15.12 POST EXHIBITION REPORT - DRAFT MARULAN FLOOD RISK MANAGEMENT STUDY AND PLAN

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Attachments:
1. Marulan FRMSP As Exhibited
2. State Agency Submissions
3. Submission Summary and Responses

Link to Community Strategic Plan:	CSP -Our Environment EN4 Maintain a balance between growth, development and environmental protection through sensible planning. LSPS -Planning Priority 8: Natural Hazards – Vision 2040 – Natural hazards are identified, planned for and mitigated where possible throughout the planning process.
Cost to Council:	$125k (2/3 grant funded by NSW Department of Climate Change, Energy, the Environment and Water).
Use of Reserve Funds:	N/A

RECOMMENDATION

THAT Council:
1. Receive the post exhibition report on the Draft Marulan Floodplain Risk Management Study and Plan.
2. Adopt the Marulan Floodplain Risk Management Study and Plan as exhibited, to commence on 20 June, 2025.
3. Review Chapter 3.8 of the Goulburn Mulwaree Development Control Plan and Flood Policy in (Appendix J) to include the relevant components of the Marulan Floodplain Risk Management Study and Plan.

BACKGROUND

Council received grant funding towards the development of a Marulan Flood Study and a Floodplain Risk Management Study and Plan from the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW). Council engaged GRC Hydro to prepare the Flood Study and a Floodplain Risk Management Study and Plan for Marulan.

Unlike Goulburn, Marulan is sited at the top of two catchments and does not have any proximity to rivers and the impacts of riverine flooding. However, Marulan does have creeks and watercourses which are located within the town and surrounding rural catchment. Furthermore, some areas within the town are known to experience problems with overland flows and stormwater. The risks to life and property still apply to flooding whether due to overland flow or riverine flooding.

In mid 2023 Council adopted the Marulan Flood Study which established a model which identified the flood extents in Marulan for a range of flood events. This Flood Study is currently being used to inform emergency services, strategic planning and capital works projects as well as to inform the development management process and to provide information to the public on known flood risks or constraints.

Based upon the modelling undertaken in the Marulan Flood Study, a Floodplain Risk Management Study and Plan (FRMSP) has been prepared and publicly exhibited. The FRMSP considers a range of risks and management or mitigation measures. These mitigations are further considered and assessed against cost for value.

This report considers the outcome from public consultation and recommends the adoption of the Floodplain Risk Management Study and Plan.

REPORT

Flood Risks and Flood Risk Management Measures
The FRMSP identifies a variety of flood risks including:

1. Identification of key flood risk areas and the development of flooding hotpots, including assessment of future urban release areas identified in the Urban and Fringe Housing Strategy;
2. Information on flooded roads;
3. Analysis of property flood liability;
4. Assessment of the economic impact of flooding on Marulan;
5. Review of critical infrastructure and sensitive land uses; and
6. Assessment of available flood warning.

Flood risk management measures are identified as appropriate based on cost and benefit and are broken up into the following categories:

- Property modification measures.

These measures seek to modify existing properties to manage flood risk and generally include Council planning and development policies such as strategic planning, zoning, development control plan controls, and information on planning certificates. Other measures can include house raising and in cases of high risk voluntary purchase schemes.

- Response modification measures

These measures are intended to improve the ability of people to react to and plan for floods and generally include flood signage on roads, community flood education programs and flood emergency management plans.

- Flood modification measures

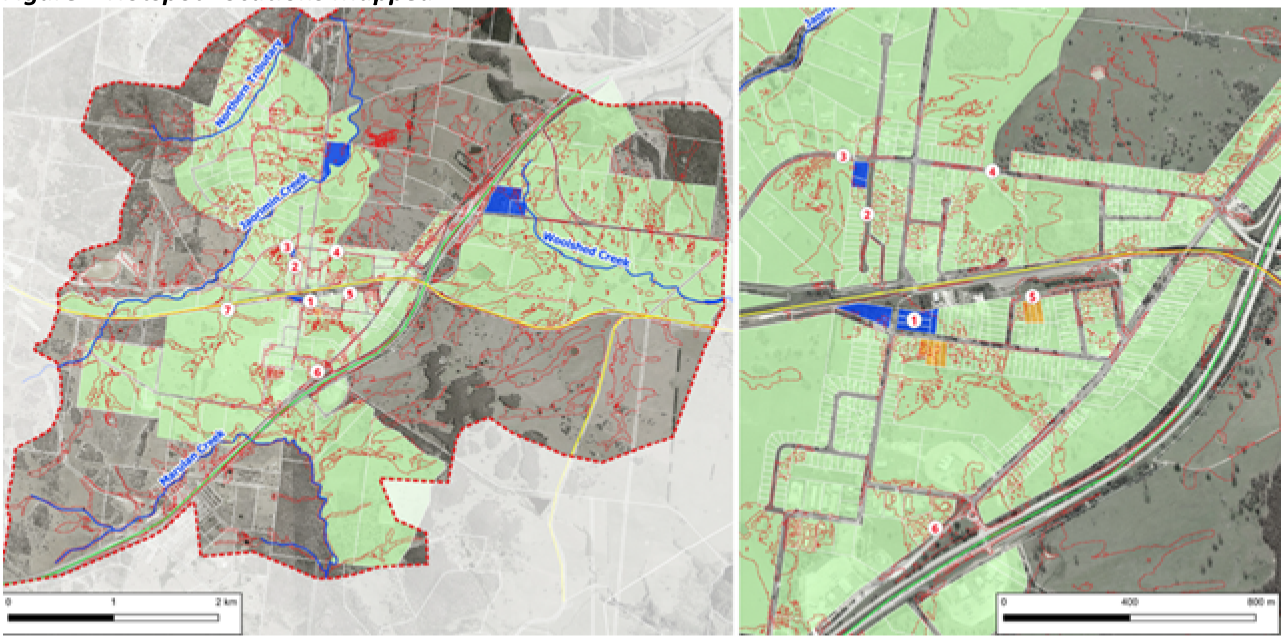
These measures typically involve works that modify flood behaviour such as levies, management of vegetation and debris, or to reduce flow such as detention basins.

Hotspots, Mitigation Assessment and Recommendations
Flooding hotspots refer to areas that are particularly flood affected and/or affected by hazardous flooding. Seven hotspot areas have been identified following the community survey (undertaken for the Flood Study) and in consultation with Council and DCCEEW staff, with a summary presented in Table 1 below.

Table 1 Flooding Hot Spots

Hotspot	Location	Risk Factors
1	Western end of Goulburn Street	Sensitive facility, road, and property flooding
2	Morris Place	Road and property flooding
3	Intersection of Morris Place and Maclura Drive	Road flooding
4	Brayton Road intersection with the Northern Flow Path	Road and property flooding
5	Along Railway Parade	Road and property flooding
6	Between Portland Avenue and George Street	Road flooding
7	South of the railway near Haddon place	Prospect Road and property flooding

Figure 1 Hotspot Locations Mapped



The hotspots were assessed by considering flood modification measures which could be used to reduce the flood impacts at each location. The outcomes of each engineered solution were modelled to gauge the level of improvement, i.e., whether the modification increased flooding downstream (which is a red flag) and whether the cost of the modification could justify the improvement.

The only flood modification which met the cost benefit analysis was the clearance of vegetation and debris at each of the railway culverts.

Marulan Sensitive and Critical Facilities

The FRMSP identified the location of sensitive and critical facilities in Marulan and considered the impacts of flooding for the full range of design flood events.

As identified in Table 2 below, most sensitive or critical facilities were not significantly affected by flooding except for the Marulan RFS site at the Goulburn Street Portland Avenue intersection. This site is not significantly affected until the 1%AEP event. Noting that access is affected at the 5%AEP event but only to a H1 standard (which means the depth and velocity of the flooding is of the lowest hazard category and can be safely access for pedestrians and small cars).

The NSW RFS was notified of the exhibition of the Draft FRMSP but did not make a submission.

Table 2 – Sensitive and Critical Facilities

ID	Facility	Location	Design Event (AEP)				Site access impacted
			5%	1%	0.2%	PMF	
1	Marulan Rural Fire Brigade	Goulburn-Portland Street intersection	H1	H4[1]	H3	H5	5% AEP
2	Water Treatment Plant (Council)	Brayton Road	NF	H2	H2	H4	1% AEP
3	Marulan Preschool	George Street	NF	NF	NF	H1	-
4	Marulan Medical Centre	George Street	NF	NF	NF	NF	-
5	Marulan Public School	Goulburn-George Street intersection	NF	NF	NF	NF	-
6	Marulan Police Station	George Street-railway crossing	NF	NF	NF	NF	-
7	Marulan Waste Management Centre	Wilson Drive	NF	NF	NF	NF	-
8	Marulan WWTP	Medway Road	NF	NF	NF	NF	-

NF = 'Not Flooded'.
[1] Note: the 1% AEP flood hazard exceeds the 0.2% AEP flood hazard at this location due to the adopted 1% AEP blockage assumption.

Marulan Roads
The FRMSP identifies roads within Marulan and the point of inundation for the full range of design flood events (Table 3).

Most roads do not exceed a H2 category of risk until a 5%AEP event (this occurs at Jaorimin Creek on Ambrose Road which is H3 hazard). Other roads do not achieve a H3 hazard until the 1%AEP event (Maclura Drive and Railway Parade). Otherwise, most roads are trafficable until a probable maximum flood (PMF).

Table 3 – Road Inundation (All design events)

ID	Location	Peak Flood Hazard per design event (AEP)							
		20%	10%	5%	2%	1%	0.5%	0.2%	PMF
1	Hume Highway at Marulan Ck	H1	H1	H1	H1	H1	H1	H1	H5
2	Hume Highway northbound offramp	H1	H1	H1	H1	H1	H1	H1	H4
3	George Street	H1	H1	H1	H1	H1	H1	H2	H4
4	Goulburn Street	H1	H1	H1	H1	H2[1]	H1	H2	H5
5	Railway Parade	H1	H1	H1	H1	H3[1]	H2	H3	H5
6	Morris Place	H1	H1	H1	H1	H1	H1	H1	H2
7	Maclura Drive	H1	H1	H1	H1	H1	H2	H2	H3
8	Brayton Road West-bound	H1	H1	H1	H1	H1	H1	H1	H2
9	Brayton Road North-bound	H1	H1	H1	H1	H1	H1	H1	H1
10	Patrick Place	H1	H1	H1	H1	H1	H1	H1	H1
11	George Street North	H1	H1	H1	H1	H1	H1	H2	H5
12	Dorsett Road	H1	H1	H1	H1	H1	H1	H1	H1
13	Southdown Road	H1	H1	H1	H1	H2	H2	H2	H5
14	Hume Highway at Woolshed Ck	H1	H1	H1	H1	H1	H1	H1	H4
15	Brayton Road at Jaorimin Ck	-	-	-	-	-	-	-	H5
16	Brayton Road at Merino Road	H1	H1	H1	H1	H1	H1	H1	H3
17	Maclura Drive at Stoney Creek Road	H2	H2	H2	H2	H3	H3	H3	H5
18	Jaorimin Creek at Ambrose Road	H1	H2	H3	H4	H4	H5	H5	H6
19	George Street at Brayton Road	H1	H1	H1	H1	H1	H1	H1	H1

[1] Note: the 1% AEP flood hazard exceeds the 0.5% AEP flood hazard at this location due to the adopted 1% AEP blockage assumption.

Future Development Areas – Urban and Fringe Housing Strategy (UFHS)
One of the reasons to develop the Marulan Flood Study and FRMSP was to inform the planning of future development in Marulan. The Urban and Fringe Housing Strategy (UFHS) was developed in consultation with State Agencies to ensure it was both informed and endorsed by the State. One of the key recommendations for precincts in Marulan identified for development was the need to undertake further assessment of flood impacts to inform future planning of urban release areas.

Table 4 – Flood Impact on UFHS Growth Precincts

Growth Area	Type*	Proposed No. lots*	Total Area (ha)	Minimum Lot Size (m^2)*	Land outside of the FPA[2] (ha)	Preliminary Feasibility Assessment
Marulan North	R1	694	98	700	74 (76%)	Feasible
Marulan North URA	R1	631	91	700	75 (83%)	Feasible
Marulan East	R5	29	217[1]	100,000	107 (49%)	Not feasible

As noted in Table 4 above the Marulan East opportunity area is identified as not being feasible due to flooding based on the preliminary assessment provided in the FRMSP. It should be noted that since the UFHS has been developed several natural disasters in relation to flooding have informed significant changes to the State's flood planning framework. This has included the development of a new NSW Flood Manual in 2023 and changes to Local Planning Directions (and their application) which impact planning proposals for rezonings.

Flood Education and Signage
The FRMSP identifies response modification measures including increased flood signage at key inundation points as identified in Table 3.

Community education is a shared responsibility between Council and NSW SES and is another recommendation of the plan.

The FRMSP is also recommended to be used to inform the next version of the NSW SES Local Flood Plan to inform emergency management responses and planning.

Recommended Flood Management Measures
Of the main recommendations, the property modification measures tend to be the main point of focus in Marulan. This means that risk is largely mitigated for new development through planning policy including:

- The adoption of a flood planning level and a flood planning area. Marulan currently has a temporary flood planning level and flood planning area based on Council's flood policy (0.5m). The FRMSP is recommending 0.5m be adopted as a freeboard for riparian area and a reduced freeboard of 0.3m for overland flow areas (which it maps).
- Amendment of the GM Development Control Plan (DCP) 2009 to introduce Flood Planning Constraint Categories (which are already in place for Goulburn). These areas are mapped in the FRMSP and colour coded to align with Goulburn's maps. Some amendments to the DCP will be required to tailor controls to Marulan and the incorporation of an overland flooding component (as opposed to Goulburn which currently focuses on riverine flooding).
- Updating planning certificates. This would include the updated flood planning area. Additional flood certificates can be issued using the updated information.
- Advice for planning proposals and consideration of new urban release areas. Zoning should be considered in conjunction with flood characteristics. The rezoning of land with a high flood hazard is to be considered.

As previously mentioned, a range of flood modification measures were considered for the various hot spots. The only modification measure that met the cost benefit analysis requirements was the clearing of vegetation and debris from the railway culverts.

Other mitigations are aimed at response modification and include additional flood signage on roads and collaboration with the NSW SES in relation to community education and an updated SES Local Flood Plan.

A summary of flood management measures recommended in the FRMSP is provided in Table 5 below.

Table 5 – Summary of Recommendations/ Flood Management Measures

Flood Management Measure	Section	Priority	Cost	Responsibility
Property Modification Measure				
Adoption of Flood Planning Level and Flood Planning Area	7.1.2.2	High	Council cost estimate	Council
Adoption of Flood Planning Constraint Categories in Council's DCP	7.1.2.3	High	Council cost estimate	Council
Update of Goulburn Development Control Plan	7.1.2.3	High	Council cost estimate	Council
Updated 10.7 Planning Certificates	7.1.2.5	High	Council cost estimate	Council
Advice on Land-use Zoning Considering Flooding	7.1.2.4	Medium	Council cost estimate	Council
Review of Future Development Areas	7.1.2.7	Medium	Council cost estimate	Council
Response Modification Measures				
Develop a LGA wide community flood education program	7.2.3	Medium	Council/SES cost estimate	Council / NSW SES
Install Flood Signage	7.2.4	Medium	~$35,000	Council
Update Local Flood Plan	7.2.5	High	SES Cost Estimate	NSW SES
Flood Modification Measures				
Clearing Debris at Railway Culverts	7.3.3.2	High	Council/ARTC cost estimate	ARTC

Public Exhibition
The Draft Floodplain Risk Management Study and Plan prepared by GRC Hydro was publicly exhibited between Friday 31 January 2025, and Friday 28 February, 2025.

The exhibition was advertised through:

- Notification letters sent to all landowners (approximately 700) within the 1% Annual Exceedance Probability (AEP) flood event.
- Notification emails to the Marulan Progress Association and Marulan Chamber of Commerce.
- Notification emails to relevant State and Federal Agencies (in their capacities as landowners or due to service provision) including, NSW State Emergency Service (SES), NSW Rural Fire Service (RFS), Water NSW, Transport for NSW, Australian Rail Track Corporation (ARTC), and National Heavy vehicle Regulator (NHVR).
- Notification of the exhibition to Council's development stakeholder list (approximately 500) including real estate agents, builders, developers, development consultants, solicitors, conveyancers etc.

Exhibition material was available online via Council's web site with hard copies also made available to view at the Civic Centre and Library.

Public Submissions
The notification letters recommended phoning or meeting with Council staff so as to provide bespoke advice on the implications of the FRMSP for each interested party. Council received several phone calls and held meetings as requested with interested members of the public, however, no public submissions were received in relation to the draft FRMSP.

The lack of submissions is attributed to the following reasons:

- The Marulan Flood Study has already been adopted and in place since mid-2023. This plan had already introduced area specific flood planning to Marulan.
- The FRMSP does not identify any capital works projects as recommended mitigations as each measure identified and assessed had a low-cost benefit outcome and could potentially intensify downstream impacts of flooding on other properties.

- The proposed freeboard above the 1%AEP for overland flooding is temporarily being applied at for both riparian/mainstream and overland flooding at0.5m. The FRMSP is recommending this be reduced to 0.3m for mapped overland flood areas given the different nature and risks associated with overland flooding (i.e in Marulan less likely to carry floating debris, or have significant wave action etc.).

State Agency Submissions
Three (3) State agencies made submissions to the Draft FRMDSP (Attachment 2) being:

- Water NSW
- Transport for NSW
- NSW State Emergency Service.

Generally, the submissions from the State agencies were supportive and included some comments for further consideration.

A summary of the submissions with GRC Hydro and Council responses is provided in Attachment 3. The summary table identifies some minor edits to the document in response to the submissions.

Goulburn Mulwaree Development Control Plan (DCP) 2009
Chapter 3.8 - Flood Affected Land of the DCP currently reflects only the adoption of the Goulburn FRMSP and will need to be updated to include the adoption of the Marulan FRMSP. Additionally, the Flood Policy in Appendix J to the DCP will need to be updated.

Planning and Flood Certificates
Planning and Flood Certificates will require updating with the adoption of the Marulan FRMSP. This will require the data to be transferred to Council and Council's information technology systems to be updated. It is proposed to delay the commencement of the FRMSP for one month following adoption to allow for systems to be updated with the new data.

Conclusion
In conclusion, given the nature and scale of flooding in Marulan most mitigations fall within the property modification measure category. No significant capital works are identified as having a feasible cost benefit outcome in relation to flood modification measures for each of the identified hot spots. The nature of flooding within the central area of Marulan is largely impacted by the presence of the Main Southern Railway Line and the size of the culverts which limit the size of flows downstream on the northern side but due to their size and management can result also in the storage of flood water on the southern side.
The FRMSP identifies a range of management measure to assist Council, emergency service providers and the public. It is recommended that the FRMSP be adopted generally in accordance with the exhibited version and subject to some minor changes in response to State agency submissions (where identified in Attachment 3) and to present a final version. It is recommended that the commencement of the FRMSP be delayed for one month to allow for the uploading of data to inform planning certificates.

Marulan Floodplain Risk Management Study & Draft Plan

Draft Final Report

December 2024

Marulan Floodplain Risk Management Study and Draft Plan

Draft Final Report

Project:	Marulan Floodplain Risk Management Study and Plan
Project Number:	210048
Client:	Goulburn Mulwaree Council
Client Contact:	Kate Wooll
Report Author:	Beth Marson, Osama Hebe, William Tang
Prepared by:	Beth Marson, Osama Hebe
Date:	4 December 2024
Verified By:	Zac Richards

Date	Version	Description
24-January-2024	1	Draft Risk Assessment
10-July-2024	2	Final Risk Assessment
20-September-2024	3	Draft Floodplain Risk Management Study and Draft Plan
4-December-2024	4	Draft Final Floodplain Risk Management Study & Plan

Filepath: J:\210048\Admin\Reports\FRMSP\DRAFT_FINAL\Marulan_FRMSP_DRAFT_FINAL_Report_v04.docx

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EXECUTIVE SUMMARY

Introduction

Partially funded by the Floodplain Management Program, Goulburn Mulwaree Council, has commissioned GRC Hydro to undertake a Flood and Floodplain Risk Management Study for Marulan township and surrounding areas in accordance with the specifications establish by the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW).

This study comprises stages 3 and 4, and continues on Marulan Flood Study (stages 1 and 2) that was published in June 2023. This effort aims to progress towards the completion of the five-stage process that is outlined in the Flood Risk Management Manual (FRMM) (NSW Government, 2023).

The objective of this study is to develop an understanding of the impacts of flooding on the existing and future local community of Marulan township and surrounding areas. The study allows for the testing and investigation of practical, feasible and economic management measures to treat existing, future and residual risk. The FRMS will provide a basis for informing the development of a FRMP which will document and convey the decisions on the management of flood risk into the future.

Analysis of Model Results

The computer model results from the Marulan Flood Study (GRC Hydro, 2023) were used to develop important information to better understand and manage flood risk in the catchment. These outputs include definition of flood hazard, flood function, emergency response categories, flood planning levels and climate change impacts.

Community Risk Assessment

An assessment of Marulan's flood behaviour and community profile has been carried out to determine specific areas of flood risk across a range of metrics, including; property flood liability, flood hazard, flood function, the economic impact of flooding, evacuation and available flood warning.

The current study has utilised the flood study results, and analysis presented in Section 5, to examine areas of risk associated with flooding of Marulan. The following sections describes the consequences of flooding at Marulan and include:

- Identification of key flood risk areas and the development of flooding hotpots (Section 6.2);
- Information on flooded roads (Section 6.3);
- Analysis of property flood liability (Section 6.4);
- Assessment of the economic impact of flooding on Marulan (Section 6.5);
- Review of critical infrastructure and sensitive land uses (Section 6.6); and
- Assessment of available flood warning (Section 6.7).

The identified flooding hotspots are summarised in Table ES 1.

Table ES 1: Flooding Hotspots and Risk Factors

Hotspot	Location	Risk Factors
1	Western end of Goulburn Street	Sensitive facility, road, and property flooding
2	Morris Place	Road and property flooding
3	Intersection of Morris Place and Maclura Drive	Road flooding
4	Brayton Road intersection with the Northern Flow Path	Road and property flooding
5	Along Railway Parade	Road and property flooding
6	Between Portland Avenue and George Street	Road flooding
7	South of the railway near Haddon place	Prospect Road and property flooding

A summary of the flood liability of individual lots and buildings within the PMF extent in Marulan is presented in Table ES 2.

Table ES 2: Property Flood Affectation

	Residential		Commercial	
Design Event (AEP)	No. of properties flooded above ground	No. of properties flooded above floor	No. of properties flooded above ground	No. of properties flooded above floor
20%	1	0	9	2
10%	2	0	10	2
5%	2	0	10	3
2%	7	0	10	3
1%	14	0	12	3
0.50%	15	0	12	3
0.20%	15	0	12	3
PMF	77	30	24	7

Net flood damage estimates of residential and commercial flood damages are presented in Table ES 3 and Table ES 4, respectively.

Table ES 3:Residential Flood Damages

Design Event (AEP)	Flood Damages Total
20%	$17,500
10%	$35,100
5%	$35,100
2%	$122,700
1%	$245,400
0.50%	$263,000
0.20%	$263,000
PMF	$4,963,300
Average Annual Damages (AAD)	$22,900

Table ES 4:Commercial Flood Damages

Design Event (AEP)	Flood Damages Total
20%	$638,600
10%	$726,600
5%	$749,100
2%	$795,800
1%	$828,600
0.50%	$844,900
0.20%	$861,300
PMF	$2,823,500
Average Annual Damages (AAD)	$402,300

The flood liability of various sensitive and critical developments and infrastructure was examined including for medical facilities, childcare, schools and other critical infrastructure.

Flood Risk Management Measures

Flood risk management measures which aim to reduce, or otherwise, manage flood risk in Marulan were assessed. These measures ranged from large scale civil works, such as drainage upgrades to non-works interventions, such as planning controls for new developments. Feasible measures, found to effectively reduce flood risk have been ranked for implementation in the Draft Floodplain Risk Management Plan (see Section 8).

Floodplain Risk Management measures are categorised in the Flood Risk Management Manual (FRMM) (Reference 20) as follows:

- Property Modification Measures (Section 7.1) are those which involve modifying existing properties to manage their flood risk. This includes planning-related measures such as minimum floor levels and zoning based on the locality's flood risk. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
- Response Modification Measures (Section 7.2) are those that improve the ability of people to plan for and react to flood events. They often involved emergency services and can be targeted at different phases of a flood, e.g., preparation, response and recovery.
- Flood Modification Measures (Section 7.3) are those that change the behaviour of the flood itself through works or other measures. These measures often work to exclude flow from an area (for example a levee bank) or to reduce the peak flow (for example a detention basin).

Assessment of each modification measure for various options has been undertaken.

Draft Flood Risk Management Plan

A Draft Floodplain Risk Management Plan was developed which aims to address existing, future and continuing flood risk for the Marulan area in accordance with Flood Risk Management Manual (NSW Government, 2023) (Reference 20). The Plan aims to achieve the following overarching objectives:

- Reduce the flood hazard and risk to people and property, now and in the future;

- Protect, maintain and where possible enhance the floodplain environment; and
- Ensure floodplain risk management decisions integrate social, economic and environmental considerations.

The flood management measures recommended for implementation in the DRAFT Plan are presented in Table ES 5. The measures have been prioritised with high, medium and low classifications along with who is responsible for implementation and cost estimates presented.

Table ES 5: DRAFT Flood Risk Management Plan

Flood Management Measure	Section	Priority	Cost	Responsibility
Property Modification Measure				
Adoption of Flood Planning Level and Flood Planning Area	7.1.2.2	High	Council cost estimate	Council
Adoption of Flood Planning Constraint Categories in Council's DCP	7.1.2.3	High	Council cost estimate	Council
Update of Goulburn Development Control Plan	7.1.2.3	High	Council cost estimate	Council
Updated 10.7 Planning Certificates	7.1.2.5	High	Council cost estimate	Council
Advice on Land-use Zoning Considering Flooding	7.1.2.4	Medium	Council cost estimate	Council
Review of Future Development Areas	7.1.2.7	Medium	Council cost estimate	Council
Response Modification Measures				
Develop a LGA wide community flood education program	7.2.3	Medium	Council/SES cost estimate	Council / NSW SES
Install Flood Signage	7.2.4	Medium	~$35,000	Council
Update Local Flood Plan	7.2.5	High	SES Cost Estimate	NSW SES
Flood Modification Measures				
Clearing Debris at Railway Culverts	7.3.3.2	High	Council/ARTC cost estimate	ARTC

This DRAFT plan is proposed for consideration only, and it is expected that stakeholder input will modify the outcomes and recommendations in this plan.

FOREWORD

The New South Wales (NSW) Government's Flood Prone Land Policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods.

Through the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) (formerly Department of Planning and Environment) and the NSW State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding, flood risk management, flood emergency management and land-use planning matters.

The Flood Risk Management Manual (FRMM) (NSW Government, 2023) assists councils to meet their obligations through a five-stage process resulting in the preparation and implementation of floodplain risk management plans. Image 1 presents the process for plan preparation and implementation.

Image 1: The floodplain risk management process in New South Wales (FRMM, 2023)

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1. INTRODUCTION

1.1 The Floodplain Risk Management Program

Partially funded by the Floodplain Management Program, Goulburn Mulwaree Council, has commissioned GRC Hydro to undertake Flood and Floodplain Risk Management Studies for Marulan township and the surrounding area in accordance with the specifications established by the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW).

This study composes stages 3 and 4, and continues on Marulan Flood Study (stages 1 and 2) that was published in June 2023. This effort aims to progress towards the completion of the five-stage process that is outlined in the Flood Risk Management Manual (FRMM) (NSW Government, 2023). This work includes:

- **Flood Study** – the Marulan Flood study (GRC Hydro, June 2023) which presents flood characteristics for a range of flood events,
- **Floodplain Risk Management Study (FRMS)** – which assesses the impacts of floods on the existing and future community and allows the identification of management measures to manage flood risk; and a
- **Floodplain Risk Management Plan (FRMP)** – that outlines a range of measures, for future implementation, to manage existing, future and residual flood risk effectively and efficiently.

Following the completion of the FRMP, the final stage of the Program will involve implementing the findings of the FRMP. Further details of each of the stages are outlined below.

Data Collection (completed as part of the 2023 Flood Study)

The collection and collation of data necessary for the completion of the flood and floodplain risk management studies is a fundamental part of the floodplain management process. It is typically begun at the outset of the study, but generally continues throughout the period of the project as data becomes available. The quality and quantity of available data is key to the success of a flood study and FRMS.

Flood Study (completed as part of the 2023 Flood Study)

A flood study is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide an understanding of flood behaviour and consequences for a range for flood events. Information obtained in the data collection phase is used to assist in the development of hydrologic and hydraulic models which are calibrated and verified to improve confidence in model results.

Floodplain Risk Management Study (included in the current study)

A floodplain risk management study increases understanding of the impacts of floods on the existing and future community. It also allows testing and investigating practical, feasible and economic management measures to treat existing, future and residual risk. The floodplain risk management study will provide a basis for informing the development of a floodplain risk management plan.

Floodplain Risk Management Plan (included in the current study)

The floodplain risk management plan documents decisions on the management of flood risk into the future. The FRMP uses the findings of a floodplain risk management study, to outline a range of measures to manage existing, future and residual flood risk effectively and efficiently. This includes an itemised list of measures and prioritised implementation strategy.

1.2 Objectives

The objective of this study is to develop an understanding of the impacts of flooding on the existing and future local community of Marulan township and surrounding areas. The study allows for the testing and investigation of practical, feasible and economic management measures to treat existing, future and residual risk. The FRMS will provide a basis for informing the development of a FRMP which will document and convey the decisions on the management of flood risk into the future.

This FRMS built upon the understanding of flood behaviour outlined in the Marulan Flood study. The overall project provides an understanding of, and information on, flood behaviour and associated risk to inform:

- relevant government information systems;
- government and strategic decision makers on flood risk to the community;
- flood risk management planning for existing and future development;
- emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk;
- other key stakeholders (including utility providers and the insurance industry) on flood risk;
- providing a better understanding of the:
  - variation in flood behaviour, flood function, flood hazard and flood risk in the study area;
  - impacts and costs for a range of flood events or risks on the existing and future community;
  - impacts of changes in development and climate on flood risk;
  - emergency response situation and limitations;
  - effectiveness of current management measures;
- facilitating information sharing on flood risk across government and with the community.

The study outputs can also inform decision making for investing in the floodplain; managing flood risk through prevention, preparedness, response and recovery activities, and informing and educating the community on flood risk and response to floods. Each of these areas has different user groups with varied needs.

A key objective of this study is to meet the requirements of the identified end user groups (see Section 1.3), which are outlined in the project brief.

1.3 Project End Users

The study outputs are suitable to inform decision making for investing in the floodplain; managing flood risk through prevention, preparedness, response and recovery activities, and informing and educating the community on flood risk and response to floods. Each of these areas has different user groups, whose needs vary. The key end-user groups that this study aims to support are identified in Table 1.

Table 1: Project End Users

Potential end user group
High-level strategic decision makers
Community
Flood risk management professionals
Engineers involved in designing, constructing and maintaining mitigation works
Emergency management planners
Land-use planners (strategic planning and planning controls)
Hydrologists and meteorologists involved in flood prediction and forecasting
Business/Industry
Other government agencies such as the Goulburn Mulwaree Council, NSW State Emergency Service and Department of Planning, Industry and Environment

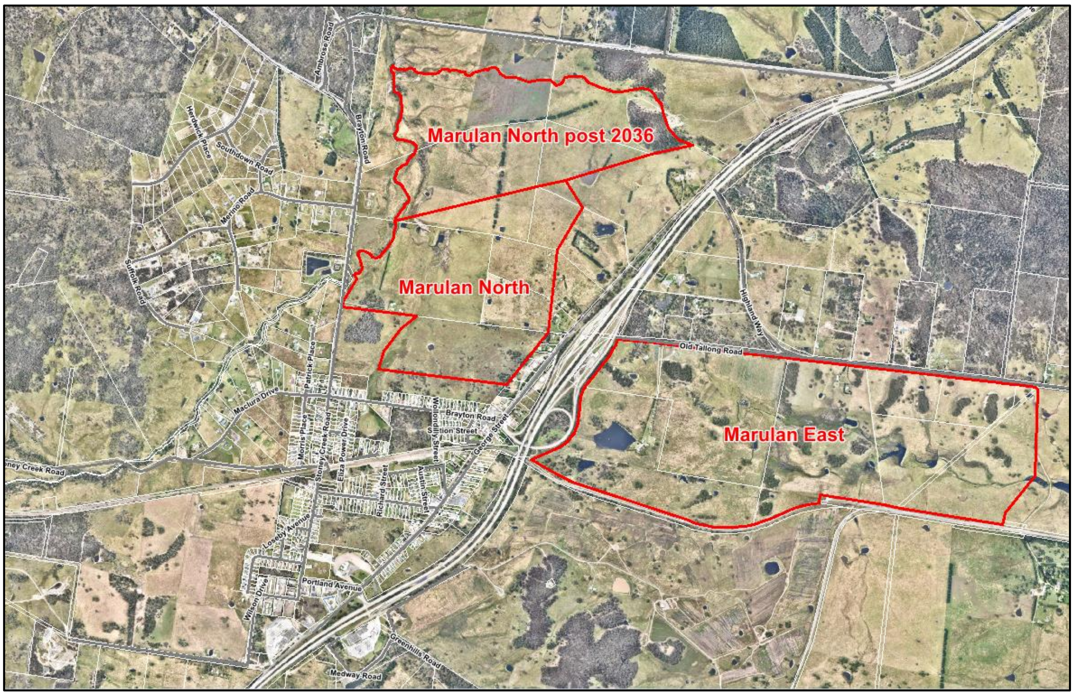
2. BACKGROUND

2.1 Study Area

Marulan is located in NSW, approximately 27 km north-east of Goulburn and 170 km south-west of Sydney. The town lies in the Goulburn Mulwaree Local Government Area (LGA) and in recent years has experienced strong population growth and residential development. It is this growth that has been a catalyst for Goulburn Mulwaree Council (Council) to undertake a Flood Study and Floodplain Risk Management Study and Plan (FRMS&P) for Marulan.

Two major overland flow paths flow through Marulan, named herein as the 'Central Flow Path' and the 'Northern Flow Path' (shown in Figure 1). These flow paths eventually flow into Jaorimin Creek. The Central Flow Path has a catchment area of approximately 66 hectares where it meets Jaorimin Creek and the Northern Flow Path has a catchment area of 44 hectares to downstream of Brayton Road. Consultation with the community highlighted these flow paths as the primary sources of flooding affecting the town. Other minor overland flow paths, also shown in Figure 1 cause inundation in some downstream areas of Marulan. The township of Marulan is situated on high ground with future development proposed in the lower lying areas of Marulan North, Marulan North (Post 2036) and Marulan East (see Image 2). Marulan North and Marulan North urban release areas (URA) are located adjacent to Jaorimin Creek, a tributary to the Wollondilly River. Marulan East is proposed on the Woolshed Creek floodplain, a tributary to the Shoalhaven River.

Image 2: Marulan Township & proposed development areas



Marulan has a population of 1,428 (2021 census), with a median age of 38 years old (same as the national average). The median household weekly income is $1,484, approximately 85% of the national average. All dwellings are free-standing or semi-detached residences with no dwellings described as flats/apartments. English is the most commonly spoken language at home (approximately 85%).

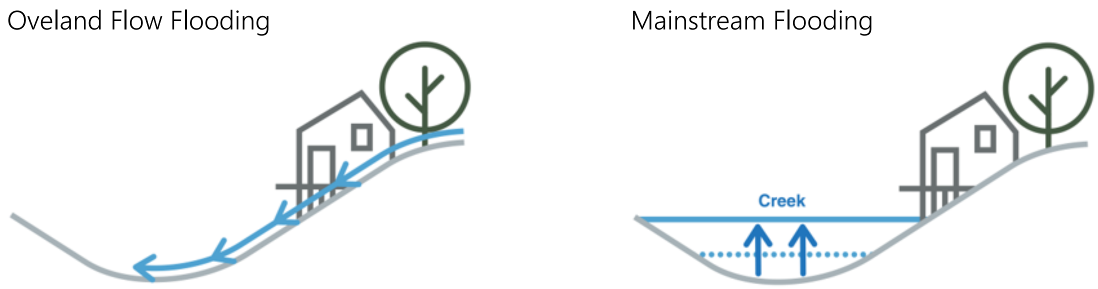
2.2 Flood Mechanisms

Flooding is often associated with inundation from large rivers however there are other flood mechanisms that can cause inundation. Marulan is affected by two key flood mechanisms: mainstream flooding and overland flow flooding. These two types of flooding are presented schematically in Image 3.

Mainstream flooding occurs from rising water on a defined water course causing the watercourse to break its banks and inundate area that are usually dry. This mechanism typically occurs over a long period of time and can result in deep flood waters. This type of flooding may occur along Jaorimin Creek, Woolshed Creek and Marulan Creek (shown in Figure 1).

The most prevalent type of flooding at Marulan is overland flow flooding which occurs when excess rainfall runoff is generated from impervious surfaces and flows toward a watercourse. This type of flooding is often referred to as "stormwater" flooding or "flash flooding" due to short warning times. Typically, this type of flooding rises and recedes over a short period of time and the floodwaters are usually relatively shallow and fast moving. Overland flow flooding at Marulan primarily occurs along the Central Flow Path and the Northern Flow shown in Figure 1. All flooding hotspots at Marulan (see Section 6.2), which have been identified through community consultation and modelling, are due to this type of flooding.

Image 3: Flood Mechanisms affecting Marulan



2.3 Social Demographics

Marulan's social demographics can provide a valuable insight into community flood awareness and identify factors that may impede residents from acting and reacting to a flood. Data from the 2021 Census (Australian Bureau of Statistics) has been obtained and assessed below.

The town has a population of 1,428 residents living in 627 private dwellings. 17.7% of the population is aged 65 or older, which matches the NSW average.

Approximately 15% of the respondents to the 2021 Census indicated that they have moved into Marulan within the last 12 months and 49% of the respondents had relocated in Marulan in the last 5 years. Such information provides insight into the general flood awareness of the community, particularly as almost half of the population moved to the area very recently making them less likely to have knowledge of previous flood events. A case like this requires additional efforts in building the awareness of the community on potential flood hazards and best preparedness practices as prior experience and sufficient knowledge of the region's topography is not expected.

Community engagement and provision of flood information is a key part of the Floodplain Risk Management Process. As such, the 2021 Census data provides useful information pertaining to the languages spoken by Marulan's residents. Based on this data, approximately 85% of Census respondents reported that English was the primary language spoken at home.

Evacuation during flood events is primarily undertaken by residents in private vehicles, however, consideration needs to be given to those dwellings that do not possess a motor vehicle and as such, alternative means of evacuation may need to be provided. The 2021 Census data indicates that only 1.5% of households in Marulan do not possess a motor vehicle which will below the national average of 7.3%.

2.4 Future Development Areas

In its Priority Projects 2023-2026, Goulburn Mulwaree Council put a Marulan Master Plan at the top of its list. This is due to the numerous state significant-scale extractive developments in the Marulan locality, providing a platform for employment opportunities on a regionally significant scale. The town of Marulan continues to experience significant growth as a result of the employment opportunities. This growth aligns with the NSW Government's strategic direction for regional growth on the Hume Highway corridor.

The Urban and Fringe Housing Strategy for Goulburn and Marulan has identified new development areas proposed to accommodate the growth in the region. This includes three residential development areas, Marulan North; with 694 dwellings, Marulan North URA; with 631 dwellings, and Marulan east; with 30 dwellings (see Figure 1)

Anticipated NSW government future development initiatives include:

- Improving accessibility to Marulan village - this is intended to be achieved by establishing a second entry and exit from Hume Highway to the village.
- Development and provision of new emergency service facilities – meeting the requirements of the growing community in Marulan as well as road safety along Hume highway, the government is planning to establish facilities for police, ambulance, and medical services as an imperative measure towards improving health and safety outcomes in the region.

Consideration of flood risk to future developments is presented in Section 7.1.2.7.

3. POLICIES, LEGISLATION AND GUIDANCE

3.1 Implemented Guidelines and References

Table 2 presents the guidelines, manuals and technical reference documents used for this study. These documents detail best practice in regard to management of flood risk. They cover both best practice regarding the technical assessment of flood behaviour and flood risk, and, more generally, who has responsibility for managing flood risk and how this management is best achieved.

Table 2: Guidelines and reference documents

Reference	Topic	Year Published
Australian Emergency Management (AEM) Handbook Series, Managing the floodplain: A guide to best practice in flood risk management in Australia – AEM Handbook 7	Best practice	2017
AEM Handbook 7, Technical flood risk management guideline – Flood Hazard	Flood hazard	
AEM Handbook 7, Technical flood risk management guideline – Flood Emergency Response Classification	Emergency response	
AEM Handbook 7, Technical flood risk management guideline – Flood risk information to support land-use planning	Land use	
AEM Handbook 7, Technical flood risk management guideline – Assessing options and service levels for treating existing risk	Mitigation options and service levels	
AEM Handbook 6, National Strategy for Disaster Resilience – community engagement framework	Community engagement	2020
Australian Rainfall & Runoff 2019	Best practice	2019
Section 733 of the Local Government Act, 1993	Flood prone land policy	1993
NSW Government's Flood Risk Management Manual (2023)	Flood prone land policy and industry practice	2023
SES requirements from floodplain risk management process	SES requirements	2007
Practical consideration of climate change	Climate change	2007
Floodplain Risk Management Toolkit (Multiple Documents)	Risk analysis and management	Varies
NSW OEH Data Handover requirements	Documentation & data handover	2017

3.2 Relevant Legislation

Management of flood risk is governed by local controls in Council's Local Environment Plan (LEP, 2009) and Development Control Plan (DCP, 2009). However, there are also various state and national plans and policies relevant to flooding that overarch the local government legislation. Information on each is presented in the following section.

3.2.1 State and National Plans and Policies

State and national plans and policies related to floodplain management are listed below, including their relevance to the current study:

- Australian Rainfall and Runoff 2019 – sets out hydrological data and procedures to be used for hydrological and hydraulic modelling of flooding in Australia and have been implemented in the current study.

- Building Code of Australia - provides a standard for the design and construction of new buildings in Flood Hazard Areas (FHA) with the aim of reducing risk to building occupants.
- NSW Environmental Planning and Assessment Act 1979 – Is the overarching state legislation for local legislation. The Act provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 9.1 of the EP&A Act, councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy.
- Local Planning Directions – Planning proposals are lodged to the Department of Planning and Environment are subject to Local Planning Directions. Direction 4.1 provides directions pertaining to flooding.
- NSW Flood Prone Land Policy - aims to reduce the impact of flooding and flood liability on individual landowners and occupiers of flood prone property and to reduce private and public losses resulting from floods via economically positive methods where possible. The NSW Flood Risk Management Manual supports the policy.
- NSW Government's Flood Risk Management Manual (2023) – Provides guidance on management flood risk within the community and across LGAs at a strategic level through the Flood Risk Management (FRM) framework. This manual defines the assessment of flood risk in NSW, including flood hazard, hydraulic categories and other variables. More broadly it sets out the objectives for floodplain development in the state, including description of types of management measures.
- State Environmental Planning Policy (Exempt and Complying Development Codes) (2008) - are environmental planning tools used to address planning issues within NSW. In a flooding context, the SEPP for Exempt and Complying Development Codes 2008 is key for defining:
    - Exempt developments, where development can occur without the need for development consent; and
    - Complying development, where development must be carried out in accordance with a complying development certificate.

  The policy provides further information on where and development of flood-prone land should occur.
- NSW Flood risk management toolkit - various guidelines have been published by DCCEEW for specific aspects of flood risk assessment in NSW. Some specifically related to the study are:
    - Understanding and managing flood risk FB01 (NSW Government, 2023);
    - Flood Function FB02 (NSW Government, 2023);
    - Flood Hazard FP03 (NSW Government, 2023);
    - Incorporating 2016 Australian Rainfall and Runoff in studies (2019);
    - Flood Damage and Cost Benefit Assessment Tool (2023);
    - Support for Emergency Management Planning (EM01, 2023);
    - Guidelines for voluntary house raising and voluntary purchase scheme (2023);
    - Flood Risk Management Measures (MM01. 2023); and
    - Flood Risk Management Manual (2023).

3.2.2 Local Policies

It is the responsibility of local governments within NSW to manage flood risk within their respective LGAs. Two key planning documents are used for the management of this risk and their purpose is outlined below:

- The Local Environment Plan (LEP): The LEP is a key planning tool for local governments whereby it sets out zoning and high-level development controls in the LGA.
- The Development Control Plan (DCP): The DCP provides detailed planning and design guidelines to support the LEP.

The following sections provide an overview of the current flood related development controls in Goulburn's LEP and DCP and the technical standards and guidelines that pertain to the current study.

3.2.2.1 Local Environmental Plan

Clause 5.21 'Flood Planning' and 5.22 'Special Flood Considerations' of the Goulburn Mulwaree Local Environmental Plan (LEP, 2009) contains provisions that control the development of flood prone land. These clauses are presented below:

5.21 Flood Planning

(1) The objectives of this clause are as follows—

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,

(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

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

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

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

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

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

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

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

(5) In this clause—

Considering Flooding in Land Use Planning Guideline means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the Flood Risk Management Manual.

Flood Risk Management Manual means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.

5.22 Special Flood Considerations

(1) The objectives of this clause are as follows—

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and

(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—

(i) cause a particular risk to life, and

(ii) require the evacuation of people or other safety considerations.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority has considered whether the development—

(a) will affect the safe occupation and efficient evacuation of people in the event of a flood, and

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

(c) will adversely affect the environment in the event of a flood.

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

(5) In this clause—

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

flood planning area—see clause 5.21(5).

Flood Risk Management Manual—see clause 5.21(5).

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

sensitive and hazardous development means development for the following purposes—

(a) caravan parks,

(b) correctional centres,

(c) educational establishments,

(d) emergency services facilities,

(e) hazardous industries,

(f) hazardous storage establishments,

(g) hospitals.

3.2.2.2 Development Control Plan

'*Chapter 3.8: Flood Affected Lands*' and '*Appendix J: Flood Policy*' of the Goulburn Development Control Plan (DCP, 2009) came into effect in September 2022 and contains provisions that control the development of flood prone land.

The flood controls presented in the DCP (2009) are based on the recommendations outlined in the Goulburn Floodplain Risk Management Study and Plan (GRC Hydro, 2021) which has a focus on mainstream flooding. The DCP implements the Flood Planning Constraint Categories (FPCC) approach to flood planning which presents flood controls based on a site's flood characteristics and proposed development type. FPCC mapping for Marulan has been devised and assessed in Section 7.1.2.3.

3.3 Goulburn Mulwaree Local Flood Plan

The Goulburn Mulwaree LGA Local Flood Plan (LFP) is a Sub-Plan of the Goulburn Local Emergency Management Plan and Volume 1 of this document was published in September 2021. This volume establishes the multi-agency arrangements for emergency management of flooding in the LGA. The Plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the LGA. The document provides details for all agencies responding to fooding within the LGA and the NSW SES are responsible for the development and maintenance of the LFP. The document does not provide any information specific to Marulan.

LFP Volumes 2 and 3 will cover hazard and risk information, and outline NSW SES response arrangements. The NSW SES were contacted to request these LFP volumes, and it was advised that at the time of preparing this report that Volumes 2 and 3 are still in draft and could not be provided.

Section 7.2.5 has provided recommendations for inclusions in the Local Flood Plan.

4. COMMUNITY CONSULTATION

Community consultation was undertaken in late 2021 to inform the community of the study, obtain community input, identify community concerns and develop community confidence in the study through collaboration. The consultation included a media release, newsletter/questionnaire and a website.

4.1 Newsletter and Questionnaire

A newsletter and questionnaire were developed for the Marulan community in collaboration with Council. The newsletter introduced the study and its objectives and requested information via the questionnaire. The newsletter and questionnaire were distributed to all property owners within the Marulan locality. This newsletter and questionnaire are presented in Appendix C. Community members were able to participate in the questionnaire either via return of the paper questionnaire, email or submission on Council's website. Image 4 presents the distribution of questionnaire responses received.

Image 4: Community Consultation Distribution

Newsletters and questionnaires were distributed by Council and 28 responses were received from the community. Approximately 68% of respondents indicated that they were aware of flooding from overland flow in their area. Around 25% of replies indicated that they had experienced flooding in their yard or garage, with one respondent noting flooding above floor level in the non-habitable areas of a commercial property. These results highlight there is a general awareness of flooding in Marulan and the potential for flooding to impact on properties.

The questionnaire asked the community about the management of flood related development controls within the floodplain and the varying degrees of restrictions that can be applied. Approximately 71% of respondents selected that property owners should be informed of potential flood risks and flood related development controls on their property and allow for development provided these controls are adhered to. These results will inform the implementation of flood related development controls for properties within the final Flood Planning Area, undertaken during the Floodplain Risk Management Study and Plan.

The questionnaire provided a range of mitigation measures to manage flood risk and asked community members to select their preferred measures. Approximately 57% of respondents selected an increase in flood awareness and education in the community as a preferred measure, while 50% of respondents identified modifying creeks and channels to increase their capacity. Other popular measures included imposing greater flood related development controls and increase strategic flood planning (46%), constructing, repairing and/or increasing the size of existing levee banks (36%) and property modification measures for severely affected properties such as voluntary purchase or voluntary house raising (32%). Consideration of these community preferences has been taken into account when deriving and assessing potential flood management measures in Section 7.3.

4.2 Future Consultation

Future consultation will include:

- Public Exhibition of this draft FRMSP document for public review and input;
- Preparation of a media release to notify the community of the public exhibition;
- One-on-one follow up meetings with community members who would like to discuss the draft FRMSP; and
- Consultation with NSW Government agency stakeholders including the NSW SES, Water NSW, Transport for NSW, and Australian Rail Track Corporation (ARTC).

5. ANALYSIS OF FLOOD MODEL RESULTS

The computer model results developed as part of the Marulan Flood Study (GRC Hydro, 2023) have been further processed to develop important information that can be used to better understand flood risk (flood hazard, flood function, emergency response categories) as well to inform floodplain management (flood planning area).

5.1 Flood Hazard

Flood hazard is defined as a source of potential harm or a situation with the potential to result in loss (ARR2019). The current study has calculated the flood hazard in accordance with the Australian Emergency Management Handbook 7 Guideline, ARR2019 and the NSW Governments Flood Hazard Guideline FB03 (Reference 15). The method considers the threat to people of various ages (children, adults) and to the community interacting with floodwaters (pedestrians, vehicles and those within buildings). Image 5 and Table 3 present the relationship between the velocity and depth of floodwaters and the corresponding classification.

Image 5: Flood Hazard Curves (Australian Emergency Management Handbook 7)

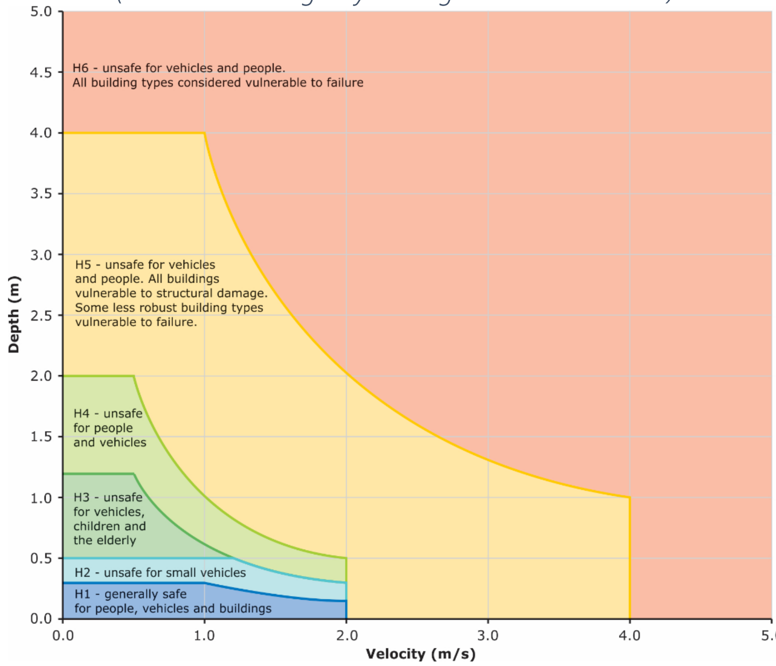


Table 3: Flood Hazard – Vulnerability Thresholds

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.

Flood hazard classifications are presented in the following figures:

- Figure 2: Flood Hazard – 5% AEP Design Event
- Figure 3: Flood Hazard – 1% AEP Design Event
- Figure 4: Flood Hazard – 0.2% AEP Design Event
- Figure 5: Flood Hazard – PMF Design Event

Most of the urban areas and land marked for future development are subject to H1 hazard classification flooding in the 1% AEP event which is considered to be generally safe for most land uses. Areas of greater flood hazard within Marulan town, typically occur behind raised obstructions such as the ARTC Railway, Maclura Drive and Brayton Road.

For events up to and including the 0.2% AEP flood, flood hazard categories affecting dwellings are generally low (H1 to H2). High hazard flow paths (typically H3 with areas of H4) through rural properties are noted, which could impact on access. During the PMF, high hazard (H3 to H5) flood conditions affect properties upstream of the rail embankment on the Central and Northern Flow Paths. Other dwellings are predominately subject to low hazard conditions during this event.

There is a number of large farm dams in the study area which have the potential to result in high hazard flood conditions if a breach to the dam embankment were to occur. This risk has not been considered as part of this study.

5.2 Flood Function

Flood Function (also known as Hydraulic Categories) refers to the classification of floodwaters into three categories; 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:

- Floodway – 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, floodway 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 is unlikely to alter flood behaviour in the surrounding area.

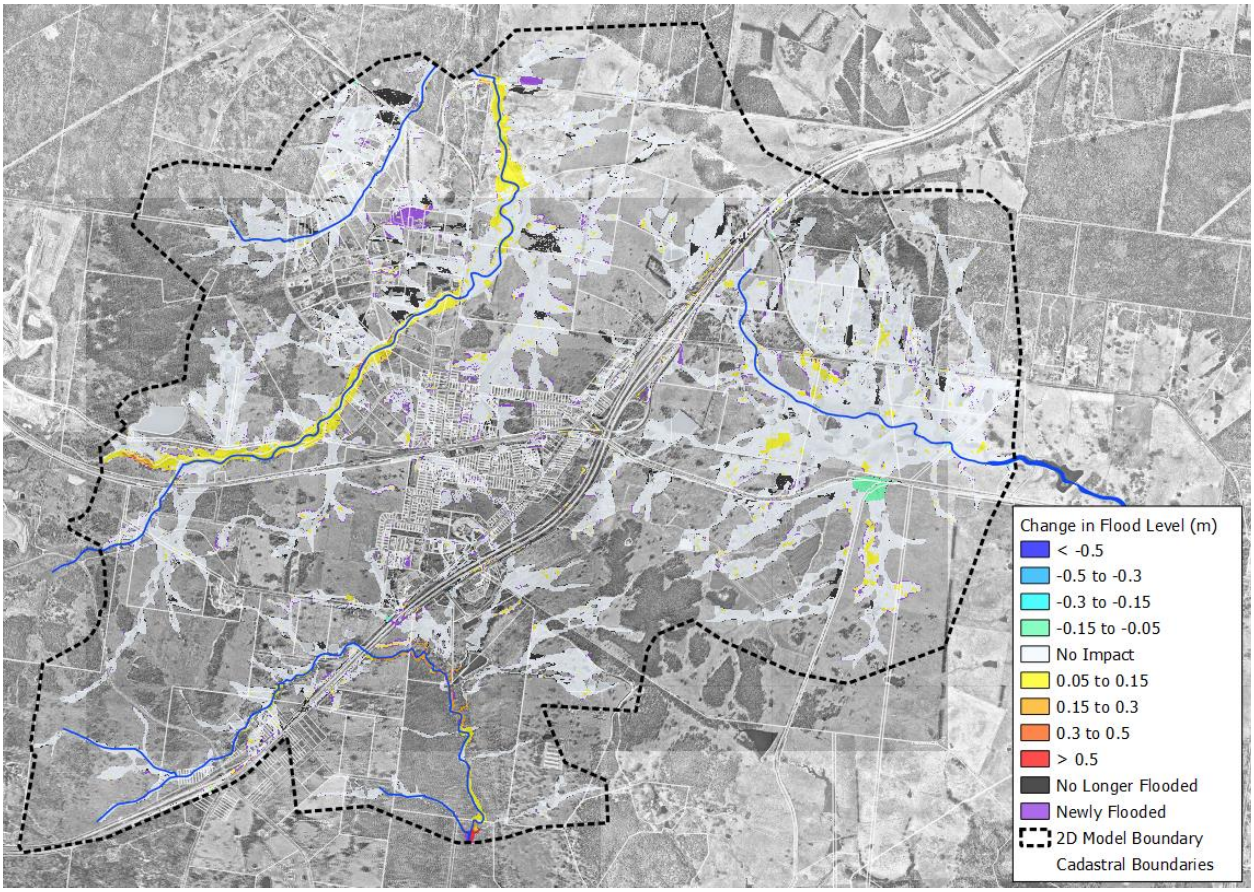
The "Flood Function - Flood Risk Management Guide FB02" (Reference 14) document provides guidance regarding the available approaches to derive each of the flood function categories. The 'conveyance method' was used in this study to identify floodway areas while the Flood Storage and Flood Fringe areas were defined via indicator methods.

The conveyance method was trialled by varying the total conveyance parameter to 70%, 80% and 90%. A total conveyance of 90% was selected to move forward as the other parameters resulted in significant floodway discontinuities.

A filtering process was applied to remove areas of floodway from minor channels and tributaries, resulting in the removal of flow paths with a total flow of less than 0.2 m^3/s and cells with a Velocity x Depth product of less than 0.02 m^2/s from the floodway definition.

Encroachment analysis was performed to verify the resulting floodway area extent as per recommendations DCCEEW (2022). This was done by applying a high Manning's roughness parameter (n=0.40) to the TUFLOW model to areas outside of the floodway extent. The resulting impacts of the encroachment analysis are presented in Image 6. The impacts are noted to be typically between 0.05 m to 0.15 m on the mainstream watercourses, which confirms that the conveyance method has identified an acceptable floodway extent. Negligible impacts are noted for the smaller overland flow paths and the Woolshed Creek catchment due to the diffuse nature of these watercourses and the increased attenuation caused by applying the high Mannings parameter.

Image 6: Flood impact map comparing encroachment analysis results to design model results



The remainder of the floodplain where flood depths exceed 0.5 m have been defined as Flood Storage, with the remainder of the floodplain being classified as Flood Fringe. The 0.5 m threshold to define Flood Storage is consistent with the Goulburn FRMS&P (GRC Hydro, 2021).

Flood Function mapping is presented in the figures outlined below:

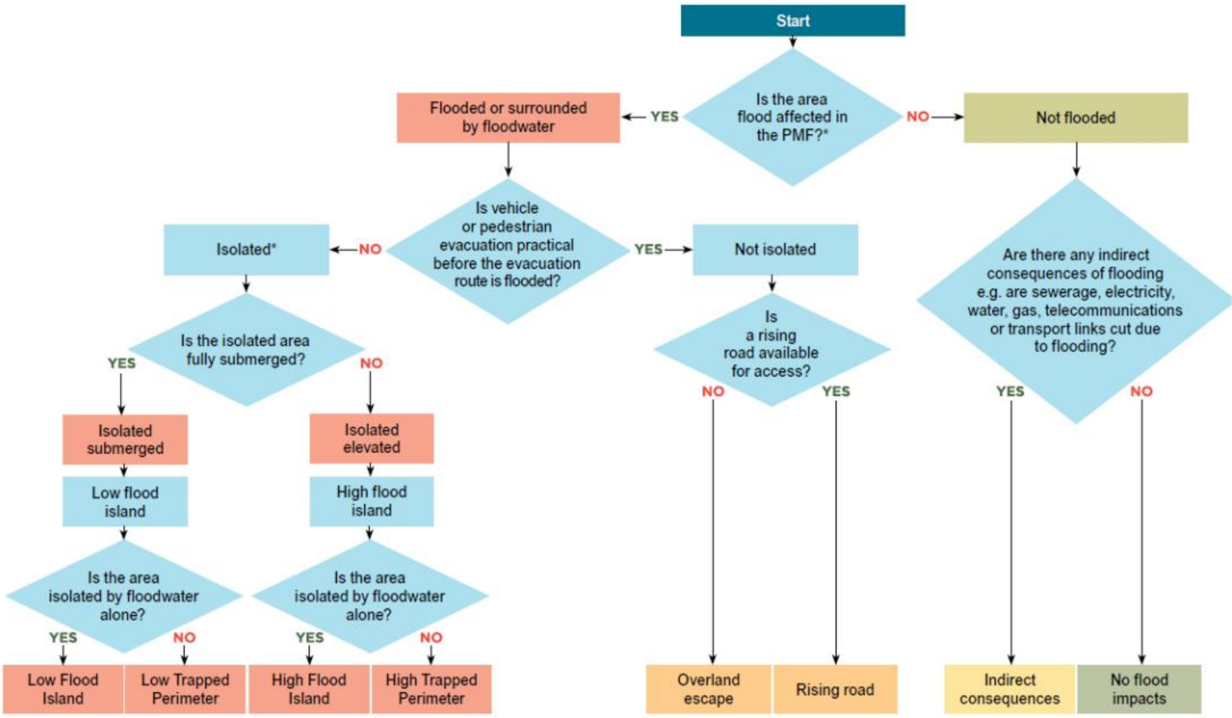
- Figure 6: Flood Function – 5% AEP Design Event
- Figure 7: Flood Function – 1% AEP Design Event
- Figure 8: Flood Function – 0.2% AEP Design Event
- Figure 9: Flood Function – PMF Design Event

5.3 Emergency Response Classifications

Flood Emergency Response pertains to a set of classifications that advise how a community is affected by flooding and informs the decision-making process during a flood event. These classifications consider the full range of flood behaviour up to the PMF event. Factors such as isolation, evacuation routes, effective warning times, the rate of rise of floodwaters and the duration of isolation are considered when determining the classification.

Flood Emergency Response classifications have been prepared in accordance with Table 18 of the Flood Risk Management Guideline EM01 (Reference 16) as reproduced below in Image 7.

Image 7: Flood Emergency Response Classifications (Flood Risk Management Guideline EM01)



Flood Emergency Response classifications are presented in the following maps.

- Figure 10: Flood Emergency Response – 5% AEP Design Event
- Figure 11: Flood Emergency Response – 1% AEP Design Event
- Figure 12: Flood Emergency Response – 0.2% AEP Design Event
- Figure 13: Flood Emergency Response – PMF Event

Localised areas of constrained flood access are noted for a small number of properties during the 5% and 1% AEP events near Hotspot 1 and 5 where ponding occurs behind the rail easement. During the 0.2% AEP event, access to Morris Place may also be constrained due to H2 flooding near the intersection with Maclura Drive. During the PMF, flooding of Brayton Road at the northern flow path results in a large area subject to access constraints to the west of Marulan oval.

5.4 Flood Planning Area

The Flood Planning Area (FPA) defines properties that are subject to flood related development controls for most types of development. The FPA is a key planning tool for managing and mitigating flood risk in an LGA.

The NSW Government's guideline on "Understanding and managing flood risk (FB01)" (2023), provides advice on deriving the FPA. This methodology can vary greatly depending on the dominant flood mechanism in the study area. The guideline notes that in areas of local overland flow a combination of methods can be used in deriving the FPA including freeboards and setback (also known as horizontal freeboard). A nominated setback (or horizontal freeboard) may be used from the flood extent where *"depths are shallow and controls are aimed at maintaining flow conveyance in the flow path and limiting impacts on development adjacent to it"*. This approach aims to avoid applying development controls in areas further away from the flow path *"where flow in the DFE is unlikely to impact on properties significantly"*.

For the reasons described above, definition of the FPA has used different methods for mainstream and overland flood areas. For the purposes of this analysis:

- Mainstream flooding - has been defined as flow paths with a peak discharge exceeding 5 m^3/s in the 1% AEP design event; whilst
- Overland flooding - has been defined as flooding that is not classified as mainstream flooding.

5.4.1 Mainstream Flood Planning Area

For mainstream flooding, the FPA has been defined as the extent of land below the Flood Planning Level (FPL) determined using the Defined Flood Event (DFE) flood level plus a freeboard.

Freeboard is used as a factor of safety and is incorporated into a FPLs & FPAs to ensure that the selected level of protection for a structure is reasonably achieved and uncertainties in the design are accounted for. In a flooding context, a freeboard is used to account for design variables such as:

- Uncertainties in design flood level estimates;
- Increased water levels due to wind and wave action;
- Localised hydraulic effects (local water surge, hydraulic jumps etc.);
- Design flood level increases due to climate change; and
- Post construction settlement and defects.

A detailed assessment has been undertaken to determine the appropriate freeboard for mainstream flooding FPA. The current study has considered a range of factors which influence the level of freeboard and utilised a joint probability framework to determine an appropriate level of freeboard for the FPA.

A joint probability analysis has been undertaken to determine an appropriate freeboard on the variables described above and their respective probability of occurrence. This analysis is presented in Appendix B. Based on the results of the mainstream freeboard assessment, a freeboard of 0.5 m has been adopted for mainstream flooding. This freeboard was applied to the 1% AEP event (with triple blockage of rail corridor structures) and used to derive the Flood Planning Level (FPL) and ensuing Flood Planning Area.

5.4.2 Overland Flood Planning Area

Due to the shallow flow nature of overland flooding and the limited potential for scaling, the FPA for this type of flooding is defined as areas that are not mainstream flood affected and where:

- Flood depths exceed 0.1 m during a 1% AEP event; OR
- Areas within the 1% AEP floodway.

The overland flow Flood Planning Level is defined as the 1% AEP event plus 0.3 m freeboard (as derived by the freeboard assessment) for areas within the FPA.

This approach may cause in the FPA to overlap with the floodway extent in certain locations. When applying the Flood Planning Constraint Categories (FPCC) (see Section 7.1.2.3), this overlap causes FPCC1 and FPCC3 to cover the same area in these locations.

5.4.3 Flood Planning Area Map

The mainstream and overland flow flood planning areas have been combined as presented in Figure 14.

5.5 Cumulative Impact Assessment

A cumulative impact assessment was conducted to evaluate the potential long-term effects of future development on flooding on Marulan's largely undeveloped rural catchment area. Although the region remains predominantly rural, there is substantial pressure for future development, which could lead to increased runoff and change in flood behaviour. This assessment has considered a 'worst-case' scenario where the maximum permissible development, based on current land zonings and areas proposed for upzoning as part of the Urban and Fringe Housing Strategy (see Section 2.4), was implemented. This scenario does not account for site-specific flood impacts but provides a broad perspective on how increased impervious surfaces, such as new buildings and infrastructure, could reduce pervious areas, diminish natural flood storage and obstruct flow conveyance, potentially exacerbating flood risks across the catchment.

To model these impacts, localised changes were made to the hydrologic model, specifically by adjusting the sub catchment imperviousness to match the highest values permitted by the current and future proposed land zoning, as outlined in Council's DCP and the Urban and Fringe Housing Strategy.

The updated hydrologic model flows were input into the TUFLOW model and flood impacts were assessed. Figure 15 to Figure 19 present the flood impacts for the 5%, 1%, 0.5%, 0.2% AEP and PMF events, respectively. With the increase in imperviousness, peak flood level impacts are primarily confined to overland flow paths in the study areas with flood impacts typically less than 0.1 m, albeit higher impacts occur in storage areas upstream of embankments such as the railway and roadways. These results indicated that future development in Marulan may have some impact on peak flood levels along overland flow paths, which should be managed during design development, however these impacts are unlikely to be widespread.

6.COMMUNITY FLOOD RISK ASSESSMENT

6.1 Overview

An assessment of Marulan's flood behaviour and community profile has been carried out to determine specific areas of flood risk across a range of metrics, including; property flood liability, flood hazard, flood function, the economic impact of flooding, evacuation and available flood warning.

The following sections utilise the flood study results, and analysis presented in Section 5, to examine areas of risk associated with flooding of Marulan. The following sections describes the consequences of flooding at Marulan and include:

- Identification of key flood risk areas and the development of flooding hotpots (Section 6.2);
- Information on flooded roads (Section 6.3);
- Analysis of property flood liability (Section 6.4);
- Assessment of the economic impact of Marulan (Section 6.5);
- Review of critical infrastructure and sensitive land uses (Section 6.6); and
- Assessment of available flood warning (Section 6.7).

The findings from this analysis have been used to focus flood risk management measures efforts on high flood risk areas (see Section 7.3).

6.2 Flooding Hotspots

Flooding hotspots refer to areas that are particularly flood affected and/or affected by hazardous flooding. Seven hotspot areas have been identified with a summary presented in Table 4, and further details presented in ensuing sections. The location of the various hotspots is presented in Figure 1.

Table 4: Flood Hazard – Vulnerability Thresholds

Hotspot	Location	Risk Factors
1	Western end of Goulburn Street	Sensitive facility, road, and property flooding
2	Morris Place	Road and property flooding
3	Intersection of Morris Place and Maclura Drive	Road flooding
4	Brayton Road intersection with the Northern Flow Path	Road and property flooding
5	Along Railway Parade	Road and property flooding
6	Between Portland Avenue and George Street	Road flooding
7	South of the railway near Haddon place	Prospect Road and property flooding

6.2.1 Hotspot 1: Western end of Goulburn Street

Hotspot 1 is located where Goulburn Street terminates at Portland Avenue upstream (south) of the ARTC railway. The Marulan Rural Fire Brigade is situated at this location with several residential dwellings and a number of undeveloped lots.

Flooding at Hotspot 1 is exacerbated by the ARTC railway embankment where a culvert acts as a constraint, limiting flow capacity in events as frequent as the 20% AEP event. Table 5 presents the peak design flood levels at Hotspot 1 for the full range of flood events. In the 1% AEP event, flood depths of up to 1 m can occur in the vicinity and up to 3.5 m in the PMF event. Figure 2 to Figure 5 show the flood hazard for the area, with H3/H4 hazard occurring during a 1% AEP event and H6 during the PMF.

Image 8: ARTC railway culvert at hotspot 1

Table 5: Hotspot 1 - Design Flood Levels

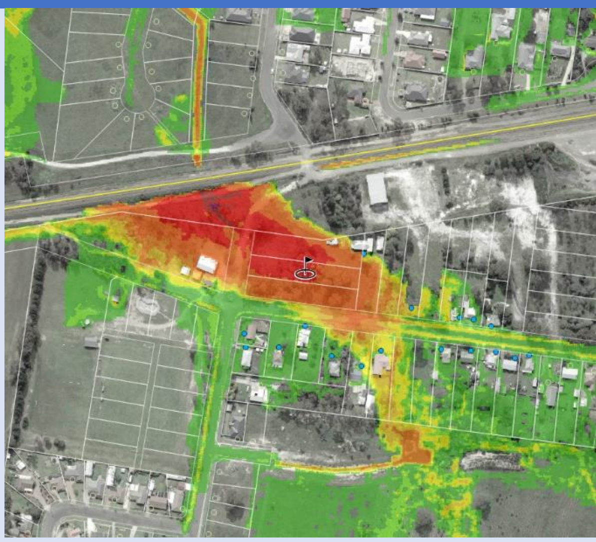
Design Event (% AEP)	Level (m AHD)	Location
Ground Level	637.8	
20% AEP	638.3	
10% AEP	638.5	
5% AEP	638.6	
2% AEP	638.7	
1% AEP	639.2[1]	
0.5% AEP	639.0	
0.2% AEP	639.2	
PMF	641.3	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20) .[1]Note – 1% AEP flood level is higher than the 0.5% AEP due to adopted 1% AEP blockage assumption.		

Table 6 provides an analysis of the flood behaviour and flood related risks at Hotspot 1.

Table 6: Hotspot 1 - Goulburn Street– Flood Risk Summary

Flood Risk Characteristics	Description	
Depth of flooding	• Flooding occurs for events as frequent as the 20% AEP event. In the 20% event, peak flood depths of up to 0.2 m occur at the Marulan Rural Fire Brigade and up to 0.6 m at the undeveloped lots to the east of Portland Avenue. • In the 1% AEP event, flood depths typically ranging between 0.5 m to 1.5 m (up to 2 m) inundate the area 200 m upstream of the railway and north of Goulburn Street. To the south of Goulburn Street flood depths along the flow path to the south of Goulburn Street, flood depths of up to 0.3 m occur at two properties. Generally, flood depths of less than 0.15 m occur at properties to the south of Goulburn Street. • Peak flood depths of greater than 2 m occur in the PMF event in the area 300 m upstream of the ARTC railway embankment. Properties along Goulburn Street and Portland Avenue extending to Richard Street are affected by flood depths greater than 0.3 m and up to 2.4 m.	
Flood hazard	• In the 5% AEP event hazard conditions of up to H3 affect the Marulan Rural Fire Brigade and the area 100 m south of the ARTC rail embankment. Typically, H1 hazard occurs at residential properties in the vicinity. • In the 1% AEP event, H3 hazard extends to the area 200 m upstream of the railway embankment (north of Goulburn Street). The Marulan Rural Fire Brigade building and one property to the north of Goulburn Street is affected by H3 hazard. • During the PMF event, the Marulan Rural Fire Brigade and several properties in the vicinity are subject to H5 hazard. Further, seven properties are affected by H4 hazard and four houses are subject to H3 hazard.	
Flood Function	• In flood events up to the 0.2% AEP event, the floodway area extends from the railway embankment, across Goulburn Street and through properties to the south. In the 0.2% AEP event, areas of flood storage occur to the north of Goulburn Street with the remaining flood extent classified as Flood Fringe. • In the PMF event, the floodway area extends from the railway embankment to properties south of Goulburn Street. The floodway is roughly 70 m wide. There are large areas of flood storage along the remaining areas of Goulburn Street.	
Properties flooded in yard (see Figure 20A)	• 4 in 20% AEP • 6 in 10% AEP • 9 in 5% AEP • 10 in 2% AEP	• 11 in 1% AEP • 12 in 0.5% AEP • 12 in 0.2% AEP • 26 in PMF
Properties flooded above floor (see Figure 20)	• 17 in PMF	
Evacuation	For events up to the 0.2% AEP, rising road access is available to the east and south of the hotspot. In the 1% AEP and 0.2% AEP event, two properties are subject to being high trapped perimeter areas indicating that evacuation may be unavailable for a period however the property will remain unaffected. During the PMF event, large areas of the hotspot has been classified as low trapped perimeter areas indicating that evacuation of these areas is critical before major flood events.	
Duration	Analysis of flood event durations causing peak flood levels found that typically a longer storm duration (approximately 3 hours) was critical for this location and as such, it is likely	

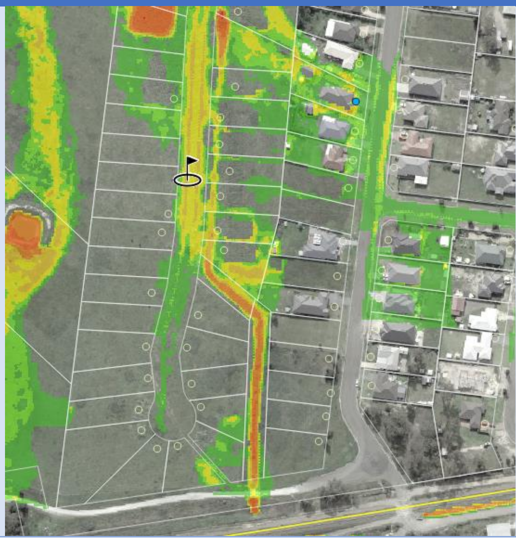
	that peak flooding in the vicinity will last several hours. These durations are dependent on the event magnitude and duration.
Additional Risk Factors	Marulan Rural Fire Brigade is a critical emergency service, with inundation of the brigade likely to impact the Brigade's operations.

6.2.2 Hotspot 2: Morris Place

Hotspot 2 is a continuation of Hotspot 1 (see Section 6.2.1) and denotes the natural overland flow path that moves north from the ARTC railway and along Morris Place. Feedback from Council and the community have noted that floodwaters have inundated the roadway and residential driveways, posing a safety and isolation risk to residents. Flooding in this area is exacerbated by an undersized stormwater system along the roadway (DN375) compared to the upstream culvert through the rail embankment (~DN900). Analysis of property flood affectation found that flooding along Morris Place is largely contained to the roadway with most properties remaining flood free for the full range of event magnitudes. Flood modelling shows that flood depths and hazard are generally low for a range of events up to the 0.2% AEP event. Given this, the key issue along Hotspot 2 is considered a drainage issue, noting that it is causing significant issue for residents of Morris Place.

Image 9: Overland Flow Inundating Road and Driveways at Hotspot 2

Table 7: Hotspot 2 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	634.6	
20% AEP	634.7	
10% AEP	634.7	
5% AEP	634.7	
2% AEP	634.7	
1% AEP	634.7	
0.5% AEP	634.7	
0.2% AEP	634.7	
PMF	635	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20)		

*Note that these levels are for a single location. Flood levels vary with ground levels along Morris Place. Refer to the flood study for peak flood level contours and depths along Morris Place.

Table 8 provides an analysis of the flood behaviour and flood related risks at Hotspot 2.

Table 8: Hotspot 2, Morris Place – Flood Risk Summary

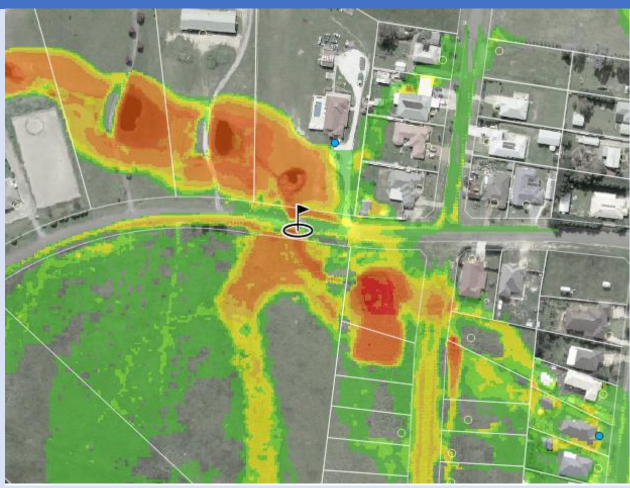
Flood Risk Characteristics	Description	
Depth of flooding	• Flooding occurs as typically shallow flows with depths less than 0.2 m in the road easement and areas of the lots fronting the road. The flood depths do not vary significantly for events ranging from 20% to 0.2% AEP due to the control formed by the upstream Hotspot 1 rail embankment and culvert. • PMF results in slightly greater flood depths of up to ~0.4 m. • Flood depths do not vary greatly with flood magnitudes at Hotspot 2 due to railway control upstream (Hotspot 1)	
Flood hazard	• For events up to the 0.2% AEP, a flood hazard classification of typically H1 is noted for Morris Place and the surrounding properties. H2/H3 flooding is noted in the channel between Morris Place and the railway. An area of H3 hazard is noted for the channel upstream and downstream of the Morris Place at the northern end of the road. • During the PMF flood hazard on Morris Place is generally H2 with areas of H3. Surrounding properties are typically classified as H1.	
Flood Function	• For flood events up the 0.2% AEP event, the floodway is contained to the roadway and driveways along Morris Place with the remaining flood extent classified as Flood Fringe. • In the PMF event, the floodway broadens to include properties to the east of Morris Place and the remaining flood extent is classified as Flood Fringe.	
Properties flooded in yard (see Figure 20A)	• 4 in 20% AEP • 4 in 10% AEP • 4 in 5% AEP • 5 in 2% AEP	• 6 in 1% AEP • 5 in 0.5% AEP • 5 in 0.2% AEP • 11 in PMF
Properties flood above floor (see Figure 20)	• 1 in PMF	

Evacuation	Morris Place is a no through road with access from the northern end. Flooding is predominately confined to the road and the front of lots, with a sag and inlet pit noted on the road near Maclura Drive. Whilst the depth of flooding is shallow, reduced visibility of the road during flood could result in difficulties for access, with potential impacts on evacuation and emergency vehicle access. During the 0.2% AEP event, Morris Place was identified as a high trapped perimeter area indicating that evacuation may be unavailable for a period however the properties will remain unaffected. Two properties were identified as Low Flood Islands to the north of Morris Place during this event and should be prioritised for evacuation during significant events. In the PMF event, large areas of the hotspot are classified as High Trapped Perimeter, Rising Road Access, Low Trapped Perimeter and Low Flood Island and as such, evacuation of these areas is critical before major flood events.
Duration	Analysis of flood event durations causing peak flood levels found that typically a shorter storm duration (< 1 hour) was critical for this location and as such, it is likely that peak flooding in the vicinity will last a few hours. These durations are dependent on the event magnitude and duration.
Additional Risk Factors	Poor access/egress once flooded. Overland flow runs over easements and driveways as there is no dedicated drainage for runoff, which hinders accessibility.

6.2.3 Hotspot 3: Intersection of Morris Place and Maclura Drive

Hotspot 3 is located near Maclura Drive just west of its intersection with Morris Place. The Hotspot is flood affected by overland flow from the Central Flow Path, with flooding of the road and various private driveways noted. Frequent shallow flooding is expected to affect these roads and driveways during events more frequent than the 20% AEP. Flood depths are typically less than 0.3 m on the road for events up to 0.2% AEP, with depths reaching 0.7 m during the PMF. Hazardous flow conditions affect two driveways that access dwellings from Maclura Drive, with H3 hazard noted in the privately owned farm dams in these properties.

Table 9: Hotspot 3 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	632.8	
20% AEP	632.9	
10% AEP	632.9	
5% AEP	632.9	
2% AEP	633.0	
1% AEP	633.0	
0.5% AEP	633.0	
0.2% AEP	633.0	
PMF	633.5	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20)		

*Note that these levels are for a single location, with flood levels varying with ground levels along Maclura Drive. Refer to the flood study to see how flood levels/depths vary with location.

Table 10 provides an analysis of the flood behaviour and flood related risks at Hotspot 3.

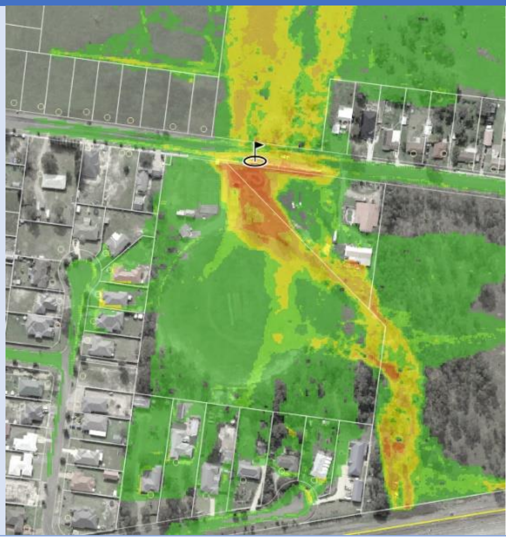
Table 10: Hotspot 3 Maclura Drive – Flood Risk Summary

Flood Risk Characteristics	Description
Depth of flooding	• Since Maclura Drive is slightly raised, flooding along the roadway is typically less than 0.2 m for events up to the 0.2% AEP event. Deeper flood depths (up to 0.7 m in the 0.2% AEP event) occur in the culvert either side of the roadway. • In the PMF event, flood depths of up to 0.5 m occur on the roadway at Maclura Drive. Up to 1.1 m of flood water pools at the culvert downstream of the roadway. • Flood depths do not vary greatly with flood magnitudes at Hotspot 3 due to railway control upstream (Hotspot 1)
Flood hazard	• For events up to the 0.2% AEP, the Maclura Drive roadway is affected by H1 hazard. Up to H3 hazard occurs either side of the roadway in these events, including two driveways to the north and isolating these two properties. • In the PMF event, the roadway is affected by up to H2 hazard with up to H5 hazard occurring either side of Maclura Drive. Three driveways to the north of Maclura Drive are affected by H5 hazard in the PMF, isolating three properties.
Flood Function	• For flood events up the 0.2% AEP event, the floodway follows the flow path across the roadway and affecting three driveways to the north of Maclura Drive. • In the PMF event, the floodway broadens to include the southern portion of the Patrick Place roadway, causing isolation for nearby residents.
Properties flooded in yard	• 1 in 20% AEP • 1 in 10% AEP • 1 in 5% AEP • 1 in 2% AEP • 1 in 1% AEP • 1 in 0.5% AEP • 1 in 0.2% AEP • 4 in PMF
Properties flood above floor	• 1 in PMF
Evacuation	Maclura Drive provides access to approximately 12 existing dwellings and a subdivision which is currently under development (to the west). Hazardous flow at two private properties to the north of Maclura Drive could result in access issues for properties in events as rare as the 1% AEP event (H3 in the 1% AEP). Inundation of the roadway in events rarer than the 0.2% AEP event can result in isolation of properties in the vicinity such as those along Patrick Place.
Duration	Analysis of flood event durations causing peak flood levels found that typically a shorter storm duration (< 1 hour) was critical for this location and as such, it is likely that peak flooding in the vicinity will last a few hours. These durations are dependent on the event magnitude and duration.
Additional Risk Factors	Poor access/egress once flooded.

6.2.4 Hotspot 4: Brayton Road intersection with the Northern Flow Path

Hotspot 4 is located along the Northern Flow Path at Brayton Road. Floodwaters approach this location through the cricket ground to the south and moves in a northerly direction. Brayton Road provides direct access to the area north of the railway and south of Jaorimin Creek. Flood levels typically do not scale significantly for rarer flood events, except for the PMF (see Table 11).

Table 11: Hotspot 4 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	633.9	
20% AEP	634.1	
10% AEP	634.1	
5% AEP	634.1	
2% AEP	634.1	
1% AEP	634.1	
0.5% AEP	634.1	
0.2% AEP	634.1	
PMF	634.3	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20)		

*Note that these levels are for a single location, with flood levels varying with ground levels along Brayton Road. Refer to the flood study to see how flood levels/depths vary with location.

Table 12 provides an analysis of the flood behaviour and flood related risks at Hotspot 4.

Table 12: Brayton Road Hotspot – Flood Risk Summary

Flood Risk Characteristics	Description
Depth of flooding	• For events up to the 0.2% AEP, Brayton Road is affected by flood depths of up to 0.3 m and depths of up to 0.8 m upstream of the roadway. • In the PMF event, flood depths up of to 0.5 m occur on Brayton Road and up to 1 m upstream of the roadway. • Flood depths do not vary greatly with flood magnitudes at Hotspot 4 due to railway control upstream (Hotspot 5)
Flood hazard	• For events up to the 0.2% AEP, Brayton Road is affected by H1 hazard along the roadway with up to H3 hazard on the land upstream of the roadway. • In the PMF event, H3 hazard affects the Brayton Road roadway, with up to H4 hazard on the land upstream and downstream of the roadway.
Flood Function	• For flood events up to the 0.2% AEP event, the floodway follows the flow path across the roadway with areas of floodway along the gutters of Brayton Road. • In the PMF event, the floodway broadens to include large portions of the Brayton Road roadway, causing isolation for nearby residents. Of note is the PMF floodway through properties at the northern and south-eastern ends of Eliza Power Drive.
Properties flooded in yard	• 8 in 20% AEP • 9 in 10% AEP • 9 in 5% AEP • 9 in 2% AEP • 9 in 1% AEP • 9 in 0.5% AEP • 9 in 0.2% AEP • 22 in PMF

Properties flood above floor	• none
Evacuation	Brayton Road provides direct access to properties to the west of Marulan. This roadway is accessible for events up to the 0.2% AEP however access is not possible in the PMF. Inundation of the roadway in events rarer than the 0.2% AEP event can result in isolation of properties to the north of the railway and south of Jaorimin Creek.
Duration	Analysis of flood event durations causing peak flood levels found that typically a shorter storm duration (< 1 hour) was critical for this location and as such, it is likely that peak flooding in the vicinity will last a few hours. These durations are dependent on the event magnitude and duration.
Additional Risk Factors	Extent of flooding may be up to 100 m along Brayton Road (near the Water Treatment Plant). Whilst depths are expected to be shallow, visibility of the road may be reduced. Poor access/egress in the PMF event.

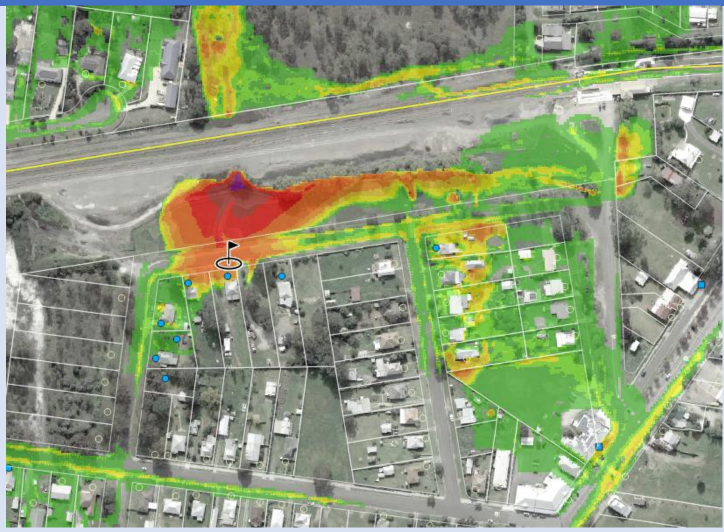
6.2.5 Hotspot 5: Along Railway Parade

Hotspot 5 denotes the area upstream of the Railway embankment at Railway Parade. Flooding in this area is controlled by the capacity of culverts crossing the railway. For more frequent events, flooding is typically expected in the sag situated between the rail and road corridors. Inundation of Railway Parade is noted to first occur in the 5% AEP; with flooding of properties expected to occur when significant culvert blockage occurs or during events approaching the 0.5% AEP event. Significant flood depths of up to 2.2 m occur during the PMF.

Image 10: Historic Flooding at Hotspot 5 (supplied by the local community)

The area is sensitive to blockage of the culvert underneath the railway embankment. With the adopted 1% AEP triple blockage scenario, flood depths increased by 0.5 m from a regular blockage scenario.

Table 4: Hotspot 5 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	639.6	
20% AEP	NA	
10% AEP	NA	
5% AEP	639.7	
2% AEP	639.7	
1% AEP	640.2[1]	
0.5% AEP	639.9	
0.2% AEP	640.2	
PMF	641.8	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20) [1]Note – 1% AEP flood level is higher than the 0.5% AEP due to adopted 1% AEP blockage assumption.		

*Note that these levels are for a single location, with flood levels varying with ground levels along Railway Parade. Refer to the flood study to see how flood levels/depths vary with location

Table 13 provides an analysis of the flood behaviour and flood related risks at Hotspot 5.

Table 13 Railway Parade Hotspot – Flood Risk Summary

Flood Risk Characteristics	Description
Depth of flooding	• For events up to the 2% AEP, flood depths typically less than 0.05 m affect properties to the west of Railway Parade. With up to 1.6 m of flood waters pooling upstream of the railway embankment. • In the 1%, 0.5% and 0.2% AEP events, pooled flood water from the railway embankment overtop Railway Parade and inundate the front of properties to the south of the roadway by up to 0.5 m. • During a PMF event, floodwaters are widespread with depths of up to 2 m affecting properties along Railway Parade and up to 1.1 m affecting properties on Austin Street. • Water depths are sensitive to railway culvert blockage at this hotspot.
Flood hazard	• For events up to the 2% AEP, H1 hazard affects properties in the vicinity of Hotspot 5 with up to H4 hazard occurring upstream of the railway embankment. • In the 1%, 0.5% and 0.2% events, H2 hazard affects the front of two properties on the southern side of Railway Parade and up to H5 hazard builds up against the railway embankment. • In the PMF event, three properties in the vicinity are subject to H2 hazard, six properties are subject to H3 hazard, two properties experience H4 hazard.
Flood Function	• For flood events up to the 0.2% AEP event, the floodway moves through properties on the eastern side of Austin Street and is otherwise contained to the roadways and reserves to the north of Railway Parade.

	• In the PMF event, the floodway broadens to include properties on Railway Parade and Richard Street. Additionally, areas of flood storage occur at properties to the south of Railway Parade.
Properties flooded in yard	• 9 in 20% AEP • 10 in 10% AEP • 11 in 5% AEP • 13 in 2% AEP • 16 in 1% AEP • 16 in 0.5% AEP • 16 in 0.2% AEP • 37 in PMF
Properties flood above floor	• 10 in PMF (8 residential, 2 non-residential)
Evacuation	Evacuation issues have been identified in the 1% and 0.2% AEP events where three properties along Railway Parade are isolated due to inundation of driveways and the roadway. During the PMF event there are three properties that are classified as low trapped perimeter areas, four properties are high trapped perimeter areas and 11 properties on Austin Street have rising road access.
Duration	Analysis of flood event durations causing peak flood levels found that several storm duration caused were critical for this location and as such, it is likely that peak flooding in the vicinity will last several hours. These durations are dependent on the event magnitude and duration.

6.2.6 Hotspot 6: Between Portland Avenue and George Street

Hotspot 6 is located in the commercial zoned area off George Street. George Street at this location forms the southern connection from the Hume Highway to the village of Marulan, making this area important for community accessibility as well as providing services to highway users. This area was noted by the community consultation process (discussed in Section 4) to experience some flooding.

Image 11: Inundation Affecting Commercial Activities around Hotspot 6

Table 14: Hotspot 6 - Design Flood Levels

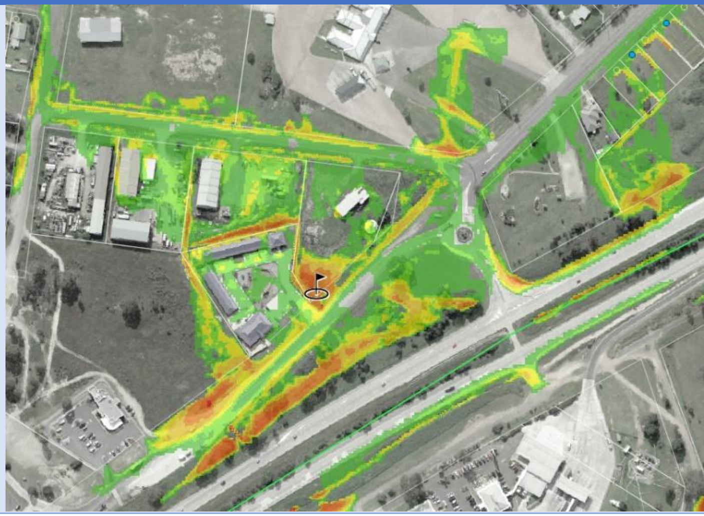
Design Event (% AEP)	Level (m AHD)	Location
Ground Level	637.9	
20% AEP	**638.2**	
10% AEP	638.3	
5% AEP	**638.3**	
2% AEP	638.3	
1% AEP	**638.3**	
0.5% AEP	638.3	
0.2% AEP	**638.3**	
PMF	638.6	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20)		

Table 15 provides an analysis of the flood behaviour and flood related risks at Hotspot 6.

Table 15: Between Portland Avenue and George Street Hotspot – Flood Risk Summary

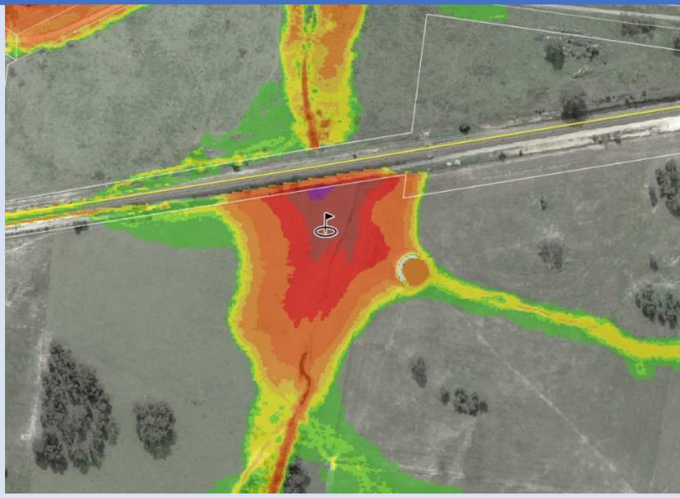
Flood Risk Characteristics	Description
Depth of flooding	• In the 20%, 10% and 5% AEP events, flood waters typically flow either side of George Street with flood depths on the roadway reaching up to 0.05 m. Floodwaters are stored upstream of George Street with depths reaching up to 1 m in these events. • As the event magnitude increases to the 2%, 1%and 0.5% AEP events, flood depths on the roadway increase to 0.1 m and flood waters upstream are maintained at 1 m. As George Street is overtopped, floodwaters are stored in the vacant land (depths up to 1.6 m) to the south-east of the roadway before being drained via the stormwater network to the southern side of the Hume Highway. • In the 0.2% AEP, flood depths of 0.2 m flow over George Street with up to 1.2 m of flood waters stored upstream and downstream of the roadway. • In the PMF event, flood depths of 0.8 m flow over George Street with up to depths of 2 m either side of the roadway. Properties between George Street and Portland Avenue experiences depths of up to 1 m.
Flood hazard	• For events up to the 0.2% AEP, George Street roadway is affected by H1 hazard. H3 hazard (and isolated areas of H4 hazard) occurs upstream and downstream of the roadway. Areas of higher hazard are confined presently to undeveloped areas. • In the PMF event, George Street experiences H4 hazard. The PMF experiences a large area of high hazard ranging from H3 to H5 where flow ponds to the north of the Hume Highway..
Flood Function	• In events up to the 1% AEP, the floodway moves around properties located between George Street and Portland Avenue,

	flows either side of George Street and crosses small areas of the roadway. • In the 0.2% AEP and PMF events, large areas of George Street are located within the floodway area. In the PMF event, large areas of floodway also move through properties on George Street and Portland Avenue.
Properties flooded	• 2 in 20% AEP • 2 in 10% AEP • 2 in 5% AEP • 2 in 2% AEP • 2 in 1% AEP • 2 in 0.5% AEP • 2 in 0.2% AEP • 6 in PMF
Properties flood above floor	• 2 in PMF (non-residential)
Evacuation	Analysis of Hotspot 6 has found that George Street is trafficable for events up to the 0.2% AEP (H1 hazard). This roadway is not trafficable in the PMF event. Properties in the vicinity will have rising road access during this event and will be able to evacuate during a flood event if required. This hotspot is at the vicinity of an arterial road that connects the community, south of the railway, to Hume highway. It is a confluence to multiple essential roads, which increases the severity of its impact on evacuation, if flooded.
Duration	Analysis of flood event durations causing peak flood levels found that typically a shorter storm duration (< 1 hour) was critical for this location and as such, it is likely that peak flooding in the vicinity will last a few hours. These durations are dependent on the event magnitude and duration.
Additional Risk Factors	Access to Marulan from the Hume Highway may be adversely affected by the flooding of this spot.

6.2.7 Hotspot 7: South of the railway from Haddon place

This area is situated upstream of the rail embankment and is subject to similar flood characteristics as Hotspots 1 and 5 (see Sections 6.2.1 and 6.2.5), where flood levels are controlled by culvert capacity through a raised rail embankment. The area is currently not developed, however, future residential development is proposed.

Table 16: Hotspot 7 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	636.3	
20% AEP	636.6	
10% AEP	636.9	
5% AEP	637	
2% AEP	637.2	
1% AEP	637.9[1]	
0.5% AEP	637.4	
0.2% AEP	637.8	
PMF	640.9	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20) [1]Note – 1% AEP flood level is higher than the 0.5% AEP due to adopted 1% AEP blockage assumption.		

*Note that these levels are for a single location, with flood levels varying with ground levels in the vicinity. Refer to the flood study to see how flood levels/depths vary with location

Table 17 provides an analysis of the flood behaviour and flood related risks at Hotspot 7.

Table 17: Hotspot 7 – Flood Risk Summary

Flood Risk Characteristics	Description
Depth of flooding	• Increases in event magnitude results in increases in flood depth with the 0.2% AEP event being 1.2 m higher than the 20% AEP event. • The PMF is expected to experience depths exceeding 4 m. • The area is sensitive to culvert blockage at the railway embankment.
Flood hazard	• For events up to the 0.5% AEP (excluding the 1% event due to blockage assumption), up to H4 hazard occurs upstream of the railway embankment. • In the 1% and 0.2% AEP events, up the H5 hazard occurs upstream of the railway embankment. • In the PMF event, up to H6 hazard occurs upstream of the railway embankment with large areas of H5 hazard.
Flood Function	• For events up to the 0.2% AEP, the flow path is considered floodway to Jaorimin Creek with areas of flood fringe. • In the PMF event, the floodway broadens significantly with large areas of flood storage outside the floodway.
Properties flooded	• 0 (currently undeveloped)
Properties flood above floor	• 0 (currently undeveloped)
Evacuation	The area is currently undeveloped. Consideration should be given to evacuation of this area during design particularly during flood events rarer than the 0.2% AEP.
Duration	Analysis of flood event durations causing peak flood levels found that several storm duration caused were critical for this location and as such, it is likely that peak flooding in the vicinity will last several hours

	to a day. These durations are dependent on the event magnitude and duration.

6.3 Road Inundation

Hazardous flooding of roads occurs when there is enough flow to knock over pedestrians or transport cars off the road due to buoyancy and frictional instability. In Australia, vehicles attempting to cross flooded roads is the largest cause of injury and fatality during a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at low flow speeds. An analysis of routes and pathways in Marulan region has been undertaken to assess the risk of flooded roads in the study area.

Table 18 presents the flood hazard at key roadways throughout the study area. The locations of these roads are presented in Figure 21.

Table 18: Inundation of Roadways in Marulan

ID	Location	Peak Flood Hazard per design event (AEP)							
		20%	10%	5%	2%	1%	0.5%	0.2%	PMF
1	Hume Highway at Marulan Ck	H1	H1	H1	H1	H1	H1	H1	H5
2	Hume Highway northbound offramp	H1	H1	H1	H1	H1	H1	H1	H4
3	George Street	H1	H1	H1	H1	H1	H1	H2	H4
4	Goulburn Street	H1	H1	H1	H1	H2[1]	H1	H2	H5
5	Railway Parade	H1	H1	H1	H1	H3[1]	H2	H3	H5
6	Morris Place	H1	H1	H1	H1	H1	H1	H1	H2
7	Maclura Drive	H1	H1	H1	H1	H1	H2	H2	H3
8	Brayton Road West-bound	H1	H1	H1	H1	H1	H1	H1	H2
9	Brayton Road North-bound	H1	H1	H1	H1	H1	H1	H1	H1
10	Patrick Place	H1	H1	H1	H1	H1	H1	H1	H1
11	George Street North	H1	H1	H1	H1	H1	H1	H2	H5
12	Dorsett Road	H1	H1	H1	H1	H1	H1	H1	H1
13	Southdown Road	H1	H1	H1	H1	H2	H2	H2	H5
14	Hume Highway at Woolshed Ck	H1	H1	H1	H1	H1	H1	H1	H4
15	Brayton Road at Jaorimin Ck	-	-	-	-	-	-	-	H5
16	Brayton Road at Merino Road	H1	H1	H1	H1	H1	H1	H1	H3
17	Maclura Drive at Stoney Creek Road	H2	H2	H2	H2	H3	H3	H3	H5
18	Jaorimin Creek at Ambrose Road	H1	H2	H3	H4	H4	H5	H5	H6
19	George Street at Brayton Road	H1	H1	H1	H1	H1	H1	H1	H1

[1] Note: the 1% AEP flood hazard exceeds the 0.5% AEP flood hazard at this location due to the adopted 1% AEP blockage assumption.

The information presented in Table 18 indicates that while most key roadways are subject to low flood hazard (H1) for events up to the 0.2% AEP, there are a few roadways affected by H2 hazard or higher in more frequent events.

Table 19 presents the approximate duration of inundation (above 0.1 m flood depth) of key roadways in Marulan. This assessment was undertaken for the 1% AEP and PMF events based on the critical duration at each location.

Table 19: Duration of Roadway Inundation in Marulan

Duration of Inundation Key (greater than 0.1 m depth)		
Short - <2 hours	Medium – 2-6 hours	Long - > 6 hours

ID	Location	Approximate Duration of Inundation (greater than 0.1 m depth) *	
		1% AEP	PMF
1	Hume Highway at Marulan Ck	Short	Medium
2	Hume Highway northbound offramp	*Less than 0.1 m depth*	Short
3	George Street	Short	Short
4	Goulburn Street	Long	Long
5	Railway Parade	Medium	Long
6	Morris Place	Medium	Long
7	Maclura Drive	*Less than 0.1 m depth*	Short
8	Brayton Road West-bound	Short	Short
9	Brayton Road North-bound	*Not flooded*	*Not flooded*
10	Patrick Place	*Less than 0.1 m depth*	Short
11	George Street North	Short	Short
12	Dorsett Road	*Less than 0.1 m depth*	Short
13	Southdown Road	Short	Short
14	Hume Highway at Woolshed Ck	*Not flooded*	Short
15	Brayton Road at Jaorimin Ck	*Not flooded*	Medium
16	Brayton Road at Merino Road	*Less than 0.1 m depth*	Short
17	Maclura Drive at Stoney Creek Road	Long	Long
18	Jaorimin Creek at Ambrose Road	Medium	Medium
19	Geroge Street at Brayton Road	*Less than 0.1 m depth*	*Less than 0.1 m depth*

*Duration based on critical duration at each respective location. Duration of inundation may change with storm duration

Based on the information shown in Table 19 these roadways are typically inundated for durations of less than one hour for areas affected by overland flow. Longer inundation durations were found in locations adjacent to mainstream flooding (such as along Jaorimin Creek) or upstream of hydraulic controls (such as the ARTC Railway embankment).

It is important to note that Maclura Drive at Stoney Creek Road (ID 17 in Table 18) has been paved and improved subsequent to the development of the hydraulic model and as such, it is likely that the reported flood hazard and duration of inundation at this location may be different under present day conditions.

6.4 Property Flood Liability

The flood liability of individual lots and buildings affected by mainstream flooding and/or overland flow at Marulan has been assessed. Flood affectation on a per property level was assessed by comparison of each lot's ground level (proximate to the building) and habitable floor level to design flood levels at the property. The comparison is made at a point location on each lot, usually at the visible entry (i.e., front door).

Figure 20 presents the event which is responsible for first inundating each property above floor level. Figure 20A presents the event which is responsible for first inundating the yard, proximate to the main building.

The analysis presents both residential and non-residential development types. A summary of Marulan's property flood liability is presented Table 20 and Table 21 for residential and non-residential properties respectively.

Table 20: Residential Property Flood Affectation

Design Event (AEP)	Number of Properties Affected**	Number of Properties affected above Floor Level*
20%	1	0
10%	2	0
5%	2	0
2%	7	0
1%	14	0
0.5%	15	0
0.2%	15	0
PMF	77	30

* 392 residential properties were included as part of this assessment. Floor level refers to habitable areas only.
** Flooding noted proximate to the main building

Table 21: Non-Residential Property Flood Affectation

Design Event (AEP)	Number of Properties Affected**	Number of Properties affected above Floor Level*
20%	9	2
10%	10	2
5%	10	3
2%	10	3
1%	12	3
0.5%	12	3
0.2%	12	3
PMF	24	7

* 55 non-residential properties were included as part of this assessment. Floor level refers to habitable areas only.
** Flooding noted proximate to the main building

6.5 Flood Damages Assessment

A flood damages assessment is used to quantitively assess the impacts of flooding on the community. Generally, a flood damages assessment aggregates the following:

- Direct costs to individual properties such as structural damages or damage to contents;
- Indirect costs to individual properties such as clean-up, disposal or loss of income; and
- Cost of damage to infrastructure.

The flood damages assessment summarised herein was undertaken as part of the Marulan Flood Study for properties within the PMF flood extent. Further details of the analysis is presented in that study. The assessment is based on the property flood liability analysis presented in Section 6.4. Based on the flood liability of each development, a monetary value is applied to each property based on the level of property damage over a range of design flood events.

The analysis has been undertaken using two different methods for residential and non-residential properties.

A residential AAD of $22,900 was calculated for the Marulan study area. Table 22 presents the AAD and the total Residential Flood Damages per design event.

Table 22: Residential Flood Damages

Design Event (AEP)	Flood Damages Total	Flood Damage per property
20%	$17,500	$17,500
10%	$35,100	$17,500
5%	$35,100	$17,500
2%	$122,700	$17,500
1%	$245,400	$17,500
0.5%	$263,000	$17,500
0.2%	$263,000	$17,500
PMF	$4,963,300	$64,500
Average Annual Damages (AAD)		$22,900

A non-residential AAD of $402,300 was calculated for the Marulan study area. Table 23 presents the AAD and the total Non-residential Flood Damages per design event.

Table 23: Non-residential Flood Damages

Design Event (AEP)	Flood Damages Total	Flood Damage per property
20%	$638,600	$79,800
10%	$726,600	$80,700
5%	$749,100	$74,900
2%	$795,800	$79,600
1%	$828,600	$82,900
0.5%	$844,900	$84,500
0.2%	$861,300	$86,100
PMF	$2,823,500	$156,900
Average Annual Damages (AAD)		$402,300

6.6 Risk to Sensitive Facilities and Services

Sensitive and critical facilities may be vulnerable to flooding due to either the function they provide or the vulnerability of their inhabitants. Table 24 presents sensitive and critical facilities in Marulan with flood hazard for a range of flood events examined. The locations of these facilities is presented in Figure 21.

Table 24: Marulan Sensitive and Critical Facilities

ID	Facility	Location	Design Event (AEP)				Site access impacted
			5%	1%	0.2%	PMF	
1	Marulan Rural Fire Brigade	Goulburn-Portland Street intersection	H1	H4[1]	H3	H5	5% AEP
2	Water Treatment Plant (Council)	Brayton Road	NF	H2	H2	H4	1% AEP
3	Marulan Preschool	George Street	NF	NF	NF	H1	-
4	Marulan Medical Centre	George Street	NF	NF	NF	NF	-
5	Marulan Public School	Goulburn-George Street intersection	NF	NF	NF	NF	-
6	Marulan Police Station	George Street-railway crossing	NF	NF	NF	NF	-
7	Marulan Waste Management Centre	Wilson Drive	NF	NF	NF	NF	-
8	Marulan WWTP	Medway Road	NF	NF	NF	NF	-

NF = 'Not Flooded'.

[1] Note: the 1% AEP flood hazard exceeds the 0.2% AEP flood hazard at this location due to the adopted 1% AEP blockage assumption.

As presented in Table 24, most of the identified sensitive/critical facilities are not at risk of being flooded. The greatest degree of flood risk is to the Marulan Rural Fire Brigade which is located adjacent to the railway at Hotspot 1. The Water Treatment Plant is also inundated, with access to the site potentially impacted during a 1% AEP event however the sludge ponds and buildings remain unaffected. Minor flooding (H1 hazard) occurs during the PMF at Marulan Preschool.

6.7 Available Flood Warning

The amount of warning available for an impending flood can significantly impact on the risk to life and the degree of flood damage. Catchment response times at Marulan are short, in the order of hours, and are classified as 'flash flood' catchments. As such it is difficult to provide warning in advance of floods. However, for flash flood catchments the Bureau of Meteorology (BoM) provides general warning services, including:

- Flood Watches – early appreciation of a developing weather system that could lead to flooding;
- Flood Warnings – water level readings from gauges;
- Severe Weather Warnings; and
- Severe Thunderstorm Warnings.

7. FLOOD RISK MANAGEMENT MEASURES

Development of flood risk management measures is a key objective of the current study which aim to reduce, or otherwise, manage the flood risk in Marulan. These measures can vary from large-scale civil works, such as the construction of levee, to non-works interventions, such as planning controls for new developments. Floodplain Risk Management measures are categorised in the Flood Risk Management Manual (FRMM) (Reference 20) as follows:

- Property Modification Measures are those which involve modifying existing properties to manage their flood risk. This includes planning-related measures such as minimum floor levels and zoning based on the locality's flood risk. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
- Response Modification Measures are those that improve the ability of people to plan for and react to flood events. They often involved emergency services and can be targeted at different phases of a flood, e.g., preparation, response and recovery.
- Flood Modification Measures are those that change the behaviour of the flood itself through works or other measures. These measures often work to exclude flow from an area (for example a levee bank) or to reduce the peak flow (for example a detention basin).

Table 25 describes typical mitigation measures in each of these categories.

Table 25: Categories & Description of Modification Measures (according to Reference 11 & Reference 19)

	Measure	Description
Property Modification Measures	Land Use Planning	Strategic assessment of flood risk to guide consent authorities to manage and reduce exposure to flood risk for future development areas.
	Zoning	Application of land use controls for flood prone areas of future development without also unjustifiably restricting development in these areas.
	Development Controls	Where development is acceptable, development controls are used to manage flood risk.
	Voluntary Purchase	In residential areas of high hazard on the floodplain posing a risk to life, the purchase of properties can their removal/demolition can be undertaken.
	Voluntary House Raising	In residential areas, exposed to frequent over floor flooding from low hazard and localised flow, this can be avoided by voluntary house raising.
	Flood Proofing of Buildings	Flood proofing pertains to the design and construction of buildings using materials that are flood compatible as to minimise flood damage to the building and its contents.
	Flood Access	In areas where isolation occurs during a flood event for long periods of time, planning measures need to be considered for access during these times.
Response Modification Measures	Flood Education, Flood Information Leaflets & Community Readiness	Flood education pertains to informing the community of the flood risk to ensure general community awareness and flood readiness.
	Flood Prediction and Warning	Flood prediction and warning can be implemented on catchments with large times of concentration to allow time to ready the community.

	Local Flood Plans	Local flood plans can be used to identify significantly flood affected areas and outline various measures to be undertaken before, during and after a flood.
	Recovery Planning	Plans for recovery planning can be developed to ensure that Council and other authorities have addressed the community's needs and provided the needed services.
Flood Modification Measures	Flood Mitigation Dams	Flood mitigation dams can be used to reduce downstream discharges. This relies on the dam having capacity to store flood waters prior to a flood.
	Retarding Basins	Retarding basins pertain to small dams to provide flood storage on overland flowpaths or small tributaries.
	Levees	Levees and embankments can be used to protect existing developed areas by excluding flood waters.
	Bypass Floodways	Bypass floodways can be used to redirect floodwaters away from flood existing developed areas to reduce flood levels along a channel.
	Channel Modifications	Channel modifications refer to modifying a channel either by widening, deepening, realigning or clearing the waterway to allow for more efficient channel flow.
	Floodgates	Floodgates can be used to control and exclude flow along small creeks or waterways.

Further details are provided in the following sections.

7.1 Property Modification Measures

7.1.1 Background

Property Modification (PM) measures are those that modify existing properties, or future development in the area, to manage the area's flood risk. These measures tend to be either interventions for specific properties with high flood risk, such as house raising or voluntary purchase, or broader policy changes that gradually reduce flood risk as development occurs. While such measures do not change the flood behaviour itself, over time they can remove dwellings and other buildings from hazardous flood areas and ensure the remaining flood-prone areas are well-equipped to deal with flooding. Such measures are particularly suited to areas where flood modification measures (works) are either not feasible or prohibitively expensive. In most cases property modification measures are implemented via Council policies, which can be used to stipulate where and how development can occur within the floodplain.

7.1.2 Flood Planning and Future Development

7.1.2.1 Overview

It is the responsibility of local governments within NSW to manage flood risk within their respective LGAs. Two key planning documents are used for the management of this risk and their purpose is outlined below:

- The Local Environment Plan (LEP) - The LEP is a key planning tool for local governments whereby it sets out zoning and high-level development controls in the LGA.

- The Development Control Plan (DCP) - The DCP provides detailed planning and design guidelines to support the LEP.

Section 3.2.2 reviews Council's current flood policies and outlines various issues that need to be addressed.

The following sections provide recommendations to be implemented in Council's planning policy, as well as review existing land zonings and proposed future development areas.

7.1.2.2 Adoption of Flood Planning Level and Flood Planning Area (Option PM01)

Flood Planning Area Overview

The Flood Planning Area (FPA) defines the spatial extent to which most flood related development controls apply. While Council's LEP and DCP have moved away from solely using the FPA to apply flood related development controls, the FPA will form the extent of the FPCC3 (see Section 7.1.2.3) and will be relevant for the implementation of Local Planning Directions for rezoning proposals.

Flood Planning Level Overview

Councils are responsible for determining an appropriate Flood Planning Levels (FPL) within their local government area. FPLs are a combination of a defined flood event (DFE) flood level and a freeboard. Freeboard is used as a factor of safety to ensure that the selected level of protection is reasonably achieved, and uncertainties in flood level estimates are accounted for.

The Flood Risk Management Guideline (FB01) (Reference 13) states that a typical freeboard for flooding from waterways in NSW is 0.5 m and a lower freeboard of 0.3 m is generally limited to some areas affected by local overland flooding. A detailed freeboard assessment was undertaken, and a freeboard of 0.5 m has been adopted for mainstream flooding and 0.3 m for overland flow flooding in the study area (See Section 5.4). Further details of the freeboard assessment are presented in Appendix B.

Summary and Recommendations

A Flood Planning Level set at the 1% AEP flood level plus 0.5 m freeboard for mainstream flooding and 0.3 m freeboard for overland flooding is recommended to be implemented by Council for residential development in Marulan, for areas within the FPA.

Implementation of the FPL can be undertaken through the Development Control Plan. Adjustment of Council's LEP with the FPA/FPL is not recommended as the LEP now uses the standard flood clauses.

The FPA will form the extent of the Flood Planning Constraint Category #3 (see Section 7.1.2.3) for Marulan flood planning Controls.

> **Recommendation**: Council is recommended to define a Flood Planning Level set at the 1% AEP flood level plus 0.5 m freeboard for mainstream flooding and 0.3 m for overland flow flooding. The FPA will delineate the extent of FPCC3 as detailed in Section 7.1.2.3.

7.1.2.3 Adoption of Flood Planning Constraint Categories (Option PM02)

Option Overview

The 'Australian Disaster Resilience Guideline 7-5, Flood Information to Support Land-use Planning' (ADR 7-5) presents a methodology for the management of flood risk through flood planning which considers variations in flood behaviour and risk across the floodplain. The methodology consolidates outputs from a flood or floodplain risk management study to group flood-related constraints into simplified Flood Planning Constraint Categories (FPCC). The FPCC approach to flood planning is considered 'best practise' and has been implemented by Council and included in the Goulburn DCP (2009), '*Chapter 3.8 Flood Affected Lands*' and '*Appendix J: Flood Policy*'.

Flood Planning Constraint Categories

The information presented in the Marulan Flood Study and the current study provide a detailed description of the flood behaviour and other considerations across the floodplain, including:

(i) Flood extents, depths and levels for a range of flood events (Marulan Flood Study)
(ii) Flood function (Section 5.2);
(iii) Flood hazard (Section 5.1) ;
(iv) Constraints on emergency management (Section 5.3); and
(v) Flood Planning Area definition (Section 5.4).

Considering the above-described flood characteristics during land-use planning, can provide greatly improved planning outcomes and community resilience to flood risk. FPCC combines these elements of flood behaviour to produce a succinct set of information that breaks the floodplain down into areas with similar degrees of constraint which can be treated similarly in land-use planning activities.

The methodology outlines four FPCCs which separate areas of the floodplain from the most constrained (and therefore least suitable for intensification of land use or development—FPCC1), to the least constrained (and therefore more suitable for intensification of land use or development—FPCC4). Where considered necessary, FPCC subcategory mapping can provide a further breakdown of FPCC1 and FPCC2 (ADR 7-5) as well as specific controls catered to these constraints.

The methodology requires consideration of regionally specific flood characteristics and constraints and as such there is no one-size-fits-all template that can be directly applied. The categories adopted in the current study and are presented in Table 26, with the FPCC extents presented in Figure 22.

Summary and Recommendations

Flood Planning Constraint Categories for Marulan have been developed consistent with the approach devised in the Goulburn Floodplain Risk Management Study and Plan (GRC Hydro, 2021) and it is recommended that these are included in the DCP. Note that the FPA is implicitly included within the FPCC approach.

Recommendation: The FPCC approach for flood planning in Marulan is recommended for inclusion in Council's DCP.

Table 26: Flood Planning Constraints (ADR 7-5) and Marulan Overland Flow Flooding Considerations

FPCC	Constraint	Implications	Key Considerations	Subcategory	Marulan Overland Flow Flooding Considerations
1	Floodway and storage areas in the DFE	Development or changes to topography within flow conveyance areas and flood storages areas affect flood behaviour, which will alter flow depth or velocity in other areas of the floodplain. Changes can negatively affect the existing community and other property	The majority of developments and uses have adverse impacts on flood behaviour. Consider limiting uses and development to those compatible with maintaining flood function	a	Figure 7 presents the DFE (1% AEP) flood function.
	Flood hazard H6 in the DFE	Hazardous conditions considered unsafe for vehicles and people. All building types are considered vulnerable to structural failure	The majority of developments and uses are vulnerable to failure in this flood hazard category. Consider limiting developments and uses to those that are compatible with flood hazard H6	b	Figure 3 presents the DFE flood hazard. H6 hazard is predominately located within Jaorimin Creek channel. These areas are unsuitable for development of most types.
2	Floodway in events larger than the DFE	Floodway areas may develop during an event larger than the DFE. For example, 0.2% AEP if 1% AEP is the DFE. People and buildings in these areas may be affected by flowing and dangerous floodwaters	Consider compatibility of developments and users with rare flood flows in this area	a	The flood function for the 5%, 1%, 0.2% AEP and PMF events are presented in Figure 6 to Figure 9. Due to the magnitude and rarity of the PMF event, use of this event for various aspects of flood planning can result in overly onerous planning controls and sterilisation of the floodplain which is contradictory to the objectives of the Flood Risk Management Guidelines (FB01) (Reference 13). As such, the flood function mapping for the 0.2% AEP event was used for the FPCC development.
	Flood hazard H5 in the DFE	Hazardous conditions are considered unsafe for vehicles and people, and all buildings are vulnerable to structural damage	Many uses and developments will be vulnerable to flood hazard. Consider limiting new uses to those compatible with flood hazard H5. Consider treatments such as filling (where this will not affect flood behaviour) to reduce the hazard to a level that allows standard development conditions to be applied. Alternatively, consider a requirement for special development conditions	b	Figure 3 presents the DFE flood hazard. Majority of development types are unsuitable in these areas. Development is potentially viable if flood hazard can be reduced, and flood evacuation/egress issues can be effectively managed without impacting on NSW SES services.
	Emergency response – isolated and submerged areas	Area becomes isolated by floodwater or impassable terrain, with loss of evacuation route to the community evacuation location. The area will become fully submerged with no flood-free land in an extreme event, with ramifications for those who have not evacuated and are unable to be rescued	Consequences of isolation and inundation can be severe. Consider the consequences of: • evacuation difficulty or inundation of the area on the development and its users, which may include limitations on land use, or on land use that has occupants who are more vulnerable to disruption and loss • the development on emergency management planning for the existing community, including the need for additional treatments • the development on community flood recovery disruption or loss of the development on the users and wider community	c	Figure 10 to Figure 13 present the Flood Emergency Response Classifications (FERC) for the 5%, 1%, 0.2% AEP and PMF events respectively. Due to the extreme magnitude of the PMF, larger areas of Marulan are classified as Isolated Submerged. As such, strict controls applied to existing residential development is likely to be considered overly onerous and the DFE has been used. However, sensitive/critical uses or density intensification should consider the FERC.
	Emergency response – isolated and elevated areas	Area becomes isolated by floodwater or impassable terrain, with loss of an evacuation route to a community evacuation location. The area has some land elevated above the extreme flood level. Those not evacuated may be isolated with limited or no services, and will need rescue or resupply until floods recede and roads are passable	Some developments and their users may be vulnerable to disruption or loss. Consider: • the consequences of disruption or loss of the development on the users and the wider community • limiting land use, or land use that has occupants who are more vulnerable to disruption and loss • additional emergency management treatment requirements issues associated with the level of support required during a flood, particularly for long-duration flood events	d	As per (2c).
	Flood hazard H6 in floods larger than the DFE	Hazardous conditions may develop in an event rarer than the DFE, which may have implications for the development and its occupants	Consider the need for additional development conditions to reduce the effect of flooding on the development and its occupants	e	The flood hazard for the 5%, 1%, 0.2% AEP and PMF events are presented in Figure 2 to Figure 5 discussed in (2a) above, the 0.2% AEP event was analysed and flood hazard mapping produced and used for development of the FPCC2 extent.
3	Outside FPCC2 – generally below the DFE and the FPL	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings that meet building standards unlikely because of flooding	Standard land-use and development controls aimed at reducing damage and the exposure of the development to flooding in the DFE are likely to be suitable. Consider the need for additional conditions for emergency response facilities, key community infrastructure and vulnerable users	-	Standard controls to be applied consistent with the objectives of the LEP. The extent of the FPCC3 is defined as the extent of the FPA discussed in Section 7.1.2.2. Note: FPCC1 and FPCC 3 have the same extent for some locations as described in Section 5.4.2.
4	Outside FPCC3, but within the probable maximum flood (or similar extreme event)	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users	-	Controls to be applied for sensitive and critical land uses as per the objectives of the LEP. In the PMF event, the study area's flat topography produces widespread very shallow overland flow. Use of the PMF extent can result in overly onerous planning controls and as such, the PMF extent has been trimmed to a depth of 0.1 m to devise FPCC4.

7.1.2.4 Update of Goulburn Development Control Plan (Option PM03)

Option Overview

A Development Control Plan (DCP) provides detailed planning and design guidelines to support the LEP. In 2022, the Goulburn DCP included '*Chapter 3.8 Flood Affected Lands*' and '*Appendix J: Flood Policy*' which uses Flood Planning Constraint Categories (FPCC) to implement flood related development controls based on a site's flood characteristics and proposed development type.

The DCP is based on the FPCC developed for mainstream flooding at Goulburn and lacks nuance for the management of flood risk due to overland flow flooding, resulting in overly onerous flood controls. Potential updates to the DCP are outlined in Table 27.

Table 27: Potential updates to Goulburn Development Control Plan

Section	Update	Reason
3.8.2.2 Controls for Development Outside of Adopted Flood Study Areas	Part (b) and (f) notes that 0.5 m freeboard should be used 'for areas outside an adopted Council Flood Study'. Consideration to an appropriate freeboard suitable for overland flow should be given. Council should consider use of a freeboard of 0.3 m applied to areas affected by overland flow flooding*.	See Section 7.1.2.2
3.8.2.3 Development on Land Identified as Flood Prone in the Goulburn Floodplain Risk Management Study and Plan	'*For the remainder of the LGA 0.5m is to be applied pending further studies being undertaken*'. Consideration to an appropriate freeboard suitable for overland flow should be given. Council should consider use of a freeboard of 0.3 m applied to areas affected by overland flow flooding*.	See Section 7.1.2.2
3.8.3 Definitions	'*Freeboard: a factor of safety expressed as the height above the FPL which is 0.8m in the Goulburn Floodplain Risk Management Study and Plan and an assumed 0.5m elsewhere*'. Consideration to an appropriate freeboard suitable for overland flow* should be given.	See Section 7.1.2.2
9.4.4 Definitions	Define a classification for determining areas subject to overland flow*.	See Section 7.1.2.2
9.4.4 Definitions	Add comment that a freeboard of 0.3 m is proposed for overland flow flooding* at Marulan.	See Section 7.1.2.2
9.9.6 Flood Planning Controls	Include controls specific to overland flow flooding*.	The controls presented are for mainstream flooding at Goulburn due to the Wollondilly and Mulwaree Rivers. Specific controls for overland flow flooding should be developed.

* Areas affected by overland flow flooding are shown in Figure 14 and the Marulan FPCC are presented in Figure 22.

Summary and Recommendations

The Goulburn DCP does not specifically consider the risk of overland flow flooding and flood controls in areas subject to overland flow may be overly onerous resulting in unnecessary expenditure for new developments.

Recommendation: Council's DCP should consider and make provision for controls for areas affected by overland flow flooding (shown in Figure 14).

7.1.2.5 Updated Flood Certificates (Option PM04)

Council is currently responsible for providing information on flooding at a per-property level. This is provided via Section 10.7 certificate. This information promotes flood awareness for current and prospective owners of a property, in communicating the different sized floods that can occur and the source or sources of flooding. The certificates also assist owners in applying the correct flood planning controls at the property, which will then tend to reduce flood risk for the study area in the long term.

It is recommended to update the flood information provided following adoption of the current study, to the latest design flood behaviour.

There are multiple ways that Council can extract the information at each property depending on what software is used at Council. Some councils have automated the extraction of data although it's noted this typically still requires some manual inputs and oversight, especially for larger lots where there is significant variation of flooding behaviour across the lot. Some councils have also established an online mapping platform that shows flood mapping outputs overlaid with a cadastral layer and other spatial information.

Recommendation: Council is recommended to continue to provide flooding information on a per property basis via a flood certificate, and that information should be updated following the adoption of this study.

7.1.2.6 Advice on Land-use Zoning Considering Flooding (Option PM05)

Overview

The NSW Government's Flood Risk Management Guideline (Reference 13) states that "*Effective consideration of flooding in land-use planning can limit the increase in flood risk as communities grow*". Council is recommended to give due consideration to selecting appropriate zones and related provisions when flood prone land is being rezoned as an effective and long term means of limiting danger to personal safety and flood damage to future developments.

A review of land use zones that considers local flood characteristics has been undertaken for the Marulan study area. The Australian Disaster Resilience Handbook Collection (Handbook 7) states that risk management can be achieved by informing land zonings through consideration of flood function, flood hazard, emergency response limitations, and vulnerability of different development types. Consideration of these characteristics has been undertaken to identify potential appropriate adjustments to land use zonings.

To reduce future flood risk potential due to development pressures, undeveloped lots situated in high hazard (H3 or greater), floodway areas and areas with significant evacuation constraints, are considered hazardous and may be considered for rezoning to a land use type that does not permit residential, business or industrial land uses.

Recommendation: Land zones should be considered in conjunction with flood characteristics. Rezoning of land can be considered for areas of high hazard to remove the risk of future development.

7.1.2.7 Review of Future Development Areas

<u>Overview</u>

As discussed in Section 2.4, Council is in the process of reviewing potential areas of future development to meet demands from expected population growth. These development areas are considered in conjunction with the FPCC discussed in Section 7.1.2.3.

A preliminary feasibility assessment of the future development areas as been undertaken and presented in Table 28. This assessment has used information from the Urban and Fringe Housing Strategy for Goulburn and Marulan (Reference 21) and the Flood Planning Constraint Category mapping (see Section 7.1.2.3) to determine the proportion of developable land within the proposed future development areas, defined as land outside of the Flood Planning Area.

Table 28: Preliminary Assessment of Future Development Areas

Growth Area	Type*	Proposed No. lots*	Total Area (ha)	Minimum Lot Size (m^2)*	Land outside of the FPA[2] (ha)	Preliminary Feasibility Assessment
Marulan North	R1	694	98	700	74 (76%)	Feasible
Marulan North URA	R1	631	91	700	75 (83%)	Feasible
Marulan East	R5	29	217[1]	100,000	107 (49%)	Not feasible

* Urban and Fringe Housing Strategy (UFHS) (Reference 21) (dated July 2020). Land zones not provided and as such, development types specified as 'Serviced Residential' assumed R1 zoning, and Large Lot Residential assumed R5 zoning.

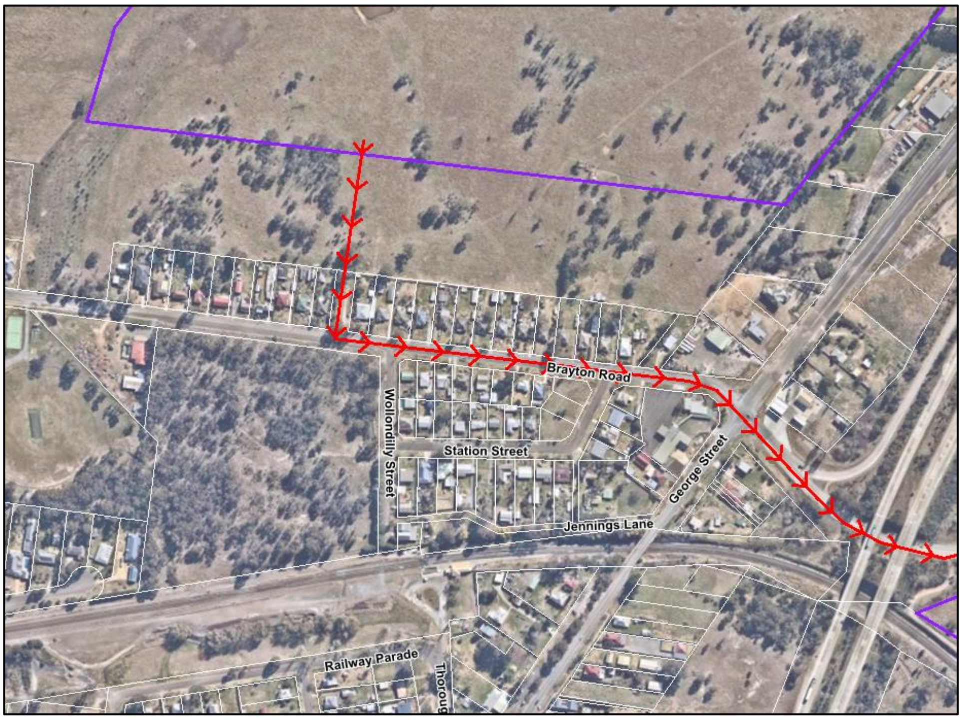
[1] Area within current study area. Marulan East extends out of the study area east to near Barbers Creek Road.

[2] Local Planning Direction 4.1 clause 2 does not allow for rezoning of land within the FPA (FPCC3) from rural to residential uses (see below).

The preliminary assessment presented in Table 28 has considered the proportion of land outside of the Flood Planning Area (FPCC3) as the Local Planning Direction (Section 4.1, clause 2) does not allow for the rezoning of land within the FPA from rural to residential uses. Development in these areas will be required to have building envelopes with flood free access. It should be noted that given the diffuse flow in the "Marulan East" growth area and a proposed minimum lot size of 10 hectares, it is expected that development potential may be constrained.

The assessment of roadway inundation (see Section 6.3) provides insight into potential access routes to the Marulan North and Marulan North URA growth areas. The Brayton Road and Geroge Street intersection experiences a maximum flood hazard of H1 and as such will be trafficable for the full range of flood magnitudes assessed (see Table 18). Given this, potential access to these growth areas may be achieved via Brayton Road and potentially through a vacant lot to the north of Brayton Road (between 39 and 41 Brayton Road) (see red outline shown in Image 12 below).

Image 12: Potential Access route for Marulan North and Marulan North URA Growth Areas



Summary and Recommendations

The flood risk to Proposed Future Development Areas should be considered in conjunction with flood characteristics. Additional detailed flood analysis of these areas should be undertaken to determine the future development potential.

7.1.3 Property Modification Measures

7.1.3.1 Voluntary Purchase (Option PM06)

Option Overview

Voluntary Purchase (VP) removes residential properties subject to high hazard flood conditions from the floodplain. VP is an effective floodplain risk management measure for existing development for which it is impractical or uneconomic to mitigate flood risk by other means. Properties must satisfy the criteria outlined in the 'Guidelines for voluntary house purchase scheme' (Reference 17) to be eligible. The document states that *"VP is a recognised and effective flood risk management measure for existing properties where:*

- *There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in the properties and reduce the risk to life of residents and potential rescuers*

- *A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain, by enabling the floodway to more effectively perform its flow conveyance function*
- *purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.'*

Eligible properties are purchased by Council with funding opportunities under the Floodplain Management Program. The process is entirely voluntary and often takes many years to implement due to budget limitations.

Preliminary Voluntary Purchase Assessment

A preliminary assessment of flood risk was undertaken to identify residential properties that are at significant risk of flooding or risk to life potential by considering the following:

- The event AEP responsible for first flooding a property above floor level. Only properties flooded in the 1% AEP event or more frequent events would be selected, unless subject to H5/H6 hazard classification which could affect the structural stability of the building;
- The maximum flood hazard at the property in the 1% AEP event;
- The maximum flood hazard at the property in the 0.2% AEP event;
- Flood access hazard in the 1% AEP event. Only properties with flood access of H4 hazard or higher were selected as resident evacuation/emergency personal access would be hazardous under these conditions.

No properties in Marulan were found to satisfy the above criteria and as such, voluntary purchase is not a recommended flood risk management measure for Marulan.

7.1.3.2 Voluntary House Raising (Option PM07)

Option Overview

Voluntary House Raising (VHR) raises the finished floor level of eligible residential properties to reduce the frequency of flooding. VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomic. The building structure must be able to withstand loadings from floodwaters and debris. Despite raised buildings providing safe refuge to residents during a flood event, the risk to life remains present should residents choose to exit the building, or a medical emergency occur during the flood events.

Properties must satisfy the criteria outlined in the 'Guidelines for voluntary house raising schemes' (Reference 18) to be eligible. The document states that *"VHR is recognised as an effective floodplain risk management measure for both riverine and overland flood conditions. It is generally undertaken:*

- *to reduce the frequency of exposure to flood damage of the house and its contents and reduce the frequency of household disruption and associated trauma and anxiety*

- *as a compensatory measure where flood mitigation works adversely affect a house, which is generally considered part of the mitigation work rather than a separate VHR scheme.*

Key to eligibility for VHR is the requirement for the property to be situated in a 'low flood hazard' area with very little scaling of flood levels between flood magnitudes, whilst also being frequently flooded. These criteria are often in conflict. The assessment of Property Flood Liability (see Section 6.4) found that residential properties in Marulan are not flooded above floor level until the PMF event. As such, Voluntary House Raising is not a recommended flood risk management measure for Marulan.

7.1.3.3 Flood Proofing (Option PM08)

Option Overview

Flood proofing aims to reduce the impact of inundation on flood affected buildings by sealing all building entry points. Both permanent and temporary flood proofing methods are available. Permanent flood proofing methods can be incorporated into the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages. Permanent methods include flood gates, sealing of gaps between brick works and electrical wiring insulation. Council's DCP requires all new developments to use flood compatible building components below the FPL. Retrofitting permanent flood proofing measures to existing development is difficult to implement and not recommended as a flood mitigation measure.

Temporary flood proofing measures such as flood barriers and sandbags can provide some flood protection if adequate warning time is available. This measure is generally less expensive compared to other property modification measures and causes less disruption. The effective deployment of temporary flood proofing measures would rely on the experience and knowledge of the user as well as sufficient warning time before the onset of flooding.

Summary and Recommendations

Retrofitting flood proofing to existing development is not a recommended flood mitigation measure, however, should not be discouraged by Council if private property owners want to implement these measures at their own expense.

7.2 Response Modification Measures

7.2.1 Background

Response Modification Measures aim to strengthen the collective flood education and preparedness of a community. These measures ensure that in the event of a predicted or imminent flood event, residents are educated and informed of the necessary emergency procedures and recovery measures before, during and after a flood event. While response modification measures do not change the flood behaviour itself, they can reduce the risk to life through improved flood preparedness, warning and response. Such measures are further beneficial to address residual flood risk for very rare to extreme floods where flood modification measures may not provide protection.

Typically flooding can occur in Marulan with limited warning and floodwaters will recede relatively quickly. Given the flash flood nature of flooding in Marulan (see Section 6.7), Response Modification Measures have limited use in flood risk management for this study area.

The following sections present the assessed response modification measures for management of existing and future flood risk.

7.2.2 Flood Prediction and Warning (RM01)

While a formalised flood warning system is not recommended for Marulan due to the flash flooding nature of surrounding catchments (see Section 6.7), the Bureau of Meteorology (BoM) and NSW State Emergency Services (SES) provide weather forecasts and warnings through a range of mediums to aid community awareness and preparedness.

The BoM, in cooperation with the NSW SES, provide flood forecasting and warning services suited mainly for mainstream riverine flooding rather than flash flooding. These services may be of some benefit in alerting residents of potential flooding despite there being inadequate time to develop or publish reliable flood warnings. The BoM and SES services include:

- Weather forecast – which may indicate the likelihood of heavy rain with often more than 24 hours' notice;
- Flood Watch – will typically provide +24 hours' notice of potential flooding;
- Severe Weather Warning – typically issued when heavy rain and/or flash flooding are forecast; and
- Severe Thunderstorm Warning – generally provide between 0.5 to 2 hours' notice of impending severe storms.

The NSW SES have also developed a phone application known as "Hazards Near Me NSW" that provides current information about local emergencies such as flooding, bushfires and tsunamis as well as evacuation advice where necessary. This application allows users to register a 'Watch Zone' at their area of interest in order to receive targeted updates and warnings.

Due to the difficulty in predicting flash flooding, and a lack of available warning time in the study area, the provision of an effective flood warning service is not feasible and is not a recommended flood risk management measure for Marulan.

7.2.3 Community Education and Flood Awareness (RM02)

<u>Option Overview</u>

The level of awareness of flooding in a community is an important indicator of how well the community can prepare for, respond to and then recover from a flood event. Beyond general awareness that flood risk exists in a particular town, flood education is most effective when it facilitates resilience to flooding in a community. This encompasses understanding of the types of flood risk, the available warning systems (if any), measures that can be taken in preparation for a flood event, personal safety and protection of assets during a flood, and recovery from a severe flood event.

The responses from the community consultation undertaken during the current study (see Section 4) indicate that there is a general awareness of flooding from overland flow in Marulan. In the absence of a recent significant rainfall event within the study area, community awareness of flooding typically declines. Further, as close to half of the population of Marulan has relocated to the area within the last five years (see Section 2.3), flood awareness within the study area is likely to be low. This is usually addressed by implementing a community awareness program.

Summary and Recommendation

The local community could benefit from a more measured flood awareness program due to the nature of flooding in Marulan. This approach could be in the form of a pamphlet or community notice indicating that flooding from overland flow can occur in a number of key Marulan locations, directing residents to BoM and NSW SES resources and reminding residents to never walk or drive into flood waters.

Recommendation: Marulan would benefit from a measured approach to community flood awareness engagement. Distribution of an LGA wide pamphlet or community notice could notify people of the risk of flooding in the area.

7.2.4 Flood Signage (RM03)

Option Overview

In Australia, the most common cause of fatality during a flood is drowning from attempting to cross a flooded bridge or road. Given this, flood signage may provide road uses of the flooding issues for key areas with flood liability issues, especially road crossings. On flood-prone roads and locations, a warning sign and a depth marker is often used to warn vehicles and pedestrians of dangerous flooding. They are used particularly in areas where a creek may completely submerge a section of road when the cross-drainage is exceeded. Recent research has found that while such signage is important, signage is often ineffective at persuading motorists to turn around, especially if it is static signage that does not change the warning when a flood is occurring.

Locations for Flood Warning Signage

The current study has undertaken a detailed analysis of the flood hazard along various roadways in Marulan (see Section 6.3). Generally, this analysis found that most roadways in Marulan experience H1 hazard for events up to the 0.2% AEP. Of note, were a few locations where hazardous flooding occurs in more frequent flood events, namely where Jaorimin Creek crosses Ambrose Road. This location already has flood signage in the form of a flood warning and flood depth marker on the eastern approach. However, the depth mark may be difficult to see when approaching from the west, with installation of an additional flood marker likely to improve visibility, particularly at night.

Maclura Drive at Stoney Creek Road experiences H2 hazard for all design events up to the 0.2% AEP however this location has been paved and improved subsequent to the development of the hydraulic model and as such, it is likely that the reported flood hazard at this location may be different under present day conditions.

Southdown Road is the key access roadway for residents of north-western Marulan. This roadway is experiences H2 hazard for events between the 1% and 0.2% AEP. Despite the rarity of these events, flood warning signage and a depth marker is recommended given the reliance on this roadway for access.

Similarly, Maclura Drive provides access for residents to the west. This roadway is subject to H2 hazard for the 0.5% and 0.2% AEP events. Given the reliance on access along this road, flood warning signage and a depth marker is recommended where the central flow path crosses Maclura Drive.

Cost Estimate

Standard flood depth markers and warning signs that comply with Austroads requirements (inclusive of posts/brackets and freight) are estimated to cost approximately $2,000 per sign.

The estimated costs of purchase for signage at Southdown Road and Maclura Drive is ~$4,000 not including the cost of installation. It is estimated that the cost of installation and management is ~$5,000.

Summary and Recommendations

Flood warning signs and depth markers are recommended for flooded roads particularly roadways that provide flood access.

Recommendation: Council are recommended to install flood warning signage to minimise the risk for motorists and pedestrians entering flood waters.

7.2.5 Local Flood Plan Updates (RM04)

Option Overview

The Goulburn Mulwaree LGA Local Flood Plan (LFP) is a Sub-Plan of the Goulburn Local Emergency Management Plan and was published in September 2021. The Plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the LGA. The NSW SES are responsible for the development and maintenance of the LFP.

As the key flood emergency management document, the LFP should be updated when additional information becomes available. Specifically, findings from the current study and recommendations presented herein provide the most up to date flood risk profile for Marulan and are recommended to be incorporated to assist in the management of flood risk through emergency response.

At the time of reporting, the Volumes 2 and 3 of the LFP are still in draft.

Recommended Inclusions

It is recommended that the LFP be updated to incorporate the findings of the current study. Specific recommendations are presented below:

- Consideration should be given to the design flood results (inclusive of Emergency Response Classifications) and findings from the Marulan Flood Study (GRC Hydro, 2023) and the current study;
- The LFP should consider the analysis of Road Inundation presented Section 6.3;
- The LFP should consider the analysis of Risk to Sensitive Facilities and Services presented in Section 6.6; and
- The LFP should consider the analysis of Property Flood Liability presented in Section 6.4.

Summary and Recommendations

The Goulburn Mulwaree Local Flood Plan (LFP) provides important flood intelligence, and it is recommended that it be updated to include the findings of the current study. The NSW SES are responsible for maintaining LFPs.

Recommendation: The NSW SES are recommended to update the Goulburn Mulwaree Local Flood Plan to include the findings of the current study and recommendations presented herein.

7.3 Flood Modification Measures

7.3.1 Background

Flood Modification (FM) measures were developed based on assessment of the flood risk and flooding hotspots, with support for measures also provided via consultation with Council and the community.

The following sections present the findings from the detailed assessment of agreed flood modification measures. A 'Longlist' of flood modification measures were development with Council and in consideration of community input obtained from the questionnaire responses (see Section 4.1). These measures are discussed in the following section. The 'Longlist' of options was then refined to produce a 'Shortlist' of options based on discussions with Council.

7.3.2 Flood Modification Measures - Longlist

A staged process was used to select measures that warrant detailed assessment. This involved development a longlist of measures, and then further assessing those that were most likely to be effective with input from Council and the DCCEEW.

The longlist of measures has been summarised in Table 29, with the location of each shortlisted option presented in Figure 23.

Table 29: Flood Modification Measures Longlist

Code	Description	Preliminary Assessment Outcome
L01	Location: Hotspot 1 The culvert through the railway near western end of Goulburn Street crossing toward Stoney Creek Road forms a flood control for even the most frequent events investigated, which causes ponding upstream of the railway in this area. Examine increasing the size of the culvert.	Selected for Assessment
E01	Location: Railway corridor Clearing debris and excess vegetation around flow paths upstream of railway to reduce potential blockage	Selected for Assessment
R01	Location: Hotspots 3 & 4 The accessibility to areas west of the northern flow path may be affected during extreme event flooding.	Not selected for further assessment as measure has been assessed individually in Options L05 and L07

Code	Description	Preliminary Assessment Outcome
	Road upgrade works to improve access to this area was considered.	
L02	Location: Hotspot 2 Morris Place is subject to frequent overland flow flooding. Increasing the drainage capacity on Morris Place could be examined to address flooding and drainage issues at this location.	Selected for Assessment
L03	Location: Hotspot 2 Morris Place is subject to frequent overland flow flooding. Diverting stormwater flows parallel to the rail corridor to the neighbouring catchment could be investigated to mitigate flooding issues at Morris Place	Selected for Assessment
L04	Location: Hotspot 2 Morris Place is subject to frequent overland flow flooding. Driveways modification to raise driveways over the flow path on Morris Place may improve access.	Not selected for further assessment. Likely to be expensive to manage low hazard (H1) flood conditions. May also result in increased flood levels due to flow obstruction. Introducing culverts in the urban domain may create risks for small children that could be pulled into the culvert during times of flood.
L05	Location: Hotspot 3 Increasing the capacity of the culvert/flow path at Maclura Drive has been requested by the local community	Selected for Assessment
L05A	Location: Hotspot 3 Removing embankments on residential land downstream of Maclura Drive	Selected for Assessment
E02	Location: Hotspot 2 Clearing debris and excess vegetation around the central flow path to improve the conveyance capacity of this flow route with no major modification	Not selected for further assessment. No reduction in property flood liability expected and unlikely to be cost effective.
L06	Location: Hotspot 5 The culvert through the railway near Railway Parade forms a flood control for even the most frequent events investigated, which causes ponding upstream of the railway in this area. Examine increasing the size of the culvert.	Selected for Assessment
L07	Location: Hotspot 4 Increasing the capacity of the culvert/flow path where the Northern flow path crosses Brayton Road	Selected for Assessment
L08	Location: Hotspot 4 Modify the northern flow path channel to increase its capacity downstream of Brayton Road.	Not selected for assessment. Mitigation works for future development would not be covered by the Floodplain Management Program and cost would typically be covered by the proponent of future development.
L09	Location: Hotspot 6 Introduction of a swale and a retarding basin to the north of George Street, may reduce the overflow	Selected for Assessment

Code	Description	Preliminary Assessment Outcome
	affecting the surrounding properties at the lower sagging part of George Street	
L10	Location: Hotspot 6 The community consultation process identified a local drainage issue with flow passing through non-residential development between Portland Avenue and George Street. Drainage works could be investigated to alleviate this issue.	Selected for Assessment
L11	Location: Hotspot 7 The culvert through the railway at Hotspot 7 forms a flood control for even the most frequent events investigated, which causes ponding upstream of the railway in this area. Examine increasing the size of the culvert.	Selected for Assessment

7.3.3 Flood Modification Measures - Shortlist

Options identified for further consideration and analysis are presented in the following sections.

7.3.3.1 Railway Culvert Upgrade at Goulburn Street (Option L01)

Option Overview

Option L01 aimed to reduce ponding upstream of the railway culvert and the surrounds at the western end of Goulburn Street. This location was identified at Hotspot 1 (see Section 6.2.1) and feedback from consultation with Council and the community indicated that this location is prone to blockage and pooling of flood waters.

This mitigation measure involves increasing the capacity of the culvert beneath the railway (from a 900 mm diameter arch to a two 900 mm diameter pipes) and as such, aid the efficient drainage of the area upstream of the railway.

Impact on Flood Liability

Figure 24 presents the 1% AEP event flood level impacts for the implementation of Option L01. Upstream of the railway peak flood levels are reduced by up to 0.56 m with impacts extending approximately 200 m, across Goulburn Street and lowering flood levels at three residential properties in the vicinity. Notably, however, are the peak flood level increases extending approximately 800 m downstream to Jaorimin Creek. With the implementation of Option L01, peak flood levels are increased by up to 0.1 m immediately downstream of the railway and by up to 0.04 m along Morris Place.

Summary and Recommendations

Option L01 has not been recommended as a strategy in the Floodplain Risk Management Plan due to the widespread increases in downstream flood level in the location identified as Hotspot 2. Additionally, Option E01 (see Section 7.3.3.2) has been recommended as a similar and less costly mitigation measure without downstream flood impacts.

7.3.3.2 Clearing Debris at Railway Culverts (Option E01)

Option Overview

Consultation during the Flood Study with Council, DCCEEW and the community indicated significant observed blockage of the railway structures near Goulburn Street. Further, the railway corridor is elevated which creates the potential for significant sensitivity to blockage of cross drainage structures. Given this, an extreme blockage scenario was adopted for cross drainage structures within the railway corridor, and this was incorporated into the 1% AEP flood envelope (as documented in Section 7.2.3.1 of the Flood Study).

Option E01 aimed to reduce exacerbated flood levels due to excessive blockage of the cross-drainage structures along the railway corridor by clearing debris and establishing a maintenance schedule in consultation with ARTC. This measure has been assessed for the 1% AEP event.

Impact on Flood Liability

Figure 25 presents the 1% AEP peak flood level impacts for the implementation of Option E01 where the existing 1% AEP design envelope has been compared against a 1% AEP design envelope with the removal of extreme blockage. These results indicate that clearing and maintaining the railway culverts would yield flood level decreases of up to 0.5 m upstream of the railway in the 1% AEP event.

Constraints

While there are significant benefits associated with Option E01, this measure will require liaison with ARTC and negotiation regarding the cost of ongoing maintenance of these structures.

Social Impacts

The reduction in flood affectation and in turn risk to life provides intangible benefits including reduced disruption, social stresses and impacts on emergency personnel.

Community Acceptance

Since Option E01 has been raised by the community this measure is likely to be supported.

Recommendation: Clearing debris and ongoing maintenance of the railway culverts (Option E01) is a recommended flood risk management measure to reduce frequency and depth of flooding upstream of the railway corridor.

7.3.3.3 Morris Place Drainage Upgrade (Option L02)

Option Overview

Consultation with Council and the community highlighted that overland flow along Morris Place is a key area of concern in Marulan. A detailed hotspot analysis of the mechanisms that cause flooding in Morris Place (see Section 6.2.2) found that flooding is exacerbated by an undersized stormwater system. Given this, Option L02 investigated a stormwater upgrade from the northern side of the railway extending approximately 400 m downstream to the stormwater outlet upstream of Maclura Drive. This measure increased the capacity of the existing stormwater network from a 0.45 m diameter stormwater pipe to a 1.05 m diameter pipe.

Impact on Flood Liability

Figure 26 presents the 20% and 1% AEP change in peak flood levels with the implementation of Option L02. In the 20% AEP event, peak flood levels are decreased by up to 0.30 m in the swale north of the railway and by up to 0.03 m at properties along Morris Place. In the 1% AEP event, peak flood levels are decreased by up to 0.32 m in the swale and by up to 0.05 m at properties and along the Morris Place roadway.

The minor decrease in flood levels is due to the limited capacity of the proposed 1.05 mm pipe relative to overland flows on Morris Place. The flow in the L02 pipe is ~1 m^3/s (which is limited by the flat pipe grade (~0.4%) and downstream tailwater levels), with ~1.4 m^3/s of overland flow (compared to 2.2 m^3/s for the existing condition). To see significant improvements to flooding on Morris Place, an even larger pipe system would be required.

Option L02 was simulated for a range of flood events with results presented in Table 30 below. The table shows that the option provides modest reductions with one property no longer flooded in the 0.5% AEP event and a reduction of $200 in Average Annual Damages.

Table 30 Economic Impacts of Option L02

Design Event (AEP)	Number of Properties No Longer Flooded Above Ground[1]	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
20%	0	0	0
10%	0	0	0
5%	0	0	0
2%	0	0	0
1%	0	0	0
0.5%	-1	0	-$17,600
0.2%	-1	0	-$17,600
PMF	-1	0	-$17,600
		Average Annual Damages (AAD)	-$200

[1] Above ground flooding refers to properties inundated by more than 0.1 m of flood water above ground level.

Cost Estimate

A preliminary cost estimate for Option L02 estimated that this measure would cost $2 million. Further cost estimate details are presented in Appendix D – Preliminary Cost Estimations. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit/Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damages reduction: $200
- NPV of reduction: $2,000
- Cost estimate of option: $2,000,000
- Benefit-Cost Ratio: 0.001

The benefit-cost ratio is 0.001, which means that the cost of Option L02 greatly outweighs the economic benefit and as such, this measure cannot be justified on economic ground alone.

Constraints

Despite the benefits associated with the implementation of Option L02, this measure has technical and administrative constraints that would need to be addressed in the planning stages. These include:

- The cost of construction;
- Disruption caused by construction to residents, pedestrians and traffic; and
- Design and construction of sections of drainage in a developed area would likely encounter issues with other underground utilities in the area.

Social Impacts

The reduction in flood affectation and in turn risk to life provides intangible benefits including reduced disruption, social stresses and impacts on emergency personnel.

Community Acceptance

The implementation of Option L02 is likely to be met with mixed support from the community. Since flood affection in this area is a known issue that was raised by the community and Council, it is likely that the community would be generally supportive. Support may decline however once the economic impact is understood along with the disruption to traffic, residents and pedestrians during the construction phase.

Summary and Recommendation

This option is unlikely to receive funding as part of the Floodplain Management Program due to the poor Benefit/Cost ratio and generally low hazard flood conditions. As such, Option L02 has not been recommended for inclusion in the Floodplain Risk Management Plan.

7.3.3.4 Morris Place Overland Flow Diversion (Option L03)

Option Overview

Overland flow along the Morris Place roadway and driveway has caused considerable disruption for residents (see Section 6.2.2). Option L03 aimed to capture overland flow at the railway, upstream of Morris Place and divert it in a westerly direction to meet the overland flow path west of Morris Place.

A swale between the railway and Stoney Creek Road was implemented to divert overland flow west. To aid this diversion, bunding was also implemented along the northern side of Stoney Creek Road up to 0.5 m high. This assessment has not incorporated a freeboard to the height the embankment however freeboard would be required during the design and construction phases if implemented. The swale was modelled with a width of 3.2 m and a varying depth based on the topography. Generally, the swale had a depth between 0.5 m to 1 m and a maximum depth of 2.4 m. The swale and bunding alignments are shown in Figure 27.

Impact on Flood Liability

The change in peak flood level with the implementation of Option L03 in the 20% AEP and 1% AEP events are shown in Figure 27.

In the 20% AEP event, peak flood levels are generally reduced by 0.07 m along the Morris Place roadway. Peak flood levels are increased to the west of Morris Place by up to 0.13 m where overland flow has been diverted. Generally peak flood level increases are less than 0.08 m in the 20% AEP event.

In the 1% AEP event peak flood level reductions of up to 0.2 m occur along Morris Place extending to the Maclura Drive crossing. Generally peak flood level decreases of 0.05 m occur along the Morris Place roadway. Peak flood level increases occur along the flowpath to the west of Morris Place where overland flow was diverted. These increases are generally less than 0.06 and up to 0.1 m in localised areas.

Option L03 was modelled for the full range of flood events to determine the economic impacts of the implementation of this measure. This analysis found that Option L03 resulted in no change in property flood affectation and flood damages outcomes across all design flood events.

The limited benefits of this Option in terms of flood level reductions is due to the flat topography of Morris Place yielding relatively shallow depths and the runoff generated along Morris Place that occur downstream of the flow diversion swale. Further improvements could potentially be achieved by combining Option L02 and L03.

Cost Estimate

A preliminary cost estimate for Option L03 estimated that this measure would cost $5.6 million. Further cost estimate details are presented in Appendix D – Preliminary Cost Estimations. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit/Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damages reduction: $0
- NPV of reduction: $0
- Cost estimate of option: $5,600,000
- Benefit-Cost Ratio: 0

The benefit-cost ratio is 0, which means that the cost of Option L03 greatly outweighs the economic benefit and as such, this measure cannot be justified on economic ground alone.

Constraints

A key constraint pertaining to the implementation of Option L03 is the development of the swale on privately owned land to the west of Morris Place and the associated increased peak flood levels on this land. Consultation with multiple private landowners would be required before Option L03 can be implemented.

Community Acceptance

This measure was assessed after residents and Council raised Morris Place as an area for concern for the community. The community would likely be supportive of works to mitigate issues in this area, however support may be reduced due to the significant cost of implementation.

Summary and Recommendations

This option is unlikely to receive funding as part of the Floodplain Management Program due to the poor Benefit/Cost ratio and generally low hazard flood conditions. As such, Option L03 has not been recommended for inclusion in the Floodplain Risk Management Plan.

7.3.3.5 Increasing conveyance capacity at Maclura Drive (Option L05)

Option Overview

Option L05 aimed to increase the conveyance capacity for the Central Flow Path at Maclura Drive to improve trafficability of this key access road. At present, flow is conveyed beneath the roadway via five box culverts. When the capacity of these structures is exceeded, overland flow overtops Maclura Drive. Option L05 has investigated implementing a bridge at Maclura Drive by increasing the conveyance capacity to prevent inundation of the roadway. The flow width beneath the roadway was increased from approximately 6 m to 15 m wide. This measure was devised based on feedback from the community.

Impact on Flood Liability

Figure 28 presents the 1% AEP change in peak flood levels with the implementation of Option L05. Upstream of the roadway, peak flood levels are decreases extend approximately 75 m upstream with decreases generally around 0.06 m and up to 0.3 m at the proposed bridge location. There are isolated increases in peak flood levels, typically 0.01 m immediately downstream of the proposed bridge. Notably, the implementation of Option L05 does not change the flood liability of any properties in the vicinity in the 1% AEP event, or result in Maclura Drive to be flood free.

Constraints

As well as limited benefits to peak flood level impacts, Option L05 also has deign, constructability and administration constraints that limit the overall feasibility of the measure. These include:

- The cost of construction;
- Disruption caused by construction to residents, pedestrians and traffic;
- Sizing of bridge deck width without encroaching on flow area; and
- No change to trafficability of the roadway during significant flood events.

Summary and Recommendations

This option is not recommended as a flood risk management measure due to the significant cost of construction and the limited improvements for the flood immunity of Maclura Drive.

7.3.3.6 Removing embankments downstream of Maclura Drive (Option L05A)

Option Overview

Approximately 80 m and 150 m downstream of where the Central Flow Path crosses Maclura Drive are two embankments on privately owned land. These embankments provide driveway access to residents living to the north of the flowpath and have a damming effect on overland flow moving north-west toward Jaorimin Creek. Option L05A investigated the associated peak flood level impacts of removing these embankments and allowing overland flow to freely move toward the creek. This measure was devised based on feedback from the community to improve the flood immunity of Maclura Drive.

Impact on Flood Liability

Figure 29 presents the changes in peak flood levels in the 1% AEP event with the implementation of Option L05A. Reductions in 1% AEP flood levels of up to 0.45 m occur in the vicinity and extend to Maclura Drive. Some isolated peak flood level increases of up to 0.05 m occur with the implementation of Option L05A. The existing flood liability of Maclura Drive and residential houses in the vicinity is unchanged in the 1% AEP event.

Constraints

Option L05A is reliant on undertaking works on private land and as such, consultation with multiple private landowners would be required and appropriate flood safe driveway alternatives would need to be determined.

Summary and Recommendations

This option is not recommended as a flood risk management measure due to the limited benefit for the flood immunity of Maclure Drive, as well feasibility issues such as undertaking works on private land and finding suitable flood-safe driveway alternatives.

7.3.3.7 Railway Culvert Upgrade at Railway Parade (Option L06)

Option Overview

Option L06 aims to reduce ponding upstream of the railway culvert and along Railway Parade. This location was identified as Hotspot 5 (see Section 6.2.536) and feedback from consultation with Council and the community indicated that this location is prone to blockage and pooling of flood waters.

This mitigation measure involved increasing the capacity of the culvert beneath the railway and as such, increase the flow conveyance of the area upstream of the railway.

Impact on Flood Liability

Figure 30 presents the 1% AEP event flood level impacts for the implementation of Option L06. Upstream of the railway, peak flood levels are reduced by up to 0.5 m with flood reduction extending to properties on the southern side of Railway Parade and lowering flood levels at two residential properties in the vicinity.

However, peak flood level increases extending approximately 1.5 km downstream to Jaorimin Creek are noted, which also affect Maclure Drive. With the implementation of Option L06, peak flood levels are increased by up to 0.08 m immediately downstream of the railway and are generally less than 0.02 m along the flow path downstream to Jaorimin Creek.

Summary and Recommendations

Option L06 has not been recommended as a flood risk management measure due to the downstream flood level increases, impacts affecting Maclure Drive, and also as Option E01 (see Section 7.3.3.2) has been recommended as a similar and less costly mitigation measure without downstream flood impacts.

7.3.3.8 Increasing conveyance capacity at Brayton Road (Option L07)

Option Overview

Option L07 aimed to increase the conveyance capacity for the Northern Flow Path at Brayton Road, identified as Hotspot 4 (see Section 6.2.4). At present, flow is conveyed beneath the roadway via a 0.45 m diameter pipe. When the capacity of this structure is reached, overland flow overtops Brayton Road. Option L07 has investigated implementing a bridge at Brayton Road by increasing the conveyance capacity to prevent inundation of the roadway. The existing pipe was replaced in the flood model with a bridge approximately 33 m long and changes to peak flood levels were assessed for the 1% AEP event. This measure was devised based on feedback from Council to improve the flood immunity of Brayton Road.

Impact on Flood Liability

Figure 31 presents the 1% AEP change in peak flood levels with the implementation of Option L07. Upstream of the roadway, peak flood levels are decreases extend approximately 72 m upstream with decreases of up to 0.15 m on Brayton Road. Downstream of Brayton Road, the increased flow conveyance beneath Brayton Road resulted in a peak flood level increases of up to 0.15 m to the west and decreases of up to 0.14 m to the east. Notably, the implementation of Option L07 does not significantly improve the flood immunity of Brayton Road during this event.

Constraints

As well as limited benefits to peak flood level impacts, Option L07 also has design and constructability constraints that limit the overall feasibility of the measure. These include:

- The cost of construction;
- Disruption caused by construction to residents, pedestrians and traffic; and
- Sizing of bridge deck width without encroaching on flow area.

Summary and Recommendations

This option is not recommended as a flood risk management measure due to the significant cost of construction and the limited improvements for the flood immunity of Brayton Road.

7.3.3.9 Introduction of a swale and retarding basins to the north of George Street (Option L09)

Option Overview

Consultation with the community highlighted that inundation from overland flow in the commercial and industrial land between George Street and Portland Avenue has resulted in above floor flooding. The existing flood mechanisms were identified as Hotspot 6 and investigated in Section 6.2.6. Accordingly, Option L09 has investigated implementing two retarding basins and swales upstream of the George Street low point in order to allow overland flow to more efficiently drain from the area. The basins were modelled with a combined storage capacity of approximately 2,200 m^3 and the swales were modelled as 3 m wide and 0.3 m deep. Figure 32 presents the indicative footprint of this measure.

Impact on Flood Liability

The 1% AEP peak flood level impacts for the implementation of Option L09 are shown on Figure 32. Upstream of George Street, minor peak flood level decreases of up to 0.3 m occur at the Marulan Motor Inn with areas no longer flooded within the grounds. Peak flood levels across George Street are lowered by up to 0.01 m and by up to 0.16 downstream of George Street as overland flow is attenuated by the proposed basin.

Constraints

While Option L09 results in minor peak flood level decreases on commercial land, this measure does not change the flood liability of any residential properties. Further, a key constraint pertaining to Option L09 is the development of two basins on privately owned land on the northwestern side of George Street and the associated newly flooded areas on this land. Consultation with multiple private landowners would be required, with significant cost of purchasing private land, before Option L09 can be implemented.

Summary and Recommendations

Option L09 has not been recommended flood risk management measure due to the limited expected benefits and the various constraints outlined above.

7.3.3.10 Portland Avenue and George Street Swale and Minor Drainage works (Option L10)

Option Overview

Option L10 aimed to address the inundation from overland flow of the industrial and commercial land between Portland Avenue and George Street. This measure lowered the existing swale along Portland Avenue and George Street by 0.3 m, added low bunding near the Portland Avenue and George Street intersection, and connected the existing stormwater network at the upstream side of George Street. Under present day conditions, the stormwater network outflows on the upstream side of George Street before flowing into the George Street cross drainage. In the Option L10 scenario, the existing stormwater network will connect straight into the cross-drainage structure rather than the current open flow discharge. The configuration of Option L10 is presented in Figure 33.

Impact on Flood Liability

The 20% and 1% AEP change in peak flood level with the implementation of Option L10 are shown in Figure 33. In the 20% AEP event, peak flood levels are reduced by up to 0.2 m in the area between Portland Avenue and George Street with large areas that are no longer flooded. Downstream of the Hume Highway peak flood levels are increased by up to 0.06 m.

Similarly in the 1% AEP event, peak flood levels reductions of up to 0.05 m occur in the area between Portland Avenue and George Street with large areas that are no longer flooded with the application of Option L10. Upstream of George Street, 1% AEP peak flood levels decrease by up to 0.02 m and by up to 0.12 m downstream of George Street.

Option L10 was simulated for a range of flood events with results presented in Table 31 below. This table shows minor benefits with one non-residential property no longer flooded above ground level in the 20% AEP event. An Average Annual Damages reduction of $23,700 is achieved with the implementation of Option L10.

Table 31: Economic Impact of Option L10

Design Event (AEP)	Number of Properties No Longer Flooded Above Ground[1]	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
20%	-1	0	-$31,000
10%	-1	0	-$74,200
5%	-1	0	-$74,100
2%	-1	0	-$31,000
1%	-1	0	-$47,400
0.5%	-1	0	-$31,000
0.2%	-1	0	-$31,000
PMF	0	0	-$70,400
Average Annual Damages (AAD)			-$23,700

[1] Above ground flooding refers to properties inundated by more than 0.1 m of flood water above ground level.

Cost Estimate

A preliminary cost estimate for Option L10 estimated that this measure would cost $1.8 million. Further cost estimate details are presented in Appendix D – Preliminary Cost Estimations. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit/Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damages reduction: $23,700
- NPV of reduction: $350,000
- Cost estimate of option: $1,800,000
- Benefit-Cost Ratio: 0.2

The benefit-cost ratio is 0.2, which means that the cost of Option L10 outweighs the economic benefit and as such, this measure cannot be justified on economic ground alone.

Constraints

Despite the benefits to commercial and industrial land associated with the implementation of Option L10, this measure has technical and administrative constraints that would need to be addressed in the planning stages. These include:

- The cost of construction;
- Consultation with land owners of the proposed works on the nature strip; and
- Disruption caused by construction to site occupants, pedestrians and traffic.

Community Acceptance

This measure was assessed after feedback from the community consultation highlighted this location as an area for concern for the community.

Summary and Recommendations

This option is unlikely to receive funding as part of the Floodplain Management Program due to the poor Benefit/Cost ratio which does not benefit residential development. As such, Option L10 has not been recommended for inclusion in the Floodplain Risk Management Plan.

7.3.3.11 Railway Culvert Upgrade at Hotspot 7 (Option L11)

Option Overview

Option L11 aimed to reduce ponding upstream of the railway culvert located at Hotspot 7 (see Section 6.2.7) as this location is prone to blockage and pooling of flood waters.

This mitigation measure involved increasing the capacity of the culvert beneath the railway and as such, increase the flow conveyance of the area upstream of the railway.

Impact on Flood Liability

Figure 34 presents the 1% AEP change in peak flood levels with the proposed culvert upgrade (Option L11). Upstream of the railway peak flood levels are reduced by up to 0.3 m with reductions extending approximately 200 m upstream of the structure. Downstream of the railway, peak flood levels are increased by up to 0.03 m, with increases extending approximately 300 m downstream to the confluence of Jaorimin Creek.

Summary and Recommendations

Option L11 has not been recommended as a flood risk management measure due to the widespread downstream flood level increases and also as Option E01 (see Section 7.3.3.2) has been recommended as a similar and less costly mitigation measure.

7.4 Multi-Criteria Assessment

The assessment of various flood modification measures is presented in Table 32. The measures are evaluated against various criteria and are scored in order to compare their relative advantages and disadvantages.

This evaluation enables options to be prioritised and is a useful tool for decision-makers and other stakeholders. It should be noted that scoring and ranking is only used for an indicative comparison and is not intended to act as a final verdict on the options. Also note that scoring and ranking may be updated following the public exhibition period, especially in regard to community acceptance.

The results of the analysis are presented in Table 32. Each criteria corresponds to a column and has been scored between -3 (lowest score) and 3 (highest score).

Table 32: Multi-criteria Assessment

Ref.	Mitigation Measure	Impact on road flooding	Impact on property	Impact on risk to life	Technical Feasibility	Community Acceptance	Economic Value	Environmental Impact	Total Score	Rank
PM01	Adoption of FPL and FPA	0	3	2	2	2	3	0	12	3
PM02	Adoption of FPCC approach in DCP	0	3	3	3	2	3	0	14	1
PM03	Update of Goulburn DCP	0	3	3	3	2	3	0	14	1
PM04	Updated Flood Certificates	0	0	2	1	1	1	0	5	7
PM05	Advice on Land-use Zoning	0	2	3	1	1	2	0	9	5
PM06	Voluntary Purchase	0	0	1	-1	-1	-3	0	-4	17
PM07	Voluntary House Raising	0	0	0	-1	-1	-3	0	-5	18
PM08	Flood Proofing	0	1	0	-2	0	1	0	0	11
RM01	Flood Prediction and Warning	0	1	1	-3	1	-2	0	-2	13
RM02	Community Education and Flood Awareness	0	1	3	1	2	2	0	9	5
RM03	Flood Signage	0	0	3	1	2	-1	0	5	7
RM04	Local Flood Plan Updates	0	1	1	1	1	1	0	5	7
L01	Railway Culvert Upgrade at Goulburn Street	-1	0	-1	-2	-2	-1	-1	-8	23
E01	Cleaning Debris at Railway Culverts	2	2	1	2	2	1	1	11	4
L02	Morris Place Drainage Upgrade	1	1	0	1	2	-3	0	2	10
L03	Morris Place Overland Flow Diversion	1	0	0	-1	1	-3	0	-2	13
L05	Increasing conveyance capacity at Maclura Drive	0	0	0	-1	0	-3	-1	-5	18
L05A	Removing embankments downstream of Maclura Drive	0	0	-1	-1	1	-1	-1	-3	16
L06	Railway Culvert Upgrade at Railway Parade	-1	1	0	-2	-1	-2	-1	-6	21
L07	Increasing conveyance capacity at Brayton Road	0	0	0	-1	0	-3	-1	-5	18
L09	Introduction of a swale and retarding basin to the north of Geroge Street	1	1	0	-2	0	-1	-1	-2	13
L10	Portland Avenue and George Street Swale and Minor Drainage works	1	1	0	-1	1	-3	0	-1	12
L11	Railway Culvert Upgrade at Hotspot 7	0	0	0	-2	0	-3	-1	-6	21

8.DRAFT FLOOD RISK MANAGEMENT PLAN

8.1 Plan Objectives

The objective of the Floodplain Risk Management Plan is to address existing, future and continuing flood risk for the Marulan area in accordance with Flood Risk Management Manual (NSW Government, 2023) (Reference 20)

The Plan aims to achieve the following overarching objectives:

- Reduce the flood hazard and risk to people and property, now and in the future;
- Protect, maintain and where possible enhance the floodplain environment; and
- Ensure floodplain risk management decisions integrate social, economic and environmental considerations.

This DRAFT plan is proposed for consideration only, and it is expected that stakeholder input will modify the outcomes and recommendations in this plan.

8.2 Recommended Flood Management Measures

The flood management measures recommended for implementation are presented in Table 33. The measures have been prioritised with high, medium and low classifications as defined below:

- High – can be undertaken in the short term (<12 months) with minimal cost and/or have the potential to provide significant reductions in flood risk;
- Medium – can be undertaken in the medium term (1 to 5 years), require input from other studies or investigations, provide reductions in flood risk but could be expensive;
- Low – measures that are unlikely to be feasible to implement in the next 5 years or that are likely subject to significant financial constraints.

Responsibility for implementation and cost estimates are also presented, along with the relevant section of this report which provides details of each option.

Table 33: DRAFT Flood Risk Management Plan

Flood Management Measure	Section	Priority	Cost	Responsibility
Property Modification Measure				
Adoption of Flood Planning Level and Flood Planning Area	7.1.2.2	High	Council cost estimate	Council
Adoption of Flood Planning Constraint Categories in Council's DCP	7.1.2.3	High	Council cost estimate	Council
Update of Goulburn Development Control Plan	7.1.2.3	High	Council cost estimate	Council
Updated 10.7 Planning Certificates	7.1.2.5	High	Council cost estimate	Council
Advice on Land-use Zoning Considering Flooding	7.1.2.4	Medium	Council cost estimate	Council
Review of Future Development Areas	7.1.2.7	Medium	Council cost estimate	Council
Response Modification Measures				
Develop a LGA wide community flood education program	7.2.3	Medium	Council/SES cost estimate	Council / NSW SES
Install Flood Signage	7.2.4	Medium	~$35,000	Council
Update Local Flood Plan	7.2.5	High	SES Cost Estimate	NSW SES
Flood Modification Measures				
Clearing Debris at Railway Culverts	7.3.3.2	High	Council/ARTC cost estimate	ARTC

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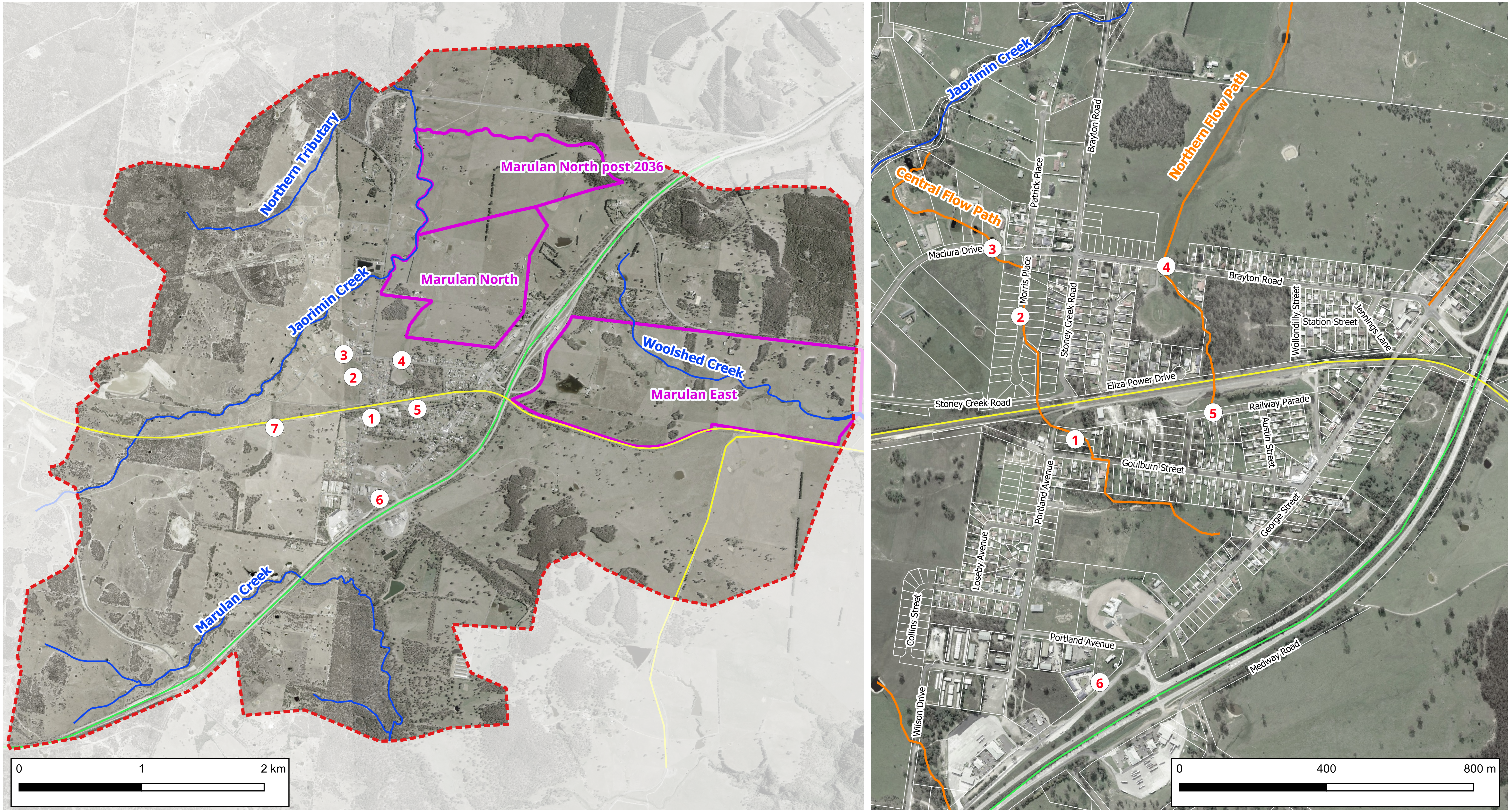
FIGURES

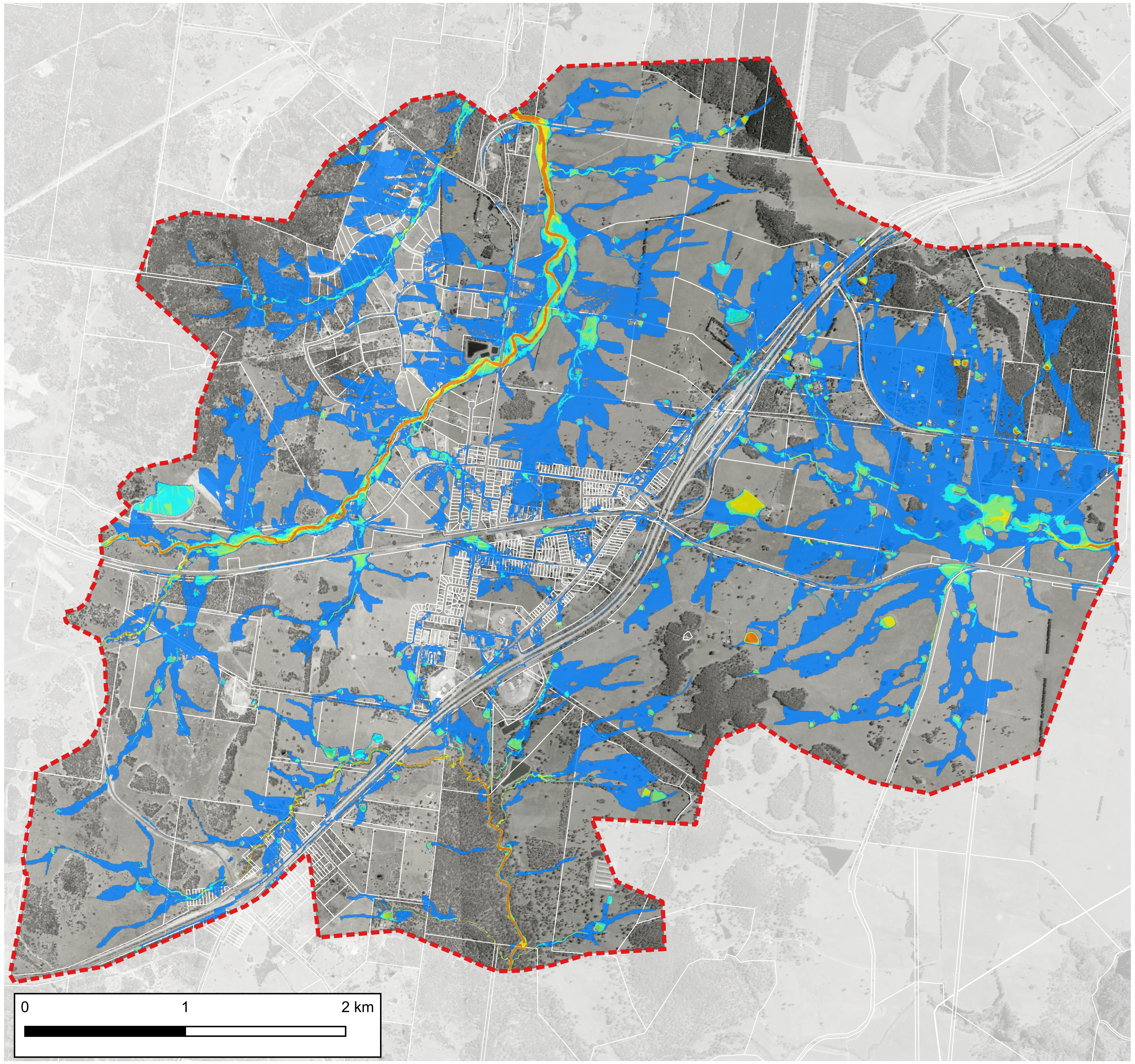


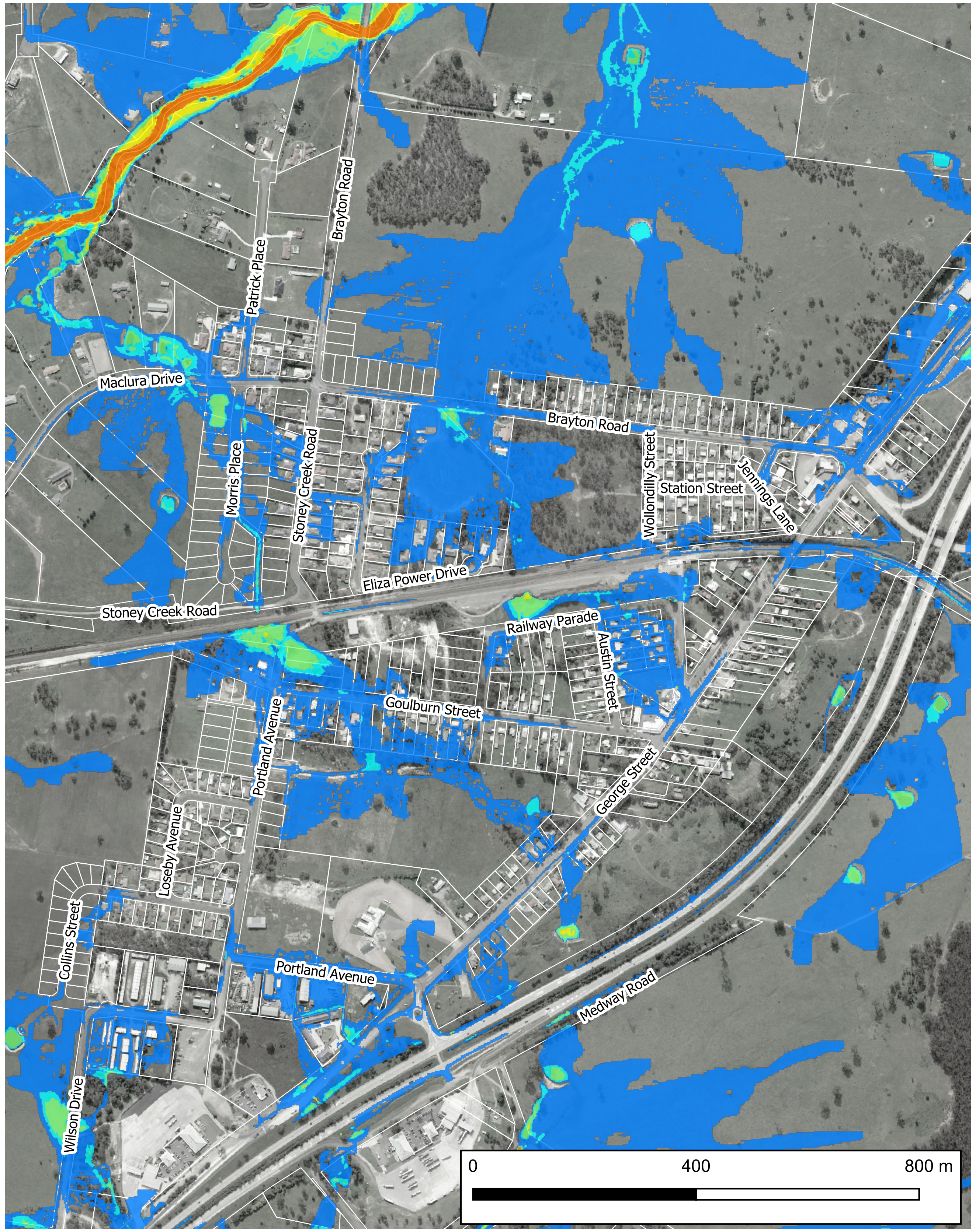
Legend

- Hotspot Locations
- Key Overland Flow Paths*
- Hume Highway
- ARTC Railway
- Creeks and Tributaries
- Cadastral Boundaries
- 2D Model Boundary
- Potential Future Development Areas

* Please note that the exact alignment of the overland flow paths will be shown in the final hydraulic model results. The alignment of the overland flow paths shown above have been used purely for the purpose of reporting.

TITLE: **Marulan Study Area**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **11-2024**	SCALE: **1:30,000**	FIGURE No. **01**





Legend

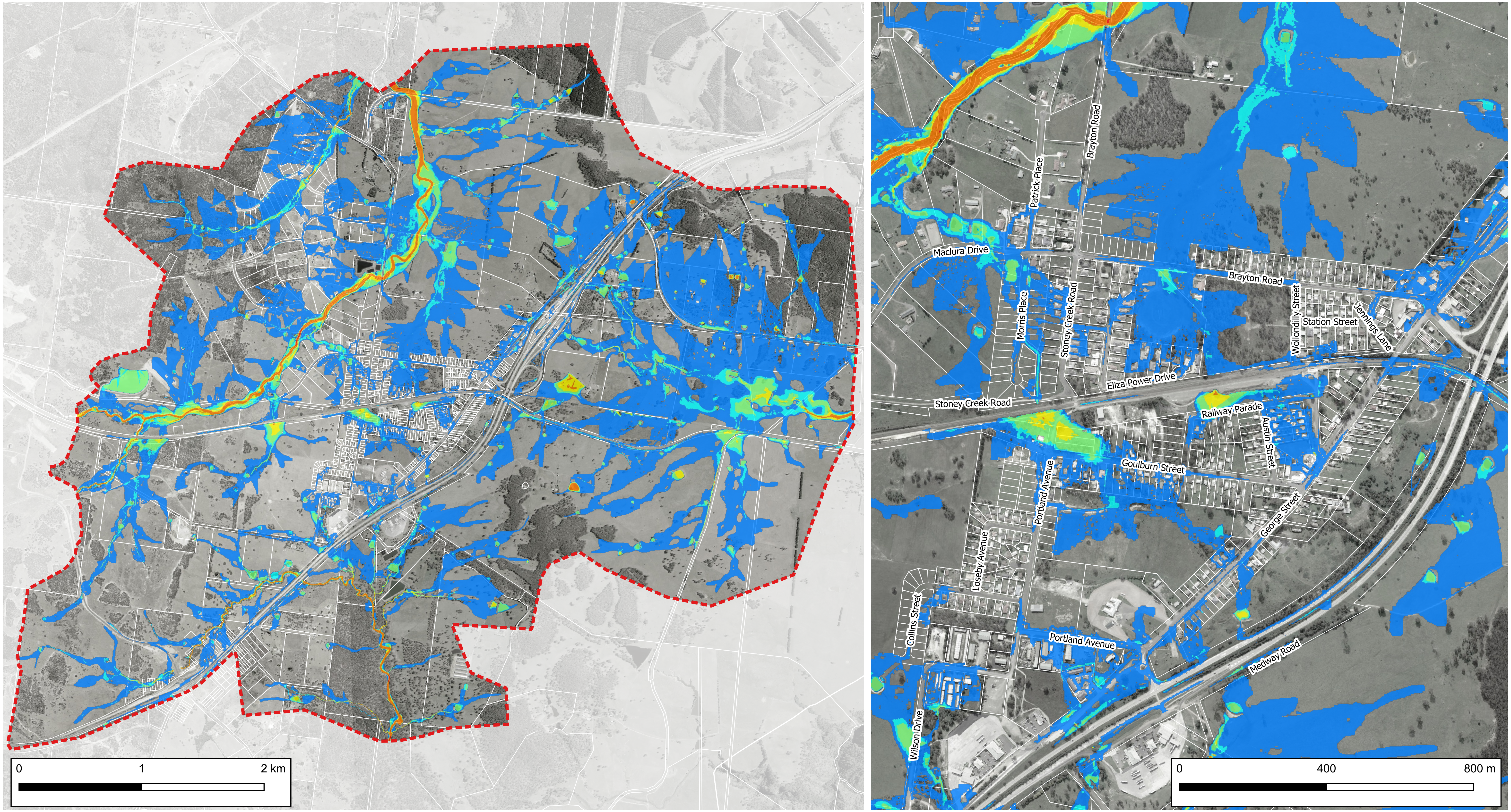
Flood Hazard Category (AEM)

- H1
- H2
- H3
- H4
- H5
- H6
- 2D Model Boundary
- Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Flood Hazard – 5% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **02**

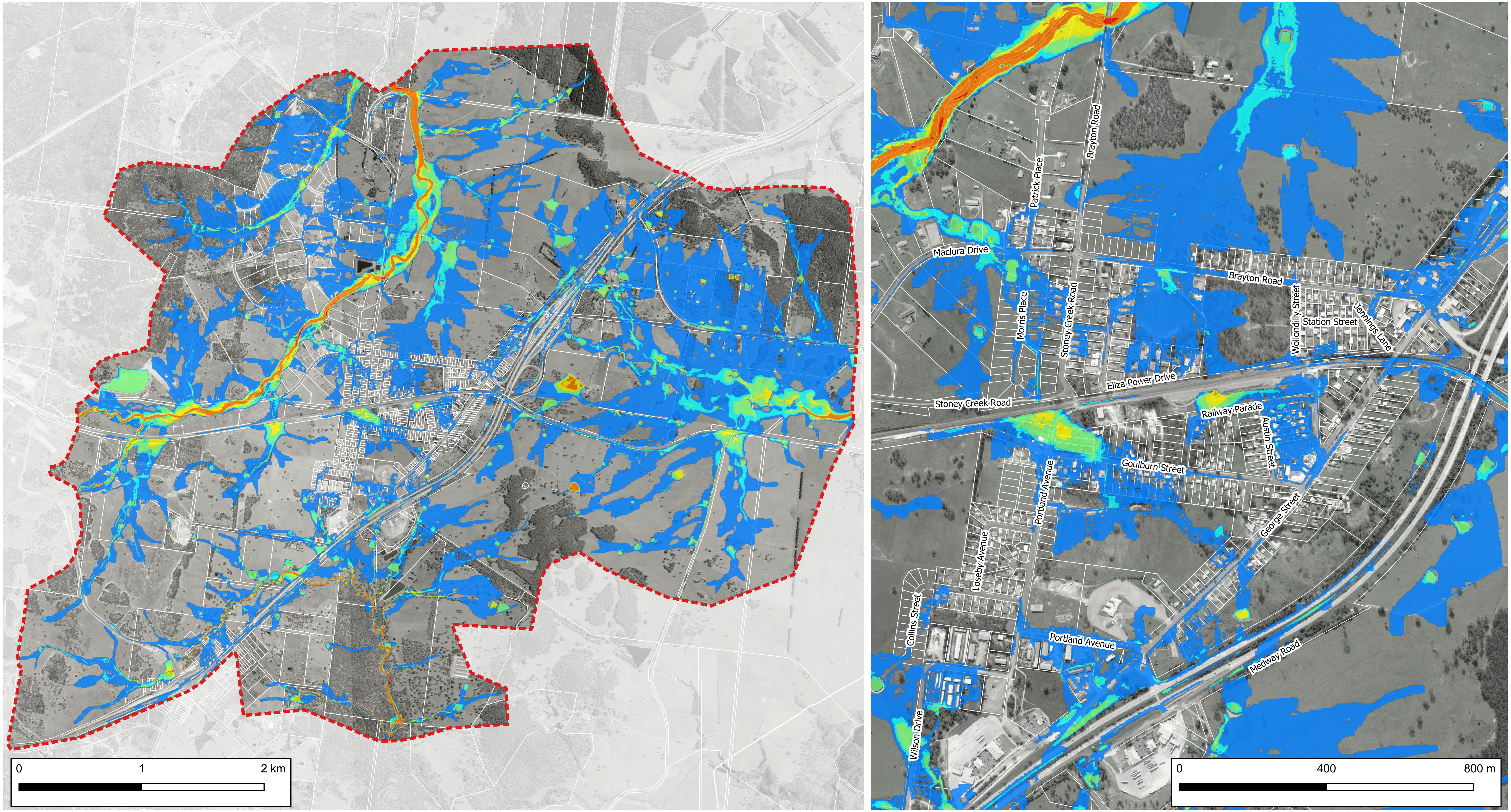


Legend

Flood Hazard Category (AEM)

- H1
- H2
- H3
- H4
- H5
- H6
- 2D Model Boundary
- Cadastral Boundaries

TITLE: **Flood Hazard – 1% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **03**



Legend

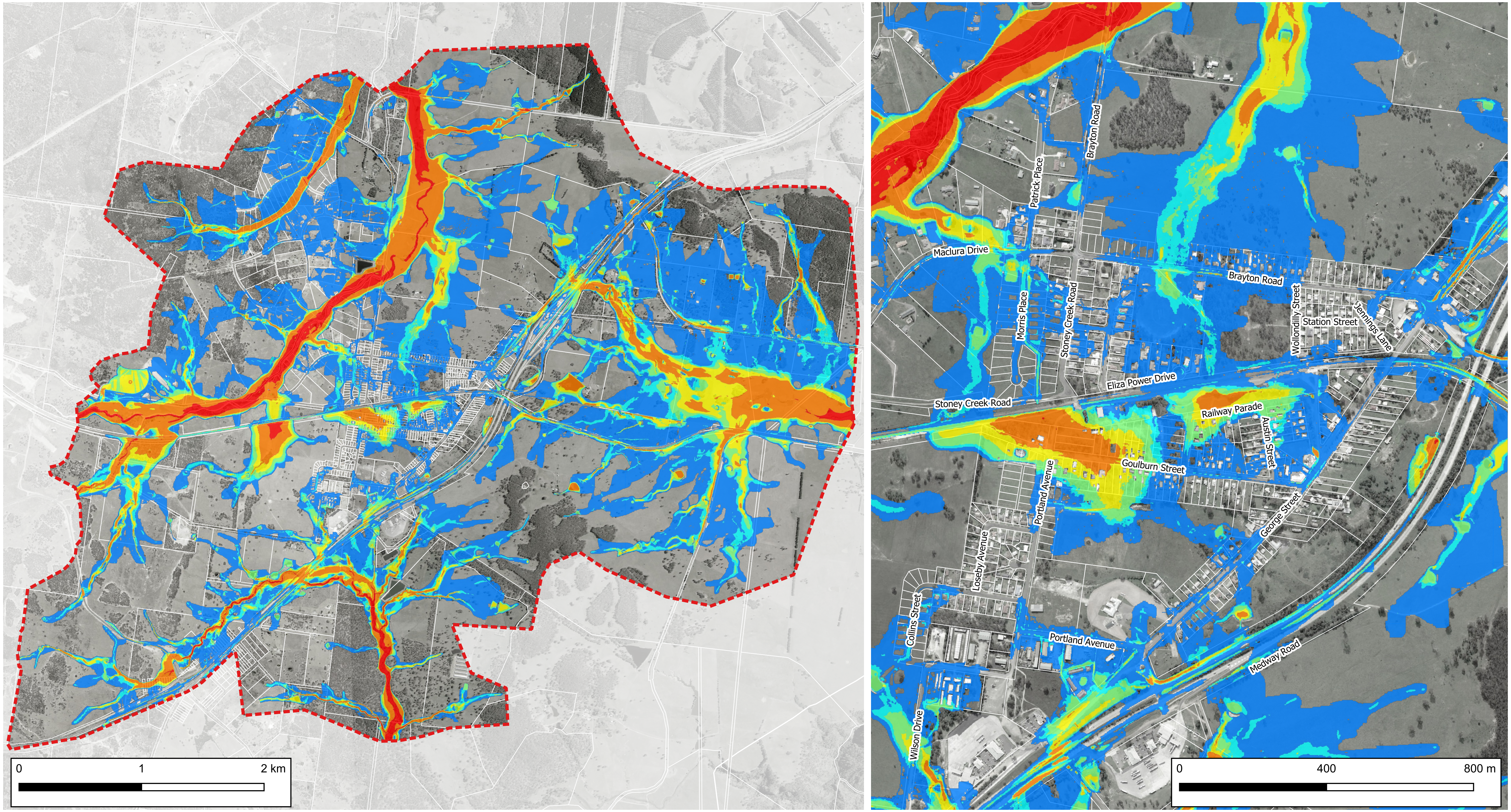
Flood Hazard Category (AEM)

- H1
- H2
- H3
- H4
- H5
- H6
- 2D Model Boundary
- Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Flood Hazard – 0.2% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **04**



Legend

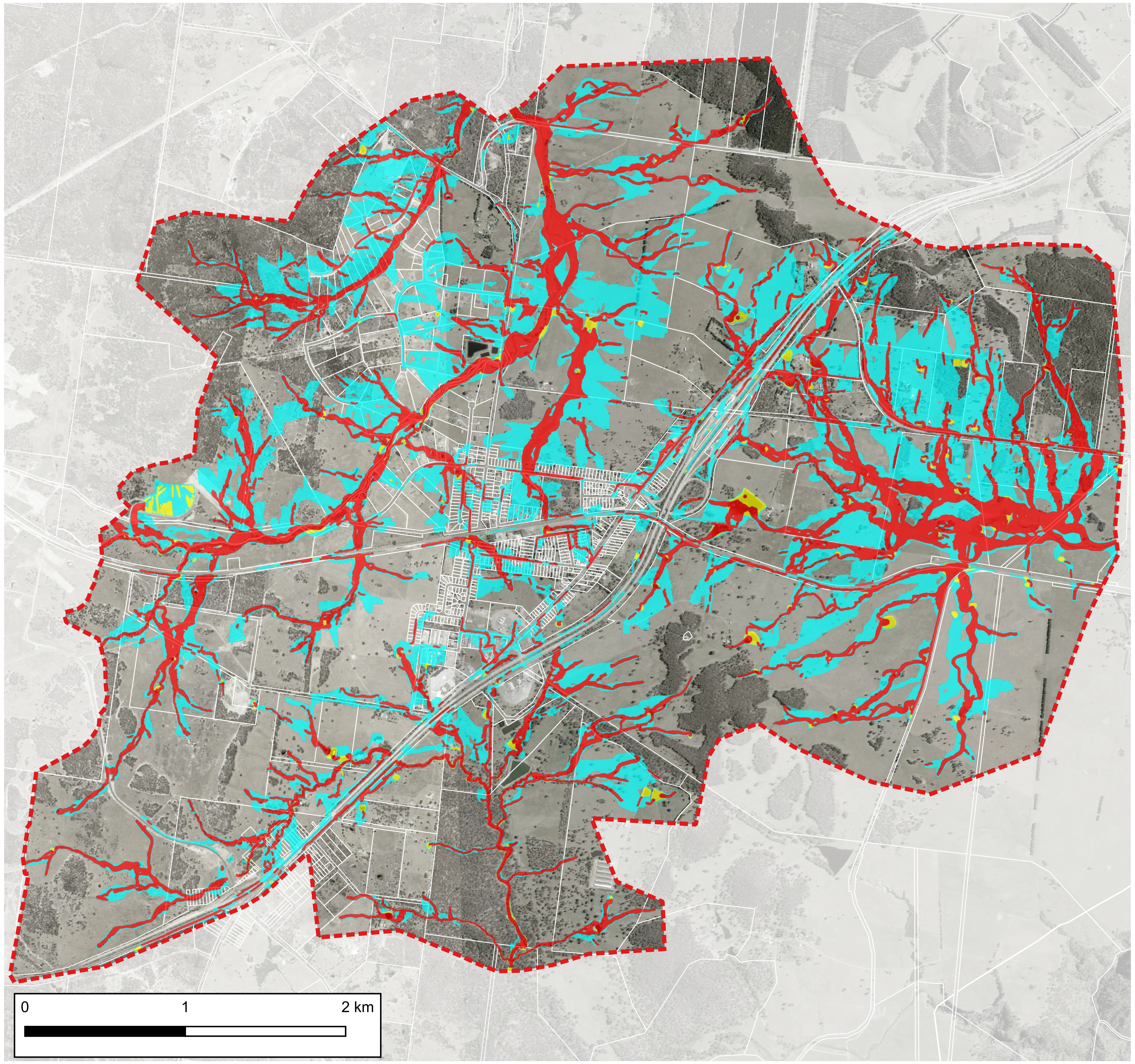
Flood Hazard Category (AEM)

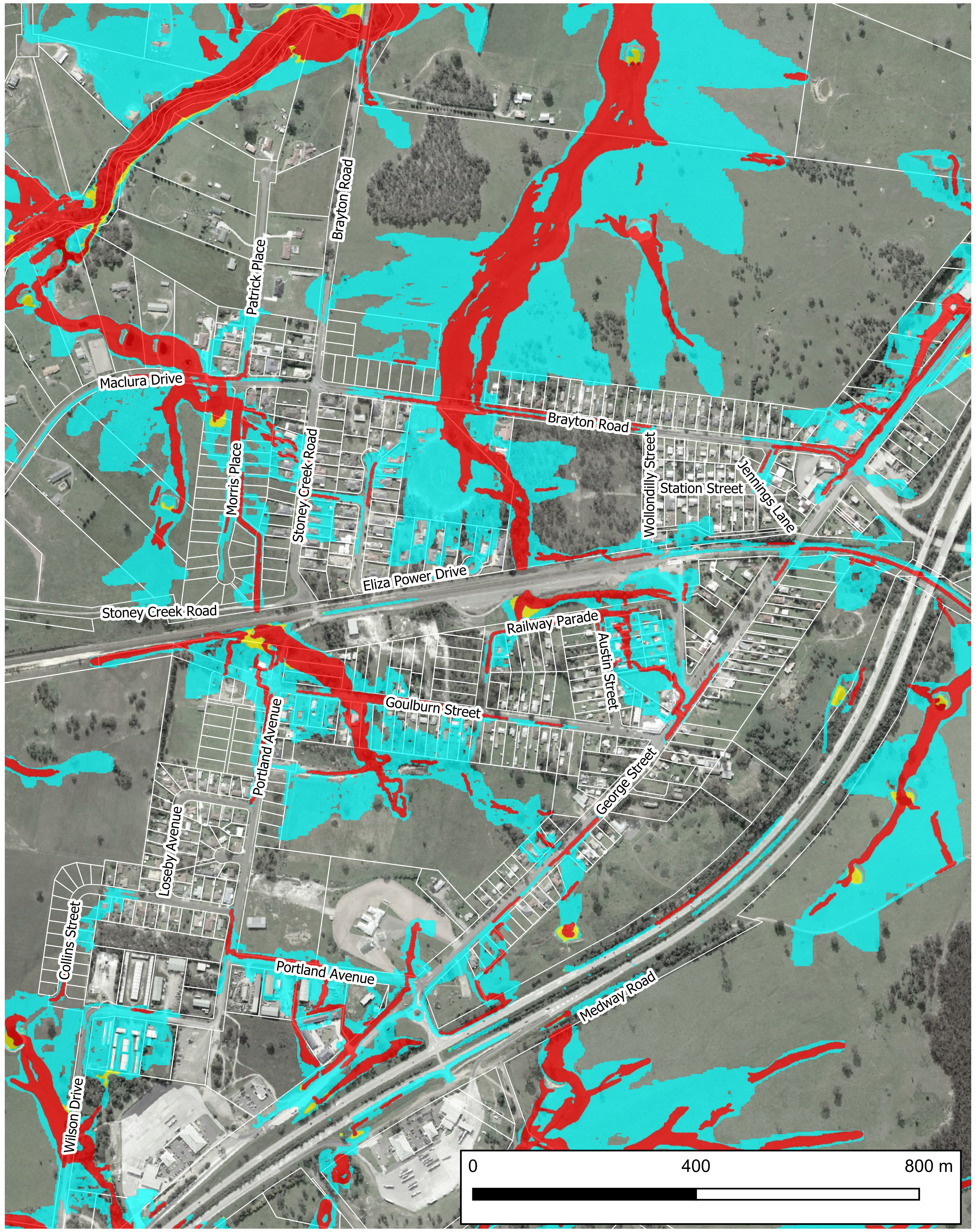
- H1
- H2
- H3
- H4
- H5
- H6
- 2D Model Boundary
- Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Flood Hazard – PMF Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **05**





Legend

Flood Function
- Flood Fringe
- Flood Storage
- Floodway

2D Model Boundary
Cadastral Boundaries

N
W E
S

grc HYDRO

TITLE: **Flood Function – 5% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **06**

Legend

Flood Function

- Flood Fringe
- Flood Storage
- Floodway

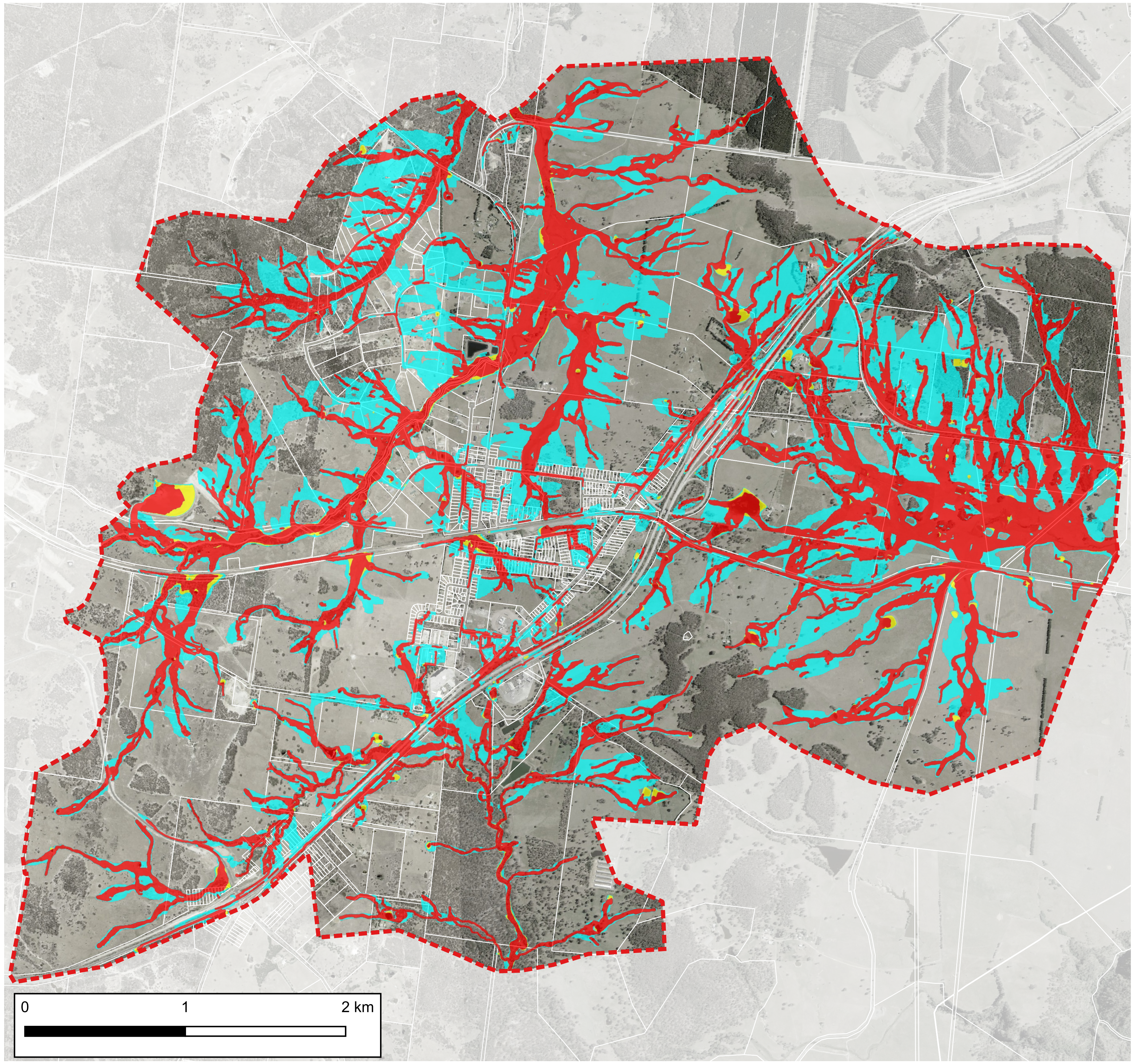
2D Model Boundary

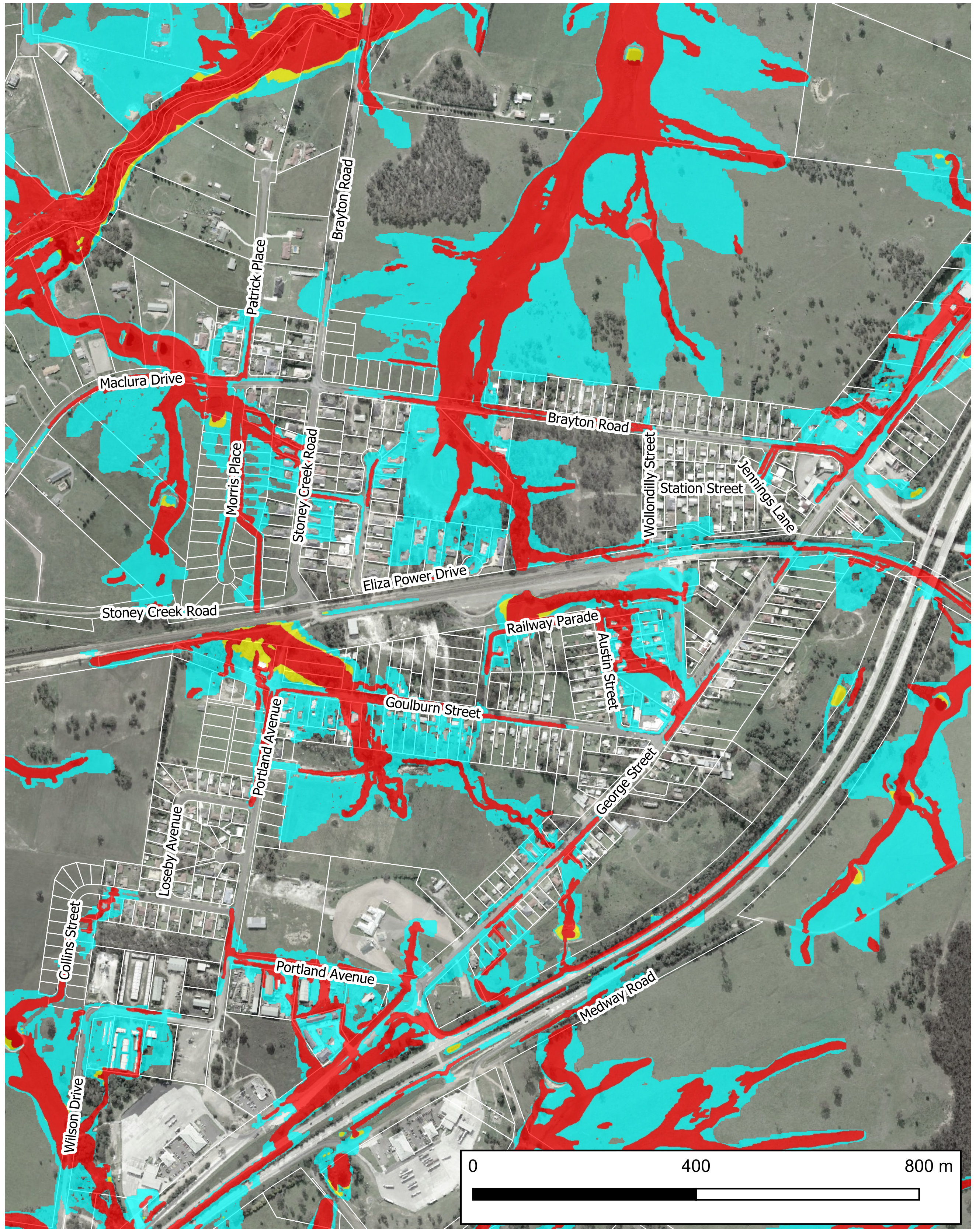
Cadastral Boundaries

N W E S

grc HYDRO

TITLE: Flood Function – 1% AEP Design Event	PROJECT: Marulan Flood Study	PROJECT No. 210048	DATE: 05-2024	SCALE: 1:30,000	FIGURE No. 07





Legend

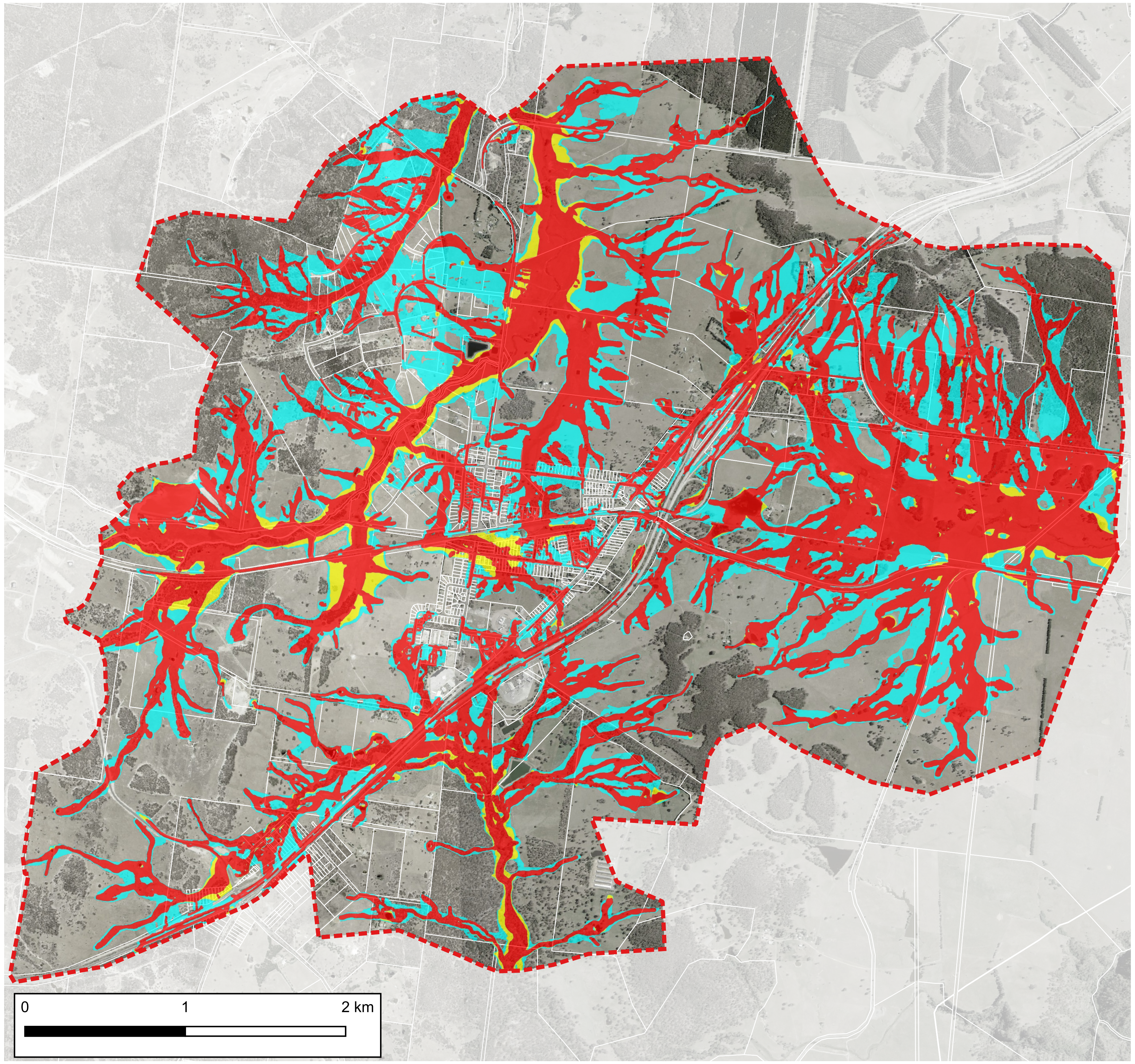
Flood Function
Flood Fringe
Flood Storage
Floodway

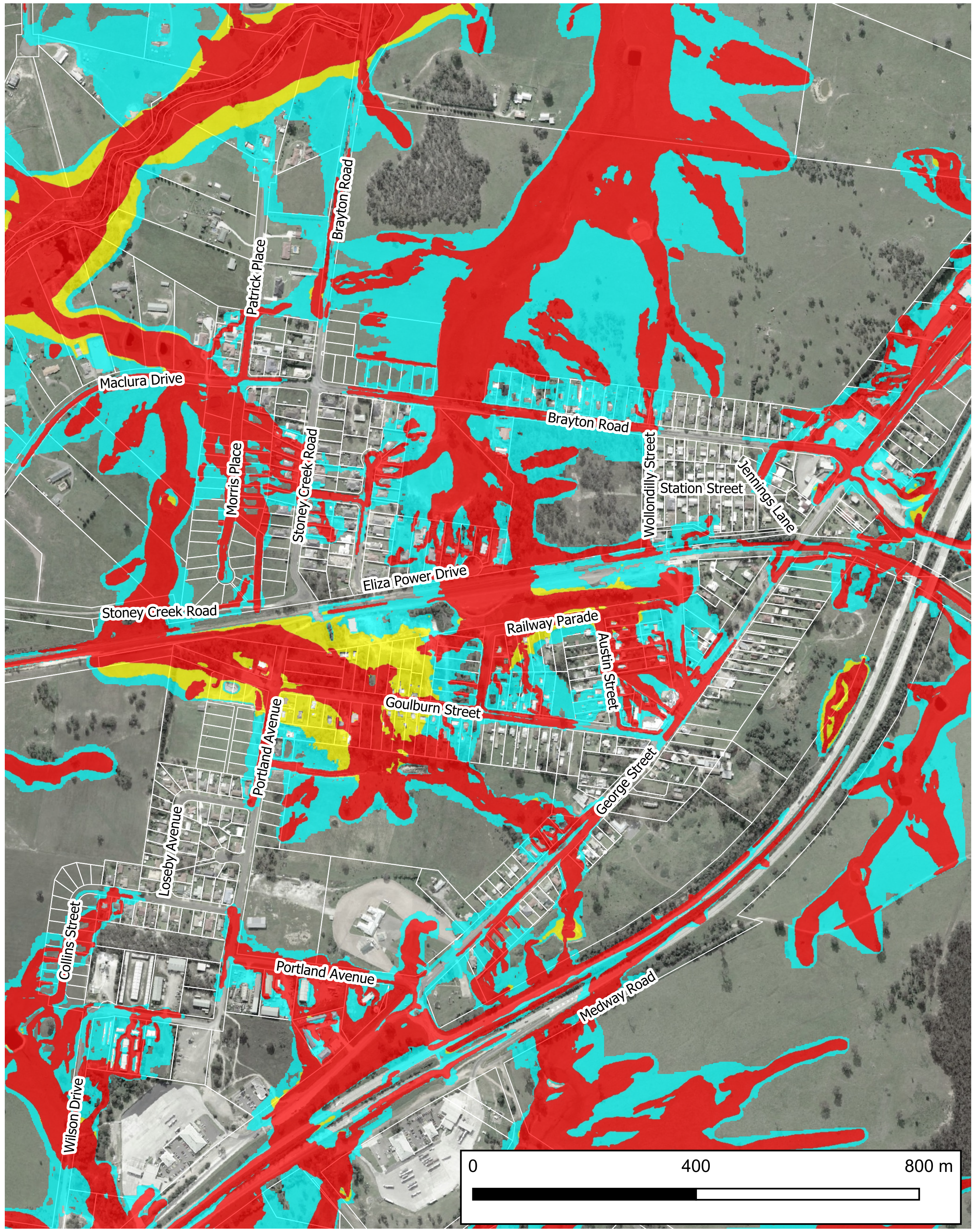
2D Model Boundary
Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Flood Function – 0.2% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **08**





Legend

Flood Function

- Flood Fringe
- Flood Storage
- Floodway

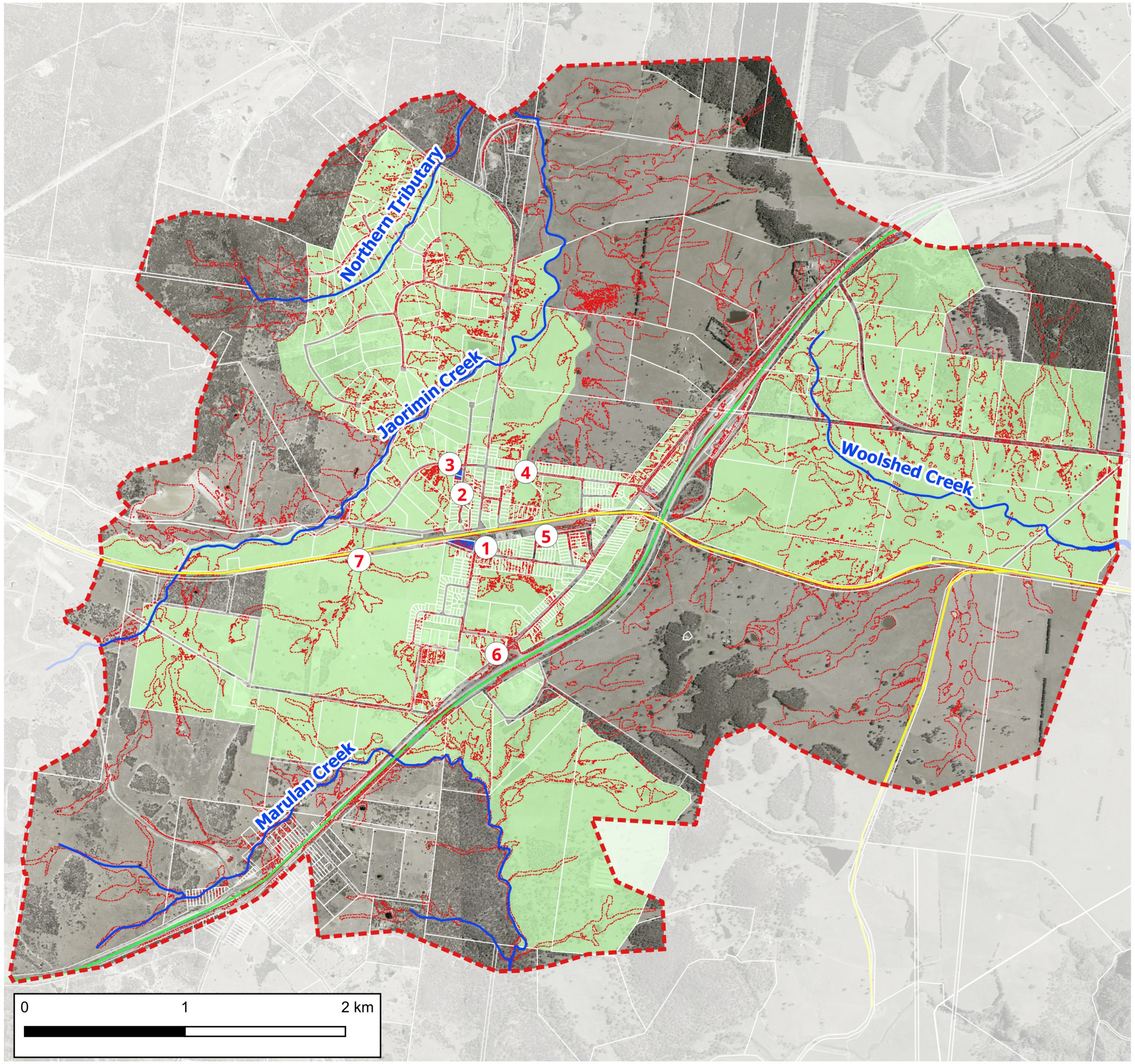
2D Model Boundary

Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Flood Function – PMF Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **09**



Legend

- Hotspot Locations
- Hume Highway
- ARTC Railway
- Creeks and Tributaries
- 2D Model Boundary
- Cadastral Boundaries

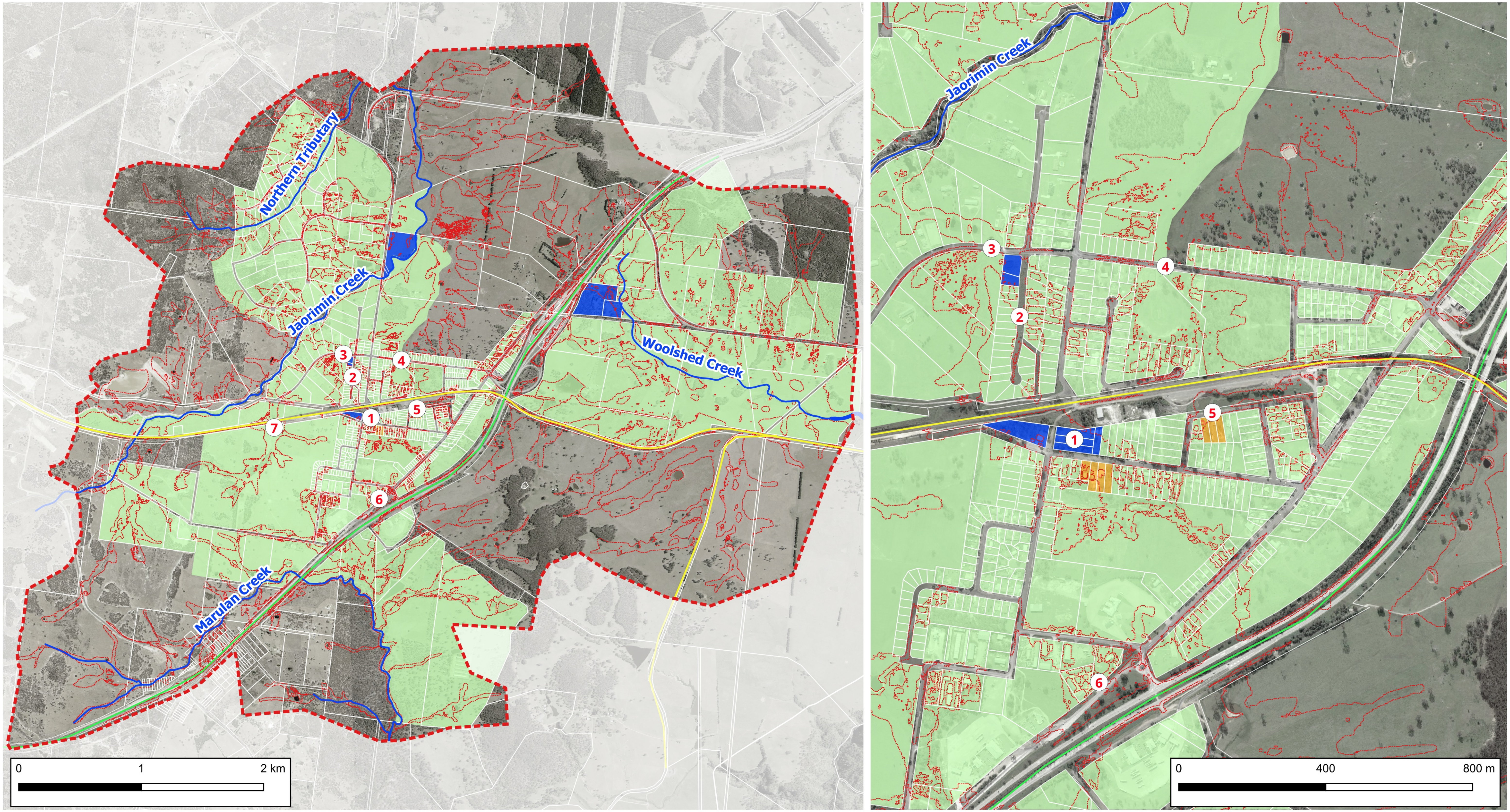
FERC

- Low Flood Island (FIS)
- Low Trapped Perimeter (FIS)
- High Flood Island (FIE)
- High Trapped Perimeter (FIE)
- Overland Escape Route (FEO)
- Rising Road (FER)
- Indirect Consequence (IC)
- No Flood Impact
- Flood Extent

N W E S

grc HYDRO

TITLE: **Flood Emergency Response – 5% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **10**



Legend

- Hotspot Locations
- Hume Highway
- ARTC Railway
- Creeks and Tributaries
- 2D Model Boundary
- Cadastral Boundaries

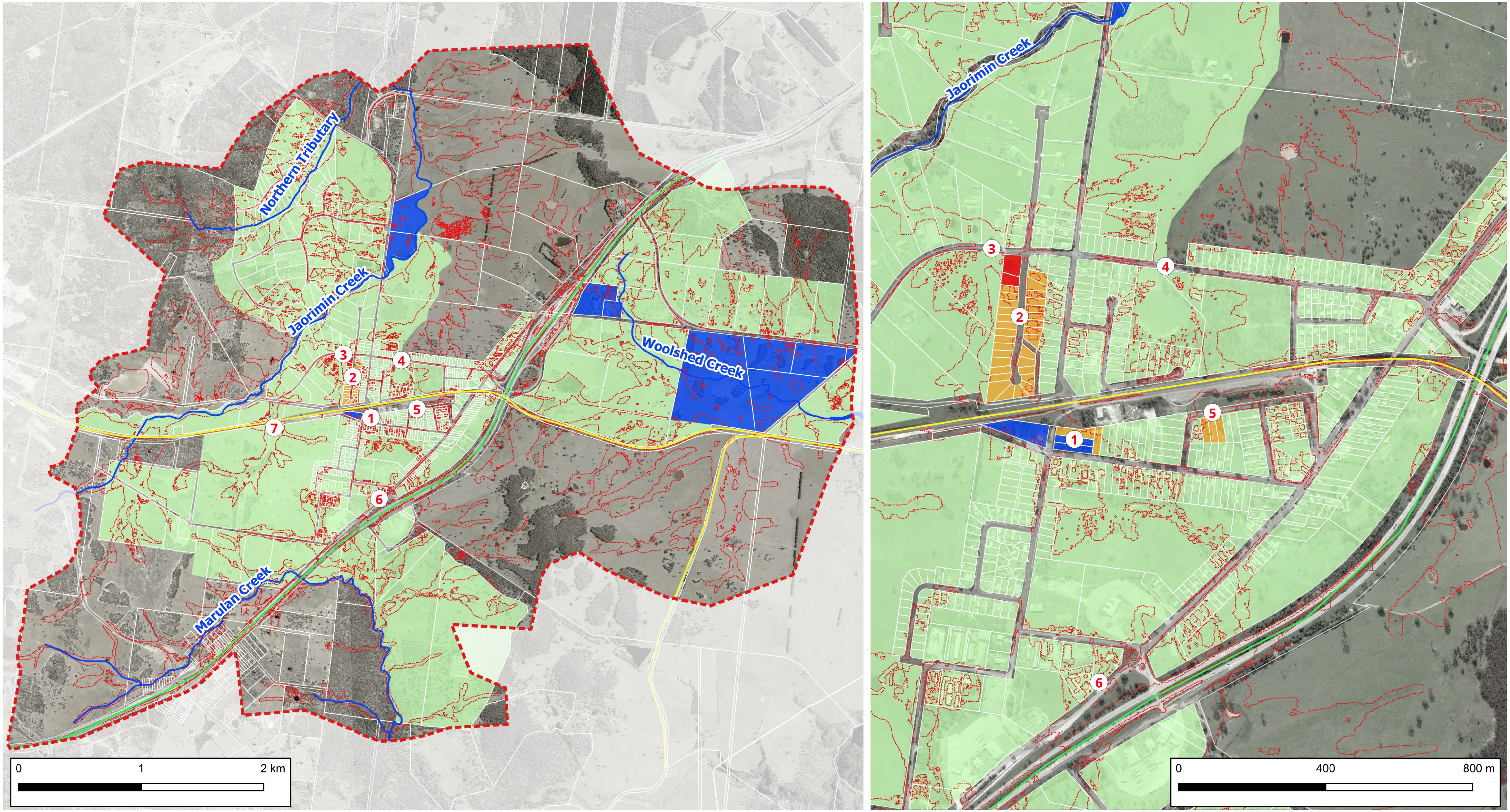
FERC

- Low Flood Island (FIS)
- Low Trapped Perimeter (FIS)
- High Flood Island (FIE)
- High Trapped Perimeter (FIE)
- Overland Escape Route (FEO)
- Rising Road (FER)
- Indirect Consequence (IC)
- No Flood Impact
- Flood Extent

N
W
E
S

grc HYDRO

TITLE: **Flood Emergency Response – 1% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **11**



Legend

- Hotspot Locations
- Hume Highway
- ARTC Railway
- Creeks and Tributaries
- 2D Model Boundary
- Cadastral Boundaries

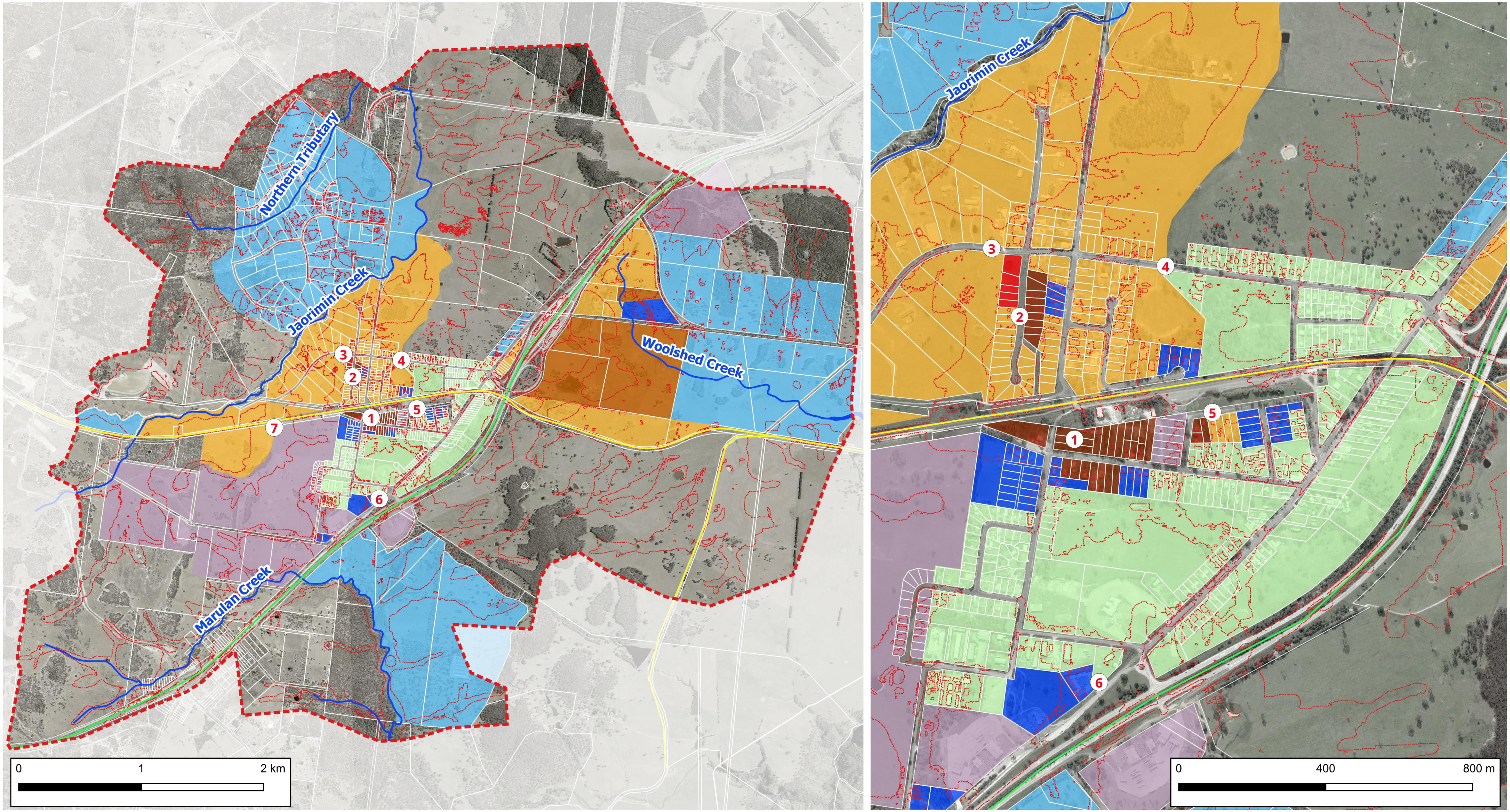
FERC

- Low Flood Island (FIS)
- Low Trapped Perimeter (FIS)
- High Flood Island (FIE)
- High Trapped Perimeter (FIE)
- Overland Escape Route (FEO)
- Rising Road (FER)
- Indirect Consequence (IC)
- No Flood Impact
- Flood Extent

N
W E
S

grc HYDRO

TITLE: **Flood Emergency Response – 0.2% AEP Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **12**



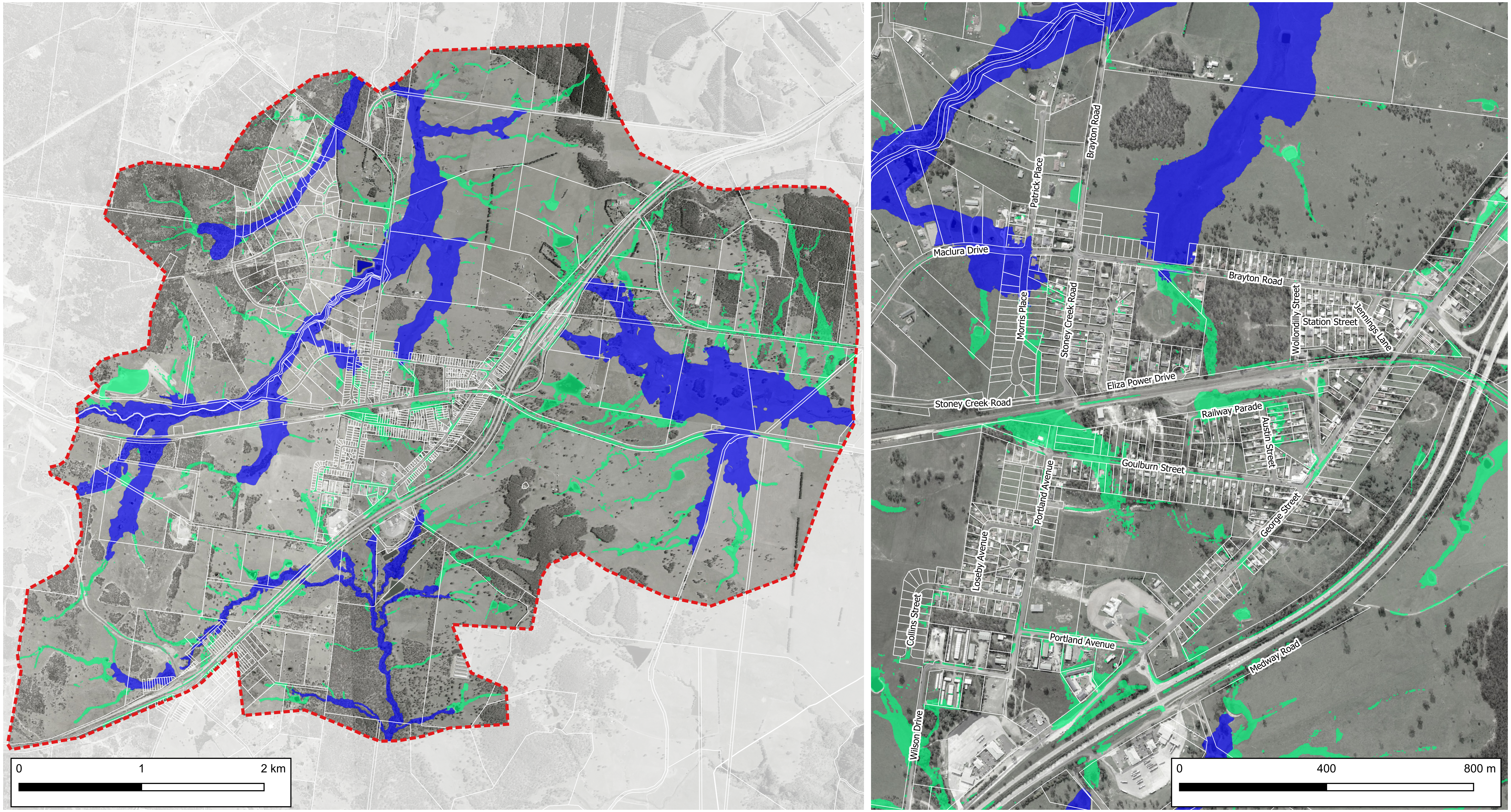
Legend

Hotspot Locations	FERC	Overland Escape Route (FEO)
Hume Highway	Low Flood Island (FIS)	Rising Road (FER)
ARTC Railway	Low Trapped Perimeter (FIS)	Indirect Consequence (IC)
Creeks and Tributaries	High Flood Island (FIE)	No Flood Impact
2D Model Boundary	High Trapped Perimeter (FIE)	Flood Extent
Cadastral Boundaries		

N
W E
S

grc HYDRO

TITLE: **Flood Emergency Response – PMF Design Event**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **13**



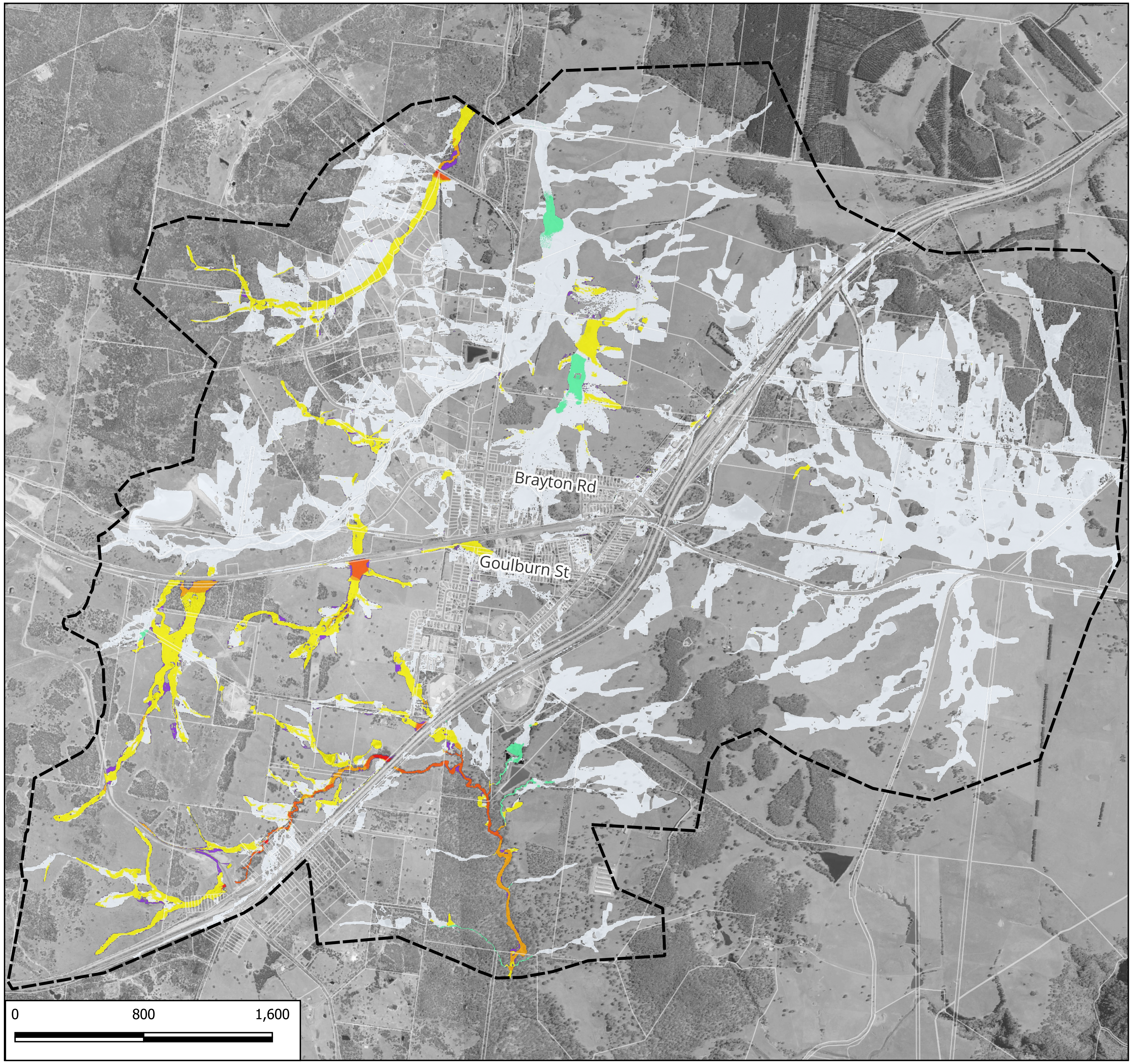
Legend

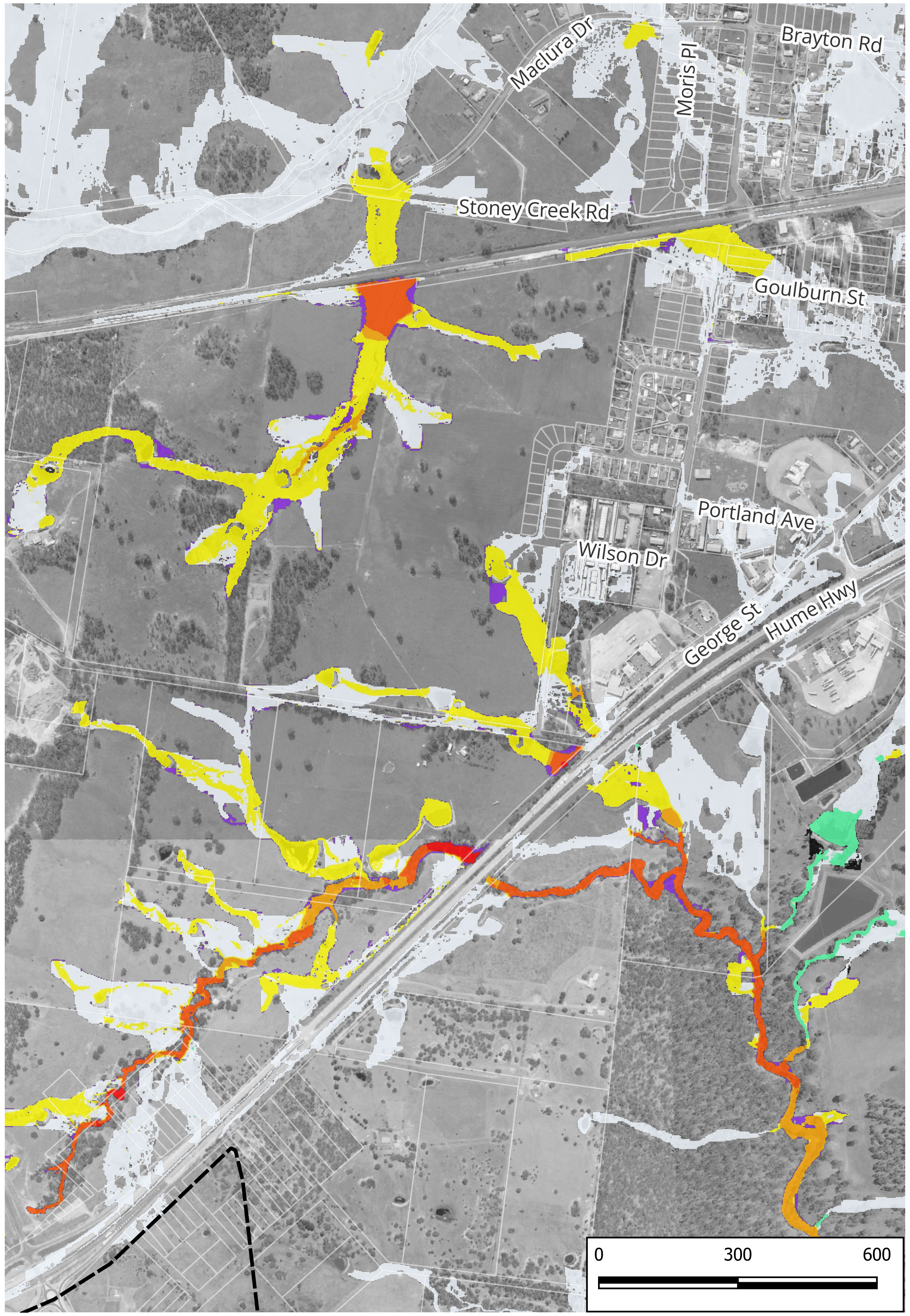
Mainstream Flooding FPA
Overland Flow Flooding FPA
2D Model Boundary
Cadastral Boundaries

N W E S

grc HYDRO

TITLE: **Preliminary Flood Planning Area**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **05-2024**	SCALE: **1:30,000**	FIGURE No. **14**





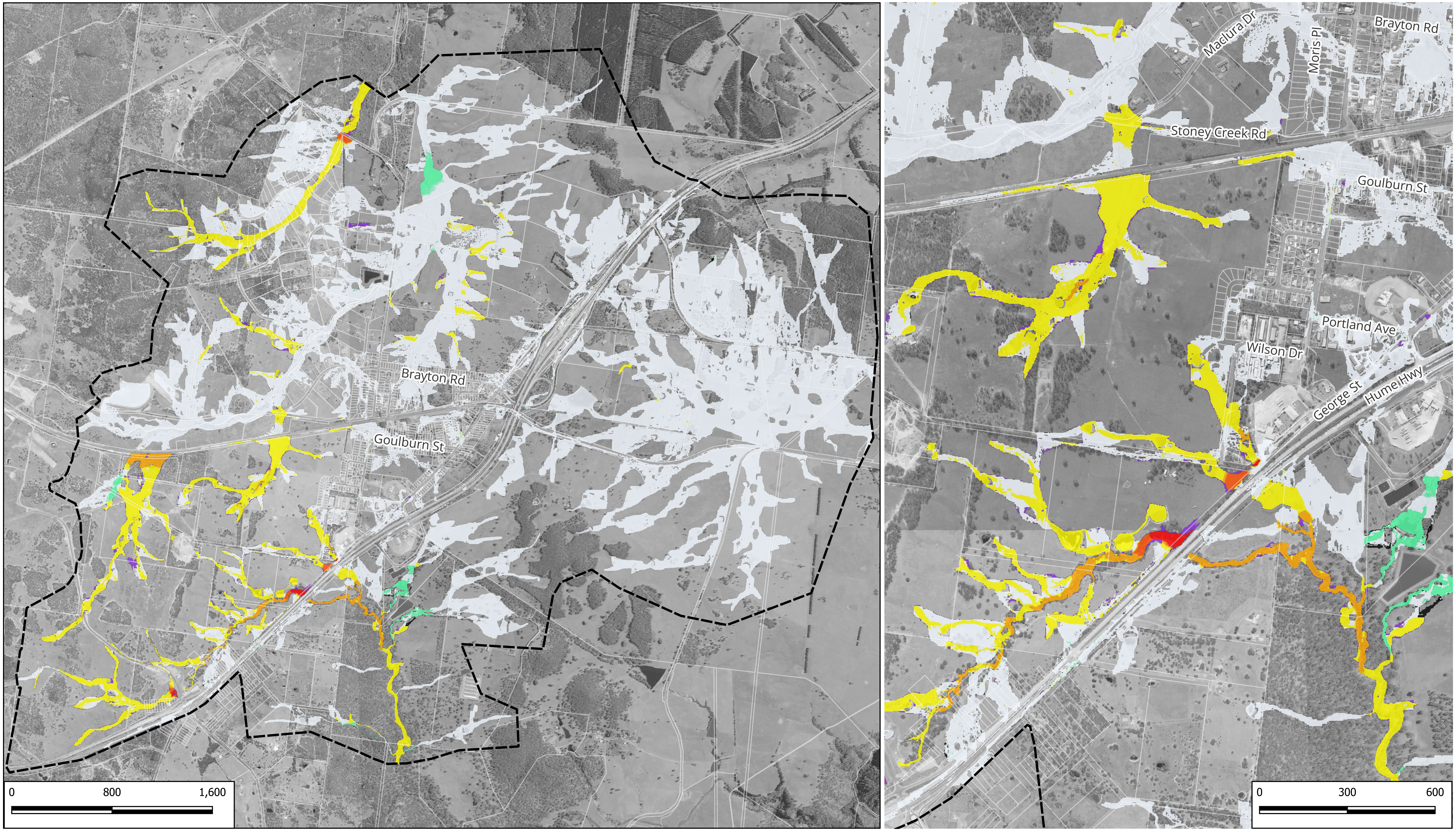
Cadastral Boundaries
2D Model Boundary

Impact (m)
- < -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
- No Longer Flooded
- Newly Flooded

N W E S

TITLE:	**Cumulative Impact Assessment - 5% AEP Flood Level Impact**	PROJECT:	**Marulan Floodplain Risk Management Study & Plan**	PROJECT No.	**210048**	DATE:	**09-2024**	SCALE:	**1:28,000**

FIGURE No. **15**



Cadastral Boundaries
2D Model Boundary

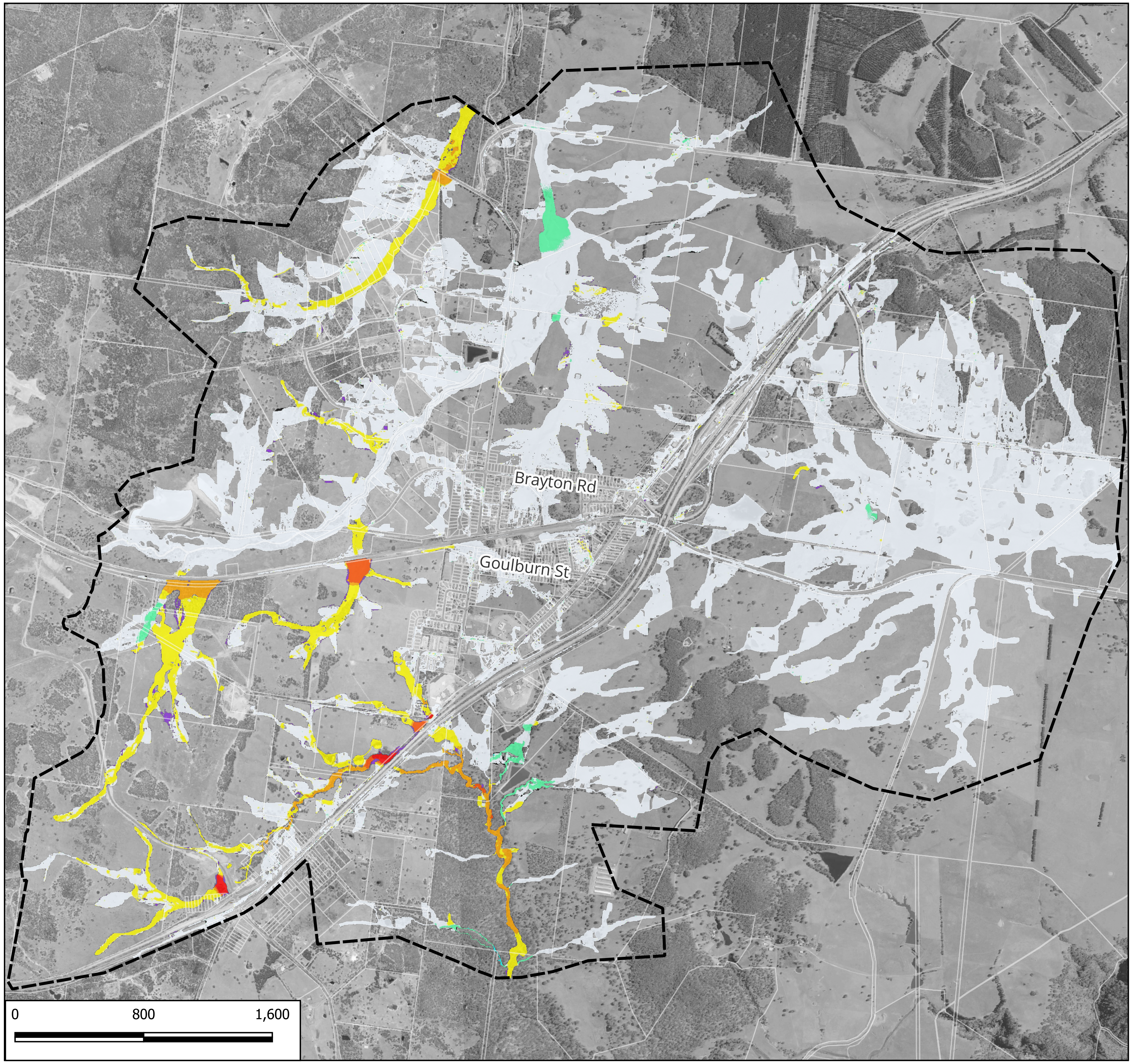
Impact (m)

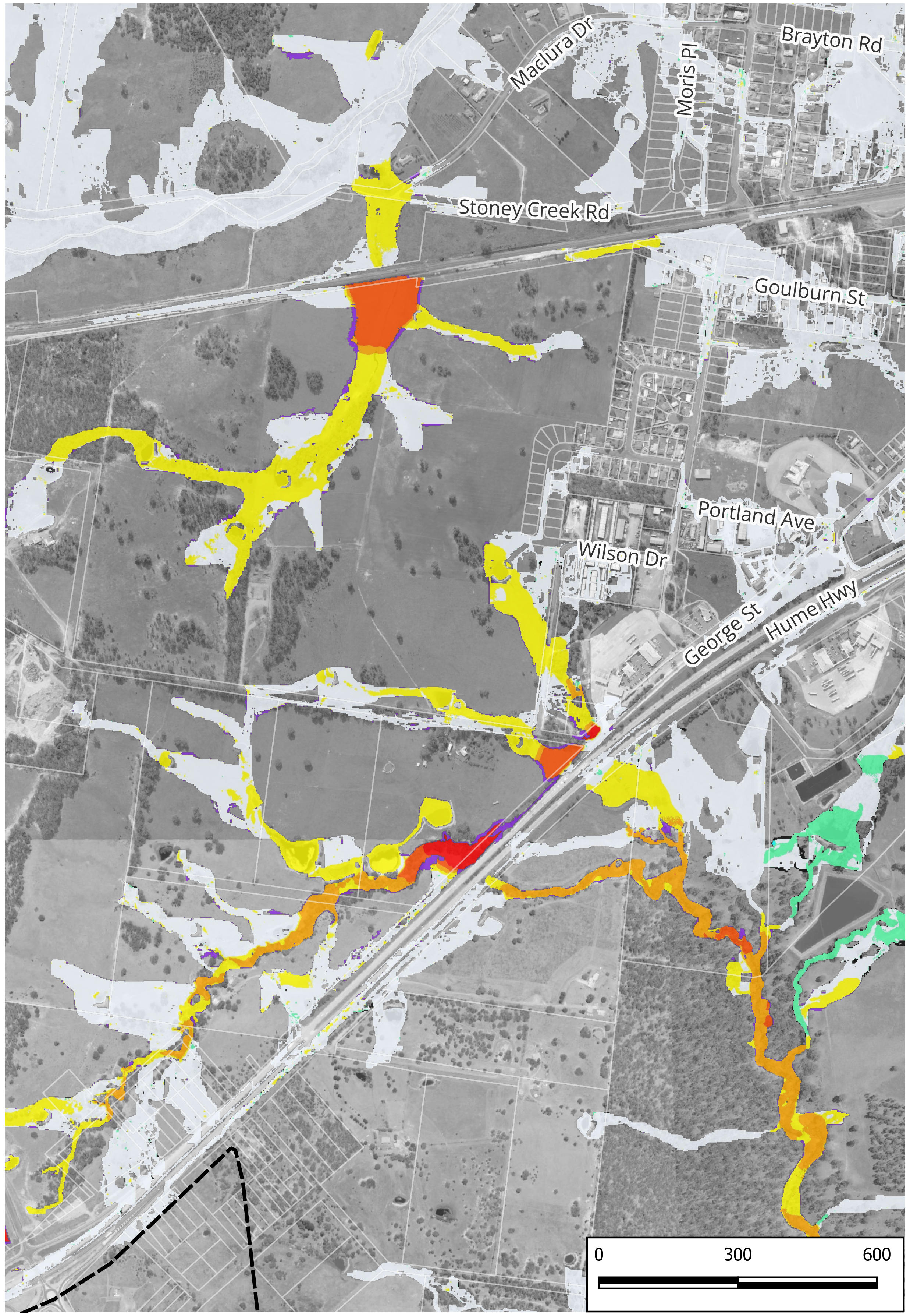
- < -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to -0.01
- No Impact
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: **Cumulative Impact Assessment - 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:28,000**	FIGURE No. **16**





Cadastral Boundaries
2D Model Boundary

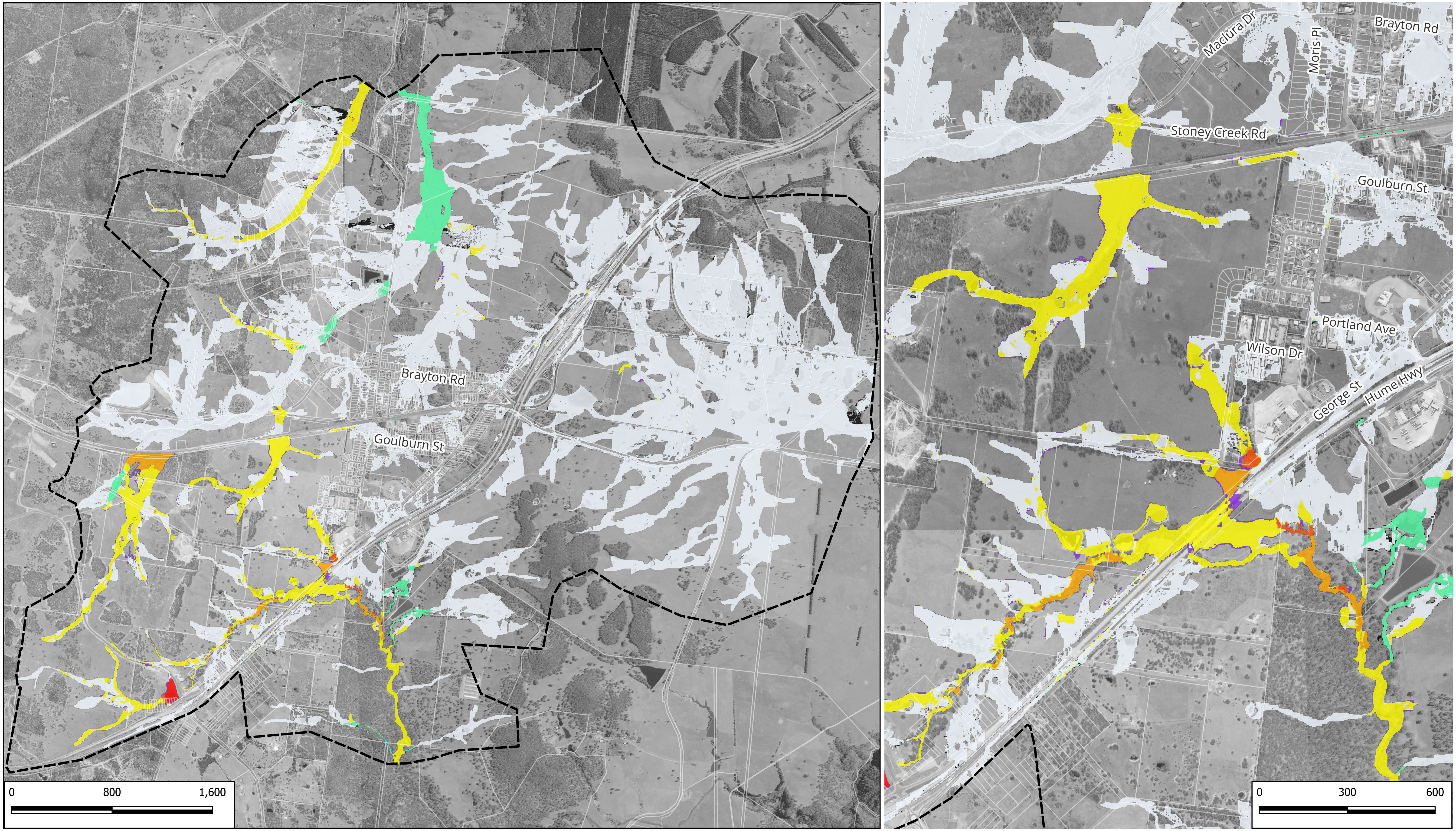
Impact (m)

- < -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
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: **Cumulative Impact Assessment - 0.5% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:28,000**	FIGURE No. **17**



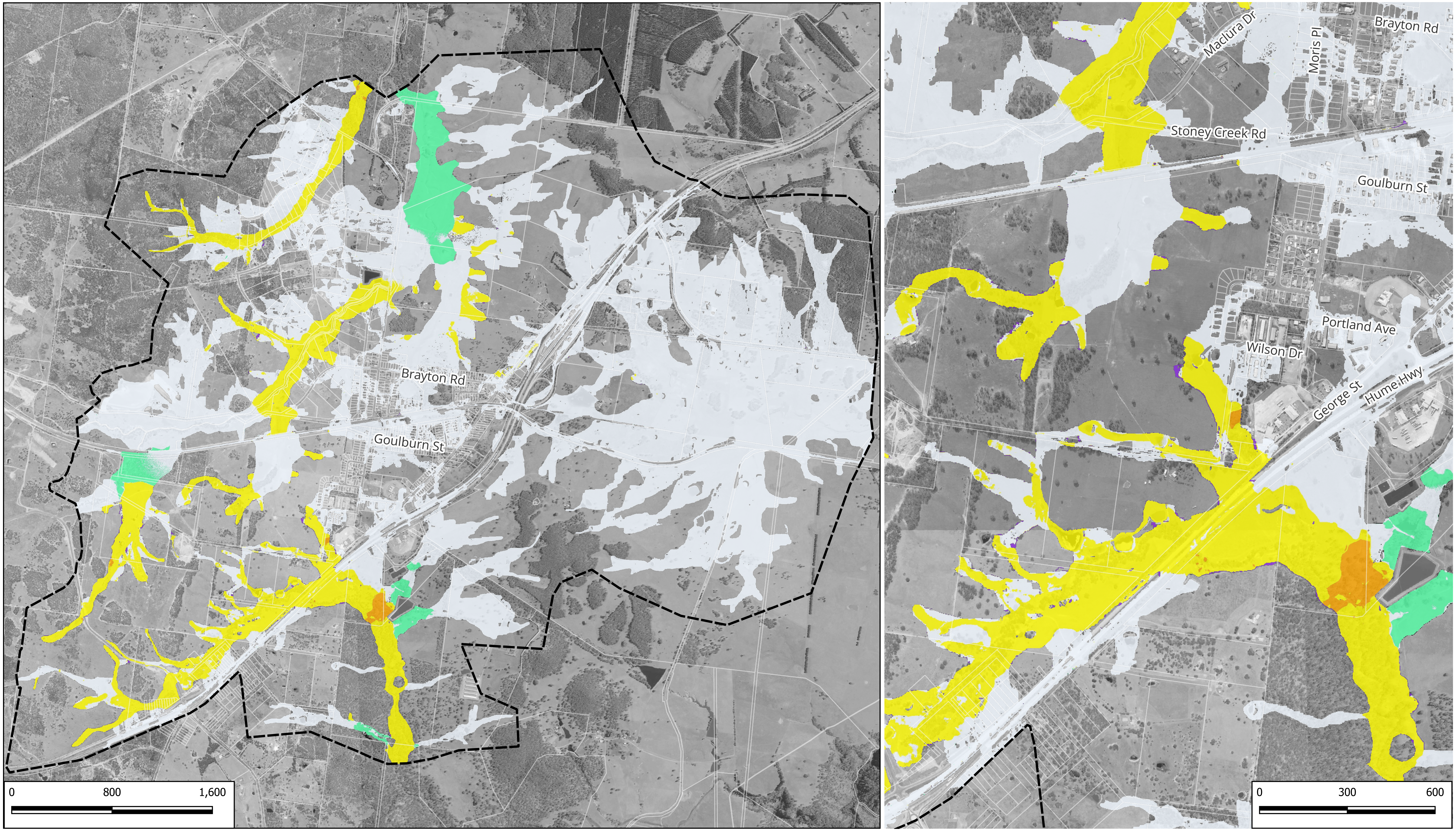
Cadastral Boundaries
2D Model Boundary

Impact (m)
- < -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
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE:	Cumulative Impact Assessment - 0.2% AEP Flood Level Impact	PROJECT:	Marulan Floodplain Risk Management Study & Plan	PROJECT No.	210048	DATE:	09-2024	SCALE:	1:28,000	FIGURE No.	18



Cadastral Boundaries
2D Model Boundary

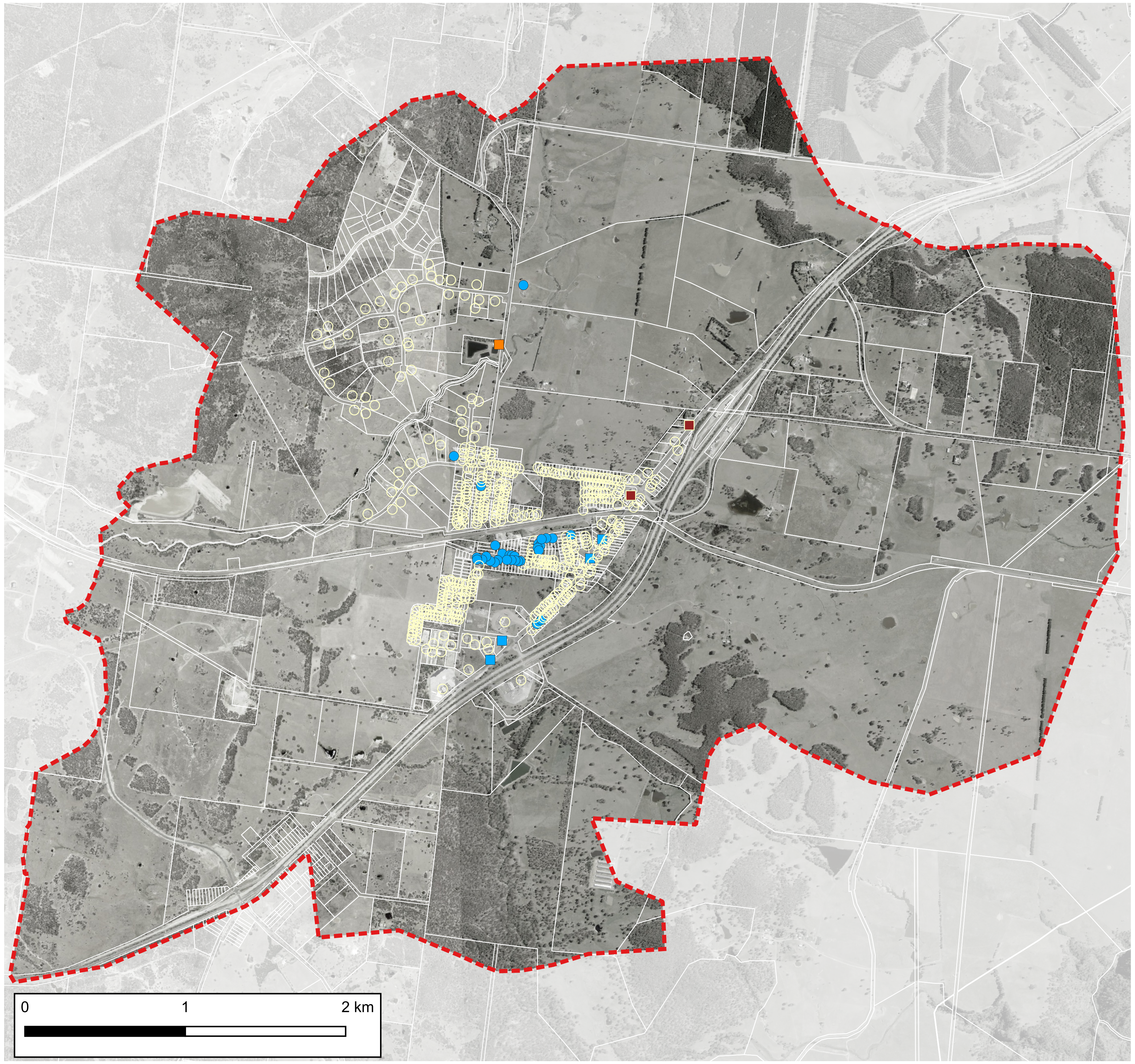
Impact (m)

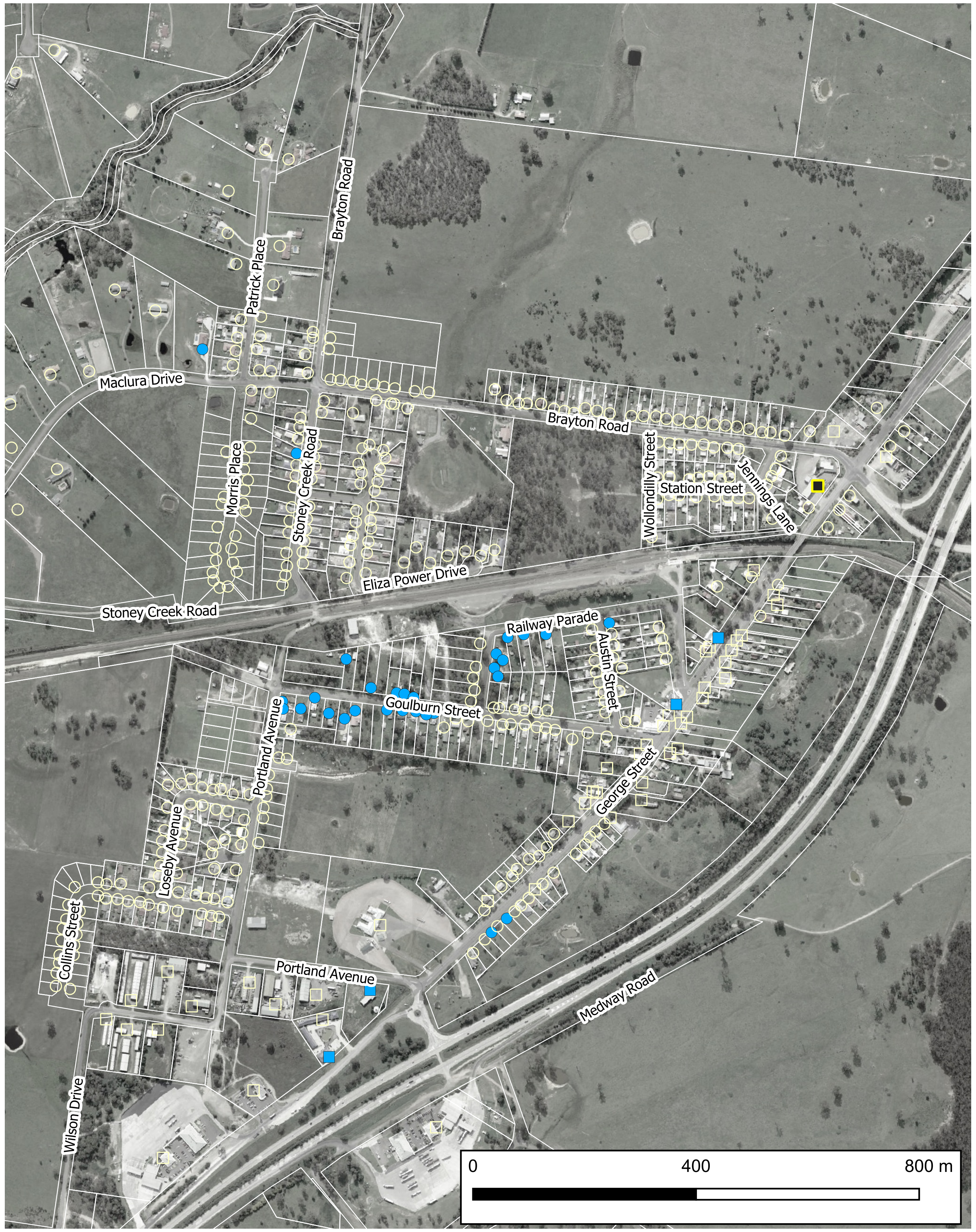
- < -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to -0.01
- No Impact
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: Cumulative Impact Assessment - PMF Flood Level Impact	PROJECT: Marulan Floodplain Risk Management Study & Plan	PROJECT No. 210048	DATE: 09-2024	SCALE: 1:28,000	FIGURE No. 19





Legend

Cadastral Boundaries
2D Model Boundary

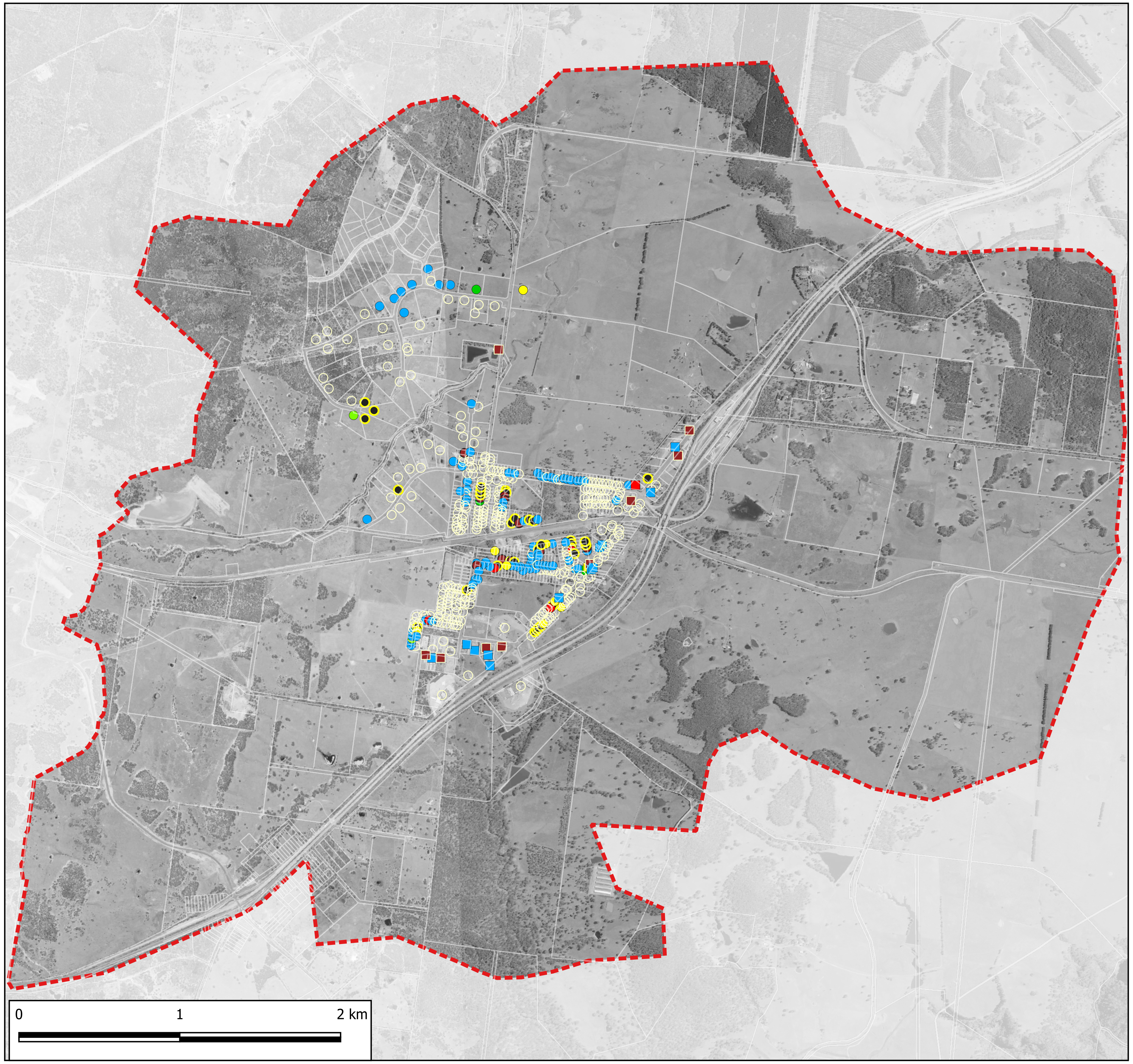
Property Type
Residential
Non-residential

First Flooded Above Floor Level
20% AEP
10% AEP
5% AEP
2% AEP
1% AEP
0.5% AEP
0.2% AEP
PMF
Not Flooded

N W E S

grc HYDRO

TITLE: **Properties Flood Liability – Event Responsible for Above Floor Flooding**	PROJECT: **Marulan Flood Study**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:30,000**	FIGURE No. **20**



Legend

Cadastral Boundaries

2D Model Boundary

Property Type

Residential

Non-Residential

First Flooded Above Ground Level

PMF

0.2% AEP

0.5% AEP

1% AEP

2% AEP

5% AEP

10% AEP

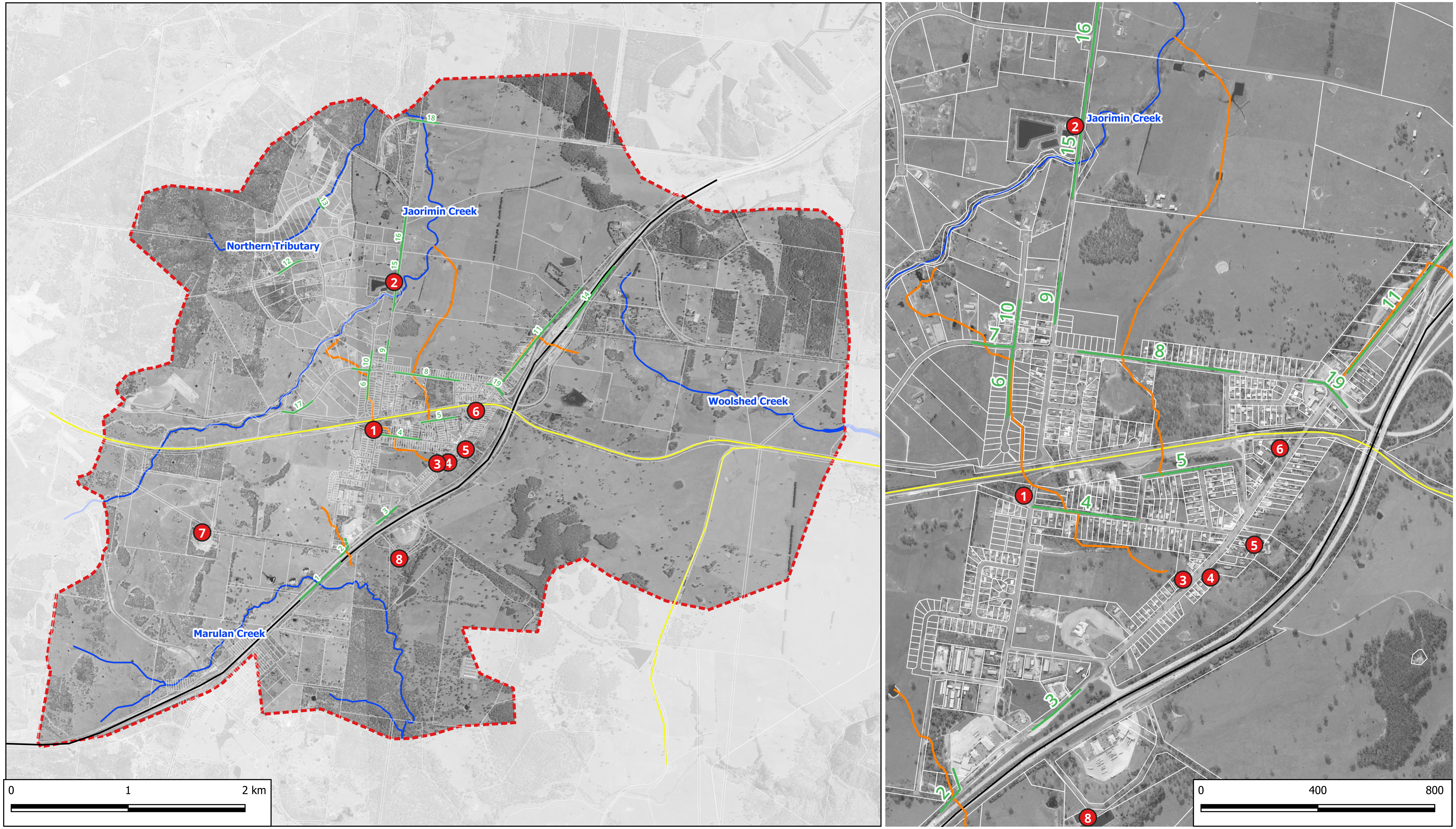
20% AEP

Not Flooded

N W E S

grc HYDRO

TITLE:	Properties Flood Liability - Event Responsible for Above Ground Flooding	PROJECT:	Marulan Floodplain Risk Management Study & Plan	PROJECT No.	210048	DATE:	11-2024	SCALE:	1:28,000	FIGURE No.	20A



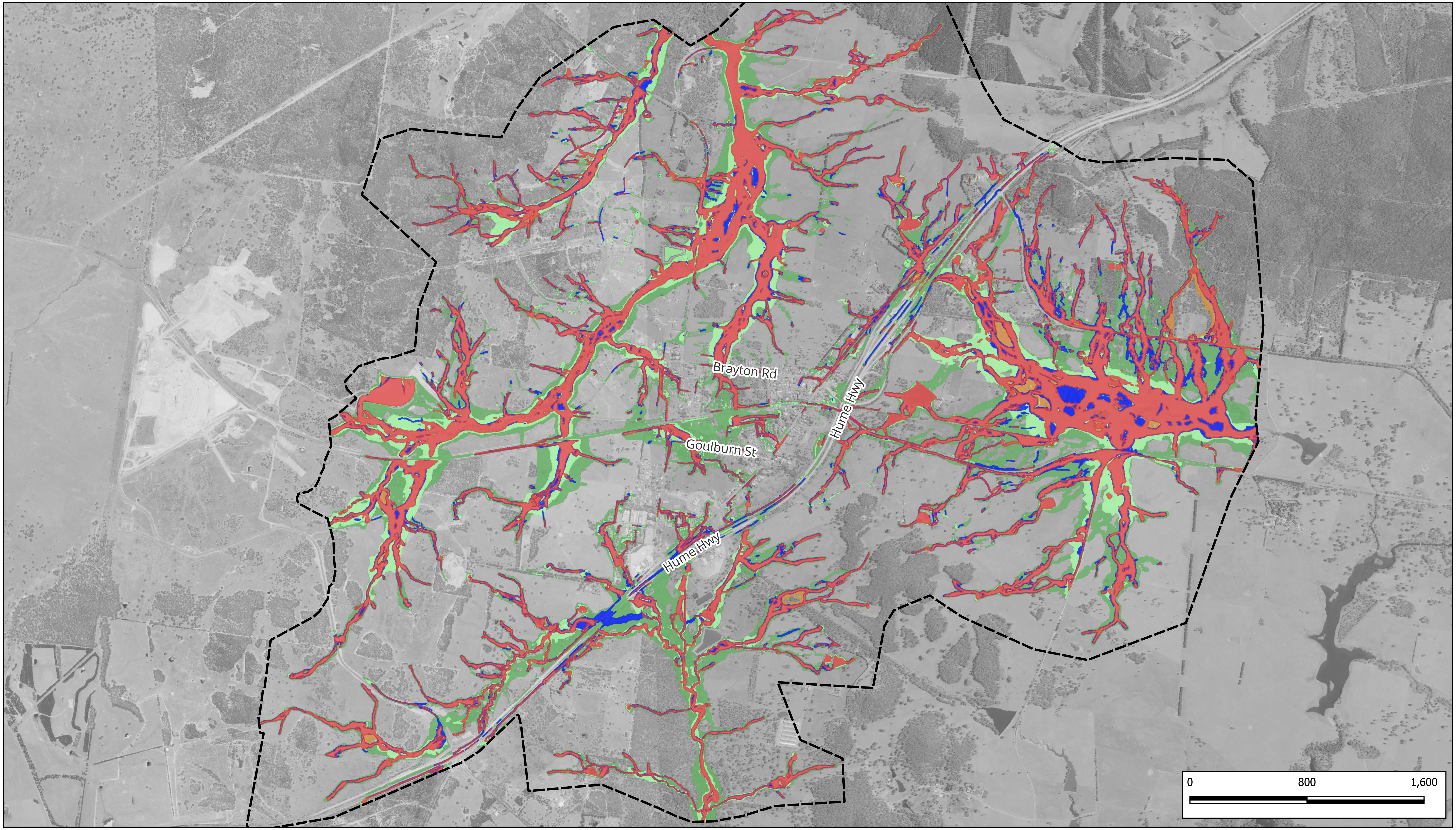
- Sensitive Land- use & Critical Infrastructure
- Road Inundation Locations
- Hume Highway
- Key Overland Flow Paths
- ARTC Railway
- Creeks and Tributaries
- Cadastral Boundaries
- 2D Model Boundary

N
W E
S

grc HYDRO

*Please note that the exact alignment of the overland flow paths will be shown in the final hydraulic model results. The alignment of the overland flow paths shown above have been used purely for the purpose of reporting.

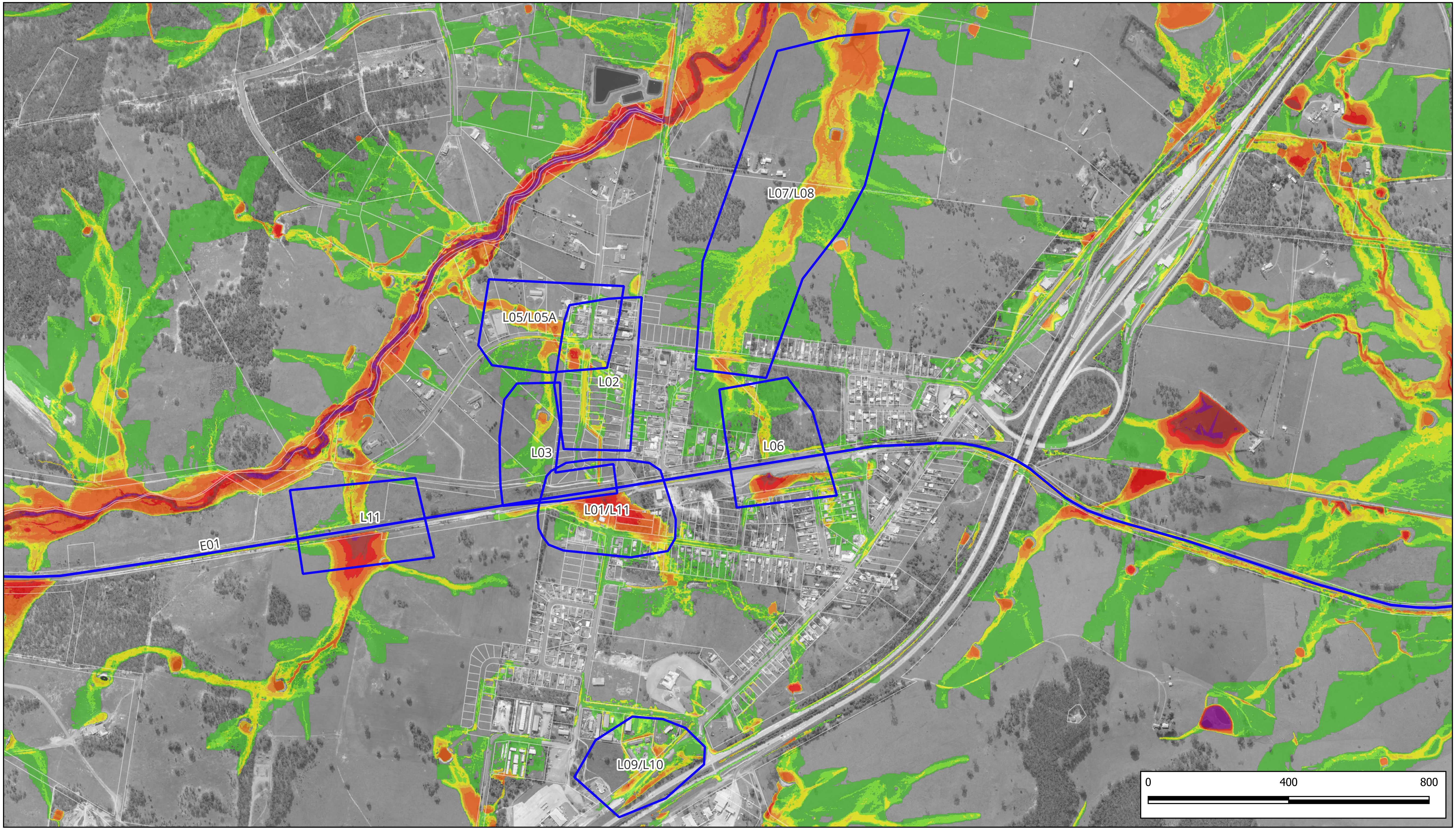
TITLE: **Location of Critical Infrastructure**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **12-2024**	SCALE: **1:30,000**	FIGURE No. **21**



Flood Planning Constraint Category 1
Flood Planning Constraint Category 2a, b, c, e
Flood Planning Constraint Category 2d
Flood Planning Constraint Category 3
Flood Planning Constraint Category 4
2D Model Boundary

N
W
E
S

TITLE: **Flood Planning Constraint Categories**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **11-2024**	SCALE: **1:24,000**	FIGURE No. **22**



Mitigation Options
Cadastral Boundaries

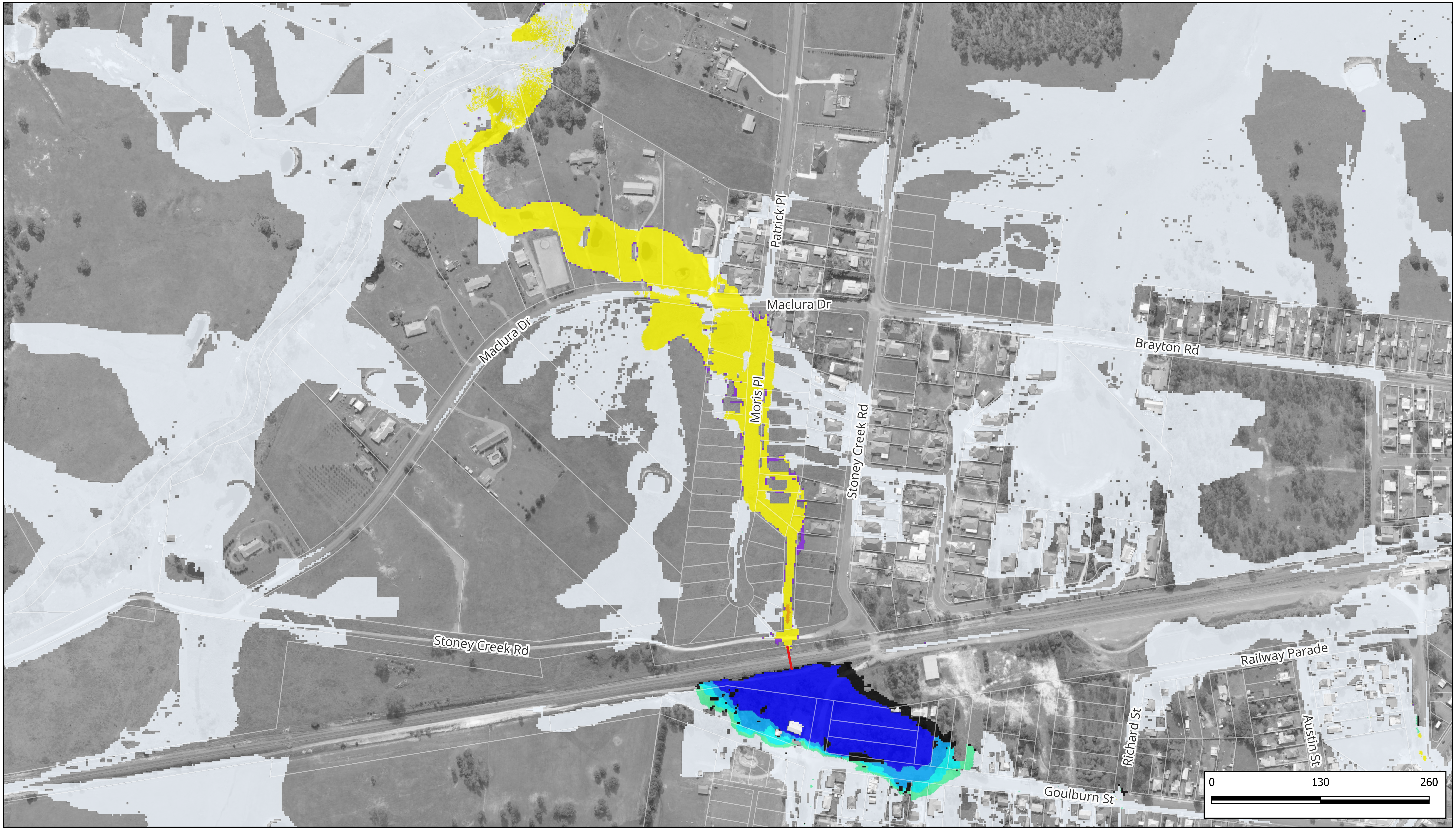
1% AEP Flood Depths (m)

- 0 - 0.05
- 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

N W E S

grc HYDRO

TITLE: **Potential Flood Modification Measures**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **11-2024**	SCALE: **1:10,000**	FIGURE No. **23**



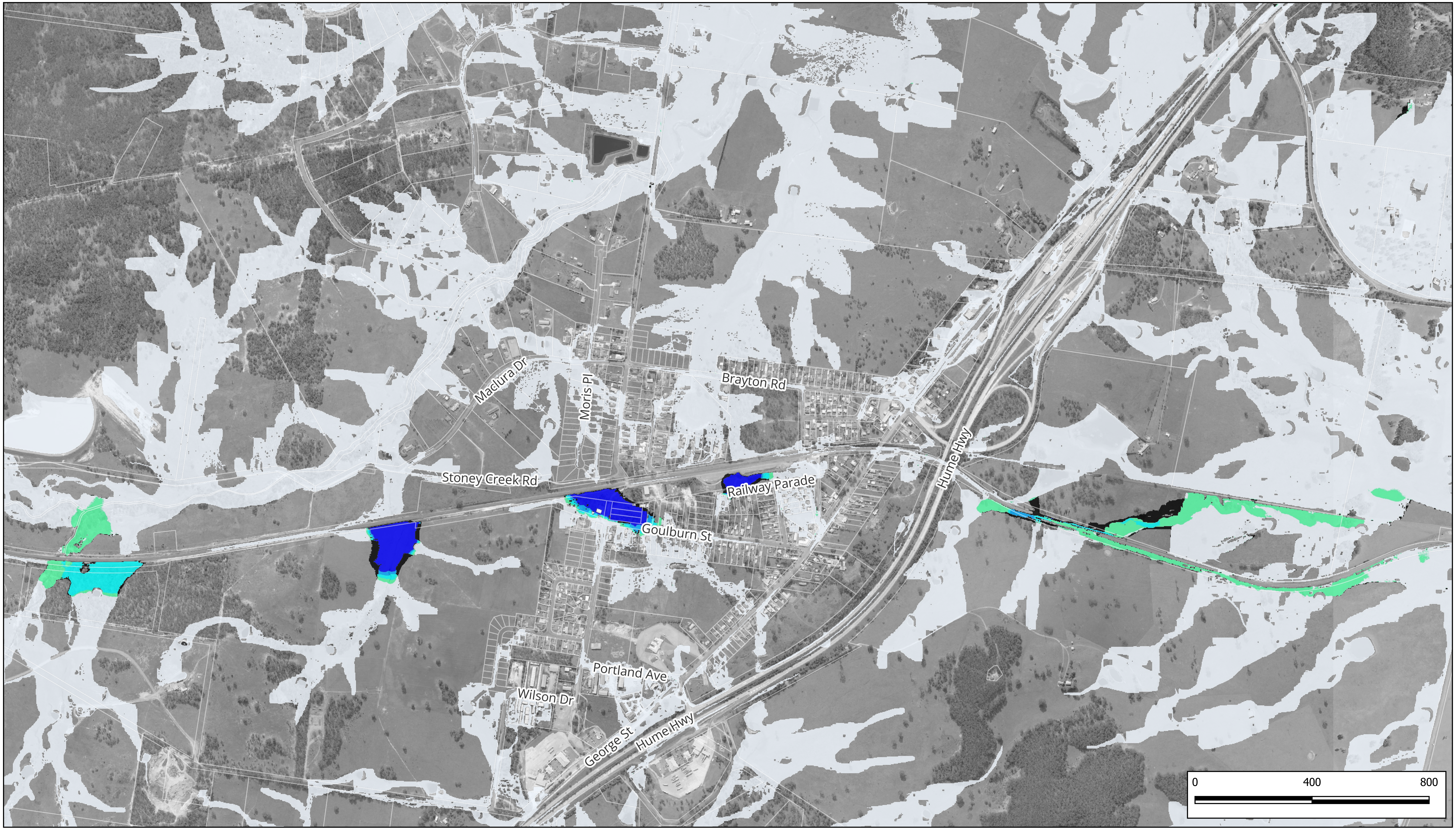
Upgraded Culvert
Cadastral Boundaries

Impact (m)
< -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
No Longer Flooded
Newly Flooded

N W E S

grc HYDRO

TITLE: Option L01 – 1% AEP Flood Level Impact	PROJECT: Marulan Floodplain Risk Management Study & Plan	PROJECT No. 210048	DATE: 09-2024	SCALE: 1:4,200	FIGURE No. 24



Cadastral Boundaries

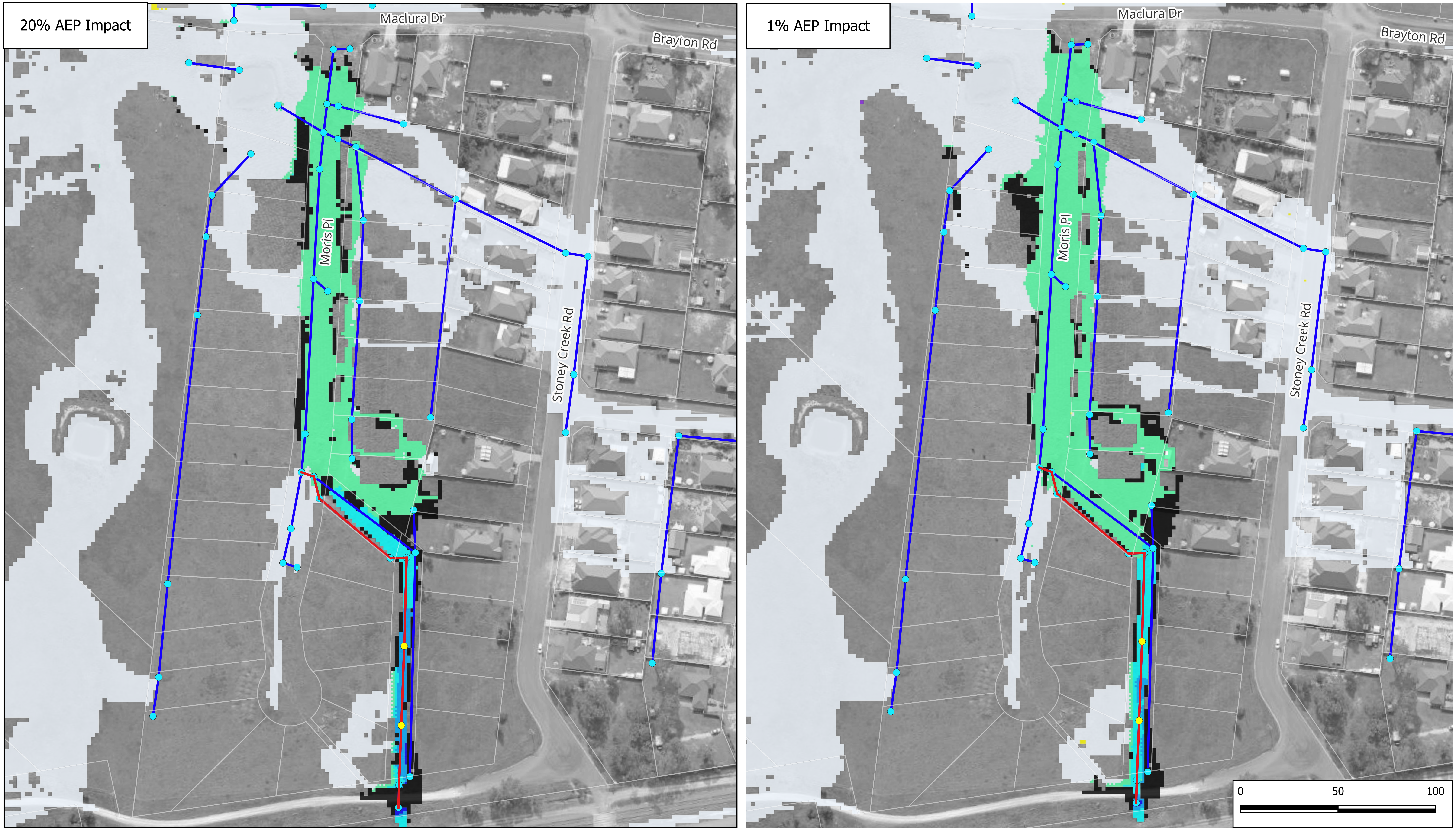
Impact (m)

- < -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
- No Longer Flooded
- Newly Flooded

N
W E
S

grc HYDRO

TITLE: **Option E01 – 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:12,000**	FIGURE No. **25**



- Existing SW Pits
- Existing SW Pipes
- Upgraded SW Pits
- Upgraded SW Pipes
- Cadastral Boundaries

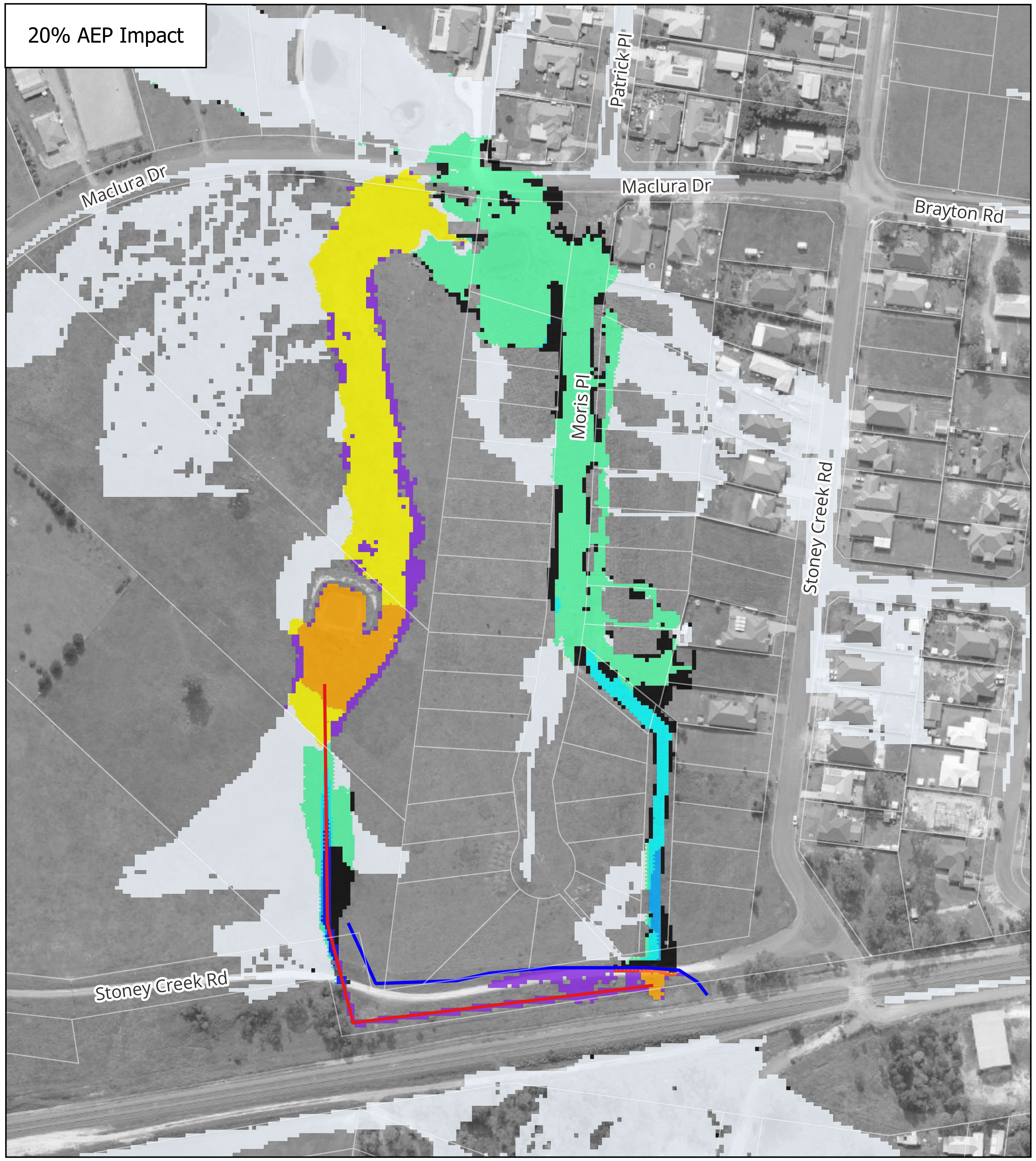
Impact (m)

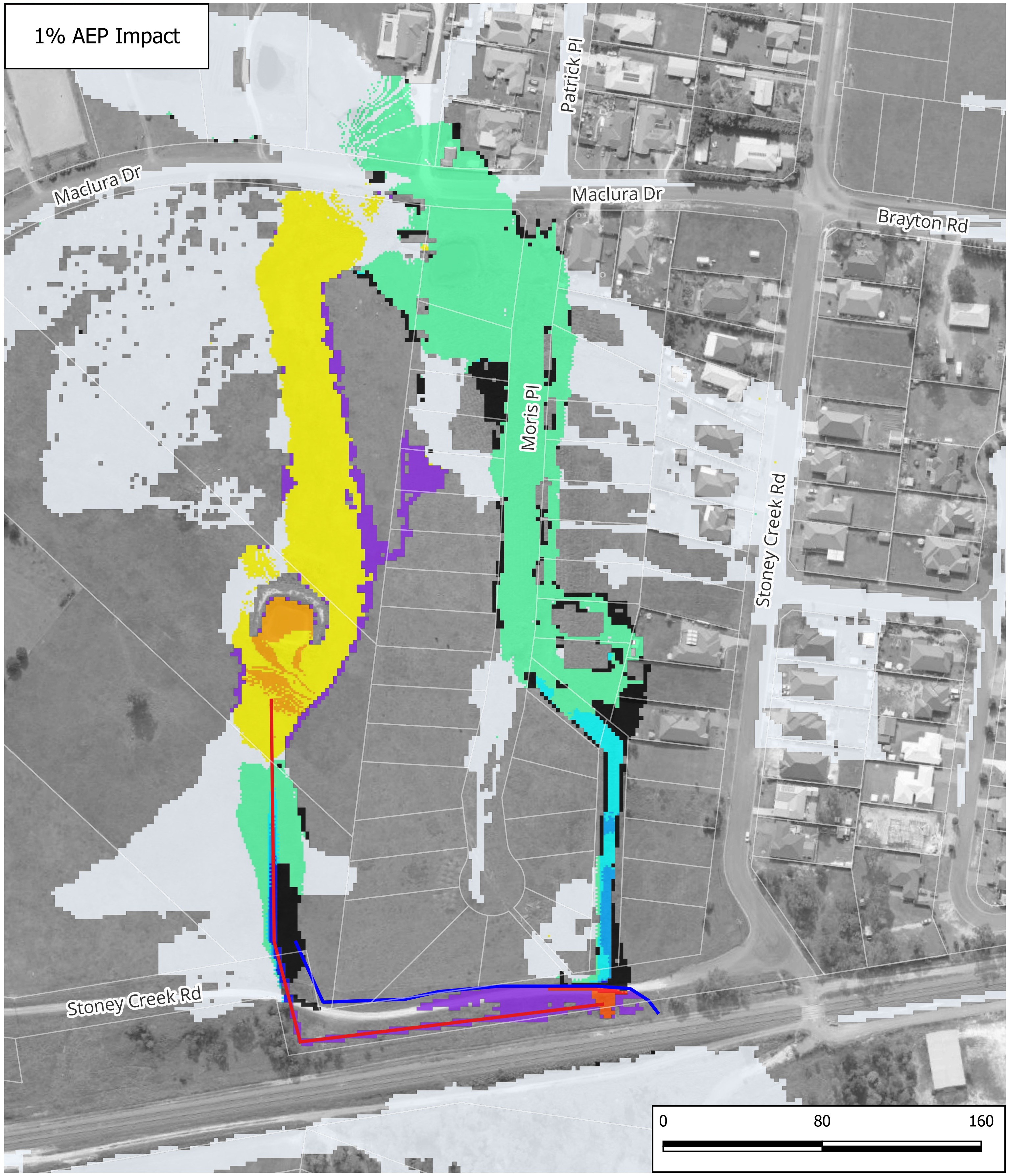
- < -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to -0.01
- No Impact
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: **Option L02 – 20% and 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:1,800**	FIGURE No. **26**





Swale
Wall
Cadastral Boundaries

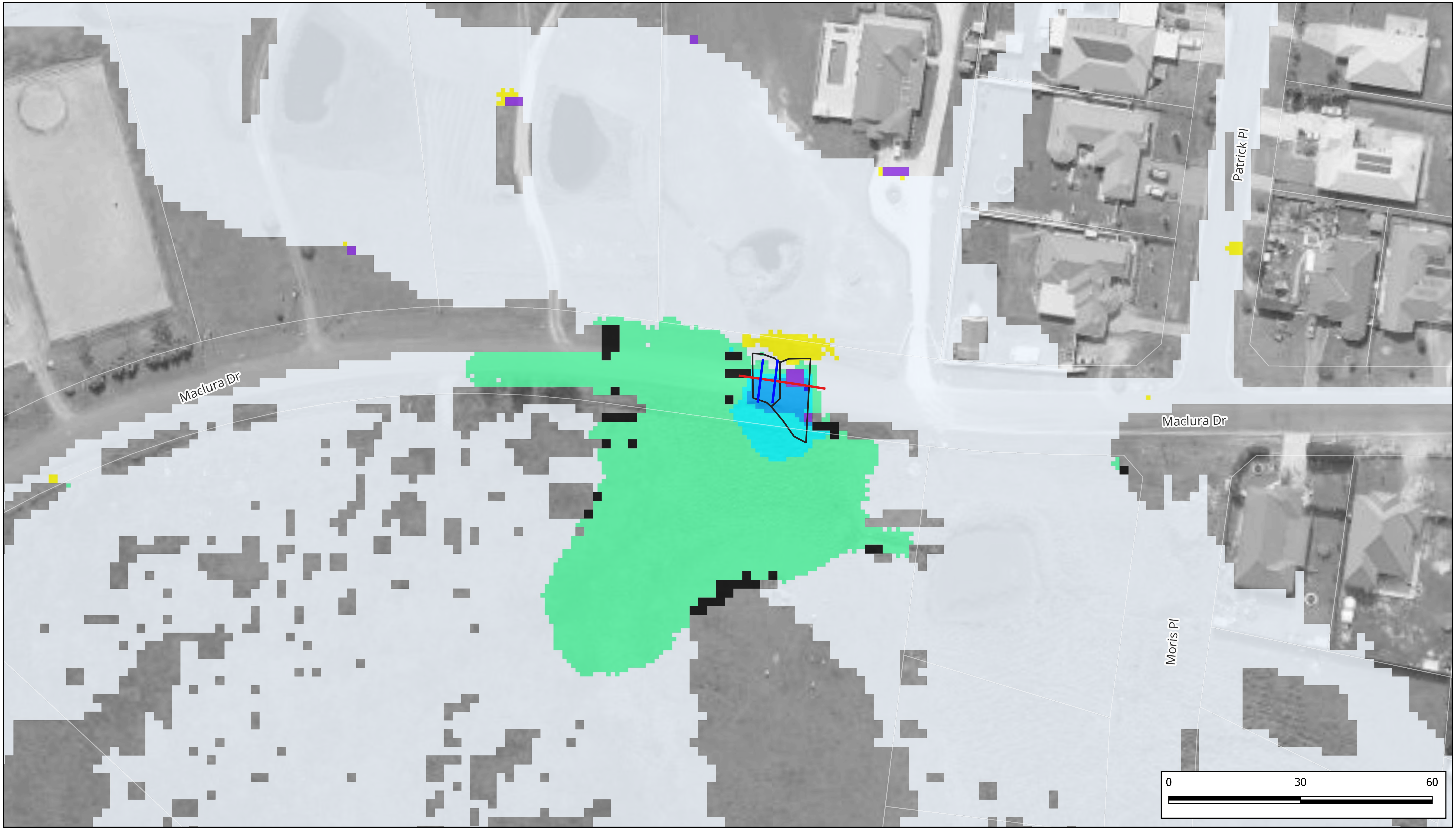
Impact (m)
< -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.01
No Impact
0.01 to 0.1
0.1 to 0.2
0.2 to 0.3
> 0.3
No Longer Flooded
Newly Flooded

N W E S

grc HYDRO

TITLE:	**Option L03 – 20% and 1% AEP Flood Level Impact**	PROJECT:	**Marulan Floodplain Risk Management Study & Plan**	PROJECT No.	**210048**	DATE:	**09-2024**	SCALE:	**1:2,500**

FIGURE No. **27**



Channel
Bridge
Culverts Removed
Cadastral Boundaries

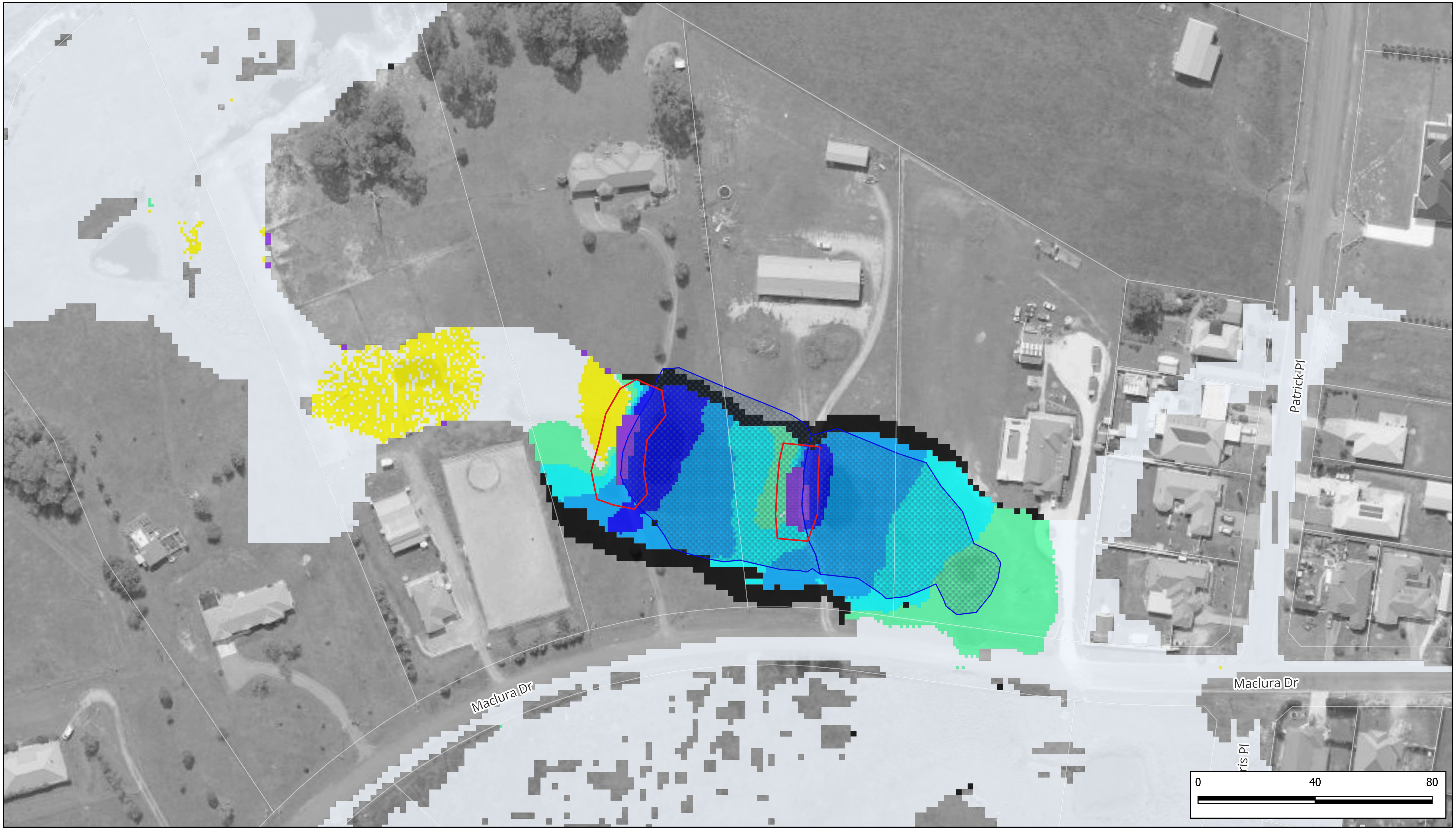
Impact (m)

< -0.3	-0.1 to -0.01
-0.3 to -0.2	No Impact
-0.2 to -0.1	0.01 to 0.1
0.1 to 0.2	0.2 to 0.3
> 0.3	No Longer Flooded
Newly Flooded	

N W E S

grc HYDRO

TITLE:	PROJECT:	PROJECT No.	DATE:	SCALE:	FIGURE No.
Option L05 – 1% AEP Flood Level Impact	**Marulan Floodplain Risk Management Study & Plan**	**210048**	**09-2024**	**1:800**	**28**



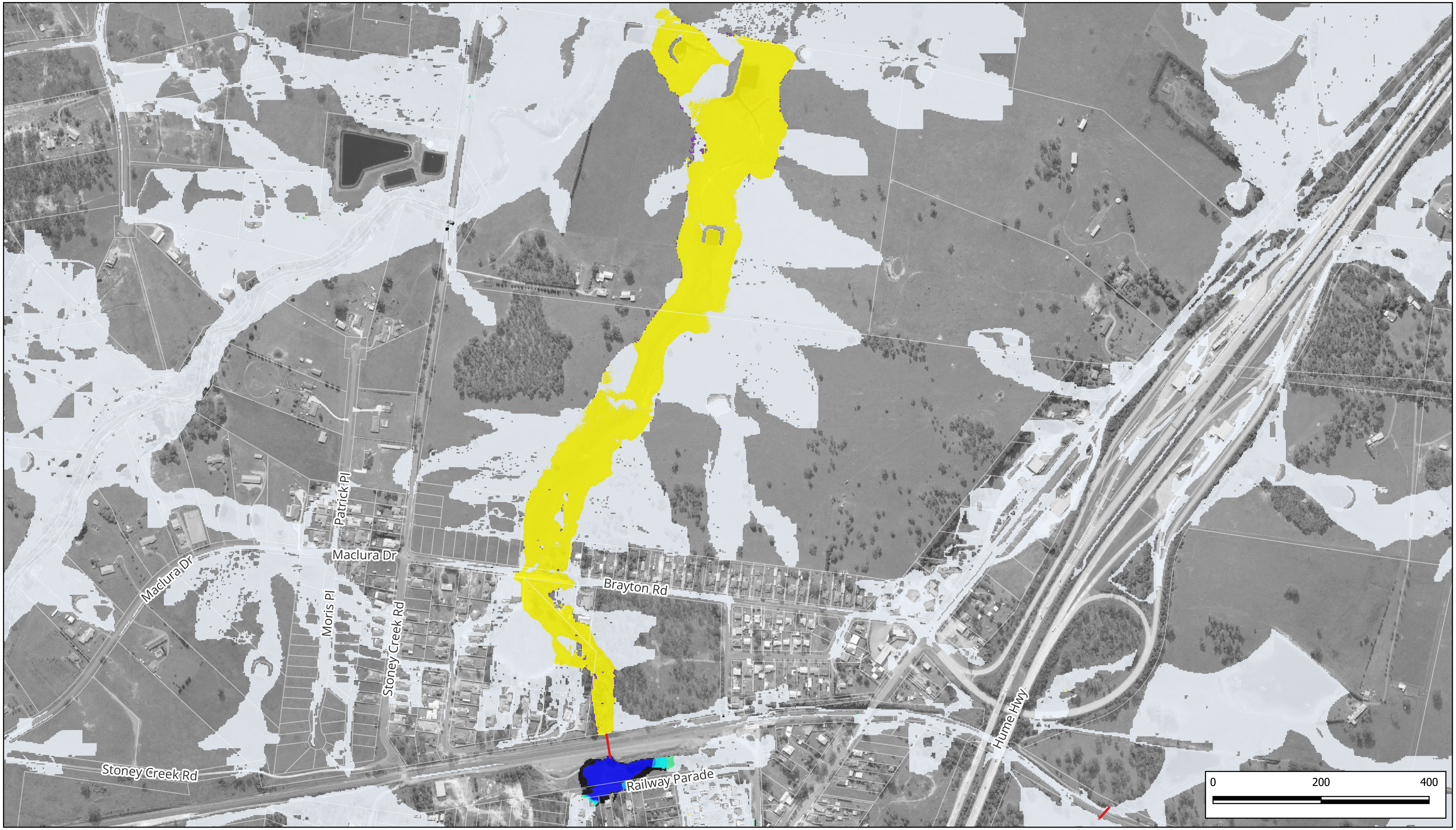
Embankments Removed
Initial Water Level Removed
Cadastral Boundaries

Impact (m)
< -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
No Longer Flooded
Newly Flooded

N W E S

grc HYDRO

TITLE: Option L05A – 1% AEP Flood Level Impact	PROJECT: Marulan Floodplain Risk Management Study & Plan	PROJECT No. 210048	DATE: 09-2024	SCALE: 1:1,200	FIGURE No. 29



Upgraded Culvert
Cadastral Boundaries

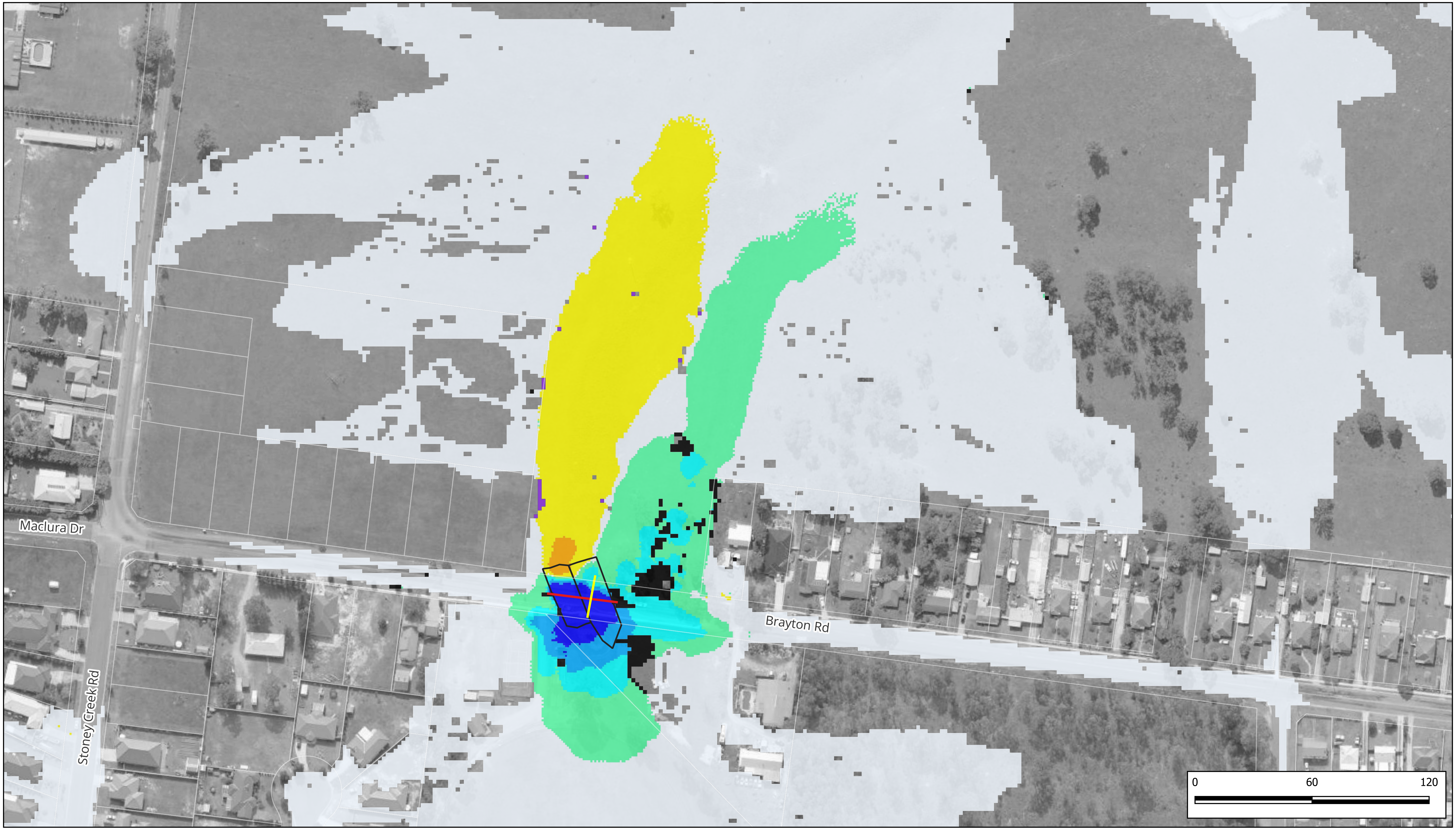
Impact (m)

- < -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
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: **Option L06 – 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:6,500**	FIGURE No. **30**



Bridge
Channel
Culvert Removed
Cadastral Boundaries

Impact (m)

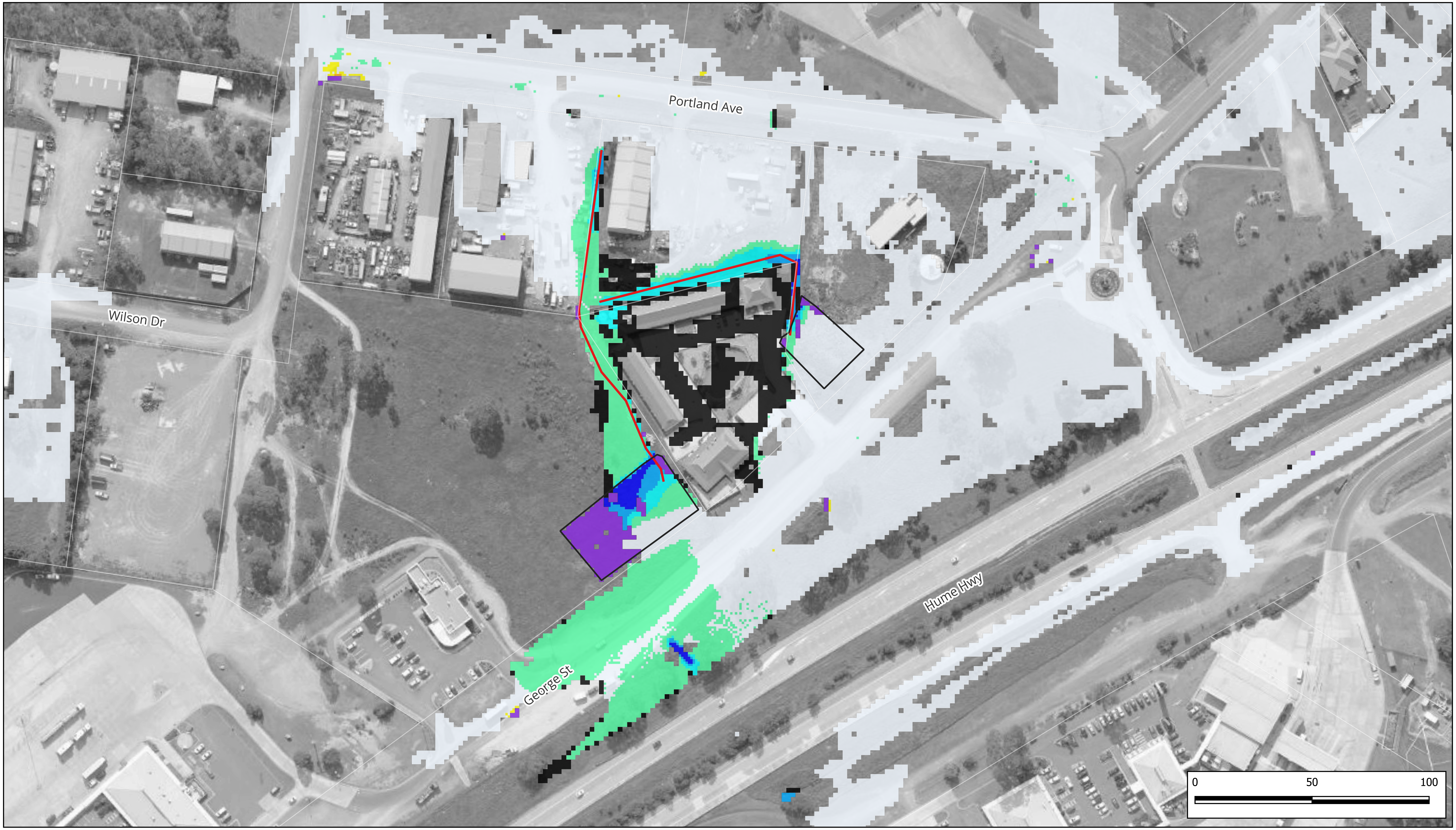
- < -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to -0.01
- No Impact
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N
W
E
S

grc HYDRO

TITLE:	**Option L07 – 1% AEP Flood Level Impact**	PROJECT:	**Marulan Floodplain Risk Management Study & Plan**	PROJECT No.	**210048**	DATE:	**09-2024**	SCALE:	**1:1,800**

FIGURE No. 31



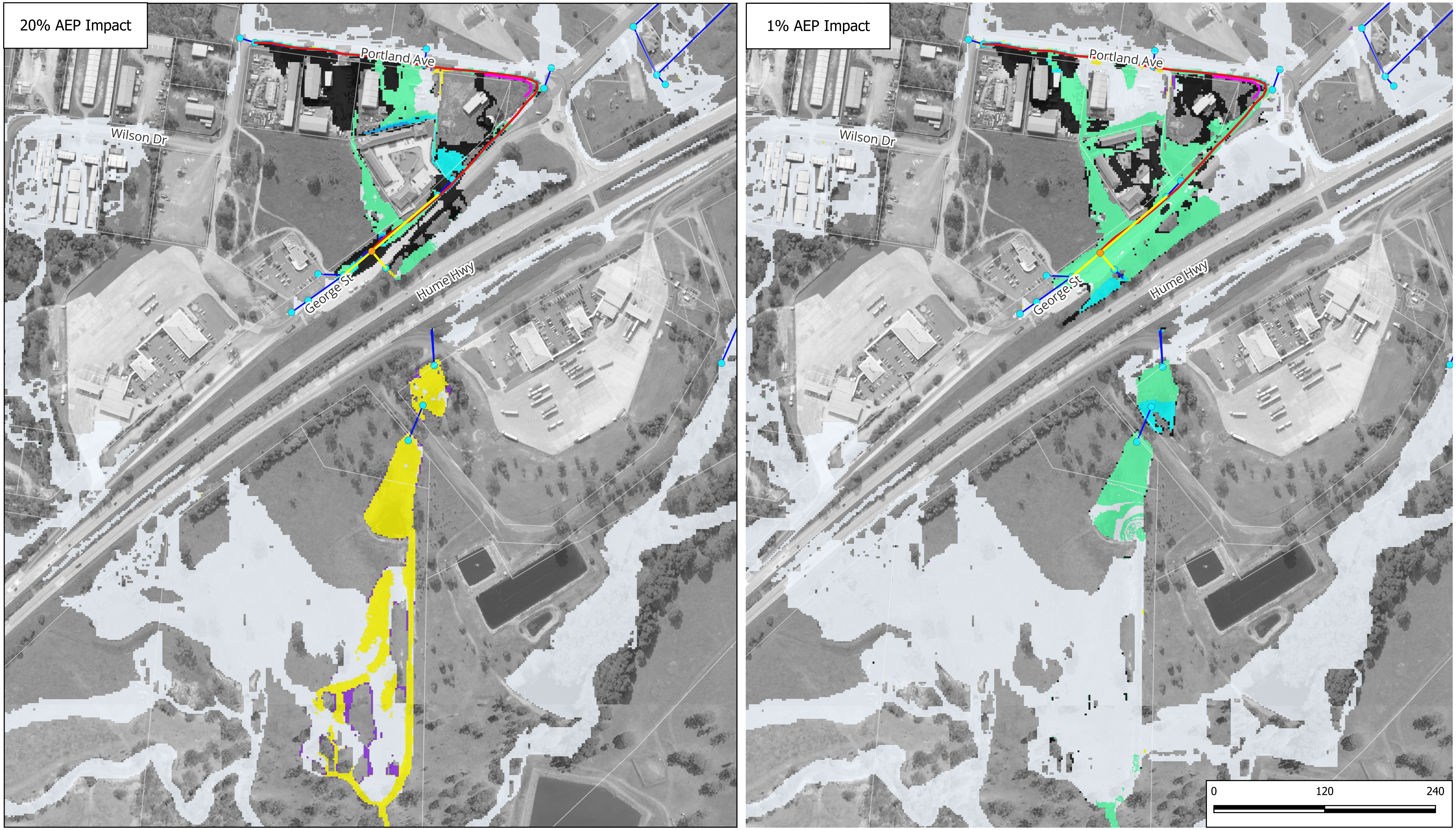
Basin
Swale
Cadastral Boundaries

Impact (m)
< -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
No Longer Flooded
Newly Flooded

N W E S

grc HYDRO

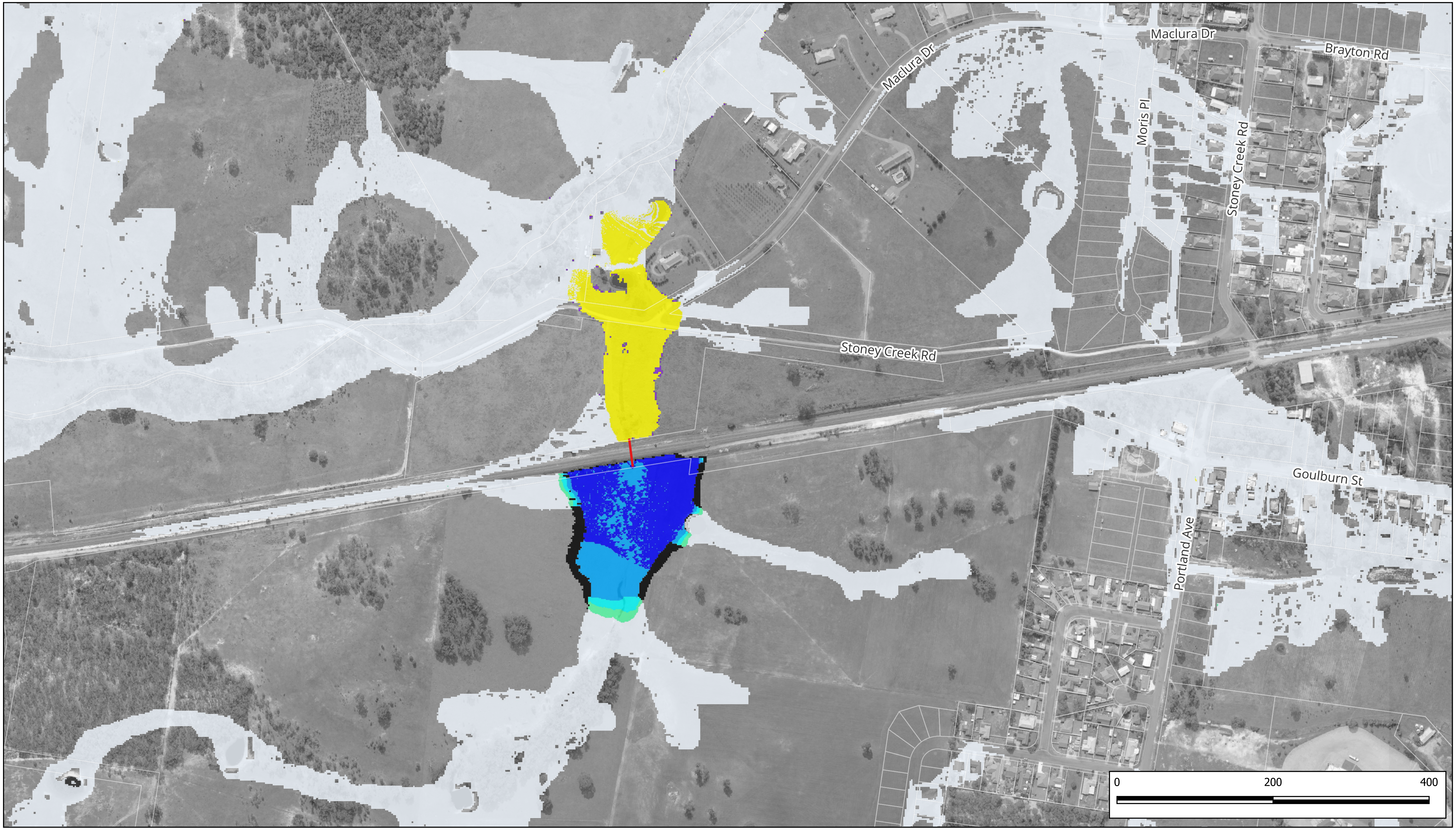
TITLE: Option L09 – 1% AEP Flood Level Impact	PROJECT: Marulan Floodplain Risk Management Study & Plan	PROJECT No. 210048	DATE: 09-2024	SCALE: 1:1,500	FIGURE No. 32



Existing SW Pits
Existing SW Pipes
Upgraded SW Pits
Upgraded SW Pipes
Wall
Swale
Cadastral Boundaries

Impact (m)
< -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
No Longer Flooded
Newly Flooded

TITLE: **Option L10 – 20% and 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:3,800**	FIGURE No. **33**



Upgraded Culvert
Cadastral Boundaries

Impact (m)

- < -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
- No Longer Flooded
- Newly Flooded

N W E S

grc HYDRO

TITLE: **Option L11 – 1% AEP Flood Level Impact**	PROJECT: **Marulan Floodplain Risk Management Study & Plan**	PROJECT No. **210048**	DATE: **09-2024**	SCALE: **1:4,500**	FIGURE No. **34**

APPENDIX A – FLOOD FUNCTION DERIVATION PRESENTATION

Marulan Flood Study and Floodplain Risk Management Study & Plan

Inception Meeting - 12 September 2023

grc HYDRO

GOULBURN MULWAREE COUNCIL

Agenda

1. Introduction
2. Consultation
3. Identification of Hotspots
4. Flood function analysis
5. Flood Planning Area
6. Other issues for discussion
7. Moving forward

Introduction

- Floodplain Risk Management Process

Compilation of existing data

Defines the nature and extent of the flood problem

Identifies the flood risk and determining measures to mitigate risk

Preferred mitigation options publicly exhibited and subject to revision in light of responses

Implementation of flood response and modification measures by council

Consultation

- Consultation completed to date:
    - *Media release*
    - *Newsletter / questionnaire*
    - *Follow up one-on-one community meetings (on request)*
    - *Public exhibition of the Flood Study*

- Proposed Consultation for the FRMSP:
    - *Media release*
    - *Public exhibition of the FRMSP*
    - *One-on-one community meetings (on request)*

- Stakeholder engagement meetings (best approach?):
    - *NSW SES*
    - *TfNSW & ARTC*
    - *WaterNSW*

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GOULBURN MULWAREE COUNCIL

Community Consultation Newsletter

Have Your Say on Flooding in Your Area

Marulan Flood Study & Floodplain Risk Management Study and Plan

Marulan Flood Study & Floodplain Risk Management Study and Plan

Goulburn Mulwaree Council are undertaking a Flood Study and Floodplain Risk Management Study & Plan for Marulan. The study is being prepared with assistance from GRC Hydro and is being undertaken as part of the NSW Government's Floodplain Risk Management Program.

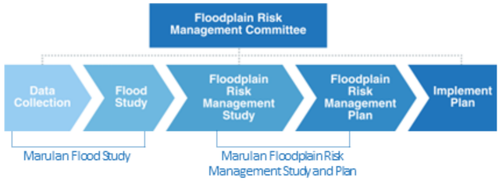
We would like to hear your experiences of flooding to better understand how flooding occurs in Marulan. This information will be used by Council to help manage flood risk for people and property, as well as potential future development.

What is the Floodplain Risk Management Program?

The Floodplain Risk Management Program is run by the NSW Government. This program helps councils to make informed decisions about managing flood risk and to provide essential information to the SES to coordinate flood emergency response.

This program consists of five stages; the Marulan Flood Study and subsequent Floodplain Risk Management Study and Plan will comprise stages one to four of this process.

The stages of the Floodplain Risk Management Program are presented below:



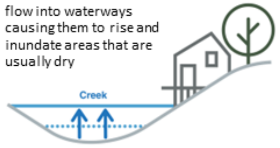
What is Flooding?

Flooding is often associated with inundation from large rivers; however, there are other flood mechanisms that can cause inundation. Two of these mechanisms are overland flow flooding and mainstream flooding.

The Marulan Flood Study will focus on both of these flood mechanisms.

Overland flow flooding occurs as rainfall runoff moves toward downstream waterways.

Mainstream flooding occurs when runoff from streets and drains flow into waterways causing them to rise and inundate areas that are usually dry



What is a Flood Study?

A flood study is a comprehensive technical investigation of flood behaviour. This study will define the nature of flood risk in your area by providing information on the extent, level and velocity of floodwaters for a full range of flood magnitudes up to and including the largest possible flood, termed the 'Probable Maximum Flood'. A commonly used outcome from a Flood Study is the 1% AEP flood result (also known as the 1 in 100 year flood). Sensitivity testing is also undertaken in these studies to account for factors such as climate change and blockage of drainage systems.

What is a Floodplain Risk Management Study and Plan?

A floodplain risk management study and plan (FRMS&P) draws on the results of the flood study to identify, assess and compare various flood risk management options and opportunities aimed at improving the existing flood situation. It provides information and tools to allow considered assessment of flood impacts of management options and provides a strategic plan for implementation.

Have Your Say on Flooding in Your Area

Marulan Flood Study & Floodplain Risk Management Study and Plan

What is a Flood Study and FRMS&P used for?

A Flood Study and FRMS&P provide key information for Council, the SES & the community for effectively managing & mitigating flood risk.

For Council, these studies are primarily a planning tool for future development in Marulan and implementing flood risk mitigation measures for existing development areas. Examples of applications for Council are listed below:

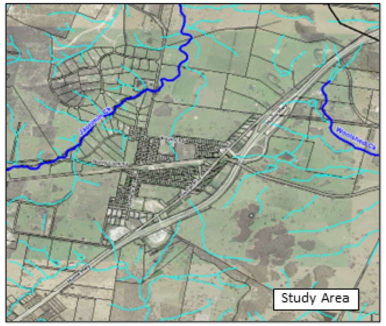
- Examination of Council's local flood risk management policies, strategies and planning instruments; and
- Identification and assessment of floodplain risk management measures for existing development areas aimed at reducing social, environmental and economic loss due to flooding on development and the community.

Information from these studies will assist the SES in its evacuation and logistics planning. The outcomes of the study will provide the SES with:

- a clear description of flood behaviour in the study area for a full range of flood events;
- a description of flood warning times for Goulburn; and
- identification of critical evacuation issues in Goulburn such as warning times where road access is cut.

The Study Area

The Flood Study and FRMPS&P will cover an area of approximately 18 square kilometres inclusive of the Marulan township and its surrounds (pictured below). Marulan is traversed by some natural overland flowpaths and Jaorimin Creek to the west.



Why your feedback is important

During the Flood Study, GRC Hydro will develop computer models to determine the existing flood affectation in Marulan. Calibration and validation to observations of flooding key in the development of these models to improve accuracy. The FRMS&P will assess flood modification measures to relieve the flood risk at affected locations. Community input and knowledge of how flooding occurs and of measures that might mitigate flooding is invaluable to this study.

What happens next?

GRC Hydro will model the flood behaviour in Marulan and produce a flood study report for Council. It will be placed on Public Exhibition in 2022 and comment will be invited. Following this, the FRMS&P will be developed with Public Exhibition expected in late 2022.

How can you help us?

Your feedback is important in helping us get a complete picture of the community's knowledge of flood behaviour and concerns in your area. There are a variety of ways you can share your experiences and knowledge with us. These are as follows:

01. Fill out the questionnaire included with this letter and send it back using the self-addressed envelope provided or email it to marson@grchydro.com.au.

02. Fill out the questionnaire online by going to the website listed or scanning the QR code below.
Website: https://www.goulburn.nsw.gov.au/Development/Plans-Strategies#section-8

03. For more information, please do not hesitate to contact the representatives nominated at the bottom of this page.

Who can we contact?

If you have any further questions regarding the study or any further flood information/photos please attach them to your questionnaire or contact the following representatives.

Beth Marson
Senior Engineer
GRC Hydro
marson@grchydro.com.au
02 9030 0342

Strategic Planning
Goulburn Mulwaree Council
Council@goulburn.nsw.gov.au
02 4823 4444

Please return your questionnaire by Friday 3 December 2021 to have your say.

Community Consultation Questionnaire

Have Your Say on Flooding in Your Area
Marulan Flood Study & Floodplain Risk Management Study and Plan Questionnaire

Contact Details

Name

Address:

Phone Number:

Email:

Can we contact you for more information? ◯ Yes ◯ No

Please note: Your personal details will be kept confidential

Your Property

What building type is your property?

◯ Residential (House/Terrace) ◯ Residential (Apartment)

◯ Commercial ◯ Industrial

Business Name:

How long have you lived or worked at this property? ____ Years ____ Months

Has your property ever been affected by flooding?

◯ Yes, above the floor level ◯ Yes, in the yard or garage ◯ No

If yes, could you please provide more information in the space below or attached to this questionnaire. Information such as dates and photos of flooding are very helpful.

Flood Observations

Have you observed flooding in your area?

◯ Yes ◯ No

If yes, please note where you have observed flooding and/or anything that has made flooding worse. For example, have blocked drainage structures or changes near your property made flooding worse? Information such as dates, maximum extent, top water level and photos of flooding are very helpful.

Have Your Say on Flooding in Your Area
The Marulan Flood Study & Floodplain Risk Management Study and Plan Questionnaire

New Development

The current study will provide advice on flood related development controls. How do you suggest Council should manage controls for developments on the floodplain?

◯ Prevent development on land subject to any flood risk (including events rarer than the 1 in 100 year ARI flood)

◯ Prevent any new development in areas where the flood risk is dangerous for people/property (i.e. deep fast moving water).

◯ Inform property owners of the potential flood risks and the related flood development controls and allow development provided the controls are adhered to

◯ Provide no advice or development controls

◯ Other (please specify)

Flood Management Options

The current study is assessing a range of measures aimed at managing the current flood risk. The study is looking for input from residents to better understand local preferences for floodplain management.

Which of the following options do you prefer for managing flood risk? (tick box based on preference)

◯ Construct, repair and/or increase the size of existing levee banks

◯ Modify creek channels to increase their capacity

◯ Impose greater flood-related development controls and increase strategic flood planning

◯ Increase flood awareness and education in the community

◯ Upgrade flood warning, evacuation planning and emergency response measures

◯ Property modification measures for severely affected properties such as voluntary purchase or voluntary house raising.

◯ Other suggestions (describe below)

Please use the space below to describe other flood management options or add detail on the preferences selected above.

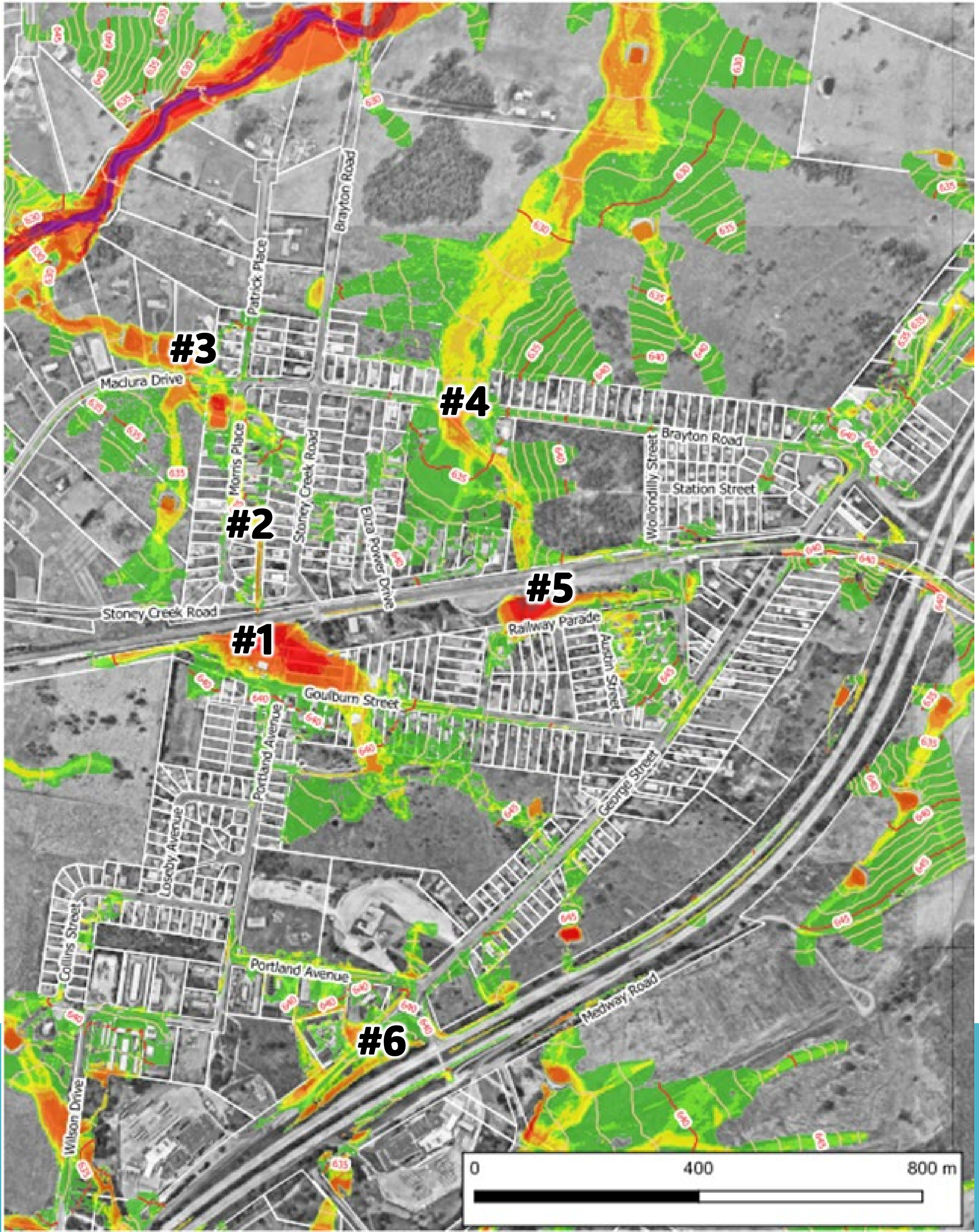
Please return your questionnaire by Friday 3 December 2021 to ensure that it is counted.
If your information does not fit in the space provided, please email it to marson@grchydro.com.au

Hotspots

- Identification of Hotspots required to focus flood risk management measures on areas of flood risk

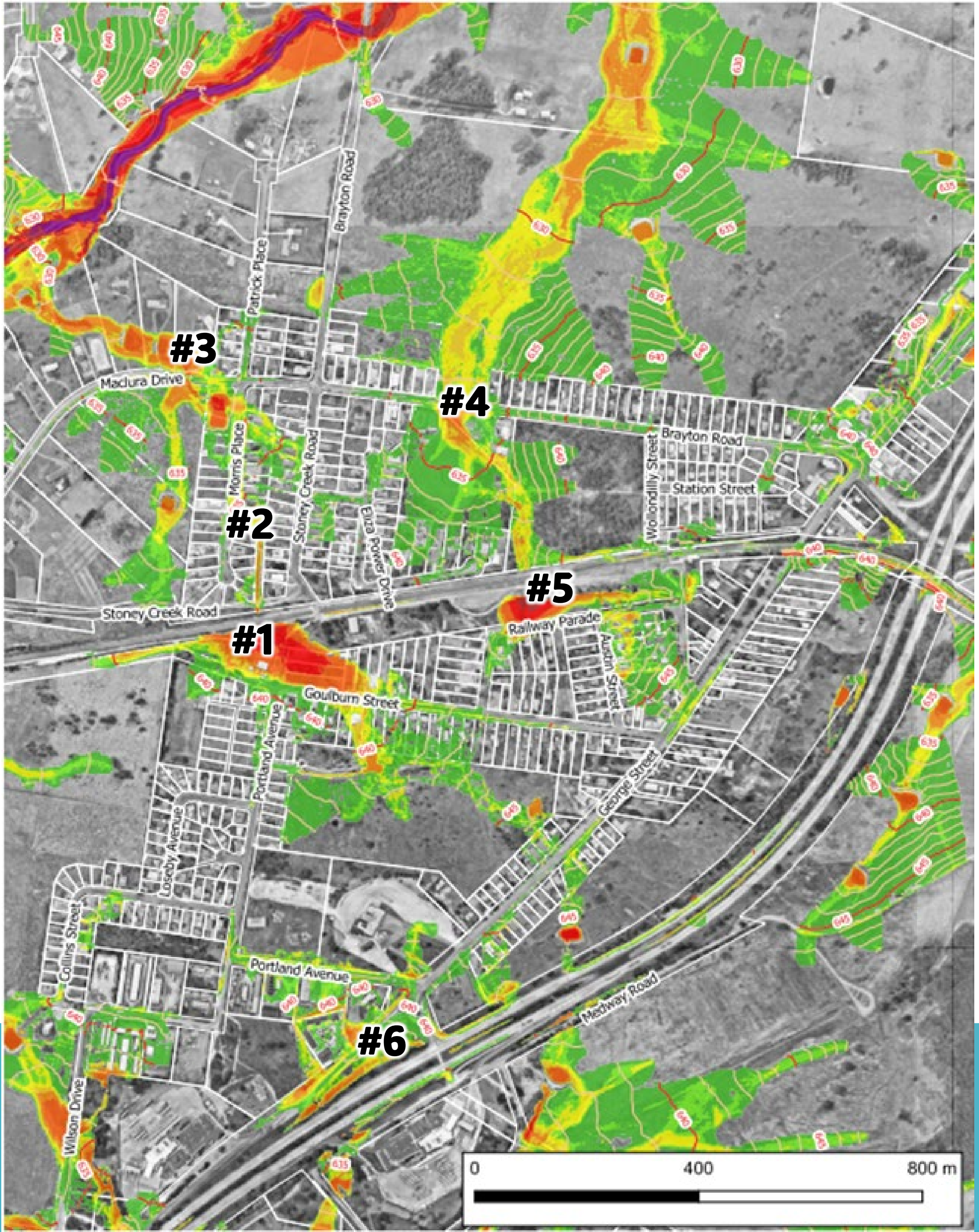
- Areas identified by:
    - *Community input*
    - *Analysis of the flood study results*

- Areas of interest to stakeholders
    - *TfNSW – Hume Highway – Flood assessment is focused on cross drainage, not road drainage. Mitigation measures can be presented as requested*
    - *WaterNSW - Urban Fringe Housing Strategy*

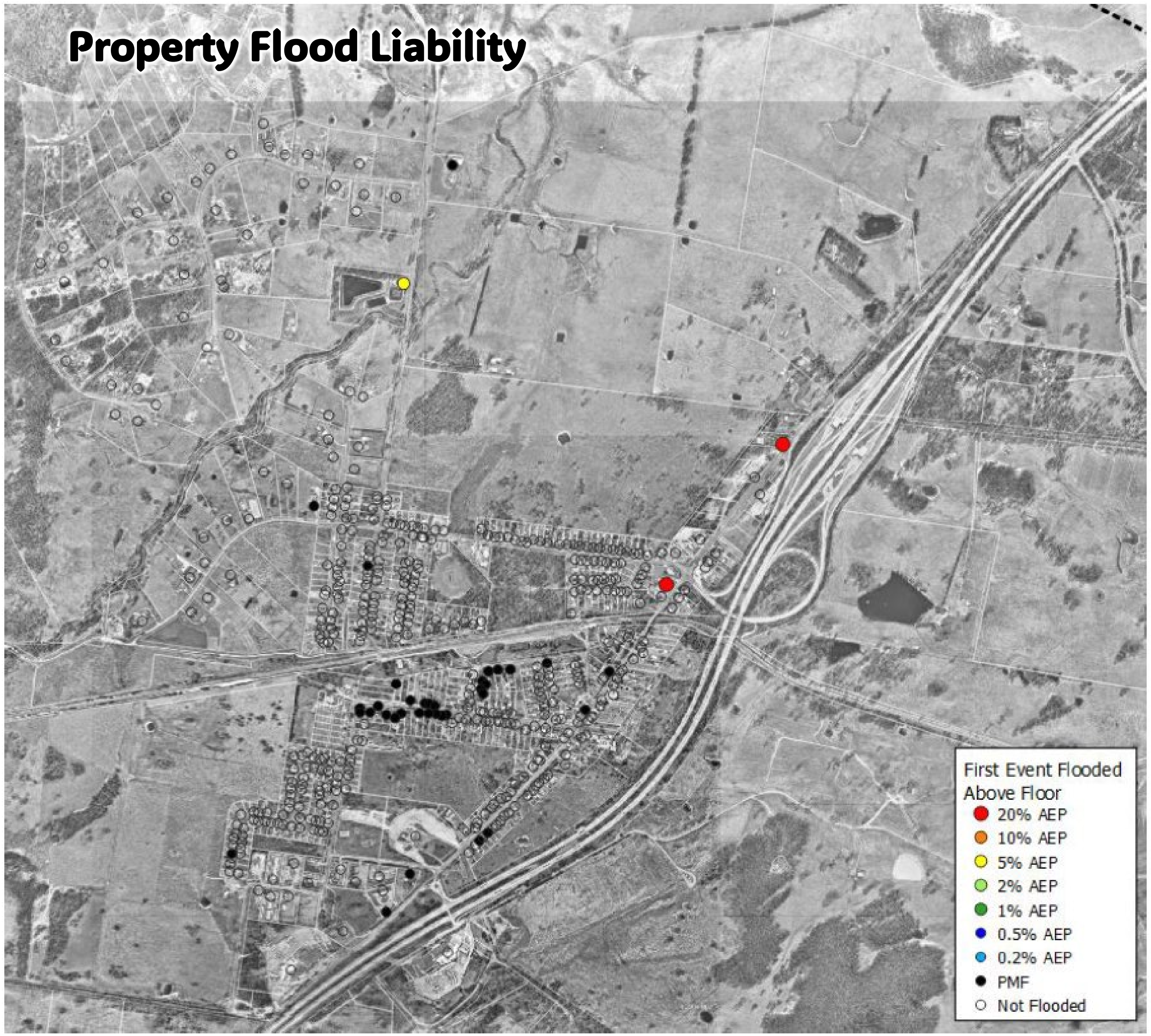


Hotspots

- #1 – Goulburn Street
- #2 – Morris Place
- #3 – Maclure Drive
- #4 – Brayton Road
- #5 – Railway Parade
- #6 – Portland Avenue

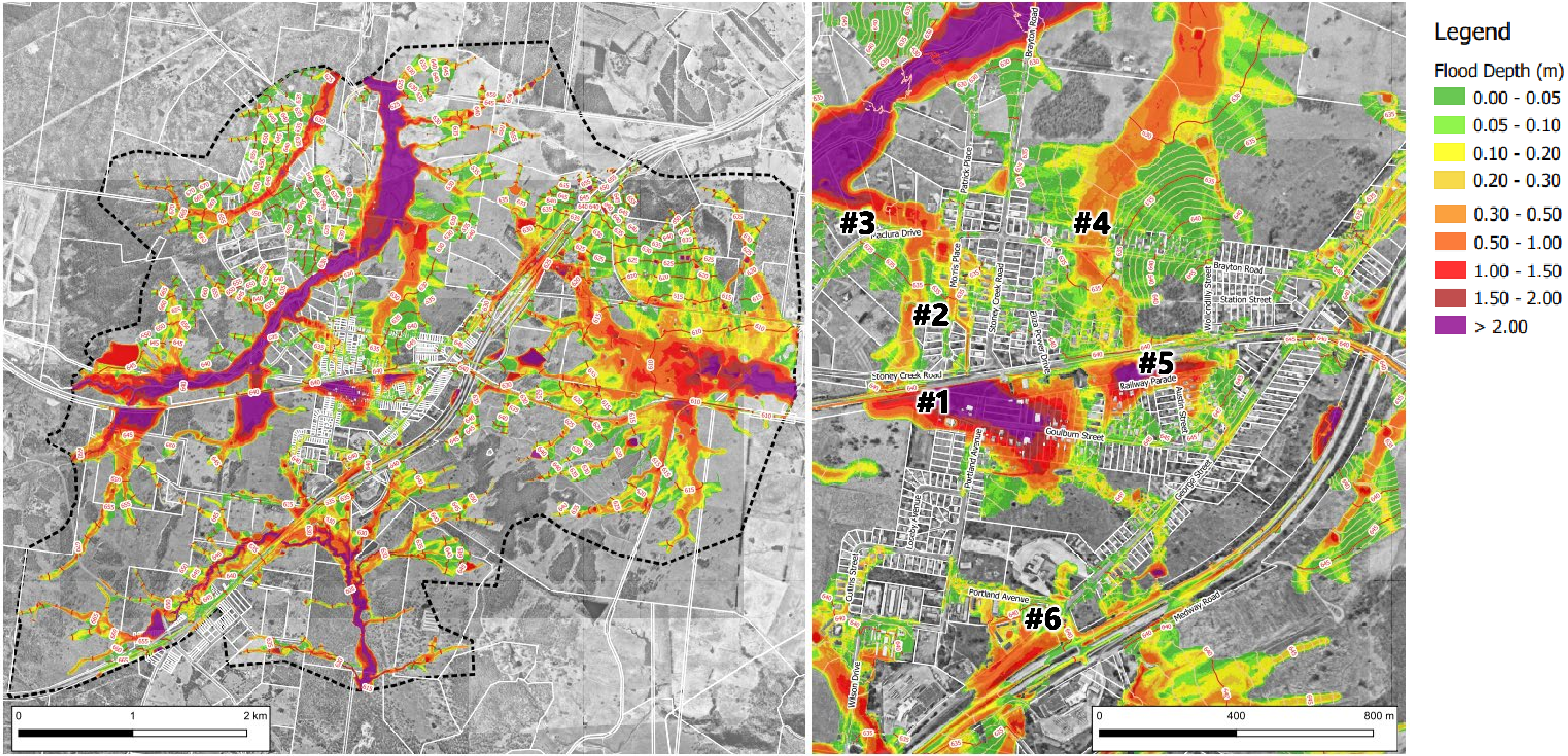


Property Flood Liability



grc HYDRO

GOULBURN MULWAREE COUNCIL



Current Flood Study Overview

PMF Results

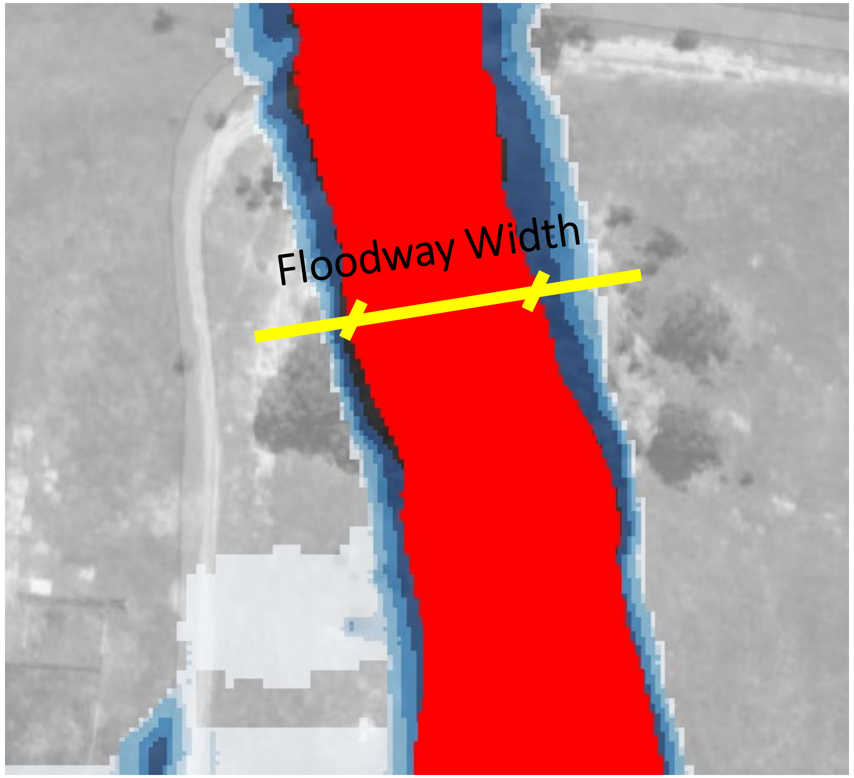
Flood Function

1. Derived via the Conveyance technique as described and exemplified in “Flood Function - Flood Risk Management Guide FB02” by DPE (2022)

2. An automated process was used via scripting.

3. To eliminate flood ways in minor tributaries / areas with ill-defined channel, a filtering process was applied:

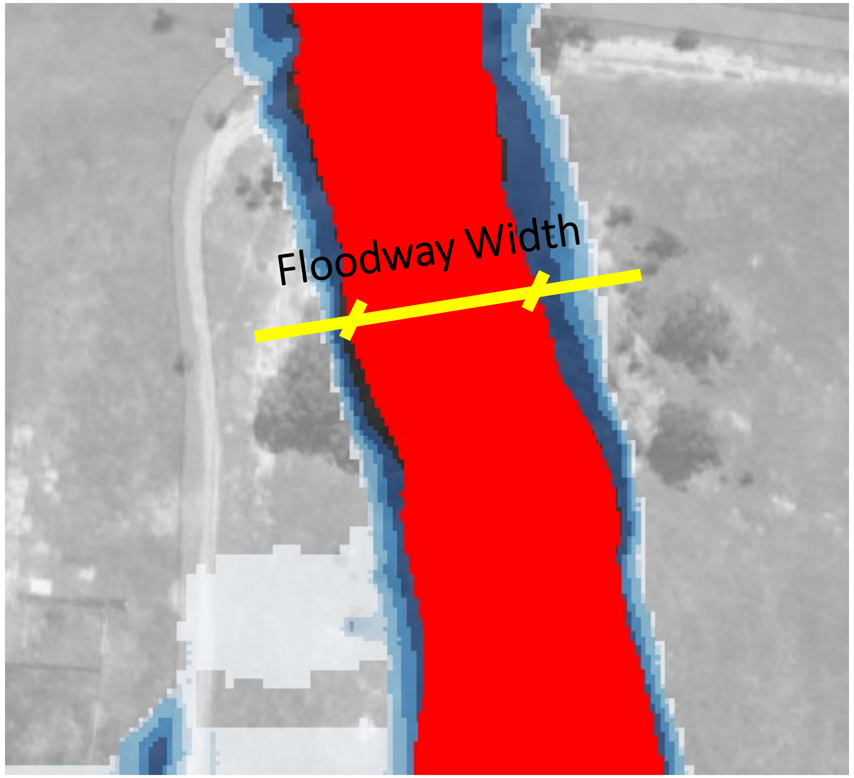
    1. *If a cross line has total conveyance of less than $0.2 m^2/s$, it was removed from the process*
    2. *If a cell has a Z0 of less than 0.02, it was also removed from the process (but retained during the computation of total conveyance)*

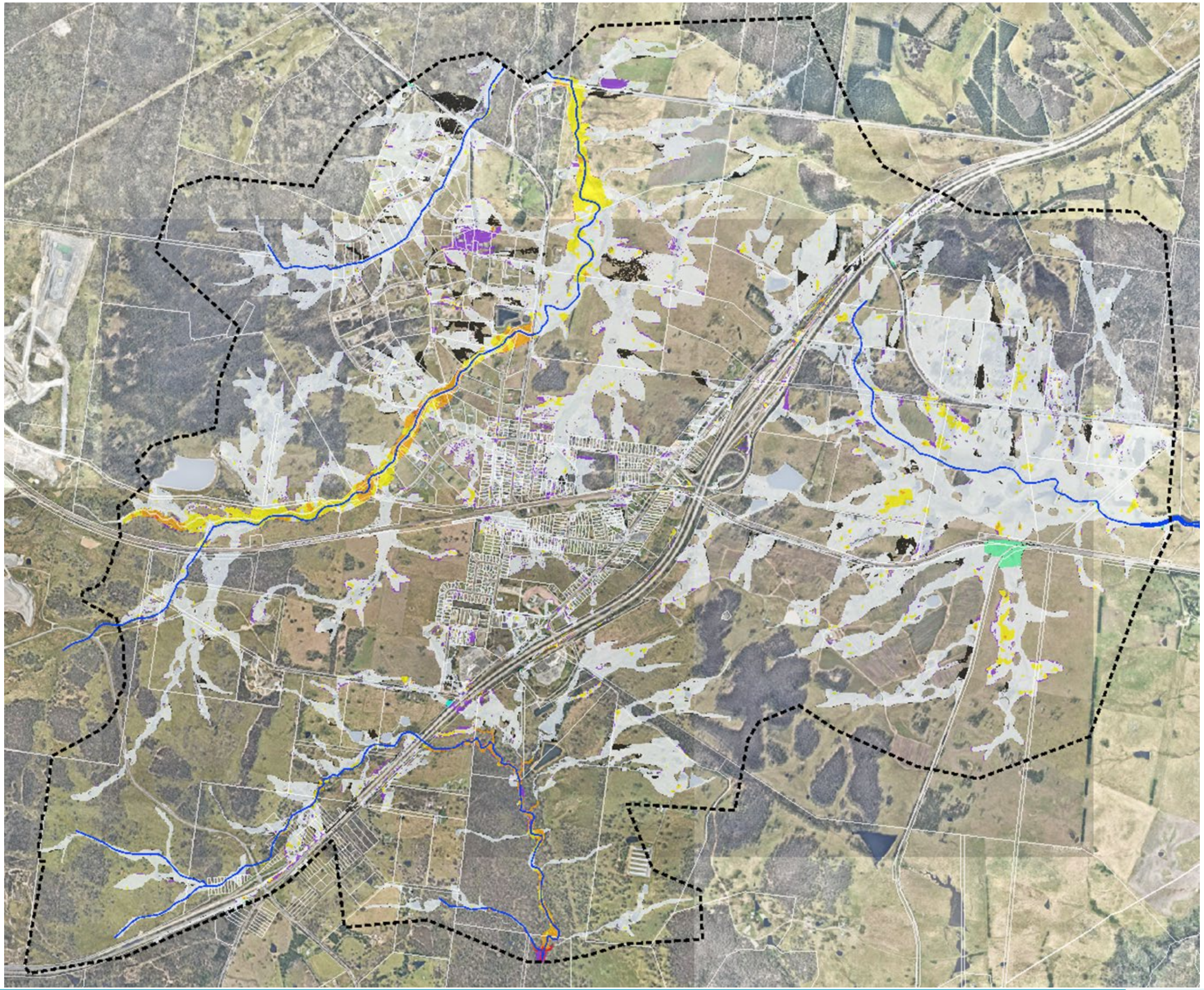


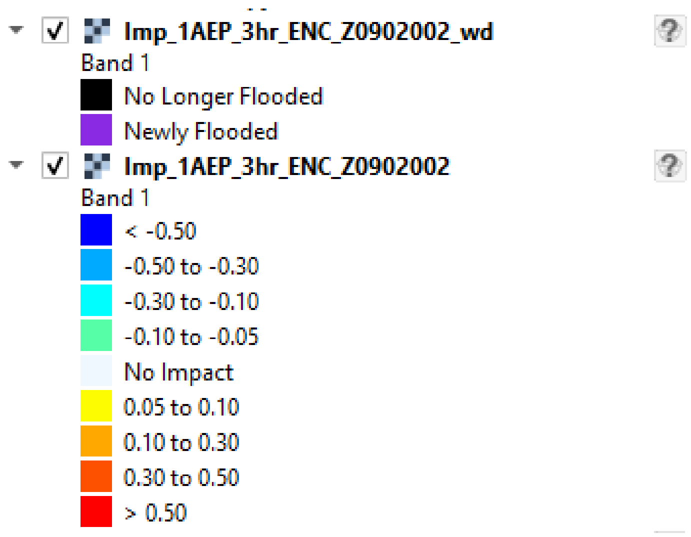
Flood Function

1. 70%, 80% and 90% of total conveyance was trialled. 90% was selected to move forward.

2. Once the floodway area has been defined, an encroachment analysis was performed by increasing manning's roughness to 0.4 to all areas that are not floodway.







1. Impacts greater than 0.1m are note but are typically less than 0.15 m for out of bank flow areas.

Encroachment Analysis Results

1% AEP Results

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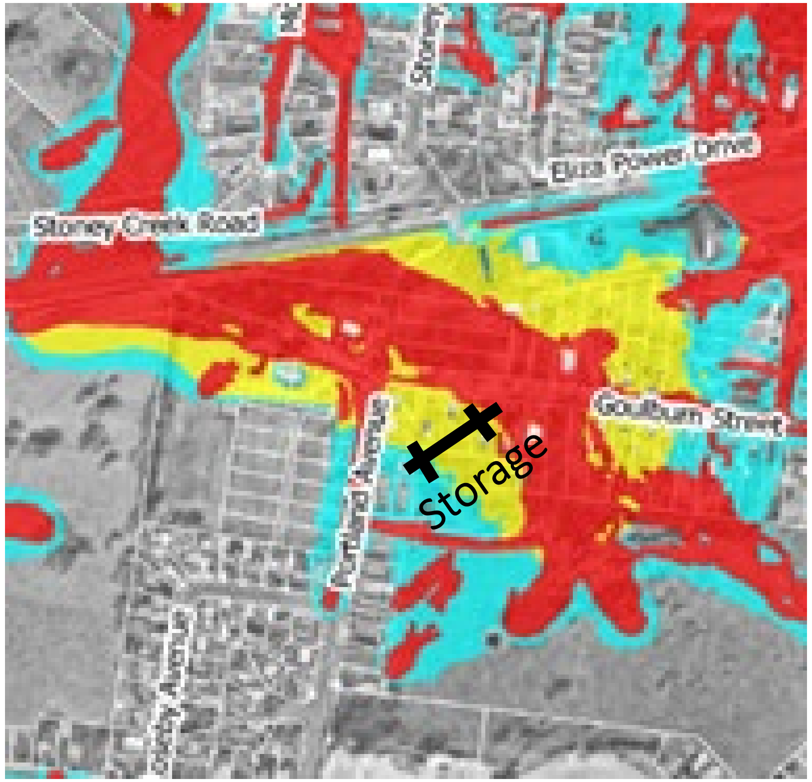
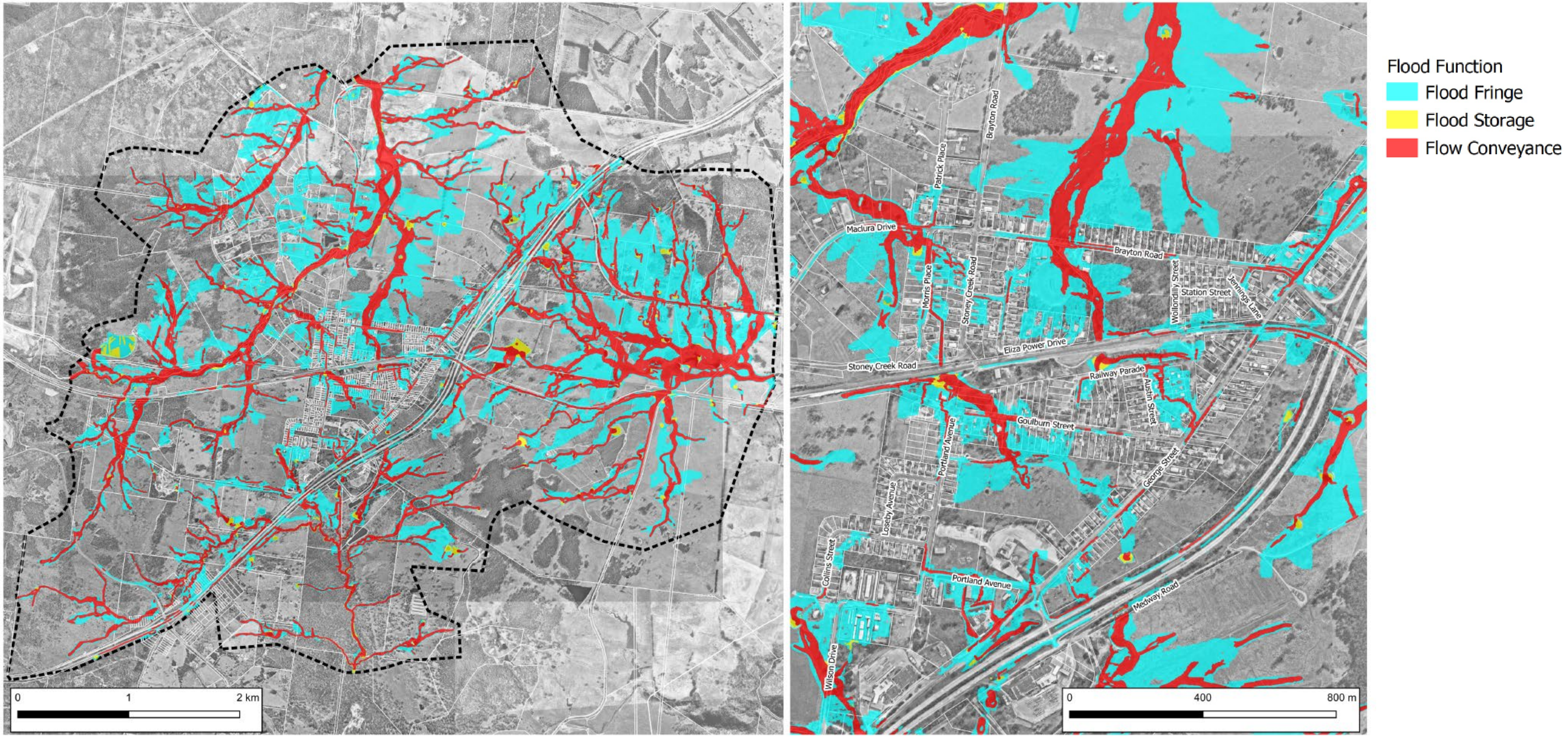
Flood Function

1. The flood storage areas have been defined as the remaining area that has flood depths greater than 0.5m

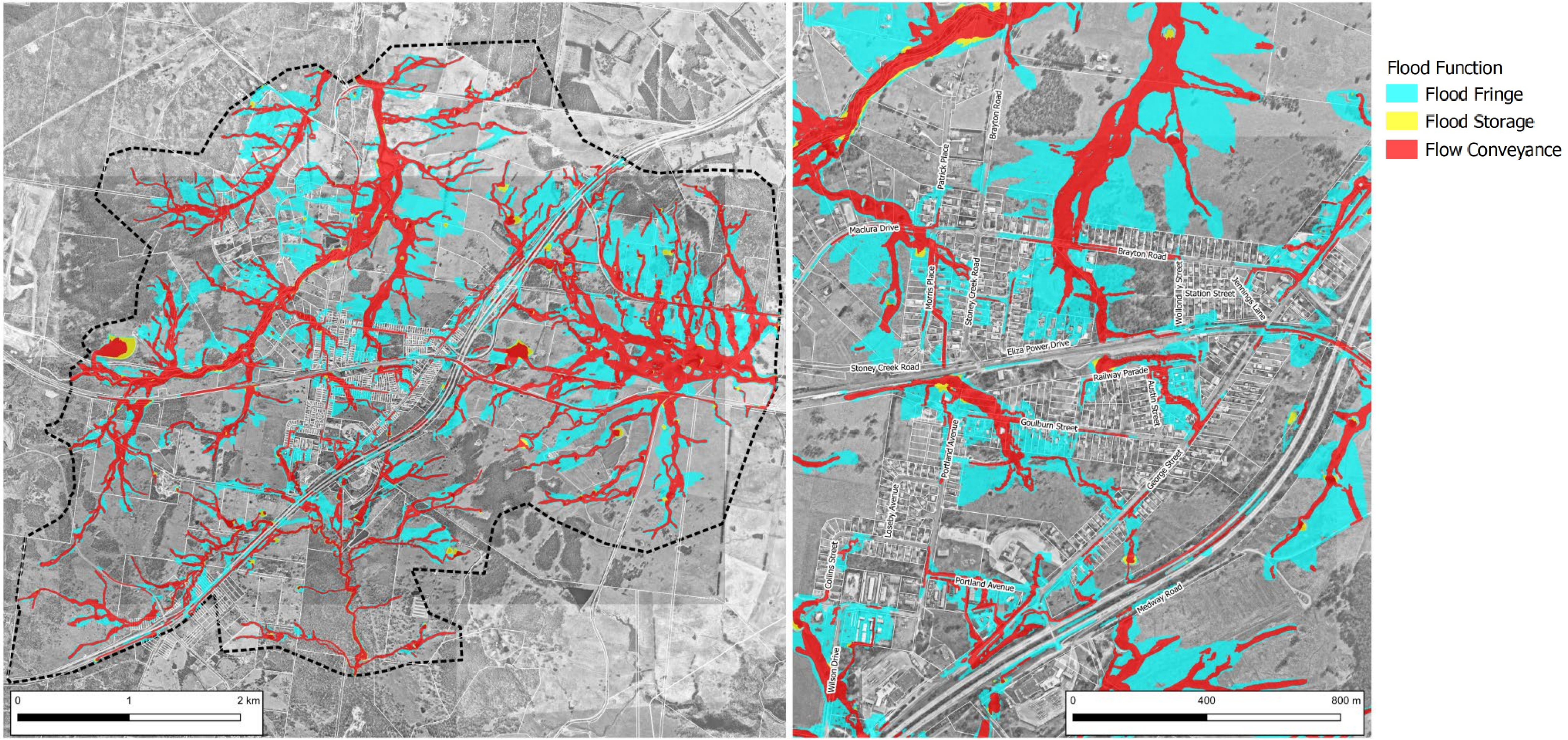
2. Flood fringe have been defined as the remaining area that is not a flood way, nor flood storage.





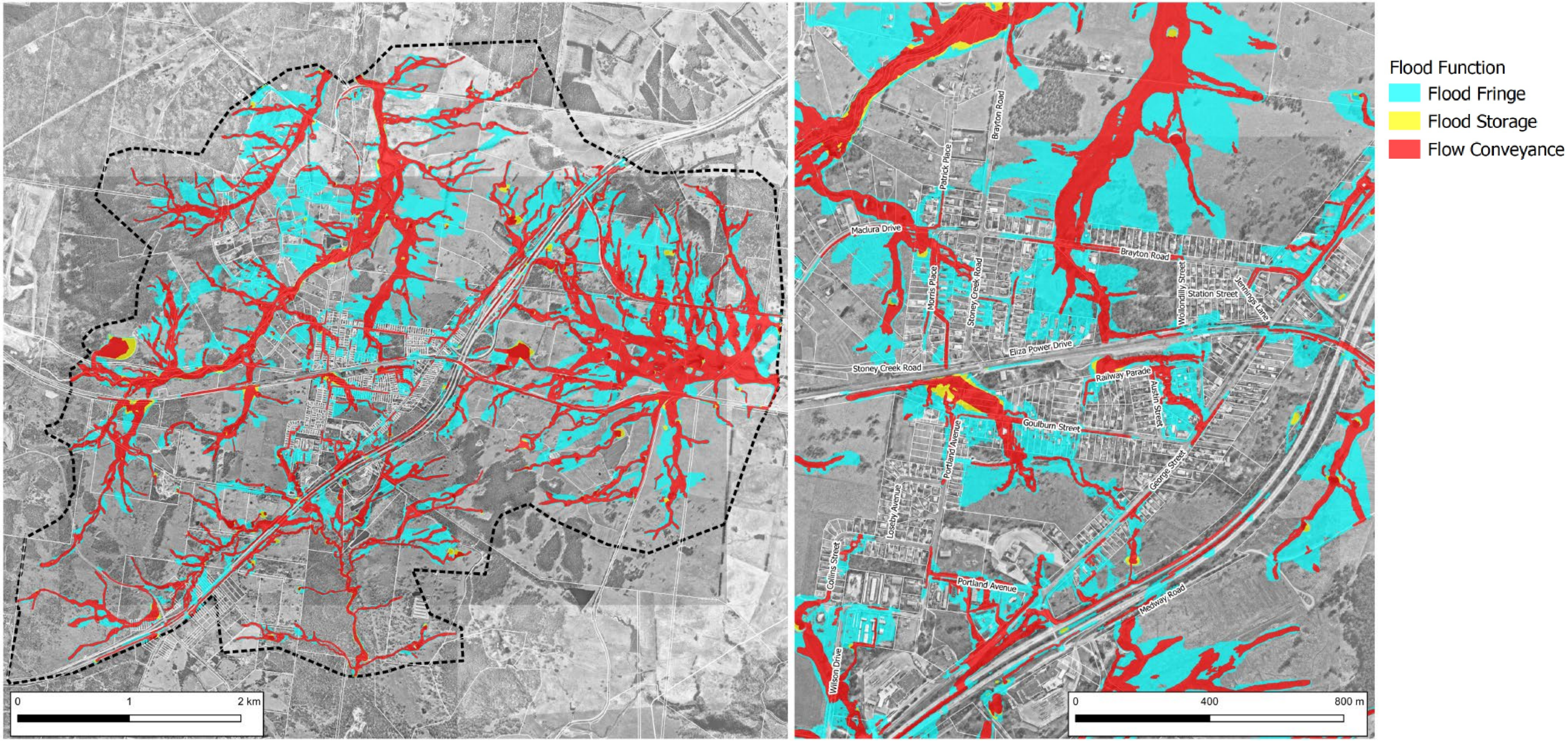
Flood Function Results

5% AEP Results



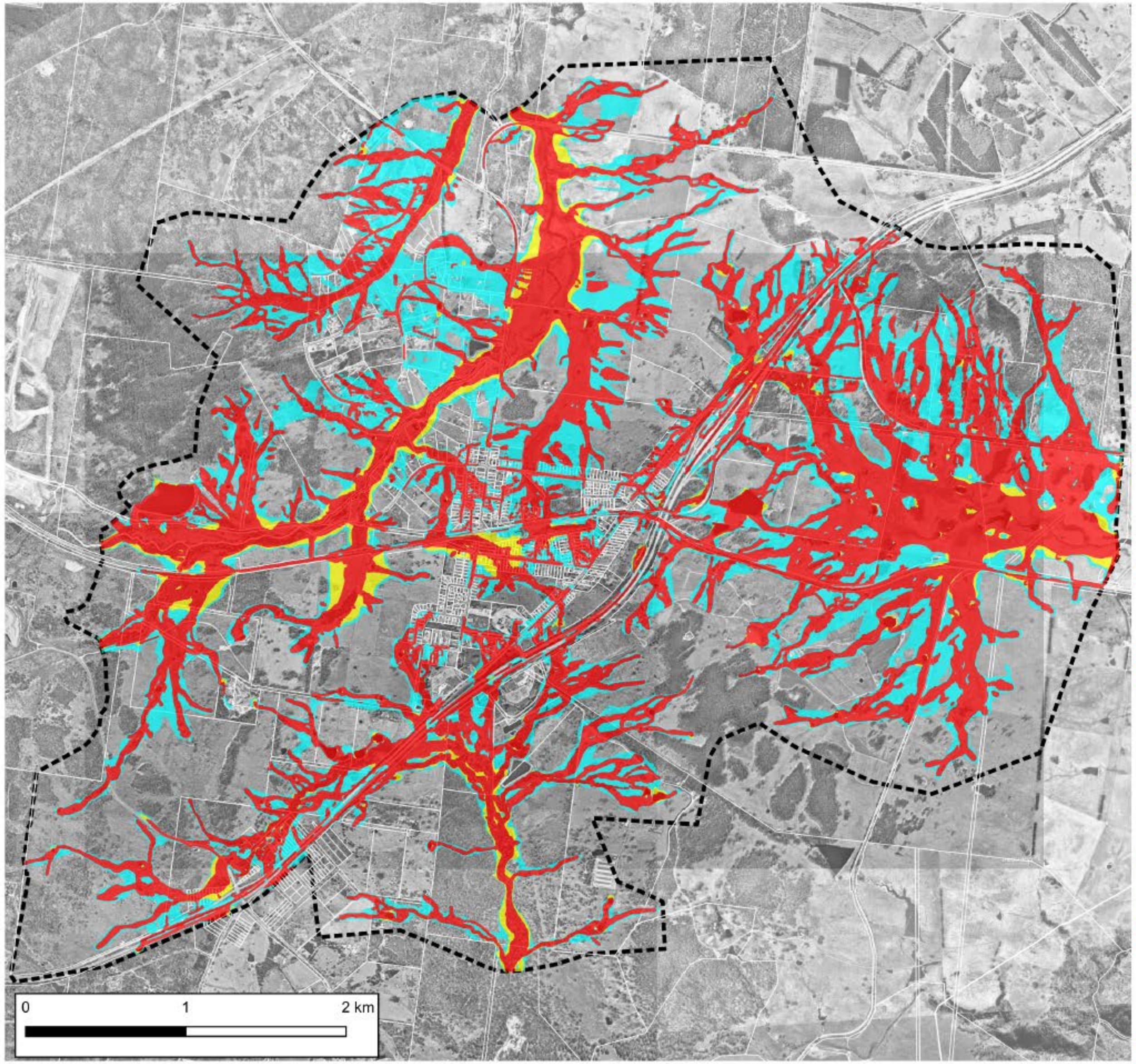
Flood Function Results

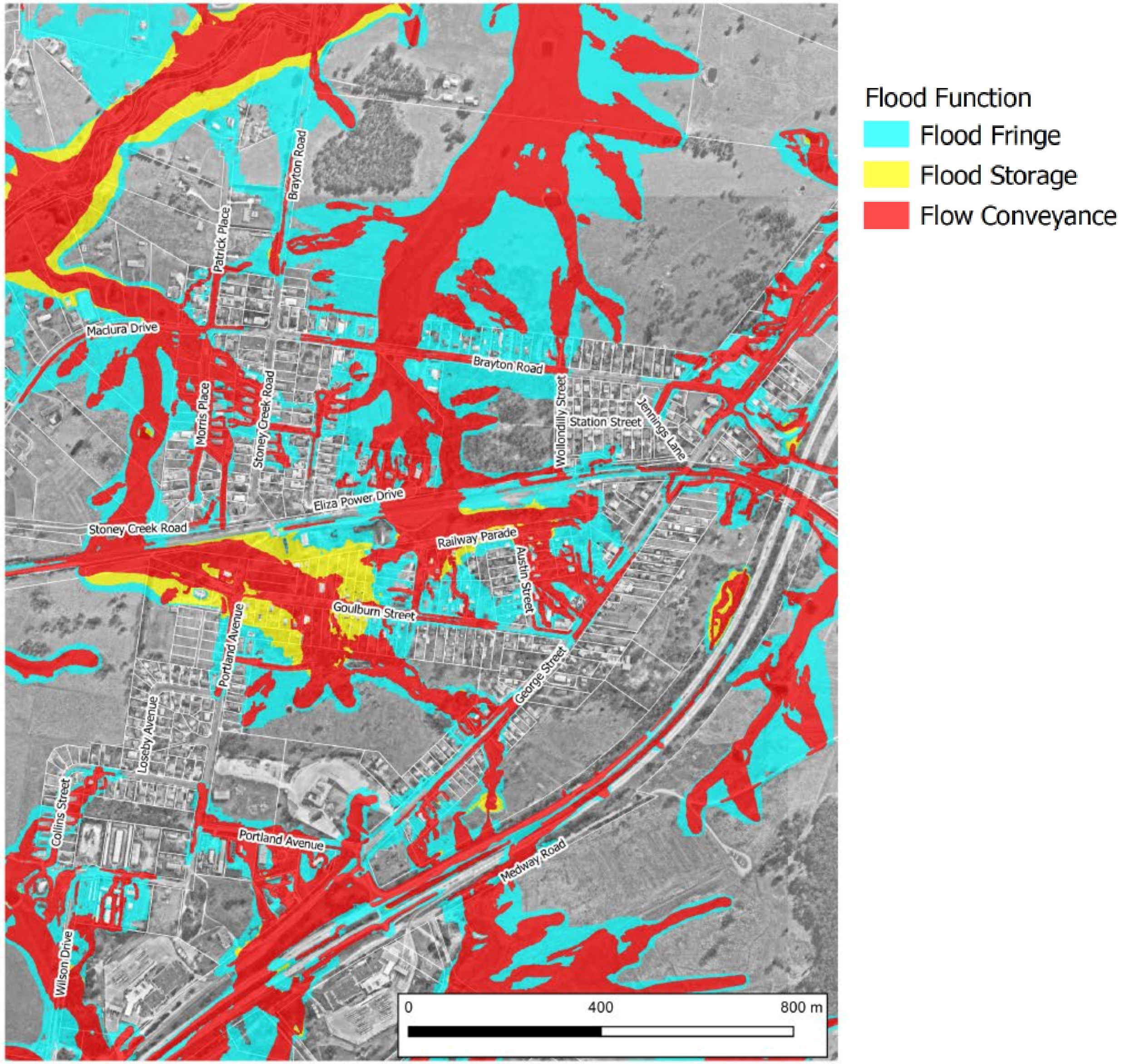
1% AEP Results



Flood Function Results

0.2% AEP Results





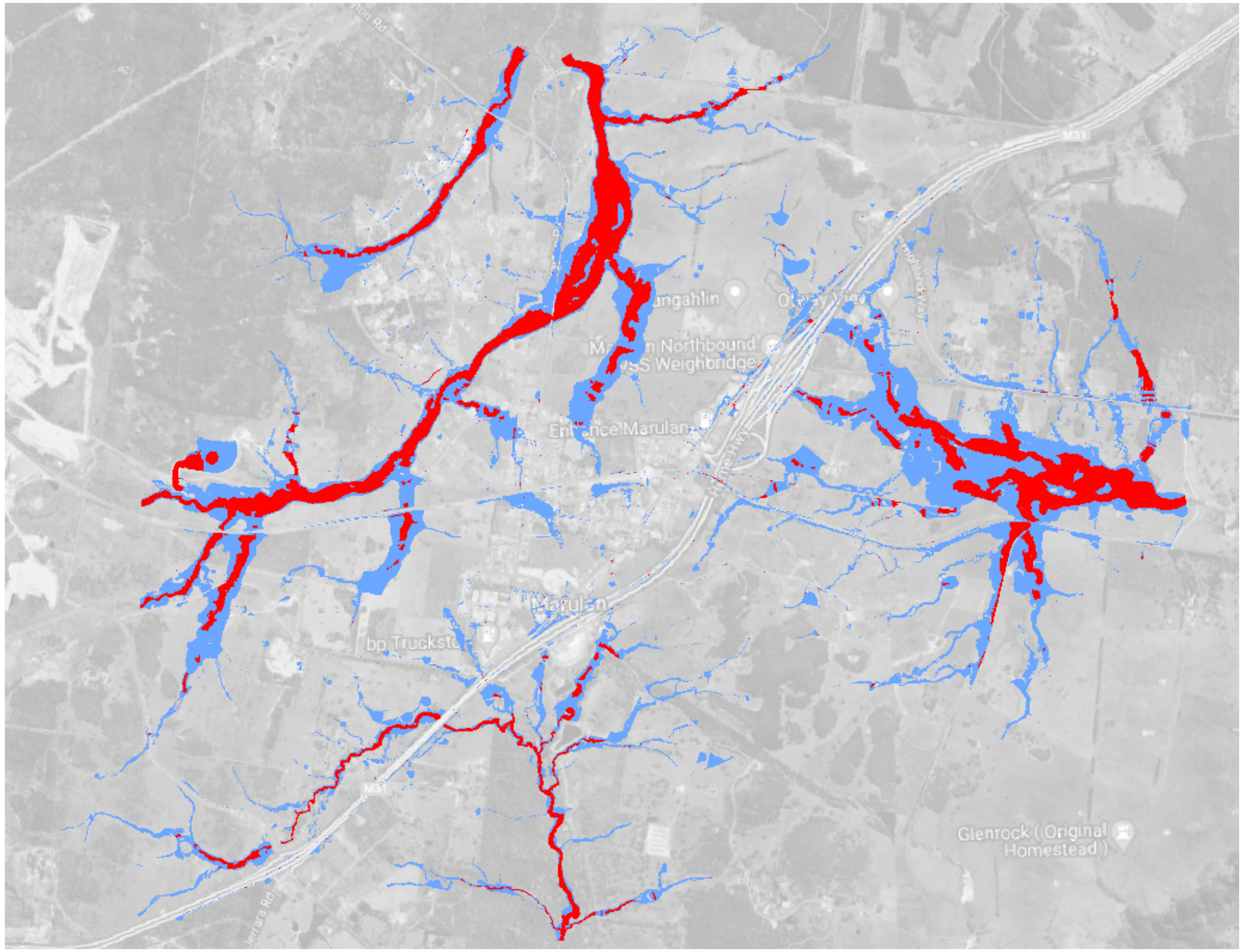
Flood Function Results

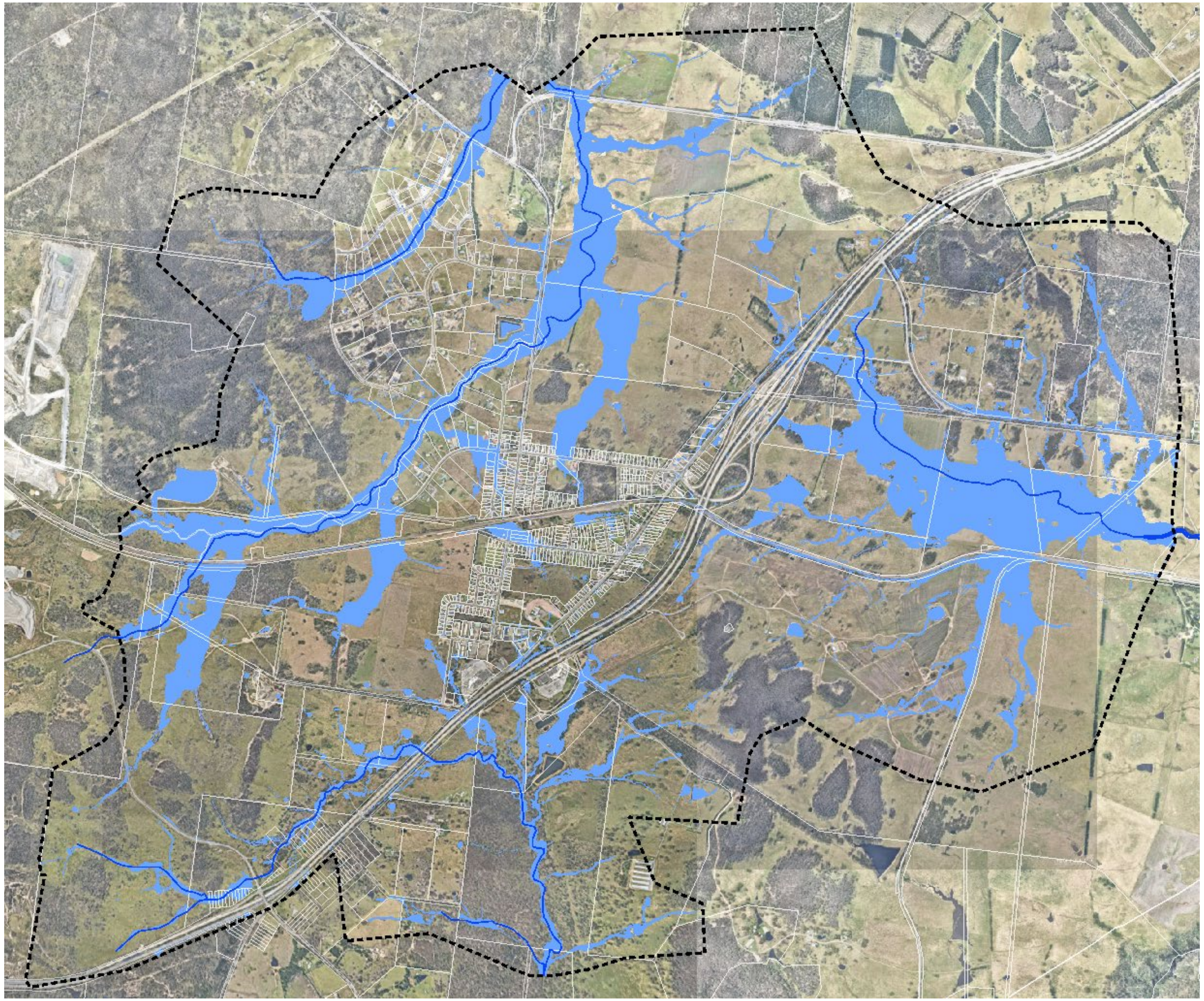
PMF Results

Flood Planning Area

1. Mainstream:
    - *Defined as flow paths with flows greater than $5m^3/s$*
    - *1% AEP Flood Level (for extreme blockage) + freeboard*
    - *Freeboard assessment to be undertaken*
    - *Areas in red in the picture on the right are the areas identified as Mainstream areas*

2. Overland flow:
    - *Defined for the remaining area not within the mainstream FPA*
    - *Extent of 1% AEP event with flood depths greater than 0.1m OR 1% AEP floodway*





Preliminary FPA (0.5 m freeboard assumed)

Items for Discussion

- Flood Planning Policy Review:
  - *Goulburn LEP Section 5.21, 5.22 required?*
  - *Goulburn DCP flooding section required?*

- Cumulative impact assessment:
  - *Modelling of increased impervious due to UFHS*
  - *Other areas proposed for development?*
  - *Treatment of existing urban areas?*

Moving Forward

- *Finalise the works discussed herein*
- *Prepare flood management measures long list*
- *Agree on five measures for quantitative investigation*
- *Prepare Draft Floodplain Risk Management Study*

GRC Hydro
Level 9, 233 Castlereagh Street
Sydney NSW 2000

Tel: +61 409 833 039
www.grchydro.com.au

Job Number: *210048*
Date: *14 September 2023*

Minutes from Floodplain Risk Management Inception Meeting- DRAFT

Project: Marulan Flood and Floodplain Risk Management Study and Plan

Date & Time: 12/09/2023 3.00 pm

Subject: FRMSP Inception Meeting

Location: MS Teams Meeting

Attendance:

Goulburn Council	DPE	GRC Hydro
Kate Wooll	Shaza Raini	Zac Richards
		William Tang
		Osama Heba

Apologies: Nil

Meeting name	Inception Meeting Marulan Flood Study and Floodplain Risk Management Study and Plan
Meeting purpose	Inception meeting to discuss way forward for Marulan Floodplain Risk Management Study.
Agenda	1. Consultation 2. Identification of Hotspots 3. Flood Function Analysis 4. Flood Planning Area 5. Other issues for discussion 6. Moving Forward

#	Item	Action (if any)
1	Consultation • Community meetings to be done at public exhibition stage. GRC Hydro to perform one-on-one meetings with interested residents on request. • Invite stakeholders (TfNSW, ARTC, and WaterNSW) to the FMC meetings moving forward. • Review responses of the community consultation for the FRMSP questions.	GRC Hydro GRC Hydro GRC Hydro
2	Identification of Hotspots • Council requested area west of Goulburn Street (Hotspot #1) to be included as Hotspot #7. o GRC Hydro notes that hotspots selection is generally done with the purpose of flood damages estimation for options assessment. As no flood risks exists in existing conditions, it will result in no benefits. o Council notes that the interest is primarily drive due to potential future development in the area. o GRC Hydro to consider inclusion as new hotspot or alternatively, to provide discussion of flood risks constraints behind the rail corridor: • Council requested area north of Hotspot #4 to be included in flood risk constraints discussion. GRC note that UFHS release areas will be considered as part of a separate exercise with mapping produced to show flood constraints and high level area estimate of low risk land identified. • DPE recommends consideration of flood mitigation measures that can benefit both existing communities as well as future communities (e.g. future developments). GRC notes that options that provide good cost/benefit ratios for existing development should be pursued.	GRC Hydro GRC Hydro GRC Hydro
3	Flood Function Analysis • DPE endorses the method used by GRC Hydro to derive flow conveyance areas, noting that reporting needs to be updated for clarity. o GRC Hydro to provide a DRAFT of the reporting section for approval as other items of the FRMSP requires the floodway to be "finalised".	GRC Hydro
4	Flood Planning Area • Council endorses the methodology demoed by GRC Hydro to derive flood planning area. • DPE notes that similar methodology has been applied in other catchments and also endorses the application for the present study area. • GRC Hydro to provide a DRAFT of the reporting section for approval.	GRC Hydro GRC Hydro GRC Hydro
5	Other issues for discussion • Council notes that there are no issues with updating/amending DCP if required. GRC Hydro to review DCP.	GRC Hydro

	• Council requests flood information to be provided for each of the UFHS:
	  ○ Map/dot points describing key flooding constraints.
	  ○ High level mitigation options assessment to maximise yield (qualitative only)
	  ○ Provide extent of land suitable for development
	• GRC Hydro advise that mitigation options for undeveloped land will not receive funding. However, it is noted that shallow flows that were of concern to Council will not be included in the FPA, which is a key constraint for rezoning of land.
	• Cumulative impacts assessment needs to incorporate existing zoned land for ultimate development potential
		GRC Hydro
		
		GRC Hydro
		
		GRC Hydro

Meeting concluded.		

APPENDIX B – FREEBOARD ANALYSIS

Assessment of a range of factors which influence the recommended freeboard has been considered. The analysis implements the joint probability framework to determine an appropriate freeboard for the FPL for mainstream and overland flow flooding. Separate calculations were undertaken for mainstream and overland flow flooding due to differences in flood characteristics and risk. This analysis builds on the sensitivity analysis presented in the Flood Study by extracting the (spatial) average difference in flood levels between the sensitivity analysis scenarios and baseline conditions for regions affected by mainstream flooding and by overland flow flooding.

The joint probability analysis is presented herein.

Local Water Surge

Local water surge can result in localised flood levels that are higher than the general flood level. Surge can occur due to changes in flow velocity associated with variation in flow direction and/or flow regime. These changes can potentially occur due to ground level changes, or obstruction of flow due to buildings. In these cases, kinetic energy may be converted to potential energy, which results in localised increased flood levels. If it is assumed that the kinetic energy is reduced to zero, the follow equation can be used to determine the resulting increase in local water level:

$$h_s = \frac{v^2}{2g}$$

Where:

h_s = surge height (m)
v = local velocity (m/sec)

Table B1 provides the peak velocities on the Jaorimin Creek, as well as two of the identified hotspots with that are subject to relatively higher velocities, and the calculated surge height.

Table B1: Calculated local water surge on the Jaorimin Creek and hotspots subject to relatively high velocities

River	1% AEP Average Velocity (m/s)	Surge Height (m)
Jaorimin Creek	1.04	0.06
Hotspot 1	0.3	0.00
Hotspot 4	0.35	0.00

The probability that the full expression of energy loss will occur is low, however some surge is likely to occur. To approximate the likely surge conditions, 75% probability has been applied to the joint probability analysis. This probability has been selected as it considers that some surge is likely, however the maximum surge associated with conversion of all kinetic energy to potential energy is unlikely.

Uncertainties in Flood Level Estimates

The results of the sensitivity analysis undertaken during the Flood Study found that variation of model parameters could increase flood levels on average by up to 0.2 m for mainstream flooding and 0.1 m for overland flow flooding. Furthermore, the LiDAR data used in the hydraulic model has an accuracy of ±0.15 m (1st confidence interval) in the vertical direction.

As described in the flood study, calibration of the model's was not possible, however, no bias in the applied model parameters is expected. For this reason, a neutral probability (50%) has been applied to LiDAR accuracy and parameter sensitivity as the variables that are responsible for the uncertainty in flood levels could equally result in lower flood levels, rather than high flood levels.

Post construction settlement and defects

Settlement and defects can occur after the construction of a building which can affect the eventual height of a floor level. To account for these factors, a settlement of 0.02 m has been adopted and a neutral probability (50%) has been applied.

Climate Change

The impact of climate change has been considered in the Flood Study by undertaking a rainfall comparison based on two emissions conditions. This assessment found that under low emissions conditions the 1% AEP event rainfall will be close to the 0.5% AEP event rainfall and under higher conditions the 1% AEP rainfall would be between 0.5% and 0.2% AEP event rainfall. Based on these higher emissions conditions (RCP8.5), peak flood levels would be expected to increase on average by 0.16 m for mainstream flooding and 0.02 m for overland flow flooding. Given the uncertainty associated with the predicted climate change impacts on flood producing rainfall, a neutral probability (50%) has been considered in the joint probability analysis as the impact of climate change on rainfall intensities is not completely understood.

Freeboard Allowance

The joint probability analysis considers the variables and probabilities previously discussed, with the analysis presented above. Individual freeboards for mainstream and overland flow flooding have been calculated as presented in Table B2.

Table B2: Flood Planning Level – joint probability analysis

Freeboard Item	Mainstream Flow Allowance (m)	Mainstream Flow Probability (%)	Mainstream Flow Joint Prob. (m)	Overland Flow Allowance (m)	Overland Flow Probability (%)	Overland Flow Joint Prob. (m)
Local Water Surge	0.06	75	0.045	0	75	0
Uncertainties in Flood levels						
- Sensitivity to parameters						
o Roughness ±25%	0.06	50	0.030	0.01	50	0.005
o Downstream slope ±25%	0	-	-	0	-	-
o Rainfall loss -25%	0.03	35	0.011	0.01	35	0.004
o Rainfall +30%	0.16	30	0.048	0.06	30	0.019
o Blockage*	0.22	50	0.112	0.08	50	0.040
- Lidar accuracy	0.15	50	0.075	0.15	50	0.075
Post Construction Settlement and Defects	0.02	50	0.010	0.02	50	0.010
Cumulative impact of future development	0.08	90	0.072	0.06	90	0.054
Climate Change (RCP 8.5)	0.16	75	0.038	0.02	75	0.015
Joint Probability Results			0.43			0.21
Adopted freeboard			0.5			0.3

* The 1% AEP triple blockage scenario has been used as the DPE to account for the flood risk due to blockage at the rail corridor.

The adopted freeboard was selected by rounding up the joint probability assessment to the nearest 0.1 m. This resulted in a:

- Mainstream flooding freeboard of 0.5 m; and an
- Overland flow flooding freeboard of 0.3 m.

These freeboards have been adopted to derive the Flood Planning Area presented in Section 5.4 of the main body of the report.

APPENDIX C – COMMUNITY CONSULTATION

Have Your Say on Flooding in Your Area

Marulan Flood Study & Floodplain Risk Management Study and Plan

Marulan Flood Study & Floodplain Risk Management Study and Plan

Goulburn Mulwaree Council are undertaking a Flood Study and Floodplain Risk Management Study & Plan for Marulan. The study is being prepared with assistance from GRC Hydro and is being undertaken as part of the NSW Government's Floodplain Risk Management Program.

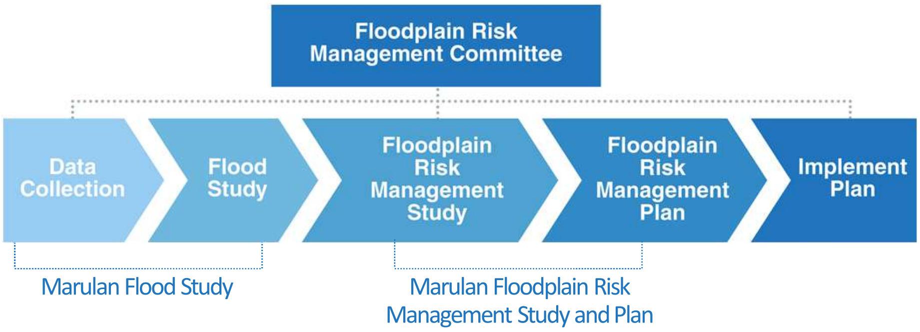
We would like to hear your experiences of flooding to better understand how flooding occurs in Marulan. This information will be used by Council to help manage flood risk for people and property, as well as potential future development.

What is the Floodplain Risk Management Program?

The Floodplain Risk Management Program is run by the NSW Government. This program helps councils to make informed decisions about managing flood risk and to provide essential information to the SES to coordinate flood emergency response.

This program consists of five stages; the Marulan Flood Study and subsequent Floodplain Risk Management Study and Plan will comprise stages one to four of this process.

The stages of the Floodplain Risk Management Program are presented below:

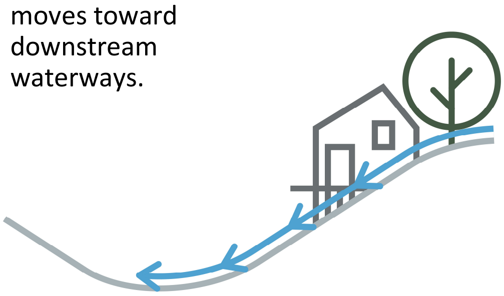


What is Flooding?

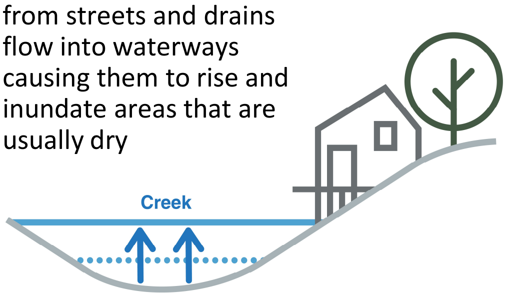
Flooding is often associated with inundation from large rivers; however, there are other flood mechanisms that can cause inundation. Two of these mechanisms are overland flow flooding and mainstream flooding.

The Marulan Flood Study will focus on both of these flood mechanisms.

<u>Overland flow flooding</u> occurs as rainfall runoff moves toward downstream waterways.



<u>Mainstream flooding</u> occurs when runoff from streets and drains flow into waterways causing them to rise and inundate areas that are usually dry



What is a Flood Study?

A flood study is a comprehensive technical investigation of flood behaviour. This study will define the nature of flood risk in your area by providing information on the extent, level and velocity of floodwaters for a full range of flood magnitudes up to and including the largest possible flood, termed the 'Probable Maximum Flood'. A commonly used outcome from a Flood Study is the 1% AEP flood result (also known as the 1 in 100 year flood). Sensitivity testing is also undertaken in these studies to account for factors such as climate change and blockage of drainage systems.

What is a Floodplain Risk Management Study and Plan?

A floodplain risk management study and plan (FRMS&P) draws on the results of the flood study to identify, assess and compare various flood risk management options and opportunities aimed at improving the existing flood situation. It provides information and tools to allow considered assessment of flood impacts of management options and provides a strategic plan for implementation.

Have Your Say on Flooding in Your Area

Marulan Flood Study & Floodplain Risk Management Study and Plan

What is a Flood Study and FRMS&P used for?

A Flood Study and FRMS&P provide key information for Council, the SES & the community for effectively managing & mitigating flood risk.

For Council, these studies are primarily a planning tool for future development in Marulan and implementing flood risk mitigation measures for existing development areas. Examples of applications for Council are listed below:

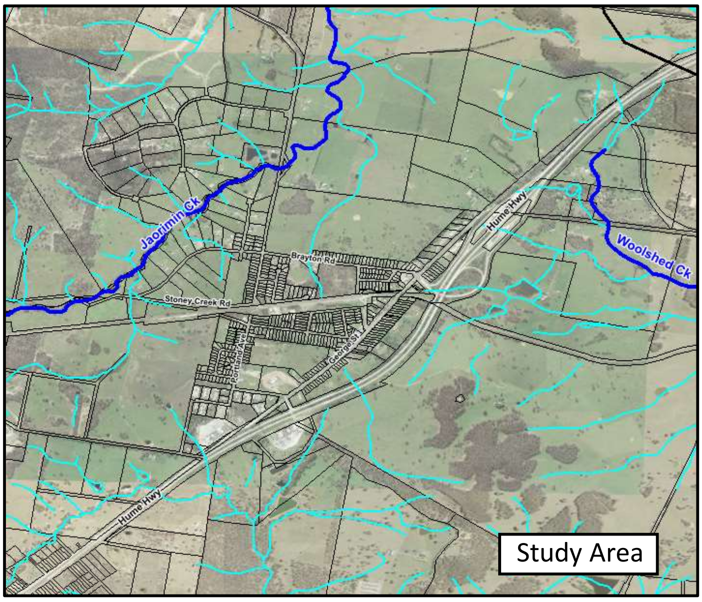
- Examination of Council's local flood risk management policies, strategies and planning instruments; and
- Identification and assessment of floodplain risk management measures for existing development areas aimed at reducing social, environmental and economic loss due to flooding on development and the community.

Information from these studies will assist the SES in its evacuation and logistics planning. The outcomes of the study will provide the SES with:

- a clear description of flood behaviour in the study area for a full range of flood events;
- a description of flood warning times for Goulburn; and
- identification of critical evacuation issues in Goulburn such as warning times where road access is cut.

The Study Area

The Flood Study and FRMPS&P will cover an area of approximately 18 square kilometres inclusive of the Marulan township and its surrounds (pictured below). Marulan is traversed by some natural overland flowpaths and Jaorimin Creek to the west.



Why your feedback is important

During the Flood Study, GRC Hydro will develop computer models to determine the existing flood affectation in Marulan. Calibration and validation to observations of flooding key in the development of these models to improve accuracy. The FRMS&P will assess flood modification measures to relieve the flood risk at affected locations. Community input and knowledge of how flooding occurs and of measures that might mitigate flooding is invaluable to this study.

What happens next?

GRC Hydro will model the flood behaviour in Marulan and produce a flood study report for Council. It will be placed on Public Exhibition in 2022 and comment will be invited. Following this, the FRMS&P will be developed with Public Exhibition expected in late 2022.

How can you help us?

Your feedback is important in helping us get a complete picture of the community's knowledge of flood behaviour and concerns in your area. There are a variety of ways you can share your experiences and knowledge with us. These are as follows:

01. Fill out the questionnaire included with this letter and send it back using the self-addressed envelope provided or email it to marson@grchydro.com.au.

02. Fill out the questionnaire online by going to the website listed or scanning the QR code below.
Website:
https://www.goulburn.nsw.gov.au/Development/Plans-Strategies#section-8

03. For more information, please do not hesitate to contact the representatives nominated at the bottom of this page.

Who can we contact?

If you have any further questions regarding the study or any further flood information/photos please attach them to your questionnaire or contact the following representatives.

Beth Marson
Senior Engineer
GRC Hydro
marson@grchydro.com.au
02 9030 0342

Strategic Planning
Goulburn Mulwaree Council
Council@goulburn.nsw.gov.au
02 4823 4444

Please return your questionnaire by Friday 3 December 2021 to have your say.

Have Your Say on Flooding in Your Area

Marulan Flood Study & Floodplain Risk Management Study and Plan Questionnaire

Contact Details

Name

Address:

Phone Number:

Email:

Can we contact you for more information? ◯ Yes ◯ No

Please note: Your personal details will be kept confidential

Your Property

What building type is your property?

◯ Residential (House/Terrace) ◯ Residential (Apartment)

◯ Commercial ◯ Industrial

Business Name:

How long have you lived or worked at this property? ____ Years ____ Months

Has your property ever been affected by flooding?

◯ Yes, above the floor level ◯ Yes, in the yard or garage ◯ No

If yes, could you please provide more information in the space below or attached to this questionnaire. Information such as dates and photos of flooding are very helpful.

Flood Observations

Have you observed flooding in your area?

◯ Yes ◯ No

If yes, please note where you have observed flooding and/or anything that has made flooding worse. For example, have blocked drainage structures or changes near your property made flooding worse? Information such as dates, maximum extent, top water level and photos of flooding are very helpful.

Have Your Say on Flooding in Your Area

The Marulan Flood Study & Floodplain Risk Management Study and Plan Questionnaire

New Development

The current study will provide advice on flood related development controls. How do you suggest Council should manage controls for developments on the floodplain?

- ◯ Prevent development on land subject to any flood risk (including events rarer than the 1 in 100 year ARI flood)
- ◯ Prevent any new development in areas where the flood risk is dangerous for people/property (i.e. deep fast moving water).
- ◯ Inform property owners of the potential flood risks and the related flood development controls and allow development provided the controls are adhered to
- ◯ Provide no advice or development controls
- ◯ Other (please specify)____

Flood Management Options

The current study is assessing a range of measures aimed at managing the current flood risk. The study is looking for input from residents to better understand local preferences for floodplain management.

Which of the following options do you prefer for managing flood risk? (tick box based on preference)

- ◯ Construct, repair and/or increase the size of existing levee banks
- ◯ Modify creek channels to increase their capacity
- ◯ Impose greater flood-related development controls and increase strategic flood planning
- ◯ Increase flood awareness and education in the community
- ◯ Upgrade flood warning, evacuation planning and emergency response measures
- ◯ Property modification measures for severely affected properties such as voluntary purchase or voluntary house raising.
- ◯ Other suggestions (describe below)

Please use the space below to describe other flood management options or add detail on the preferences selected above.

____

____

____

____

____

____

Please return your questionnaire by Friday 3 December 2021 to ensure that it is counted.
If your information does not fit in the space provided, please email it to **marson@grchydro.com.au**

APPENDIX D – PRELIMINARY COST ESTIMATIONS

Cost Estimate - L02 Morris Place Drainage Upgrade					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Site establishment		1		$ -
1.2	Provision of sediment and erosion control, geotechnical supervision		1		$ -
1.3	Detailed Design and Survey (Construction and WAE)		1		$ -
		Assume 20% of works cost			$ 253,750.14
2	**Construction**				
2.1	Pull up and dispose existing road surface	3.8	1156.0	m^2	$ 4,392.80
2.2	Excavation of fill (soft rock)	239	1662.0	m^3	$ 397,218.00
2.3	Supply and install of 1.05 m diameter pipe	1152.5	379.0	m	$ 436,797.50
2.4	Disposal of displaced pipe volume fill	325	710.0	m^3	$ 230,761.43
2.5	Drainage pit, assume 1 per 50 m	3800	10.0	each	$ 38,000.00
2.5	Backfilling, compaction and reinstate disturbed road pavement with bitumin surface	40	1156.0	m^2	$ 46,240.00
2.6	Adjustment of existing services (assume 10% works cost)				$ 115,340.97
3	Contingency (assume 20% works cost)				$ 253,750.14
				Subtotal	$ 1,776,250.98
Note: these costs are indicitive only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment				GST	$ 177,625.10
				Total	$ 1,953,876.08

Cost Estimate - L03 Morris Place Overland Flow Diversion					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Site establishment		1		$ -
1.2	Provision of sediment and erosion control, geotechnical supervision		1		$ -
1.3	Detailed Design and Survey (Construction and WAE)		1		$ -
		Assume 20% of works cost			$ 732,840
2	**Lowering Swale**				
2.1	Excavation of lowered swale (soil)	$33.80	3624.5	m^3	$ 134,106
2.2	Disposal of excess fill	$37.00	3624.5	m^3	$ 122,507
2.3	Placement, compaction and shaping	$7.60	36244.8	m^2	$ 275,460
2.4	Top soil placement	$12.25	36244.8	m^2	$ 443,999
2.5	Hydro mulch, sprayed grass seed compound	$3,650.00	3.6	ha	$ 13,229
2.6	Geotextile layer for embankment	64	36245	m^2	$ 2,319,666
2.8	Adjustment of existing services (assume 10% works cost)				$ 330,897
3	**Construction of berm**				
3.1	Excavation of fill	$8.85	125.0	m^3	$ 1,106.29
3.2	Haulage of fill (assumed <10 km), placement, compaction and shaping	$65.70	125.0	m^3	$ 8,212.78
3.3	Trim filling to batter	$3.25	1250.0	m^2	
3.4	Top soil placement	$10.60	1250.0	m^2	$ 13,250.45
3.5	Hydro mulch, sprayed grass seed compound	$3,650.00	0.13	ha	$ 456.27
3.6	Geotextile layer for embankment	1.05	1250.0	m^2	$ 1,312.54
4	Contingency (assume 20% works cost)				$ 732,840
				Subtotal	$ 5,129,883
Note: these costs are indicitive only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment				GST	$ 512,988
				Total	$ 5,642,872

Cost Estimate - L10 Portland Avenue and George Street Swale and Minor Drainage works					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Site establishment		1		$ -
1.2	Provision of sediment and erosion control, geotechnical supervision		1		$ -
1.3	Detailed Design and Survey (Construction and WAE)		1		$ -
		Assume 20% of works cost			$ 36,282.77
2	**Construction**				
2.1	Pull up and dispose existing road surface	3.8	331.0	m^2	$ 1,257.80
2.2	Excavation of fill (soft rock)	239	364.1	m^3	$ 87,019.90
2.3	Supply and install of 0.375 m diameter pipe	255	94.0	m	$ 23,970.00
	Supply and install of 0.6 m diameter pipe	430	40.0	m	$ 17,200.00
2.4	Disposal of displaced pipe volume fill	325	56.7	m^3	$ 18,434.00
2.5	Drainage pit, assume 1 per 50 m	3800	1.0	each	$ 3,800.00
2.5	Backfilling, compaction and reinstate disturbed road pavement with bitumin surface	40	331	m^2	$ 13,240.00
2.6	Adjustment of existing services (assume 10% works cost)				$ 16,492.17
3	**Lowering Swale**				
3.1	Disposal of excess fill	$37.00	1117.9	m^3	$ 41,362
3.2	Excavation of lowered swale (soil)	$33.80	1117.9	m^3	$ 37,784
3.3	Placement, compaction and shaping	$7.60	11178.8	m^2	$ 84,959
3.4	Top soil placement	$12.25	11178.8	m^2	$ 136,940
3.5	Hydro mulch, sprayed grass seed compound	$3,650.00	1.1	ha	$ 4,080
2.6	Geotextile layer for embankment	64	11179	m^2	$ 715,443
3.6	Adjustment of existing services (assume 10% works cost)				$ 102,057
4	**Construction of berm**				
4.1	Excavation of fill	$8.85	85.9	m^3	$ 760.27
4.2	Haulage of fill (assumed <10 km), placement, compaction and shaping	$65.70	85.9	m^3	$ 5,644.06
4.3	Trim filling to batter	$3.25	859.1	m^2	
4.4	Top soil placement	$10.60	859.1	m^2	$ 9,106.09
4.5	Hydro mulch, sprayed grass seed compound	$3,650.00	0.09	ha	$ 313.56
4.6	Geotextile layer for embankment	1.05	859.1	m^2	$ 902.02
5	Contingency (assume 20% works cost)				$ 264,152.93
				Subtotal	$ 1,621,200.33
Note: these costs are indicitive only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment				GST	$ 162,120.03
				Total	$ 1,783,320.36

5 March 2025

TfNSW reference: STH24/01657/20

Strategic Planner
Goulburn Mulwaree Council
By Email: kate.wooll@goulburn.nsw.gov.au
CC: cory.roberts@goulburn.nsw.gov.au, council@goulburn.nsw.gov.au

Attention: Kate Wooll

MARULAN FLOODPLAIN RISK MANAGEMENT STUDY & DRAFT PLAN

Dear Kate

Transport for NSW (TfNSW) is responding to the notification received on 2 February 2025.

TfNSW has reviewed the information that has been made available and provides comments in Attachment 1. TfNSW notes that the abovementioned study & plan include a proposed secondary access between the Hume Highway and Marulan Village. TfNSW is concerned that appropriate consultation regarding this proposed secondary access has not occurred.

If you have any questions, please contact Liliana Hutchinson, Development Services Case Officer, on 9595 5038 or email development.south@transport.nsw.gov.au.

Yours faithfully

Elira Reynolds
A Team Leader, Development Services

Attachment 1

MARULAN FLOODPLAIN RISK MANAGEMENT STUDY & DRAFT PLAN

Context

TfNSW notes:

- The key state road potentially impacted by flood events is the Hume Highway (refer to **Attachment 2**),
- Council is exhibiting a Marulan Floodplain Risk Management Study & Draft plan prepared by GRC Hydro, Project No. 210048, Version. 4, dated 4 December 2024,
- The Floodplain Risk Management Study & Draft Plan is stage 3 of a broader staged flood risk management process inclusive of Data Collection (Stage 1), Flood Study (Stage 2), Flood risk study and management plan,
- Council has sought separate comments from the Australian Rail Track Corporation (ARTC). ARTC operates and manages the rail line (Main Southern Line) that goes through Marulan as shown in **Attachment 2**.
- The Weigh Station is owned by the National Heavy Vehicle Regulator. Council needs to seek separate comments from this governing body for potential impacts to this infrastructure,
- Previous comments were provided for the Draft Marulan Flood Study in April 2023,
- Based on information provided it appears that no water will cross the carriageway of the Hume Highway,
- The documentation provided for assessment indicates a second entry and exit is intended from the Hume Highway to Marulan Village. This intention stems from the Goulburn Mulwaree Urban and Fringe Housing Strategy (UFHS – adopted July 2020). However, TfNSW also notes that the Consultation Report (October 2019 – appendix D to the UFHS) does not include any reference to consultation with TfNSW.

Comments

TfNSW has identified the following areas that need to be considered in an updated plan:

Proposed secondary access to Hume Highway from Marulan Village: In section 2.4 Future Development Areas (p.18) – Anticipated NSW government future development initiatives include improving accessibility to Marulan Village via a second entry and exit from Hume Highway to the Village.

TfNSW's concerns regarding a proposed new secondary access are listed below:

- Has Council demonstrated that a new access is needed and reasonable?
- What is the estimated timeframe for consultation with TfNSW to occur for this proposed secondary access to the Hume Highway?
- Has appropriate traffic impact assessment been completed?

Level 4, 90 Crown St (PO Box 477 2520) Wollongong NSW 2500
193-195 Morgan Street (PO Box 484) Wagga Wagga NSW 2650
ABN 18 804 239 602
transport.nsw.gov.au

TfNSW notes that the Hume Highway is a Controlled Access Road (CAR) and direct access across its boundary is denied. Further consultation with TfNSW regarding a second access to Marulan Village is required.

Infrastructure upgrades: All proposed infrastructure upgrades relating to this plan (i.e., culvert upgrades, bunding, etc.,) must be demonstrated to have no adverse impact on the Hume Highway or associated ramps.

Flood hazard: In section 6.2.1 under 'Hotspot 1: Western end of Goulburn Street'. 300mm is a big impact on Hume Highway as the speed limit is 110km/hr. This may not be representative of the actual risk to motorists.

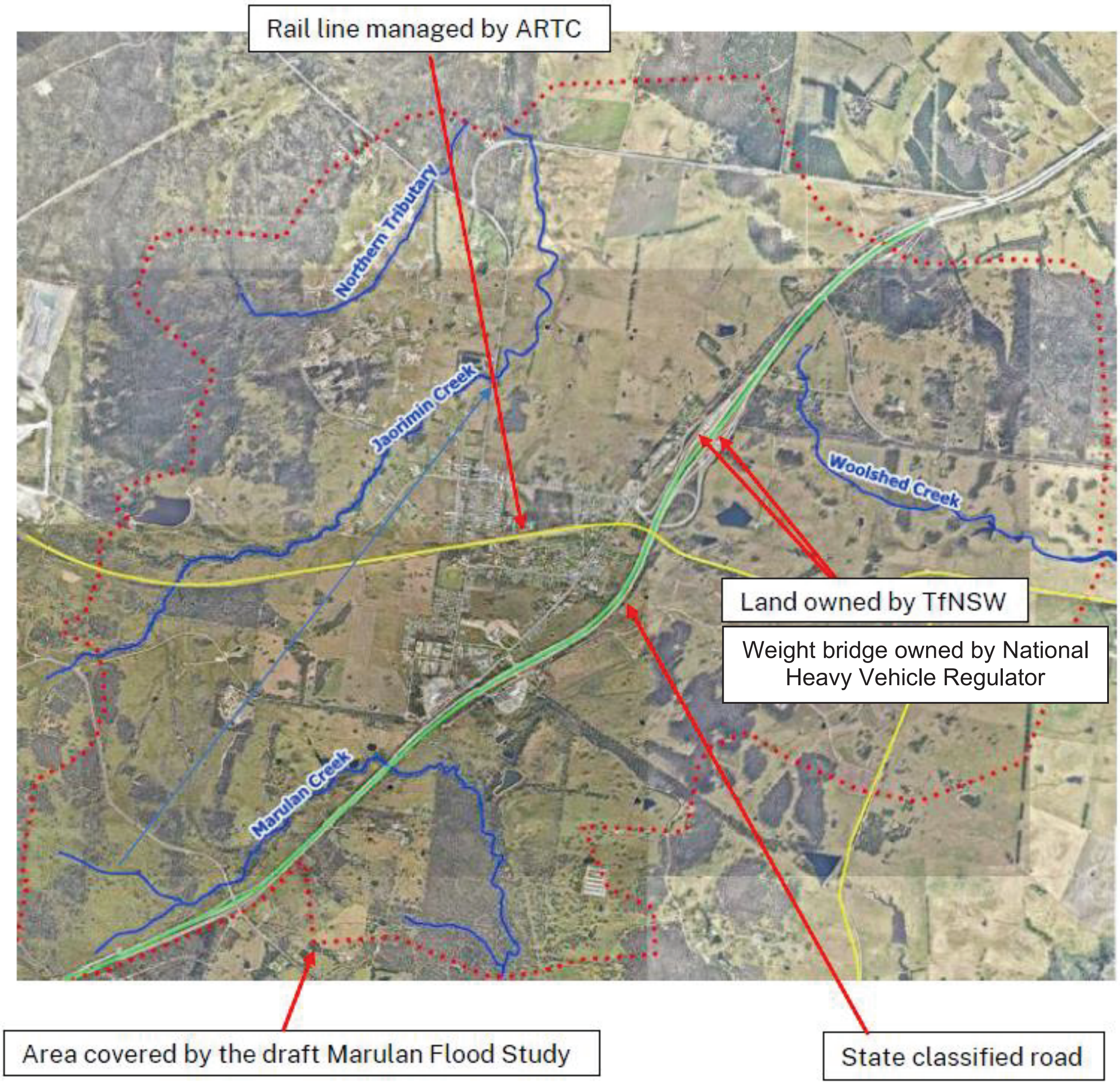
Hotspot 6: In section 6.2.6 under 'Hotspot 6: Between Portland Avenue and George Street', concerns were raised that the green line on the Hume Highway median seem to be misleading as there is kerb and gutter on Medway Road. It must be verified whether the green line flow path as indicated in **Attachment 3** is correct.

Level 4, 90 Crown St (PO Box 477 2520) Wollongong NSW 2500
193-195 Morgan Street (PO Box 484) Wagga Wagga NSW 2650

ABN 18 804 239 602
transport.nsw.gov.au

MARULAN FLOODPLAIN RISK MANAGEMENT STUDY & DRAFT PLAN

Attachment 2: State road



MARULAN FLOODPLAIN RISK MANAGEMENT STUDY & DRAFT PLAN

Attachment 3: Hotspot 6 – Design flood levels

Table 14: Hotspot 6 - Design Flood Levels

Design Event (% AEP)	Level (m AHD)	Location
Ground Level	637.9	
20% AEP	638.2	
10% AEP	638.3	
5% AEP	638.3	
2% AEP	638.3	
1% AEP	638.3	
0.5% AEP	638.3	
0.2% AEP	638.3	
PMF	638.6	
Image (right) shows the flood depth for the 1% AEP event. The points indicate individual property flood affectation with varied colours showing the flood event where above floor level flood affection occurs (refer to Figure 20)		

4 March 2025

Contact: Stuart Little
Telephone: 0436 948 347
Our ref: D2025/19596

General Manager
Goulburn Mulwaree Council
Locked Bag 22
GOULBURN NSW 2580

Dear Sir/Madam,

RE: Draft Marulan Floodplain Risk Management Study and Plan

I refer to Council's email of 31 January 2025 advising WaterNSW of the public exhibition of the Draft Marulan Floodplain Risk Management Study and Plan (FRMSP). We note that the Draft Plan follows from Council's adoption of the Marulan Flood Study in 2023.

While WaterNSW has no land or major assets in the Marulan Study Area, Marulan is located in the declared Sydney Drinking Water Catchment (SDWC). WaterNSW has particular responsibilities for protecting water quality in land use rezoning and new development decisions under s9.1 Ministerial Direction 3.3 Sydney Drinking Water Catchment and under Part 6.5 of Chapter 6 of State Environmental Planning Policy (Biodiversity and Conservation) 2021, respectively. WaterNSW has an interest in the FRMSP given that flooding generally increases water quality risks to catchment streams and downstream water storages by mobilising potential pollutants that would not otherwise be available for transport and suspension.

WaterNSW provided comment on the earlier Draft Flood Study on 3 April 2023 (Our Ref: D2023/30122) where we indicated our support for the Study in understanding Marulan's flood risk and its implications for currently developed and future growth areas. We also raised a number of specific comments on the draft Study including for flood risk and post-development flood risk scenarios to be prepared for the three future development areas (Marulan North, Marulan North URA and South Marulan (also known as Marulan East)) as identified in Council's Urban Fringe and Housing Strategy (UFHS).

WaterNSW supports Council's preparation of the Draft FRMSP. We particularly note the emphasis and consideration given to the flooding risk for the three future development areas as well as the existing Marulan township, and its consideration of flood risk interactions with land use zoning. We are also generally supportive of the recommendations contained in the Plan.

Our detailed comments are provided in Attachment 1. We have underlined those comments where changes to the Plan should be considered.

Our main concern is in relation to the potential future development of the Marlan East area, which is likely to remain unsewered and is significantly constrained by flooding risk. Further investigation of the interaction of flooding and water quality risks is required to inform the suitability and capability of this area for future Large Lot Residential development.

If you have any questions regarding this letter, please contact Stuart Little at stuart.little@waternsw.com.au.

Yours sincerely

ALISON KNIHA
Environmental Planning, Assessments and Approvals Manager

ATTACHMENT 1 – DETAILED COMMENTS

Approach

We note that the objective of the study is to develop an understanding of the impacts of flooding risk on the existing and future local community of Marulan township and surrounding areas (P. 9). This includes new future development areas.

Flood Planning Level and Flood Planning Area

The FRMSP considers flooding risk from both riverine flooding (referred to as 'mainstream flooding' in the document) and overland flow (stormwater runoff/ flash flooding) with overland flow presenting the most prevalent risk. It also distinguishes two different Flood Planning Level (FPL) approaches on this basis.

The FPL for mainstream flooding is set at the 1% AEP event level plus 0.5 m freeboard while the FPL for overland flooding is based on 1% AEP event plus 0.3 m freeboard. Derivation of appropriate FPL is a matter for Council, with implementation of the FPL proposed to be undertaken through Council's DCP.

The FPL will also inform the derivation of the Flood Planning Area (FPA) for planning and development control purposes. We note that the FPA will be informed by the extent of the Flood Planning Constraint Category #3 (FPCC3) for flood planning controls. The FPCC approach for flood planning in Marulan is also recommended for inclusion in Council's DCP.

Risk to Sensitive Facilities and Services

We note and support the FRMSP's inclusion of flood risk to sensitive facilities and services (Table 24, P. 46). We particularly note the consideration of risks to (and potentially from) the Water Treatment Plant (WTP) and Wastewater Treatment Plant (WWTP). We note that the FRMSP identifies that the WTP is inundated during the 1% AEP event although the sludge ponds and building remain unaffected. Table 24 indicates that the Marulan WWTP is not flooded under any of the flood risk scenarios presented. It would be helpful if the document clarified whether this absence of flooding risk equally applies to the treatment ponds associated with the WWTP facility. We assume that the FRMSP will also inform the planning and design of the upgrade of the Marulan WWTP to minimise flooding and associated water quality risks.

Land-use Zoning Considering Flooding

We strongly support the FRMSP's consideration of land use zones with respect to local flood characteristics (P. 53). We particularly note the approach that to reduce future flood risk potential from development pressures, undeveloped lots situated in high hazard areas (H3 or greater), floodway areas or areas with significant evacuation constraints, may be considered for rezoning to a land use type that does not permit residential, business or industrial uses. We support the corresponding recommendation on page 54 in this regard. This will also implicitly help protect water quality by quarantining high flood hazard areas from future development.

Review of Future Development Areas

We note and support that the FRMSP takes account of Marulan Township and the future proposed development areas including Marulan North, Marulan North Urban Release Area (URA) and Marulan East (Pp. 11, 13). While the township of Marulan is situated on high ground, the FRMSP notes that the future development areas are situated in lower lying areas (P. 11). Flooding risk operates to varying degrees as a constraint for the three new development areas.

Under section 7.1.2.7, initial yields for Marulan North, Marulan North URA and Marulan East are projected at 694, 631 and 29 dwellings over an area of 98, 91 and 217 ha, respectively (Table 28, P. 54). We note that the

FRMSP identifies that for the three development areas, 76%, 83% and 49% of the land occurs outside the designated FPA. Development yields may not be as great as initially anticipated due to the FPA constraint and associated flooding risk. Marulan East appears particularly constrained in this regard (see below).

The FRMSP identifies that Marulan North and Marulan North URA are targeted for R1 General Residential zoning and would be serviced. We note that Marulan East is proposed for R5 Large Lot Residential with a potential 10 ha Minimum Lot Size (MLS; P. 54). We assume that the Marulan East area would remain unsewered. This could be made clearer in the notes to Table 28 (P. 54).

The Preliminary Assessment of the three sites indicates that while Marulan North and Marulan North URA would be feasible, Marulan East would be 'not feasible' based on flooding risk (Table 28, P.54). The Marulan East area is located on the Woolshed Creek floodplain and is bisected by Woollshed Creek. As development in Marulan East would be unsewered, we are concerned about the potential interaction of flooding and water quality risks in this area. Flood risk is also likely to influence the location of Effluent Management Areas and the overall broader suitability and capacity of the land for unsewered development. We note and support the recommendation that flood risk should be considered in conjunction with flood risk and that additional detailed flood analysis should be undertaken to further inform future development potential for the new proposed development areas (P. 55).

Draft Flood Risk Management Plan

The Draft Flood Risk Management Plan component of the document is provided in Chapter 8 (Pp. 75-76). Table 33 provides a summary of the proposed actions and measures to be undertaken. We generally note and support the inclusion of these measures.

Our Ref: 581

Kate Wooll
Business Manager Strategic Planning
Goulburn Mulwaree Council
Locked Bag 22, Goulburn, 2580

email: Kate.Wooll@goulburn.nsw.gov.au
cc: amanda.pollock@ses.nsw.gov.au

Dear Kate,

Thank you for the opportunity to provide comment on the Marulan Floodplain Risk Management Study & Draft Plan (FRMS&P).

NSW State Emergency Service (NSW SES) is the agency responsible for dealing with floods, storms and tsunami in NSW. This includes providing emergency management advice to Councils on flood risk management and the preparation of emergency plans containing evidence from the flood risk management process. This study and plan provides SES with key information about the impacts and risk for the area. This information is used in planning, preparing and responding to flood events. Please see our feedback regarding the Marulan FRMS&P study below.

In summary:

- Thank you for including key information such as hazard, FERC (Flood Emergency Response Classifications) and number of properties impacted.

- We request a spreadsheet of properties affected by over floor flooding to assist in planning for flood events.

- Thank you for including the cumulative impact of potential impacts of future development relevant to Goulburn Mulwaree Council's inclusion of the Marulan Master Plan as a Priority Project 2023-2026. We recommend that all future developments be prepared in accordance with the Flood Risk Management Guide and other relevant policies and requirements and consider flood risk to the site, such as evacuation constraints and risk of isolation.

- Under the Flood Damages Assessment, the cost of intangible damages be considered such as fatalities, injuries, and social impacts, as stated in the Flood Risk Management Guide.

- Could you please provide the number of residential and non-residential properties affected by over floor flooding at every identified flood hotspot? This data is essential for our comprehensive flood risk assessment.

- We wish to clarify – it should be the NSW State Emergency Service. Hazards Near Me also provides warnings for storms, both on page 58.

- The NSW SES is updating the Goulburn Mulwaree Local Flood Plan Volumes 2 and 3 and will include information from the Marulan Flood Study and this Risk Management Study and Plan.

Please feel free to contact Adam James via email at adam.james3@ses.nsw.gov.au should you wish to discuss any of the matters raised in this correspondence. The NSW SES would also be interested in receiving future correspondence regarding the outcome of this referral via this email address.

Yours Sincerely,

Amanda Pollock
Coordinator Planning
NSW State Emergency Service

Other Comments:

Evacuation Centres

NSW SES would like to note that evacuation centres are identified by the LEMC under the EMPLAN (it is important to highlight that the EMPLAN relates to all hazards) and these evacuation centres have not been assessed specific to each hazard. During flood operations, the Incident Controller of the combat agency evaluates the evacuation centres in the EMPLAN and assesses suitable locations against forecast and predictions specific to the hazard. The Incident Controller also evaluates the risk in association to an emergency unfolding and provides recommendations on suitability back to the REOCON/LEOCONs for communities to use under the context of that hazard.

The LEOCON maintains consultation with Welfare Services regarding any evacuation requirements, and NSW SES in consultation with LEOCONs, to assess need for activation of welfare services support plan who are responsible to facilitate opening of evacuation and / or relief centres as required.

The release of suitable evacuation centres will be published and announced during the emergency event.

Flood Emergency Response Plans

People can access the NSW SES Website and access the suite of resources available to them to understand their risk and better prepare for floods, storms and Tsunamis, and can create their own Home Emergency Plan via the NSW SES website.

Flood preparedness and resilience is a shared responsibility – NSW SES supports resource sharing to support communities to understand their flood risk, however we cannot accommodate doorknocking all residents and businesses to answer questions regarding risk.

Flood Risk Communication

The NSW SES have established a multifaceted communications strategy, in the local flood plan. This strategy includes disseminating information to the wider community using social media, traditional media, the HazardWatch website and Hazards Near Me app. Unofficial community Facebook groups may not be monitored by official sources such as the NSW SES. By accessing the HazardWatch and Hazards Near Me app, people can zoom in to the interactive maps to receive property-specific updated warnings from the NSW SES with very clear actions to follow to make informed decisions about their safety.

The NSW SES provides flood awareness education and community advice information on NSW SES websites, and also holds community hubs to provide flood information directly to communities and answer questions. Communication to flood risk communities is important and ongoing, and we want to work together with councils so that we can achieve this successfully, noting however that NSW SES does not have the capacity to doorknock residents and businesses to answer questions.

Communication to communities could focus on education about the new Australian Warning System (AWS) and warning polygons, so that people can understand the warnings in their area on the HazardWatch website during an event. More information on the Australian Warning System can be found on the website here: https://www.australianwarningsystem.com.au/.

Submission Summary (State Agencies) and Responses – Marulan Floodplain Risk Management Study & Draft Plan

State Agency	Comment	GRC Response	GMC response
Transport for NSW (TfNSW) - 1	**Proposed secondary access to Hume Highway from Marulan Village:** In section 2.4 Future Development Areas (p.18) – Anticipated NSW government future development initiatives include improving accessibility to Marulan Village via a second entry and exit from Hume Highway to the Village. TfNSW's concerns regarding a proposed new secondary access are listed below: • Has Council demonstrated that a new access is needed and reasonable? • What is the estimated timeframe for consultation with TfNSW to occur for this proposed secondary access to the Hume Highway? • Has appropriate traffic impact assessment been completed? TfNSW notes that the Hume Highway is a Controlled Access Road (CAR) and direct access across its boundary is denied. Further consultation with TfNSW regarding a second access to Marulan Village is required.	For Council	The FRMSP does not make any recommendations for an additional access but refers to other Council policy documentation. Council has advocated for improved access arrangements to Marulan via the Hume Highway and for intersection upgrades with Highland Way in various submissions and sought inclusion of consideration of this in various relevant policy documents. The most recent of these being the TfNSW Draft Strategic Regional Integrated Transport Plan. Council understands that any upgrades to access or intersections with the Hume Highway would need to be in consultation with and subject to the approval of TfNSW. Any funding for such projects is outside of Council's operational or delivery plans and would only be likely via Commonwealth or State funding or in relation to a development proposal (again subject to the approval of TfNSW).

State Agency	Comment	GRC Response	GMC response
TfNSW - 2	**Infrastructure upgrades:** All proposed infrastructure upgrades relating to this plan (i.e., culvert upgrades, bunding, etc.,) must be demonstrated to have no adverse impact on the Hume Highway or associated ramps.	Noted. No works have been recommended as a part of the plan	The infrastructure upgrades identified in the FRMSP mainly relate to clearing of debris from existing railway culverts. None of the railway culverts identified have flows in any proximity to the Hume Highway and ramps. No works near the Highway are identified.
TfNSW - 3	**Flood hazard:** In section 6.2.1 under 'Hotspot 1: Western end of Goulburn Street'. 300mm is a big impact on Hume Highway as the speed limit is 110km/hr. This may not be representative of the actual risk to motorists.	Unclear. Flood impacts have not been assessed under the hotspot investigation and Hotspot 1 is not located near the Hume Highway. Perhaps this has been confused with Hotspot 6: Between Portland Avenue and George Street - see next response.	This hotspot does not affect the Hume Highway being located on the opposite end of Goulburn Street. The downstream flows from this intersection do not impact the Hume Highway and are distant from it. This comment would appear to be an error.
TfNSW - 4	**Hotspot 6**: In section 6.2.6 under 'Hotspot 6: Between Portland Avenue and George Street', concerns were raised that the green line on the Hume Highway median seem to be misleading as there is kerb and gutter on Medway Road. It must be verified whether the green line flow path as indicated in Attachment 3 is correct.	Green line is water in the median between the Hume Highway and Medway Road. Typically, in rare flood events, such as the 1% AEP event presented, kerb and guttering alone is insufficient to accommodate the volume of overland flow.	Refer to GRC Hydro comment. Furthermore, the FRMSP states: *In the PMF event, George Street experiences H4 hazard. The PMF experiences a large area of high hazard ranging from H3 to H5 where flow ponds to the north of the Hume Highway".* Otherwise, flooding is identified at a H1 (Lowest hazard) level for flood events up to the PMF H5 hazard level during a PMF event at Woolshed Creek and H4 level

State Agency	Comment	GRC Response	GMC response
			hazard at the Hume Highway northbound offramp. *A table is provided in the FRMSP which* identifies the point and hazard level for road inundations. Refer to Table 3 in the Council Report.
TfNSW	**Consultation with National Heavy Vehicle Regulator (NHVR)** Suggests that Council should consult also with the National Heavy Vehicle Regulator as it is the operator of the weigh stations in Marulan.	For Council	Council did notify the NHVR via email after receiving the TfNSW submission and provided a period of three (3) weeks for comment/submission. No response was received from the NHVR in relation to this matter.
WaterNSW - 1	**Risk to Sensitive Facilities and Services** We note and support the FRMSP's inclusion of flood risk to sensitive facilities and services (Table 24, P. 46). We particularly note the consideration of risks to (and potentially from) the Water Treatment Plant (WTP) and Wastewater Treatment Plant (WWTP). We note that the FRMSP identifies that the WTP is inundated during the 1% AEP event although the sludge ponds and building remain unaffected. Table 24 indicates that the Marulan WWTP is not flooded under any of the flood risk scenarios presented. It would be helpful if the document clarified whether this absence of flooding risk equally applies to the treatment ponds associated with the WWTP	Note added to final report	The FRMSP identifies that only the access to the Marulan drinking water treatment plant (WTP) is affected by flooding, the treatment ponds are not affected. The Marulan FRMSP will be used to inform the planning and design of any future infrastructure including the proposed Marulan wastewater treatment plant (WWTP)..

State Agency	Comment	GRC Response	GMC response
	facility. We assume that the FRMSP will also inform the planning and design of the upgrade of the Marulan WWTP to minimise flooding and associated water quality risks.		
WaterNSW - 2	**Review of Future Development Areas** We note and support that the FRMSP takes account of Marulan Township and the future proposed development areas including Marulan North, Marulan North Urban Release Area (URA) and Marulan East (Pp. 11, 13). While the township of Marulan is situated on high ground, the FRMSP notes that the future development areas are situated in lower lying areas (P. 11). Flooding risk operates to varying degrees as a constraint for the three new development areas. Under section 7.1.2.7, initial yields for Marulan North, Marulan North URA and Marulan East are projected at 694, 631 and 29 dwellings over an area of 98, 91 and 217 ha, respectively (Table 28, P. 54). We note that the FRMSP identifies that for the three development areas, 76%, 83% and 49% of the land occurs outside the designated FPA. Development yields may not be as great as initially anticipated due to the FPA constraint and associated flooding risk. Marulan East appears particularly constrained in this regard (see below). The FRMSP identifies that Marulan North and Marulan North URA are targeted for R1	Note added to final report	Council will use the FRMSP to inform future planning of development in and around Marulan. The constraints in relation to the Marulan East precinct in the Urban and Fringe Housing Strategy are noted. Any future review of the Strategy will consider the information provided by the FRMSP and Water NSW in relation to both flooding and potential water quality impacts. The Marulan East area was not intended to be sewered as per the Urban and Fringe Housing Strategy. It is also noted that Council's DCP does not recommend that lots over 2000m2 be connected to reticulated public sewer and this area was identified for lots 10ha and over. Flooding and water quality issues would need to be addressed should any planning proposal be submitted to reduce minimum lot sizes in Marulan East.

State Agency	Comment	GRC Response	GMC response
	General Residential zoning and would be serviced. We note that Marulan East is proposed for R5 Large Lot Residential with a potential 10 ha Minimum Lot Size (MLS; P. 54). We assume that the Marulan East area would remain unsewered. This could be made clearer in the notes to Table 28 (P. 54). The Preliminary Assessment of the three sites indicates that while Marulan North and Marulan North URA would be feasible, Marulan East would be 'not feasible' based on flooding risk (Table 28, P.54). The Marulan East area is located on the Woolshed Creek floodplain and is bisected by Woollshed Creek. As development in Marulan East would be unsewered, we are concerned about the potential interaction of flooding and water quality risks in this area. Flood risk is also likely to influence the location of Effluent Management Areas and the overall broader suitability and capacity of the land for unsewered development. We note and support the recommendation that flood risk should be considered in conjunction with flood risk and that additional detailed flood analysis should be undertaken to further inform future development potential for the new proposed development areas (P. 55).		
NSW State Emergency Service (SES) - 1	Thank you for including key information such as hazard, FERC (Flood Emergency Response Classifications) and number of properties impacted.	Noted	Noted.

State Agency	Comment	GRC Response	GMC response
SES - 2	We request a spreadsheet of properties affected by over floor flooding to assist in planning for flood events.	Flood Damages spreadsheet will be included in GRC Handover data to Council. Properties are also shown in Figures 20 and 20A.	All data will be uploaded for public use to the SES Flood Data Portal.
SES - 3	Thank you for including the cumulative impact of potential impacts of future development relevant to Goulburn Mulwaree Council's inclusion of the Marulan Master Plan as a Priority Project 2023-2026. We recommend that all future developments be prepared in accordance with the Flood Risk Management Guide and other relevant policies and requirements and consider flood risk to the site, such as evacuation constraints and risk of isolation.	Noted	Noted, the intention of this project is partly to inform the future development of Marulan.
SES - 4	Under the Flood Damages Assessment, the cost of intangible damages be considered such as fatalities, injuries, and social impacts, as stated in the Flood Risk Management Guide.	Flood damages assessment was completed as a part of the Flood Study, prior to the release of the Flood Risk Management Guide. It was agreed with DCCEEW and Council that the Flood Damages Assessment would not be revised to align with the subsequent release of the Flood Risk Management Guidelines	This was a timing issue in relation to the adoption of the new guidelines having occurred after this work was undertaken. FRMSPs are to be reviewed every 5 years where possible, and this will be provided in future with a subsequent review.
SES - 5	Could you please provide the number of residential and non-residential properties affected by over floor flooding at every	These are listed in the individual hotspot tables in Section 6.2 at Hotspots 5 and 6 where there are non-	Refer to GRC comment.

State Agency	Comment	GRC Response	GMC response
	identified flood hotspot? This data is essential for our comprehensive flood risk assessment.	residential properties in the vicinity. Figures 20 and 20A present the residential and non-residential properties as different shapes.	
SES - 6	We wish to clarify – it should be the NSW State Emergency Service. Hazards Near Me also provides warnings for storms, both on page 58.	Amended	As per GRC comment, this will be amended in the final version.
SES - 7	The NSW SES is updating the Goulburn Mulwaree Local Flood Plan Volumes 2 and 3 and will include information from the Marulan Flood Study and this Risk Management Study and Plan.	Noted	Noted.
SES - 8	**Evacuation Centres** NSW SES would like to note that evacuation centres are identified by the LEMC under the EMPLAN (it is important to highlight that the EMPLAN relates to all hazards) and these evacuation centres have not been assessed specific to each hazard. During flood operations, the Incident Controller of the combat agency evaluates the evacuation centres in the EMPLAN and assesses suitable locations against forecast and predictions specific to the hazard. The Incident Controller also evaluates the risk in association to an emergency unfolding and provides recommendations on suitability back to the REOCON/LEOCONs for communities to use under the context of that hazard.	Noted	Noted.

State Agency	Comment	GRC Response	GMC response
	The LEOCON maintains consultation with Welfare Services regarding any evacuation requirements, and NSW SES in consultation with LEOCONs, to assess need for activation of welfare services support plan who are responsible to facilitate opening of evacuation and / or relief centres as required. The release of suitable evacuation centres will be published and announced during the emergency event.		
SES - 8	**Flood Emergency Response Plans** People can access the NSW SES Website and access the suite of resources available to them to understand their risk and better prepare for floods, storms and Tsunamis, and can create their own Home Emergency Plan via the NSW SES website. Flood preparedness and resilience is a shared responsibility – NSW SES supports resource sharing to support communities to understand their flood risk, however we cannot accommodate doorknocking all residents and businesses to answer questions regarding risk.	Noted	Noted.
SES - 10	**Flood Risk Communication** The NSW SES have established a multifaceted communications strategy, in the local flood plan. This strategy includes disseminating information to the wider community using social media, traditional media, the HazardWatch website and Hazards Near Me app. Unofficial community	Noted	Noted, any future consideration of communication and education will be undertaken in consultation with NSW SES as required noting this falls more within the SES' responsibilities.

State Agency	Comment	GRC Response	GMC response
	Facebook groups may not be monitored by official sources such as the NSW SES. By accessing the HazardWatch and Hazards Near Me app, people can zoom in to the interactive maps to receive property-specific updated warnings from the NSW SES with very clear actions to follow to make informed decisions about their safety. The NSW SES provides flood awareness education and community advice information on NSW SES websites, and also holds community hubs to provide flood information directly to communities and answer questions. Communication to flood risk communities is important and ongoing, and we want to work together with councils so that we can achieve this successfully, noting however that NSW SES does not have the capacity to doorknock residents and businesses to answer questions. Communication to communities could focus on education about the new Australian Warning System (AWS) and warning polygons, so that people can understand the warnings in their area on the HazardWatch website during an event. More information on the Australian Warning System can be found on the website here: https://www.australianwarningsystem.com.au/.		