Flood Risk Assessment

Aspect Industrial Estate (AIE)

AWE200083

Prepared for
Mirvac

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Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

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

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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 13**.

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.

Hydraulic assessments were undertaken using flows estimated using both ARR1987 and ARR2019. 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.

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

Executive Summary **ii**

1 Introduction **1**

1.1 Purpose of this Report 1
1.2 Location 1
1.3 Planning Context 1
1.3.1 Penrith Local Environmental Plan 2010 2
1.3.2 Penrith Development Control Plan 2014 2
1.3.3 2020 Flood Prone Land Package 3
1.3.4 State Environmental Planning Policy (Western Sydney Employment Area) 2009 4
1.3.5 NSW Flood Risk Management Framework 6
1.4 Approach 8
1.4.1 Hydrology 8
1.4.2 Hydraulics 9
1.5 Terminology 9

2 Previous Studies **11**

2.1 2015 Updated South Creek Flood Study 11
2.2 2006 Penrith Overland Flow Flood "Overview Study" 12

3 Hydrology **14**

3.1 Site Inspection 14
3.2 Farm Dams 14
3.3 Initial Sensitivity Assessment 15
3.3.1 ARR1987 16
3.3.2 ARR2019 16
3.4 Hydrological Modelling 17
3.4.1 ARR1987 Assessments 17
3.4.2 ARR2019 Assessments 18
3.4.3 Comparisons 18

4 Flooding Assessment **20**

4.1 Benchmark Conditions 20
4.1.1 2 yr ARI 20
4.1.2 5 yr ARI 21
4.1.3 100 yr ARI 21
4.1.4 200 yr ARI 21
4.1.5 500 yr ARI 21
4.1.6 PMF 21

5 References **22**

Appendix

Appendix A Figures

Appendix B Summaries of Results

List of Tables

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

Table 2 Summary of Estimated Peak Flows at Mamre Road Crossing

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

List of Figures

Figure 1 Location of Aspect Industrial Estate

Figure 2 Relationship of University of Aspect Industrial Estate to Proposed Precincts

Figure 3 Penrith LEP 2010 Flood Planning Area

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

Figure 5 Layout and Extent of the RMA-2 Hydraulic Model (after Inset A, Figure 5.1, Worley Parsons, 2015)

Figure 6 100 yr ARI Flood Depths and Velocities (after Figures 6.109 & 6.110, Worley Parsons, 2015)

Figure 7 100 yr ARI Hydraulic Categories (after Figures 6.109 & 6.110, Worley Parsons, 2015)

Figure 8 PMF Depths and Velocities (after Figures 6.143 & 6.144 Worley Parsons, 2015)

Figure 9 20 yr ARI, 100 yr ARI and PMF Overland Flow Flood Extents (after Figure 6.1K, Cardno Lawson Treloar, 2006)

Figure 10 Subcatchment Boundaries in the overall Catchment XP-RAFTS model under Existing Conditions

Figure 11 Local Subcatchment Boundaries in AIE XP-RAFTS model under Benchmark Conditions

Figure 12 Location of Farm Dams within the Local Catchment

Figure 13 Adopted Roughness Zones

Benchmark Conditions

Figure 14 2 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

Figure 15 2 yr ARI Flood Depths - Benchmark Conditions

Figure 16 2 yr ARI Flood Velocities - Benchmark Conditions

Figure 17 2 yr ARI Flood Hazards - Benchmark Conditions

List of Figures Continued

Figure 18 5 yr ARI Flood Extents and Flood Levels - Benchmark Conditions
Figure 19 5 yr ARI Flood Depths - Benchmark Conditions
Figure 20 5 yr ARI Flood Velocities - Benchmark Conditions
Figure 21 5 yr ARI Flood Hazards - Benchmark Conditions

Figure 22 100 yr ARI Flood Extents and Flood Levels - Benchmark Conditions
Figure 23 100 yr ARI Flood Depths - Benchmark Conditions
Figure 24 100 yr ARI Flood Velocities - Benchmark Conditions
Figure 25 100 yr ARI Flood Hazards - Benchmark Conditions

Figure 26 200 yr ARI Flood Extents and Flood Levels - Benchmark Conditions
Figure 27 200 yr ARI Flood Depths - Benchmark Conditions
Figure 28 200 yr ARI Flood Velocities - Benchmark Conditions
Figure 29 200 yr ARI Flood Hazards - Benchmark Conditions

Figure 30 500 yr ARI Flood Extents and Flood Levels - Benchmark Conditions
Figure 31 500 yr ARI Flood Depths - Benchmark Conditions
Figure 32 500 yr ARI Flood Velocities - Benchmark Conditions
Figure 33 500 yr ARI Flood Hazards - Benchmark Conditions

Figure 34 PMF Flood Extents and Flood Levels - Benchmark Conditions
Figure 35 PMF Flood Depths - Benchmark Conditions
Figure 36 PMF Flood Velocities - Benchmark Conditions
Figure 37 PMF Flood Hazards - Benchmark Conditions

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 Elizabeth Enterprise Precinct is indicated in **Figure 1**.

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*

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.

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**.

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 2020 Flood Prone Land Package

As advised on the DPIE website (https://www.planning.nsw.gov.au/Policy-and-Legislation/Managing-risk-in-land-use-planning/Flooding):

> *The Department has been working to update the Flood Prone Land Package which provides advice to councils on considering flooding in land use planning and consists of:*
>
> - *a proposed amendment to schedule 4, section 7A of the Environmental Planning and Assessment Regulation 2000*

- *a revised planning circular*
- *a revised local planning direction regarding flooding issued under section 9.1 of the Environmental Planning and Assessment Act 1979*
- *revised Local Environmental Plan flood clauses*
- *a new guideline: Considering Flooding in Land Use Planning (2020).*

The updated Flood Prone Land Package was on exhibition until **25 June 2020.**

As described by BMT Eastern Australia, 2020:

> *The overarching theme of this documentation is the application of risk-based land use planning controls, that consider flood risk up to the full range of flood magnitude event up to the Probable Maximum Flood (PMF). This includes increased consideration of flood behaviour and impacts above the 1% Annual Exceedance Probability (AEP) which has typically defined Flood Planning Areas (land subject to flood related development controls) and setting of Flood Planning Levels for proposed development.*

1.3.4 State Environmental Planning Policy (Western Sydney Employment Area) 2009

Current version for 11 June 2020 to date

The site is located in the Mamre Road Precinct (MRP) was rezoned on 12 June 2020.

The State Environmental Planning Policy (Western Sydney Employment Area) 2009 (SEPP (WSEA)) was amended and the Mamre Road Structure Plan was introduced.

The aims of the SEPP (WSEA) are set out in Part 1 Preliminary as follows:

3 Aims of Policy

*(1) This Policy aims to protect and enhance the land to which this Policy applies (the **Western Sydney Employment Area**) for employment purposes.*

(2) The particular aims of this Policy are as follows—

(a) to promote economic development and the creation of employment in the Western Sydney Employment Area by providing for development including major warehousing, distribution, freight transport, industrial, high technology and research facilities,

(b) to provide for the co-ordinated planning and development of land in the Western Sydney Employment Area,

(c) to rezone land for employment, environmental conservation or recreation purposes,

(d) to improve certainty and regulatory efficiency by providing a consistent planning regime for future development and infrastructure provision in the Western Sydney Employment Area,

(e) to ensure that development occurs in a logical, environmentally sensitive and cost-effective manner and only after a development control plan (including specific development controls) has been prepared for the land concerned,

(f) to conserve and rehabilitate areas that have a high biodiversity or heritage or cultural value, in particular areas of remnant vegetation.

The relevant primary considerations are set out in 33I Development on flood prone land under Part 6 Miscellaneous provisions.

33I Development on flood prone land

(1) This clause applies to development requiring consent that is carried out on flood prone land.

The SEPP (WSEA) defines ***flood prone land*** means land impacted up to the level of the probable maximum flood and identified in a map adopted by the relevant council or published by the Government. It is noted that the while the 2020 WSEA Maps includes a map of 1 in 100 AEP Flood Extent it does not include a map titled flood prone land.

The Penrith LEP 2010 includes Flood Planning Land Maps defining the Flood Planning Area (FPA) (refer **Figure 3).** The site is not located within the mapped flood extent in the 2020 WSEA map nor in the Flood Planning Area under the Penrith LEP 2010.

(2) Consent is not to be granted to the carrying out of development to which this clause applies unless the consent authority has taken into consideration whether or not

(a) the development will adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(b) the development will alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain, and

(c) the development will enable safe occupation of the flood prone land, and

(d) the development will detrimentally affect the floodplain environment or cause avoidable erosion, siltation, salinity, destruction of riparian vegetation or a reduction in the stability of the riverbank/watercourse, and

(e) the development will be likely to result in unsustainable social and economic costs to the flood affected community or general community, as a consequence of flooding, and

(f) the development is compatible with the flow conveyance function of the floodway, and

(g) the development is compatible with the flood hazard, and

(h) in the case of development consisting of the excavation or filling of land, the development—

(i) will detrimentally affect the existing drainage patterns and soil stability in the locality, and

(ii) will adversely impact or alter flood behaviour.

Note. *Clause 33H contains other matters that the consent authority must consider before granting development consent for earthworks.*

1.3.5 NSW Flood Risk Management Framework

As described by Jacobs, 2016:

NSW FRM Policy and Guidelines

The NSW Flood Prone Land Policy as produced within Section 1.1 of the Floodplain Development Manual (FDM 2005) is consistent with that first introduced in 1984, which places the primary responsibility for implementation on local councils. Penrith City Council has adopted the principles and recommendations in the 2005 FDM and applied them to the plans and policies they have implemented.

The primary objective of the NSW Flood Prone Land Policy recognises the following two important facts:

- flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development; and
- if all development applications and proposals for rezoning of flood prone land are assessed according to rigid and prescriptive criteria, some appropriate proposals may be unreasonably disallowed or restricted, and equally, quite inappropriate proposals may be approved.

The primary objective is as follows:

> "*To reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.*"

The flood study for South Creek was completed in 2015 and Penrith City Council is currently finalising the South Creek Floodplain Risk Management Study and Plan. A Draft South Creek Floodplain Risk Management Study and Plan, was placed on public exhibition by Council from Thursday 31 October to Thursday 28 November 2019.

2007 Flood Planning Guideline

On January 31, 2007 the NSW Planning Minister announced a new guideline for development control on floodplains (the "Flood Planning Guideline"). An overview of the new Guideline and associated changes to the Environmental Planning and Assessment Act, 1979 (EPA Act) and Environmental Planning and Assessment Regulation 2000 (Regulation) was issued by the Department of Planning in a Circular dated January 31, 2007 (Reference PS 07-003). The Flood Planning Guideline issued by the Minister in effect relates to a package of directions and changes to the EPA Act, Regulation and the FDM.

This Flood Planning Guideline provides an amendment to the Manual. The Guideline confirms that unless there are "exceptional circumstances", Councils are to adopt the 100 year ARI flood as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Guideline does provide that controls on residential development above the 100 year ARI flood may be imposed subject to an "exceptional circumstance" justification being agreed to by the Department of Natural Resources (now the Office of Environment and Heritage - OEH) and the Department of Planning (now the Department of Planning and Environment) prior to the exhibition of a Draft LEP or Draft DCP.

The "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual" defines Standards for Flood Controls for Residential Development. Whilst the flood used to define the residential FPL is a decision of Council, FDM highlights that FPLs for typical residential development would generally be based on the 100 year ARI flood plus an appropriate freeboard (typically 0.5m). Penrith City Council has adopted these recommendations provided in the guideline.

State Environmental Planning Policies

A State Environmental Planning Policy (SEPP) is a planning document prepared in accordance with the EPA Act by the NSW Department of Planning and Environment and eventually approved by the Minister, which deals with matters of significance for environmental planning for the State. Clause 1.19 of the Codes SEPP has been amended so that land identified as 'flood control lot' is no longer excluded from the application of the General Housing Code.

Instead, specified development and development standards have been added to the General Housing Code for development on low hazard flood control lots. The development standards have been designed to ensure that complying development is not allowed on high hazard or high risk flood control lots including floodways, flood storage areas, a flowpath or areas identified in local flood plans as high hazard or high risk.

Section 117 Directions

Ministerial directions pursuant to Section 117(2) of the EPA Act specify matters which local councils must take into consideration in the preparation of LEPs. Direction 4.3, as currently applies, deals specifically with flood [liable] prone land and has the following two objectives:

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

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

The Direction applies to all councils that contain flood prone land when an LEP proposes to "*create, remove or alter a zone or provision that affects flood prone land*." In such cases, the Direction requires draft LEPs to ensure the following:

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

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

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

a. permit development in floodway areas,

b. permit development that will result in significant flood impacts to other properties,

c. permit a significant increase in the development of that land,

d. are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or

> e. *permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

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

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

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.

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
	0.0005	0.05	2000	2000
Extreme	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

2.1 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 km² 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 5**. As indicated in Figure 5, 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 6**.

The 100 yr ARI hydraulic categories mapped in the 2015 study downstream of the site are plotted in **Figure 7**.

The PMF depths and velocities mapped in the 2015 study downstream of the site are plotted in **Figure 8.**

2.2 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.

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 10**. 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 11**.

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.

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 12.** 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.

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 11**.

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 13**.

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. 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.

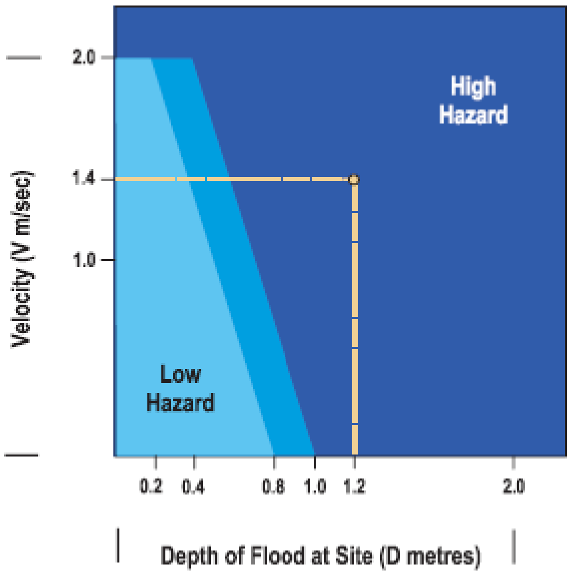
4.1 Benchmark Conditions

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 14, 15** and **16** 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 17**.

4.1.2 5 yr ARI

The estimated 5 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted in **Figures 18, 19, 20** and **21** respectively.

4.1.3 100 yr ARI

The estimated 100 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted in **Figures 22, 23, 24** and **25** respectively.

4.1.4 200 yr ARI

The estimated 200 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted in **Figures 26 27, 28** and **29** respectively.

4.1.5 500 yr ARI

The estimated 500 year ARI flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted in **Figures 30, 31, 32** and **33** respectively.

4.1.6 PMF

The estimated PMF flood levels and extent, depths, velocities and hazards under Benchmark Conditions are plotted in **Figures 34, 35, 36** and **37** respectively.

5 References

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

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

Cardno
Shaping the Future

Figure 1 Location of Aspect Industrial Estate

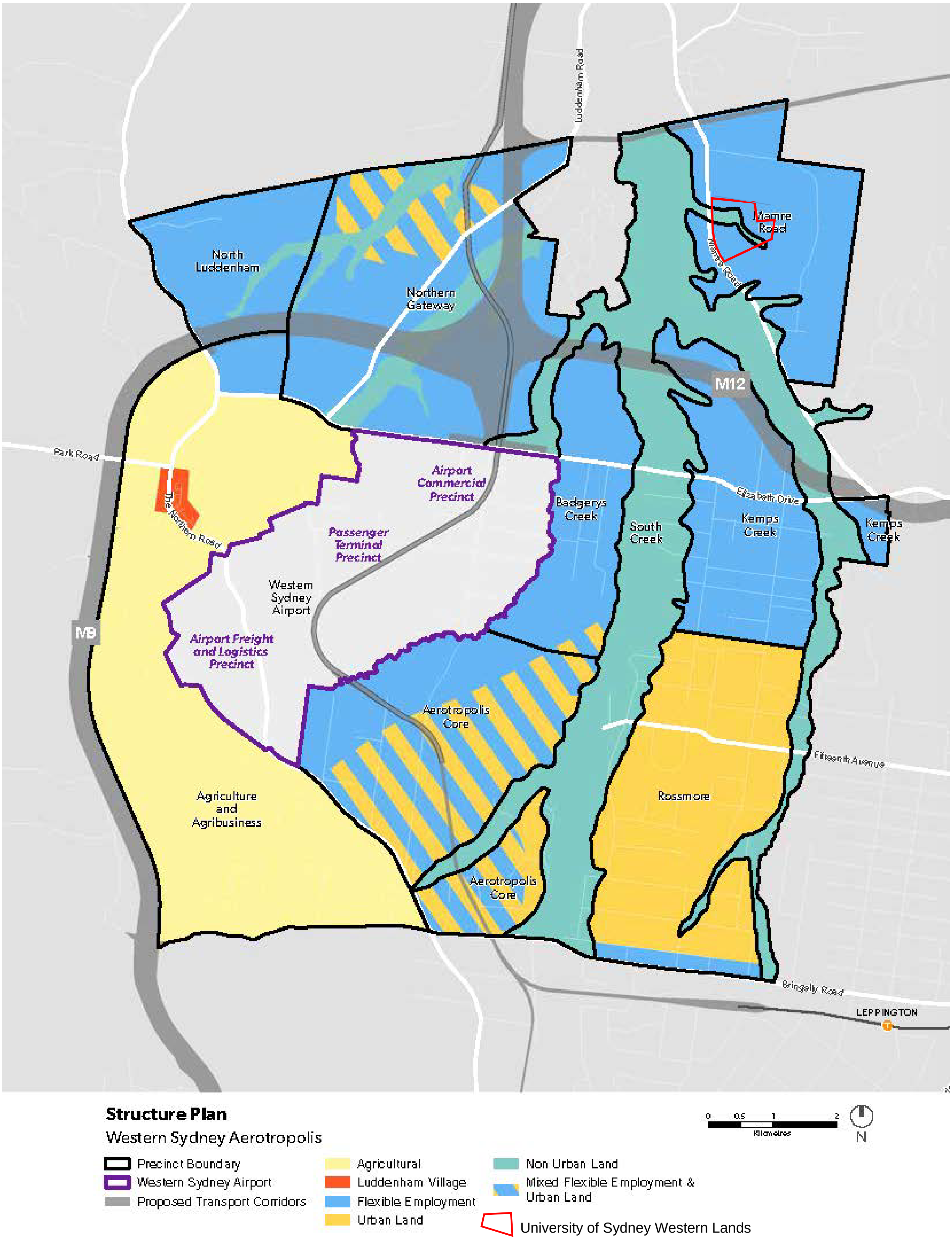


Figure 2 Relationship of University of Aspect Industrial Estate to Proposed Precincts

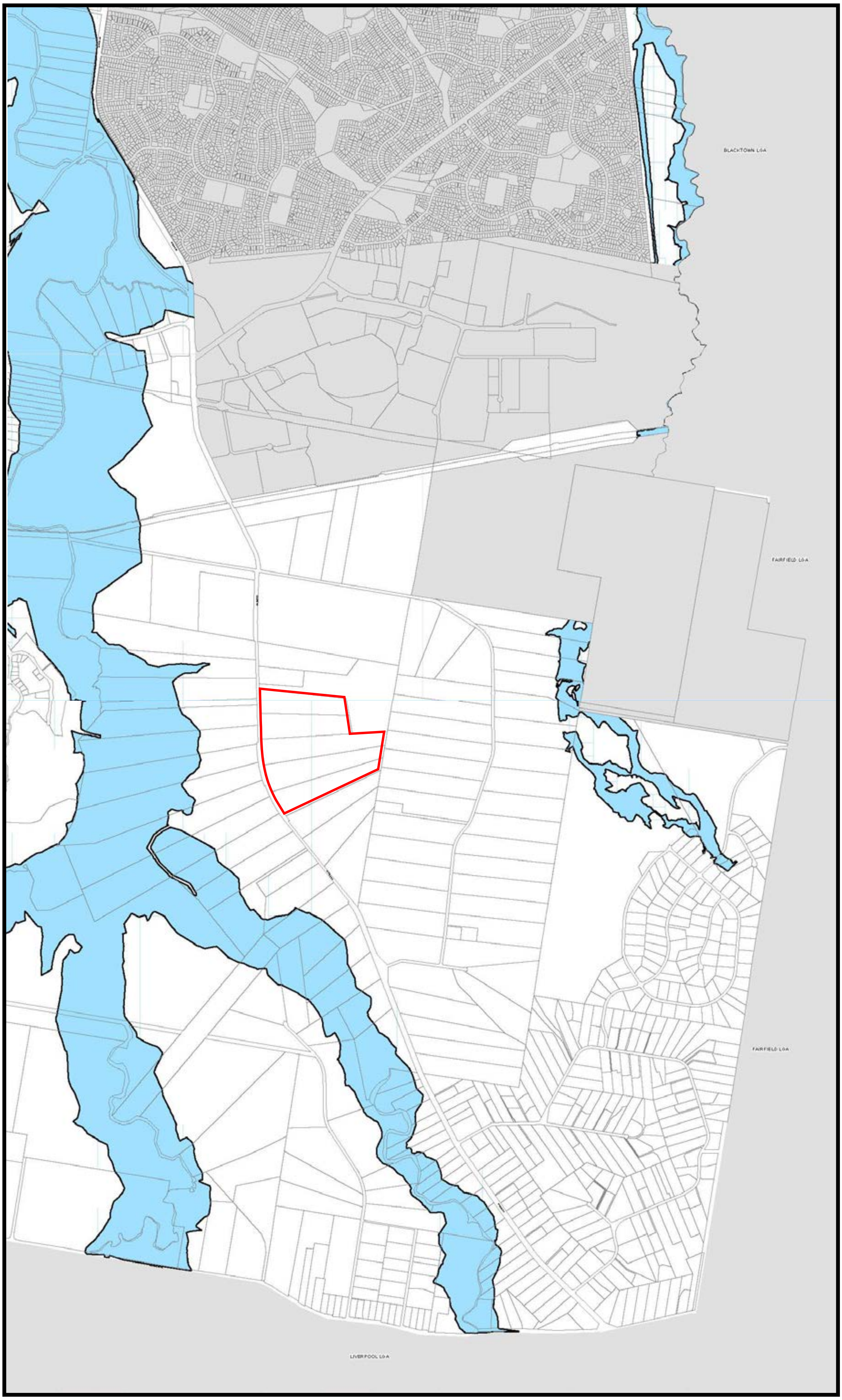


Figure 3 Penrith LEP 2010 Flood Planning Area

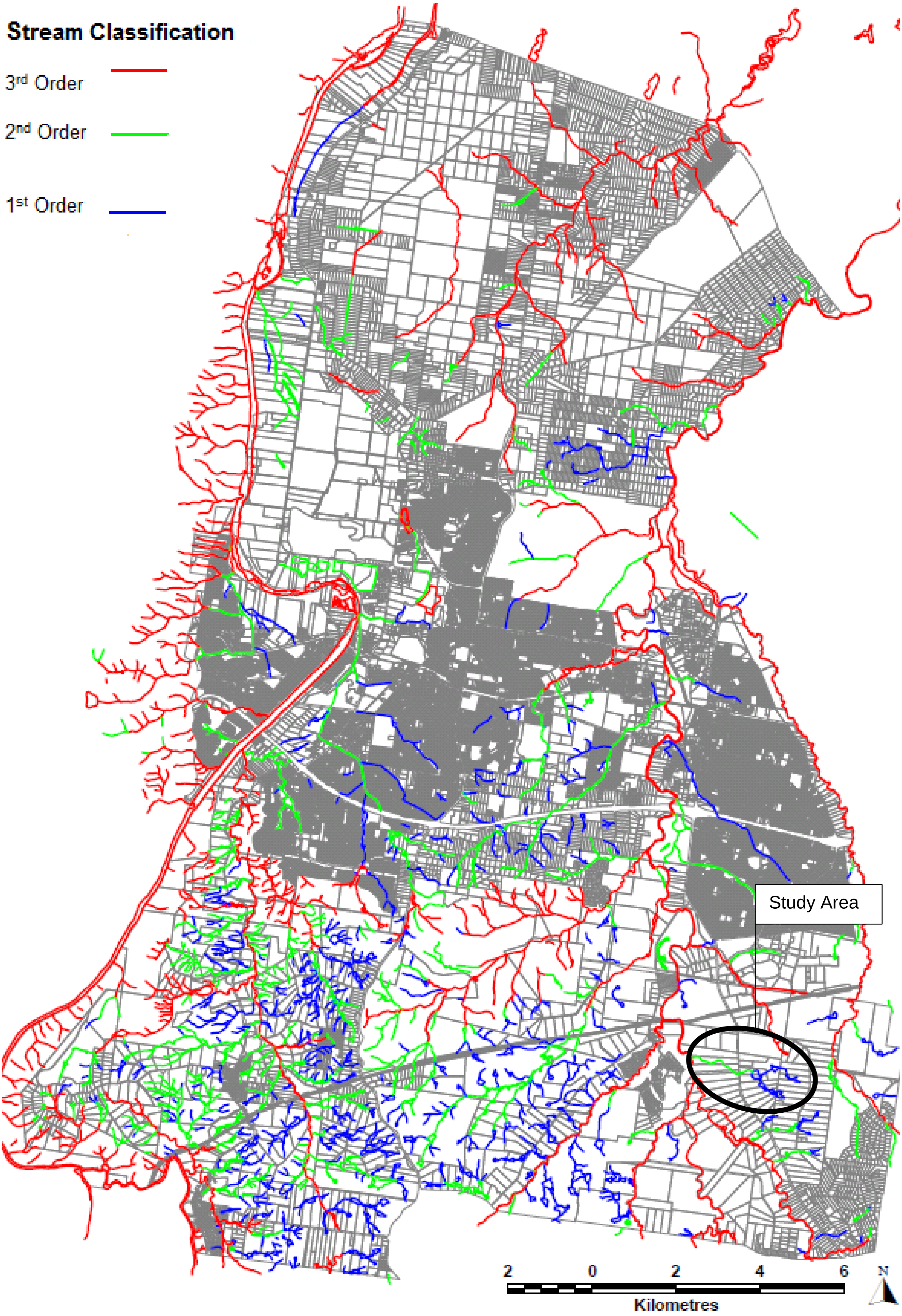


Figure 4 Stream Classification (after Figure C3.2, Penrith DCP 2014)

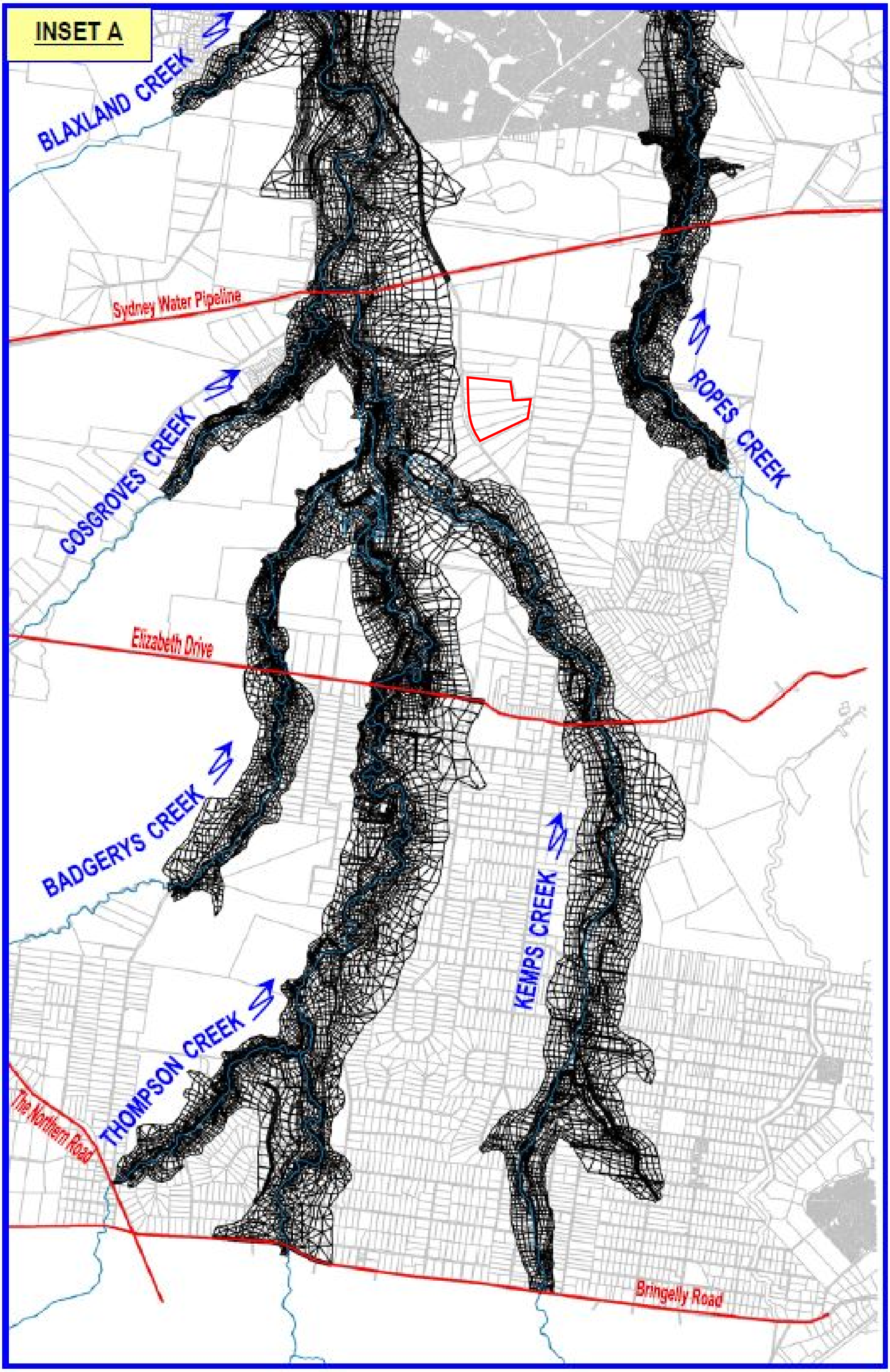


Figure 5 Layout and Extent of the RMA-2 Hydraulic Model (after Inset A, Figure 5.1, Worley Parsons, 2015)

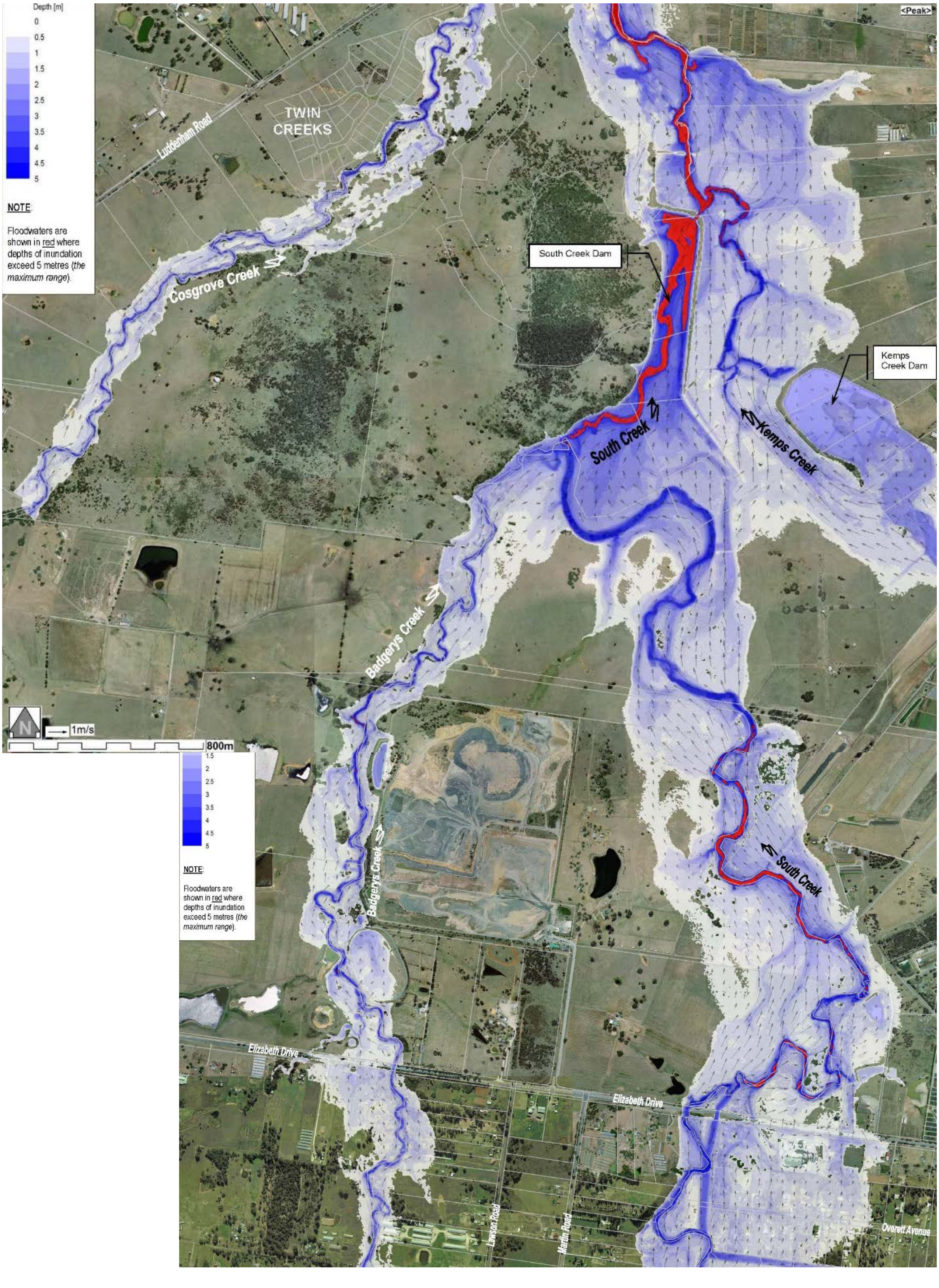


Figure 6 100 yr Flood Depths and Velocities (after Figures 6.109 & 6.110, Worley Parsons, 2015)

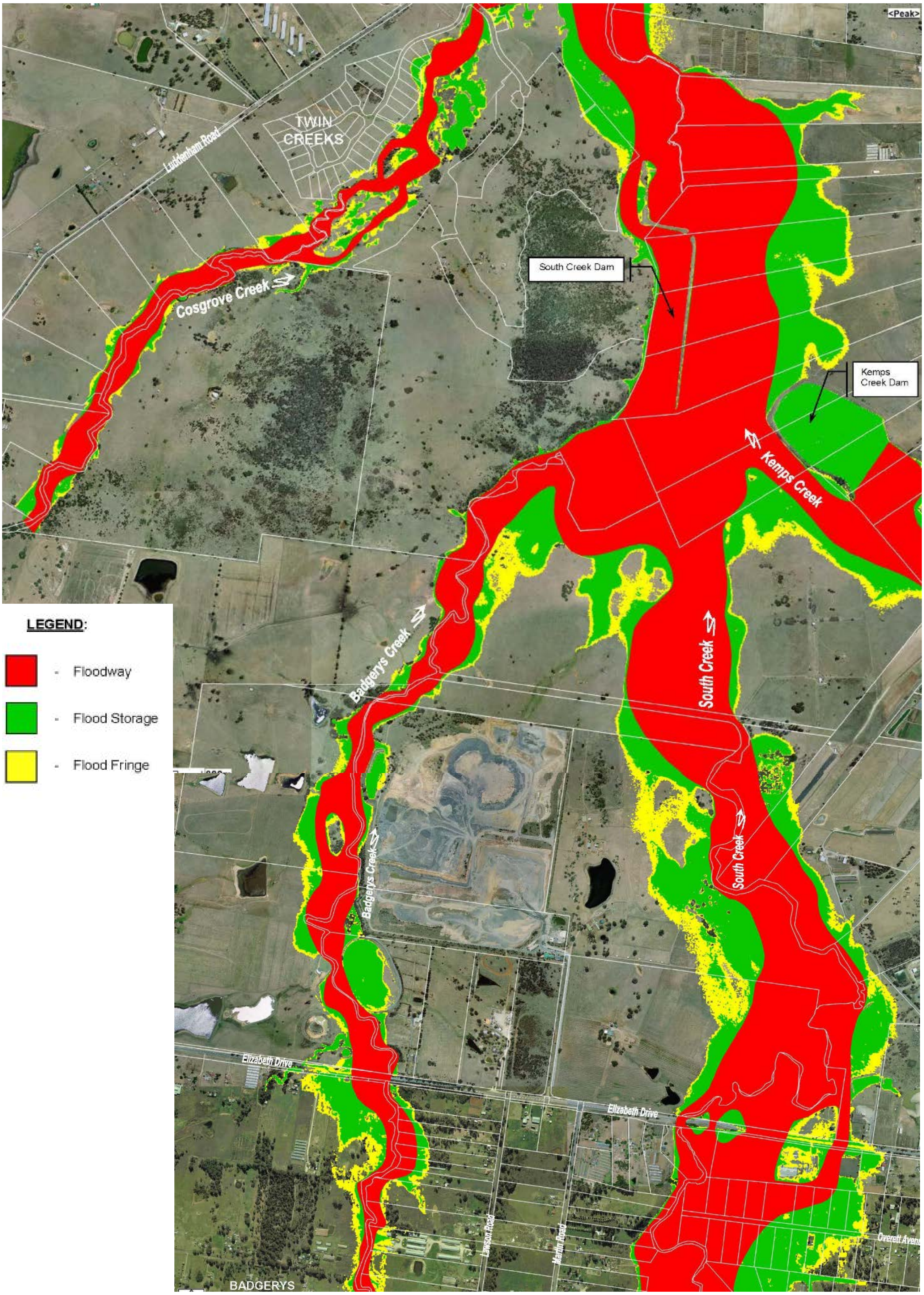


Figure 7 100 yr Hydraulic Categories (after Figures 6.109 & 6.110, Worley Parsons, 2015**)**

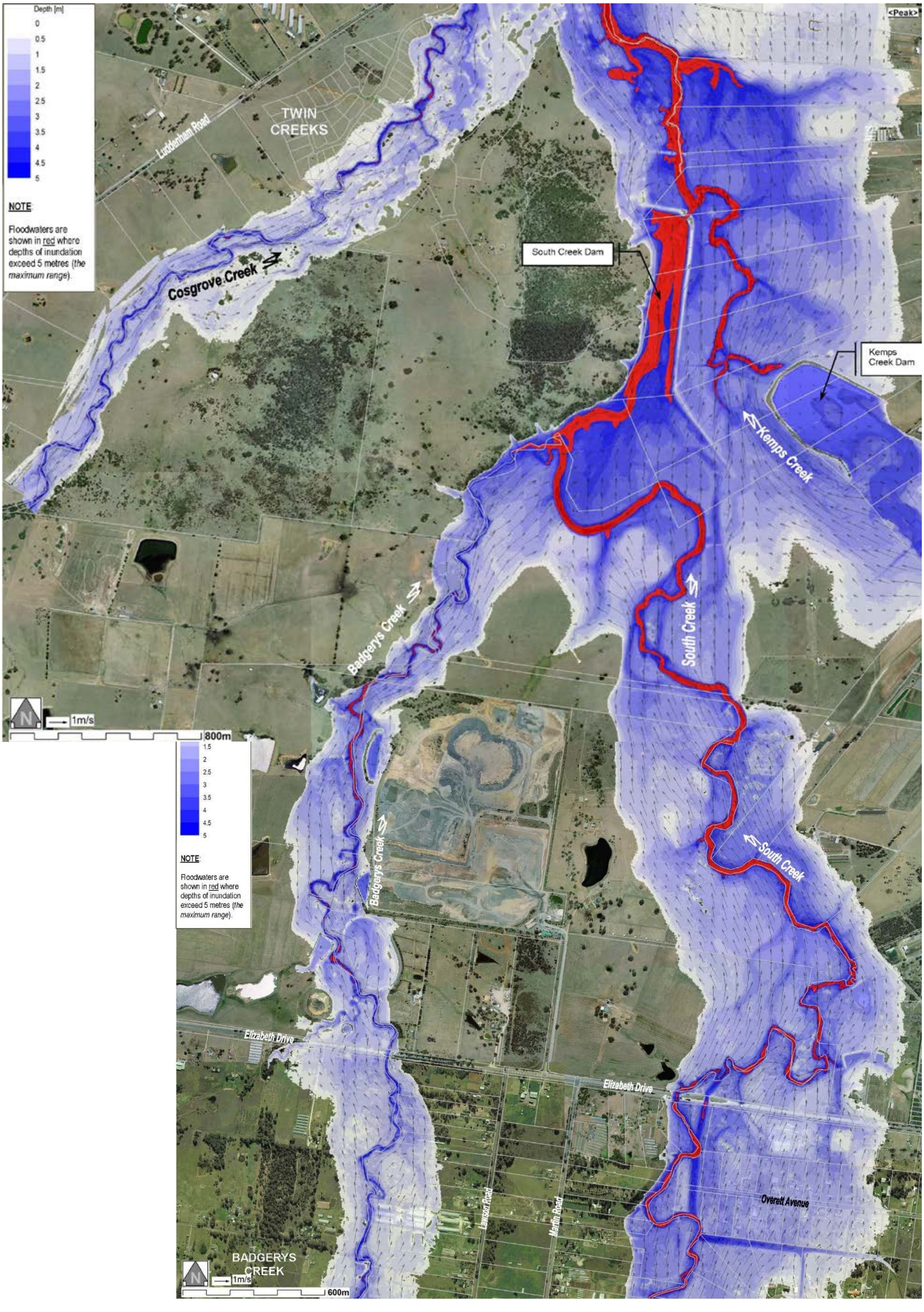


Figure 8 PMF Depths and Velocities (after Figures 6.143 & 6.144, Worley Parsons, 2015)

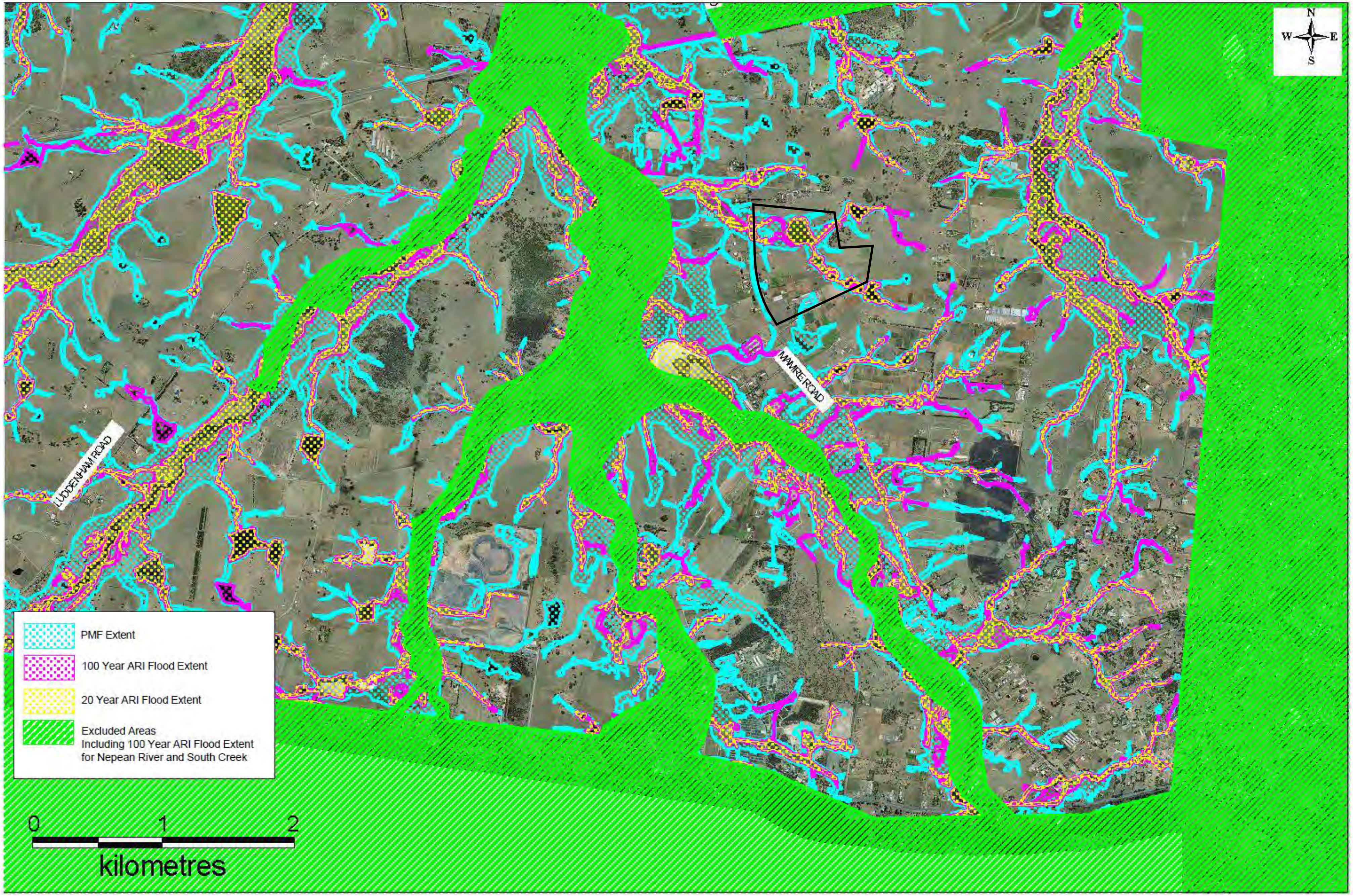


Figure 9 20 yr ARI, 100 yr ARI and PMF Overland Flow Flood Extents (after Figure 6.1K, Cardno Lawson Treloar, 2006)

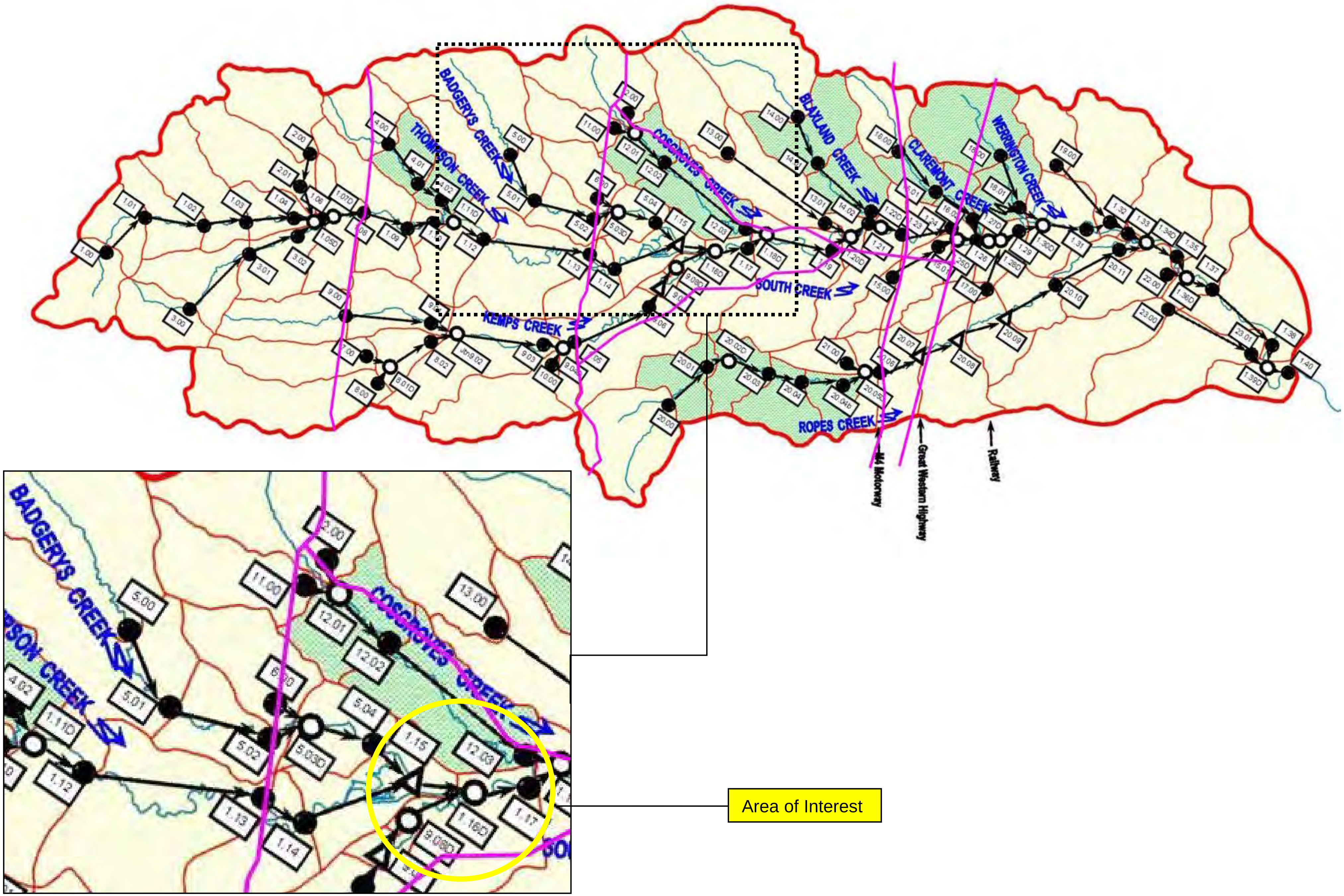


Figure 10 Subcatchment Boundaries in the overall Catchment XP-RAFTS model under Existing Conditions

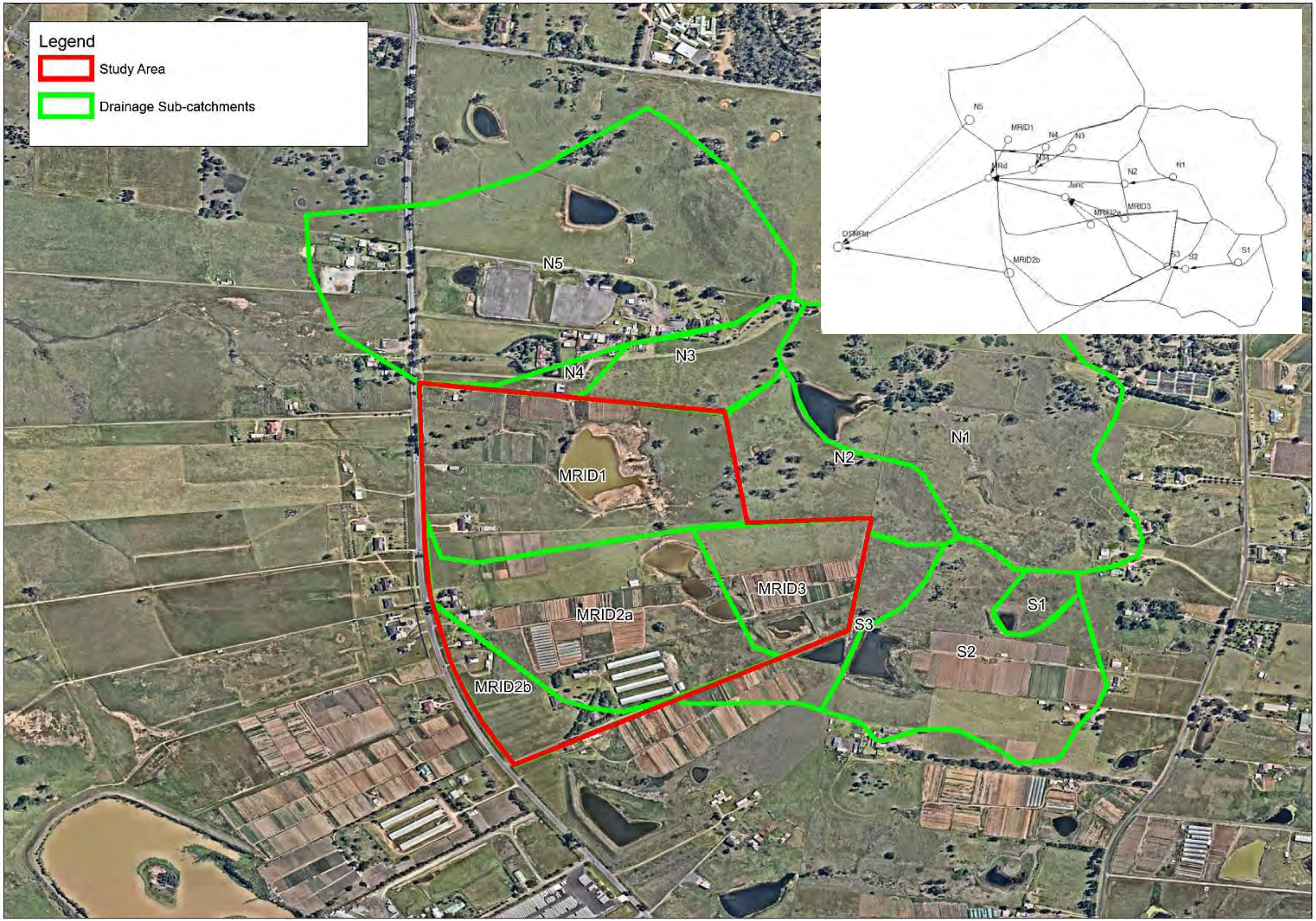


Figure 11 Local Subcatchment Boundaries in AIE XP-RAFTS model under Benchmark Conditions

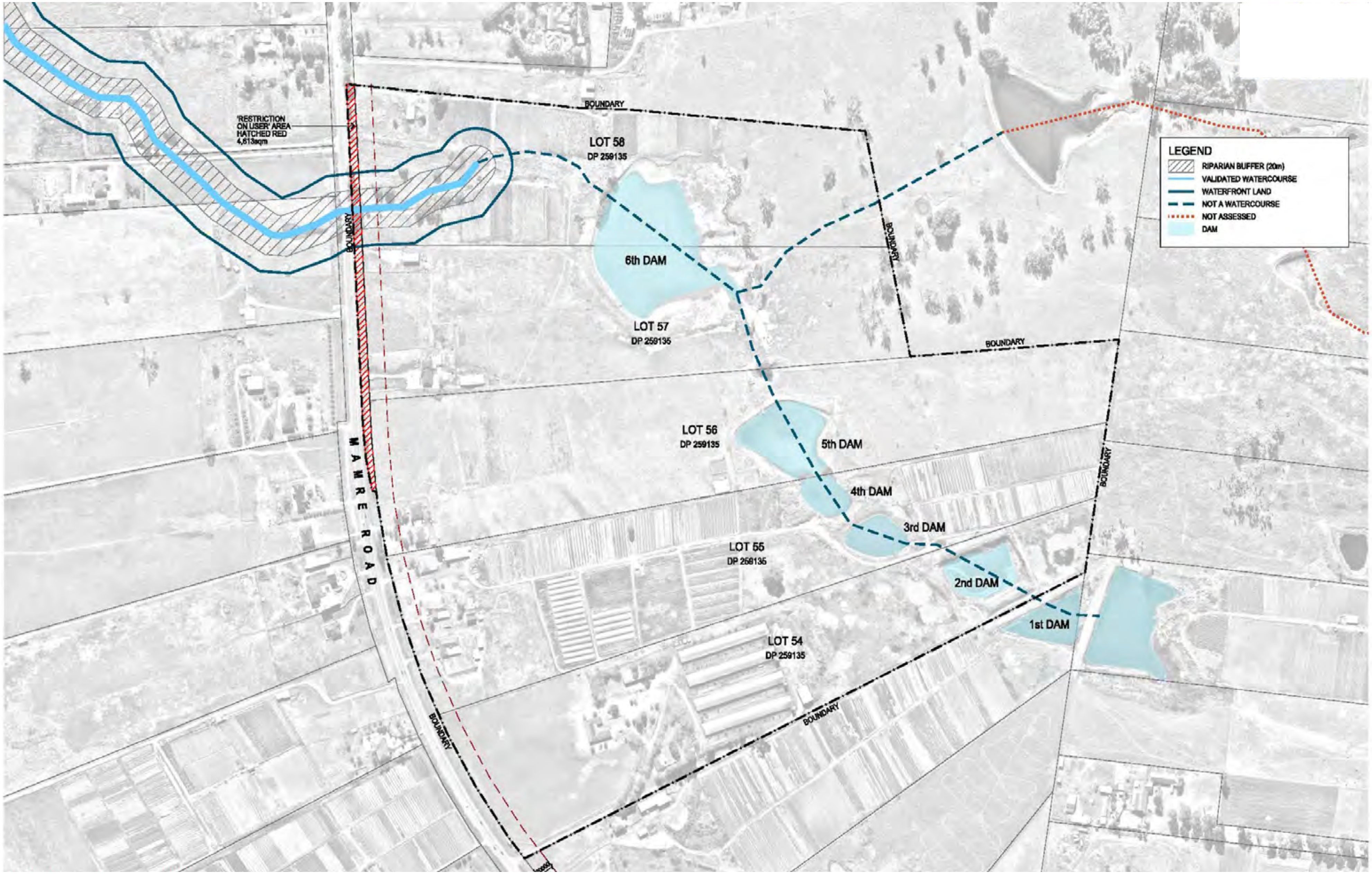


Figure 12 Location of Farm Dams within the Local Catchment

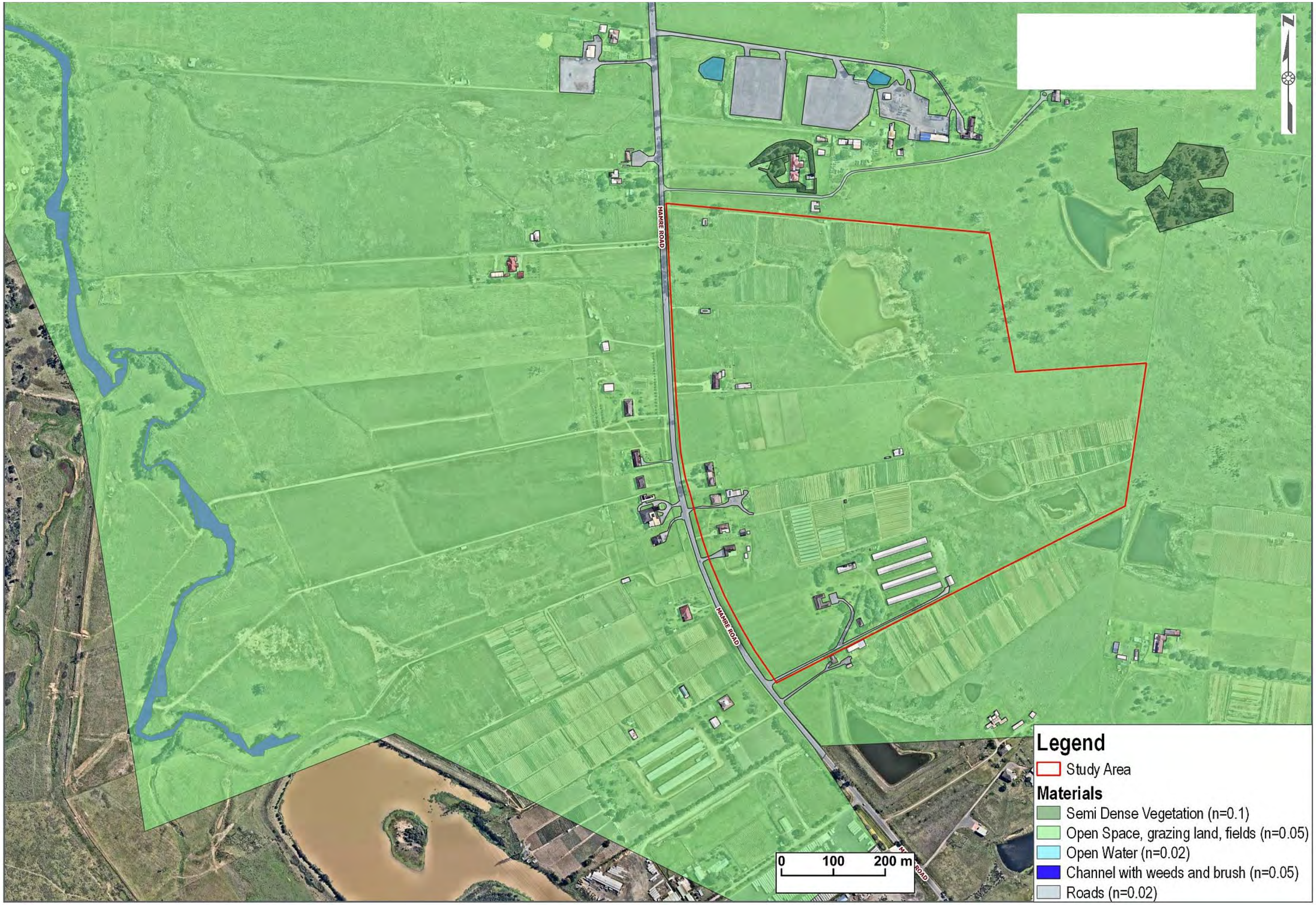


Figure 13 Adopted Roughness Zones

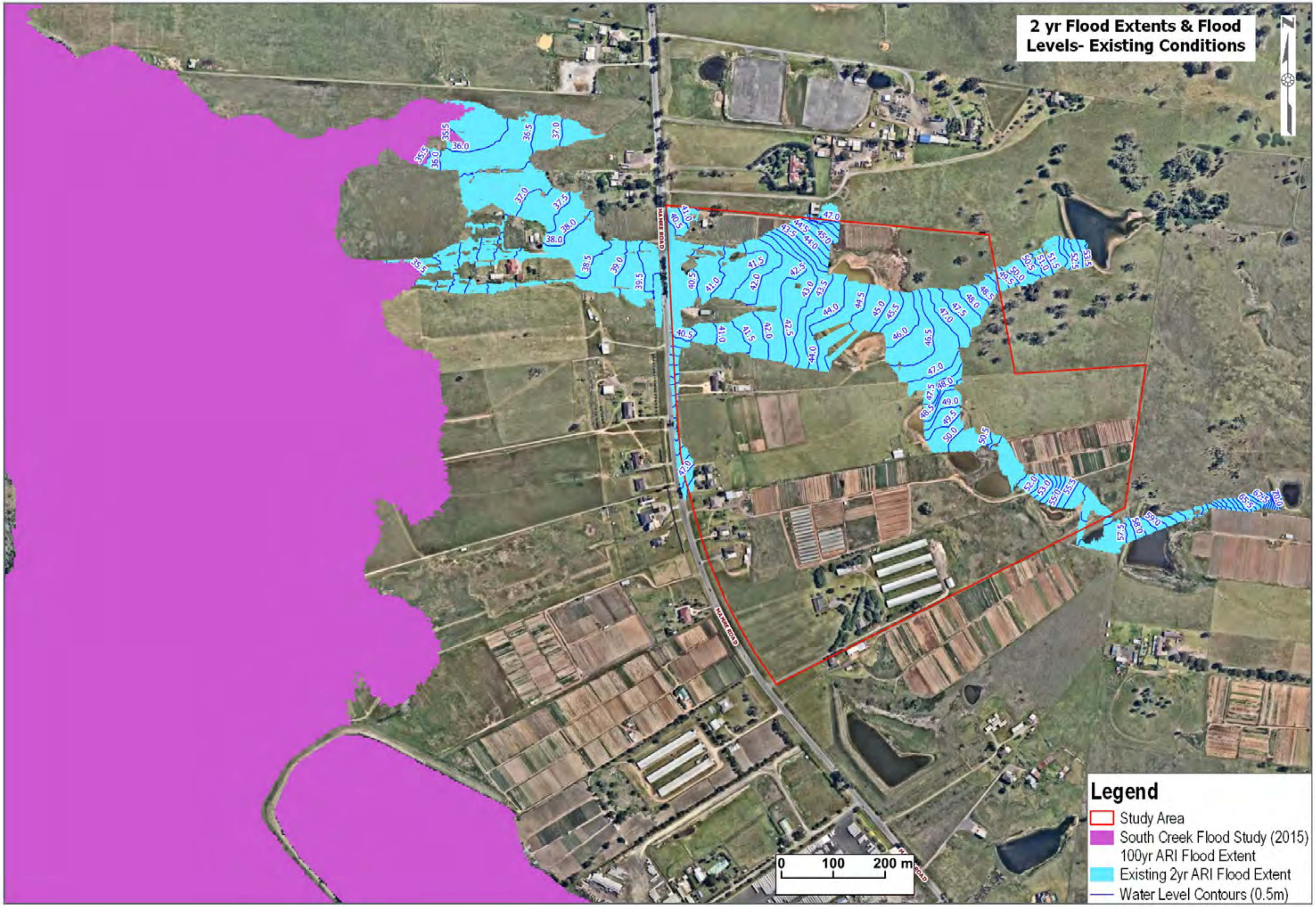


Figure 14 2 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

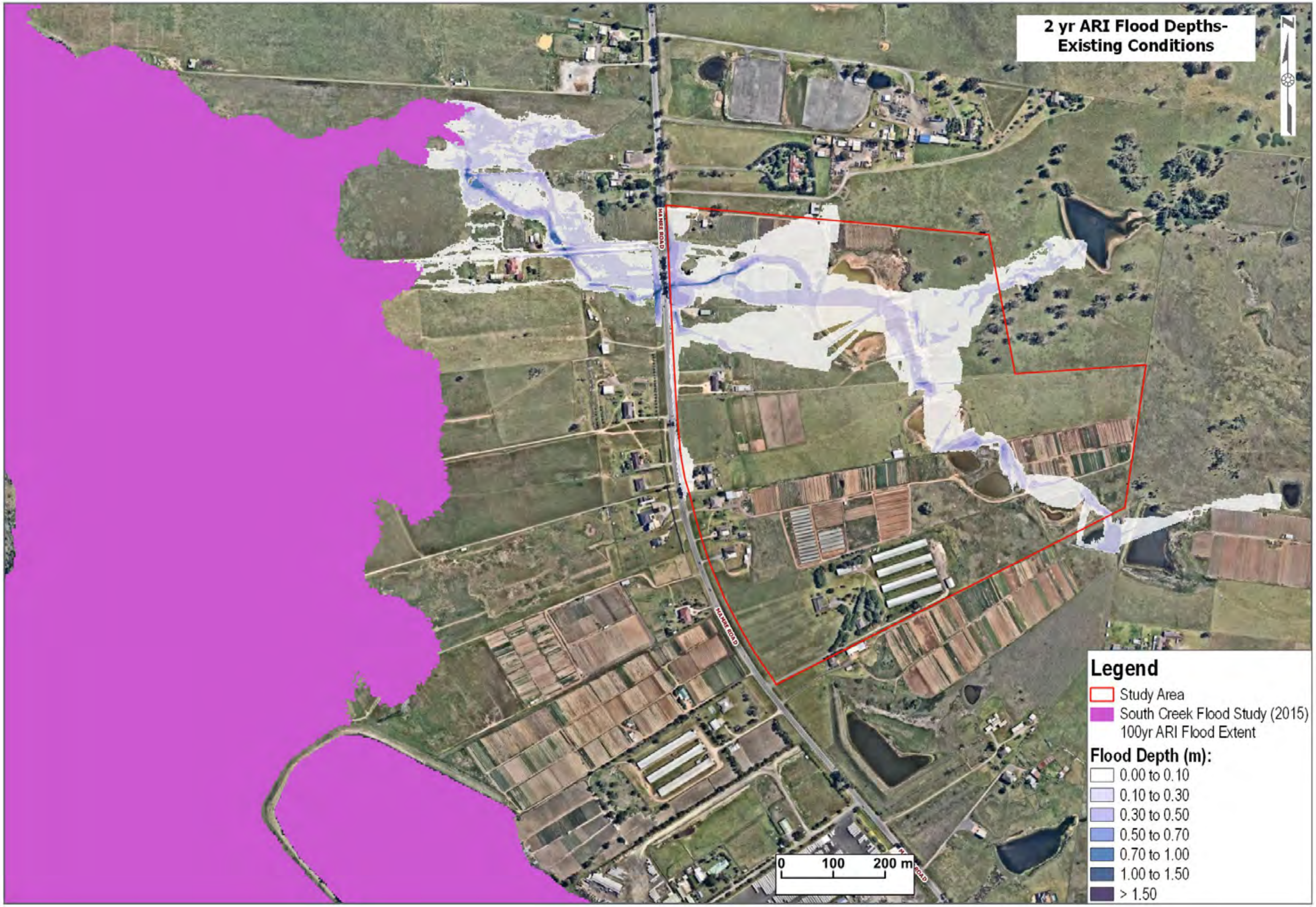


Figure 15 2 yr ARI Flood Depths - Benchmark Conditions

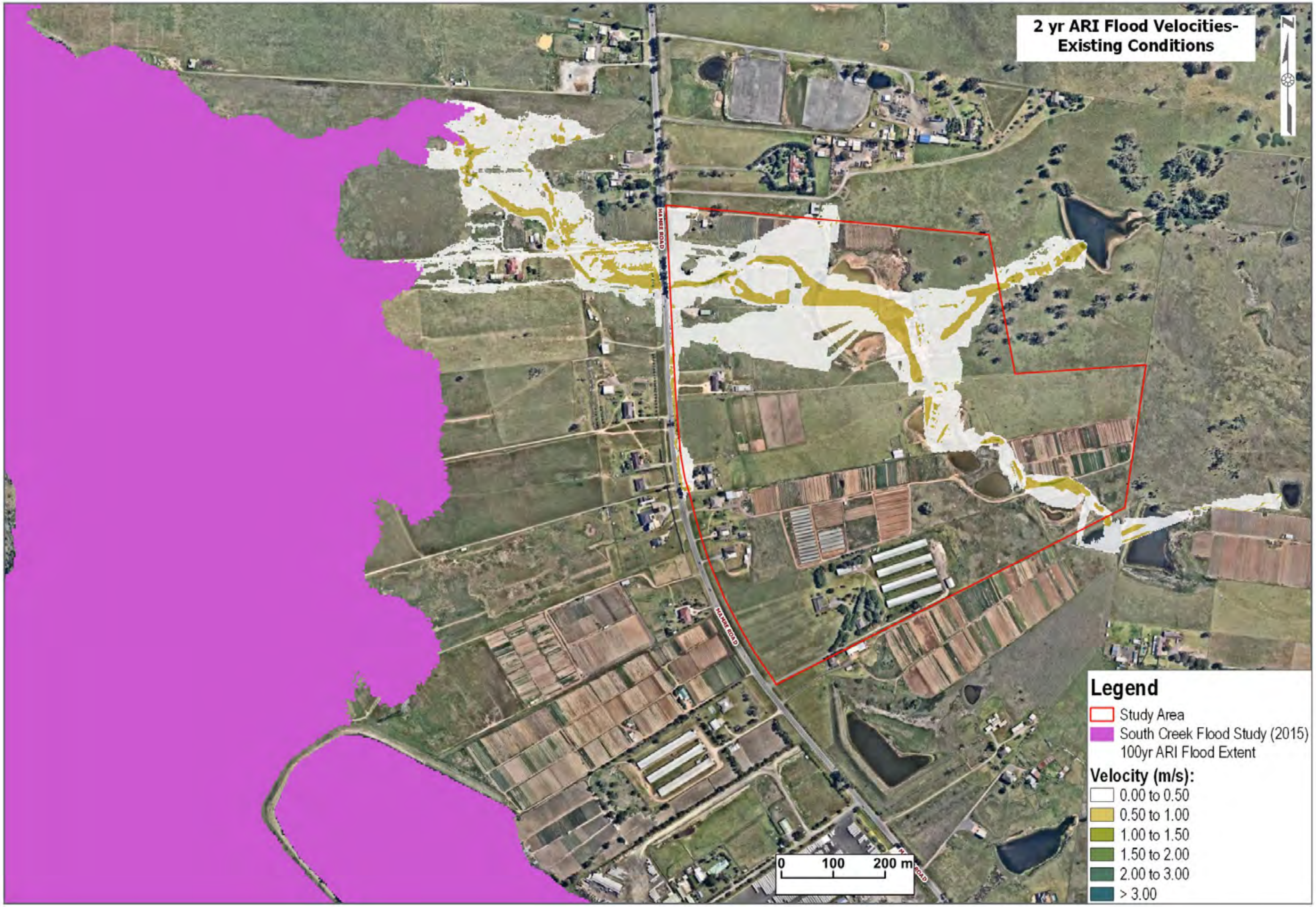


Figure 16 2 yr ARI Flood Velocities - Benchmark Conditions

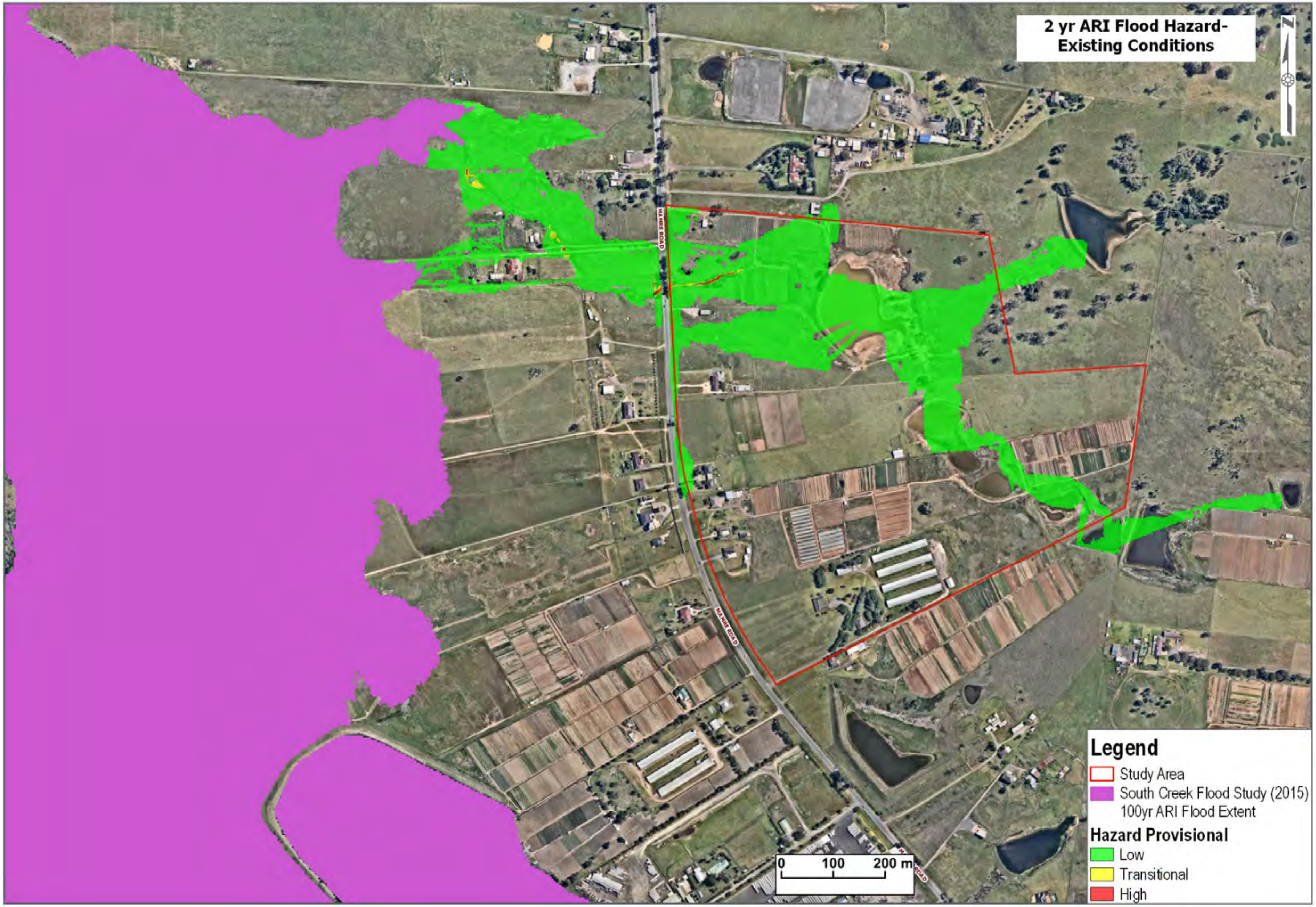


Figure 17 2 yr ARI Flood Hazards - Benchmark Conditions

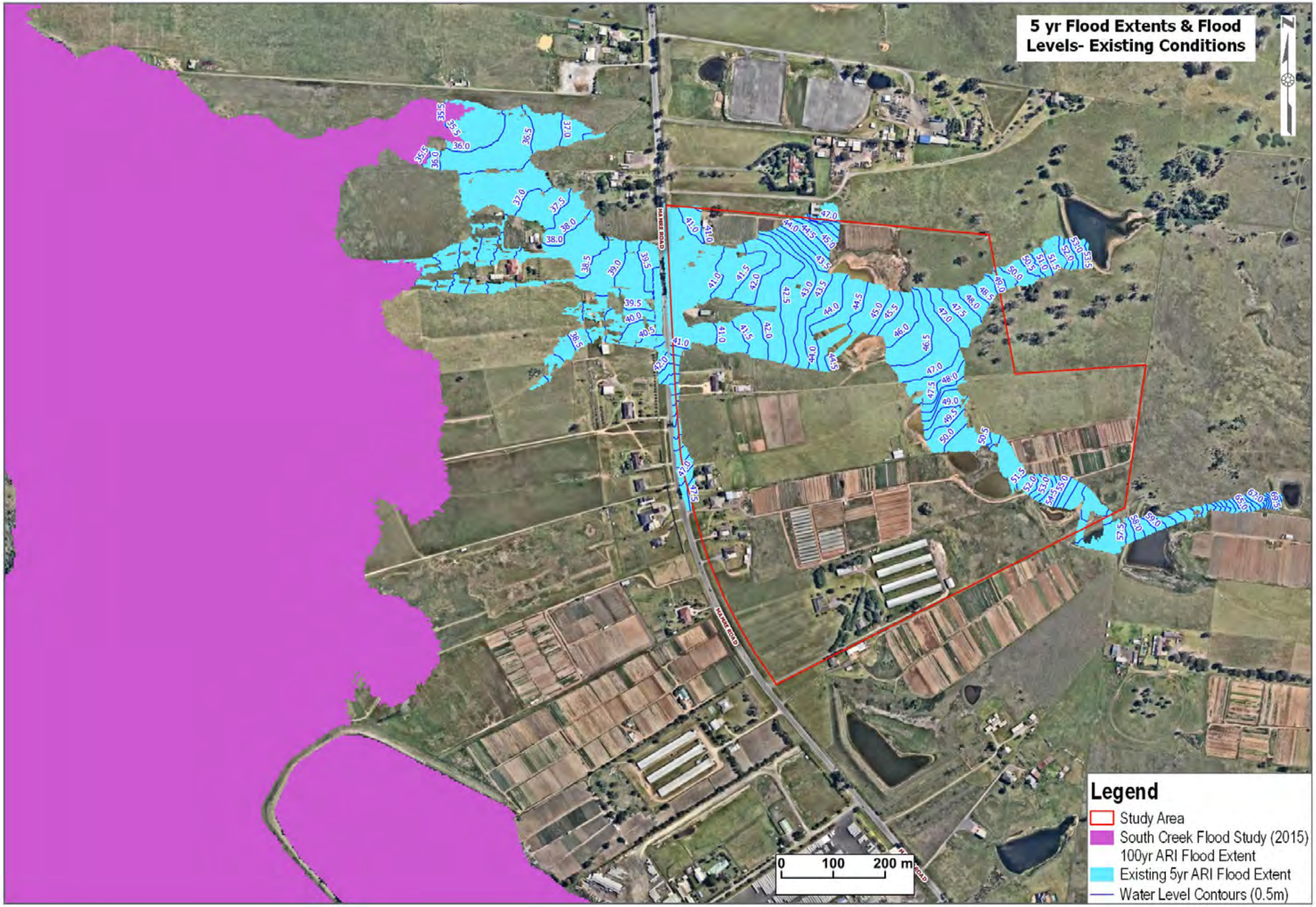


Figure 18 5 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

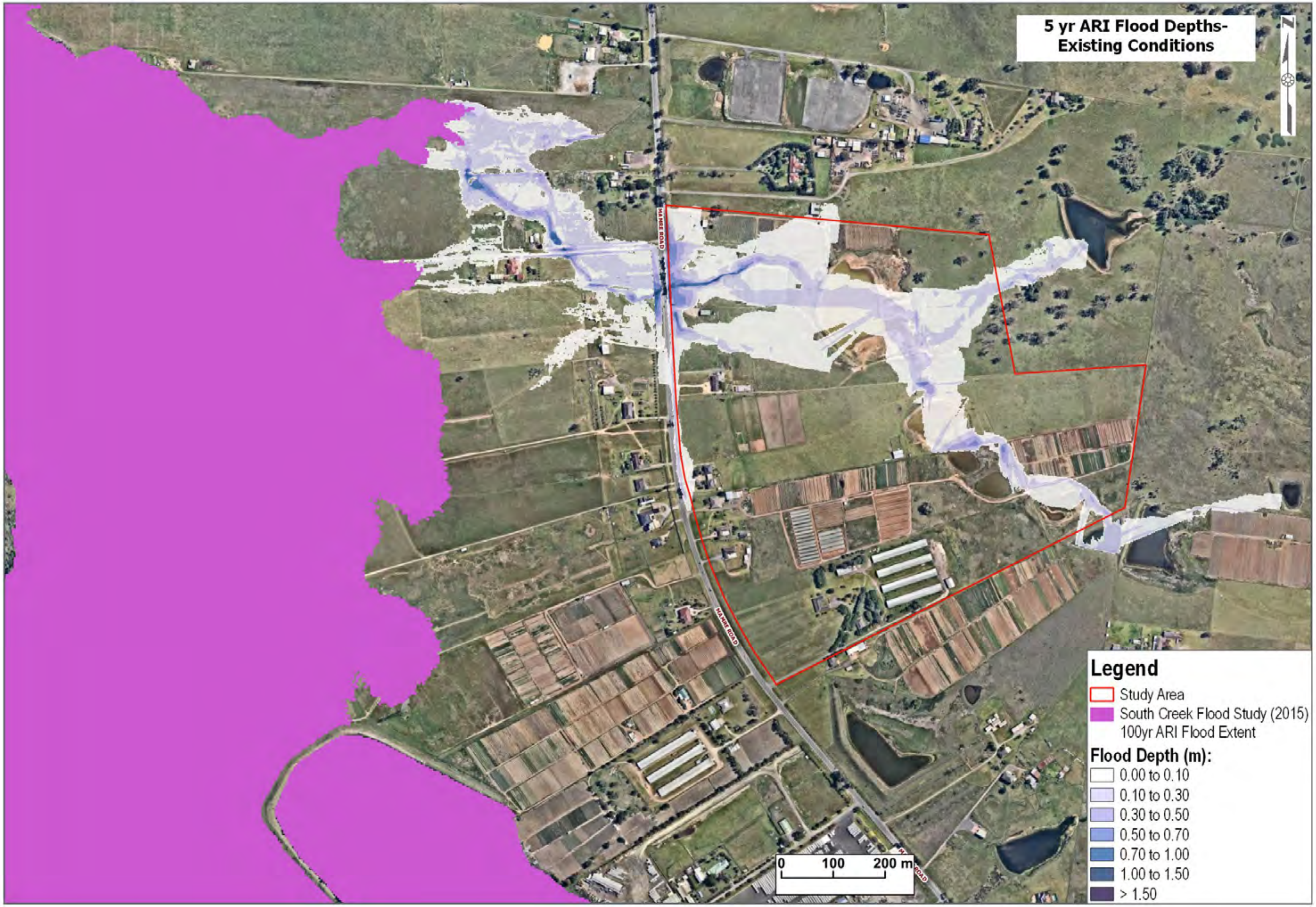


Figure 19 5 yr ARI Flood Depths - Benchmark Conditions

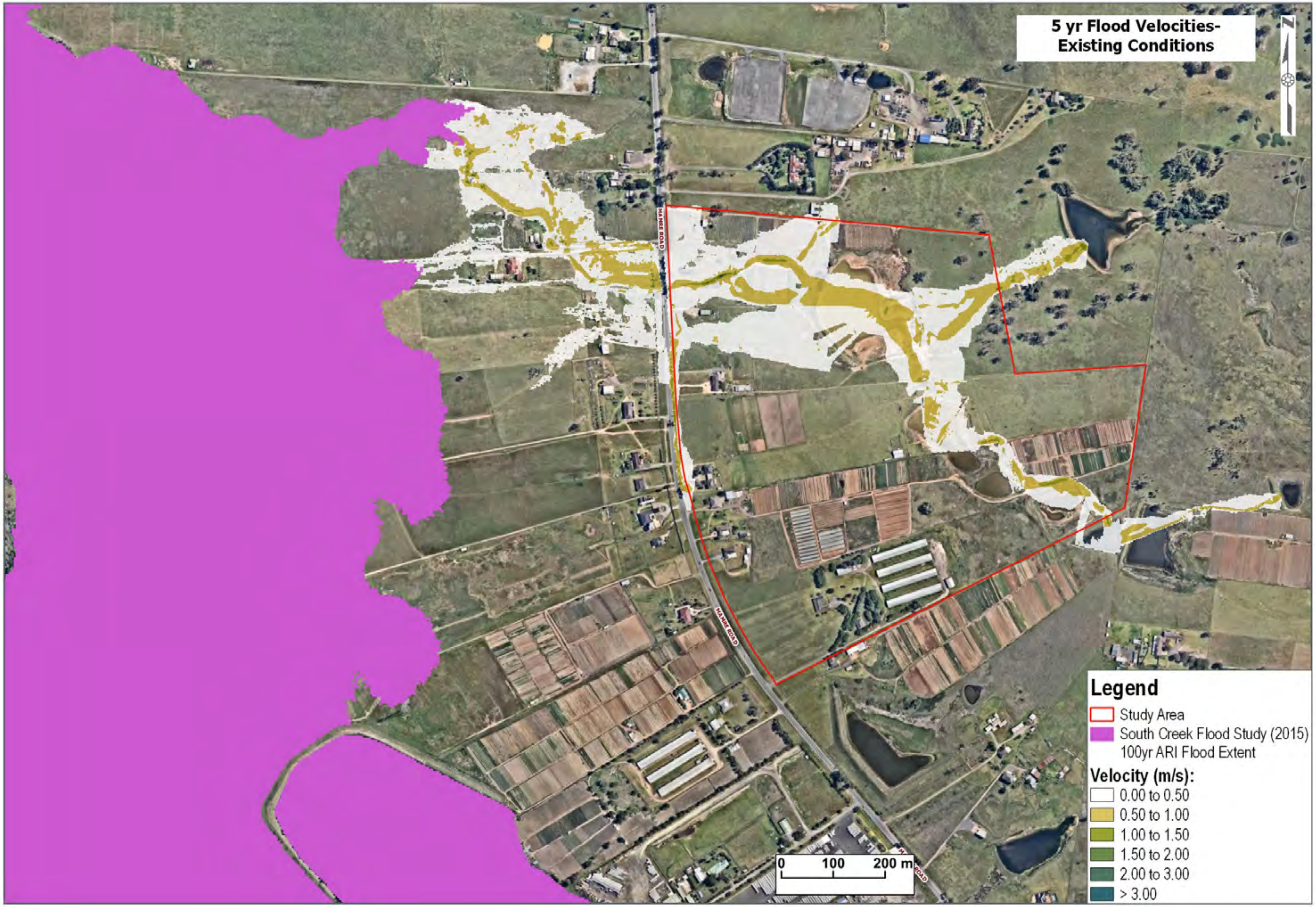


Figure 20 5 yr ARI Flood Velocities - Benchmark Conditions

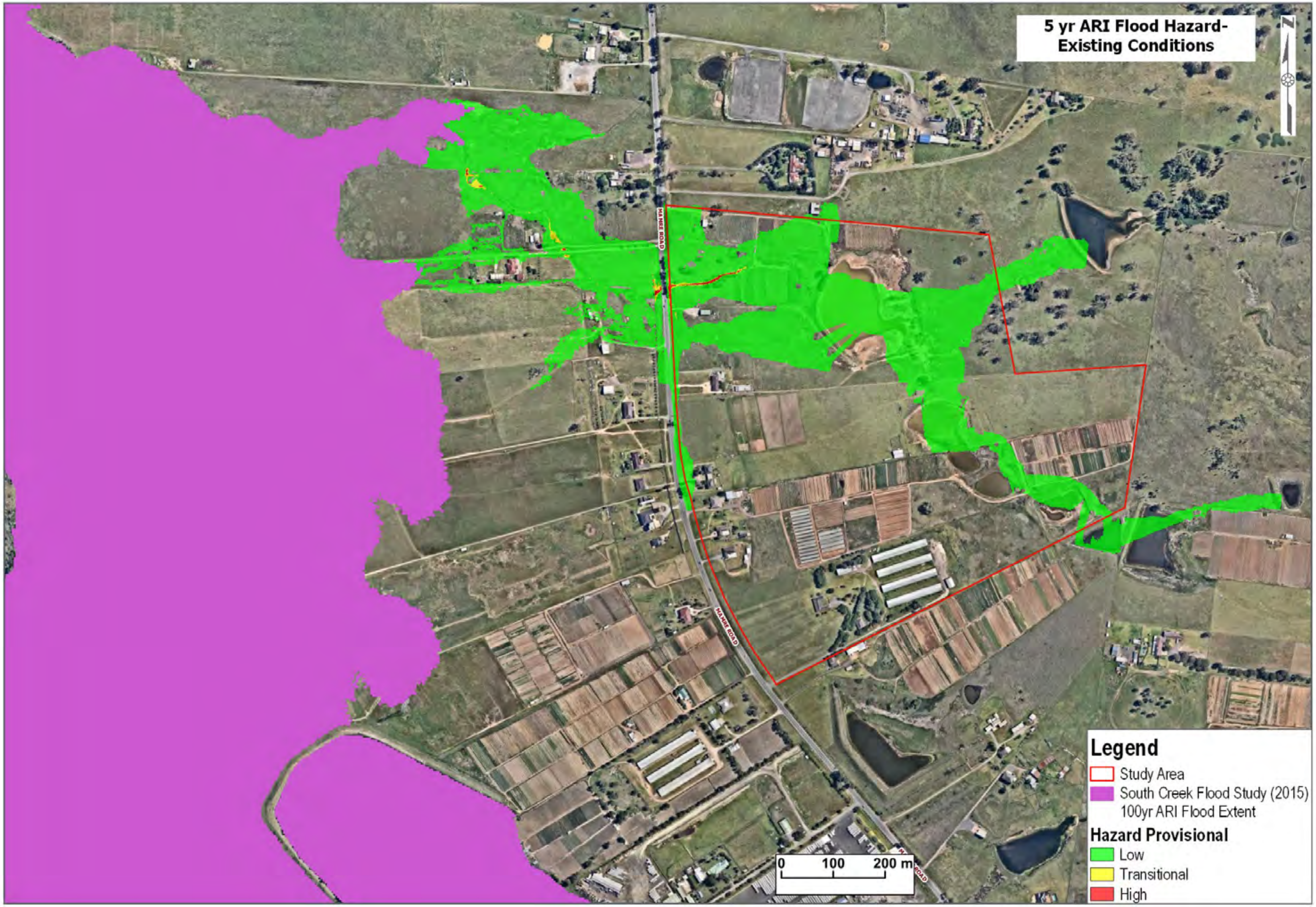


Figure 21   5 yr ARI Flood Hazards - Benchmark Conditions

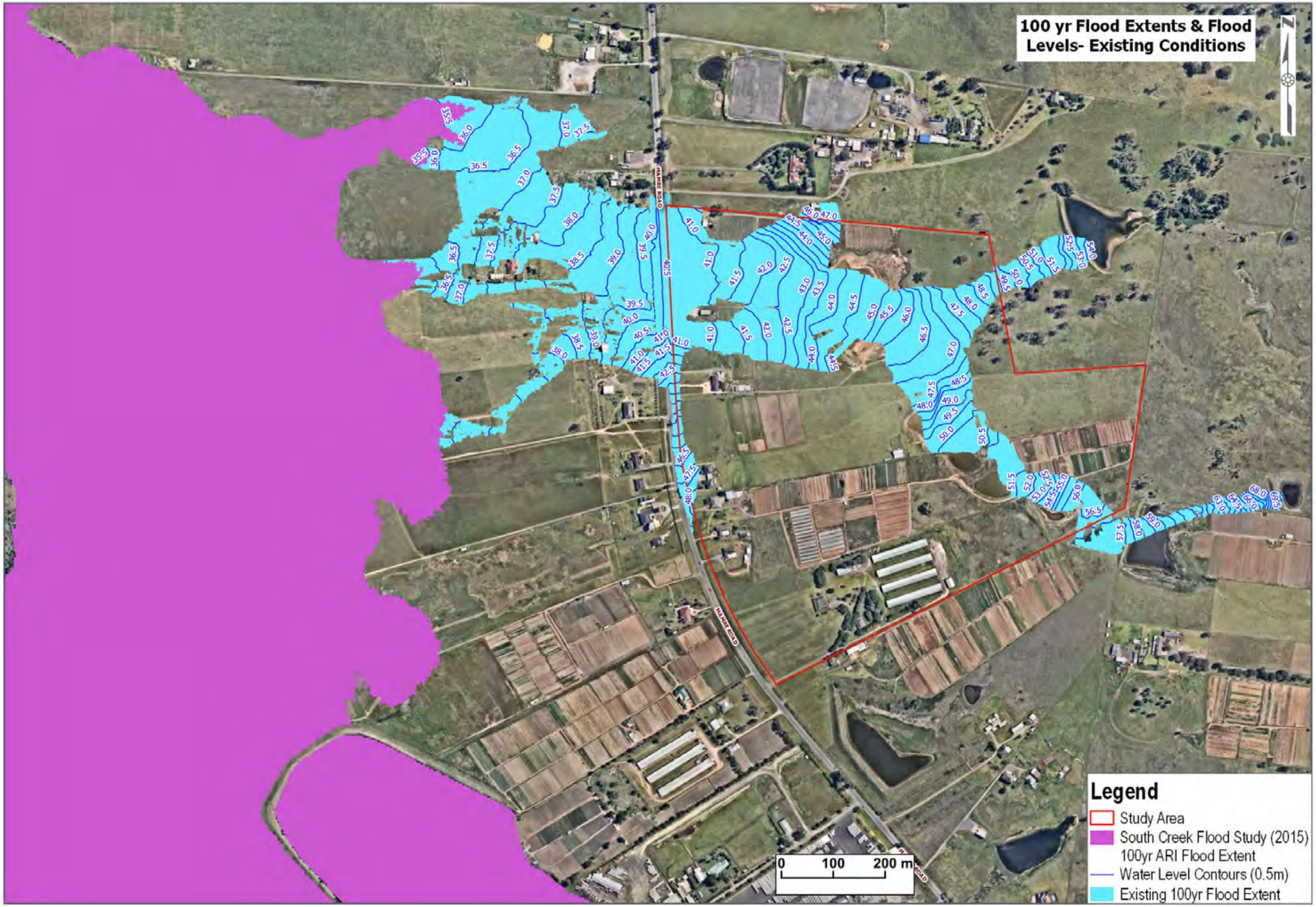


Figure 22 100 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

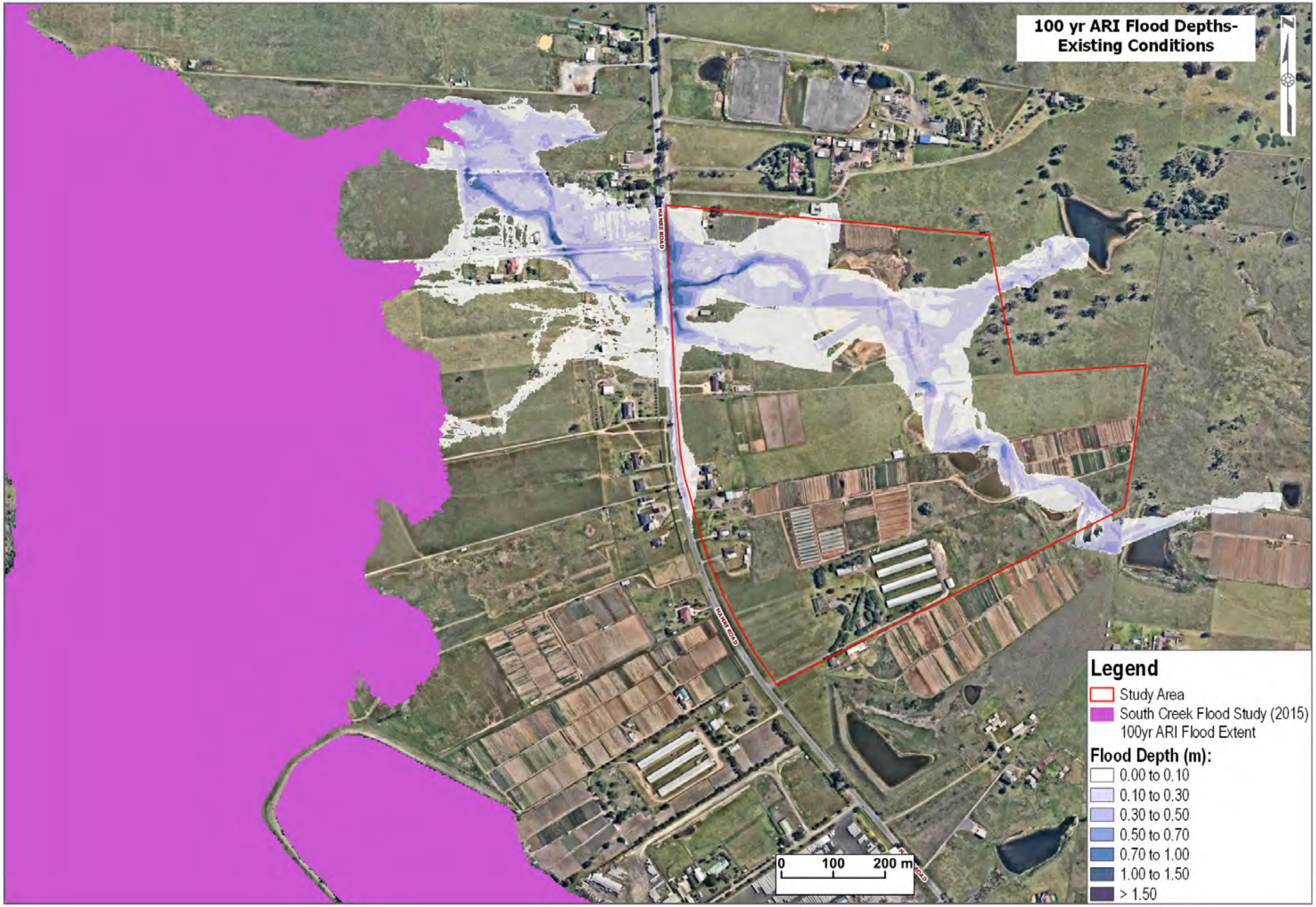


Figure 23 100 yr ARI Flood Depths - Benchmark Conditions

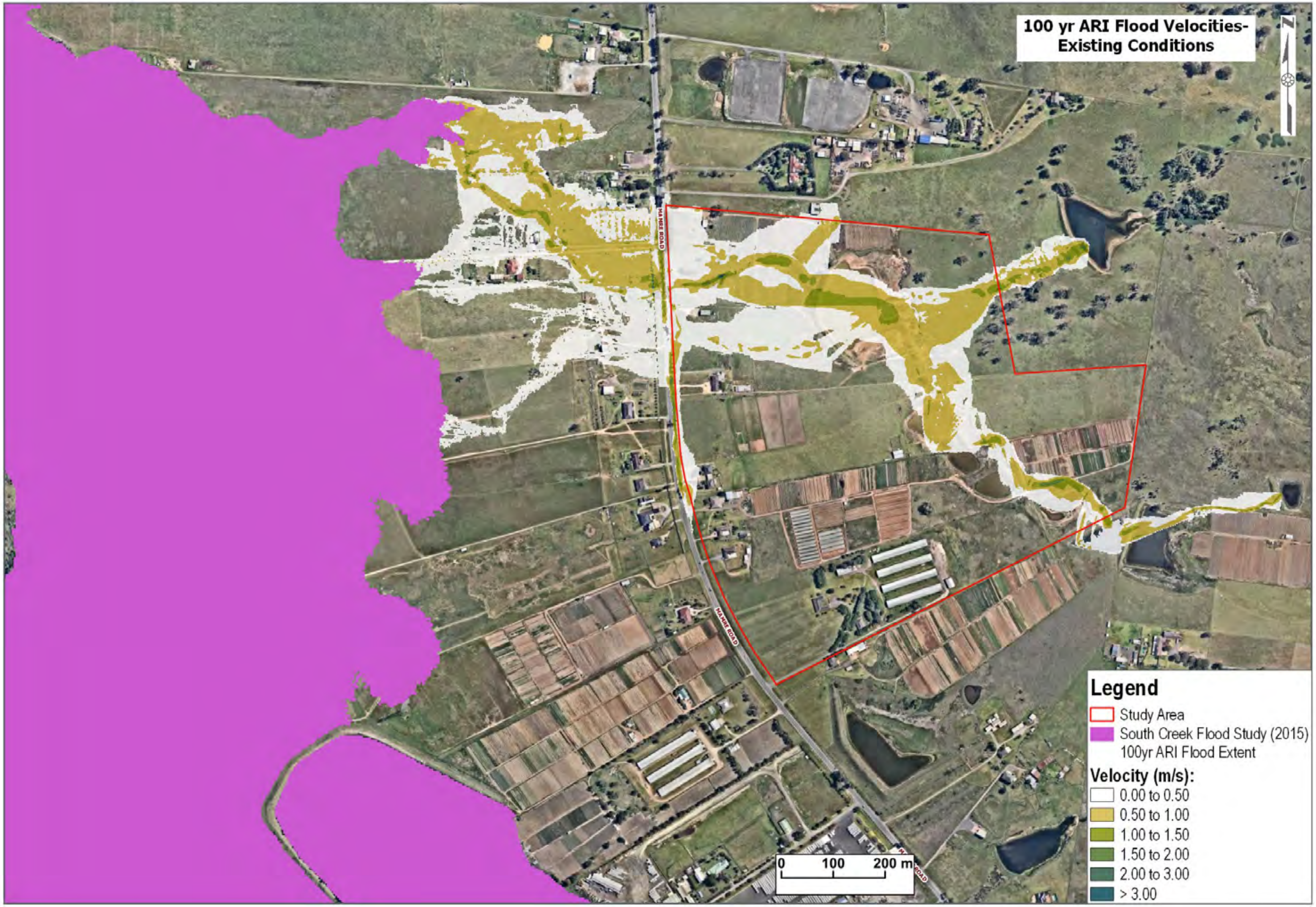


Figure 24 100 yr ARI Flood Velocities - Benchmark Conditions

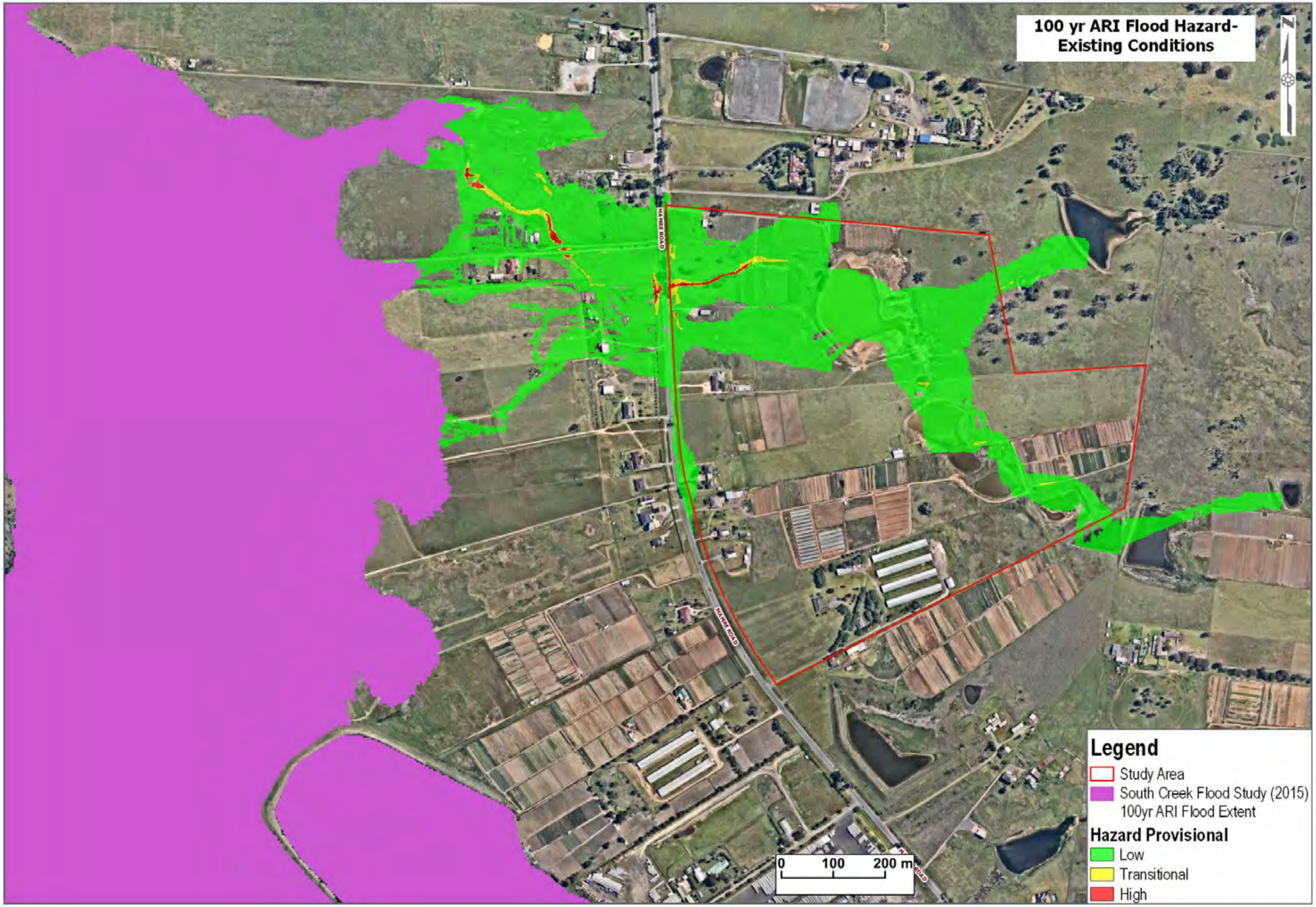


Figure 25 100 yr ARI Flood Hazards - Benchmark Conditions

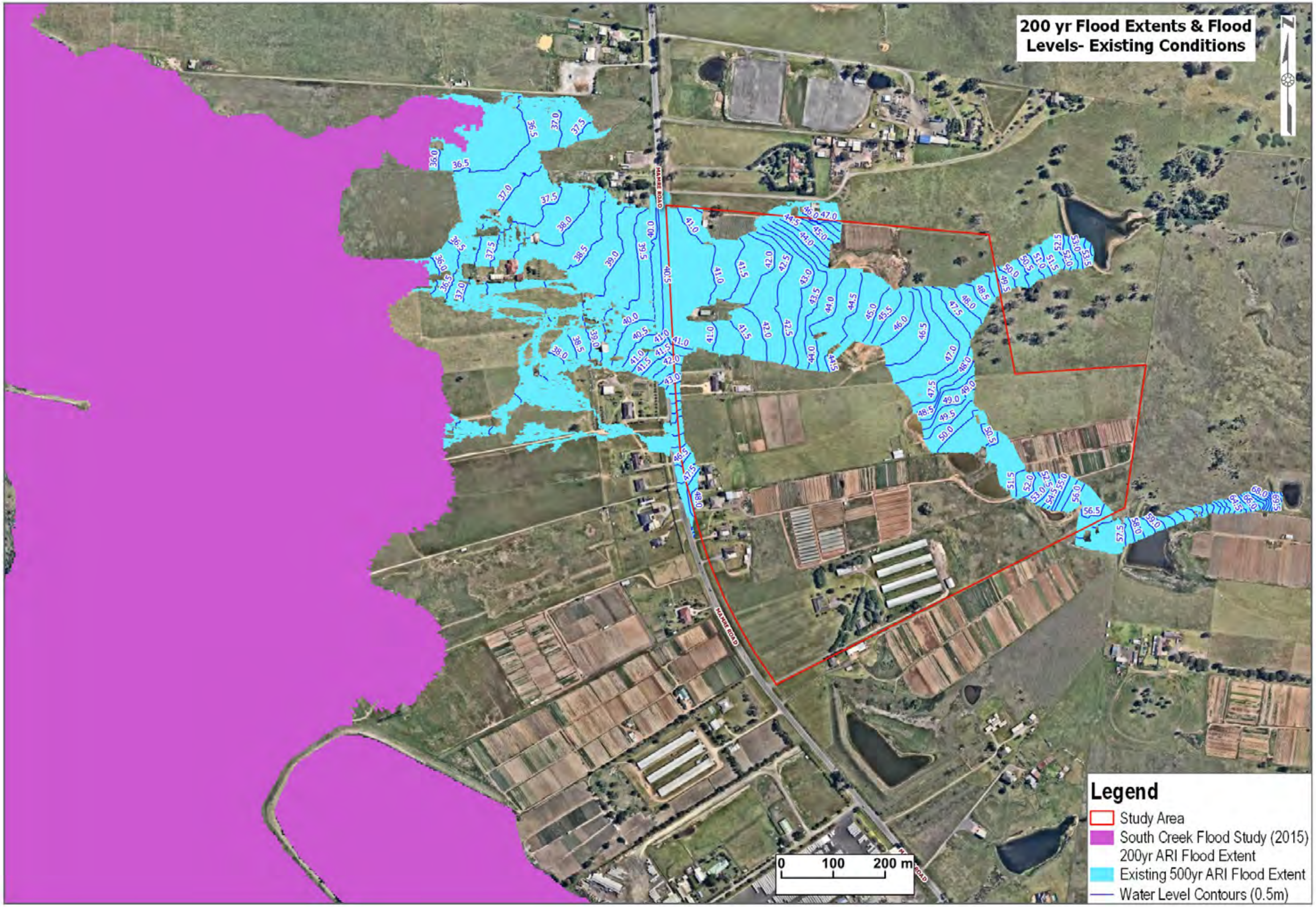


Figure 26 200 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

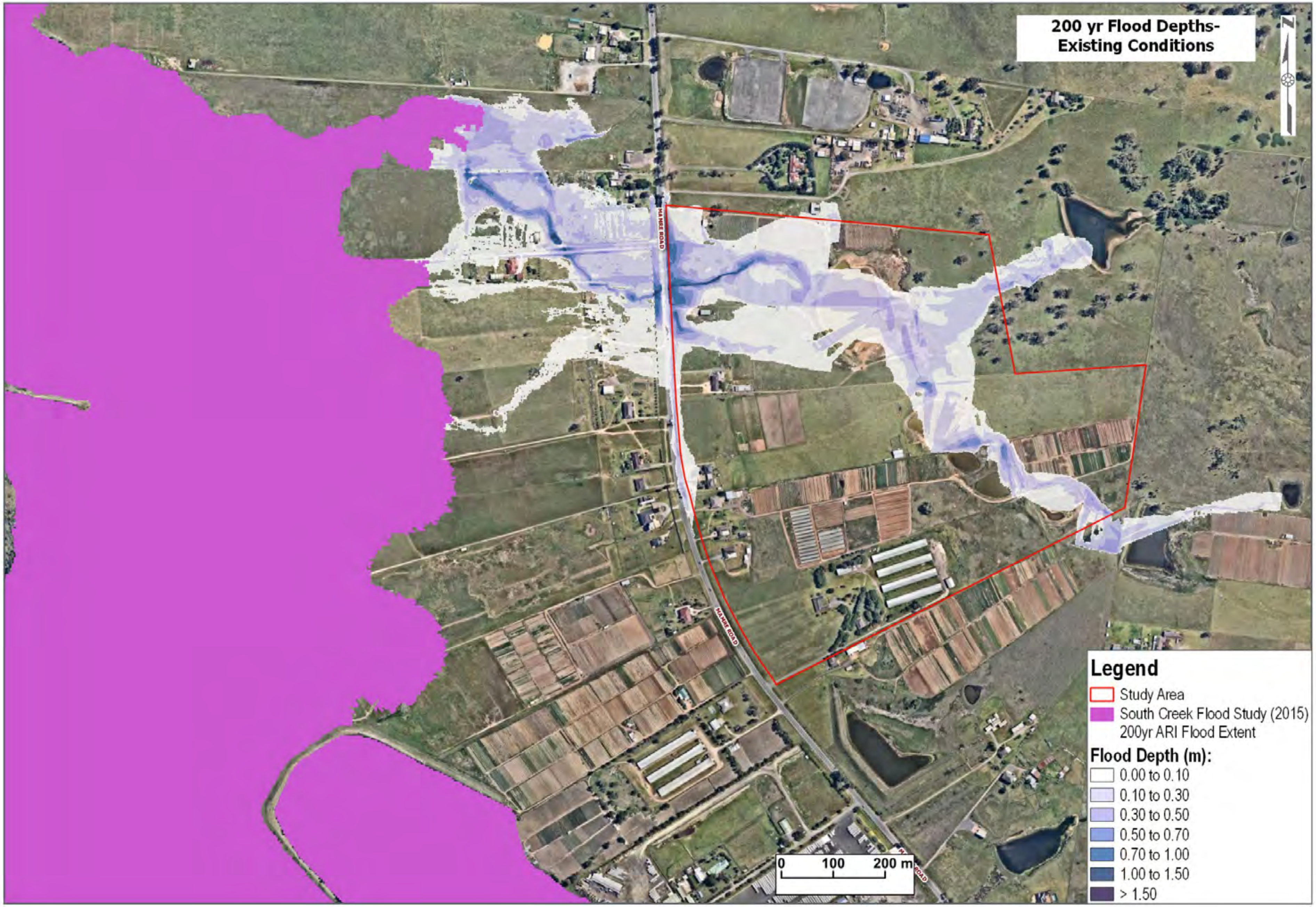


Figure 27 200 yr ARI Flood Depths - Benchmark Conditions

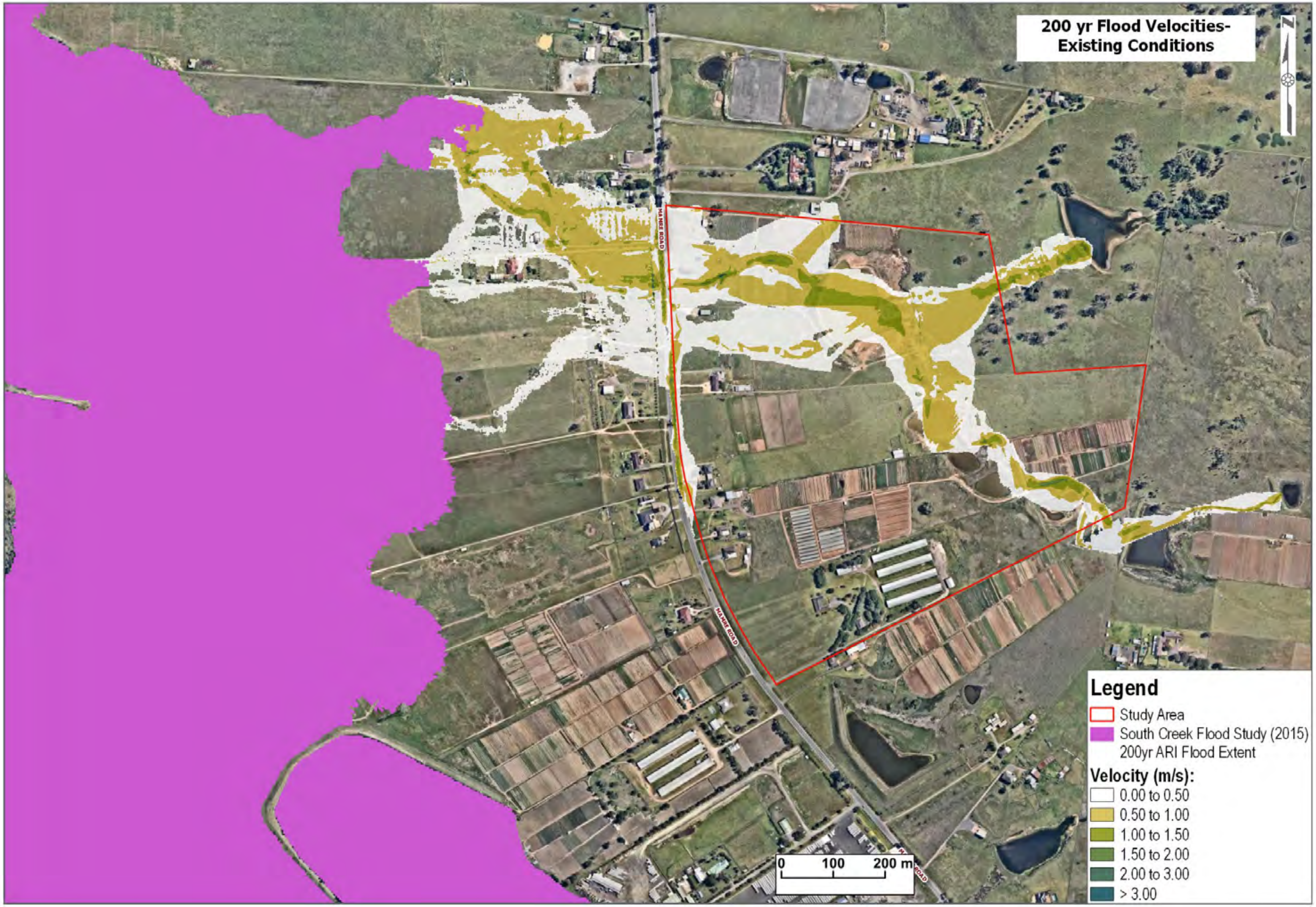


Figure 28 200 yr ARI Flood Velocities - Benchmark Conditions

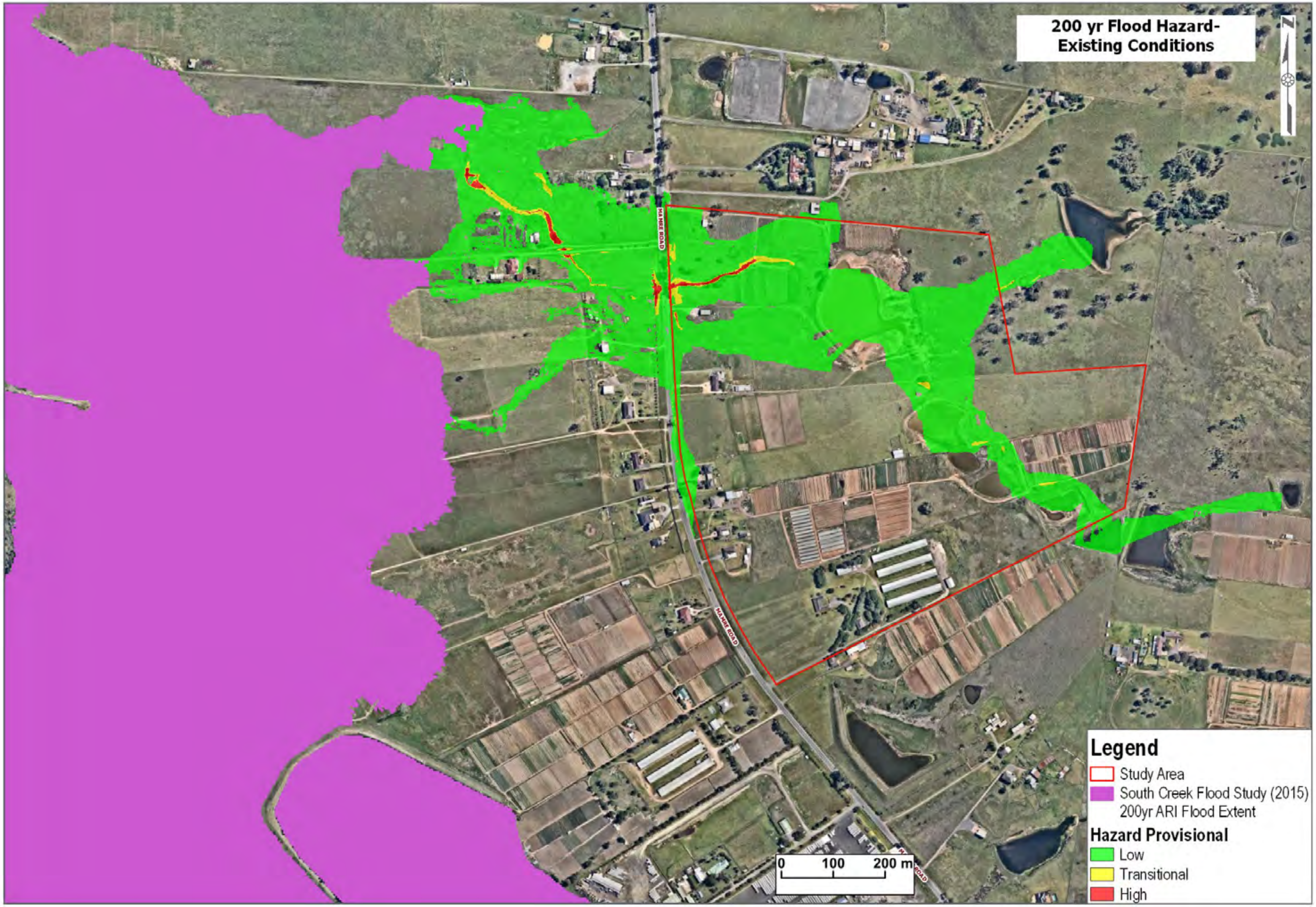


Figure 29 200 yr ARI Flood Hazards - Benchmark Conditions

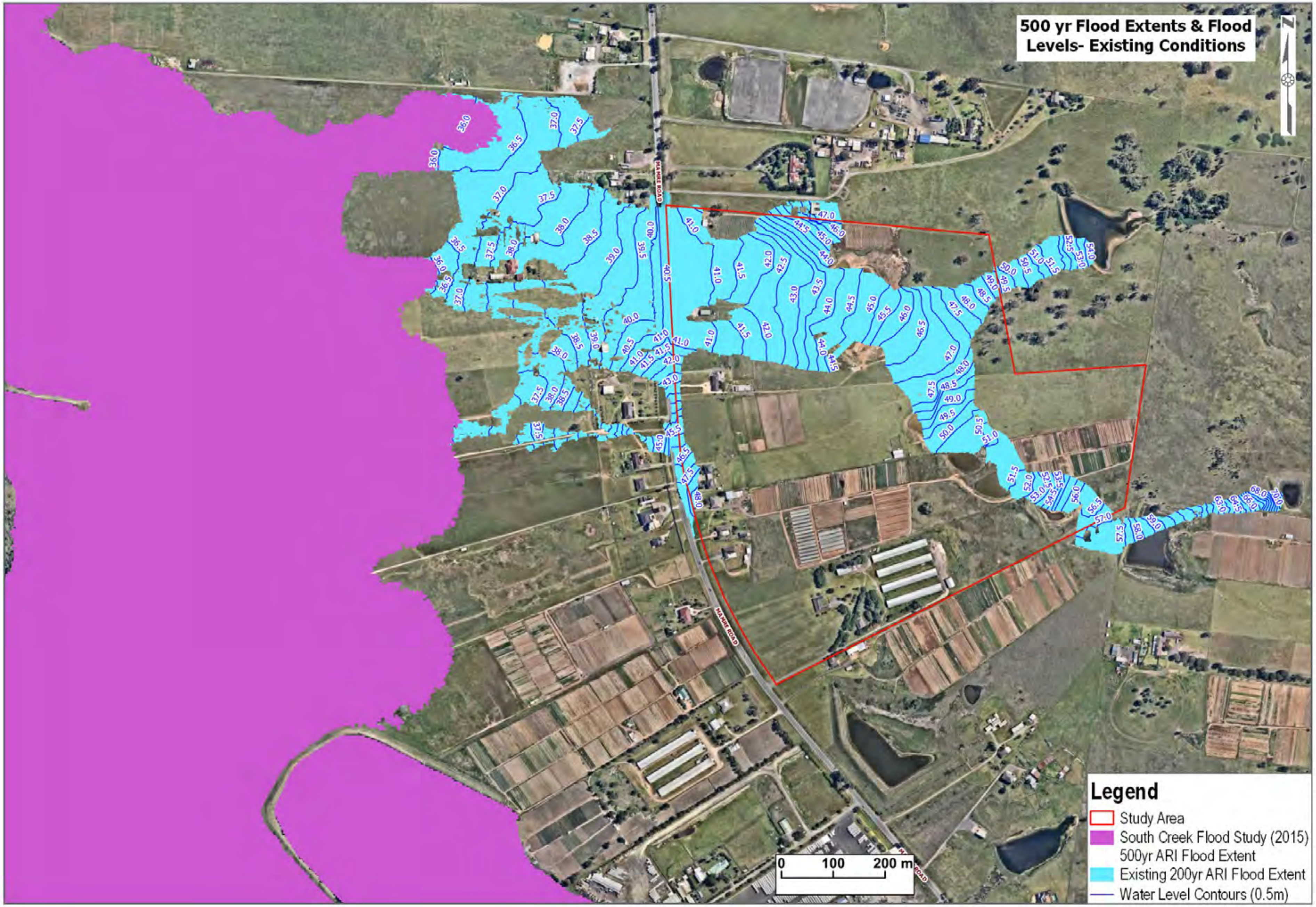


Figure 30 500 yr ARI Flood Extents and Flood Levels - Benchmark Conditions

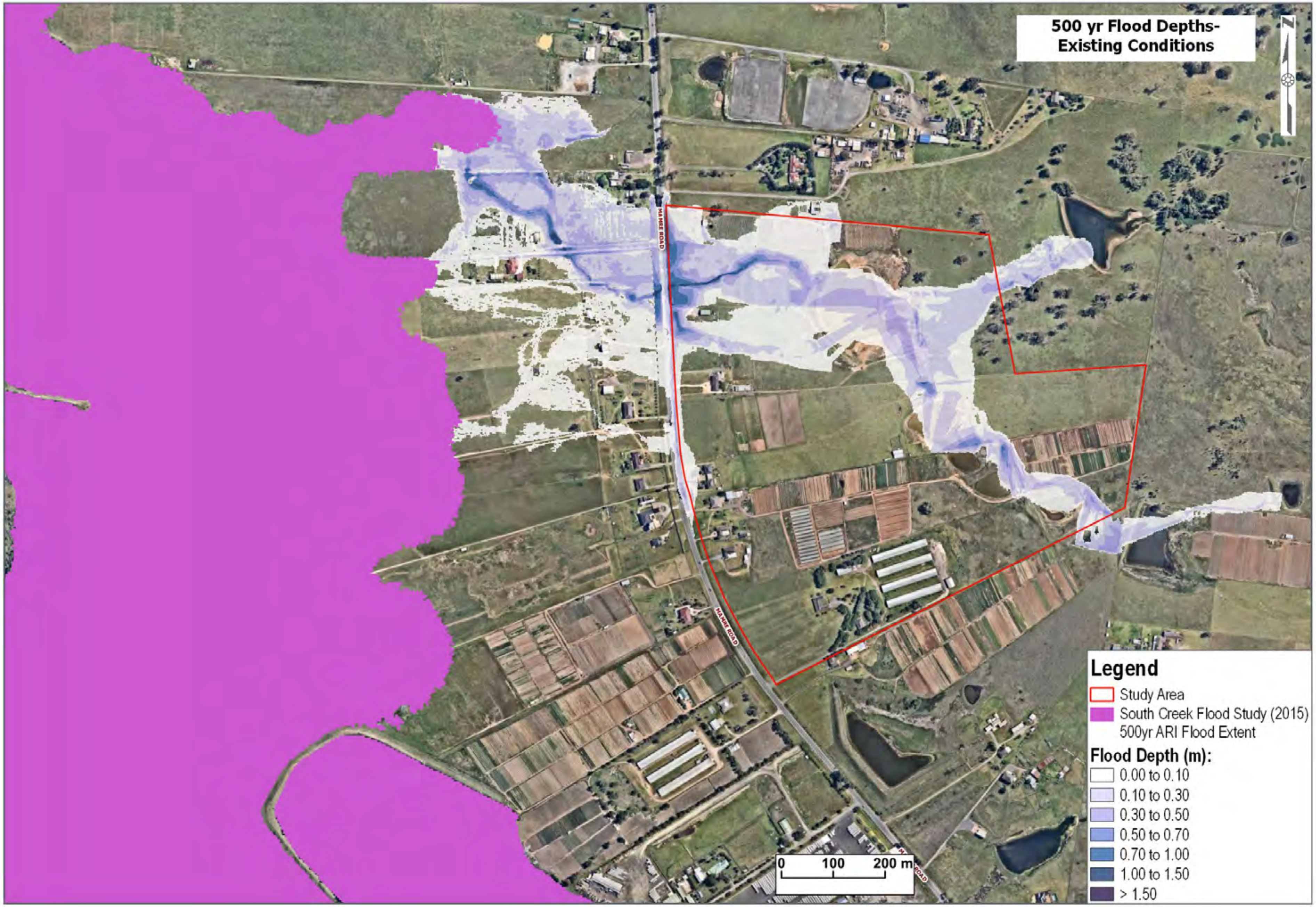


Figure 31 500 yr ARI Flood Depths - Benchmark Conditions

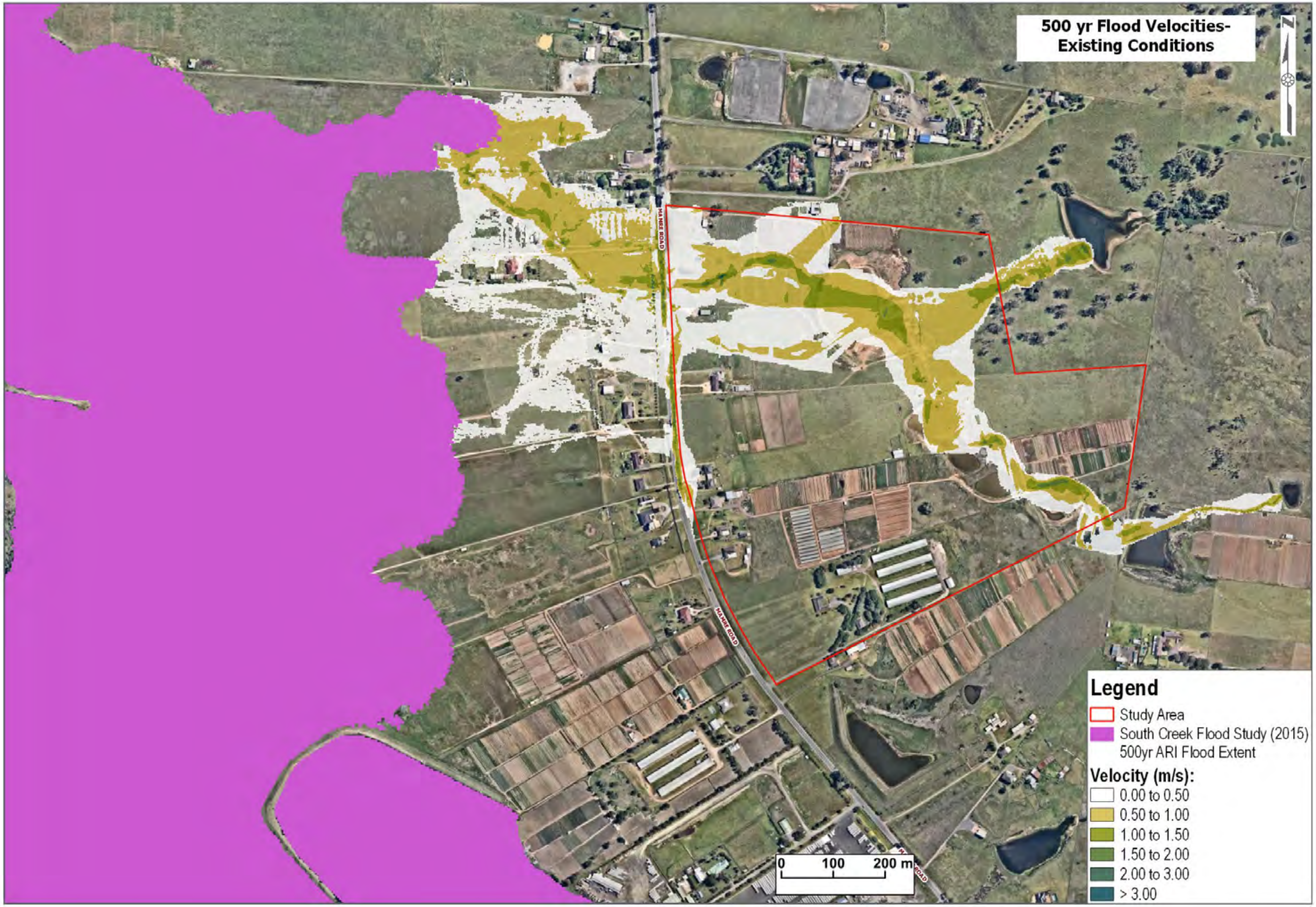


Figure 32 500 yr ARI Flood Velocities - Benchmark Conditions

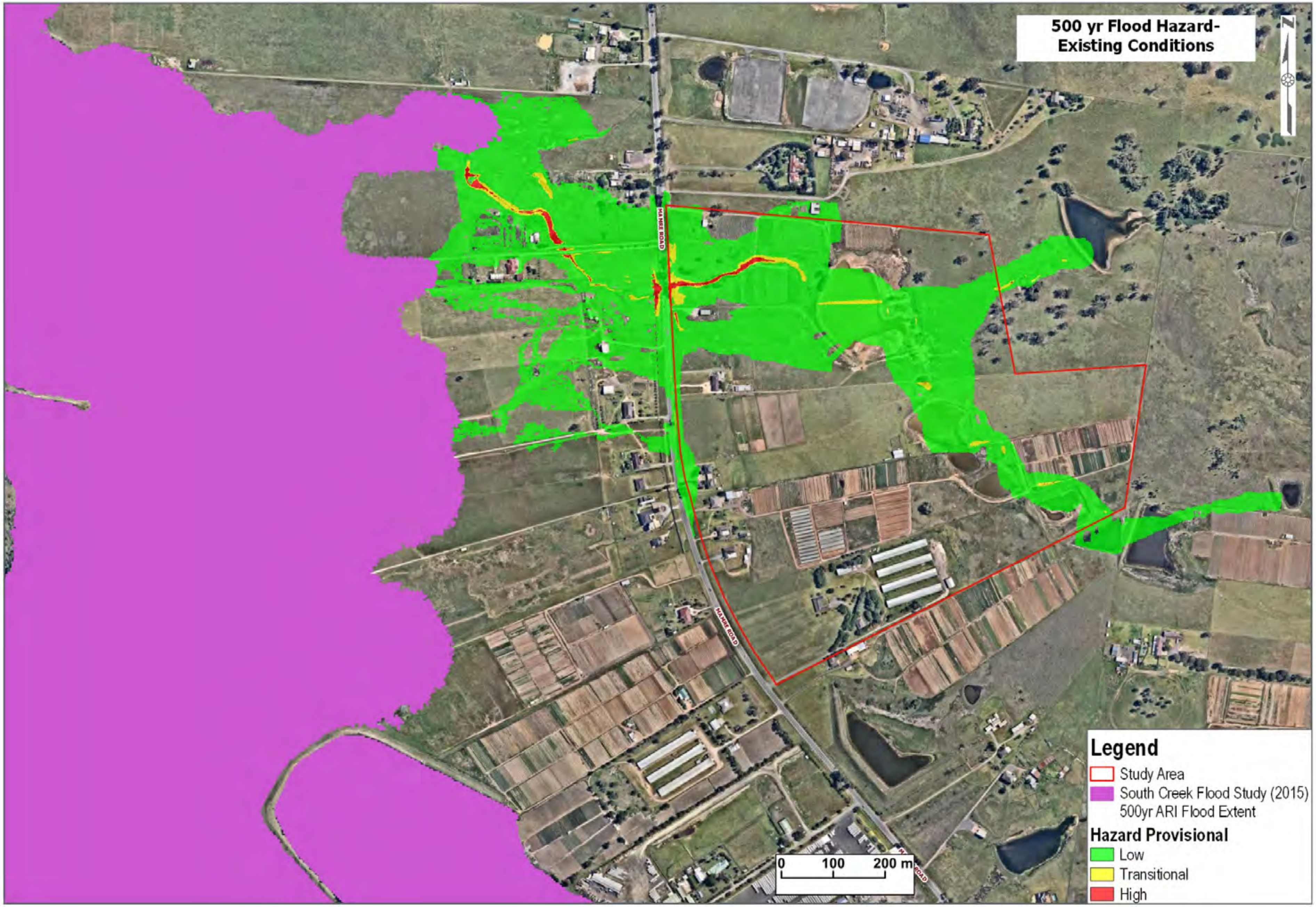


Figure 33 500 yr ARI Flood Hazards - Benchmark Conditions

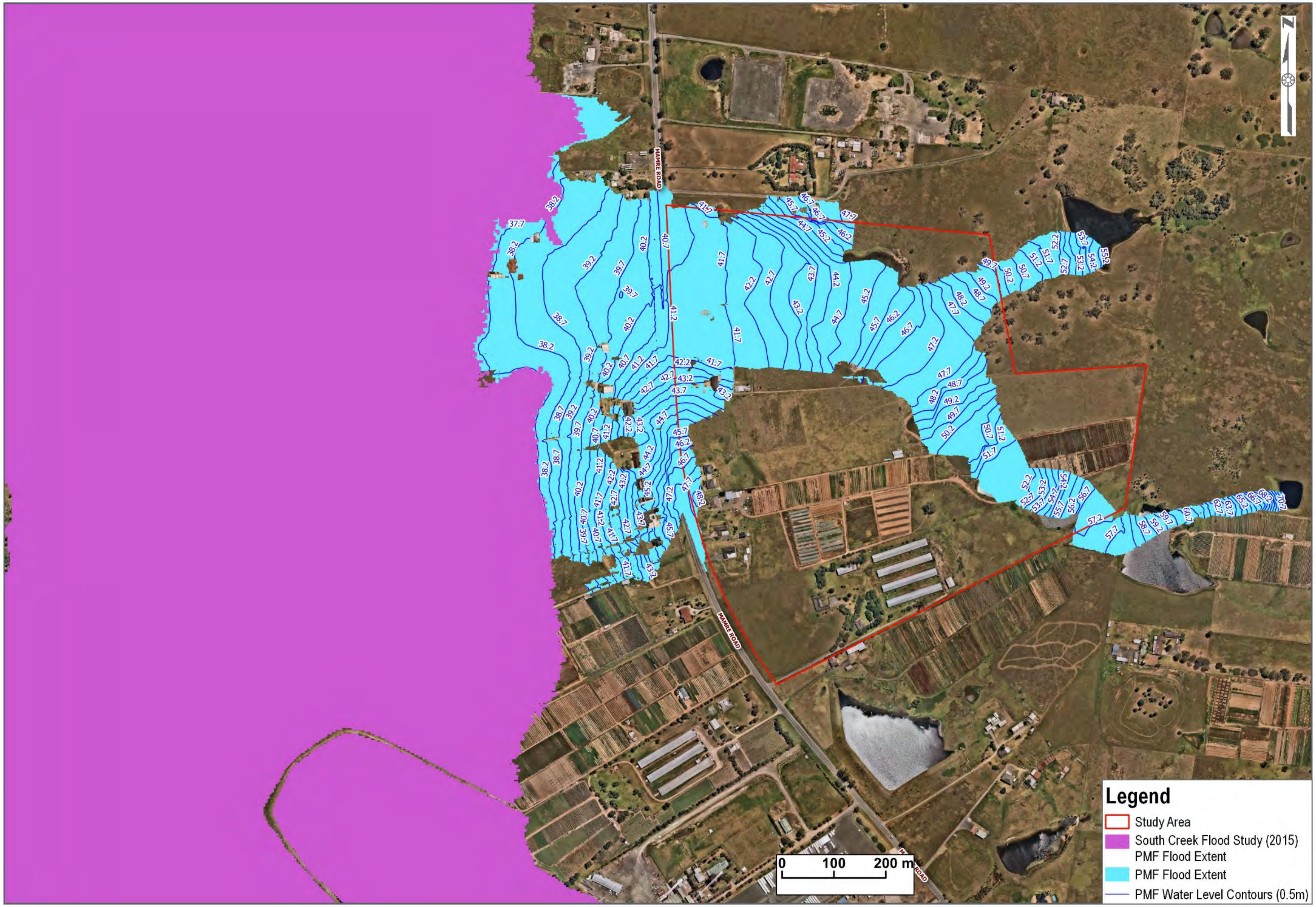


Figure 34 PMF Flood Extents and Flood Levels - Benchmark Conditions

Figure 35 PMF Flood Depths - Benchmark Conditions

Figure 36 PMF Flood Velocities - Benchmark Conditions

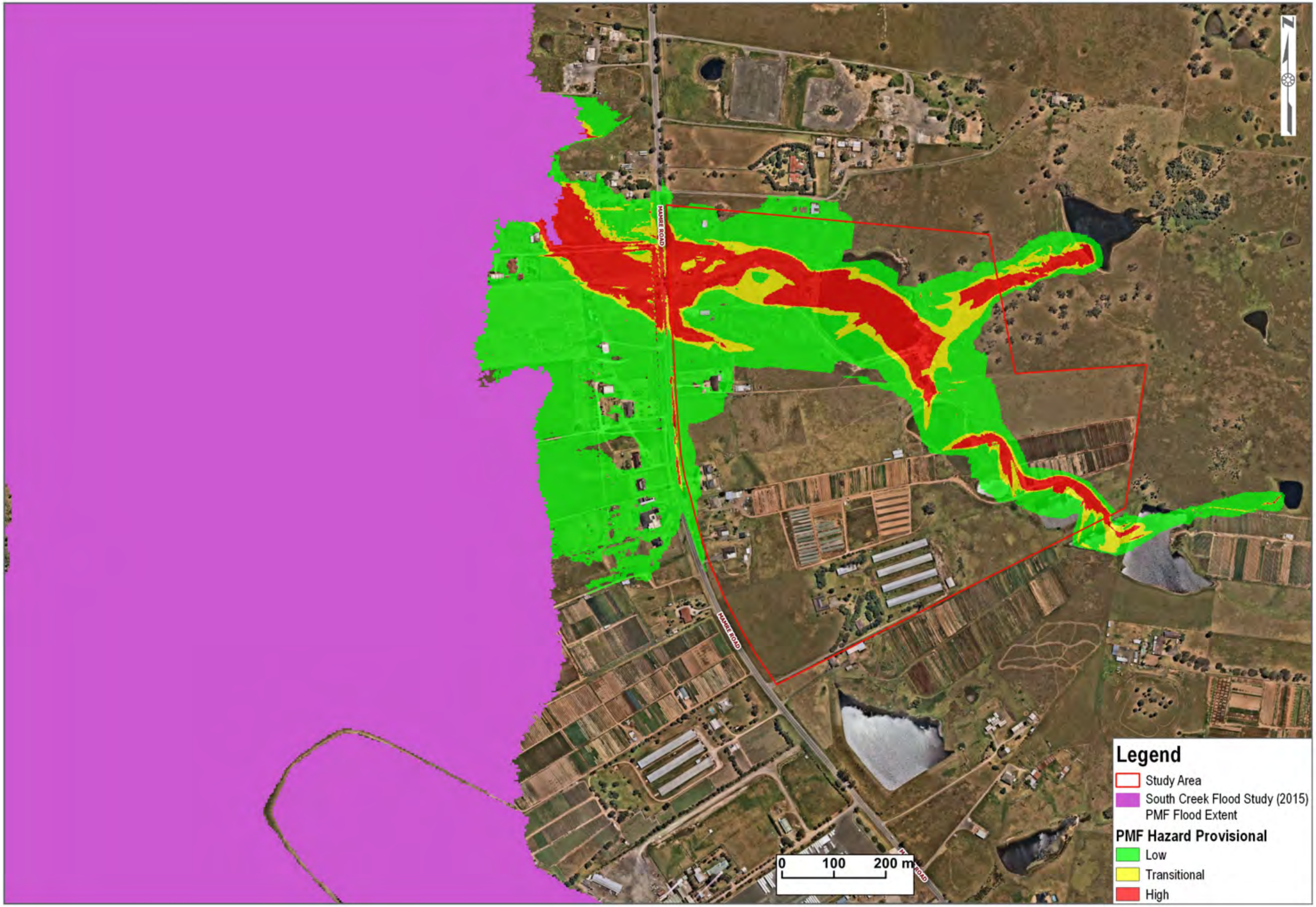


Figure 37 PMF Flood Hazards - Benchmark Conditions

APPENDIX B
SUMMARIES OF RESULTS

AWE200083 Aspect Industrial Estate ARR1987 Hydrology

Benchmark Conditions

Attachment B1

Updated PMF

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		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical 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		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical 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	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
N2	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
S1	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
S2	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
S3	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	4.5
MRID3	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
MRID2a	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	4.5
Junc	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
MRID1	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	4.5
N3	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	2.0
N4	0.11	0.15	0.17	0.17	0.18	0.14	0.17	0.16	0.14	0.14	0.09	0.07	0.18	2.0
N34	0.54	0.71	0.81	0.83	0.87	0.65	0.86	0.76	0.68	0.69	0.46	0.35	0.87	2.0
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		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical 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		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical 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		
Subcatchment ID	Storm Burst Duration (mins)												Peak Flow (m3/s)	Critical 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	6.11	6.84	7.50	7.42	7.74	6.01	6.54	5.58	4.77	4.93	3.56	2.82	2.31	2.0
N2	8.13	9.03	9.99	9.90	10.51	8.19	8.57	7.38	6.35	6.47	4.67	3.71	0.61	2.0
S1	0.88	0.78	0.90	0.92	0.87	0.58	0.51	0.37	0.32	0.32	0.22	0.17	2.92	2.0
S2	3.84	4.31	4.72	4.75	5.07	3.90	4.16	3.59	3.08	3.18	2.29	1.82	7.74	2.0
S3	5.16	5.64	6.35	6.66	7.00	5.36	5.36	4.70	4.03	4.14	2.96	2.35	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	1.78	1.88	2.12	2.18	2.31	1.78	1.56	1.31	1.14	1.14	0.78	0.61	4.78	2.0
N4	0.46	0.48	0.55	0.58	0.61	0.46	0.40	0.33	0.29	0.29	0.19	0.15	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)										
Subcatchment ID	Storm Burst Duration (mins)								Peak Flow (m3/s)	Critical Duration (hrs)
	15	30	45	60	90	120	180	240		
N5	45.96	51.94	49.34	46.22	39.78	34.88	27.86	23.97	51.94	0.50
N1	35.06	43.31	42.02	39.60	34.43	30.81	24.56	20.99	43.31	0.25
N2	52.02	58.51	56.37	52.90	45.80	40.73	32.51	27.81	58.51	0.25
S1	4.41	3.63	3.10	2.74	2.32	2.07	1.68	1.42	4.41	0.25
S2	26.10	28.80	27.71	25.86	22.48	20.03	15.95	13.61	28.80	0.50
S3	35.65	37.06	35.61	33.40	29.01	25.78	20.50	17.50	37.06	0.50
MRID3	11.43	12.74	12.09	11.31	9.72	8.55	6.83	5.85	12.74	0.25
MRID2a	24.13	28.59	27.67	25.92	22.56	20.21	16.12	13.75	28.59	0.50
Junc	69.25	76.73	74.60	70.06	61.02	54.27	43.38	37.02	76.73	0.50
MRID1	13.66	21.25	24.27	24.62	22.80	21.24	17.61	15.20	24.62	0.50
N3	11.97	11.29	10.41	9.37	7.85	6.84	5.55	4.81	11.97	0.50
N4	3.10	2.84	2.60	2.35	1.95	1.71	1.39	1.21	3.10	0.50
N34	15.05	14.13	13.01	11.71	9.80	8.55	6.94	6.02	15.05	0.75
MRd	134.66	157.38	162.19	155.94	137.58	124.06	100.10	85.11	162.19	0.75
MRID2b	12.23	10.11	8.87	7.77	6.49	5.75	4.74	4.06	12.23	0.25
DSMRd	148.06	183.47	202.02	198.42	177.74	162.23	131.83	111.84	202.02	0.75

Based on the Preliminary Masterplan

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	0.59	1.18	1.46	1.60	1.76	1.61	1.75	1.81	1.88	1.98	1.39	1.07	1.98	12.0
N1	0.43	0.87	1.14	1.29	1.38	1.31	1.35	1.54	1.60	1.66	1.21	0.95	1.66	12.0
N2	1.18	2.13	2.60	2.76	2.96	2.85	3.12	3.23	3.45	3.59	2.59	2.03	3.59	12.0
N3	0.16	0.28	0.34	0.35	0.37	0.34	0.42	0.38	0.39	0.40	0.27	0.21	0.42	4.5
N4	0.04	0.07	0.09	0.09	0.09	0.09	0.11	0.10	0.10	0.10	0.07	0.05	0.11	4.5
N34	1.37	2.44	2.99	3.11	3.34	3.22	3.54	3.62	3.90	3.99	2.91	2.29	3.99	12.0
S1	0.10	0.14	0.16	0.18	0.19	0.13	0.16	0.14	0.12	0.12	0.08	0.06	0.19	2.0
S2	0.33	0.57	0.71	0.80	0.86	0.84	0.86	0.97	1.02	1.08	0.78	0.61	1.08	12.0
S3	0.53	0.86	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
MRID3	0.12	0.22	0.29	0.33	0.36	0.33	0.34	0.38	0.40	0.41	0.30	0.23	0.41	1.5
MRID2	5.52	4.97	5.31	5.62	5.34	2.87	2.54	1.92	1.72	1.72	1.13	0.88	5.62	1.5
Junc2	7.35	6.62	7.05	7.47	7.10	3.83	3.39	2.56	2.29	2.30	1.50	1.17	7.47	1.5
MRID1	`	4.88	5.18	5.50	5.18	2.83	2.50	1.85	1.67	1.68	1.11	0.86	5.50	1.5
Junc1	0.65	1.08	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
Dummy1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5
MRIDBas	10.97	10.27	9.44	9.18	10.77	6.62	5.84	4.35	3.95	3.97	2.61	2.03	10.97	0.5
MRd	10.97	10.27	9.57	9.43	10.92	6.71	6.69	6.56	7.16	7.63	5.47	4.32	10.97	0.5
DSMRd	10.99	10.30	10.14	10.31	11.69	7.65	8.42	8.32	9.04	9.61	6.86	5.39	11.69	2.0

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													0.00	4.5
N1													0.00	4.5
N2													0.00	4.5
N3													0.00	4.5
N4													0.00	2.0
N34													0.00	4.5
S1													0.00	2.0
S2													0.00	4.5
S3													0.00	2.0
MRID3													0.00	1.5
MRID2													0.00	1.5
Junc2													0.00	1.5
MRID1													0.00	1.5
Junc													0.00	2.0
Dummy1													0.00	0.5
MRIDBas													0.00	0.5
MRd													0.00	2.0
DSMRd													0.00	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	5.34	6.05	6.68	6.60	6.95	5.30	5.93	5.11	4.36	4.49	3.17	2.49	6.95	2.0
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	2.0
N2	9.16	10.50	11.62	11.75	12.33	9.38	10.70	9.27	8.06	8.21	5.99	4.75	12.33	2.0
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	2.0
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	2.0
N34	10.20	11.77	13.17	13.29	13.95	10.64	11.93	10.41	9.07	9.13	6.72	5.35	13.95	1.5
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	2.0
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	2.0
MRID3	3.32	3.08	3.33	3.56	3.35	1.88	1.66	1.22	1.07	1.07	0.72	0.57	3.56	1.5
MRID2	11.66	10.79	11.57	12.26	11.68	6.45	5.74	4.28	3.74	3.74	2.53	2.00	12.26	1.5
Junc2	14.98	13.85	14.88	15.77	15.00	8.33	7.40	5.50	4.80	4.80	3.24	2.57	15.77	1.5
MRID1	10.06	9.29	9.91	10.47	9.98	5.48	4.88	3.66	3.20	3.21	2.18	1.73	10.47	1.5
Junc	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	2.0
Dummy1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
MRIDBas	21.92	20.96	19.62	19.15	22.17	13.61	12.13	9.13	7.97	7.99	5.41	4.30	22.17	2.0
MRd	22.20	21.54	23.69	25.56	25.95	18.54	20.72	18.18	15.91	16.60	12.09	9.65	25.95	2.0
DSMRd	24.55	26.34	29.17	31.79	31.92	23.83	26.64	23.29	20.22	21.10	15.26	12.15	31.92	2.0
	0.5	0.75	1	1.5	2	3	4.5	6	9	12	24	36		

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													0.00	2.0
N1													0.00	2.0
N2													0.00	2.0
N3													0.00	2.0
N4													0.00	2.0
N34													0.00	2.0
S1													0.00	1.5
S2													0.00	2.0
S3													0.00	2.0
MRID3													0.00	1.5
MRID2													0.00	1.5
Junc2													0.00	1.5
MRID1													0.00	2.0
Junc													0.00	1.5
Dummy1													0.00	2.0
MRIDBas													0.00	0.5
MRd													0.00	2.0
DSMRd													0.00	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													0.00	2.0
N1													0.00	2.0
N2													0.00	2.0
N3													0.00	2.0
N4													0.00	2.0
N34													0.00	2.0
S1													0.00	1.5
S2													0.00	2.0
S3													0.00	2.0
MRID3													0.00	1.5
MRID2													0.00	1.5
Junc2													0.00	1.5
MRID1													0.00	1.5
Junc													0.00	2.0
Dummy1													0.00	2.0
MRIDBas													0.00	2.0
MRd													0.00	2.0
DSMRd													0.00	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									0.00	0.5
N1									0.00	0.5
N2									0.00	0.5
N3									0.00	0.3
N4									0.00	0.3
N34									0.00	0.3
S1									0.00	0.3
S2									0.00	0.5
S3									0.00	0.5
MRID3									0.00	0.3
MRID2									0.00	0.3
Junc2									0.00	0.3
MRID1									0.00	0.5
Junc									0.00	0.3
Dummy1									0.00	0.5
MRIDBas									0.00	0.3
MRd									0.00	0.5
DSMRd									0.00	0.5

Basin sized to meet target at Mamre Road - 2 yr ARI (12 hr) & 100 yr ARI (2 hr)

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	2	2	2	2	2	2	2	2	2	2	2	2		
	Storm Burst Duration (mins)													
N5	0.59	1.18	1.46	1.60	1.76	1.61	1.75	1.81	1.88	1.98	1.39	1.07	1.98	12.0
N1	0.43	0.87	1.14	1.29	1.38	1.31	1.35	1.54	1.60	1.66	1.21	0.95	1.66	12.0
N2	1.18	2.13	2.60	2.76	2.96	2.85	3.12	3.23	3.45	3.59	2.59	2.03	3.59	12.0
N3	0.16	0.28	0.34	0.35	0.37	0.34	0.42	0.38	0.39	0.40	0.27	0.21	0.42	4.5
N4	0.04	0.07	0.09	0.09	0.09	0.09	0.11	0.10	0.10	0.10	0.07	0.05	0.11	4.5
N34	1.37	2.44	2.99	3.11	3.34	3.22	3.54	3.62	3.90	3.99	2.91	2.29	3.99	12.0
S1	0.10	0.14	0.16	0.18	0.19	0.13	0.16	0.14	0.12	0.12	0.08	0.06	0.19	2.0
S2	0.33	0.57	0.71	0.80	0.86	0.84	0.86	0.97	1.02	1.08	0.78	0.61	1.08	12.0
S3	0.53	0.86	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
MRID3	1.83	1.66	1.77	1.88	1.79	0.96	0.85	0.64	0.57	0.57	0.38	0.29	1.88	1.5
MRID2	5.52	4.97	5.31	5.62	5.34	2.87	2.54	1.92	1.72	1.72	1.13	0.88	5.62	1.5
Junc2	7.35	6.62	7.05	7.47	7.10	3.83	3.39	2.56	2.29	2.30	1.50	1.17	7.47	1.5
MRID1	5.44	4.88	5.18	5.50	5.18	2.83	2.50	1.85	1.67	1.68	1.11	0.86	5.50	1.5
Junc	0.53	0.86	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
Dummy1														
MRIDBas	10.97	10.27	9.44	9.18	10.77	6.62	5.84	4.35	3.95	3.97	2.61	2.03	10.97	0.5
MRd	3.15	4.52	5.26	5.43	5.72	5.49	5.85	5.98	6.19	6.27	4.93	4.14	6.27	12.0
DSMRd	3.73	5.63	6.70	6.99	7.34	7.01	7.52	7.69	8.01	7.96	6.25	5.20	8.01	9.0
Peak Inflow (m3/s)	10.97	10.27	9.44	9.18	10.77	6.62	5.84	4.35	3.95	3.97	2.61	2.03		
Peak Outflow (m3/s)	1.91	2.15	2.29	2.32	2.39	2.27	2.34	2.36	2.38	2.29	2.02	1.85		
Max Vol (m3)	8,811	9,956	10,705	10,882	11,247	10,624	10,962	11,085	11,196	10,718	9,312	8,536	11,247	
Max Stage (m)	1.10	1.24	1.34	1.36	1.41	1.33	1.37	1.39	1.40	1.34	1.16	1.07	1.41	

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	5	5	5	5	5	5	5	5	5	5	5	5		
	Storm Burst Duration (mins)													
N5	1.58	2.32	2.71	2.73	2.88	2.48	3.06	2.73	2.56	2.66	1.89	1.47	3.06	4.5
N1	1.17	1.81	2.13	2.23	2.37	2.14	2.41	2.27	2.19	2.27	1.66	1.30	2.41	4.5
N2	2.99	4.13	4.79	4.87	5.11	4.46	5.29	4.85	4.74	4.88	3.55	2.79	5.29	4.5
N3	0.40	0.55	0.63	0.64	0.66	0.50	0.68	0.60	0.54	0.55	0.37	0.28	0.68	4.5
N4	0.11	0.14	0.16	0.17	0.18	0.13	0.17	0.15	0.14	0.14	0.09	0.07	0.18	2.0
N34	3.39	4.65	5.45	5.55	5.87	4.97	5.94	5.48	5.34	5.41	3.98	3.14	5.94	4.5
S1	0.20	0.22	0.29	0.34	0.36	0.25	0.24	0.18	0.16	0.16	0.10	0.08	0.36	2.0
S2	0.81	1.16	1.32	1.35	1.46	1.34	1.52	1.42	1.39	1.46	1.07	0.84	1.52	4.5
S3	1.26	1.63	1.88	1.92	2.11	1.72	2.08	1.85	1.83	1.93	1.38	1.08	2.11	2.0
MRID3	2.39	2.15	2.32	2.46	2.34	1.27	1.13	0.86	0.75	0.75	0.50	0.39	2.46	1.5
MRID2	7.20	6.46	6.92	7.36	7.03	3.81	3.39	2.55	2.25	2.26	1.49	1.17	7.36	1.5
Junc2	9.59	8.62	9.23	9.82	9.37	5.08	4.52	3.41	3.00	3.01	1.99	1.56	9.82	1.5
MRID1	7.11	6.36	6.79	7.22	6.85	3.72	3.29	2.47	2.19	2.20	1.46	1.15	7.22	1.5
Junc	1.26	1.63	1.88	1.92	2.11	1.72	2.08	1.85	1.83	1.93	1.38	1.08	2.11	2.0
Dummy1														
MRIDBas	14.35	13.37	12.36	12.07	14.17	8.69	7.71	5.83	5.17	5.20	3.45	2.71	14.35	0.5
MRd	5.79	7.35	8.32	8.43	8.77	7.84	8.84	8.28	8.09	8.20	6.50	5.50	8.84	4.5
DSMRd	7.24	9.52	10.93	11.15	11.65	10.07	11.58	10.91	10.58	10.57	8.31	6.95	11.65	2.0
Peak Inflow (m3/s)	14.35	13.37	12.36	12.07	14.17	8.69	7.71	5.83	5.17	5.20	3.45	2.71		
Peak Outflow (m3/s)	2.45	2.72	2.87	2.92	2.99	2.87	2.90	2.94	2.91	2.79	2.52	2.36		
Max Vol (m3)	11,610	13,234	14,275	14,607	15,115	14,292	14,483	14,772	14,564	13,698	12,034	11,083	15,115	
Max Stage (m)	1.45	1.65	1.78	1.83	1.89	1.79	1.81	1.85	1.82	1.71	1.50	1.39	1.89	

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
	Storm Burst Duration (mins)													
N5	5.34	6.05	6.68	6.60	6.95	5.30	5.93	5.11	4.36	4.49	3.17	2.49	6.95	2.0
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	2.0
N2	9.16	10.50	11.62	11.75	12.33	9.38	10.70	9.27	8.06	8.21	5.99	4.75	12.33	2.0
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	2.0
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	2.0
N34	10.20	11.77	13.17	13.29	13.95	10.64	11.93	10.41	9.07	9.13	6.72	5.35	13.95	2.0
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	2.0
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	2.0
MRID3	3.74	3.46	3.74	3.97	3.77	2.11	1.86	1.38	1.20	1.20	0.81	0.64	3.97	1.5
MRID2	11.23	10.41	11.17	11.82	11.25	6.21	5.53	4.12	3.60	3.60	2.43	1.93	11.82	1.5
Junc2	14.96	13.86	14.90	15.78	14.98	8.32	7.40	5.50	4.80	4.80	3.23	2.57	15.78	1.5
MRID1	11.07	10.26	10.93	11.54	10.96	6.02	5.35	4.01	3.50	3.51	2.38	1.89	11.54	1.5
Junc	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	2.0
Dummy1														
MRIDBas	22.92	21.71	20.10	19.51	22.87	14.14	12.60	9.47	8.27	8.29	5.61	4.46	22.92	0.5
MRd	14.59	17.67	19.70	19.60	20.37	15.46	18.27	15.77	14.31	14.44	10.83	9.03	20.37	2.0
DSMRd	18.96	23.00	25.80	25.58	26.61	20.07	23.45	20.29	18.37	18.30	13.80	11.48	26.61	2.0
Peak Inflow (m3/s)	22.92	21.71	20.10	19.51	22.87	14.14	12.60	9.47	8.27	8.29	5.61	4.46		
Peak Outflow (m3/s)	4.40	5.90	6.56	6.37	6.58	6.07	6.34	5.96	5.79	5.31	4.13	3.70		
Max Vol (m3)	20,565	22,666	23,459	23,238	23,483	22,874	23,197	22,739	22,526	21,904	20,107	19,248	23,483	
Max Stage (m)	2.57	2.83	2.93	2.90	2.94	2.86	2.90	2.84	2.82	2.74	2.51	2.41	2.94	

Basin sized to meet target at Mamre Road - 2 yr ARI (36 hr) & 100 yr ARI (36 hr)

Based on the Preliminary Masterplan

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	2	2	2	2	2	2	2	2	2	2	2	2		
	Storm Burst Duration (mins)													
N5														
N1	0.43	0.87	1.14	1.29	1.38	1.31	1.35	1.54	1.60	1.66	1.21	0.95	1.66	12.0
N2	1.18	2.13	2.60	2.76	2.96	2.85	3.12	3.23	3.45	3.59	2.59	2.03	3.59	12.0
N3	0.16	0.28	0.34	0.35	0.37	0.34	0.42	0.38	0.39	0.40	0.27	0.21	0.42	4.5
N4	0.04	0.07	0.09	0.09	0.09	0.09	0.11	0.10	0.10	0.10	0.07	0.05	0.11	4.5
N34	1.37	2.44	2.99	3.11	3.34	3.22	3.54	3.62	3.90	3.99	2.91	2.29	3.99	12.0
S1	0.10	0.14	0.16	0.18	0.19	0.13	0.16	0.14	0.12	0.12	0.08	0.06	0.19	2.0
S2	0.33	0.57	0.71	0.80	0.86	0.84	0.86	0.97	1.02	1.08	0.78	0.61	1.08	12.0
S3	0.53	0.86	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
MRID3	1.83	1.66	1.77	1.88	1.79	0.96	0.85	0.64	0.57	0.57	0.38	0.29	1.88	1.5
MRID2	5.52	4.97	5.31	5.62	5.34	2.87	2.54	1.92	1.72	1.72	1.13	0.88	5.62	1.5
Junc2	7.35	6.62	7.05	7.47	7.10	3.83	3.39	2.56	2.29	2.30	1.50	1.17	7.47	1.5
MRID1	5.44	4.88	5.18	5.50	5.18	2.83	2.50	1.85	1.67	1.68	1.11	0.86	5.50	1.5
Junc	0.53	0.86	1.04	1.06	1.15	1.11	1.24	1.24	1.34	1.43	1.01	0.79	1.43	12.0
Dummy1														
MRIDBas	10.97	10.27	9.44	9.18	10.77	6.62	5.84	4.35	3.95	3.97	2.61	2.03	10.97	0.5
MRd	1.90	3.04	3.63	3.79	4.04	3.91	4.21	4.35	4.70	4.77	3.69	3.11	4.77	12.0
DSMRd														
Peak Inflow (m3/s)	10.97	10.27	9.44	9.18	10.77	6.62	5.84	4.35	3.95	3.97	2.61	2.03		
Peak Outflow (m3/s)	0.53	0.61	0.66	0.71	0.75	0.78	0.81	0.83	0.89	0.90	0.87	0.95		
Max Vol (m3)	10,384	12,439	13,984	15,730	16,942	18,364	19,353	20,326	22,660	23,142	21,623	24,505	24,505	
Max Stage (m)	1.30	1.55	1.75	1.97	2.12	2.30	2.42	2.54	2.83	2.89	2.70	3.06	3.06	

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	5	5	5	5	5	5	5	5	5	5	5	5		
	Storm Burst Duration (mins)													
N5														
N1	1.17	1.81	2.13	2.23	2.37	2.14	2.41	2.27	2.19	2.27	1.66	1.30	2.41	4.5
N2	2.99	4.13	4.79	4.87	5.11	4.46	5.29	4.85	4.74	4.88	3.55	2.79	5.29	4.5
N3	0.40	0.55	0.63	0.64	0.66	0.50	0.68	0.60	0.54	0.55	0.37	0.28	0.68	4.5
N4	0.11	0.14	0.16	0.17	0.18	0.13	0.17	0.15	0.14	0.14	0.09	0.07	0.18	2.0
N34	0.20	0.22	0.29	0.34	0.36	0.25	0.24	0.18	0.16	0.16	0.10	0.08	0.36	2.0
S1	0.81	1.16	1.32	1.35	1.46	1.34	1.52	1.42	1.39	1.46	1.07	0.84	1.52	4.5
S2	1.26	1.63	1.88	1.92	2.11	1.72	2.08	1.85	1.83	1.93	1.38	1.08	2.11	2.0
S3	3.39	4.65	5.45	5.55	5.87	4.97	5.94	5.48	5.34	5.41	3.98	3.14	5.94	4.5
MRID3	2.39	2.15	2.32	2.46	2.34	1.27	1.13	0.86	0.75	0.75	0.50	0.39	2.46	1.5
MRID2	7.20	6.46	6.92	7.36	7.03	3.81	3.39	2.55	2.25	2.26	1.49	1.17	7.36	1.5
Junc2	9.59	8.62	9.23	9.82	9.37	5.08	4.52	3.41	3.00	3.01	1.99	1.56	9.82	1.5
MRID1	7.11	6.36	6.79	7.22	6.85	3.72	3.29	2.47	2.19	2.20	1.46	1.15	7.22	1.5
Junc	1.26	1.63	1.88	1.92	2.11	1.72	2.08	1.85	1.83	1.93	1.38	1.08	2.11	2.0
Dummy1														
MRIDBas	14.35	13.37	12.36	12.07	14.17	8.69	7.71	5.83	5.17	5.20	3.45	2.71	14.35	0.5
MRd	4.04	5.38	6.21	6.32	6.63	5.80	6.74	6.29	6.31	6.36	4.93	4.35	6.74	4.5
DSMRd														
Peak Inflow (m3/s)	14.35	13.37	12.36	12.07	14.17	8.69	7.71	5.83	5.17	5.20	3.45	2.71		
Peak Outflow (m3/s)	0.65	0.74	0.79	0.85	0.90	0.97	1.08	1.18	1.46	1.55	1.40	1.64		
Max Vol (m3)	13,822	16,633	18,731	21,133	22,818	24,796	26,074	26,951	29,099	29,681	28,639	30,230	30,230	
Max Stage (m)	1.73	2.08	2.34	2.64	2.85	3.10	3.26	3.37	3.64	3.71	3.58	3.78	3.78	

100 yr ARI

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

Subcatchment ID	30	45	60	90	120	180	270	360	540	720	1440	2160	Peak Flow (m3/s)	Critical Duration (hrs)
ARI (yrs)	100	100	100	100	100	100	100	100	100	100	100	100		
	Storm Burst Duration (mins)													
N5														
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	2.0
N2	9.16	10.50	11.62	11.75	12.33	9.38	10.70	9.27	8.06	8.21	5.99	4.75	12.33	2.0
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	2.0
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	2.0
N34	10.20	11.77	13.17	13.29	13.95	10.64	11.93	10.41	9.07	9.13	6.72	5.35	13.95	2.0
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	2.0
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	2.0
MRID3	3.74	3.46	3.74	3.97	3.77	2.11	1.86	1.38	1.20	1.20	0.81	0.64	3.97	1.5
MRID2	11.23	10.41	11.17	11.82	11.25	6.21	5.53	4.12	3.60	3.60	2.43	1.93	11.82	1.5
Junc2	14.96	13.86	14.90	15.78	14.98	8.32	7.40	5.50	4.80	4.80	3.23	2.57	15.78	1.5
MRID1	11.07	10.26	10.93	11.54	10.96	6.02	5.35	4.01	3.50	3.51	2.38	1.89	11.54	1.5
Junc	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	2.0
Dummy1														
MRIDBas	22.92	21.71	20.10	19.51	22.87	14.14	12.60	9.47	8.27	8.29	5.61	4.46	22.92	0.5
MRd	11.15	13.14	14.62	14.71	15.39	11.66	13.76	12.15	12.78	12.78	10.15	9.04	15.39	2.0
DSMRd														
Peak Inflow (m3/s)	22.92	21.71	20.10	19.51	22.87	14.14	12.60	9.47	8.27	8.29	5.61	4.46		
Peak Outflow (m3/s)	0.95	1.49	1.99	2.50	2.77	3.06	3.02	3.04	4.36	3.65	3.70	3.70		
Max Vol (m3)	24,608	29,296	32,260	34,928	36,197	37,511	37,362	37,457	42,881	40,043	40,252	40,268	42,881	
Max Stage (m)	3.08	3.66	4.03	4.37	4.52	4.69	4.67	4.68	5.36	5.01	5.03	5.03	5.36	