54,000**	**$724,000**	-	-	-
Oxley Park Levee	30	**$9,000**	**$120,700**	$694,000	$603,300	**0.87**

9.3.4 Measure F-3: Railway Bridge Widening

Description of Proposed Works

Mitigation Measure F-3 involves widening of the existing Railway Crossing over Ropes Creek located to the north-east of Oxley Park. Based on the data available from the *Updated South Creek Flood Study* (*2015*), the existing crossing is understood to have a clear span of 32 metres with two piers located approximately 10 metres either side of the approach abutments.

Plate 9.1 and **Plate 9.2** show photographs of the eastern and western bridge abutments taken facing downstream along Ropes Creek (*facing north*).

The upgrades proposed as Mitigation Measure F-3 consist of widening of the crossing by adding an additional span with a width of approximately 10 metres. This results in the clear waterway opening for the bridge to be increased from 32 metres to 42 metres. As shown in **Figure 9-8**, the increase in waterway area was added to the western side of the bridge. No other changes to the bridge crossing, channel dimensions or roughness were made.

Hydraulic Assessment

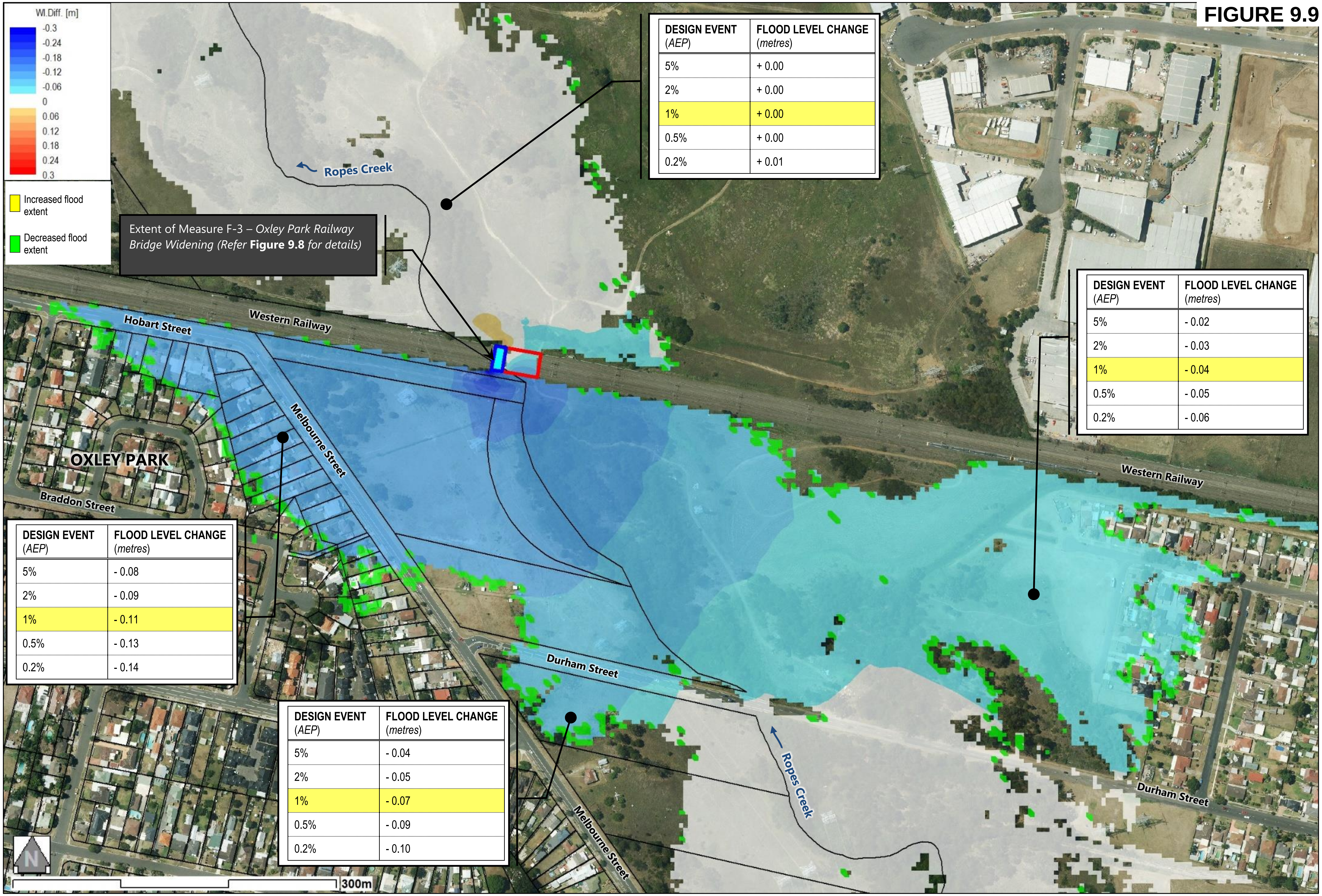
Changes in peak 1% AEP flood levels due to mitigation Measure F-3 are shown in **Figure 9-9**. The predicted changes to peak flood levels for the 5%, 2%, 0.5% and 0.2% floods are shown in tables on **Figure 9-9** at key locations.

Widening of the Railway Crossing by 10 metres (*reflecting a 31% increase in total waterway width*) is predicted to reduce peak 1% AEP flood levels across properties located along Melbourne Street by 0.11 metres. The magnitude of the reduction in levels is predicted to increase for rarer events as shown in **Table 9-10**.

FIGURE 9.8

OVERVIEW OF PROPOSED MEASURE F-3 -
OXLEY PARK RAILWAY BRIDGE WIDENING

FIGURE 9.9



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.00
0.2%	+ 0.01

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.02
2%	- 0.03
1%	- 0.04
0.5%	- 0.05
0.2%	- 0.06

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.08
2%	- 0.09
1%	- 0.11
0.5%	- 0.13
0.2%	- 0.14

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.04
2%	- 0.05
1%	- 0.07
0.5%	- 0.09
0.2%	- 0.10

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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.9_DRM Oxley Park Railway Bridge Impacts (100yr)

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-3 – OXLEY PARK RAILWAY BRIDGE WIDENING
[CHANGES FOR THE 1% AEP FLOOD SHOWN]

Plate 9-1 Photograph taken facing north of the eastern railway bridge abutments

Plate 9-2 Photograph taken facing north of the western railway bridge abutments

Table 9-10 Predicted Change in Flood Levels to Properties along Melbourne Street, Oxley Park, as a Result of Mitigation Measure F-3

Design Event (AEP)	**Predicted Flood Level Change** (*metres*)
5%	- 0.08
2%	- 0.09
1%	- 0.11
0.5%	- 0.13
0.2%	- 0.14

The bridge widening is also predicted to reduce peak 1% AEP flood levels to the east of Ropes Creek at Colyton by up to 0.04 metres. As shown in **Figure 9-9**, the magnitude of the flood level reduction is predicted to increase with the severity of the event. Accordingly, the magnitude of predicted flood level decrease is greatest at the peak of the 0.2% AEP event with a reduction of 0.06 metres.

Figure 9-9 shows a minor and localised increase in peak 1% AEP flood levels of up to 0.05 metres immediately downstream of the widened section of the crossing.

Cost Estimate

The cost of implementing Mitigation Measure F-3 is estimated to be between $1,000,000 and $1,500,000. The wide range in costs recognises that there are numerous factors that could affect the construction cost and which are difficult to quantify. These include complications due to rail line disruptions, requirements for night or weekend construction and environmental management constraints associated with the required works being adjacent to Ropes Creek.

Environmental Factors

Mitigation Measure F-3 requires construction works to be undertaken within the Ropes Creek channel and riparian corridor. Excavation of the western embankment would be necessary and would impact overbank vegetation in this location upstream and downstream of the existing crossing.

The construction works would also require closure of the train line which would force commuters onto roads and into transport options with a larger emissions footprint. This could be mitigated if the works were to be completed on already scheduled track maintenance days; i.e., no further disruptions than already planned.

Benefit / Cost Analysis

Recognising that Mitigation Measure F-3 is predicted to result in similar reductions to flood levels as Measure F-1A whilst costing over double to construct, the BCR for this measure is expected to be approximately 0.3.

Given there are other mitigation measures proposed for Oxley Park with a lower capital cost and higher BCR no further analysis of Measure F-3 has been completed.

9.3.5 Measure F-4: Additional Storage Upstream of the Railway Crossing at Oxley Park and Colyton

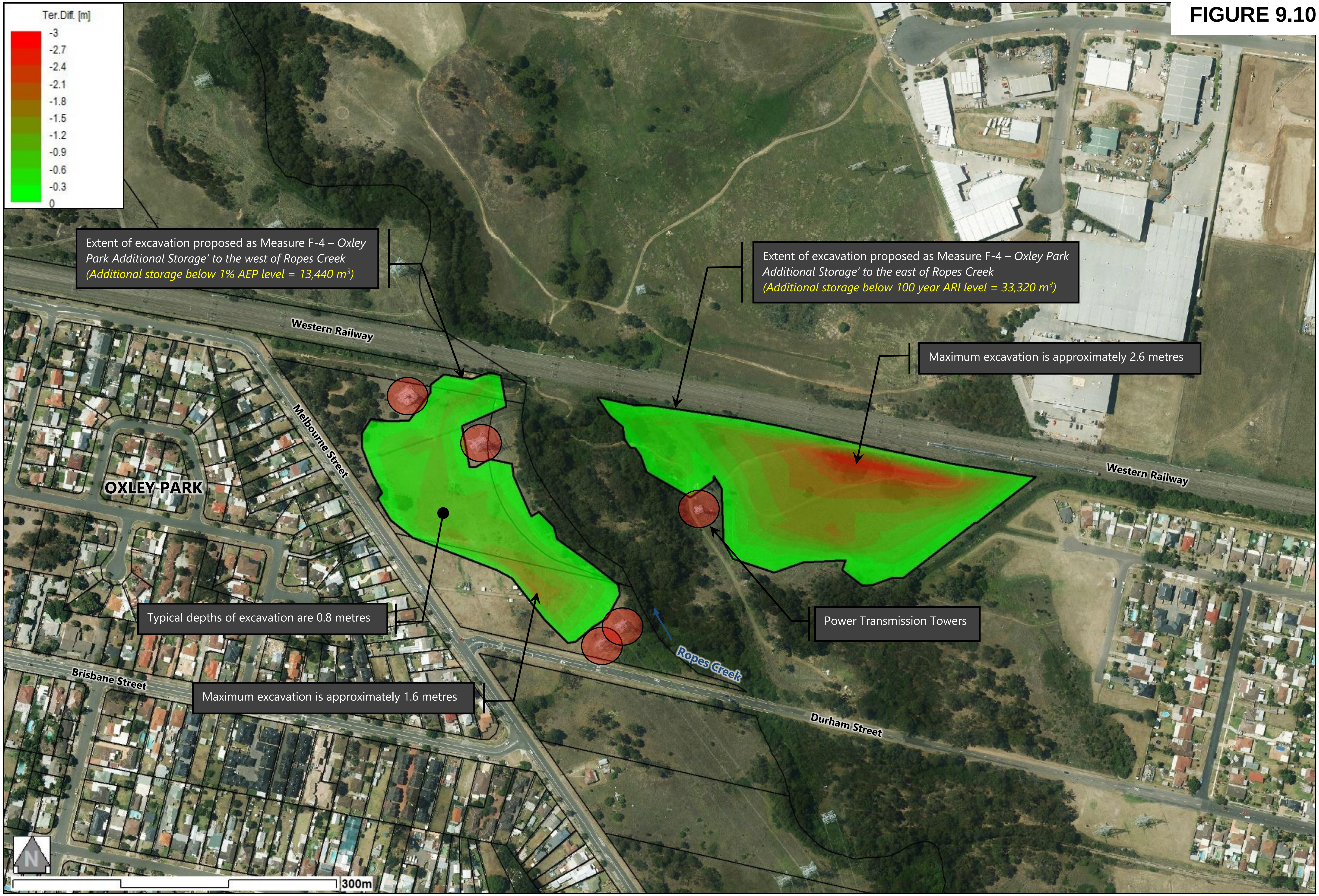
Description of Proposed Works

Mitigation Measure F-4 consists of providing additional active flood storage across areas upstream (*to the south*) of the Railway Crossing near Oxley Park. For this option, opportunities for excavation of the floodplain were investigated on the western and eastern floodplain of Ropes Creek; that is, within Penrith and Blacktown LGAs, respectively.

Figure 9.10 shows the extent of excavation adopted with a description of the works included below:

- Excavation to the west of Ropes Creek (*Penrith City Council LGA*) has an approximate surface area of 2.4 ha and a maximum depth of cut of 1.6 metres.
- Excavation to the east of Ropes Creek (*Blacktown City Council LGA*) has an approximate surface area of 3.4 ha and a maximum depth of cut of 2.6 metres.
- The western and eastern cut areas provide an additional 13,400 m^3 and 33,300 m^3 of active flood storage below the peak 1% AEP flood level, respectively.

FIGURE 9.10



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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.10_DRM Oxley Park Additional Storage Overview

OVERVIEW OF PROPOSED MEASURE F-4 – ADDITIONAL FLOOD STORAGE

- Both cut extents have been kept away from existing transmission lines as shown in **Figure 9.10**.

Measure F-4 provides an additional 46,700 m^3 of active flood storage upstream of the Railway Crossing at Oxley Park.

Hydraulic Assessment

Changes in peak 1% AEP flood levels due to Mitigation Measure F-4 are shown in **Figure 9.11**. The results indicate that the excavation will afford the greatest benefit in terms of reduced flood levels to those properties located on the eastern floodplain; that is, within Colyton in the Blacktown City Council LGA. The maximum decrease in peak 1% AEP flood levels to the east is predicted to be 0.22 metres compared to only 0.02 metres to the west at Oxley Park.

Similar changes to flood levels are predicted for the 5% AEP flood with decreased flood levels of up to 0.22 and 0.03 predicted to the east and west of Ropes Creek, respectively (*refer* **Figure 9.11**).

Based on the modelling results for the 5% and 1% AEP flood events it is evident that Mitigation Measure F-4 will provide the greatest benefit to properties within the Blacktown LGA. The benefit to properties within the Penrith LGA is minimal compared to other options of a similar scale.

On this basis the hydraulic analysis did not progress to modelling of the remaining design events.

Cost Estimate

A cost estimate has not been prepared for Mitigation Measure F-4 based on the hydraulic assessment finding there to be only minor flood level decreases to properties located along Melbourne Street, Oxley Park.

Environmental Factors

Mitigation Measure F-4 requires excavation of the floodplain across an area covering 46.7 hectares. The areas to be excavated are largely un-vegetated and appear to already be disturbed due to recent earthworks in the area; most applicable to the Blacktown City Council side. The excavation would also only re-grade the land to create a flatter surface whilst still grading towards Ropes Creek. Accordingly, the finished surface is not expected to result in any amenity issues or significant environmental issues.

Benefit / Cost Analysis

A benefit/cost analysis was not undertaken for Mitigation Measure F-4 due to the minimal benefits predicted for properties along Melbourne Street and comparatively high extent and depths of cut required. A better BCR is expected for other comparable measures such as Measure F-1A.

9.3.6 Measure F-5: Raise Werrington and Rance Road

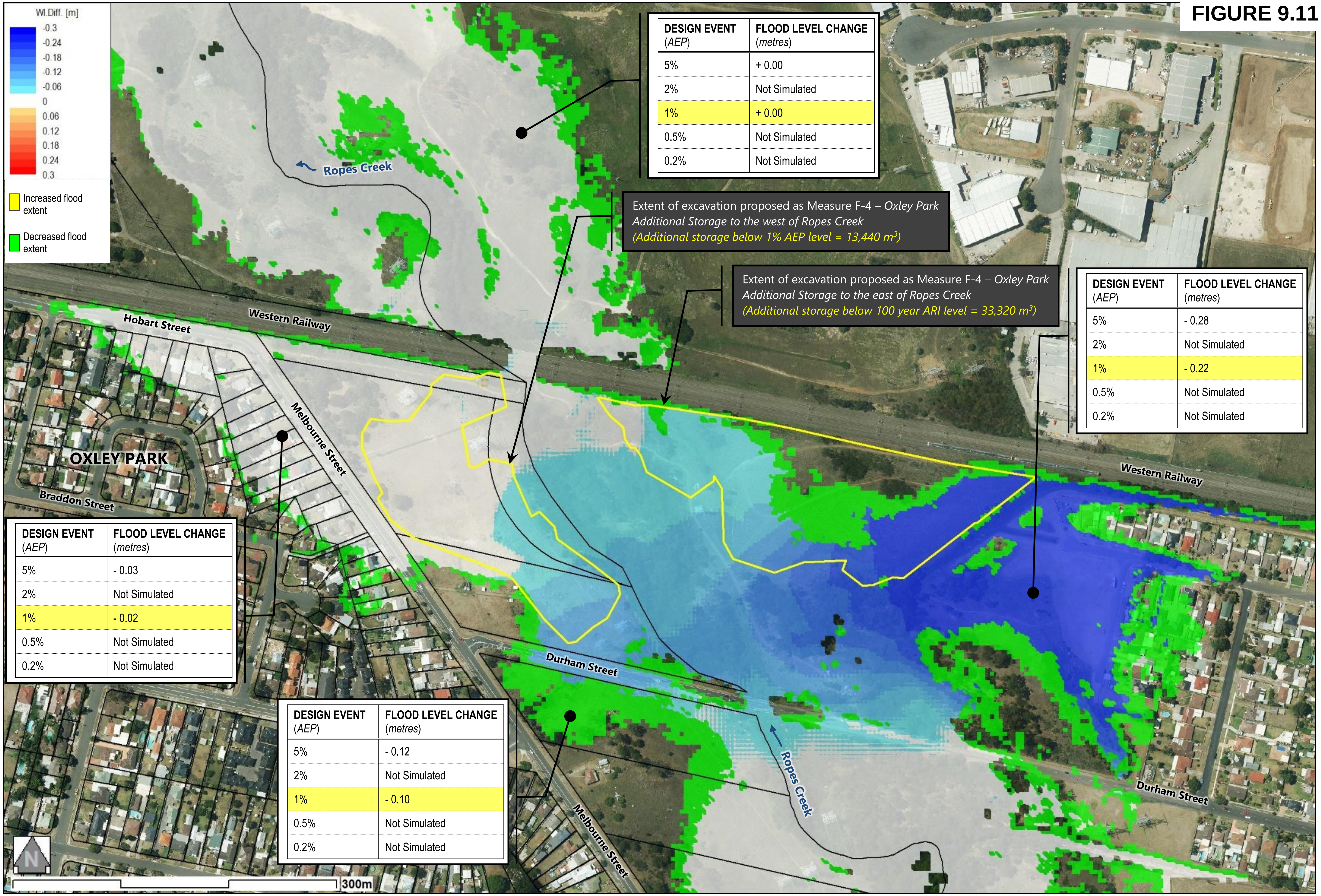
Description of Proposed Works

Mitigation Measure F-5 involves raising of a 380 metre length of Werrington Road and 140 metre length of Rance Road to protect the existing properties to the north-west from inundation. The length of proposed road raising has been determined by setting the road crest elevations to be at the peak 1% AEP flood level plus 0.5 metres freeboard. For Werrington Road and Rance Road this translates to maximum surface elevations of up to 24.65 mAHD.

The extent of road raising proposed as Measure F-5 is shown in **Figure 9.12**.

Figure 9.13 shows a thematic map of the proposed road elevations relative to the surrounding floodplain. Where the proposed road raising is constrained laterally by existing development, or the

FIGURE 9.11



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	Not Simulated
1%	+ 0.00
0.5%	Not Simulated
0.2%	Not Simulated

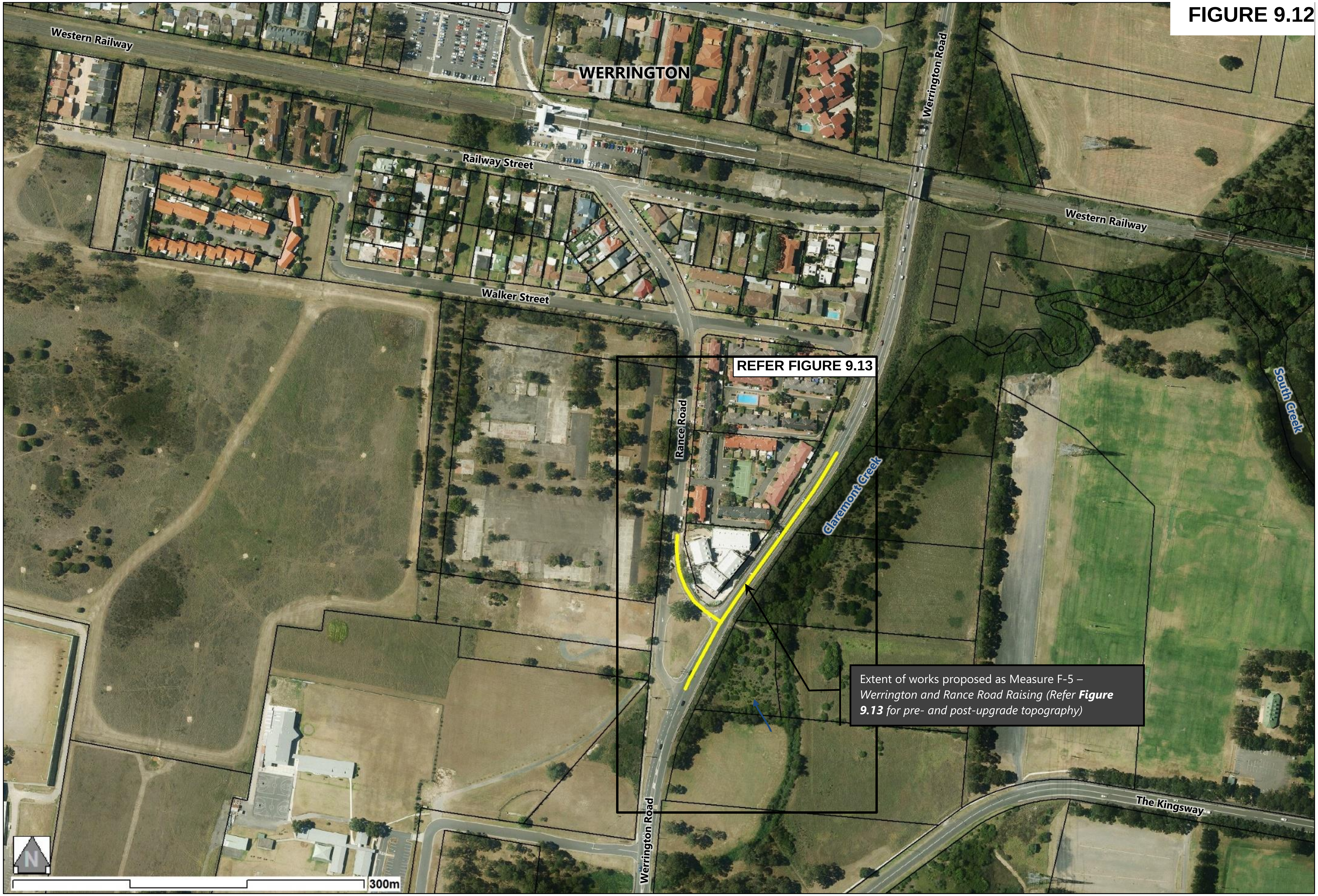
DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.28
2%	Not Simulated
1%	- 0.22
0.5%	Not Simulated
0.2%	Not Simulated

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.03
2%	Not Simulated
1%	- 0.02
0.5%	Not Simulated
0.2%	Not Simulated

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	- 0.12
2%	Not Simulated
1%	- 0.10
0.5%	Not Simulated
0.2%	Not Simulated

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-4 – OXLEY PARK ADDITIONAL STORAGE
[CHANGES FOR THE 1% AEP FLOOD SHOWN]

FIGURE 9.12



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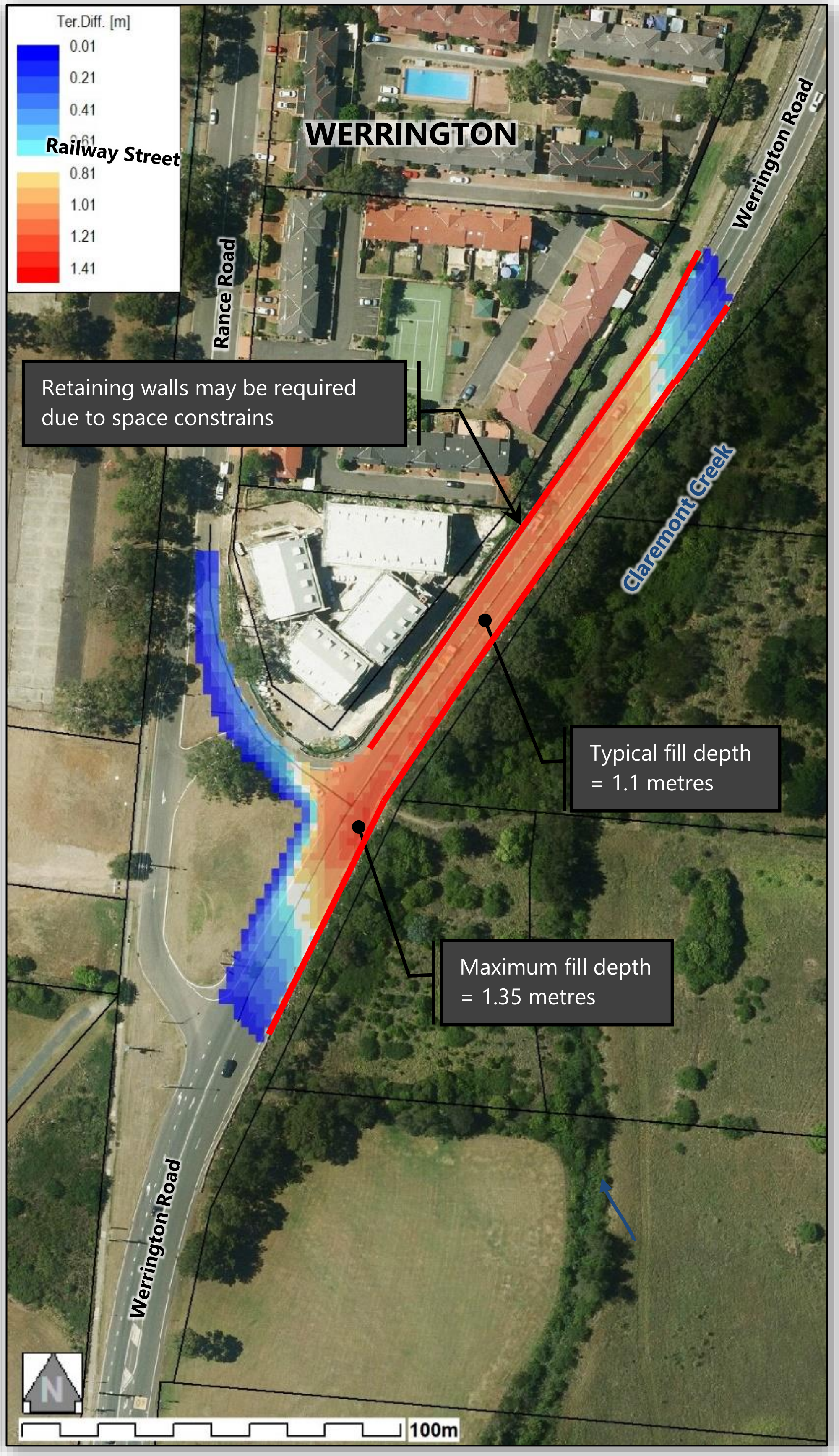
301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.12_DRM Rance & Werrington Road - Overview 1of 2

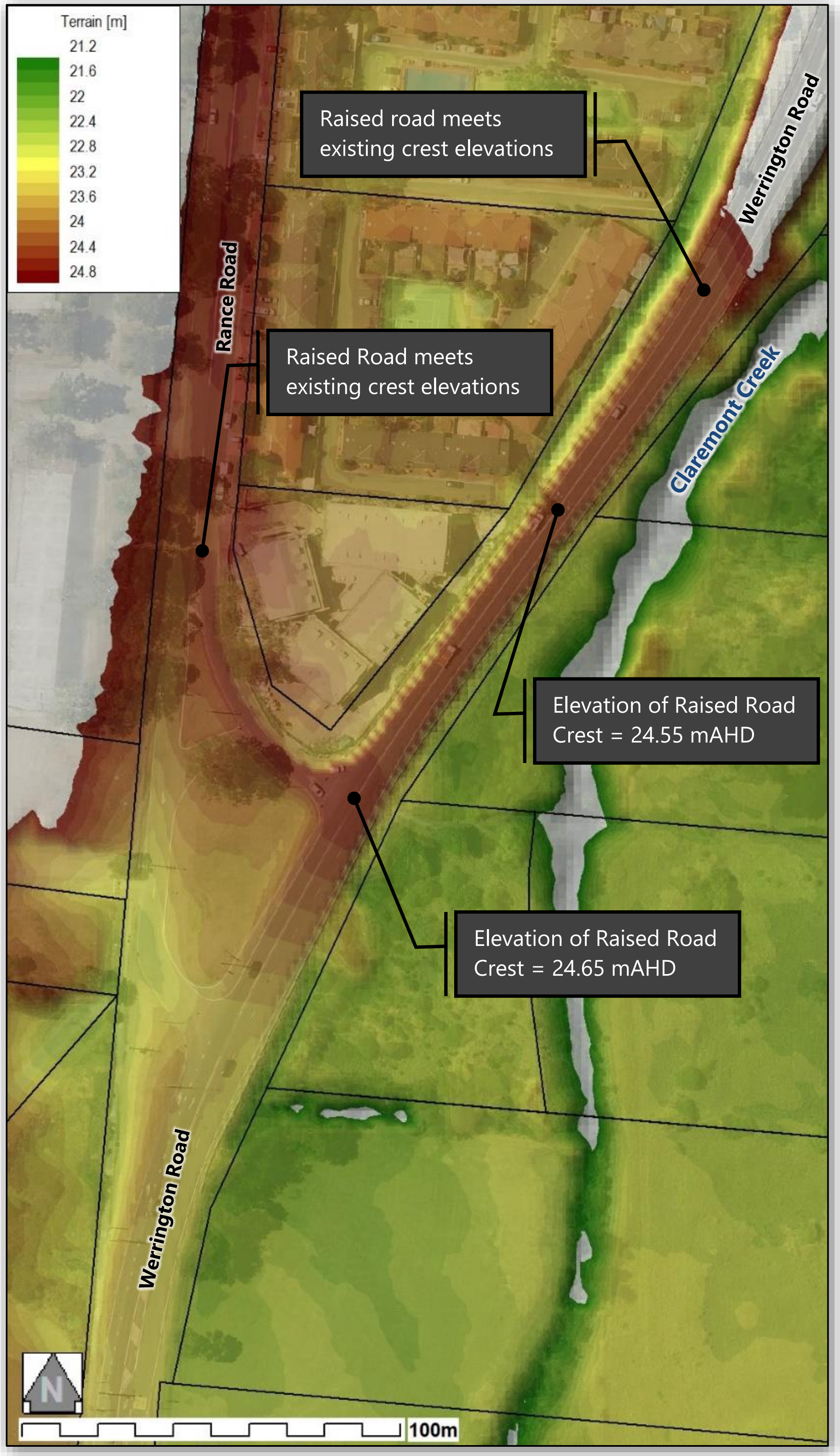
OVERVIEW OF PROPOSED MEASURE F-5 – WERRINGTON AND RANCE ROAD RAISING
[LOCATION OF PROPOSED ROAD RAISING]

FIGURE 9.13

PRE-UPGRADE TOPOGRAPHY



TERRAIN CHANGES ASSOCIATED WITH MEASURE F-5



POST-UPGRADE TOPOGRAPHY

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301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.12_DRM Rance & Werrington Road - Overview 2of 2

OVERVIEW OF PROPOSED MEASURE F-5 – WERRINGTON AND RANCE ROAD RAISING
[OVERVIEW OF PRE- AND POST ROAD ELEVATIONS]

riparian corridors of Claremont Creek and South Creek, a retaining wall is proposed in lieu of side batters.

Figure 9.13 also shows the approximate depths to which the road will need to be raised to achieve the proposed road crest elevations. As shown, Werrington Road and Rance Road would need to be raised by up to 1.35 metres and 0.9 metres, respectively.

Hydraulic Assessment

Changes in peak 1% AEP flood levels due to Mitigation Measure F-5 are shown in **Figure 9.14**. The predicted changes in flood levels for the 5%, 2%, 0.5% and 0.2% AEP floods are shown in **Figure 9.14** at key locations within the provided tables.

The modelling predicts that the proposed road raising would cause flood levels to increase upstream of the Rance Road and Werrington Road intersection by up to 0.03 metres and 0.05 metres during a 1% and 0.2% AEP flood event, respectively (*refer* **Figure 9.14**).

The proposed road raising is predicted to have a negligible impact to flood levels elsewhere, including to areas east of Werrington Road. As shown in **Figure 9.14**, the maximum flood level increase predicted to the east of Werrington Road is 0.01 metres, occurring only at the peak of the 0.2% AEP flood.

The benefit of the predicted reduction in flood extents on the affectation of properties to the west of Werrington Road is shown in **Table 9-11**. The benefit is measured based on the total number of properties predicted to be flooded below and above floor levels with and without the mitigation measure in place.

As shown in **Table 9-11**, Measure F-5 is predicted to prevent flooding of all properties bounded by Werrington and Rance Road during events up to and including the 1% AEP flood; i.e., the design event. No change to flood affectation is predicted for larger events. This allows for potential failure mechanisms which could lead to inundation behind the levee for occurrences where the design flood has been exceeded.

Table 9-11 Predicted Change in Flood Affectation of Properties in Local Area (Below and Above Floor Flooding)

Design Event (*AEP*)	Below Floor Flooding		Above Floor Flooding	
	Existing	Post Mitigation	Existing	Post Mitigation
5%	1	0 *(- 1)*	1	0 *(- 1)*
2%	28	0 *(- 28)*	7	0 *(- 7)*
1%	29	0 *(- 29)*	34	0 *(- 34)*
0.5%	13	13 *(- 0)*	63	63 *(- 0)*
0.2%	5	5 *(- 0)*	78	78 *(- 0)*
PMF	0	0 *(- 0)*	239	239 *(- 0)*

FIGURE 9.14

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.01
1%	+ 0.03
0.5%	+ 0.04
0.2%	+ 0.05

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.00
0.2%	+ 0.00

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.00
0.2%	+ 0.01

DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (metres)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.00
0.5%	+ 0.01
0.2%	+ 0.01

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301311-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.14_DRM Rance Road Impacts (100yr)

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF MEASURE F-5 – WERRINGTON & RANCE ROAD RAISING
[CHANGES FOR THE 1% AEP FLOOD SHOWN]

Cost Estimate

The cost of implementing Measure F-5 is estimated to be $1,204,000 (*refer* **Appendix F**), which represents the total present value of upfront costs with a 20% contingency.

The capital cost includes an allowance for the required road raising, repaving roads, retaining walls (*where the road is constrained laterally due to existing development and/or Claremont Creek*) and site clean-up.

Environmental Assessment

Mitigation Measure F-5 will require construction within close proximity to Claremont Creek and within the riparian corridor. Retaining walls will be required along a length of approximately 160 metres to avoid encroaching into Claremont Creek and impacting the creek channel. The distance between Werrington Road and Claremont Creek ranges between 12 to 32 metres along the length of road likely to require retaining.

The proposed road raising may reduce the visual amenity of the area by making the road a more prominent feature and by obstructing views from the properties to the west of the Kingsway sporting fields to the east.

Benefit/Cost Analysis

As shown in **Table 9-12**, Mitigation Measure F-5 is calculated to result in a reduction in the NPV of damages for the Rance Road area of $470,000. Based on an estimated construction cost for the measure of $1,086,000 this translates to a benefit/cost ratio of 0.43.

Table 9-12 Benefit/Cost Ratio for Measure F-5

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Rance Road Existing	30	**$77,000**	**$1,033,000**	-		
Rance Road Proposed	30	**$42,000**	**$563,000**	$1,086,000	$470,000	**0.43**

9.3.7 Measure F-6: Raise Mamre Road near St Clair

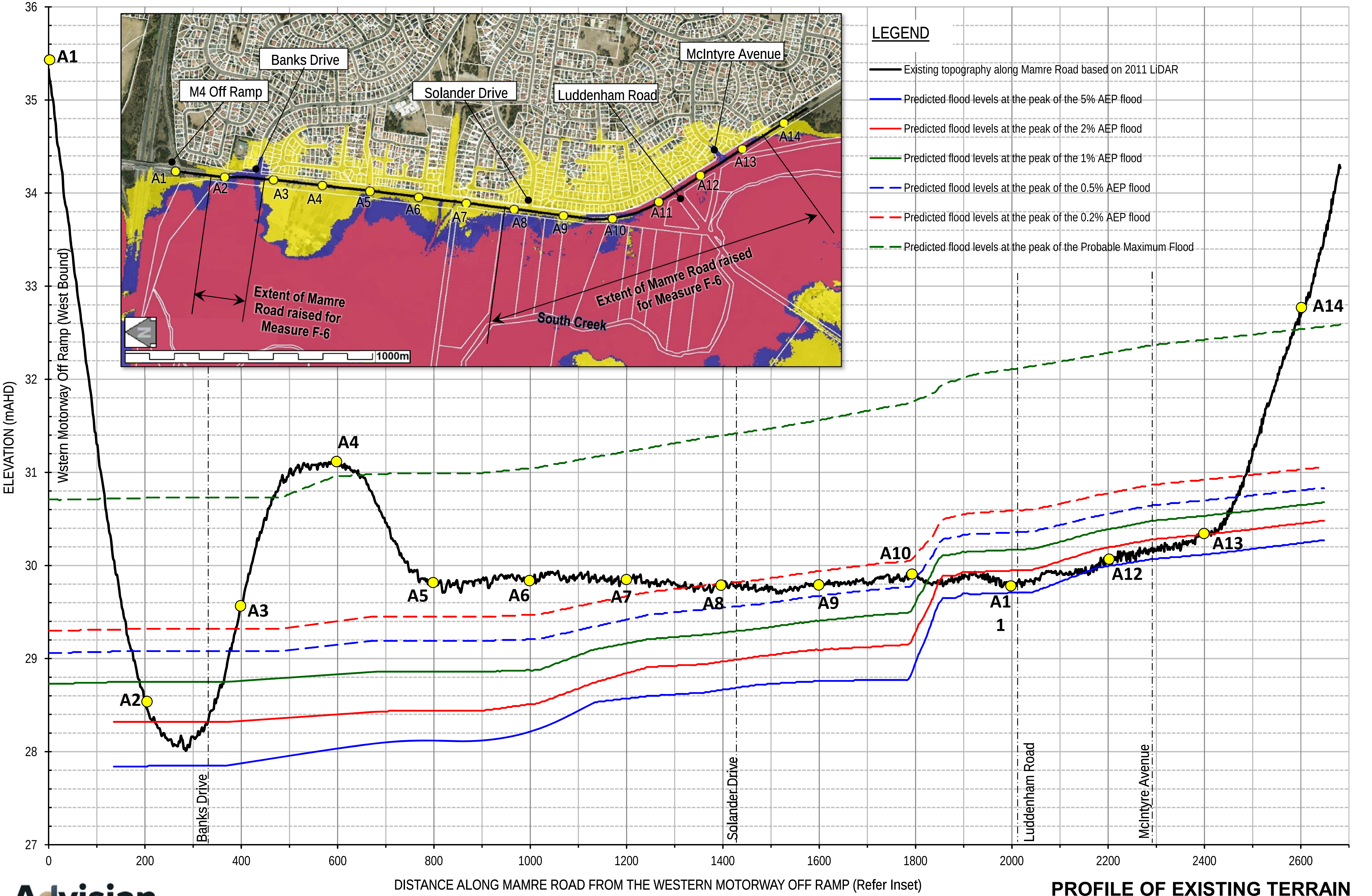
Description of Proposed Works

Mitigation Measure F-6 involves raising low-lying parts of Mamre Road between the Western Motorway to the north and McIntyre Avenue to the South (*refer* **Figure 9.15**). A profile plot comparing existing road elevations and peak flood levels for a range of design floods is shown in **Figure 9.15**.

Existing elevations along this reach of Mamre Road range between 25.0 to 35.5 mAHD. The low-point is located near the intersection with Banks Drive approximately 260 metres south of the west bound off ramp from the Western Motorway (*refer* **Figure 9.15**).

The superimposed flood levels show that Mamre Road would first be overtopped prior to the peak of a 2% AEP flood to a maximum flood depth of 0.3 metres. During more frequent flood events such as

FIGURE 9.15



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301311-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.15_amre Road Profiles (FINAL)

PROFILE OF EXISTING TERRAIN AND PREDICTED FLOOD LEVELS ALONG MAMRE ROAD

the 5% AEP flood, there is predicted to be less than 0.05 metres of freeboard available (*refer Point A12 on* **Figure 9.15**).

The damages analysis confirmed that properties to the east of Mamre Road will only be at risk of external property damage during floods up to and including the 0.2% AEP flood. During the 1% AEP flood only four properties will experience inundation. It is not until the PMF that over floor flooding is predicted.

Based on the low number of properties at risk of inundation from floodwaters overtopping Mamre Road, Mitigation Measure F-6 is focused on improving safety by improving the flood immunity of Mamre Road. Accordingly, the proposed upgrades are not focused on reducing flood damages.

Hydraulic Assessment

Hydraulic modelling was undertaken to assess whether the proposed road raising could lead to impacts in peak flood levels to the west of Mamre Road. As no target level of flood immunity for Mamre Road was established, the modelling was undertaken based on Mamre Road being flood free during floods up to and including the 0.2% AEP flood. Although this scenario is unlikely to manifest, it will provide a good indication of whether flooding to the west of Mamre Road will be sensitive to any future proposals to raise the road.

Changes in peak 1% and 0.2% AEP flood levels due to Mitigation Measure F-6 are shown in **Figure 9.16** as flood level difference mapping. The predicted changes in flood levels for the 5%, 2% and 0.5% AEP floods are shown in **Figure 9.16** at key locations within the provided tables.

The modelling predicts that the proposed road raising would lead to a maximum increase in peak 1% AEP flood levels of up to 0.01 metres and peak 0.2% AEP flood levels of up to 0.02 metres (*refer* **Figure 9.16**). Based on these low magnitudes of level increases it could be concluded that Mamre Road could be raised between the Western Motorway (*M4*) and McIntyre Avenue with a low risk of generating unacceptable flood impacts on adjoining properties to the west.

Cost Estimate

No cost estimate has been prepared for Mitigation Measure F-6 as it is dependent on the level of flood immunity required and whether the upgrades would occur concurrently with a proposal to increase the capacity of Mamre Road by adding additional lanes. It is envisaged these factors would be considered by RMS should road upgrades by pursued.

Environmental Assessment

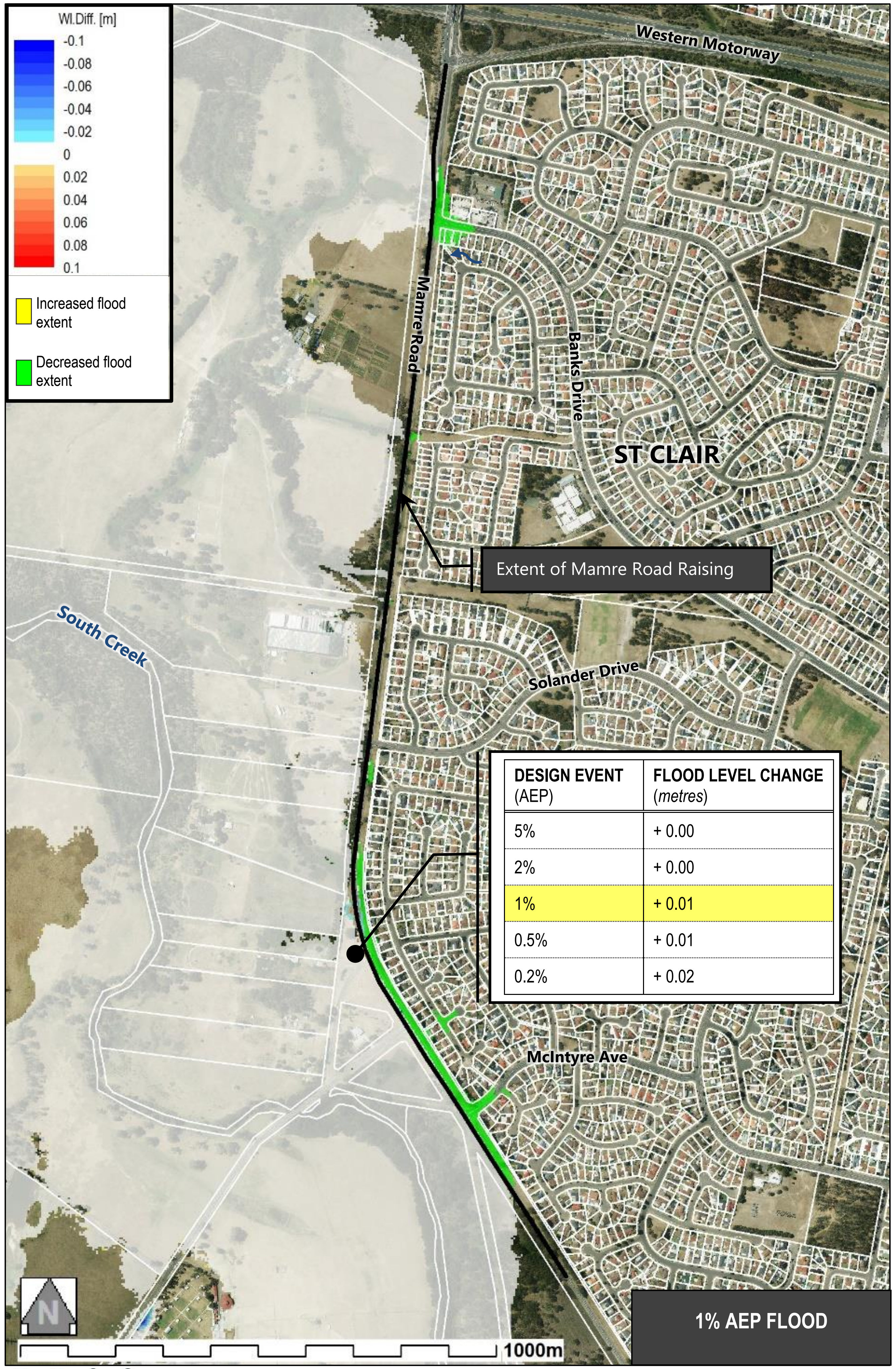
Mitigation Measure F-6 will not require any construction to occur within close proximity to any watercourses or within the riparian corridor. It is understood that there is sufficient space available within the Mamre Road corridor to account for any proposed road raising and additional lanes.

Construction would be disruptive to the community by potentially closing off a popular route for accessing the Western Motorway, St Clair, Erskine Park and the employment lands to the south. Construction could require detours into suburban areas and onto suburban roads.

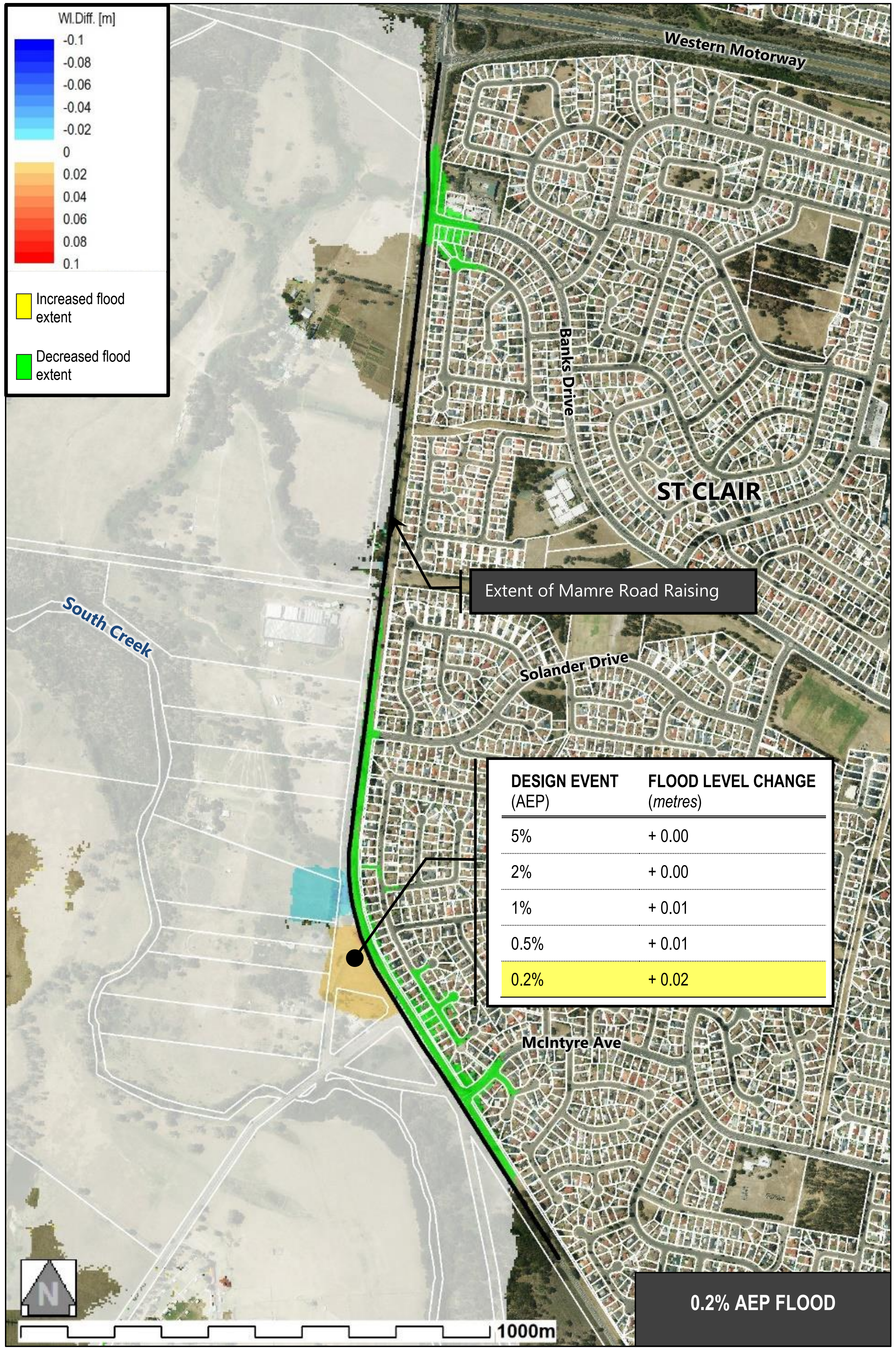
Benefit/Cost Analysis

Measure F-6 is proposed to increase the flood immunity of Mamre Road to provide safer access to St Clair and Erskine Park during South Creek flood events. Although a small number of properties will benefit from the road raising the potential reduction in damages is negligible compared to the capital costs requires to complete the upgrades. This is supported by **Chart 7-4** in **Section 7** which shows that across St Clair only two (*2*) properties are predicted to experience overfloor flooding

FIGURE 9.16



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (*metres*)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.01
0.5%	+ 0.01
0.2%	+ 0.02



DESIGN EVENT (AEP)	FLOOD LEVEL CHANGE (*metres*)
5%	+ 0.00
2%	+ 0.00
1%	+ 0.01
0.5%	+ 0.01
0.2%	+ 0.02

PREDICTED CHANGES IN FLOOD LEVELS AS A RESULT OF 'DRM 6 – RAISED MAMRE ROAD'
[CHANGES FOR THE 1% and 0.2% AEP FLOOD SHOWN]

Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.16_DRM Mamre Road Impacts (1% AEP)

during floods up to and including the 0.2% AEP flood. The number of properties experiencing overfloor flooding during the PMF is predicted to increase to two hundred and forty four (*244*).

Based on the above it is considered that any decision making regarding upgrades to Mamre Road will be made based on emergency response benefits instead of potential reductions in damages.

9.3.8 Measure F-7A: Upgrades to St Marys Levee

Description of Proposed Works

As discussed in **Section 8.4.1**, a review of the St Marys levee has been undertaken based on the latest topographic data and site observations. The review identified:

- Three locations where crest elevations either fall below the predicted 1% AEP flood level or do not meet the 0.5 metre freeboard design criteria; and
- A potential flow path around the levee at the downstream end of the concrete levee; i.e., at the tie-in to the Great Western Highway.

Although these issues have been identified as part of this FRMS and recommended for further investigation via a levee audit and detailed survey (*refer* **Section 8.4.1**), the modelling completed as part of the *Updated South Creek Flood Study* (*2015*) had not taken them into consideration. On this basis, peak flood levels predicted across St Marys behind the levee and the predicted damages are based on the levee not being overtopped until the 0.5% AEP flood and no floodwaters flowing around the concrete levee at the Great Western Highway tie-in. The Flood Study (*2015*) modelling of the St Marys Levee therefore represents the proposed upgrade scenario.

To complete a benefit/cost assessment for the required levee upgrades it is necessary to determine flood behaviour and damages for the existing ‘pre-upgrade’ scenario.

Hydraulic Assessment

Pre-upgrade flood levels for areas behind the St Marys Levee for the pre-upgrade scenario were determined through the following process:

A. Manning’s calculations to determine the volume of floodwaters that would flow around the downstream end of the concrete levee for floods where the Great Western Highway is predicted to be overtopped,

B. Stage-discharge curves for the Byrnes Creek culvert (*3.7m by 3.5m RCBC*) based on the HY-8 culvert analysis tool for scenarios where flood levels upstream of the Great Western Highway exceed those downstream, and

C. Stage-storage analysis for the floodplain behind the levee based on storage volumes extracted from the 2011 LiDAR.

The differential in flows entering and leaving the area protected by the St Mary Levee was translated to a peak flood level based on the stage-storage curve. Peak flood levels determined for the pre-upgrade and post-upgrade levee scenarios are listed in **Table 9-13**.

Table 9-13 Peak Flood Levels Across St Marys Behind the St Marys Levee with Measure F-7A

Levee Scenario	Design Flood Event (AEP)					
	5%	2%	1%	0.5%	0.2%	PMF
Pre-Upgrade (*Reflects Existing Levee Crest Elevations*)	24.08 (*+ 0.11 m*)	24.30 (*+ 0.12 m*)	24.50 (*+ 0.10 m*)	24.72 (*+ 0.08 m*)	25.06 (*+ 0.00 m*)	27.60 (*+ 0.00 m*)
Post-Upgrade (Measure F-7A) (*Extracted from the Updated South Creek Flood Study 2015*)	23.97	24.18	24.40	24.64	25.06	27.60

The analysis found that peak flood levels across the area protected by the St Marys Levee would rise a stage where flood levels matched those at the downstream outlet of the Byrnes Creek culvert. Flood levels would not exceed the level at the culvert outlet due to the conveyance capacity through the culvert quickly exceeding that of the flows entering around the concrete levee and via the Great Western Highway. Accordingly, peak flood levels behind the St Marys Levee for pre-upgrade conditions are predicted to match those at the downstream end of the Byrnes Creek culvert for design events up to and including the 0.5% AEP flood. For rarer events there is predicted to be no change to flood levels (*refer* **Table 9-13**).

Cost Estimate

The cost estimate has been derived based on undertaking the works required to achieve the level of protection simulated as part the *Upgraded South Creek Flood Study* (*2015*). Accordingly, the following upgrade works are included in the cost estimate.

- Extension of the St Marys Levee at the upstream end (*south of Hall Street*) by a length of approximately 20 metres;
- Upgrades to the levee near Saddington Street to raise the levee by approximately 0.2 metres along a length of 80 metres to meet freeboard requirements.
- Upgrades to the levee near the transition from earthen levee to concrete levee to raise crest elevations to be at the predicted 1% AEP flood level plus 0.5 metres freeboard; and
- Sandbagging (*allowance for one occurrence*) across the Great Western Highway downstream of the concrete levee to prevent floodwaters flowing around the levee.

Although a more permanent solution to prevent floodwaters flowing down the Great Western Highway and around the concrete levee is preferred, no viable option has been identified. Given this issue is predicted to occur on average once every 20 years sandbagging may be appropriate and a cost-effective solution.

In accordance with the detailed costings contained within **Appendix F**, the proposed upgrades are estimated to cost $782,000. This represents the total present value of upfront costs with a 20% contingency.

It is worth noting that the temporary sandbagging could be used at a number of upgrade locations as a viable alternative. The two locations considered to be particularly suitable are:

- Upstream end of the levee where a 20 metre extension to the levee is required, and

- Near Saddington Street where the levee crest needs to be raised by approximately 0.2 metres to meet freeboard requirements.
- The construction costs for the two locations above are estimated to be $64,000 and $96,000, respectively.

Environmental Assessment

Mitigation Measure F-7A will require construction works within close proximity to Byrnes Creek and an unnamed tributary. The location where this occurs is at the transition between the earthen and concrete levee where the levee crest will need to be raised.

Byrnes Creek and the unnamed tributary are classified as 1st order streams in Council's DCP (*2014*) at the location of required upgrades. This classification translates to a 10 metre Vegetated Riparian Zone (*VRZ*) which will extend into, or very close to the zone of construction works. Care and environmental assessments will therefore be required.

The other works at the southern and northern ends of the St Marys Levee will be less intrusive based on their location away from watercourses and/or the temporary nature of the proposed works; i.e., sandbagging.

Benefit/Cost Analysis

Flood extents across St Marys corresponding to the peak flood levels listed in **Table 9-13** were applied to the damages analysis to determine the Average Annual Damage (AAD) that applies to the pre-upgrade scenario. As discussed, the post-upgrade scenario was modelled as part of the Flood Study (*2015*) and is reflected in the base damage analysis documented in **Section 7**.

As shown in **Table 9-14**, Mitigation Measure F-7A is calculated to result in a reduction in the NPV of damages for the area protected by the St Marys Levee of $174,000. Based on an estimated construction cost for the measure of $634,000 this translates to a benefit/cost ratio of 0.27.

Table 9-14 Benefit/Cost Ratio for Measure F-7A

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
St Marys Levee Pre-Upgrade (*Existing*)	30	$131,000	$1,757,000			
St Marys Levee Post-Upgrade F-7A (*Base case scenario adopted for the 2015 Flood Study*)	30	$118,000	$1,582,000	$634,000	$174,000	**0.27**

9.3.9 Measure F-7B: F-7A plus Installation of a Flap Gate Downstream of the St Marys Levee

Description of Proposed Works

Measure F-7B is an extension to Measure F-7A with the same upgrade works proposed to the St Marys Levee plus the installation of a 'flap gate' at the outlet of the Byrnes Creek culvert. Because of the large dimensions of the Byrnes Creek culvert, 3.7 metres high by 3.5 metres wide, it is very likely that the flap gate will need to be custom made to suit.

Although not critical to the assessment of flood hydraulics or costings, it is envisaged that the flap gate will be of a hinged design and by self-opening and closing based on flood levels at the inlet/outlet.

Flap gates can be constructed from cast-iron, fibreglass, rubber, polymer amongst other less common materials.

Hydraulic Assessment

RMA-2 hydraulic modelling was undertaken to confirm the changes to flood behaviour predicted due to Measure F-7B. In particular, the modelling was undertaken to confirm peak flood levels, or lack thereof, behind the St Marys Levee and any changes to flood levels downstream of the Great Western Highway associated with the reduction in flood storage caused by the flap gate preventing backwater flooding along Byrnes Creek.

Analysis of the modelling results from the Flood Study (*2015*) for the 1% AEP flood indicates that up to 2.9 m^3/s is predicted to flow upstream through the Byrnes Creek culvert into the area protected by the St Marys Levee. Installation of the flap gate would prevent this backwater flooding and would therefore direct an additional 2.9 m^3/s to flow downstream along South Creek.

Analysis of results for the 1% AEP flood indicates that the additional flow of 2.9 m^3/s would represent an increase of up to 0.25% for areas downstream of the Great Western Highway. RMA-2 modelling with the flap gate included confirms that this increase would not result in any measurable increase to flood levels downstream. Accordingly, the increase in peak 1% AEP flows of up to 0.25% is considered to represent a negligible increase.

The impact of the flap gate (*Measure F-7B*) on peak flood levels across St Marys behind the Levee (*to the east*) are listed in **Table 9-15**. As shown, the flap gate is predicted to prevent flows from South Creek entering areas behind the levee for floods up to and including the 1% AEP flood. For larger events, overtopping of the levee and backwater flooding from South Creek due to floodwaters overtopping the Great Western Highway to the east is predicted to govern flood levels.

Table 9-15 Peak Flood Levels Across St Marys Behind the St Marys Levee with Measure F-7B

Levee Scenario	Design Flood Event (AEP)					
	5%	2%	1%	0.5%	0.2%	PMF
Post-Upgrade (Measure F-7A) (*Extracted from the Updated South Creek Flood Study 2015*)	23.97	24.18	24.40	24.64	25.06	27.60
Post-Upgrade (Measure F-7B) (*Measure F-7A plus Flap gate)*	DRY	DRY	DRY	24.47	25.06	27.60

Cost Estimate

The cost estimate for Measure F-7B includes the works proposed as per Measure F-7A plus installation of the flap gate at the outlet of the Byrnes Creek culvert. In preparing the cost estimate it has been assumed that investigations will initially be required to confirm no environmental or fish habitat issues may occur if backwater flows from South Creek are prevented from entering Byrnes Creek. A cost estimate for the design, construction and installation of the flap gate of $80,000 has been adopted plus an ongoing and annual maintenance allowance of $2,000. It is envisaged maintenance will be required to ensure the flap gate is operating as intended and that no debris or vegetation blocks closure of the gate.

- In accordance with the detailed costings contained within **Appendix F**, Measure F-7B (*including Measure F-7A*) is estimated to cost $744,000. This represents the total present value of upfront costs with a 20% contingency.

Environmental Assessment

The flap gate proposed as part of Mitigation Measure F-7B will require all construction works proposed as part of Measure F-7A plus installation of a flap gate at the outlet of the Byrnes Creek culvert.

The additional environmental concerns associated with the flap gate include:

- Changes to flow behaviour along Byrnes Creek for areas upstream of the Great Western Highway due to the removal of backwater flows associated with South Creek;
- Potential for head loss for Byrnes Creek flood events, and
- Potential implications on fish habitat due to the blockage of backwater flows through the culvert.

Benefit/Cost Analysis

Flood extents across St Marys corresponding to the peak flood levels listed in **Table 9-15** were applied to the damages analysis to determine the Average Annual Damage (*AAD*) that applies for Measure F-7B.

As shown in **Table 9-16**, Mitigation Measure F-7B is calculated to result in a reduction in the NPV of damages for the area protected by the St Marys Levee of $563,000. Based on an estimated construction cost for the measure of $744,000 this translates to a benefit/cost ratio of 0.76.

Table 9-16 Benefit/Cost Ratio for Measure F-7B

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
St Marys Levee Pre-Upgrade (*Existing*)	**30**	**$131,000**	**$1,757,000**			
St Marys Levee Post-Upgrade F-7B (*Base case scenario adopted for the 2015 Flood Study plus Flap Gate installation*)	30	**$89,000**	**$1,193,000**	**$744,000**	$563,000	**0.76**

9.3.10 Measure P-1: Voluntary House Raising

Voluntary house raising has been considered as a property modification measure with the objective of reducing existing flood damages. This measure can be applied to houses of piered construction. Which means that single storey high-set dwellings are typically best suited to house raising. Houses of slab-on-ground construction are excluded as raising is not feasible or cost effective.

The inclusion of a house within a proposed voluntary house raising (VHR) scheme does not place any obligation on the owner of the property to raise the house. Landowner application is voluntary (*OEH, 2013a*).

OEH requires any potential VHR to consider the following:

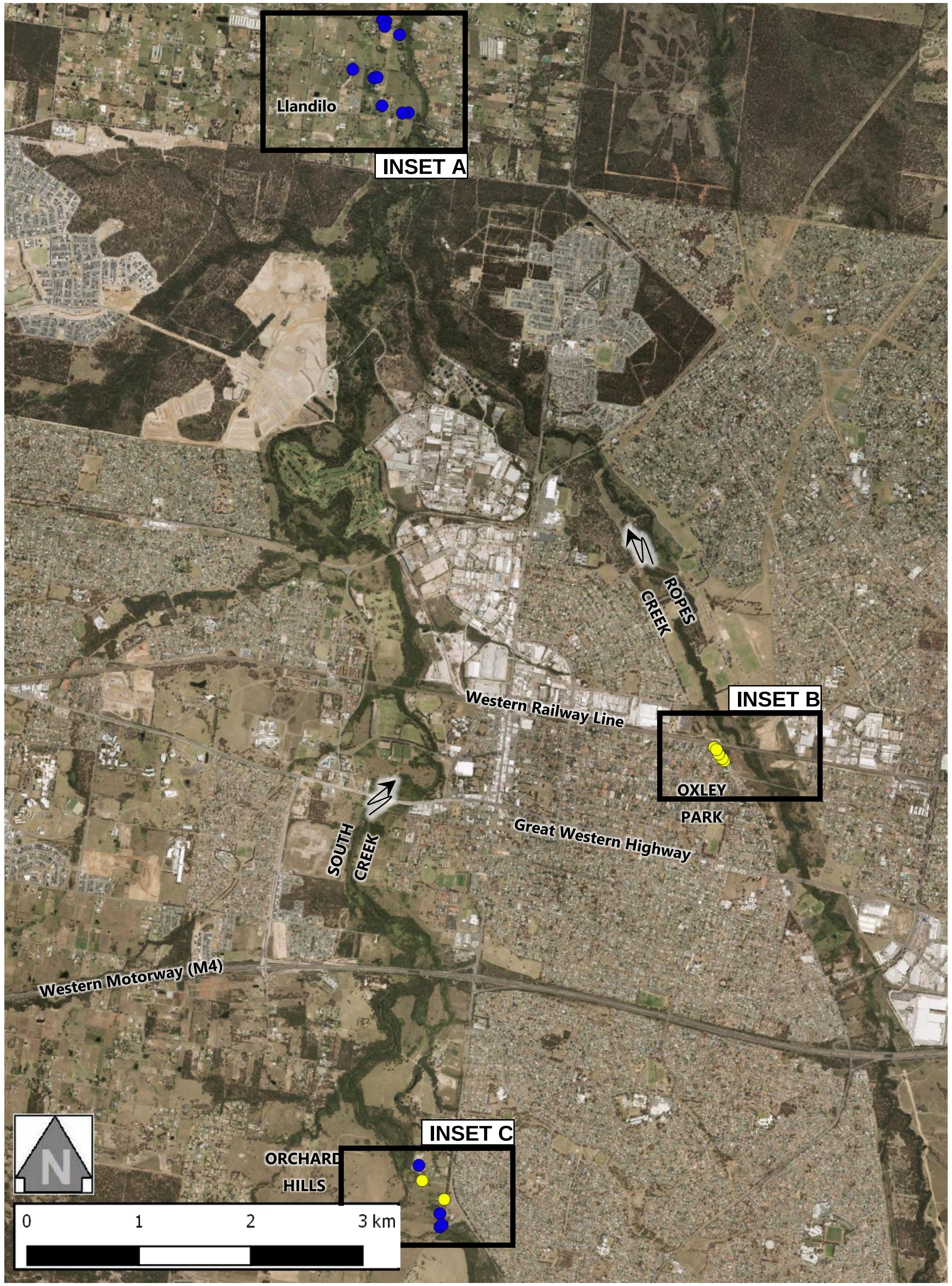
- The full range of design flood events and their impacts;
- VHR is generally excluded in floodway and high hazard areas;
- Cost-effectiveness of the proposed house raising scheme, with the aim of damages reductions outweighing the house raising costs (i.e., a BCR > 1.0);
- The viability of the scheme and its prioritisation;
- The support of the affected community, as determined through consultation.
- The OEH grant funding criteria also includes the following:
- Funding is only available for residential properties and not commercial or industrial;
- Dwellings constructed after 1986 are not eligible as this is the date of gazettal of the original Floodplain Development Manual which outlined construction principles to avoid flood damage;
- Properties already substantially benefited by other floodplain mitigation measures are not eligible for VHR funding;
- VHR should involve raising dwellings above a minimum design level, such as Councils Flood Planning Level (i.e., 1% AEP level plus 0.5 metres freeboard).
- VHR is generally excluded in floodway and high hazard areas;
- Cost-effectiveness of the proposed house raising scheme, with the aim of damages reductions outweighing the house raising costs (i.e., a BCR > 1.0);

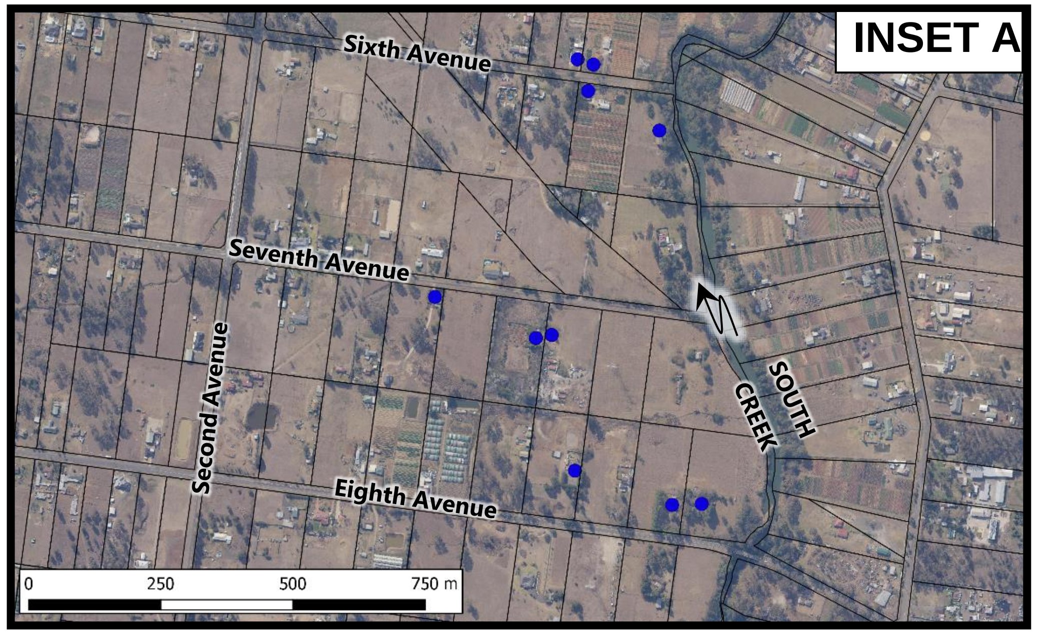
Prior to undertaking a detailed review of properties relative to flood heights and depths of over-floor flooding, properties were first excluded that fell within areas identified as being subject to high flood hazard and/or properties that fell within the floodway corridor (*refer OEH grant conditions above*). This led to the exclusion of properties in Llandilo and Berkshire Park, many of which were within both high hazard and the floodway corridor. The significant differences in flood levels between design events for these lower reaches also means that dwellings raised to the 1% AEP flood level plus 0.5 metres freeboard could still experience over-floor flooding to depths of 0.9 to 1.2 metres at the peak of the design 0.5% AEP flood. Accordingly, even if raised, properties in Llandilo and Berkshire Park would still be at significant risk of above-floor flooding.

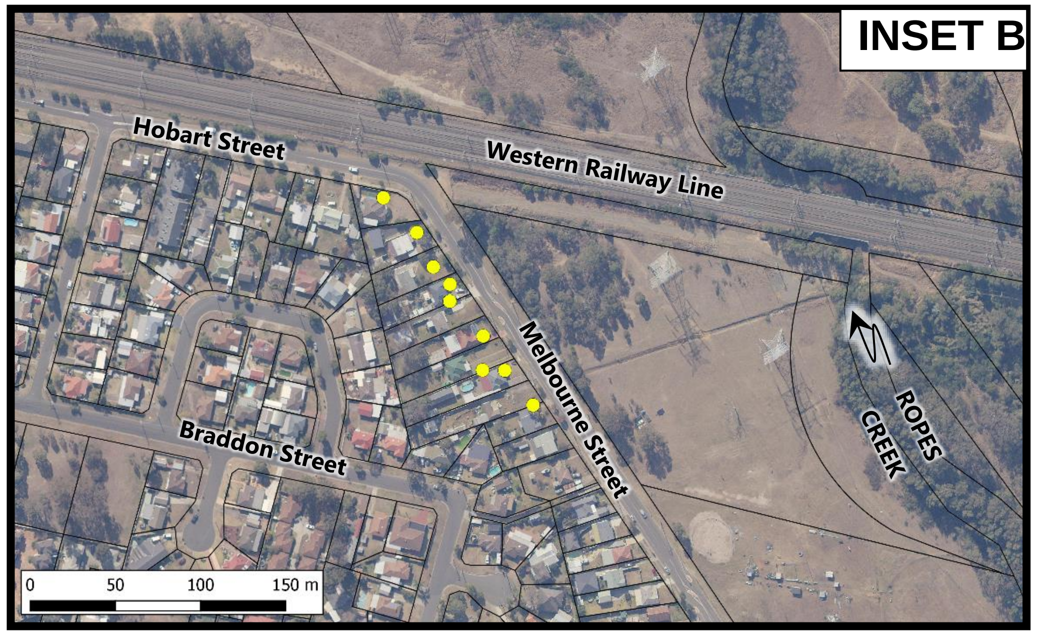
The RMA-2 model results were reviewed against eligible properties located south of Llandilo to determine which properties would benefit from house raising. A range of design events and depth criteria were considered through an iterative approach to obtain the highest Benefit-Cost-Ratio (*BCR*), whilst also limiting the VHR scheme to a manageable overall cost.

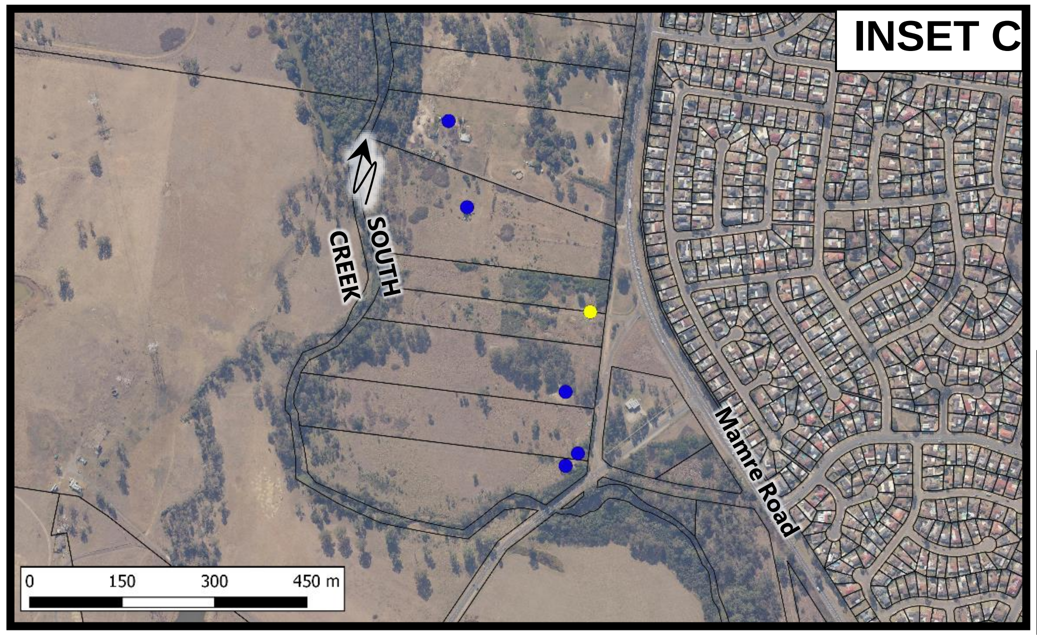
The results of this testing resulted in the selection of ten (10) properties that are considered suitable for house raising and which give the highest BCR ratio. As shown in **Figure 9.17**, nine of the ten properties are located in Oxley Park along Melbourne Street, plus one in Orchard Hills along Mamre Road.

The nine dwellings at Oxley Park would need to be raised by an average height of 0.8 metres achieve minimum floor levels equal to the Flood Planning Level (FPL); i.e., 1% AEP flood level plus 0.5 metres freeboard. The maximum and minimum heights to be raised are 0.88 metres and 0.72 metres,









Legend

- Property Identified for Voluntary Raising
- Property Identified for Voluntary Purchase

Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220_Fig 9.17_Properties Identified for VP and VR

PROPERTIES IDENTIFIED FOR VOLUNTARY PURCHASE OR RAISING

respectively. The dwelling at Oxley Park would need to be raised by 1.1 metres to have floor levels at the FPL.

Cost Estimate

The cost of implementing Measure P-1 is estimated to be $98,800 per house raised (*refer* **Appendix F**). This amount includes alternative accommodation while houses are being raised, an allowance for removalists to assist with temporary removal of home contents for raising, plus a contingency of 20%.

If it assumed that ten houses are to be raised over the course of 5 years, the total present value of costs would be $988,000, which includes allowances to further develop the VHR scheme, consult with landowners and a yearly administration cost.

Environmental Assessment

No environmental issues are foreseen for Voluntary Raising.

Flood Damages Reduction

The raising of the ten identified dwellings is expected to result in a reduction in the net present value of damages of $517,000. This is calculated based on a design life of 30 years and the measure leading to a reduction in total AAD of $35,000.

Benefit/Cost Analysis

AAD for Option P-1 was calculated according to the reduction in flood damages across the entire range of design events, from the 5% AEP flood to the PMF. The reduction in AAD over a standard 30 year design life was brought back to present value using a real discount rate of 7%.

The present value of costs were compared to the present value of benefit for all ten properties to determine the BCR presented in **Table 9-17**. As shown, the Voluntary Raising Scheme has a BCR of 0.43.

Table 9-17 Benefit/Cost Ratio for Measure P-1

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Base Case	**30**	**$38,700**	**$514,000**	**-**		
With Voluntary Raising	30	**$6,700**	**$88,200**	$988,000	$425,800	**0.43**

If a BCR is prepared for the ten properties individually, we find that one property located at Orchard Hills has a BCR of 1.13 and the remaining nine located at Oxley Park between 0.17 and 0.40. Accordingly, although the voluntary house raising proposed as Measure P-1 has a low BCR overall, one property is considered economically viable based on the calculated BCR of greater than 1.0.

9.3.11 Measure P-2: Voluntary House Purchase

Voluntary house purchase has also been considered as a property modification measure with the objective of reducing flood damages.

Guidance from OEH outlines that Voluntary Purchase (VP) is effective for properties in situations where there are highly hazardous flood conditions, where the property is to be removed from a floodway, or when purchase of the property enables other flood mitigation works to be implemented (*OEH, 2013b*). OEH also specifies that VP will only be considered where no other feasible risk management options are available to address the risk to life at the property.

Properties located in Llandilo, Berkshire Park and Orchard Hills were ineligible for VHR due to their position within the floodway corridor and/or highly hazardous floodwaters. These properties have been prioritised for VP based on the following:

- No other options for flood mitigation identified to reduce the flood risks or flood damages.
- High AAD calculated due to over-floor flooding first occurring during events ranging between the 5% and 1% AEP flood.
- High risks of structural damage to existing dwellings with flood depths of over 10 metres predicted at the peak of the PMF (Llandilo and Berkshire Park) or high flow velocities (*Orchard Hills*).

All properties identified as suitable for VP were ranked based on the depths of above floor flooding predicted and the resulting AAD. The fifteen (15) highest ranked properties were recommended for inclusion in the Voluntary Purchase Scheme and progressed to a Benefit-Cost-Analysis (*BCA*).

The location of all fifteen properties is shown on **Figure 9.17**.

Cost Estimate

The cost of implementing Measure P-2 is estimated to be $1.18 Million per property including all costs associated with the purchase and demolition (*refer* **Appendix F**). It includes allowance for stamp duty and legal fees, as well as rehabilitation of the dwelling footprint once demolition is complete. A 20% contingency is included.

If it assumed that all fifteen houses are purchased over the course of 15 years (*one every 2 years on average*), the total present value costs would be to be raised over the course of 5 years, the total present value of costs would be $8,569,000, which includes allowances to further develop the VP scheme, consult with landowners and a yearly administration cost.

This translates to a present value cost of $571,000 per property.

Environmental Assessment

A positive impact on the environment is expected with Voluntary Purchase as purchased properties can be returned to their natural state.

Flood Damages Reduction

The purchase of the fifteen properties identified is expected to result in a reduction in the net present value of damages of $1,660,000. This is calculated based on a design life of 30 years and the measure leading to a reduction in total AAD of $125,000.

Benefit/Cost Analysis

AAD for Option P-2 was calculated according to the reduction in flood damages across the entire range of design events, from the 5% AEP flood to the PMF. The reduction in AAD over a standard 30 year design life was brought back to present value using a real discount rate of 7%.

The present value of costs were compared to the present value of benefit for all fifteen properties to determine the BCR presented in **Table 9-18**. As shown, the Voluntary Purchase Scheme has a BCR of 0.19.

Table 9-18 Benefit/Cost Ratio for Measure P-2

Damages Scenario	Design Life of Options *(Years) - 50 years max for structural options*	AAD	NPV of Damage	Present Cost Of Works	Benefit Relative to Base Case	Benefit/Cost Relative to Base Case
Base Case	**30**	**$125,000**	**$1,660,000**	**-**		
With Voluntary Purchase	30	**$0**	**$0**	$8,569,000	$1,660,000	**0.19**

If the BCR for the VP scheme were assessed individually for properties the highest and lowest BCR is 0.30 and 0.12, respectively. Accordingly, there is no significant variation in BCR between all 15 properties nominated.

9.4 Benefit-Cost Assessment

The assessment of mitigation measures documented in Section 10.3, included a benefit-cost analysis to assess the economic viability of implementing each measure. This was undertaking to allow the economic viability of each measure to be assessed individually and to allow the monetary benefit of each measure to be compared.

As discussed in Section 10.3, the 'benefit' of each measures was calculated over a design life of 30 years as the present value of the reduction in AAD for each mitigation measure relative to the AAD that would be incurred under existing conditions. A real discount rate of 7% was adopted, which is the same used to determine the present value of the cost of each measure.

The Benefit-Cost-Ratio (*BCR*) determined for each mitigation measure is shown below in **Table 9.19**. A BCR has not been determined for those measures that were found to give benefits lower than expected despite comparatively high costs (*compared to other similar measures*) or where the focus of the measure was not on damage reduction (*such as for measures focused on improving emergency response*).

Table 9-19 Benefit/Cost Ratio for Proposed DRM Options

Mitigation Measure	Cost of Works (*PV*)	Reduction in AAD	Present Value of Damage Reduction	Benefit-Cost Ratio
F-1A - Oxley Park Low Cut	**$356,600**	**$20,000**	**$268,100**	**0.75**
F-1B - Oxley Park High Cut	**$914,400**	**$28,000**	**$375,400**	**0.41**
F-2 - Oxley Park Levee	**$694,000**	**$45,000**	**$603,000**	**0.87**
F-3 - Railway Bridge Widening	**$1M to $1.5M**	Measure did not progress beyond modelling to benefit-cost analysis based on low benefit compared to F-1A		
F-4 - Additional Storage Upstream of the Railway Crossing	Measure did not progress beyond modelling to benefit-cost analysis based on low benefits compared to F-1A			
F-5 - Raise Werrington and Rance Road	**$1,086,000**	**$35,000**	**$470,000**	**0.43**
F-6 - Raise Mamre Road	Measure focused on improving emergency response with minimal reduction in flood damages			
F-7A – Upgrades to St Marys Levee	**$634,000**	**$13,000**	**$174,000**	**0.27**
F-7B – F-7A plus Installation of Flap Gate	**$744,000**	**$42,000**	**$563,000**	**0.76**
P-1 - Voluntary House Raising	**$988,000**	**$32,000**	**$425,800**	**0.43**
P-2 - Voluntary House Purchase	**$8,569,000**	**$125,000**	**$1,660,000**	**0.19**

9.5 Triple Bottom Line Assessment of Mitigation Options

In addition to assessment of the economic benefit for each flood mitigation measure, further assessment was undertaken to compare them according to a range of additional criteria, including social and environmental factors.

The assessment criteria and their weighting are outlined in **Table 9-20**.

It is acknowledged that there will be some overlap between the flood impact criteria and the criteria for economic assessment. For example, an impact on flooding is likely to affect the cost of flood damages and therefore, impact on the benefit-cost ratio. However, in light of the primary objectives of this floodplain risk management study and plan, and the relevance of the associated flood modelling results, it is considered appropriate to give additional weighting to direct flood impacts and also the indirect consequences.

Each flood modification measure was assigned a score of 0 to 5 against each criterion; 5 being the best score indicating the most beneficial impacts and zero being the lowest score or negative impacts. For the more qualitative criteria, such as ecological impacts and disruption to the natural character of the area, a median score of 2.5 was applied in the case of neutral impacts.

Where possible, the criteria were scored quantitatively; for example, the life cycle cost for each option was scored according to the present dollar value of the total life cycle costs.

Table 9-20 Triple-Bottom-Line Assessment Criteria

Evaluation Criteria	Scoring Approach (0 to 5)	Weighting
Flood Impacts		
Impact on hydraulic behaviour	Worst/adverse=0, neutral=2.5, best=5	x 5
Reduction in flood damages	<$0.2M=0, >$0.2M=1, >$0.4M=2, >$0.6M=3, >$1M=4, >$2M=5 (present value)	x 4
Economic		
Benefit / Cost Ratio	<0.2=0, <0.3=1, <0.5=2, <1= 3, ≥1=4, >1.5=5	x 4
Life cycle cost of option	>$5M=0, >$1M=1, >$0.8M=2, >$0.5M=3, >$0.3M=4, <$0.3M=5	x 4
Social		
Impact on local community	Worst/adverse=0, neutral=2.5, best=5	x 4
Likely community acceptance	Least support=0, neutral=2.5, most support=5	x 3
Environmental		
Disruption to the natural character of the area	Worst/adverse=0, neutral=2.5, best=5	x 3
Ecological impacts	Worst/adverse=0, neutral=2.5, best=5	x 4

The Triple-Bottom-Line assessment for all flood modification measures is shown in **Table 9-21**.

Table 9-21 Triple-Bottom-Line Assessment (Flood Modification Measures)

Raw Scores

Evaluation Criteria	Weighting	F-1A Floodplain Excavation downstream of the Railway Line (Low Cut)	F-1B Floodplain Excavation downstream of the Railway Line (High Cut)	F-2 Flood Protection Levee (Oxley Park)	F-3 Ropes Creek Railway Bridge Widening	F-4 Additional Storage Upstream of the Ropes Creek Railway Crossing	F-5 Raise Werrington & Rance Road	F-6 Raise Mamre Road at Low-Points	F-7A Upgrade St Marys Levee	F-7B Upgrade St Marys Levee & Install Flap Gate	P-1 Voluntary House Raising	P-2 Voluntary House Purchase
Flood Impacts												
Impact on hydraulic behaviour	5	4	5	4	3	4	3	2.5	4	5	2.5	2.5
Reduction in flood damages	4	1	1	3	1	0	2	0	0	2	2	4
Economic												
Benefit / Cost Ratio	4	3	2	3	0	0	2	0	1	3	2	0
Life cycle cost of option	4	4	2	3	1	3	1	1	2	2	2	1
Social												
Impact on local community	4	3.5	3	3	3.5	3	3	3	3	3.5	3	3
Likely community acceptance	3	4	4	3	4	4	3.5	3	3	4	2.5	2
Environmental												
Disruption to the natural character of the area	3	2.5	2	1	2.5	2.5	2.5	2.5	2.5	2	2.5	2.5
Ecological impacts	4	2	1.5	2	1.5	2	2	2.5	2	1.5	2.5	2.5

Weighted Scores

Evaluation Criteria	F-1A Floodplain Excavation downstream of the Railway Line (Low Cut)	F-1B Floodplain Excavation downstream of the Railway Line (High Cut)	F-2 Flood Protection Levee (Oxley Park)	F-3 Ropes Creek Railway Bridge Widening	F-4 Additional Storage Upstream of the Ropes Creek Railway Crossing	F-5 Raise Werrington & Rance Road	F-6 Raise Mamre Road at Low-Points	F-7A Upgrade St Marys Levee	F-7B Upgrade St Marys Levee & Install Flap Gate	P-1 Voluntary House Raising	P-2 Voluntary House Purchase
Flood Impacts											
Impact on hydraulic behaviour	20	25	20	15	20	15	12.5	20	25	12.5	12.5
Reduction in flood damages	4	4	12	4	0	8	0	0	8	8	16
Economic											
Benefit / Cost Ratio	12	8	12	0	0	8	0	4	12	8	0
Life cycle cost of option	16	8	12	4	12	4	4	8	8	8	4
Social											
Impact on local community	14	12	12	14	12	12	12	12	14	12	12
Likely community acceptance	12	12	9	12	12	10.5	9	9	12	7.5	6
Environmental											
Disruption to the natural character of the area	7.5	6	3	7.5	7.5	7.5	7.5	7.5	6	7.5	7.5
Ecological impacts	8	6	8	6	8	8	10	8	6	10	10
TOTAL SCORE	**93.5**	**81**	**88**	**62.5**	**71.5**	**73.0**	**55**	**70.5**	**91**	**73.5**	**68**
RANK	**1**	**4**	**3**	**10**	**7**	**6**	**11**	**8**	**2**	**5**	**9**

9.6 Recommendations

Table 9-21 outlines the recommended Flood Modification Measures for inclusion as potential works within the Floodplain Risk Management Plan for South Creek.

Table 9-21 Recommended Flood Modification Measures

ID	Recommended Flood Modification Measures
FM.1	The '*Low Cut*' option (*Measure F-1A*) for excavation downstream of the Western Railway Line crossing of Ropes Creek is recommended based on it returning the highest ranking following the Triple Bottom Line (*TBL*) assessment and third highest Benefit-Cost-Ratio (*BCR*) of 0.75. The measure is considered a viable option to reducing flood damages to properties located along Melbourne Street in Oxley Park. There is potential for the BCR to increase for this measure if the benefits to residential properties located to the east and within Blacktown City Council are taken into consideration.
FM.2	The proposed upgrades to the St Marys Levee plus installation of a flap gate (*Measure F-7B*) at the outlet of the Byrnes Creek culvert is recommended based on it returning the second highest TBL ranking and second highest BCR of 0.76. The measure has been shown to prevent backwater flooding from South Creek into St Marys during floods up to and including the 1% AEP event. Further investigation of Measure F-7B is required to confirm levee crest elevations and the existing condition of the levee (*refer* **Section 8.4.1**).
FM.3	The proposed Earthen Levee (*Measure F-2*) at Oxley Park is proposed to be included in the Floodplain Risk Management Plan for further investigation, design and implementation. The proposed Oxley Park Levee was calculated to have the highest BCR at 0.87 and third highest TBL ranking.

10. Flood Emergency Response Management

The NSW State Emergency Service (*SES*) is the legislated Combat Agency for floods and is responsible for coordinating other agencies involved with emergency response management. SES, with the support of the NSW Office of Environment and Heritage (*OEH*), has developed guideline documents which detail desired outcomes from the Floodplain Risk Management process for the management of emergency response to flood risk and evacuation planning. These guidelines are:

- 'SES Requirements from the Floodplain Risk Management Process' (2007); and,
- 'Flood Emergency Response Planning Classification of Communities' (2007).

Due to the potential for flooding of South Creek to lead to damage to property and / or loss of life, it is considered appropriate to assess the risk to the potentially flood affected communities. This requires the updating of flood risk management procedures in light of the guidelines and recent flood modelling results, identification of those who are at risk from flooding and the assessment of measures that could be implemented to reduce the exposure of the community to flood risk. It is envisaged that the information contained in this report will be of assistance to the SES in the verification and refinement of existing flood emergency response procedures or the development of additional protocols.

Due to the size of the study area, the assessment of flood emergency response for the community has been divided into fifteen (*15*) Flood Management Sectors. The Sectors have been delineated with consideration for suburb boundaries, the source of flooding (*different creeks*) and size. The adopted Sectors are listed below and shown in **Plate 10-1** and **Plate 10-2** on the following pages.

- North of Elizabeth Drive (Affected by flooding from South and Badgerys Creek)
- Kemps Creek (Affected by flooding from Kemps Creek)
- Twin Creek (Affected by flooding from Cosgroves Creek)
- Orchard Hills West (Affected by flooding from South and Blaxland Creeks)
- Mamre Road (Affected by flooding from South Creek)
- Claremont Creek (Affected by flooding from Claremont and South Creeks)
- St Marys (Affected by flooding from South Creek)
- Erskine Park (Affected by flooding from Ropes Creek)
- Colyton/Oxley Park (Affected by flooding from Ropes Creek)
- North St Marys and Ropes Creek (Affected by flooding from Ropes Creek)
- The Kingsway (Affected by flooding from South Creek)
- North St Marys Industrial Area (Affected by flooding from Ropes, South Creek and the Hawkesbury-Nepean River)
- Werrington (Affected by flooding from Werrington Creek and Hawkesbury-Nepean River)
- Former ADI Site (Affected by flooding from South Creek and Hawkesbury-Nepean River)
- Llandilo and Berkshire Park (Affected by South Creek and Hawkesbury-Nepean River)

PLATE 10-1 FLOODPLAIN MANAGEMENT SECTORS (SOUTH STUDY AREA)

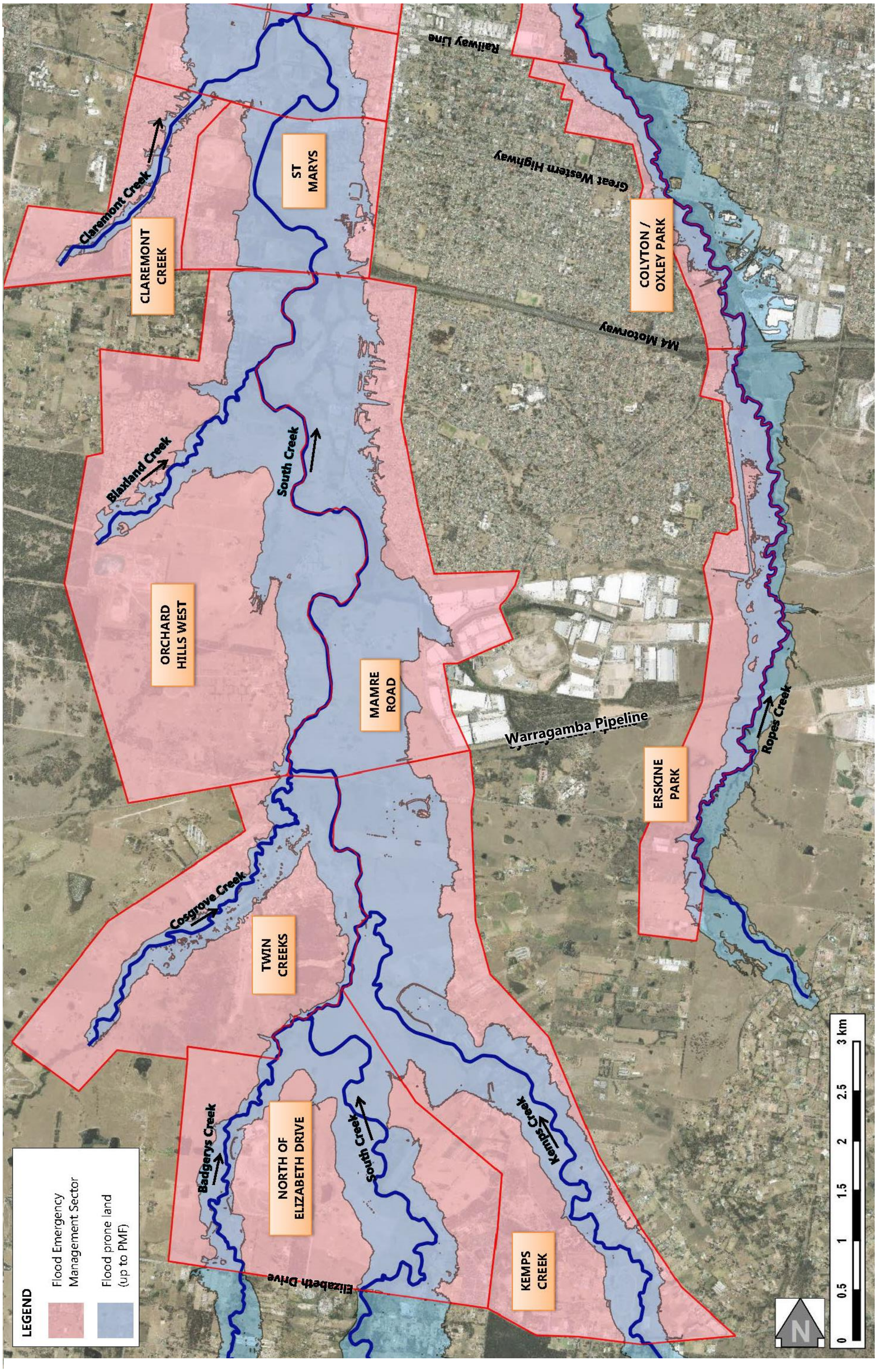
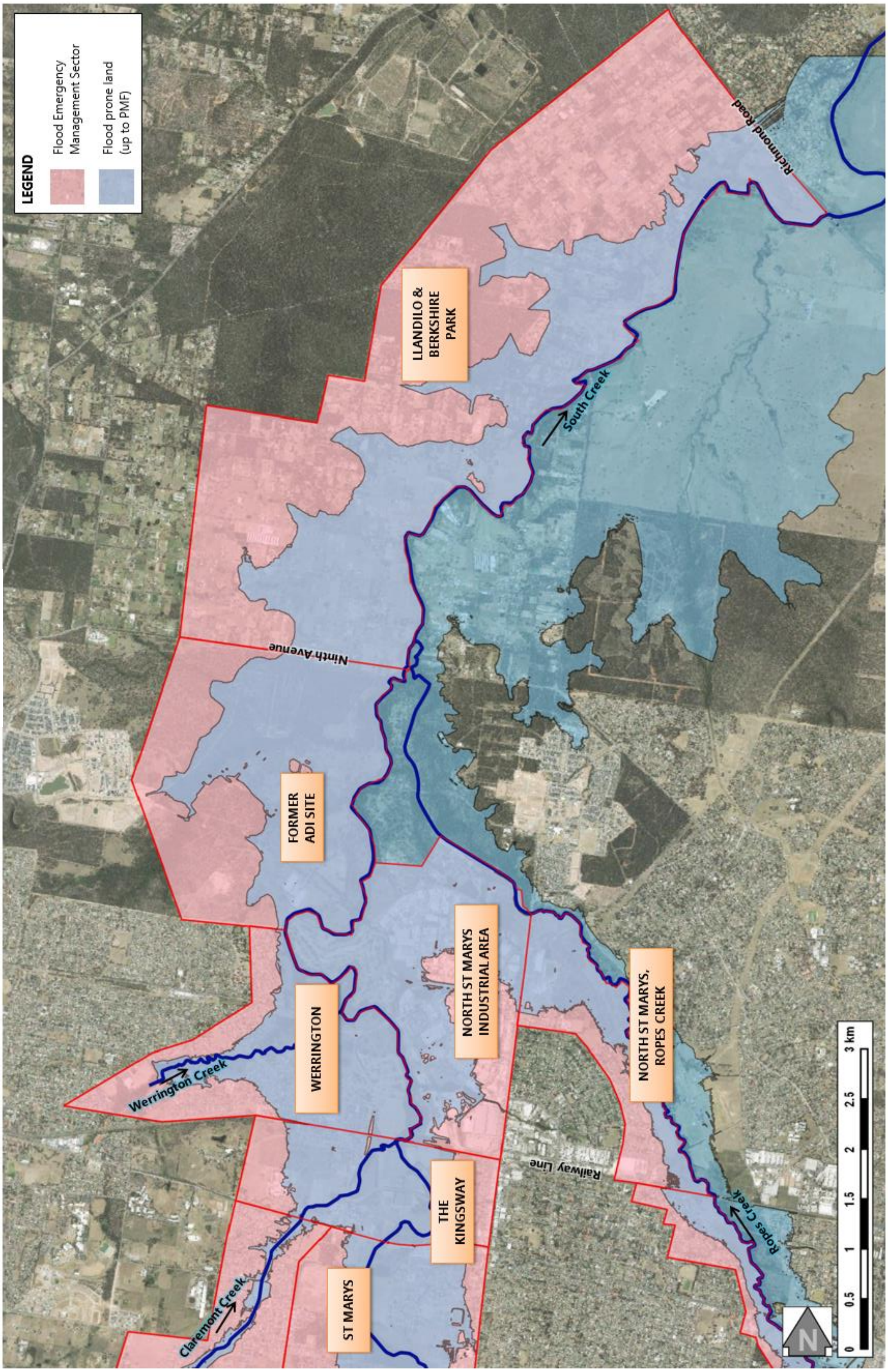


PLATE 10-2 Flood Emergency Management Sectors (North Study Area)



10.1 Emergency Response Planning Communities

The SES guidelines highlight the need to identify Flood Management Communities. The delineation of communities within the SES' wider Operational Areas allows emergency response to be tailored for areas with differing degrees of vulnerability. Classification provides an indication of the relative vulnerability of communities located on the floodplain and helps identify the information required by SES to manage the risk. Community risk may be influenced by such factors as flooding patterns, topography and the availability of safe access and egress routes.

10.1.1 Classification Criteria and Approach

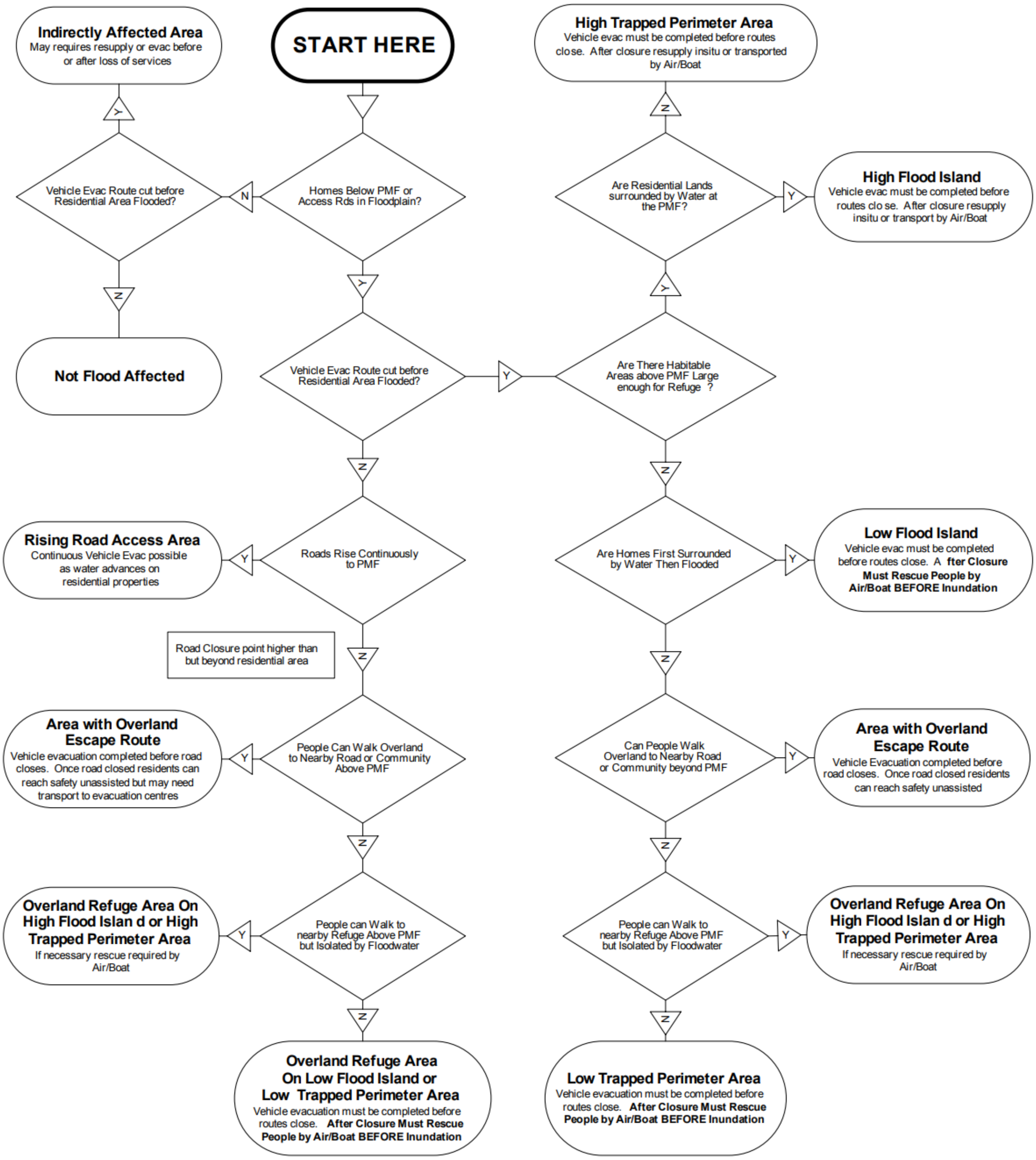
The SES classifies communities according to the impact that flooding has on them. The primary purpose for doing this is to assist SES in the planning and implementation of response strategies. Flood impacts relate to where the normal functioning of services is altered due to a flood, either directly or indirectly, and relates specifically to the operational issues of evacuation, re-supply and rescue.

A summary of the definitions of each Flood Emergency Response Planning (*ERP*) community is provided in **Table 10-1**. Further detailed descriptions are provided afterward within the text.

A flow chart showing the approach recommended to identify the classification that applies to each community is shown in **Figure 10-1**.

Table 10-1 Flood Emergency Response Planning Classifications

ID	Recommendation
Flood Island	▪ **High Flood Island** – land higher than peak PMF level but area surrounded by floodwaters. ▪ **Low Flood Island** – land lower than the peak PMF level. Area is isolated by floodwaters before being inundated.
Trapped Perimeter	▪ **High Trapped Perimeter** – area isolated as evacuation route may be cut. Ground above the PMF available. ▪ **Low Trapped Perimeter** - area isolated as evacuation route may be cut. Ground above the PMF is not available and area may become inundated.
Rising Road Access	▪ Access roads steadily rise away from floodwaters to land above the PMF. Vehicular evacuation is possible.
Overland Escape Route	▪ Access roads to flood free land cross lower lying flood prone land but pedestrian escape is possible by walking overland to higher ground.
Indirectly Affected Areas	▪ Outside the area of flooding, however may be affected by loss of services or infrastructure or become isolated due to road closures.



Source: (DECC, 2007)

Figure 10-1 SES Process for Classification of Communities for Flood Emergency Response Planning

Flood Islands

Flood Islands are inhabited areas of high ground within a floodplain which are linked to the flood-free valley sides by only one access / egress route. If the road is cut by floodwaters, the community becomes an island, and access to the area may only be gained by boat or aircraft. Flood islands are classified according to what can happen after the evacuation route is cut and are typically separated into:

- High Flood Islands; and,
- Low Flood Islands.

A High Flood Island includes sufficient land located at a level higher than the limit of flooding (*i.e., above the PMF*) to provide refuge to occupants. During flood events properties may be inundated and the community isolated. However, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it is not possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

The highest point of a Low Flood Island is lower than the limit of flooding (*i.e., below the PMF*) or does not provide sufficient land above the limit of flooding to provide refuge to the occupants of the area. During flood events properties may be inundated and the community isolated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown.

Trapped Perimeter Areas

Trapped Perimeter Areas are inhabited areas located at the fringe of the floodplain where the only practical road or overland access is through flood prone land which becomes inaccessible during a flood. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows.

High Trapped Perimeter Areas include sufficient land located at a level higher than the limit of flooding (*i.e., above the PMF*) to provide refuge to occupants. During flood events properties may be inundated and the community isolated. However, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it is not possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

Low Trapped Perimeter Areas are areas that are lower than the limit of flooding (*i.e., below the PMF*) or which do not provide sufficient land above the limit of flooding to provide refuge to those seeking to occupy the area. During a flood event the area is isolated by floodwaters and the property may be inundated. If floodwaters continue to rise after isolation, the area will eventually be completely covered. People trapped in the area may drown.

Areas Able to be Evacuated

These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated. However, their categorisation depends upon the type of evacuation access available, as follows.

Areas with Overland Escape Route are those areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground.

Anyone not able to walk out must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.

Areas with Rising Road Access are those areas where access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example, people living in two storey homes may initially decide to stay but reconsider after water surrounds them.

These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.

Indirectly Affected Areas

These are areas outside of the limit of flooding and therefore will not be inundated nor will they lose road access.

However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

Overland Refuge Areas

These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas. They should be categorised accordingly, and these categories used to determine their vulnerability.

Note that Flood Management Communities identified as Overland Refuge Areas on Low Flood Island have been classified according to the SES Flow Chart for Flood Emergency Response Classification. These are areas where vehicular evacuation routes are inundated before residential areas of the Community.

10.1.2 Classification of Emergency Response Planning Communities

Mapping of Flood Management Communities for each of the sectors shown in **Plates 10-1** and **10-2** is provided in **Figures G-1** to **G-14** in **Appendix G**.

The key classifications and findings for each sector are outlined in **Table 10-2** on the following pages.

The classifications listed in **Table 10-2** indicate that ERP communities in the Flood Emergency Management Sectors of Werrington, The Kingsway and St Marys have the greatest number of people at risk. However, the most "at risk" ERP communities are considered to be the Low Flood Island communities. Although there are few of these in the floodplain, these should be high priority areas for evacuation. For these communities there is no land for refuge above the PMF level and vehicular evacuation must be completed before evacuation routes are cut-off by rising floodwaters. If this does not take place, rescue may then only be facilitated by air or boat. Isolated Low Flood Islands include Dolphin Close (*Claremont Creek*), Parkes Avenue (*Werrington*), and Mandalong Close (*Mamre Road*).

The most common ERP community classification is Rising Road Access. Communities with this classification have access to a continuous vehicular evacuation route as floodwaters advance toward properties. However, if evacuation does not take place in a timely manner, or occupants ignore flood warnings, then the population would be at risk.

Table 10-2 Flood Emergency Response Planning Communities and Potentially "At Risk" Population

Flood Management Sector For Emergency Response	Flood ERP Community	Community Classification	Area	Potentially "At Risk" Population	Comment
NORTH OF ELIZABETH DRIVE	Badgerys Creek and South Creek north of Elizabeth Drive	Rising Road Access or Indirectly Affected	780 ha	50	No residential properties. Includes Resource Recovery Centre, SUEZ landfill and wholesale nursery. Inundated areas have Rising Road Access to Indirectly Affected Areas. Elizabeth Drive inundated at both Badgerys Creek and South Creek crossings in 5% AEP and 2% AEP floods respectively, so area could become isolated. Sufficient land above PMF for refuge.
KEMPS CREEK	Kemps Creek to Warragamba Pipeline	Rising Road Access or Indirectly Affected	4 km^2	150	Few properties on west of Kemps Creek could become isolated due to inundation of Elizabeth Drive crossing of Kemps Creek in 5% AEP event and also inundation of Elizabeth Drive at the South Creek and Badgerys Creek crossings. Properties on east of Kemps Creek have access to Mamre Road.
TWIN CREEKS	Portush Crescent, Medinah Avenue and Twin Creeks Golf Course	Rising Road Access	65 ha	190	Includes residential properties on the southern side of Portush Crescent. Not all dwellings expected to be inundated but inundation in yards likely to occur. Also includes Twin Creeks Golf Course and residential properties on the north-east side of Medinah Avenue.
	Properties between Cosgrove Creek and South Creek Floodplains	Indirectly Affected	83 ha	310	Area becomes isolated as Twin Creeks Drive is inundated in a PMF event.
MAMRE ROAD	Mandalong Close	Low Flood Island	37 ha	40	About 11 properties are isolated as the low point on Mandalong Close is inundated in the 5% AEP event. Flood levels may continue to rise inundating properties.
	Private Drive, Mamre Road West	Low Flood Island	4.5 ha	20	About six residential properties along a private track from Mamre Road are isolated in the 5% AEP flood event as a low point in the roadway becomes inundated.
	Old MacDonalds Child Care	Overland Escape Route	3 ha	100	Old MacDonalds Child Care access to Mandalong Close is inundated in 1% AEP event. However overland access to land above the PMF level on Mamre Road is available.
	Mamre Road West	Rising Road Access / Overland Escape Route	3.4 km^2	40	Other areas west of Mamre Road which are not Mandalong Close, the private road or Old MacDonalds Child Care. Includes Mamre Homestead. Evacuation would be via routes from Mamre Road.
	Mamre Road East	Rising Road Access	31 ha	1120	Generally not inundated to events greater than 0.2% AEP event. Safe road access available through residential streets towards the east.
ORCHARD HILLS WEST	East of Samual Marsden Road	Low Flood Island	0.9 ha	4	One residential property becomes a Low Flood Island.
	Samual Marsden Road	Rising Road Access	68 ha	80	Mainly properties affected by inundation from South Creek. Includes the Riding for the Disabled Association.
	Luddenham Road	Rising Road Access	1 km^2	50	Rising Road Access is available to the south. Includes the Centre for Canine Affairs.
	Bordeaux Place	Rising Road Access	7.5 ha	30	Eight properties on Bordeaux Place inundated by Blaxland Creek in the 0.2% AEP flood event and greater.
	Rural Residential Properties	High Trapped Perimeter	43 ha	20	Several rural properties are located above the PMF extent however access is inundated and the properties could become isolated. There is habitable areas above the PMF large enough for refuge.
	Agricultural Areas	Overland Escape Route	1.5 km^2	10	Other areas of the floodplain are less populated and used generally as agriculture. Overland escape routes are possible to land above the PMF. Occupants of area likely to be rural land owners and/or employees.
ST MARYS	St Marys - East of South Creek	Rising Road Access	1.2 km^2	1930	Levee overtopped in events greater than a 0.5% AEP flood however inundation from backing up at Byrnes Creek occurs. Approximately 750 residential properties and 20 commercial properties at risk.
	St Marys - West of South Creek	Overland Escape Route	57 ha	10	Areas are generally undeveloped and used for agricultural or recreational purposes.
	Caddens Road / Doncaster Avenue	Low Trapped Perimeter / Rising Road Access	11.5 ha	50	Rising Road Access generally available for properties off Caddens Road with the exception of six townhouses on Doncaster Avenue where the road is predicted to be inundated in events greater than the 2% AEP event.

Flood Management Sector For Emergency Response	Flood ERP Community	Community Classification	Area	Potentially "At Risk" Population	Comment
CLAREMONT CREEK	Dolphin Close	Low Flood Island	1.2 ha	60	13 residential properties on Dolphin Close are classified as Low Flood Island as the roadway is inundated by the peak of a 5% AEP event. These properties start to be inundated in floods greater than a 2% AEP event. A further five properties are classed as High Trapped Perimeter as they do not become inundated but are isolated.
	Claremont Meadows Creek Corridor	Rising Road Access, High Trapped Perimeter and Indirectly Affected areas	20 ha	740	All properties adjacent to the creek are potentially subject to yard inundation or becoming high trapped perimeter areas as roads adjacent to the creek corridor are inundated. Claremont Meadows Public School outdoor areas subject to inundation in PMF.
THE KINGWAY	St Marys Commercial area and High School	Rising Road Access	40 ha	1000	Includes St Marys High School and St Marys shopping centre
	Kurrambee School and surrounds	Low Trapped Perimeter	29 ha	1000	Includes Penrith Assisted Learning School and Kurrambee School. Access available onto Great Western Highway via Werrington Road. However, the GWH is inundated at Claremont Creek and at South Creek in the 5% AEP event. Therefore, people would need to continue to the south.
	Rance Road area	Overland Escape Route	53 ha	650	Werrington Road becomes inundated in a 5% AEP event before properties are inundated. Therefore, the only safe access once the road is inundated is by foot overland to the west. Includes a number of blocks of units.
	Recreation Areas	Overland Escape Route	48 ha	50	Generally, the population in this area should be at a lower risk as the area is used for recreational purposes and it is less likely people will be there in heavy rain. Notwithstanding, The Kingsway is inundated during the 5% AEP flood and likely events as frequent as the 20% AEP flood. Closure of The Kingsway therefore needs to be closely monitored.
WERRINGTON	Werrington Creek (*north bank*)	Rising Road Access	29 ha	160	Properties along Hume Crescent affected.
	Malcolm Avenue	Low Trapped Perimeter	2.8 ha	30	About 15 residential properties on Malcom Avenue are affected as flooding cuts access. Properties could become inundated as water levels increase.
	Properties at junction of Heavey St and Burton Street and properties on Lack Place	High Trapped Perimeter	2.8 ha	90	About 35 residential properties are not inundated in PMF but become isolated as access roads are inundated.
	Properties east of Parkes Avenue and west of Werrington Road Levee	Low Flood Island	17 ha	830	Area contains many blocks of units. The area is protected from flooding from South Creek by Werrington levee until floods larger than a 0.2% AEP event.
	Area protected by Werrington Levee System	Rising Road Access	78 ha	1430	Levee expected to overtop in the 0.2% AEP event and greater. Rising Road Access to Victoria Road (*assuming Victoria Road is not inundated by Werrington Creek*)
NORTH ST MARYS INDUSTRIAL ESTATE	St Marys Industrial Estate and Sewerage Treatment Plant and Dunheved Golf Course	Low Trapped Perimeter	2.6 km^2	1360	Access to Forrester Road inundated in the 5% AEP event prior to properties becoming inundated.
	Dunheved Circuit - South	High Trapped Perimeter	19 ha	190	Industrial properties on the southern part of Dunheved Circuit are not inundated in the PMF event although access is cut.
	Lee Holm Road area	Rising Road Access	65 ha	940	Industrial and commercial uses protected by St Marys Levee until overtopping occurs.
FORMER ADI SITE	n/a	n/a	n/a	n/a	The Former ADI Site Flood Emergency Management Sector and ERP classifications will need to be re-assessed once development is complete in the area.
LLANDILO AND BERKSHIRE PARK	Llandilo and Berkshire Park	Rising Road Access	6.5 km^2	790	All properties have rising road access to land above the PMF. Access to Richmond Road is available via St Marys Road.

Flood Management Sector For Emergency Response	Flood ERP Community	Community Classification	Area	Potentially "At Risk" Population	Comment
ERKSINE PARK	Aldington Road	Rising Road Access	77 ha	20	Rural residential properties and fruit and vegetable business.
	Warbler Street and Swamphen Street	Rising Road Access	2.6 ha	100	All properties generally have access to land above the PMF from the road frontage.
COLYTON / OXLEY PARK	Melbourne Street and Braddon and Brisbane Streets	Rising Road Access	21 ha	390	Properties upstream of the railway line are affected by backing up of water upstream of the railway embankment.
	East of Melbourne Street	Rising Road Access	27 ha	20	Other properties on the east side of Melbourne Street. Generally large rural lots where dwellings are unlikely to be inundated.
NORTH ST MARYS, ROPES CREEK	Boronia Road	High Trapped Perimeter	0.75 ha	20	Road in front of properties inundated in PMF but dwellings unlikely to be inundated. Dwellings to rear prevent egress from the property.
	Gross Avenue and St Marys Rugby League Club	Rising Road Access	28 ha	580	About 30 residential properties inundated in the PMF event. Assumed 500 people at the St Marys Rugby Leagues Club. Access to Forrester Road above the PMF level is available from both areas.

10.2 At Risk Population

The "at risk" population within each Flood ERP Community has been determined using census data to estimate the population density for each Community and the floor level data used in the damages assessment to estimate the number of flood affected properties.

Where estimates were considered to be low, a manual estimate was made. For example, in areas where a Flood Emergency Management Sector comprised blocks of units where only the ground floor units would be considered flood affected in a damages assessment, whereas all residents in the block would actually be affected by flooding. The estimate was based on a visual count of dwellings (*undertaken during the survey and drive-by for most areas*) and the application of an assumed occupancy rate.

An estimate of the "at risk" population for each ERP Community is presented in **Table 10-2**. In the rural areas of the floodplain of South Creek and its major tributaries many properties have Rising Road Access or an Overland Escape Route to areas above the PMF flood level. These properties are not all detailed in the table as it is likely they would notice flooding in the property before floodwaters reach the dwelling and inundate evacuation routes. Accordingly, these properties are considered lower priority compared to the areas detailed in **Table 10-2**.

10.3 Vulnerable Groups

An assessment has been made to identify vulnerable groups who, due to their age or health, may be more vulnerable to flooding and may need special consideration during a flood event. This has been undertaken using available Census data as well as the results of an internet business registry search.

The 2011 Census data showed that nearly 10% of the population of the Penrith LGA are aged over 65. Based on an average household size of three people for suburbs in the South Creek study area the number of residential properties at risk during the PMF, this equates to about 750 elderly residents at risk, who may require help in moving furniture/valuables to higher floors. They may also be less mobile and require assistance should they be required to evacuate. Provision should be made in the updated Local Flood Plan to allow for door knocking to confirm the evacuation and/or transportation needs of these less mobile residents.

A search was undertaken to identify hospitals, care homes and schools located within the extent of the PMF.

No hospitals were identified within the flood prone area of the study area. One care home / day centre was identified as Summit Care Home, Saddington Street, St Marys. The Home is located near to the tributary of South Creek which flows through Cook Park from the south in a north-west direction where it joins South Creek near the Great Western Highway. Flood modelling of South Creek shows that the care home is not likely to be inundated until events greater than the 0.2% AEP event and has Rising Road Access to Mamre Road.

Census data shows only a very small percentage of residents are not fluent in English and as such, groups susceptible to language barriers should not be a major issue.

Eight schools are located within the PMF flood extent and range from partially to entirely flood affected. These are summarised in **Table 10-3**.

Table 10-3 Schools within the Flood Prone Area (in order of flood risk severity)

School	Comment
Kurrambee School, Werrington Road, Werrington *(FEM Sector: The Kingsway)*	Claremont Creek is located along the north-west of the school grounds. The school is for children with learning disabilities and therefore the occupants at the school likely to be more vulnerable to flooding. The carpark is first flooded in less than a 5% AEP flood event from Claremont Creek. Flooding first reaches buildings in a 1% AEP event, although above floor level flooding is not expected. The school is classified as Low Tapped Perimeter as access to the Great Western Highway is inundated at the Claremont Creek crossing to the west and the South Creek Crossing to the east. Evacuation is therefore necessary despite the school buildings likely to remain dry above floor in a 1% AEP event. School buildings in the north may be inundated to depths of up to 0.5 m in a 0.2% AEP event and the site is entirely flooded by the PMF event.
Penrith Valley Learning Centre, Werrington Road, Werrington *(FEM Sector: The Kingsway)*	The school site is entirely inundated in the 0.2% AEP event. In a 1% AEP event school grounds to the north are inundated. The school is considered to be an area with a Low Tapped Perimeter as access to the Great Western Highway is available highway is inundated at the Claremont Creek crossing to the west and the South Creek Crossing to the east. In that regard evacuation is necessary despite the school buildings likely to remain dry above floor in a 1% AEP event.
Wollemi College, Gipps Street, Werrington (*FEM Sector: The Kingsway*)	The access road to the college in inundated in events smaller than the 5% AEP event. In the 5% AEP event flood depths on the access reach up to 0.6 m due to flooding from Claremont Creek and would prevent access to Werrington Road for evacuation. The college buildings are not inundated until events greater than the 0.2% AEP event. However, there is no formal road access from the site once the entrance road is inundated and evacuation would need to be overland to the west. Therefore, the college is classified under the SES ERP classifications as having and Overland Escape Route.
St Marys Senior High School, St Marys *(FEM Sector: St Marys)*	The 0.2% AEP flood encroaches onto playing fields. PMF event would inundate the western four buildings to depths of up to 0.5 m. Rising Road Access is available from the site.
St Marys Public School *(FEM Sector: St Marys)*	Located within PMF extent but not flooded in 0.2% AEP event. Rising Road Access is available to the Great Western Highway. Peak flood depths of up to 2.3 m are expected in a PMF event.
Werrington Public School, Werrington *(FEM Sector: Werrington)*	The PMF encroaches onto the northern boundary of the site but does not reach the school buildings. An Overland Escape Route is available to the south and then to the west.
Llandilo Public School, Seventh Ave, Llandilo *(FEM Sector: Llandilo and Berkshire Park)*	Located partially within PMF extent. Some buildings are flood free but not all. Rising Road Access is available towards the west. Maximum flood depths expected are 3.0 m in the south-east corner of the site.

School	Comment
Claremont Meadows Public School *(FEM Sector: Claremont Meadows)*	Some minor flooding in the playing fields in a 0.5% AEP event. Extent of PMF reaches to rear of buildings but over floor flooding considered unlikely.

10.4 Flood Management Community Data Sheets

A summary of the available emergency response management data and salient issues for each Flood Emergency Management Sectors have been compiled into Community Data Sheets. The information included on the Community Data Sheets generally comprises:

- Flood Management Community name and extent;
- Assessment of the population at risk;
- A description of flood characteristics for major floods such as the 1% AEP flood and PMF events;
- Identification of critical areas within the Community;
- Identification of evacuation routes, including the elevation of low points along each route;
- The magnitude of flooding that would cause the evacuation route to be cut;
- The available flood warning time relative to upstream gauge levels if available; and
- The location of potential refuge centres.
- Community data sheets, or flood intelligence sheets, are available in **Appendix H** for each of the fifteen (15) Flood Emergency Management Sectors.

10.5 Inundation of Local Roads

For each of the fifteen (15) Flood Emergency Management Sectors (*refer* **Section 10.4**) mapping has been prepared that shows the extent of all local roads that are predicted to be inundated for each design flood event. The maps have been included with all Community Data Sheets (**Appendix H**) to provide a snapshot to the SES of the flood risks along local roads, potential evacuation routes and the order at which road closures may need to be considered.

Inundation of local roads have therefore been assessed based on road elevations defined by the 2011 LiDAR and based on the Flood Study (2015) modelling results for the 5%, 2%, 1%, 0.5% and 0.2% AEP floods and the PMF.

10.5.1 Opportunities to Reduce Local Risk

Community consultation completed as part of the FRMS process identified the Eighth Avenue bridge crossing at Llandilo as being a location where there is the potential for significant risk during major flooding. As shown in the local roads inundation mapping included within **Appendix H** and the community data sheet for Llandilo, Eighth Avenue is predicted to be inundated during events up to and including the 5% AEP (*1 in 20-year recurrence interval*) flood.

As the 5% AEP event is the smallest flood simulated, it is likely that the bridge crossing would be inundated during more frequent events. Community consultation indicates that the crossing could be inundated as frequently as once every 5 years; i.e., during a 20% AEP event.

To reduce the risk that motorists and pedestrians would try use the Eighth Avenue bridge crossing during significant floods it is proposed that flood boom gates be installed on either side of the crossing. The protocols for operation of the gates during the onset of flooding would need to be determined in consultation with Penrith and Blacktown City Councils, and the SES. However, it it is likely that these protocols would include defining the details of responsibilities for operation and maintenance of the boom gates during normal operation and following inundation as a result of flooding; i.e., during the flood recovery phase.

To reduce the frequency of inundation of the Eighth Avenue bridge crossing, it is recommended that a vegetation management plan be implemented. The plan would outline protocols for removing excess vegetation at and immediately upstream and downstream of the crossing, maintenance of vegetation and inspection routines. The plan would also need to include consideration of flood recovery actions such as inspection of the bridge crossing and removal of debris following significant flood events.

10.6 Flood Warning

Flood warning for properties in Berkshire Park and Llandilo which are at risk from flooding from the "backing-up" of floodwaters from the Hawkesbury River is available and is based upon the Bureau of Meteorology (*BOM*) flood warnings for the Hawkesbury River at Windsor. However, there is little flood warning specific to the South Creek catchment for areas upstream, or for flooding of Llandilo and Berkshire Park under a local South Creek flood scenario.

Information on the flood warning arrangements for the Penrith City Council LGA is presented in the SES's Local Flood Plan (*April 2012*). It is understood that the plan is currently under review will be updated to incorporate the findings of this study.

Flood warnings are provided to the community by the SES based on rainfall and river data, which is provided by the BOM. The BOM provides catchment wide Flood Watches, which give an early warning of developing weather systems which could lead to flooding, and Flood Warnings, which include river height readings and height-time predictions. The BOM also provides severe weather warnings and warnings of flash flooding for fast response catchments.

10.6.1 Available Gauges within the South Creek Catchment

A number of rainfall and river level gauges are located within the South Creek catchment, although according to the current Local Flood Plan (*2012*) the only river level gauges used for flood warnings for South Creek are located on the Hawkesbury River.

River Level Gauges on South Creek

NSW Office of Water (*NOW*) operates two river level gauges on South Creek. The gauge at Elizabeth Drive (*NOW site number 212320, BOM reference 567070*) records water level and rainfall and estimates flows based on a rating curve. At the time of preparing this report the gauge has been found to be incorrectly called '*South Creek at Mulgoa Road*' on both the NOW and BOM websites. All location identifiers however, place the gauge at the correct location a short distance upstream of Elizabeth Drive.

A second gauge is located at the Great Western Highway crossing of South Creek about 20 km downstream of the gauge near Elizabeth Drive. The Great Western Highway gauge (*NOW site number 212048*) is located at a weir under the road bridge. This gauge records instantaneous level and discharge (*flow*) data. Flow data is derived from a rating curve. Rainfall data is also recorded at the same location.

The Sydney Catchment Management Authority (*SCMA*) also operates two river level gauges on South Creek. Less reliance is placed on these gauges due to the recorded data not being available online and only upon request from SCMA.

The SCMA Richmond Road Gauge (*Site ID 212297*) is located at the downstream boundary of the study area and records instantaneous water level and discharge (*flow*) data.

The SCMA Mandalong Park gauge (*Site ID 2122971*) is located along South Creek approximately 1.2 km north of the Warragamba Pipeline.

River Level Gauges on Ropes Creek

NOW operates a gauge on Ropes Creek at Debrincat Avenue (*Site number 212049*) which crosses the creek between Forester Road and the railway line located 1.6 km upstream. This gauge records instantaneous level and discharge (*flow*) data. Flow data is derived with the use of a rating curve.

Other River Level Gauges

There are no other river level gauges within the South Creek catchment.

A gauge is located on the Hawkesbury River at Windsor Bridge (*gauge number 567044 (BOM), station number 21246 (MHL)*). A number of other gauges are located on the Hawkesbury River Upstream of Windsor at Freemans Reach (*MHL 212410, BOM 563001*) and Castlereagh (*MHL 212404, BOM 567045*) as well as others extending into the upper catchment.

Gauges located along the Nepean River Penrith (*Victoria Bridge*) (*BOM 567047*) and at Wallacia (*BOM 67093*) are used by the BOM to provide flood warnings for areas downstream along the Hawkesbury River. As a result, there is usually good data available for the Hawkesbury River to give reasonable warning time for flooding of Llandilo and Berkshire Park areas due to "backing-up" of floodwaters from the Hawkesbury River along South Creek.

10.6.2 Opportunities to Improve Flood Warning

A review of the Local Flood Plan (*April 2012*) identified that all references to the monitoring of gauges is focussed on flooding from the Hawkesbury-Nepean River; that is, flooding due to the "backing-up" of floodwaters from the Hawkesbury-Nepean River. The plan does not currently propose reliance on any of the existing gauges within the South Creek catchment located upstream of Elizabeth Drive, the Great Western Highway or Debrincat Avenue (*refer* **Section 10.5.1**). Hence, no warnings are currently triggered by flood conditions / levels from the upper catchment and there is no reference point against which preparation, evacuation or recovery can be co-ordinated.

It is recommended that the Local Flood Plan for the South Creek catchment be updated to include:

(i) Reference to all existing gauges within the study area which can be used to monitor the progression of a local flood event.

(ii) Nominate minor, moderate and major gauge heights so that reference markers are available against which warning times and known problem locations can be monitored.

(iii) Prepare flood intelligence cards for the existing gauges that shows the predicted stage-hydrograph for a range of design events plus indicators of times when roads, regions and critical facilities (*such as nursing homes, childcare centres, schools*) would start to be flooded or are at risk of isolation.

Table 27 in Section 7.1 of the *'Updated South Creek Flood Study'* (*2015*) gives an indication of the potential warning times that the SES could gain through monitoring of only the flood peaks at existing gauge locations.

For example, Table 27 shows that a flood wave for the design 1% AEP flood is predicted to take approximately 3½ hours to travel between Elizabeth Drive and the Great Western Highway. The flood wave would take a further 1½ hours to reach Llandilo or 2 hours to reach the Richmond Road bridge crossing at the downstream boundary of the study area. This indicates that if the Elizabeth Drive or Great Western Highway gauges were monitored, the SES could gain 5 or 1½ hours of advanced warning of a flood peaking at Llandilo, respectively.

By also monitoring gauge levels during the rising limb of a flood (*i.e., not just the flood peak*) additional warning could be gained to aid decision making. For example, if the Minor, Moderate and Major gauge heights are set as recommended, it is estimated that a further 2 hours or 5 hours warning could be gained between Elizabeth Drive and the Great Western Highway or Llandilo, respectively. This is based on the time elapsed between when the peak 5% AEP flood level occurs at the gauge for the design 1% AEP flood compared to the flood peak.

A consideration for adopting the existing gauges for flood monitoring is the percentage of the total catchment that is captured upstream of each gauge. This is a potential issue for South Creek due to the numerous tributaries that capture and convey runoff to South Creek along its length, thereby, boosting and potential altering flow behaviour. For example, the Elizabeth Drive, Great Western Highway and Debrincat Avenue gauges capture only 20%, 65% and 15% of the total South Creek catchment upstream of Richmond Road.

Although the Great Western Highway gauge captures the greatest percentage of the total catchment, the gauge is located over 17 kilometres downstream of the Elizabeth Drive Gauge and downstream of several suburban areas such as Kemps Creek, St Clair, St Marys South and Claremont Meadows. Therefore, although recorded flood levels at the gauge will be a good indication of flood behaviour across most of the catchment, the additional warning time that can be gained will be limited.

Based on consideration of the trade-off between the percentage of total catchment captured and the objective of maximising warning times, it is recommended that a new gauge be installed along South Creek near the Warragamba Pipeline crossing. This location is a sufficient distance downstream to include the major tributaries of Kemps, Badgerys and Cosgroves Creeks, while also being approximately 9 kilometres upstream of the existing gauge located at the Great Western Highway crossing. A new gauge at this location would capture almost 50% of the South Creek catchment (*up to Richmond Road*) and could provide over 1 hour of additional warning time compared to the Great Western Highway gauge.

10.7 Recommendations

Table 10-3 outlines the recommended Emergency Response Management measures that have been identified as part of the floodplain risk management study for South Creek.

Table 10-3 Recommended Emergency Response Management Measures

ID	Recommended Emergency Response Management Measures
RM.1	It is recommended the Local Flood Plan for the South Creek catchment be updated to include: a. Reference to all existing gauges within the study area which can be used to monitor the progression of a local flood event. b. Nominate minor, moderate and major gauge heights so that reference markers would be available against which warning times and known problem location can be monitored. c. Prepare flood intelligence cards for the existing gauges that show the predicted flood level hydrograph for a range of design events plus indicators of times when roads, regions and critical facilities (*such as nursing homes, childcare centres, schools*) would start to be flooded or at risk of isolation.
RM.2	Provision of flood data to the SES for consideration in updating the Local Flood Plan. It is recommended the following information be considered: a. Mapping of Emergency Response Management Planning Communities (ERMPC), particularly areas of high risk where isolation is possible; i.e., high and low flood islands (*refer* **Appendix G** *and* **Table 10-2**) b. Identified schools and vulnerable communities within the study area (*refer* **Table 10-3**) c. Community Data Sheets and flood risk mapping along all local roads within the study area (*refer* **Appendix H**) d. Include reference to river gauges within the study area for the purposes of monitoring flood risks. Existing gauges along South Creek at Elizabeth Drive and the Great Western Highway should be adopted for flood monitoring and for the dissemination of minor, moderate and major flood warnings (*refer* **Section 10.6.1**)
RM.3	Install a continuous river level gauge along South Creek near the Warragamba Pipeline to maximise potential warning times whilst still capturing approximately 50% of catchment runoff.
RM.4	Install flood boom gates either side of the Eighth Avenue bridge crossing at Llandilo and implement a vegetation management plan for the crossing and areas immediately upstream and downstream.

11. Flood Planning

11.1 Background

Flooding is a significant naturally occurring hazard to the utilisation of land. Since the early days of European settlement of New South Wales, development has occurred within the floodplain which has not fully appreciated the implications of the nature and extent of the flood hazard. Development of these areas has occurred due to the proximity of transport corridors such as the rivers flowing through the floodplain, the flatness of floodplain lands which rendered them easier to build on, and more recently, the relatively lower cost per hectare.

Further development of areas along the fringes of the South Creek floodplain has occurred in recent times, including residential estates, industrial precincts and extensive filling.

In this context, appropriate floodplain management needs to recognise the full flood risk. That is, it must relate to the whole of the floodplain and not just to one isolated component of the floodplain defined by a particular flood occurrence, such as the area inundated in the 100 year ARI flood.

This, however, does not mean that there should be restrictions on development within the entire floodplain. Instead, there should be a holistic approach to the management of the floodplain commencing from its broadest extent and progressively focusing inwards to more critical aspects of the use of the floodplain, such as development on land frequently affected by floods. This holistic approach may in some cases, reveal the capacity for more intense development for certain types of land-uses, as opposed to the rigid application of a global flood standard.

Generally, the management of a floodplain is approached by the imposition of either structural or non-structural measures. Traditionally, structural measures have played a major role. However, contemporary thinking in floodplain management is more focussed toward the implementation of non-structural measures. Non-structural measures include increased public awareness, property acquisition and the establishment of flood evacuation procedures. More recently, there has been an increased emphasis on developing floodplain management plans that recommend changes to planning controls contained within Council planning instruments such as Local Environmental Plans (LEPs) and Development Control Plans (DCPs).

Flooding is an important constraint that influences land use planning in the *Penrith Local Environmental Plan 2010* (PLEP 2010). In LEP 2010, flood planning land, is not the same as the flood planning level. Land identified as flood planning land comprises areas above and surrounded by flood risk where it is known that there will be evacuation constraints.

In addition, requirements for the consideration of flooding issues in development and planning are outlined in the *Penrith Development Control Plan 2014* (*the DCP*) which was adopted in March 2015. Part C3 of the DCP is specific to Water Management issues including Flood Planning. It was developed to set out the flood policy for the Penrith LGA and allow landowners, developers and Council officers to be able to assess ongoing flood related issues associated with development.

One of the objectives of the South Creek Floodplain Risk Management Study was to review Council's land-use planning and flood policy with reference to its application to flooding issues along South Creek and to recommend policy changes that could be incorporated to improve the management of development within flood prone land.

While this particular study focuses on the South Creek catchment, it is important to bear in mind that flood policy can be applied generically to the flood planning areas of all rivers and tributaries within the Penrith City Council LGA. In this regard, it needs to be acknowledged that Council has, and is currently, in the process of completing several studies including the:

- Lower Nepean River Flood Study (*in draft*),
- Byrnes Creek Flood Study (*Final, November 2015*)
- Werrington Creek Floodplain Risk Management Study (*in draft*).

In addition, the NSW Government, through Infrastructure NSW, is undertaking the Hawkesbury-Nepean Flood Management Review and is expected to publish a regional flood study covering the entirety of the Hawkesbury-Nepean river system downstream from Bents Basin in early 2019. It is envisaged that this report will comprise a detailed cost-benefit assessment of the most practical and cost effective flood management options for the Hawkesbury-Nepean Valley, including the lower reaches of South Creek. This will include measures for emergency response management and presumably, recommendations for the future planning of land use across floodplain lands.

There is also a need to consider state polices which focus on strategic planning and urban growth. Development on land covered by a state policy is not necessarily subject to the clauses set out in the Penrith LEP. State policies applicable to the South Creek catchment study area include:

- State Environmental Planning Policy (*Western Sydney Employment Area*) 2009;
- Sydney Regional Environmental Plan No. 30 – St Marys; and
- Western Sydney Aerotropolis Stage 1 Land Use and infrastructure Implementation Plan – Stage 1: Initial Precincts 2018.

Plans and State Policy which apply to the Penrith LGA are shown in **Figure 11.1**.

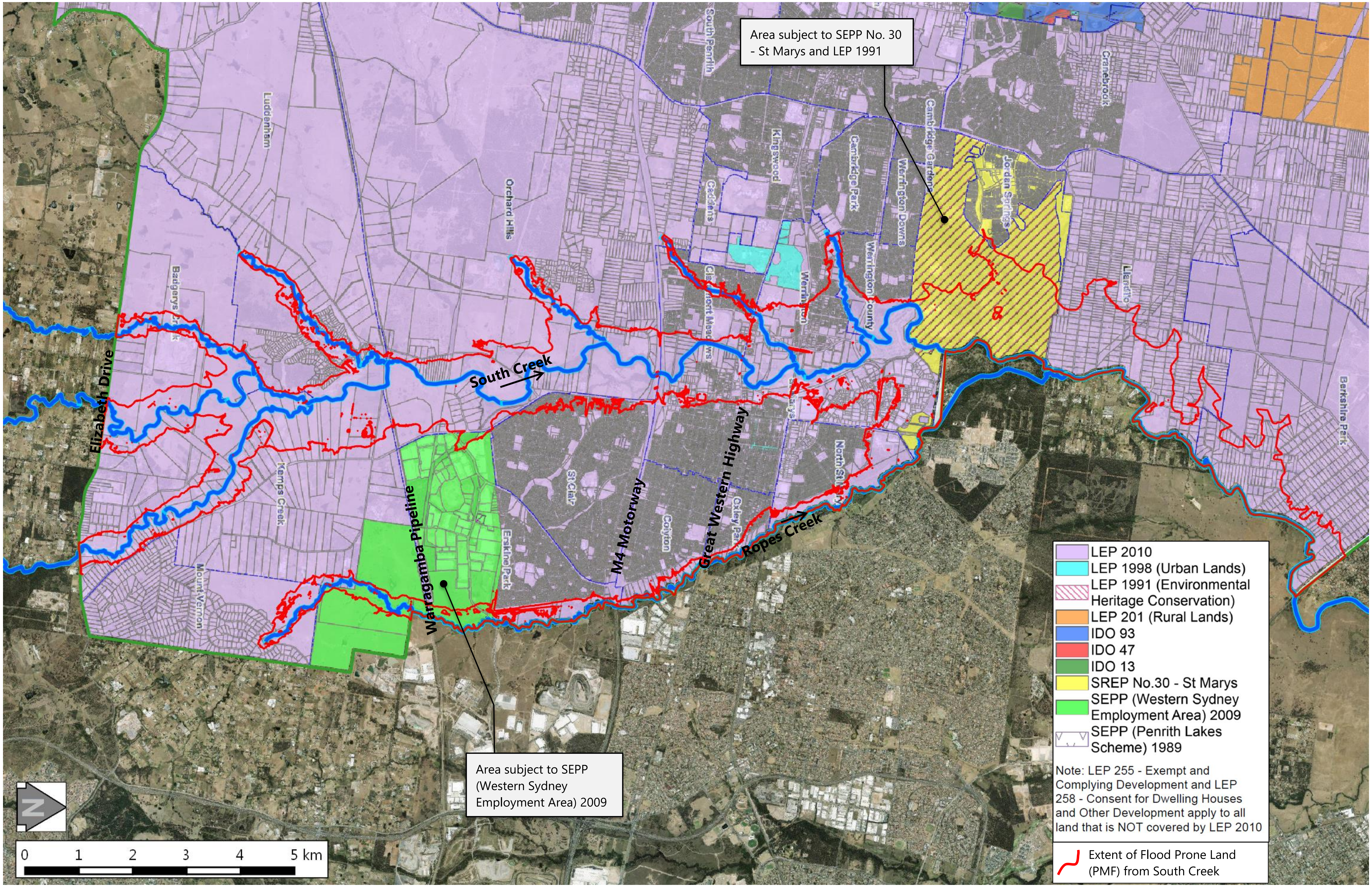
11.2 Objectives

The objective of this section of the floodplain risk management study is to document those flood related issues that will influence future development and which could influence planning in the South Creek catchment of the Penrith LGA. This includes an assessment of land-use zones against flood hazards and consideration of appropriate development for areas of different flood risk and hazard.

The purpose is to identify problems with application of policy requirements set out in the current planning controls and where appropriate, assess alternative measures that could be incorporated into a revised flood policy. In this context, it is important to recognise that any Flood Policy or DCP needs to be “owned” by those parties that will be responsible for implementing it. Therefore, it needs to:

- be able to be interpreted and applied by planners and engineers involved in development assessment;
- be able to be interpreted and applied by developers, planners and engineers working in the private sector;
- be able to guide strategic planning at a regional and local level; and,
- be able to inform emergency response managers such as the NSW State Emergency Services (SES).

FIGURE 11.1



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 11.1_Planning Penrith LGA

PLANS AND POLICIES APPLICABLE TO THE SOUTH CREEK AREA WITHIN PENRITH LGA

In recognition of these objectives, this section identifies potential modifications that could be made to planning controls for the purpose of improving the management of flood risk. It is based on a review of the following council plans and policies:

- Penrith City Council Local Environment Plan 2010 (*LEP*)
- Penrith City Council Development Control Plan (*DCP*) 2014 - Section C3 Water Management

11.3 Flood Risk and Land Use Planning

11.3.1 Land Use Planning

Land use planning is an important component of flood risk management. However, simply preventing development in flood prone areas can unnecessarily sterilise land and cause areas to become derelict and unusable. Therefore, effective land-use planning from a floodplain management perspective is a trade-off between the risk associated with increased usage of the floodplain and the need for economic development. At the same time, it needs to be recognised that certain types of development are prohibitive because of the nature of flooding (e.g., high hazard floodway) or the nature of the development (e.g., hazardous materials storage).

Current land use zones are set out in the Penrith LEP 2010 and reproduced in **Figure 11.2** for the study area.

11.3.2 The Flood Planning Area

The Flood Planning Area (*FPA*) is defined as land at or below the Flood Planning Level (*FPL*) and additional land with evacuation constraints. The FPA is otherwise referred to as "*Flood planning land*" within the PLEP 2010. The FPL is defined in PLEP 2010 as "*the level of the 1:100 ARI (average recurrence interval) flood plus 0.5 metres freeboard*". Assessment and consideration of flood related development controls is required for any development proposed at or below the FPL and/or within the FPA.

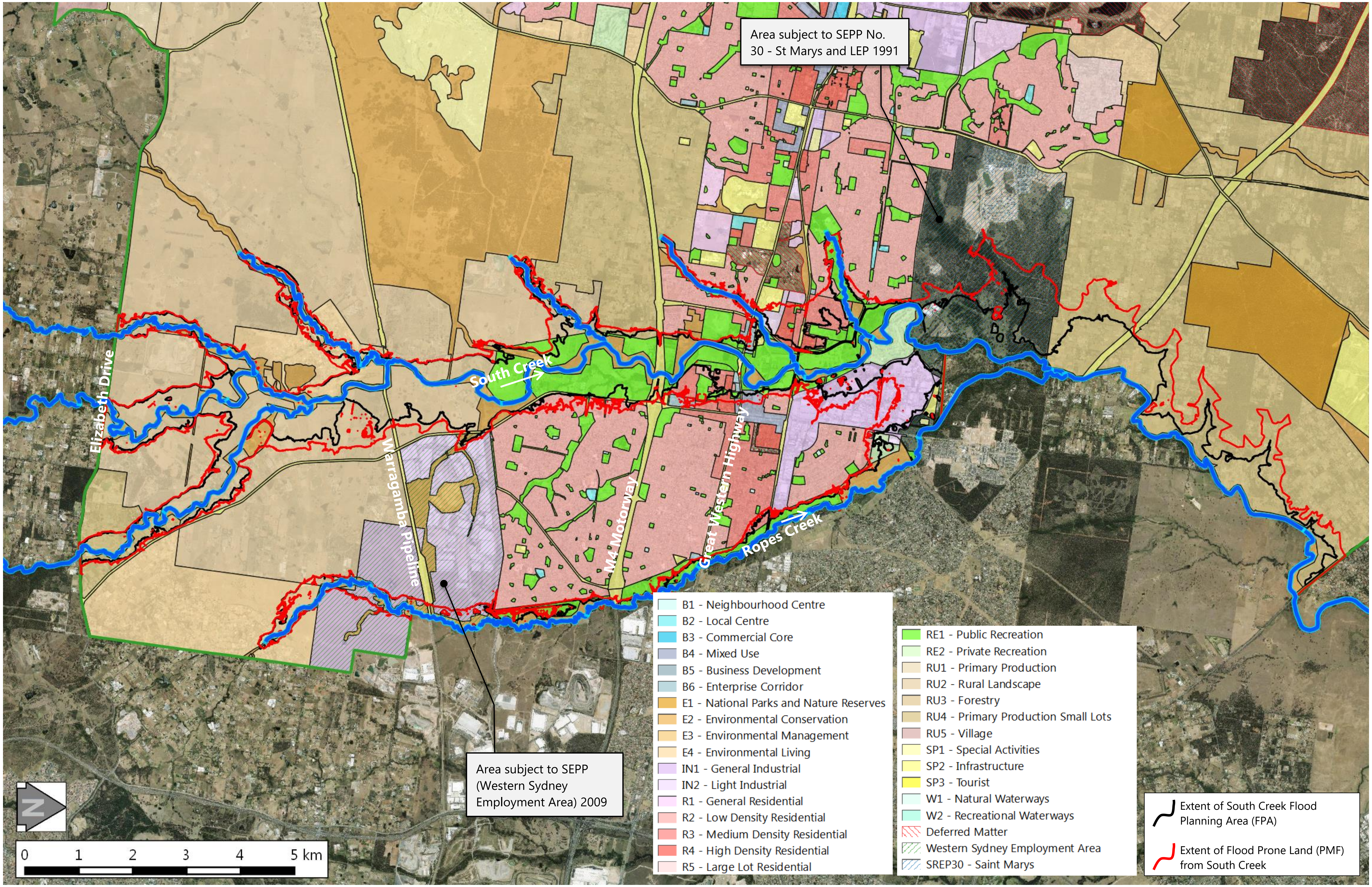
PLEP 2010 is supported by the DCP which sets out a number of development controls which need to be met in order to satisfy the flood related clauses of PLEP 2010. Current FPA extents are based upon the results of hydraulic modelling completed for South Creek and its tributaries as part of the *Updated South Creek Flood Study* (*WorleyParsons, 2015*) mapped to align with topographic elevations defined by the 2002 Aerial Laser Survey (ALS).

The availability of more recent topographic data such as the 2011 Light Detection and Ranging (*LiDAR*) survey is recommended for consideration in re-mapping the FPA extent. This would align the FPA mapping better with recently produced True Hazard Mapping and mapping of Flood Planning Constraints Categories (*FPCC*).

11.3.3 Assessment of Land Use Zones and Flood Risk

A broad-scale review of existing land use zones against predicted flood risks was undertaken for key areas across the South Creek study area. To facilitate the review, current land use zones have been mapped for specific sub areas of the overall study area against the predicted flood related constraints. These flood related constraints include the floodway corridor, extent of predicted '*high hazard*' flooding, FPA extent and the PMF extent.

Mapping for each sub-area is provided in the following figures:



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301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 5
fg301310-08772rg200220_Fig 11.2_Land Use Planning Study Area

LAND USE PLANNING ZONES FROM PENRITH LOCAL ENVIRONMENTAL PLAN 2010 AROUND SOUTH CREEK AND ITS TRIBUTARIES

- Sub-Area 1- **Figure 11.3**
  Floodplain between Elizabeth Drive and the Warragamba Pipeline
- Sub-Area 2- **Figure 11.4**
  Floodplain between the Warragamba Pipeline and the Western Motorway (M4)
- Sub-Area 3- **Figure 11.5**
  St Marys upstream of the South Creek Railway Line Crossing
- Sub-Area 4- **Figure 11.6**
  Claremont Meadows and Land Affected by inundation from Claremont Creek
- Sub-Area 5- **Figure 11.7**
  Werrington and Rance Road residential areas
- Sub-Area 6- **Figure 11.8**
  North St Marys including the former ADI site
- Sub-Area 7- **Figure 11.9**
  Llandilo and Berkshire Park
- Sub-Area 8- **Figure 11.10**
  Ropes Creek upstream of the Railway Line

The review of land use zones on a sub-area basis is presented in the following sections.

Area 1 – Floodplain between Elizabeth Drive and the Warragamba Pipeline; includes the localities of Kemps Creek and Twin Creeks

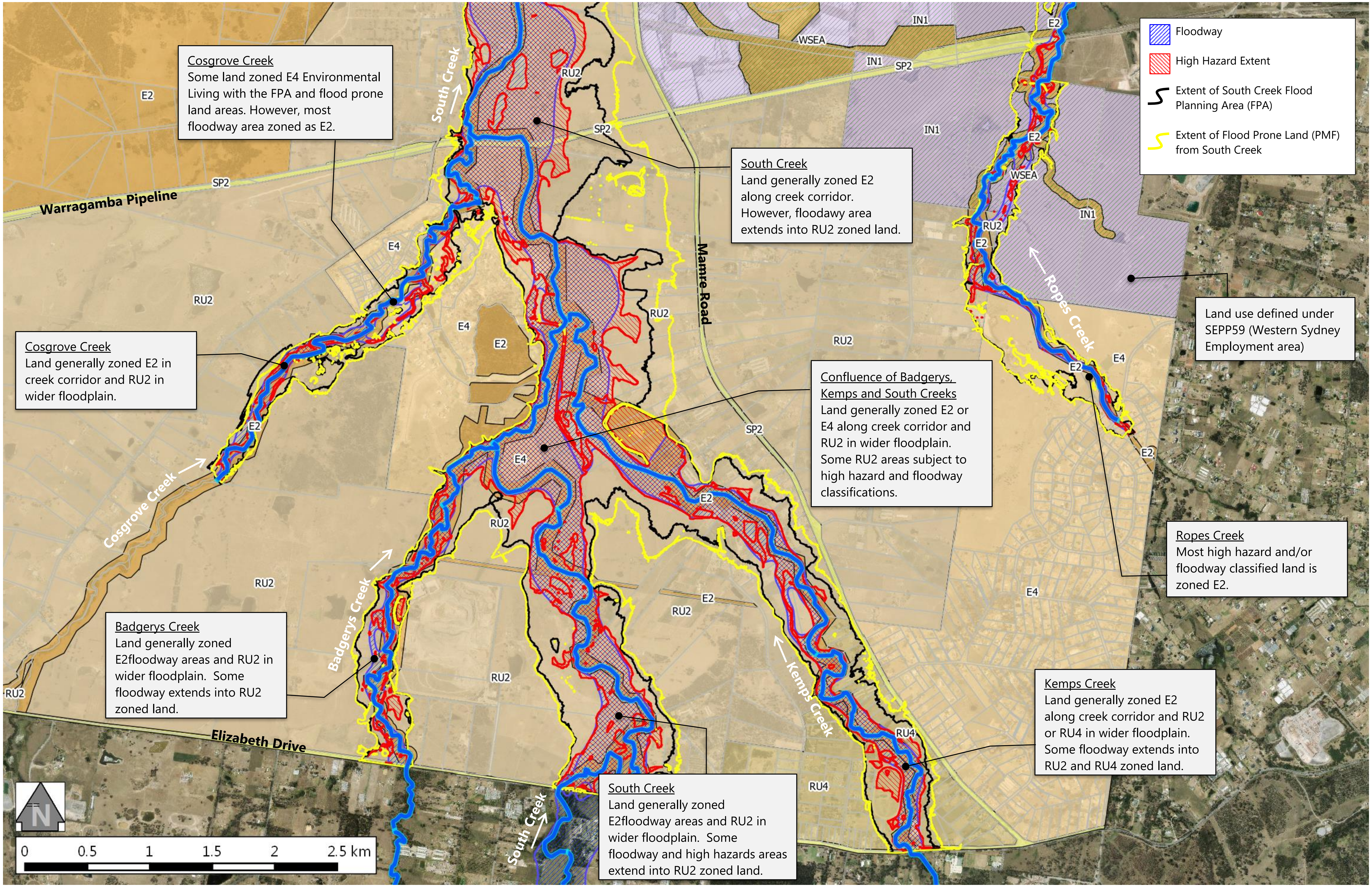
As shown in **Figure 11.3**, the prominent land use in this area is *RU2 Rural Landscape*. *E2 Environmental Conservation* is also common, however, it is generally constrained to the riparian corridors of the creeks or across existing waterbodies such as the Kemps Creek dam.

In the most part, the land use zones appear appropriate when reviewed against the flood constraints. That is, approximately 50% of areas zoned as floodway or 'high-hazard' are classified as *E2 Environmental Conservation*. E2 prohibits most development and as such is appropriate for floodway corridors and high-hazard flooding.

The remaining areas of floodway and high-hazard are generally occupied by land classified as *RU2 Rural Landscape* or *RU4 Primary Production Small Lots* (Kemps Creek). Both land use zones allow for low density development including residential uses. As current DCP controls restrict new development in floodways or high flood hazard areas, development would generally be prevented in areas of concern. In recognition of this, no changes to existing land use zones are recommended for Area 1 for the purposes of managing flood risk.

Area 2 – South Creek floodplain between the Warragamba Pipeline and the Western Motorway (M4)

As shown in **Figure 11.4**, flood prone land to the west of Mamre Road, St Clair and Erskine Park is generally zoned *RE1 Public Recreation*, with the exception of land outside the FPA (*refer* **Figure 11.4**). This zoning allows for limited development and is considered appropriate for land within high hazard and/or floodway areas.



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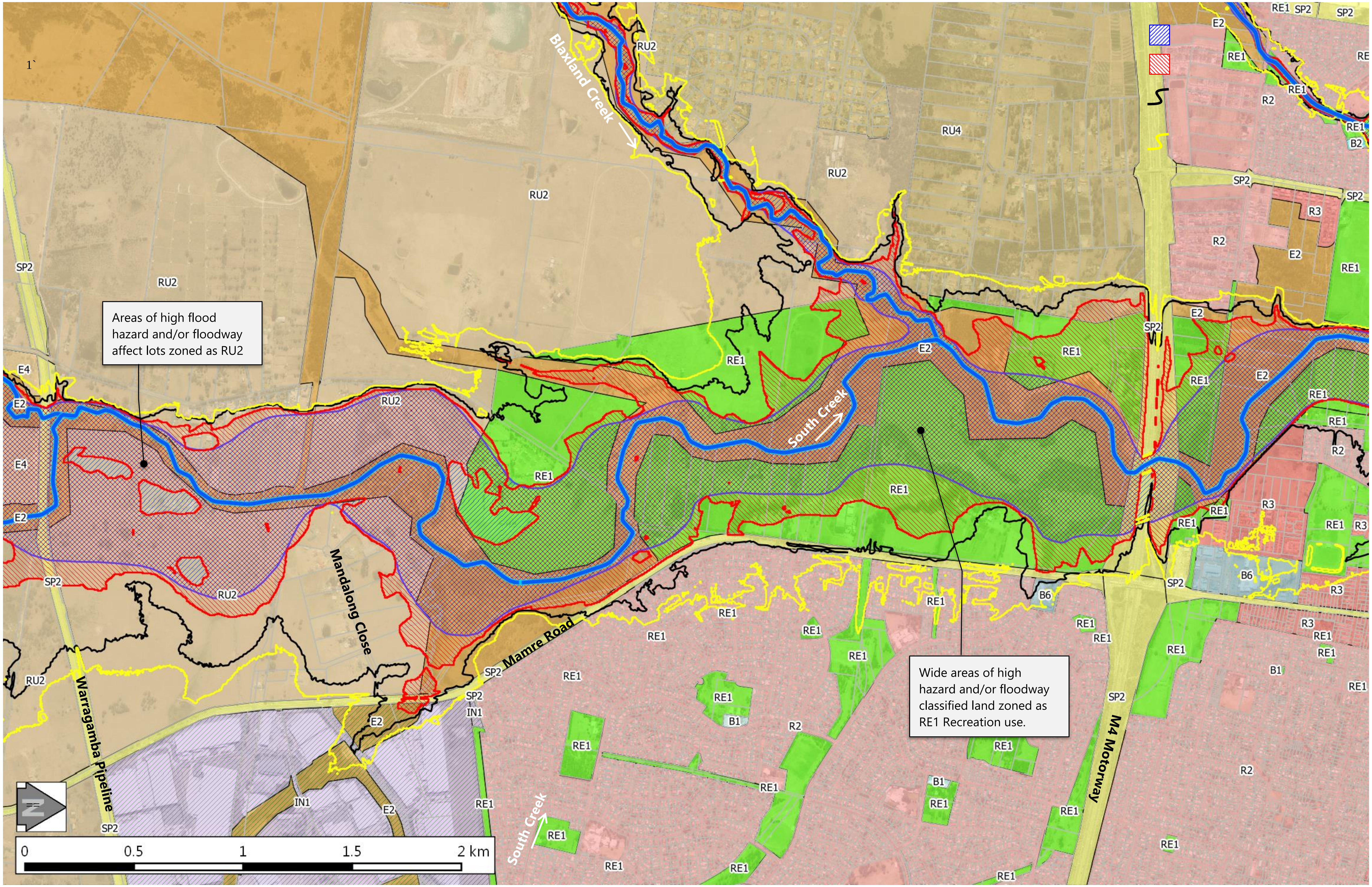
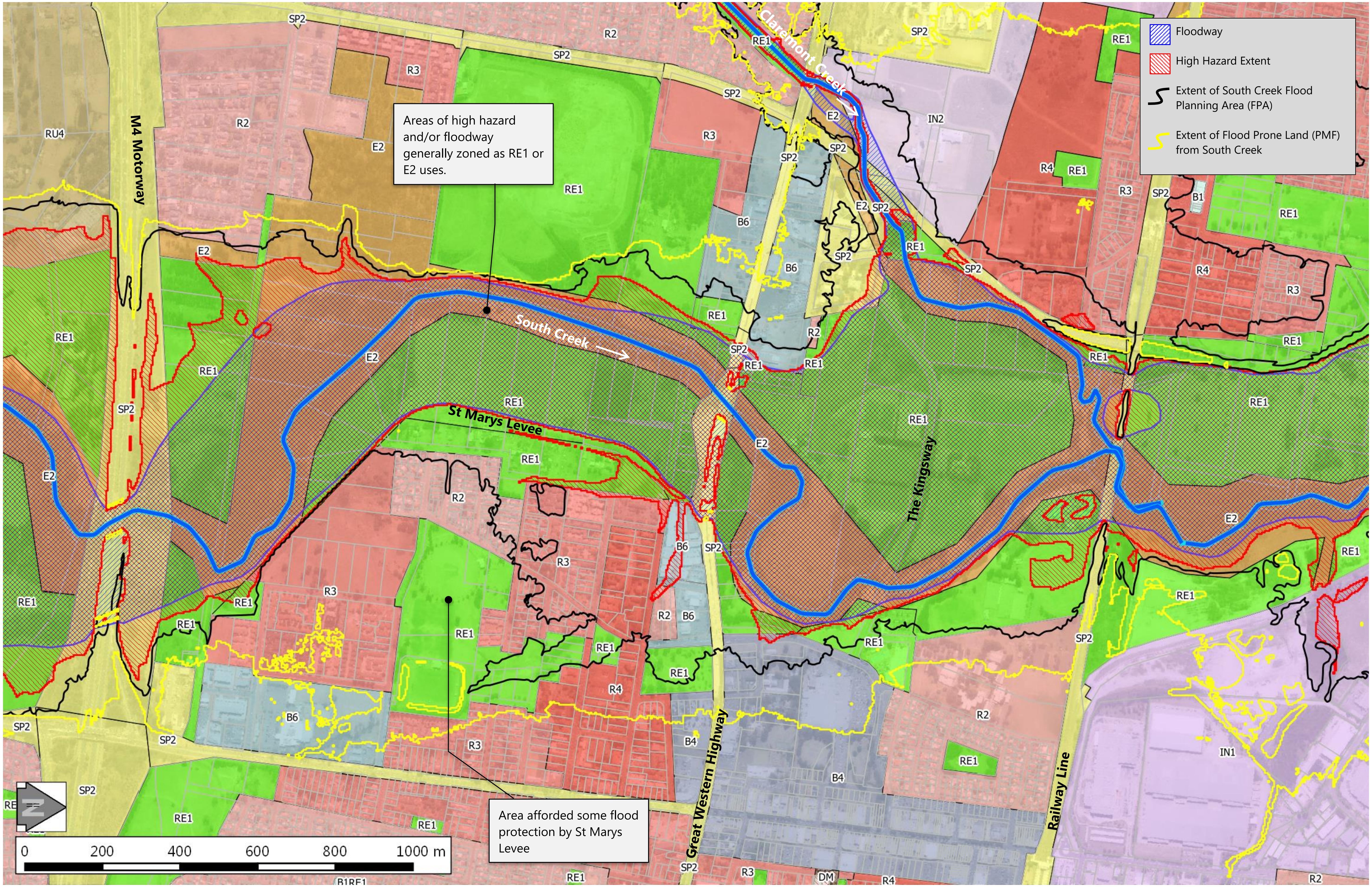
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220_Fig 11.3_LandUse_Area1

LAND USE ZONES AND FLOOD AFFECTATION IN AREA 1
FLOODPLAIN BETWEEN ELIZABETH DRIVE
AND THE WARRAGAMBA PIPE LINE

FIGURE 11.4



LAND USE ZONES AND FLOOD AFFECTATION IN AREA 2
SOUTH CREEK FLOODPLAIN BETWEEN THE WARRAGAMBA PIPELINE AND THE WESTERN MOTORWAY (M4)



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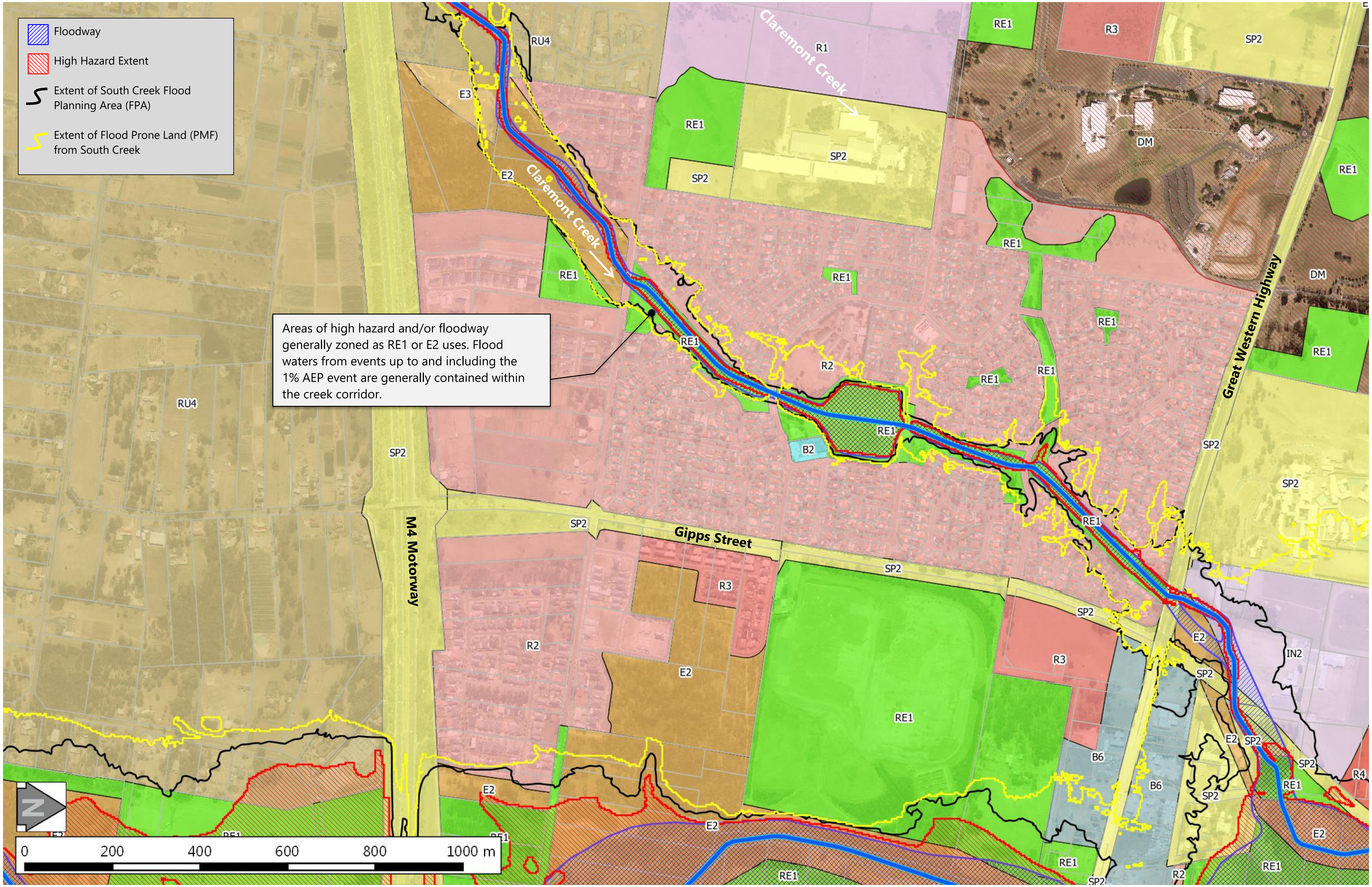
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig 11.5_LandUse_Area3

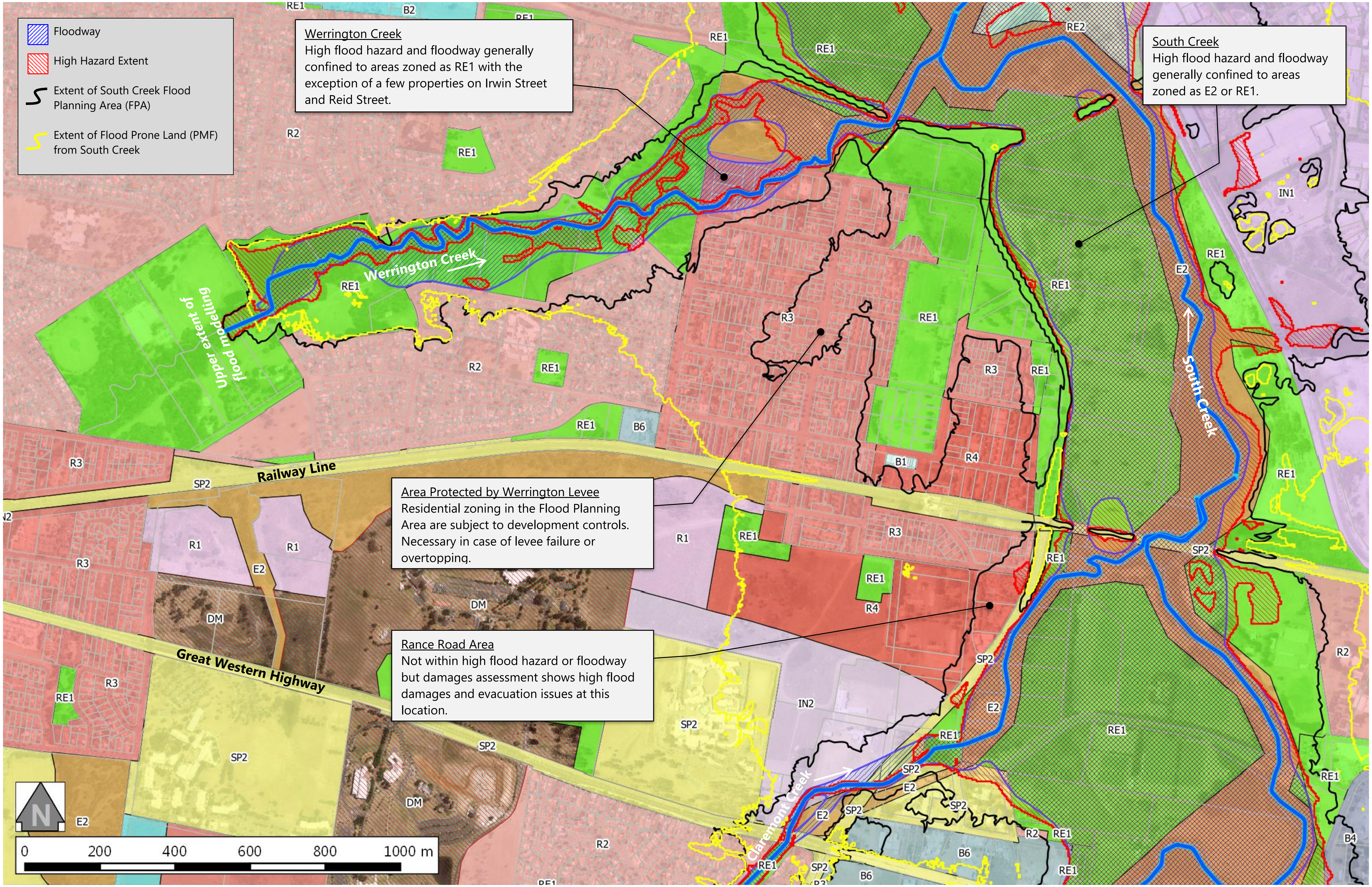
LAND USE ZONES AND FLOOD AFFECTATION IN AREA 3
ST MARYS UPSTREAM OF THE SOUTH CREEK RAILWAY LINE CROSSING

FIGURE 11.6



LAND USE ZONES AND FLOOD AFFECTATION IN AREA 4 CLAREMONT MEADOWS AND LAND AFFECTED BY INUNDATION FROM CLAREMONT CREEK

FIGURE 11.7



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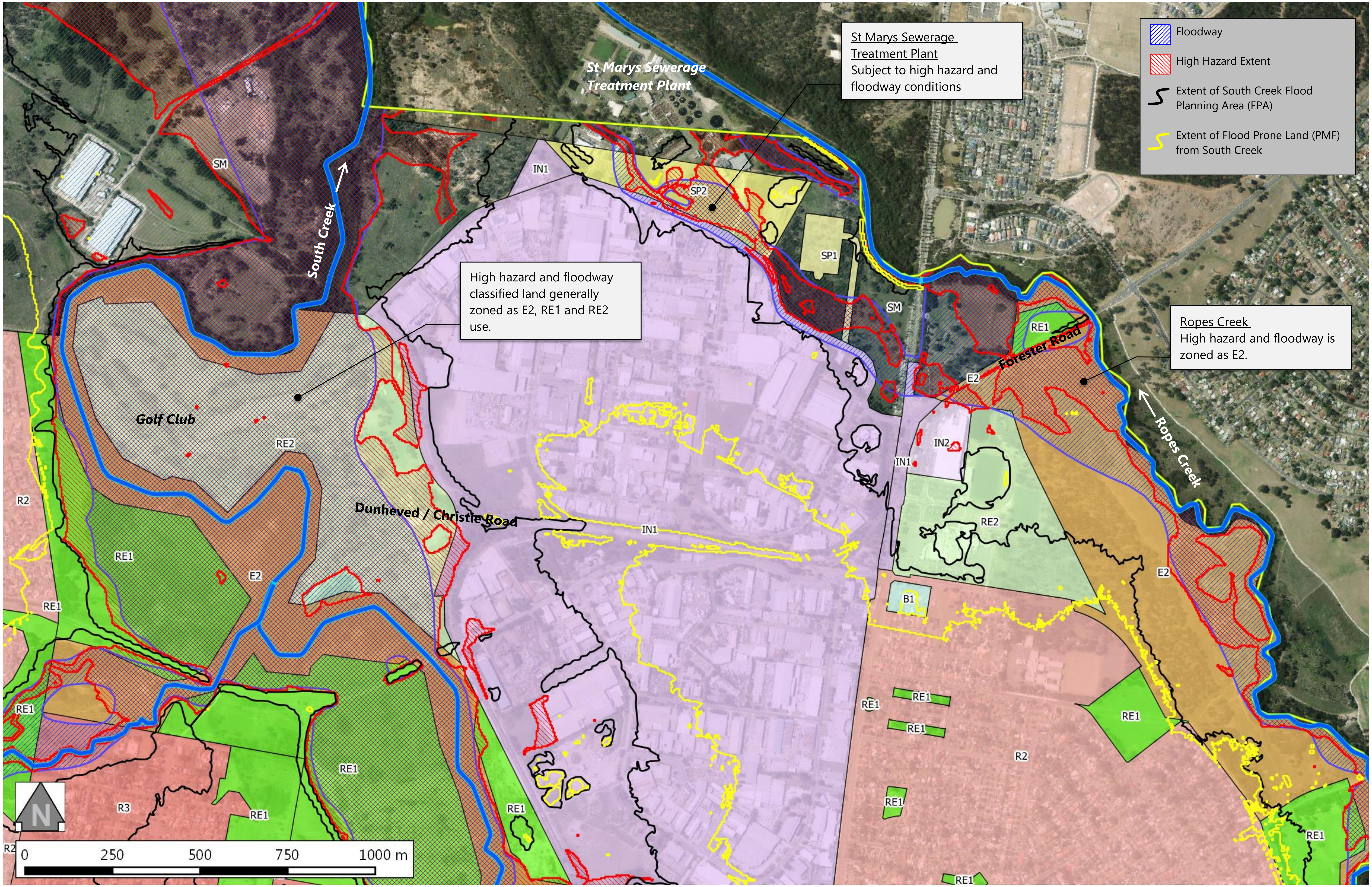
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig 11.7_LandUse_Area5

LAND USE ZONES AND FLOOD AFFECTATION IN AREA 5
WERRINGTON AND RANCE ROAD
RESIDENTIAL AREAS

FIGURE 11.8



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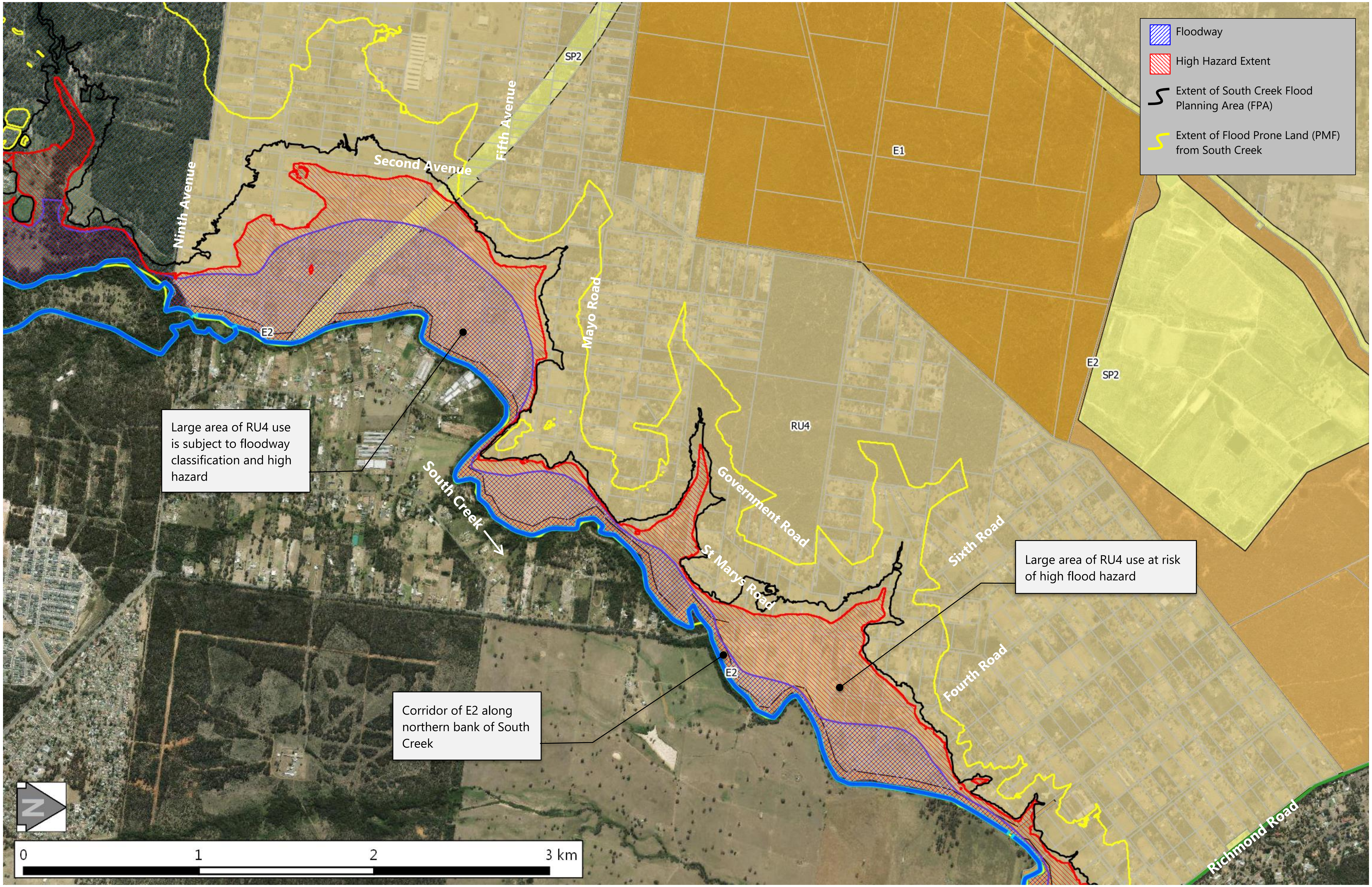
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig 11.8_LandUse_Area6

LAND USE ZONES AND FLOOD AFFECTATION IN AREA 6
NORTH ST MARYS
INCLUDING THE FORMER ADI SITE

FIGURE 11.9



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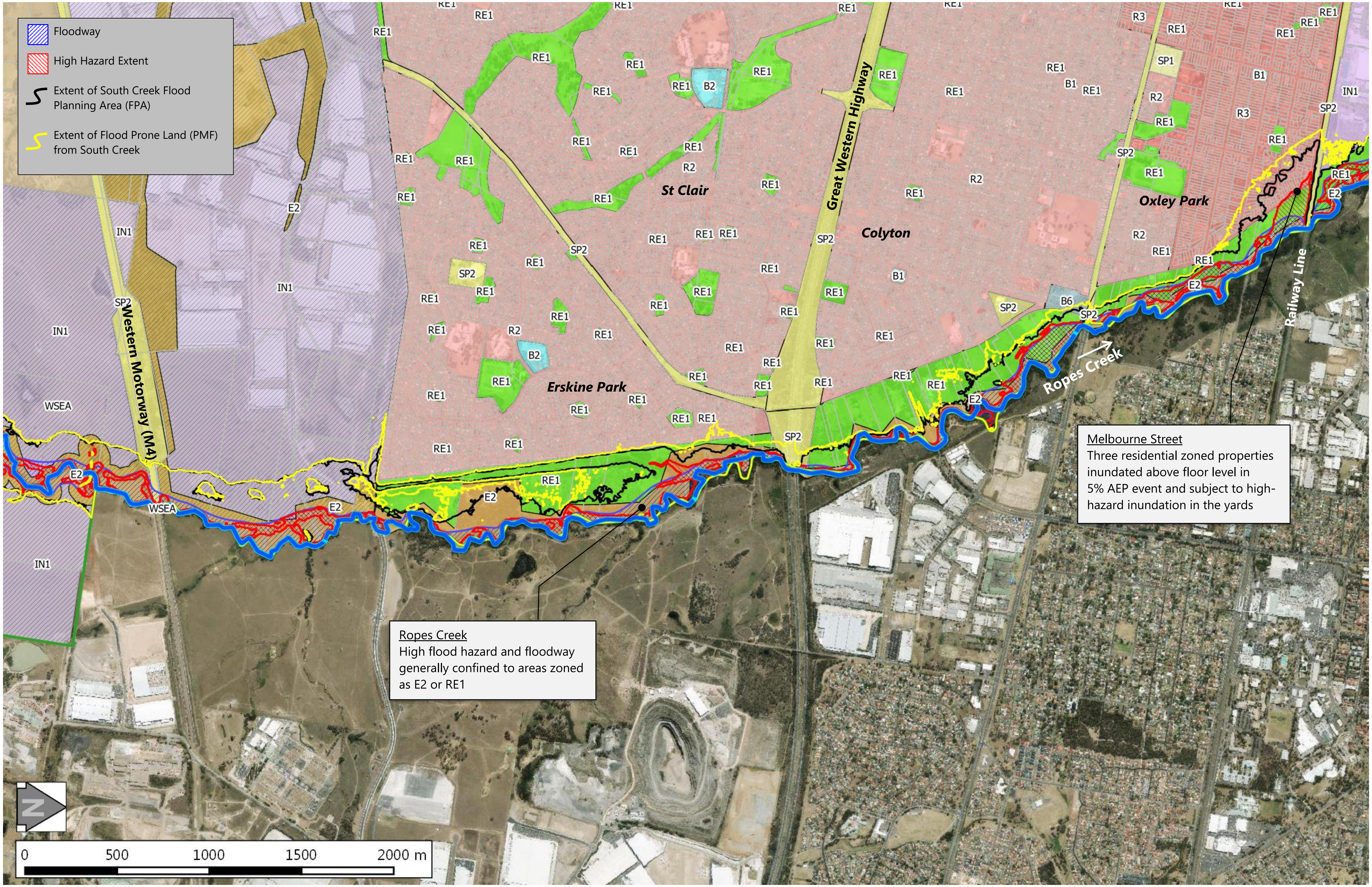
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig 11.9_LandUse_Area7

LAND USE ZONES AND FLOOD AFFECTATION IN AREA 7 - LLANDILO AND BERKSHIRE PARK

FIGURE 11.10



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Worley Group

301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig 11.10_LandUse_Area8

LAND USE ZONES AND FLOOD AFFECTATION IN AREA 8
ROPES CREEK UPSTREAM
OF THE RAILWAY LINE

Between the Warragamba Pipeline and Mandalong Close there is a large area of land on both sides of South Creek zoned *RU2 Rural Landscape*. As shown in **Figure 11.4**, this land is subject to high flood hazard and/or floodway classification. Development density in RU2 zoned land is generally low and flood related control in the Penrith DCP 2014 would provide the appropriate constraint to limit development in the high hazard or floodway areas. Therefore, no changes to the land use zones in this area are considered necessary.

An area of land known as the Mamre West Precinct, located to the east of South Creek between the Warragamba Pipeline and properties on Mandalong Close, has been approved for rezoning to industrial use as part of the Western Sydney Employment Area (WSEA). Suitable development controls will be necessary to limit flood risk and prevent changes to flood behaviour as a result of development and filling that is likely to be proposed in this area to facilitate development.

A specific DCP (*Mamre West Land Investigation Area DCP 2016*) has been adopted by the State Government (*NSW Planning & Environment*) for this area for the assessment of future development applications. The Mamre West DCP has not been reviewed as part of this investigation.

Area 3 – St Marys Upstream of the South Creek Railway Line Crossing

As shown in **Figure 11.5**, the extent of high flood hazard and/or floodway is extensive in this sub-area covering much of the total floodplain width. Nearly all high flood risk land is zoned either E2 Environmental Conservation or RE1 Public Recreation. As potential for development within these land use zones is limited, the zoning is considered appropriate from a flood risk management perspective.

Land protected by the St Marys Levee and within the FPA extent is largely classified as either RE1 Public Recreation, R2 Low Density Residential or R3 Medium Density Residential. The land use zones appear to be appropriately applied with the land most-susceptible to inundation and subject to high-hazards classified as RE1 (*refer* **Figure 11.5**).

Area 4 - Claremont Meadows and Properties/Infrastructure affected by Claremont Creek

Areas of predicted high flood hazard and/or floodway are generally contained to the Claremont Creek corridor and land use zones E2 and RE1 as shown in **Figure 11.6**. Residential development (*land use zone R2*) is allowed within the flood planning area, however, existing development controls set through the Penrith DCP 2014 will assist to minimise the flood risk to new development in this area.

Land uses in this area are considered appropriate.

Area 5 - Werrington and Rance Road Residential Areas

As presented in **Figure 11.7**, most of the high flood hazard and/or floodway areas of Werrington Creek are contained within land zoned as RE1. The exception to this is several properties located on the corner of Lethbridge Avenue and Reid Street which are completely within the floodway corridor. Aerial photography and the recently completed floor level survey indicates that these lots are vacant (*lot nos. 157 to 162, DP 1573*).

Rezoning of these six vacant floodway affected lots to E2 or RE1 to be in keeping with adjoining land would ensure that future development in this area would be compatible with the flood risk. However, although vacant, it is recommended that the following options be considered prior to any rezoning:

(i) Leave as is and manage development proposals with the existing development controls thereby ensuring no development is permitted, no acquisition is required and no compensation is applicable.

(ii) Down-zone, which would serve to formally safeguard other environmental values as well as remove expectation of development potential.

(iii) Purchase (*and then down zone*) but will require negotiation of value.

Several residential lots are partially within the floodway corridor, however, all existing dwellings on these lots are located outside of the floodway and are therefore not expected to be subject to significant flood damages.

Most of the Werrington residential area is protected from inundation by the presence of the levee system. While it is reasonable to allow development in areas protected by a levee, it is still important that flood planning controls are applied to new development to safeguard residents and dwellings in case of failure or overtopping of the levee. The FPA ensures that development controls apply to properties likely to be inundated in a 1% AEP event should the levee fail.

While there is generally no high hazard flooding in the Rance Road area, the Flood Study identified that low lying parcels of land in the area are subject to inundation during flood events as low as the 5% AEP event. The area is also at risk of high flood damages and evacuation issues as Werrington Road becomes inundated. Given the high average flood damages and evacuation issues in this area, it may be prudent to reduce the density of future development unless flood mitigation options to reduce inundation are to be implemented (*refer Option FM15 under Flood Damages*).

Notwithstanding, the majority of the Rance Road area is currently zoned *R4 High Density Residential*. Some development is already underway and there is a substantial area that is approved for development. This area has been identified by Council planners as an important contribution to housing targets. Any proposal to down zone to lower density residential and therefore lower yield, may be difficult to achieve.

It is recommended that any proposal to downzone significant areas at Rance Road be subject to a cost benefit analysis that considers these impacts as well as flood risk reduction benefits.

Area 6 - North St Marys including the former ADI site

Land use zones for the former ADI site are not defined in the Penrith LEP 2010. Instead the site is subject to Sydney Regional Environmental Plan No. 30 – St Marys (*SREP30*) considered as a State Environmental Planning Policy. As planning for development of the former ADI site occurs, Council should recommend that the conveyance capacity of the floodway corridor is maintained, and development occurs in accordance with the controls set out in Council’s DCP where possible.

Land use zones for North St Marys, including the Links Road Industrial Estate and St Marys Sewerage Treatment Plant, are presented in **Figure 11.8**. With the exception of the St Marys Sewerage Treatment Plant, most areas which are subject to either floodway classification and/or high flood hazard are classified as RE1, RE2 and E2 land use zones. These are considered flood compatible zones given the land use prohibits most development. This is considered appropriate for the area and as such no changes to land use zones are recommended.

Amended land use zoning is not considered an appropriate tool to manage flood risk at the existing St Marys Sewerage Treatment Plant as the site and associated infrastructure is well established. Any future development of the plant would be required to take into account the existing flood risks and would be the responsibility of Sydney Water.

Area 7 - South Creek floodplain downstream of the ADI site; includes the localities of Llandilo and Berkshire Park

A comparison of land use zoning and flood affectation for Sub-Area 7 is shown in **Figure 11.9**. This area is subject to large areas of designated floodway and high hazard flooding. The damages analysis also established that this area is subject to high Average Annual Damages.

The area is almost entirely zoned *RU4 Primary Production Small Lots* which allows for new development including dwellings, educational establishments, home business and industries.

Although the density of development on RU4 land use is generally low, future development in the zone could lead to an increase in the population at risk from flooding. This would be undesirable given the high vulnerability of the area to flooding that is high hazard and which is also predicted to occur relatively frequently compared to other parts of the study area; i.e., properties are impacted by flooding during events as frequent as the 5% AEP flood.

While the Penrith DCP prevents new development within the floodway and high hazard areas, there is less restriction on extensions to existing development. Many residential properties exist within the floodway and high hazard flood corridor. As outlined in earlier sections, it is recommended that voluntary purchase and/or voluntary house raising of properties be considered. This is focused on those properties at most risk in the areas of Llandilo and Berkshire Park.

A number of properties are subject to inundation in smaller flood events *(<5% AEP event*) but are not within floodway or high flood hazard areas. Although the risk is lower, flood damages to these properties can still be high making voluntary house raising a viable option. In addition to this, measures to prevent an increase in population within the 5% AEP floodplain should be encouraged.

It is recommended that a specific flood precinct referred to as *Llandilo and Berkshire Park Precinct* be included in the Penrith DCP. The precinct would apply to all land within the FPA at Llandilo and Berkshire Park, and should not be limited to land only within the floodway.

The following recommendation are made for the Llandilo and Berkshire Park Precinct.

(i) The zone of *E2 Environmental Conservation* be extended where no development currently exists to include areas that fall within the floodway extent. This would prevent most development in this area and the floodway areas would essentially become a <u>floodway clearance zone</u>.

(ii) A <u>floodway clearance zone</u> is defined in the DCP. This zone applies to all land within which no new development is allowed and where current residential development should be removed where opportunities occur (*through a voluntary purchase scheme*).

(iii) A <u>voluntary house raising zone</u> is defined in the DCP as all land within High to Extreme Hazard but outside of the floodway (*this approximately corresponds to the 5% AEP flood extent*).

(iv) For proposed development within the voluntary house raising zone, the relevant requirements of the DCP for the development type will be required to be met, and in addition:

- For proposed extensions to dwellings within the voluntary house raising zone, new habitable rooms will not be allowed unless the floor level is raised to above the FPL.

- Raising of existing dwellings will be encouraged.
- Any "voluntary purchase" scheme(s) should be handled outside of the DCP process (to avoid adding additional controls); rezoning of properties would follow purchase.

Area 8 - Ropes Creek floodplain upstream of the Railway Line; includes the localities of Erskine Park, St Clair, Colyton and Oxley Park

As shown in **Figure 11.10**, areas subject to high flood hazard and floodway are generally confined to land use zones E2 and RE1 which are considered to be land uses that are compatible with the flood risk.

A few properties in Oxley Park along Melbourne Street are flood affected in the 5% AEP event. Several flood modification options are to be considered for this location to reduce the flood liability of these properties and in that regard, land use changes are not considered necessary.

11.4 Summary of Land Use Planning Recommendations

Table 11.1 lists the recommended actions for land use planning amendments of investigations that have been determined as part of the study. These recommendations are provided to Council for consideration, and, if agreed could be incorporated into any future amendment of the PLEP 2010 via a Planning Proposal submitted by Council.

Table 11.1 Recommended Revisions to Land Use Planning in the Penrith LEP 2010

Area		Recommendation
1	Elizabeth Drive to Warragamba Pipeline	No land use changes recommended.
2	Warragamba Pipeline to the Western Motorway (M4)	No land use changes recommended. Suitable development controls for land rezoned within the Mamre West area should be enforced.
3	St Marys upstream of the South Creek railway line crossing	No land use changes recommended. Ensure that development controls are still applied to properties protected by the levee.
4	Claremont Meadows / Claremont Creek	No land use changes recommended.
5	Werrington and Rance Road residential areas	Rezoning of six vacant lots on the corner of Lethbridge Avenue and Reid Street which fall entirely within the floodway corridor and are subject to high flood hazard classification (*lot nos. 157 to 162, DP 1573*). Alternatively, ensure development is managed based on existing development controls. Ensure that development controls are still applied to properties protected by the levee. Investigate options to reduce development density to the west of Rance Road where the potential for flood damages is high. It is noted that mitigation measures are proposed to reduce damages (*i.e. Option FM15 (refer Discussion Paper no. 3 Flood Damages)*).

6	North St Marys including the former ADI site	No land use changes recommended. Sydney Water to manage flood risk at the St Marys Sewerage Treatment Plant.
7	Llandilo and Berkshire Park	Implement a Voluntary Purchase Scheme to remove dwellings currently located in high risk areas of the floodway.
8	Ropes Creek upstream of the Great Western Railway	No land use changes recommended.

11.5 Flood Related Issues for Development Control

Part C3.5 of the Penrith DCP 2014 sets out development controls with regard to flood planning. DCP 2014 is applied only to land subject to the flood planning provisions in the PLEP 2010; i.e., land that falls within the FPA.

Important considerations when preparing a development control plan and flood policy include:

- Appropriate development controls across a range of specific land uses and range of flood hazards;
- Presentation and format of the flood policy; and,
- Consideration of potential future effects of climate change (*increased rainfall*) on flooding.
- Development controls recommended in the DCP apply to flood prone land as defined by the *NSW Floodplain Development Manual* (*2005*). This refers to land affected by flooding for events up to and including the PMF. In this regard, the DCP will supplement and provide additional information on the flood related clauses in the LEP, which applies to land affected by the 'standard' Flood Planning Level (*i.e., the 1% AEP flood level plus 0.5 m*).

The following general recommendations are made with regard to flooding for inclusion in DCP 2014.

- A summary of flood and floodplain management studies completed to-date should be provided, including a summary of the data available which is relevant for development application assessment (e.g. flood surface mapping (levels), flood flow velocity mapping, hydraulic categorisation mapping).
- Mapping of "no new development areas" (those areas within floodway or high or greater hazard) be provided as an updatable annex to the DCP. Alternatively, the mapping could be held by Council and referred to in the DCP. Mapping of "no new development areas" should exclude identified release precincts, such as the Mamre Road Precinct.
- Flood precincts to which specific development controls may apply should be identified where necessary. A Flood Precinct covering Llandilo and Berkshire Park is recommended for the South Creek floodplain. This would include a Floodway Clearance (*Voluntary Purchase*) Zone and Voluntary House Raising Zone.

11.6 Hydraulic Classification, True Flood Hazard and Flood Planning Constraints Categories

11.6.1 True Flood Hazards

Provisional Flood Hazard mapping for the 1% AEP flood was prepared as part of the *Updated South Creek Flood Study* (*2015*).

As discussed in **Section 6**, True Hazard Mapping has been prepared as part of the Floodplain Risk Management Study to take into consideration other factors that can influence hazard other than the predicted depths and velocity of floodwaters. Factors considered include:

- the size of the flood;
- effective warning time;
- duration of the flooding;
- any evacuation problems that may be encountered; and
- effective flood access.

In addition to the above, the adopted categorisations and criteria for flood hazards has been updated to reflect the latest guidelines available within *Australian Rainfall & Runoff 2019 "Book 6"* and the *Australian Institute for Disaster Resilience Council's "Handbook 7"* (*2017*). This has resulted in hazard categories being defined as H1 to H6 rather than Low to Extreme. The extents of all true hazard mapping have been prepared in accordance with topographic elevations defined by the 2011 LiDAR.

The True Flood Hazard Mapping prepared as part of the FRMS is included within **Appendix B** as **Figures B1** to **B12**.

It is recommended that the True Flood Hazard Mapping be provided as an updateable annexure to the DCP. This is recommended to assist with the enforcing of Controls 2a and 15a (*see* **Section 11.7** *below*).

11.6.2 Hydraulic Categories

Detailed hydraulic category mapping, which defines the extent of the floodway corridor and flood storage and flood fringe areas, was prepared as part of the *Updated South Creek Flood Study* (*2015*).

Based on the rigorous methodology that was applied as part of the flood study assessment and recognising that the modelling has not changed as part of floodplain risk management study, the floodway corridor has not been modified. Mapping of flood fringe and flood storage has been updated as a function of the RMA-2 flood study results being mapped to the 2011 LiDAR; compared to the 2002 ALS previously.

The updated hydraulic category mapping for the 1% AEP flood is included in **Appendix C** as **Figure C1** to **Figure C12**.

It is recommended that the updated Hydraulic Category Mapping be provided as an updateable annexure to the DCP. This is recommended to assist with the enforcing of Controls 2a and 15a (*see* **Section 11.7** *below*).

11.6.3 Flood Planning Constraints Categories

Flood Planning Constraints Categories (*FPCC*) have been prepared for the South Creek floodplain for the first time as part of the FRMS. As discussed in **Section 6.5**, FPCC is a holistic approach to assessing the relative severity of flood risks and constraints to development across the floodplain. The approach is recommended within the *Australian Institute of Disaster Resilience (ADR) Guideline 7-5 Flood Information to Support Land Use Planning Activities* as a tool to assist land use planners with strategic decision making.

The mapping of FPC Categories was based on an assessment of flood behaviour for the full range of design flood events and the updated mapping of True Flood Hazards (*refer* **Section 11.6.1** *and* **Appendix B**) and Hydraulic Categories (*refer* **Section 11.6.2** *and* **Appendix C**). Evacuation constraints identified as part of the mapping of Emergency Response Planning Communities (ERPC) were also taken into consideration.

It is recommended that the FPCC mapping contained within Appendix D be incorporated into future versions of the DCP once similar mapping has been prepared for the remainder of the LGA. Should FPCC mapping be available for the LGA it should be implemented into the DCP to guide land use planning and for the application of development controls.

Accordingly, it is recommended that all new studies include a requirement for the preparation of FPCC mapping.

11.7 Development Controls and Land Use / Development Type

Flood related controls which may apply to development are typically defined by a combination of the hydraulic and hazard classification and the proposed land use.

Development controls within the Penrith DCP 2014 that are specifically related to land use, include:

- Development consent will not be granted to new development in floodways or high hazard areas (control 2a);
- Council will not support the rezoning of any land located in the floodway or high hazard area (control 15a);
- Council will generally not support the rezoning of rural land situated below the 100 year ARI flood where the development of that land may require or permit the erection of buildings or works even if the surface of the land can be raised to a level above the 100 year ARI flood by means of filling (control 15b); and
- Where land below the FPA is currently zoned to permit urban development, Council will generally not support the rezoning of land to higher economic use or an increase in the density of development (control 15c).

The above controls limit development in areas at greater risk of flooding and attempt to prevent an increase in the number of people residing within the flood prone area. These are supported.

Further development controls apply depending on the vulnerability of the land use type to flooding. Comment on the existing development controls and recommendations for amendments to the DCP are outlined in the following sections.

11.7.1 Development Type and Vulnerability to Flooding

Controls for development of residential, industrial and commercial premises are specifically detailed in the DCP. However, controls for development considered more vulnerable such as hospitals, schools, aged-care facilities etc. are lacking with no specific controls provided.

Critical infrastructure is in most cases more vulnerable to the impacts of flooding given the potentially greater concentration of people affected and, in cases, the reduced physical or mental ability of those impacted. For facilities such as hospitals and aged care homes, it is unreasonable to evacuate all patients and hence a shelter-in-place policy is often necessary and safer. Such a policy however requires that the facility be safe and operational over the duration of the flood event. The alternative of evacuation would not only come at considerable monetary cost but could put at risk the lives of patients already within the hospital and those that may need access to the service as a result of flooding.

It is therefore recommended that specific controls are set out in the DCP for vulnerable uses. While the DCP gives some mention of development which may attract large numbers of people, this is not specific and is considered in the DCP under the heading 'Residential Accommodation and Caravan Parks'.

Specific development controls for more vulnerable development should be presented in a similar format to other land uses and would include schools, assisted living for the elderly or disabled, hospitals and some health care facilities, emergency service stations and critical infrastructure at the least.

It should be recognised that locating these more vulnerable development types within flood prone land may be unavoidable and may even be necessary i.e. to ensure appropriate service cover. However, consent for the development should be on a merits based approach and should consider as a minimum:

(i) Vulnerable development is located outside of the 1% AEP flood extent, and outside of the PMF extent, where possible.

(ii) Flood behaviour at the development site and surrounding area is defined for a range of flood events up to and including the PMF. As a minimum this is to include peak flood levels, depths, flow velocities, hazard and hydraulic category mapping.

(iii) Evacuation and emergency response procedures must be carefully considered and detailed. This must include information such as the effective warning time available, nominated evacuation routes (in case necessary) and evacuation and/or shelter-in-place procedures.

(iv) Where emergency response procedures may be reliant (even if partly) on the SES this is to be detailed. Consultation with the SES is required to review emergency response plans and to identify if the additional pressure on emergency services can be accommodated. Reference should be made to *Guidelines on Safety Design Criteria* outlined in *Australian Rainfall and Runoff 2016* (*Chapter 7, ARR16*) which also considers children and the elderly in its flood hazard classifications and should be applied depending on the development use.

11.7.2 Extensions to Existing Development

The presence of an existing development within the floodplain should not provide precedent to carry out any modifications as desired. Modifications to existing development should be subject to flood related development controls. However, there is scope to modify existing development in certain circumstances where new development would not normally be permitted.

Modifications should only be carried out where it can be shown that flood behaviour on adjacent properties is not adversely altered or the demand on flood evacuation resources is not increased.

While it is recognised that extensions to existing development may be necessary, development controls should be used to minimise the population at risk. Penrith DCP 2014 already sets out some controls regarding extensions to existing development. These are separated into residential or industrial/commercial development.

A number of controls for minor extensions to residential development are set out in the Penrith DCP 2014 and are supported. Additional controls are also recommended for all extensions to existing development as follows.

- No flood related restrictions will apply to an increase in the floor area sited above the FPL, provided the applicant can satisfy that there is no increase to the population at risk associated with the proposal (*i.e. no additional strain on emergency services*) and the increase in floor level does not result in an increase in building footprint within the floodplain with the potential to impact flood behaviour.
- If a dwelling exists in a floodway and is destroyed by fire or other natural event the replacement of the dwelling may be considered only if the following can be achieved;
  - The dwelling had been permanently occupied prior to the loss of the dwelling; and
  - The replacement dwelling must meet current flood planning requirements. This may require the dwelling to be relocated to a less hazardous area within the property and/or for floor levels to be raised.
  - Similar controls should also apply for non-residential development.
- A Flood Impact Assessment or Flood Risk Assessment will be required for all development within the FPA including any extensions which will lead to an increase in the overall building footprint.

11.7.3 Infill Development

The recommendations listed above in **Section 1017.2** for modifications to existing development will in general also apply to non-residential infill development.

The Penrith 2014 DCP includes a number of controls for industrial and commercial infill development which are supported. However, although the DCP requires consideration of the frequency and depths of flooding it makes no reference to limiting infill development in high hazard or floodway areas, or limiting the increase in temporary (i.e. working) population in a flood prone area. In that regard, the following recommendations are made for inclusion in the DCP with regard to infill development:

- Infill development should not be allowed in areas of high flood hazard and/or floodway in keeping with current development controls 2a and 15a;
- Residential infill development should be treated as new development;

- The applicant will be required to show that all personnel within the building can be evacuated safely in the event of a flood;
- Infill development will be subject to future controls regarding change of use so that the property cannot be changed to a use of greater susceptibility to the effects of flooding;
- Each proposal will be considered on a case by case merits basis; and
- A Flood Impact Assessment (*FIA*)and/or Flood Risk Assessment (*FRA*) may be required for the applicant to demonstrate that the development proposals meet the DCP criteria.

11.7.4 Change of Use

Current controls in the Penrith DCP 2014 require that for a change of use, where existing building floor levels are below the 1% AEP flood level, measures for flood proofing such as raising floor levels and/or stock and machinery storage to above the 1% AEP flood level are undertaken. In addition, the following is recommended:

- A change of use will generally not be supported if a use is proposed with greater vulnerability to flooding; i.e. a change from commercial to residential.

11.7.5 Rural Development

A number of recommendations are made in regard to assessing development proposals for rural land use. Given the nature of the development, these are principally associated with appropriate evacuation requirements. It is recommended that additional controls are applied for rural properties where it may be harder for door-knocking exercises to encourage evacuation, and where evacuation routes can become inundated before floodwaters enter the property and before the occupants realise they could be at risk.

The following is proposed for any rural development classed as '*flood island*', '*trapped perimeter*', '*rising road access*' and '*overland escape routes*' as defined by the DECC (*now OEH*) Floodplain Risk Management Guideline titled, *Flood Emergency Response Planning Classification of Communities* (DECC, 2007).

- The applicant must demonstrate that there is sufficient warning time available (*eight hours*) to facilitate evacuation along the proposed route.
- Safe evacuation will need to be provided from the development to land above the PMF level.
- Where the above is not possible, the proposed evacuation route must conform with the following requirements as a minimum:
- The minimum flood immunity for an evacuation route, including any proposed access road, is the 5% AEP flood level.
- The evacuation route should grade upwards towards land above the PMF.
- Where it is not feasible for an access road to facilitate safe evacuation to an area flood free during the PMF, an alternate all weather access track must be available which leads to land above the PMF (*i.e. high ground on or adjacent to the site*).
- If access to a site above the PMF is not possible the FPL shall be raised to the PMF to provide on-site flood security (*subject to consideration of hazards and risks of structural damage*).

11.8 Voluntary Purchase

While not strictly part of the DCP, it is proposed that voluntary purchase be adopted for those properties with existing dwellings that are located within the floodway, high hazard areas and areas subject to frequent inundation; i.e., < 5% AEP flood.

Llandilo and Berkshire Park are the two locations within the study area that have been identified to be most suitable for Voluntary Purchase. The aim of voluntary purchase in Llandilo and Berkshire Park is not to prevent agricultural and business on the sites but rather for the removal of permanent residents.

11.9 Assessment of Impact

No specific reference to mitigating the impacts of development on flood behaviour are included in the Penrith DCP 2014. However, in regard to filling in land at or below the FPL (*1% AEP flood level plus 0.5 m freeboard*), the DCP sets out specific criteria in section C.14.

Development within the floodplain can also be considered as "filling" where, for example, a new building may have the potential to reduce floodplain storage and displace water; or a new fence or wall may cause the direction of flows to be altered. Therefore, it is recommended that:

- Further clarification is included in the DCP to ensure that the controls currently set out for "filling" also apply to any development which has the potential to displace or divert floodwaters.

The DCP sets out nine 'impact' criteria which are discussed in the following:

11.9.1 Increase in Peak Flood Levels

Current Criteria	Peak flood levels not increased by more than 0.1 m (100 mm) *(DCP reference C.14.a.i)*
Recommended Criteria	Peak flood levels not increased by more than 0.02 m (20 mm) outside of the development site

Justification for Recommendation

<u>Flood Damages</u> - An increase of 100 mm in peak flood levels is considered significant and can affect the development potential of adjoining properties, increase flood damages and can lead to an increase in the hazard categorisation. A 100mm increase in flood levels can also lead to a substantial increase in flood extents, particularly in relatively flat floodplain areas.

Whereas 100mm is considered to be a significant increase, 20mm is considered a reasonable upper limit which is commonly applied as both an official and unofficial limit, reflecting the order of accuracy of the data relied upon for flood modelling (eg., survey data) and the order of accuracy of the resultant calculations. A 20mm increase in flood levels would not be expected to cause any measurable increase in flood damages or hazard categorisation.

11.9.2 Change in Velocities and Redistribution of flows

Current Criteria	Downstream velocities are not increased by more than 10% by the proposed filling *(DCP reference C.14.a.ii)* Proposed filling does not distribute flows by more than 15% *(DCP reference C.14.a.iii)*
Recommended Criteria	On the development site itself, flood hazard is not increased to greater than "low" based on current ARR criteria for hazard. Low hazard zones are defined in ARR as where D.V < 0.4 m^2/s for children and D.V < 0.6 m^2/s for adults and should be applied depending on the type of development. Isolated areas of high hazard may be considered at Council's discretion where people are prevented from entering the area i.e. dedicated flow paths. Hazard should never increase to exceed 0.8 m^2/s as this is the limiting working flow for experienced personnel such as trained rescue workers. Flood hazard should be assessed for the duration of the event and is not necessarily the flood hazard at the time of the peak flood level. Flood hazard on surrounding properties should not increase.

Justification for Recommendation

The existing criteria used in the DCP for velocity and flow is considered too prescriptive and, as such, can limit innovative solutions to managing flooding within a site. For example, redistribution of flows within a larger development site may be supported where the redistribution of flows is designed to follow formally created and designated flow path routes and may reduce flood hazard to other parts of the site and/or offsite impacts.

Where high velocities already exist, hazard is likely to already be high and risk of erosion also high. In that regard, an increase of 10% is unlikely to have a significant effect.

Therefore, it is recommended that a more suitable criterion for assessment for a assessing offsite impact would be flood hazard.

11.9.3 Cumulative Effects

Current Criteria	The potential for cumulative effects of possible filling proposals in that area is minimal *(DCP reference C.14.a.iv)*
Recommended Criteria	The potential for cumulative effects of possible development proposals in that area is minimal.

Justification for Recommendation

All development should be considered, not just filling proposals. Generally, should new development adhere to the recommended development controls set out above and below then the cumulative impact of development should be negligible.

11.9.4 Alternative Options for Flood Storage

Current Criteria	There are alternative options for flood storage *(DCP reference C.14.a.v)*
Recommended Criteria	Where possible, any losses in floodplain storage are to be offset by compensatory cut at the same or a similar elevation.

Justification for Recommendation

This recognises the importance of flood storage within the lower reaches of the study area where backwater flooding from the Hawkesbury-Nepean River can occur. Upstream of the Hawkesbury-Nepean River flood extent flood storage is less important. Notwithstanding, where it is possible landowners should investigate potential options for compensatory cut to manage the cumulative impact of flooding.

It is recommended that this criteria be enforced more strictly for larger developments such as future residential and commercial precincts.

11.9.5 Development Potential of Surrounding Properties and Flood Liability of Surrounding Properties

Current Criteria	The development potential of surrounding properties is not adversely affected by the filling proposal *(DCP reference C.14.a.vi)* The flood liability of buildings on surrounding properties is increased *(DCP reference C.14.a.vii)*
Recommended Criteria	The flood liability and flood hazard of surrounding land is not adversely affected by the development.

Justification for Recommendation

It is important that the flood risk to surrounding properties, not just the buildings on surrounding properties, is considered. Otherwise, although flood liability of the building may not increase, increased flooding on neighbouring property could result in increased risk to occupants of the building when evacuating or leaving the site.

Meeting the depth and hazard criteria should achieve this.

11.9.6 Local Drainage / Runoff Problems

Current Criteria	No local drainage flow/runoff problems are created by the filling *(DCP reference C.14.a.viii)*
Recommended Criteria	No local drainage flow/runoff problems are created by the development

Justification for Recommendation

The clause should be relevant to all development, not just filling proposals. Future development could cause obstructions to local drainage and runoff if not planned for.

11.9.7 Impact Criteria not Currently in the DCP

Flood Hazard – this has been recommended above as an alternative criteria to change in velocities and flow distribution (*refer* **Section 10.9.2**).

Offsite Impacts – the DCP makes no specific reference to where the impact criteria applies. Offsite impacts exceeding the criteria should not be approved. Within the development site, the criteria may be exceeded where the developer can show that there is no increased risk to future occupants of the site, no increased pressure on emergency services and suitable evacuation plans are maintained and practiced. Such development should be assessed by Council on a merits based approach and should not be approved where opportunities to achieve the criteria are feasible.

Design Flood Events for Consideration – the DCP does not reference which design events the above criteria are relevant to and it is assumed therefore that Council expects only the 1% AEP ARI event flood needs to be considered. It is recommended that Council specify that as a minimum the development be shown to comply with the criteria for the design 1% AEP flood event. Notwithstanding, Council reserves the right to request that a more detailed assessment be completed that considers additional events.

11.10 Evacuation Controls

Consideration of evacuation is important for several reasons; to ensure that evacuation routes from surrounding area are not worsened by development, to ensure safe evacuation from new development and to avoid unnecessary additional pressure on emergency response services.

For proposed development, including extensions, the following development controls are recommended:

- Consideration must be given to evacuation from the site where necessary. Evacuation should be considered in terms of effective warning time, duration of inundation, flood levels, depths and hazard for a range of design flood events. If necessary, an evacuation plan must be prepared and appropriate signage placed around the development. The applicant must show that there is sufficient time to evacuate all persons from the site during all events up to and including the Probable Maximum Flood (PMF).
- Proposed development should not adversely impact on the potential of existing properties to evacuate (i.e. no increase in hazard or flood duration on nearby roadways) nor place undue stress on emergency response services.
- In rural areas, new residential development should consider evacuation to ground located above the PMF.
- Development in areas defined as a Flood Island (high or low), Trapped Perimeter or Overland Escape Route1 will need an appropriate plan for evacuation.

[1] High Flood Islands and Overland Escape Routes are defined in OEH's Flood Risk Planning Guidelines

11.11 Flood Risk and/or Impact Assessment

A Flood Impact Assessment (*FIA*) or Flood Risk Assessment (*FRA*) must be submitted for any development within the FPA. The assessment should be commensurate with the scale of development and the vulnerability of the development to flooding and flood risk. For example, a small extension to an existing dwelling in a low hazard flood area would require only a simple assessment to show no offsite impacts and no increase in population at risk. For a larger development within the FPA, the assessment should consider the impact of the development on flood behaviour and evacuation at the least. Flood modelling may be required for some development, but not all, at Council's discretion.

11.12 Complying Developments

It is recommended that mapping prepared by Council, which defines 'exclusion zones' for complying development applications, be updated to account for the "floodway" and "flood storage" areas defined by the South Creek Floodplain Risk Management Study (*as well as other flood studies within the Penrith LGA*). That is, any development that falls within a floodway or flood storage area should not by definition be a complying development.

11.13 Management of Climate Change

Statutory obligations require that planning policies account for projected sea level rise and the impact of climate change. At present, there are no triggers for consideration of climate change (*increased rainfall*) within the DCP.

11.14 Presentation and Format of the Flood DCP

In regard to the structure of the DCP, it is recommended that each land use type (*and/or precinct*) is addressed in an individual sub-section of a chapter addressing applicable flood related development controls. This could also include a section listing what (*if any*) controls are common to all land uses.

While this approach may generate a certain repetition of controls, it is considered to better delineate different controls for the majority of users of the Flood DCP. Similarly, this process can be streamlined when used in conjunction with a matrix approach.

A matrix approach is recommended to summarise the development controls applicable to different types of development. A sample matrix is provided in the Hawkesbury Nepean Floodplain Management Steering Committee's report *Managing Flood Risk Through Planning Opportunities: Guidance on Land Use Planning in Flood Prone Areas* (*2006*).

This will also assist in providing a summary of the flood related planning controls, which will be addressed in greater detail in the DCP text.

11.15 Flood Related Planning Controls for Strategic Planning

The Penrith LEP 2010 and DCP 2014 do not apply to all land within the LGA as some areas are governed by the various SEPPs and Precinct Plans. Within the South Creek catchment the following apply:

- State Environmental Planning Policy (Western Sydney Employment Area) 2009
- Sydney Regional Environmental Plan No. 30 – St Marys

- Mamre West Land Investigation Area DCP (applies to land known as the Mamre West Precinct and as a result, the Penrith DCP 2014 no longer applies to this land)

Flood related issues should not just relate to development control, but should also inform strategic planning decisions that determine and shape future development precincts. Flood related constraints need to be considered as part of the strategic planning for future development and land release areas and need to be addressed fully by the Regional Strategy, Local Strategy (*e.g. the Penrith Urban Strategy*) or the planning proposal for a site specific rezoning. The flood constraints of greatest importance to this process are:

- Has the Flood Planning Area been considered in terms of defining development precincts?
- Has the full range of floods been considered? If the land release precinct will be suitable for development in floods up to the planning flood (i.e., the 100 year ARI flood), will there be the risk of a disaster if a flood that is a little larger occurs?
- Have emergency response management issues been considered? Can people who would live in future development precincts be safely evacuated should a flood rarer than the planning flood occur? What happens in a PMF?

In conjunction with this, it is important for Council's planners to consider the potential cumulative impact of future development on flooding before actually promoting development as part of separate land release precinct; for example, the Mamre West Precinct.

The *South Creek Flood Study* (*2015*) provides flood data that will identify those areas of the floodplain that will need to be preserved into the future for the purposes of flood conveyance. Further details will be included within the Floodplain Risk Management Study.

As population grows, pressures will increase for development to encroach into the floodplain of South Creek and its tributaries. For example, the Western Sydney Employment Area (*WSEA*) will involve substantial future development within the South Creek catchment and floodplain areas. Hence, the pressures for future development are likely to extend beyond the flood fringes into areas of flood storage. The loss of some of these flood storage areas can be justified both hydraulically and from the perspective of not sterilising all of the floodplain. However, it will be necessary to establish the cumulative impact of potential future development scenarios on flooding. Therefore, the following should be considered:

- Identification of the future development precincts that are earmarked for the next 50 years and a hydraulic analysis of the cumulative impact of all of those areas being developed (i.e., filled);
- Assessment of individual development precincts in total rather than ad-hoc site-specific FIA and FRAs.

11.16 Recommendations

Table 11-2 outlines the recommended changes to planning controls that have been identified as part of the floodplain risk management study for South Creek.

Table 11-2 Recommended Changes to Planning Controls

ID	Recommended Planning Measures
PM.1	Updateable annexures be added to the DCP to include the following mapping: a. True Flood Hazard Mapping (*refer* **Section 11.6.1** *and* **Appendix B**) b. Updated Hydraulic Category Mapping (*refer* **Section 11.6.2** *and* **Appendix C**)
PM.2	Future Floodplain Risk Management Studies for watercourses within the Penrith LGA be required to prepare Flood Planning Constraints Category (FPCC) mapping similar to the FPCC prepared for South Creek and included as **Appendix D**. Once FPCC mapping is available for the LGA it is recommended that DCP controls be updated to ensure development is guided by the FPCC mapping.
PM.3	Amendment to development controls regarding: c. Extensions to existing development – no increase to population at risk (*refer* **Section 11.7.2**) d. Change of use – consider location, proposed use and evacuation (*refer* **Section 11.7.3**) e. Rural development – consider evacuation (*refer* **Section 11.7.4**)
PM.4	Revise DCP regarding assessment of impact including (*refer* **Section 11.9**): a. Reduce criteria for maximum allowable increase in peak flood levels b. Remove control for velocity and flow distribution and replace with a hazard control c. Modify wording for requirements of cumulative impact assessment. d. Update control for additional flood storage where it can be shown there is no offsite impact e. Combine controls requiring consideration of impacts on surrounding properties f. Require assessment of impact criteria in regard to all development (not just existing buildings or potential development sites) g. Specify that controls must be met for the 1% AEP flood, however, Council may request additional events to be assessed at their discretion.
PM.5	Additions to the DCP including: a. Additional controls for critical facilities (e.g. schools, hospitals, aged care facilities etc.) b. Require consideration of evacuation from the proposed development as well as the effect of new development on evacuation from existing areas c. Requirement for FIA / FRA commensurate to development size, type and flood risk d. Need to include consideration of climate change
PM. 6	Revise format of the DCP to set out different development types and flood risk into matrix approach (*refer* **Section 11.14**)

12. Recommended Inclusions for the Floodplain Risk Management Plan

The recommendations, which will form the basis for the South Creek Floodplain Risk Management Plan are summarised in the following. The recommendations have been developed from the Committee's consideration of the flood, property and response modification measures that have been assessed as part of this study. The prefix "FM" has been used to signify a flood modification recommendation, "RM" for response modification, and "PM" for planning recommendations.

12.1 Flood Modification Measures

Table 12-1 lists the recommended Flood Modification Measures for inclusion as potential works within the Floodplain Risk Management Plan for South Creek.

Table 9-21 Recommended Flood Modification Measures

ID	Recommended Flood Modification Measures
FM.1	The '*Low Cut*' option (*Measure F-1A*) for <u>excavation downstream of the Western Railway Line crossing of Ropes Creek</u> is recommended based on it returning the highest ranking following the Triple Bottom Line (*TBL*) assessment and third highest Benefit-Cost-Ratio (*BCR*) of 0.75. This measure is considered a viable option to reducing flood damages to properties located along Melbourne Street in Oxley Park. There is potential for the BCR to increase for this measure if the benefits to residential properties located to the east and within the Blacktown City Council LGA are taken into consideration.
FM.2	The proposed <u>upgrades to the St Marys Levee</u> plus installation of a flap gate (*Measure F-7B*) at the outlet of the Byrnes Creek culvert is recommended based on it returning the second highest TBL ranking and second highest BCR of 0.76. Implementation of this measure will prevent backwater flooding from South Creek into St Marys during floods up to and including the 1% AEP event. Further investigation of Measure F-7B is required to confirm the existing condition of the levee and final levee crest elevations (*refer* **Section 8.4.1**).
FM.3	The proposed Earthen Levee (*Measure F-2*) at Oxley Park is proposed to be included in the Floodplain Risk Management Plan for further investigation, design and implementation. The proposed Oxley Park Levee was determined to have the highest BCR at 0.87 and third highest TBL ranking.

12.2 Emergency Response Management Recommendations

Table 12-2 lists the recommended Emergency Response Management measures that have been identified as part of the floodplain risk management study for South Creek.

Table 12-2 Recommended Emergency Response Management Measures

ID	Recommended Emergency Response Management Measures
RM.1	The Local Flood Plan for the South Creek catchment should be updated to include: a. Reference to all existing gauges within the study area which can be used to monitor the progression of a local catchment flood event. b. Nomination of minor, moderate and major gauge heights so that reference markers are available against which warning times and known problem locations can be monitored. c. Flood intelligence cards for the existing gauges that show the predicted stage-hydrograph for a range of design events plus indicators of times when roads and critical facilities (*such as nursing homes, childcare centres, schools*) would start to be flooded or at risk of isolation.
RM.2	Provision of flood data to the SES for consideration in updating the Local Flood Plan. It is recommended that the following information be considered: a. Mapping of Emergency Response Management Planning Communities (ERMPC), particularly areas of high risk where isolation is possible; i.e., high and low flood islands (*refer* **Appendix G** *and* **Table 10-2**) b. Identification of schools and vulnerable communities within the study area (*refer* **Table 10-3**) c. Community Data Sheets and flood risk mapping along all local roads within the study area (*refer* **Appendix H**) d. Inclusion of reference to river gauges within the study area for the purposes of monitoring flood risks. Existing gauges along South Creek at Elizabeth Drive and the Great Western Highway should be adopted for flood monitoring and for the dissemination of minor, moderate and major flood warnings (*refer* **Section 10.6.1**)
RM.3	Install a continuous river level gauge along South Creek near the Warragamba Pipeline to maximise potential warning times while still capturing approximately runoff from 50% of the contributing catchment.
RM.4	Install flood boom gates either side of the Eighth Avenue bridge crossing at Llandilo and implement a vegetation management plan for the crossing and areas immediately upstream and downstream.

12.3 Planning Modification Recommendations

Table 12-3 outlines the recommended changes to planning controls that have been identified as part of the floodplain risk management study for South Creek.

Table 12-3 Recommended Changes to Planning Controls

ID	Recommended Planning Measures
PM.1	Updateable annexures be added to the DCP to include the following mapping: a. True Flood Hazard Mapping (*refer* **Section 11.6.1** *and* **Appendix B**) b. Updated Hydraulic Category Mapping (*refer* **Section 11.6.2** *and* **Appendix C**)
PM.2	Future Floodplain Risk Management Studies for watercourses within the Penrith LGA be required to prepare Flood Planning Constraints Category (FPCC) mapping similar to the FPCC prepared for South Creek and included as **Appendix D**. Once FPCC mapping is available for the LGA it is recommended that DCP controls be updated to ensure development is guided by the FPCC mapping.
PM.3	Amendment to development controls regarding: a. Extensions to existing development – no increase to population at risk (*refer* **Section 11.7.2**) b. Change of use – consider location, proposed use and evacuation (*refer* **Section 11.7.3**) c. Rural development – consider evacuation (*refer* **Section 11.7.4**)
PM.4	Revise DCP regarding assessment of impact including (*refer* **Section 11.9**): a. Reduce criteria for maximum allowable increase in peak flood levels b. Remove control for velocity and flow distribution and replace with a hazard control c. Update control for additional flood storage where it can be show there is no offsite impact d. Require assessment of impact criteria in regard to all development (not just existing buildings or potential development sites) e. Specify that controls must be met for the 1% AEP flood, however, Council may request additional events to be assessed at their discretion.
PM.5	Additions to the DCP including: a. Additional controls for critical facilities (e.g. schools, hospitals, aged care facilities etc.) b. Require consideration of evacuation from the proposed development as well as the effect of new development on evacuation from existing areas c. Requirement for FIA / FRA commensurate to development size, type and flood risk d. Need to include consideration of climate change
PM. 6	Revise format of the DCP to set out different development types and flood risk into matrix approach (*refer* **Section 11.14**)

13. References

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Appendix A – Newsletter and Questionnaire

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

INFORMATION SHEET

INTRODUCTION

Penrith City Council is preparing a Floodplain Risk Management Study and Plan for the South Creek floodplain and we would like your help. The study will tell us what flood management measures are required and help us plan for and manage known flood risks. Sound flood management is important to reduce flood damage, enhance resilience and improve social and economic opportunities.

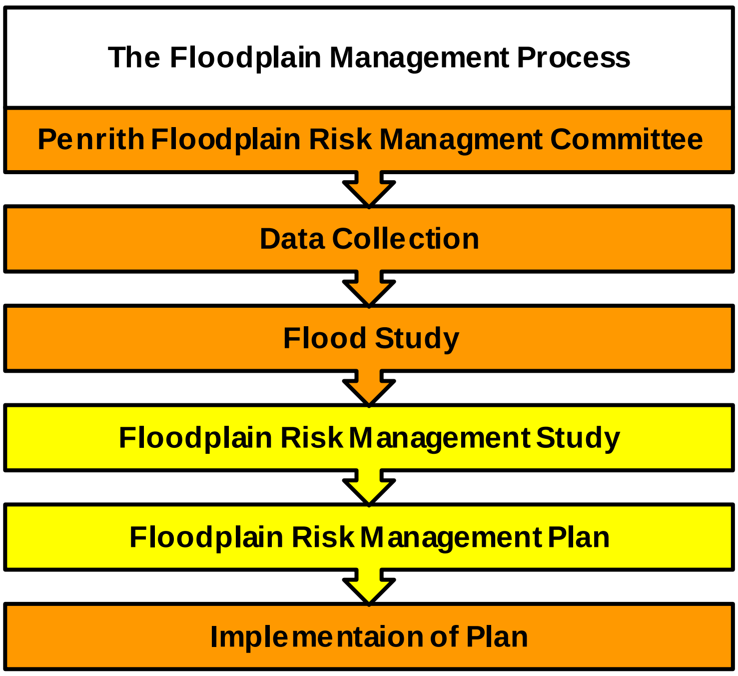
The extent of the study area is the floodplain of South Creek from Elizabeth Drive to Richmond Road. This also includes floodplains of Ropes Creek, Kemps Creek, Badgerys Creek and parts of Cosgrove and Werrington Creek which are tributaries of South Creek.

Council has appointed engineering consultants Advisian to prepare the Study and Plan.

The study will be overseen by the Penrith Floodplain Risk Management Committee, and will receive financial support from the State Government under its Floodplain Management Program.

WHY DO WE NEED A FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN?

Under the NSW Government Flood Prone Land Policy, management of flood prone land is, primarily, the responsibility of councils. The policy specifies a staged process involving data collection, a flood study, a floodplain risk management study and plan, and implementation of the plan (see flowchart).



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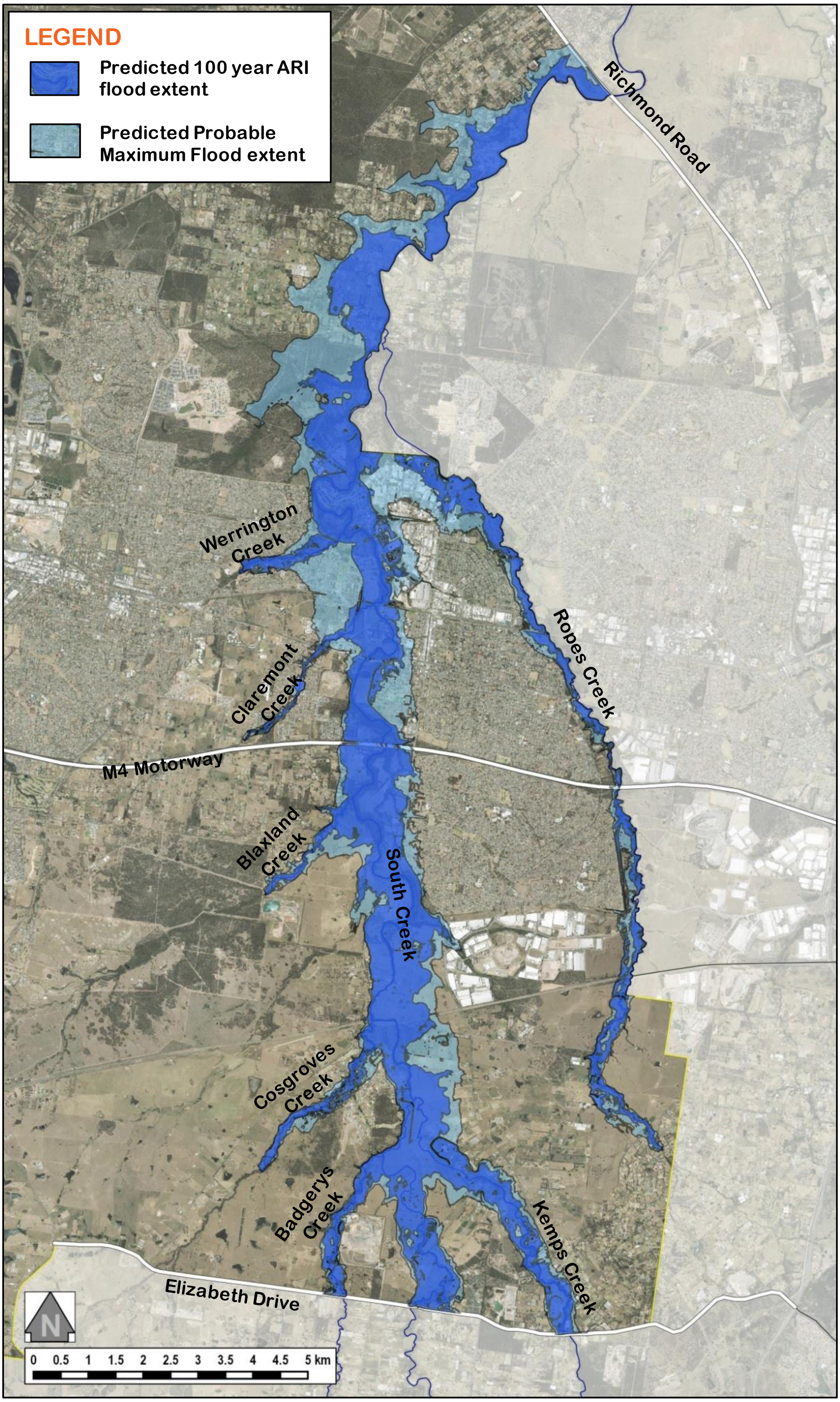

Extent of study area within Penrith LGA (flood extents not shown for areas outside the LGA)

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We will follow this process to manage our floodplains. The South Creek Flood Study was completed in 2015 and we are now starting the Floodplain Risk Management Study and Plan.

The preparation of a Floodplain Risk Management Study and Plan will identify which flood risk reduction measures may be best implemented to reduce the cost of flooding to the community, assist with emergency management and guide future development. The best of these options will be developed further in the Floodplain Risk Management Plan.

The process will also consider measures by which we can make the community more resilient, including community education and preparation.

WHAT'S INVOLVED IN PREPARING A FLOODPLAIN RISK MANAGEMENT STUDY?

The primary objective of the Floodplain Risk Management Study is to assess flooding issues within the study area and investigate measures to address existing, future and continuing flood risk. Selected measures will be followed through to the Floodplain Risk Management Plan before being implemented by Council.

A considerable amount of work is involved in preparing a Floodplain Risk Management Study, including to:

- identify areas at risk of flooding, through use of the computer modelling completed for the Flood Study and from the community questionnaire.
- develop a range of options for managing flood risk. These can include modifying the creek channel, constructing levees, enforcing planning controls for new development, planning for evacuation, education and awareness.
- analyse the options, considering environmental, social and economic benefits as well as their potential to reduce flood risk.
- prepare a Floodplain Risk Management Report which summarises the outcome of all stages of the investigation and makes recommendations to be carried forward to the Floodplain Risk Management Plan.

HOW YOU CAN BE INVOLVED?

Council recognises that the local knowledge and personal experience of people in the community is valuable to help identify flooding 'trouble spots' and develop floodplain risk management measures that are acceptable to the community.

The study team will consult with the community at various stages:

• a **questionnaire** is included with this information sheet and is also available online at (https://www.surveymonkey.com/r/SouthCreekFRMS) – we encourage you to complete it to share your experiences and opinions.

• once the draft Floodplain Risk Management Study report is prepared, a **community workshop** will be held to give you an opportunity to review the report and ask questions about the flood management options investigated. Any comments from the workshop will be reviewed and addressed as part of the final report.

WEBSITE

Council's website will be updated throughout the study to provide the latest available information including details of the above community consultations.

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FURTHER INFORMATION

To submit any information you think may be helpful to the study, please send with your questionnaire response, or contact:

Roy Golaszewski - Advisian

Level 17, 141 Walker Street, North Sydney NSW 2060

Phone: 8456 7231

Email: South.Creek@advisian.com

Myl Senthilvasan - Penrith City Council

PO Box 60, Penrith NSW 2751

Phone: 4732 7947

Email: myl.senthilvasan@penrith.city

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

COMMUNITY QUESTIONNAIRE

Penrith City Council is preparing a Floodplain Risk Management Study and Plan for the South Creek floodplain, which includes properties potentially at risk of flooding from South Creek and its tributaries of Ropes Creek, Kemps Creek, Cosgrove Creek, Werrington Creek and others.

We have appointed Engineering Consultants Advisian to help carry out the study.

Community input will be valuable in helping us to understand the perceived risks and to identify floodplain risk management options that are acceptable to the community – See the "Information Sheet" for more information.

Please share your local flood experiences by completing our questionnaire before **Friday 8th April 2016**:

1. **online** at:

   https://www.surveymonkey.com/r/SouthCreekFRMS

2. or **on paper** using the following pages, which can be returned by email (*South.Creek@advisian.com*) or mail (*fold as per instructions to form a pre-paid envelope*, *no postage stamp required*)

Please answer as many questions as you can and give as much detail as possible (attach additional pages if necessary).

If you have any questions or require further information, contact Council's Engineering Coordinator – Policy and Projects, Myl Senthilvasan on 4732 7947.

No information provided in this questionnaire will be supplied to insurance agencies.

CONTACT DETAILS

Providing contact details is optional, but useful so we can contact you for more information if required. If you choose to provide contact details, this information will remain confidential at all times and will not be published.

Name: ____

Address: ____

____

Phone number: _______________________________________

Email: ____

Please indicate if and how you would like us to contact you for more information or to provide you with study updates.

☐ Yes (telephone/email/mail)

☐ No

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WHAT TYPE OF PROPERTY IS THIS ADDRESS?

Residential	Commercial	Industrial	Other
☐	☐	☐	☐

If non-residential, please provide details: ________________________________

HOW LONG HAVE YOU LIVED / WORKED:

At this address? __________ (*years*) __________ (*months*)
In the general area? __________ (*years*) __________ (*months*)

HAVE YOU EVER BEEN AFFECTED BY FLOODING?

- ☐ Yes – in the local area (*eg roads, shops, park lands*)
- ☐ Yes – at this address

Please provide details of the dates and location of flooding. Additional information and photographs can be attached to this questionnaire or emailed to South.Creek@advisian.com

____

____

IN YOUR OPINION, WHAT WAS THE MAIN CAUSE OF THIS FLOODING?

(select all that apply)

- ☐ Insufficient creek capacity
- ☐ Insufficient stormwater drain capacity
- ☐ Blockage of creeks, stormwater inlets, bridges or stormwater drains
- ☐ Overland flow impediments (eg surface water runoff becoming trapped by fences, buildings etc)
- ☐ Other

If other, please provide details

____

____

IN YOUR OPINION, COULD THE FLOODING HAVE BEEN PREVENTED OR REDUCED?

- ☐ Yes - prevented
- ☐ Yes - reduced
- ☐ No
- ☐ Don't know

If yes, please provide brief details:

____

____

ARE THERE ANY AREAS WITHIN THE STUDY AREA WHERE YOU THINK REDUCING FLOOD RISK SHOULD BE A PRIORITY?

- ☐ Yes
- ☐ No
- ☐ Don't know

If yes, where is this?

____

____

WHAT APPROACHES WOULD YOU LIKE TO SEE USED IN MANAGING EXISTING FLOOD PROBLEMS?

(Select all that apply)

- ☐ Levees and other 'hard engineering' defence options
- ☐ Creek channel modifications eg widening, straightening, concrete lining
- ☐ Removal of properties from high hazard areas of the floodplain
- ☐ Road improvements to allow for better evacuation, eg road raising, increased bridge spans over watercourses
- ☐ Increasing size of stormwater drains and detention basins
- ☐ Increased maintenance of stormwater drains and creek channels
- ☐ Other

If other, please provide details

____

____

ARE YOU AWARE OF WHETHER OR NOT YOUR PROPERTY IS AT RISK OF FLOODING?

- ☐ Yes
- ☐ No

DO YOU BELIEVE CLIMATE CHANGE WILL POTENTIALLY INCREASE THE SEVERITY AND FREQUENCY OF FLOODING?

- ☐ Yes
- ☐ No

KEY FINDINGS FROM THE SOUTH CREEK FLOOD STUDY

A flood study was completed for South Creek and its tributaries in 2015, to gain a detailed understanding of the potential issues and risks that may impact the community. This includes information such as where and if floodwaters could inundate roads, where businesses and residential properties may

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experience flooding, and where floodwaters may be most hazardous to existing and future infrastructure.

As we progress to the next stages of the floodplain management process, we're interested in gauging the community's perception of flooding and the level of awareness of some of the key issues identified in the flood study.

The risk of flooding is often expressed by the term Average Recurrence Interval (ARI). For example, a flood with a 100 year ARI has a 1 in 100 chance of occurring, on average, in any given year. Just because a 100-year ARI flood happens this week it does not mean that another 100 year ARI flood cannot happen again next week.

Please indicate which best describes your reaction to each of the following statements:

A Flood Study was recently completed for South Creek, completing the first stage of the Floodplain Risk Management Process.

I've seen the report	I was aware	Not sure if I knew	I was not aware	Other
☐	☐	☐	☐	☐

The Flood Study determined that over 1,000 residential properties could experience flooding during a 100 year ARI flood.

I was aware of this risk	I'm not surprised	This surprises me	This greatly surprises me	I don't believe this
☐	☐	☐	☐	☐

The Flood Study determined that over 2,000 residential properties could experience flooding during the Probable Maximum Flood.

I was aware of this risk	I'm not surprised	This surprises me	This greatly surprises me	I don't believe this
☐	☐	☐	☐	☐

Major roads such as the Great Western Highway and Elizabeth Drive could be overtopped by floodwaters during a 20 year ARI flood.

I was aware of this risk	I'm not surprised	This surprises me	This greatly surprises me	I don't believe this
☐	☐	☐	☐	☐

The Western Motorway (*M4*) is predicted to be overtopped during a 1 in 100 year flood.

I was aware of this risk	I'm not surprised	This surprises me	This greatly surprises me	I don't believe this
☐	☐	☐	☐	☐

At the peak of a 100 year ARI flood, the floodplain would stretch 500 - 900 metres wide along much of South Creek within Penrith LGA.

I was aware of this risk	I'm not surprised	This surprises me	This greatly surprises me	I don't believe this
☐	☐	☐	☐	☐

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HOW OFTEN DO YOU CONSIDER FLOODING TO BE "ACCEPTABLE"?

In many areas of existing development, the risk of flooding cannot be removed entirely. However, with appropriate measures sometimes the risk or frequency of flooding can be reduced.

Please select the option that best describes how you feel about the following statements:

Flooding to existing development is not acceptable.

Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

The acceptable frequency of flooding depends on the type of development, eg residential or commercial or premises such as schools, hospitals etc.

Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Flooding to <u>residential</u> development should not be more frequent than *an average* of once every how many years?

Never	More than 100 years	50-100 years	10-50 years	1-10 years	Less than 1 year
☐	☐	☐	☐	☐	☐

Flooding to <u>commercial/industrial</u> development should not be more frequent than *an average* of once every how many years?

Never	More than 100 years	50-100 years	10-50 years	1-10 years	Less than 1 year
☐	☐	☐	☐	☐	☐

Flooding to <u>other development such as schools, hospitals, sewerage treatment plants etc</u> should not be more frequent than *an average* of once every how many years?

Never	More than 100 years	50-100 years	10-50 years	1-10 years	Less than 1 year
☐	☐	☐	☐	☐	☐

PLEASE USE THIS SECTION TO PROVIDE ANY ADDITIONAL INFORMATION OR COMMENTS YOU HAVE.

Photographs and other information can also be emailed to South.Creek@advisian.com (please include your name and address so we can link your email to this questionnaire).

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Advisian WorleyParsons Group

Thank you for taking the time to complete this questionnaire.

It can be returned without a postage stamp or scanned and emailed to: South.Creek@advisian.com by **Friday 8th April 2016**. Flood photos and videos can also be sent to this email address or posted to:

Advisian
Level 17, 141 Walker Street,
North Sydney NSW 2060

Fold Here First

No stamp required
if posted in Australia

Delivery Address:
PO Box 60
PENRITH NSW 2751

Penrith City Council
Engineering Services – South Creek FRMS&P
Reply Paid 60
PENRITH NSW 2751

Fold Here Second

How to send back this questionnaire...

Please fold this questionnaire using 'Fold Here' lines as a guide to form a business sized envelope with the address on the front and this text box on the back. Seal the folded pages with tape on all sides to help maintain privacy (please do not use staples) and then post it.

Penrith City Council
PO Box 60, Penrith
NSW 2751 Australia
T 4732 7777
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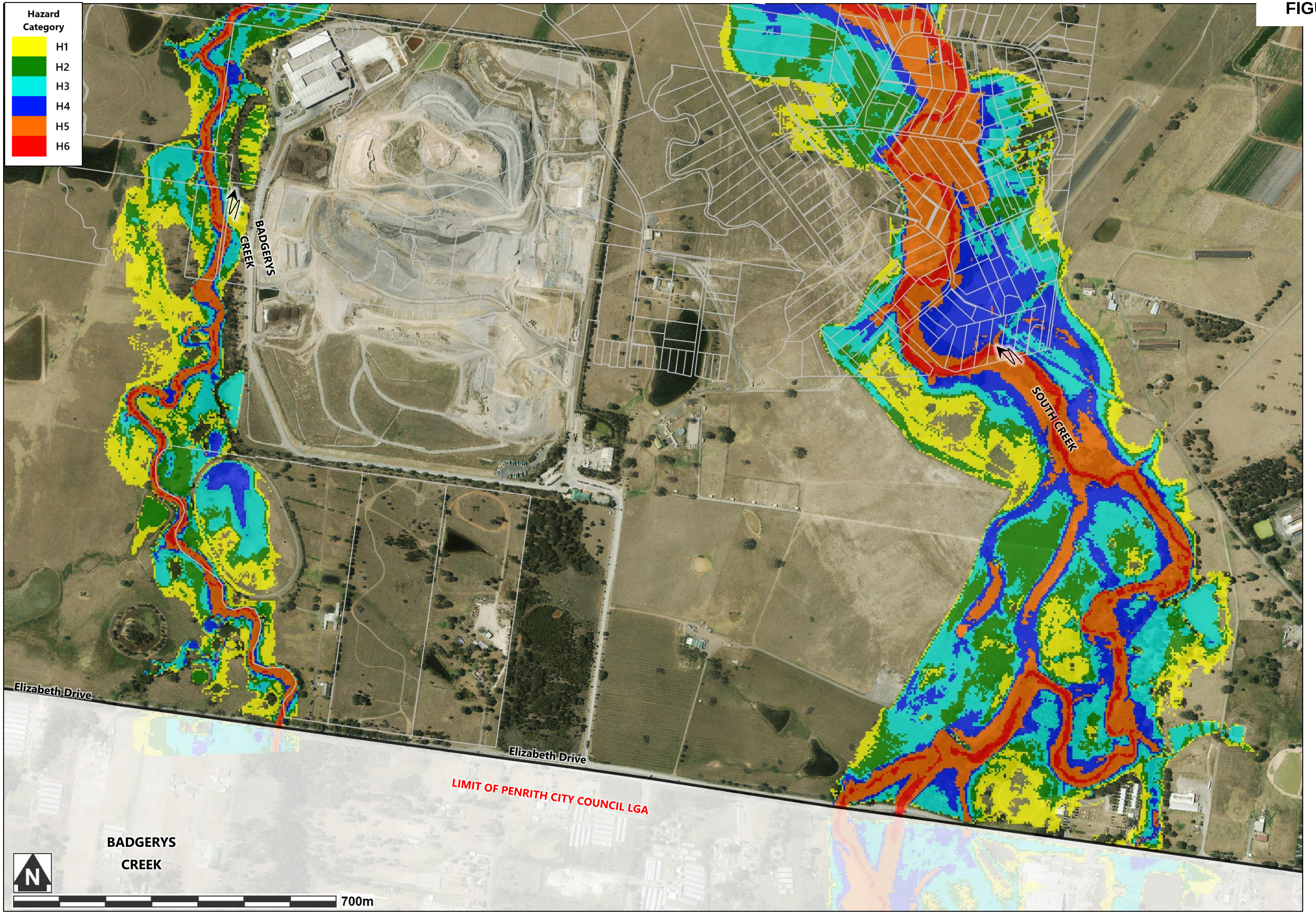
PENRITH CITY COUNCIL · NSW GOVERNMENT Office of Environment & Heritage · SES NSW STATE EMERGENCY SERVICE · Advisian WorleyParsons Group

Appendix B – True Flood Hazard Mapping

(5% AEP and 1% AEP floods and the PMF)

FIGURE B.1



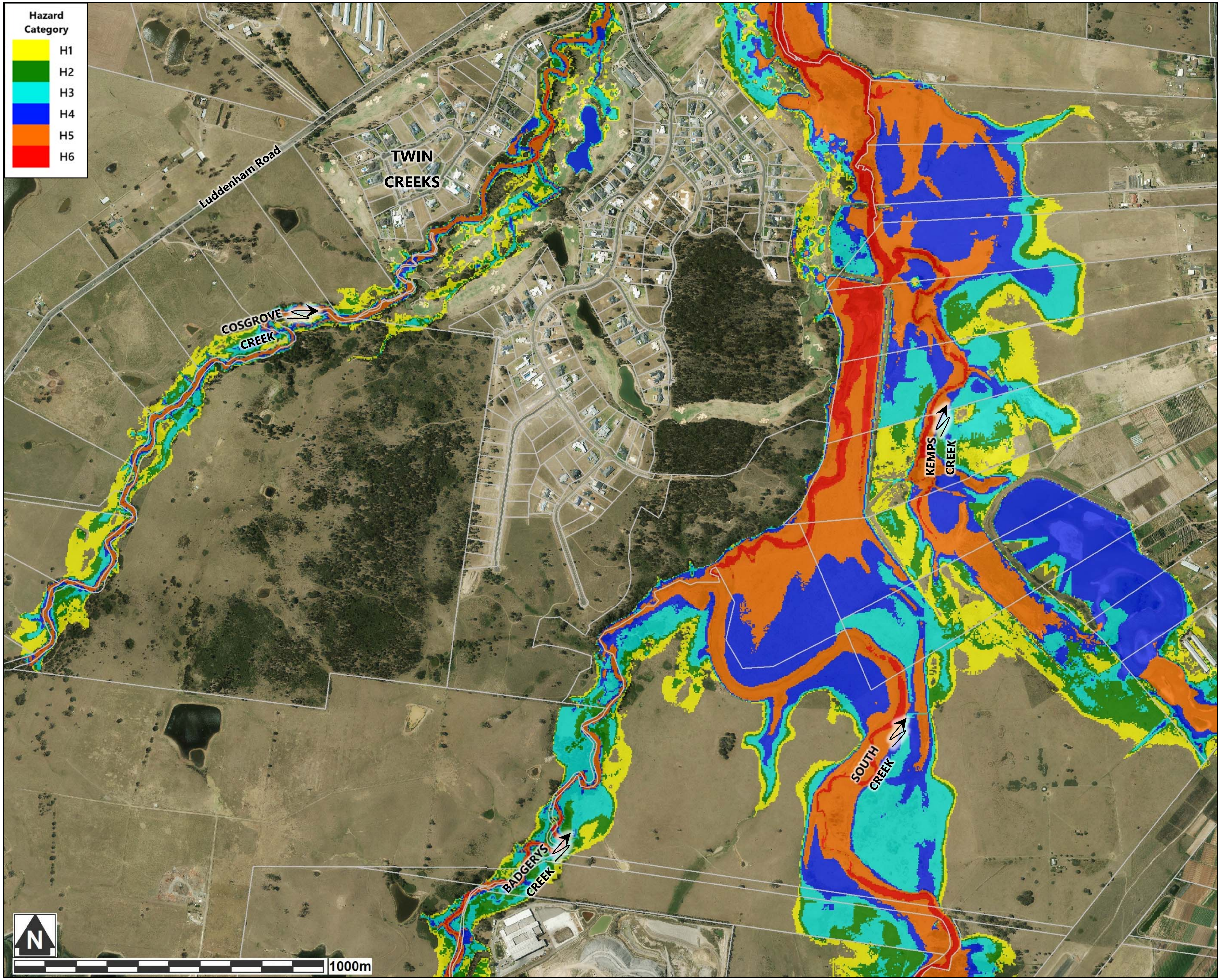
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.1-20yr ARI True Hazard (1 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 1 OF 12]



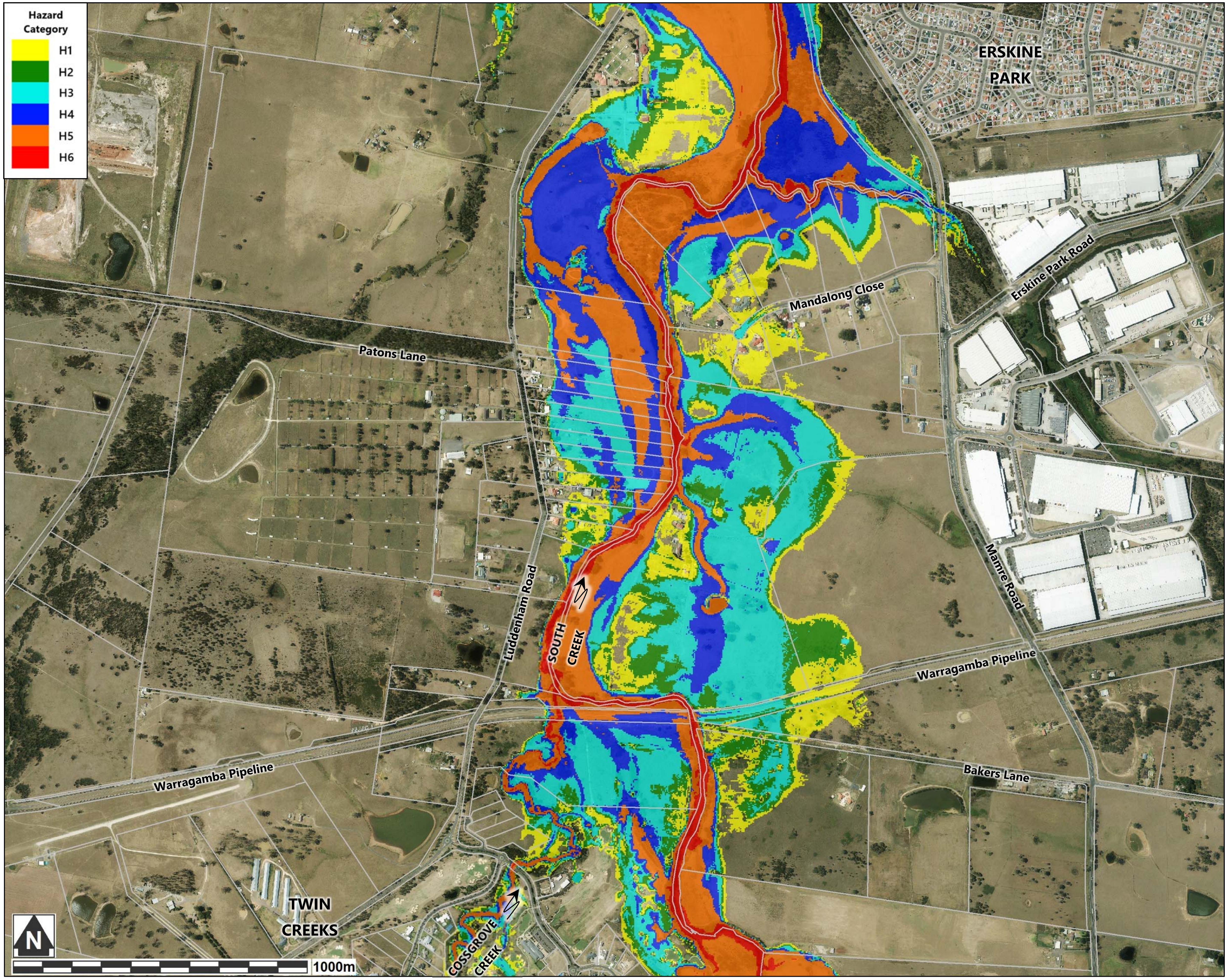
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.2-20yr ARI True Hazard (2 of 12)

NOTES:
1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.*

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 2 OF 12]

FIGURE B.3



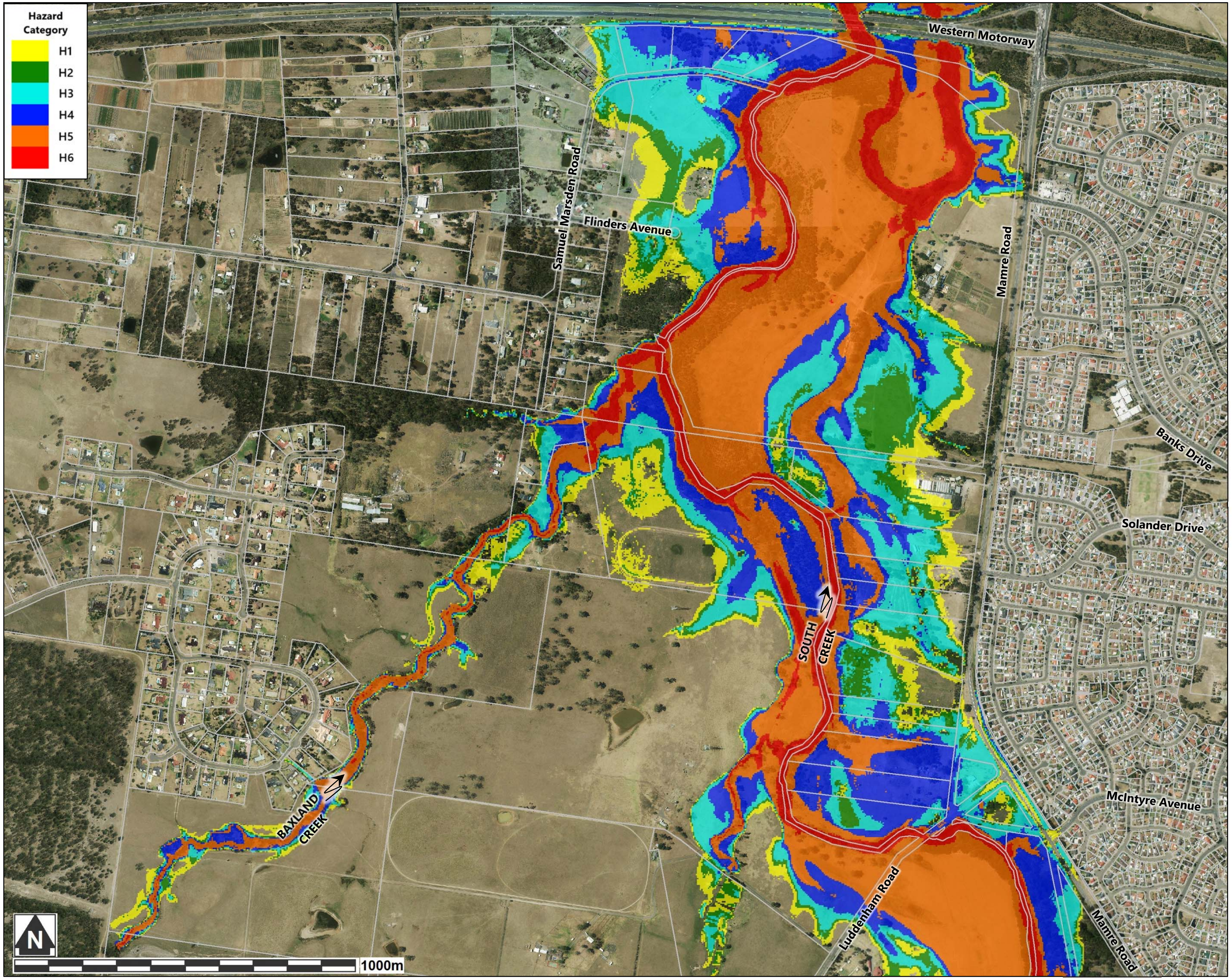
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.3-20yr ARI True Hazard (3 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 3 OF 12]



Advisian
Worley Group

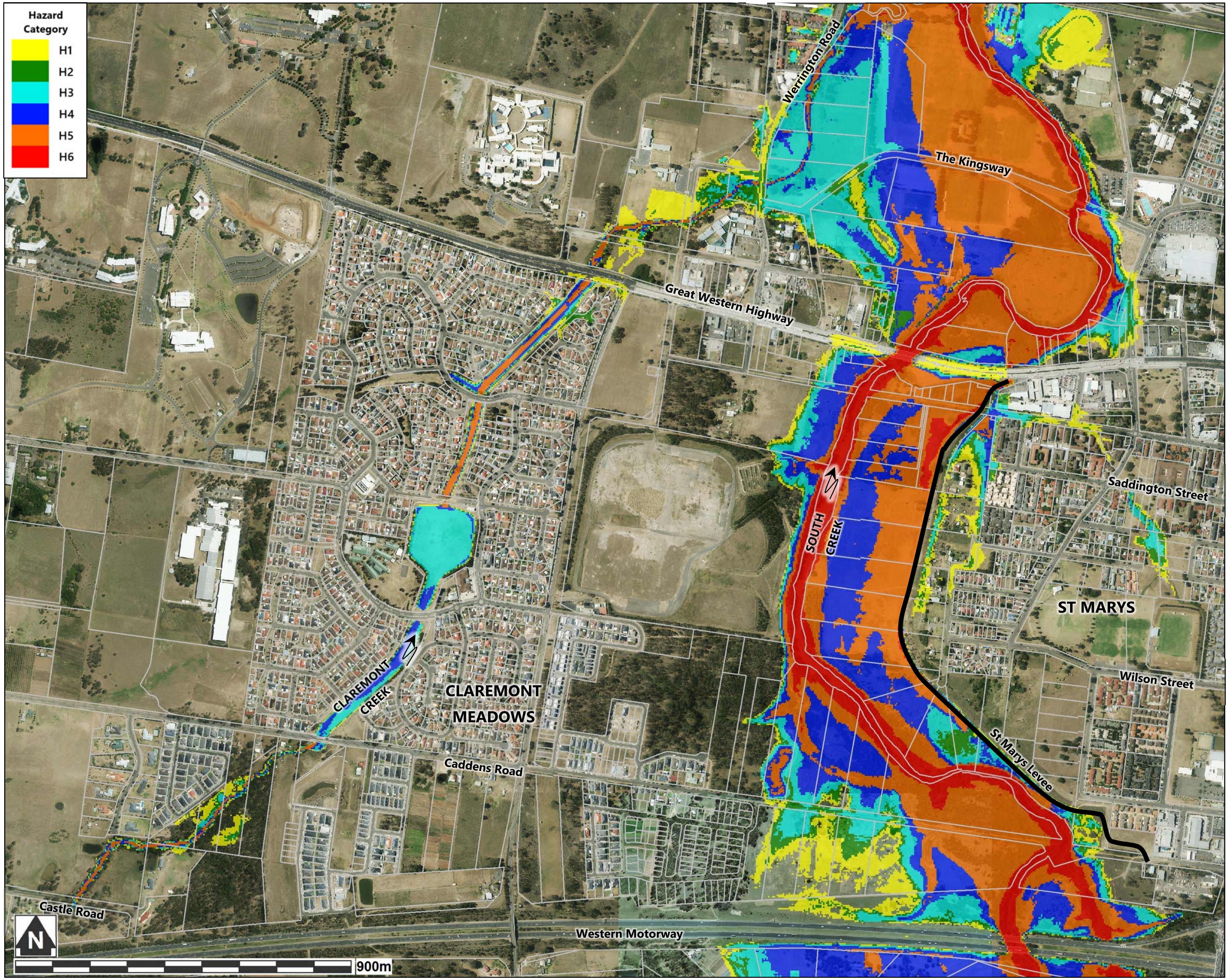
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.4-20yr ARI True Hazard (4 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 4 OF 12]

FIGURE B.5



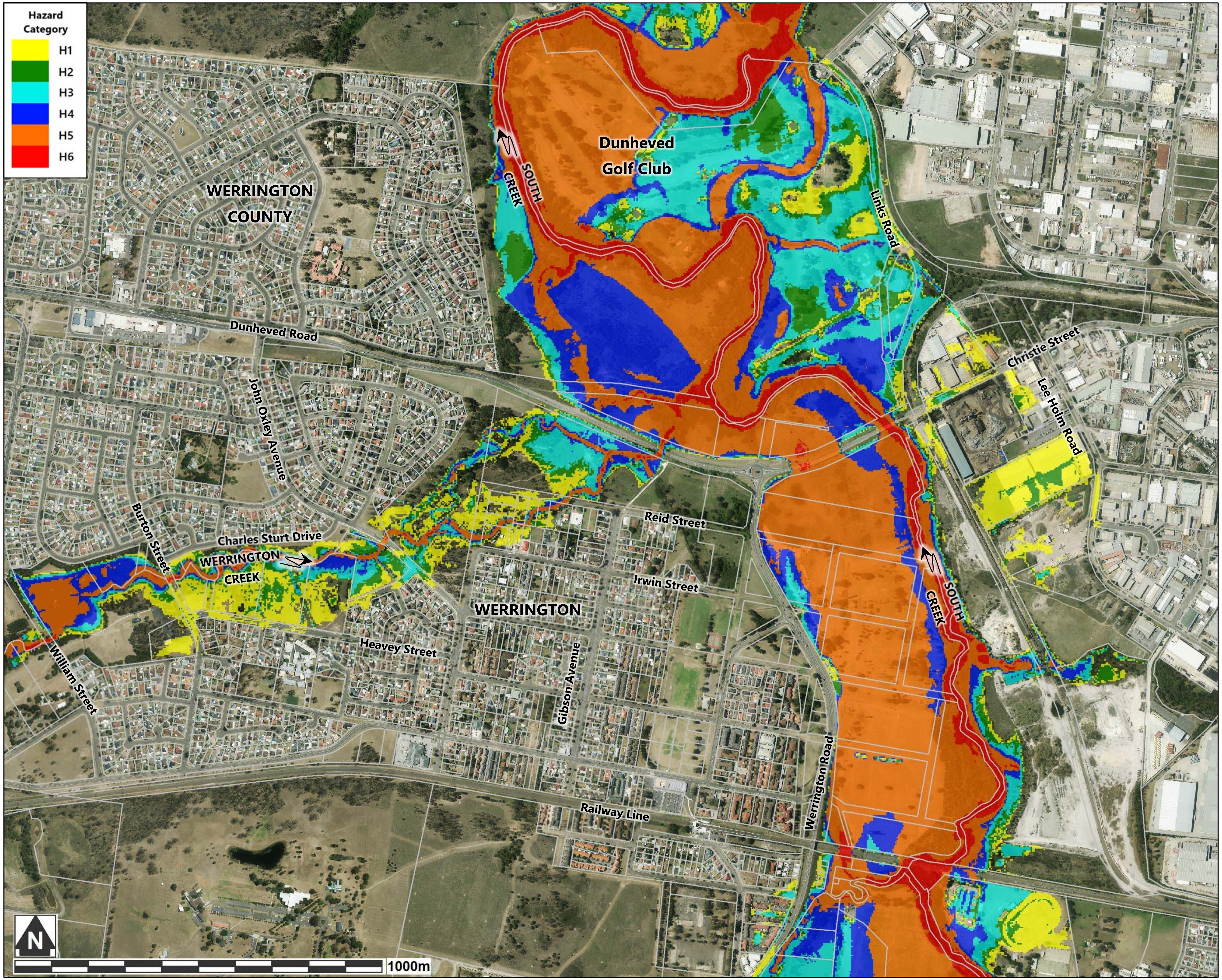
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.5-20yr ARI True Hazard (5 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 5 OF 12]

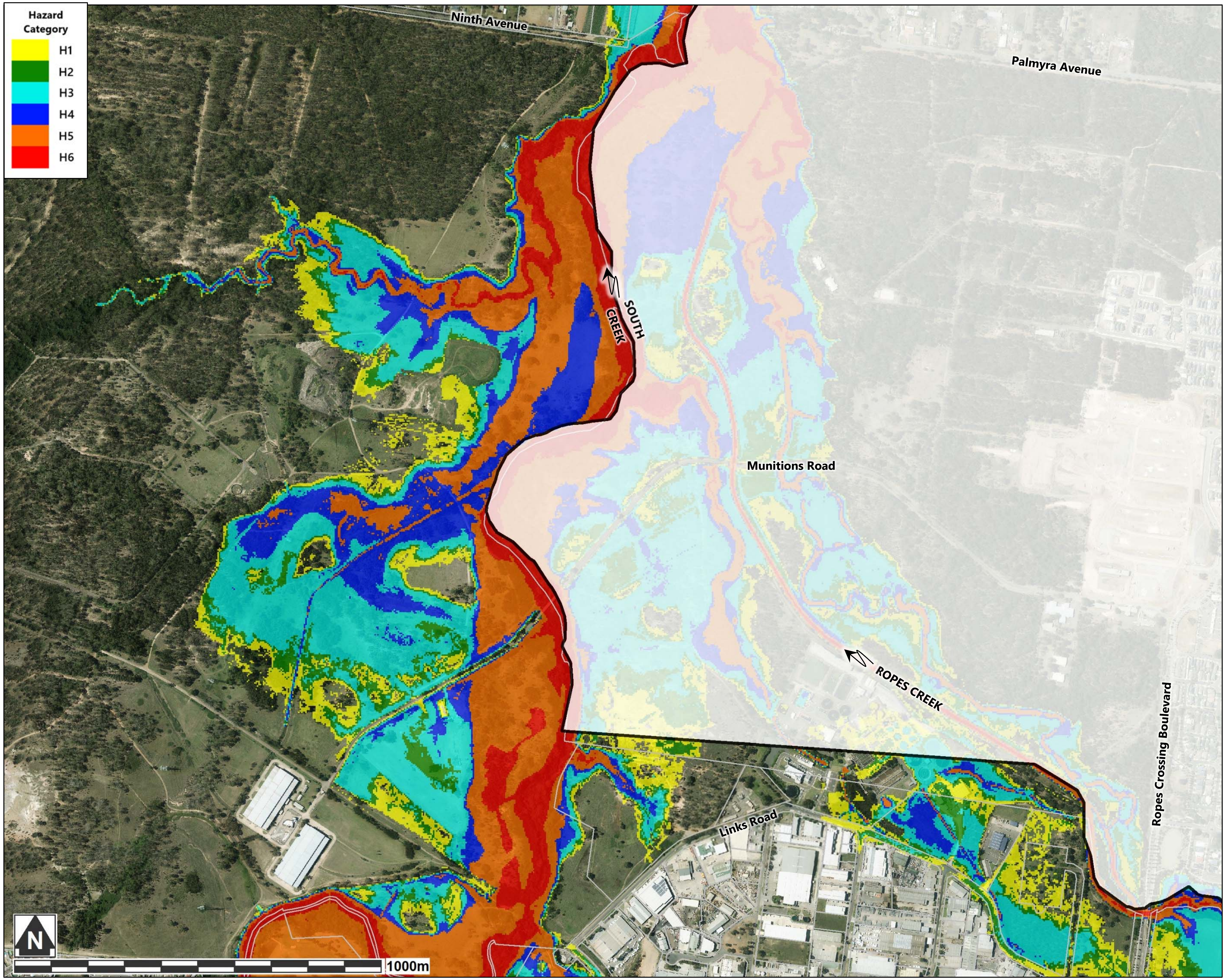


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.6-20yr ARI True Hazard (6 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 6 OF 12]



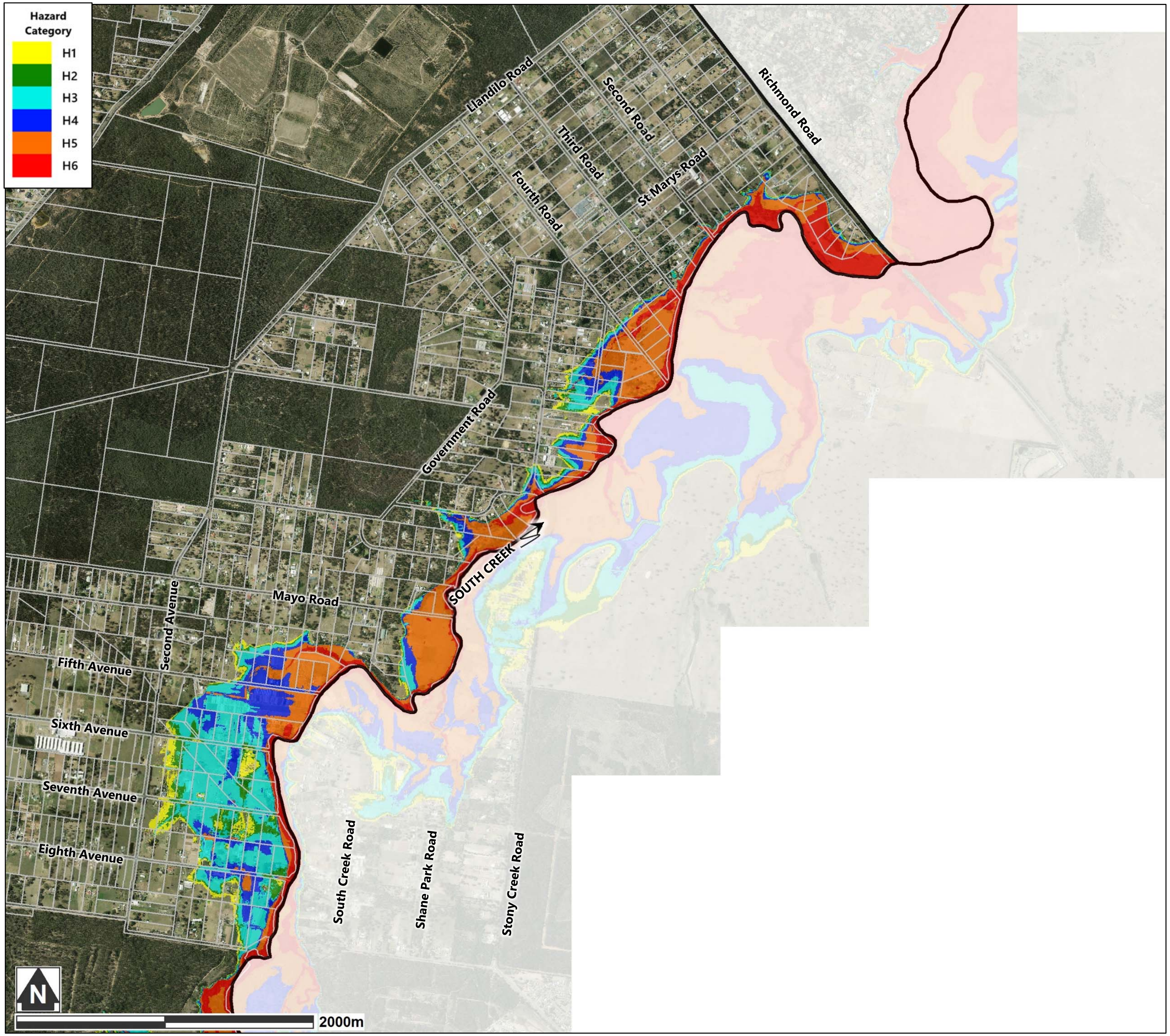
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.7-20yr ARI True Hazard (7 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 7 OF 12]

FIGURE B.8



Advisian

Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.8-20yr ARI True Hazard (8 of 12)

NOTES:
1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.*

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 8 OF 12]

FIGURE B.9

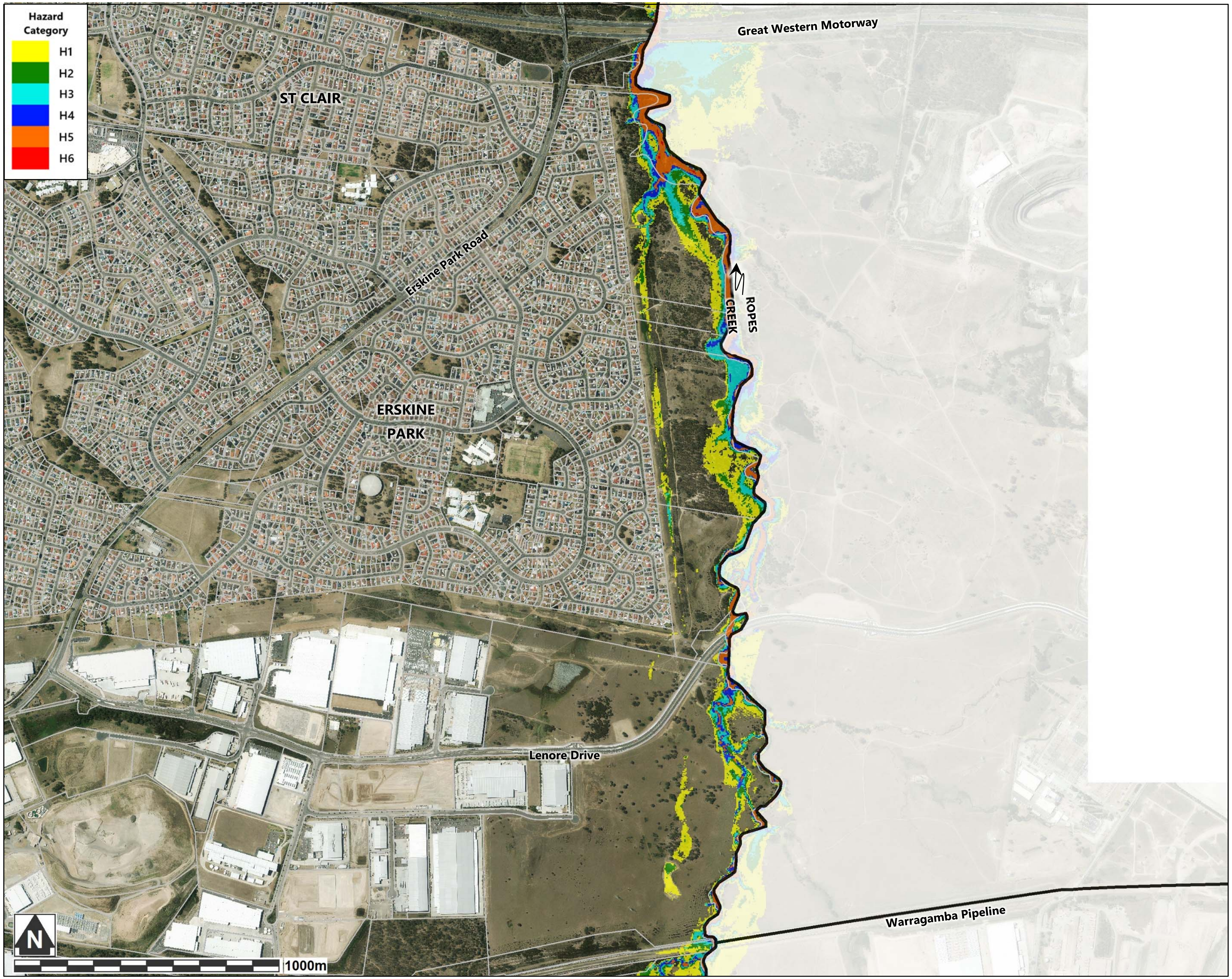
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.9-20yr ARI True Hazard (9 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 9 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.10-20yr ARI True Hazard (10 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 10 OF 12]

Advisian
Worley Group

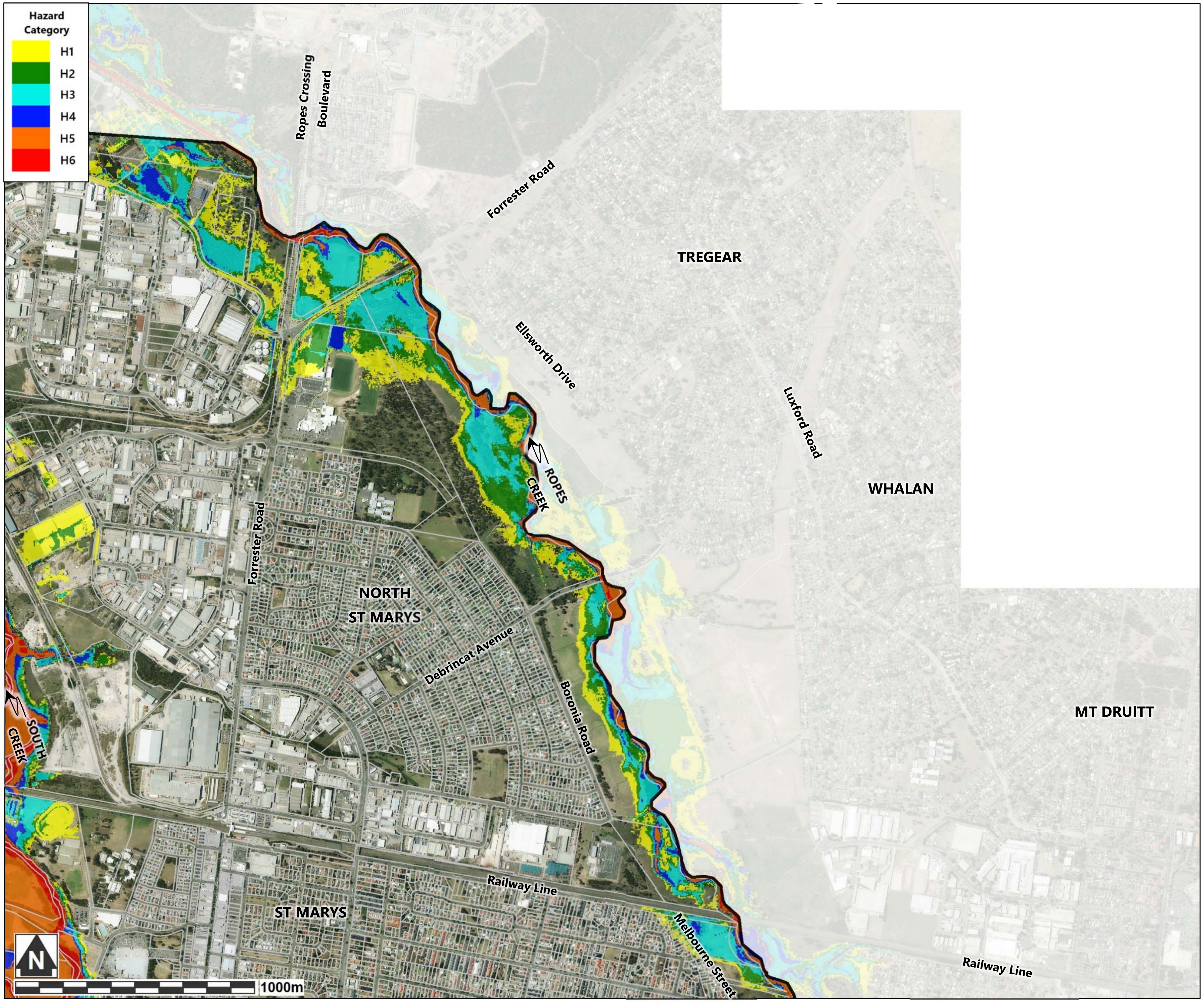
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.11-20yr ARI True Hazard (11 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 11 OF 12]

FIGURE B.12



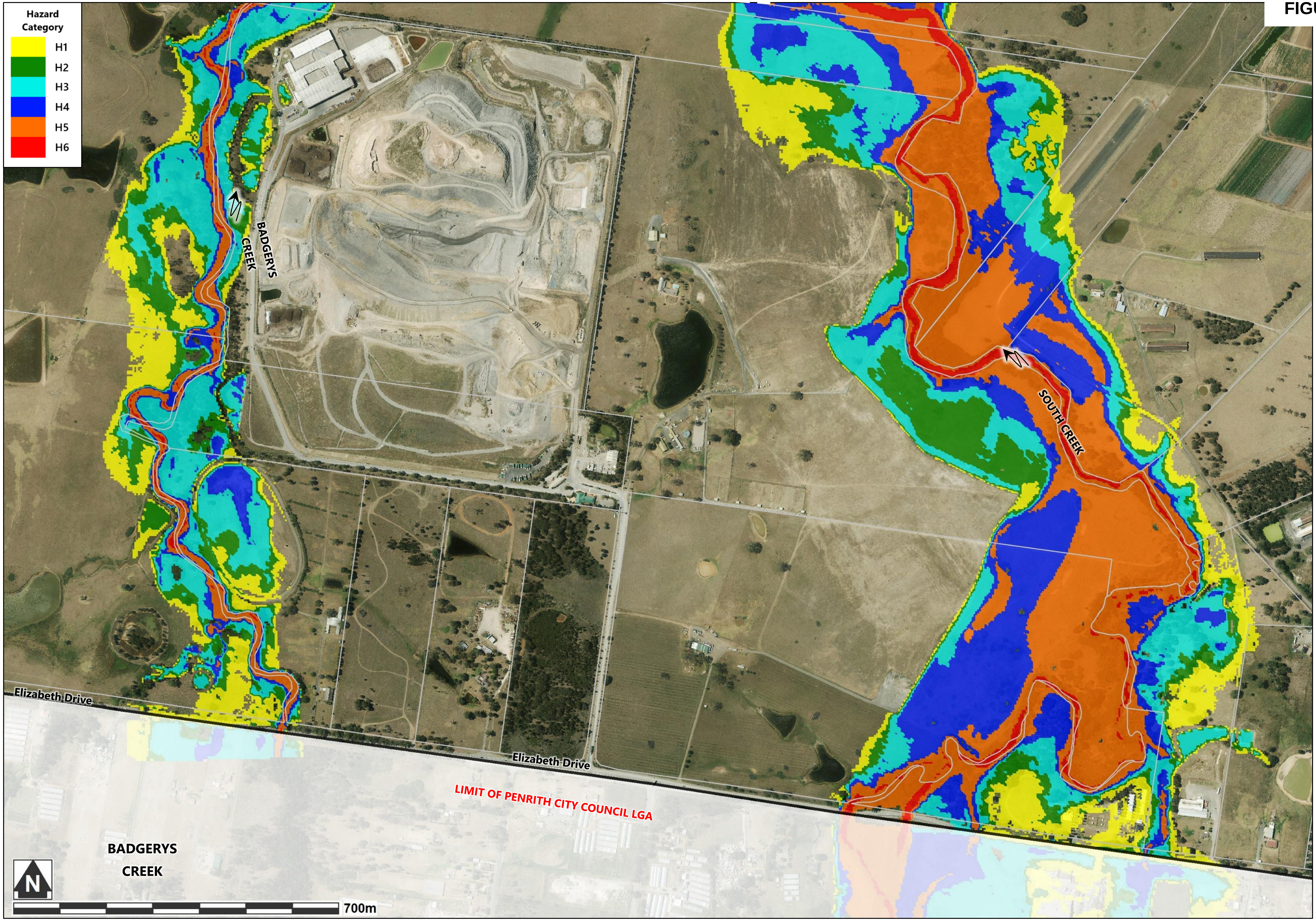
Advisian
WorleyParsons Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.12-20yr ARI True Hazard (12 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 5% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 12 OF 12]



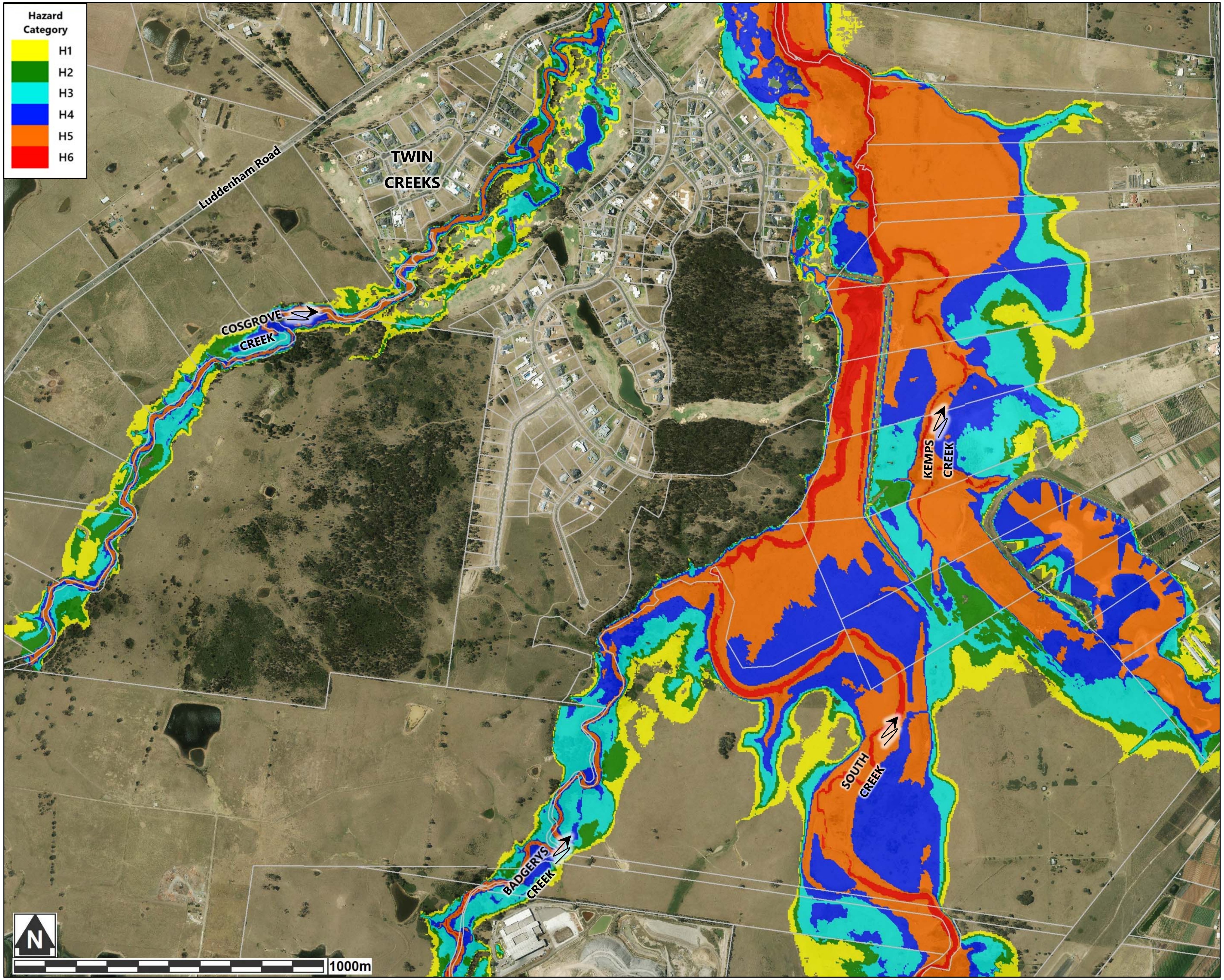
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.13-100yr ARI True Hazard (1 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 1 OF 12]



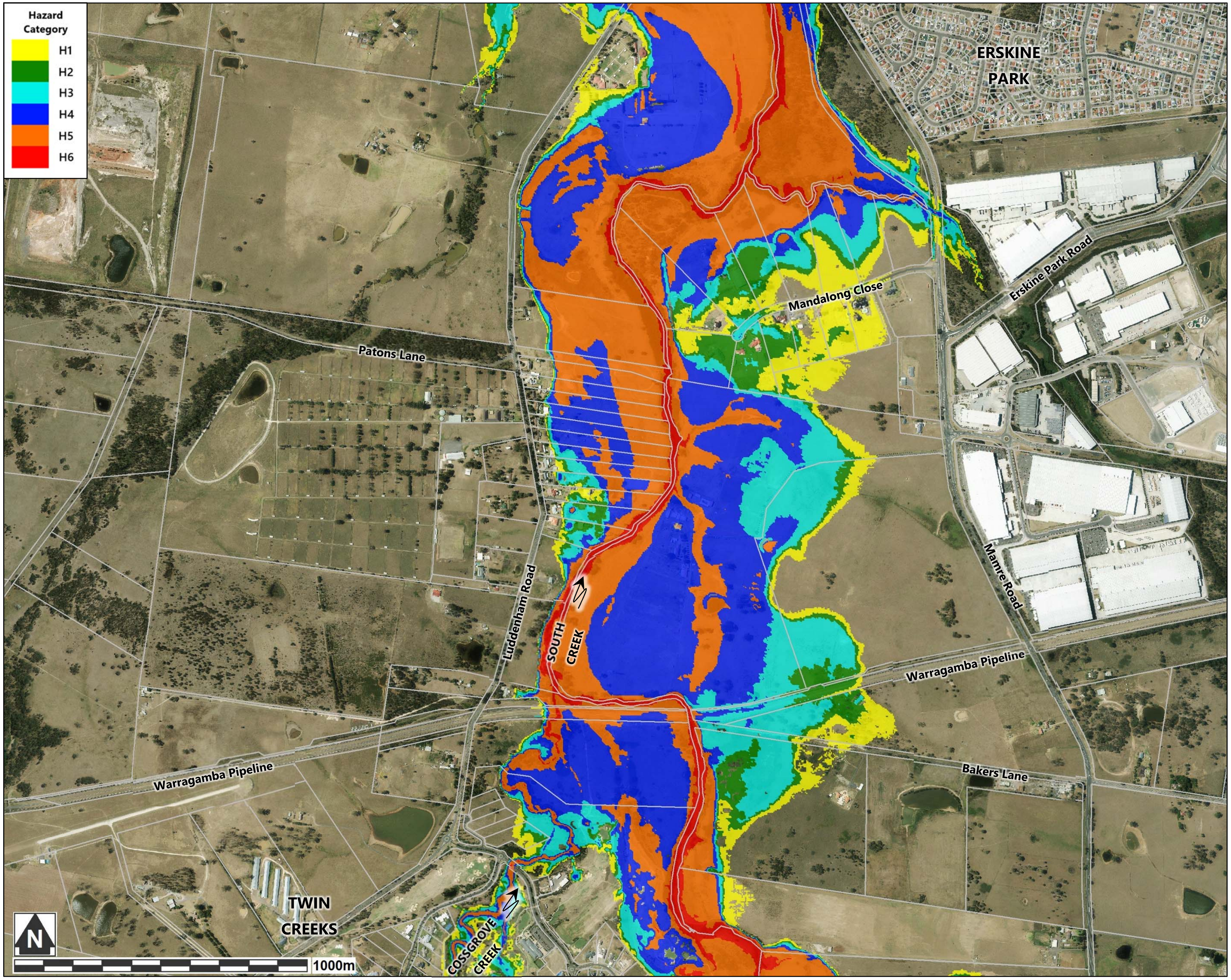
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.14-100yr ARI True Hazard (2 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 2 OF 12]



Advisian
Worley Group

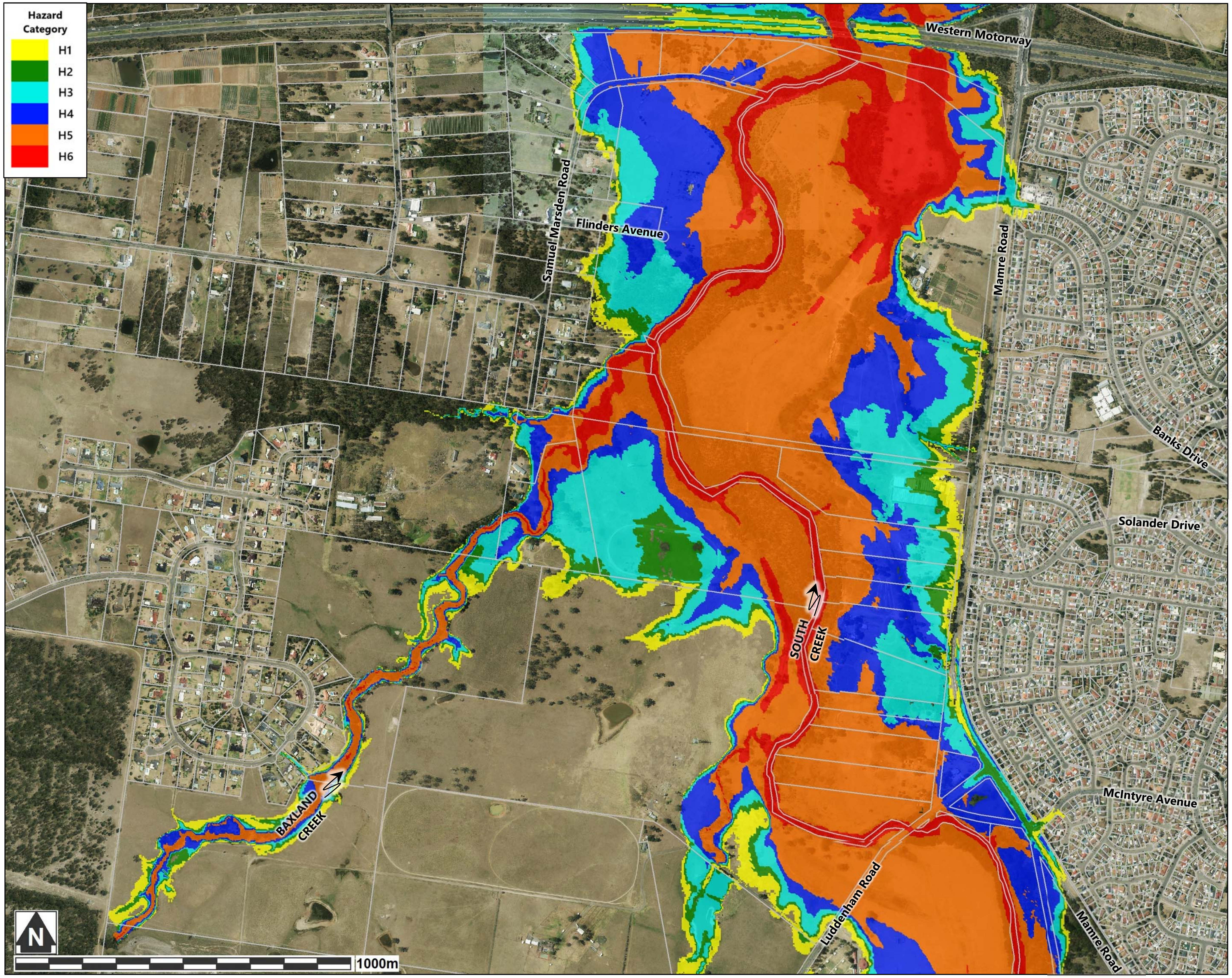
301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig B.15-100yr ARI True Hazard (3 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 3 OF 12]

FIGURE B.16



Advisian
Worley Group

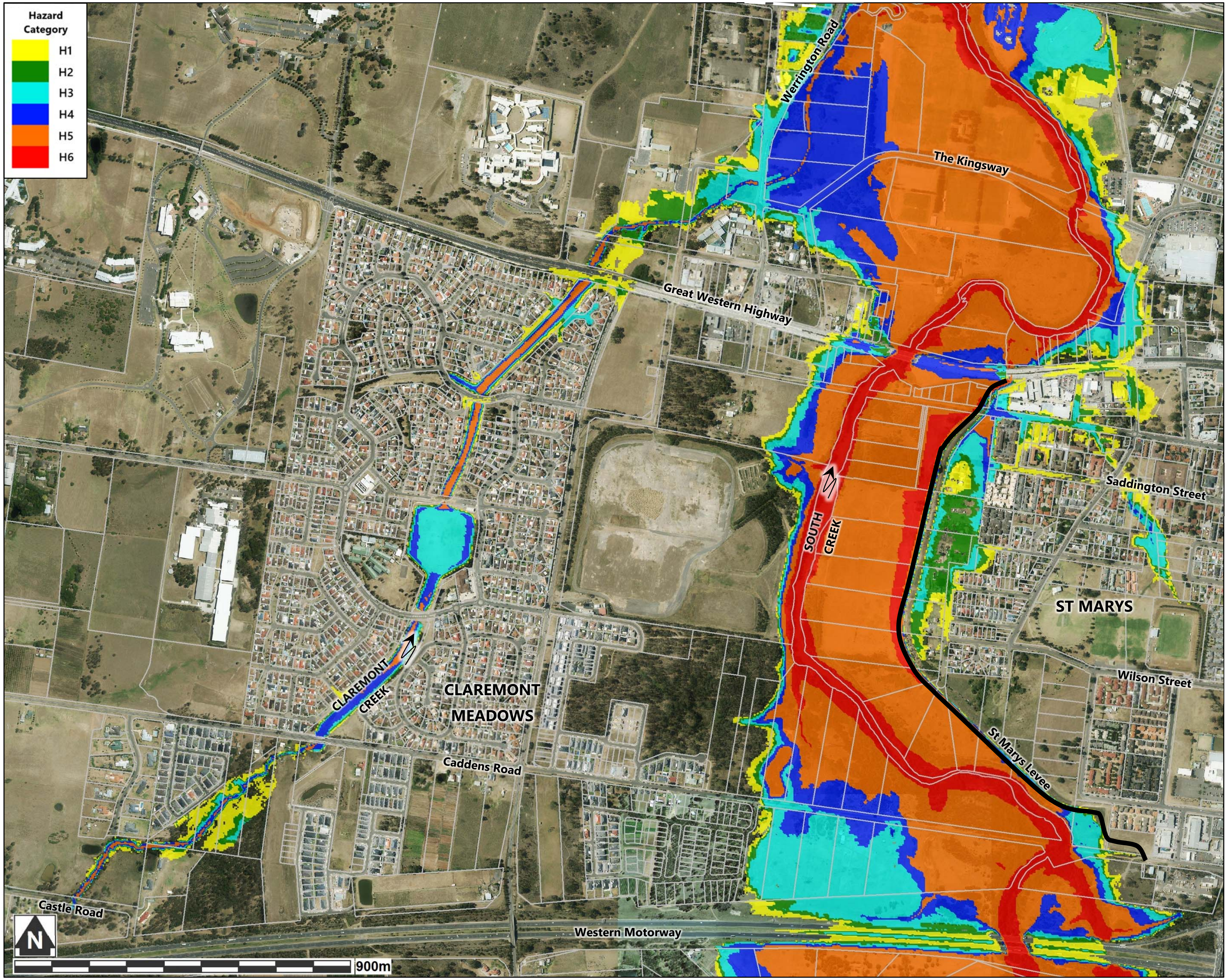
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.16-100yr ARI True Hazard (4 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 4 OF 12]

FIGURE B.17



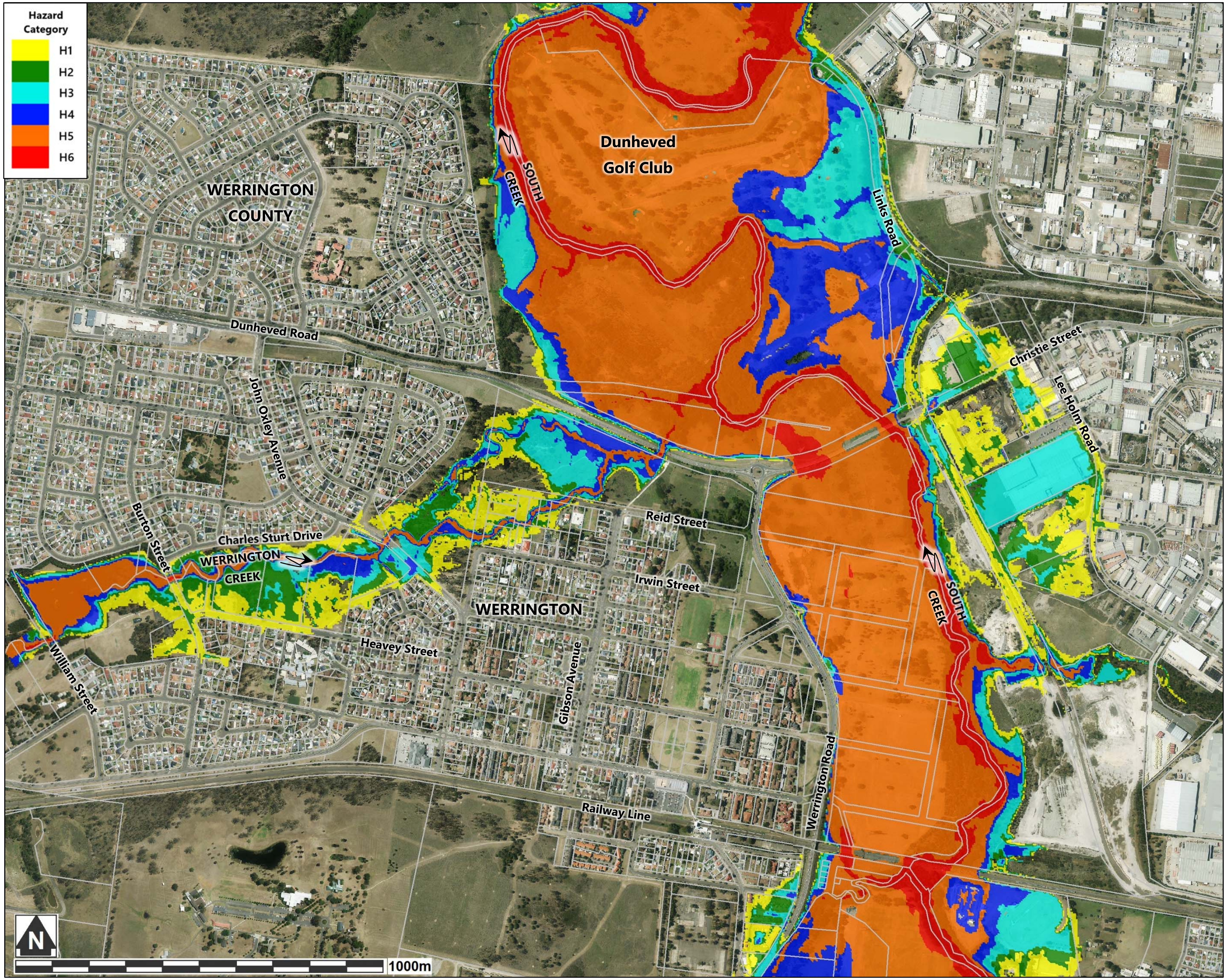
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.17-100yr ARI True Hazard (5 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 5 OF 12]

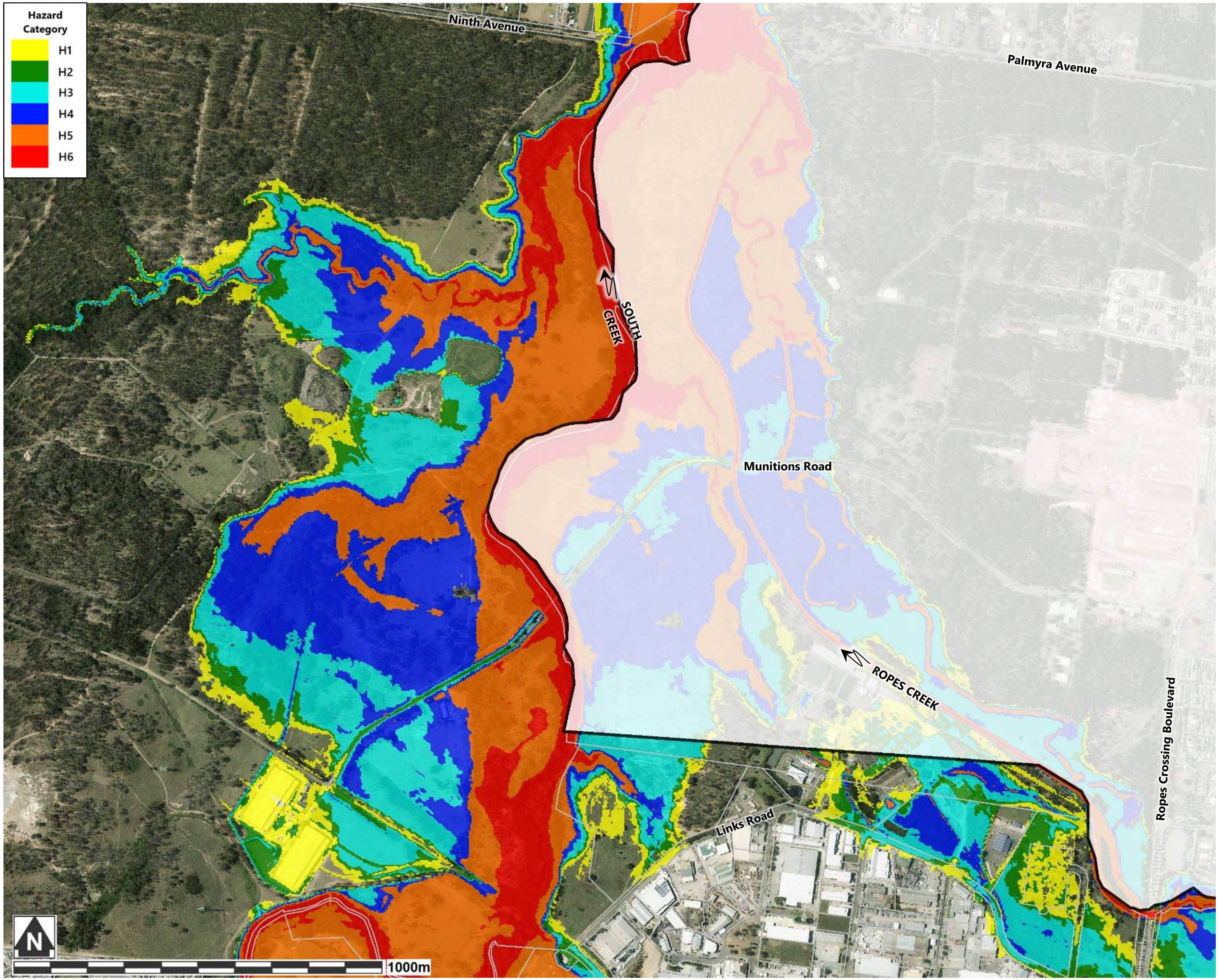


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.18-100yr ARI True Hazard (6 of 12)

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 6 OF 12]

FIGURE B.19

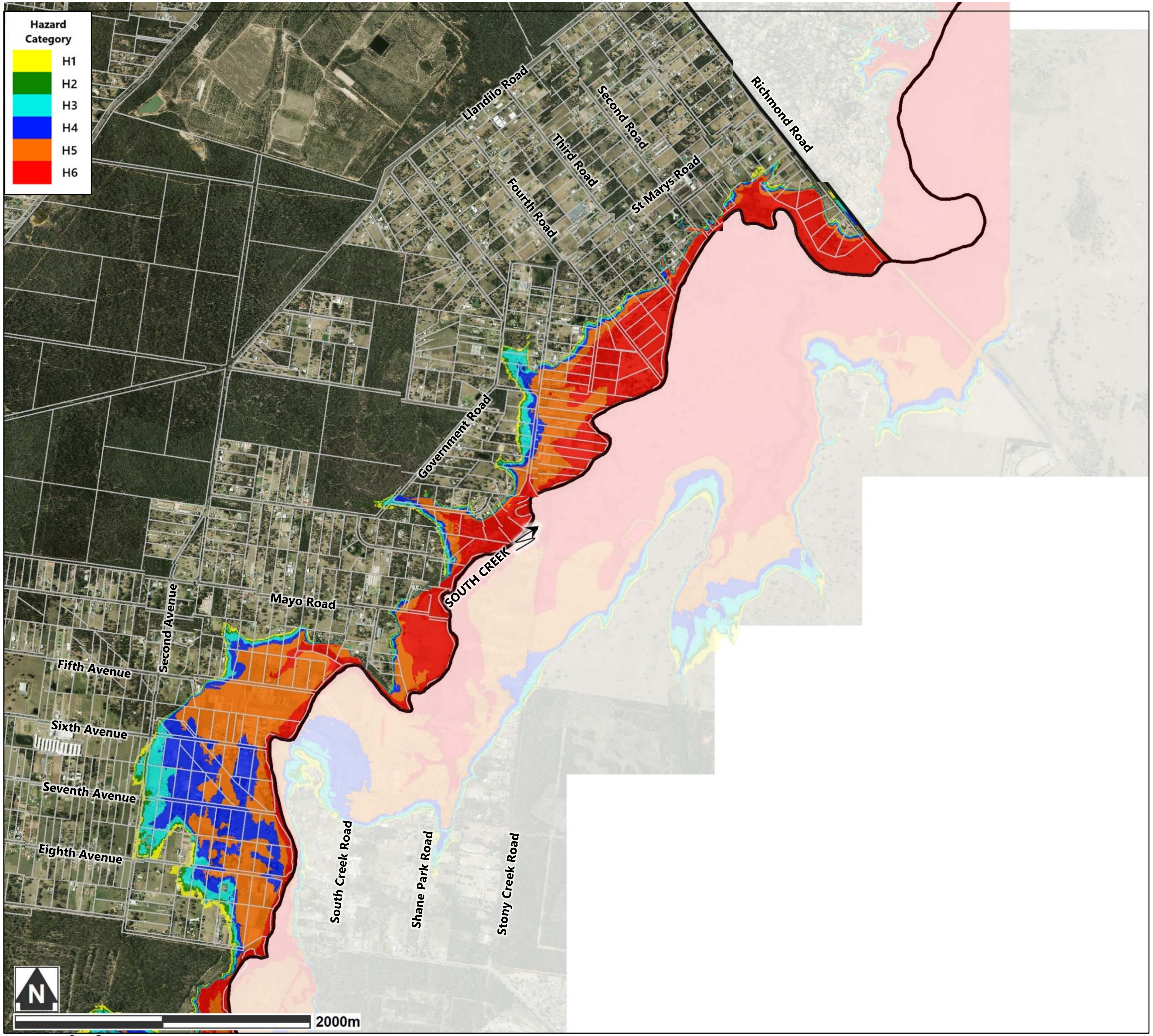


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.19-100yr ARI True Hazard (7 of 12)

NOTES:
1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.*

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 7 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.20-100yr ARI True Hazard (8 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 8 OF 12]

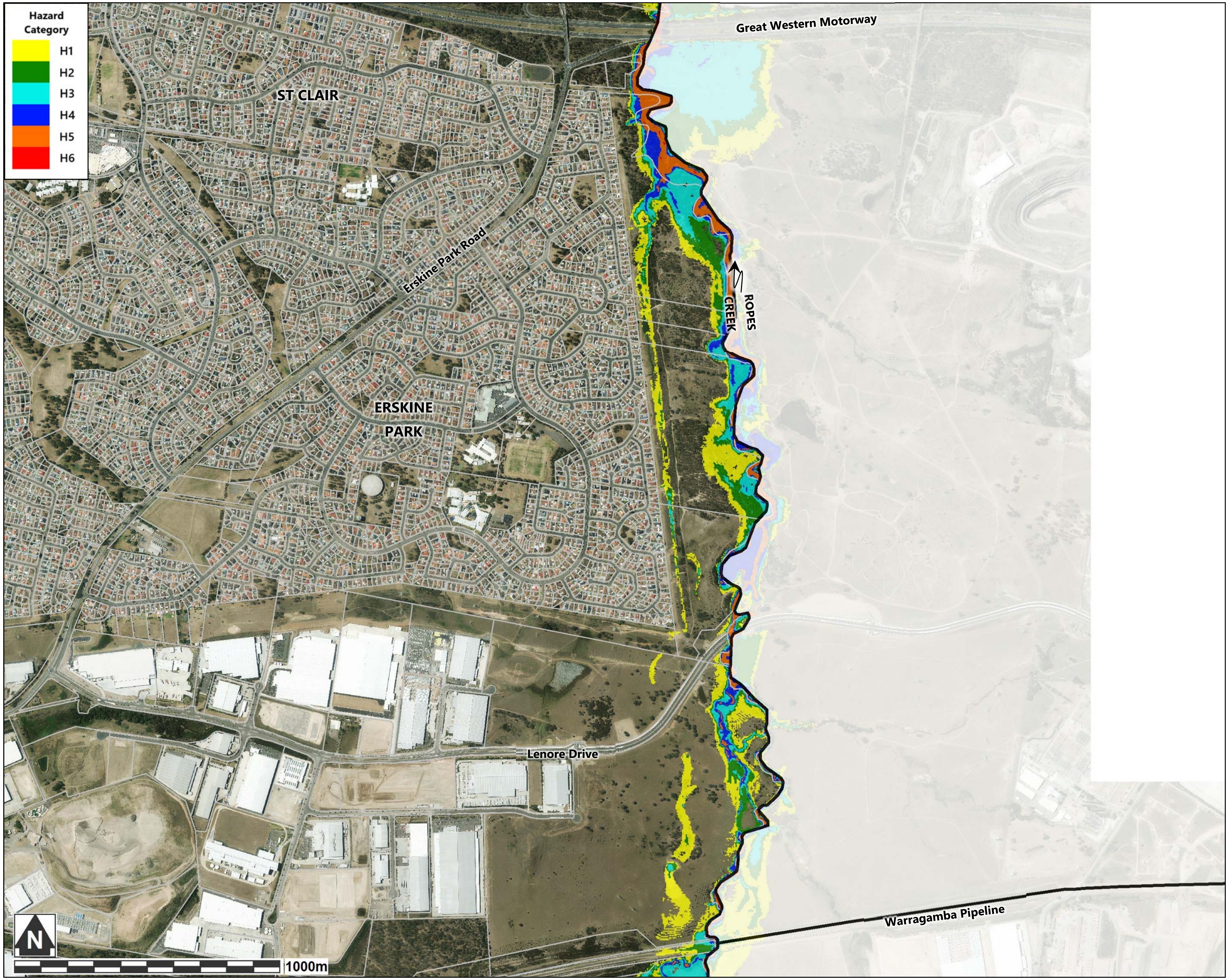
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.21-100yr ARI True Hazard (9 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 9 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.22-100yr ARI True Hazard (10 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 10 OF 12]

FIGURE B.23

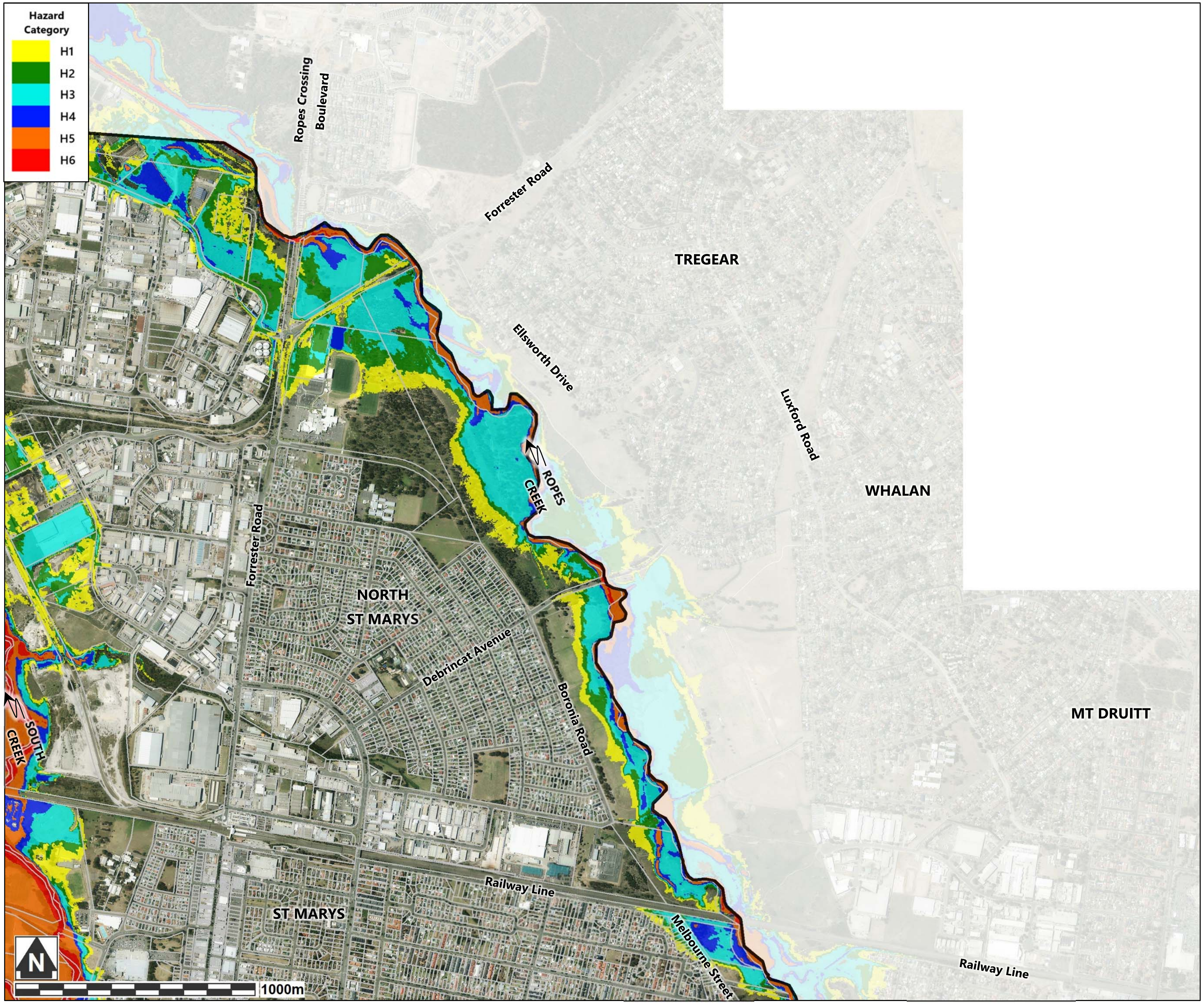
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.23-100yr ARI True Hazard (11 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 11 OF 12]

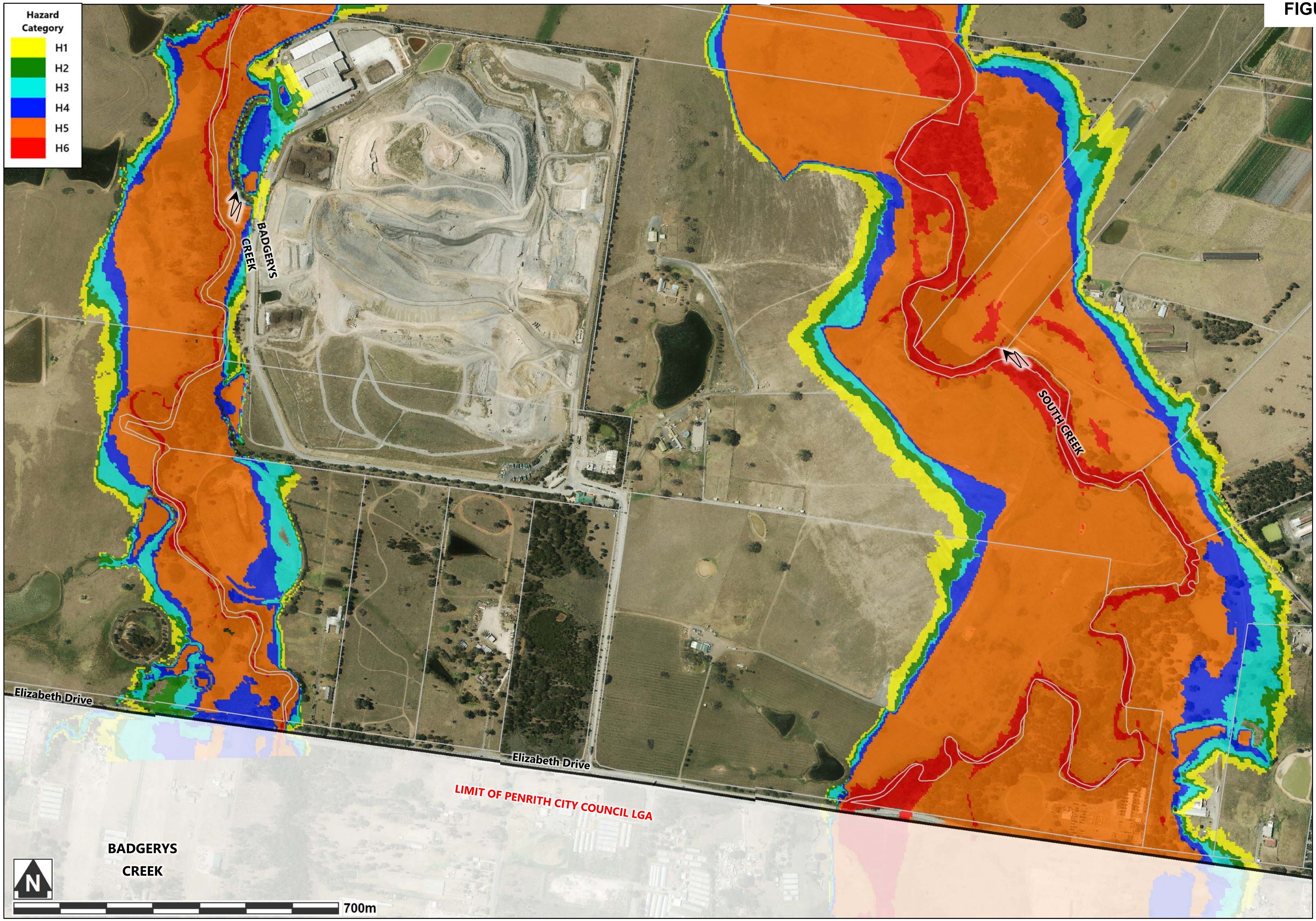


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.24-100yr ARI True Hazard (12 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE 1% ANNUAL EXCEEDANCE PROBABILITY (AEP) FLOOD [EXTENT 12 OF 12]



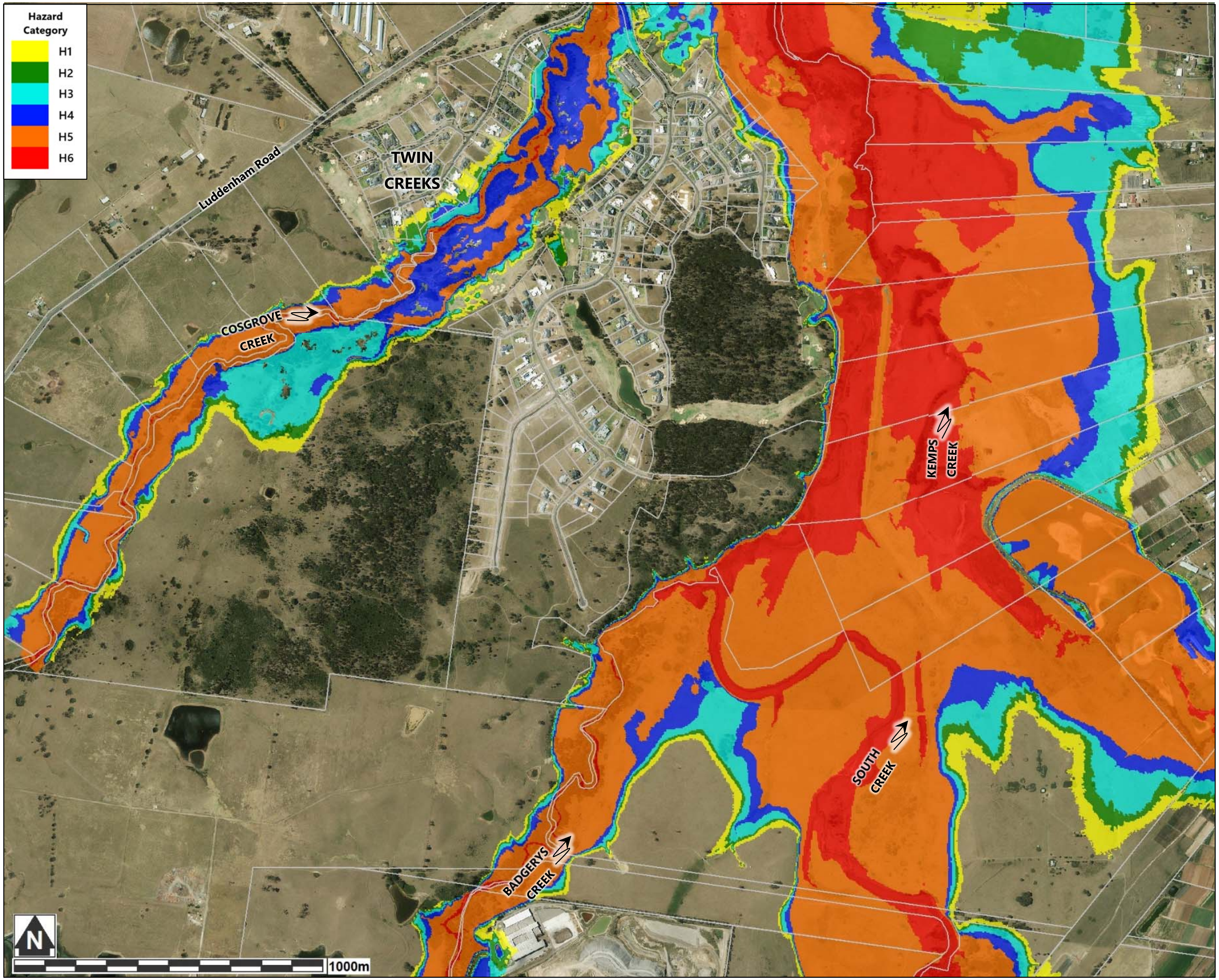
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.25-PMF True Hazard (1 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 1 OF 12]



Advisian
Worley Group

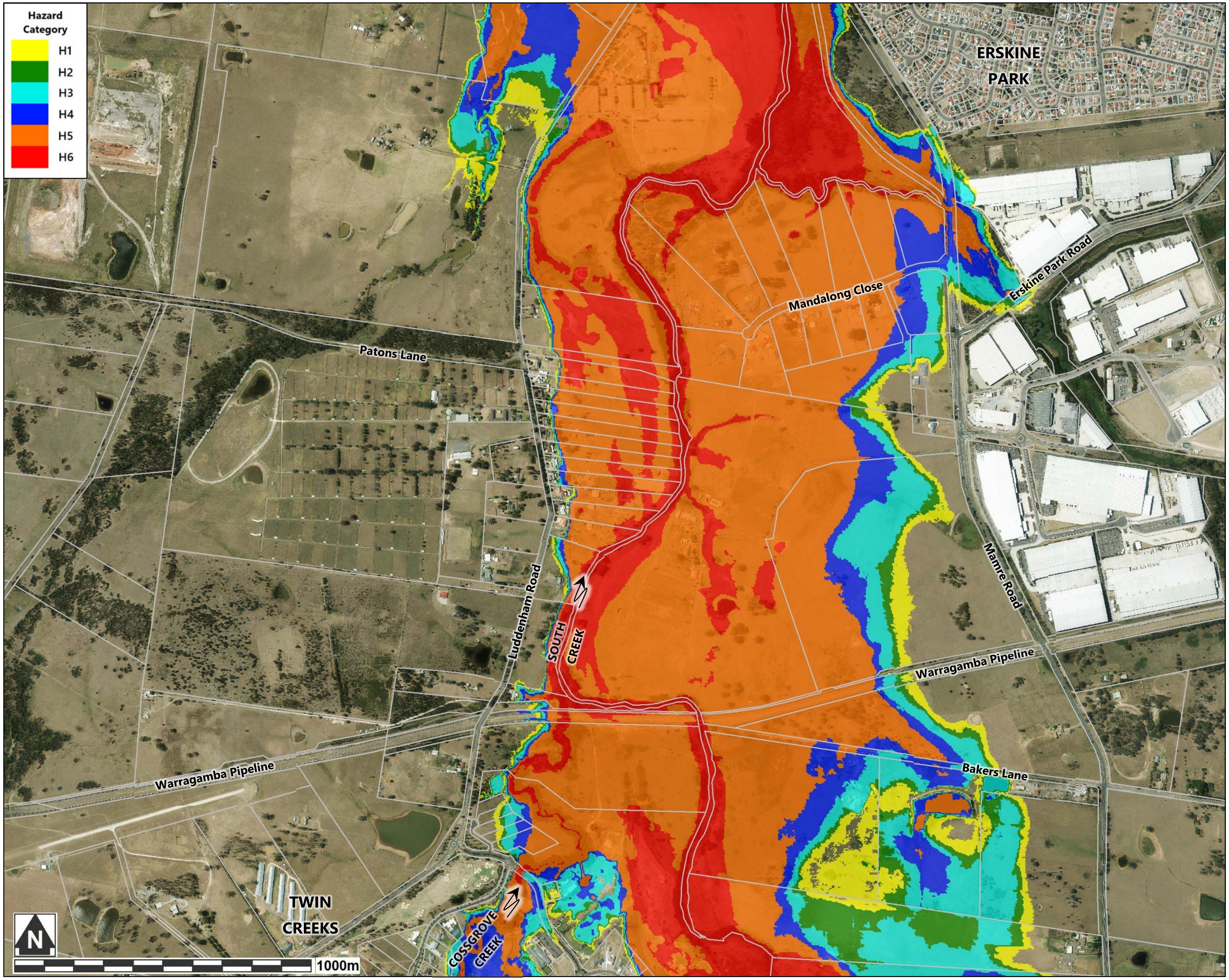
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.26-PMF True Hazard (2 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 2 OF 12]

FIGURE B.27



Advisian
Worley Group

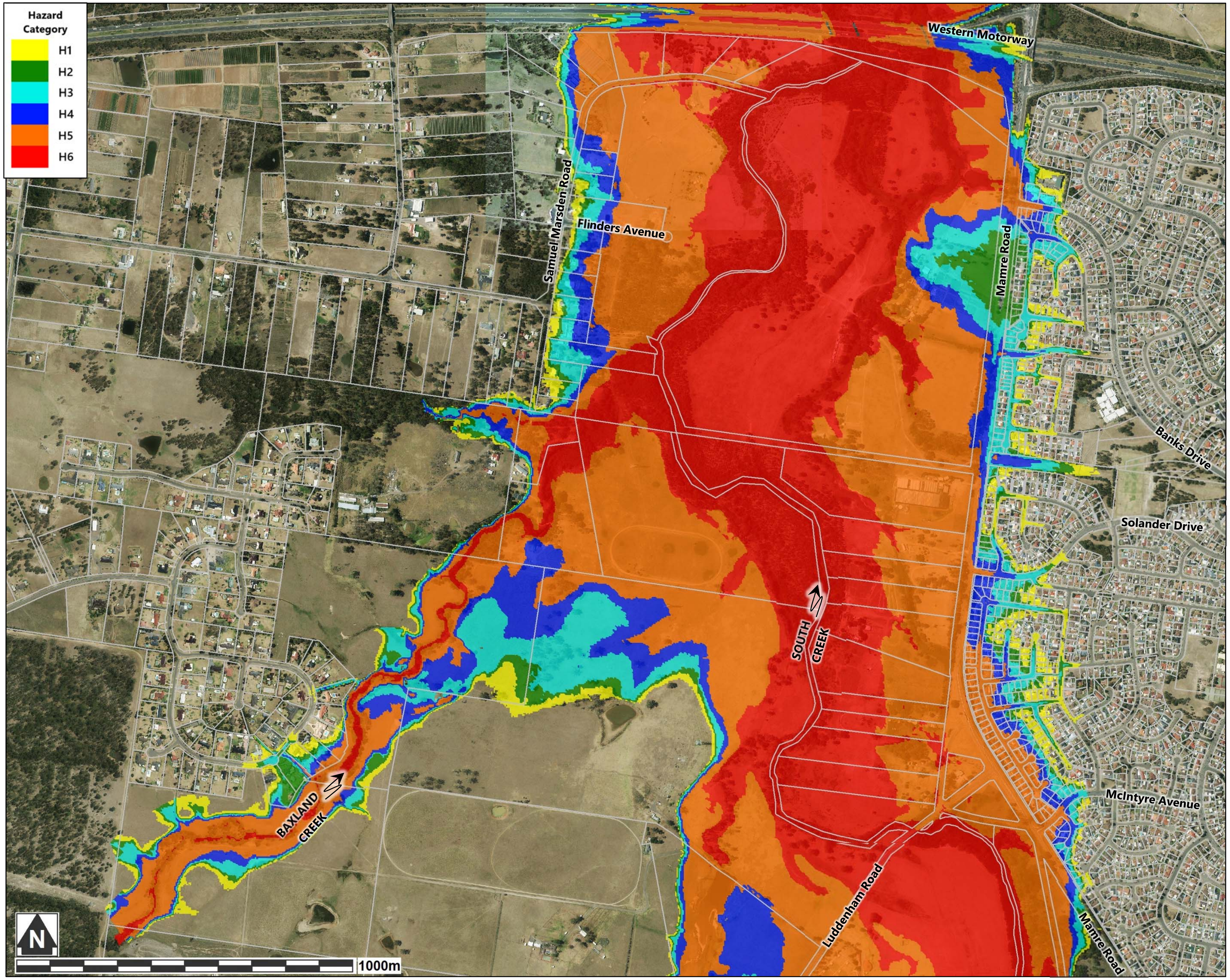
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.27-PMF True Hazard (3 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 3 OF 12]

FIGURE B.28

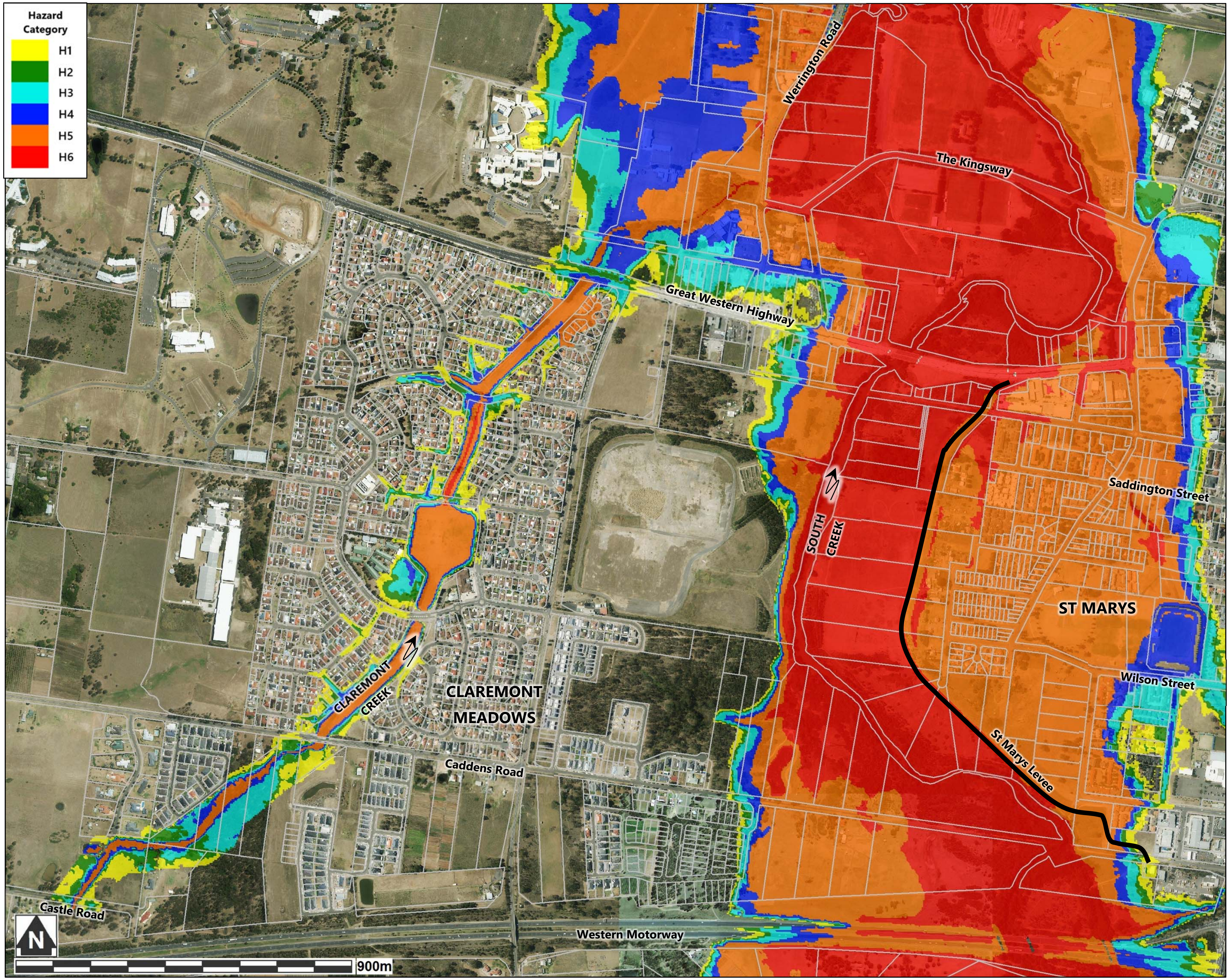


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.28-PMF True Hazard (4 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 4 OF 12]



Advisian
Worley Group

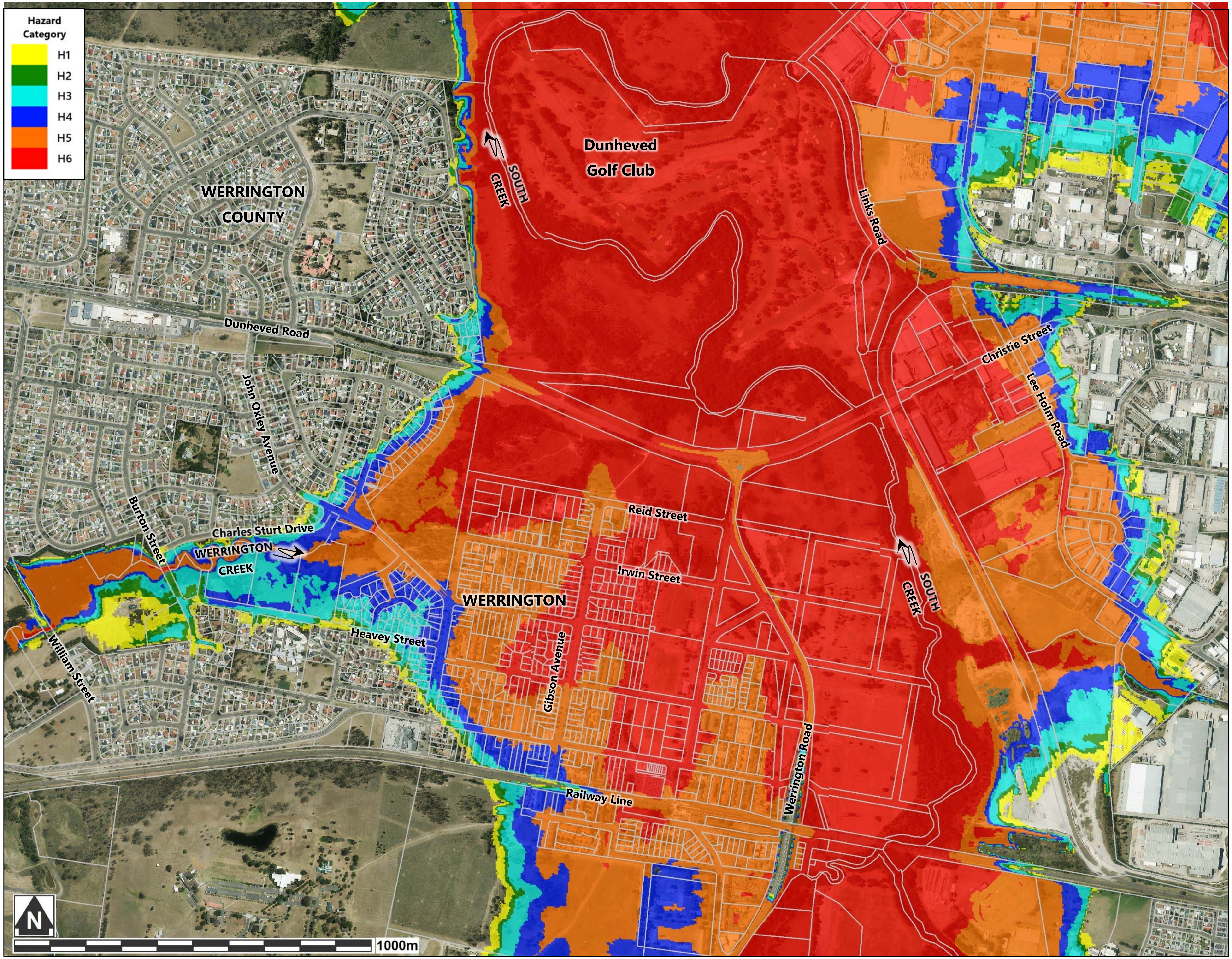
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.29-PMF True Hazard (5 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 5 OF 12]

FIGURE B.30



Advisian
Worley Group

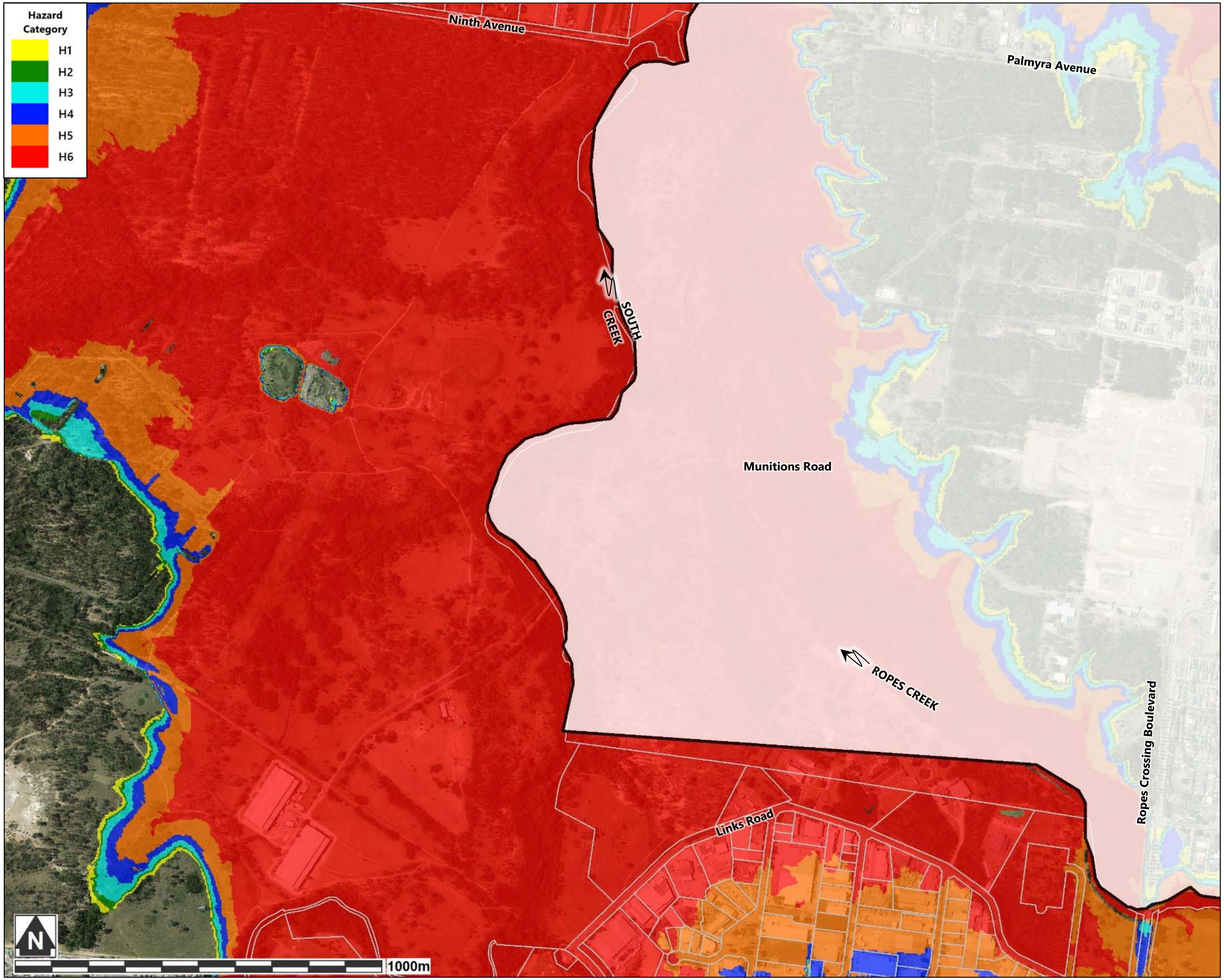
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.30-PMF True Hazard (6 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 6 OF 12]

FIGURE B.31



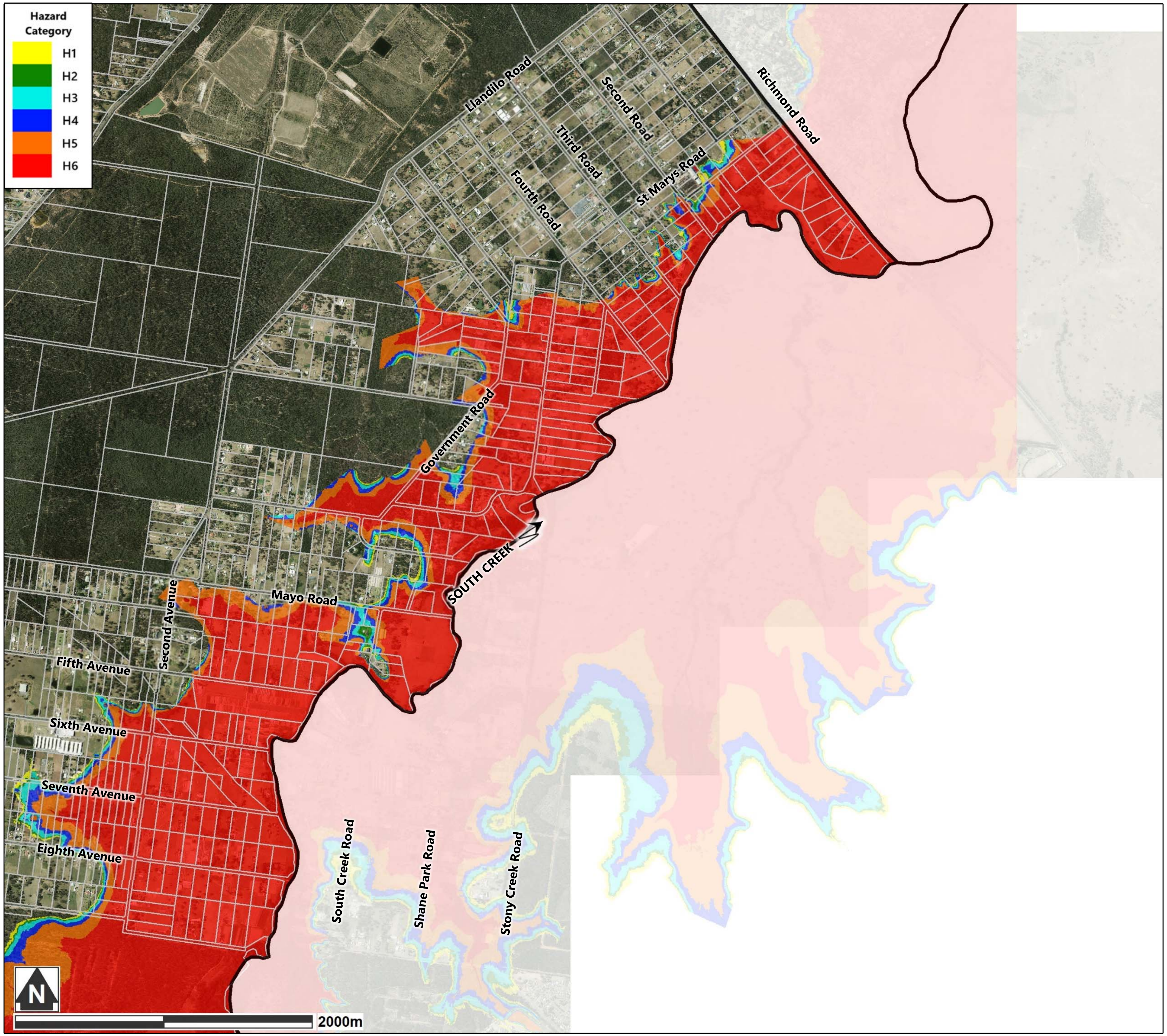
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.31-PMF True Hazard (7 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 7 OF 12]



Advisian
Worley Group

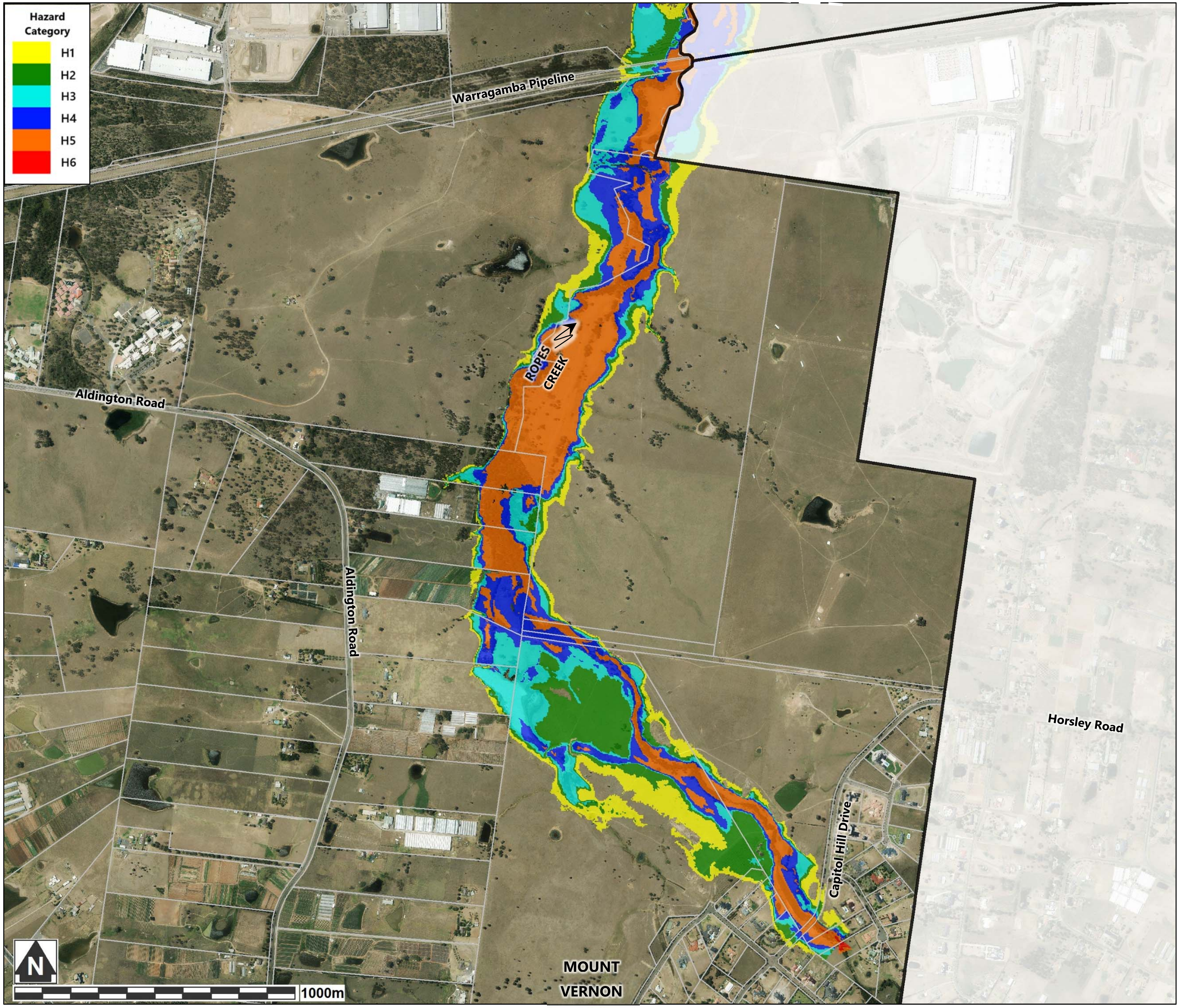
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.32-PMF True Hazard (8 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 8 OF 12]

FIGURE B.33



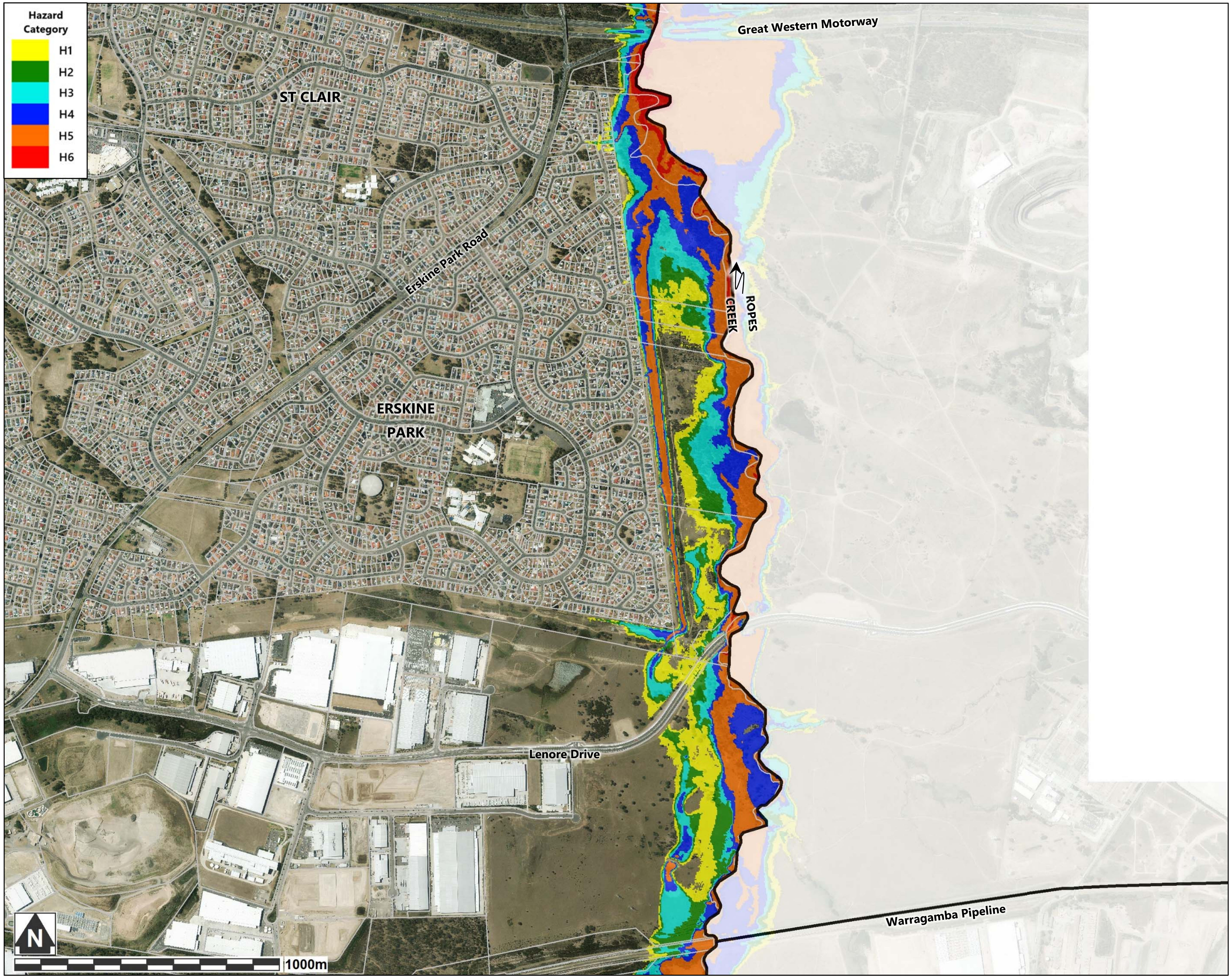
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.33-PMF True Hazard (9 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 9 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.34-PMF True Hazard (10 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 10 OF 12]

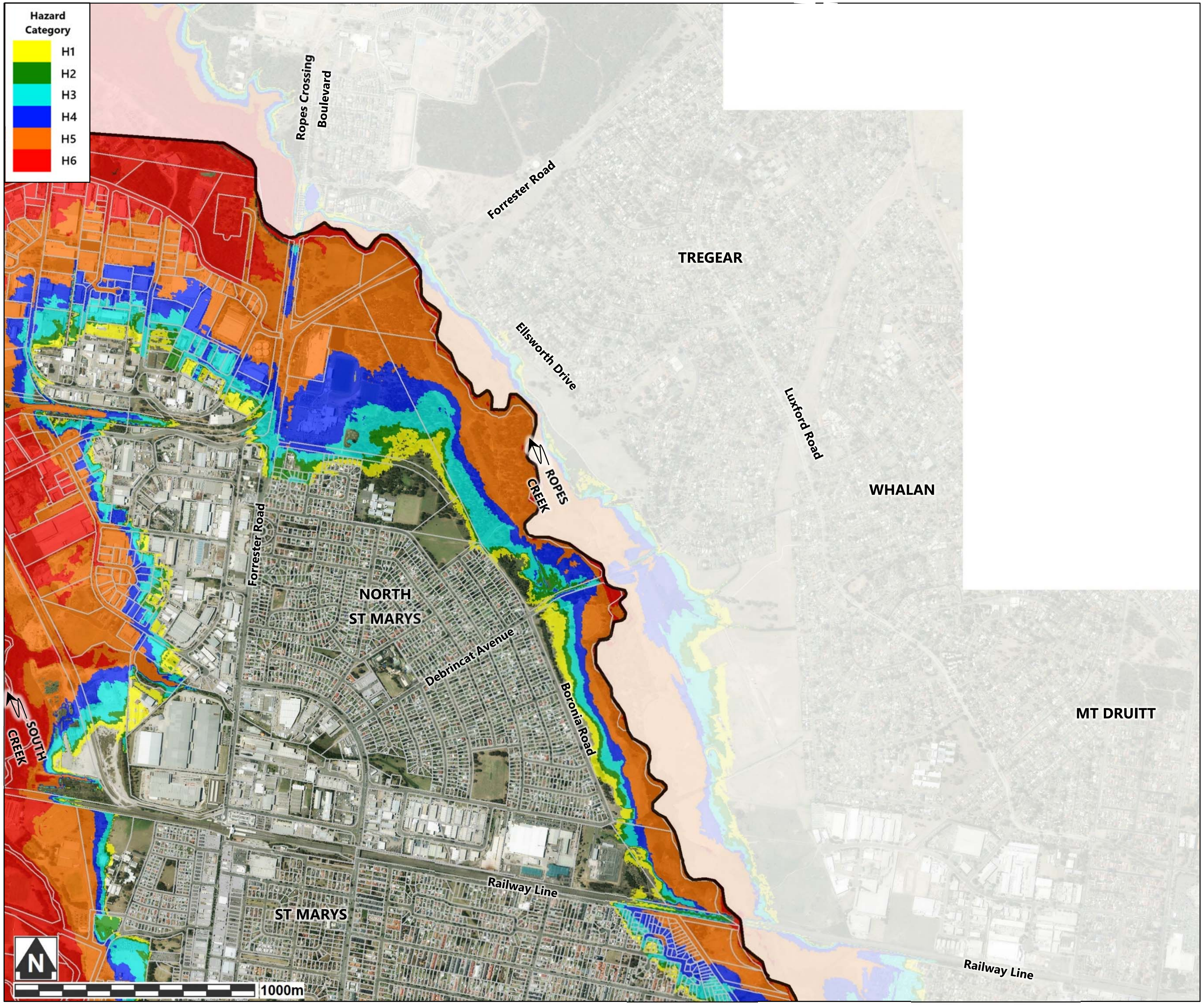
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.35-PMF True Hazard (11 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 11 OF 12]



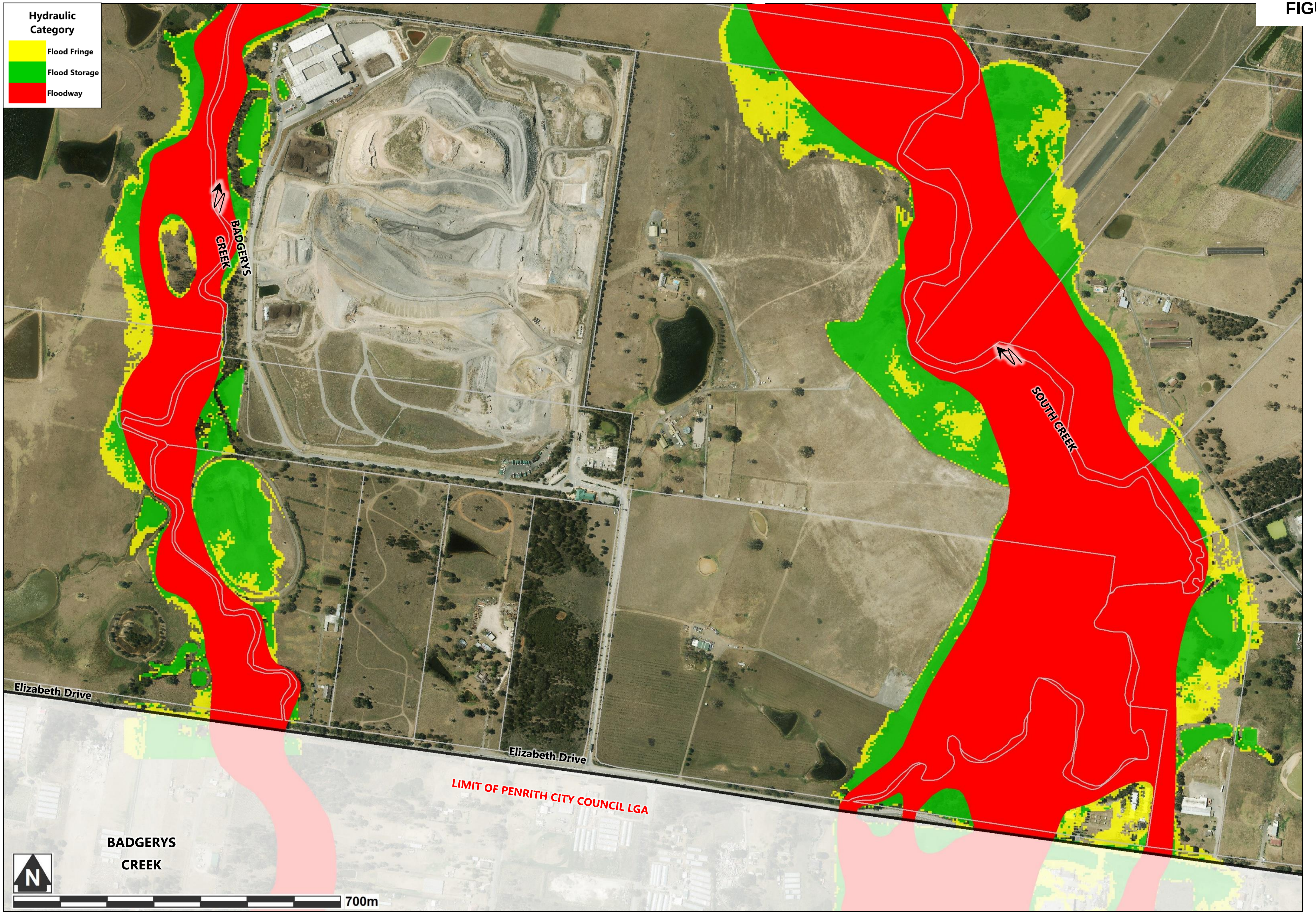
Advisian
Worley Group
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig B.36-PMF True Hazard (12 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 12 OF 12]

Appendix C – Updated Hydraulic Category Mapping

(Re-Mapped Fringe and Storage)

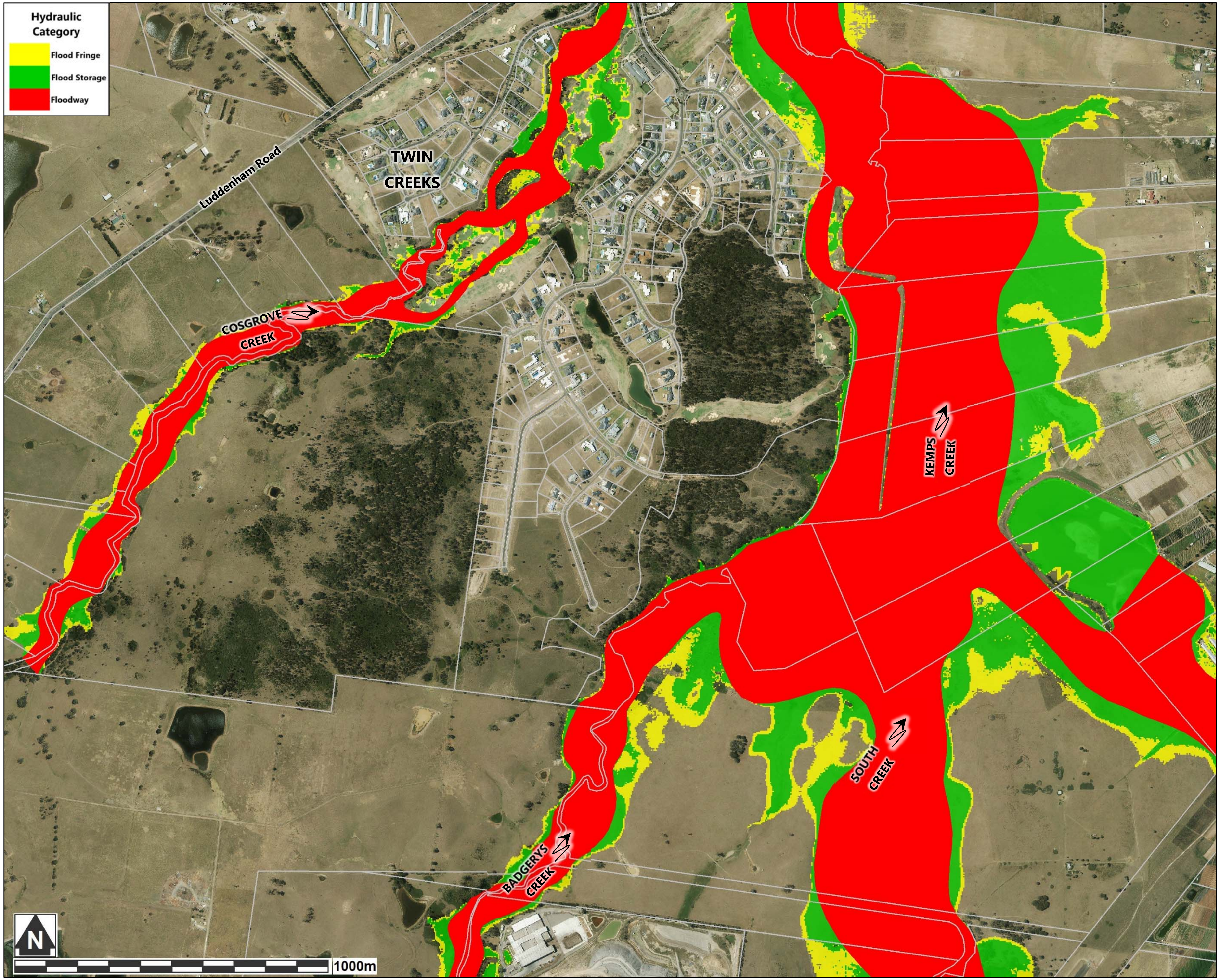


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.1-Hyd Cat (1 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 1 OF 12]



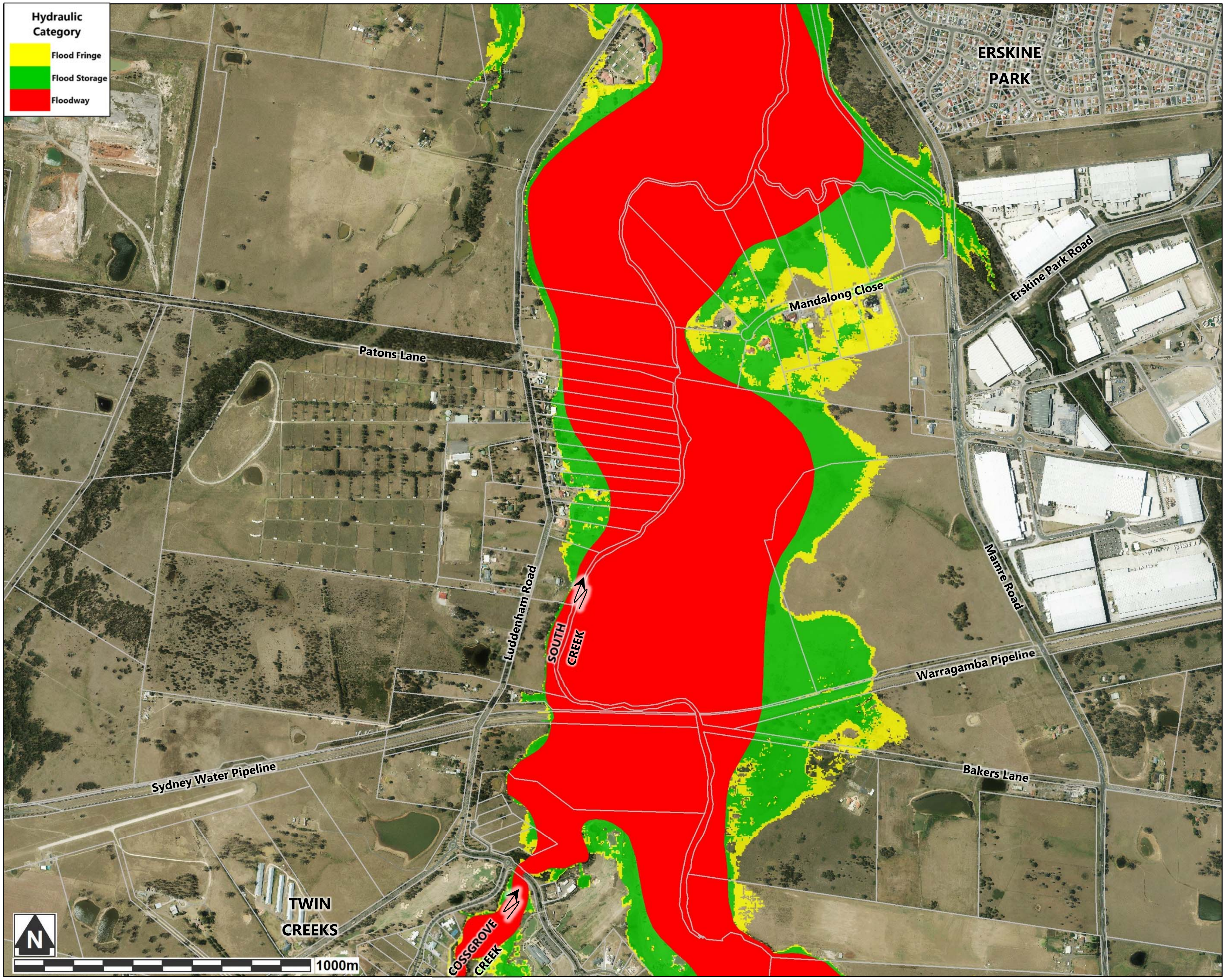
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.2-Hyd Cat (2 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 2 OF 12]

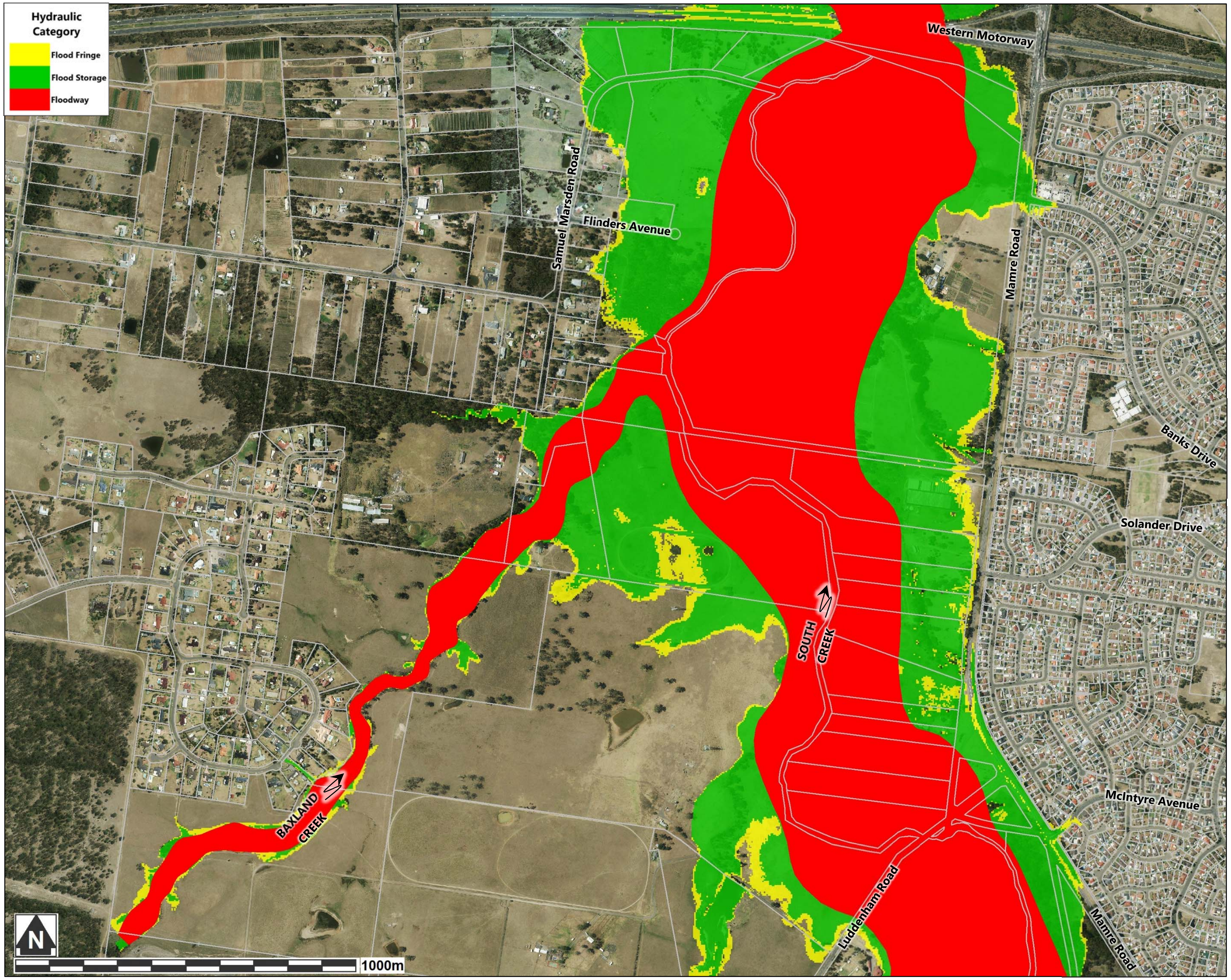


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.3-Hyd Cat (3 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 3 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.4-HydCat (4 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING [EXTENT 4 OF 12]

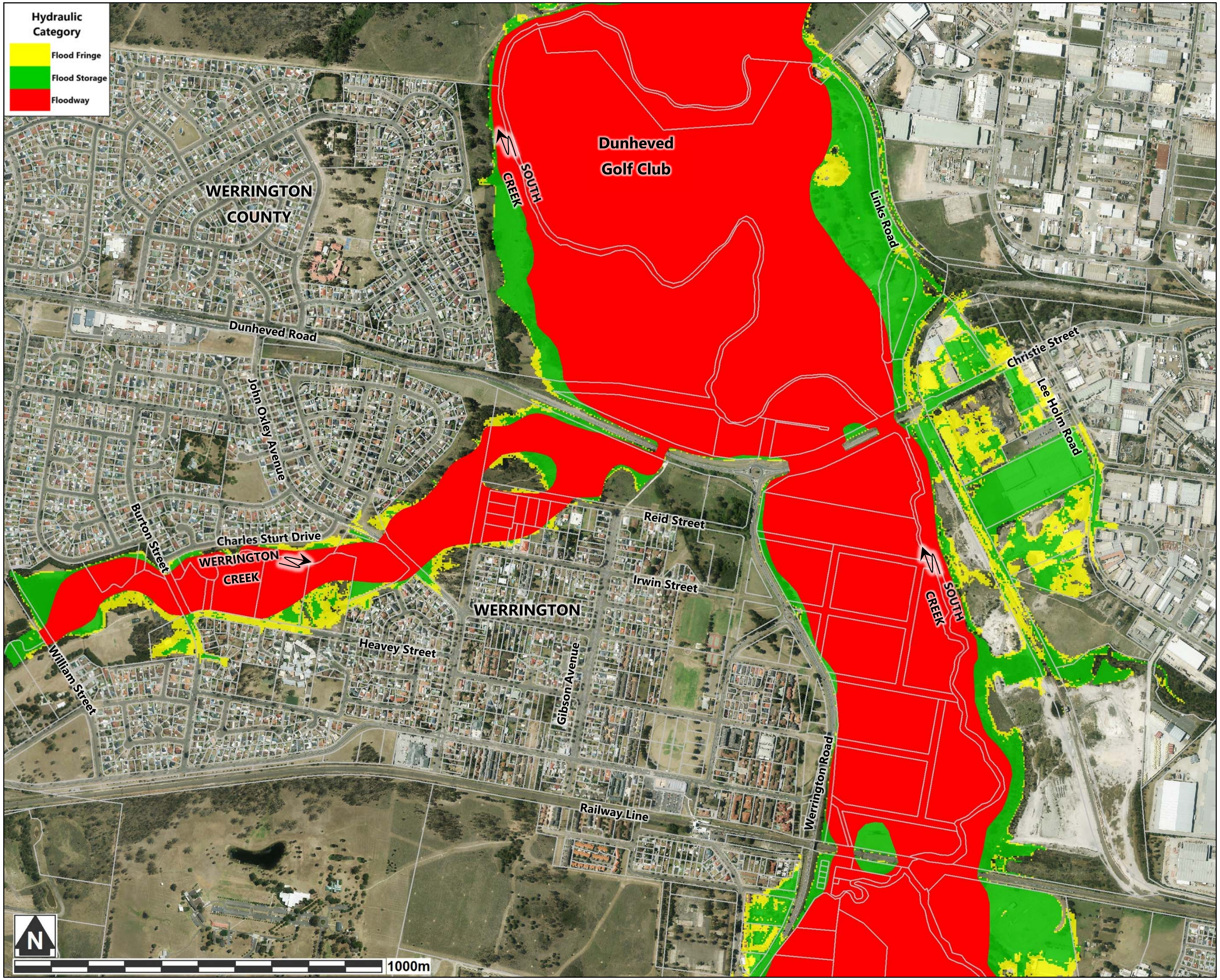
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.5-Hyd Cat (5 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

**HYDRAULIC CATEGORY MAPPING
[EXTENT 5 OF 12]**



Advisian
Worley Group

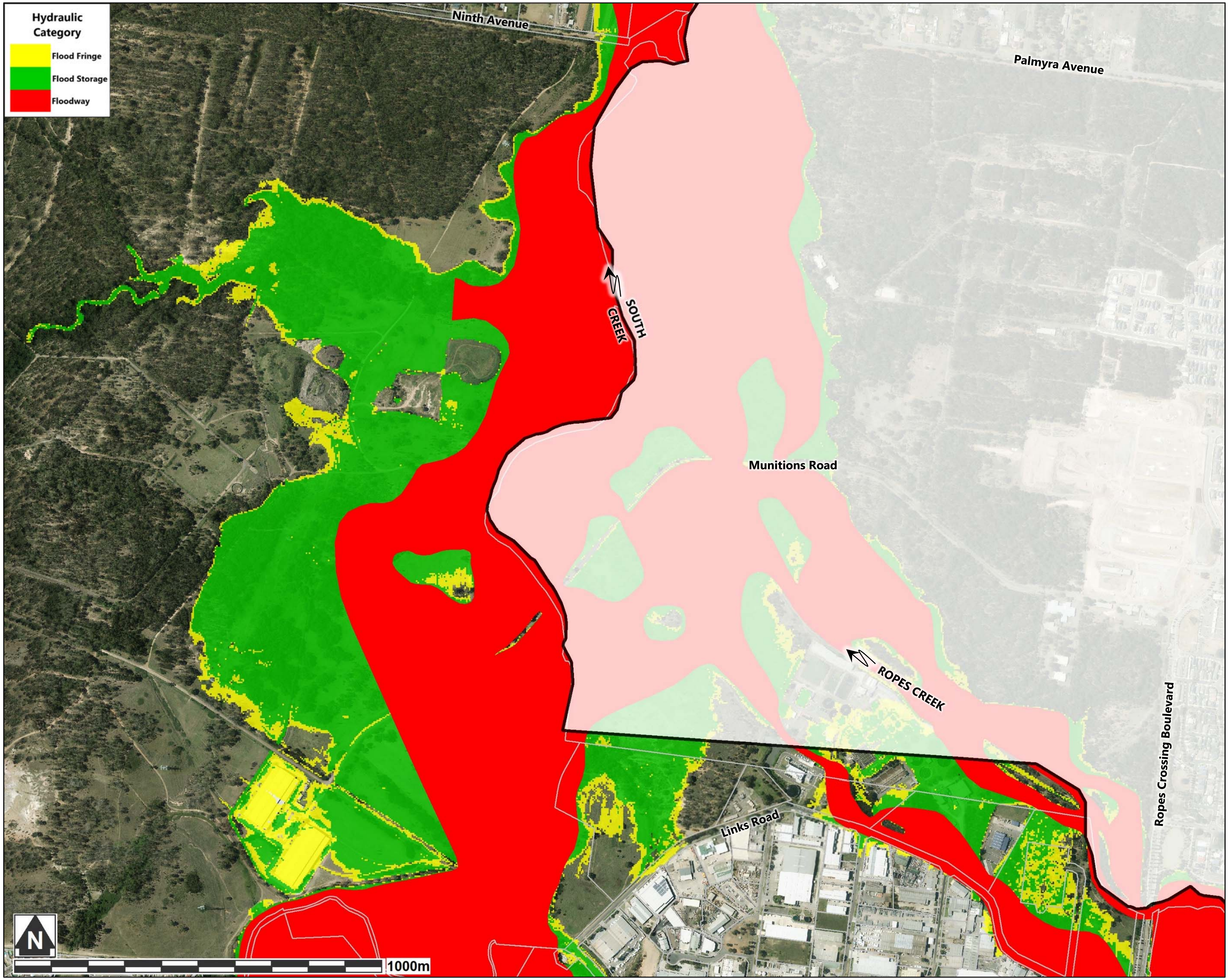
301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig C.6-Hyd Cat (6 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 6 OF 12]

FIGURE C.7



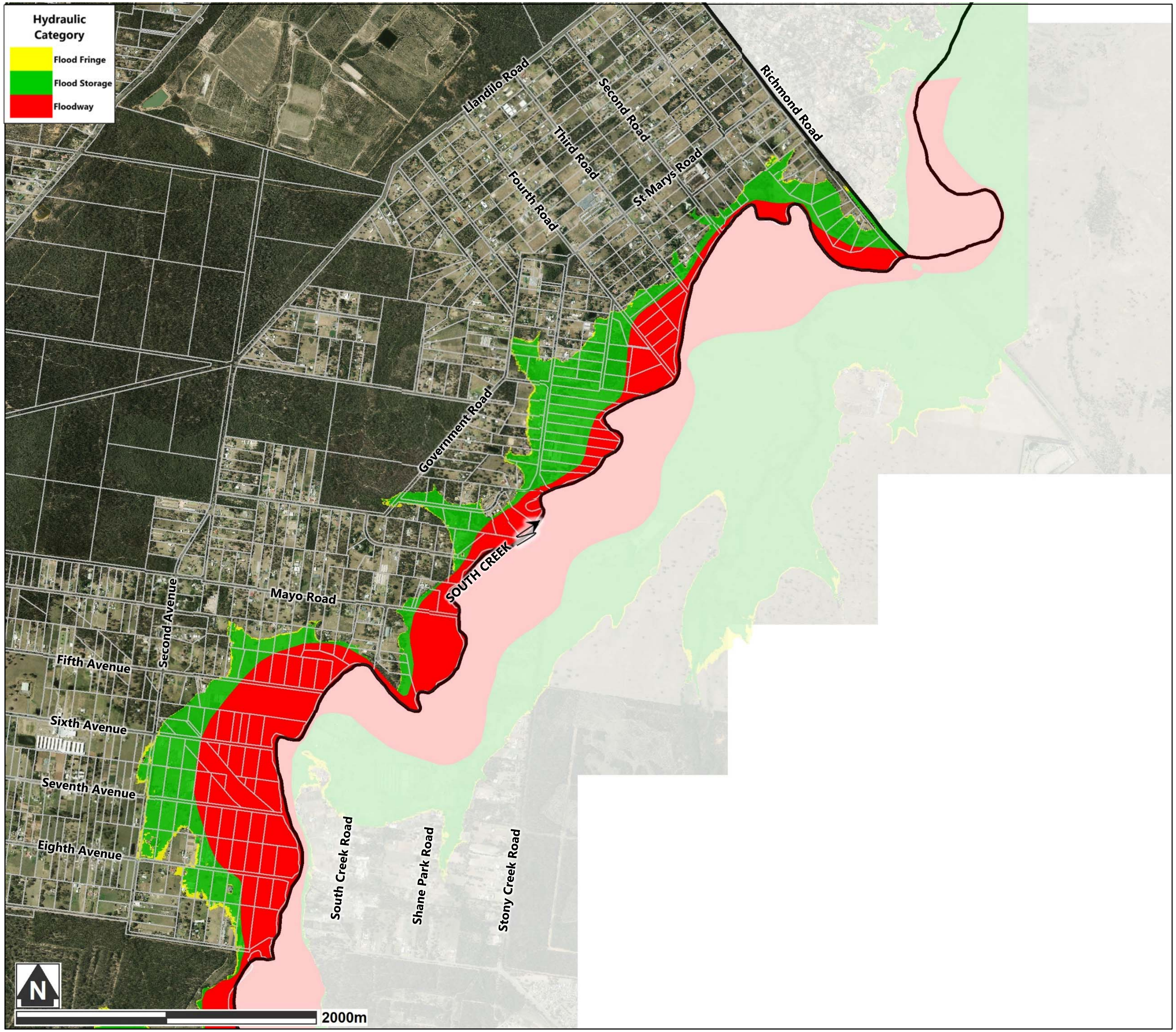
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.7-Hyd Cat (7 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING [EXTENT 7 OF 12]

FIGURE C.8



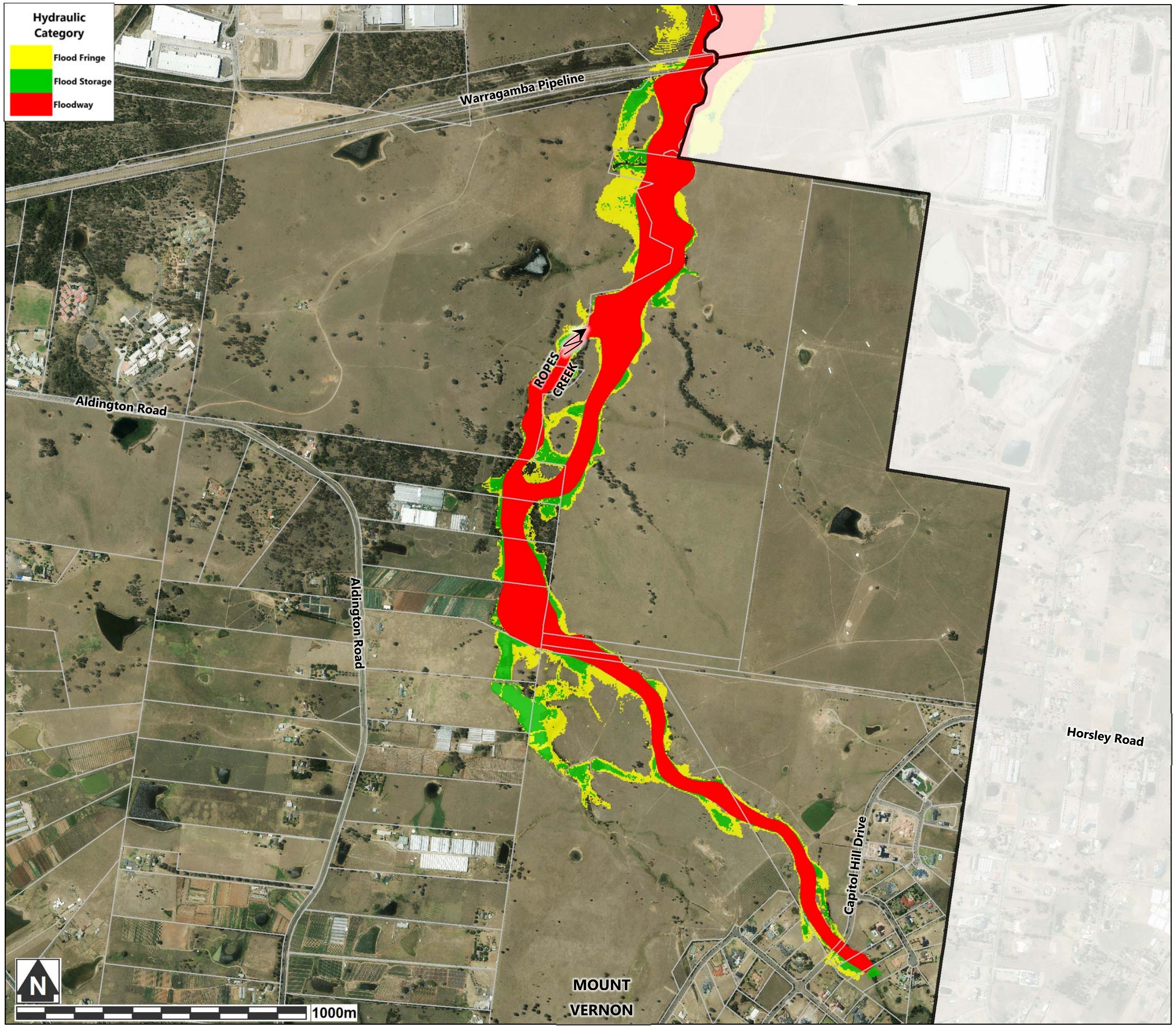
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig C.8-Hyd Cat (8 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 8 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig C.9-Hyd Cat (9 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING [EXTENT 9 OF 12]

Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig C.10- HydCat (10 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING [EXTENT 10 OF 12]

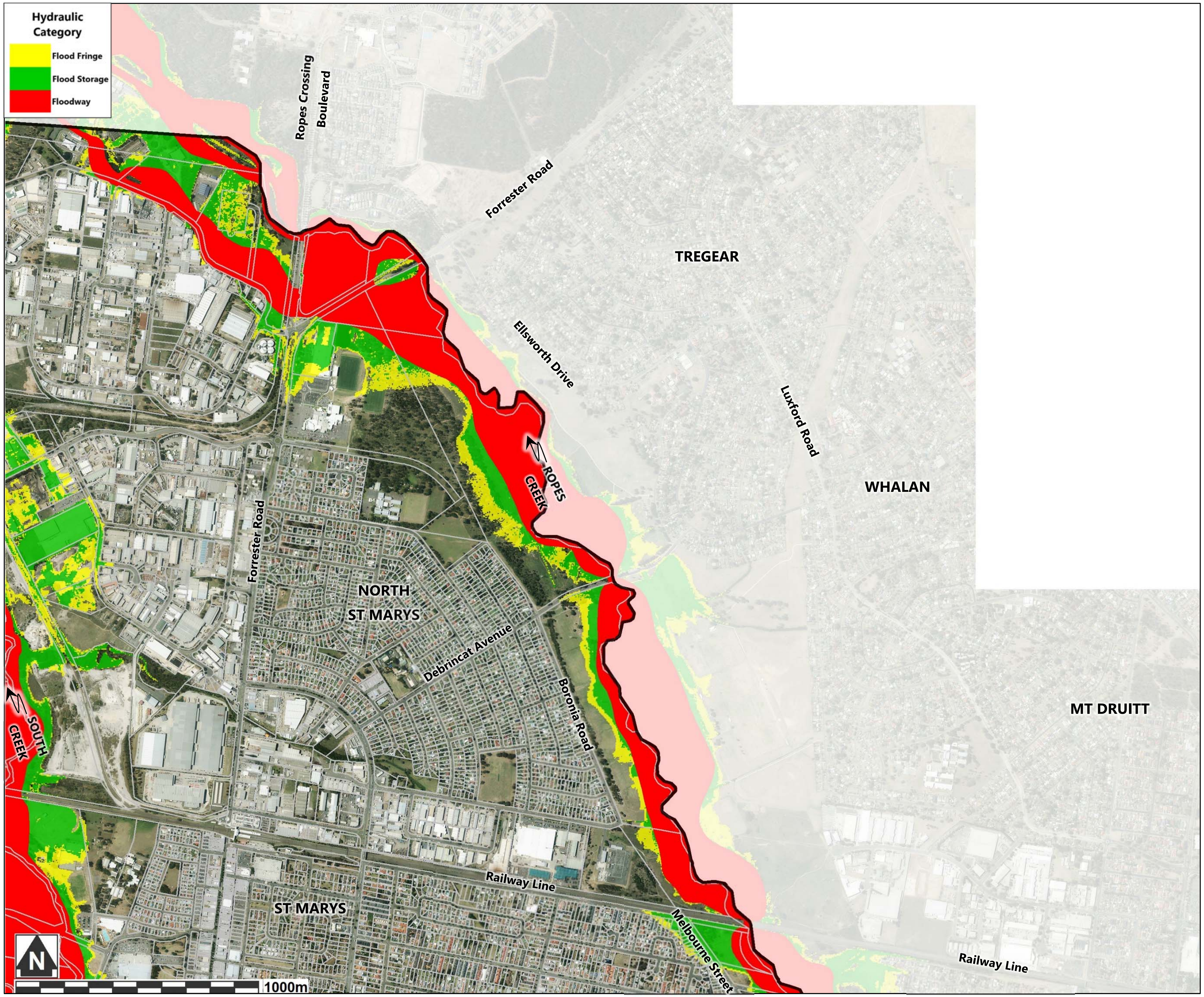
FIGURE C.11

Advisian
WorleyParsons Group
301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig C.11-Hyd Cat (11 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 11 OF 12]



Advisian
Worley Group

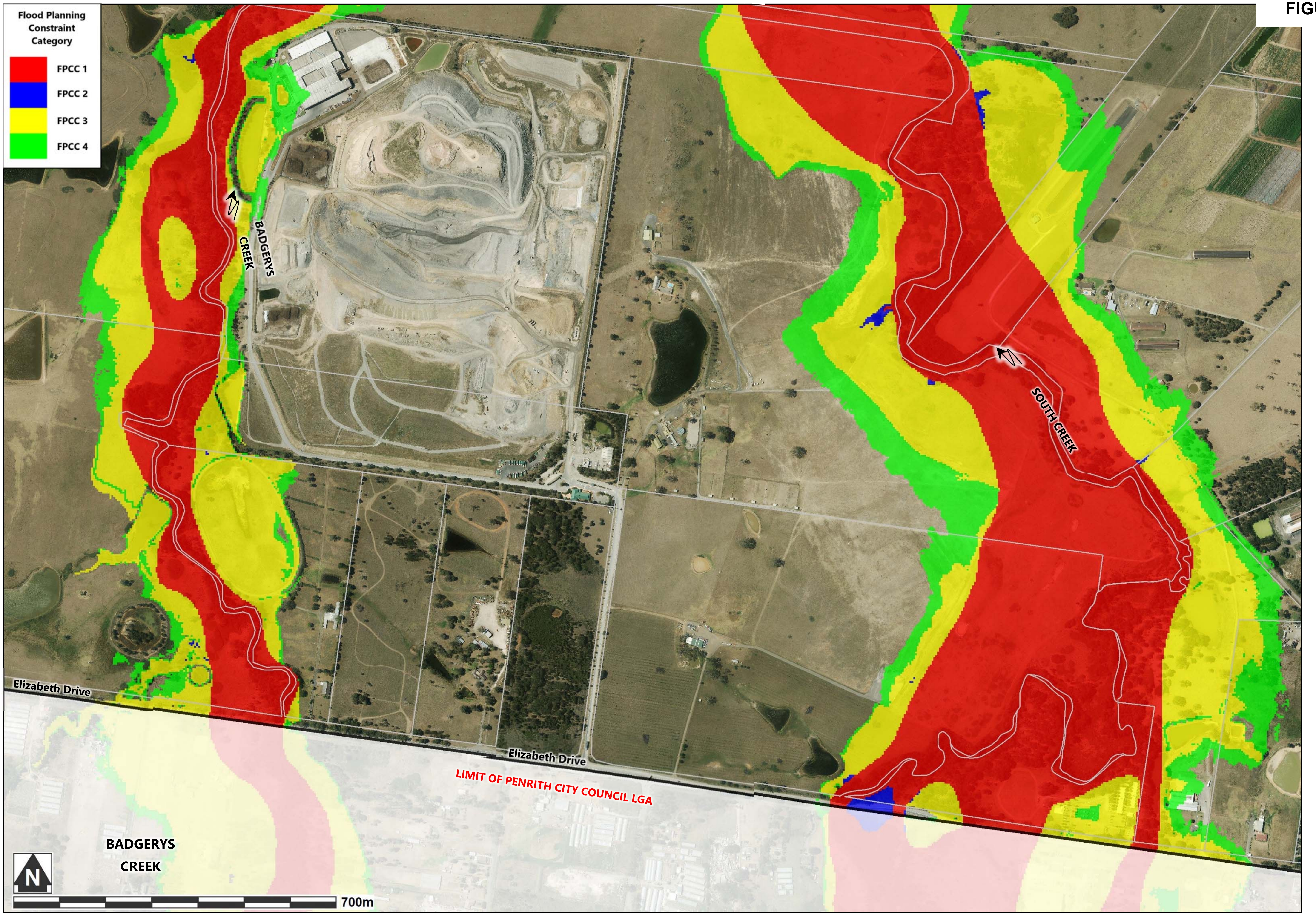
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig C.12-Hyd Cat (12 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

HYDRAULIC CATEGORY MAPPING
[EXTENT 12 OF 12]

Appendix D – Flood Planning Constraints Category Mapping (FPCC)



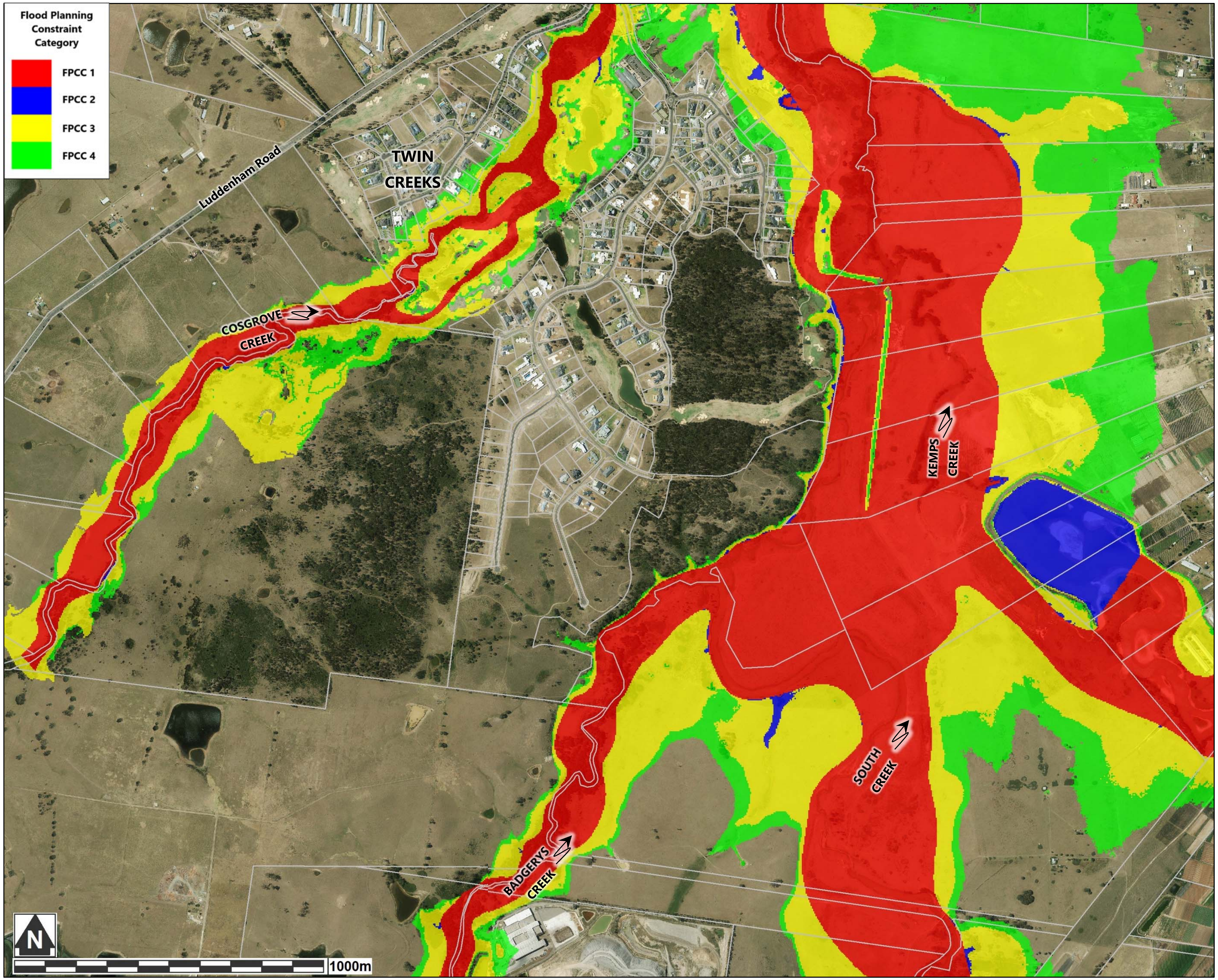
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.1 FPCC (1 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 1 OF 12]



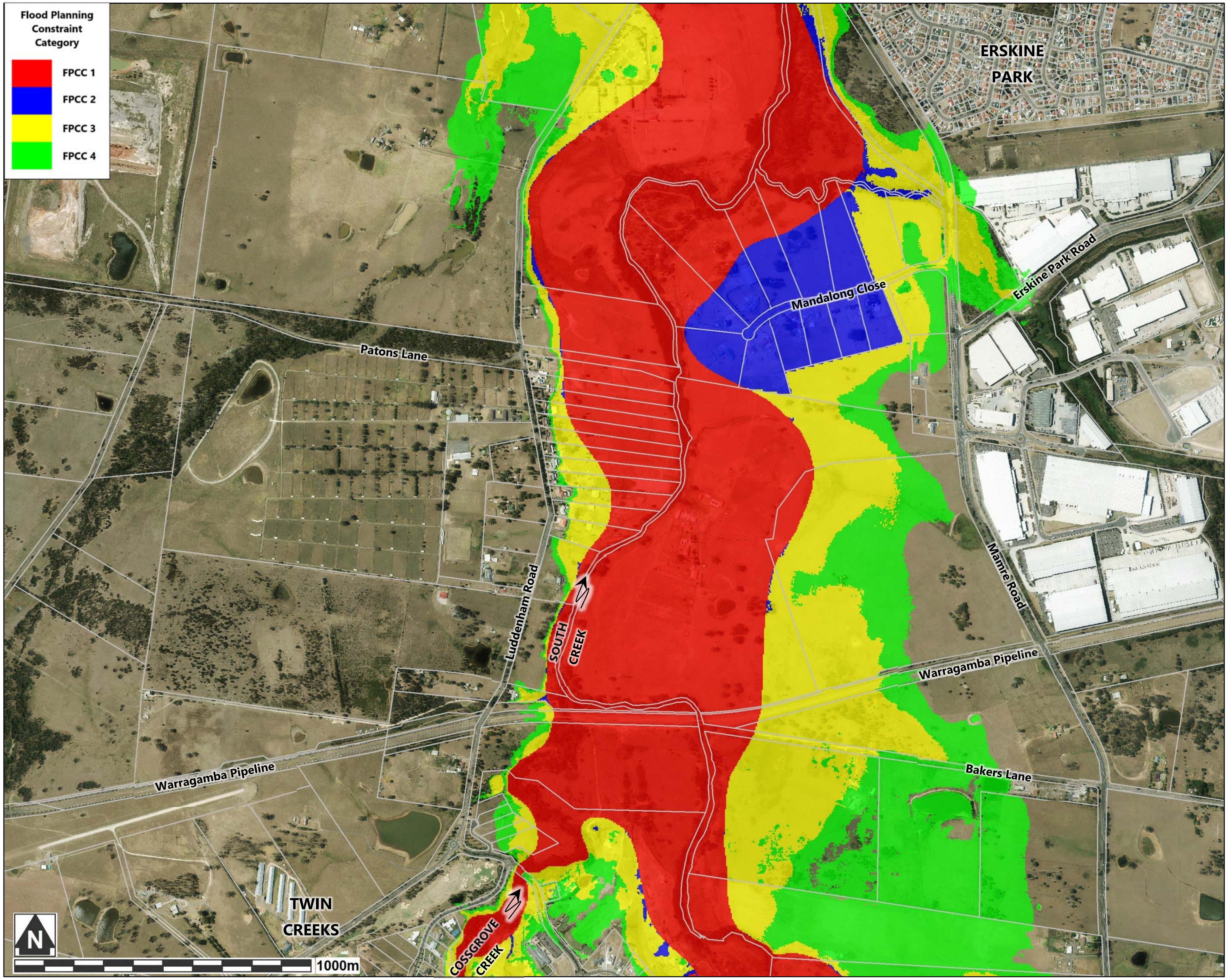
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.2-FPCC (2 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 2 OF 12]



Advisian
Worley Group

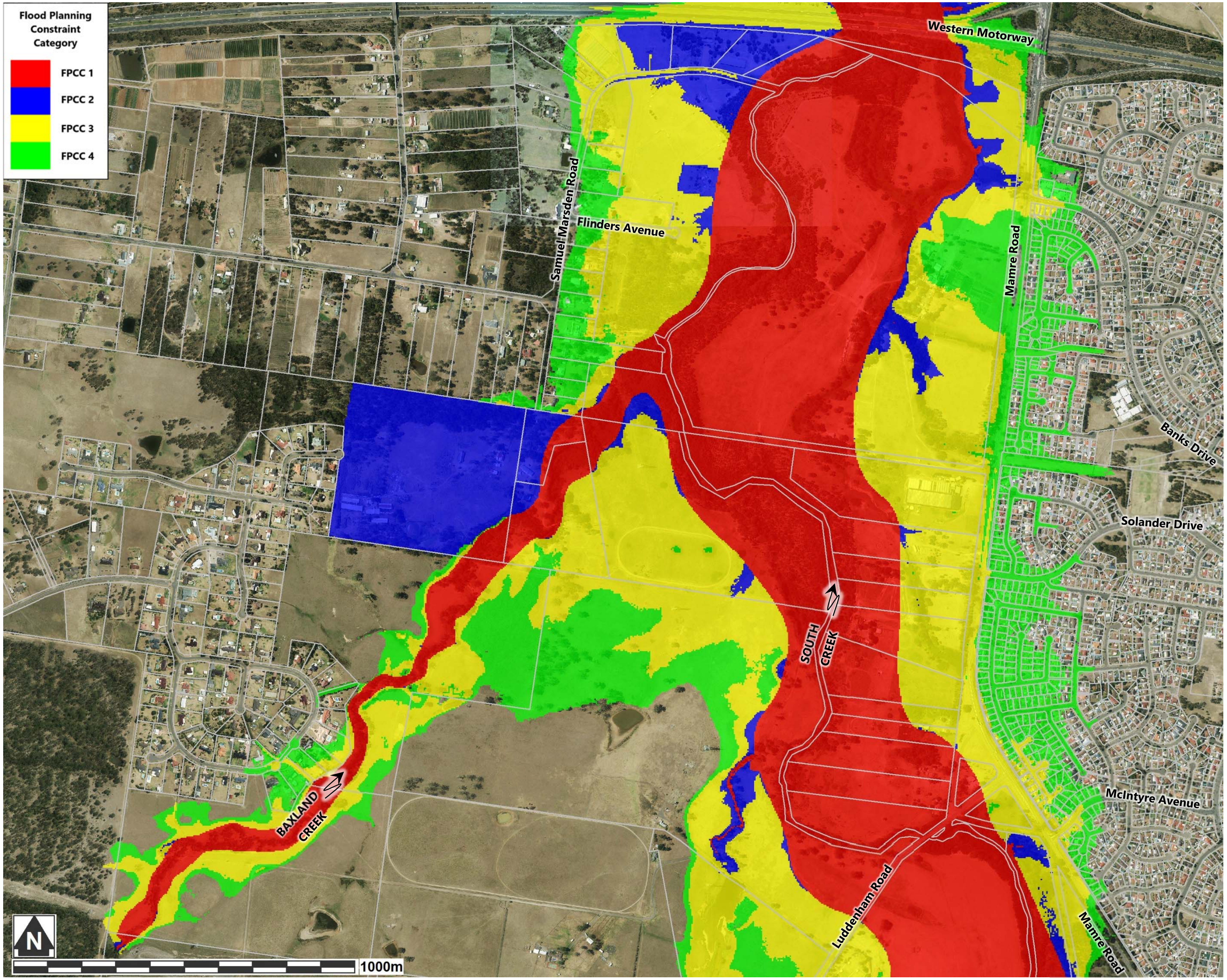
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.3-FPCC (3 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 3 OF 12]

FIGURE D.4



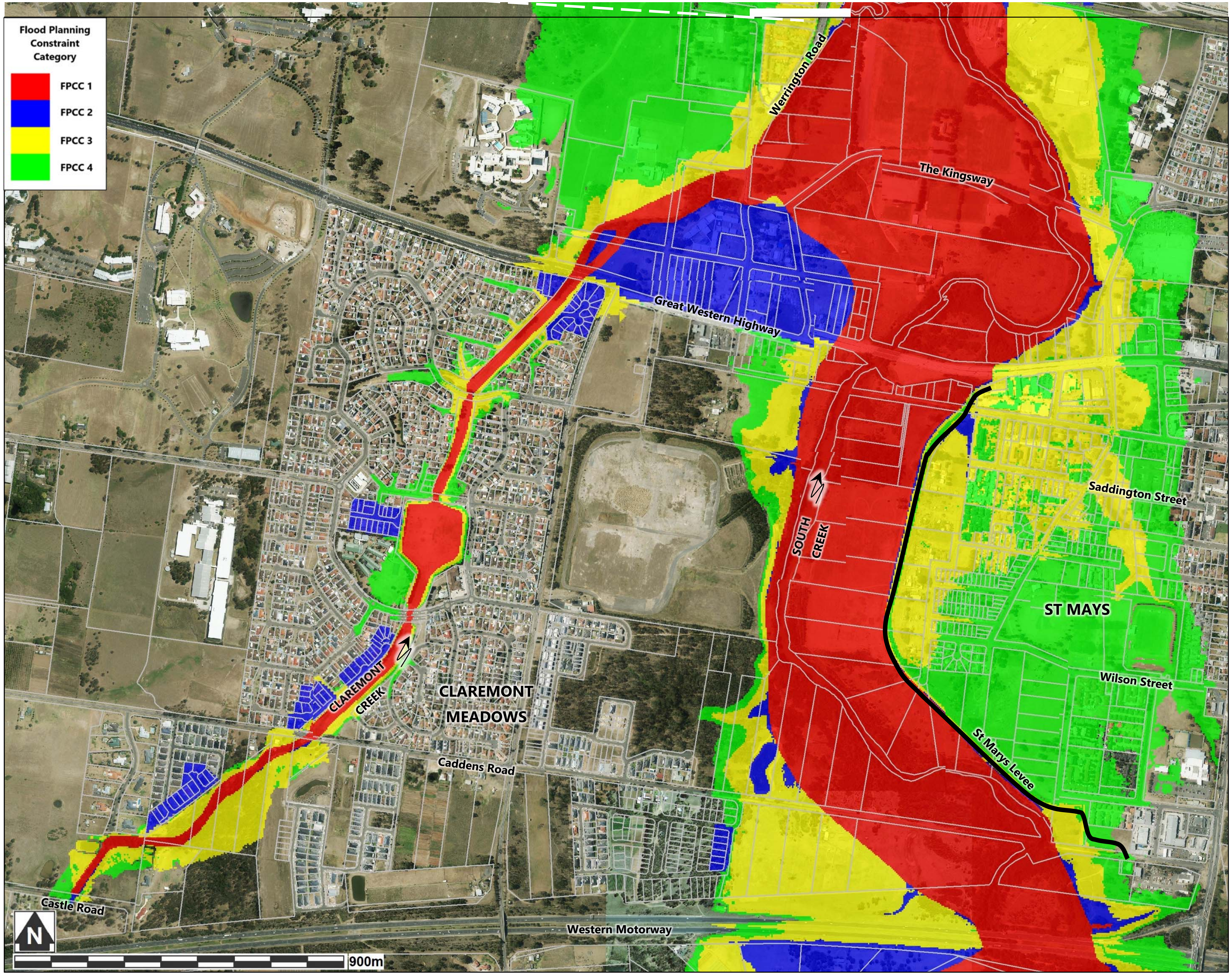
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg190726-Fig D.4-FPCC (4 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 4 OF 12]



Advisian
Worley Group

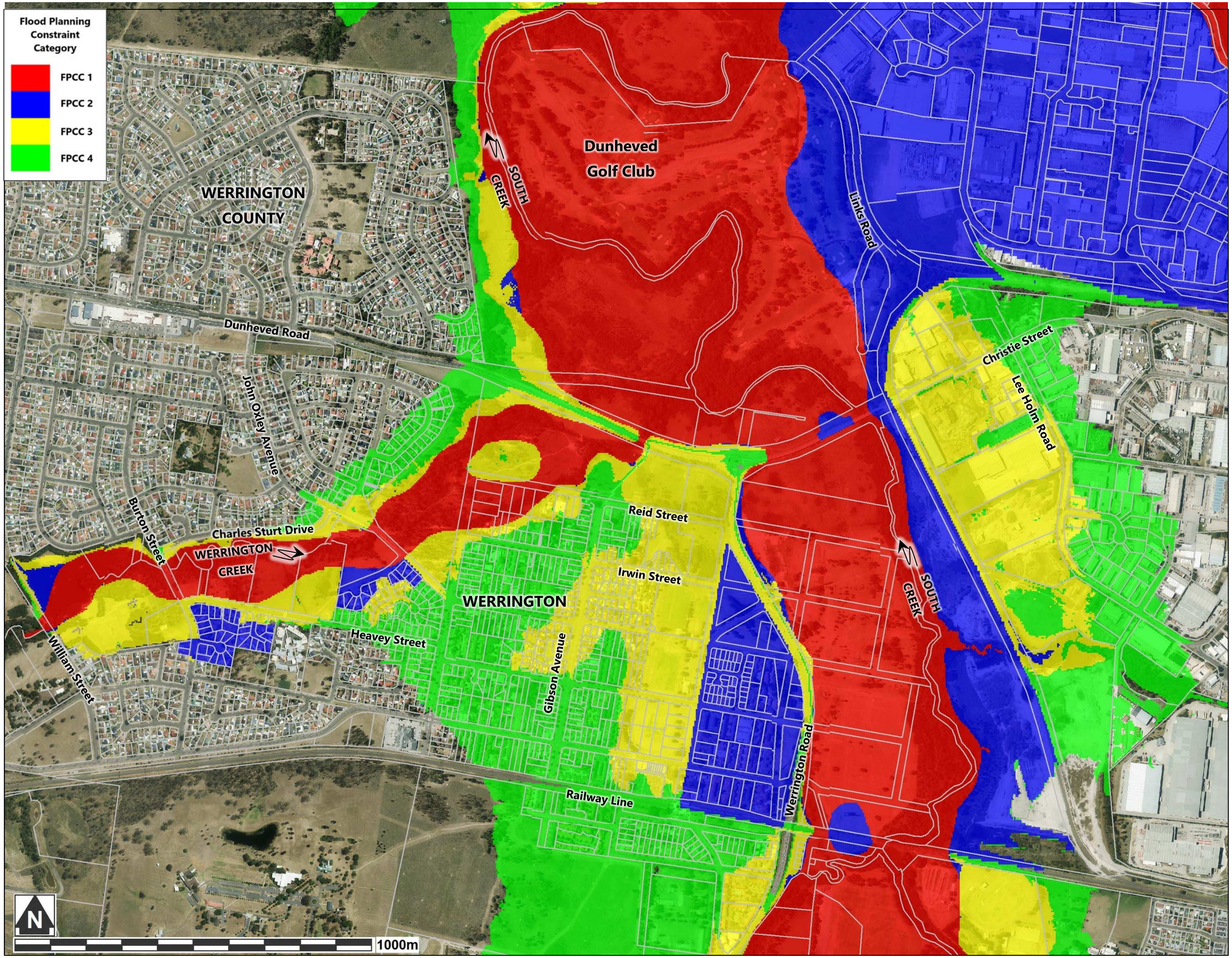
301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.5-FPCC (5 of 12)

NOTES:

1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.*

FLOOD PLANNIGN CONSTRAINT CATEGORY MAPPING [EXTENT 5 OF 12]

FIGURE D.6

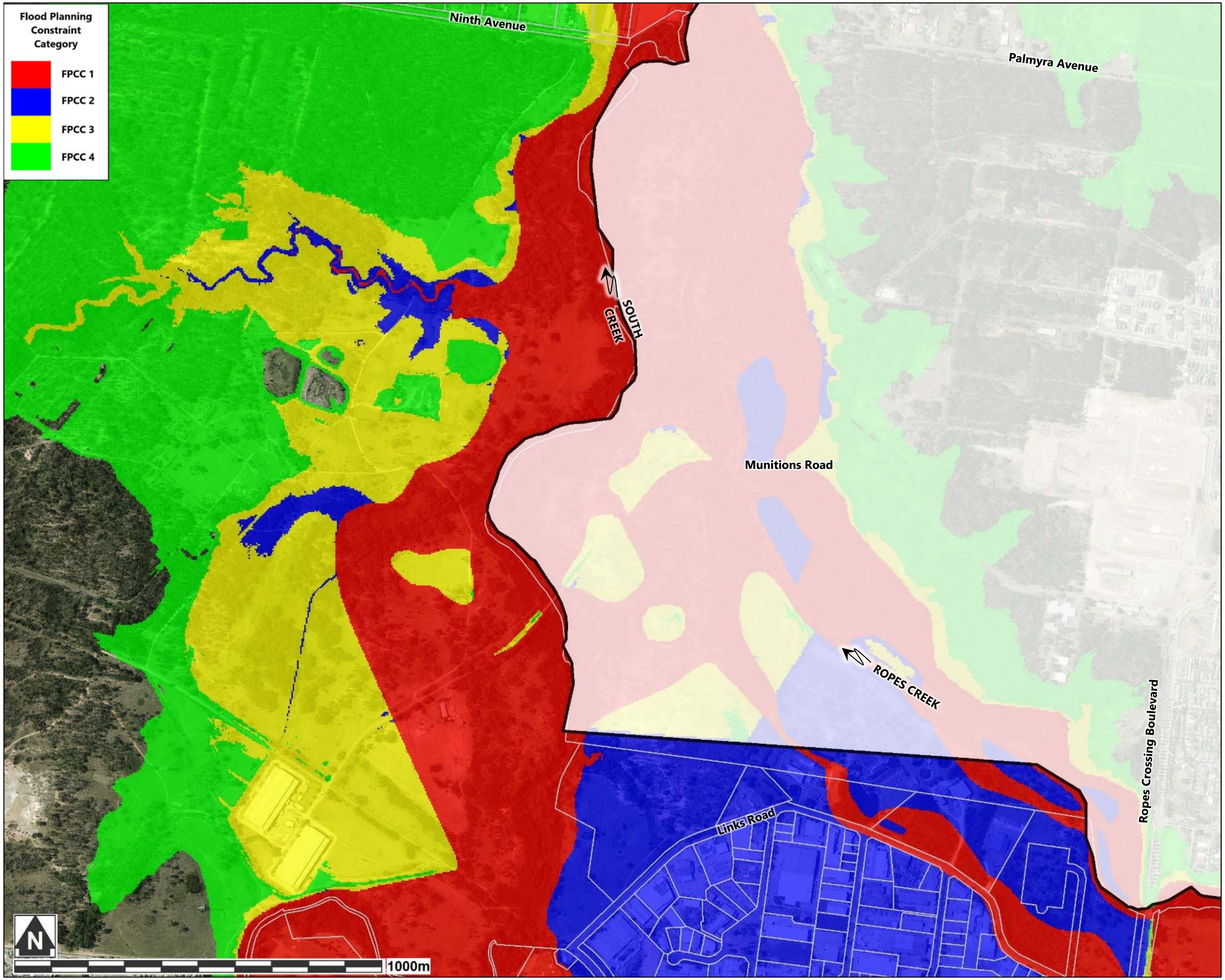


Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.6-FPCC (6 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 6 OF 12]



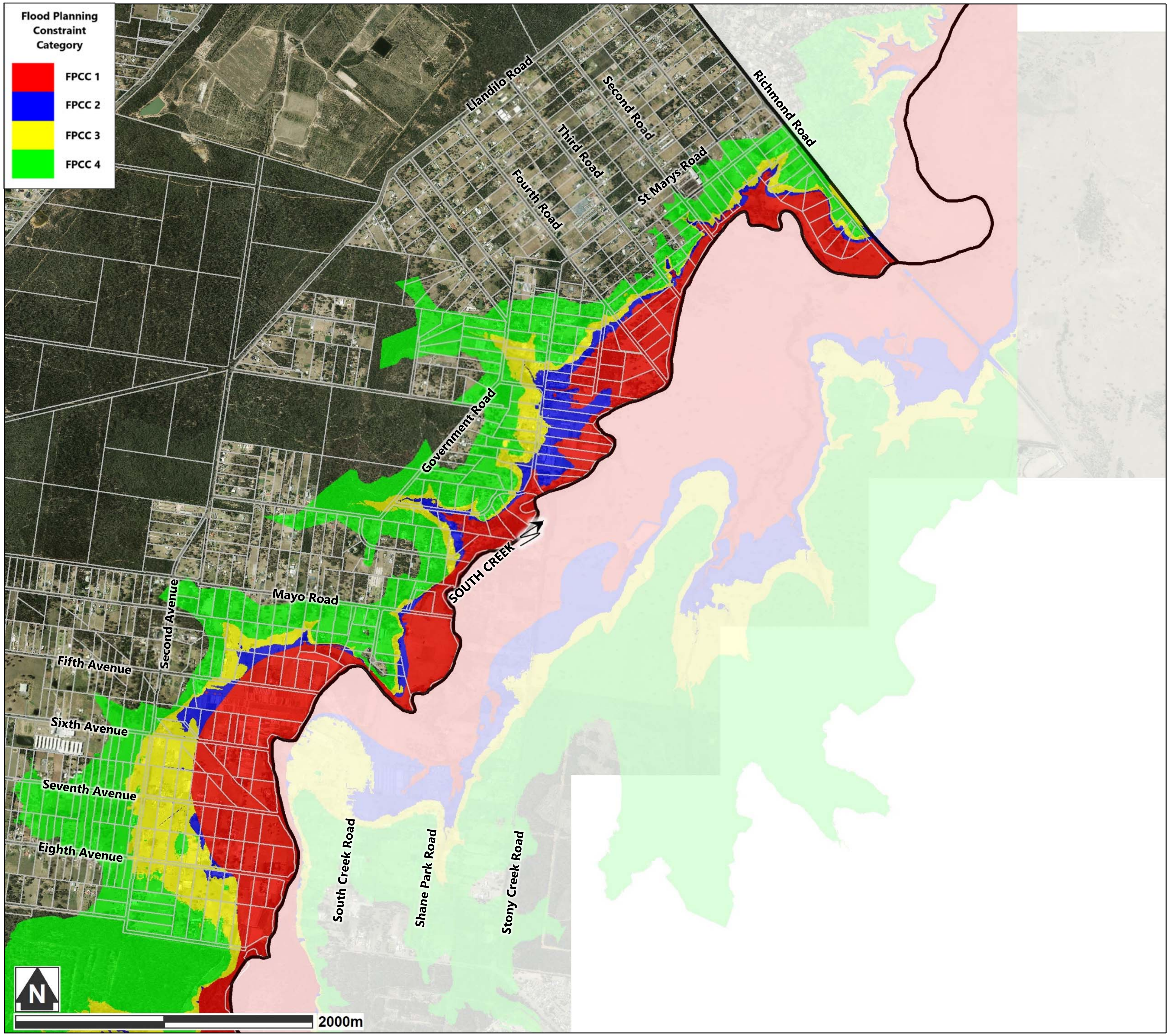
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.7-FPCC (7 of 12)

NOTES:
1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 7 OF 12]

FIGURE D.8



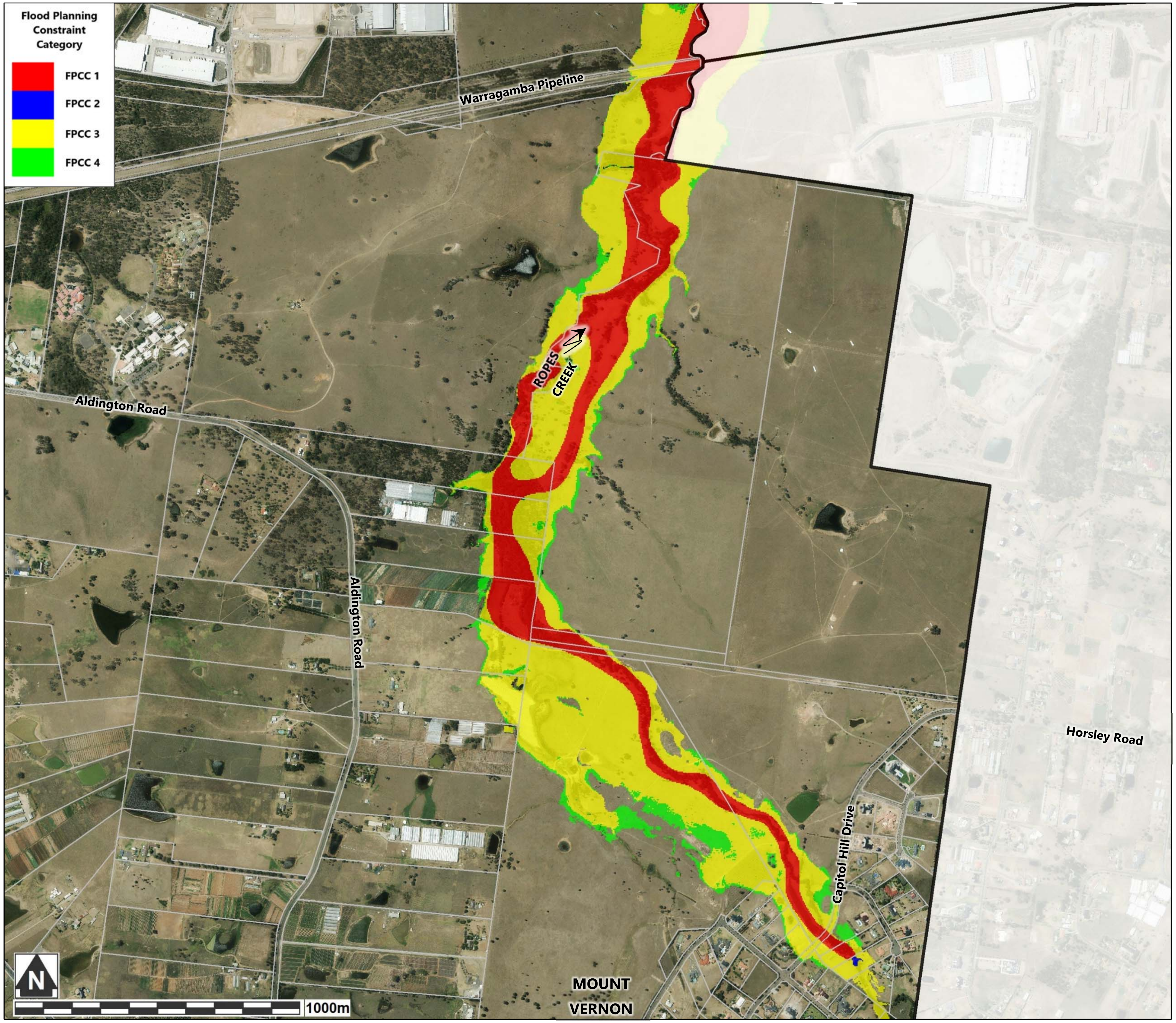
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.8-FPCC (8 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 8 OF 12]



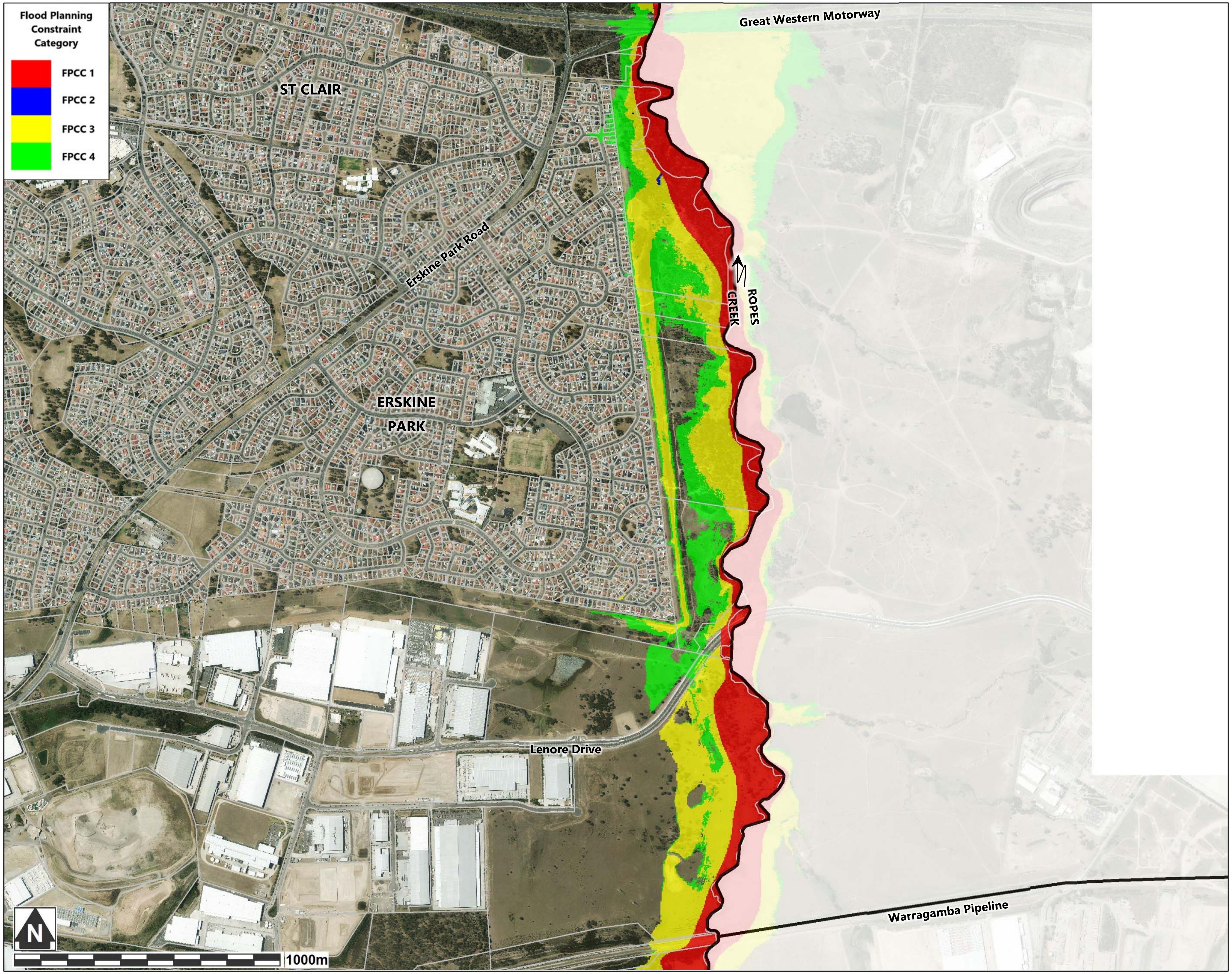
Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.9-FPCC (9 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 9 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.10-FPCC (10 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

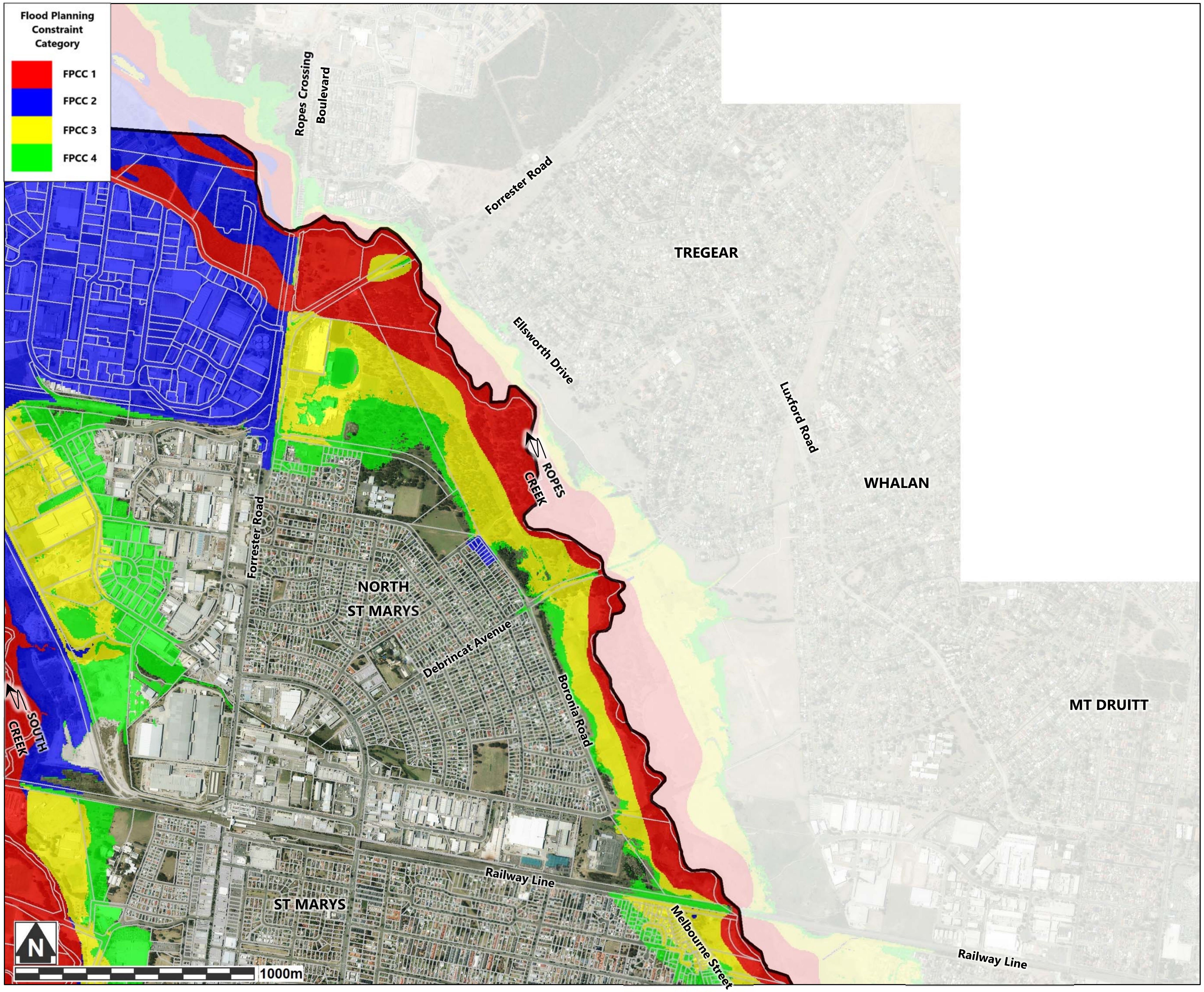
FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 10 OF 12]

Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.11-FPCC (11 of 12)

NOTES:
1. *Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.*

FLOOD PLANNING CONSTRAINT CATEGORY MAPPING [EXTENT 11 OF 12]



Advisian
Worley Group

301310-08772 – South Creek FRMS
fg301310-08772rg200220-Fig D.12-FPCC (12 of 12)

NOTES:

1. Flood mapping is prepared based on modelling completed as part of the Updated South Creek Flood Study (2015). The broad scale nature of the study must be taken into consideration when assessing flood characteristics at a local scale. Detailed investigations should be undertaken for site specific assessments, including those associated with future release areas.

TRUE FLOOD HAZARD MAPPING FOR THE PROBABLE MAXIMUM FLOOD [EXTENT 12 OF 12]

Appendix E – Preliminary Options Assessment

Table E1 List of Preliminary Issues for Consideration/Investigation as part of the FRMS

ID	PRELIMINARY ISSUE RAISED	RELAVANT SUB AREA	CONSIDERED FLOODPLAIN MANAGEMENT OPTIONS				PRIORITY (*Based on Triple Bottom Line Assessment*)	COMMENTS
			STRUCTURAL	PROPERTY MODIFICATION / PLANNING	EMERGENCY RESPONSE	RISK ASSESSMENT		
1	Flooding of Elizabeth Drive, Badgerys Creek crossing and food free access.	Area 1 – Floodplain between Elizabeth Drive and the Warragamba Pipeline (*Refer* **Figure 8.1**)	1. Investigate potential to raise road and/or increase conveyance capacity of crossings	N.A.	1. Alternate evacuation routes and improved monitoring of flood levels to inform road closures.	N.A.	Medium	It is understood that the Roads and Maritime Services are currently undertaking an options assessment to upgrade the Elizabeth Drive road corridor. Accordingly, options do not need to be assessed as part of the FRMS.
2	Flooding of Elizabeth Drive, South Creek crossing and food free access							
3	Flooding of Elizabeth Drive, Kemps Creek crossing and food free access							
4	Kemps Creek - Two Farm Dams - effectiveness and impacts of dam failure		N.A.	N.A.	N.A.	1. Test a combined dam failure scenario to assess potential risks to downstream landowners.	High	Recommended for inclusion in the FRMS as a structural mitigation measure and for modelling using RMA-2.
5	Flood protection to properties near Twins Creek Drive, Luddenham		N.A.	N.A.	N.A.	N.A.	Low	No over-floor flooding or emergency response issues predicted during the design 1% AEP flood. Accordingly, this is not recommended to be a priority for the FRMS.
6	Warragamba Pipeline - assessment of risks due to flooding by the three creeks		N.A.	N.A.	N.A.	1. Review existing RMA-2 results to assess velocities and hazards at the pipeline.	Medium	Results from the *Updated South Creek Flood Study* (2015) are available to WaterNSW to undertake a risk assessment of their existing infrastructure.
7	Flooding of Mamre Road and adjacent St Claire residential properties and flood evacuation route	Area 2 – Floodplain between the Warragamba Pipeline and the Western Motorway (M4) crossing of South Creek (*Refer* **Figure 8.2**)	*1. Raise Mamre Road* 2. Construct Levees along Mamre Rd 3. Strategic development of land to the west of Mamre Road 4. Increase Conveyance Capacity of the M4 Crossing	N.A.	1. Alternate evacuation routes and improved monitoring of flood levels to inform road closures.	N.A.	High	Recommended for inclusion in the FRMS as a structural mitigation measure and for modelling using RMA-2.
8	Flood protection to properties near Mamre Road / McIntyre Avenue / Banks Drive, St Claire							
9	Flood protection to properties near Mandalong Close, Orchard Hills		N.A.	1. Review land use zonings and development controls to ensure future development of the land is appropriate (*assuming no upgrade to access*)	*1. Review emergency response procedures for the evacuation of properties to ensure priority is given based on risks of isolation [Low Flood Island]*	N.A.	High	Recommended to be further assessed within the FRMS as part of a review of existing emergency response procedures.
10	M4 freeway overtopping the three creeks		1. Assess options to raise the M4 and increase crossing capacity	N.A.	1. Alternate evacuation routes and improved monitoring of flood levels to inform road closures.	N.A.	Medium	Although reducing the flood affectation of the M4 has significant benefits socially, it was not recommended to be assessed in the FRMS given it is a known risk to the RMS having been identified within the Flood Study (*2015*)
11	Adequacy of St Marys Levee including flood protection and planning controls for the areas behind the levee as well as Wilson Street new release areas.	Area 3 - St Marys Upstream of the South Creek Railway Line Crossing	1. Assess adequacy of the levee and potential to raise or extend vulnerable sections	1. Review of planning controls to ensure appropriate freeboard requirements are adopted.	1. Emergency response procedures to consider the potential for levee failure	N.A.	High	Recommended for assessment based on large number of properties at risk and potentially high B/C ratio given relatively low costs associated with installation of a flap gate.

			2. Install flap gate on downstream culvert to prevent floodwaters backing-up behind the levee					
12	Great Western Highway flooding by Claremont Creek, South Creek and Ropes Creek		1. Raise the GWH and increase culvert capacity at the Claremont Creek and/or South Creek crossings.	N.A.	1. Emergency response procedures to consider alternative evacuation route and take into consideration flood risks associated with potential inundation and closer of the GWH.	N.A.	Medium	
13	Flood protection to St Marys Shopping and Senior High School areas		1. Assess potential for a levee to prevent flooding and reduce damages.	1. Flood compatible materials for any future development or re-development of flood prone sites.	1. Review emergency response procedures to ensure isolation is not a risk.	N.A.	Low	St Marys Senior High School and the St Marys Shopping Centre experience only minor inundation for all flood up to and including the 500 year ARI flood.
14	Overtopping of The Kingsway, St Marys. Feasibility of road access.		< *Raising The Kingsway deemed unfeasible given significant depths of inundation predicted* >	1. Flood warning signs and flood markers should be placed on the road and surrounding parklands.	1. Ensure isolation risks are reflected in the SES Emergency Response Planning Community mapping.	N.A.	High	Due to high risk associated with frequent inundation of The Kingsway and nearby sporting fields it is important that this is reflected in emergency response measures and community data sheets.
15	M4 Freeway overtopping at the Claremont Creek crossing	Area 4 – Claremont Meadows and Properties Affected by Claremont Creek	The Western Motorway (*M4*) crossing of Claremont Creek is outside of the extents of the study area of the Updated South Creek Flood Study (*2015*)					
16	Flood protection to properties upstream of the Great Western Highway, Claremont Meadows.		1. Combination of localised levees and channel optimisation 2. Increase conveyance capacity of the Great Western Highway crossing to reduce flood levels upstream	1. Voluntary house raising if economical and subject to other criteria	1. Ensure assessment of emergency response highlights risks along Great Western Highway. 2. Ensure Emergency Response Planning Communities pick-up isolation risk to properties along Dolphin Close.	N.A.	High	Focus on emergency response and identifying overtopping and isolation risks. Potential upgrades to the Great Western Highway crossing deemed responsibility of the Roads and Maritime Services.
17	Flood protection to the special needs Kurrambee School, Werrington		1. Assess opportunities for localised levees.	1. Assess potential to raise vulnerable buildings. 2. Consider flood proofing options and potential for flood barriers to be deployed at building entrances.	1. Ensure assessment of emergency response highlights potential isolation risks due to overtopping of the Great Western Highway crossings of Claremont Creek and South Creek	N.A.	High	Focus on emergency response and identifying isolation risks.
18	Werrington Road flooding - flood free access	Area 5 – Werrington Road and Rance Road Residential Areas	1. Raise the low point of Werrington Road and increase crossing capacity to prevent inundation during a 20 year ARI flood	N.A.	1. Alternative evacuation routes when crossing is inundated.	N.A.	Low	Properties that would benefit from road raising are inundated only during extreme events.

19	Flood protection to residential development, Rance Road, Werrington		1. Investigate potential to raise Rance and Werrington Road to reduce frequency of property damage.	1. Voluntary house raising if economically viable and properties are suitable.	1. Review of emergency response procedures to confirm potential evacuation routes.	N.A.	High	Options for raising Werrington and Rance Road are recommended based on potential for high Benefit-Cost ratio and increase to flood immunity of evacuation routes.
20	Adequacy and integrity of the Werrington Road levee and the areas behind the levee		N.A.	N.A.	N.A.	1. Review of levee crest elevations against predicted peak 100 year ARI flood levels.	High	Levee review to consider latest topographic data.
21	Management plan for Victoria Street / Irwin Street, Werrington		1. Consider potential for localised levee to protect properties at the western end of Irwin Street.	1. Review of existing planning controls	1. Ensure flood liability of local roads are defined and Emergency Response Planning Communities pick-up risks of isolation	N.A.	Medium	/
22	Flooding of Werrington properties by Werrington Creek							
23	Flood Access - Werrington Creek Crossings - Burton Street, Victoria Street, John Oxley Avenue		1. Assess potential to raise one or more road crossings	N.A.	1. Assess potential for alternate evacuation routes. 2. Ensure flood liability of road crossings is defined.	N.A.	High	Emergency response assessment to focus on identifying flood immunity of local roads and Werrington Creek crossings
24	Flood Impacts of Lee Holm Road to Link Road, St Marys, connection	Area 6 – North St Marys including the Former ADI Site	N.A.	N.A.	N.A.	N.A.	Low	Considered to be more appropriate as part of a site specific development assessment instead of a FRMS measure.
25	Filling for east rail corridor							
26	Flooding of Sewerage Treatment Plant, St Marys		1. Ring levee to divert potentially damaging floodwaters away from critical infrastructure. 2. Increase capacity of local channels.	1. Raise critical infrastructure to keep the plan operational during rarer events.	1. Emergency response procedures to identify liability of local roads to inundation. Evacuation of the site may be contingent of low-points elsewhere.	N.A.	Medium	/
27	Flood impacts by the development of the former ADI site		N.A.	N.A.	N.A.	N.A.	Low	Development of the ADI site and Ropes Crossing to be assessed as part of a Development Application. Impacts on South Creek flooding expected to be low given requirement to comply with Penrith City Council DCP criteria.
28	Ropes Crossing Urban development							
29	Link Road levee to protect St Mary's industrial areas		1. Raise links road to create a levee adjacent to Links Road	1. Flood barriers or sand bagging could be used at industrial properties to prevent damage to buildings and contents.	N.A.	N.A.	Medium	/
30	Adequacy of the Forrester Road bridge crossing and flooding of St Marys Rugby League Club		1. Raise localised low-points to the west and north of the St Marys Leagues Club. Widening of the bridge crossing may be required to prevent flood level increase	1. Flood barriers for the Leagues Club at entrances most at risk of flooding.	1. Ensure flood immunity of Forrestor Road is captured in Community data sheets	N.A.	Low	Based on alternate safer evacuation routes being readily available for at risk properties.
31	Flooding of Dunheved (Christie) Road crossing of South Creek		1. Raise low-point along Dunheved Road located approximately 80	/	1. Ensure flood immunity of Dunheved Road at low-	N.A.	Medium	Would be beneficial to investigate levee options due to potential reductions in flood damages

			metres east of the South Creek crossing. 2. Increase capacity of the South Creek crossing and causeway. 3. Investigate potential for levees to be constructed upstream of Dunheved Road to protect Dunheved Road and industrial properties.		point is captured in Community data sheets 2. Alternate evacuation routes to be considered			associated with providing protection to industrial properties.
32	Flooding of properties around Fifth Avenue to Eighth Avenue, Llandilo (assumed as properties to the west of Second Ave)	Area 7 – South Creek Floodplain Downstream of the Former ADI Site	Due to significant floodwater depths which are dominated by backwater flooding from the Hawkesbury-Nepean River structural works will not be effective at reducing flood damages.	1. Voluntary House Raising (VHR) may be suitable for dwellings outside of the floodway and high hazard areas 2. Voluntary Purchase (VHP) scheme may be appropriate for properties located within the floodway corridor.	1. Review local flood plan to ensure properties in Llandilo east of Second Ave are a priority for evacuation. 2. Investigate potential locations for a stream gauge upstream to maximise warning times. 3. Semi-automated gates and/or depth markers to be installed on crossings susceptible to overtopping.	N.A.	High	Considered high priority based on risks to existing residents. Investigations to be focused on improving emergency response and available flood warning. VHR and VP to be investigated as an option to remove most at-risk properties and to reduce flood damages (*VHR*).
33	Flooding of properties around (east of) Second Avenue, Llandilo							
34	Adequacy of Richmond Road Bridge and flooding of properties located upstream							
35	M4 Freeway overtopping by Ropes Creek	Area 8 – Ropes Creek Floodplain Upstream of the Railway Line Crossing	Crossing not predicted to be overtopped until events greater than the 0.2% AEP flood				Low	Due to high flood immunity relative to other roads this is considered to be a low priority.
36	Great Western Highway flooding by Ropes Creek		Crossing not predicted to be overtopped until events greater than the 0.2% AEP flood				Low	Due to high flood immunity relative to other roads this is considered to be a low priority.
37	Ropes Creek flooding of Oxley Park properties behind the railway line		1. Assess potential for a flood protection levee to the east of Melbourne Street 2. Assess potential for increase crossing capacity to reduce flood level upstream and at properties along Melbourne Street. 3. Assess potential for excavation downstream of the Railway Crossing to reduce flood levels upstream	1. Voluntary House Raising (VHR) may be suitable for dwellings outside of the floodway and high hazard areas	1. Ensure flood immunity of local roads are captured in Community data sheets	N.A.	High	Structural and property modification options recommended for further investigation

Appendix F – Mitigation Option Cost Estimates

DRM Measure F-1A - Oxley Park Low Cut

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 5-Jul-19

Advisian
Worley Group

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit		Total
1	**Construction Site Establishment**					
	- mobilisation of excavator, equipment	1	10,000	item	$	10,000
	- Site establishment, including envrionmental controls	1	15,000	item	$	15,000
2	**Surface Regrading**					
	- remove vegetation	11700	$0.52	sqm	$	6,084
	- remove top soil (150mm)	1750	$8.70	cum	$	15,225
	- excavate surface	3000	$30.00	cum	$	90,000
	- compaction of surace	11700	$3.50	sqm	$	40,950
	- topsoil placement from stockpiles	1750	$8.15	cum	$	14,263
	- leveling top soil	11700	$8.25	sqm	$	96,525
3	**Site Clean-Up**					
	- clean-up	1	5	%	$	13,152
		TOTAL CONSTRUCTION COSTS			$	302,000
4	**Additional Upfront Costs**					
	- further approvals and investigations	1	30,000	item	$	30,000
	- detail design	1	15,000	item	$	15,000
		TOTAL PRESENT VALUE OF COSTS (7% Real Discount Rate)			$	297,200
		TOTAL (+20% CONTINGENCY)			**$**	**356,640**

DRM Measure F-1B - Oxley Park High Cut

Project No.:	301310-08772
Project Name:	South Creek FRMS
Date:	5-Jul-19

Disclaimer

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit		Total
1	**Construction Site Establishment**					
	- mobilisation of excavator, equipment	1	10,000	item	$	10,000
	- Site establishment, including envrionmental controls	1	20,000	item	$	20,000
2	**Surface Regrading**					
	- remove vegetation	18500	$0.52	sqm	$	9,620
	- remove top soil (150mm)	2775	$8.70	cum	$	24,143
	- excavate surface	16975	$30.00	cum	$	509,250
	- compaction of surace	18500	$3.50	sqm	$	64,750
	- topsoil placement from stockpiles	2775	$8.15	cum	$	22,616
	- level, grade, prepare, grass seed and water/maintain for 6 months	18500	$8.25	sqm	$	152,625
3	**Site Clean-Up**					
	- clean-up	1	5	%	$	39,150
		TOTAL CONSTRUCTION COSTS			$	852,000
4	**Additional Upfront Costs**					
	- further approvals and investigations	1	30,000	item	$	30,000
	- detail design	1	15,000	item	$	15,000
				TOTAL	$	762,000
		TOTAL (+20% CONTINGENCY)			**$**	**914,400**

DRM Option 2 - Oxley Park Flood Protection Levee

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 22-Oct-18

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit	Cost
1	**Preliminaries**				
	- equipment mobilisation and site establishment	1	5	%	$21,502
2	**Key Foundation**				
	- excavation of foundation channel	1210	$60.00	cum	$72,600
	- shaping of batter slopes	2405	$2.90	sqm	$6,975
	- compact foundation	2,405	$3.40	sqm	$8,177
	- crushed rock filling laid and consolidated in 150mm layers	1,210	$90	cum	$108,900
	- geotextile layer	2,405	$8.45	sqm	$20,322
3	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	480	$90.00	cum	$43,200
	- shaping of batter slopes	1,000	$2.90	sqm	$2,900
4	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	960	$40.80	cum	$39,168
	- vapour barrier sand fill (100mm thick)	580	$86.00	cum	$49,880
	- shaping of batter slopes	5,750	$2.90	sqm	$16,675
5	**Surface Treatment and Landscaping**				
	- jute mat	5,750	$2	sqm	$11,500
	- grass seed, including maintenance	5,750	$8.65	sqm	$49,738
6	**Site Disestablishment**				
	- including clean up	1	5	%	$21,502
7	**Drainage**				
	- Allowance for cross-drainage investigation and construction	1	$50,000	item	$50,000
8	**30 Year Design Life Costs**				
	- further approvals and investigations (including REF)	1	$50,000	item	$50,000
	- concept and detail design	1	$100,000	item	$100,000
	- levee inspection and maintenance (every 3 years)	10	$10,000	item	$100,000
				TOTAL	$773,038
				TOTAL (+20% CONTINGENCY)	**$928,000**

DRM Option F5 - Rance Road Raising

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 18-Oct-18

Advisian
Worley Group

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit		Cost
1	**Preliminaries**					
	- equipment mobilisation and site establishment	1	$5	%	$	11,680
	- site clearing	10,000	$0.52	sqm	$	5,200
	- tree removal	100	$180	No.	$	18,000
	- tree disposal	50	$200	t	$	10,000
	- erosion and sedimentation control measures		Lump Sum		$	10,000
	- OH&S procedures		Lump Sum		$	5,000
	- stormwater diversion and flood protection during construction		Lump Sum		$	5,000
2	**Roadworks**					
	Breakup and remove bitumen oavubg with basecourse under	4130	$3.35	sqm	$	13,836
	Roadbase (assume crushed rock/blue metal, 300mm layer)	4130	$32.20	sqm	$	132,986
	Prime and sprayed bitumen sealing, two coats	4130	$7.50	sqm	$	30,975
	Roadmarking - 4 lines, 75mm wide	1630	$1.60	m	$	2,608
3	**Earth Works**					
	Bulk Filling	1930	$89	cum	$	171,770
	Retaining wall	590	$297	sqm	$	175,230
	Reinforced concrete footing including excavation	410	$539	cum	$	220,990
6	**Site Disestablishment**					
	- including clean up	1	5	%	$	40,080
7	**Extras**					
	Further approvals and investigations	1	$50,000	item	$	50,000
	Concept and detail design	1	$100,000	item	$	100,000

TOTAL	$1,003,000
TOTAL (+20% CONTINGENCY)	**$1,204,000**

DRM Option F-7A - St Marys Levee

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 7-Aug-19

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit	Cost
Preliminaries					
	- equipment mobilisation	3	$10,000	**item**	$30,000
	- site establishment, including envrionmental controls	3	$15,000	**item**	$45,000
Levee Section 1 - 25m Long Earthen Levee (Max Height is 0.7m)					
1.1	**Key Foundation**				
	- excavation of foundation channel	90	$60.00	cum	$5,400
	- shaping of batter slopes	168	$2.90	sqm	$488
	- compact foundation	168	$3.40	sqm	$572
	- crushed rock filling laid and consolidated in 150mm layers	90	$90	cum	$8,100
	- geotextile layer	168	$8.45	sqm	$1,422
1.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	110	$90.00	cum	$9,900
	- shaping of batter slopes	340	$2.90	sqm	$986
1.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	110	$40.80	cum	$4,488
	- vapour barrier sand fill (100mm thick)	40	$86.00	cum	$3,440
	- shaping of batter slopes	340	$2.90	sqm	$986
1.4	**Surface Treatment and Landscaping**				
	- jute mat	340	$2	sqm	$680
	- grass seed, including maintenance	340	$8.65	sqm	$2,941
			Sub Total (Levee Section 1) -		$64,403.72
Levee Section 2 - 80m of Upgrades to Existing Earthen Levee (Increase height by 0.2m)					
2.1	**Key Foundation**				
	- excavation of parts of the existing levee (0.5m) plus foundation channel	200	$60.00	cum	$12,000
	- shaping of batter slopes	394	$2.90	sqm	$1,143
	- compact foundation	394	$3.40	sqm	$1,341
2.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	280	$90.00	cum	$25,200
	- shaping of batter slopes	790	$2.90	sqm	$2,291
2.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	280	$40.80	cum	$11,424
	- vapour barrier sand fill (100mm thick)	80	$86.00	cum	$6,880
	- shaping of batter slopes	790	$2.90	sqm	$2,291
2.4	**Surface Treatment and Landscaping**				
	- jute mat	790	$2	sqm	$1,580
	- grass seed, including maintenance	790	$8.65	sqm	$6,834
			Sub Total (Levee Section 2) -		$95,983.51
Levee Section 3 - 65m of Upgrades to Existing Earthen Levee (Increase height by up to 0.7m)					
3.1	**Key Foundation**				
	- excavation of parts of the existing levee (0.5m) plus foundation channel	270	$60.00	cum	$16,200
	- shaping of batter slopes	688	$2.90	sqm	$1,996
	- compact foundation	688	$3.40	sqm	$2,340
3.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	340	$90.00	cum	$30,600
	- shaping of batter slopes	1080	$2.90	sqm	$3,132
3.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	340	$40.80	cum	$13,872
	- vapour barrier sand fill (100mm thick)	110	$86.00	cum	$9,460
	- shaping of batter slopes	1080	$2.90	sqm	$3,132
3.4	**Surface Treatment and Landscaping**				
	- jute mat	1080	$2	sqm	$2,160
	- grass seed, including maintenance	1080	$8.65	sqm	$9,342
			Sub Total (Levee Section 3) -		$117,233.22

Levee Section 4 - Length of Upgrades 40m

4.1	**Concrete Levee Structure**					
	Preliminary cost estimate for the required concrete levee only. Review of original design drawings required and detailed survey of existing crest elevations. It is expected the existing levee panels will need to be removed at location of upgrades and reconstructed to higher elevation.	1	$120,000	item		$120,000

Site Disestablishment

4	**Site Disestablishment**					
	- including clean up	1	5	%		$30,012
			TOTAL CONSTRUCTION COSTS			**$427,700**

Additional Costs

5	**Additional Upfront Costs**					
	- Detailed survey of the levee crest and surrounds	1	$ 20,000.00	item	$	20,000
	- further approvals and investigations (including REF)	1	$ 50,000.00	item	$	50,000
	- concept and detail design	1	$ 80,000.00	item	$	80,000
6	**30 Year Design Life Costs**					
	- levee inspection and maintenance (every 3 years)	10	$10,000	item		$100,000

TOTAL PRESENT VALUE OF COSTS (7% Real Discount Rate)	**$528,500**
TOTAL (+20% CONTINGENCY)	**$634,000**

DRM Option F-7B - St Marys Levee

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 7-Aug-19

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit	Cost
Preliminaries					
	- equipment mobilisation	3	$10,000	**item**	$30,000
	- site establishment, including envrionmental controls	3	$15,000	**item**	$45,000
Levee Section 1 - 25m Long Earthen Levee (Max Height is 0.7m)					
1.1	**Key Foundation**				
	- excavation of foundation channel	90	$60.00	cum	$5,400
	- shaping of batter slopes	168	$2.90	sqm	$488
	- compact foundation	168	$3.40	sqm	$572
	- crushed rock filling laid and consolidated in 150mm layers	90	$90	cum	$8,100
	- geotextile layer	168	$8.45	sqm	$1,422
1.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	110	$90.00	cum	$9,900
	- shaping of batter slopes	340	$2.90	sqm	$986
1.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	110	$40.80	cum	$4,488
	- vapour barrier sand fill (100mm thick)	40	$86.00	cum	$3,440
	- shaping of batter slopes	340	$2.90	sqm	$986
1.4	**Surface Treatment and Landscaping**				
	- jute mat	340	$2	sqm	$680
	- grass seed, including maintenance	340	$8.65	sqm	$2,941
			Sub Total (Levee Section 1) -		$64,403.72
Levee Section 2 - 80m of Upgrades to Existing Earthen Levee (Increase height by 0.2m)					
2.1	**Key Foundation**				
	- excavation of parts of the existing levee (0.5m) plus foundation channel	200	$60.00	cum	$12,000
	- shaping of batter slopes	394	$2.90	sqm	$1,143
	- compact foundation	394	$3.40	sqm	$1,341
2.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	280	$90.00	cum	$25,200
	- shaping of batter slopes	790	$2.90	sqm	$2,291
2.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	280	$40.80	cum	$11,424
	- vapour barrier sand fill (100mm thick)	80	$86.00	cum	$6,880
	- shaping of batter slopes	790	$2.90	sqm	$2,291
2.4	**Surface Treatment and Landscaping**				
	- jute mat	790	$2	sqm	$1,580
	- grass seed, including maintenance	790	$8.65	sqm	$6,834
			Sub Total (Levee Section 2) -		$95,983.51
Levee Section 3 - 65m of Upgrades to Existing Earthen Levee (Increase height by up to 0.7m)					
3.1	**Key Foundation**				
	- excavation of parts of the existing levee (0.5m) plus foundation channel	270	$60.00	cum	$16,200
	- shaping of batter slopes	688	$2.90	sqm	$1,996
	- compact foundation	688	$3.40	sqm	$2,340
3.2	**Levee Core Construction**				
	- crushed rock filling laid and consolidated in 150mm layers	340	$90.00	cum	$30,600
	- shaping of batter slopes	1080	$2.90	sqm	$3,132
3.3	**Levee Bulk Construction**				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	340	$40.80	cum	$13,872
	- vapour barrier sand fill (100mm thick)	110	$86.00	cum	$9,460
	- shaping of batter slopes	1080	$2.90	sqm	$3,132
3.4	**Surface Treatment and Landscaping**				
	- jute mat	1080	$2	sqm	$2,160
	- grass seed, including maintenance	1080	$8.65	sqm	$9,342
			Sub Total (Levee Section 3) -		$117,233.22

Levee Section 4 - Length of Upgrades 40m

4.1	**Concrete Levee Structure**					
	Preliminary cost estimate for the required concrete levee only. Review of original design drawings required and detailed survey of existing crest elevations. It is expected the existing levee panels will need to be removed at location of upgrades and reconstructed to higher elevation.	1	$120,000	item		$120,000

Supply and Installation of a Flap Gate on Byrnes Creek Culvert

5.1	**Flap Gate to Cover 3.7m (H) by 3.5m (W) Culvert**					
	Due to the size of the gate required it is expected that it will need to be specially designed to fit and function as intended.	1	$80,000	item		$80,000

Site Disestablishment

4	**Site Disestablishment**					
	- including clean up	1	5	%		$34,012

TOTAL CONSTRUCTION COSTS **$511,700**

Additional Costs

5	**Additional Upfront Costs**					
	- Detailed survey of the levee crest and surrounds	1	$ 20,000.00	item	$	20,000
	- further approvals and investigations for the levee upgrades (including REF)	1	$ 50,000.00	item	$	50,000
	- concept and detail design	1	$ 80,000.00	item	$	80,000
6	**30 Year Design Life Costs**					
	- levee inspection and maintenance (every 3 years)	10	$10,000	item		$100,000
	- Flap Gate inspection and maintenance (every year)	28	$2,000	item		$56,000

TOTAL PRESENT VALUE OF COSTS (7% Real Discount Rate) **$620,000**

TOTAL (+20% CONTINGENCY) **$744,000**

Option P-1 - Voluntary House Raising

Project No.:	301310-08772
Project Name:	South Creek FRMS
Date:	5-Jul-19

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 35, 2017

Item	Description	Quantity	Rate	Unit	Cost
1	**House Raising Works (Per Dwellling)**				
	- raise house by 0.8m (average height)	1	90,000	item	90,000
	- cost for residents alternative accommodation (rent for 6 weeks)	6	800	week	4,800
	- cost for residents removals	2	2,000	item	4,000
			TOTAL COST PER DWELLING		98,800
2	**Additional Costs**				
	- develop VHR Scheme documentation	1	30,000	item	30,000
	- consult with affected landowners	1	20,000	item	20,000
	- ongoing administration of Scheme	1	25,000	item	25,000
	TOTAL PRESENT VALUE OF COSTS FOR RAISING TEN (10) DWELLINGS (7% Real Discount Rate)				$823,000
			TOTAL (+20% CONTINGENCY)		**$988,000**

Option P-2B - Voluntary House Purchase (High Estimate)

Project No.: 301310-08772
Project Name: South Creek FRMS
Date: 5-Jul-19

Disclaimer
This cost estimate is based on Advisians' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 26, 2017

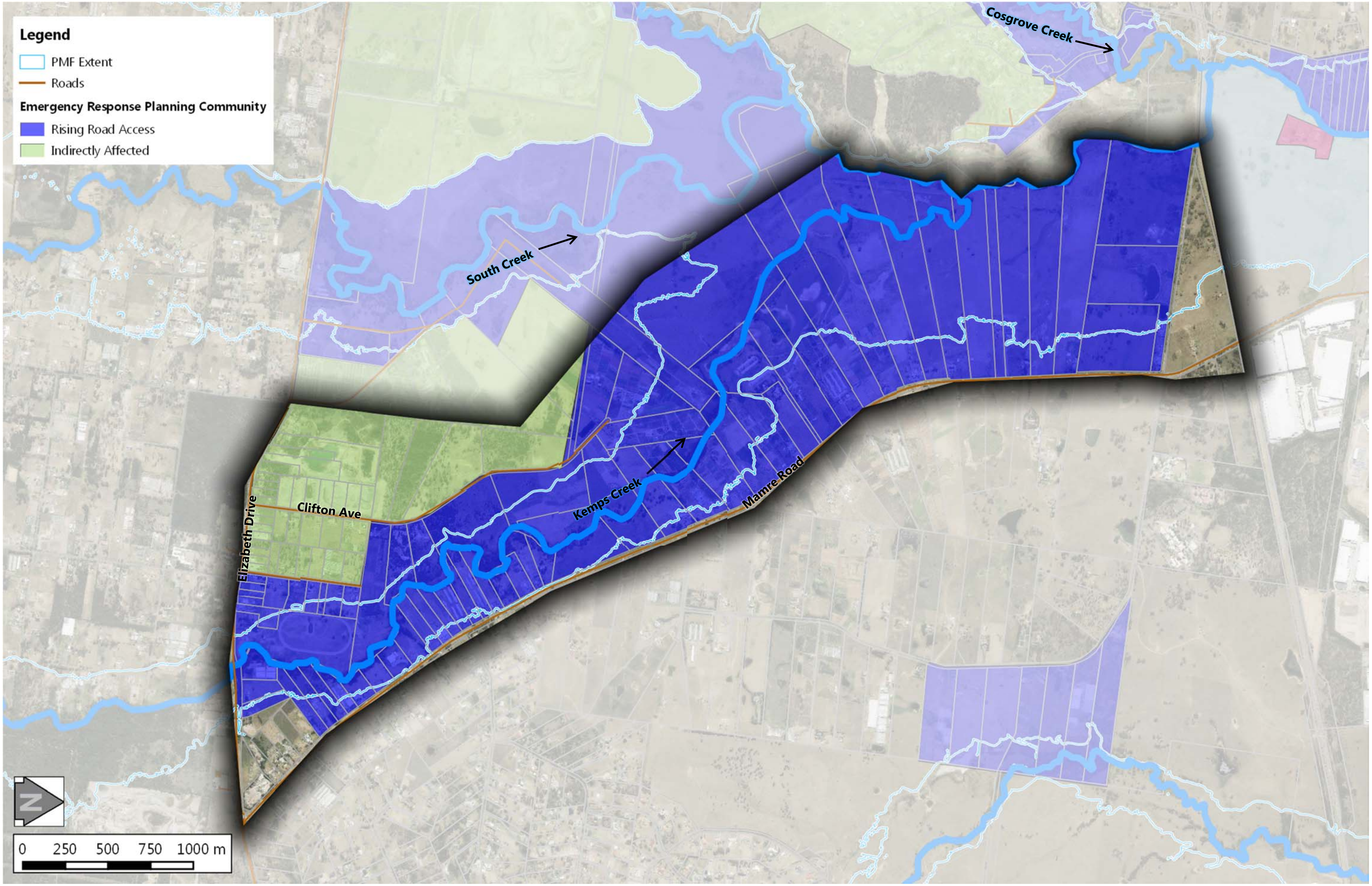
Item	Description	Quantity	Rate	Unit	Cost
1	**House Purchase (per Dwelling)**				
	- cost of purchase (based on average sale price)	1	1,300,000	item	1,300,000
	- legal fees	1	3,000	item	3,000
	- stamp duty	1	4.0	%	52,000
2	**Demolition (per Dwelling)**				
	- demolition of house, including waste disposal charges	1	25,000	item	25,000
3	**Surface Treatment and Landscaping (per Dwelling)**				
	- jute mat	400	2.00	sqm	800
	- grass seed, including loam layer	400	8.65	sqm	3,460
		TOTAL COST PER DWELLING			$1,384,260
4	**Additional Costs**				
	- develop VP Scheme documentation	1	40,000	item	40,000
	- consult with affected landowners	1	20,000	item	20,000
	- ongoing administration of Scheme	1	15,000	item	15,000

TOTAL PRESENT VALUE OF COSTS FOR PURCHASING FIFTEEN (15) PROPERTIES (7% Real Discount Rate) $10,036,000

TOTAL (+20% CONTINGENCY) $12,043,000

Appendix G – Mapping of Flood Risk Management Communities

FIGURE G-1



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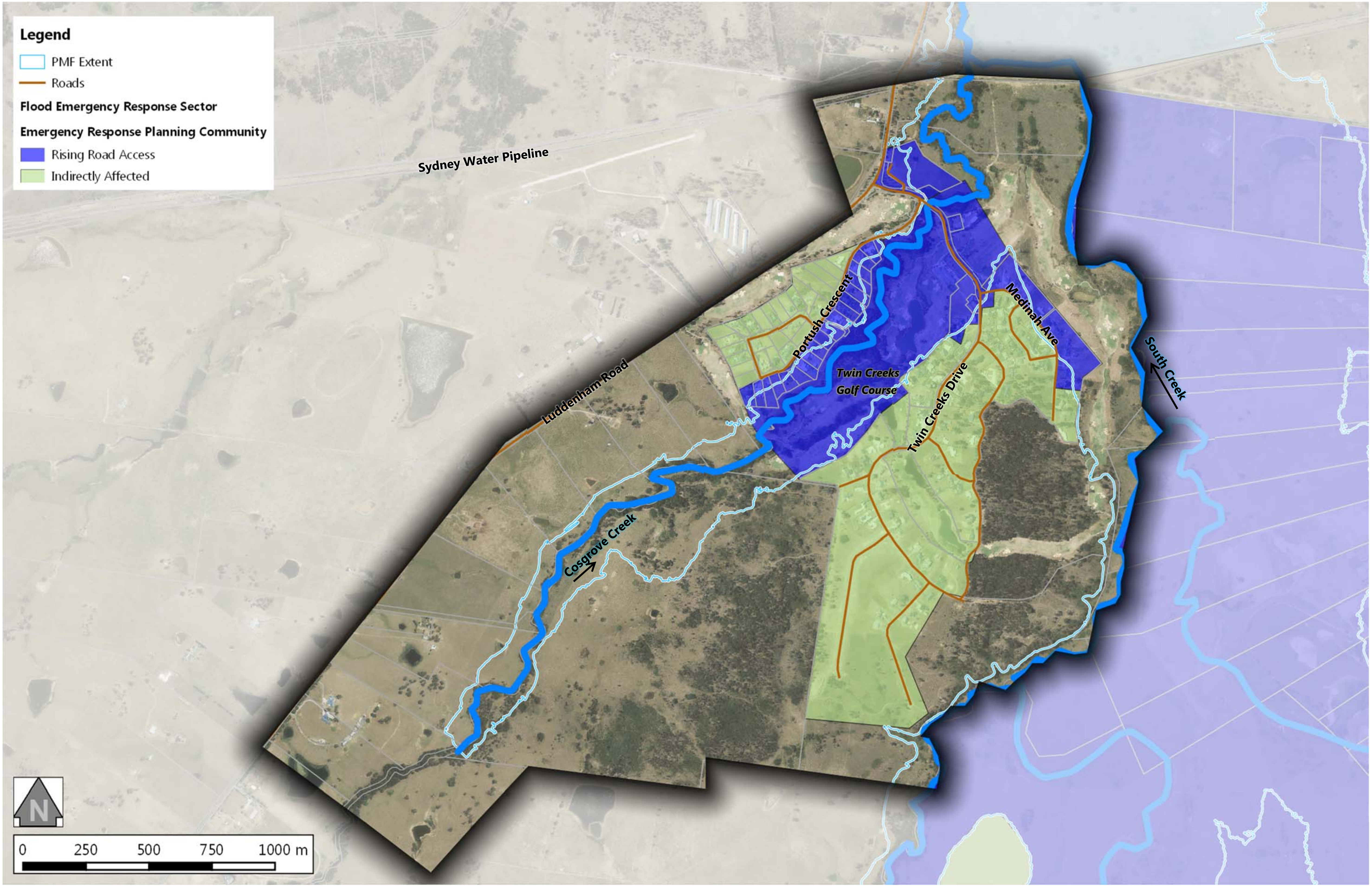
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.1_ERP_KempsCreek

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: KEMPS CREEK

FIGURE G.2



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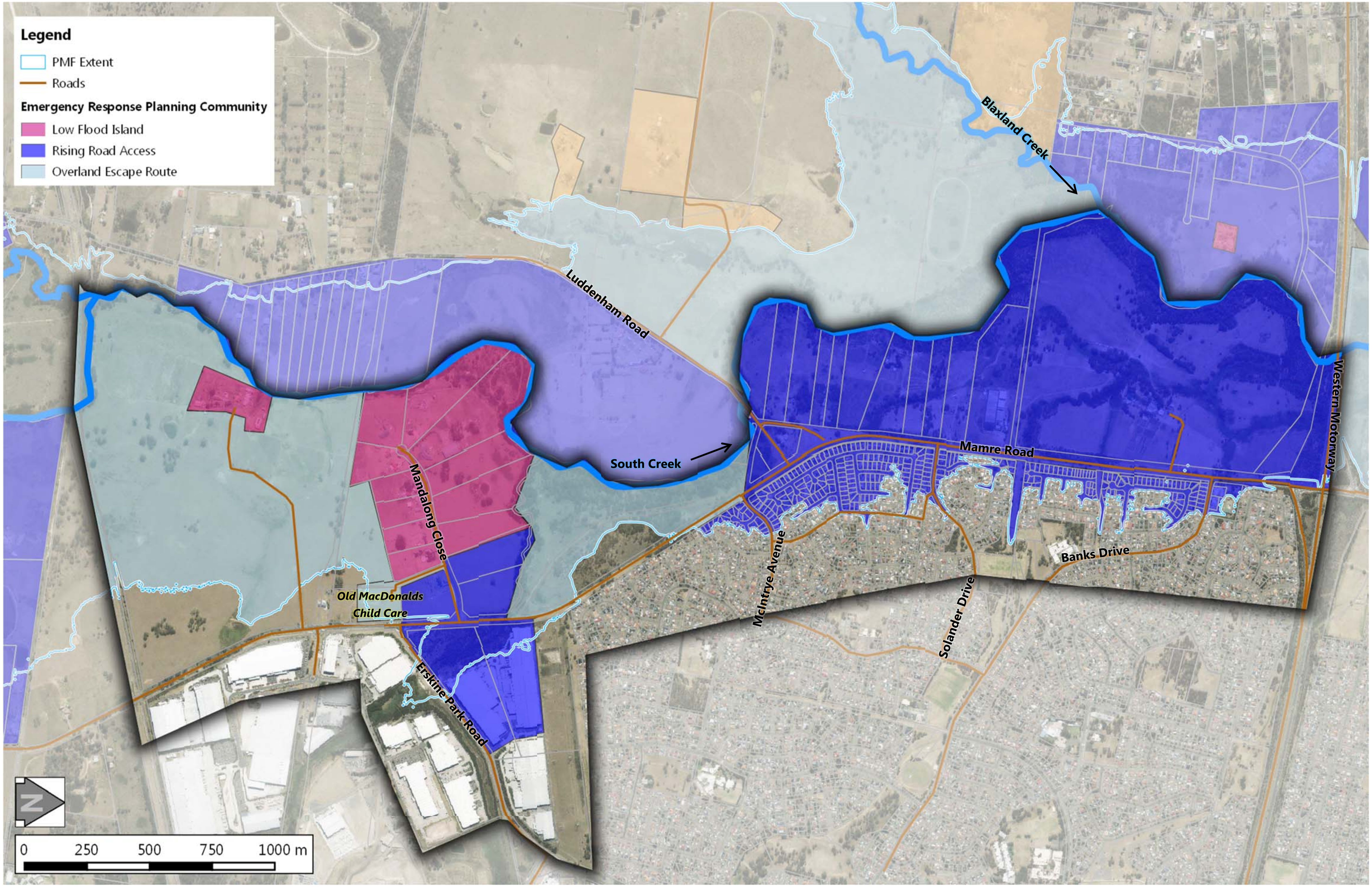
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.1_ERP_TwinCreeks

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: TWIN CREEKS

FIGURE G.3



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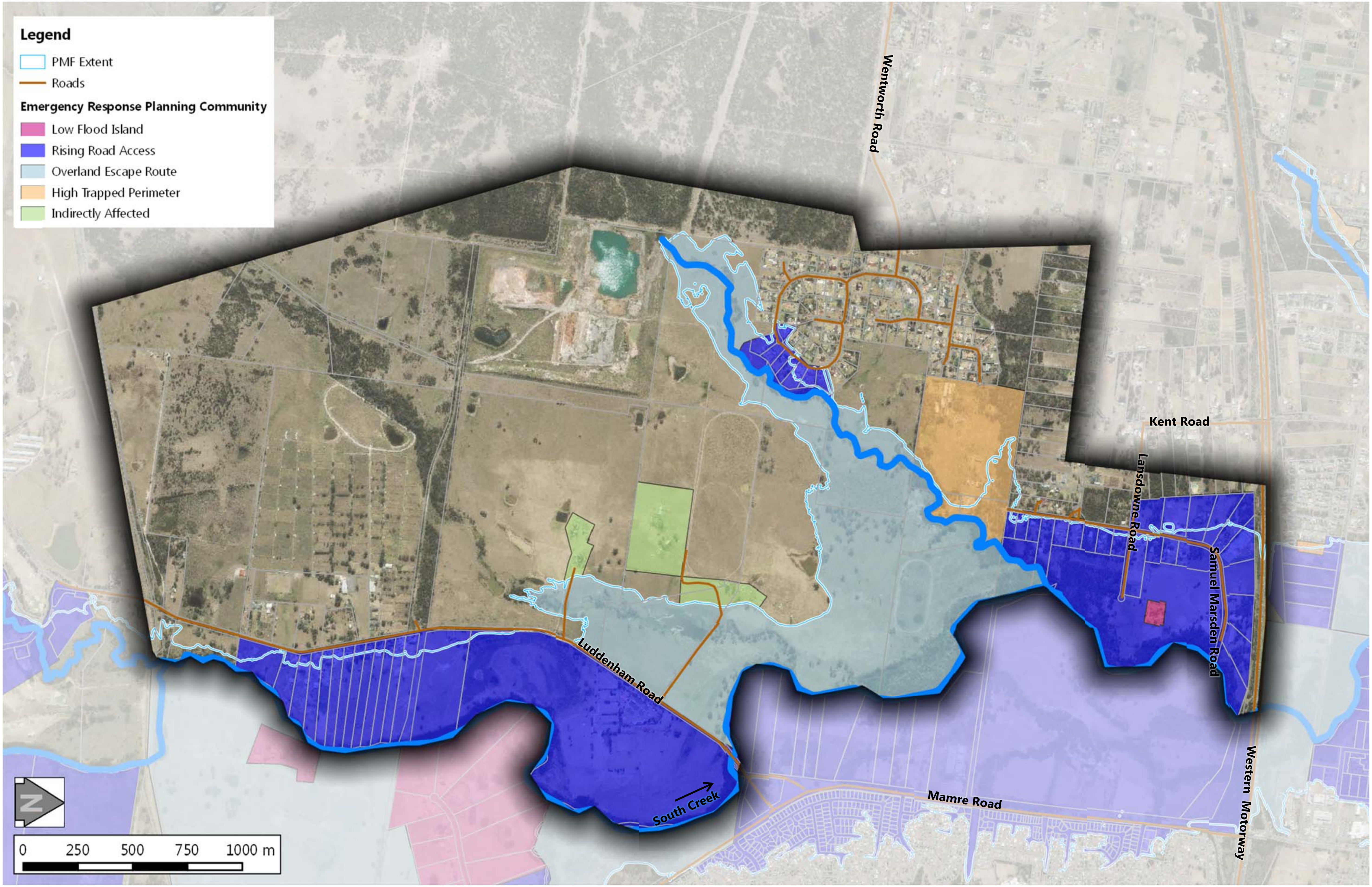
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.3_ERP_MamreRoad

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES
FOR FLOOD EMERGENCY MANAGEMENT SECTOR:
MAMRE ROAD

FIGURE G.4



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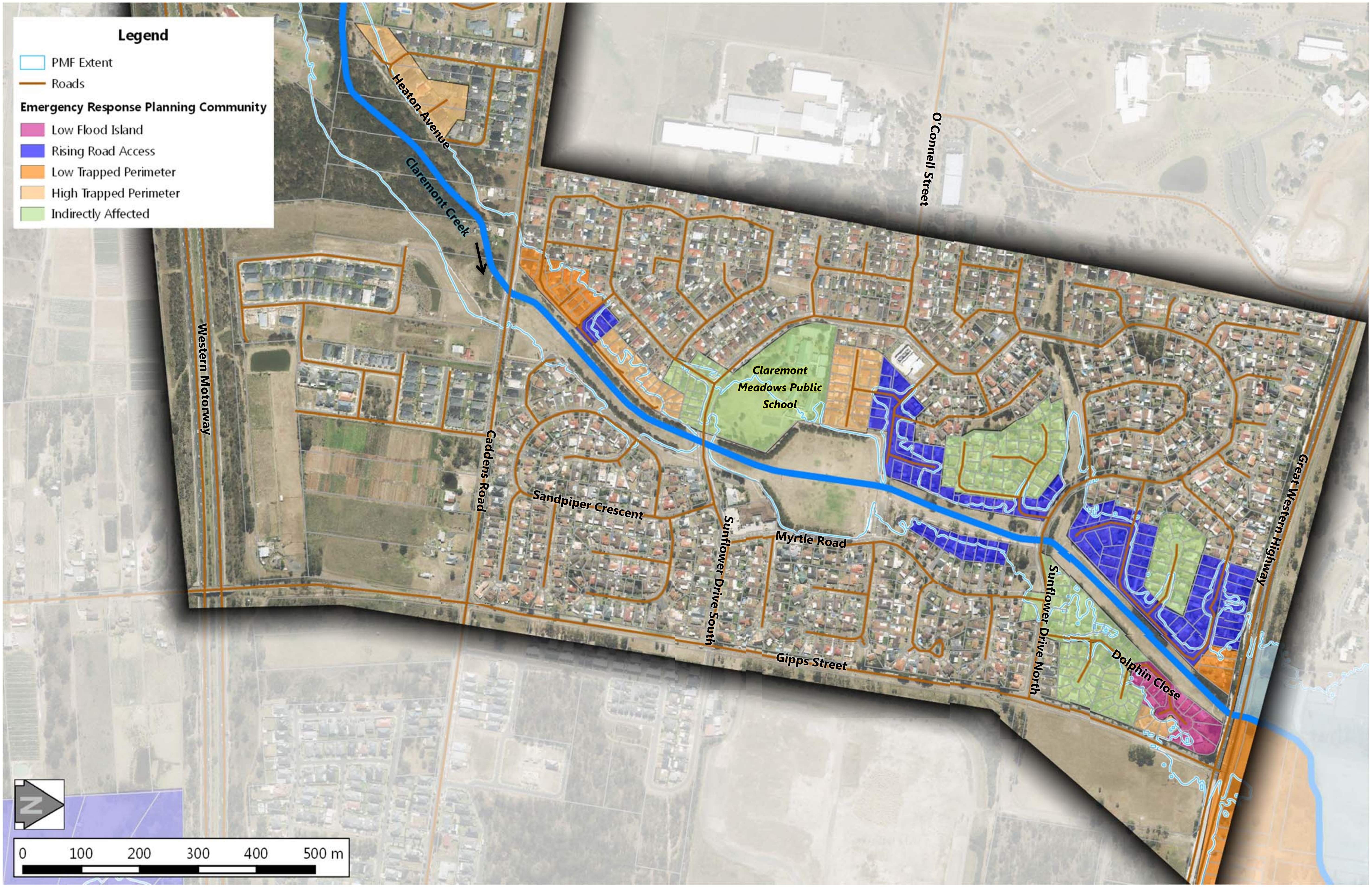
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.4_ERP_OrchardHillsWest

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES
FOR FLOOD EMERGENCY MANAGEMENT SECTOR:
ORCHARD HILLS WEST

FIGURE G.5



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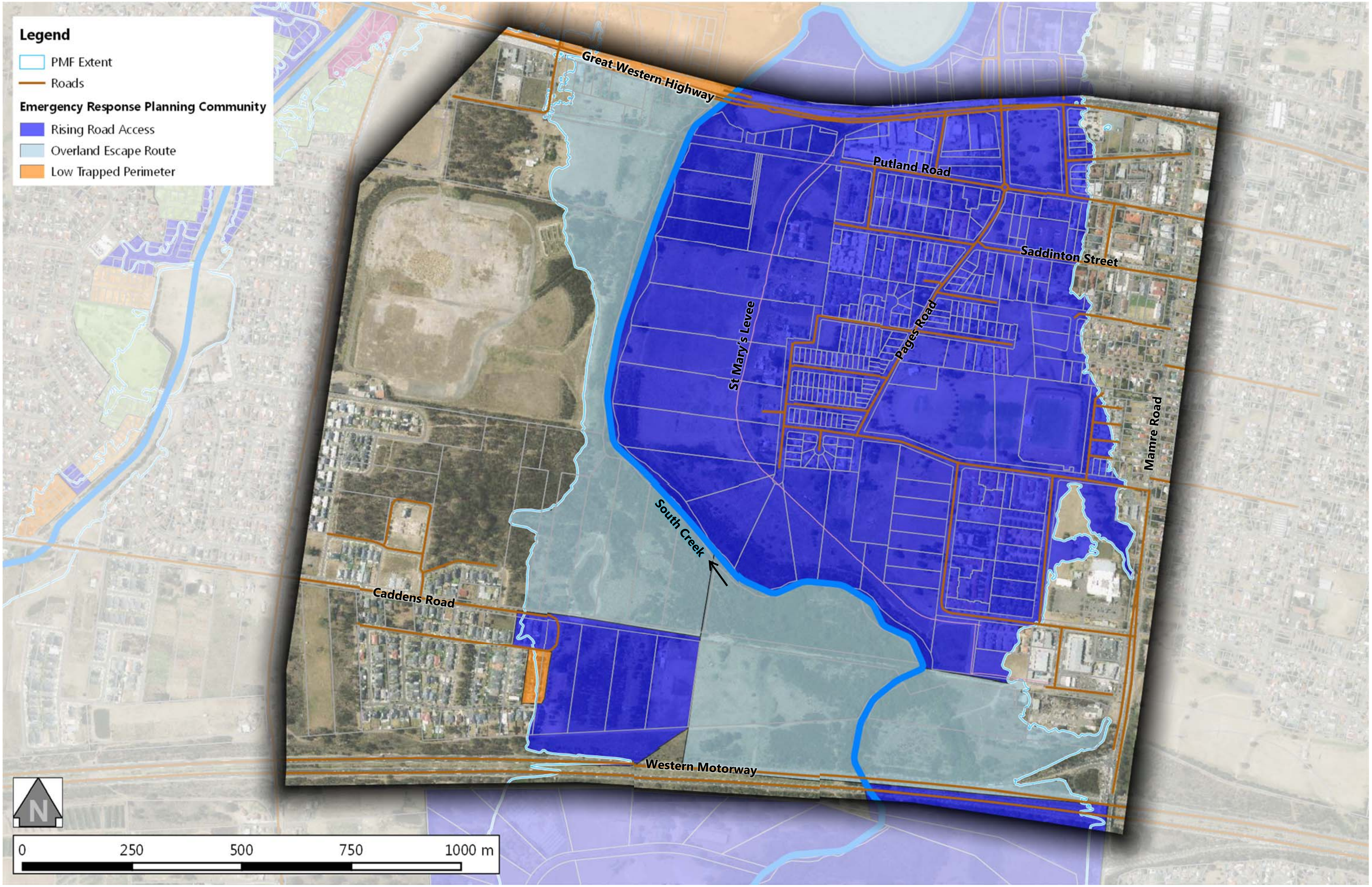
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.5_ERP_ClaremontCreek

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES
FOR FLOOD EMERGENCY MANAGEMENT SECTOR:
CLAREMONT CREEK

FIGURE G.6



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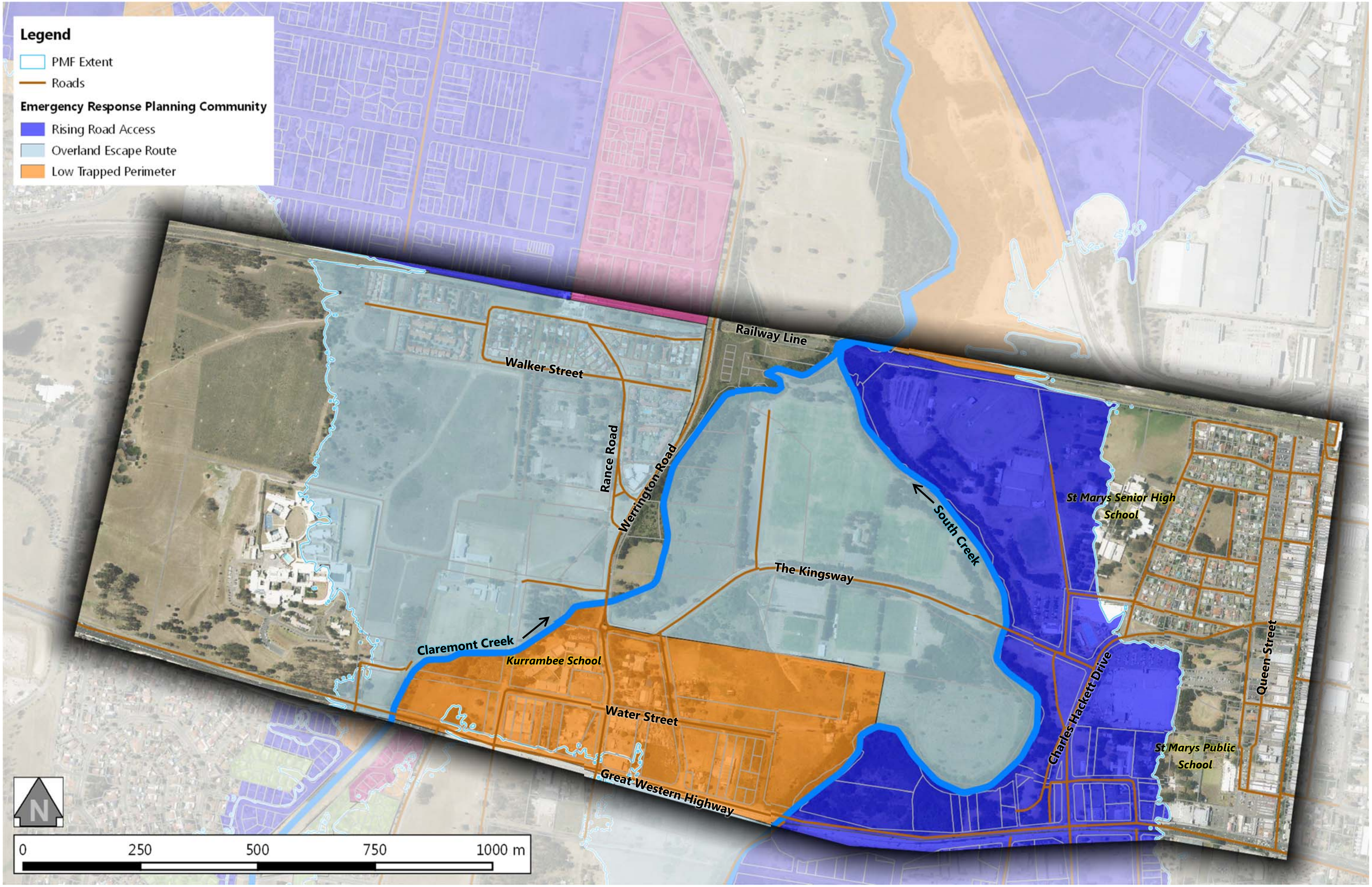
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.6_ERP_StMarys

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES
FOR FLOOD EMERGENCY MANAGEMENT SECTOR:
ST MARYS



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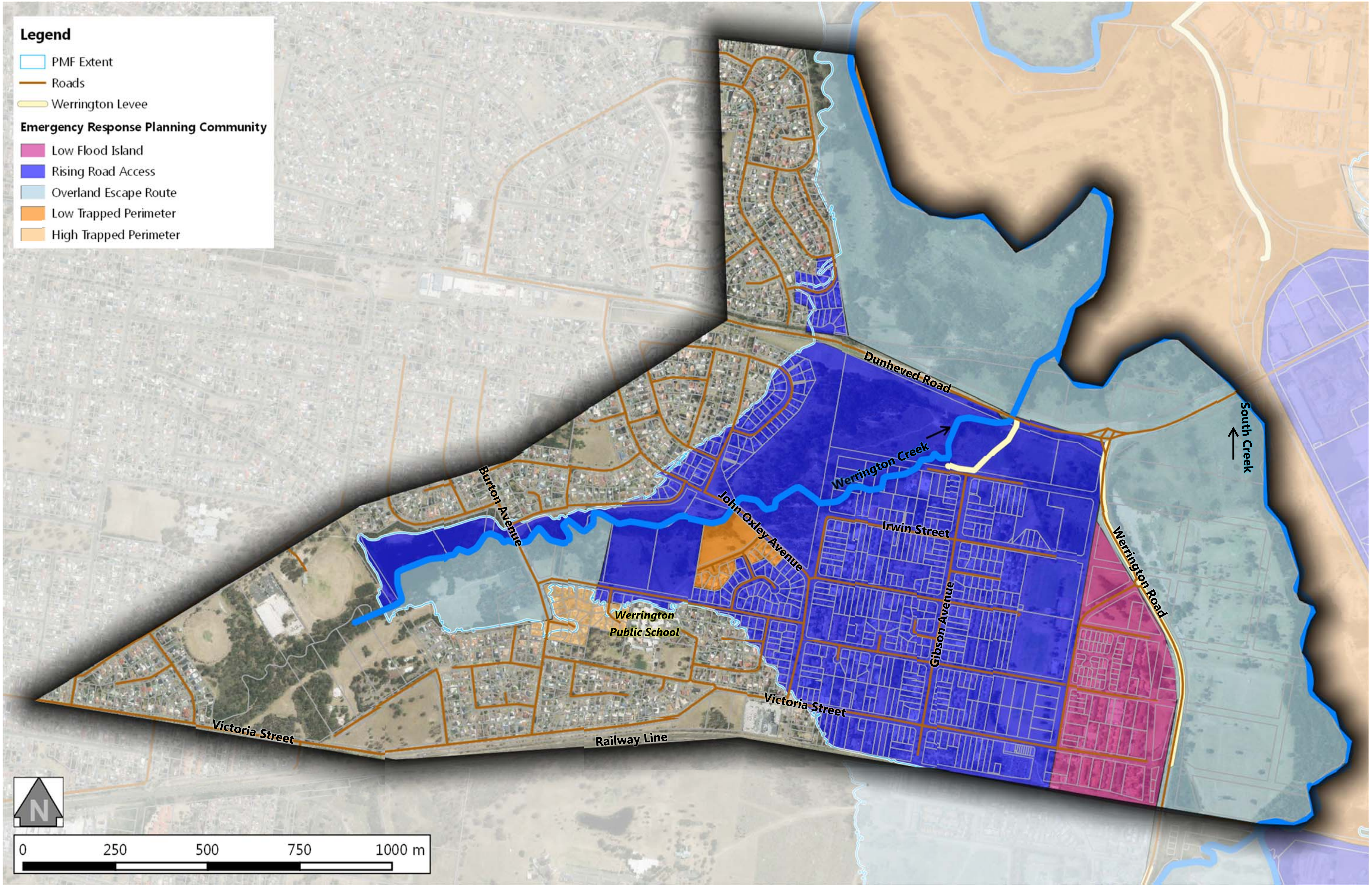
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.7_ERP_TheKingsway

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: THE KINGSWAY



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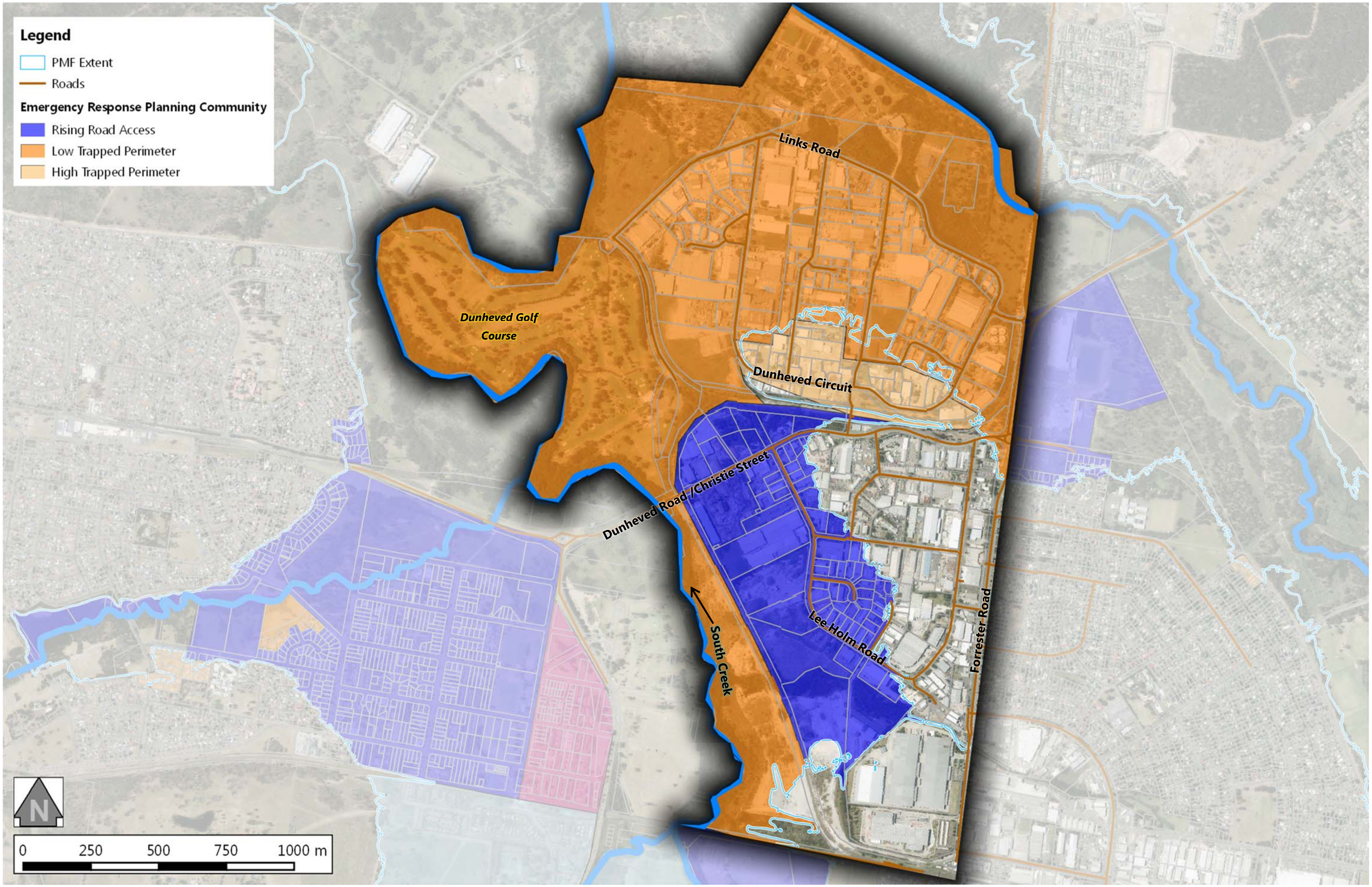
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.8_ERP_Werrington

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: WERRINGTON



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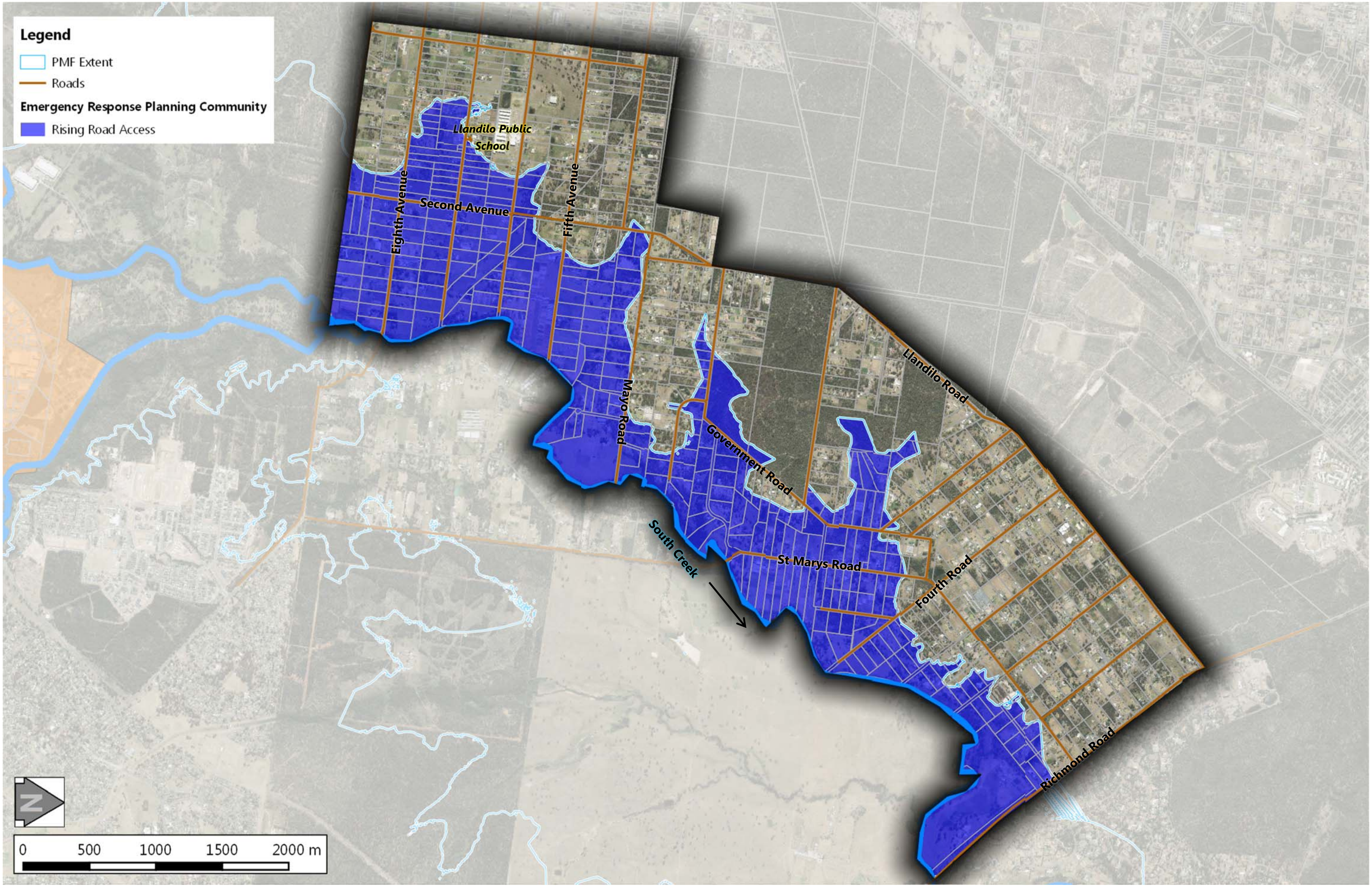
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.9_ERP_Werrington

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, INDUSTRIAL AREA



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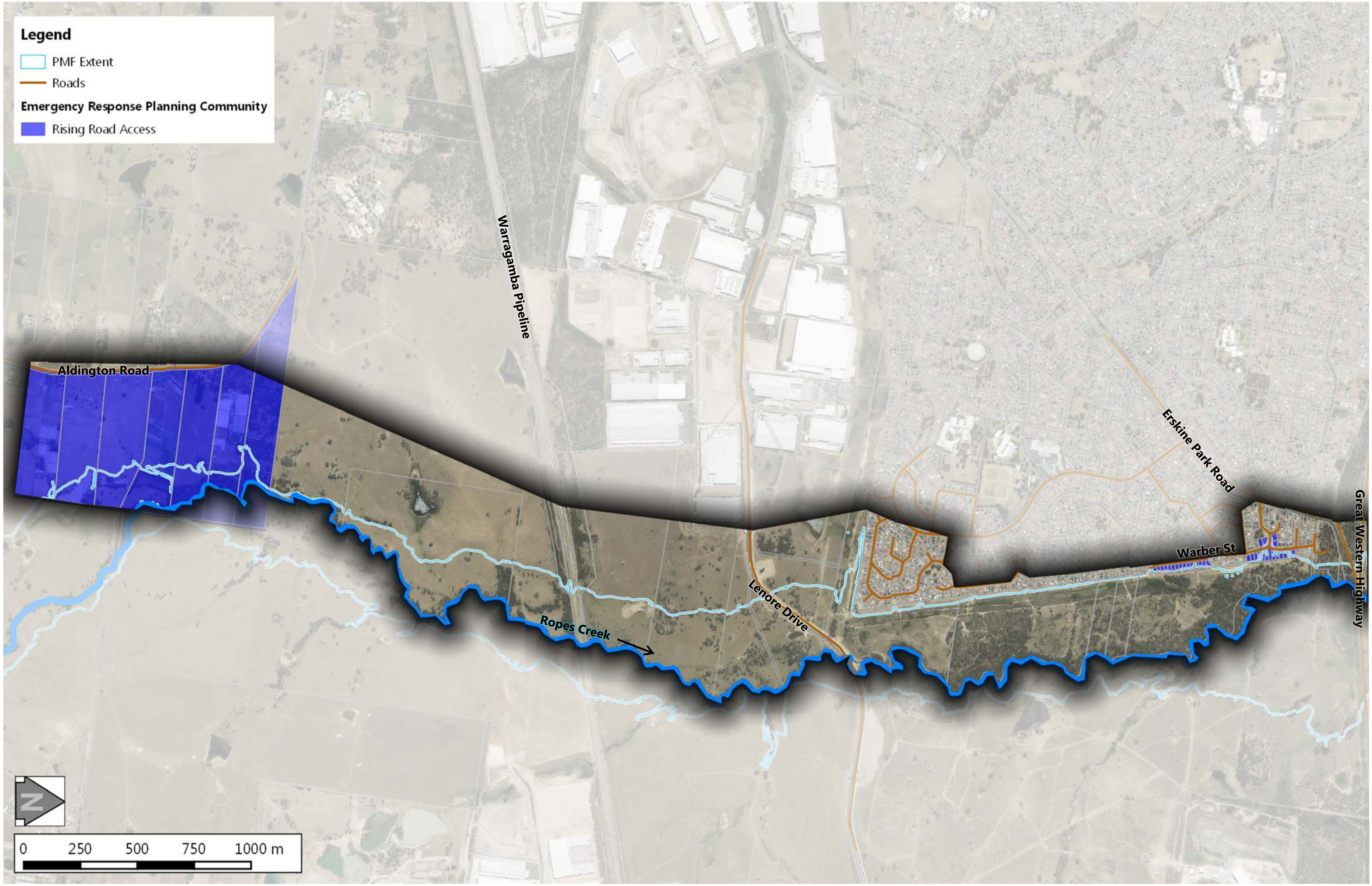
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.10_ERP_Llandilo

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: LLANDILO AND BERKSHIRE PARK



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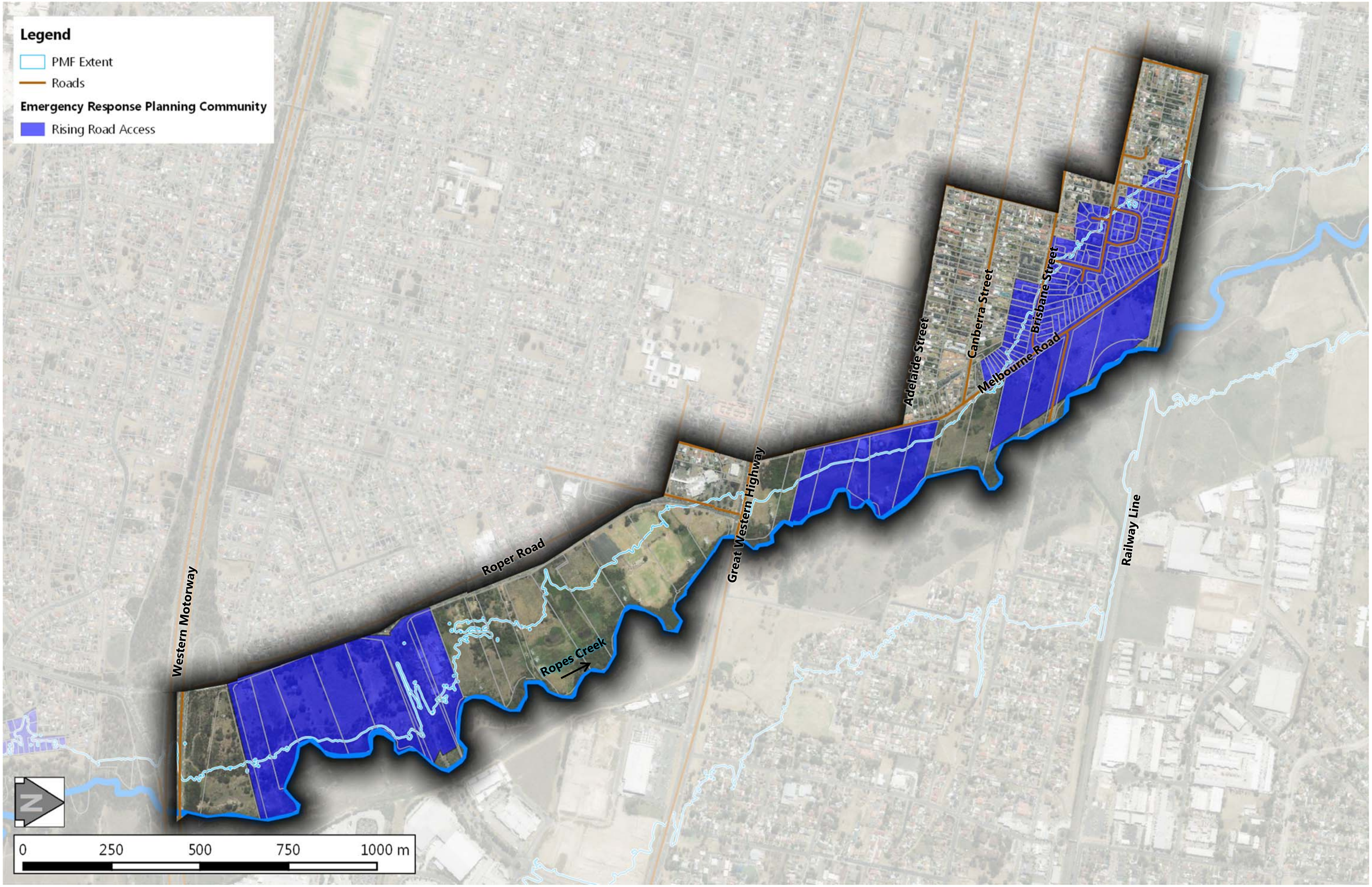
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.11_ERP_Erskine Park

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: ERSKINE PARK

FIGURE G.12



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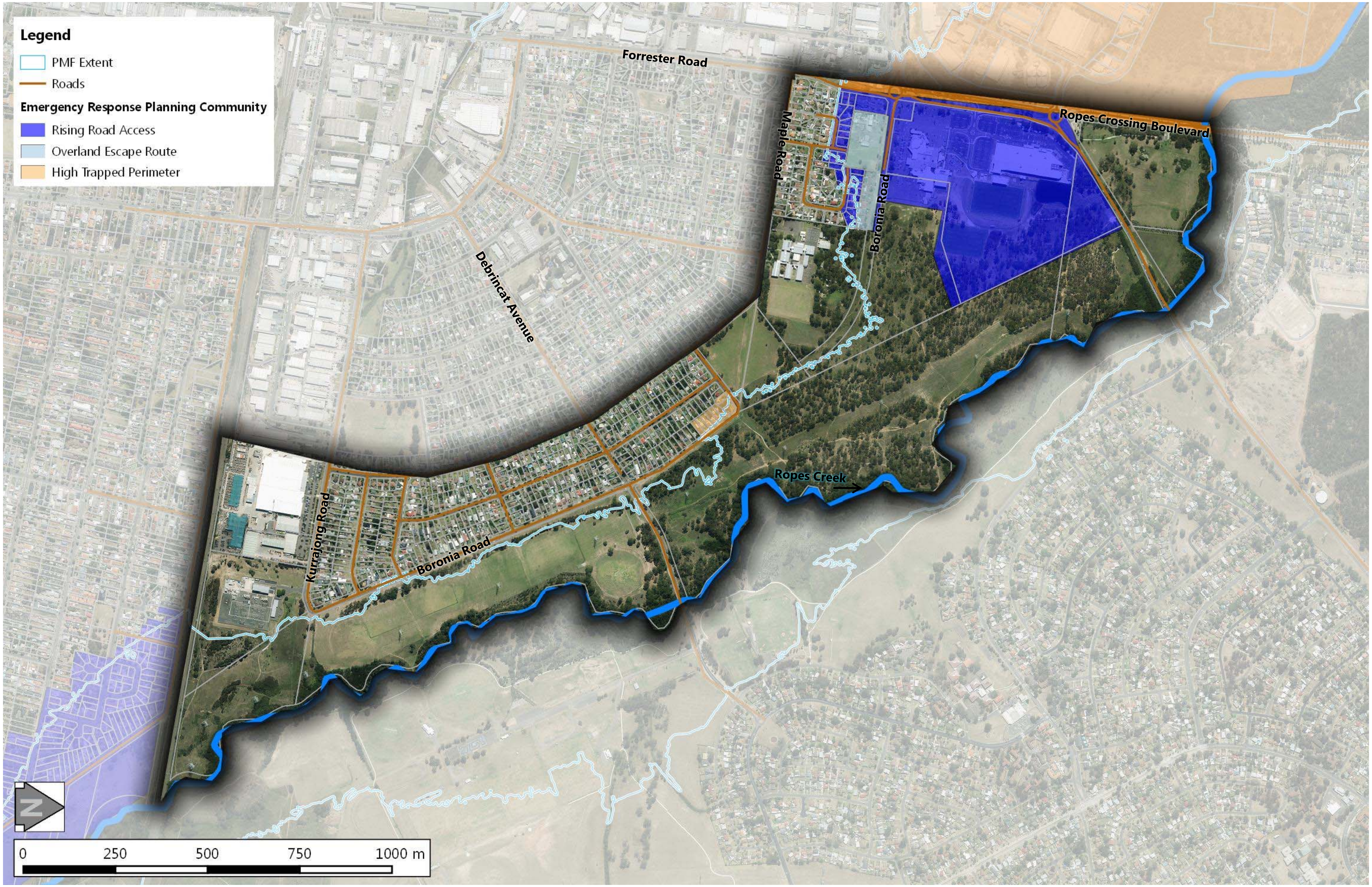
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.12_ERP_Colyton_OxleyPark

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: COLYTON / OXLEY PARK

FIGURE G.13



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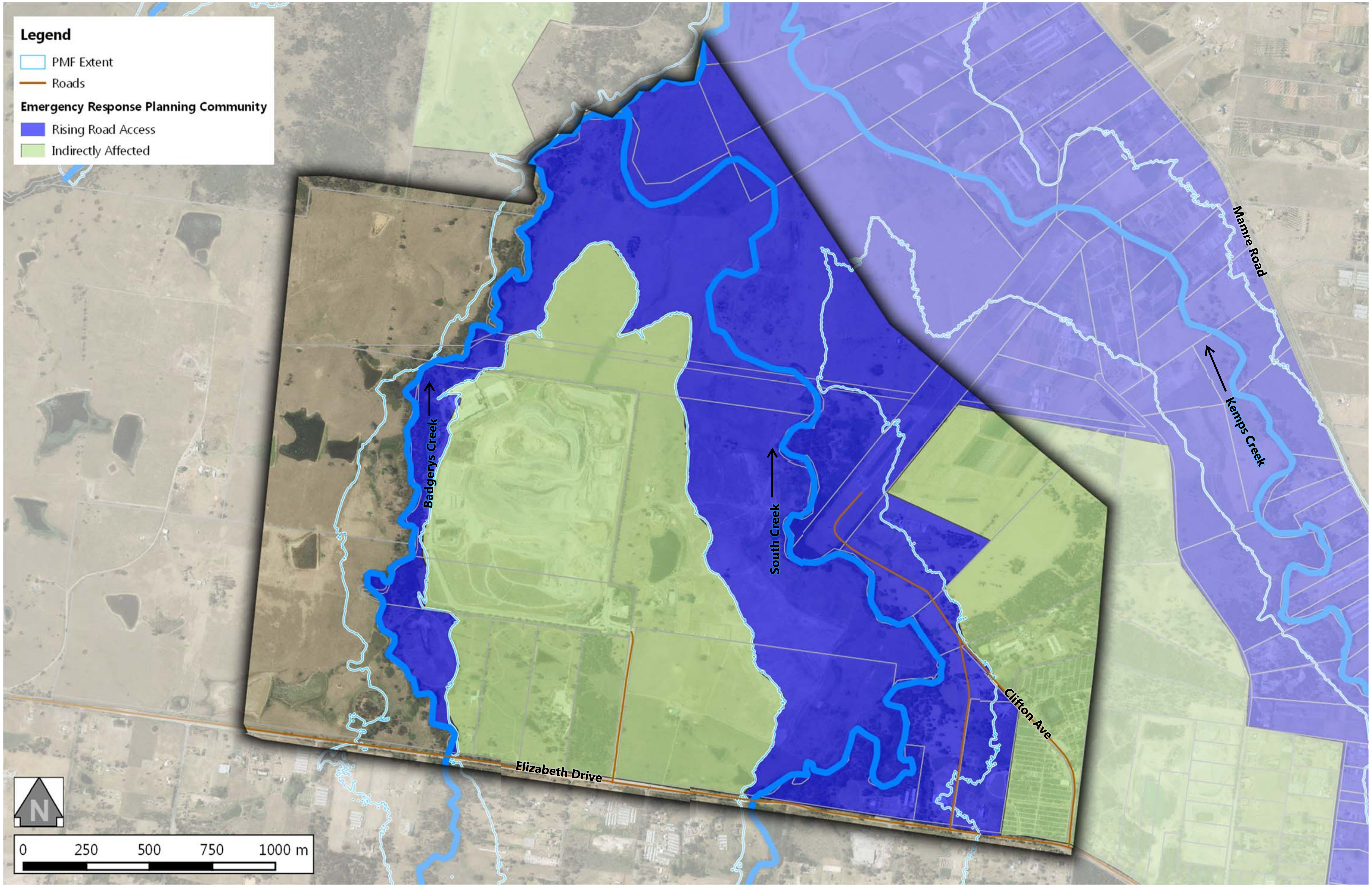
301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 4
fg301310-08772rg200220-Fig G.13_ERP_NorthStMarys_RopesCreek

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, ROPES CREEK



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.14_ERP_NorthofElizabethDrive

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH OF ELIZABETH DRIVE

Appendix H – Community Data Sheets for Emergency Response Management

COMMUNITY DATA SHEET – CLAREMONT CREEK

Population at Risk	Area for Evacuation Management
800	21 ha

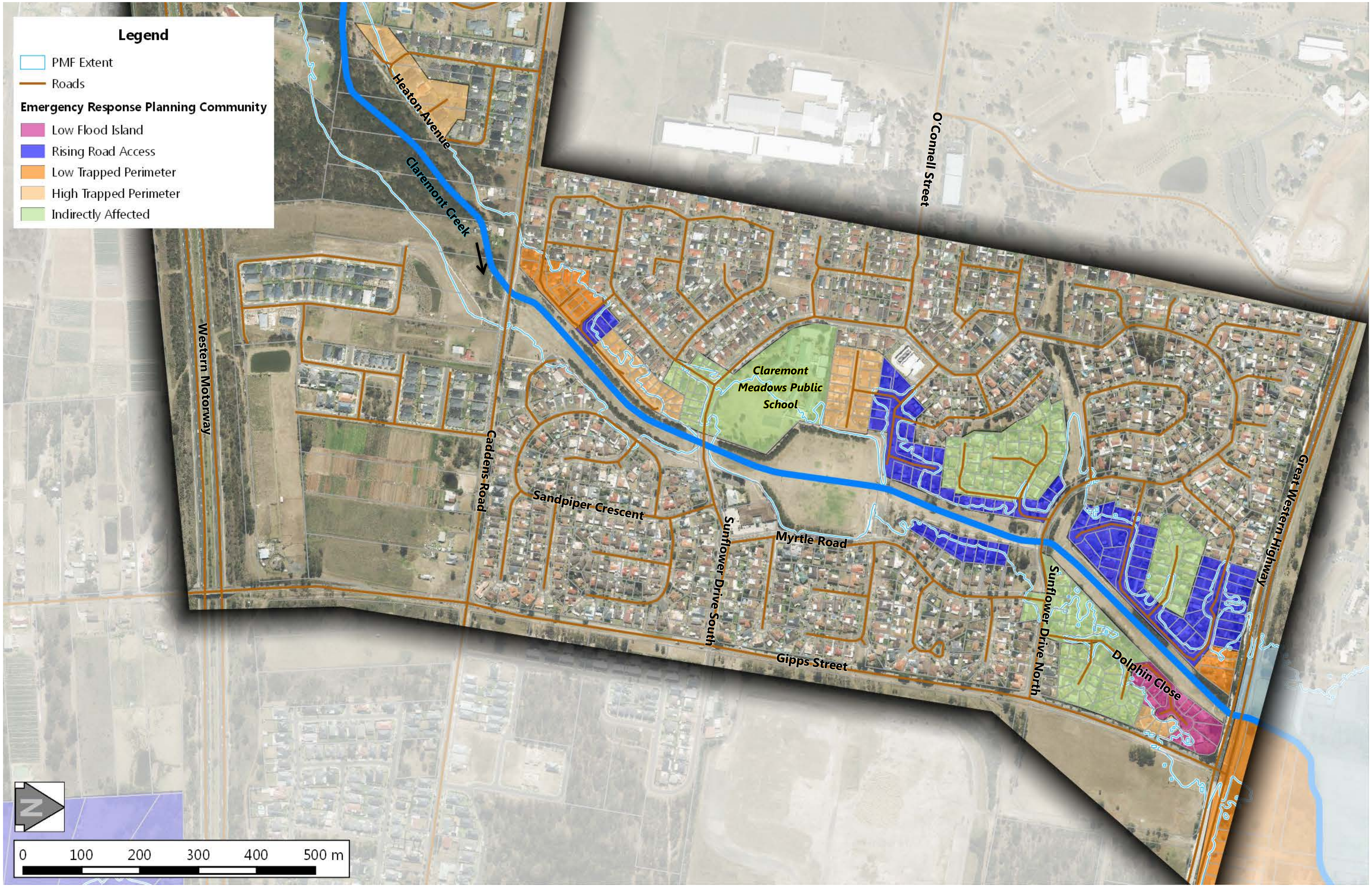
ERP Community Classifications	• Generally **Rising Road Access**. • A few areas of **Low or High Trapped Perimeter** or **Indirectly Affected** areas occur due to the road layout. • Properties on Dolphin Close are subject to **Low Flood Island**.
Summary	Generally most areas are classified as **Rising Road Access** or **Indirectly Affected**. There is little inundation to property in the 1% Annual Exceedance Probability (*AEP*) flood event as flows remain in channel. The area immediately upstream of the Great Western Highway is the most flood prone with properties inundated on Dolphin Close as floodwaters backup upstream of the Great Western Highway crossing during floods as frequent as the 5% AEP event. Those properties immediately upstream of the Great Western Highway should be given priority for evacuation based on risks of isolation. The majority of other properties are predicted to experience only minor flooding until the PMF.
Vulnerable Populations/ Services	**<u>Claremont Meadows Public School</u>** • Inundation of playing fields in 0.5% AEP event • PMF extent reaches rear of buildings but over floor flooding unlikely
Evacuation Priorities	**Dolphin Close** – becomes **Low Flood Island** by peak of 5% AEP flood event and should be prioritised for door-knocking and evacuation.
Evacuation Routes	In the event that evacuation is required, those on the west side of the creek would head towards Western Sydney University via O'Connell Street or Caddens Road. Those on the eastern side of the creek would head towards the M4 Motorway via Gipps Street and Kent Road. Crossing of Claremont Creek would need to be avoided when conditions pose risk to the bridge structure or inundation of the roadway occurs. In particular the crossing at Sunflower Drive (*north*) is predicted to be inundated in a 1% AEP flood.
Major Roads	**<u>Great Western Highway</u>** • Access cut by peak of 2% AEP flood at crossing of Claremont Creek • Crossing of South Creek towards the east is also inundated by peak of 5% AEP flood

<u>Predicted maximum flood depth and duration of inundation (based on 9 hour event) at Claremont Creek</u>

Event	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.45	0.55	0.65	0.9
Duration (hours)	1	2.5	3	3.5	5

Other Roads	• **Dolphin Close** - Inundated in the 5% AEP event to depths of 300 mm isolating properties • **Gipps Street -** Inundated in 5% AEP event at junction with Great Western Highway. Evacuation will need to be towards the south if the area is inundated • **Sunflower Drive (North) -** Inundated in 1% AEP event by 100 mm • **Sunflower Drive (South) -** Inundated in PMF event by 100 mm • **Caddens Road** - Inundated in the PMF event by 100 mm

ROAD INUNDATION MAPPING FOR FLOOD EMERGENCY MANAGEMENT SECTOR: CLAREMONT CREEK



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.5_ERP_ClaremontCreek

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: CLAREMONT CREEK

COMMUNITY DATA SHEET – THE KINGSWAY

Population at Risk	Area for Evacuation Management
2,700 (*includes occupants of schools*)	170 ha

ERP Community Classifications	• **Overland Escape** Route from recreational areas and Rance Road areas. • **Rising Road Access** from the St Marys Commercial area (east of South Creek) • Area immediately north of the Great Western Highway is **Low Trapped Perimeter** including Kurrambee School.
Summary	Inundation occurs from floodwaters breaking the banks of both Claremont Creek and South Creek. The majority of areas at risk of inundation are recreational use and unlikely to be occupied during such a flood event which would require significant and heavy rainfall prior. Nonetheless, closure of the road will be required with access shut at Ripples Swimming Centre to the east and Werrington Road to the west. Low lying properties in the Rance Road area start to experience inundation by the peak of the 5% Annual Exceedance Probability (*AEP*) event. Evacuation by vehicle is not available at this time due to inundation of the low point on Werrington Road. Accordingly, evacuation of this area is a priority. Residential properties in the Rance Road area largely comprise blocks of units. Ground floor inundation is likely. Evacuation by foot is possible towards the west to land above the PMF.
Vulnerable Populations/ Services	**<u>Kurrambee School</u>** • Buildings not predicted to be inundated until a 1% AEP event • The school has **Rising Road Access** to the south via Werrington Road and Reserve Road. **<u>Penrith Valley Learning Centre</u>** • Buildings are not predicted to be inundated until a 0.2% AEP event, however, school grounds to the north are inundated to a maximum depth of 0.6 m in the 5% AEP event • The school has **Rising Road Access** to the south via Werrington Road and Reserve Road. **<u>Wollemi College</u>** • 5% AEP event encroaches onto the southern playing fields • Buildings are not predicted to be inundated in events up to and including the 0.2% AEP flood. The entirety of the school grounds are inundated in the PMF • **Overland Escape Route** is available from the site to the north west. **<u>St Marys Senior High School</u>** • 0.2% AEP flood encroaches onto playing fields • PMF event would inundate the western four buildings to depths of less than 0.5 m • **Rising Road Access** is available from the site towards the east **<u>St Marys Public School</u>** • Located within PMF extent but not flooded in 0.2% AEP flood (*peak depths of up to 2.3 m in the PMF*) • **Rising Road Access** is available to the Great Western Highway to travel east
Evacuation Priorities	**The Kingsway** – road inundated in events < 5% AEP flood **Kurrambee School / Penrith Valley Learning Centre -** Given the more vulnerable nature of the occupants at these two schools, evacuation of this area should be a priority and be completed prior to inundation of Werrington Road at the school entrances. **Rance Road area** – Inundation of the low point in Werrington Road hinders evacuation. Once Werrington Road is overtopped, residents have Overland Escape Route through rural fields towards the west.
Evacuation Routes	Residents of the Rance Road area would head towards Werrington Road and towards the Great Western Highway. Evacuation is hindered by inundation of the low point on Werrington Road and of the Great

	Western Highway as it crosses Claremont Creek and South Creek. If evacuation is delayed and Werrington Road or the Great Western Highway is overtopped alternative evacuation would be via foot to the west. Occupants of the schools would head towards the Great Western Highway and evacuation would be required before the Great Western Highway is inundated, otherwise shelter-in-place would be necessary.
Major Roads	**The Kingsway** • Becomes inundated in events smaller than the 5% AEP event. Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	2.0	2.2	2.4	2.6	3.0	5.3
Duration (hours)	28	30	32	33	38	40

Great Western Highway at Claremont Creek

• Access cut by peak of 2% AEP flood at crossing of Claremont Creek

Predicted maximum flood depth and duration of inundation (based on 9 hour event) at Claremont Creek

Event	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.45	0.55	0.65	0.9
Duration (hours)	1	2.5	3	3.5	5

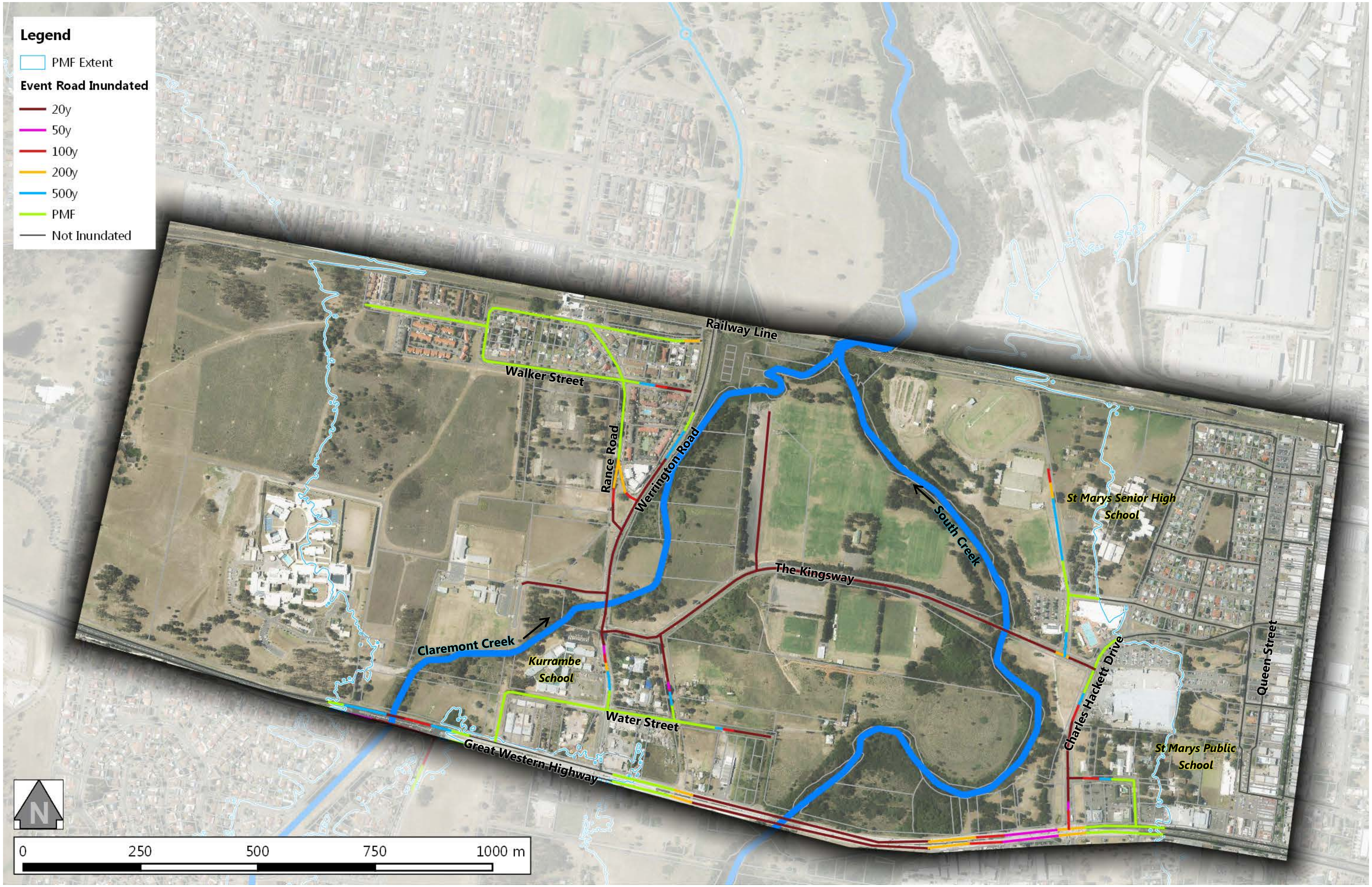
Great Western Highway at South Creek

• Access cut by peak of 5% AEP flood at crossing of South Creek

Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.6	0.7	0.9	1.1	> 2m
Duration (hours)	3	5	7	9	11	13

Other Roads	• **Werrington Road** – low point inundated in the 5% AEP event to depths of 0.3 m over a duration of up to 12 hours



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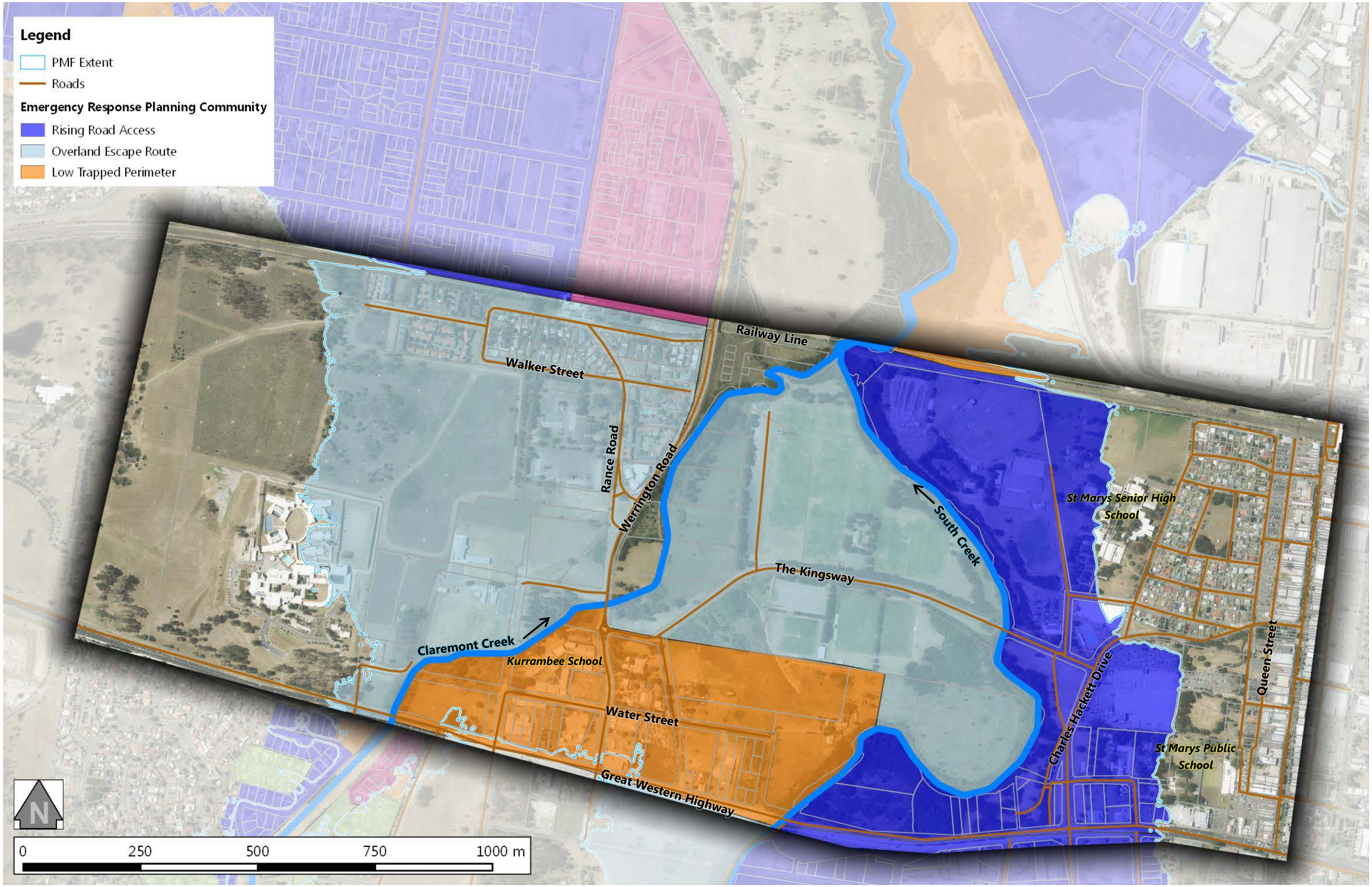
301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 4
fg301310-08772rg200220-Fig H.10_Innundated Roads_TheKingsway

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: THE KINGSWAY

FIGURE G.7



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.7_ERP_TheKingsway

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: THE KINGSWAY

COMMUNITY DATA SHEET – ST MARYS

Population at Risk	Area for Evacuation Management
1,990	188.5 ha

ERP Community Classifications	• Generally **Rising Road Access** for residential areas • Generally **Overland Escape Route** for more underdeveloped areas • A few lots classified as **Low Trapped Perimeter** along Doncaster Ave
Summary	Inundation occurs from flood flows from South Creek and Byrnes Creek, as well as backwater flooding through the Great Western Highway culverts. The St Marys Levee is overtopped in events greater than the 1% AEP flood, however, properties could potentially experience inundation from Byrnes Creek or South Creek from floodwaters backing up through the Great Western Highway culverts, or from floodwaters overtopping the Great Western Highway and flowing around the concrete component of the levee (*potential during smaller events such as the 20 year ARI event*). Without overtopping of the levee during events larger than the 1% AEP flood inundation is predicted to be limited to nuisance flooding of properties. The Great Western Highway crossing of South Creek is inundated in the 5% AEP flood event and is therefore not recommended for evacuation purposes. Safer evacuation would be achieved by directing people to the east towards the St Marys CBD. Six townhouses on Doncaster Avenue become a **Low Trapped Perimeter** where the road is predicted to be inundated in events greater than the 2% AEP flood.
Vulnerable Populations/ Services	**<u>Summit Care Home</u>** • Buildings are not predicted to be inundated until a 0.2% AEP event • **Rising Road Access** available to Mamre Road
Evacuation Priorities	**Summit Care Home -** Given the more vulnerable nature of the occupants at Summit Care Home, evacuation should be a priority prior to inundation of Saddington Street. **Neale Street, Putland Road, George Street, Saddington Street & Schleicher Street** – parts of these roads (*i.e. within a distance of 400 m from the St Marys Levee*) are inundated in events < 5% AEP flood **Doncaster Avenue** – Inundation of the eastern portion of Doncaster Avenue hinders evacuation. Once Doncaster Avenue becomes inundated in events greater than the 2% AEP flood, the six townhouses closest to South Creek become **Low Trapped Perimeter**. Evacuation before inundation of Doncaster Avenue is required.
Evacuation Routes	Residents of the areas west of South Creek would head west towards Kent Road, either via Caddens Road or via an **Overland Escape Route** along Central Park Drive or Doncaster Avenue. Residents of the areas east of South Creek would head east towards Mamre Road via any street parallel to the Great Western Highway (*e.g. Saddington Street, John Street, Wilson Street etc.*). The St Marys RSL Club on Mamre Road may be a suitable refuge centre. The parallel roads may experience overtopping from local flooding along Byrnes Creek and therefore localised issues may still be present which could have impacts on the evacuation potential.
Major Roads	**<u>Great Western Highway at South Creek</u>** • Sections of the highway at the South Creek crossing becomes inundated in the 5% AEP flood. <u>Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek</u>

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.4	0.6	0.9	1.1	2.1
Duration (hours)	2	6	8	10.5	11	11

M4 Western Motorway at South Creek

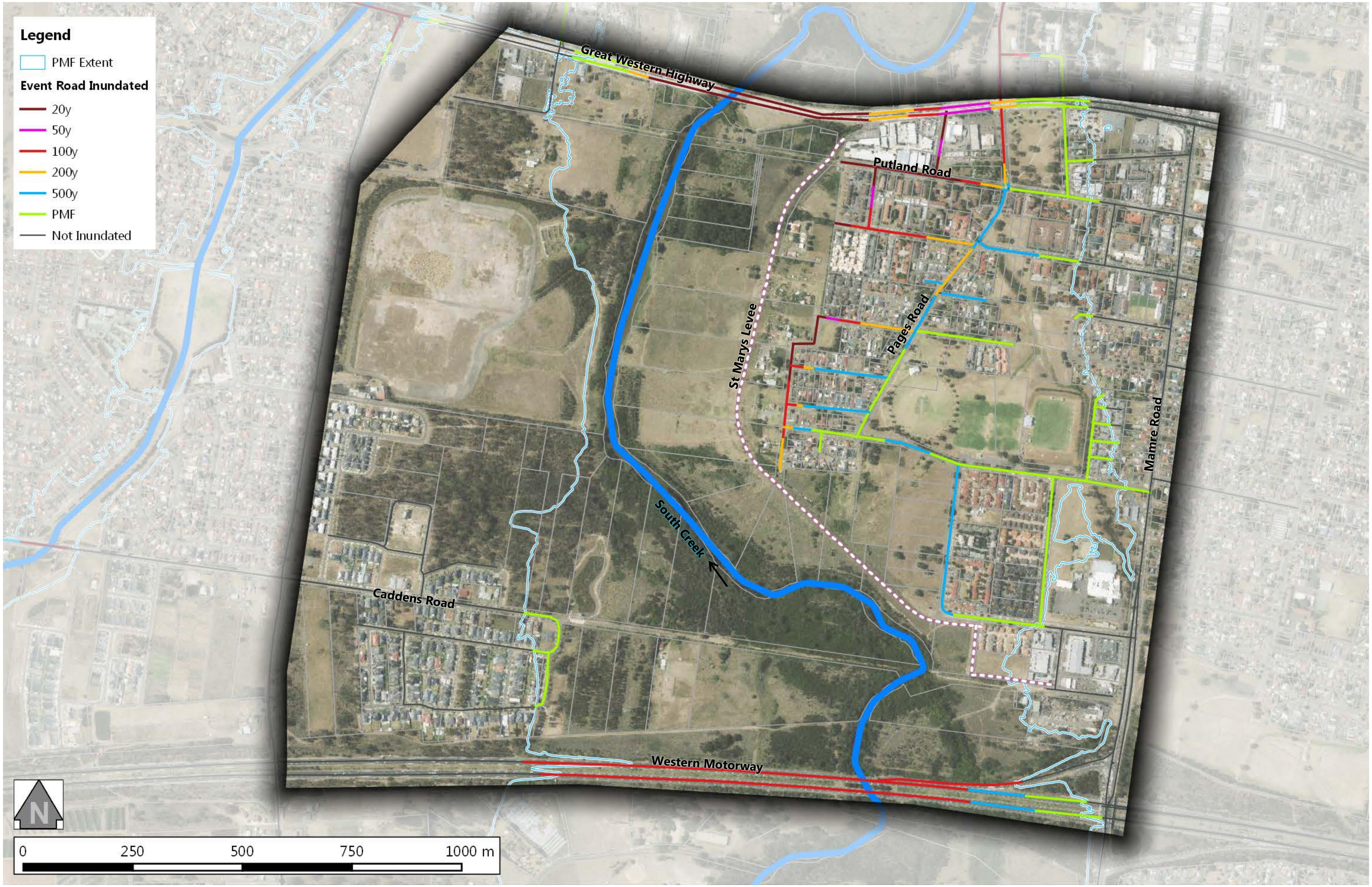
- Access cut by peak of 1% AEP food at crossing of South Creek

Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek

Event	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.6	0.8	2.2
Duration (hours)	4	6	8	9

Other Roads

- **Doncaster Ave** – low point inundated in the PMF event to depths of 1.2 m isolating six townhouses to be Low Trapped Perimeter
- **Schleicher Street** – inundated in the 5% AEP flood by 0.3 m (*near intersection with Vincent St*)
- **Putland Road** - The westernmost portion of the road is inundated in the 5% AEP flood by 1.4 m
- **Neale Street –** Southern half of Neale Street is inundated in the 5% AEP flood by 0.2 m
- **George Street** – Northern half of George Street is inundated in the 5% AEP flood by 0.3 m
- **Saddington Street –** The westernmost end of Saddington Street is inundated in the 5% AEP flood by up to 1.0 m. Saddington Street west of Pages Road is inundated in the 1% AEP flood by up to 0.2 m



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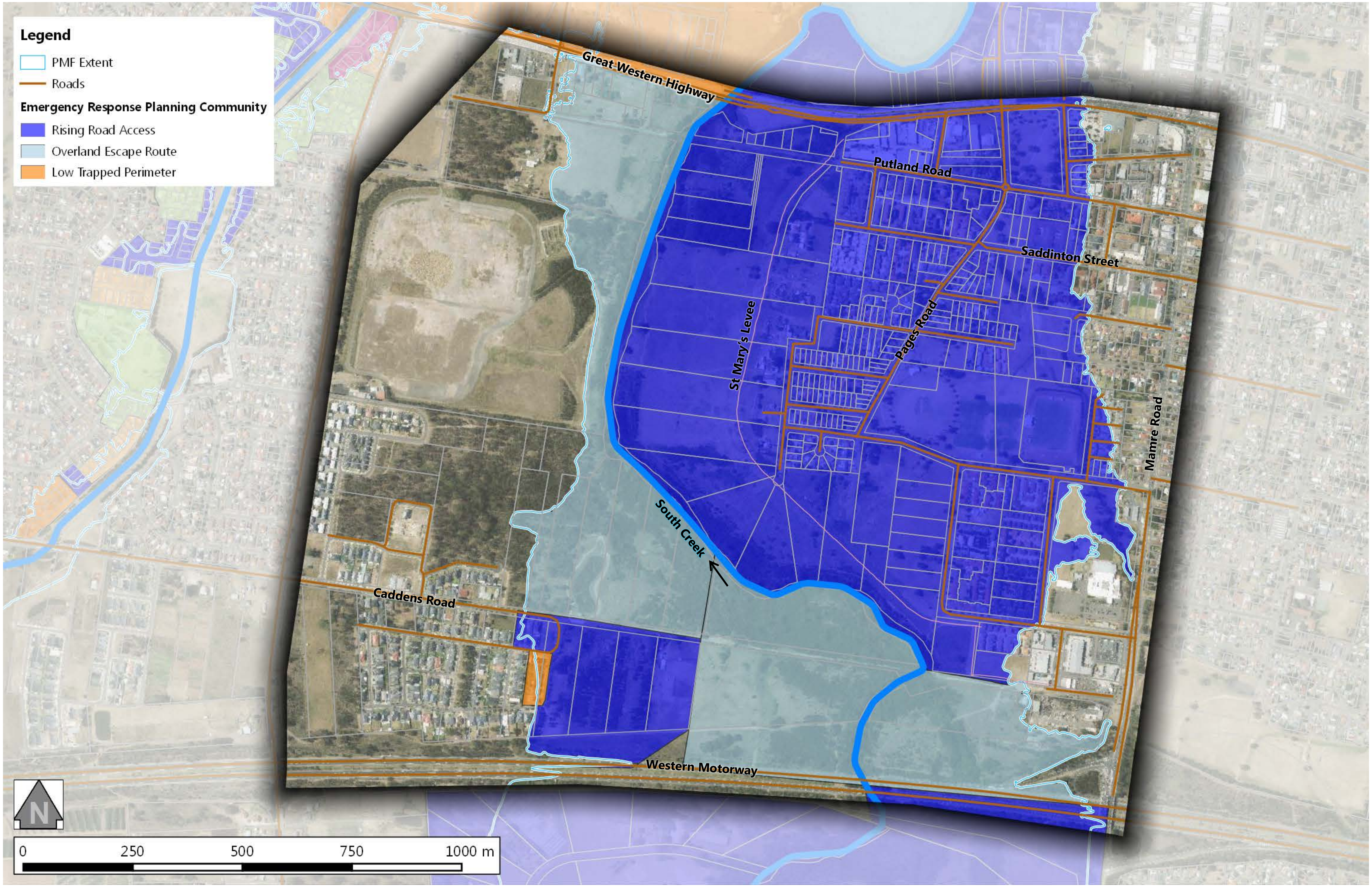
301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 4
fg301310-08772rg200220-Fig H.9_Innundated Roads_StMarys

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: ST MARYS

FIGURE G.6



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.6_ERP_StMarys

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: ST MARYS

Advisian PENRITH CITY COUNCIL SES STATE EMERGENCY SERVICE

COMMUNITY DATA SHEET – WERRINGTON

Population at Risk	Area for Evacuation Management
2,540	129.6 ha

ERP Community Classifications	• Mostly **Rising Road Access** • **Overland Escape Route** for areas closer to the perimeter of the Flood Emergency Management Sector • Properties bounded by Werrington Road, Parkes Avenue and the railway line are classified as being located in a **Low Flood Island** • Small areas of **Low** or **High Trapped Perimeter** between John Oxley Avenue and Burton Avenue
Summary	Inundation occurs from floodwaters breaking the banks of South Creek and Werrington Creek, with areas also heavily influenced by backwater flooding from the Hawkesbury River in the PMF. Minimal property inundation is predicted during a 1% AEP South Creek or Werrington Creek flood. Properties are located along the 1% AEP flood fringe or are protected by the Werrington Road levee. The Werrington earthen levee is only overtopped in events greater than the 0.2% AEP flood, while the Werrington Road levee is only overtopped in events greater than the 0.5% AEP flood. Inundation of the Werrington Creek crossings is predicted to occur during the 5% AEP flood and therefore early monitoring of rising floodwaters at the crossings and potential road closures is necessary.
Vulnerable Populations/ Services	**Werrington Public School** • PMF encroaches onto the northern boundary of the school but does not reach the buildings. • An **Overland Escape Route** is available to the south and then west along Armstein Crescent.
Evacuation Priorities	**Parkes Avenue, Princess Street, Belwood Close, Rosewood Way, Albert Street** & eastern portion of **Victoria Street** – properties in this locality are classified as Low Flood Island and are trapped by flood waters in the 0.2% AEP flood before being inundated to depths of up to 4.5 m in the PMF. Evacuation before inundation of Parkes Avenue and Victoria Street is required otherwise residents will need to shelter-in-place. **Malcolm Avenue, Catherine Street, Isabella Street** & **John Oxley Avenue** – Properties along Malcolm Avenue become Low Trapped Perimeter due to the inundation of access points to Malcolm Avenue by the peak of the 5% AEP flood. Other properties in the surrounding area including Catherine Street, Isabella Street and John Oxley Avenue also become Low Trapped Perimeter by the peak of the PMF. Evacuation is required prior to inundation of Malcolm Avenue. **Burton Street, Heavey Street, Lack Place** & **Andro Place** – residents of these properties would be trapped inside the property (*albeit outside of the PMF extents*) due to inundation of these roads in the PMF.
Evacuation Routes	In the event that evacuation is required, residents living to the south-east of Werrington Creek would head south towards Victoria Street and then west along Victoria Street until they are out of the PMF extents. Due to the inundation risk of the Victoria Street crossing care and careful monitoring of rising floodwaters at the crossing will be required. Werrington Public School is a potential refuge centre as most school buildings are out of the PMF extent. Residents living to the north of Werrington Creek will head north or west along roads such as John Oxley Avenue or Burton Avenue.
Major Roads	**Dunheved Road** • Dunheved Road in the Werrington Flood Emergency Management Sector (*to the west of South Creek*) is predicted to be flood-free in events up to and including the 0.2% AEP event. • At the peak of the 0.2% AEP flood the low point along Dunheved Road is predicted to be less than 0.2 m above flood levels. • During the PMF, Dunheved Road is predicted to be inundated to a maximum depth of 4.3 m. Flooding is dominated by the Hawkesbury-Nepean River and duration of inundation is dependent on the flood hydraulics of the Hawkesbury.

	<u>Werrington Road</u> • Access cut by peak of 0.2% AEP flood near intersection of Werrington Road and Dunheved Road. • The low point is inundated to 0.3 m in the 0.2% AEP flood, with the duration of inundation predicted to be in the order of six hours. • During the PMF Werrington Road is predicted to be inundated to a maximum depth of 4.4 m. The area is influenced by backwater flooding of the Hawkesbury River and duration of inundation is dependent on the flood hydraulics of the Hawkesbury.
Other Roads	• **Burton Street** crossing of Werrington Creek – the southern approach of the bridge crossing (*near the intersection with Malcolm Avenue*) is inundated to depths of up to 0.6 m by the peak of the 5% AEP flood. The duration of inundation in the 5% AEP flood is predicted to be one hour. • **John Oxley Avenue** crossing of Werrington Creek – the southern approach of the bridge crossing (*near the intersection with Heavey Street*) is inundated to depths of up to 0.3 m by the peak of the 2% AEP flood. The duration of inundation in the 2% AEP flood is predicted to be one hour.

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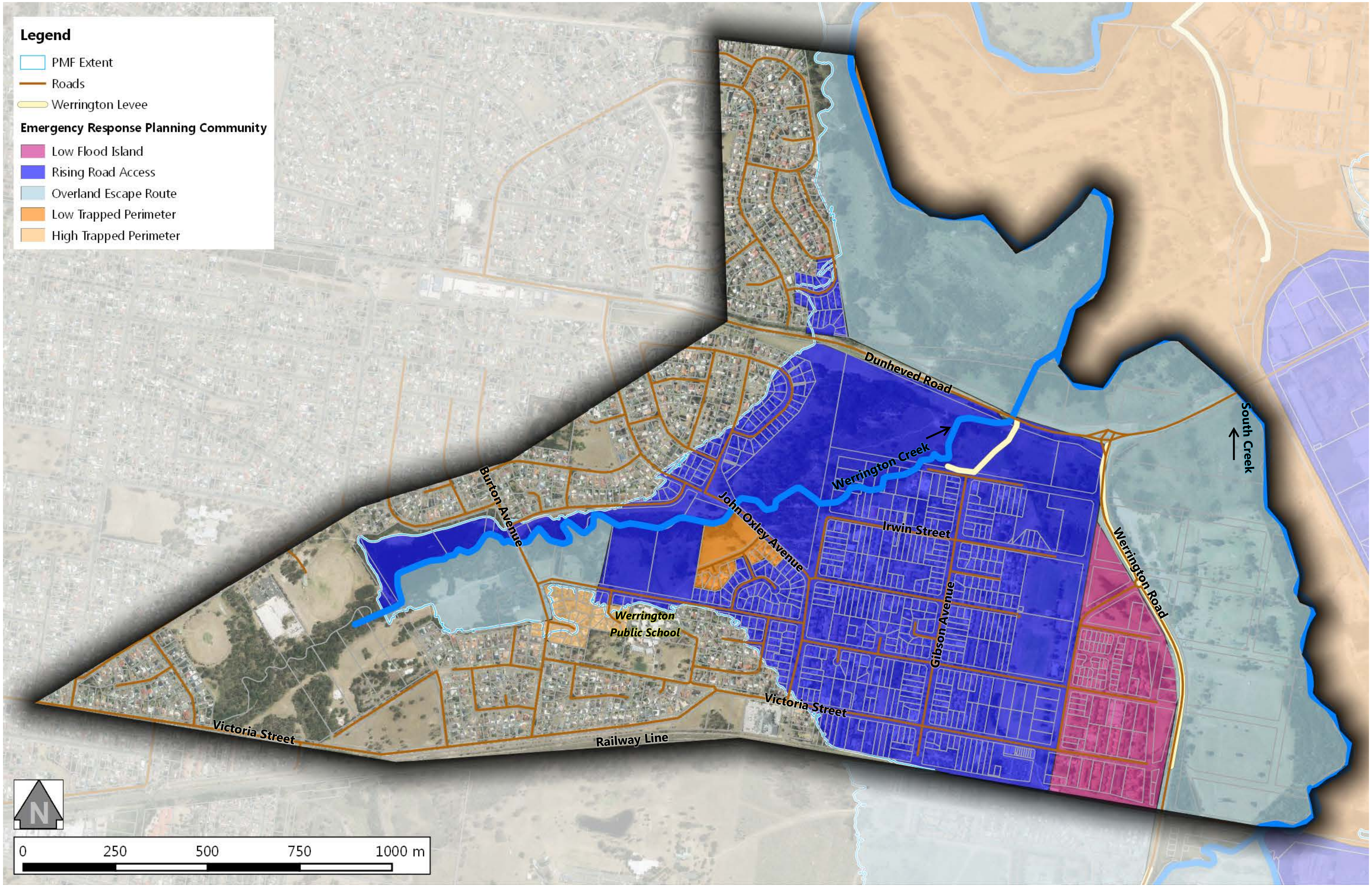
fg301310-08772rg200220-Fig H.11_Innundated Roads_Werrington

NOTE: The Victoria Street crossing of Werrington Creek has not been assessed as part of the South Creek Floodplain Risk Management Study and may be subject to inundation.

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: WERRINGTON



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FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: WERRINGTON

COMMUNITY DATA SHEET – NORTH ST MARYS INDUSTRIAL AREA

Population at Risk	Area for Evacuation Management
2,490	344 ha

ERP Community Classifications	• Large portions of land are classified as **Low Trapped Perimeter**, including Dunheved Golf Course, the sewerage treatment plant and St Marys Industrial Estate. • The southern part of Dunheved Circuit in the industrial estate is **High Trapped Perimeter** • The Lee Holm Road area is designated as **Rising Road Access**
Summary	Inundation occurs from floodwaters breaking the banks of South Creek and Ropes Creek. Dunheved Golf Course is predicted to be completely inundated in the 5% AEP flood to depths of up to 2 metres across areas in close proximity to South Creek. Similarly, the sewerage treatment plant bound by Ropes Creek to the north and Links Road to the south is very flood-prone, with flood depths predicted to reach up to 1 metre in the 5% AEP flood. These areas are considered to be high risk and designated as **Low Trapped Perimeter**. Most of the St Marys Industrial Estate is protected from inundation for events during floods up to and including the 0.2% AEP flood. Links Road keeps much of the area dry in these storm events. At the peak of the PMF almost the entire industrial estate north of Christie Road is flooded and is classified as **Low Trapped Perimeter**. The southern portion of the industrial estate around Dunheved Circuit is out of the PMF extent but is designated as **High Trapped Perimeter.** Elsewhere, the parts of the industrial estate to the south of Christie Road experience inundation beginning from the 5% AEP flood, however, these areas have **Rising Road Access** to the east and as such are at lower risk.
Vulnerable Populations/ Services	None identified – no schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	**Dunheved Golf Course** and **St Marys Sewerage Treatment Plant –** both facilities are Low Trapped Perimeter and are at risk of hazardous flooding in the 5% AEP event. Evacuation will prove to be difficult as access roads to both properties are already inundated in the 5% AEP flood to depths greater than 0.5 m. These areas should be prioritised for flood awareness programs, advanced warning and evacuation at the earliest opportunity. **St Marys Industrial Estate (north of Christie Road)** – the industrial properties located in this area do not become inundated until events greater than the 0.2% AEP flood, however, long sections of Links Road and parts of Forrester Road are already flooded in a 5% AEP flood. As Links Road is the only means of vehicular egress from the area, residents/workers will become trapped in the industrial estate, as Low Trapped Perimeter. The southern portion of this industrial estate are High Trapped Perimeter. Evacuation should be prioritised after evacuation of the golf course and sewerage treatment plant. **Areas bound by South Creek and Lee Holm Road** – inundation begins to occur in the 5% AEP flood and progressively increases to the PMF. These areas are designated as **Rising Road Access**, as residents/workers are able to use Lee Holm Road / Power St to travel eastward before taking Forrester Road to the south. Nonetheless, the more flood prone areas should be nominated for flood awareness programs and receive advanced flood warnings.
Evacuation Routes	For the industrial estate north of Christie Road (*including the golf course and sewerage treatment plant*), residents / workers should head east on Links Road as early as possible and turn onto Forrester Road. Evacuees should travel south on Forrester Road until they are clear of the PMF extent. The residents and workers in the industrial estate south of Christie Road should head east on Lee Holm Road until they are out of the PMF extent. Evacuees on Anne Street can travel towards the eastern half of Anne Street.

Major Roads

<u>Dunheved Road / Christie Street</u>

- The low point in Christie Street (*approximately 100 metres east of the South Creek crossing*) is inundated in the 5% AEP event.

<u>Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek</u>

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.9	1.2	1.4	1.6	1.9	3.0
Duration (hours)	13	15	18	19	21	18

<u>Forrester Road</u>

- Access to south of Links Road / Forrester Road roundabout cut in the 5% AEP event

<u>Predicted maximum flood depth and duration of inundation (based on 36 hour event) at Ropes Creek</u>

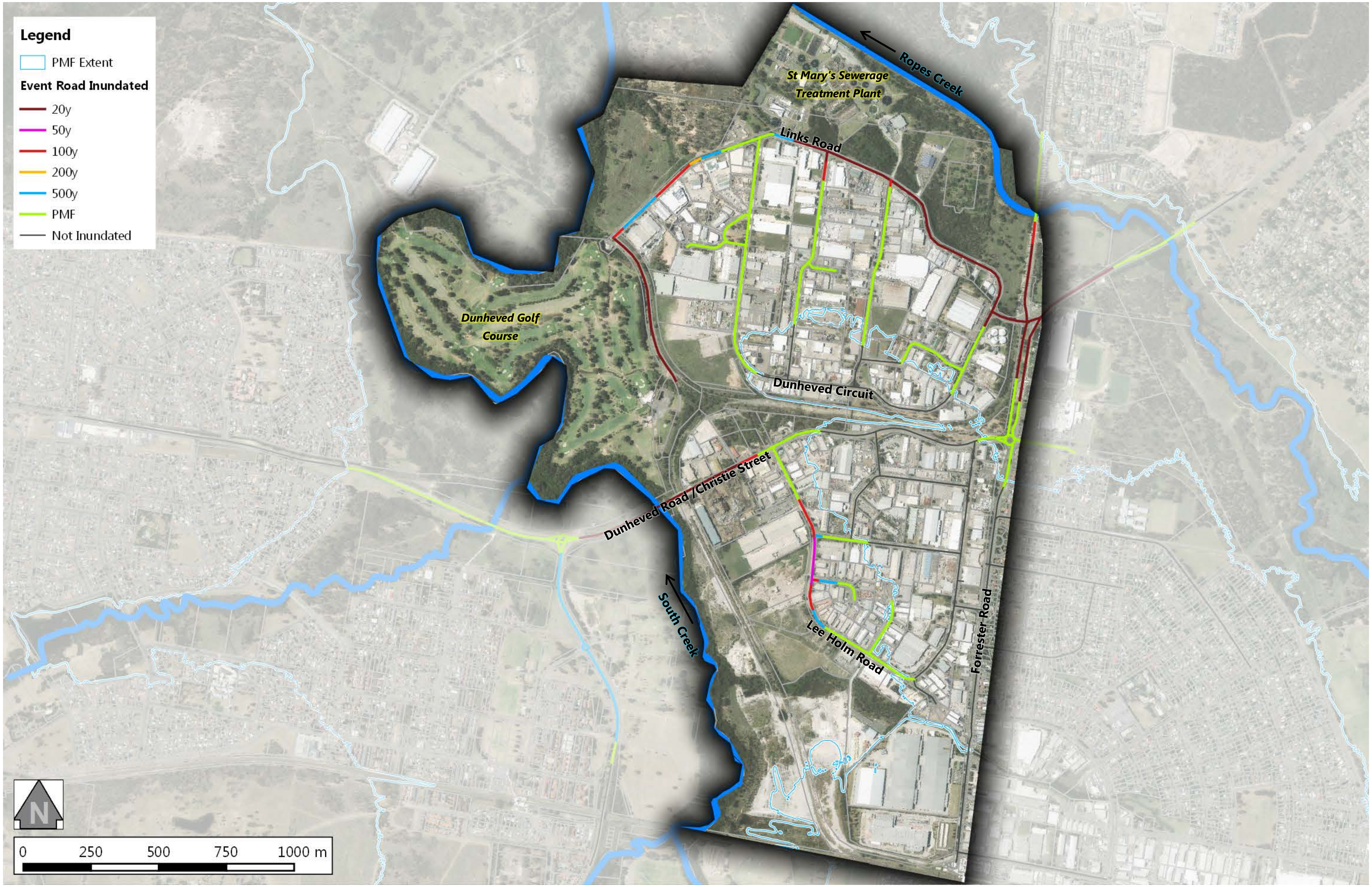
Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.4	0.5	0.6	0.6	0.7	2.6
Duration (hours)	11	13	14	15	17	*

* The area is influenced by backwater flooding of the Hawkesbury River and duration of inundation is dependent on the flood hydraulics of the Hawkesbury.

Other Roads

- **Links Road** – low point (*adjacent to NE corner of golf course*) inundated by 0.6 m in the 5% AEP flood
- **Lee Holm Road –** low point inundated by 0.3 m in the 2% AEP flood

FIGURE H-12



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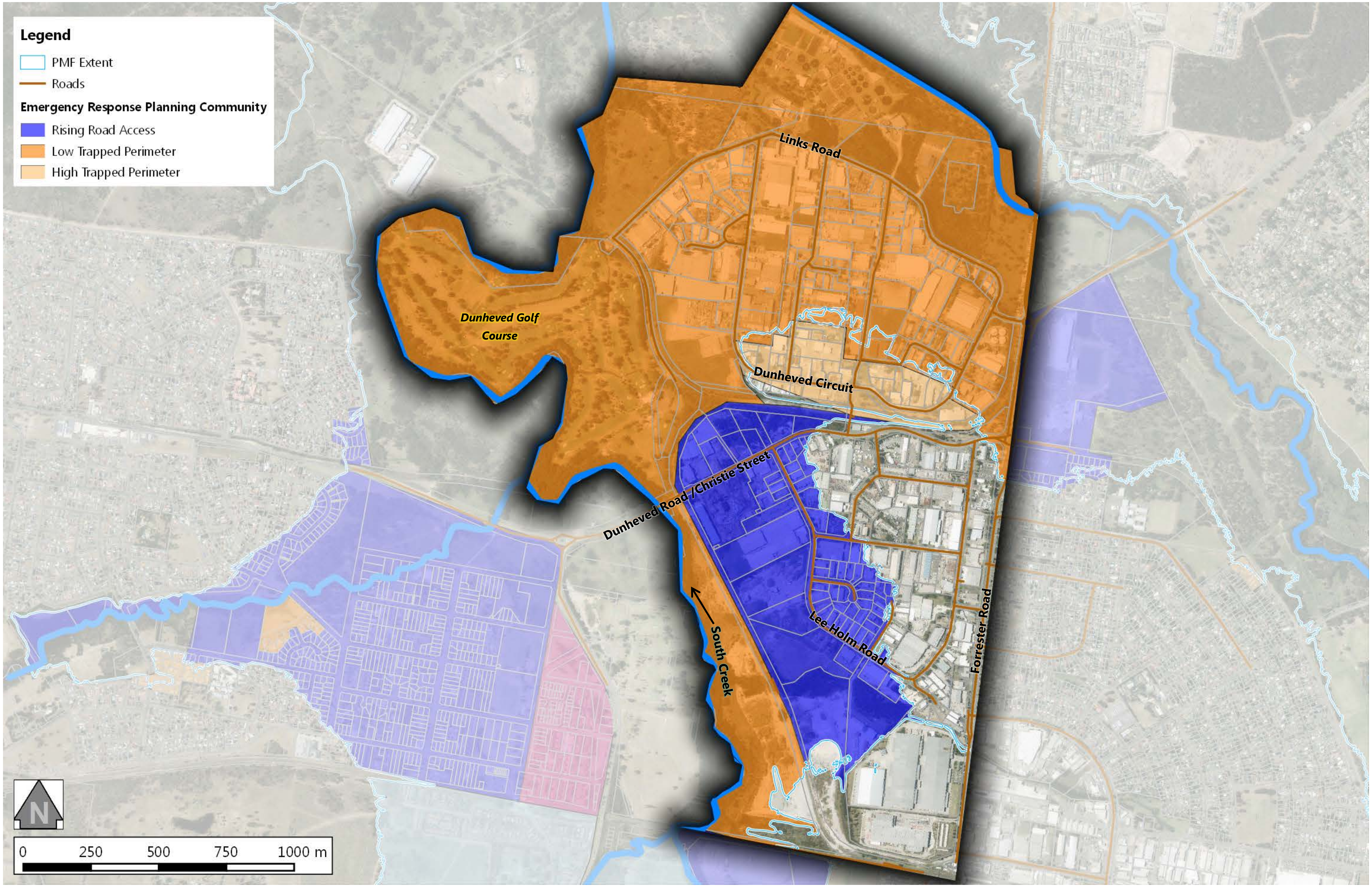
ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, INDUSTRIAL AREA



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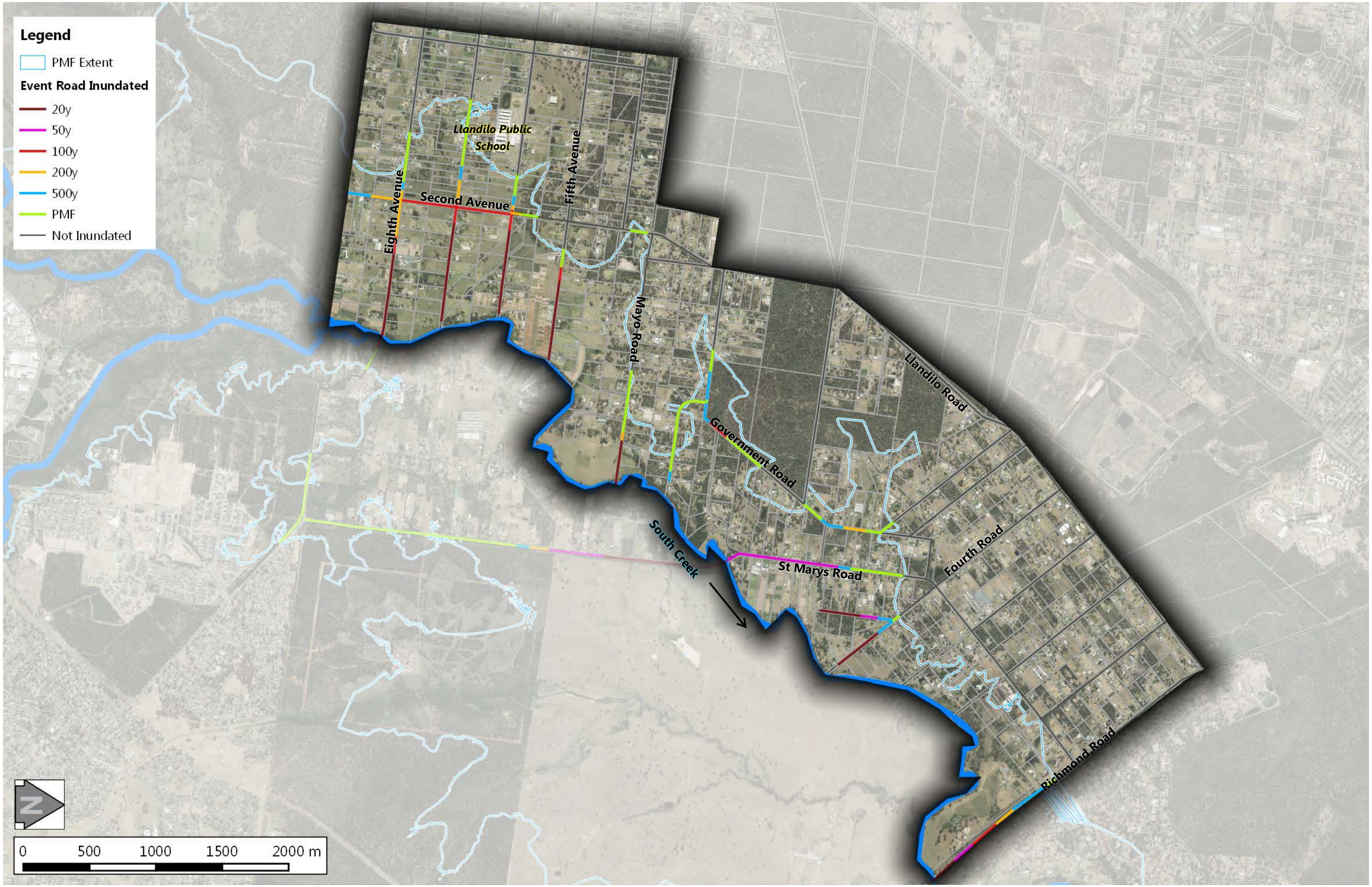
FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, INDUSTRIAL AREA

COMMUNITY DATA SHEET – LLANDILO & BERKSHIRE PARK

Population at Risk	Area for Evacuation Management
790	650 ha

ERP Community Classifications	All flood-affected properties have **Rising Road Access** to land above the PMF
Summary	All properties which are predicted to be affected by the PMF are able to evacuate through **Rising Road Access** towards the west / north west. Early evacuation is required however to avoid properties being surrounded by floodwaters for long periods and high flood depths. The community is at risk of flooding originating along South Creek and/or the Hawkesbury-Nepean River.
Vulnerable Populations/ Services	<u>**Llandilo Public School**</u> • The school grounds are located partially within the PMF extent. Maximum flood depths of up to 3.0 m are predicted in the south-east corner of the site • Some buildings are flood free, but not all • It has **Rising Road Access** to the west via Seventh Avenue
Evacuation Priorities	**Llandilo Public School -** Given the more vulnerable nature of the occupants at Llandilo Public School, evacuation of the school should be a priority prior to inundation of Seventh Avenue. Failing that, occupants could take an Overland Escape Route towards the north-west corner of the school, which is not predicted to be inundated in the PMF event. The need to evacuate should be based on SES monitoring of the Windsor Bridge Gauge along the Hawkesbury-Nepean River. **Fifth, Sixth, Seventh and Eighth Avenue** – A large number of properties are at risk of inundation during a 5% AEP flood. These residents should be targeted for flood awareness education to avoid complacency and risks of residents sheltering at properties. Due to the significant flood depths possible evacuation is a priority.
Evacuation Routes	All residents are able to travel west out of the PMF extent via one of the many roads leading away from South Creek. Residents are able to travel north-east on St Marys Road before turning onto Richmond Road and travelling north-west away from South Creek.
Major Roads	<u>**Richmond Road**</u> • During flooding from South Creek only, the Richmond Road crossing of South Creek is inundated by 0.5 m at the peak of the PMF. Duration of inundation is predicted to be four hours. • During flooding from South Creek occurring concurrently with regional flooding of the Hawkesbury River, the Richmond Road crossing of South Creek is inundated in events greater than the 5% AEP flood. Monitoring of flood levels along the Hawkesbury-Nepean River at the Windsor Bridge Gauge can assist with organising road closure, if required.
Other Roads	• **Fifth Avenue** – low point in road inundated by 1.8 m at the peak of the 5% AEP flood • **Sixth Avenue** – low point in road inundated by 0.7 m at the peak of the 5% AEP flood • **Seventh Avenue** – low point in road inundated by 0.8 m at the peak of the 5% AEP flood • **Eighth Avenue** – low point in road inundated by 1.0 m at the peak of the 5% AEP flood



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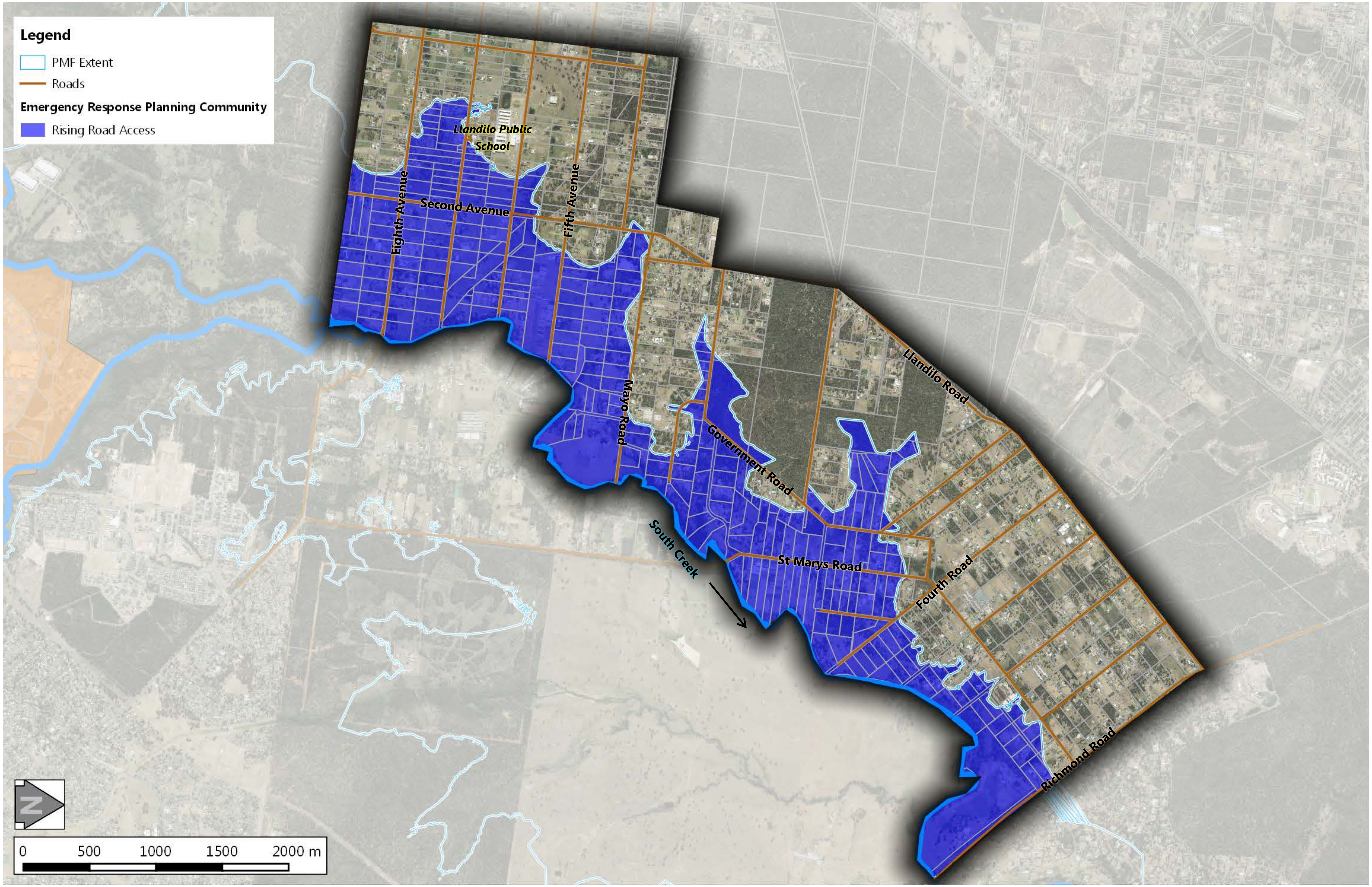
FigB13_RoadInundation_Llandilo.docx

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: LLANDILO AND BERKSHIRE PARK



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FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: LLANDILO AND BERKSHIRE PARK

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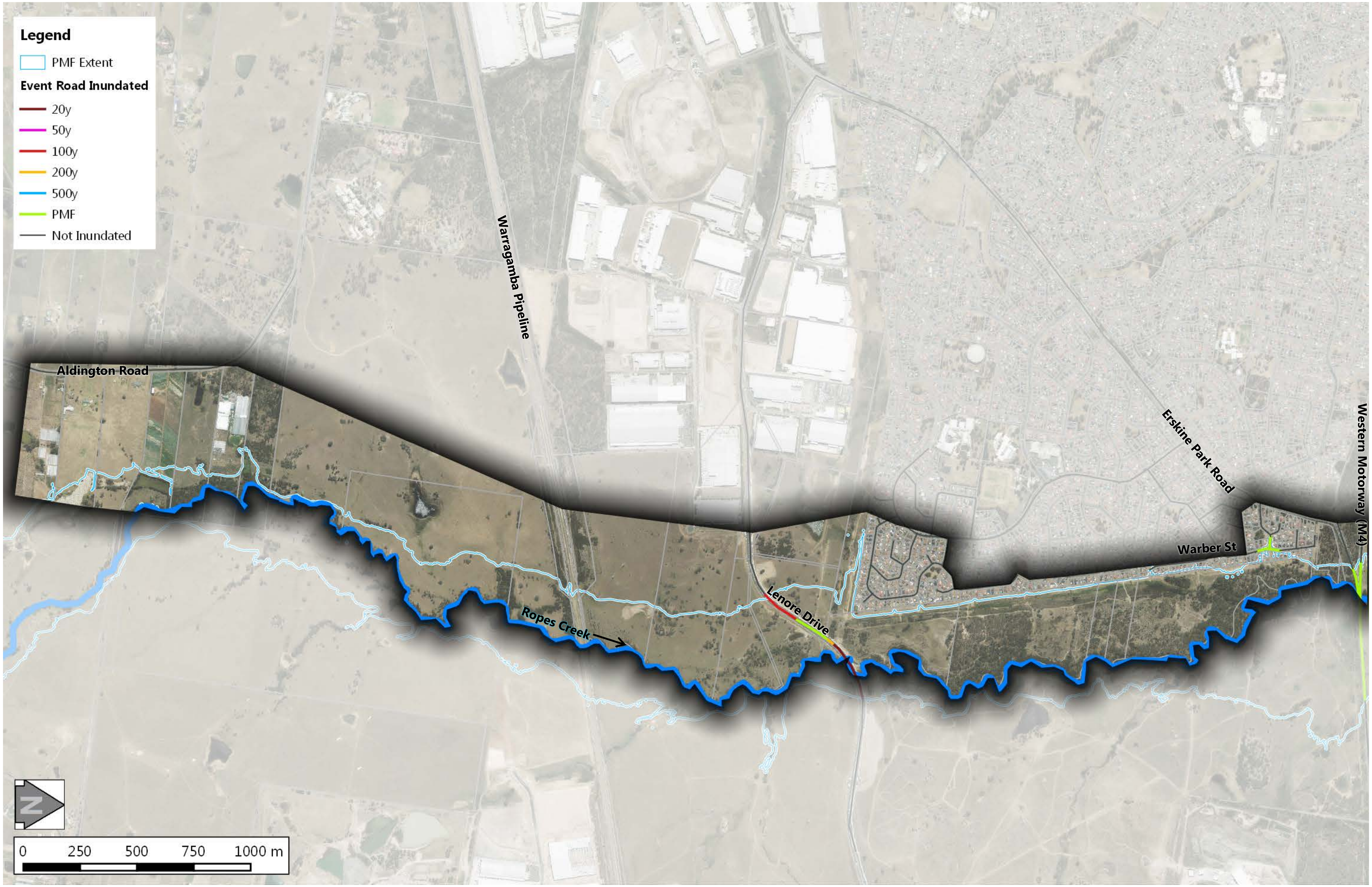
COMMUNITY DATA SHEET – ERSKINE PARK

Population at Risk	Area for Evacuation Management
120	79.6 ha

ERP Community Classifications	All flood-affected properties have **Rising Road Access** to land above the PMF
Summary	Residents of properties which are predicted to be affected by the PMF event are able to travel towards the east to evacuate.
Vulnerable Populations/ Services	None identified – no flood affected schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	There are no high priority areas in this Flood Emergency Management Sector, however, the houses of 12-22 Warbler Street are predicted to be impacted by events greater than the 0.2% AEP flood. These houses are predicted to be inundated by up to 0.3 m in the PMF event.
Evacuation Routes	For the rural properties to the south of the Warragamba pipeline, residents are able to escape the PMF extents by moving to the western half of their property. Should they wish to leave the property, Aldington Road / Bakers Lane is accessible via their property's road frontage. For the residential properties on Warbler Street which are inundated by the PMF, egress is available to Warbler Street via road frontage. From there, residents can travel west on Warbler Street to escape the PMF extent.
Major Roads	**Lenore Drive** • Lenore Drive was constructed with a low-point along the western approach to the Ropes Creek bridge crossing (*at the location where overhead power lines cross the road*). It is understood that the low-point has a level of flood immunity equal greater than the 1% AEP flood. **Western Motorway (M4) crossing of Ropes Creek** • The low point at the M4 crossing of Ropes Creek is inundated by a maximum depth of 1.0 m in the PMF. The duration of inundation is predicted to be 4 hours.
Other Roads	Intersection of **Warbler Road** and **Spoonbill Street** – the low point at the intersection is inundated by up to 0.3 m in the PMF event.



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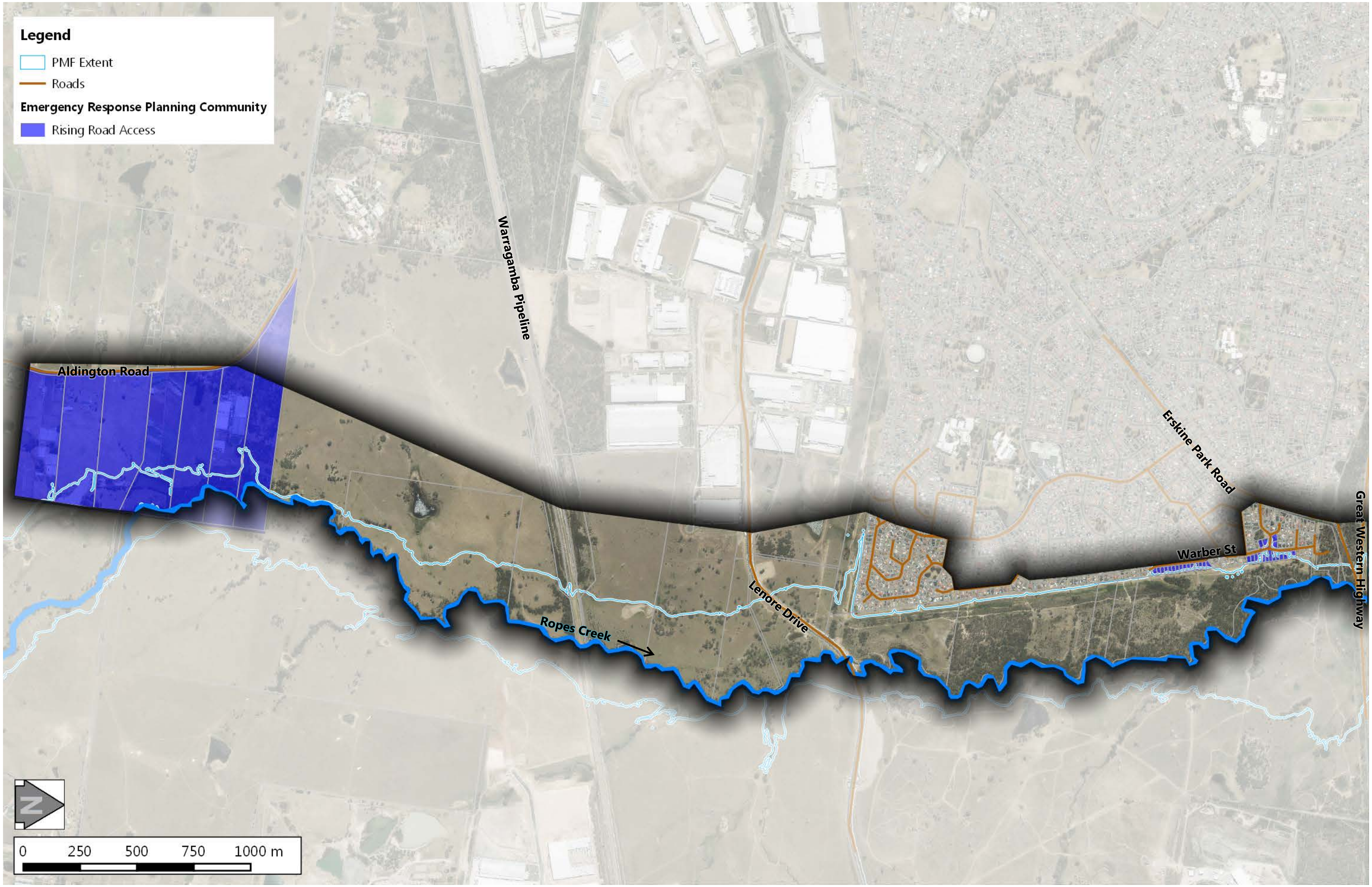
ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: ERSKINE PARK



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301310-08772 – South Creek Floodplain Risk Management Study
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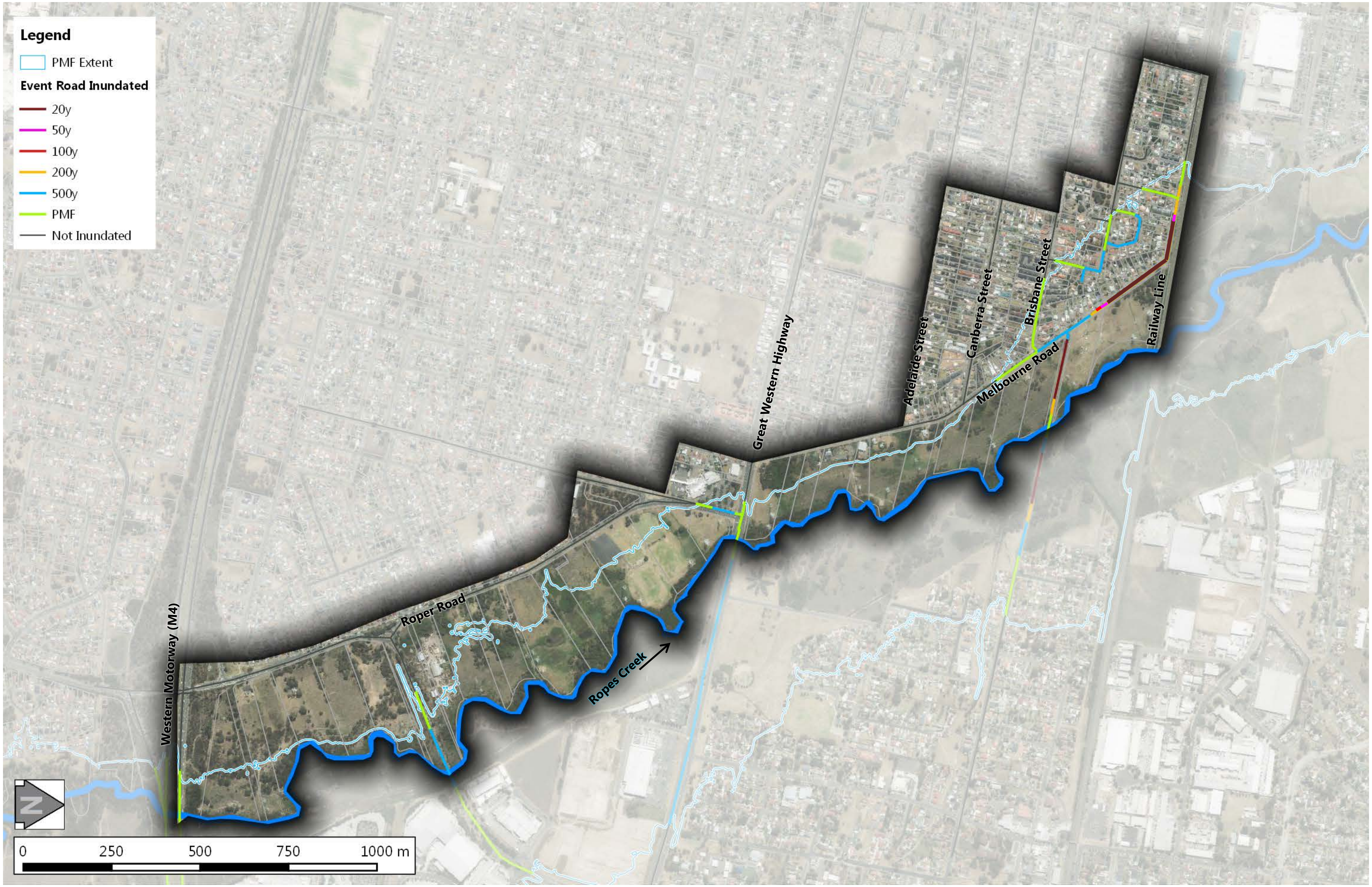
FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: ERSKINE PARK

COMMUNITY DATA SHEET – COLYTON / OXLEY PARK

Population at Risk	Area for Evacuation Management
410	48 ha

ERP Community Classifications	All flood-affected properties have **Rising Road Access** to land above the PMF
Summary	Residents of properties along **Melbourne Street** upstream of the Railway Line are most at risk of flooding with evacuation and property damage predicted during a 5% AEP flood. Evacuation to higher ground to the south (*along Melbourne Street*) or west (*along Hobart Street*) will need to be commenced early to ensure conditions along Melbourne Street do not become hazardous. Residents of properties which are predicted to be affected by the PMF event are able to travel westward to evacuate. All properties have access to road frontage. The Great Western Highway is not overtopped during floods up to and including the 0.2% AEP flood due to the flood protection levee immediately upstream of the highway.
Vulnerable Populations/ Services	None identified – no flood affected schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	Properties along **Melbourne Street** upstream of the Railway Line are at risk of flooding during the 5% AEP flood. Evacuation of these properties will need to be prioritised before depths of inundation along Melbourne Street and across property frontages becomes hazardous.
Evacuation Routes	For properties north of the Great Western Highway, all flood-affected residents in the PMF can access Melbourne Road via the front of their property. From there, residents can turn into Brisbane Street, Canberra Street or Adelaide Street to travel west away from Ropes Creek. For the properties to the south of the Great Western Highway, all flood-affected residents in the PMF can access Roper Road via the front of their property. Higher ground to the west can be accessed via any road connected to Roper Road.
Major Roads / Infrastructure	**Great Western Highway crossing of Ropes Creek** • The flood protection levee immediately upstream of the Great Western Highway is overtopped by 0.3 m in the PMF event. Accordingly, the Great Western Highway is also inundated by a maximum depth of 0.3 m in the PMF. The duration of inundation is predicted to be three hours. **T1 Western Line (Railway)** • The low point in the railway line is predicted to be inundated by a maximum depth of 0.1 m in the PMF event. The inundation duration is predicted to be two hours.
Other Roads	• The western approach of the **Carlisle Avenue** bridge crossing of Ropes Creek is predicted to be inundated by a maximum depth of 0.2 m in the 0.2% AEP flood. • **Hewitt Street** near intersection of Hewitt St and Great Western Highway – inundated by a maximum depth of 0.3 m in the 2% AEP flood • The western and eastern approach to the **Durham Street** bridge crossing of Ropes Creek are predicted to be inundated by depths of up to 0.5 metres at the peak of the 5% AEP flood



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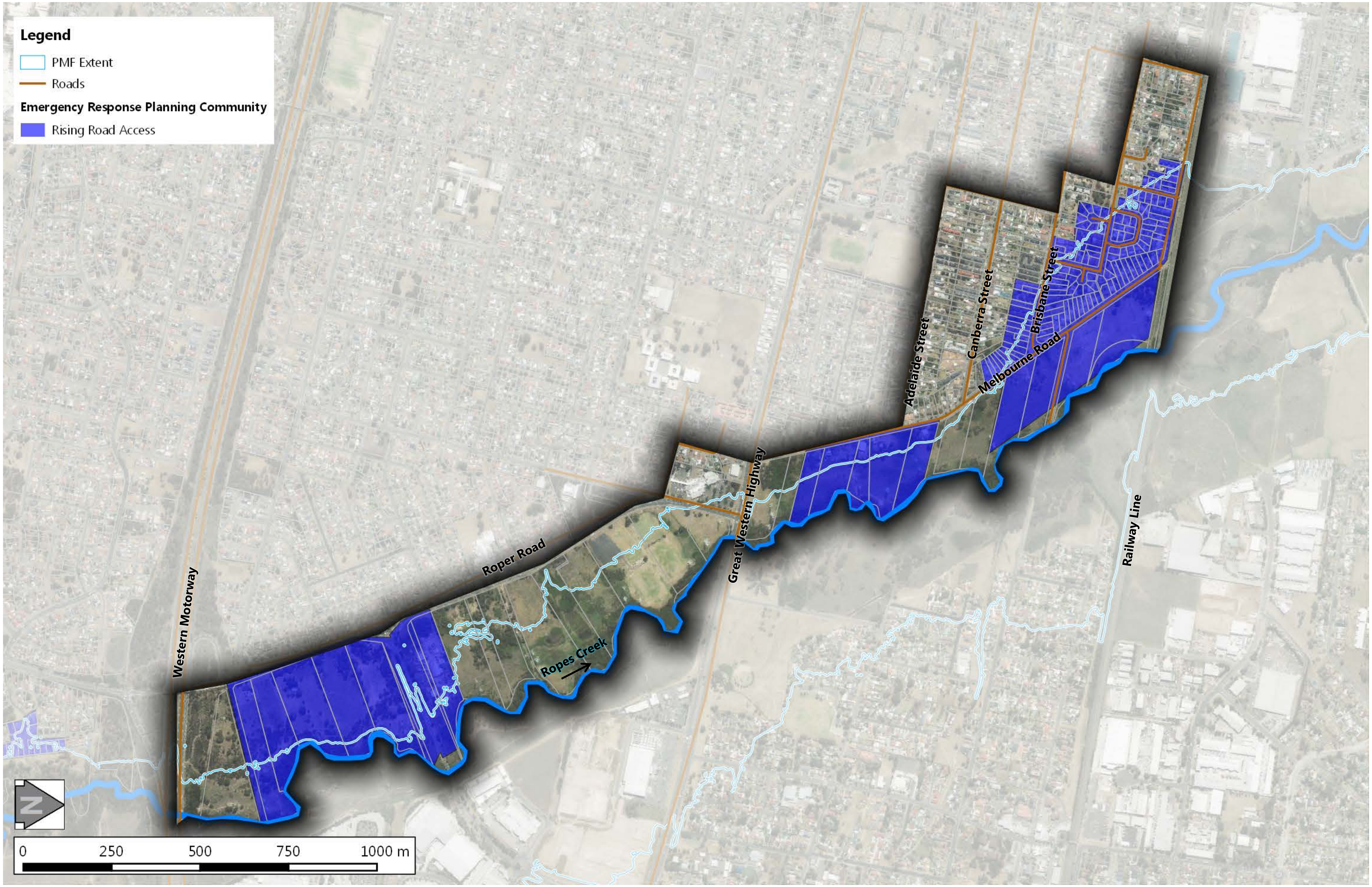
ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: COLYTON / OXLEY PARK

FIGURE G.12



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301310-08772 – South Creek Floodplain Risk Management Study
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FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: COLYTON / OXLEY PARK

COMMUNITY DATA SHEET – NORTH ST MARYS, ROPES CREEK

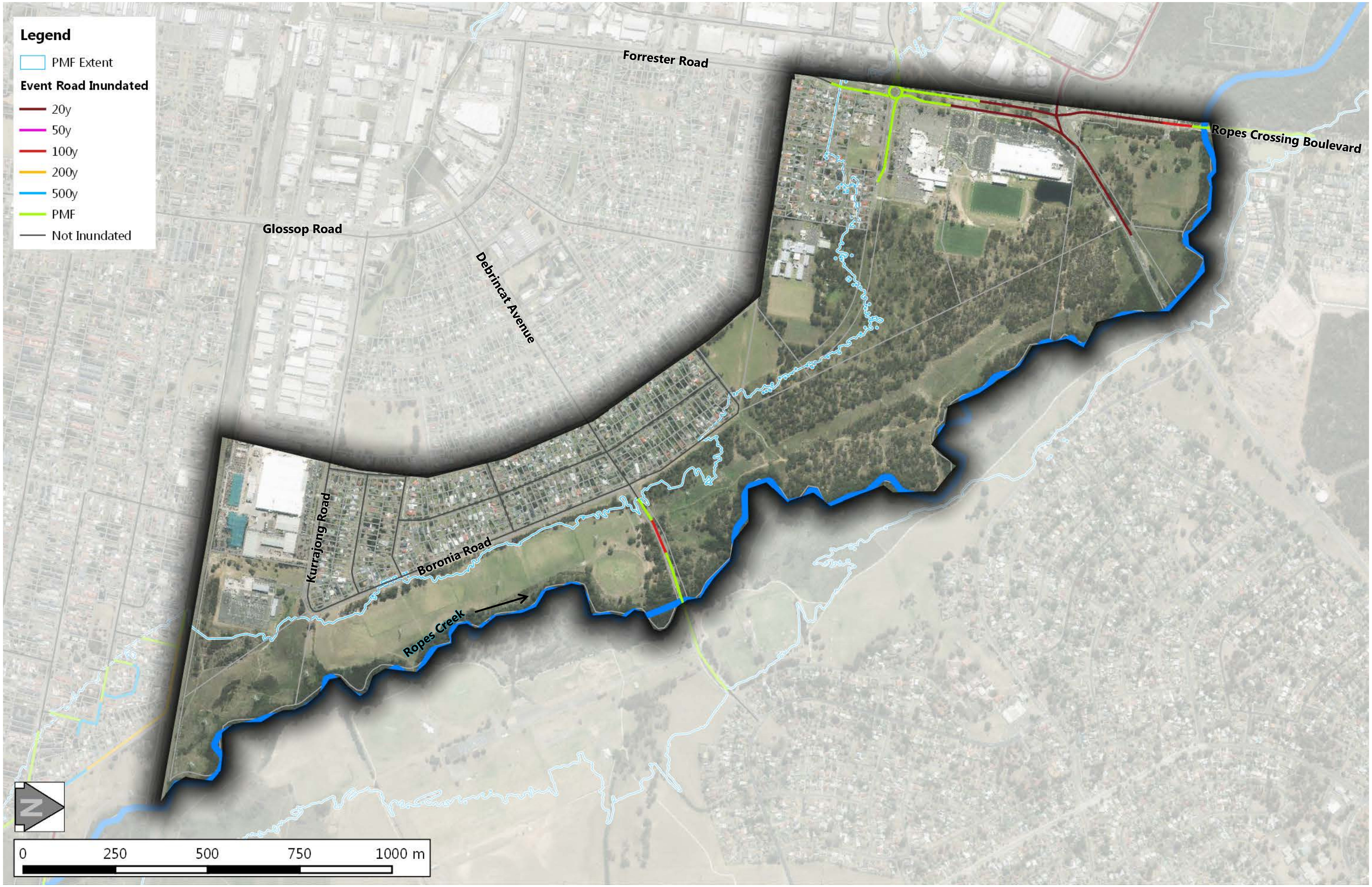
Population at Risk	Area for Evacuation Management
600	29 ha

ERP Community Classifications	The St Marys Rugby League Club, the commercial property to the north and some residential properties to the south which are affected in the PMF event have **Rising Road Access** Residential properties fronting Boronia Road immediately south of the league club have an **Overland Escape Route** to the east via Boronia Road. Flood affected properties in the northern portion of Boronia Road are **High Trapped Perimeter**
Summary	Most of the site at 213 Forrester Road comprising a large commercial building and its carpark are part;y inundated in the 5% AEP flood up to a maximum depth of 0.6 m. The St Marys Rugby League Club, the playing field and car park are only marginally affected up to and including the 0.2% AEP flood but are completely inundated in the PMF. These facilities all have **Rising Road Access** to the south. Some residential properties to the south of the rugby leagues club likewise have **Rising Road Access** to the south. These properties encompass dwellings along Forrester Road, Hinton Glen and Grose Avenue. The properties affected in the PMF along Boronia Road have an **Overland Escape Route** to the east via Boronia Road. Seven properties at the northern end of Boronia Road are affected in the PMF, with the eastern half of the lots inundated by up to 0.5 m in the PMF. These properties are designated as **High Trapped Perimeter** as the buildings are unlikely to be inundated and residents are also unable to escape.
Vulnerable Populations/ Services	None identified – no schools or aged care facilities have been identified to be flood prone in this flood emergency management sector.
Evacuation Priorities	Although properties along Boronia Road immediately to the south of the leagues club have an **Overland Escape Route** to the east, evacuation will need to occur in a timely manner. These residents should be prioritised for a flood awareness program as these dwellings may become **Low Trapped Perimeter** should timely evacuation not eventuate. Residents will have enough time to walk east along Boronia Road and then continue into the grassland when they see floodwaters approaching from the north. Vehicular evacuation would need to occur prior to inundation of Boronia Road. The properties designated as **High Trapped Perimeter** should be evacuated before inundation of Boronia Road occurs.
Evacuation Routes	People present in the commercial property, St Marys Rugby League Club, the playing field and car parks are all able to evacuate the area via first accessing the rugby league club car park and then exiting via Forrester Road to the west or Boronia Road to the south. Once on these roads, evacuees are able to access Forrester Road and travel in a southerly direction towards the St Marys CBD away from the PMF extent. Residents in flood affected properties along Forrester Road are able to drive south along Forrester Road to evacuate. Residents in flood affected properties along Hinton Glen or Grose Avenue are likewise able to travel south via Aylett Street. Residents of properties along Boronia Road (*immediately south of the rugby league club*) will not be able to evacuate by vehicle once inundation of Boronia road occurs. In this event, evacuation is directed to the east by walking along Boronia Road before continuing past the end of the road and into grassland until they are out of the flood extent. For the properties to the south of the Great Western Highway, all flood-affected residents in the PMF can access Roper Road via the front of their property. Higher ground to the west can be accessed via any road

	connected to Roper Road. Alternatively, residents can move to the western half of their properties which is not predicted to be inundated in the PMF.
Major Roads	**<u>Forrester Road</u>** • The low point to the south of the Forrester Road / Boronia Road roundabout is inundated by up to 1.5 m in the PMF event. The area is influenced by backwater flooding from the Hawkesbury River and duration of inundation is dependent on the flood hydraulics of the Hawkesbury. **<u>Debrincat Avenue crossing of Ropes Creek</u>** • The low point along Debrincat Avenue is inundated in events greater than the 2% AEP flood. <u>Predicted maximum flood depth and duration of inundation (*based on 36 hour event*) at Ropes Creek</u>
Other Roads	• The low point on **Boronia Road** (*adjacent to The St Marys Rugby League Club*) is predicted to be inundated by a maximum depth of up to 2.0 m in the PMF event. The area is influenced by backwater flooding of the Hawkesbury River and duration of inundation is dependent on the flood hydraulics of the Hawkesbury. • The low point at **Boronia Road** (*near intersection of Sycamore Street and Boronia Road*) is inundated by depths of up to 0.5 m in the PMF event

Event	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.2	0.3	0.4	1.0
Duration (hours)	4	7	8	9

FIGURE H-16



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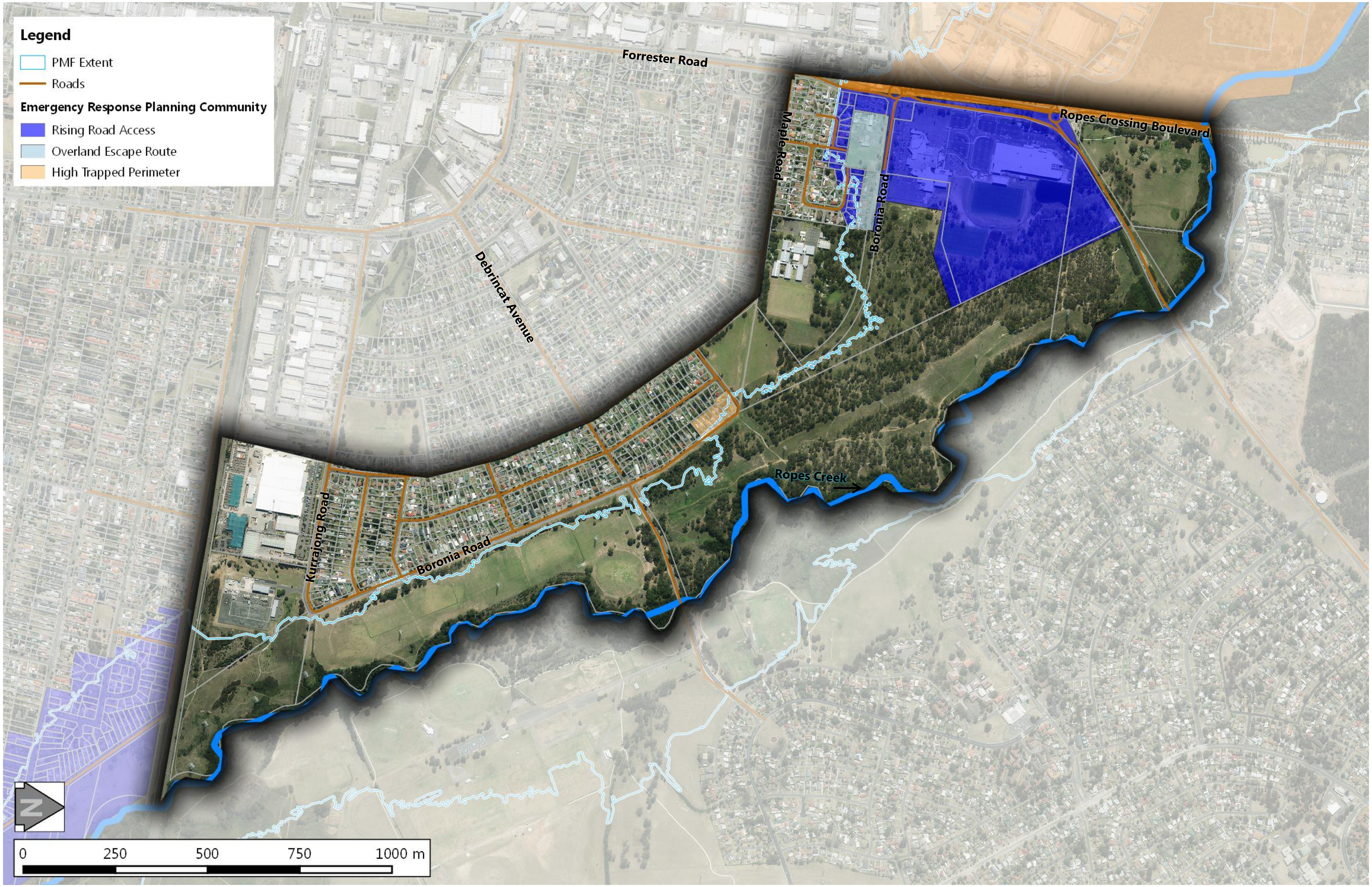
ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, ROPES CREEK



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FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH ST MARYS, ROPES CREEK

COMMUNITY DATA SHEET – NORTH OF ELIZABETH DRIVE

Population at Risk	Area for Evacuation Management
150	780 ha

ERP Community Classifications	All properties / facilities are either **Indirectly Affected** or have **Rising Road Access** out of the flood extent.
Summary	There are no residential properties in this Flood Emergency Management Sector. Facilities which are in this sector include a SUEZ landfill, a SUEZ resource recovery centre and commercial developments including a wholesale nursery. All inundated areas have **Rising Road Access** to **Indirectly Affected** areas. Elizabeth Drive crossings of South Creek and Badgerys Creek are both inundated in the 2% AEP flood and 5% AEP flood, respectively. Due to inundation of Elizabeth Drive there is potential for evacuation issues, notwithstanding, there is sufficient land above the PMF for refuge.
Vulnerable Populations/ Services	None identified – no schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	There are no high priority areas in this Flood Emergency Management Sector, however, properties which depend on Elizabeth Drive for evacuation to Indirectly Affected areas should be evacuated prior to inundation of Elizabeth Drive.
Evacuation Routes	To the east of South Creek, evacuees could access Elizabeth Drive and travel east until they are out of the PMF extent. Caution is required however, with the Kemps Creek crossing at risk of inundation. Businesses located along the unnamed road immediately to the east of South Creek are able to travel north out of the PMF, or alternatively to travel south and turn onto Elizabeth Drive. Workers in the SUEZ facilities only need to relocate to the eastern half of the site to avoid floodwaters. SUEZ offices may be a suitable location for a refuge centre to wait for floodwaters to recede.
Major Roads	See below

Major Roads

Elizabeth Drive near South Creek crossing

- The low point in the road is overtopped in the 2% AEP flood.

Predicted maximum flood depth and duration of inundation (*based on 36 hour event*) at South Creek

Event	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.2	0.3	0.4	1.2
Duration (hours)	2	4	6	7	6

Elizabeth Drive crossing of Badgerys Creek

- The low point in the road is overtopped in the 5% AEP flood.

Predicted maximum flood depth and duration of inundation (based on 36 hour event) at Badgerys Creek

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.2	0.3	0.4	0.4	0.9
Duration (hours)	2	5	6	7	8	7

Other Roads: The low point in the **unnamed road** immediately to the east of South Creek is inundated to a maximum depth of 1.2 m in the 5% AEP flood.

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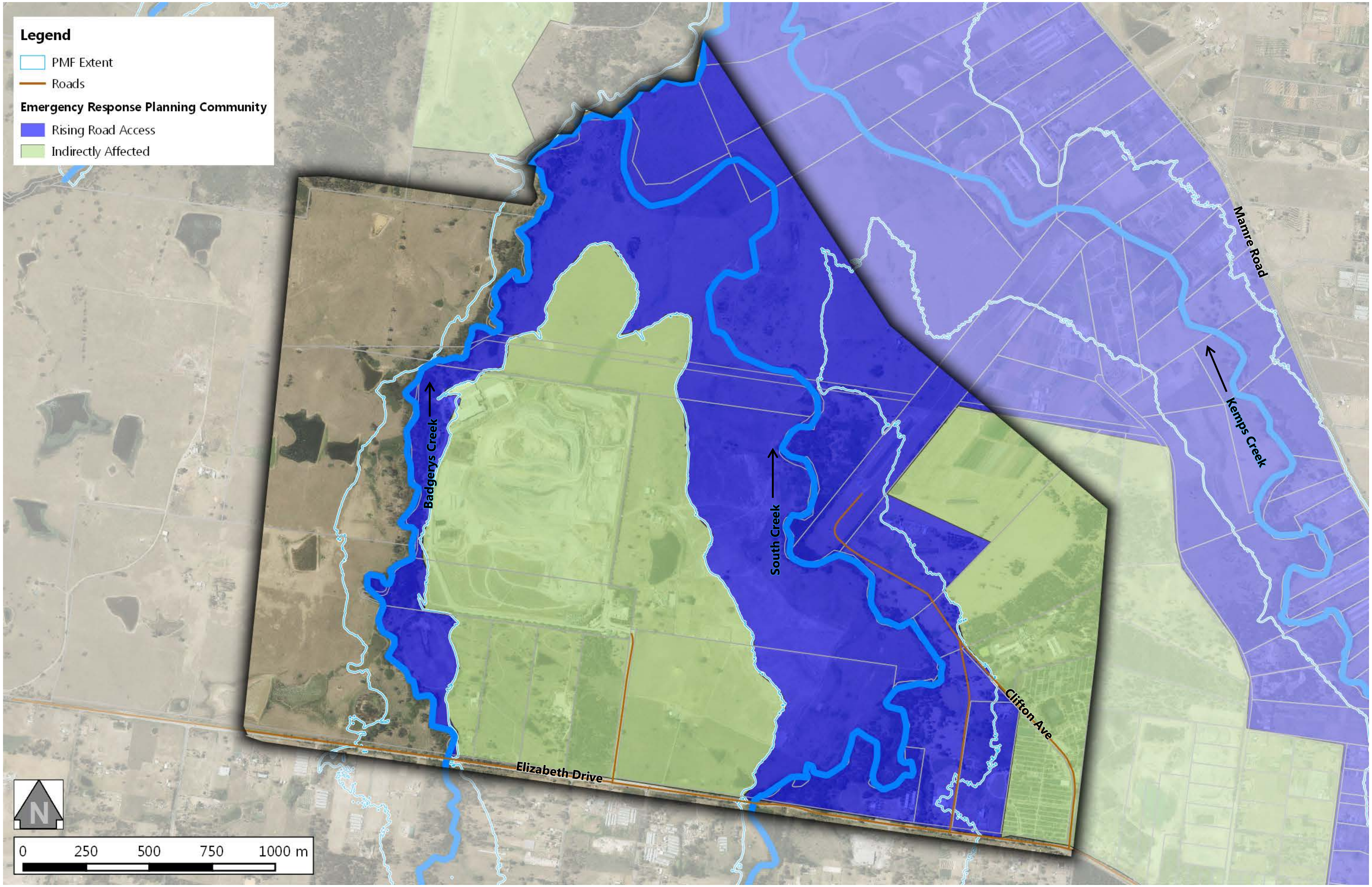
ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH OF ELIZABETH DRIVE

FIGURE G.14



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fg301310-08772rg200220-Fig G.14_ERP_NorthofElizabethDrive

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: NORTH OF ELIZABETH DRIVE

Advisian PENRITH CITY COUNCIL SES STATE EMERGENCY SERVICE

COMMUNITY DATA SHEET – KEMPS CREEK

Population at Risk	Area for Evacuation Management
50	400 ha

ERP Community Classifications	All properties / facilities are either **Indirectly Affected** or have **Rising Road Access** out of the flood extent.
Summary	There are very few properties in this Flood Emergency Management Sector. The properties to the west of Kemps Creek have **Rising Road Access** out of the PMF extent into **Indirectly Affected** areas via Clifton Avenue. Properties to the east of Kemps Creek have **Rising Road Access** out of the PMF via Mamre Road to the east.
Vulnerable Populations/ Services	None identified – no schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	There are no high priority areas in this Flood Emergency Management Sector, however, some properties to the west of Kemps Creek which are predicted to be affected in the 5% AEP flood should evacuate via Mamre Road at the earliest opportunity.
Evacuation Routes	To the east of Kemps Creek, residents can access the flood-free Clifton Avenue to travel to Indirectly Affected Areas. To the west of Kemps Creek, residents can access Mamre Road at the front of their property and from there travel south until turning east onto Elizabeth Drive.

Major Roads

Elizabeth Drive near South Creek crossing

- The low point in the road is overtopped in the 2% AEP flood.

Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek

Event	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.2	0.3	0.4	1.2
Duration (hours)	2	4	6	7	6

Elizabeth Drive near Kemps Creek crossing

- The low point in the road is overtopped in the 5% AEP flood.

Predicted maximum flood depth and duration of inundation (based on 36 hour event) at Kemps Creek

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.4	0.5	0.6	0.8	1.7
Duration (hours)	5	6	8	9	10	9

Other Roads N/A

FIGURE B-4

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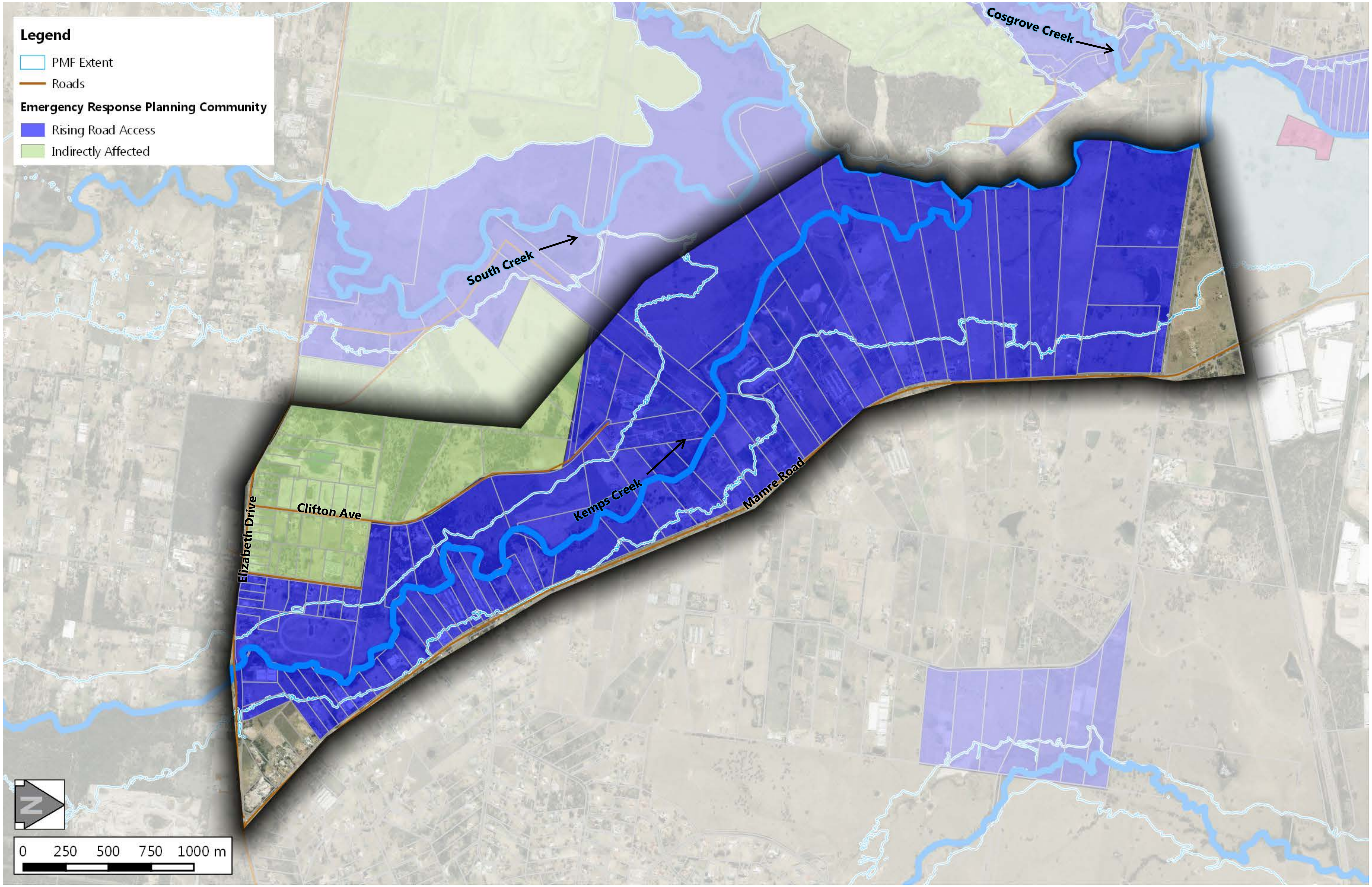
fg301310-08772rg200220-Fig H.4_Innundated Road_Kemps Creek

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: KEMPS CREEK



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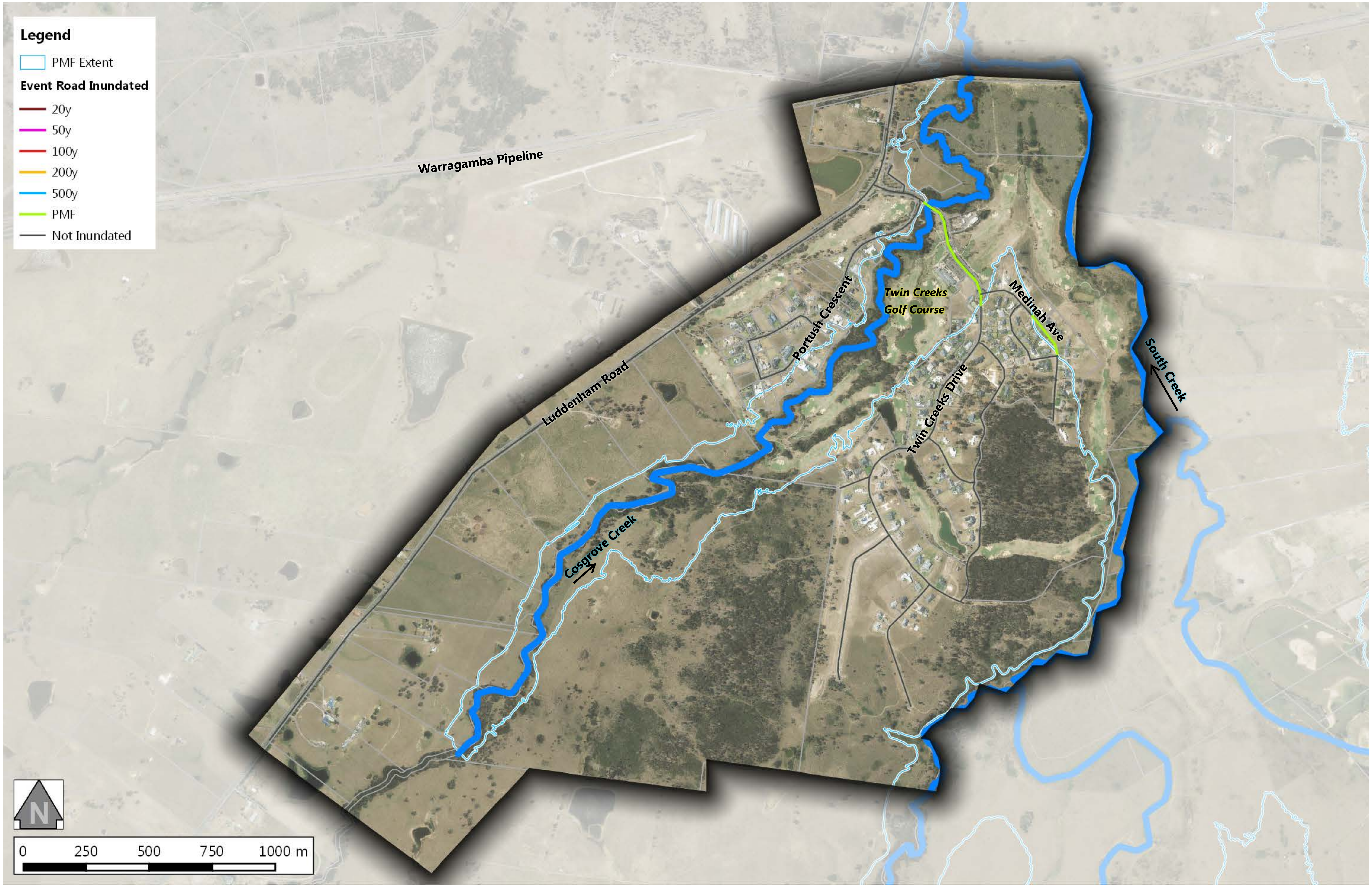
301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.1_ERP_KempsCreek

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: KEMPS CREEK

COMMUNITY DATA SHEET – TWIN CREEKS

Population at Risk	Area for Evacuation Management
500	148 ha

ERP Community Classifications	All properties / facilities are either **Indirectly Affected** or have **Rising Road Access** out of the flood extent.
Summary	Twin Creeks Golf & Country Club is predicted to be fully inundated in the PMF event. Other properties which are predicted to be inundated are the residential properties on the southern side of Portush Crescent, residential properties on the north-east side of Medinah Avenue and properties along the northern portion of Twin Creeks Drive. Not all dwellings are predicted to be inundated but inundation in yards is likely to occur. All of these affected properties have **Rising Road Access** via Twin Creeks Drive and then Luddenham Road. The southern half of the Twin Creeks community lies outside of the PMF extent but are **Indirectly Affected** as egress is blocked once Twin Creeks Road is inundated in the PMF.
Vulnerable Populations/ Services	None identified – no schools or aged care facilities are in this flood emergency management sector.
Evacuation Priorities	There are no high priority areas in this Flood Emergency Management Sector, however, properties which are affected by flooding and which depend on Twin Creeks Drive for evacuation should be evacuated to avoid isolation.
Evacuation Routes	Evacuees should access Twin Creeks Drive and travel north before turning onto Luddenham Road to avoid being isolated. This should occur before inundation of the Twin Creeks Drive crossing of Cosgrove Creek in the PMF.
Major Roads	**<u>Twin Creeks Drive crossing of Cosgrove Creek</u>** • The low point in the road on the southern approach to the bridge is inundated to depths of up to 1.6 m at the peak of the PMF. Duration of inundation is predicted to be four hours.
Other Roads	**Medinah Avenue** is predicted to be inundated to a depth of 0.6 m during the peak of the PMF.



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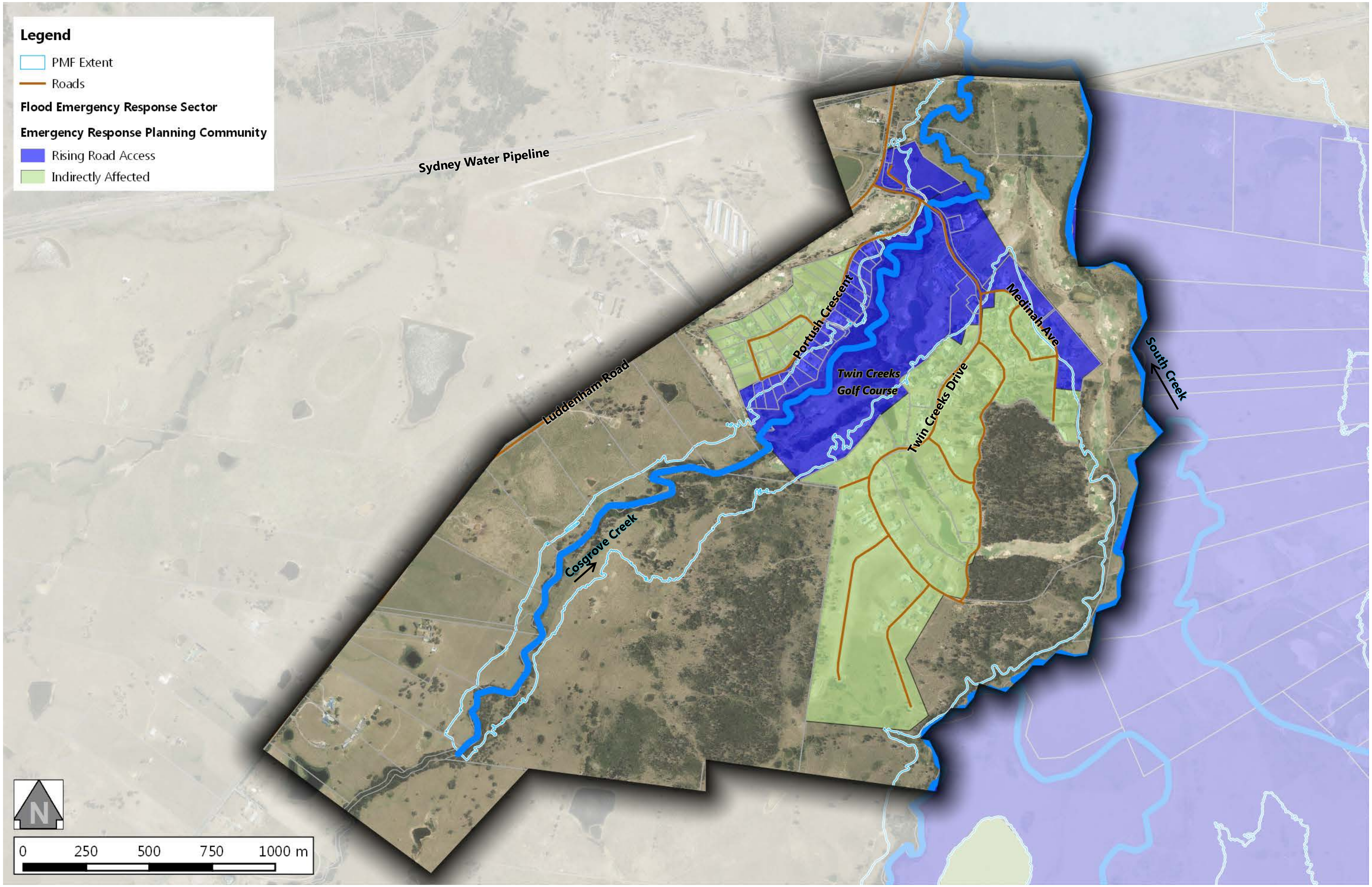
ROAD INUNDATION FOR THE
FLOOD EMERGENCY MANAGEMENT SECTOR:
TWIN CREEKS



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.1_ERP_TwinCreeks

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: TWIN CREEKS

COMMUNITY DATA SHEET – MAMRE ROAD

Population at Risk	Area for Evacuation Management
1,320	416 ha

ERP Community Classifications	• Large portions of land are classified as **Rising Road Access** • About 11 residential properties in Mandalong Close are **Low Flood Island** • A further six residential properties at the end of a private track and adjacent to South Creek are also **Low Flood Island** • Other flood affected properties have **Overland Escape Routes**
Summary	All properties in the PMF extent located between the McIntyre Avenue / Mamre Road intersection and the M4 Western Motorway have **Rising Road Access** towards the east. Properties to the east of the low point along Mandalong Close, and also the industrial estate along Erskine Park Road have **Rising Road Access** to the east. The primary concern in this Flood Emergency Management Sector are the two areas designated as **Low Flood Island**. Residents in Mandalong Close and at the end of the private track are unable to evacuate once the low points in the respective roads become inundated in the 20 year ARI event. Elsewhere in the sector, the remaining flood affected land is mostly just grassland. Old MacDonald's Child Care access to Mandalong Close is inundated in the 100 year ARI event, however, an **Overland Escape Route** to the south is available.
Vulnerable Populations/ Services	**<u>Old MacDonald's Child Care</u>** • The 0.2% AEP flood extent encroaches onto the northern boundary of the site. The site is completely inundated in the PMF to depths between 1.0 - 1.5 m. • An **Overland Escape Route** is available to the south.
Evacuation Priorities	• **Mandalong Close** Low Flood Island – the residents of the 11 properties in Mandalong Close require evacuation prior to inundation of the low point after which vehicular evacuation is not possible. • Likewise, the six residential properties at the end of the **Private Track** south of Mandalong Close will require evacuation prior to inundation of the low point in the track. • Due to the vulnerable nature of the occupants in **Old MacDonald's Child Care**, Overland Escape Route may not be a practical solution. The occupants should be prioritised for evacuation prior to inundation of the access point on Mandalong Close. • Properties which depend on Rising Road Access via flood-prone parts of Mamre Road.
Evacuation Routes	• Sections of some southbound lanes of Mamre Road near the intersection of Mamre Road and Luddenham Road and Mamre Road and McIntyre Avenue are inundated in the5% AEP flood. Occupants in this area should evacuate north on Mamre Road and travel east via Banks Drive or Solander Drive towards Erskine Park Road and the M4 Western Motorway • For properties to the north of this flood prone stretch of Mamre Road, evacuation should occur in an easterly direction via Banks Drive or Solander Drive. • Occupants of flood prone properties south of this area should travel south along Mamre Road before turning east onto Erskine Park Road. The Mamre Road crossing of an unnamed tributary of South Creek is inundated to 0.1 m in the 0.5% AEP flood, so residents may be trapped if timely evacuation does not occur. • Residents of the Low Flood Island areas should evacuate at the earliest opportunity by access Mamre Road and turning onto Erskine Park Road. • Ideally occupants of Old MacDonald's Child Care should also evacuate prior to inundation of the access point to Mandalong Close, access Mamre Road and then turn east onto Erskine Park Road. Failing that, Overland Escape Routes are available by walking in a southerly direction, parallel to Mamre Road.

Major Roads

Mamre Road near McIntyre Avenue

- The low point in the road is overtopped in the 2% AEP flood.

Predicted maximum flood depth and duration of inundation (*based on 36 hour event*) at South Creek

Event	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.1	0.4	0.6	0.8	2.2
Duration (hours)	4	6	7	9	8

Mamre Road near crossing of Blind Kemps Creek

- The low point in the road is predicted to be overtopped in the 0.5% AEP flood.
- Inundation associated with flooding along Blind Kemps Creek has not been assessed.

Predicted maximum flood depth and duration of inundation (*based on 36 hour event*) at South Creek

Event	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.5	2.0
Duration (hours)	5	6	8

M4 Western Motorway at South Creek

- Access cut by peak of 1% AEP flood at crossing of South Creek

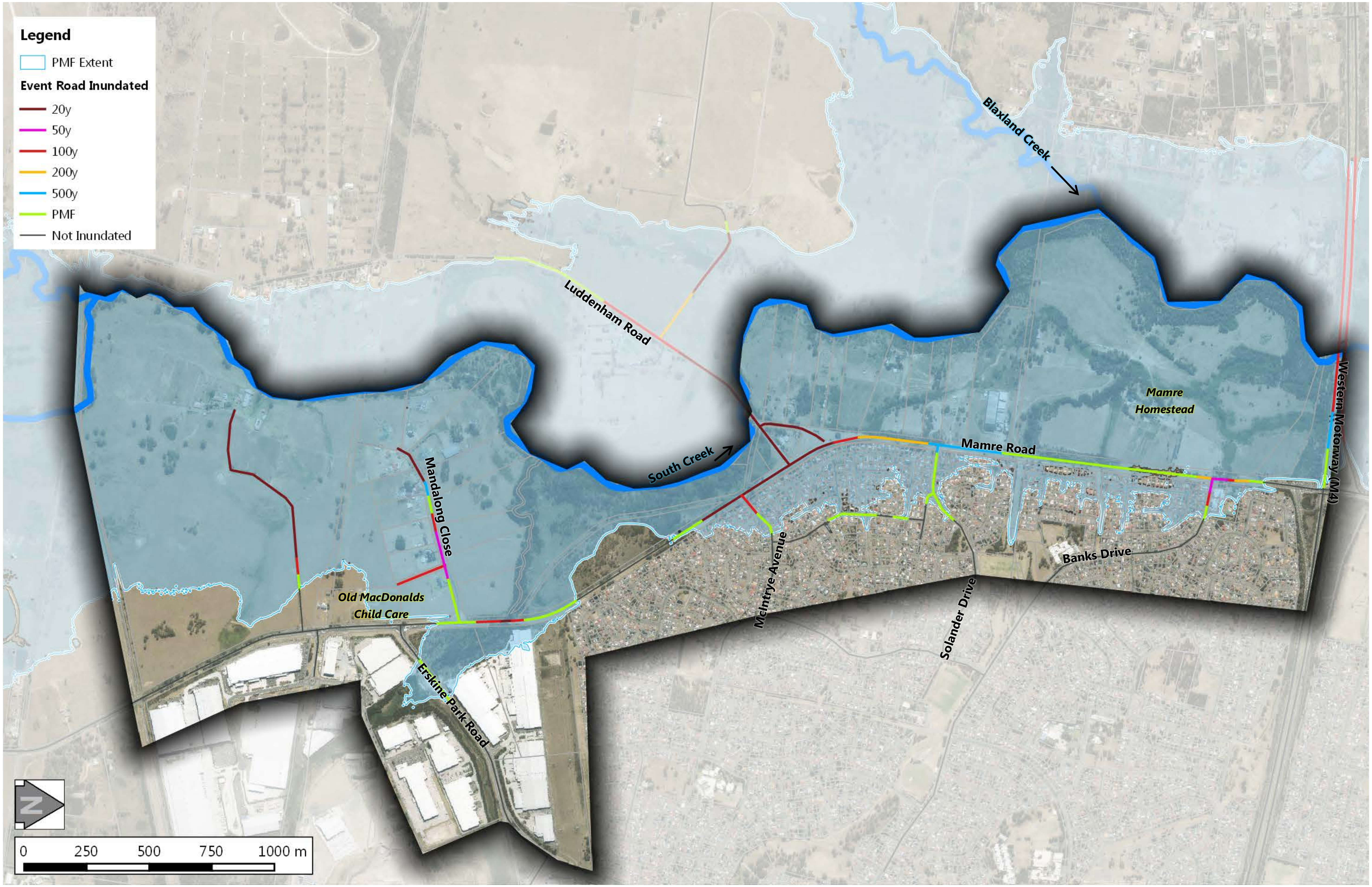
Predicted maximum flood depth and duration of inundation (*based on 36 hour event*) at South Creek

Event	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.6	0.8	2.2
Duration (hours)	4	6	8	9

Other Roads

- The cul-de-sac at the very end of **Mandalong Close** is inundated in the 5% AEP flood by depths of up to 0.5 m. Another low point in the road (*closer to access track to Old MacDonald's Child Care*) is inundated to depths of up to 0.2 m in the 2% AEP flood.
- The majority of the **Private Track** south of Mandalong Close is inundated in the 5% AEP flood event. The end of the road is inundated to a depth of 1.0 m in the 5% AEP flood.

FIGURE H-6



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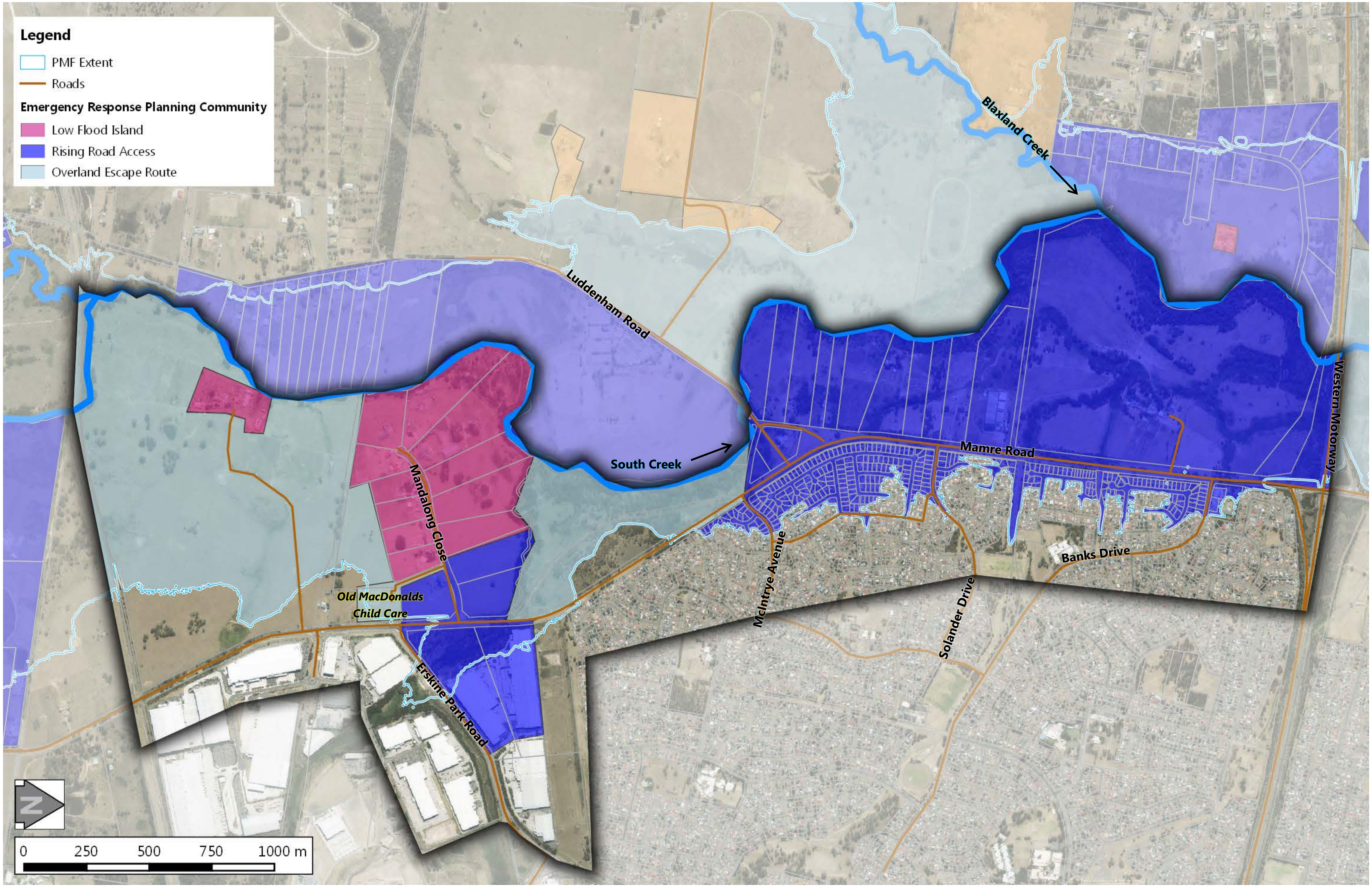
301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 4
fg301310-08772rg200220-Fig H.6_Innundated Road_Mamre Road

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: MAMRE ROAD



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301310-08772 – South Creek Floodplain Risk Management Study
fg301310-08772rg200220-Fig G.3_ERP_MamreRoad

FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: MAMRE ROAD

COMMUNITY DATA SHEET – ORCHARD HILLS WEST

Population at Risk	Area for Evacuation Management
194	370 ha

ERP Community Classifications	• Most flood affected properties are either **Rising Road Access, Overland Escape Route** or **Indirectly Affected** • A few rural residential properties immediately to the west of Blaxland Creek are **High Trapped Perimeter** • One residential property at the end of Flinders Lane becomes a **Low Flood Island**
Summary	Properties situated between Luddenham Road and South Creek have **Rising Road Access** via Luddenham Road. A few properties located off long private driveways are **Indirectly Affected** as they are out of the PMF extent but are unable to leave due to inundation of the access tracks. Most flood-affected properties to the west of Blaxland Creek also have **Rising Road Access** to escape floodwaters via vehicle evacuation to the west. However, Samuel Marsden Road is flood-prone during a 5% AEP flood and therefore properties relying on this road for evacuation need to evacuate as soon as possible. A few rural residential properties off a private track are designated as **High Trapped Perimeter** due to inundation of the access route. The property at the end of Flinders Lane becomes a **Low Flood Island**. Other areas of the floodplain are mainly used for agricultural purposes and most have an **Overland Escape Route**.
Vulnerable Populations/ Services	**Riding for the Disabled Association** • The whole site is inundated by the 5% AEP flood to depths of greater than 1.5 m • **Rising Road Access** is available by following Samuel Marsden Road to the south before turning west onto Lansdowne Road. This will need to be done before inundation of Samuel Marsden Road, which is predicted to be inundated by over 1 metre of water in the 5% AEP flood.
Evacuation Priorities	• The Low Flood Island at the end of **Flinders Lane**. Evacuation needs to occur as soon as possible as Flinders Lane is already inundated by 0.4 m at the peak of the 5% AEP flood. • Due to the vulnerable nature of the occupants at **Riding for the Disabled Association** and the flood-prone nature of the land, evacuation also needs to occur as soon as possible and before inundation of Samuel Marsden Road.
Evacuation Routes	• Flood affected properties off Luddenham Road should be evacuated by directing residents to access Luddenham Road at the front of their properties and to travel in a southerly direction. • The northern portion of Samuel Marsden Drive is especially flood-prone and evacuation needs to occur prior to inundation. Residents in this area will travel south on Samuel Marsden Road before turning west onto Lansdowne Road. • The eight properties on Bordeaux Place inundated by Blaxland Creek in the 0.2% AEP flood and greater can evacuate by travelling north along Bordeaux Place out of the flood extent. • Agricultural areas affected in the PMF have overland escape routes to the south-west.

<table>
<tr><td>Major Roads</td><td>

<u>Luddenham Road crossing of South Creek</u>

• Access is cut at the southern approach during the 5% AEP flood.

<u>Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek</u>

Event	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	1.6	1.8	2.0	2.2	2.4	4.0
Duration (hours)	17	17	20	22	25	18

<u>M4 Western Motorway at South Creek</u>

• Access cut by peak of the 1% AEP flood at the South Creek crossing.

<u>Predicted maximum flood depth and duration of inundation (based on 36 hour event) at South Creek</u>

Event	1% AEP	0.5% AEP	0.2% AEP	PMF
Max. depth (m)	0.3	0.6	0.8	2.2
Duration (hours)	4	6	8	9

</td></tr>
<tr><td>Other Roads</td><td>

• The low point in Samuel Marsden Road is inundated by depths of up to 0.9 m in the 5% AEP flood

• The low point in Flinders Lane is inundated by depths of up to 0.5 m in the 5% AEP flood.

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</table>

FIGURE H-7

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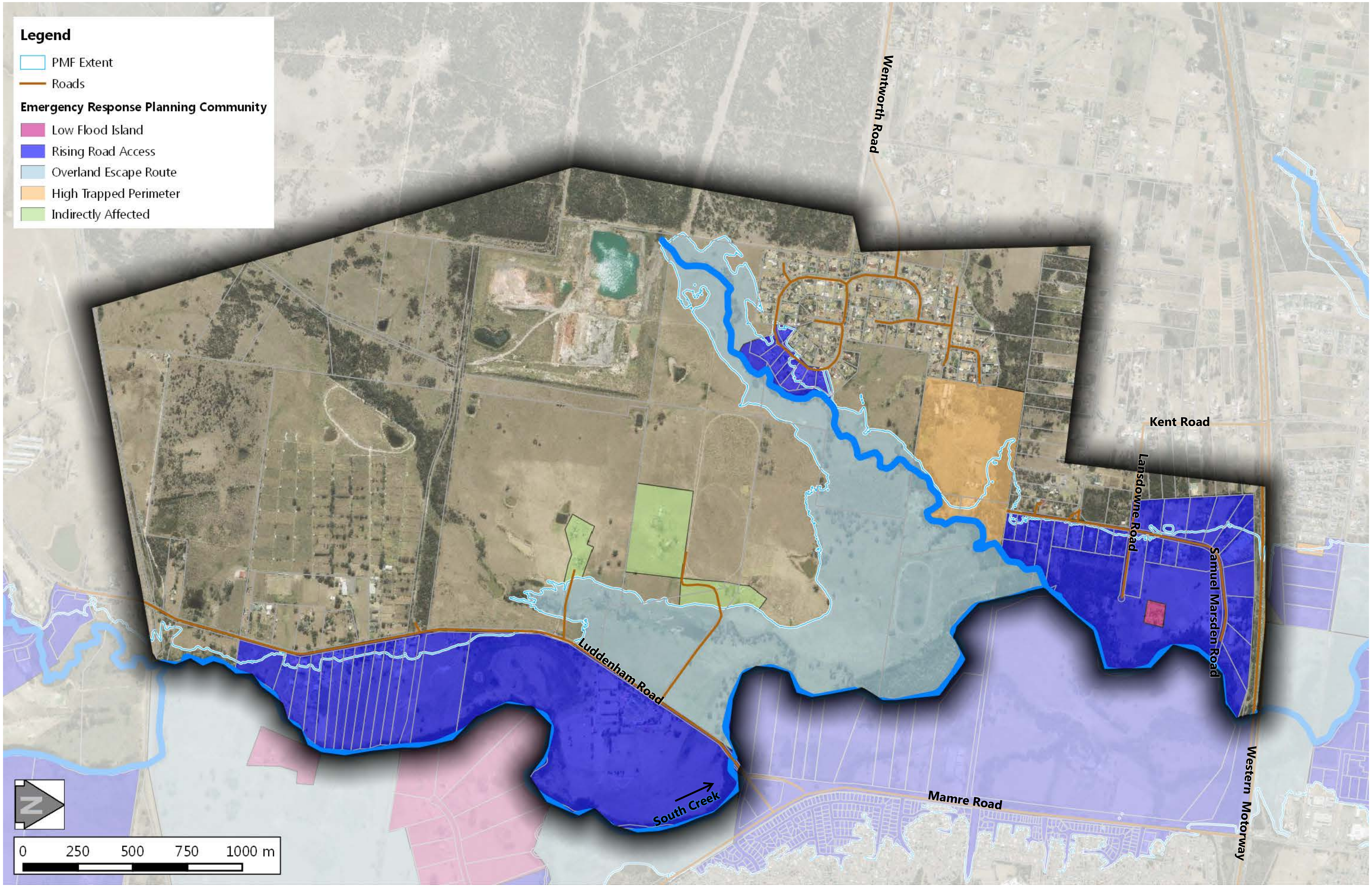
301310-08772 – South Creek Floodplain Risk Management Study Discussion Paper no. 4
FigB07_RoadInundation_OrchardHillsWest

ROAD INUNDATION FOR THE FLOOD EMERGENCY MANAGEMENT SECTOR: ORCHARD HILLS WEST

FIGURE G.4



FLOOD EMERGENCY RESPONSE PLANNING COMMUNITIES FOR FLOOD EMERGENCY MANAGEMENT SECTOR: ORCHARD HILLS WEST

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fg301310-08772rg200220-Fig G.4_ERP_OrchardHillsWest