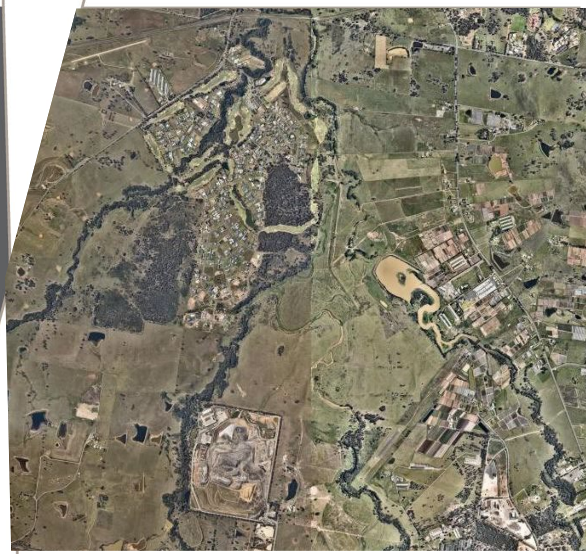
Flood Risk Assessment

Aspect Industrial Estate (AIE)

AWE200083



Prepared for
Mirvac

27 July 2022

Cardno

now

Stantec

Contact Information

Stantec Australia Pty Ltd
ABN 17 007 820 322

Level 9, The Forum
203 Pacific Highway St Leonards NSW 2065

Telephone: 61 2 9496 7700
Facsimile: 61 2 9439 5170
International: 61 2 9496 7700

sydney@cardno.com.au
www.cardno.com

Document Information

Prepared for	Mirvac
Project Name	Aspect Industrial Estate
File Reference	AWE200083 AIE FRA Rpt v6C 27Jul22.docx
Job Reference	AWE200083
Date	27 July 2022

Document Control

Version	Date	Description of Revision	Prepared By	Prepared (Signature)	Reviewed By	Reviewed (Signature)
5	24/2/21	Final	BCP	Brett C. Phillips		
6	17/6/22	Final	BCP	Brett C. Phillips		
6B	23/6/22	Final	BCP	Brett C. Phillips		
6C	27/7/22	Final	BCP	Brett C. Phillips		

Version	Reason for Issue	Approved for Release By	Approved (Signature)	Approved Release Date
5	Final Report includes update of PMF results	BCP	Brett C. Phillips	24/2/21
6	Final Report includes update of PMF results	BCP	Brett C. Phillips	17/6/22
6B	Final Report includes update of PMF results	BCP	Brett C. Phillips	23/6/22
6C	Final Report	BCP	Brett C. Phillips	27/7/22

Document Reference:

Y:\2304\Projects_AWE\FY20\0083_Aspect_Industrial_Estate\4_ISSUED_DOCS\2_Report\220727_E_FRA_Rpt_Final_v2\AWE200083 AIE FRA Rpt v6C 27Jul22.docx

Executive Summary

The purpose of this report is to provide a high-level understanding of the opportunities and constraints of the site due to flooding and to inform the development of a stormwater strategy/management plan for the Aspect Industrial Estate based on an assessment of flooding under Pre-development conditions.

Hydrology

Hydrological modelling of the South Creek catchment was undertaken in 2015 at the catchment scale using XP-RAFTS. The hydrological model assembled by WorleyParsons in 2015 was based on ARR1987 IFD. The local catchment is located within the larger South Creek subcatchment 1.17.

It should be noted that the 2015 study identified the critical storm burst duration for South Creek downstream of Bringelly Road to be 36 hours. While any future development would be expected to have an adverse impact of peak flows in short duration storm bursts it is likely that any future development will have minimal or nil adverse or beneficial impact on peak flows in a 36 hour storm due to the duration of the storm and timing effects due to runoff from impervious areas occurring more rapidly than runoff from pervious areas.

A local hydrological model was created to assess runoff under benchmark conditions and to facilitate the assessment of impacts of proposed development.

An issue which was considered was whether the airspace in existing farms dams is to be included in the benchmark conditions. An initial assessment was undertaken of the regional significance or otherwise of the farm dams based on criteria formulated in the upper South Creek catchment.

It was concluded that:

(i) The combined capacity in 8 farm dams within the local catchment is just under the criterion for classification as a regional farm dam system; and on this basis;
(ii) the farm dams have been ignored when assessing "Benchmark Conditions".

Hydrological assessments were undertaken using both ARR1987 and ARR2019.

Design rainfall and storm burst patterns were obtained from ARR1987 for 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI and 500 yr ARI events.

The Probable Maximum Precipitation (PMP) was estimated using The Estimation of Probable Maximum Precipitation in Australia: Generalised Short – Duration Method (Bureau of Meteorology, 2003). The PMP depths were obtained for ellipses A and were applied to each subcatchment in the local model.

For the 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI and 500 yr ARI events the adopted initial rainfall loss = 15 mm and continuing rainfall loss = 1.5 mm/h. For the PMF the adopted rainfall losses were an initial loss = 1 mm and a continuing loss = 0 mm/h.

Design rainfall and storm burst patterns were obtained from ARR2019 were obtained from the ARR Data Hub for 50%, 20%, 1%, 0.5% and 0.2% AEP events.

For the for 50%, 20%, 1%, 0.5% and 0.2% AEP events the adopted initial burst rainfall loss (IL) varied while a constant continuing rainfall loss (CL) = 2.3 mm/h was adopted. The adopted average initial burst losses were as follows.

AEP	Burst IL (mm)	CL (mm/h)
50%	28.5	2.3
20%	16	2.3
10%	14	2.3
5%	13.5	2.3
2%	12	2.3
1%	10	2.3
0.5%	10	2.3
0.2%	10	2.3

The peak flows estimated at the Mamre Road crossing for the various events are summarised as follows.

Summary of Estimated Peak Flows at Mamre Road Crossing

ARR1987 Hydrology			**ARR2019 Hydrology**		
ARI (yrs)	Peak Flow (m3/s)	Critical Duration (hrs)	AEP	Peak Flow (m3/s)	Critical Duration (hrs)
2	6.31	9	50%	3.23	6
5	9.09	4.5	20%	7.73	2
100	21.0	2	1%	23.3	0.75
200	24.4	2	0.50%	26.2	0.75
500	29.2	2	0.20%	30.9	0.75
PMF	233	0.75	PMF	233	0.75

It should be noted, as discussed in Section 1.5, that 2 yr ARI equates to 39% AEP while 5 yr ARI equates to 18% AEP.

It was also noted that the

- Critical storm burst durations for ARR2019 storm burst are all shorter than the critical storm burst durations for ARR1987 storm burst;
- The 1% AEP peak flow at Mamre Road is around 11% higher than the estimated 100 yr ARI peak flow at Mamre Road.

It was also of interest to compare the estimated peak flows at Mamre Road with the estimated peak flows in South Creek in the vicinity of the local catchment at Node 1.17 (refer Figure 10). The estimated peak flows at Node 1.17 are summarised as follows.

The indicativeARR2019 peak flows were obtained by modifying the 2015 Worley Parsons model by adopting a global storm (not catchment dependent storms) and a uniform initial burst loss (refer Section 3.4.2) across the catchment. An areal reduction factor was not applied to the rainfall intensities obtained from the ARR Data Hub.

Summary of Estimated Peak Flows in South Creek at Node 1.17

	Storm Burst			
Event	2 hr	9 hr	36 hr	
2 yr ARI	13.6	151	305	ARR1987 - Worley Parsons, 2015 Model
100 yr ARI	360	774	956	ARR1987 - Worley Parsons, 2015 Model
1% AEP	558	727	563	ARR2019 - Modified WorleyParsons, 2015 Model

It was noted that the indicative peak flow under ARR2019 is lower than estimated under ARR1987 and the critical storm burst duration reduces from 36 hours to 9 hours.

Hydraulics

A local TUFLOW model of the drainage lines through the site was assembled.

The Digital Elevation Model (DEM) was created by combining detailed survey and ALS data external to the site. Based on the assessment of the combined impact of the farm dams in the Mamre Road local catchment discussed in Section 3.1, the farm dams were removed from the DEM by interpolating the terrain through each of the farm dams.

The roughness zones for the floodplain are mapped in **Figure 14**.

From the detailed survey it was determined that the crossing under Mamre Road is 3 x 1.85 m x 0.77 m culverts. For assessment purposes it was assumed that this crossing would be partially blocked and that only two of the three culverts would convey floodwaters.

Inflows to the TUFLOW model were exported from the hydrological model and input at the locations of the subcatchment outlets (nodes). For assessment purposes, the Scenario 2 conditions were adopted to maintain compatibility with the 2015 South Creek flooding assessments which were based on ARR1987. A review of the vertical alignment of Mamre Road beside Subcatchment MRID2b disclosed that Mamre Road has a local crest located around 95 m north of the southwest corner of the subject property. Consequently, runoff from Subcatchment MRID2b was partitioned 50:50 based on contributing subcatchment areas with 50% of the runoff input at the northern limit of Subcatchment MRID2b and 50% input at the southwest corner of the subject property.

The downstream boundary condition was a fee outfall. The flood extent in South Creek was overlaid over the results of the local TUFLOW model to identify where mainstream flooding takes over from overland flows.

The TUFLOW floodplain model was run for the critical storm burst durations for the 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI, 500 yr ARI and PMF events.

Flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted for each of these events.

Table of Contents

Appendix

List of Tables

List of Figures

List of Figures Continued

1 Introduction

Aspect Industrial Estate (the site) is legally described as Lots 54 – 58 in DP 259135, with an area of approximately 56.3 hectares (ha). The site is located east of Mamre Road, Kemps Creek within the Penrith Local Government Area (LGA).

The site has approximately 950m of direct frontage to Mamre Road with a proposed intersection providing vehicular access via Mamre Road to the M4 Motorway and Great Western Highway to the north and Elizabeth Drive to the south.

The site is located approximately 4km north-west of the future Western Sydney Nancy-Bird Walton Airport, 13km south-east of the Penrith CBD and 40km west of the Sydney CBD.

The Department of Planning, Industry and Environment (DPIE) rezoned Mamre Road Precinct, including the site, in June 2020 under the *State Environmental Planning Policy (Western Sydney Employment Area) 2009* (WSEA SEPP). The rezoning of this precinct responds to the demand for industrial land in Western Sydney. The site primarily zoned IN1 General Industrial with a small sliver of land zoned E2 Environmental Conservation.

1.1 Purpose of this Report

The purpose of this report is to provide a high-level understanding of the opportunities and constraints of the site due to flooding and to inform the development of a stormwater strategy/management plan for the Aspect Industrial Estate based on an assessment of flooding under Pre-development conditions.

1.2 Location

The location of the Aspect Industrial Estate is indicated in **Figure 1**.

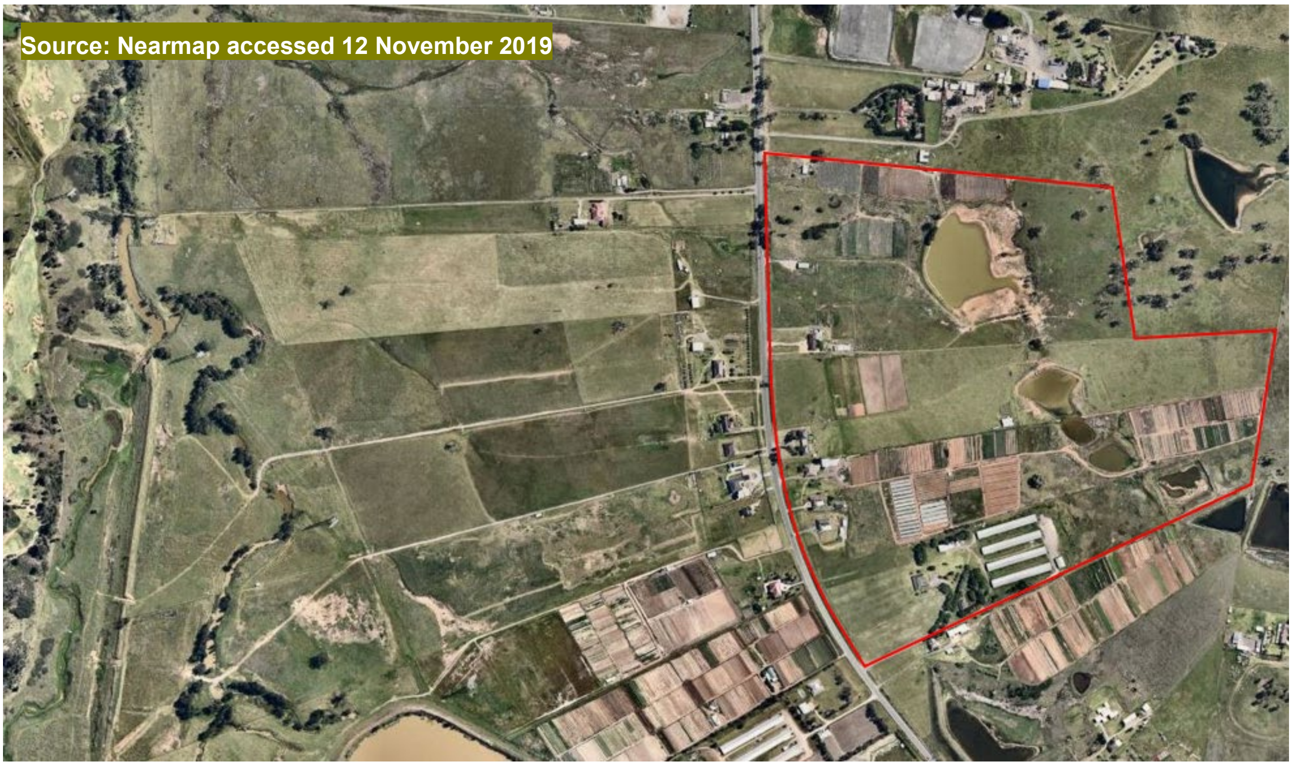


Figure 1 Location of Aspect Industrial Estate

1.3 Planning Context

In August 2018 the Department of Planning and Environment released the Western Sydney Aerotropolis Land Use and Infrastructure Implementation Plan (LUIIP) – Stage 1 Initial Precincts which applies to the land comprising the Aerotropolis (including the property).

The LUIIP:

- identifies a first-stage Structure Plan (3 precincts) with the balance of 6 precincts to form part of Stage 2;
- states how the initial precincts will be delivered and the desired uses for each precinct;
- describes how the Aerotropolis' precincts will be planned to integrate with designated growth areas and the delivery of infrastructure;
- identifies the South Creek Precinct;
- identifies key policy drivers (for example, aircraft noise and aviation safety) that will influence where appropriate development will be delivered within the precincts; and
- a flexible and adaptive planning framework through a new SEPP which will identify three key zones (infrastructure, environment and urban development zones).

Figure 2 shows the relevant precincts that are proposed to apply to the site. They include the accelerated precincts of the Northern Gateway and South Creek, as well as the Stage 2 precincts of Badgerys Creek and Kemps Creek.

There are also various planning instruments and development controls that are applicable to development located in the Penrith Local Government Area (LGA). These were identified by Jacobs, 2016, in part, as follows.

1.3.1 Penrith Local Environmental Plan 2010

The first stage of the Penrith Local Environmental Plan 2010 was published in 2010 and applied to Penrith's rural and industrial areas and St Marys Town Centre. The second stage of the Penrith LEP was published on 28 January 2015 and came into effect on 25 February 2015 to set planning controls for much of the areas not covered by Stage 1 of Penrith Local Environmental Plan 2010, including the City's residential and commercial areas.

The Penrith Local Environmental Plan (LEP) zones the land within the Penrith LGA and imposes standards to control development, or implements a state or local policy outcome. Clause 7.2 'Flood Planning' in the Penrith LEP provides the details of items which the consent authority must satisfy themselves of before providing development consent. The clause applies to all land at or below the flood planning level (100 year average recurrence interval (ARI) event plus 0.5m freeboard). The LEP aims to ensure that the development:

- *Is compatible with the flood hazard of the land*
- *Is not likely to adversely affect flood behaviour, flow distributions or velocities resulting in detrimental increases in the potential flood affectation of other development or properties or the environment (including stability of waterways and riparian vegetation)*
- *Is not likely to adversely affect the safe and effective evacuation of the land and the surrounding area*
- *Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding*
- *Manages the risk to life from flood*

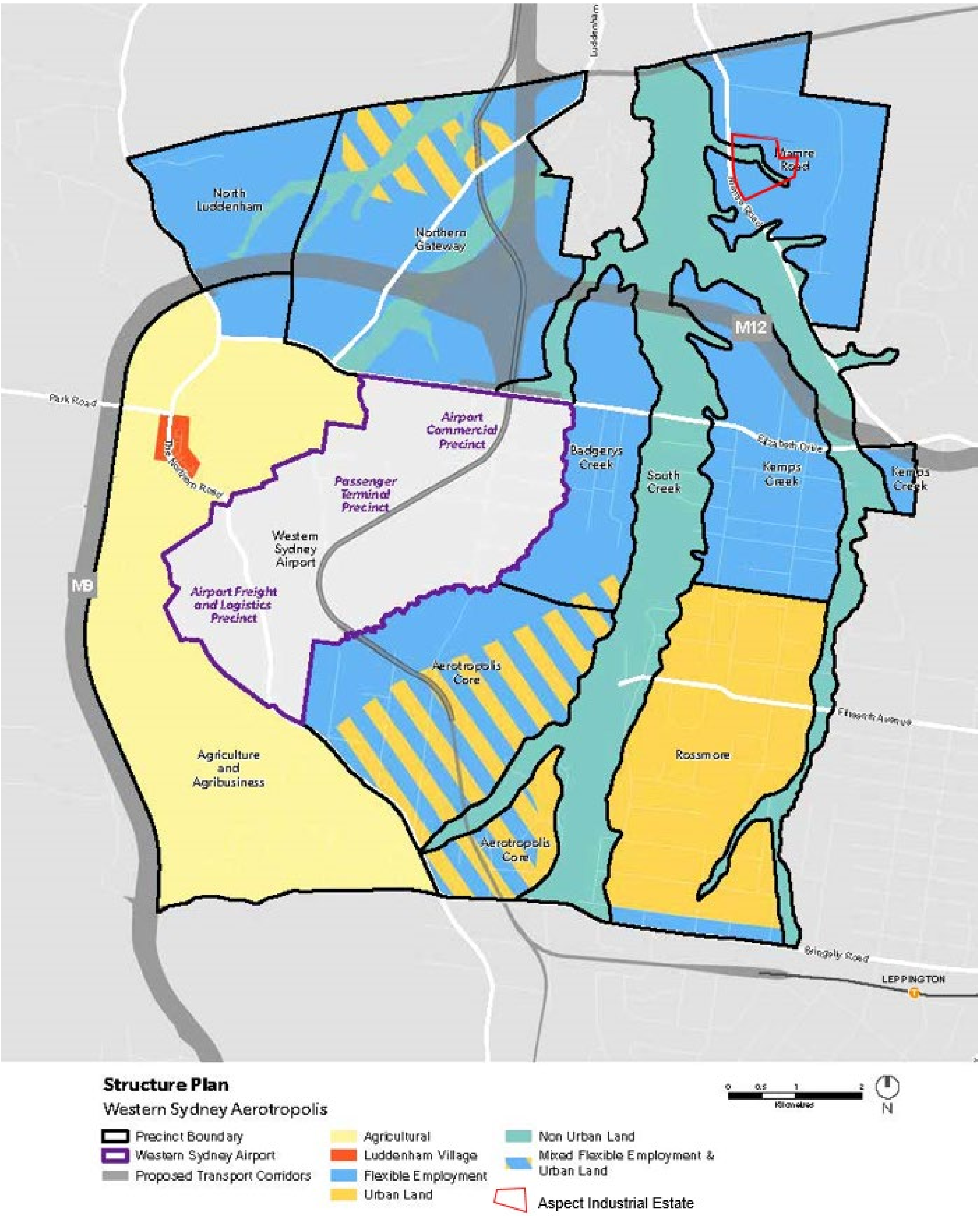


Figure 2 Relationship of University of Aspect Industrial Estate to Precincts

The LEP also includes Flood Planning Land Maps defining the Flood Planning Area (FPA) (refer **Figure 3**). It appears that these maps have been prepared based on the 'Flood Study Report South Creek' (NSW Department of Water Resources, 1990) and/or 'South Creek Floodplain Management Study' (Willing & Partners, 1991). It is noted that the site is located outside Council's Flood Planning Area.

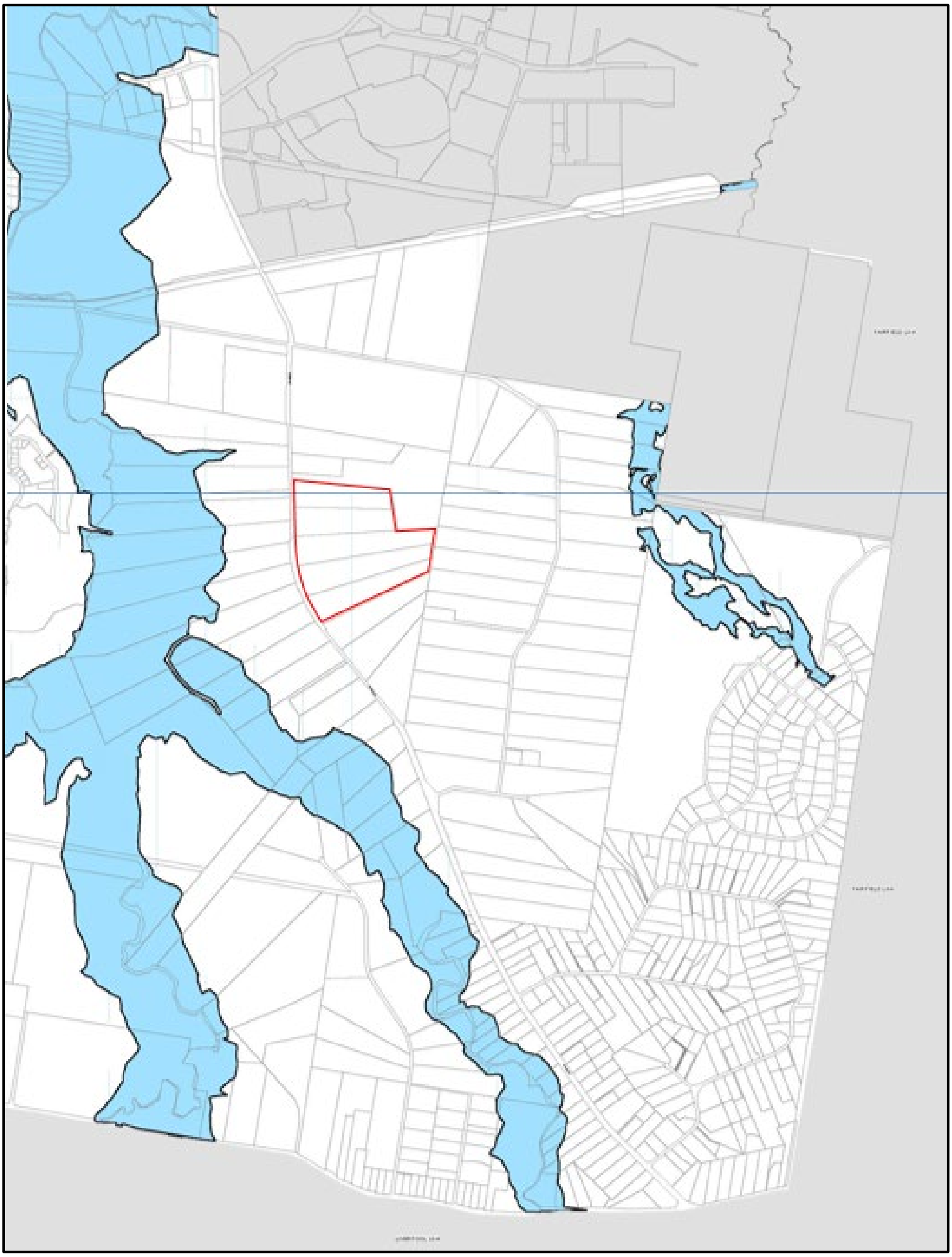


Figure 3 Penrith LEP 2010 Flood Planning Area

1.3.2 Penrith_Development Control Plan 2014

Chapter C3 Water Management of the Penrith Development Control Plan (DCP) 2014 outlines the controls on riparian corridors in Chapter 3.3 and flooding constraints on developments in Chapter 3.5.

Chapter 3.3 states in part:

> *Council reserves the right to assess each riparian corridor and each development on its merits. In general, however, the width will depend on the order of the stream/watercourse (see Figure C3.2) which provides an indication. The width should be measured from the top of the highest bank on both sides of the stream/watercourse, excluding any managed buffer zone, and shall comply with the requirements outlined in Table C3.3.*

The stream classifications in the local catchment are plotted in **Figure 4**.

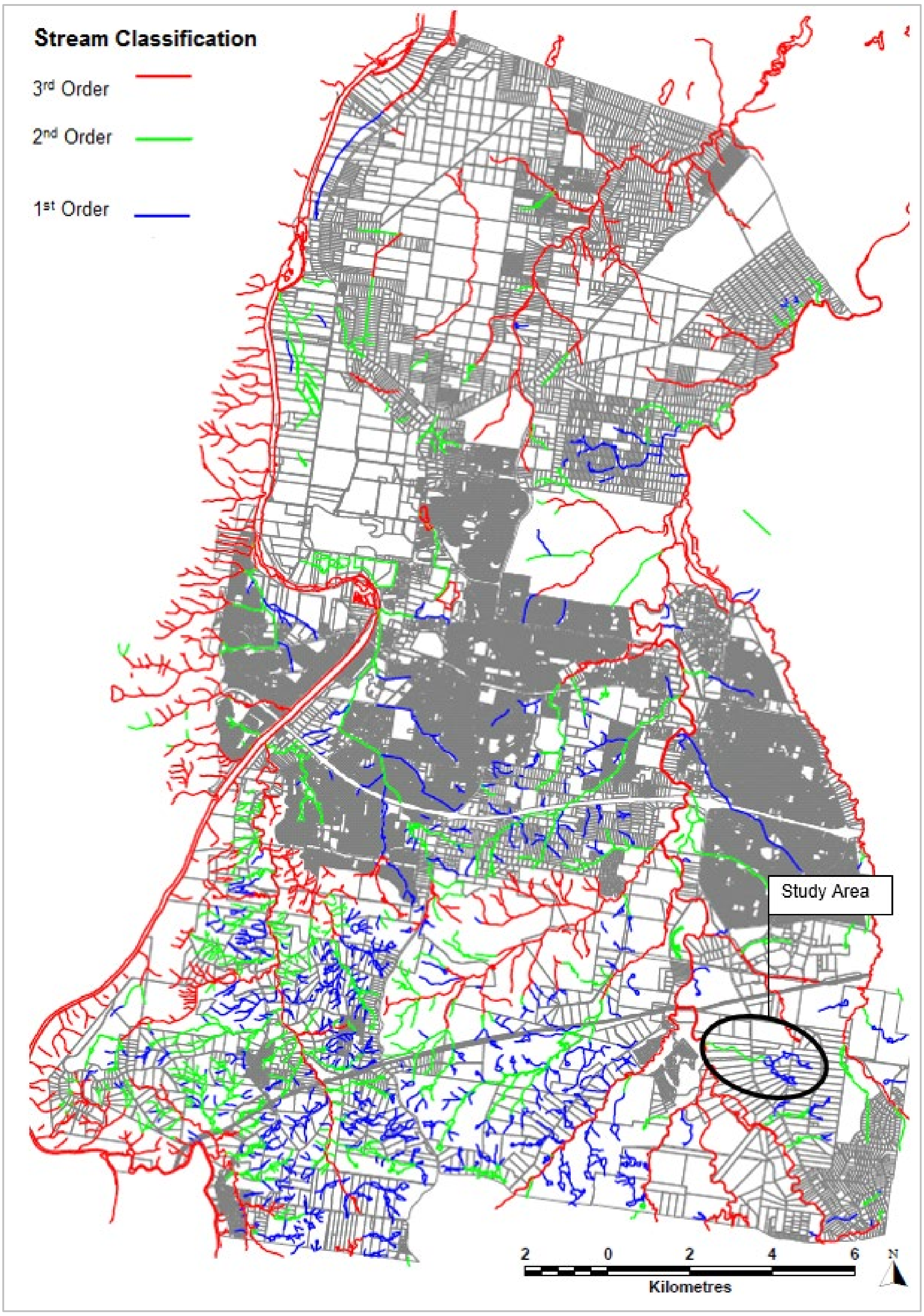


Figure 4 Stream Classification (after Figure C3.2, Penrith DCP 2014)

Table 3.3 identifies a Total Riparian Corridor Width for a second order watercourse of “40m + channel width”.

As stated in Chapter 3.5:

The LEP contains provisions for development on land at or below the flood planning level, defined in the LEP as the level of a 1:100 Average Recurrence Interval (ARI) (1% AEP (100 year ARI)) flood event plus 0.5m freeboard.

The 1% AEP (100 year ARI) flood event is a tool for broadly assessing the suitability of land for development. It is not an assessment of flood risk, nor does reference to the 1% AEP (100 year ARI) flood event mean that properties and development above this level are not subject to flood risk.
….

Significant areas of Penrith are affected by the Probable Maximum Flood (PMF) and in some cases this will need to be considered in determining flood hazard.
….

13 Overland Flow Flooding

a) Council has undertaken a Penrith Overland Flow Flood 'Overview' Study. Consideration must be given to the impact on any overland flow path. Generally, Council will not support development obstructing overland flow paths. Development is required to demonstrate that any overland flow is maintained for the 1% AEP (100 year ARI) overland flow. A merit based approach will be taken when assessing development applications that affect the overland flow.

b) Council’s Stormwater Drainage Specification for Building Developments provides information on the details required in the preparation of an overland flow study.

15 Rezoning of Land

a) Council will not support the rezoning of any land located in a floodway or high hazard area.

b) Council will generally not support the rezoning of rural land situated below the 1% AEP (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 1% AEP (100 year ARI) flood by means of filling.

c) Where land below the flood planning level is currently zoned to permit urban development, Council will generally not support the rezoning of land to permit a higher economic use or an increase in the density of development.

1.3.3 2021 Mamre Road Precinct DCP

The Mamre Road Precinct DCP came into force on 19 November 2021. Relevant sections of the DCP include:

2.4 Integrated Water Cycle Management

The Mamre Road Precinct Flood, Riparian Corridor and Integrated Water Cycle Management Strategy (Sydney Water) describes the principles of the integrated water management strategy for the Precinct.

2.5 Flood Prone Land

Objectives

a) To ensure development in the floodplain is consistent with the NSW Flood Prone Land Policy and principles in the NSW Government Floodplain Development Manual.

b) To ensure floodplain risk management minimises the potential impact of development upon the aesthetic, recreational and ecological values of waterways.

c) To maintain the existing flood regime, velocities, flow conveyance and stream hydrology.

d) To ensure development does not alter flood behaviour resulting in adverse impacts to surrounding properties, land uses and infrastructure.

e) To enable safe occupation and evacuation of flood prone land.

f) To ensure development is compatible with flood hazard and flood behaviour.

g) To avoid adverse or cumulative impacts on flood behaviour and environment.

Controls

1) A comprehensive Flood Impact Risk Assessment (FIRA) (prepared by a qualified hydrologist and hydraulic engineer) is to be submitted with development applications on land identified as fully or partially flood affected. The FIRA should utilise Council's existing data and data arising from the Wianamatta (South) Creek Catchment Flood Study[1] to provide an understanding of existing flooding condition and developed conditions consistent with the requirements of the NSW Flood Prone Land Policy and Floodplain Development Manual. The FIRA shall determine:

- *Flood behaviour for existing and developed scenarios for the full range of flooding including the 5% Annual Exceedance Probability (AEP), 1% AEP, 0.5% AEP, 0.2% AEP and Probable Maximum Flood (PMF);*
- *Flood Function (floodways, flood fringe and flood storage areas);*
- *Flood Hazard; and*
- *Flood constraints, including evacuation constraints (if applicable).*

2) The FIRA shall adequately demonstrate to the satisfaction of the consent authority that:

- *Development will not increase flood hazard, flood levels or risk to other properties;*
- *Development has incorporated measures to manage risk to life from flooding;*
- *For development located within the PMF, an Emergency Response Plan is in place;*
- *Structures, building materials and stormwater controls are structurally adequate to deal with PMF flow rates and velocities (including potential flood debris);*
- *Development siting and layout maintains personal safety during the full range of floods and is compatible with the flood constraints and potential risk;*
- *The impacts of sea level rise and climate change on flood behaviour has been considered;*
- *Development considers Construction of Buildings in Flood Hazard Areas and accompanying handbook developed by the Australian Building Codes Board (2012); and*

[1] Advisian Pty Ltd (November 2020) Wianamatta (South) Creek Catchment Flood Study – Existing Conditions – Report. https://flooddata.ses.nsw.gov.au/related-dataset/wianamatta-south-creek-catchment-flood-study-existing- conditions-main-report

- *Fencing does not impede the flow of flood waters/overland flow paths.*

Flood Constraints

3) *New development in floodways, flood fringe and/or flood storages or in high hazard areas in the 1% AEP flood event considering climate change is not permitted.*
4) *Development applications are to consider the depth and nature of flood waters, whether the area forms flood storage, the nature and risk posed to the development by flood waters, the velocity of floodwaters and the speed of inundation, and whether the development lies in an area classed as a 'floodway', 'flood fringe area' or 'flood storage area'.*

Subdivision

5) *Subdivision of land below the flood planning level will generally not be supported.*
6) *Subdivision must comply with Designing safer subdivisions guidance on subdivision design in flood prone areas 2007 (Hawkesbury-Nepean Floodplain Management Steering Committee).*

New Development

7) *Finished floor levels shall be at 0.5m above the 1% AEP flood.*
8) *Flood safe access and emergency egress shall be provided to all new and modified developments consistent with the local flood evacuation plan, in consultation with Council and the State Emergency Services (SES).*

Storage of Potential Pollutants

9) *Potential pollutants stored or detained on-site (such as on-site effluent treatment plants, pollutant stores or on-site water treatment facilities) shall be stored above the 1% AEP flood. Details must be provided as part of any development application.*

Overland Flow Flooding

10) *Development should not obstruct overland flow paths. Development is required to demonstrate that any overland flow is maintained for the 1% AEP overland flow with consideration for failsafe of flows up to the PMF.*
11) *Where existing natural streams do not exist, naturalised drainage channels are encouraged to ensure overland flows are safely conveyed via vegetated trunk drainage channels with 1% AEP capacity plus 0.5 m freeboard. Any increase in peak flow must be offset using on- site stormwater detention (OSD) basins.*
12) *OSD is to be accommodated on-lot, within the development site, or at the subdivision or estate level, unless otherwise provided at the catchment level to the satisfaction of the relevant consent authority.*
13) *Stormwater basins are to be located above the 1% AEP.*
14) *Post-development flow rates from development sites are to be the same or less than pre-development flow rates for the 50% to 1% AEP events.*
15) *OSD must be sized to ensure no increase in 50% and 1% AEP peak storm flows at the Precinct boundary or at Mamre Road culverts. OSD design shall compensate for any local roads and/or areas within the development site that does not drain to OSD.*

Filling of Land At or Below the Flood Planning Level

16) E*arthworks up to the PMF must meet the requirements of Clauses 33H and 33J of the WSEA SEPP as well as Sections 2.5 and 4.4 of this DCP.*
17) *Filling of floodways and/or critical flood storage areas in the 1% AEP flood will not be permitted.*

Filling of other land at or below the 1% AEP is also discouraged, but will be considered in exceptional circumstances where:

- *The below criteria have been addressed in detail in the supporting FIRA;*
- *The purpose for which the filling is to be undertaken is adequately justified;*
- *Flood levels are not increased by more than 10mm on surrounding properties;*
- *Downstream velocities are not increased by more than 10%;*
- *Flows are not redistributed by more than 15%;*
- *The cumulative effects of filling proposals is fully assessed over the floodplain;*
- *There are alternative opportunities for flood storage;*
- *The development potential of surrounding properties is not adversely affected;*
- *The flood liability of buildings on surrounding properties is not increased;*
- *No local drainage flow/runoff problems are created; and*
- *The filling does not occur within the drip line of existing trees.*

1.3.4 2020 Mamre Road Flood, Riparian Corridor and Integrated Water Cycle Management Strategy

As described by Sydney Water, 2020:[2]

This Integrated Water Cycle Management study has been prepared to inform and support the rezoning of the Mamre Road Precinct. Controls prescribed by this study will inform the Precinct DCP and ensures that:

- *Land use is compatible with flood risk*
- *Flood management approaches are effective and consistent across the catchment*
- *Water sensitive urban design approaches achieve pollution reduction targets and contribute to emerging waterway health targets in a flexible and cost-effective way*
- *Sufficient land is allocated for stormwater and flood management on private lots and in the public domain*

…….
An assessment of flood constraints associated with the land use change includes:

- *defining flood behaviour within the Precinct's unnamed tributaries*
- *an assessment of flood behaviour post-development and the impacts the change in land use will have on local catchment flood behaviour, including impacts on existing infrastructure and lands outside the Precinct*
- *an assessment of the flood mitigation requirements for the Precinct*

…. The local XP-RAFTS model was run for the 1EY, 5% AEP, 1%AEP, 0.2% AEP and PMF events for all durations between 15 minutes to 36 hours.

Mapping of hydraulic modelling results is only reported for 5% AEP, 1% AEP and 0.2% AEP events. It is noted from **Figure 5** that flooding is a consideration for the site.

In Section 6.4.2 Detention Strategy:

It is recommended that each industrial lot implements on-site stormwater detention as prescribed by Table 6.

[2] Sydney Water (2020) "Mamre Road Flood, Riparian Corridor and Integrated Water Cycle Management Strategy", *Final Report*, October, 61 pp + Apps

Table 6 OSD requirements on industrial lots within Mamre Road Precinct

Zone	50% AEP SSR (m^3/ha)	50% AEP PSD (l/s/ha)	1% AEP SSR inclusive of 50% AEP SSR (m^3/ha)	1% AEP PSD (l/s/ha)
East Catchments draining towards Ropes Creek	190	40	393	150
North Catchment draining towards WaterNSW Warragamba Pipeline	190	40	393	150
West Catchments draining towards Ropes Creek	190	40	393	150

1.4 Approach

The approach adopted to the hydrological and hydraulic assessments is outlined as follows.

1.4.1 Hydrology

ARR1987

The hydrological model assembled by WorleyParsons in 2015 was based on ARR1987 IFD. 100 yr ARI runoff in the upper South Creek catchment south of Bringelly Road has been assessed previously for 2 hour, 9 hour and 36 hour storm bursts. An assessment of the sensitivity of 100 yr ARI peak runoff to storm burst rainfall losses has also been undertaken.

It should be noted that the 2015 study identified the critical storm burst duration for South Creek downstream of Bringelly Road to be 36 hours. While any future development would be expected to have an adverse impact of peak flows in short duration storm bursts it is likely that any future development will have minimal or nil adverse or beneficial impact on peak flows in a 36 hour storm due to the duration of the storm and timing effects due to runoff from impervious areas occurring more rapidly than runoff from pervious areas.

A local hydrological model was created to assess runoff under benchmark conditions and to facilitate the assessment of impacts of proposed development.

An issue which was considered was whether the airspace in existing farms dams is to be included in the benchmark conditions. An initial assessment was undertaken of the regional significance or otherwise of the farm dams based on criteria formulated in the upper South Creek catchment.

ARR2019

We note the comments provided by email from Sydney Water:

> *Until the transition to ARR2019 is completed, we'd recommend that flood impact assessments consider both ARR1987 and ARR2019 hydrology.*

An additional assessment was undertaken using ARR2019 IFD and burst losses.

1.4.2 Hydraulics

Given that the proposed development is located in a local catchment which drains to South Creek and is located beyond the extent of the South Creek floodplain model, a local 1D/2D floodplain model was assembled to assess flooding under benchmark conditions and to facilitate the assessment of impacts of proposed development.

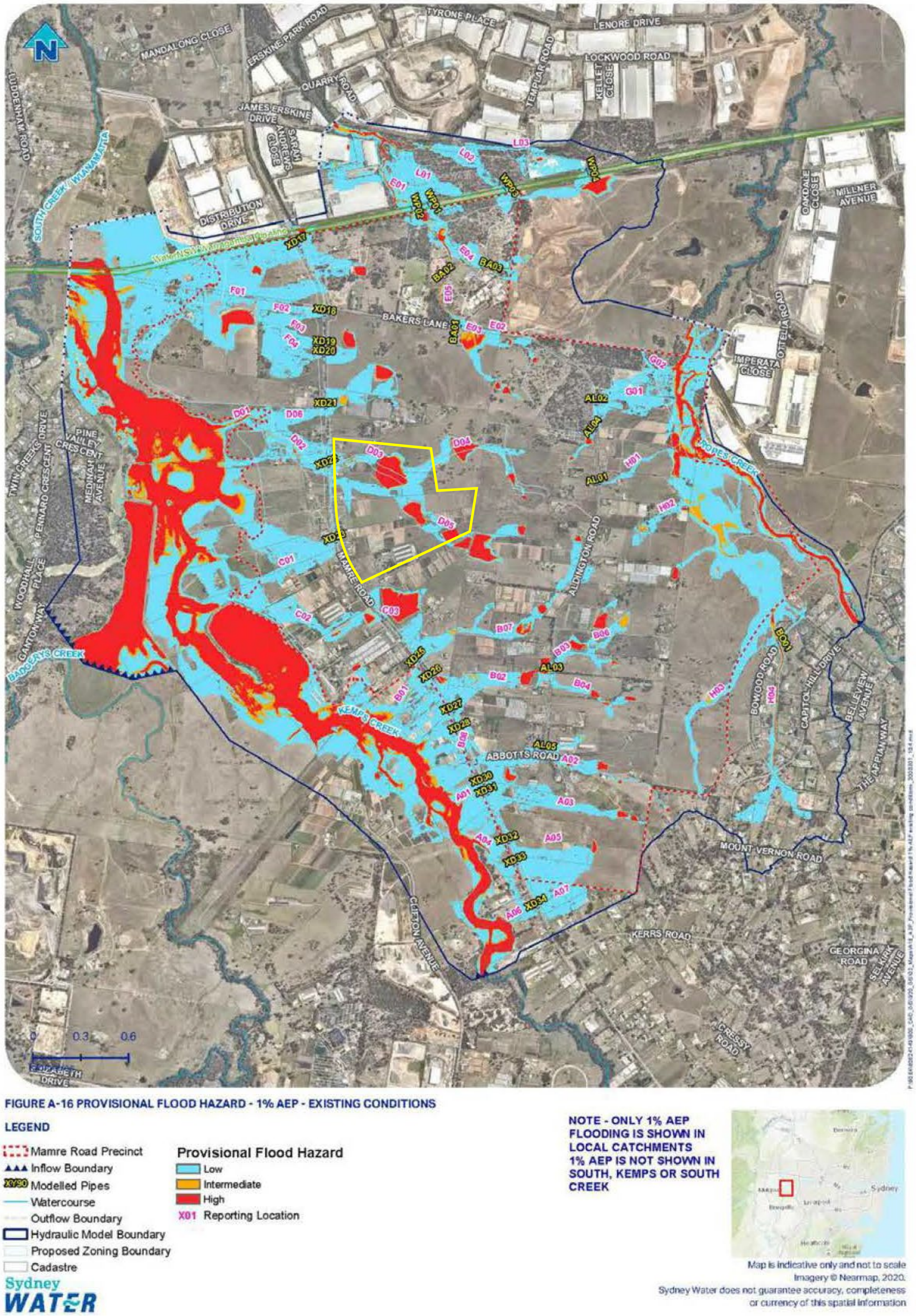


Figure 5 1% AEP Provisional Flood Hazard under Existing Conditions
(after Figure A-16, Sydney Water, 2020)

1.5 Terminology

Book 1, Chapter 2, Section 2.2.5. Adopted Terminology in Australian Rainfall & Runoff, 2016 describes the adopted terminology as follows:

> *To achieve the desired clarity of meaning, technical correctness, practicality and acceptability, the National Committee on Water Engineering has decided to adopt the terms shown in Figure 1.2.1 and the suggested frequency indicators.*
>
> *Navy outline indicates preferred terminology. Shading indicates acceptable terminology which is depends on the typical use. For example, in floodplain management 0.5% AEP might be used while in dam design this event would be described as a 1 in 200 AEP.*

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

Figure 1.2.1. Australian Rainfall and Runoff Preferred Terminology

> *As shown in the third column of Figure 1.2.1, the term Annual Exceedance Probability (AEP) expresses the probability of an event being equalled or exceeded in any year in percentage terms, for example, the 1% AEP design flood discharge. There will be situations where the use of percentage probability is not practicable; extreme flood probabilities associated with dam spillways are one example of a situation where percentage probability is not appropriate. In these cases, it is recommended that the probability be expressed as 1 in X AEP where 100/X would be the equivalent percentage probability.*

For events more frequent than 50% AEP, expressing frequency in terms of annual exceedance probability is not meaningful and misleading, as probability is constrained to a maximum value of 1.0 or 100%. Furthermore, where strong seasonality is experienced, a recurrence interval approach would also be misleading. An example of strong seasonality is where the rainfall occurs predominately during the Summer or Winter period and as a consequence flood flows are more likely to occur during that period. Accordingly, when strong seasonality exists, calculating a design flood flow with a 3 month recurrence interval is of limited value as the expectation of the time period between occurrences will not be consistent throughout the year. For example, a flow with the magnitude of a 3 month recurrence interval would be expected to occur or be exceeded 4 times a year; however, in situations where there is strong seasonality in the rainfall, all of the occurrences are likely to occur in the dominant season.

Consequently, events more frequent than 50% AEP should be expressed as X Exceedances per Year (EY). For example, 2 EY is equivalent to a design event with a 6 month recurrence interval when there is no seasonality in flood occurrence.

The terminology adopted herein depends on the edition of Australian Rainfall and Runoff provide the IFD data. In the case of assessments based on ARR1987 the ARI terminology was adopted design floods. In the case of assessments based on ARR2019 the AEP terminology was adopted design floods.

2 Previous Studies

Previous studies include the:

(i) 2006 Penrith Overland Flow Flood "Overview Study"

(ii) 2015 Updated South Creek Flood Study

(iii) 2020 Wianamatta (South) Creek Catchment Flood Study – Existing Conditions

These are overviewed as follows.

2.1 2006 Penrith Overland Flow Flood "Overview Study"

In 2006 a study was undertaken to generate sufficient information to define flood risk and prioritise flood risk management across the Penrith LGA (Cardno Lawson Treloar, 2006). The results from this study provide Council with a sound basis upon which to undertake a program of more detailed overland flood studies. This will ultimately lead to a complete Floodplain Risk Management Plan for the LGA.

The study area covers the LGA and was divided into the following three zones:

- Zone 1 – 'Central Urban'
- Zone 2 – 'Northern Rural'
- Zone 3 – 'Southern Rural'.

The majority of the population resides within Zone 1, which also includes the Penrith CBD.

The primary objectives of the study were to:

- Identify, validate and map all major overland flow paths within the Study Area;
- Identify and map sub catchments for all catchments within the Study Area;
- Identify properties at risk of major overland flooding;
- Define local flood behaviour in the Study Area by producing information on flows, flood levels, depth of flows and velocities for the 20 year, 100 year ARI and the PMF events under existing catchment conditions;
- Assess provisional flood hazard for properties at risk from flooding for the 20 year and 100 year ARI events and the PMF; and
- Rank the nominated sub-catchment areas in terms of severity of flooding for further investigations. Council may also consider landuse, known flood affected areas and cost of potential mitigation works when prioritising the sub-catchments.

The above objectives were achieved through detailed hydrological/hydraulic modelling of the entire LGA described in the report. It is to be noted that ranking of the sub-catchments for further investigation was the main objective of the study and the majority of the other objectives were achieved through the process of establishing the sub-catchment rankings.

The mapped extents of overland flow flooding through the site under existing conditions are given in **Figure 9**. Note the property boundaries are indicative only. It will be noted that the 100 yr ARI flood extent (mainstream flooding) was excluded from the study.

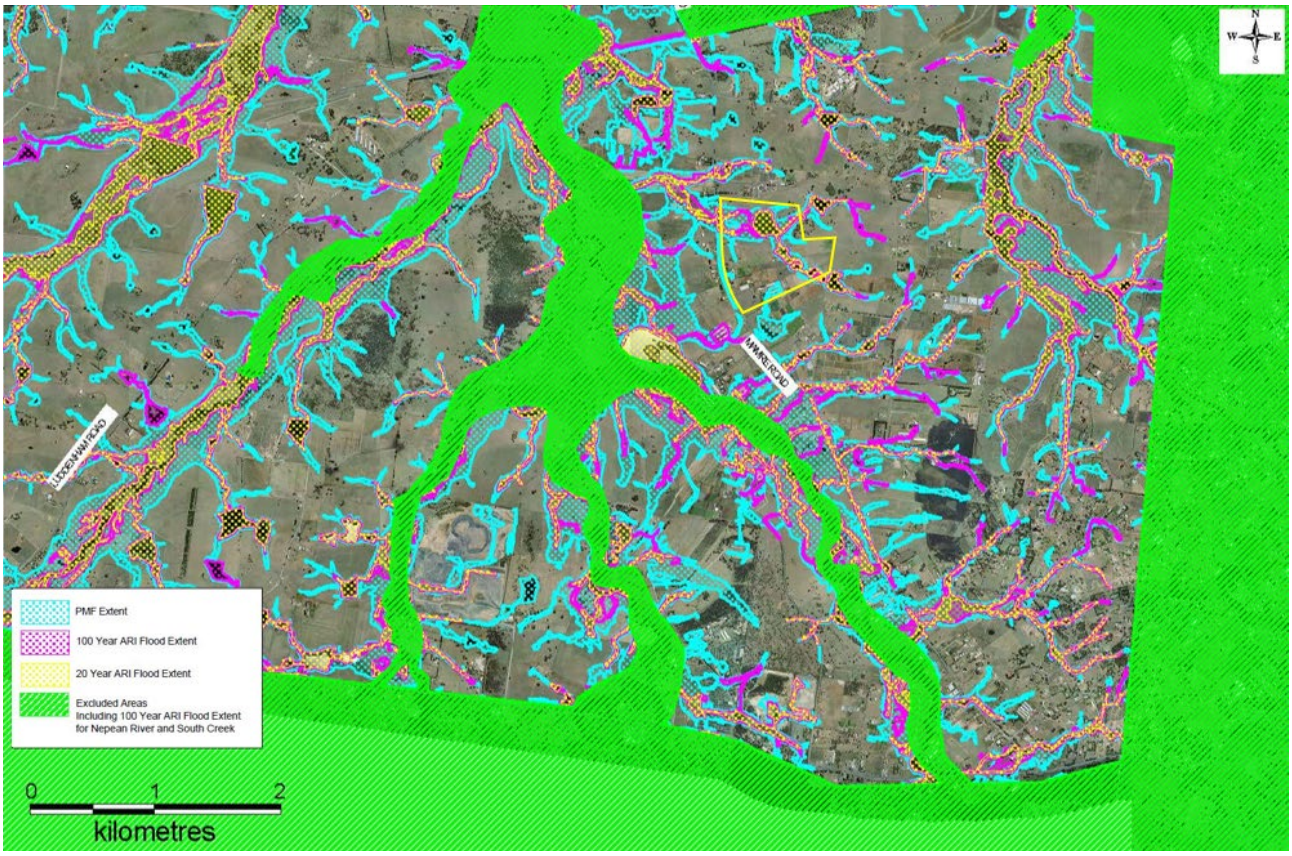


Figure 6 20 yr ARI, 100 yr ARI and PMF Extents for Overland Flow Flooding
(after Figure 6.2 K, Cardno Lawson Treloar (2006))

2.2 2015 Updated South Creek Flood Study

The Updated South Creek Flood Study was prepared by WorleyParsons Services on behalf of Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils. As described by WorleyParsons, 2015:

This flood study covers the South Creek catchment extending from Bringelly Road in the south to the Blacktown/Richmond Road Bridge crossing in the north. The total study area is about 240 km^2 and lies within the Hawkesbury, Penrith, Blacktown, Liverpool and Fairfield LGAs.

The hydrologic modelling for this study is based on the previous RAFTS (Runoff Analysis and Flow Training Simulation) hydrologic modelling (Version 2.56, 1991) that was developed by the Department of Water Resources for the 'South Creek Flood Study' (1990). As part of this study, the RAFTS model of the South Creek catchment has been updated to Version 6.52 (2005) XPRAFTS.

As part of the current study, the sub-catchment delineation and break-up was compared against the latest topographic data available for the study area to determine whether the sub-catchment boundaries required adjustments. Some further refinement of subcatchments was undertaken in order to improve the inter-relationship between the XPRAFTS model and the RMA-2 hydraulic flood model. This improved the interconnectivity between the hydrologic and hydraulic models and made possible the creation of additional localised inflows within the RMA-2 model. ….

The adopted roughness parameters for each sub-catchment were also reviewed against aerial photography in order to determine any changes in vegetation and/or floodplain development that may have occurred since 1990. ….

Intensity-Frequency-Duration (IFD) data was developed for the study catchment according to the standard procedures outlined in Chapter 2 of 'Australian Rainfall & Runoff – A Guide to Flood Estimation' (1987). Due to the significant spatial extent of the study area, across which numerous local catchments and tributaries apply, a total of nine (9) different IFDs were adopted. ….

As no definitive loss rate data is available for the catchment of South Creek and its tributaries, the adopted rainfall loss rates were based on data contained in the 1990 Flood Study. …

The validation of the updated XP-RAFTS model was based on a comparison between the peak discharge and hydrograph shape produced by the RAFTS model developed for the 1990 Flood Study and the results of the latest XP-RAFTS model. ….

In order to undertake validation of the model, the updated XP-RAFTS model was used to simulate the 100 year ARI storm with a critical storm duration of 36 hours. ….

Since completion of the 1990 Flood Study, there have been many changes occur across the South Creek catchment. These changes include the implementation of a number of measures recommended in the South Creek Floodplain Management Study, including works upstream of Elizabeth Drive, at Overett Avenue, and at South St Marys. Major development of the ADI site at St Marys and small areas on the fringe of Erskine Park has also occurred. Changes have also occurred to areas of the floodplain including the construction of levees and earthworks that have the potential to alter flooding patterns. …..

Accordingly, a two-dimensional hydrodynamic model of the South Creek system has been developed using the RMA-2 software package. The model is based on the latest topographic data for the catchment, which was derived from Light Detection and Ranging (LiDAR) data that was gathered for the entire South Creek floodplain between 2002 and 2006. ….

The RMA-2 flood model that has been developed for this study has not been calibrated against historic floods. The Project Brief specified that the model only needed to be validated against predicted peak flood levels generated for the 100 year ARI flood using the MIKE-11 and HEC-2 modelling that was developed for the 1990 Flood Study.

…. The computer models identified in Sections 4 and 5 were used to derive design flood estimates for the 20, 50, 100, 200 and 500 year recurrence floods as well as an Extreme Flood.

The layout and extent of the 2015 South Creek floodplain model is shown in **Figure 7**. As indicated in Figure 7, the proposed development is located in a local catchment which drains to South Creek and is located beyond the extent of the South Creek floodplain model.

The 100 yr ARI flood depths and velocities in South Creek mapped in the 2015 study downstream of the site are plotted in **Figures 8**.

The 100 yr ARI hydraulic categories mapped in the 2015 study downstream of the site are plotted in **Figure 9**.

The PMF depths and velocities mapped in the 2015 study downstream of the site are plotted in **Figure 10.**

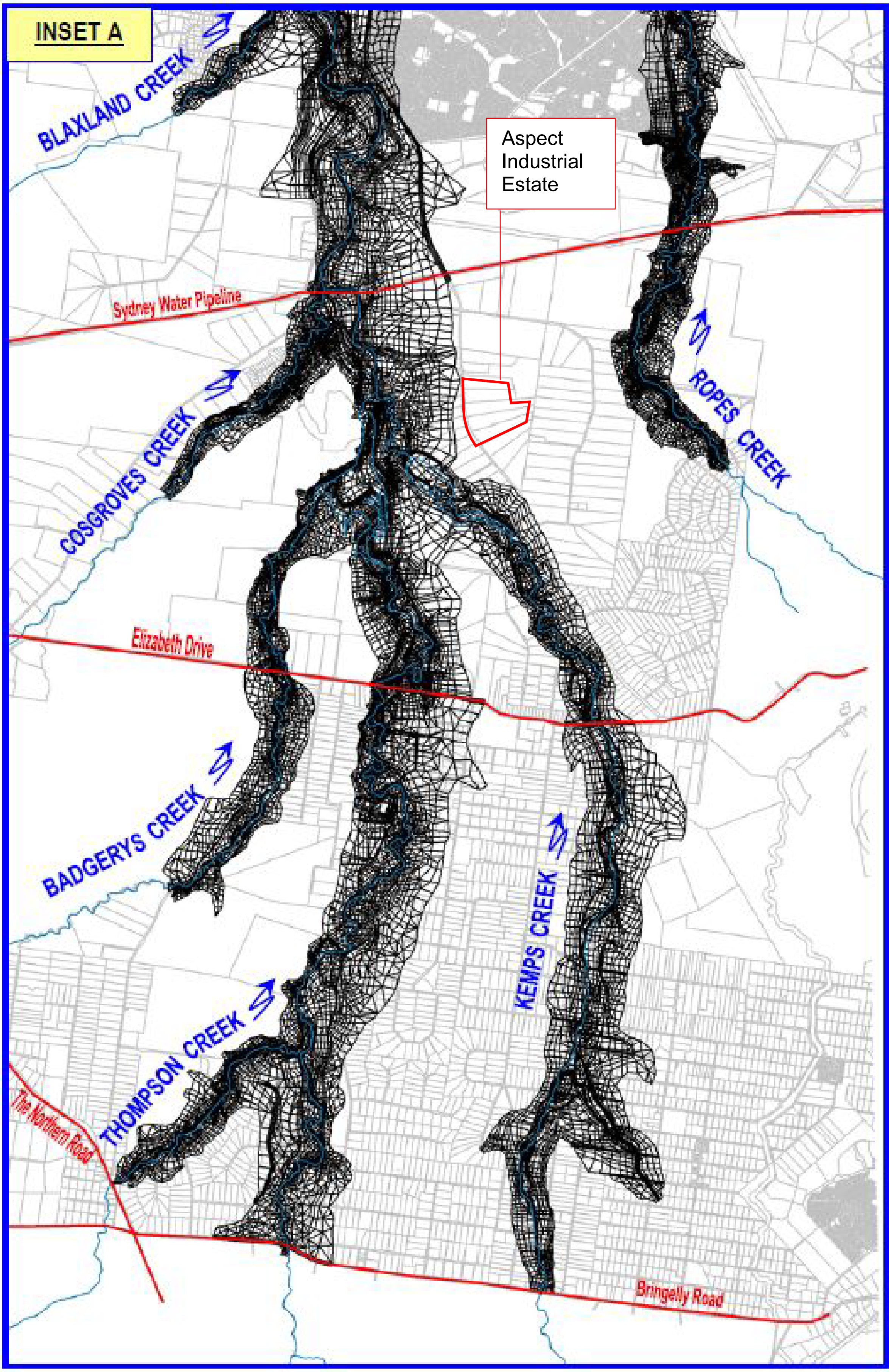


Figure 7 Extent of the RMA-2 Hydraulic Model (after Inset A, Figure 5.1, Worley Parsons, 2015)

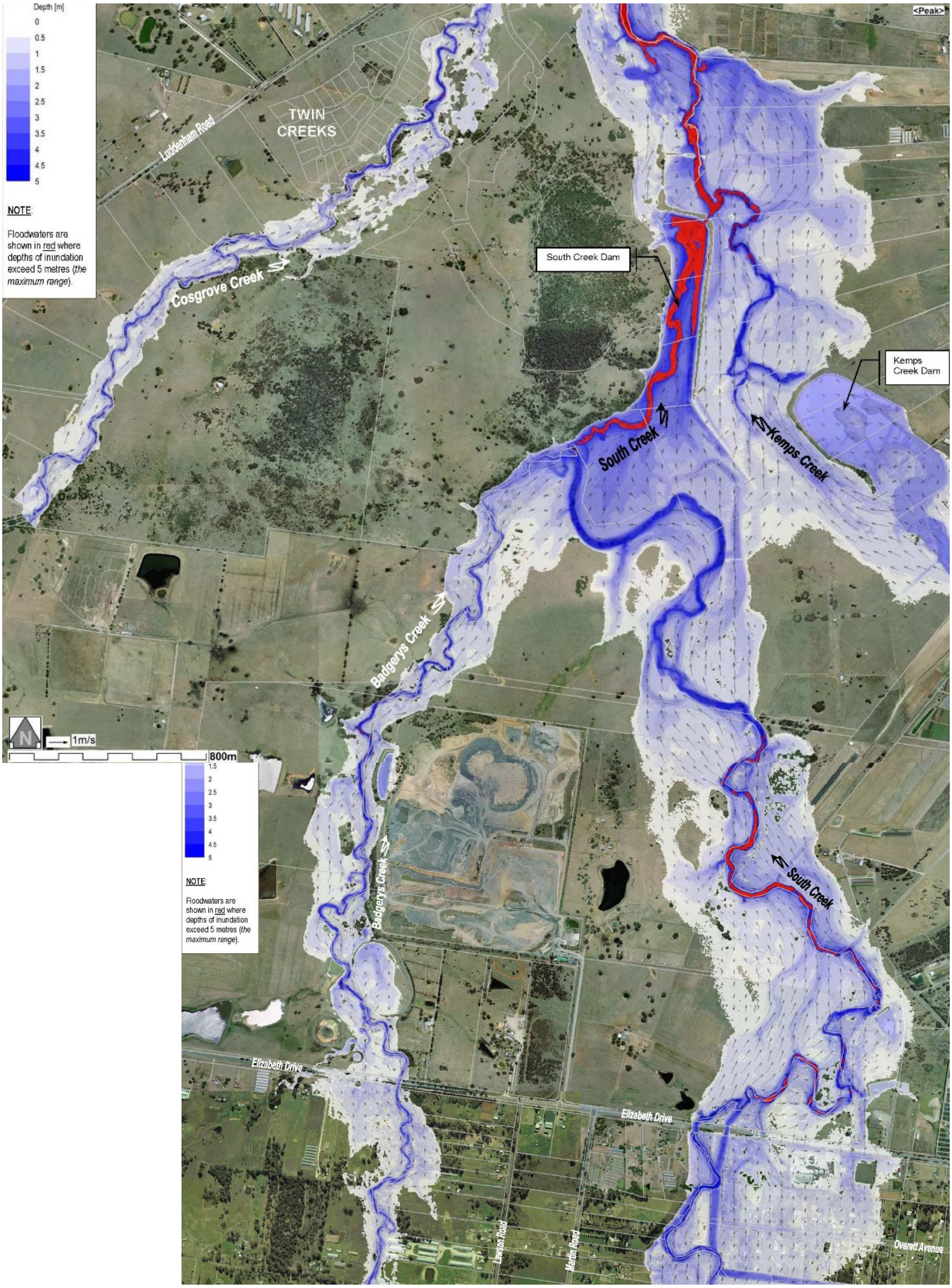


Figure 8 100 yr Flood Depths and Velocities (after Figures 6.109 & 6.110, Worley Parsons, 2015)

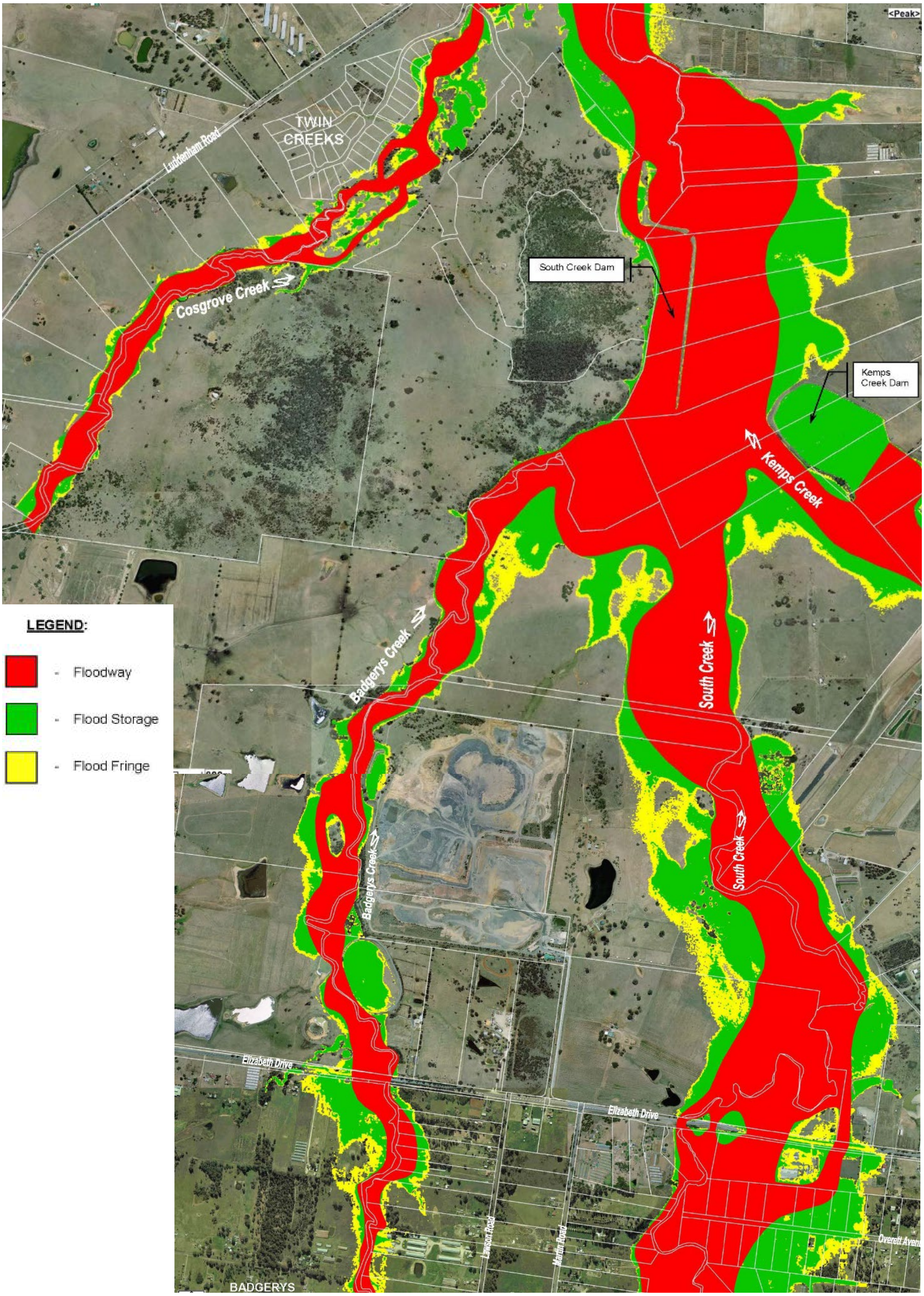


Figure 9 100 yr Hydraulic Categories (after Figures 6.109 & 6.110, Worley Parsons, 2015**)**

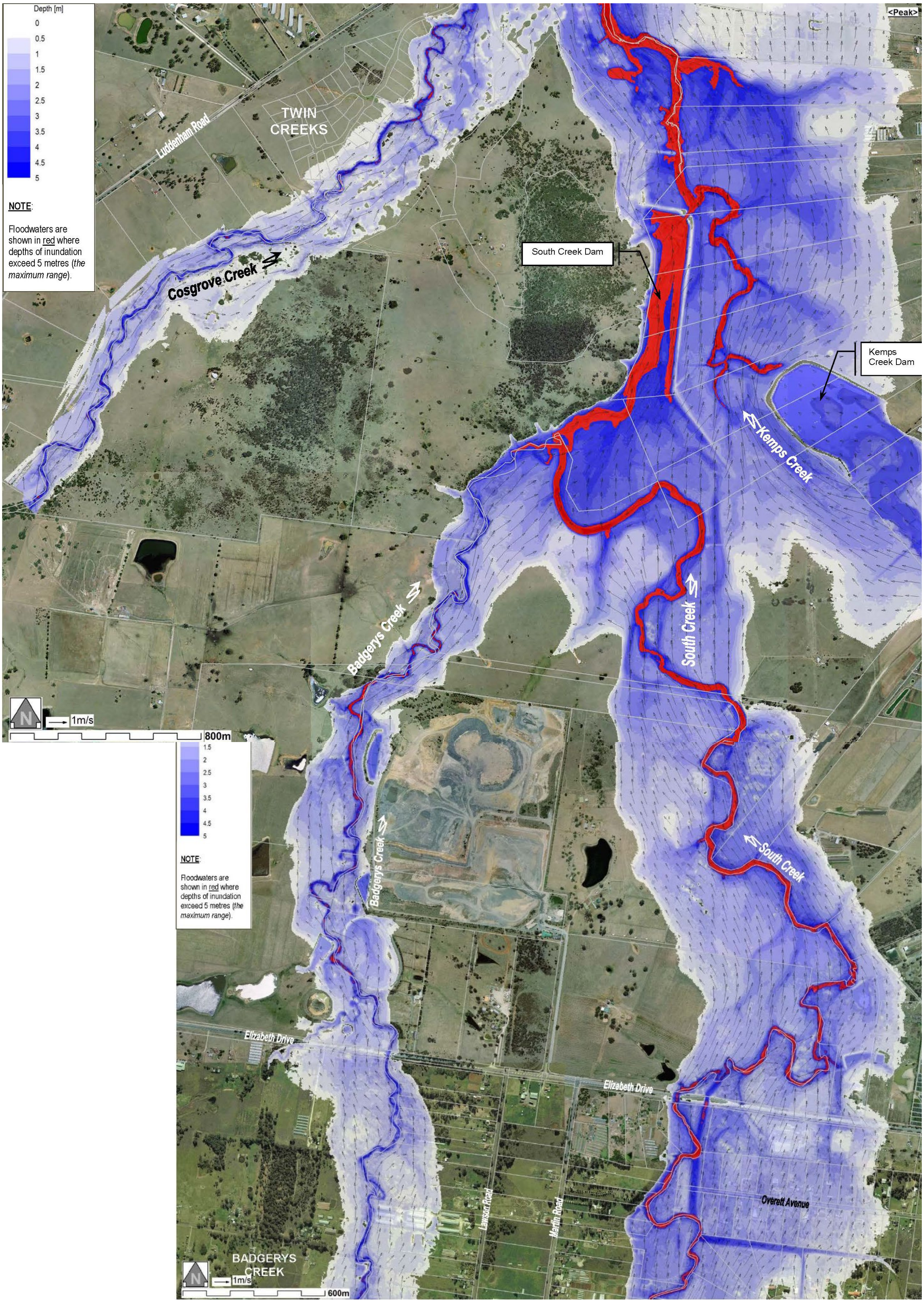


Figure 10 PMF Depths and Velocities (after Figures 6.143 & 6.144, Worley Parsons, 2015)

2.3 2020 Wianamatta (South) Creek Catchment Flood Study – Existing Conditions

As concluded by Advisian, 2020:

> *The RMA-2 hydraulic flood model that was developed for the 'Upper South Creek Flood Study' (2015) has been updated to incorporate the latest available topographic data which has been derived from LiDAR, as well as information from recent flood investigations and recent industrial and urban developments that have occurred in parts of the catchment. This has included extensions to the RMA-2 flood model in the upper reaches of the study area, particularly in the vicinity of Bringelly Road.*
>
> *The XP-RAFTS hydrologic model that was applied as part of the 2015 Flood Study has also been updated. The results of simulations undertaken using the updated XP-RAFTS model indicate that peak flows for the 1% AEP 36 hour critical duration event are similar to those determined as part of the modelling completed for the 2015 Flood Study. Peak flows along South Creek are generally within 2% of the corresponding flows determined in 2015, with a maximum change of up to 8% near the downstream boundary at Richmond Road. Changes along tributaries have greater variability with a maximum change of up to 15% (refer Figure 4.9).*
>
> *The 36 hour storm duration has been confirmed to be critical for the study area generating the largest peak flows along South Creek and at many of the major bridge crossings. Although shorter storm durations such as the 2 and 9 hour storms generate the largest flows along many of the smaller tributaries such as Thompsons, Bonds, Claremont and Werrington creeks (refer Table 4.3), the 36 hour duration is considered most relevant to the study and the assessment of impacts along the length of South Creek.*
>
> *The updated XP-RAFTS hydrologic model was also used to simulate the 1% AEP flood based on ARR 2019 inputs and procedures. Peak flows at the Elizabeth Drive crossing were derived based on both ARR 1987 and ARR 2019 inputs and procedures, and the results were compared to peak flows derived at Elizabeth Drive from Flood Frequency Analysis (FFA). The comparison established that the modelling based on ARR 1987 generated a peak flow for the 1% AEP event that matched more closely (9% lower) to the FFA than was the case based on ARR 2019 (29% lower) (refer Table 4.5). Hence, it was determined that the assessment of flood hydrology for the South Creek catchment should continue to be based on ARR 1987 temporal patterns and Intensity-Frequency-Duration (IFD) data. This is consistent with the 'Updated South Creek Flood Study' (Advisian, 2015).*
>
> *Revised mapping has been prepared for flood levels, depths and hazard for a range of design events. The hydraulic category mapping prepared previously for Penrith City Council as part of the 'South Creek Floodplain Risk Management Study & Plan' (2020) has also been updated according to the revised modelling results. Some differences have been observed between the 2015 and 2020 flood model results for the 1% AEP flood. This is not unexpected given the catchment and floodplain changes associated with recent development and also the incorporation of more detailed topographic data that has led to a significant increase in the number of RMA-2 model nodes; i.e., greater network detail.*
>
> *Detailed inspection of the modelling results has established that the areas where the changes occur and their magnitude are consistent with the expected impact due to the local changes to the floodplain and catchment that have been observed over the last 5 years.*

Accordingly, the updated flood models are considered to suitably represent the contemporary conditions across the South Creek catchment and floodplain. The models are therefore considered to be fit for purpose and appropriate tools for assessing the potential impact of future development scenarios on flood characteristics, including the potential impact of the blue-green grid infrastructure that is proposed as part of the Western Sydney Aerotropolis.

3 Hydrology

Hydrological modelling of the South Creek catchment was undertaken in 2015 at the catchment scale using XP-RAFTS. The hydrological model assembled by WorleyParsons in 2015 was based on ARR1987 IFD. The subcatchment boundaries in the 2015 overall South Creek catchment under Existing Conditions are plotted in **Figure 11**. The local catchment is located within the larger South Creek subcatchment 1.17.

It should be noted that the 2015 study identified the critical storm burst duration for South Creek downstream of Bringelly Road to be 36 hours. While any future development would be expected to have an adverse impact of peak flows in short duration storm bursts it is likely that any future development will have minimal or nil adverse or beneficial impact on peak flows in a 36 hour storm due to the duration of the storm and timing effects due to runoff from impervious areas occurring more rapidly than runoff from pervious areas.

A local hydrological model was created to assess runoff under benchmark conditions and to facilitate the assessment of impacts of proposed development. The subcatchment boundaries and the link-node layout of the local XP-RAFTS model are given in **Figure 12**.

An issue which was considered was whether the airspace in existing farms dams is to be included in the benchmark conditions. An initial assessment was undertaken of the regional significance or otherwise of the farm dams based on criteria formulated in the upper South Creek catchment.

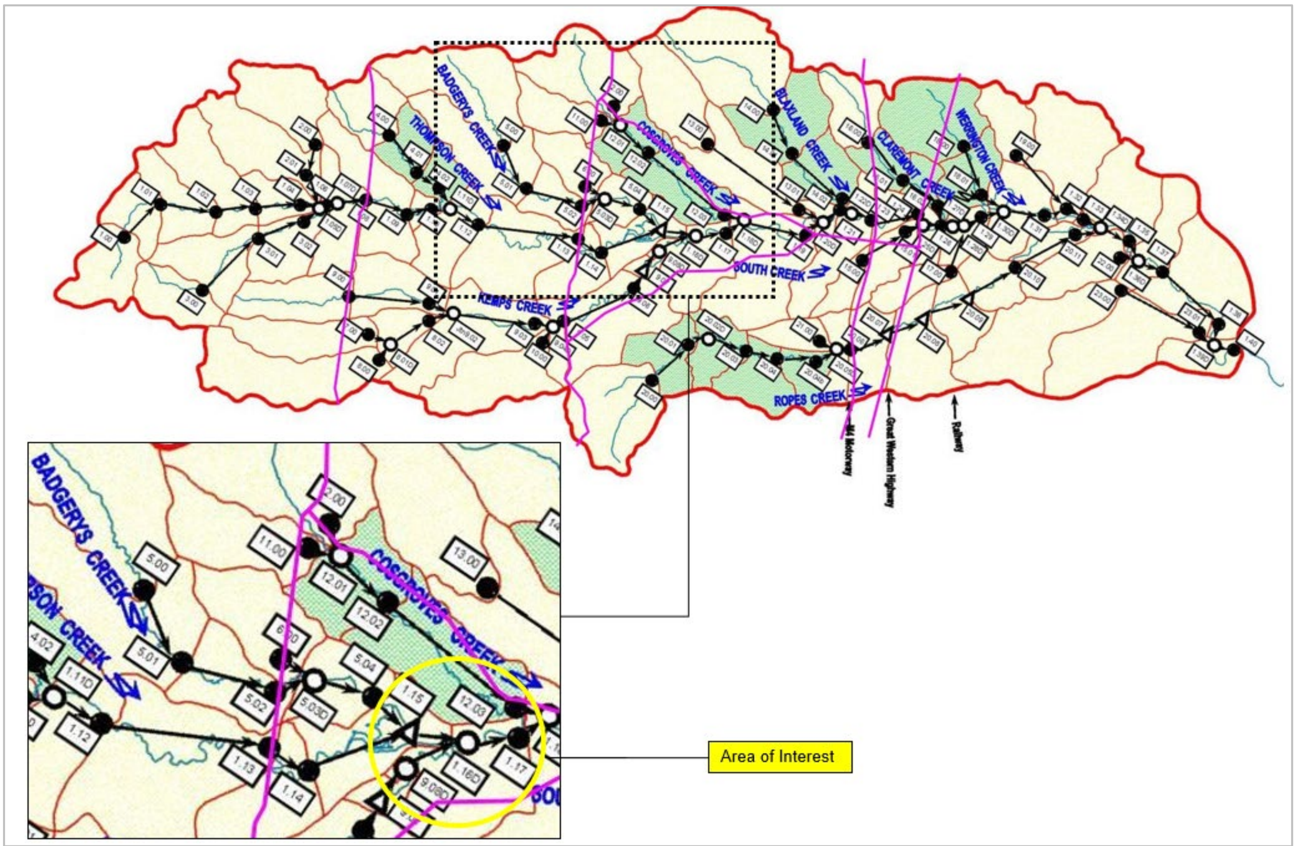


Figure 11 Subcatchment Boundaries in the overall Catchment XP-RAFTS model under Existing Conditions

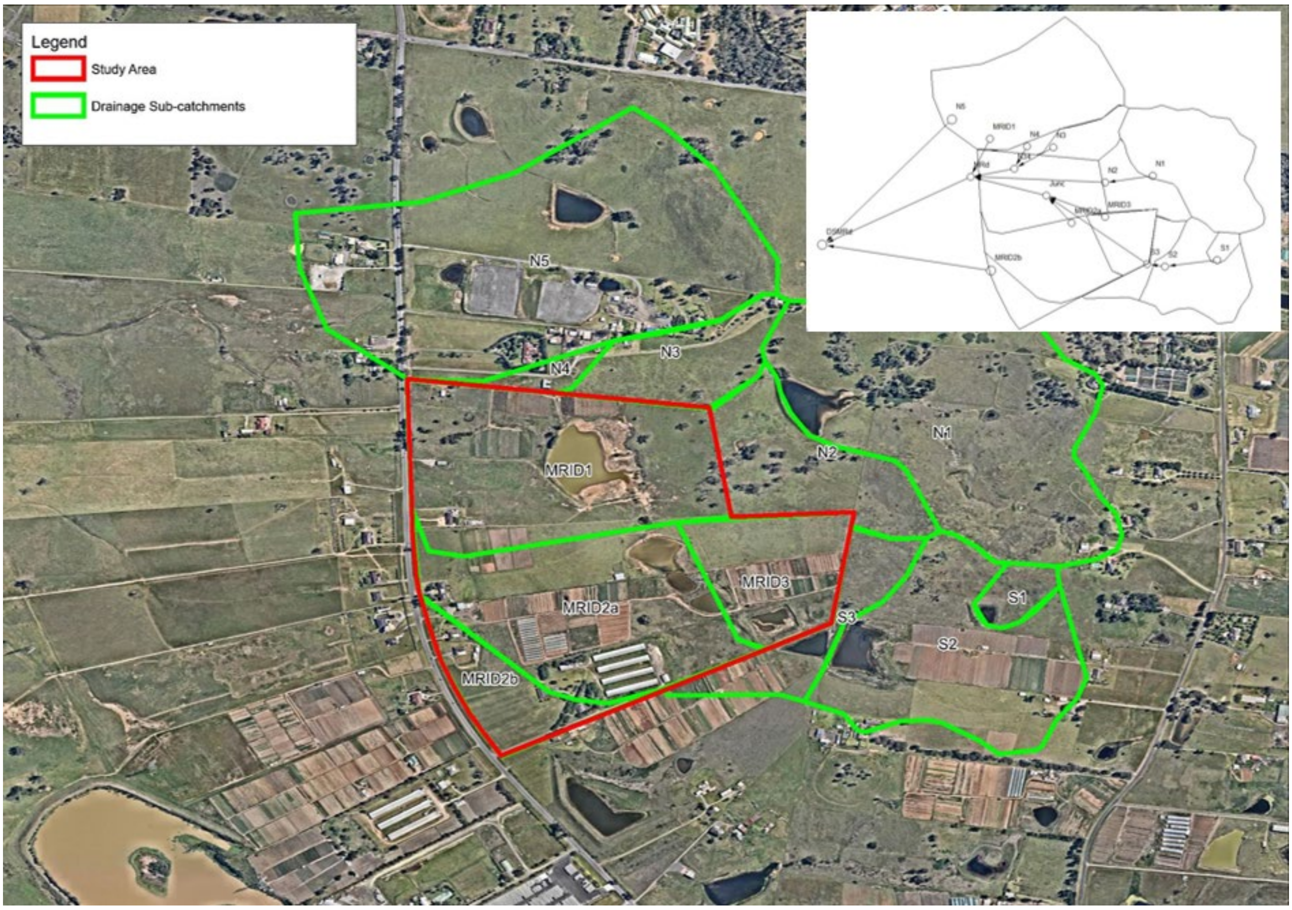


Figure 12 Local Subcatchment Boundaries in AIE XP-RAFTS model under Benchmark Conditions

3.1 Site Inspection

A site inspection was undertaken on 4 November 2019 and assisted in defining the local catchment boundary under current conditions.

3.2 Farm Dams

As outlined in Section 1.4.1, an issue which was considered was whether the airspace in existing farms dams is to be included in the benchmark conditions. An initial assessment was undertaken of the regional significance or otherwise of the farm dams based on criteria formulated in the upper South Creek catchment ((Cardno (NSW/ACT), 2016), as follows.

A feature of the upper South Creek catchment upstream of Bringelly Road is the current operation of seven regional farms dams which have an impact of the flooding experienced on the upper South Creek floodplain. The properties of these dams are given in **Table 1**. The Area Ratio is the Dam Surface Area divided by the Catchment Area.

The objective of the 2016 study was to assess the impact of regional farm dams in the upper South Creek catchment and to inform Camden Council and DPE of the amount of active storage in regional farm dams which should be retained to achieve minimal adverse impact on flood events up to the 1% AEP event at the boundary between the Camden and Liverpool LGAs (ie. downstream of Bringelly Road).

Hydrological and hydraulic modelling was undertaken. Based on these findings, the indicative benchmark criteria for classifying of a farm dam as a regional farm dam whose active flood storage may need to be matched by compensatory flood storage in the event the regional farm dam is removed during development are:

- A catchment area greater than 125 ha;
- A dam surface area to catchment area ratio which exceeds 0.05; and
- Active storage which exceeds 50,000 m^3.

Table 1 Properties of Regional Farm dams in the upper South Creek catchment

Dam	Catchment Area	Dam Surface Area	Airspace used in 1% AEP Flood	Area Ratio
	(ha)	(ha)	(m3)	
A	209	18.06	216,720	0.086
B	376	19.42	213,620	0.052
C	87	35.36	388,960	0.139
D	76	17.46	192,060	0.096
E	461	34.17	410,040	0.074
F	125	6.07	78,897	0.049
G	181	6.16	43,134	0.034

Notes: Outflow from Dam E flows into Dam D
Outflow from Dam D flows into Dam C
Active Storage based on Farm Dams at Full Supply Level at start of 1% AEP flood
Area ratio for Dams D and C based on cumulative areas

The location of farm dams located upstream of Mamre Road is shown in **Figure 13.** It should be noted that the assessment of active storage assumes all farm dams are at full supply level.

The assessment of the combined impact of the farm dams in the Mamre Road local catchment was as follows.

Regional Farm Dams Indicative Criteria	**Metric for Mamre Road Catchment**	**Exceeds Criterion**
A catchment area greater than 125 ha	Catchment area = 129 ha	Just
An area ratio which exceeds 0.05	Surface Area Ratio = 5.31/129 = 0.041	No
Active storage which exceeds 50,000 m3	Combined active storage approx 40,000 m^3	No

It was concluded that:

(i) The combined capacity in 8 farm dams is just under the criterion for classification as a regional farm dam system; and on this basis;
(ii) the farm dams have been ignored when assessing "Benchmark Conditions".

3.3 Initial Sensitivity Assessment

Runoff from a 100 yr ARI storm in the upper South Creek catchment south of Bringelly Road has been assessed previously for 2 hour, 9 hour and 36 hour storm bursts (under ARR1987 IFD and temporal patterns).

A similar assessment of the sensitivity of 100 yr ARI peak runoff to storm burst rainfall losses was undertaken in order to identify the benchmark conditions for this study.

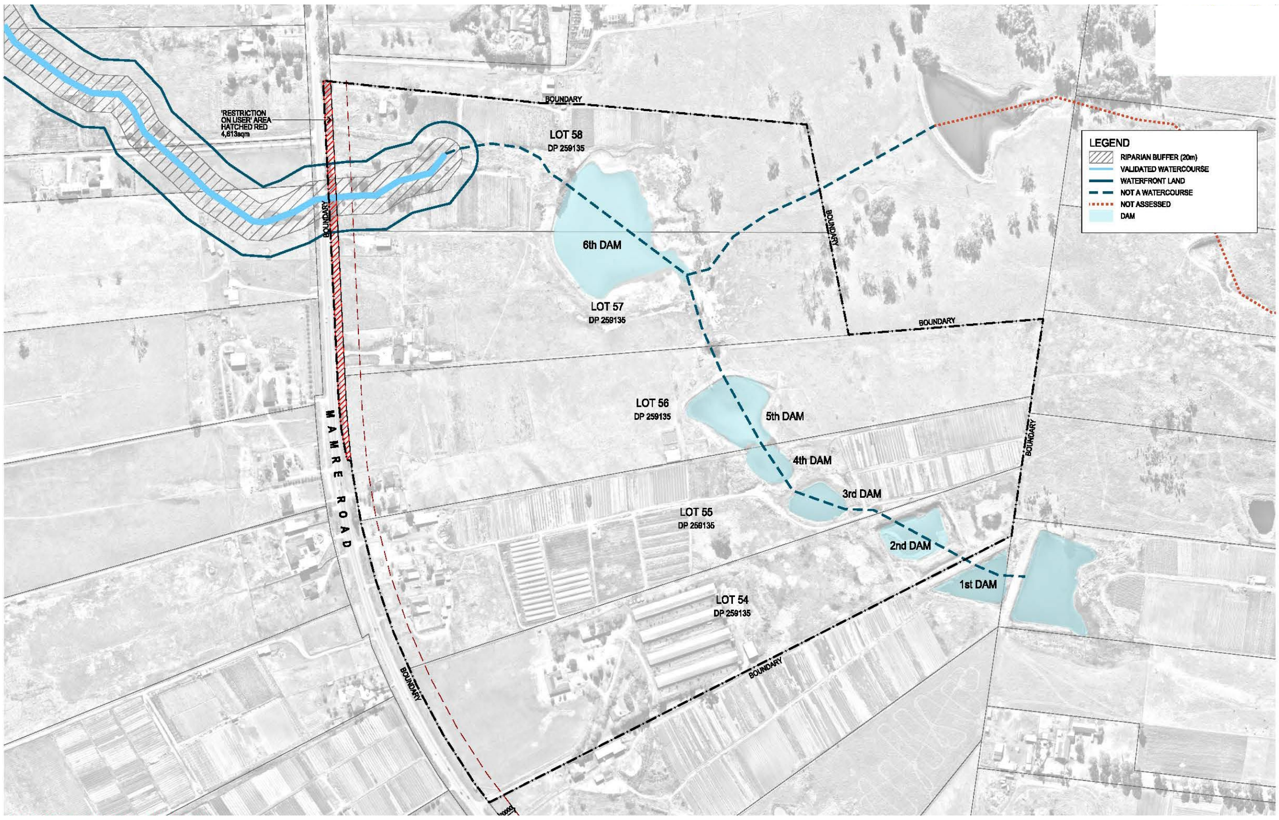


Figure 13 Location of Farm Dams within the Local Catchment

3.3.1 ARR1987

The sensitivity of the adopted pervious area rainfall losses was assessed for two sets of values as follows:

- Initial loss = 37.1 mm and continuing loss = 0.94 mm/h (adopted by Worley Parsons, 2015 in the vicinity of the Mamre Road local catchment); and
- Initial loss = 15 mm and continuing loss = 1.5 mm/h (adopted by WMAwater, 2012 for the Upper South Creek catchment)

The sensitivity of the 100 yr ARI peak flows to the roughness vale and BX value was assessed for two sets of values as follows:

- Roughness value = 0.025 and BX = 1.3 (adopted by Worley Parsons, 2015); and
- Roughness value = 0.04 and BX = 1.0 (guided by the preliminary farm dam assessment by Cardno, 2015 for Upper South Creek catchment)

Attachment B1 summarises the estimated 100 yr ARI peak flows at all nodes for storm burst durations ranging from 30 minutes to 36 hours for Scenarios 1, 2, 3 and 4.

It was noted that

(i) The rainfall losses adopted by Worley Parsons, 2015 give critical storm burst durations that range between 4.5 hours to 12 hours depending on location;

(ii) The rainfall losses adopted by WMAwater, 2012 give critical storm burst durations of 2 hours in almost all locations; and

(iii) The adjustment of BX and pervious roughness values only has a small impact on the estimated peak flows.

It was also noted that the 1% AEP storm burst initial loss and continuing rainfall losses advised by the ARR2019 data hub are around 10 mm and 2.3 mm/h respectively. This suggested that greater weight should be given to the results of Scenarios 2 and 4.

For subsequent ARR1987 assessment purposes the benchmark conditions were based on Scenario 2.

3.3.2 ARR2019

The ARR2019 sensitivity assessments of 1% AEP runoff were based on the following adopted pervious area rainfall:

- Initial burst loss = 10.0 mm (average of 1% AEP burst losses for 1 hour to 3 hour burst storm bursts) and continuing loss = 2.3 mm/h

The sensitivity of the 100 yr ARI peak flows to the roughness vale and BX value was assessed for two sets of values as follows:

- Roughness value = 0.025 and BX = 1.3 (adopted by Worley Parsons, 2015); and
- Roughness value = 0.04 and BX = 1.0 (guided by the preliminary farm dam assessment by Cardno, 2015 for Upper South Creek catchment)

Attachment B1 also summarises the estimated 1% AEP peak flows at all nodes for storm burst durations ranging from 30 minutes to 36 hours for Scenarios 5 and 6.

It is noted that

(i) The rainfall losses and storm temporal patterns obtained from the ARR Data Hub give critical storm burst durations of 0.5 – 0.75 hours in almost all locations under ARR2019;

(ii) The Scenario 5 and 6 peak flows are 10% - 20% higher than the Scenario 2 and 4 peak flows;

(iii) The Scenario 5 and 6 peak flows are 60% - 90% higher than the Scenario 1 and 3 peak flows;

(iv) The adjustment of BX and pervious roughness values only has a small impact on the estimated peak flows.

For subsequent ARR2019 assessment purposes the benchmark conditions were based on Scenario 5.

3.4 Hydrological Modelling

3.4.1 ARR1987 Assessments

A local hydrological model was created to assess runoff under benchmark conditions and to facilitate the assessment of impacts of proposed development. The subcatchment boundaries and the link-node layout of the local XP-RAFTS model are given in **Figure 12**.

Design rainfall and storm burst patterns were obtained from ARR1987 for 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI and 500 yr ARI events.

The PMP depths were generated using the procedures built into XP-RAFTS which estimate PMP depths in accordance with in The Estimation of Probable Maximum Precipitation in Australia: Generalised Short – Duration Method (Bureau of Meteorology, 2003). The PMP depths for the local catchment (which would fall wholly within Ellipse A) were as follows:

Duration (mins)	Ellipse A Depth (mm)	Ellipse A Intensity (mm/h)
15	243	972
30	347	694
45	437	583
60	507	507
90	622	415
120	716	358
180	847	282
240	950	238

For the 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI and 500 yr ARI events the adopted initial rainfall loss = 15 mm and continuing rainfall loss = 1.5 mm/h. For the PMF the adopted rainfall losses were an initial loss = 1 mm and a continuing loss = 0 mm/h.

The results of the ARR1987 hydrological modelling are summarised in **Attachment B2**.

3.4.2 ARR2019 Assessments

Design rainfall and storm burst patterns were obtained from ARR2019 were obtained from the ARR Data Hub for 50%, 20%, 1%, 0.5% and 0.2% AEP events.

For the for 50%, 20%, 1%, 0.5% and 0.2% AEP events the adopted initial burst rainfall loss (IL) varied while a constant continuing rainfall loss (CL) = 2.3 mm/h was adopted. The adopted average initial burst losses were as follows.

AEP	Burst IL (mm)	CL (mm/h)
50%	28.5	2.3
20%	16	2.3
10%	14	2.3
5%	13.5	2.3
2%	12	2.3
1%	10	2.3
0.5%	10	2.3
0.2%	10	2.3
PMF	1	0

The results of the ARR2019 hydrological modelling are summarised in **Attachment B3**.

3.4.3 Comparisons

The peak flows estimated at the Mamre Road crossing for the various events are summarised in **Table 2**.

Table 2 Summary of Estimated Peak Flows at Mamre Road Crossing

ARR1987 Hydrology			ARR2019 Hydrology		
ARI (yrs)	Peak Flow (m3/s)	Critical Duration (hrs)	AEP	Peak Flow (m3/s)	Critical Duration (hrs)
2	6.31	9	50%	3.23	6
5	9.09	4.5	20%	7.73	2
100	21.0	2	1%	23.3	0.75
200	24.4	2	0.50%	26.2	0.75
500	29.2	2	0.20%	30.9	0.75
PMF	233	0.75	PMF	233	0.75

It should be noted, as discussed in Section 1.5, that 2 yr ARI equates to 39% AEP while 5 yr ARI equates to 18% AEP.

It was also noted that the

- Critical storm burst durations for ARR2019 storm burst are all shorter than the critical storm burst durations for ARR1987 storm burst;
- The 1% AEP peak flow at Mamre Road is around 11% higher than the estimated 100 yr ARI peak flow at Mamre Road.

It was also of interest to compare the estimated peak flows at Mamre Road with the estimated peak flows in South Creek in the vicinity of the local catchment at Node 1.17 (refer Figure 10). The estimated peak flows at Node 1.17 are summarised in **Table 3**.

Table 3 Summary of Estimated Peak Flows in South Creek at Node 1.17

	Storm Burst			
Event	2 hr	9 hr	36 hr	
2 yr ARI	13.6	151	305	ARR1987 - Worley Parsons, 2015 Model
100 yr ARI	360	774	956	ARR1987 - Worley Parsons, 2015 Model
1% AEP	558	727	563	ARR2019 - Modified WorleyParsons, 2015 Model

The indicativeARR2019 peak flows were obtained by modifying the 2015 Worley Parsons model by adopting a global storm (not catchment dependent storms) and a uniform initial burst loss (refer Section 3.4.2) across the catchment. An areal reduction factor was not applied to the rainfall intensities obtained from the ARR Data Hub.

It was noted that the indicative peak flow under ARR2019 is lower than estimated under ARR1987 and the critical storm burst duration reduces from 36 hours to 9 hours.

4 Flooding Assessment

A local TUFLOW model of the drainage lines through the site was assembled. The Digital Elevation Model (DEM) was created by combining detailed survey and ALS data external to the site. Based on the assessment of the combined impact of the farm dams in the Mamre Road local catchment discussed in Section 3.1, the farm dams were removed from the DEM by interpolating the terrain through each of the farm dams.

The roughness zones for the floodplain are mapped in **Figure 14**.

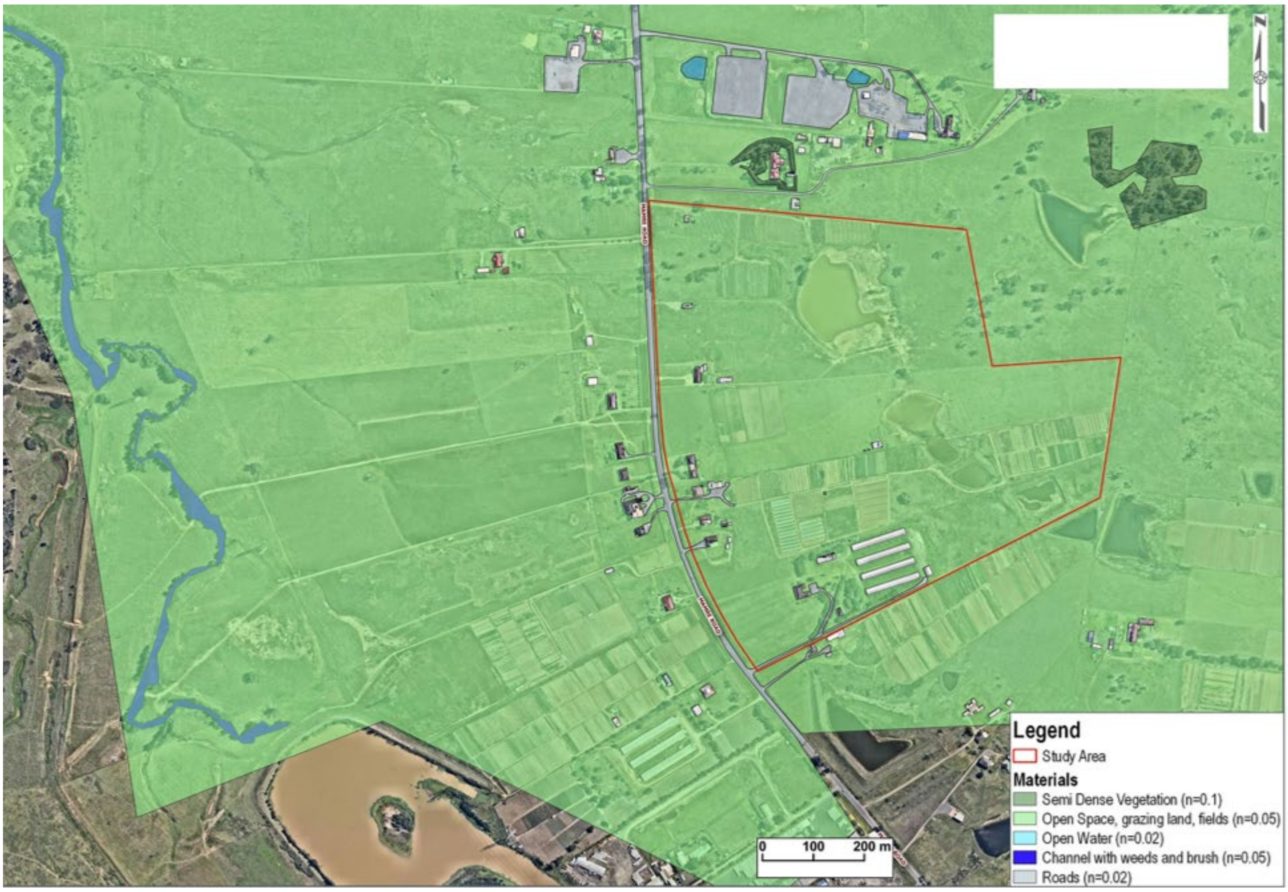


Figure 14 Adopted Roughness Zones under Benchmark Conditions

From the detailed survey it was determined that the crossing under Mamre Road is 3 x 1.85 m x 0.77 m culverts. For assessment purposes it was assumed that this crossing would be partially blocked and that only two of the three culverts would convey floodwaters.

Inflows to the TUFLOW model were exported from the hydrological model and input at the locations of the subcatchment outlets (nodes). For assessment purposes, the Scenario 2 conditions were adopted to maintain compatibility with the 2015 South Creek flooding assessments which were based on ARR1987. A review of the vertical alignment of Mamre Road beside Subcatchment MRID2b disclosed that Mamre Road has a local crest located around 95 m north of the southwest corner of the subject property. Consequently, runoff from Subcatchment MRID2b was partitioned 50:50 based on contributing subcatchment areas with 50% of the runoff input at the northern limit of Subcatchment MRID2b and 50% input at the southwest corner of the subject property.

The downstream boundary condition was a fee outfall. The flood extent in South Creek was overlaid over the results of the local TUFLOW model to identify where mainstream flooding takes over from overland flows.

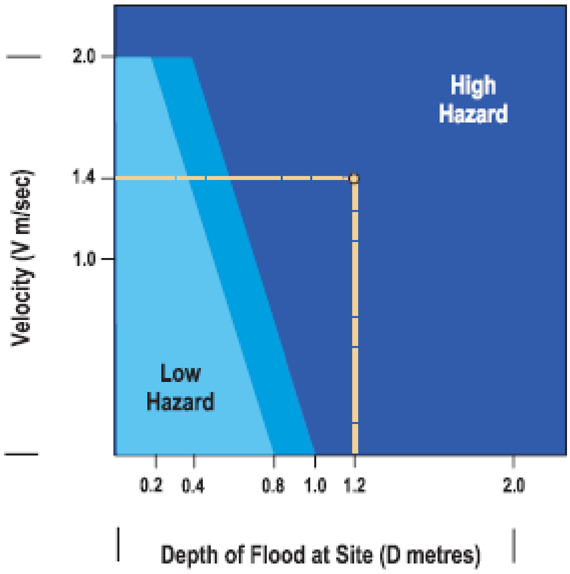
4.1 Benchmark Conditions

The TUFLOW floodplain model was run for the critical storm burst durations for the 2 yr ARI, 5 yr ARI, 100 yr ARI, 200 yr ARI, 500 yr ARI and PMF events.

4.1.1 2 yr ARI

The estimated 2 year ARI flood levels and extent, depths and velocities under Benchmark Conditions are plotted in **Figures E1, E2** and **E3** respectively.

Experience from studies of floods throughout NSW and elsewhere has allowed authorities to develop methods of assessing the hazard to life and property on floodplains. This experience has been used in developing the NSW Floodplain Development Manual to provide guidelines for managing this hazard. These guidelines are shown schematically below.



Provisional Hazard Categories (after Figure L2, NSW Government, 2005)

To use the diagram, it is necessary to know the average depth and velocity of floodwaters at a given location. If the product of depth and velocity exceeds a critical value (as shown below), the flood flow will create a high hazard to life and property.

There will probably be danger to persons caught in the floodwaters, and possible structural damage. Evacuation of persons would be difficult. By contrast, in low hazard areas people and their possessions can be evacuated safely by trucks. Between the two categories a transition zone is defined in which the degree of hazard is dependent on site conditions and the nature of the proposed development.

This calculation leads to a provisional hazard rating. The provisional hazard rating may be modified by consideration of effective flood warning times, the rate of rise of floodwaters, duration of flooding and ease or otherwise of evacuation in times of flood. The estimated 2 year ARI provisional flood hazard under Benchmark Conditions are plotted in **Figure E4**.

4.1.2 5 yr ARI

The estimated 5 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted respectively in **Figures E5, E6, E7** and **E8**.

4.1.3 100 yr ARI

The estimated 100 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted respectively in **Figures E9, E10, E11** and **E12**.

4.1.4 200 yr ARI

The estimated 200 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted respectively in **Figures E13, E14, E15** and **E16.**

4.1.5 500 yr ARI

The estimated 500 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted respectively in **Figures E17, E18, E19** and **E20**.

4.1.6 PMF

The estimated PMF flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted respectively in **Figures E21, E22, E23** and **E24**.

5 References

Advisian Pty Ltd (2020) Wianamatta (South) Creek Catchment Flood Study – Existing Conditions – Report, November, https://flooddata.ses.nsw.gov.au/related-dataset/wianamatta-south-creek-catchment-flood-study-existing- conditions-main-report

Cardno (NSW/ACT). (2016) "Discussion Paper on Flooding Impact of Regional Farm Dams in the Upper South Creek Catchment", *Internal Report*, prepared for Camden Council, September, 26 pp + Attachments

Cardno Lawson Treloar (2006) "Penrith Overland Flow Flood "Overview Study", *Report J2453/R2251*, Version 4, prepared for Penrith City Council, August

Jacobs (2016) "Appendix H Flooding Analysis", *Western Sydney Airport Gateway, Badgerys Creek: Planning Proposal Submission*, prepared for the University of Sydney by Jacobs Group (Australia) Pty Ltd, Revision 5, 21 October 2016

NSW Government (2005*). Floodplain Development Manual, The management of flood liable land*, April, 29 pp + Apps

Sydney Water (2020) "Mamre Road Flood, Riparian Corridor and Integrated Water Cycle Management Strategy", *Final Report*, October, 61 pp + Apps

WMAwater (2012) "Upper South Creek Flood Study", *Final Report 2011 Revision 1*, prepared for Camden Council, May, 39 pp + Apps.

WorleyParsons (2015) "Updated South Creek Flood Study", *Final Report*, 2 Vols, prepared for Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils, 74 pp + Apps.

APPENDIX A
FIGURES

now

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
2 Year ARI
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

FIGURE E1

1:7,500 **Scale at A3**

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
2 Year ARI
Flood Depths

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

FIGURE E2

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
2 Year ARI
Flood Velocities

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE E3

1:7,500 Scale at A3

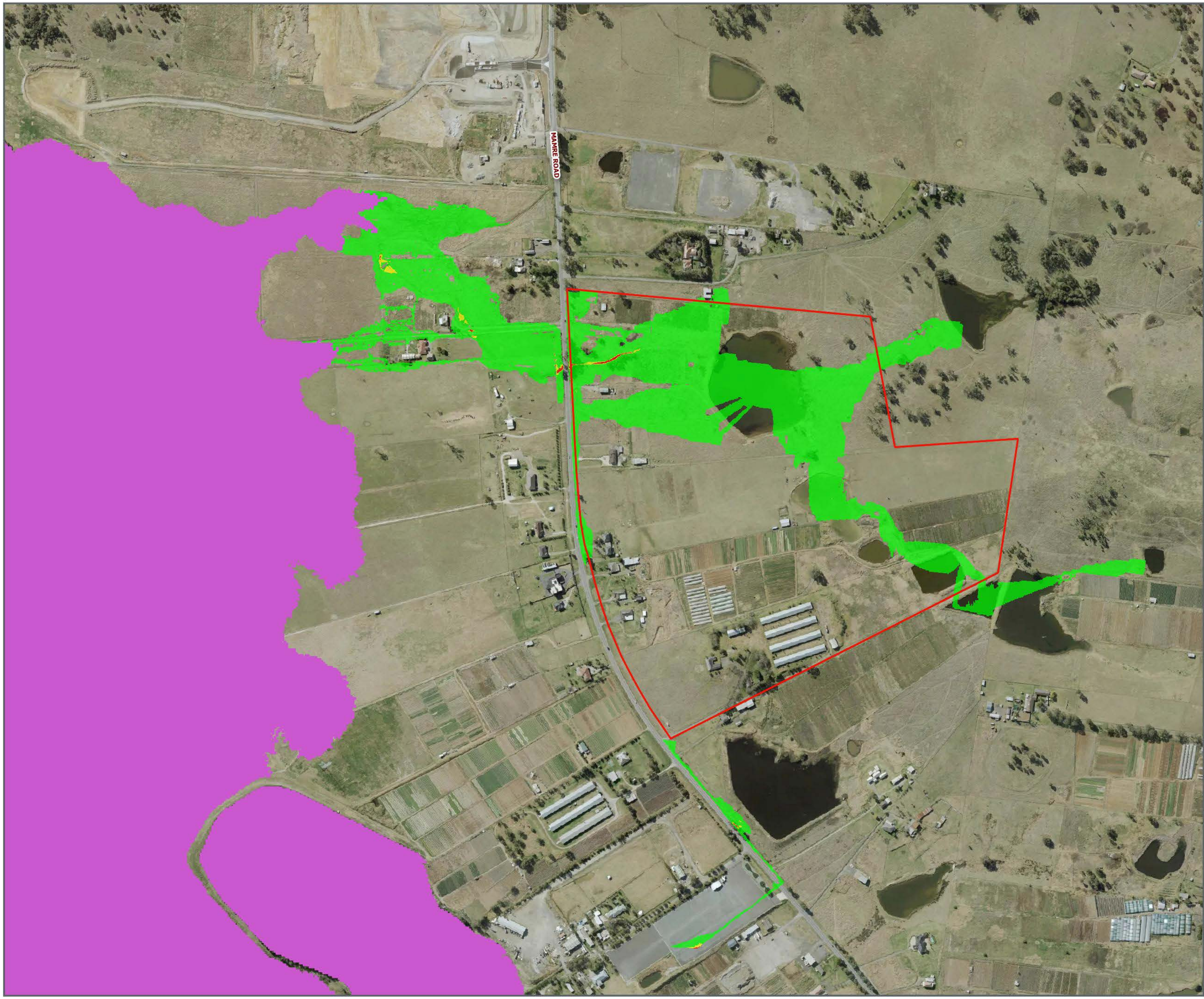
0 80 160 240 320 400 m

N

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
2 Year ARI
Flood Hazard



Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E4

1:7,500 **Scale at A3**

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
5 Year ARI
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

FIGURE E5

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
5 Year ARI
Flood Depths

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

FIGURE E6

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
5 Year ARI
Flood Velocities

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

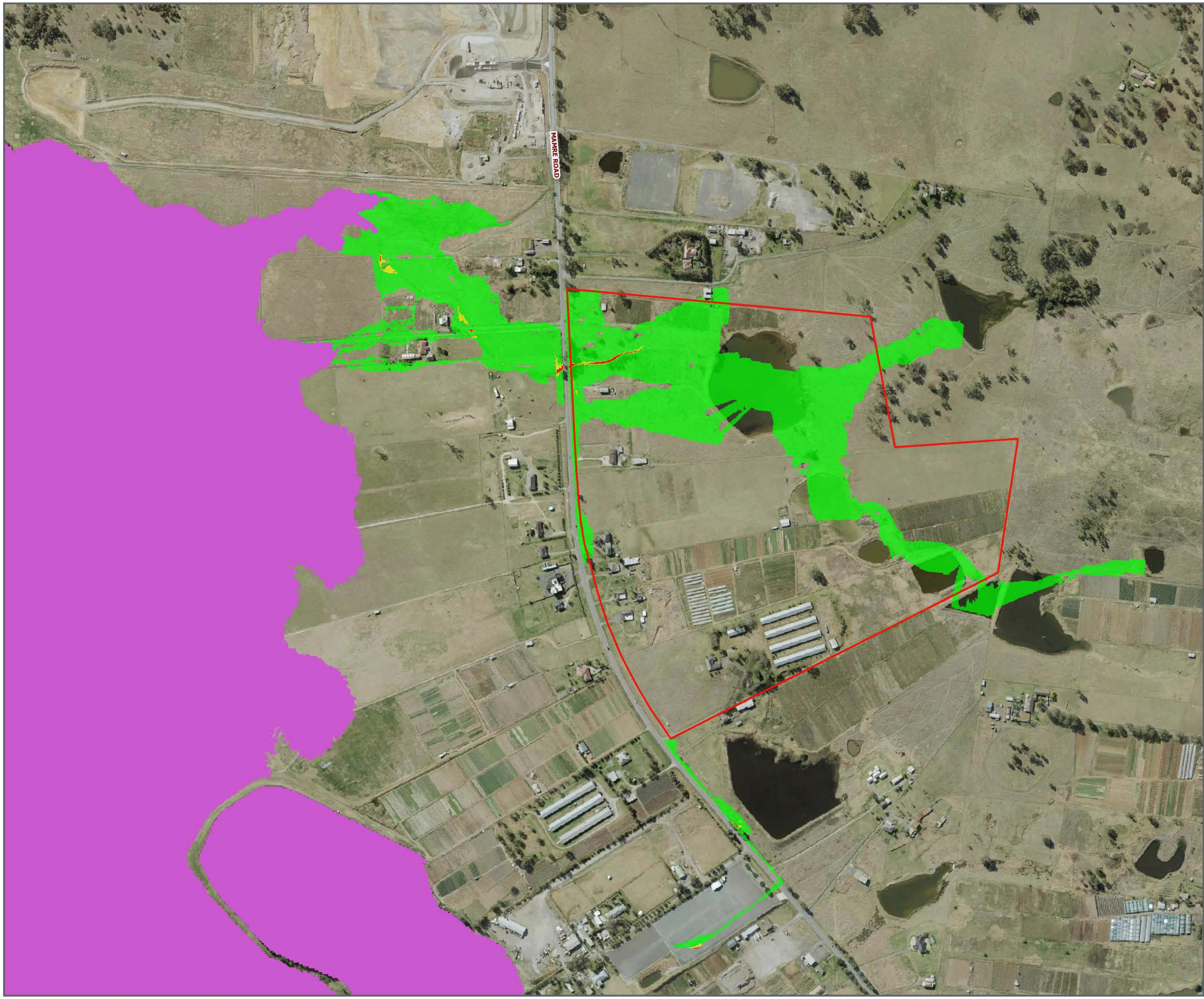
FIGURE E7

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
5 Year ARI
Flood Hazard

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E8

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
100 Year ARI
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

FIGURE E9

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
100 Year ARI
Flood Depths

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

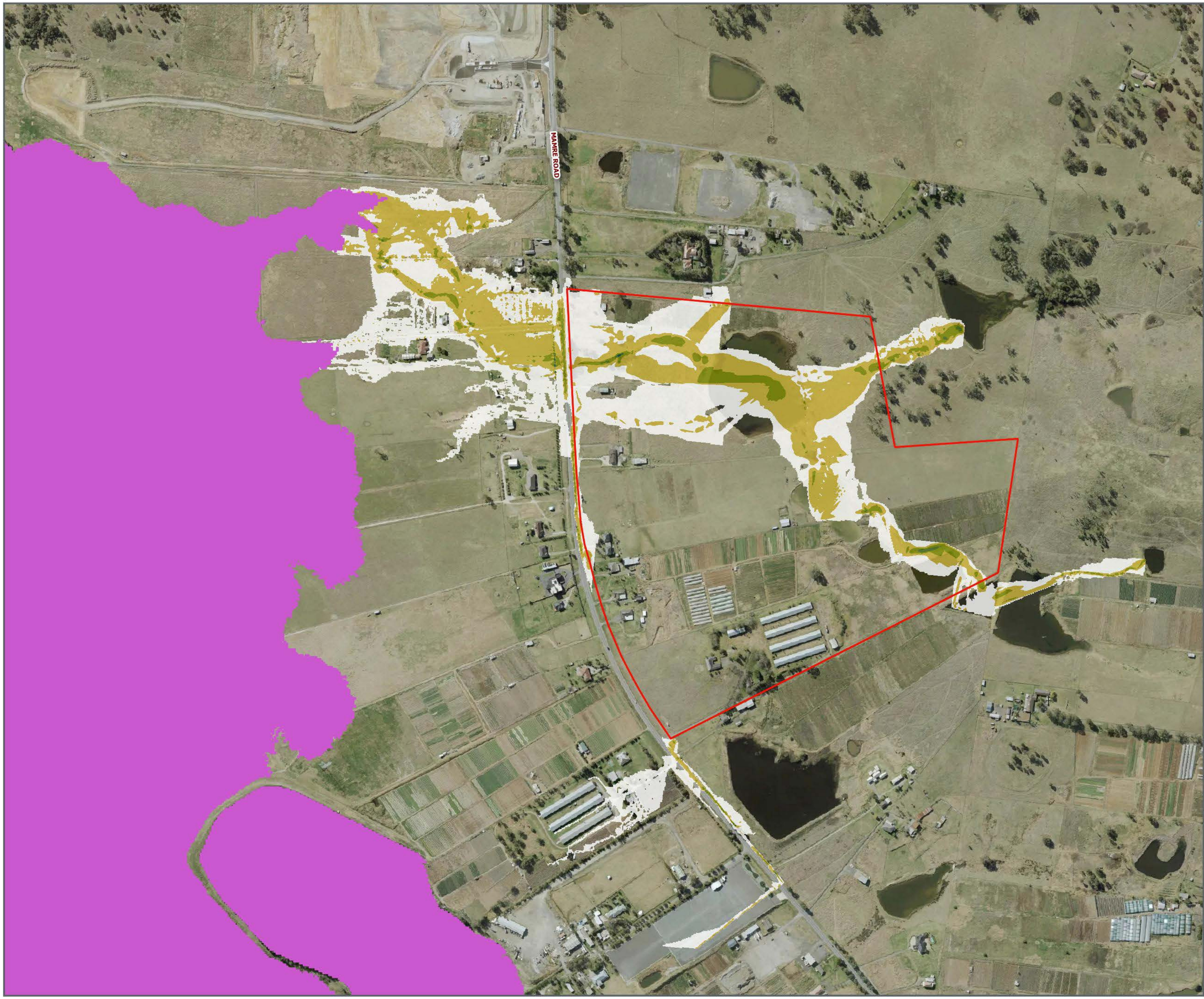
FIGURE E10

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
100 Year ARI
Flood Velocities

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Velocity (m/s)

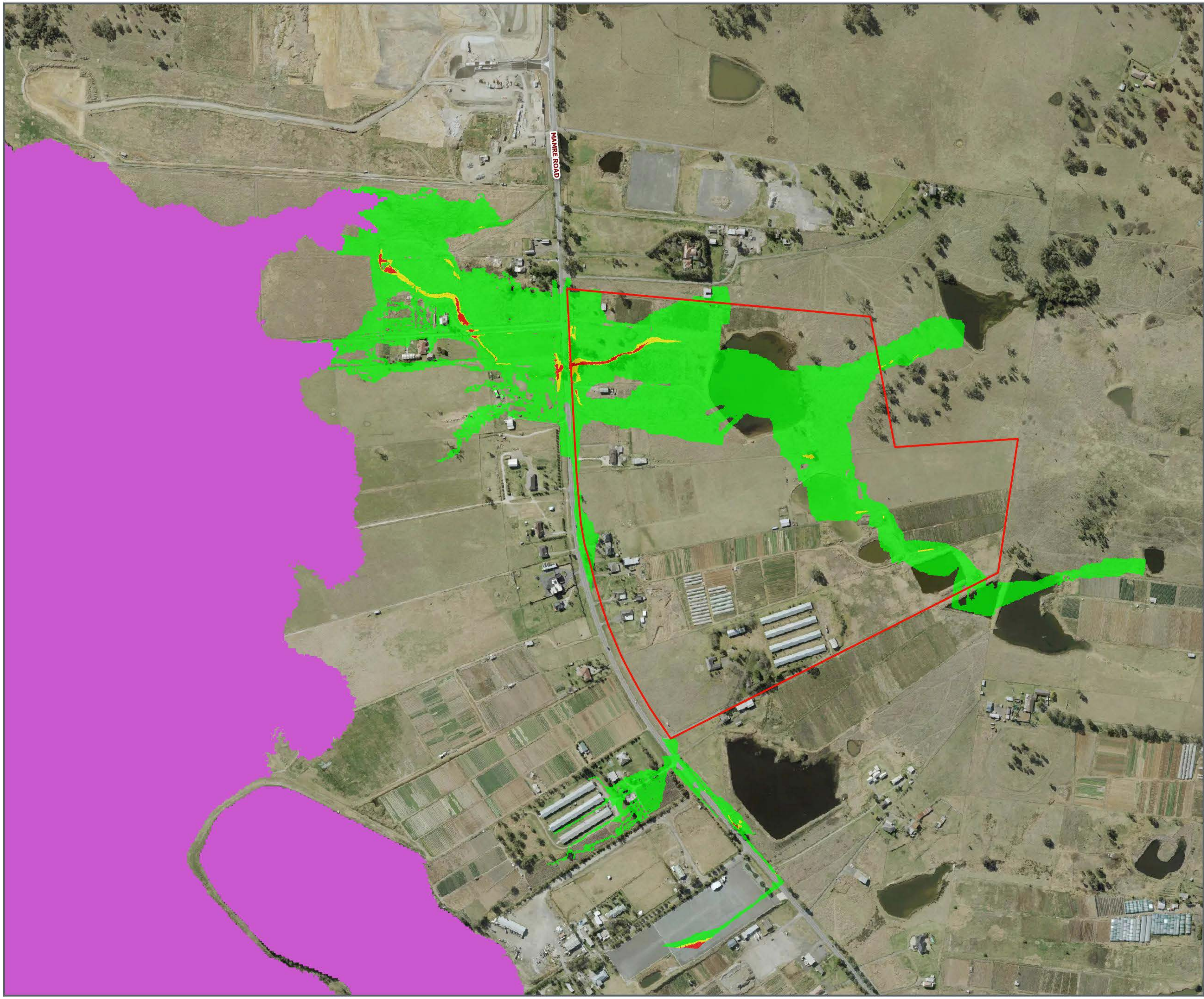
- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE E11

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
100 Year ARI
Flood Hazard

Legend

- South Creek Flood Study (2015) 100yr ARI Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E12

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
200 Year ARI
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) 200yr ARI Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

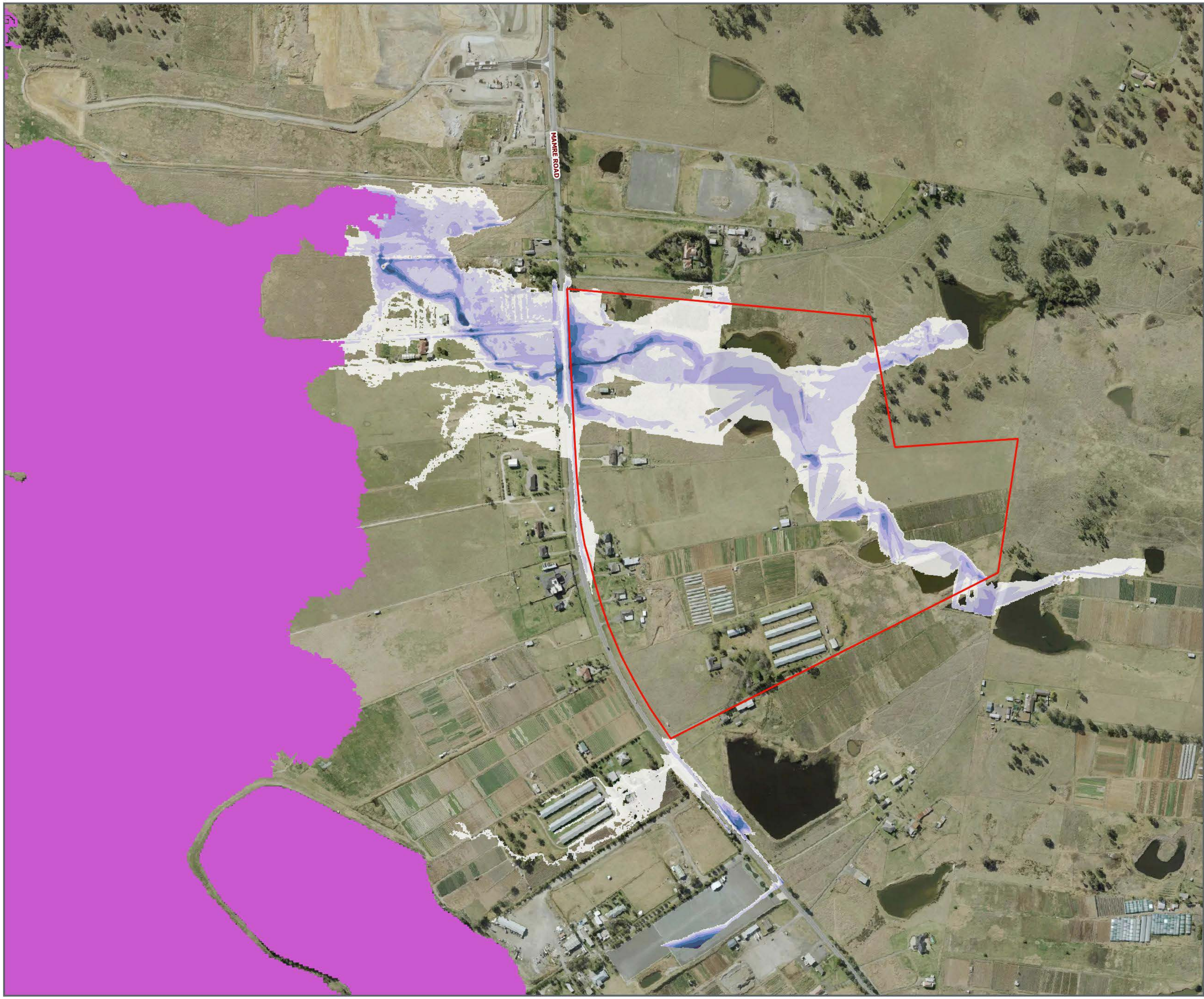
FIGURE E13

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
200 Year ARI
Flood Depths

Legend

- South Creek Flood Study (2015) 200yr ARI Flood Extent
- Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

FIGURE E14

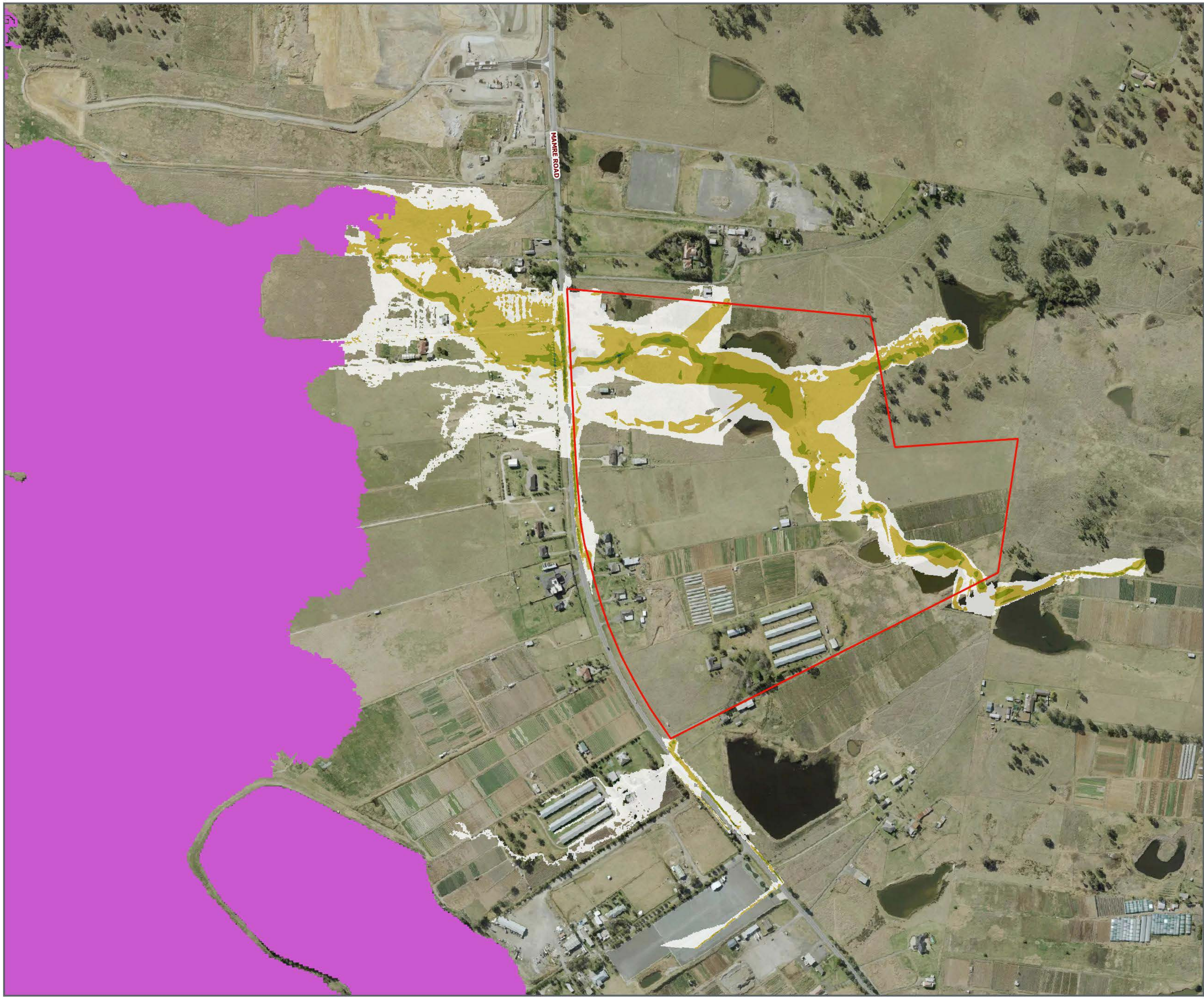
1:7,500 Scale at A3

0 80 160 240 320 400 m

N

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
200 Year ARI
Flood Velocities

Legend

- South Creek Flood Study (2015) 200yr ARI Flood Extent
- Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

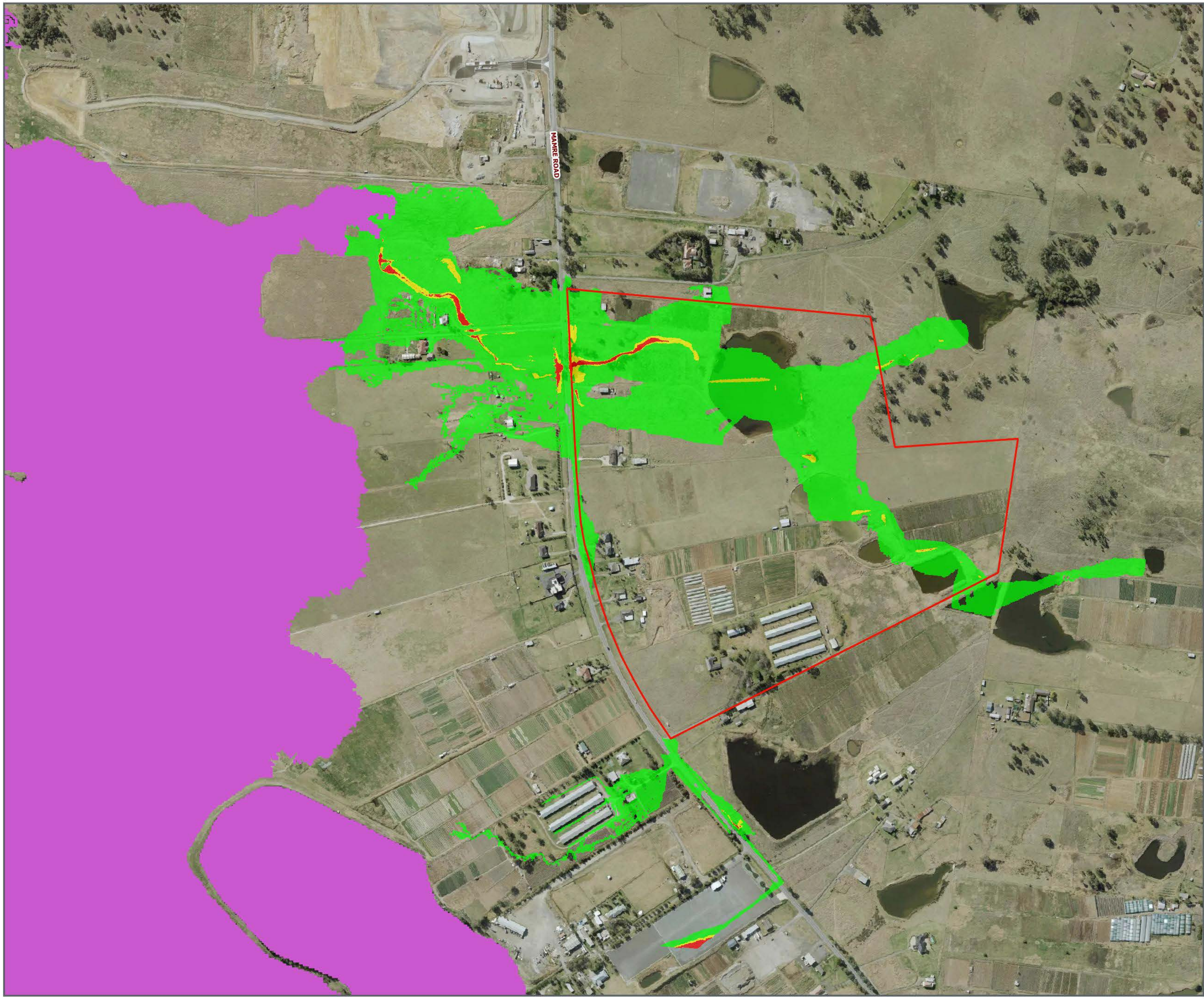
FIGURE E15

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
200 Year ARI
Flood Hazard

Legend

- South Creek Flood Study (2015) 200yr ARI Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E16

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
500 Year ARI
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) 500yr ARI Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

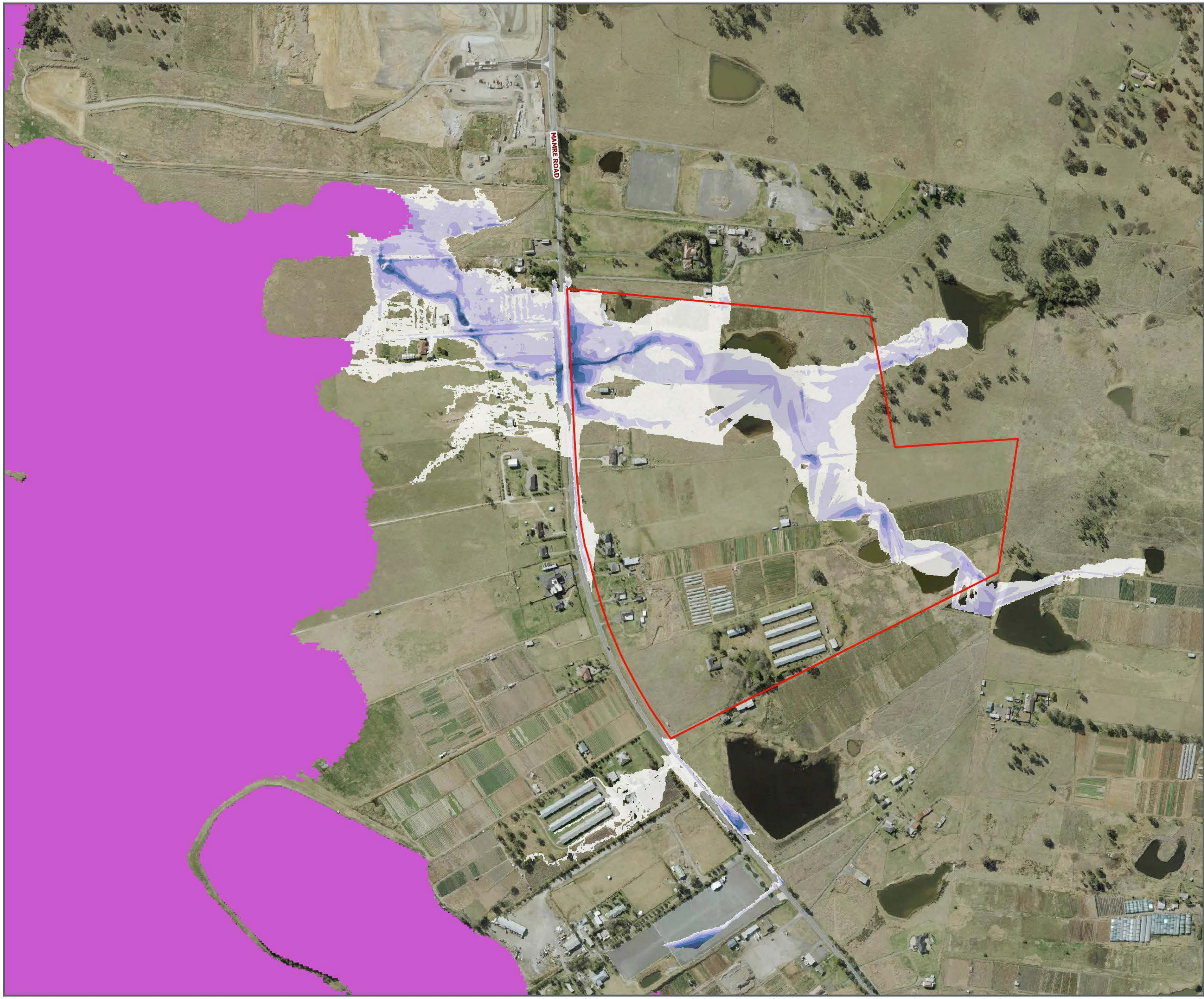
FIGURE E17

1:7,500 **Scale at A3**

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
500 Year ARI
Flood Depths

Legend

- South Creek Flood Study (2015) 500yr ARI Flood Extent
- Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

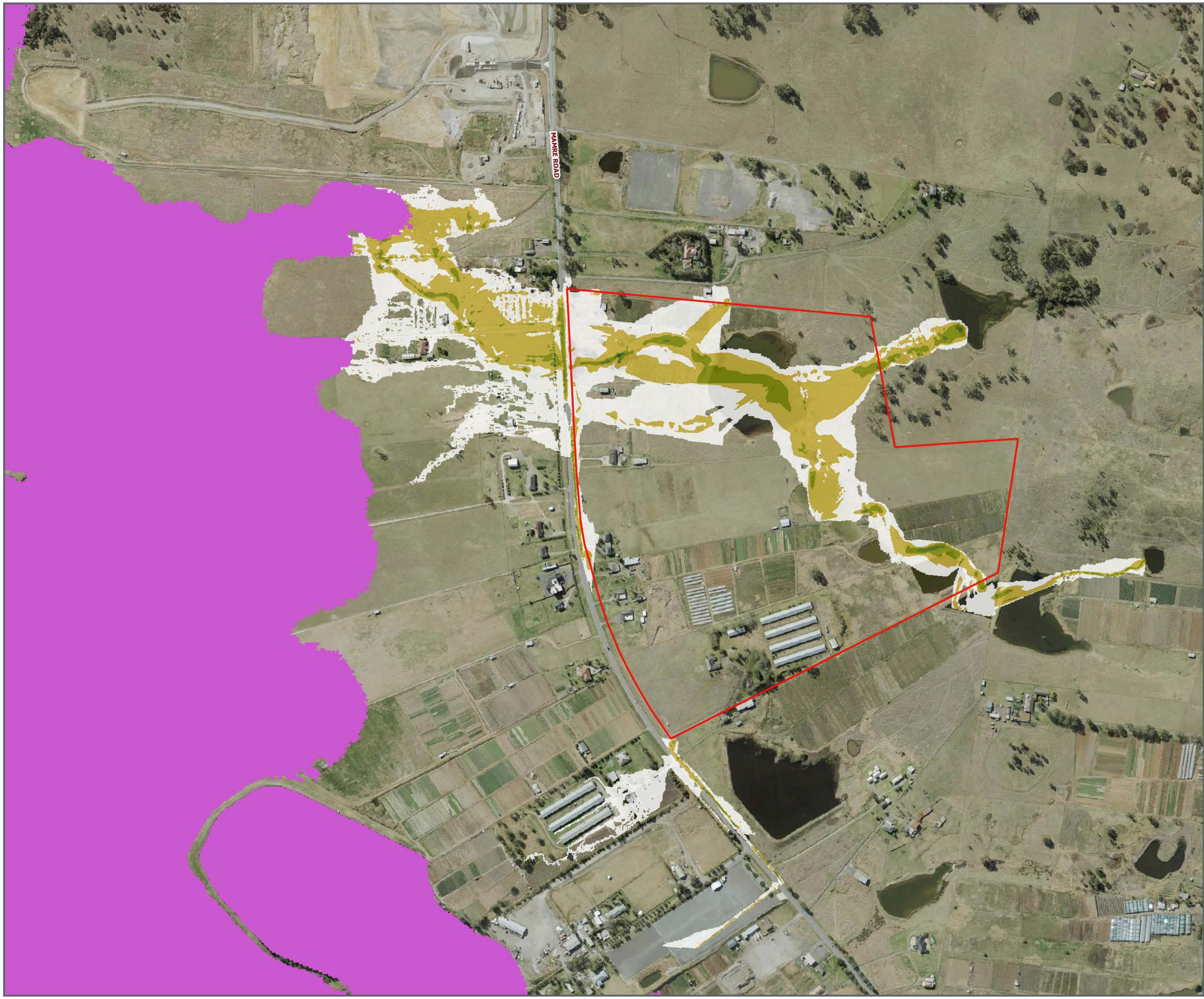
FIGURE E18

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
500 Year ARI
Flood Velocities

Legend

- South Creek Flood Study (2015) 500yr ARI Flood Extent
- Study Area

Flood Velocity (m/s)

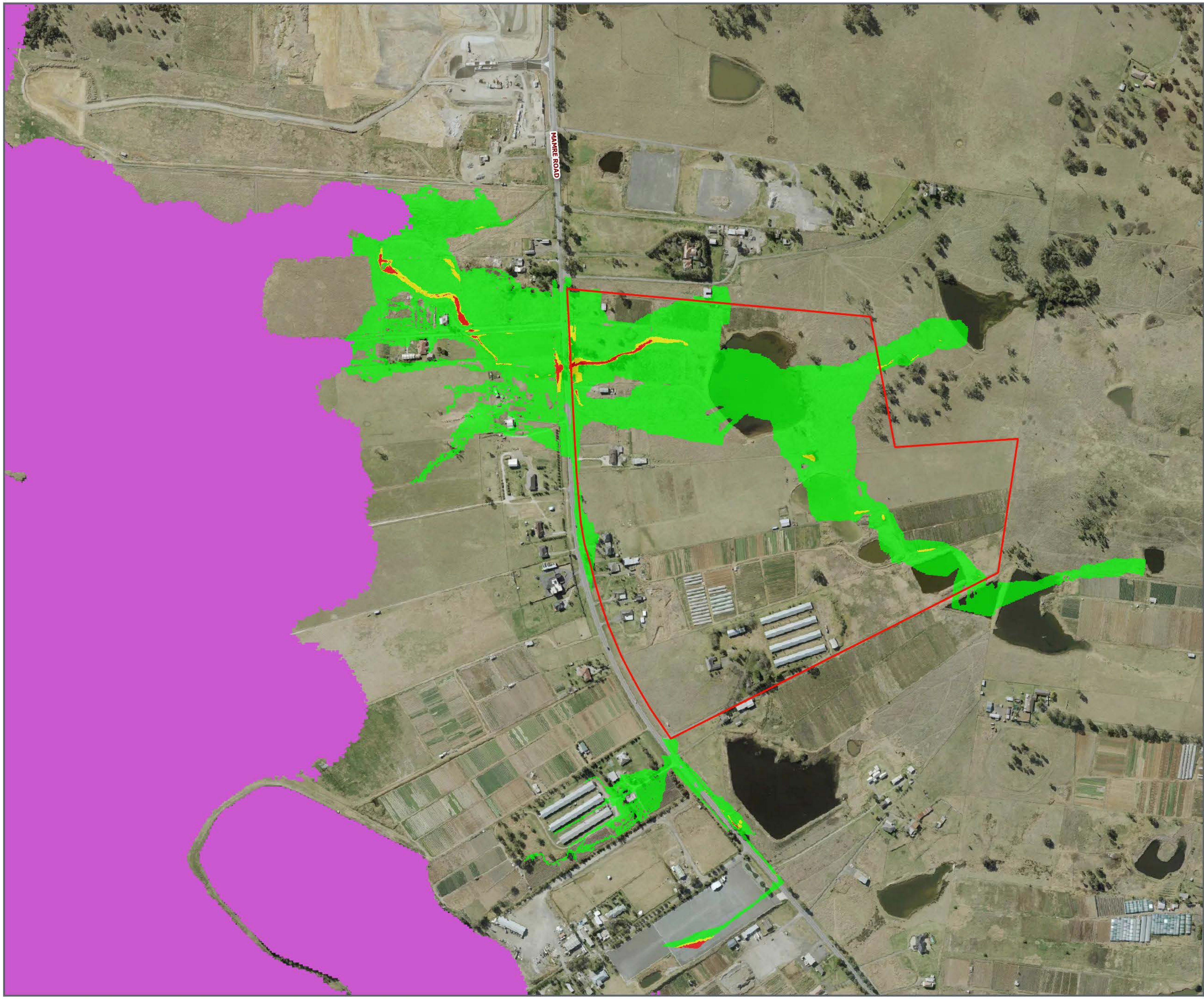
- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE E19

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz



Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
500 Year ARI
Flood Hazard

Legend

- South Creek Flood Study (2015) 500yr ARI Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E20

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-16| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
PMF
Flood Extents & Flood Levels

Legend

- South Creek Flood Study (2015) PMF Flood Extent
- Study Area
- 0.5m Water Level Contour (mAHD)
- Flood Extent

FIGURE E21

1:7,500 Scale at A3

0 80 160 240 320 400 m

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-22| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
PMF
Flood Depths

Legend

Magenta fill	South Creek Flood Study (2015) PMF Flood Extent
Red outline	Study Area

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.30
- 0.30 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- > 1.50

FIGURE E22

1:7,500 Scale at A3

0 80 160 240 320 400 m

N

Cardno now Stantec

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-22| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
PMF
Flood Velocities

Legend

- South Creek Flood Study (2015) PMF Flood Extent
- Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE E23

1:7,500 Scale at A3

0 80 160 240 320 400 m

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-22| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

Flood Risk Assessment Aspect Industrial Estate (AIE)

Benchmark Conditions
PMF
Flood Hazard

Legend

- South Creek Flood Study (2015) PMF Flood Extent
- Study Area

Flood Hazard

- Low
- Transitional
- High

FIGURE E24

1:7,500 Scale at A3

0 80 160 240 320 400 m

N

Map Produced by Cardno Now Stantec (NatW&E)
Date: 2022-6-22| Project: AWE200083
Coordinate System: MGA Zone 56
Map: Figure generation_20220615.qgz

APPENDIX B
SUMMARIES OF RESULTS

Scenario 1

ARR Edition: 1987

Pervious Area Losses — Initial Loss (mm): 37.1; Continuing (mm/h): 0.94

Source: 2015 Updated South Creek Flood Study (Worley Parsons); BX: 1.3; Roughness: 0.025

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical Duration (mins)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	0.32	0.71	0.82	0.79	0.81	0.77	0.96	0.86	0.91	0.92	0.62	0.49	0.96	4.5
N4	0.09	0.18	0.21	0.20	0.21	0.19	0.24	0.22	0.23	0.23	0.15	0.12	0.24	4.5
N34	0.41	0.90	1.03	0.98	1.02	0.96	1.20	1.08	1.14	1.15	0.78	0.61	1.20	4.5
N1	0.93	2.21	2.82	3.07	3.27	3.09	3.11	3.46	3.75	3.89	2.85	2.26	3.89	12
N2	1.49	3.15	3.76	4.04	4.32	4.09	4.27	4.51	4.99	5.12	3.74	2.97	5.12	12
S1	0.23	0.31	0.34	0.33	0.38	0.24	0.33	0.30	0.26	0.26	0.17	0.14	0.38	2
S2	0.75	1.45	1.74	1.96	2.08	1.99	2.02	2.20	2.44	2.52	1.84	1.46	2.52	12
S3	1.15	2.12	2.37	2.53	2.70	2.61	2.81	2.81	3.20	3.30	2.37	1.88	3.30	12
MRID3	0.27	0.64	0.81	0.88	0.94	0.87	0.90	0.96	1.06	1.09	0.78	0.62	1.09	12
MRID2	0.68	1.56	2.14	2.38	2.52	2.44	2.38	2.79	3.02	3.11	2.34	1.87	3.11	12
Junc	2.10	4.30	5.28	5.74	6.11	5.90	6.03	6.54	7.25	7.39	5.48	4.37	7.39	12
MRID1	0.29	0.72	1.08	1.47	1.64	1.74	1.62	1.86	2.41	2.32	1.92	1.66	2.41	9
MRd	4.18	8.66	10.75	11.88	12.71	12.32	12.30	13.70	15.51	15.42	11.77	9.62	15.51	9
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

Scenario 3

ARR Edition: 1987

Pervious Area Losses — Initial Loss (mm): 37.1; Continuing (mm/h): 0.94

Source: 2015 Updated South Creek Flood Study (Worley Parsons); BX: 1.0; Roughness: 0.04

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical Duration (mins)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	0.30	0.67	0.76	0.76	0.80	0.76	0.90	0.83	0.90	0.91	0.62	0.49	0.91	12
N4	0.08	0.17	0.20	0.19	0.20	0.19	0.23	0.21	0.22	0.23	0.15	0.12	0.23	4.5
N34	0.37	0.85	0.96	0.96	1.00	0.95	1.13	1.05	1.12	1.13	0.78	0.61	1.13	12
N1	0.85	2.05	2.65	2.92	3.09	3.00	2.92	3.40	3.67	3.80	2.83	2.26	3.80	12
N2	1.35	2.96	3.56	3.88	4.14	3.96	3.96	4.43	4.87	5.03	3.72	2.97	5.03	12
S1	0.22	0.29	0.33	0.32	0.36	0.23	0.32	0.30	0.26	0.26	0.17	0.14	0.36	2
S2	0.68	1.35	1.64	1.86	1.95	1.92	1.84	2.17	2.39	2.48	1.83	1.46	2.48	12
S3	1.06	2.01	2.26	2.43	2.55	2.51	2.62	2.77	3.14	3.25	2.36	1.88	3.25	12
MRID3	0.23	0.58	0.76	0.84	0.88	0.84	0.84	0.95	1.03	1.07	0.78	0.62	1.07	12
MRID2	0.61	1.38	2.01	2.26	2.42	2.38	2.24	2.73	2.96	3.03	2.32	1.87	3.03	12
Junc	1.90	3.95	4.99	5.50	5.80	5.70	5.62	6.42	7.10	7.24	5.44	4.37	7.24	12
MRID1	0.26	0.64	1.00	1.39	1.55	1.68	1.59	1.76	2.35	2.24	1.87	1.65	2.35	9
MRd	3.79	8.01	10.12	11.36	12.11	11.87	11.51	13.32	15.18	15.13	11.69	9.61	15.18	9
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

Scenario 2

ARR Edition: 1987

Pervious Area Losses — Initial Loss (mm): 15; Continuing (mm/h): 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater); BX: 1.3; Roughness: 0.025

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
ID	Storm Burst Duration (mins)												(m3/s)	Duration
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	1.23	1.35	1.55	1.53	1.65	1.26	1.22	1.04	0.90	0.91	0.61	0.48	1.65	2
N4	0.31	0.34	0.39	0.39	0.42	0.32	0.31	0.26	0.22	0.22	0.15	0.12	0.42	2
N34	1.54	1.69	1.94	1.92	2.07	1.58	1.52	1.30	1.12	1.13	0.77	0.60	2.07	2
N1	4.04	4.91	5.33	5.27	5.37	4.20	5.06	4.30	3.70	3.84	2.80	2.22	5.37	2
N2	5.51	6.48	7.10	7.04	7.43	5.60	6.63	5.72	4.92	5.05	3.67	2.91	7.43	2
S1	0.58	0.55	0.68	0.72	0.69	0.47	0.41	0.30	0.26	0.26	0.17	0.13	0.72	1.5
S2	2.63	3.06	3.31	3.26	3.45	2.67	3.20	2.77	2.41	2.49	1.81	1.43	3.45	2
S3	3.65	4.04	4.53	4.71	4.94	3.79	4.13	3.64	3.16	3.26	2.33	1.84	4.94	2
MRID3	1.17	1.38	1.52	1.52	1.55	1.20	1.42	1.21	1.04	1.08	0.77	0.61	1.55	2
MRID2	2.89	3.62	4.01	3.96	4.03	3.36	3.93	3.36	2.97	3.07	2.30	1.83	4.03	2
Junc	7.67	9.04	9.93	9.96	10.40	8.06	9.41	8.19	7.15	7.29	5.38	4.28	10.40	2
MRID1	1.37	1.96	2.30	2.45	2.56	2.40	2.35	2.52	2.38	2.28	1.88	1.62	2.56	2
MRd	15.34	18.33	20.43	20.50	21.36	16.74	19.40	17.27	15.30	15.20	11.56	9.42	21.36	2
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

Scenario 4

ARR Edition: 1987

Pervious Area Losses — Initial Loss (mm): 15; Continuing (mm/h): 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater); BX: 1.0; Roughness: 0.04

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
Subcatchment ID	Storm Burst Duration (mins)												Flow	Duration
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	1.18	1.30	1.47	1.45	1.56	1.18	1.19	1.03	0.89	0.90	0.61	0.48	1.56	2
N4	0.30	0.33	0.38	0.37	0.40	0.30	0.30	0.26	0.22	0.22	0.15	0.12	0.40	2
N34	1.48	1.62	1.84	1.82	1.95	1.48	1.49	1.28	1.11	1.12	0.77	0.60	1.95	2
N1	3.68	4.60	5.03	4.98	5.02	4.11	4.90	4.14	3.62	3.75	2.78	2.22	5.03	1
N2	5.15	6.12	6.70	6.64	6.91	5.30	6.43	5.56	4.80	4.96	3.66	2.91	6.91	2
S1	0.54	0.53	0.66	0.70	0.67	0.47	0.40	0.30	0.26	0.26	0.17	0.13	0.70	1.5
S2	2.44	2.89	3.10	3.08	3.19	2.55	3.08	2.69	2.35	2.45	1.80	1.43	3.19	2
S3	3.47	3.87	4.28	4.47	4.67	3.60	4.01	3.55	3.09	3.21	2.32	1.84	4.67	2
MRID3	1.09	1.32	1.44	1.42	1.45	1.14	1.38	1.18	1.02	1.06	0.77	0.61	1.45	2
MRID2	2.64	3.40	3.74	3.72	3.86	3.29	3.74	3.26	2.92	2.99	2.28	1.83	3.86	2
Junc	7.12	8.54	9.34	9.32	9.72	7.57	9.04	7.96	7.00	7.14	5.35	4.28	9.72	2
MRID1	1.20	1.73	2.12	2.32	2.43	2.29	2.19	2.42	2.32	2.20	1.83	1.62	2.43	2
MRd	14.28	17.28	19.19	19.30	20.03	16.01	18.66	16.76	14.97	14.92	11.47	9.41	20.03	2
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

Scenario 5

ARR Edition: 2019

Pervious Area Losses — Initial Burst Loss (mm): 10; Continuing (mm/h): 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater); BX: 1.3; Roughness: 0.025; net probability loss: 11.2

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
ID	Storm Burst Duration (mins)												(m3/s)	Duration
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	1.81	1.74	1.59	1.32	1.28	1.00	0.84	0.84	0.69				1.81	0.5
N4	0.47	0.45	0.41	0.3410	0.3266	0.26	0.22	0.21	0.17				0.47	0.5
N34	2.28	2.18	2.00	1.66	1.60	1.26	1.06	1.05	0.86				2.28	0.5
N1	6.16	6.45	6.10	4.99	4.96	3.99	3.30	3.48	2.83				6.45	0.75
N2	8.33	8.55	8.09	6.72	6.61	5.33	4.39	4.64	3.77				8.55	0.75
S1	0.72	0.62	0.57	0.47	0.45	0.34	0.31	0.26	0.20				0.72	0.5
S2	3.97	4.11	3.90	3.25	3.20	2.58	2.12	2.26	1.83				4.11	0.75
S3	5.52	5.53	5.20	4.43	4.29	3.43	2.81	2.99	2.41				5.53	0.75
MRID3	1.79	1.84	1.73	1.41	1.40	1.13	0.93	0.97	0.79				1.84	0.75
MRID2	4.49	4.91	4.71	3.92	3.89	3.12	2.61	2.79	2.26				4.91	0.75
Junc	11.45	11.96	11.49	9.53	9.41	7.56	6.28	6.69	5.42				11.96	0.75
MRID1	2.12	2.62	2.85	2.84	2.66	2.26	1.90	2.11	1.76				2.85	1
MRd	22.78	24.15	23.41	19.74	19.38	15.74	13.20	14.22	11.51				24.15	0.75
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

Scenario 6

ARR Edition: 2019

Pervious Area Losses — Initial Burst Loss (mm): 10; Continuing (mm/h): 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater); BX: 1.0; Roughness: 0.04; net probability loss: 11.2

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
Subcatchment ID	Storm Burst Duration (mins)												Flow	Duration
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N3	1.73	1.68	1.54	1.27	1.24	0.98	0.82	0.82	0.68				1.73	0.5
N4	0.45	0.43	0.40	0.328	0.317	0.25	0.21	0.21	0.17				0.45	0.5
N34	2.18	2.11	1.93	1.60	1.55	1.23	1.03	1.03	0.85				2.18	0.5
N1	5.67	6.11	5.83	4.82	4.79	3.85	3.21	3.41	2.76				6.11	0.75
N2	7.82	8.15	7.78	6.48	6.39	5.16	4.27	4.55	3.69				8.15	0.75
S1	0.70	0.61	0.56	0.469	0.438	0.33	0.31	0.26	0.20				0.70	0.5
S2	3.69	3.89	3.74	3.14	3.10	2.49	2.06	2.21	1.79				3.89	0.75
S3	5.21	5.27	4.99	4.27	4.16	3.32	2.73	2.93	2.37				5.27	0.75
MRID3	1.66	1.75	1.66	1.36	1.353	1.087	0.90	0.95	0.77				1.75	0.75
MRID2	4.10	4.61	4.48	3.81	3.74	3.00	2.53	2.73	2.21				4.61	0.75
Junc	10.71	11.35	11.01	9.21	9.10	7.32	6.10	6.56	5.30				11.35	0.75
MRID1	1.91	2.37	2.62	2.70	2.54	2.19	1.84	2.04	1.71				2.70	1.5
MRd	21.35	22.88	22.43	19.05	18.72	15.25	12.81	13.93	11.28				22.88	0.75
Storm Burst (hrs)	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

AWE200083 Aspect Industrial Estate ARR1987 Hydrology

Attachment B2

2 yr ARI **ARR Edition** **1987**

Pervious Area Losses
Initial Burst Loss (mm) 15
Continuing (mm/h) 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)	2	2	2	2	2	2	2	2	2	2	2	2		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N5	0.62	1.20	1.49	1.64	1.77	1.63	1.77	1.81	1.89	1.97	1.39	1.07	1.97	12.0
N1	0.46	0.90	1.16	1.32	1.42	1.34	1.38	1.54	1.61	1.66	1.22	0.95	1.66	12.0
N2	0.72	1.31	1.60	1.76	1.90	1.79	1.93	2.02	2.13	2.21	1.60	1.25	2.21	12.0
S1	0.10	0.14	0.17	0.18	0.20	0.14	0.16	0.14	0.12	0.12	0.08	0.06	0.20	2.0
S2	0.35	0.60	0.72	0.82	0.88	0.85	0.88	0.98	1.02	1.08	0.78	0.61	1.08	12.0
S3	0.56	0.91	1.06	1.07	1.16	1.12	1.28	1.25	1.35	1.43	1.01	0.79	1.43	12.0
MRID3	0.14	0.27	0.34	0.38	0.41	0.38	0.40	0.43	0.45	0.47	0.34	0.26	0.47	12.0
MRID2a	0.28	0.54	0.72	0.82	0.88	0.85	0.85	0.99	1.03	1.06	0.78	0.62	1.06	12.0
Junc	0.98	1.70	2.05	2.25	2.43	2.34	2.49	2.65	2.81	2.92	2.12	1.67	2.92	12.0
MRID1	0.15	0.29	0.42	0.57	0.64	0.70	0.68	0.76	0.97	0.88	0.75	0.67	0.97	9.0
N3	0.17	0.30	0.36	0.36	0.38	0.34	0.44	0.39	0.40	0.41	0.27	0.21	0.44	4.5
N4	0.05	0.08	0.10	0.10	0.10	0.09	0.11	0.10	0.10	0.10	0.07	0.05	0.11	4.5
N34	0.22	0.38	0.46	0.46	0.48	0.43	0.55	0.49	0.50	0.51	0.34	0.26	0.55	4.5
MRd	2.01	3.56	4.39	4.85	5.25	5.07	5.30	5.74	6.31	6.27	4.76	3.84	6.31	9.0
MRID2b	0.24	0.35	0.40	0.42	0.46	0.31	0.42	0.39	0.35	0.35	0.22	0.17	0.46	2.0
DSMRd	2.66	4.66	5.89	6.35	6.90	6.70	7.02	7.58	8.35	7.95	6.24	5.07	8.35	9.0

5 yr ARI **ARR Edition** **1987**

Pervious Area Losses
Initial Burst Loss (mm) 15
Continuing (mm/h) 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)	5	5	5	5	5	5	5	5	5	5	5	5		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N5	1.61	2.36	2.74	2.78	2.89	2.49	3.12	2.75	2.57	2.68	1.89	1.47	3.12	4.5
N1	0.42	0.56	0.65	0.66	0.69	0.51	0.69	0.61	0.54	0.55	0.37	0.28	0.69	4.5
N2	0.11	0.15	0.17	0.17	0.18	0.13	0.17	0.15	0.14	0.14	0.09	0.07	0.18	2.0
S1	0.54	0.71	0.81	0.83	0.87	0.65	0.86	0.76	0.67	0.69	0.46	0.35	0.87	2.0
S2	1.19	1.83	2.14	2.25	2.39	2.14	2.45	2.29	2.19	2.28	1.66	1.30	2.45	4.5
S3	1.79	2.54	2.92	2.96	3.10	2.79	3.34	3.02	2.90	3.01	2.18	1.71	3.34	4.5
MRID3	0.20	0.23	0.30	0.36	0.37	0.26	0.25	0.18	0.16	0.16	0.10	0.08	0.37	2.0
MRID2a	0.83	1.16	1.34	1.38	1.48	1.36	1.55	1.44	1.40	1.47	1.07	0.84	1.55	4.5
Junc	1.29	1.65	1.89	1.97	2.14	1.75	2.12	1.89	1.85	1.94	1.38	1.08	2.14	2.0
MRID1	0.35	0.53	0.62	0.64	0.68	0.60	0.71	0.65	0.61	0.64	0.46	0.36	0.71	4.5
N3	0.72	1.12	1.32	1.41	1.51	1.36	1.51	1.46	1.40	1.46	1.08	0.85	1.51	2.0
N4	2.36	3.27	3.75	3.80	3.99	3.67	4.30	3.96	3.84	3.97	2.90	2.29	4.30	4.5
N34	0.39	0.63	0.83	1.01	1.11	1.09	1.05	1.23	1.36	1.26	1.06	0.94	1.36	9.0
MRd	4.85	6.82	7.98	8.26	8.60	7.99	9.09	8.71	8.61	8.56	6.54	5.29	9.09	4.5
MRID2b	0.51	0.59	0.72	0.78	0.84	0.62	0.65	0.53	0.46	0.46	0.30	0.23	0.84	2.0
DSMRd	6.26	8.78	10.52	11.09	11.70	10.31	11.61	11.48	11.37	10.90	8.59	6.98	11.70	2.0

100 yr ARI **ARR Edition** **1987**

Pervious Area Losses
Initial Burst Loss (mm) 15
Continuing (mm/h) 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N5	5.39	6.10	6.75	6.70	7.03	5.37	5.95	5.12	4.40	4.51	3.17	2.49	7.03	2.0
N1	4.15	4.95	5.40	5.34	5.47	4.29	5.09	4.34	3.73	3.87	2.80	2.22	5.47	2.0
N2	5.65	6.54	7.18	7.13	7.50	5.75	6.66	5.77	4.98	5.09	3.68	2.91	7.50	2.0
S1	0.59	0.56	0.69	0.72	0.69	0.47	0.41	0.30	0.26	0.26	0.17	0.13	0.72	1.5
S2	2.64	3.11	3.38	3.34	3.56	2.71	3.23	2.79	2.41	2.50	1.81	1.43	3.56	2.0
S3	3.65	4.09	4.61	4.79	5.05	3.81	4.17	3.67	3.16	3.26	2.33	1.84	5.05	2.0
MRID3	1.21	1.41	1.55	1.53	1.59	1.23	1.43	1.22	1.04	1.08	0.77	0.61	1.59	2.0
MRID2a	2.54	3.09	3.37	3.34	3.39	2.70	3.24	2.76	2.39	2.49	1.82	1.44	3.39	2.0
Junc	7.29	8.49	9.33	9.34	9.90	7.54	8.71	7.61	6.58	6.72	4.90	3.90	9.90	2.0
MRID1	1.40	1.98	2.33	2.49	2.59	2.42	2.38	2.55	2.39	2.29	1.87	1.62	2.59	2.0
N3	1.26	1.37	1.56	1.56	1.67	1.29	1.22	1.04	0.90	0.91	0.61	0.48	1.67	2.0
N4	0.33	0.36	0.40	0.41	0.44	0.34	0.31	0.26	0.23	0.23	0.15	0.12	0.44	2.0
N34	1.58	1.72	1.97	1.97	2.11	1.63	1.53	1.30	1.13	1.13	0.77	0.60	2.11	2.0
MRd	14.99	17.83	19.91	19.98	20.96	16.35	18.68	16.76	14.77	14.54	11.10	9.03	20.96	2.0
MRID2b	1.32	1.33	1.65	1.82	1.83	1.31	1.13	0.86	0.75	0.75	0.49	0.39	1.83	2.0
DSMRd	18.62	22.74	25.54	25.78	26.99	21.53	23.78	21.70	19.34	18.69	14.67	11.91	26.99	2.0

200 yr ARI **ARR Edition** **1987**

Pervious Area Losses
Initial Burst Loss (mm) 15
Continuing (mm/h) 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)	200	200	200	200	200	200	200	200	200	200	200	200		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N5	6.39	7.09	7.85	7.77	8.23	6.29	6.65	5.72	4.91	5.03	3.53	2.78	8.23	2.0
N1	4.97	5.74	6.28	6.20	6.41	5.00	5.72	4.88	4.17	4.32	3.12	2.47	6.41	2.0
N2	6.70	7.59	8.36	8.28	8.77	6.76	7.49	6.46	5.56	5.68	4.10	3.25	8.77	2.0
S1	0.72	0.66	0.78	0.80	0.76	0.52	0.45	0.33	0.29	0.29	0.19	0.15	0.80	1.5
S2	3.15	3.61	3.95	3.91	4.19	3.21	3.63	3.13	2.69	2.78	2.01	1.60	4.19	2.0
S3	4.28	4.75	5.34	5.57	5.86	4.46	4.68	4.11	3.53	3.64	2.59	2.06	5.86	2.0
MRID3	1.45	1.64	1.80	1.78	1.86	1.44	1.59	1.37	1.17	1.21	0.86	0.68	1.86	2.0
MRID2a	3.05	3.60	3.92	3.87	3.97	3.13	3.66	3.11	2.67	2.78	2.03	1.61	3.97	2.0
Junc	8.63	9.88	10.88	10.92	11.58	8.86	9.82	8.53	7.35	7.49	5.47	4.35	11.58	2.0
MRID1	1.71	2.36	2.73	2.90	3.01	2.78	2.77	2.87	2.67	2.58	2.10	1.82	3.01	2.0
N3	1.48	1.59	1.80	1.82	1.94	1.51	1.37	1.16	1.00	1.01	0.68	0.54	1.94	2.0
N4	0.39	0.41	0.46	0.48	0.51	0.39	0.35	0.29	0.25	0.25	0.17	0.13	0.51	2.0
N34	1.87	2.00	2.26	2.29	2.45	1.90	1.71	1.45	1.25	1.26	0.85	0.67	2.45	2.0
MRd	17.78	20.76	23.18	23.25	24.45	19.09	21.14	18.83	16.50	16.21	12.39	10.08	24.45	2.0
MRID2b	1.57	1.56	1.90	2.07	2.05	1.46	1.26	0.95	0.83	0.83	0.55	0.43	2.07	1.5
DSMRd	21.90	26.46	29.55	29.77	31.18	24.91	27.14	24.30	21.56	20.88	16.38	13.30	31.18	2.0

500 yr ARI **ARR Edition** **1987**

Pervious Area Losses
Initial Burst Loss (mm) 15
Continuing (mm/h) 1.5

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)	500	500	500	500	500	500	500	500	500	500	500	500		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	30	45	60	90	120	180	270	360	540	720	1440	2160		
N5	7.72	8.43	9.40	9.25	9.86	7.60	7.59	6.52	5.61	5.72	4.02	3.18	9.86	2.0
N1	1.78	1.88	2.12	2.18	2.31	1.78	1.56	1.31	1.14	1.14	0.78	0.61	2.31	2.0
N2	0.46	0.48	0.55	0.58	0.61	0.46	0.40	0.33	0.28	0.29	0.19	0.15	0.61	2.0
S1	2.24	2.36	2.66	2.75	2.92	2.24	1.96	1.64	1.42	1.43	0.97	0.77	2.92	2.0
S2	6.11	6.84	7.50	7.42	7.74	6.01	6.54	5.58	4.77	4.93	3.56	2.82	7.74	2.0
S3	8.13	9.03	9.99	9.90	10.51	8.19	8.57	7.38	6.35	6.47	4.67	3.71	10.51	2.0
MRID3	0.88	0.78	0.90	0.92	0.87	0.58	0.51	0.37	0.32	0.32	0.22	0.17	0.92	1.5
MRID2a	3.84	4.31	4.72	4.75	5.07	3.90	4.16	3.59	3.08	3.18	2.29	1.82	5.07	2.0
Junc	5.16	5.64	6.35	6.66	7.00	5.36	5.36	4.70	4.03	4.14	2.96	2.35	7.00	2.0
MRID1	1.77	1.96	2.15	2.13	2.25	1.73	1.82	1.56	1.34	1.37	0.98	0.78	2.25	2.0
N3	3.76	4.30	4.69	4.63	4.78	3.75	4.21	3.58	3.06	3.17	2.31	1.84	4.78	2.0
N4	10.46	11.78	13.03	13.16	13.88	10.69	11.30	9.76	8.40	8.53	6.23	4.97	13.88	2.0
N34	2.15	2.91	3.30	3.48	3.61	3.28	3.31	3.30	3.05	2.97	2.42	2.08	3.61	2.0
MRd	21.60	24.83	27.70	27.85	29.24	22.93	24.42	21.60	18.85	18.48	14.15	11.52	29.24	2.0
MRID2b	1.93	1.89	2.26	2.38	2.35	1.66	1.43	1.07	0.94	0.93	0.62	0.49	2.38	1.5
DSMRd	26.48	31.53	35.07	35.34	36.93	29.57	31.65	27.77	24.57	23.86	18.71	15.19	36.93	2.0

PMF

Pervious Area Losses
Initial Burst Loss (mm) 1
Continuing (mm/h) 0

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)										Critical
Subcatchment ID	Storm Burst Duration (mins)								Peak Flow (m3/s)	Duration (hrs)
	15	30	45	60	90	120	180	240		
N5	73.12	74.86	70.52	64.53	54.98	47.72	38.47	33.27	74.86	0.50
N1	17.90	15.92	14.38	12.99	10.75	9.41	7.67	6.68	17.90	0.25
N2	4.61	4.02	3.60	3.23	2.68	2.35	1.92	1.68	4.61	0.25
S1	22.47	19.93	17.96	16.22	13.42	11.76	9.59	8.36	22.47	0.25
S2	61.31	65.23	60.94	56.90	48.67	42.42	33.96	29.28	65.23	0.50
S3	79.21	84.36	79.70	73.59	63.63	55.71	44.50	38.40	84.36	0.50
MRID3	6.49	5.00	4.25	3.77	3.21	2.85	2.30	1.95	6.49	0.25
MRID2a	40.08	41.76	39.21	36.51	31.30	27.37	21.86	18.86	41.76	0.50
Junc	53.21	53.35	50.28	46.91	40.30	35.22	28.06	24.35	53.35	0.50
MRID1	17.78	18.26	17.12	15.75	13.43	11.67	9.37	8.09	18.26	0.50
N3	38.13	41.66	39.36	36.81	31.53	27.63	22.07	19.02	41.66	0.50
N4	105.47	111.06	105.64	98.23	84.62	74.43	59.40	51.35	111.06	0.50
N34	22.50	32.72	36.38	35.30	32.09	29.70	24.43	20.80	36.38	0.75
MRd	203.74	230.73	232.52	218.69	191.71	170.54	136.93	117.68	232.52	0.75
MRID2b	17.40	14.04	12.11	10.65	8.97	7.99	6.51	5.59	17.40	0.25
DSMRd	221.49	270.18	290.87	278.52	248.24	222.83	180.15	154.27	290.87	0.75

50% AEP ARR Edition 2019

Pervious Area Losses
Initial Burst Loss (mm) 28.5
Continuing (mm/h) 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

AEP	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	15	20	25	30	45	60	90	120	180	270	360	540		
N5				0.00	0.00	0.00	0.08	0.31	0.67	0.88	1.03	0.90	1.03	6.0
N1				0.00	0.00	0.00	0.06	0.22	0.52	0.71	0.83	0.76	0.83	6.0
N2				0.00	0.00	0.00	0.10	0.36	0.73	0.97	1.14	1.02	1.14	6.0
S1				0.00	0.00	0.00	0.02	0.06	0.07	0.08	0.09	0.07	0.09	6.0
S2				0.00	0.00	0.00	0.05	0.18	0.34	0.46	0.54	0.49	0.54	6.0
S3				0.00	0.00	0.00	0.08	0.28	0.49	0.64	0.75	0.67	0.75	6.0
MRID3				0.00	0.00	0.00	0.02	0.07	0.15	0.20	0.24	0.21	0.24	6.0
MRID2a				0.00	0.00	0.00	0.04	0.14	0.32	0.44	0.52	0.48	0.52	6.0
Junc				0.00	0.00	0.00	0.14	0.48	0.94	1.27	1.50	1.34	1.50	6.0
MRID1				0.00	0.00	0.00	0.02	0.07	0.18	0.31	0.40	0.40	0.40	6.0
N3				0.00	0.00	0.00	0.02	0.08	0.16	0.20	0.23	0.19	0.23	6.0
N4				0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.05	0.06	6.0
N34				0.00	0.00	0.00	0.03	0.11	0.20	0.25	0.29	0.24	0.29	6.0
MRd				0.00	0.00	0.00	0.29	1.00	1.99	2.72	3.23	2.91	3.23	6.0
MRID2b				0.00	0.00	0.00	0.04	0.12	0.17	0.20	0.23	0.19	0.23	6.0
DSMRd				0.00	0.00	0.00	0.40	1.35	2.64	3.62	4.26	3.82	4.26	6.0

20% AEP ARR Edition 2019

Pervious Area Losses
Initial Burst Loss (mm) 16
Continuing (mm/h) 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

AEP	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	15	20	25	30	45	60	90	120	180	270	360	540		
N5				1.58	2.24	2.47	2.45	2.48	2.09	1.92	1.86	1.60	2.48	2.00
N1				1.16	1.67	1.92	2.03	2.00	1.75	1.59	1.56	1.33	2.03	1.50
N2				1.81	2.44	2.71	2.70	2.75	2.35	2.16	2.10	1.79	2.75	2.00
S1				0.24	0.25	0.25	0.20	0.23	0.16	0.15	0.15	0.11	0.25	0.75
S2				0.87	1.13	1.28	1.30	1.32	1.13	1.04	1.01	0.86	1.32	2.00
S3				1.37	1.69	1.84	1.76	1.84	1.53	1.42	1.36	1.15	1.84	1.00
MRID3				0.35	0.49	0.56	0.57	0.57	0.49	0.45	0.44	0.38	0.57	1.50
MRID2a				0.70	1.01	1.18	1.27	1.26	1.11	1.01	0.99	0.85	1.27	1.50
Junc				2.41	3.18	3.51	3.49	3.63	3.09	2.85	2.75	2.34	3.63	2.00
MRID1				0.38	0.55	0.68	0.85	0.95	0.93	0.87	0.85	0.75	0.95	2.00
N3				0.43	0.56	0.59	0.54	0.57	0.44	0.41	0.40	0.34	0.59	1.00
N4				0.12	0.15	0.15	0.14	0.15	0.11	0.11	0.10	0.09	0.15	1.00
N34				0.54	0.71	0.74	0.68	0.71	0.56	0.52	0.50	0.43	0.74	1.00
MRd				4.91	6.57	7.28	7.41	7.73	6.74	6.21	6.01	5.13	7.73	2.00
MRID2b				0.57	0.63	0.63	0.53	0.58	0.42	0.41	0.39	0.30	0.63	0.75
DSMRd				6.38	8.44	9.29	9.57	10.08	8.78	8.10	7.83	6.67	10.08	2.00

1% AEP ARR Edition 2019

Pervious Area Losses
Initial Burst Loss (mm) 10
Continuing (mm/h) 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

AEP	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	15	20	25	30	45	60	90	120	180	270	360	540		
N5		6.69	7.59	7.90	7.93	7.35	6.02	5.92	4.77	3.93	4.07	3.34	7.93	0.75
N1		4.94	5.72	6.16	6.45	6.10	4.99	4.96	3.99	3.30	3.48	2.83	6.45	0.75
N2		7.34	8.05	8.33	8.55	8.09	6.72	6.61	5.33	4.39	4.64	3.77	8.55	0.75
S1		0.78	0.75	0.72	0.62	0.57	0.47	0.45	0.34	0.31	0.26	0.20	0.78	0.33
S2		3.46	3.80	3.97	4.11	3.90	3.25	3.20	2.58	2.12	2.26	1.83	4.11	0.75
S3		5.19	5.47	5.52	5.53	5.20	4.43	4.29	3.43	2.81	2.99	2.41	5.53	0.75
MRID3		1.47	1.69	1.79	1.84	1.73	1.41	1.40	1.13	0.93	0.97	0.79	1.84	0.75
MRID2a		2.98	3.47	3.78	4.04	3.85	3.17	3.15	2.53	2.11	2.23	1.81	4.04	0.75
Junc		9.51	10.37	10.73	11.11	10.62	8.80	8.68	6.98	5.79	6.13	4.98	11.11	0.75
MRID1		1.61	1.89	2.12	2.62	2.85	2.84	2.66	2.26	1.90	2.11	1.76	2.85	1.00
N3		1.75	1.86	1.81	1.74	1.59	1.32	1.28	1.00	0.84	0.84	0.69	1.86	0.42
N4		0.47	0.49	0.47	0.45	0.41	0.34	0.33	0.26	0.22	0.21	0.17	0.49	0.42
N34		2.22	2.34	2.28	2.18	2.00	1.66	1.60	1.26	1.06	1.05	0.86	2.34	0.42
MRd		19.10	21.12	22.07	23.32	22.57	19.03	18.68	15.16	12.72	13.67	11.07	23.32	0.75
MRID2b		2.02	1.93	1.85	1.66	1.52	1.29	1.19	0.93	0.82	0.74	0.57	2.02	0.33
DSMRd		23.47	25.85	27.09	29.14	28.71	24.47	24.04	19.53	16.60	17.77	14.37	29.14	0.75

0.5% AEP ARR Edition 2019

Pervious Area Losses
Initial Burst Loss (mm) 10
Continuing (mm/h) 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

AEP	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	15	20	25	30	45	60	90	120	180	270	360	540		
N5	6.13	7.70	8.64	8.91	8.87	8.17	6.70	6.55	5.26	4.33	4.40		8.91	0.50
N1	4.50	5.70	6.55	7.00	7.25	6.81	5.56	5.50	4.42	3.64	3.76		7.25	0.75
N2	6.90	8.38	9.13	9.40	9.59	9.01	7.47	7.31	5.88	4.84	5.02		9.59	0.75
S1	0.87	0.86	0.82	0.79	0.69	0.62	0.52	0.49	0.37	0.34	0.28		0.87	0.25
S2	3.33	3.95	4.32	4.50	4.63	4.35	3.61	3.55	2.85	2.33	2.44		4.63	0.75
S3	5.10	5.87	6.16	6.20	6.19	5.81	4.92	4.76	3.78	3.10	3.23		6.20	0.50
MRID3	1.34	1.69	1.93	2.03	2.07	1.92	1.57	1.55	1.24	1.02	1.05		2.07	0.75
MRID2a	2.72	3.45	3.98	4.31	4.55	4.31	3.53	3.50	2.81	2.32	2.42		4.55	0.75
Junc	9.09	10.83	11.74	12.11	12.48	11.85	9.79	9.61	7.70	6.39	6.63		12.48	0.75
MRID1	1.46	1.86	2.18	2.45	3.01	3.25	3.17	2.96	2.49	2.10	2.29		3.25	1.00
N3	1.65	1.99	2.08	2.02	1.93	1.77	1.47	1.41	1.10	0.93	0.91		2.08	0.42
N4	0.45	0.53	0.54	0.52	0.50	0.45	0.38	0.36	0.28	0.24	0.23		0.54	0.42
N34	2.10	2.53	2.62	2.54	2.43	2.23	1.85	1.77	1.38	1.17	1.14		2.62	0.42
MRd	18.09	21.74	23.91	24.91	26.23	25.23	21.17	20.72	16.76	14.02	14.79		26.23	0.75
MRID2b	2.14	2.24	2.14	2.06	1.84	1.68	1.42	1.32	1.02	0.91	0.80		2.24	0.33
DSMRd	22.29	26.54	29.09	30.48	32.69	32.10	27.14	26.63	21.54	18.29	19.20		32.69	0.75

0.2% AEP ARR Edition 2019

Pervious Area Losses
Initial Burst Loss (mm) 10
Continuing (mm/h) 2.3

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

AEP	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%		Critical
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Duration (hrs)
	15	20	25	30	45	60	90	120	180	270	360	540		
N5	7.62	9.46	10.42	10.57	10.37	9.51	7.82	7.57	6.03	5.02	5.03	4.14	10.57	0.50
N1	5.60	7.03	7.98	8.39	8.52	7.94	6.49	6.35	5.09	4.21	4.30	3.53	8.52	0.75
N2	8.48	10.17	10.94	11.15	11.26	10.48	8.70	8.44	6.76	5.60	5.73	4.68	11.26	0.75
S1	1.01	0.99	0.95	0.91	0.79	0.71	0.59	0.56	0.42	0.39	0.32	0.24	1.01	0.25
S2	4.07	4.79	5.21	5.38	5.46	5.08	4.21	4.10	3.29	2.69	2.79	2.27	5.46	0.75
S3	6.19	7.03	7.31	7.32	7.25	6.78	5.72	5.50	4.34	3.58	3.69	2.99	7.32	0.50
MRID3	1.67	2.08	2.34	2.42	2.42	2.24	1.83	1.78	1.43	1.18	1.20	0.99	2.42	0.75
MRID2a	3.38	4.26	4.87	5.19	5.36	5.04	4.11	4.04	3.24	2.69	2.76	2.26	5.36	0.75
Junc	11.14	13.09	14.05	14.41	14.67	13.82	11.40	11.11	8.85	7.39	7.58	6.17	14.67	0.75
MRID1	1.82	2.30	2.68	3.00	3.67	3.89	3.70	3.44	2.87	2.43	2.65	2.19	3.89	1.00
N3	2.03	2.40	2.46	2.37	2.25	2.06	1.71	1.63	1.26	1.08	1.04	0.84	2.46	0.42
N4	0.55	0.64	0.64	0.61	0.57	0.53	0.44	0.41	0.32	0.28	0.26	0.21	0.64	0.33
N34	2.59	3.04	3.09	2.98	2.82	2.59	2.15	2.04	1.58	1.35	1.30	1.06	3.09	0.42
MRd	22.10	26.26	28.64	29.62	30.86	29.52	24.66	23.98	19.29	16.23	16.92	13.72	30.86	0.75
MRID2b	2.54	2.59	2.49	2.39	2.12	1.93	1.63	1.51	1.16	1.05	0.91	0.70	2.59	0.33
DSMRd	26.96	31.76	34.53	36.06	38.33	37.56	31.43	30.70	24.76	21.14	21.92	17.79	38.33	0.75

PMF

Pervious Area Losses
Initial Burst Loss (mm) 1
Continuing (mm/h) 0

Source: 2012 Upper South Creek Flood Study (WMAwater)
BX 1.3
Roughness 0.025

ARI (yrs)										Critical
Subcatchment ID	Storm Burst Duration (mins)								Peak Flow (m3/s)	Duration (hrs)
	15	30	45	60	90	120	180	240		
N5	73.12	74.86	70.52	64.53	54.98	47.72	38.47	33.27	74.86	0.50
N1	17.90	15.92	14.38	12.99	10.75	9.41	7.67	6.68	17.90	0.25
N2	4.61	4.02	3.60	3.23	2.68	2.35	1.92	1.68	4.61	0.25
S1	22.47	19.93	17.96	16.22	13.42	11.76	9.59	8.36	22.47	0.25
S2	61.31	65.23	60.94	56.90	48.67	42.42	33.96	29.28	65.23	0.50
S3	79.21	84.36	79.70	73.59	63.63	55.71	44.50	38.40	84.36	0.50
MRID3	6.49	5.00	4.25	3.77	3.21	2.85	2.30	1.95	6.49	0.25
MRID2a	40.08	41.76	39.21	36.51	31.30	27.37	21.86	18.86	41.76	0.50
Junc	53.21	53.35	50.28	46.91	40.30	35.22	28.06	24.35	53.35	0.50
MRID1	17.78	18.26	17.12	15.75	13.43	11.67	9.37	8.09	18.26	0.50
N3	38.13	41.66	39.36	36.81	31.53	27.63	22.07	19.02	41.66	0.50
N4	105.47	111.06	105.64	98.23	84.62	74.43	59.40	51.35	111.06	0.50
N34	22.50	32.72	36.38	35.30	32.09	29.70	24.43	20.80	36.38	0.75
MRd	203.74	230.73	232.52	218.69	191.71	170.54	136.93	117.68	232.52	0.75
MRID2b	17.40	14.04	12.11	10.65	8.97	7.99	6.51	5.59	17.40	0.25
DSMRd	221.49	270.18	290.87	278.52	248.24	222.83	180.15	154.27	290.87	0.75