ICETON PLACE FLOOD ASSESSMENT – PLANNING PROPOSAL 2020/03

REVISED REPORT

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ICETON PLACE FLOOD ASSESSMENT – PLANNING PROPOSAL 2020/03

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EXECUTIVE SUMMARY

This report has been prepared by GRC Hydro Pty Ltd on behalf of Genium Civil Engineering in response to the Department of Planning, Industry & Environment (DPIE) submission for Planning Proposal 2020/03. The Planning Proposal seeks to reduce minimum lot sizes from 10 ha to 1 ha to 2 ha for 7 Iceton Place, Yass.

Flood modelling has been undertaken using the 'Iceton Place Development – Flood Study' (GRC Hydro, 2019) flood models which have been updated to assess indicative post development conditions for the site. Extreme events and potential future conditions due to increased urbanisation and climate change impacts have been assessed.

An indicative lot layout has been produced by Genium Civil Engineering and considered against flood characteristics for the development site. Key findings of the assessment include:

- All lots have building envelopes that are situated outside of the mainstream 1% AEP event extent;
- All lots have room for development outside of the 1% AEP overland flow extent;
- Flows within proposed building envelopes are low hazard (H1 to H2) during the 1% AEP event;
- All building envelopes have sufficient space for development outside of the high hazard areas of O'Briens Creek and overland flow PMF flooding;
- 12 lots have building envelopes situated within the high hazard (H3 – H6) areas of the Yass River PMF flood extent. All of these lots have rising road access to land above the PMF.
- There are no off-site flood impacts in the 1% AEP event and PMF flood impacts are negligible;
- Potential Future Conditions, which considered increased urbanisation and increases in rainfall associated with climate change, are expected to result in an increase in 1% AEP flood level of less than 0.2 m, which is within the freeboard of the Flood Planning Level (0.5 m).
- All building envelopes have room for development outside of the Flood Planning Area.
- No building envelopes are situated within the 1% AEP event Flow Conveyance areas.
- Internal and external site access is available for events exceeding the 1% AEP event. There are expected to be limited isolation potential and emergency services access issues.

The following issues are required to be address at the DA stage to ensure that the development adequately manages flood risk:

- Development of the site is to achieve, at a minimum, the flooding outcomes described above.
- Bulk earthworks should result in a neutral cut/fill ratio within the FPA to minimise loss of flood storage. However, it is not expected that significant bulk earth works are required to manage flood risk for the site.
- Internal roads and driveways are to be designed to allow for flood free access in the 1% AEP event and to minimise hazard for extreme events.
- Drainage easements are required for all significant flow paths to ensure that development does not occur in these areas.

Provided these measures are adopted, the Planning Proposal for development of 7 Iceton Place, Yass is consistent with the Section 9.1 Direction 4.3 Flood Prone Land directives.

1. INTRODUCTION

This report has been prepared by GRC Hydro Pty Ltd on behalf of Genium Civil Engineering in response to the Department of Planning, Industry & Environment (DPIE) submission for 'Planning Proposal 2020/03 – LEP Amendment to reduce minimum lot size from 10 ha to 1 ha to 2 ha - 7 Iceton Place, Yass' (11 December 2020). The DPIE letter is presented in Attachment A.

Existing Conditions design flood characteristics for the 1% AEP event for the site were assessed in the 'Iceton Place Development – Flood Study' (GRC Hydro, 6 September 2019). The Flood Study (2019) is presented in Attachment C. The Flood Study has been updated to assess Post Development Conditions, the 0.5%, 0.2% AEP and Probable Maximum Flood[1] (PMF) events and Future Conditions associated with potential future development and climate change.

1.1 Study Area

The planning proposal is for 7 Iceton Place, Yass (the site) which is situated approximately 5 km south-east of Yass, in southern NSW. O'Briens Creek flows through the site in a northerly direction towards the Yass River (see Image 1). Catchment elevations range from ~638 to 498 mAHD. Various overland flow paths pass through the site on their way O'Briens Creek from the east and west

O'Briens Creek is a tributary of the Yass River, which at the confluence of the two watercourses has a catchment area of 29 km². The Yass River catchment area at this location is ~1,200 km². The region is predominantly rural in nature with few roads and houses and Yass Valley Highway to the north of the site.

1.2 Planning Proposal

The intent of the Planning Proposal (2020/03) is to allow for reduced minimum lot sizes from 10 ha to 1 - 2 ha for 7 Iceton Place, Yass. An indicative lot configuration which considers the site constraints has been developed by Genium Civil Engineering and is presented in Attachment B.

[1] The PMF is the largest flood that could conceivably occur at a particular location. The expected probability of such an event for O'Briens Creek is in the order of one in 10,000,000 (Generalised Short Duration Method, Bureau of Meteorology, 2003).

Image 1: Iceton Place Planning Proposal Site (red) and O'Briens Creek (blue)

1.3 Objectives

This report addresses the DPIE submission for 'Planning Proposal 2020/03 – LEP Amendment to reduce minimum lot size from 10 ha to 1 ha to 2 ha - 7 Iceton Place, Yass' (Attachment A). In response to the DPIE submission the following analysis has been undertaken:

- Development of a Post Development scenario which incorporates an O'Briens Creek bridge crossing, landform changes and assumed increased runoff characteristics associated with urban development;
- Modelling of the 1%, 0.5% and 0.2% AEP and PMF events for Existing and Post Development conditions;
- Modelling of potential future catchment conditions associated with urbanisation and climate change;
- Assessment of flood impacts due to the development;
- Provision of flood hazard, hydraulic categorisation, and flood planning area mapping; and
- Consideration of potential isolation, accessibility and risk to life.

1.4 Previous Studies

The 'Iceton Place Development – Flood Study' (GRC Hydro, 6 September 2019) has been used as the basis of flood modelling analysis presented herein. The Flood Study (2019) is presented in Attachment C.

Hydrology for the Flood Study used WBNM to determine mainstream flows and the direct rainfall (TUFLOW) approach for overland flows. Australian Rainfall and Runoff (ARR) 2019 methods and techniques were applied using calibrated model parameters from regional Council flood studies with the results validated to Flood Frequency Analysis (FFA) for three gauges within the Yass River catchment.

A TUFLOW hydraulic model was developed for the Flood Study to model Existing Conditions (pre-development) for the site. TUFLOW is 2D numerical modelling package which is suitable for creeks and floodplains such as Yass River, O'Briens Creek and its tributaries at the site.

The Flood Study (2019) models have been used as the basis of the modelling analysis undertaken herein. Additional modelling has been undertaken to address the objectives detailed in Section 1.3.

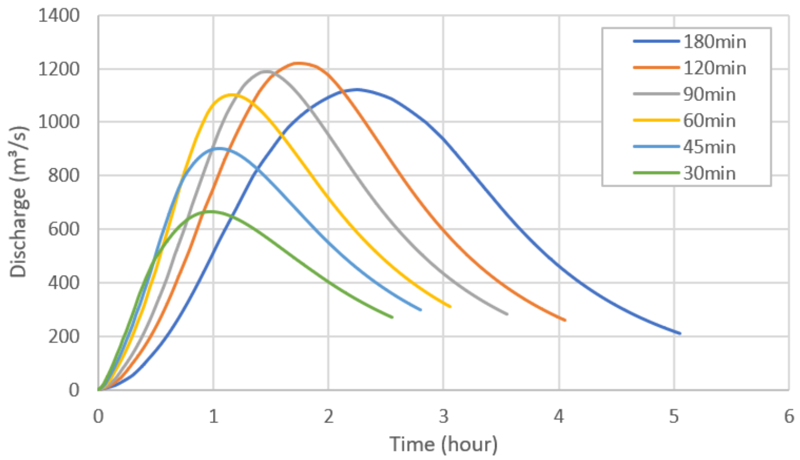
2. FLOOD MODELLING

2.1 Model Updates

The following updates to the Flood Study (see Attachment C) hydrologic and hydraulic models were made:

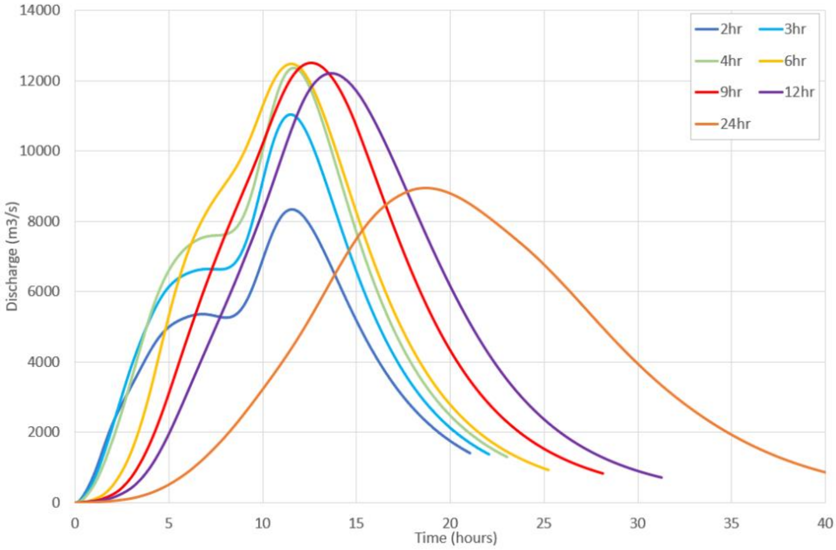
- The TUFLOW model was extended from upstream of O'Briens Creek to downstream of the Yass River dam so that Yass River PMF flooding could be assessed for the site. When assessing the Yass River PMF, the grid size was increased from 5 to 10 m to improve model stability due to significant flood depths relative to cell size.
- PMF event was modelled in WBNM for O'Briens Creek and its tributaries. The Generalised Short Duration Method (GSDM) was implemented due to the catchment area of the Creek being less than 1,000 km^2. Initial and Continuing Losses of 0 mm and 1 mm/hr were applied. A critical duration assessment was undertaken (see Image 2) with the 120 minute duration found to be critical. The O'Briens Creek PMF flow at the site is estimated to be ~1,200 m^3/s.

Image 2: O'Briens Creek PMF Critical Duration Assessment Hydrographs



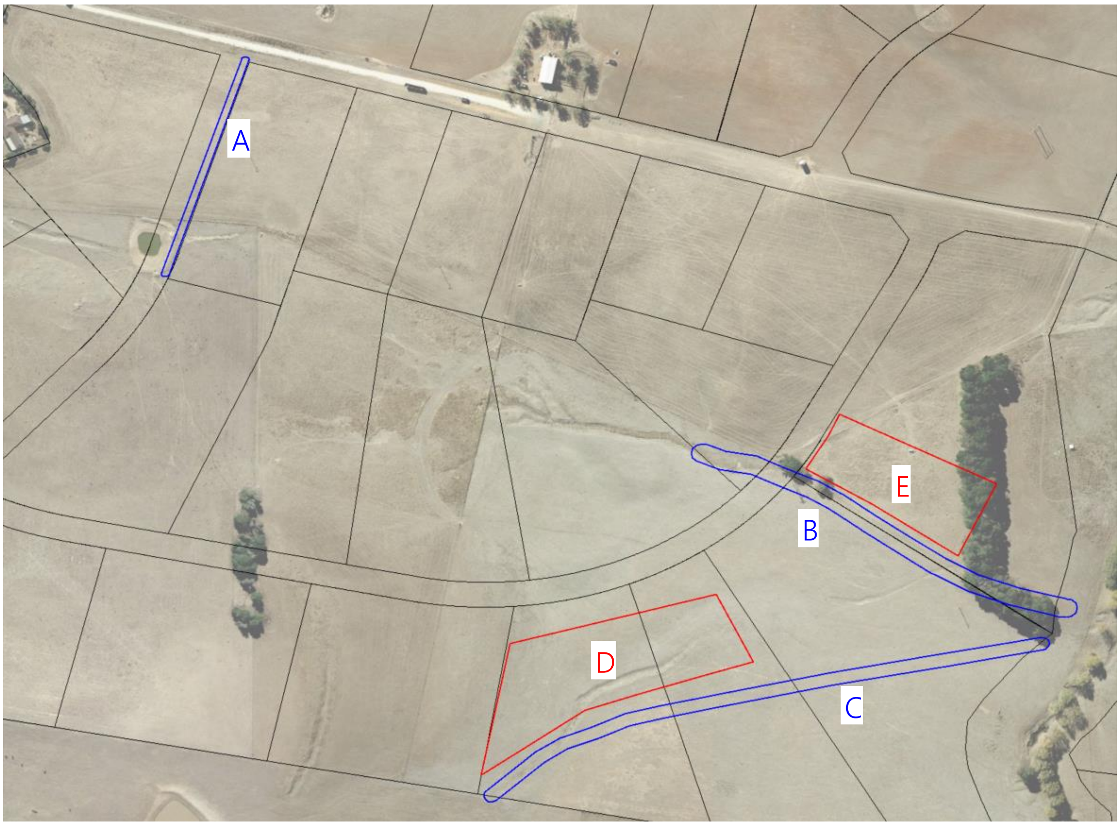
- A Yass River PMF design flow of 12,500 m^3/s was calculated using the hydrologic model developed in the "Yass River Catchment Hydrology Report" (GRC Hydro 2019) presented in Attachment D. The GSDM and Generalised South-east Australia Methods were implemented. A critical duration assessment was undertaken (see Image 3) with the 9 hour duration found to be critical. This flow is noted to be comparable to the PMF flow at Yass of 12,100 m^3/s, derived in the Draft Yass River Floodplain Risk Management Study (Lyall, 2021). The flow was applied to the TUFLOW model to determine the Yass River PMF flood characteristics.

Image 3: Yass River PMF Critical Duration Assessment Hydrographs



- The Existing Conditions TUFLOW model was amended to develop a Post Development scenario. The following model amendment were made to simulate indicative site changes associated with development:
  - Concept design for a bridge crossing of O'Briens Creek was provided by Genium Civil Engineering. This included bridge approaches and assumed deck thickness. The bridge was modelled in TUFLOW using a layered flow constriction in 2d.
  - Channel diversion and landform changes. Indicative swale concepts were modelled at three locations as presented in Image 4. Swales A, B and C have been modelled as 5, 15 and 10 m wide respectively and aim to reduce flood hazard at proposed building envelope locations during extreme events as well as improve driveway access to potential building envelopes. The concept included fill at locations D and E to assist in diverting overland flow paths away from indicative building envelopes. The fill could be obtained from cut from the above mention channels with additional fill obtain from within the site if required to result in a neutral cut/fill ratio to minimise loss of flood storage. Significant bulk earth works are not required to manage flood risk for the site.

Image 4: Concept swale and fill areas



- The % impervious of all road easements within the development are assumed to be 100% impervious.
- The fraction impervious of each block was increased from 0% to 10% to account for potential future development. This allows for 1,000 to 2,000 m^2 of impervious development per lot which is a conservative assumption.
- Overland flow road and driveway crossings have not been modelled. These structures can be designed at the DA stage of development to minimise flood impacts and ensure safety for vehicles.
- It is proposed that drainage easements are implemented at the DA stage for significant flow paths to ensure that development does not occur in these areas.

- A potential Future Conditions model scenario was developed by implementing the following assumptions:
  - The O'Briens Creek catchment is assumed to be developed as large lot subdivisions with a similar lot size as the current planning proposal. As such, the account for potential urbanisation of the upstream catchment, the fraction impervious was increased to 10% imperviousness.
  - The 1% AEP rainfall intensity was increased by 12% to account for potential increases in rainfall intensity associated with climate change. The procedures outlined in Book 1, Chapter 6 of ARR2019 were applied with the following parameters/assumptions; Murray Basin Cluster, medium consequence risk rating, RCP4.5, 2090 planning horizon.

2.2 Analysis of Flood Model Results

2.2.1 Flood hazard

Flood hazard mapping has been developed through application of ARR2019 and Australian Emergency Management Institute (AEMI) flood hazard guidelines. The guidelines consider the threat to people, vehicles and buildings based on flood depth and velocity at a specific location. The AEMI flood hazard mapping can be used to assess the flood hazard for site occupants and proposed site usage, as well as for the community surrounding the site.

Chart 1 and Table 1 present the relationship between the velocity and depth of floodwaters and the corresponding classification.

Chart 1: Flood Hazard Curves (Australian Emergency Management Handbook 7)

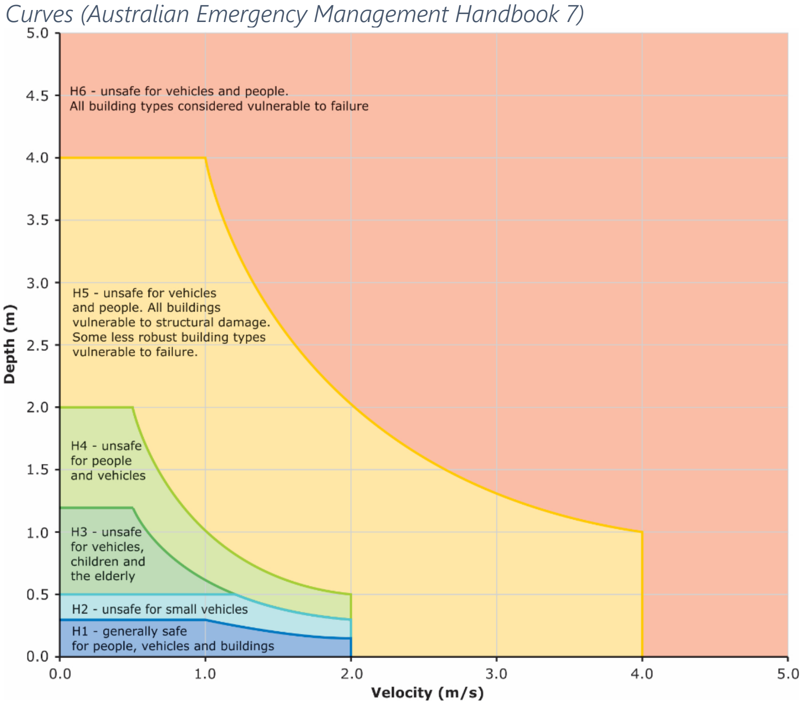


Table 1: Flood Hazard – Vulnerability Thresholds

Hazard Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

2.2.2 Hydraulic Categories

Hydraulic Categories (also known as Flood Function) refers to the classification of floodwaters into three categories; flow conveyance (previously known as the floodway), flood storage and flood fringe. These categories help to describe the nature of flooding across the floodplain and aid planning when assessing developable areas. According to the Australian Emergency Management Handbook 7, these three categories can be defined as:

- Flow Conveyance – the areas where a significant proportion of the floodwaters flow and typically align with defined channels. If these areas are blocked or developed, there will be significant redistribution of flow and increased flood levels across the floodplain. Generally, the flow conveyance are areas of deep and/or fast-moving floodwaters;
- Flood Storage – areas where, during a flood, a significant proportion of floodwaters extend into, water is stored and then recedes after a flood. Filling or development in these areas may increase flood levels nearby.
- Flood Fringe – areas that make up the remainder of the flood extent. Development in these areas are unlikely to alter flood behaviour in the surrounding area.

There is no prescribed methodology for deriving each category and as such categorisation has been based on the methodology presented in the Gundaroo Flood Study (WMAwater, 2016). The Gundaroo Flood Study applies the criteria proposed by Howells et. al. (2003) as reproduced in Image 5.

Image 5: Gundaroo Hydraulic Categorisation (WMAwater, 2016)

Floodway:		**Velocity x Depth > 0.25 m^2/s AND Velocity > 0.25m/s**
	OR	**Velocity > 1m/s AND Depth > 0.15m**
Flood Storage:		Land outside the floodway where Depth > 0.5m
Flood Fringe		Land outside the floodway where Depth < 0.5m

The applied criteria overestimates Flow Conveyance for mainstream flooding and extreme events and is thus conservative in its application.

2.2.3 Flood Planning Area

The Flood Planning Area (FPA) has been defined for the concept Proposed Conditions scenario. The FPA has been derived using the following methods:

- Mainstream flooding – The mainstream FPA has been set as the extent of land below the Flood Planning Level which has been defined as the 1% AEP event plus 0.5 m freeboard. A freeboard of 0.5 m is consistent with the Yass FRMSP (Lyall, 2021) which adopted a freeboard of 0.5 m for tributaries of the Yass River.
- Overland flows – The overland flow FPA has been determined using the methodology outlined in the Yass FRMSP (Lyall, 2021) which defined the FPA as 'the extent of areas which act as a floodway, as well as areas where depths of inundation exceed 0.1 m in a 1% AEP event'.

2.3 Hydraulic Model Results

This section presents the hydraulic model results for the 1%, 0.5%, 0.2% AEP and PMF events. The following flood maps are provided:

- Figure 1: Existing and Post Development Conditions - 1% AEP Event Flood Depths
- Figure 2: Existing and Post Development Conditions - 1% AEP Event Flood Hazard

- Figure 3: Existing and Post Development Conditions - PMF Event Flood Depths
- Figure 4: Existing and Post Development Conditions - PMF Event Flood Hazard
- Figure 5: Flood Level Impact Maps – 1% AEP and PMF Events
- Figure 6: Mainstream Flood Planning Area & Future Conditions Flood Level Increase
- Figure 7: Post Development Conditions Hydraulic Categories - 1% AEP and PMF Events
- Figure 8: Existing and Post Development Conditions – 0.5% AEP Event Flood Depths
- Figure 9: Existing and Post Development Conditions – 0.5% AEP Event Flood Hazard
- Figure 10: Existing and Post Development Conditions – 0.2% AEP Event Flood Depths
- Figure 11: Existing and Post Development Conditions – 0.2% AEP Event Flood Hazard

The Yass River PMF event inundates a large portion of the site due to backwater. The flood depths are significant and generally described as high hazard flood storage due to the low velocities associated with backwater conditions. The flood risk profile associated with Yass River PMF flooding for the site, whilst significant, differs from O'Briens Creek flooding due to the comparatively low velocities and slower rate of rise. Accordingly, the Yass River PMF extent only is shown on Figure 3, with low (H1 to H2) and high (H3 to H6) hazard areas indicated on Figure 4. Areas of O'Briens Creek affected by Yass River PMF flooding are considered storage areas due to the backwater characteristics. Table 2 presents the peak flood depth, velocity and duration of inundation for flood affected building envelopes in the PMF Yass River event.

Table 2: Yass River PMF flood affected building envelopes*

Building Envelope ID#	Peak Depth (m)	Peak Velocity (m/s)	Duration of Inundation (hours)
15	0.40	0.02	2.95
16	1.22	0.04	5.01
17	1.60	0.03	5.54
18	3.23	0.05	7.96
22	6.93	0.08	12.72
24	4.29	0.05	9.36
25	1.83	0.03	5.92
26	2.98	0.05	7.60
28	6.38	0.06	12.01
27	6.99	0.04	12.81
44	2.56	0.04	7.00
69	0.38	0.03	2.89
70	2.99	0.25	7.57
71	4.53	0.08	9.70

* No proposed building envelopes are affected by O'Briens Creek or Yass River for events up to an including the 0.2% AEP event.

Key findings from comparison of the indicative lot layout (see Section 1.2) and flood mapping results include:

- All lots have building envelopes that are situated outside of the mainstream 1% AEP event extent;

- All building envelopes have room outside of the 1% AEP overland flow extent for development. It is proposed that drainage easements are implemented at the DA stage for significant flow paths to ensure that development does not occur in these areas;
- Flows within the proposed building envelopes are low hazard (H1 to H2) during the 1% AEP event;
- All building envelopes have sufficient space for development outside of the high hazard areas of O'Briens Creek and overland flow PMF flooding;
- There are 12 lots which have building envelopes situated within the high hazard (H3 – H6) areas of the Yass River PMF flood extent. The Yass River PMF event is an area of backwater and thus velocities are typically low and flood hazard is due to significant water depths. Due to the large catchment size of the Yass River (~1,200 km^2 at the site), the rate of rise is slower than that associated with O'Briens Creek PMF flooding.
- There are no off-site flood impacts in the 1% AEP event and PMF flood impacts are negligible;
- The increase in fraction impervious due to development does not significantly increase peak flood levels;
- Potential Future Conditions, which considered increased urbanisation and increases in rainfall associated with climate change, are expected to result in an increase in 1% AEP flood level of less than 0.2 m, which is within the freeboard of the Flood Planning Level (0.5 m).
- All building envelopes have room for development outside of the Flood Planning Area.
- No building envelopes are situated within the 1% AEP event Flow Conveyance areas. Localised areas of overland flow Flow Conveyance impact some building envelopes during the PMF, however all buildings envelopes are situated outside of the PMF mainstream Flow Conveyance area.

2.4 Flood Access

2.4.1 External Flood Access

Consideration of isolation potential and access issues for emergency services during flood is discussed below. The proposed development site has two external access points:

- Access Point #1 - Yass Valley Way to the east of O'Briens Creek; and
- Access Point #2 - Iceton Place to the western side of the development site.

The external access point locations are presented in Image 6.

The Yass Valley Way access point (#1) provides flood free access to Yass and the Barton Highway for events up to and including the 1% AEP event. The Yass Valley Way crossing of O'Briens Creek is noted not to be flooded in this event as presented in Figure 1, with the 1% AEP flood level estimated to be approximately 0.5 m below the level of the road. Review of flood extent mapping presented in 'Yass Dam Upstream Tailwater Investigation' (NSW Public Works, 2012) also shows that the Yass Valley Way crossing of the Yass River is also not overtopped with the road level estimated to be approximately 2 m above the 1% AEP event.

The Iceton Place access point (#2) provides flood access to Yass via Cusack Place, Gums Road and Wee Jasper Road. The access route is unlikely to be significantly flooded during any event up to and including the PMF. The maximum catchment size upstream of the road is ~3 ha and any flows overtopping the road would be shallow and short in duration.

With two access routes available to the site from Yass and one from the Barton Highway, all of which experience limited flood liability, flood access to the site is good. The access availability reduces isolation potential and improves access to the site for emergency services.

Image 6: Access Points to External Roads

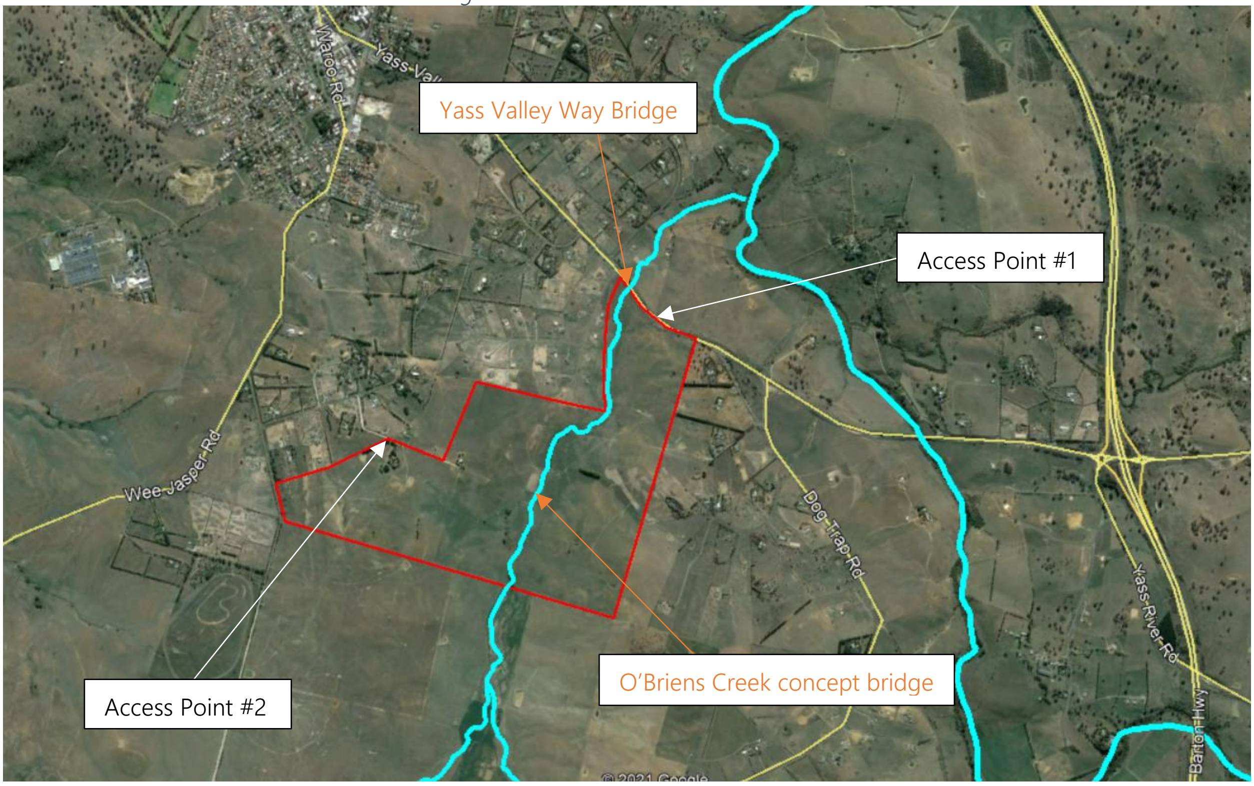


Table 3 presents the Yass River flood affectation of key flood access routes at the Yass Valley Way bridge and O'Briens Creek concept bridge (shown in Image 6). Flooding of these routes affects the flood access for properties on the eastern side of O'Briens Creek (Building envelope ID #1 – 28). Table 3 indicates that while these properties will have flood access via the O'Briens Creek concept bridge in the 0.5% and 0.2% AEP events, these properties will be isolated in the Yass River PMF event for approximately 15 hours.

Table 3: Yass River flood affectation of key access routes

Location	Flood Event	Peak Depth (m)	Peak Velocity (m/s)	Duration of Inundation (hours)
Yass Valley Way Bridge	0.5% AEP	0.67	0.14	5.5
	0.2% AEP	1.78	0.26	8.5
	PMF	12.95	0.81	20.8
O'Briens Creek concept bridge	0.5% AEP	*Not flooded*		
	0.2% AEP	*Not flooded*		
	PMF	12.86	0.29	15.4

2.4.2 Internal Site Access

Internal site access is key for evacuation if required. Review of the Post Development flood hazard categories presented in Figure 2 indicates that:

- Internal roads are expected to be generally flood free or subject to, at worst, H1 flood hazard conditions in the 1% AEP event. Road design at the later stages of development is required to ensure this outcome.
- Overland flow path road crossing locations experience localised areas of higher hazard. Road raising and construction of culverts can be developed at the DA stage to provide flood free access in the 1% AEP event and low hazard access in extreme events.
- The concept bridge crossing provides flood free access in the 1% AEP event with the road level approximately 1.2 m above the 1% AEP flood level.

Road PMF flood hazard (Figure 4) due to overland flows is predominantly H1 with localised areas of H2 affecting internal site access roads. The O'Briens Creek concept bridge crossing is overtopped during the PMF and numerous roads are cut during a Yass River PMF event. Properties on the eastern side of O'Briens Creek are likely to have access to Yass during a PMF and all properties have rising road access to areas above the PMF level for both O'Briens Creek and the Yass River flooding.

3. PLANNING POLICY DISCUSSION

3.1 Overview of Relevant Planning Policy

The Section 9.1 Direction 4.3 *'applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land'*. The Direction aims to ensure that '*the development of flood prone land is consistent with NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005*' (FDM, 2005), including the principles of Planning Circular PS 07-003, '*Guideline on development controls on low risk flood areas*'.

The FDM (2005) *'promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable'* and aims to *'avoid the unnecessary sterilisation of flood prone land'*.

Direction 4.3 states that *'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'* and that a *'planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005'*.

Direction 4.3 states that, *'a planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that', 'the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005*'.

Planning Circular PS 07-003, 'Guideline on development controls on low risk flood areas' outlines a set of guidelines for *'flood-related development controls on residential development on land above the 1-in-100 year flood and up to the Probable Maximum Flood (PMF)'*. The Guideline confirms that:

- *'unless there are exceptional circumstances, councils should adopt the 100-year flood as the FPL for residential development; and*
- *unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL.'*

Council has not developed a flood risk management plan for the site. The Yass River Floodplain Risk Management Study and Plan (FRMSP) is currently being prepared but has not yet been adopted by Council. However, the Gundaroo and Sutton FRMSP (WMAwater, 2016) were reviewed and found to have a recommendation for applying for exceptional circumstances. The recommendation was to implement a Flood Risk Management clause into the LEP so that controls for sensitive and critical uses can be applied for areas above the FPL up to the PMF. The FRMSP do not suggest that additional exceptional circumstances are applied for residential development and as such the proposal is consistent with the recommendations presented in Council's floodplain risk management study.

Further to this, Section 6.2 'Flood Planning', of the Yass Valley Local Environmental Plan 2013 (YVLEP), *'applies to land at or below the flood planning level'* with *'the flood planning level'* classified as the *'1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard'*.

Accordingly, assessment of the Iceton Place Planning Proposal must necessarily have consideration for the nominated flood planning level of the '*1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard'* as per Council's LEP and the requirements of the Section 9.1 of Direction 4.3.

3.2 Recent Policy Updates

In June 2020, the Department of Planning, Infrastructure & Environment (DPIE) exhibited a draft Flood Prone Land Package which includes a draft Local Planning Direction and a draft Planning Guideline for the consideration of flooding in land use.

The draft Local Planning Direction prescribes, inter alia, that land should not be rezoned to permit development in a floodway, or development that will result in significant flood impacts to other properties or which permits a significant increase in the dwelling density in a high hazard areas. Further, the Direction requires that a council's Flood Planning Level(s) must be consistent with the Floodplain Development Manual 2005 (or its update) or as otherwise determined by an adopted Floodplain Risk Management Study.

It is noted that in the subject case the Iceton Place Planning proposal does not seek to rezone the land to permit development – it merely seeks to decrease minimum lot sizes that applies to development on the land. Further, the site experiences limited flood liability in the 1% AEP and development is not proposed within a floodway or high hazard area during Council's nominated design flood event.

The draft Planning Guideline reinforces the purpose and usefulness of a flood risk management (FRM) process to understand the implication of flood events, up to and including the PMF, in considering the development of flood-prone land. The Guideline nominates the 1% AEP flood event (plus freeboard) as the appropriate flood planning level and the area of land beneath this level as the Flood Planning Area (FPA), where the majority of flood-related development controls apply. The Guideline allows Councils to set a different FPL where the merit of such an approach is demonstrated and documented.

The Guideline also identifies other categories of flood management – a Regional Evacuation Consideration Area (RECA) and a Special Flood Considerations (SFC) category – these allow for areas of land to be identified for special evacuation consideration and/or for specific controls to be developed for flood events between the FPL and the PMF. These typically relate to the identification and prohibition of sensitive, vulnerable or critical land uses. The Guideline suggests that circumstances defined through an FRM process where development controls might be needed to address risk to life may include areas where development is isolated by floodwaters and terrain for an extended period, areas where development may have evacuation capacity limitations and areas impacted by either high hazard or/and H3 to H6 hazard vulnerability thresholds in the PMF and are unable to safely evacuate.

In the subject case Council's FPL remains at the 1% AEP + 500mm freeboard level and no action has been taken thus far, or suggested to be taken, to nominate the Iceton Place site as a Regional Evacuation Consideration Area (RECA). Similarly, there is no policy direction from Council that requires special consideration of events rarer than the FPA.

Notwithstanding, for the subject site and for the purpose of advancing agency consideration of the Iceton Place Planning Proposal, additional consideration of flood risk due to flood events exceeding the flood planning level is prudent given the magnitude of Yass River and O'Briens Creek flooding for areas of the site during extreme events.

3.3 Consideration of Section 9.1 Direction 4.3

The pertinent aspects of Section 9.1 Direction 4.3 are reproduced below and addressed in blue.

The direction requires that:

- *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).*

Response:

Consideration of a range of flood events up to the PMF, including flood hazard and flood function classification, has been undertaken. Further, site access and the potential for isolation and emergency vehicle access issues are considered. The analysis and findings are consistent with the objectives of the Floodplain Development Manual 2005.

- *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.*

Response:

The Planning Proposed does not rezone land. It seeks to amend the minimum lot size for the site.

- *A planning proposal must not contain provisions that apply to the flood planning areas which:*
  - *i. permit development in floodway areas,*
  - *ii. permit development that will result in significant flood impacts to other properties,*
  - *iii. permit a significant increase in the development of that land,*
  - *iv. are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*
  - *v. 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.*

Response:

The indicative lot layout produced by Genium Civil Engineering show that all lots have sufficient space outside of floodway areas for development (Figure 7). Flood impact analysis shows that the development will not result in significant flood impacts to other properties (Figure 5). All developable land is situated outside of the flood planning area (Figure 6). Limited flood liability of developable areas will mean that flood mitigation works will not be required to manage flood risk. Further, available flood access reduces *isolation potential and access issues for emergency services, meaning that road upgrades to existing roads would not be required to address evacuation issues.*

- *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).*
- *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).*

Response:

The Iceton Place Planning Proposal has consideration for the nominated flood planning level of the '*1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard*' as per Council's LEP. Land below this level is not proposed to be developed. This flood planning level is consistent with the FDM (2005).

4. CONCLUSIONS

This report has been prepared by GRC Hydro Pty Ltd on behalf of Genium Civil Engineering in response to the Department of Planning, Industry & Environment (DPIE) submission for Planning Proposal 2020/03. The Planning Proposal seeks to reduce minimum lot sizes from 10 ha to 1 ha to 2 ha for 7 Iceton Place, Yass.

Flood modelling has been undertaken using the 'Iceton Place Development – Flood Study' (GRC Hydro, 2019) flood models which have been updated to assess indicative post development conditions for the site. Extreme events and potential future conditions due to increased urbanisation and climate change impacts have been assessed.

An indicative lot layout has been produced by Genium Civil Engineering and considered against flood characteristics for the development site. Key findings of the assessment include:

- All lots have building envelopes that are situated outside of the mainstream 1% AEP event extent;
- All lots have room for development outside of the 1% AEP overland flow extent;
- Flows within proposed building envelopes are low hazard (H1 to H2) during the 1% AEP event;
- All building envelopes have sufficient space for development outside of the high hazard areas of O'Briens Creek and overland flow PMF flooding;
- 14 lots have building envelopes situated within the high hazard (H3 – H6) areas of the Yass River PMF flood extent. All of these lots have rising road access to land above the PMF.
- There are no off-site flood impacts in the 1% AEP event and PMF flood impacts are negligible;
- Potential Future Conditions, which considered increased urbanisation and increases in rainfall associated with climate change, are expected to result in an increase in 1% AEP flood level of less than 0.2 m, which is within the freeboard of the Flood Planning Level (0.5 m).
- All building envelopes are situated outside of the Flood Planning Area.
- No building envelopes are situated within the 1% AEP event Flow Conveyance areas.
- Internal and external site access is available for events exceeding the 1% AEP event. There are expected to be limited isolation potential and emergency services access issues.

The following issues are required to be address at the DA stage to ensure that the development adequately manages flood risk:

- Development of the site is to achieve, at a minimum, the flooding outcomes described above.
- Bulk earthworks should result in a neutral cut/fill ratio within the FPA to minimise loss of flood storage. However, it is not expected that significant bulk earth works are required to manage flood risk for the site.
- Internal roads and driveways are to be designed to allow for flood free access in the 1% AEP event and to minimise hazard for extreme events.
- It is proposed that drainage easements are implemented at the DA stage for significant flow paths to ensure that development does not occur in these areas.

Provided these measures are adopted, the Planning Proposal for development of 7 Iceton Place, Yass is consistent with the Section 9.1 Direction 4.3 Flood Prone Land directives.

5. REFERENCES

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   WMAwater, 2016

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   WMAwater, 2016

4. Yass Valley Council
   Sutton Flood Study
   WMAwater, 2016

5. Yass Valley Council
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   WMAwater, 2016

6. Yass Valley Council
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   WMAwater, 2016

7. NSW Office of Environment and Heritage
   Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in Studies
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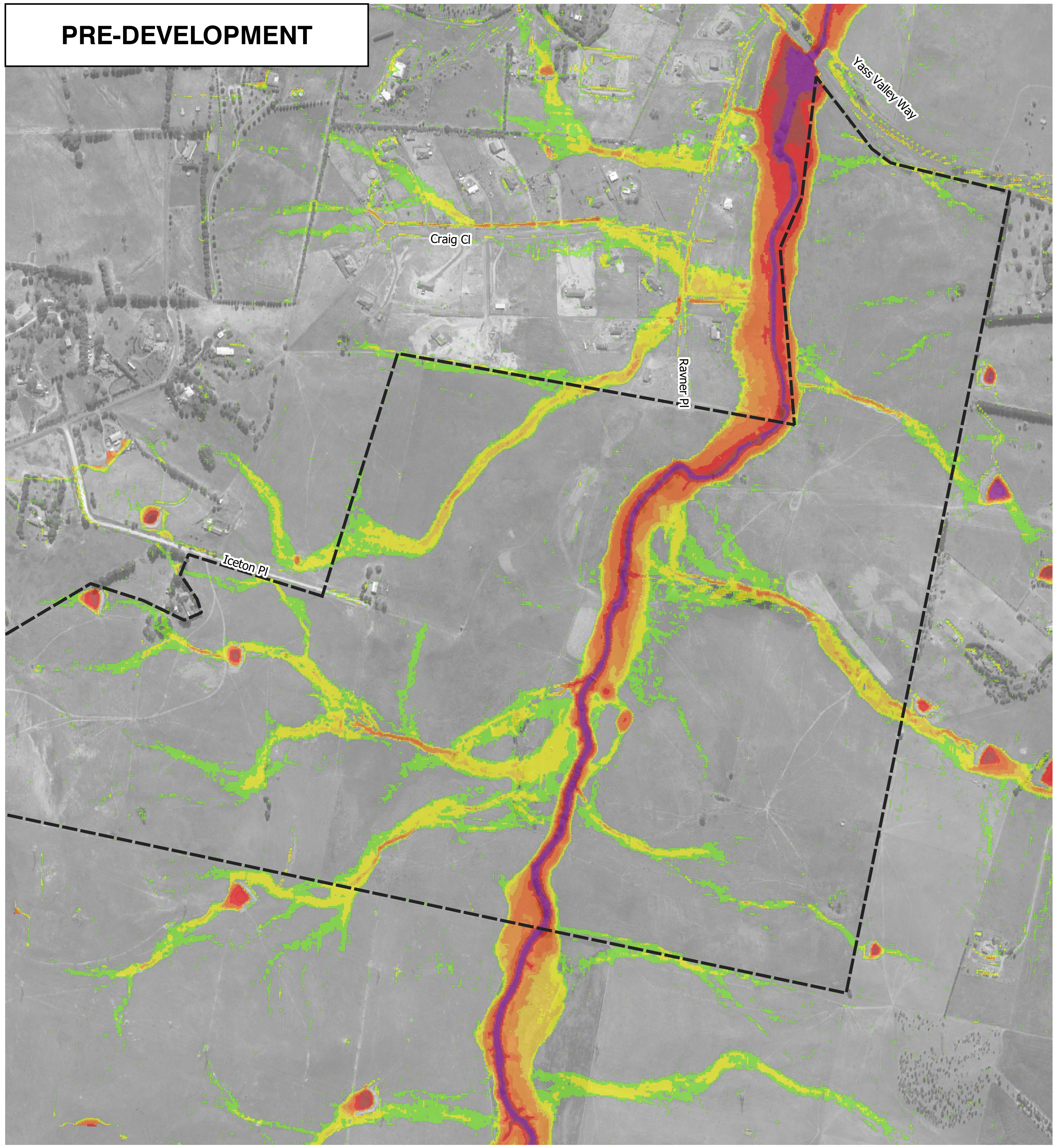
   TUFLOW, 2016

9. Australian Government
   The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method
   Bureau of Meteorology, 2006

10. Australian Government
    AEM Handbook 7, Technical flood risk management guideline – Flood Hazard
    Australian Emergency Management Institute, 2014

Figures



--------- Site Extent
Cadastral Boundaries
Building Envelopes

Flood Depths (m)
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

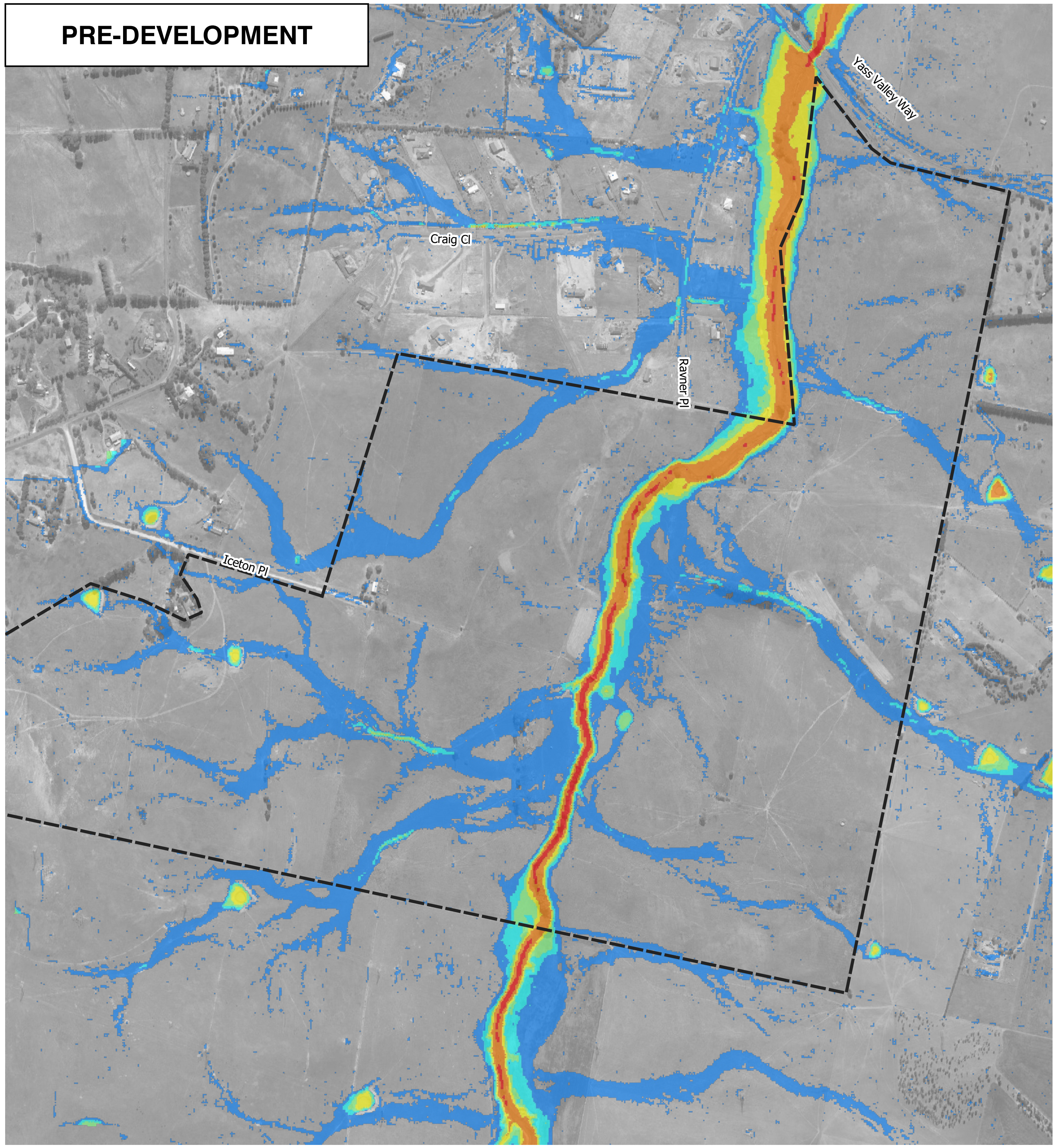
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

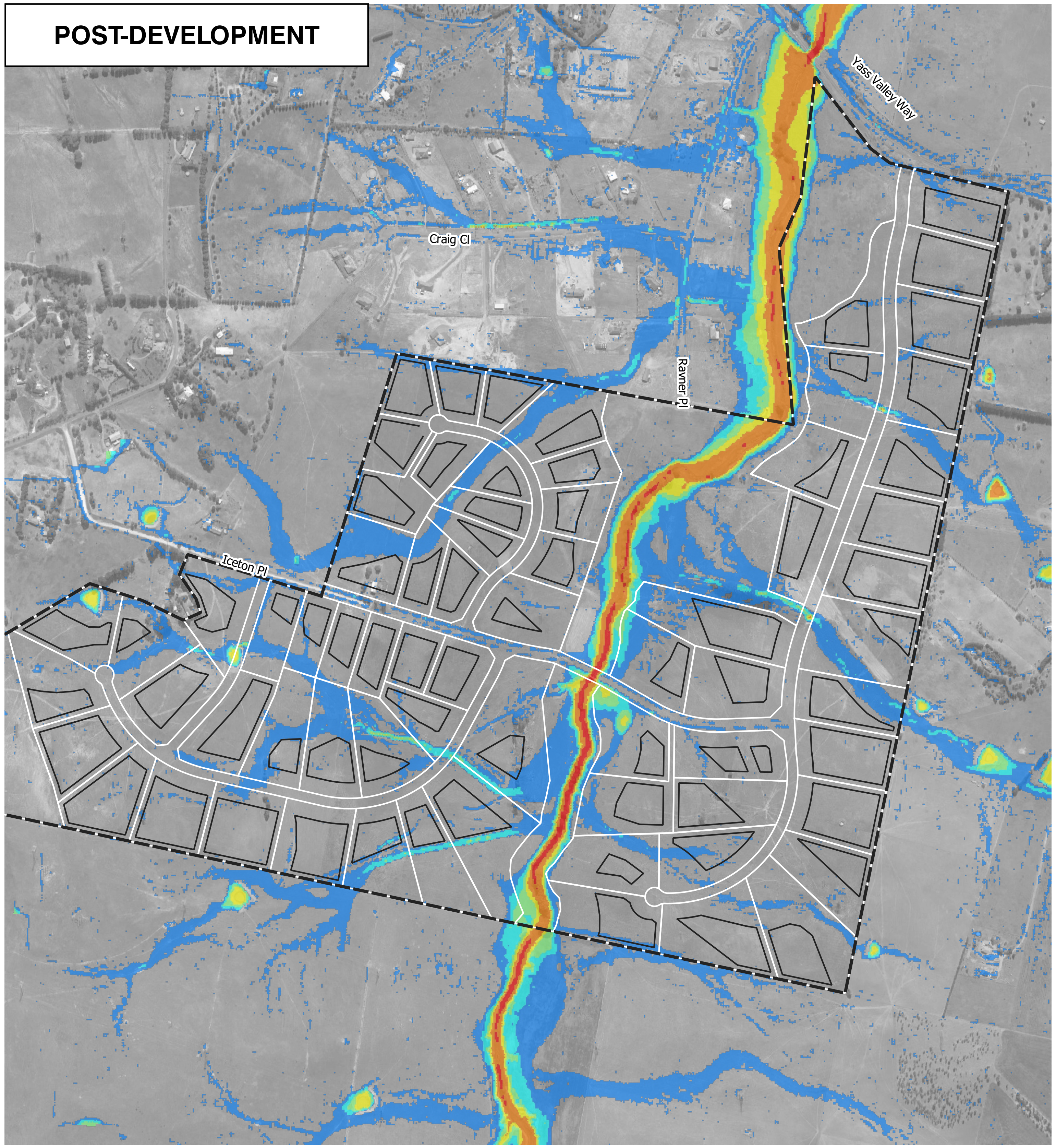
N
W E
S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Depth - 1% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **04-2021**	SCALE: **1:10000**	FIGURE No. **01**





--------- Site Extent
Cadastral Boundaries
Building Envelopes

Flood Hazard (ZAEM1)
H1
H2
H3
H4
H5
H6

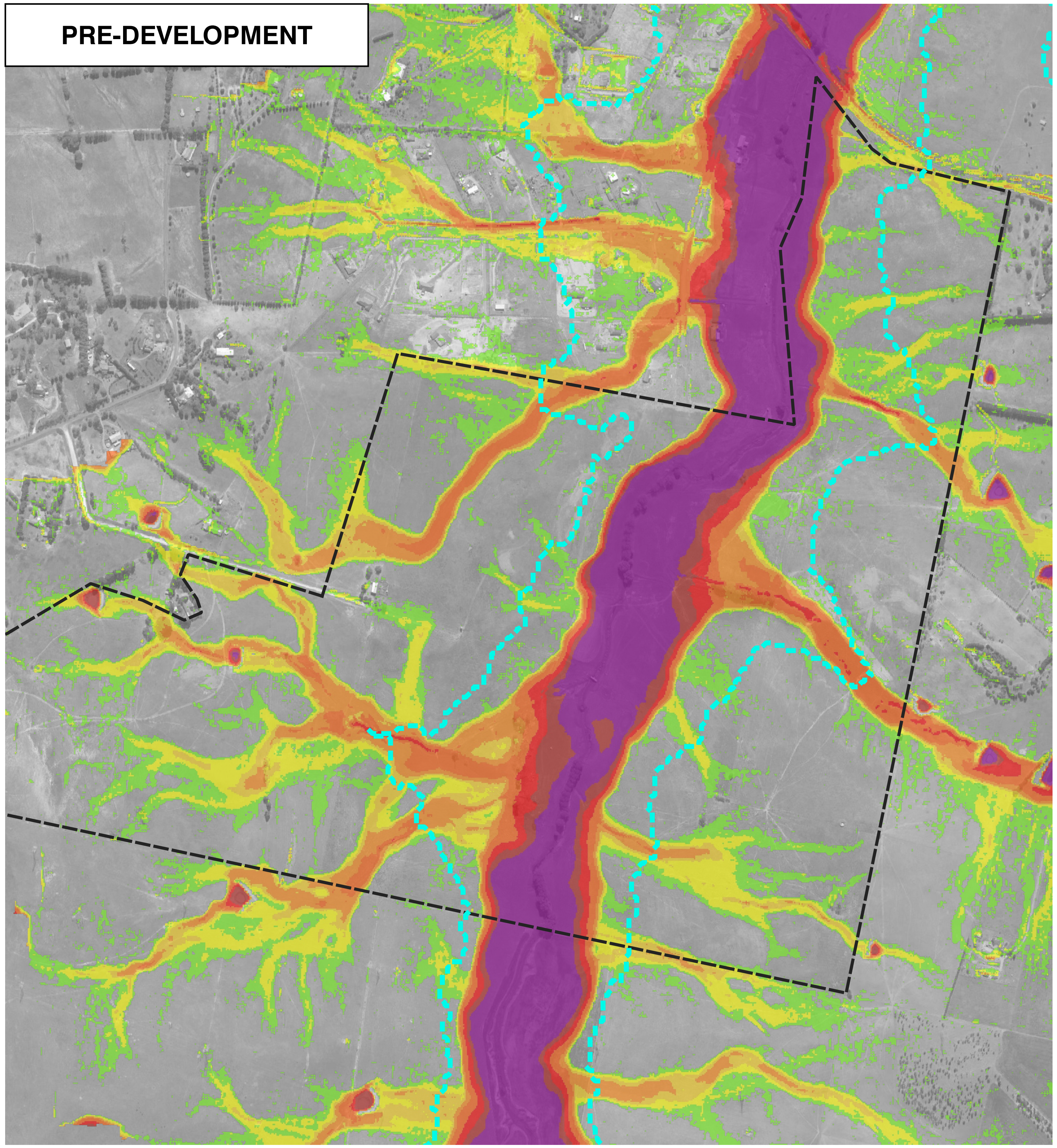
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

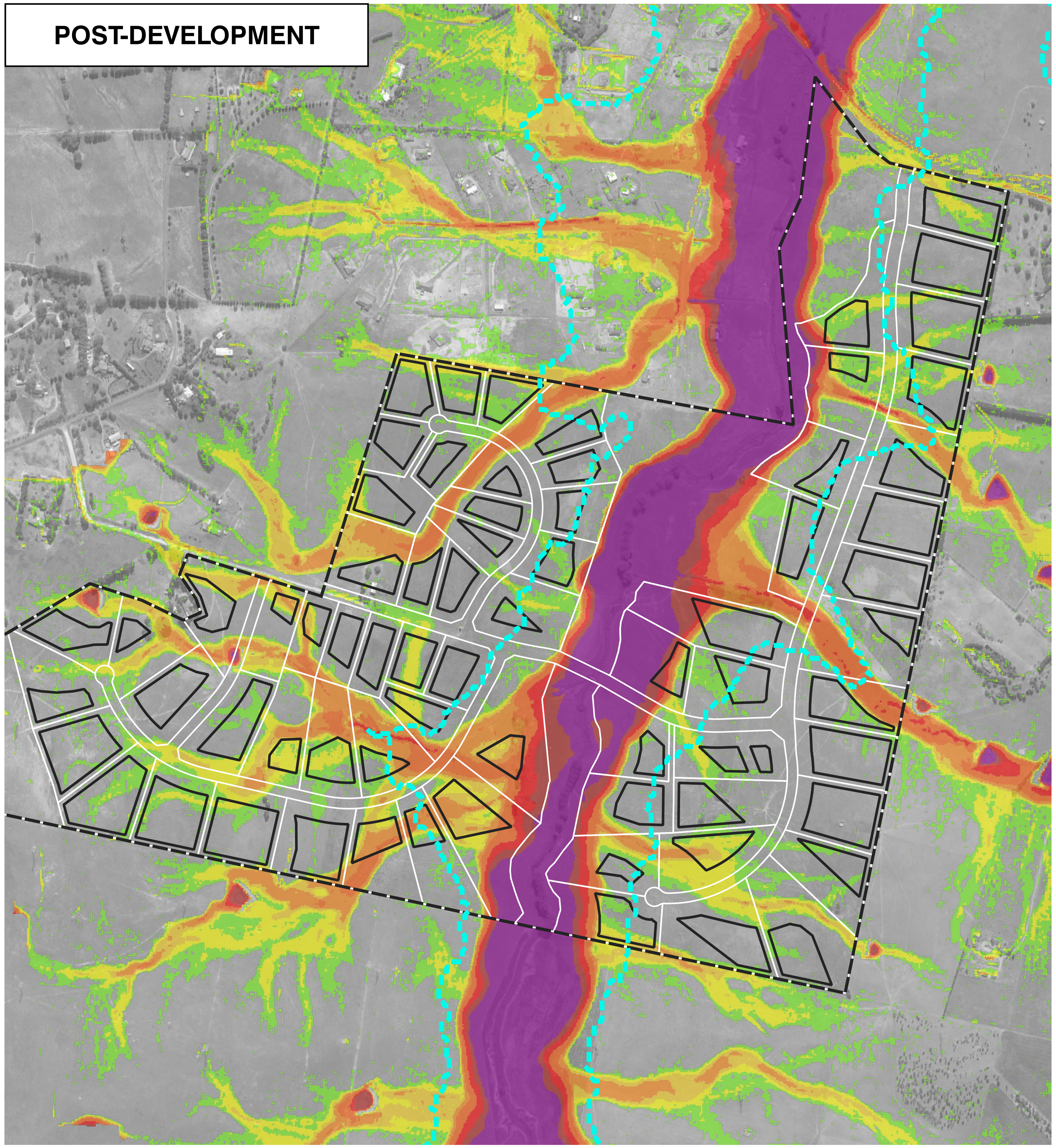
N W E S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Hazard - 1% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **04-2021**	SCALE: **1:10000**	FIGURE No. **02**





Site Extent
Cadastral Boundaries
Building Envelopes

Flood Depths (m)
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

Yass River PMF Flood Extent

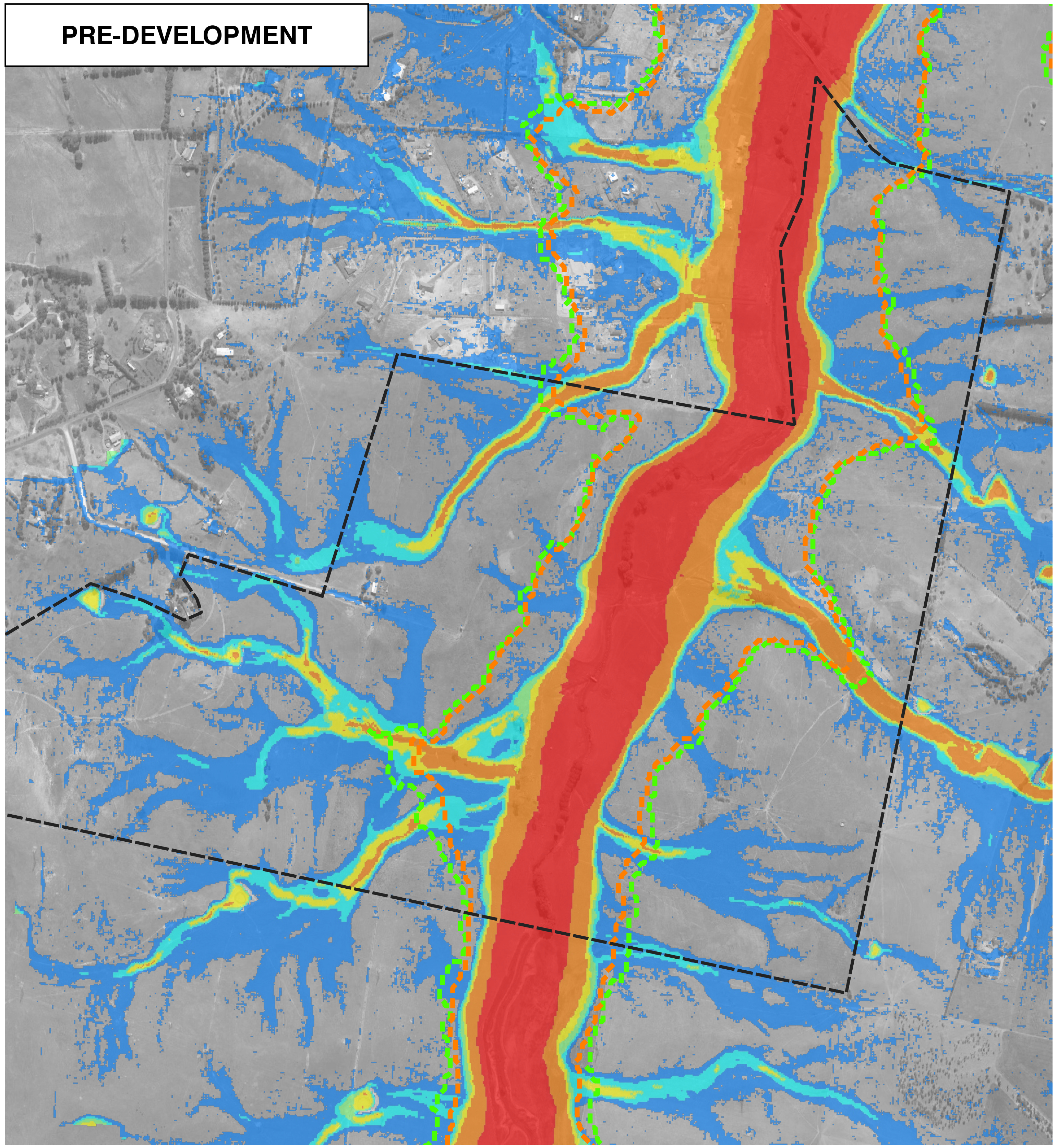
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

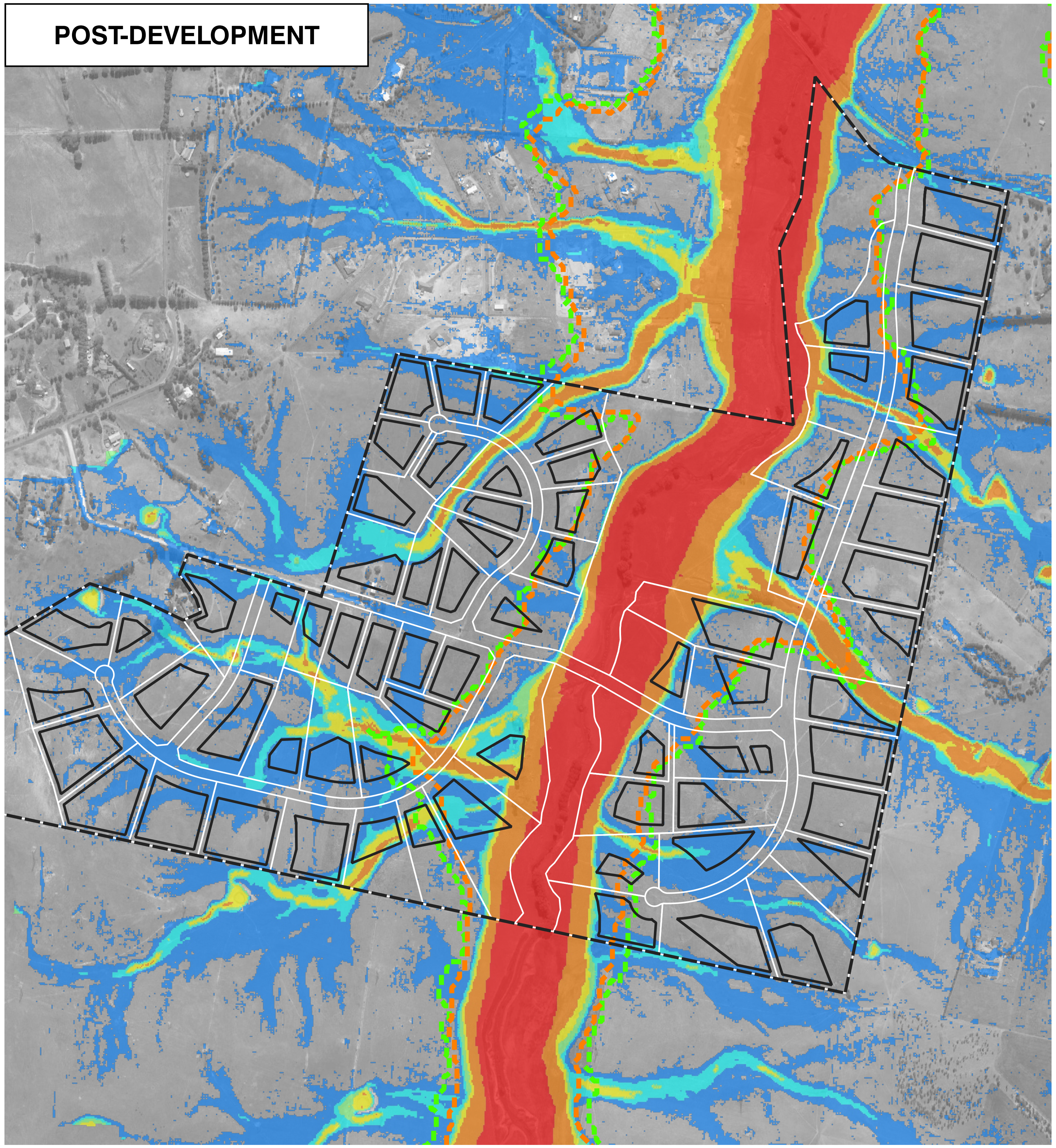
N
W E
S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Depth - PMF**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10000**	FIGURE No. **03**





Site Extent
Cadastral Boundaries
Building Envelopes

Flood Hazard (ZAEM1)
H1
H2
H3
H4
H5
H6

Yass River PMF Flood Extent
Yass River PMF High Hazard Extent

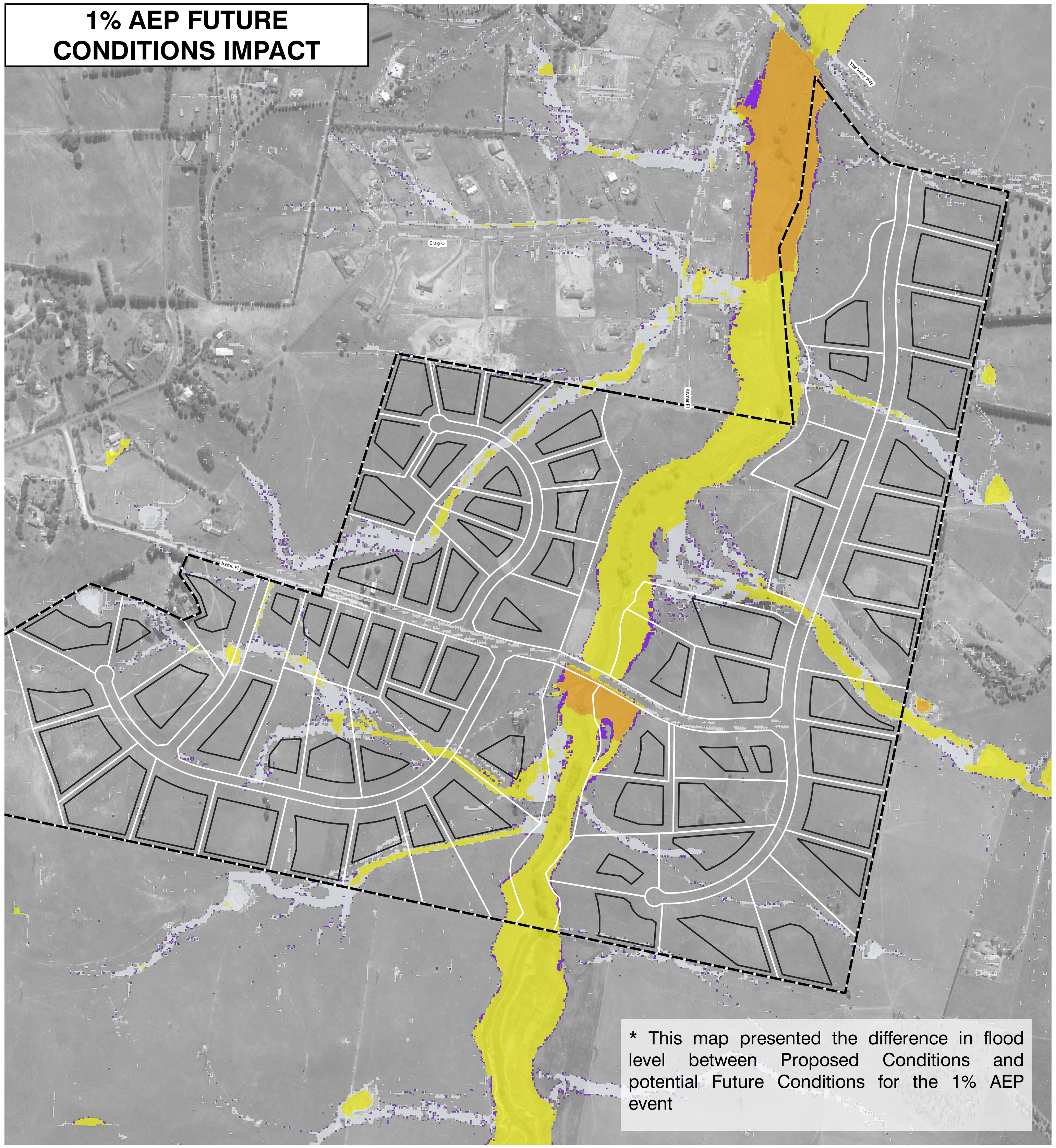
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N W E S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Hazard - PMF**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10000**	FIGURE No. **04**



Site Extent
Cadastral Boundaries
Building Envelopes

* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

Flood Planning Area
Extent

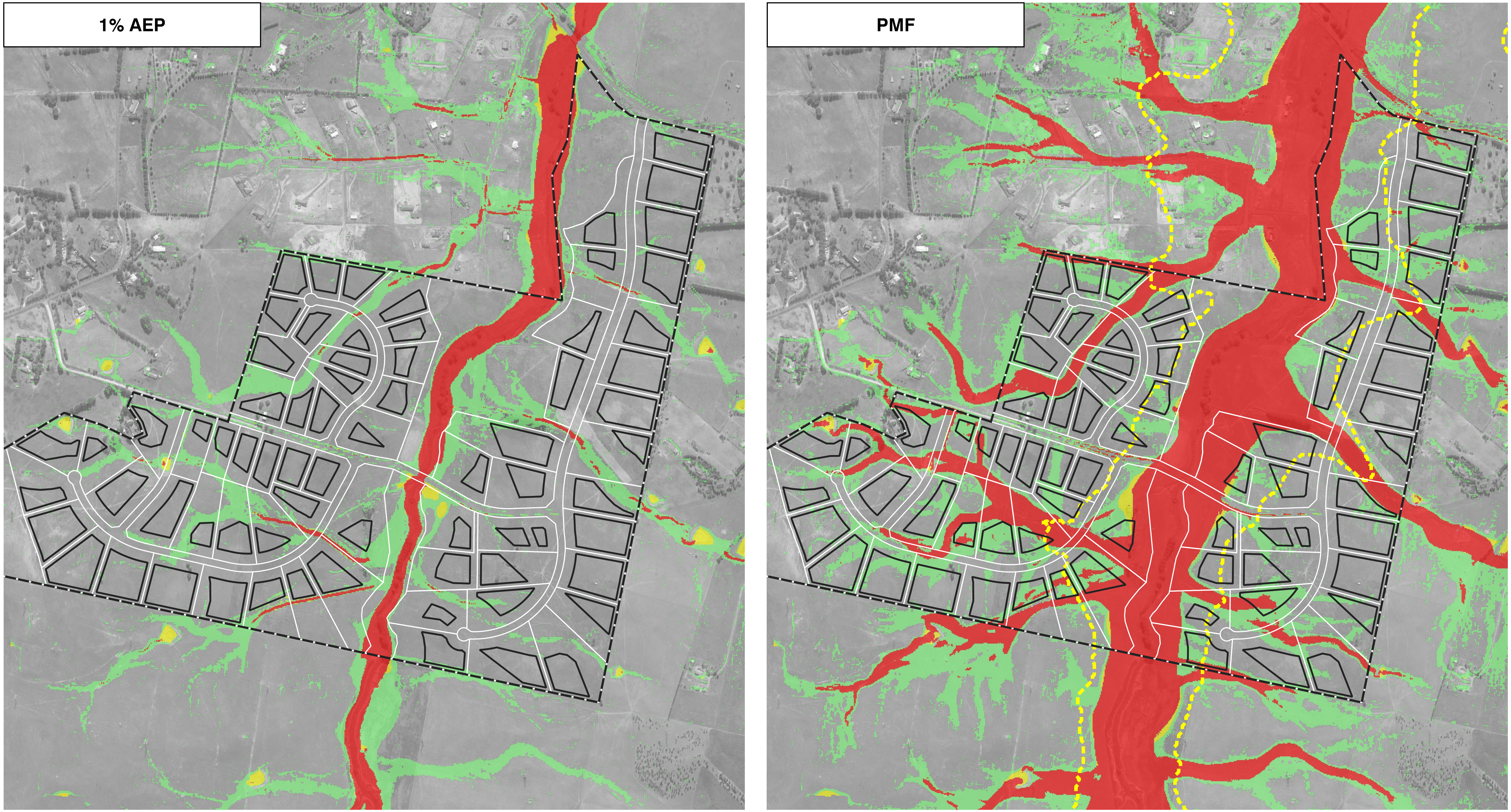
Flood Impact
< -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.01
No Impact
0.01 to 0.1
0.1 to 0.2
0.2 to 0.3
> 0.3

Newly Flooded

N
W E
S

0 300 600 900 1,200 metre

TITLE: **Flood Planning Level & Future Conditions Flood Impact**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10,000**	FIGURE No. **06**



Site Extent
Cadastral Boundaries
Building Envelopes

Hydraulic Categories
Flow Conveyance
Flood Storage
Flood Fringe

Yass River PMF Flood Storage

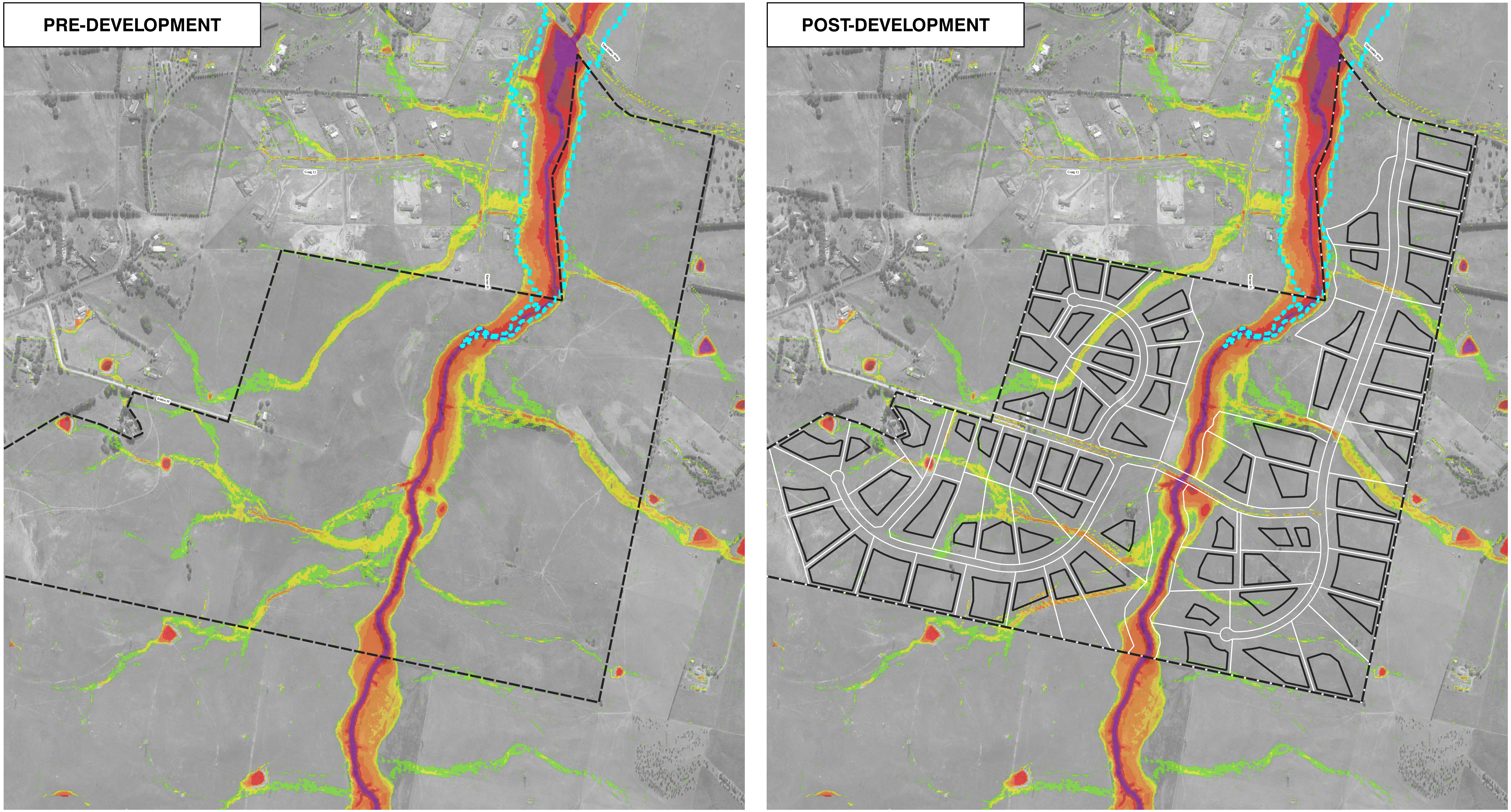
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N W E S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Hydraulic Categories**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10000**	FIGURE No. **07**



---------	Site Extent
———	Cadastral Boundaries
———	Building Envelopes

Flood Depths (m)

- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

Yass River 0.5% AEP Flood Extent

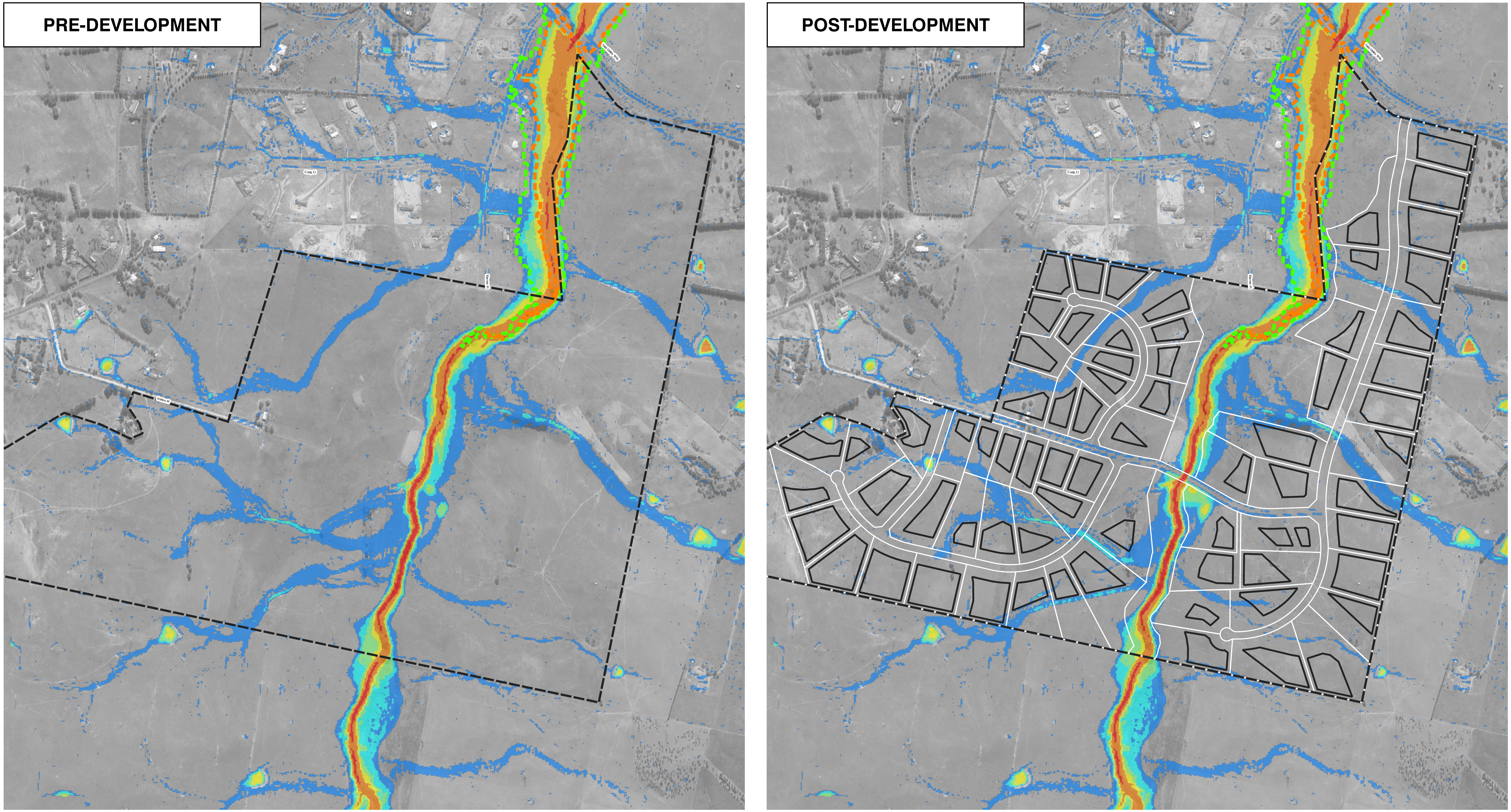
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N W E S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Depth - 0.5% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:1**	FIGURE No. **08**



Site Extent
Cadastral Boundaries
Building Envelopes

Flood Hazard (ZAEM1)
H1
H2
H3
H4
H5
H6

Yass River 0.5% AEP Flood Extent
Yass River 0.5% AEP High Hazard Extent

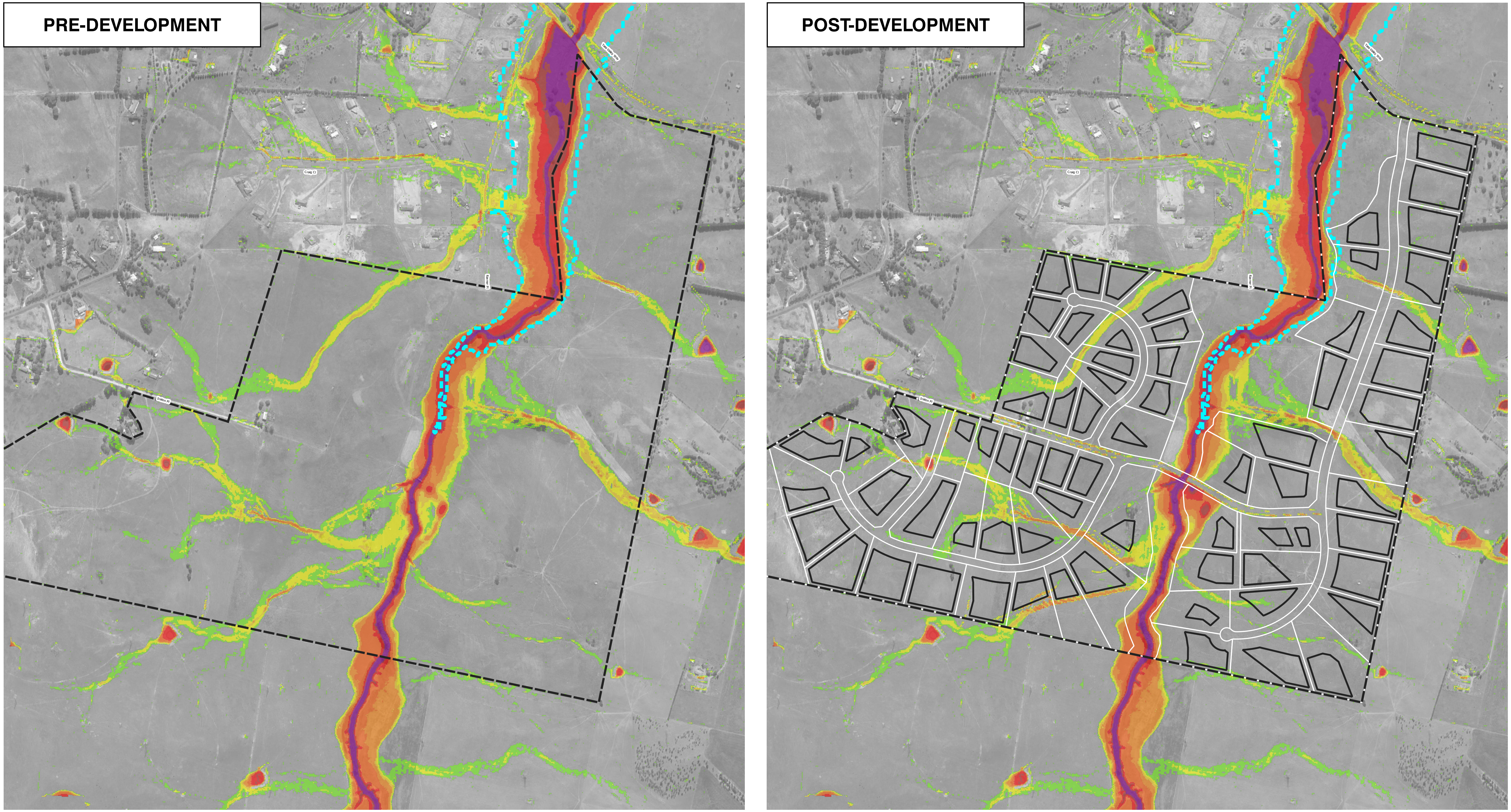
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N
W E
S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Hazard - 0.5% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10000**	FIGURE No. **09**



Site Extent
Cadastral Boundaries
Building Envelopes

Flood Depths (m)
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

Yass River 0.2% AEP Flood Extent

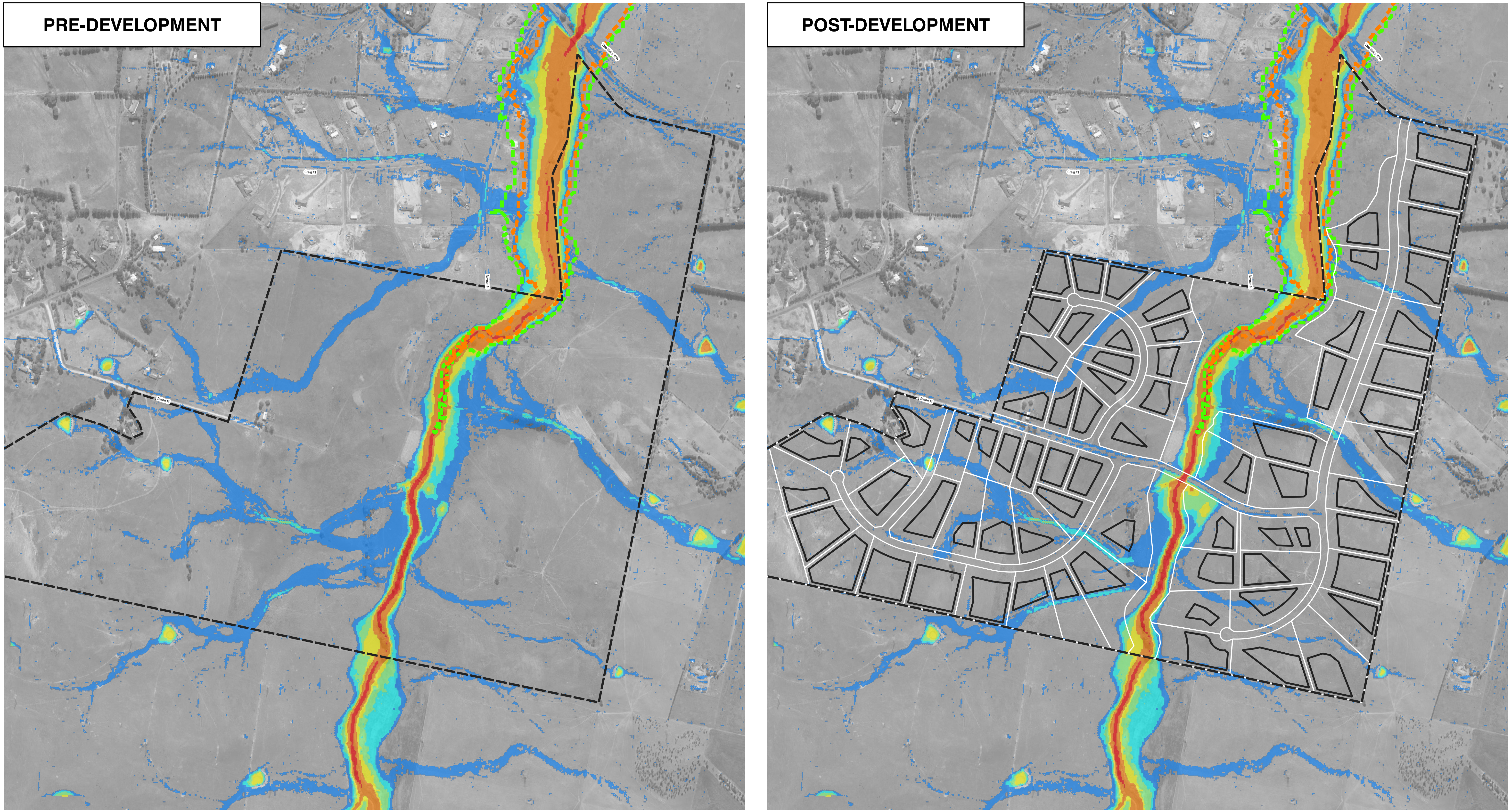
* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N
W E
S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Depth - 0.2% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:1**	FIGURE No. **10**



Legend	
- - - - - - - -	Site Extent
————	Cadastral Boundaries
————	Building Envelopes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Yass River 0.2% AEP Flood Extent

Yass River 0.2% High Hazard Extent

* Areas with water depths of less than 50 mm are considered 'minor drainage' and are not shown on this map

N W E S

0 300 600 900 1200 metre

grc HYDRO

TITLE: **Flood Hazard - 0.2% AEP**	PROJECT: **Iceton - Planning Proposal**	PROJECT No. **190032**	DATE: **09-2021**	SCALE: **1:10000**	FIGURE No. **11**

Attachment A

DOC20/978477-11

Arif Chohan

Strategic Planner
Yass Valley Council
PO BOX 6
Yass NSW 2582

11 December 2020

Dear Mr Chohan

Subject: Planning Proposal 2020/03 – LEP Amendment to reduce minimum lot size from 10 ha to 1 ha to 2 ha - 7 Iceton Place, Yass

The Department of Planning, Industry and Environment (the Department) has undertaken a review of the Planning proposal submitted. Please note that our Aboriginal Cultural Heritage Team is now separate to our Department and we will therefore only be commenting on biodiversity and flooding.

The Department objects to this Planning Proposal in its current form. We do not consider that the direct and indirect impacts to threatened species habitat has been mitigated and avoided. The Department also does not consider that the planning proposal is consistent with the South East and Tablelands Regional Plans, section s14.2, nor in line with the Ministerial Directions s2.1.

Biodiversity
We consider that the planning proposal in its current form does not demonstrate adequate ongoing protection measures to the threatened species present on site. The Golden Sun Moth (GSM), is a Serious and irreversible impact species (SAII), the planning proposal in its current form does not demonstrate adequate avoidance and ongoing protection of this species and it habitat. Striped legless lizards were recorded onsite, and it is estimated that more than 40% of their habitat will be impacted. Further avoidance of the habitat for this species should be demonstrated in the Planning proposal.
The Department does not consider that ongoing protection measures were adequately outlined, and no long-term conservation outcomes were proposed. Please see more detailed comments in **Attachment 1**.

Flooding
The planning proposal does not adequately assess or consider the implications of increased development and encroachment on flooding; allow for appropriate flood and riparian buffers; assess climate change nor address risk to life in extreme flood events (PMF). It is recommended that the approval authority consider the more detailed floodplain risk management comments in **Attachment 2** to resolve these matters.
If it will be helpful we would to arrange a site inspection early next year with Council following these comments.

If you would like to discuss this matter further, please contact Nicola Hargraves, Senior Conservation Planner on 02 6229 7195 or at rog.southeast@environment.nsw.gov.au.

Yours sincerely

Allison Treweek

ALLISON TREWEEK
Senior Team Leader – South East
Biodiversity and Conservation Division

Attachment 1 – Biodiversity Comments

The Department does not consider that the planning proposal in its current form is consistent with the South East and Tablelands Regional Plan requirement to *protect and validate high environmental lands in the LEPs s14.2*. Nor does it demonstrate how it is consistent with the Ministerial Directions, in particular 2.1 Environment Protection Zones (4) *A planning proposal must include provisions that facilitate the protection and conservation of environmentally sensitive areas.*

The Department acknowledges the Draft Biodiversity Development Assessment Report (BDAR). The high biodiversity values present on site have not been adequately protected and avoided, therefore without appropriate protection measures the Department will not be able to support the reduction in LEP minimum lot size at this stage.

Avoidance of threatened species

Of particular concern is that the site is habitat to the Golden Sun moth, which is a potential Serious and irreversible impact species. The Draft BDAR (page 3 Threatened ecological communities) claims that the proposed development will impact 24.6% of the GSM habitat that occurs in the subject land. This exceeds the 10% clearing thresholds outlined in the Threatened Biodiversity Data Collection (TBDC). This may be considered a Serious and Irreversible Impact and Council may be required to refuse the development at the DA stage.

The land also supports Striped legless lizard habitat and will be impacting 6.9 ha (40.3%) of that habitat, with 10.2 ha proposed for protection. At this stage we consider that further avoidance measures for this species needs to be demonstrated.

We do not consider that the direct and indirect impacts have been adequately addressed in the proposed lot layout and conservation areas. Lot 63 (Large lot conservation area to the South West) has a large building envelop in the middle, directly impacting the threatened species habitat. The other two large lot conservation areas to the North of the subject area (Lots 29, 28 and 43) appear to have little to no buffer between the development and avoided areas. No significant detail was given to the 'avoid, protected and managed' claims made within the Draft BDAR and it is unclear as to why more of the striped legless lizard habitat to the east (estimate lots 27, 26 & 25) of the site cannot be avoided. . It is not sufficient protection to leave these area in larger lots which still have the potential to be further sub divided once the Planning proposal has been approved.

Ongoing both direct and indirect impacts of the reduction in lot size have not been adequately addressed. As a result of the reduction in lot size there will be an increase in the amount development on the land, this will result in long term ongoing impacts. Including increase in ground disturbance the introduction and intensification of hard hooved grazing animals, increase potential for further clearing of habitat, rock removal and the introduction of dogs and cats

Long-term protection measures

No long-term conservation outcomes were outlined within the Draft BDAR. Sufficient ongoing protection measures need to be identified upfront to guarantee ongoing persistence of the threatened species on this site. Ongoing protection measure for areas of habitat of Serious and irreversible impact species is a consideration in the assessment of these impacts and therefore these measure should be described and achievable onsite to ensure the long term survival of the species.

There are a variety of options that can be investigated into that will protect the high biodiversity value of this land in perpetuity. Biodiversity certification, a voluntary planning agreement, community title with attached vegetation management plans, building exclusion zones, large lot stewardships and re-zoning to an E3, or a combination of this options could be used to ensure the long term viability of the species

The Department is open to further discussions to assist Council with this process.

Attachment 2: Floodplain Risk Management Comments

As the proposed development area is affected by flooding, it will need to be considered in accordance with the NSW Government's Flood Prone Land Policy as set out in the NSW Floodplain Development Manual, 2005 (FDM 2005) and Councils Yass Valley LEP 2013. As the planning proposal is altering the zoning of flood prone land section 9.1 direction 4.3 also applies.

In order to be consistent with FDM2005, the implications of the full range of floods, including events greater than the design flood, up to the Probable Maximum Flood (PMF) should be considered by the approval authority, including:

- The impact of flooding on the proposed development
- The impact of the proposed development on flood behaviour (particularly flood impacts as a result of land use and landform changes; bridge, culvert and waterway encroachment);
- The impact of flooding on the safety of people for the full range of floods including issues linked with isolation and accessibility for emergency services;
- the implications of climate change (particularly increased rainfall intensity) and cumulative development impacts on flooding and estimated flood planning levels;

Based on the information provided, adequate consideration has not been given to all these matters in their entirety, particularly:

- Consideration of cumulative development impacts (post development scenario), flood hazard and categorisation, freeboard, the implications of climate change and extreme floods (PMF);
- Appropriate buffers to accommodate flood and riparian constraints; and
- Potential isolation, appropriate measures to manage risk to life and accessibility for emergency services during floods.

It is recommended that modelling of post-development flood behaviour with consideration of increased impervious areas, riparian planting within the community title lot (lot 73), bridge and culvert crossing encroachment be undertaken for the 5%, 1% and PMF flood design events. This will include flood depth, velocity, hazard and hydraulic categorisation. Further, the modelling of increased rainfall intensity associated with climate change and its implications on estimated flood planning levels will better enable the approval authority to satisfy itself of consistency with the NSW Governments Flood Prone Land Policy, Yass Valley LEP and Section 9.1 direction 4.3. This also includes a more appropriate and considered width and zoning (e.g: W1, RE2, or E2) of the community title lot (lot 73) and thus schematisation of adjoining property boundaries to facilitate flood management and riparian outcomes.

The recommended additional flood behaviour modelling will also assist at the Subdivision DA stage, to ensure appropriate drainage easements; culvert, bridge and road design; and development controls are achieved to manage the impacts of flooding.

Should the approval authority require any further advice on flood risk management matters, it should not hesitate to contact the SE Water, Flood and Coast team.

Attachment B

Rev	Date	Description
A	23/04/2020	Inital Issue
B	22/05/2020	Revised Lot Layout
C	17/02/2021	Revised lot layout to address BDC & NRAR comments
D	05/04/2021	Revised lot layout (PPS6) for re-submission to Council
E	07/10/2021	Minor revisions to lot layout

Proposed Plan of Subdivision

Lots 13 & 14 DP786575, Lot 2 DP1243702

Genium CIVIL ENGINEERING

ABN: 36 169 355 122
10 Crago Street Yass NSW
Ph: 0418 484 138
PO Box 15 Yass NSW 2582
email: admin@genium.com.au

Client: Iceton Investments Pty Ltd

Status: DA Submission

Proposed Plan of Subdivision
PPS7

Datum	Scale	Size
MGA/AHD	1:7500	A3

Drawing Number	Sheet	Revision
17037 -100	1 of 6	E

Attachment C

Job Number: *190032*
Date: *6 September 2019*

GRC Hydro
Level 9, 233 Castlereagh Street
Sydney NSW 2000

Tel: +61 413 631 447
www.grchydro.com.au

Simon Cassidy
Genium Civil Engineering
10 Crago Street
YASS NSW 2582

Dear Simon,

Re: Iceton Place Development – Flood Study

Introduction

GRC Hydro has been appointed by Genium Civil Engineering to undertake a flood study for O'Briens Creek and its tributaries in the vicinity of Iceton Place (the site). The results of this flood study will inform a planning proposal for the rezoning of land to reduce the minimum lot size from 10ha to 2ha. The site is situated approximately 5 km south of Yass, in southern NSW. The location of the site, along with a preliminary subdivision plan, is presented in Image 1.

Image 1: Site Location and Preliminary Subdivision Plan

Objectives

The key objectives of this study are to:

- Define 1% AEP flood behaviour for the site due to O'Briens Creek and its tributaries in terms of flows, extents, levels and depths; and
- Provide 1% AEP and 0.05% AEP flood flow rates and velocities at a proposed bridge crossing of O'Briens Creek (see Image 1).

Previous Studies

No existing flood study is available for the site. The Yass Flood Study (WMAwater, 2016) was undertaken on behalf of Yass Valley Council for the township of Yass, however the site is situated outside of the Council model extent.

Due to a lack of existing flood information, hydrologic and hydraulic analysis has been undertaken to define design flood behaviour.

Hydrology

O'Briens Creek is a tributary of the Yass River, which at the confluence of the two watercourses has a catchment area of 2,925 ha. The Creek flows from south to north with catchment elevations ranging from 638 to 498 mAHD (see Figure 1). The catchment shape is elongated (catchment shape factor= 0.97). The region is predominantly rural in nature with few roads and houses and Yass Valley Highway to the north of the site.

The hydrologic analysis is based on the WBNM model detailed in the *'Yass River Catchment Hydrology Report'* (GRC Hydro, 2019) presented in Attachment A. The WBNM model applied calibrated model parameters determined by the Gundaroo and Sutton Flood Studies (WMAwater, 2016) and a model validation process was undertaken by comparing design flow estimates to FFA. A good match was noted when comparing WBNM design flows to FFA for the Yass and Gundaroo stream gauges, thus providing confidence in model results.

The GRC Hydro (2019) model was used to model design flows for O'Briens Creek at the site. Image 1 presents the WBNM model layout and the location of the site, inclusive of the O'Briens Creek catchment.

Modification of the GRC Hydro (2019) model was required to accurately model design flows for the site. The modification was limited to changing applied temporal patterns methodology from areal to point temporal patterns and adjusting the Areal Reduction Factor (ARF) to suit the catchment area upstream of the site. These changes were made to align with the methods and techniques outlined in ARR2019. ARR2019 ensemble results for the site for the 1% AEP and 0.05% AEP events are presented in Image 2.

Design flows for the 1% and 0.05% AEP events at the site are presented in Table 1 along with the critical duration and critical storm number.

Table 1: O'Briens Creek Design Flow Estimates at the Site

AEP %	Average Ensemble Flow (m^3/s)	Critical Duration (hours)	Critical Storm #
1	88	6	7
0.05	160	6	7

Image 2: ARR2019 Ensemble Results for the 1% and 0.05% AEP Events

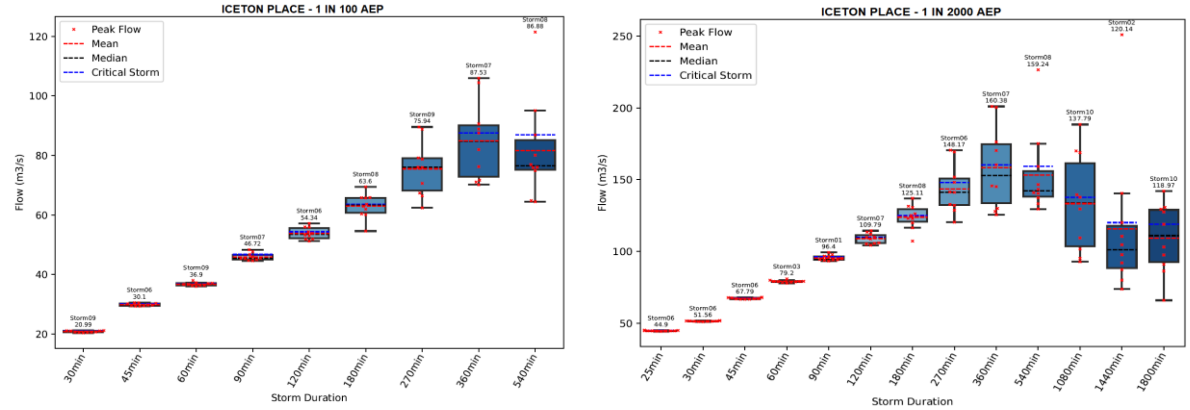
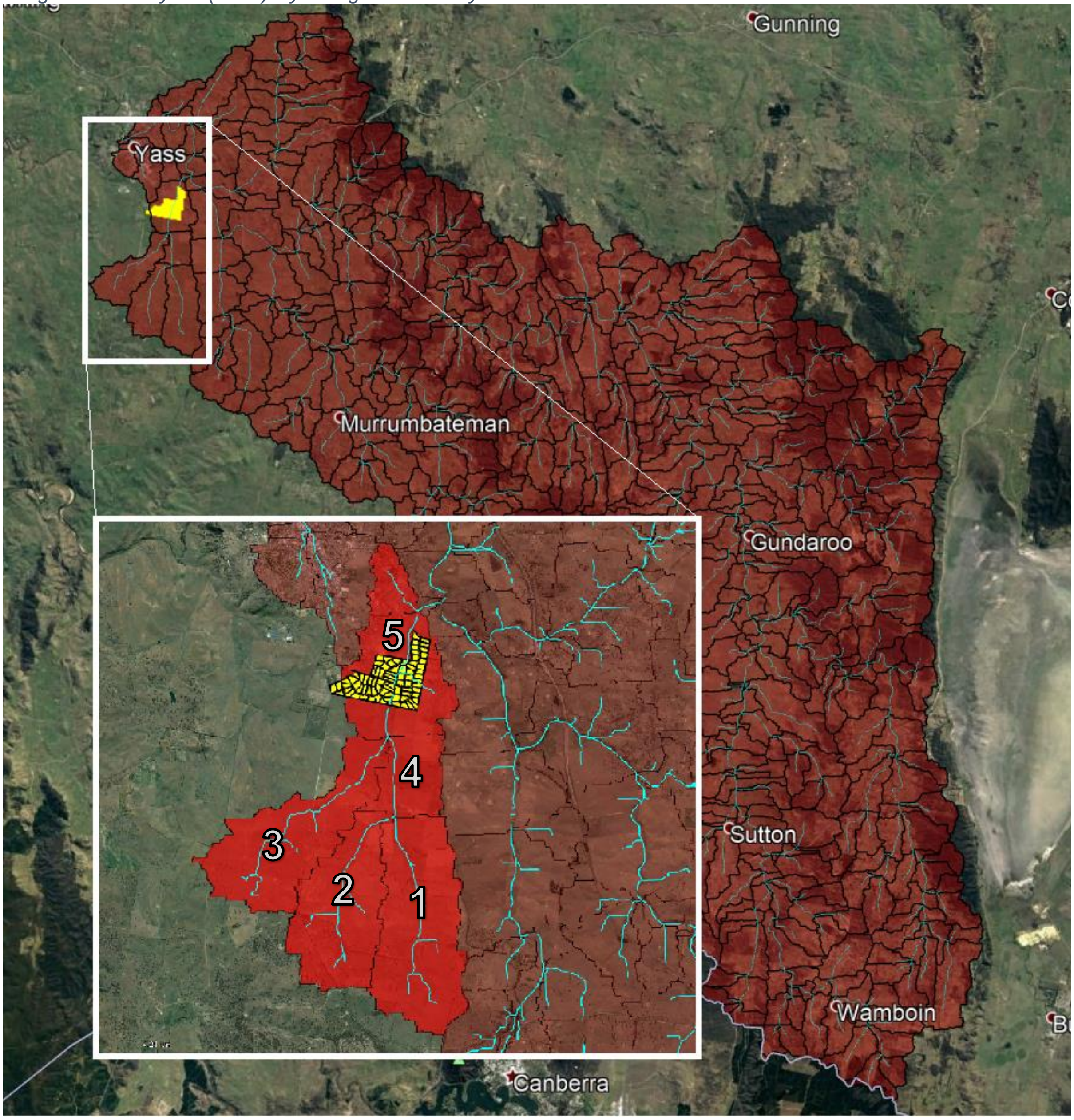


Image 3: GRC Hydro (2019) Hydrologic Model Layout and Site Location



Hydrologic analysis for the overland flow and tributaries of O'Briens Creek was undertaken using a direct rainfall approach in TUFLOW with the results of this analysis discussed in the 'Hydraulics' section of this report.

Hydraulics

A TUFLOW hydraulic model was constructed to model baseline (pre-development conditions) for the site. TUFLOW is 2D numerical modelling package which is suitable for creeks and floodplains such as O'Briens Creek and its tributaries at the site. The 2D hydraulic model layout for the site is presented in Figure 2.

Various data and parameters implemented in the TUFLOW model are discussed below:

- Model Domain and Grid Size – The hydraulic model domain covers an area of 690 ha and is represented by the area defined as sub-catchment # 5 in Image 3. A 5m-grid has been implemented which allows adequate representation of key hydraulic features whilst keeping the simulations run times within acceptable limits. The model was noted to be insensitive to selected grid size with comparison to a 2m-grid simulation resulting in negligible differences in peak flood level;
- Digital Elevation Model (DEM) – The 1 m DEM obtained from NSW Spatial Services ELVIS website has been used to inform the topography of the 2D hydraulic model;
- Mannings Roughness – Manning' s values were selected based on inspection of aerial imagery. A global Manning value of 0.055 has been applied to all rural areas, Manning of 0.05 was applied to the creek in-banks areas and 0.09 where dense vegetation is identified. Roads were assigned a Manning value of 0.02. The selected Manning's values are consistent with previous studies conducted by others (Yass Flood Study) and ARR2016 guidelines;
- Upstream Boundary Conditions – WBNM critical flow hydrographs downstream of Sub-Catchment 3 and 4 (see Image 3) were input as an upstream boundary condition. Flow hydrographs for durations ranging from 30 minutes to 6 hours were modelled;
- Internal Boundary Conditions – Direct rainfall was applied to the 2d-model domain as the TUFLOW model's internal boundary condition. This approach modelled mainstream (O'Briens Creek) and overland flow flooding simultaneously. The critical storm was selected based on local catchment flow results for catchment #5 from the GRC Hydro (2019) WBNM model, such that the critical duration for the smaller local catchments could be better assessed. The approach applied the critical storm noted to provide the highest peak water level, rather than the mean as recommended by ARR2019, to provide slightly conservative results for the overland flow paths. A peak flood enveloped was developed for the site based on the assessed durations;
- Downstream Boundary Conditions – The downstream model boundary was applied as a static tailwater level equal to 505.2 mAHD. This is the 100 year ARI dam level at the O'Briens Creek/ Yass River confluence based on the "Yass Dam Upstream Tailwater Investigation" (Public Works -2012)";
- Breaklines – Road embankments, farm dams, open drains and levees are hydraulic features that can have a significant impact on flood behaviour. Such features have been represented in the model by breaklines with crest and invert heights determined by analysis of the DEM;
- Hydraulic Structures – the Yass Valley Way bridge was modelled as a "Layered Flow Constriction" in TUFLOW. Structure blockage was determined using ARR2016 Blockage Guidelines. Blockage of the existing bridge has been set to 50% to consider the effect of debris, sediments and vegetation which may be transported by the water during the rarer flooding

events. Form loss coefficients were calculated according to technical literature ("Hydraulics of Bridge Waterways – U.S. Department of Commerce – Bureau of Public Roads").

It should be noted that the proposed conditions (post-development) have not been modelled. This includes the proposed bridge crossing of O'Briens Creek.

Model Results

1% AEP event peak flood depths and levels are presented in Figure 3 to Figure 8 for baseline conditions.

The peak flow and velocity for the 1% AEP and 0.05% AEP events at the location of the proposed bridge crossing are presented in Table 2.

Table 2: Flow and velocity at the location of the proposed O'Briens Creek bridge

AEP %	Flow (m^3/s)	Average Velocity (m/s)*	Maximum Velocity (m/s)
1	88	0.9	2.3
0.05	160	1.2	2.7

* Average velocity across the width of the floodplain.

It should be noted that introduction of the proposed bridge could significantly increase velocities as flows pass through the constriction.

Conclusions

A flood study for has been undertaken for O'Briens Creek and its tributaries in the vicinity of Iceton Place (the site). The results of this flood study will inform a planning proposal for the rezoning of land to reduce the minimum lot size.

Hydrologic analysis was based on the WBNM model detailed in the *'Yass River Catchment Hydrology Report'* (GRC Hydro, 2019) presented in Attachment A. The WBNM model applied calibrated model parameters determined by the Gundaroo and Sutton Flood Studies and a model validation process was undertaken by comparing design flow estimates to FFA. A good match was noted when comparing WBNM design flows to FFA for the Yass and Gundaroo stream gauges, thus providing confidence in model results.

Hydraulic analysis was undertaken using TUFLOW with baseline (pre-development conditions) assessed for the site. 1% AEP event peak flood depths and levels are presented in Figure 3 to Figure 8 for baseline conditions. Peak flow and velocity for the 1% AEP and 0.05% AEP events at the location of the proposed bridge crossing are presented herein.

Yours Sincerely

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Director

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Yass Valley Council
2. Gundaroo Flood Study
WMAwater, 2016.

Yass Valley Council
3. Sutton Flood Study
WMAwater, 2016.

Public Works
4. Yass Dam Upstream Tailwater Investigation
2012

U.S. department of Commerce- Bureau of Public Roads
5. Hydraulic of Bridge Waterways
1960

Figure List

FIGURES

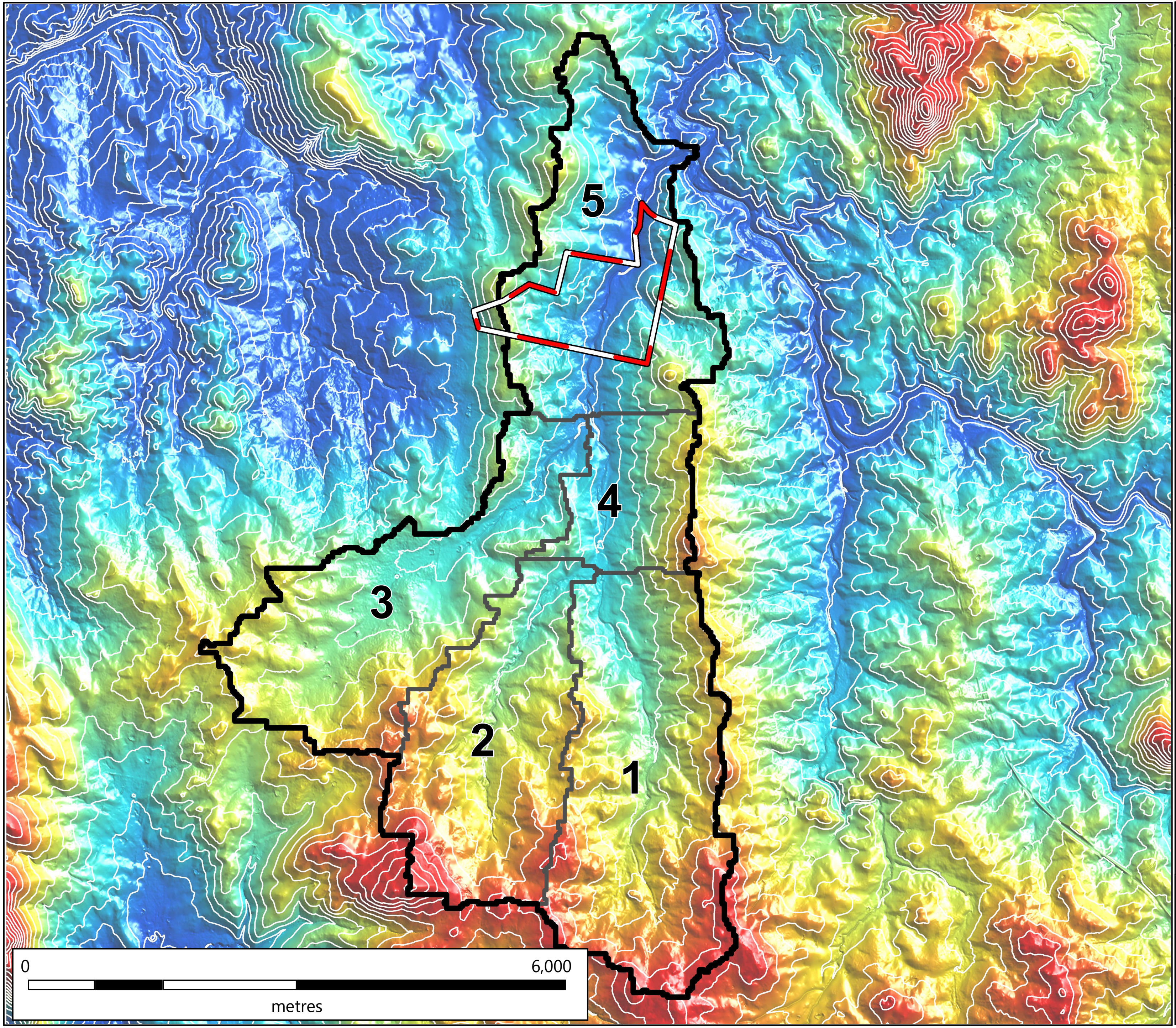

FIGURE NUMBER:	1
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	190032
SCENARIO:	
EVENT:	
TITLE: **GROUND LEVELS AND CATCHMENT AREA**	

Ground Levels (m AHD)

- 500 to 510
- 510 to 520
- 520 to 530
- 530 to 540
- 540 to 550
- 550 to 560
- 560 to 570
- 570 to 580
- 580 to 590
- 590 to 600

Project Area

2 Sub-Catchment Areas

N W E S

grc HYDRO

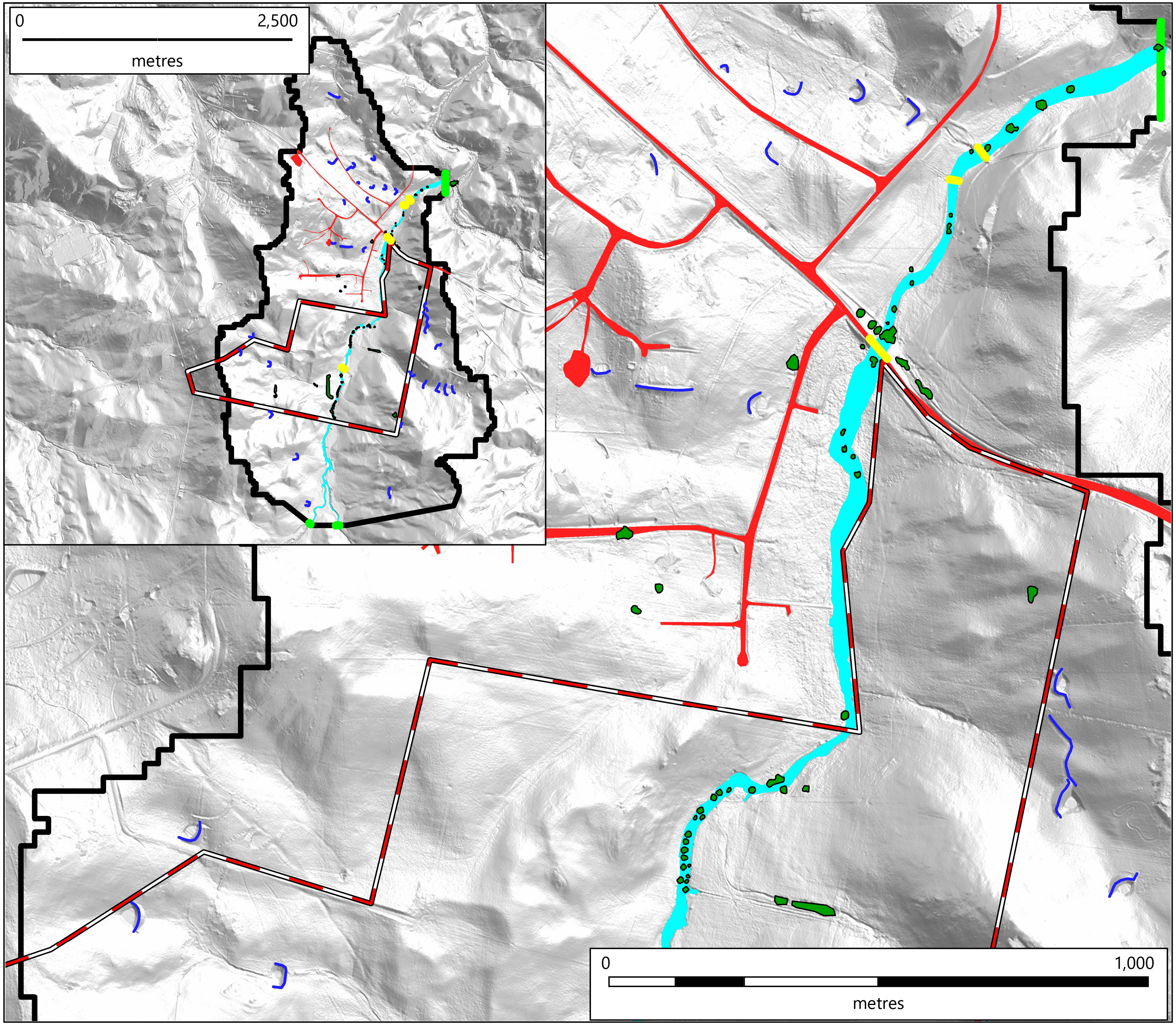

FIGURE NUMBER:	**2**
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	**190032**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	
TITLE: **2D HYDRAULIC MODEL SETUP**	

Project Area

2D Model Extent

Upstream and Downstream Boundary Conditions

Break Lines

Creek Area (Manning = 0.05)

Asphalt Roads (Manning = 0.02)

Vegetation (Manning = 0.09)

Bridge

N W E S

grc HYDRO

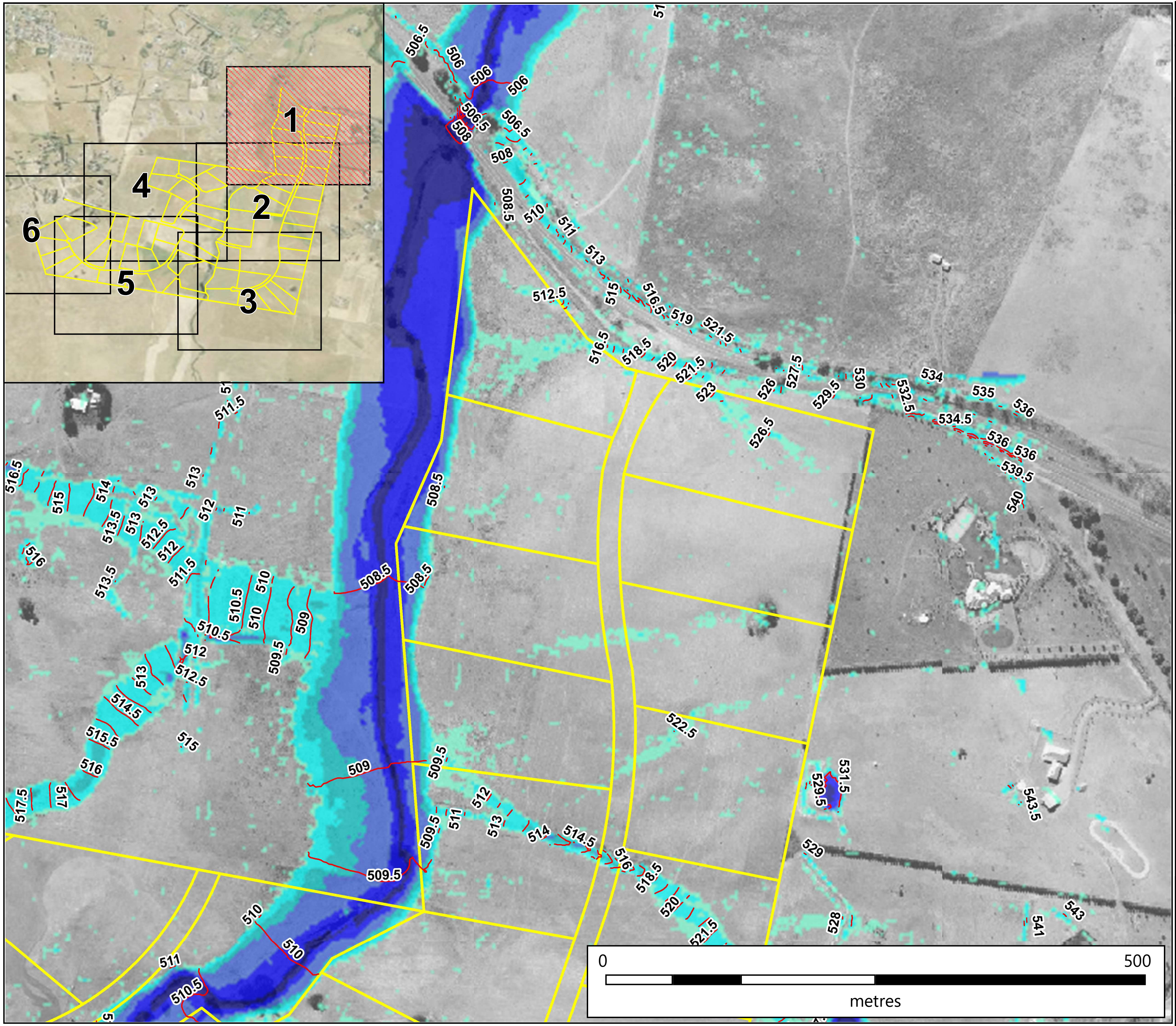

FIGURE NUMBER:	**3**
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	**190032**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (1 OF 6)**	

Flood Depth (m)

- < 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)

N
W E
S

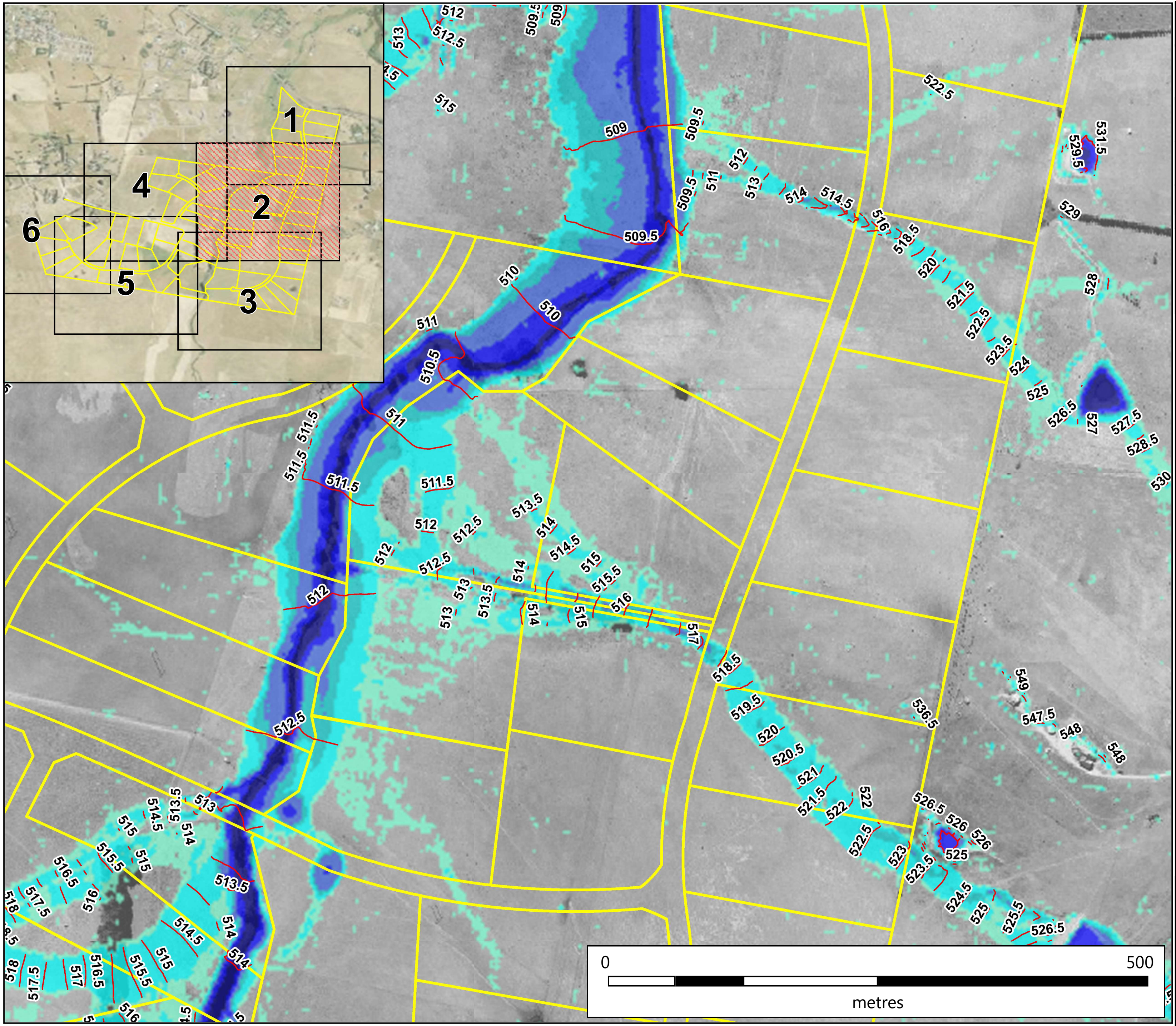

FIGURE NUMBER:	4
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	190032
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (2 OF 6)**	

Flood Depth (m)

< 0.05
0.05 to 0.1
0.1 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)

N
W E
S

grc HYDRO

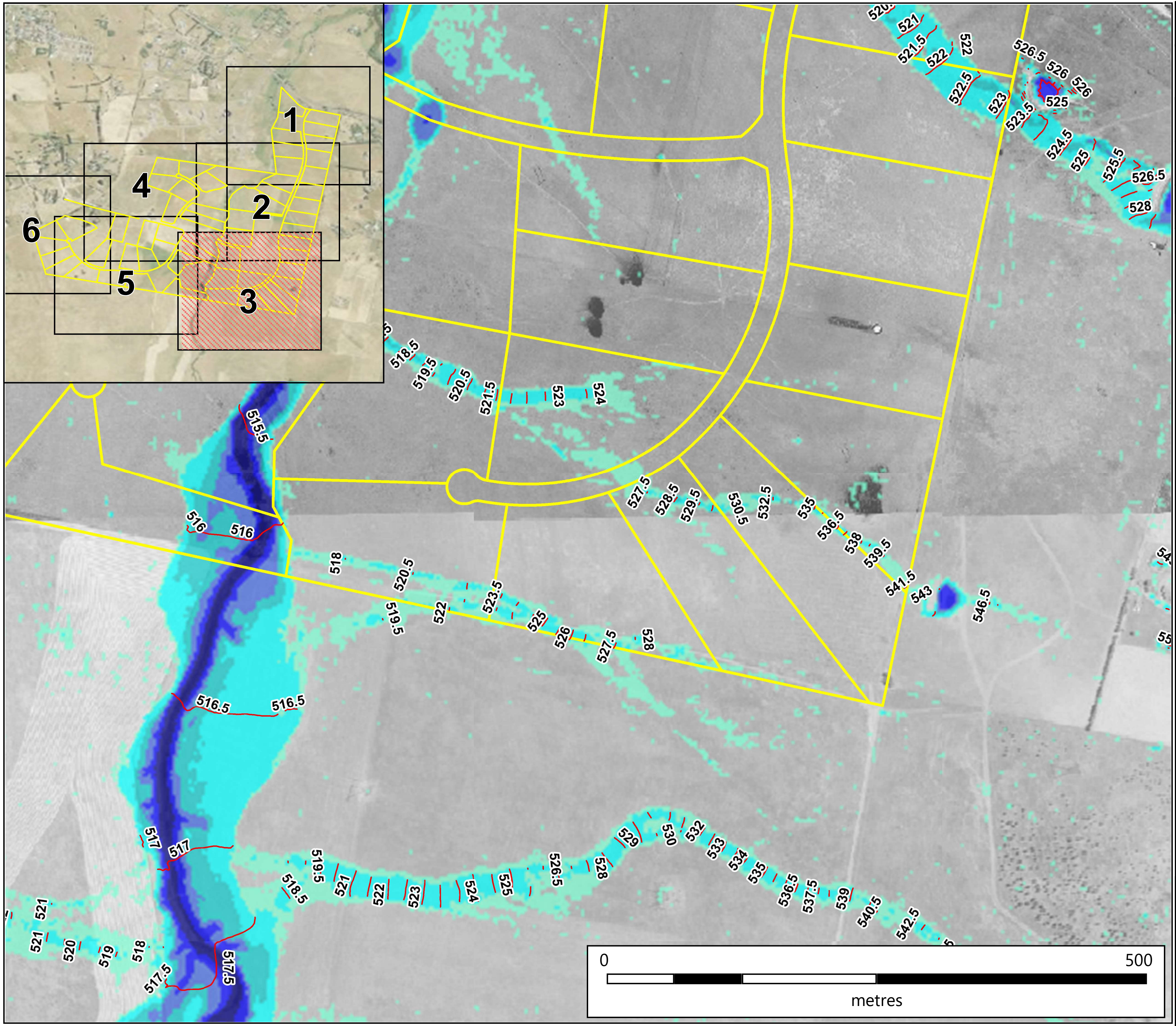

FIGURE NUMBER:	5
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	190032
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (3 OF 6)**	

Flood Depth (m)

- < 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)

N
W E
S

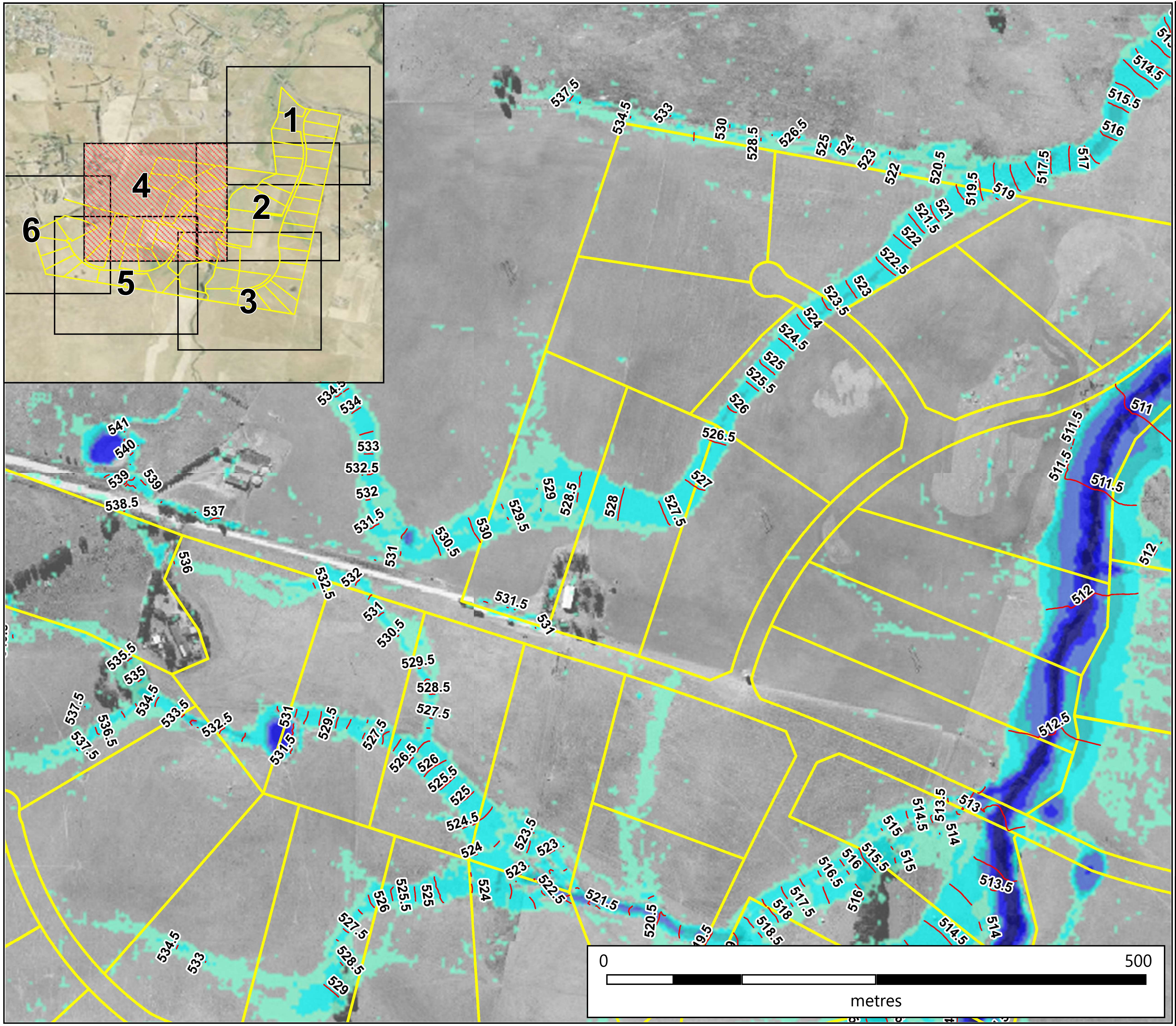

FIGURE NUMBER:	6
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PROJECT NUMBER:	**190032**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (4 OF 6)**	

Flood Depth (m)

- < 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)

N W E S

grc HYDRO

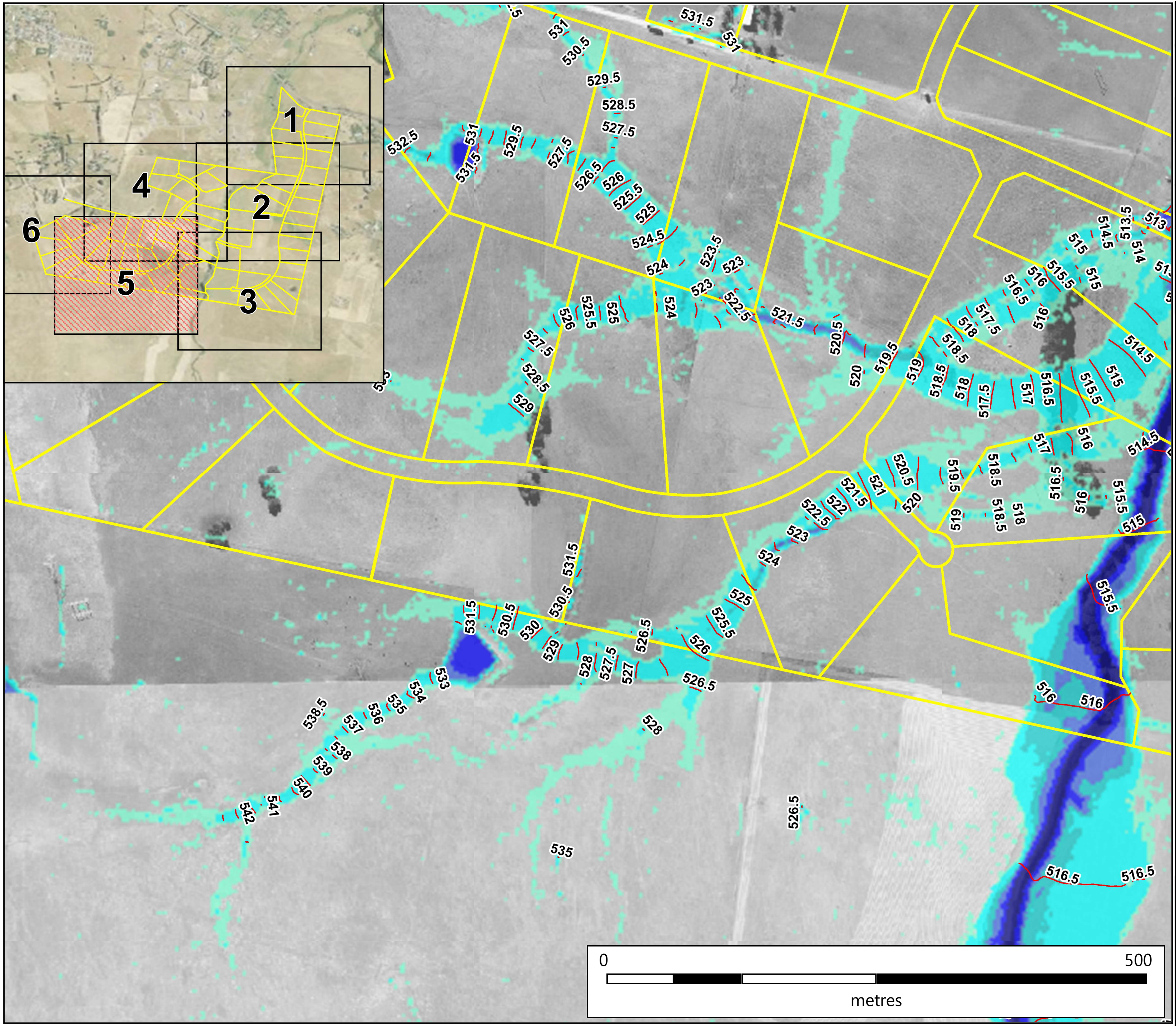


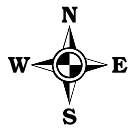
FIGURE NUMBER:	7
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	190032
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (5 OF 6)**	

Flood Depth (m)

- < 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)



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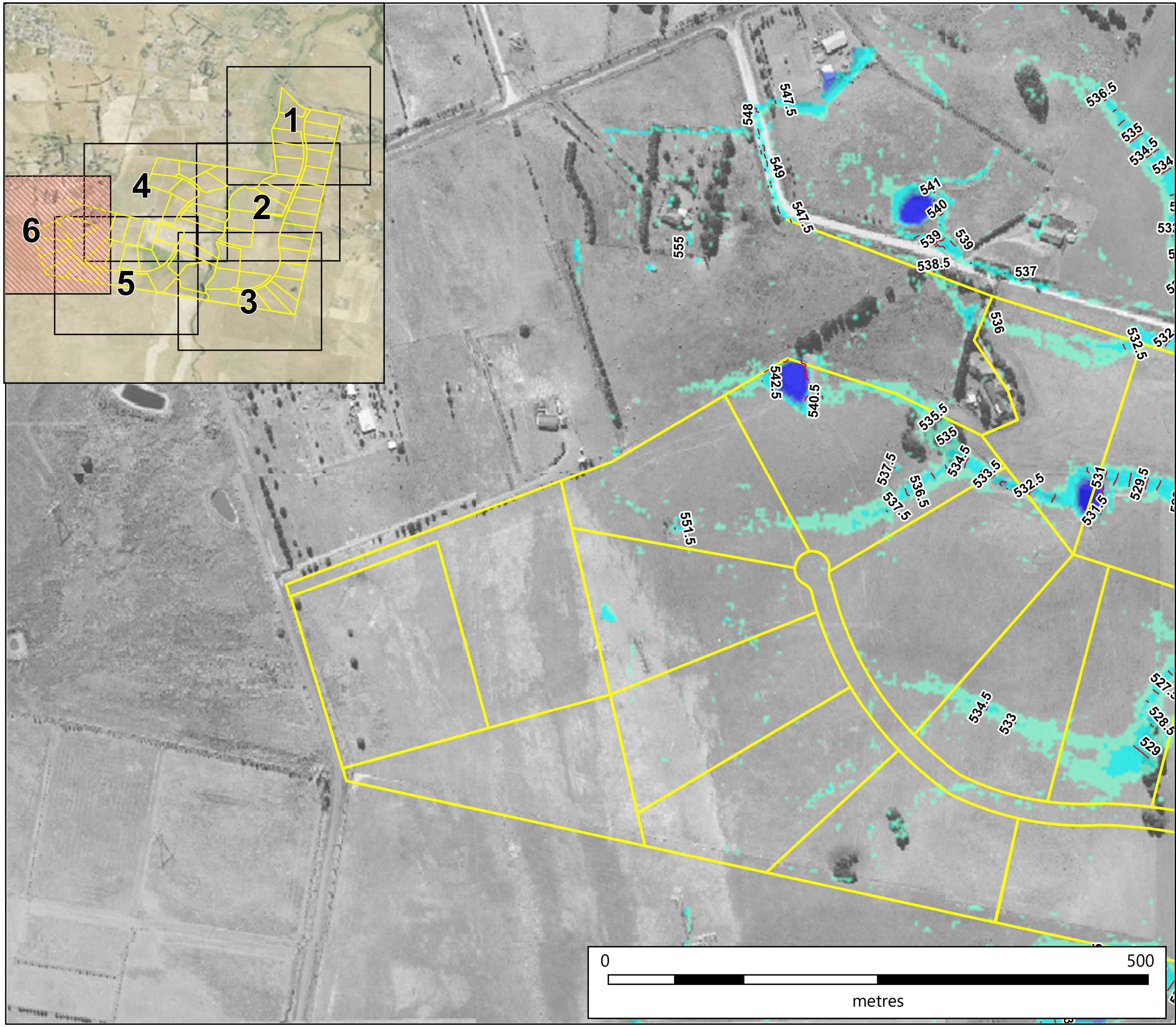

FIGURE NUMBER:	8
PROJECT: **ICETON PLACE - YASS**	
PROJECT NUMBER:	190032
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1%AEP**
TITLE: **FLOOD DEPTH AND LEVELS (6 OF 6)**	

Flood Depth (m)

< 0.05
0.05 to 0.1
0.1 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0

Proposed Plots

Flood Level Contour (0.5m Spacing)

N W E S

grc HYDRO

ATTACHMENT A

YASS RIVER CATCHMENT HYDROLOGY REPORT

SEPTEMBER 2019

Yass River Catchment – Hydrology Report

Project Number: 190032

Report Author: Nicola De Paolis, Zac Richards

Date: 4 September 2019

Verified By: Zac Richards

Date	Version	Description
4 September 2019	1	Yass River Catchment – Hydrology Report

Filepath: J:\190032\Admin\Report\Yass_River_Hydrology_Assessment.docx

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EXECUTIVE SUMMARY

A high resolution WBNM hydrologic model has been developed for the Yass River catchment. ARR2019 modelling methods and techniques have been applied. The model used calibrated model parameters determined in the Gundaroo and Sutton flood studies and then validated design flow estimates to Flood Frequency Analysis (FFA) undertaken for three stream gauges. The validation process found a good match to FFA undertaken at the Yass and Gundaroo stream gauges providing confidence in the model results.

The WBNM model was developed with the intent of extracting design flow estimates for the Yass River and its tributaries across the catchment upstream of Yass. The analysis presented herein shows that the model is suitable for use for this purpose.

It should be noted that this report details the model build and validation efforts only. Additional modelling, including modification of parameters such as temporal patterns and Areal Reduction Factors, will need to be undertaken when assessing specific sites within the model domain. These will be detailed in accompanying documentation provided for site specific investigations.

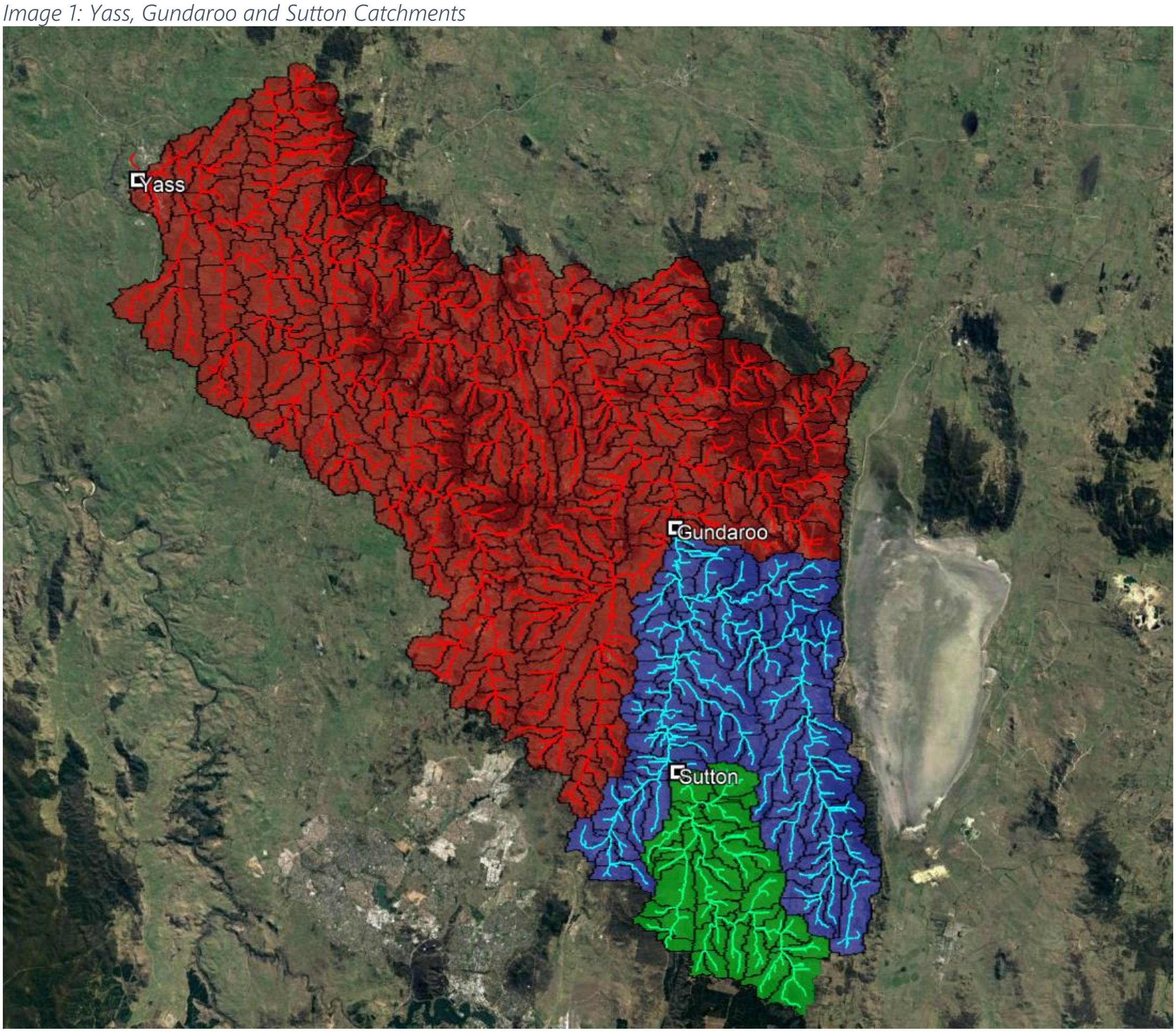
1. INTRODUCTION

This report presents hydrologic analysis for the Yass River catchment. A WBNM hydrologic model applying ARR2019 methods has been developed with design flows validated to Flood Frequency Analysis (FFA) undertaken for local stream gauges. The WBNM model was developed with the intent of extracting design flow estimates for the Yass River and its tributaries across the catchment upstream of Yass.

1.1 Study Area

The Yass River catchment is situated in south-east New South Wales (NSW) to the north of the Australian Capital Territory (ACT). The catchment contains the townships of Yass, Gundaroo and Sutton. The Yass River flows in a north-west direction and is a tributary of the Murrumbidgee River. The catchment is bounded by the Murrumbidgee River, Lake George and Mulwaree River catchments to the west, east and north. Image 1 presents the Yass River catchment, with demarcation of catchments upstream of Yass, Gundaroo and Sutton.

Image 1: Yass, Gundaroo and Sutton Catchments



1.2 Objectives

The key objective of this study was the development of a hydrologic model using ARR2019 methods, suitable for extracting design flow estimates throughout the Yass River catchment.

To satisfy the key objective, the following analysis has been undertaken:

- Review of local flood studies undertaken within the catchment at the townships of Yass, Gundaroo and Sutton to glean useful information for model build and calibration;
- Development of FFA for gauges within the catchment based on work undertaken in the above-mentioned flood studies;
- Development of a high resolution WBNM hydrologic model suitable for extracting flows for all areas of the catchment;
- Modelling of design rainfall events using ARR2019 methods and techniques; and
- Validation of the design flow estimates to FFA.

It should be noted that this report details the model build and validation efforts only. Additional modelling, including modification of parameters such as temporal patterns and Areal Reduction Factors, will need to be undertaken when assessing specific sites within the model domain. These will be detailed in accompanying documentation provided for site specific investigations.

2. YASS RIVER CATCHMENT FLOOD STUDIES

Three flood studies have been undertaken within the catchment for the townships of Yass, Gundaroo and Sutton. Information from these studies has been used to inform WBNM model parameters and FFA.

2.1 Yass River Flood Study

The Yass Flood Study (WMAwater, 2016) was prepared on behalf of the Yass Valley Council. The objective of the study was to define the flood behaviour at Yass due to flooding from Yass River, Chinaman's Creek, Bango's Creek and major overland flow.

The hydrological analysis for the Yass River comprised FFA incorporating data from the Yass Stream Gauge (410026) and Railway Gauge (410046) at Yass. The FFA significantly increased the record period using anecdotal information prior to the official period of record. The analysis used 180 years of data for the period 1835 to 2014 and follows the method prescribed by Australian Rainfall and Runnoff (ARR87). The analysis applied a Log Pearson III distribution to the annual series.

The Yass Flood Study FFA has been reproduced for use in model validation for the current study.

Hydrology for local catchments surrounding Yass was undertaken using a DRAINS hydrologic model, the parameters of which have limited use for input into the current study.

2.2 Gundaroo Flood Study

The Gundaroo Flood Study (WMAwater, 2016) was prepared on behalf of the Yass Valley Council. The objective of this study is to define flood behaviour at Gundaroo due to flooding from Yass River, Back Creek, McLeod's Creek and major overland flows. The following pertinent analysis was undertaken as highlighted in the Gundaroo Flood Study Executive Summary:

- *Investigation of the accuracy of the Gundaroo Stream Gauge (410090) rating and liaison with NOW hydrographers;*
- *Yass River Flood Frequency Analysis (FFA) at the Gundaroo Stream Gauge for use in hydrologic model calibration. The FFA was performed to determine design flows for more frequent events (5% AEP and smaller) due to the limited record period;*
- *A hydrologic/hydraulic modelling system was developed:*
    - o *The hydrologic model was calibrated to the FFA and verified to three historic flood events at Gundaroo;*
    - o *The hydraulic model was calibrated/verified to two recent flood events; and*
    - o *Design floods were then run in the calibrated/verified modelling system.*

The calibration process determined a WBNM Lag Parameter of C = 1.3 and a continuing loss of 2 mm/hr are appropriate for the catchment. Calibrated hydrologic model parameters determined via the calibration/validation process outlined in the Gundaroo Flood Study have been used to inform the current study WBNM model.

2.3 Sutton Flood Study

The Sutton Flood Study (WMAwater, 2016) was prepared on behalf of the Yass Valley Council. The objective of this study is to define flood behaviour at Gundaroo due to flooding from River, McLaughlin's Creek and major overland flows.

The following pertinent analysis was undertaken as highlighted in the Sutton Flood Study Executive Summary:

- *Investigation of the accuracy of the Sutton Stream Gauge (410851) rating and liaison with NOW hydrographers;*
- *Yass River Flood Frequency Analysis (FFA) at the Sutton Stream Gauge for use in hydrologic model calibration. The FFA was performed to determine design flows for more frequent events (5% AEP and smaller) due to the limited record period;*
- *A hydrologic/hydraulic modelling system was developed:*
    - o *The hydrologic model was calibrated to the FFA and verified to three historic flood events at Sutton;*
    - o *The hydraulic model was calibrated/verified to two recent flood events; and*
    - o *Design floods were then run in the calibrated/verified modelling system.*

The calibration process determined a WBNM Lag Parameter of C = 1.3 and a continuing loss of 2 mm/hr are appropriate for the catchment. Calibrated hydrologic model parameters determined via the calibration/validation process outlined in the Sutton Flood Study have been used to inform the current study WBNM model.

3. HYDROLOGY

3.1 Introduction

The key purpose of this study is to develop a hydrologic model suitable for defining design flows for the Yass River catchment. The hydrologic model aims to simulate the hydrologic response to flood-producing rainfall events within the catchment.

A WBNM hydrologic model was developed with calibrated model parameters determined in the Gundaroo and Sutton Flood Studies applied. Design event modelling was undertaken using ARR2019 techniques. Validation of the hydrologic model was undertaken by comparing design flows to FFA undertaken at gauges near Yass, Gundaroo and Sutton. The FFA was undertaken using the same methodology as applied in the flood studies for these towns.

3.2 Flood Frequency Analysis

FFA is a technique used by hydrologists to estimate flows corresponding to specific exceedance probabilities. The analysis requires that stream gauge information of a suitable quality and length is available.

FFA has been undertaken by applying the same methods as outlined in the Yass, Gundaroo and Sutton Flood Studies (WMAwater, 2016). The results of this analysis are presented in Table 1 to Table 3, with frequency curves presented in Section 3.5.

Table 1: Yass Stream Gauge (410026) FFA Flows

AEP Event	LPIII Parameter Fit Probability Flow (m^3/s)	90% Confidence Limits Flow (m^3/s)	
20%	292	235	363
10%	487	386	618
5%	732	569	957
2%	1,141	855	1,575
1%	1,522	1,100	2,191

Table 2: Gundaroo Stream Gauge (410090) FFA Flows

AEP Event	LPIII Parameter Fit Probability Flow (m^3/s)	90% Confidence Limits Flow (m^3/s)	
20%	142	88	214
10%	222	152	293
5%	290	224	384
2%	361	290	520
1%	401	317	630

Table 3: Sutton Stream Gauge (410851) FFA Flows

AEP Event	LPIII Parameter Fit Probability Flow (m^3/s)	90% Confidence Limits Flow (m^3/s)	
20%	43	27	71
10%	66	42	115
5%	90	85	175
2%	121	76	277
1%	142	86	378

3.3 Hydrologic Model Build

The hydrologic model was developed using the WBNM software (Watershed Bounded Network Model), whereby the catchment subdivided into a series of subcatchments, and a rainfall runoff routing approach was applied. The output hydrographs can then be used to inform future hydraulic models which can be used to define design flood behaviour such as extents, depths, levels and velocities.

3.3.1 Model Schematisation

The hydrologic model covered the Yass River catchment to Yass, with a total catchment area of 1,240km^2. The catchment areas to Gundaroo and Sutton are 353 and 101 km^2 respectively. The model divided the catchment into 444 sub-catchments with average size of ~ 279 ha. A summary of the model sub-catchments is presented in Table 4, with the sub-catchment delineation presented in Image 1.

Table 4: WBNM sub-catchment details

Catchment	Number of catchments	Total Area (km^2)	Average Area (ha)	Minimum Area (ha)	Maximum Area (ha)
Sutton	35	101	288	69	787
Gundaroo	106	353	324	58	1,073
Yass	444	1,239	280	11	1,073

3.3.2 Applied Model Parameters

The current study has applied WBNM model parameters consistent with the calibrated model parameters developed in the Gundaroo and Sutton Flood Studies. Details of the applied WBNM parameters are presented below:

- The nonlinearity parameter 'm' has been set as default (0.77) which is in agreement with ARR guidelines.
- The routing parameter 'C' was set to be 1.3 based on model calibration undertaken as part of the flood studies; and
- A continuing loss of 2.0 mm/hr was applied, again determined via model calibration in the flood studies.

Updates to the following model parameters/inputs have been made to apply ARR2019 techniques:

- Design rainfalls applied as per ARR2019 and obtained from the Bureau of Meteorology (BoM);
- Rainfall temporal patters applied using the ensemble approach outlined in ARR2019 and obtained from the datahub;
- Initial losses have been applied as per the methods outlined in *'OEH Floodplain Risk Management Guide (2019)'*; and
- Areal Reduction Factors (ARF) have been applied as per the methods outlined in ARR2019.

Details of the updated model parameters are presented in the following sections.

3.3.2.1 Design Rainfall

ARR2019 design rainfall data was obtained from the BoM as Intensity Frequency Duration (IFD) data. IFD data describes the rainfall intensity (mm/hour) for a range of annual exceedance probabilities (AEP) and for a range of durations (1 minute to 168 hours), for any location in Australia. The data is provided online on the BoM website. The IFD data in the form of rainfall grids (with latitude/longitude length of 0.025°) was obtained so that the spatial variation in design rainfall across a catchment could be applied.

3.3.2.2 Temporal Patterns

ARR2019 design temporal patterns were obtained from the ARR2019 data hub. Rainfall temporal patterns are used to describe how rainfall is distributed as a function of time. The recommended ARR2019 ensemble approach to applying temporal patterns has been utilised in the current study. The ensemble approach to flood modelling applies a suite of 10 different temporal patterns for each duration. Areal Temporal Patterns have been implemented for analysis of the Yass, Gundaroo and Sutton catchments as catchment areas exceed 75 km². The temporal patterns were obtained from ARR2019 for the 'Murray Basin' region for theoretical catchment areas ranging from 100 to 2,000 km² depending on the catchment being investigated. Ensemble modelling techniques aim to overcome issues associated with the application of a single temporal pattern as per the methods used in ARR87.

3.3.2.3 Initial Losses

Rainfall losses are defined as the amount of precipitation in a rainfall event that does not appear as direct surface runoff at the catchment outlet. The Initial and Continuous Loss (IL / CL) model is the most commonly adopted conceptual loss model in Australia and has been used in the current study.

An IL / CL model was implemented with initial losses obtained from the ARR2019 datahub. The Probability Neutral Burst initial loss was implemented based on recommendations in the *'OEH Floodplain Risk Management Guide (2019)'* as presented in Table 2. A continuing loss of 2 mm/hr was applied as determined via model calibration in the Gundaroo and Sutton flood studies.

Table 5: Probability Neutral Burst Initial Losses

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.9	14.2	11.8	11.7	11.6	11.0
90 (1.5)	19.4	14.7	12.9	12.8	12.7	11.9
120 (2.0)	21.3	14.2	12.6	12.8	12.3	11.8
180 (3.0)	23.5	13.9	13.0	14.0	14.3	13.5
360 (6.0)	25.2	16.8	15.3	16.0	13.6	9.9
720 (12.0)	25.9	18.4	16.8	17.1	14.3	7.9
1080 (18.0)	26.9	20.8	19.7	20.9	16.2	9.8
1440 (24.0)	28.5	22.8	22.5	23.7	19.9	12.8
2160 (36.0)	30.0	24.7	25.4	27.2	24.8	16.5
2880 (48.0)	31.2	26.0	26.3	28.3	25.3	16.8
4320 (72.0)	31.9	26.7	28.6	30.2	26.9	22.6

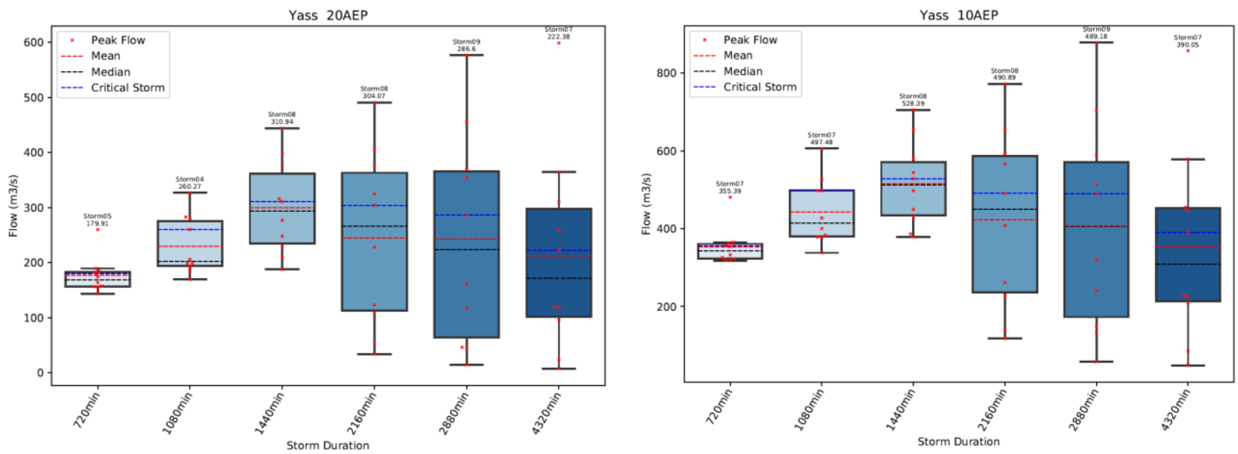
3.3.2.4 Areal Reduction Factor

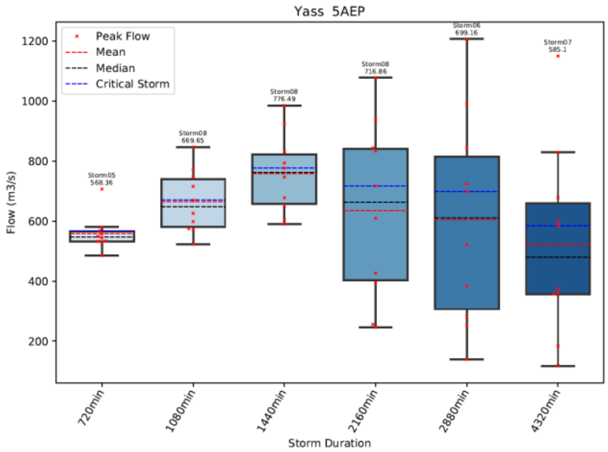
Areal Reduction Factors (ARF) were applied to design rainfall depths to adjust for a catchment's areal average rainfall intensity. The ARFs were determined following the methods outlined in ARR2019 for the 'South-East Coast' temporal region. Calculated ARFs were based on each of the study area's catchments, event duration and probability.

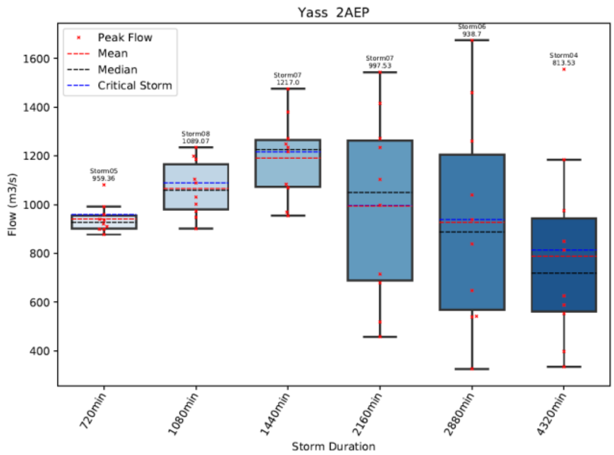
3.4 Hydrologic Model Results

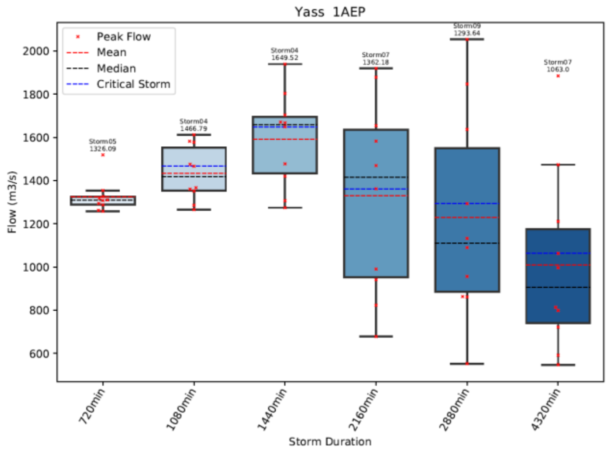
A critical duration assessment was undertaken by implementing the ARR2019 ensemble approach. The results of this analysis for the Yass Stream Gauge (410026) are presented in Chart 1. A critical duration of 24 hours is noted for the catchment to Yass. The critical durations for Gundaroo and Sutton were found to be 12 hours.

Chart 1: WBNM Ensemble Flow Results - Yass









Design flow estimates for Yass, Gundaroo and Sutton are presented in Table 6.

Table 6: WBNM Design Flow Estimates

Catchment	Sutton Flow (m^3/s)	Gundaroo Flow (m^3/s)	Yass Flow (m^3/s)
20%	74	159	311
10%	113	242	528
5%	145	342	776
2%	201	491	1,217
1%	256	626	1,650

3.5 Hydrologic Model Validation

Validation of the WBNM model was undertaken by comparing model derived flows to FFA with the results of this analysis presented in Chart 2 to Chart 4 for the Yass, Gundaroo and Sutton stream gauges respectively.

The validation process found that the WBNM model is producing a very good match to the Yass Stream Gauge FFA, with slightly higher flows produced by the model, thus providing slightly conservative results. This provides robustness in design flow estimates produced by the model.

The Gundaroo Stream Gauge (410090) comparison notes a good match for more frequent events (20% and 10% AEP), however, hydrologic model and FFA flow begins the diverge for rarer events. This is not unexpected due to the relative short record period used in the Gundaroo FFA, which reduces confidence in rare event estimates. Notwithstanding, the comparison improves confidence in hydrologic model design flow estimates.

The Sutton Stream Gauge (410851) comparison does not exhibit a good match between the FFA and WBNM model flows, with the WBNM flow being higher than FFA estimates. Due to the short record period available for the Sutton Stream Gauge (19 years), limited confidence is had in design flow estimates derived by FFA. As the WBNM flows are higher than the FFA flows, and the match to the Yass and Gundaroo Gauges is good, the results of this analysis do not reduce confidence in the WBNM model's ability to derived design flow estimates. It is also important to note that calibrated model parameters determined in the Sutton Flood Study have been applied which further improves confidence in the hydrologic model flow estimates.

Chart 2: Yass Stream Gauge (410026) – Comparison of FFA and WBNM Flows

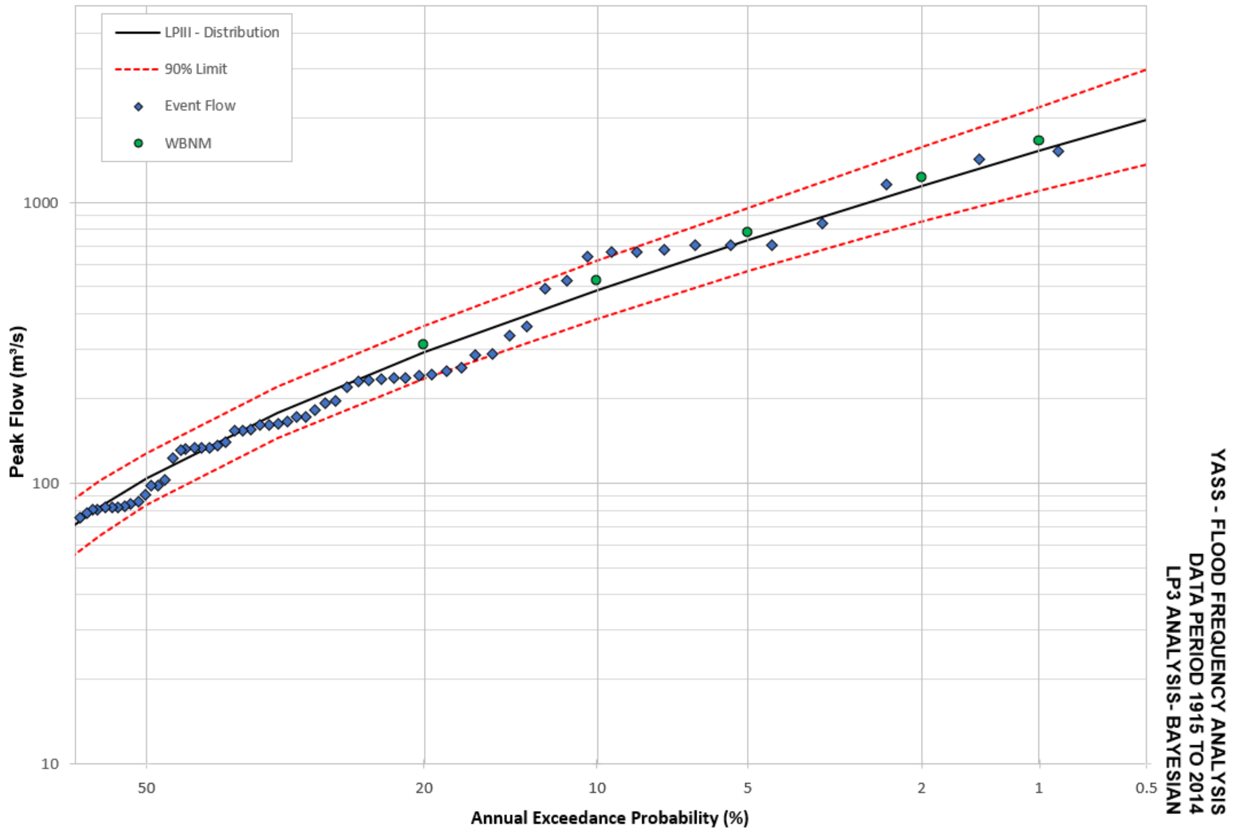


Chart 3: Gundaroo Stream Gauge (410090) – Comparison of FFA and WBNM Flows

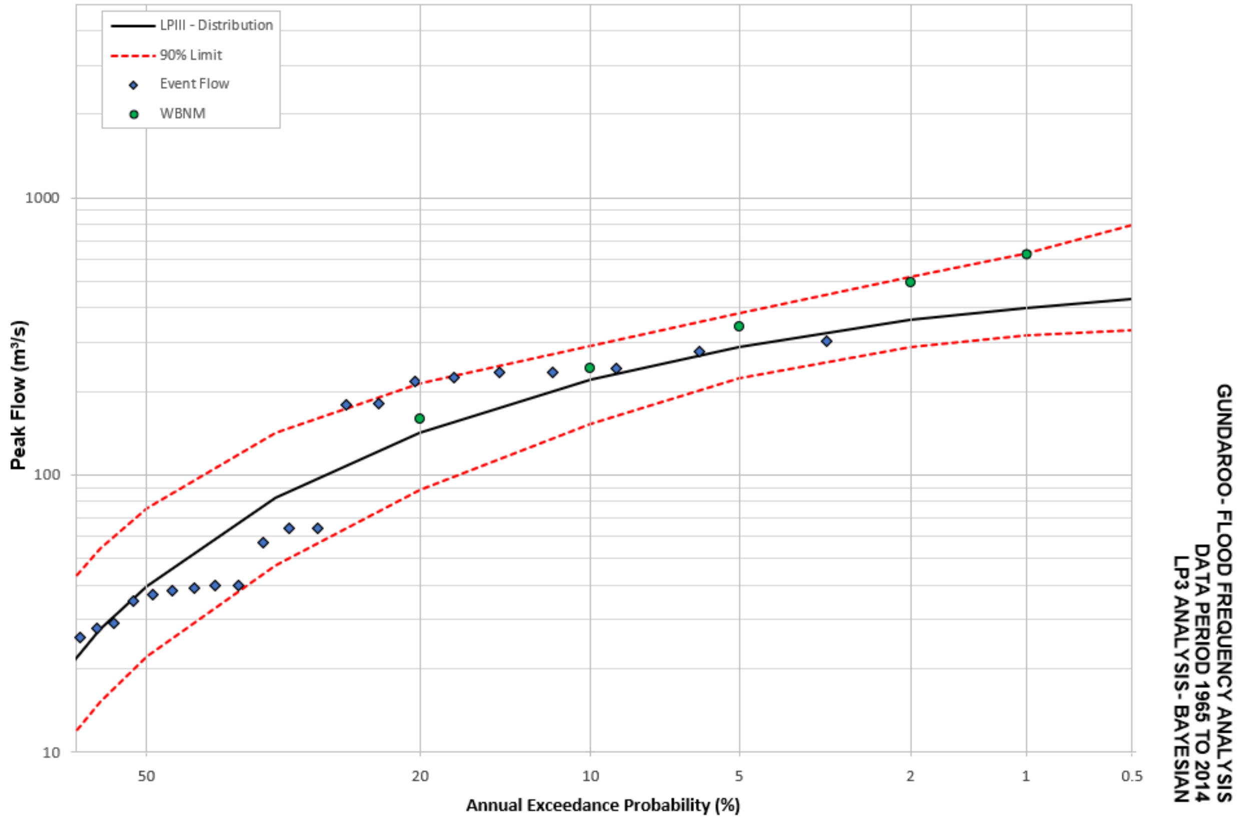
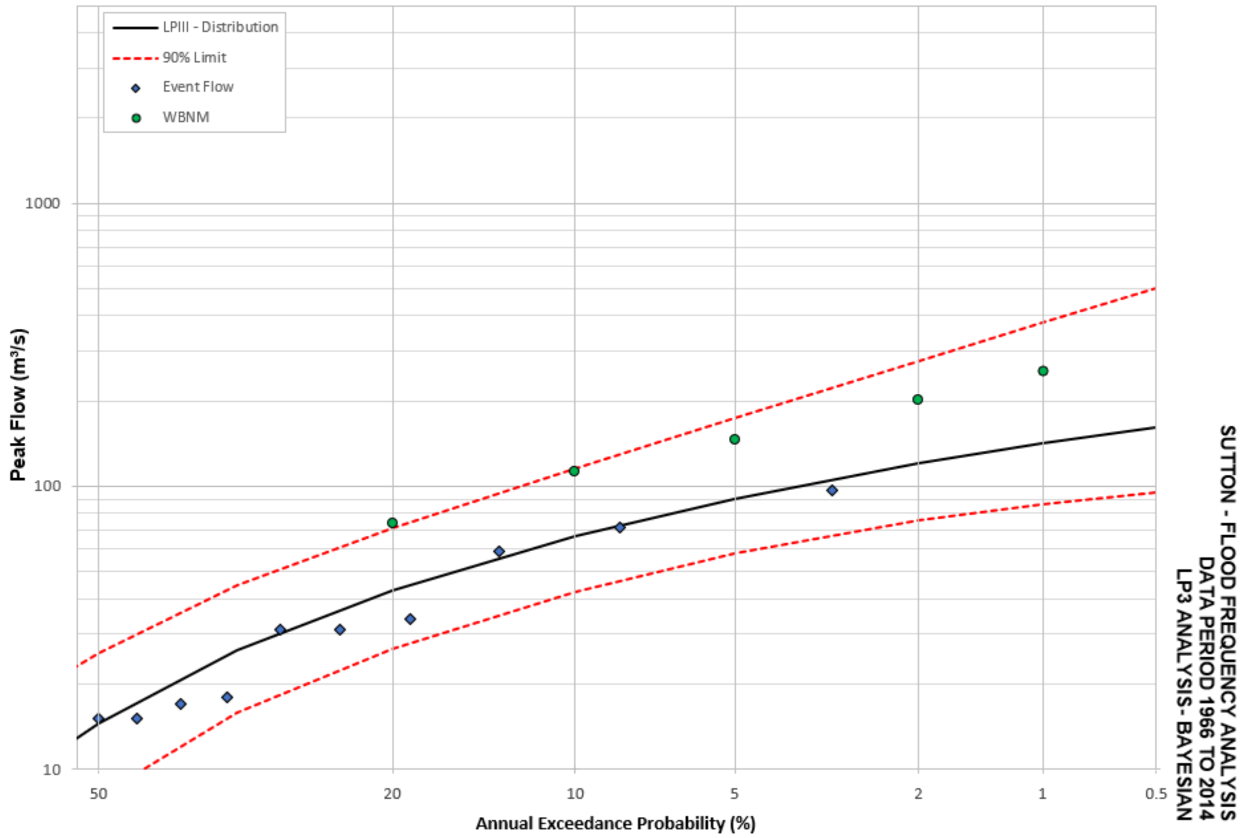


Chart 4: Sutton Stream Gauge (410851) – Comparison of FFA and WBNM Flows



4. CONCLUSIONS

A high resolution WBNM hydrologic model has been developed for the Yass River catchment. ARR2019 modelling methods and techniques have been applied. The model used calibrated model parameters determined in the Gundaroo and Sutton flood studies and validated design flow estimates to Flood Frequency Analysis (FFA) undertaken for three stream gauges. The validation process found a good match to FFA undertaken at the Yass and Gundaroo stream gauges providing confidence in the model results.

The WBNM model was developed with the intent of extracting design flow estimates for the Yass River and its tributaries across the catchment upstream of Yass. The analysis presented herein shows that the model is suitable for use for this purpose.

It should be noted that this report details the model build and validation efforts only. Additional modelling, including modification of parameters such as temporal patterns and Areal Reduction Factors, will need to be undertaken when assessing specific sites within the model domain. These will be detailed in accompanying documentation provided for site specific investigations.

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5. REFERENCES

1. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I
   Australian Rainfall and Runoff (ARR2019)
   Commonwealth of Australia, 2019

2. Yass Valley Council
   Yass Flood Study
   WMAwater, 2016

3. Yass Valley Council
   Gundaroo Flood Study
   WMAwater, 2016

4. Yass Valley Council
   Sutton Flood Study
   WMAwater, 2016

5. NSW Office of Environment and Heritage
   Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in Studies
   NSW Government, 2019

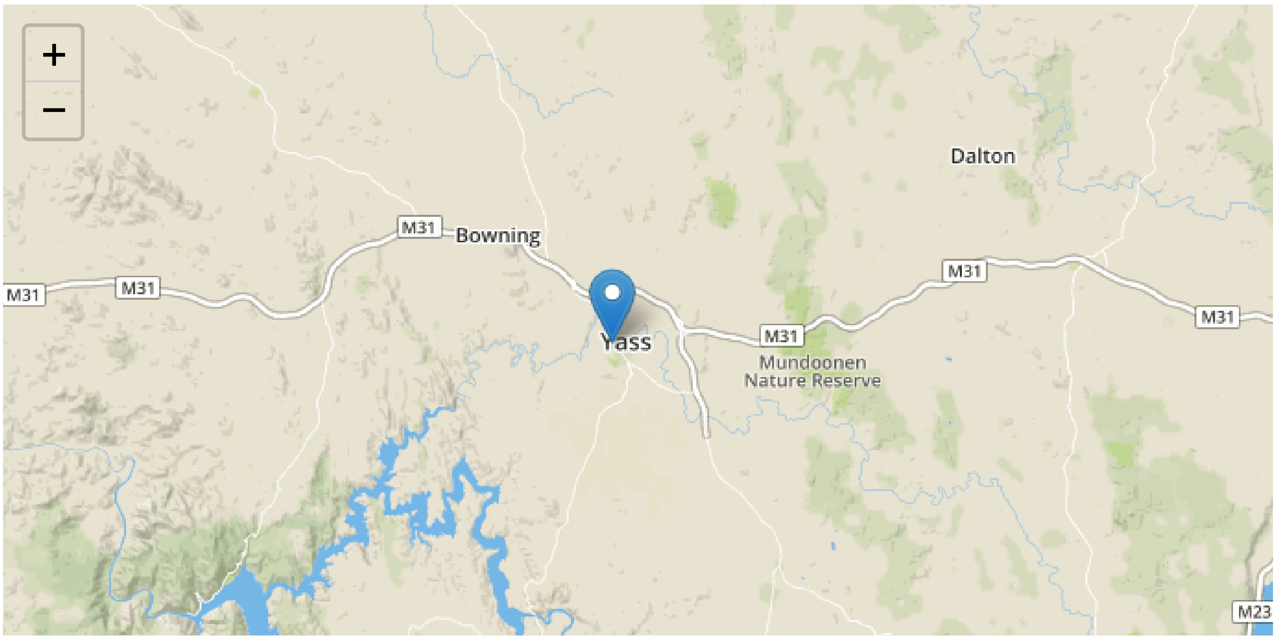
Appendix A: Datahub

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.905
Latitude	-34.838
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	Murray-Darling Basin
River Number	12
River Name	Murrumbidgee River

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	13889.0
Storm Initial Losses (mm)	31.0
Storm Continuing Losses (mm/h)	4.1

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.838&longitude=148.905&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	23 July 2019 11:10AM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.4 (0.025)	0.2 (0.011)	0.1 (0.004)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.7 (0.035)	0.4 (0.015)	0.2 (0.006)	0.0 (0.000)	0.2 (0.005)	0.3 (0.007)
120 (2.0)	0.4 (0.021)	0.3 (0.010)	0.2 (0.005)	0.0 (0.001)	0.2 (0.005)	0.4 (0.007)
180 (3.0)	2.2 (0.092)	1.7 (0.052)	1.3 (0.035)	1.0 (0.022)	0.5 (0.009)	0.1 (0.001)
360 (6.0)	0.9 (0.030)	0.9 (0.021)	0.8 (0.017)	0.8 (0.014)	0.8 (0.011)	0.7 (0.009)
720 (12.0)	0.1 (0.002)	1.2 (0.023)	2.0 (0.031)	2.7 (0.036)	6.3 (0.068)	8.9 (0.084)
1080 (18.0)	0.0 (0.000)	0.8 (0.013)	1.3 (0.018)	1.9 (0.021)	6.7 (0.063)	10.4 (0.084)
1440 (24.0)	0.0 (0.000)	0.3 (0.004)	0.4 (0.005)	0.6 (0.006)	2.8 (0.023)	4.4 (0.032)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	9.0 (0.543)	8.1 (0.369)	7.6 (0.292)	7.0 (0.236)	8.0 (0.227)	8.6 (0.221)
90 (1.5)	9.3 (0.494)	8.7 (0.346)	8.4 (0.281)	8.0 (0.234)	10.5 (0.259)	12.4 (0.273)
120 (2.0)	12.0 (0.577)	10.7 (0.385)	9.8 (0.300)	9.0 (0.239)	10.9 (0.242)	12.2 (0.242)
180 (3.0)	13.1 (0.552)	12.9 (0.404)	12.8 (0.337)	12.6 (0.288)	10.8 (0.207)	9.5 (0.160)
360 (6.0)	8.5 (0.282)	11.1 (0.271)	12.8 (0.262)	14.5 (0.252)	20.4 (0.293)	24.8 (0.312)
720 (12.0)	4.9 (0.125)	10.0 (0.188)	13.4 (0.210)	16.7 (0.220)	29.4 (0.319)	39.0 (0.368)
1080 (18.0)	2.5 (0.054)	6.9 (0.112)	9.9 (0.132)	12.7 (0.143)	24.3 (0.227)	33.1 (0.269)
1440 (24.0)	0.8 (0.015)	4.0 (0.059)	6.2 (0.075)	8.3 (0.085)	13.5 (0.115)	17.5 (0.129)
2160 (36.0)	0.1 (0.001)	1.8 (0.022)	2.9 (0.031)	3.9 (0.036)	7.8 (0.059)	10.8 (0.072)
2880 (48.0)	0.0 (0.000)	0.8 (0.009)	1.3 (0.013)	1.8 (0.015)	5.1 (0.036)	7.6 (0.047)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.001)	0.3 (0.002)

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.6 (1.246)	21.2 (0.959)	21.5 (0.830)	21.8 (0.734)	23.5 (0.671)	24.8 (0.632)
90 (1.5)	20.3 (1.073)	21.1 (0.838)	21.7 (0.732)	22.3 (0.652)	23.5 (0.580)	24.3 (0.536)
120 (2.0)	24.8 (1.197)	25.5 (0.918)	26.0 (0.792)	26.4 (0.698)	28.1 (0.625)	29.3 (0.580)
180 (3.0)	28.0 (1.182)	26.8 (0.840)	26.0 (0.687)	25.2 (0.575)	24.2 (0.462)	23.5 (0.396)
360 (6.0)	18.8 (0.619)	26.2 (0.639)	31.1 (0.635)	35.9 (0.624)	51.2 (0.737)	62.8 (0.790)
720 (12.0)	18.0 (0.460)	30.7 (0.575)	39.0 (0.609)	47.1 (0.621)	66.7 (0.723)	81.4 (0.768)
1080 (18.0)	15.1 (0.332)	21.7 (0.351)	26.1 (0.350)	30.3 (0.343)	52.5 (0.489)	69.1 (0.561)
1440 (24.0)	9.2 (0.183)	17.5 (0.256)	23.0 (0.279)	28.3 (0.290)	34.7 (0.294)	39.5 (0.293)
2160 (36.0)	6.2 (0.108)	11.3 (0.145)	14.7 (0.157)	18.0 (0.163)	23.2 (0.175)	27.0 (0.180)
2880 (48.0)	1.4 (0.023)	8.1 (0.096)	12.5 (0.124)	16.8 (0.141)	22.6 (0.160)	27.0 (0.169)
4320 (72.0)	1.5 (0.021)	5.4 (0.059)	8.1 (0.073)	10.6 (0.082)	10.6 (0.070)	10.6 (0.062)

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.816 (4.1%)**	0.726 (3.6%)	**0.934 (4.7%)**
2040	**1.046 (5.2%)**	1.015 (5.1%)	**1.305 (6.6%)**
2050	**1.260 (6.3%)**	1.277 (6.4%)	**1.737 (8.8%)**
2060	**1.450 (7.3%)**	1.520 (7.7%)	**2.214 (11.4%)**
2070	**1.609 (8.2%)**	1.753 (8.9%)	**2.722 (14.2%)**
2080	**1.728 (8.8%)**	1.985 (10.2%)	**3.246 (17.2%)**
2090	**1.798 (9.2%)**	2.226 (11.5%)	**3.772 (20.2%)**

Layer Info

Time Accessed	23 July 2019 11:10AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	16.9	14.2	11.8	11.7	11.6	11.0
90 (1.5)	19.4	14.7	12.9	12.8	12.7	11.9
120 (2.0)	21.3	14.2	12.6	12.8	12.3	11.8
180 (3.0)	23.5	13.9	13.0	14.0	14.3	13.5
360 (6.0)	25.2	16.8	15.3	16.0	13.6	9.9
720 (12.0)	25.9	18.4	16.8	17.1	14.3	7.9
1080 (18.0)	26.9	20.8	19.7	20.9	16.2	9.8
1440 (24.0)	28.5	22.8	22.5	23.7	19.9	12.8
2160 (36.0)	30.0	24.7	25.4	27.2	24.8	16.5
2880 (48.0)	31.2	26.0	26.3	28.3	25.3	16.8
4320 (72.0)	31.9	26.7	28.6	30.2	26.9	22.6

Layer Info

Time Accessed	23 July 2019 11:10AM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

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