Lower Macleay River Floodplain Risk Management Study and Plan

Final Floodplain Risk Management Study and Plan Report

Revision E

24 October 2024

Reissue 16 December 2024

Kempsey Shire Council

Lower Macleay River Floodplain Risk Management Study and Plan

Project No:	IA252400
Document Title:	Final Floodplain Risk Management Study and Plan Report
Document No.:	IA252400-REP-09_FinalFRMS
Revision:	E
Date:	24 October 2024
Client Name:	Kempsey Shire Council
Project Manager:	Lih Chong
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File Name:	IA252400-REP-09_FinalFRMS_E_Reissue.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
0	6/05/2024	Prelim Draft FRMSP – For client review	L Chong	A Hossain	A Hossain
B	8/07/2024	Draft FRMSP – For public exhibition	L Chong	A Hossain	A Hossain
C	12/09/2024	Draft Final FRMSP report – For client review	L Chong	A Hossain	A Hossain
D	30/09/2024	Final FRMSP report	L Chong	A Hossain	A Hossain
E	24/10/2024	Final FRMSP report – Minor edits Reissue 16/12/2024 – Minor edits	L Chong	A Hossain	A Hossain

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Executive Summary

Introduction

The Lower Macleay River floodplain (refer to Figure 1-1) occupies approximately 500km^2 of coastal floodplain downstream of Kempsey, to the Macleay River's main outlet at South West Rocks. The floodplain drains a catchment area of 11,500km^2, has several secondary outlets to the ocean at Hat Head and Crescent Head and a hydraulic link to the Hastings River to the south, all owing to improved channel linkages constructed during implementation of historic flood mitigation schemes between 1955 and mid-1970s. The river's historic outlet to the ocean was at Grassy Head, to the north of its current outlet, until a major flood in 1893 cut an entrance at its current location. River training walls have been constructed to stabilise the current river course.

The floodplain is generally low lying and contains numerous watercourses including Belmore River, Kinchela Creek, Collombatti Creek and Clybucca River, in addition to a number of wetland areas. The towns and villages of Smithtown, Gladstone, Kinchela, Jerseyville, Fishermans Reach and Stuarts Point are situated in the floodplain, with South West Rocks, Hat Head and Crescent Head accessed by roads through the floodplain.

Significant floods occurred in the valley in 1838, 1893, 1949, 1950, 1963, 2001, 2009, 2011 and 2013. A major flood mitigation scheme was implemented from 1955 to the mid-1970s consisting of numerous flood gates, drainage channels and levees to help protect Kempsey township and the agricultural area, and to provide flood warning and improved drainage. Recent infrastructure works in the floodplain include the Pacific Highway Kempsey Bypass, which crosses the river and floodplain via a 3.2km bridge to the east of Kempsey.

Kempsey Shire Council has engaged Jacobs to undertake the Lower Macleay River Floodplain Risk Management Study and Plan. The study will build on the previous Lower Macleay Flood Study Update (Jacobs, 2022) which provided information on flood behaviour in the Lower Macleay floodplain based on detailed hydraulic modelling developed for this Floodplain Risk Management Study (FRMS) project. This report is the FRMS which defines the flooding behaviour and its impact on the community, identifies and appraises potential management measures to reduce existing and future flood risk. Based on the study findings, a list of prioritised measures for consideration and implementation by Council will be prepared in the subsequent Floodplain Risk Management Plan (FRMP).

Key objectives of this study include.

- Update of previous flood study modelling including extension of TUFLOW hydraulic model upstream to Turners Flat and southward to the Kempsey LGA boundary to include the Maria River floodplain. utilising revised main catchment hydrologic modelling and update local catchment hydrologic modelling to Australian Rainfall and Runoff (ARR) 2019. Redefine design flood conditions.
- Understanding of impacts and consequences of flooding on the community. This includes knowledge of properties (numbers of properties, flood damages), roads, infrastructure and critical services impacted by current and future flooding conditions, which will inform town planning, emergency management and evaluation of feasibility of mitigation works.
- Develop a list of recommended and prioritised physical works and strategic planning flood risk mitigation measures to improve current and future flood risk.
- Assistance with development of guidelines to manage future and proposed developments on the floodplain.

Flood Behaviour

The configuration of the Macleay catchment is practically suited to the production of high peak flood flows. The major tributaries join the main stem of the river within a small distance of each another causing a rapid concentration of floodwater in the main stream below their confluences, and the large upstream catchment funnels to a narrow bottleneck upstream of Kempsey. Following major rain storms the Macleay River at Kempsey may rise from a normal dry weather discharge of about 56m^3/sec to 12,000m^3/sec (the estimated discharge of the August 1949 flood) within a 30 hour period.

The main river flows are the dominant cause of flooding in the study area. Floodwaters tend to overflow from the river particularly between Kempsey and Smithtown, filling the adjacent floodplain areas. Floodwaters slowly drain through the floodplain, flowing in parallel to the main river, conveyed in natural and man-made floodplain channels and watercourses, converging on the main river in the lower reaches of the catchment.

During flood events floodwaters may break out to the ocean at a number of minor creek outlets. There is also potential for overtopping of the coastal beach foredune system at a number of locations in rare flood events, which may scour out additional discharge points in such events.

It is quite likely that there would be coinciding flooding in the adjacent Hastings River to the south of the Macleay, in addition to other river systems during a regional flooding event. Depending on the relative size of flood events in the Macleay River floodplain and Hastings River floodplain, floodwaters may flow into the Macleay floodplain or out to the Hastings floodplain via the low-lying area connecting the two floodplains to the south-west of Crescent Head. Flows may occur in both directions over the course of particular flood events.

Flooding can also occur in tributary watercourses and creeks such as Christmas Creek, Euroka Creek, Dungay Creek, Collombatti Creek, Maria River and Pipers Creek among others. This flooding may coincide with riverine flooding in the Macleay River. Local flooding can also occur in minor local catchments and gullies, of which there are several in urban areas in Kempsey and Frederickton, and inside levee systems such as in Kempsey, Smithtown and Hat Head.

History of Flooding

Significant floods occurred in the valley in 1838, 1893, 1949, 1950, 1963, 2001, 2009, 2011, 2013 and 2021. A major flood mitigation scheme was implemented from 1955 to the mid-1970s consisting of numerous flood gates, drainage channels and levees to help protect Kempsey township and the agricultural area, and to provide flood warning and improved drainage. Recent major infrastructure works in the floodplain include the Pacific Highway Kempsey Bypass, which crosses the river and floodplain via a 3.2km bridge to the east of Kempsey.

The largest flood on record is the 1949 event followed by the 1950 event. The 1949 flood reached 8.52m AHD at Kempsey Traffic Bridge resulting in the loss of six (6) lives and more than 7,000 head of stock and 600 buildings damaged or destroyed (source: Kempsey Shire Council. https://archive.kempsey.nsw.gov.au/ environment/ floodplain/background-lower-macleay-flood-risk-management.html). Based on new flood frequency analysis of recorded flood levels at Kempsey Traffic Bridge, the 1949 event was estimated as larger than a 0.5% (1 in 200) Annual Exceedance Probability (AEP) event, while the 1950 flood was estimated as an approximately 1% (1 in 100) AEP event.

The March 2001 flood event is the largest flood event in the valley in recent years and was the largest to occur since the 1963 event. Over 1,000 residents were evacuated by air from the floodplain urban centres. This flood event was estimated at 5% (1 in 20) AEP. One of the most recent flood events occurred in March 2021, which was estimated as a 10% (1 in 10) AEP event.

Following the 1949 and 1950 floods, there was significant community reaction which demanded action to mitigate the impacts of flooding on the Lower Macleay Floodplain. This led to the formation of the Macleay Valley Flood Mitigation Committee which formulated a basis of the flood problem and developed options for the Lower Macleay Flood Mitigation Scheme, a series of works to address flooding problems. Works on the Scheme commenced in 1955 and were progressively implemented until the mid-1970's that included the construction of 47 flood-gated structures (of various sizes), 116km of drainage channels and 180km of levee.

The stated aims of the flood mitigation scheme were (source: Kempsey Shire Council):

1. Protection of the Kempsey township up to a 1 in 10 year flood event;
2. Protection for the Lower Macleay agricultural area from a 1 in 2.5 year flood event;
3. Rapid drainage of floodwaters;
4. Provision for erosion protection;

5. Improved flood mapping, proofing and data; and
6. Provision of flood warning.

Community Consultation

Community consultation is an important part of the flood study and floodplain risk management study process. Its objectives are to inform the community about the study, gather information on experiences of flooding in the study area and provide an opportunity for the community to communicate their concerns about flooding issues. Consultation undertaken during this study included:

- Consultation with Flooding Reference Group – Meetings with this study steering group comprised of councillors, Council officers, agency officers (SES, NSW Reconstruction Authority), community groups and community members.
- Community workshops
- Community feedback through Council's Your Say Macleay webpage
- Direct engagement with stakeholders
- Public exhibition of study reports.

Flood Modelling and Mapping

A numerical flood model was developed in the TUFLOW hydraulic modelling software as a part of the *Lower Macleay Flood Study* (Jacobs, 2019) and expanded in the Lower Macleay Flood Study Update (Jacobs, 2022). This model was used in this current FRMS to defined flood behaviour, assess flooding impacts to the community and test flood risk mitigation options and works.

The model domain extends to the southern boundary of Kempsey LGA outside of the Lower Macleay to include the Maria River, Pipers Creek, Smiths Creek and Connection Creek. The model also extends upstream to Turners Flat and including the lower section of Dungay Creek. Another objective of the modelling was to incorporate the Kempsey CBD area, previously analysed in a more localised TUFLOW model extending from Greenhill to downstream of Frederickton, into a unified hydraulic model of the Lower Macleay system.

Towns and villages were modelled in finer resolution within the overall 20m model grid of the TUFLOW model. The urban areas in Kempsey CBD, South and East Kempsey were modelled with a 10m grid, consistent with the Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017). Areas around floodplain villages including South West Rocks, Frederickton, Smithtown, Gladstone, Kinchela, Hat Head, Crescent Head, Stuarts Point and Fishermans Reach are represented with a 5m grid. Watercourses and drains on the floodplain and in rural areas are represented with either a 5m or 10m grid, mainly depending on channel width.

Design flood event inflows in the Macleay River were revised based on recent flood frequency analysis of river gauge data at Kempsey Traffic Bridge, which has a longer length of record and improved data of historic major flood events compared to previous assessment using Bellbrook stream gauge data. The updated flood frequency analysis was used to calibrate the WBNM hydrologic model of the Macleay catchment including incorporation of new Australian Rainfall and Runoff (ARR) 2019 design rainfall. Additional hydrologic modelling was undertaken in DRAINS using the RAFTS hydrologic module to define rainfall-runoff generated from on local tributary catchments and local catchments onto the floodplain. Analysis of design flood data from the Hastings River Flood Study (Patterson Britton and Partners, 2006, for Port Macquarie Hastings Council) was undertaken to define the inflow and outflow conditions at the Maria River interface. Time-varying tidal conditions were defined in the ocean boundaries.

The TUFLOW model was calibrated and verified to the March 2001 flood and the March 2021 flood. These events were selected given their recent occurrence in addition to the large amount of data collected on observed flooding. The 2001 event represents the largest event in the last 20 years while the 2021 event is one of the most recent flood events. There have been a number of significant flood events prior to 2001 including the 1949 (greater than 0.5% AEP), 1950 (1% AEP) and 1963 (2-5% AEP) events which were not considered for calibration

in this study due to uncertainties in input data, in addition to significant changes in the floodplain since these events, including construction the Macleay Flood Mitigation Scheme, built between the 1950s and 1970s.

The calibrated model was used to derive design flood conditions within Lower Macleay. The design events considered in this study include the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP and PMF events.

Existing Flooding Conditions

Flood mapping was produced including:

- Design flood inundation,
- Peak flood water levels and depths
- Peak flood velocities.
- Flood hazard
- Hydraulic categorisation
- Flood emergency classification of communities
- Flood planning area and flood planning level.

Zoomed in flood mapping on each of the floodplain villages in the study area was also prepared. Design flood levels are summarised at key locations as shown in Table 1.

Table 1: Design Flood Levels at Selected Locations (m AHD)

Event AEP	AEP								
	50%	20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Turners Flat	17.13	19.94	21.42	23.13	25.81	27.19	28.86	29.36	38.87
Greenhill	4.61	7.87	9.17	10.29	11.82	12.69	13.76	14.49	23.23
Kempsey Rail Bridge (upstream)	4.05	6.49	7.36	8.19	9.22	9.90	10.84	11.54	19.75
Kempsey Traffic Bridge (upstream)	3.96	6.24	6.90	7.39	8.04	8.42	8.95	9.31	14.90
Frederickton	3.61	5.48	5.90	6.12	6.38	6.53	6.73	6.87	9.87
Smithtown (Nestle)	3.14	4.47	4.56	4.62	4.86	5.04	5.48	5.86	9.28
Smithtown (Gauge)	2.94	4.14	4.22	4.27	4.47	4.77	5.37	5.79	9.18
Kinchela Creek Entrance	2.32	3.30	3.35	3.47	4.07	4.61	5.30	5.74	9.11
Jerseyville	1.43	1.83	1.94	2.58	3.67	4.31	5.09	5.55	8.89
South West Rocks (Gauge)	1.14	1.17	1.28	1.80	3.19	3.88	4.68	5.17	8.26
Fishermans Reach	1.05	1.14	1.31	1.91	3.19	3.86	4.65	5.12	8.02
Stuarts Point	1.02	1.15	1.34	1.92	3.19	3.85	4.64	5.11	7.04
Collombatti D/S of Pacific Highway	1.66	2.00	2.86	3.30	4.05	4.64	5.35	5.78	9.21
Clybucca Floodgates	1.04	1.85	2.56	3.03	3.94	4.53	5.25	5.69	9.04
Upper Belmore	1.17	2.23	2.98	3.67	4.28	4.71	5.34	5.76	9.08
Upper Kinchela	1.03	2.04	2.61	3.42	4.22	4.69	5.35	5.77	9.14
Hat Head	1.14	1.14	1.18	1.34	2.43	2.65	3.18	3.91	7.11

Event AEP	AEP								
	50%	20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Crescent Head	1.13	1.13	1.15	1.43	2.45	2.67	2.77	3.35	5.22
Big Hill	1.60	1.99	2.43	2.85	3.14	3.46	3.85	4.35	6.60
Maria River	2.11	2.33	2.60	2.84	3.21	3.59	3.97	4.42	6.84

Flood Classification

Flood warning classifications are locally defined flood levels developed by SES to give an indication of the severity of the impact of expected flooding. These impacts are defined as Minor, Moderate and Major. Definitions for Minor, Moderate and Major are provided below (SES, 2019):

- **Minor Flooding**. Flooding which causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.
- **Moderate Flooding**. In addition to Minor Flooding, flooding which inundates low-lying areas, requiring removal of stock and/or evacuation of some houses. Main traffic routes may be flooded. In addition to the effects of minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required
- **Major Flooding**. In addition to Moderate Flooding, flooding which causes inundation of extensive rural areas, with properties, villages and towns isolated and/or appreciable urban areas flooded. Evacuation of flood affected areas may be required. Utility services may be impacted.

The flood levels relating to Minor, Moderate and Major Floods are defined for Kempsey and Smithtown gauges in Table 2.

Table 2: Flood classification levels at gauges in the Lower Macleay

Flood Classification	Flood level at gauge (m AHD)	
	Kempsey	Smithtown
Minor	4.5	3.4
Moderate	5.7	4.0
Major	6.6	4.2

Climate change

Assessment was undertaken to estimate the potential impact of climate change on flooding in the Lower Macleay, including sea level rise, increased storm rainfall intensity and resulting increased flood runoff, and their combined effects on flooding.

The combined sea level rise and increased rainfall/runoff scenarios assessed in the sensitivity assessment were:

- Year 2050: Sea level rise of +0.4m and a 9.7% increase in rainfall/runoff; and
- Year 2100: Sea level rise of +0.9m and a 19.7% increase in rainfall /runoff.

Mapping of the change in flood levels for the year 2050 and 2100 was prepared. Flooding conditions in the 2050 scenario include increase of 0.5 – 0.8m from Greenhill to Kempsey, while the 2100 scenario sees increases of over 1m. At Turners Flat the increases are 0.9m in 2050 and 1.7m in 2100. At Frederickton the increases are up to 0.2m in 2050 and 0.4m in 2100. These increases are due mainly to the increase in flood flows in the river.

Between Frederickton and Seven Oaks the change in flood levels drop as a result of the river channel hydraulics. Increases at Seven Oaks are up to 0.1m in 2050 and 0.3m in 2100. The constrained flow capacity of the river in

this section results in the limited increase in flood levels. Consequently, the increased river flood flows spill out onto the floodplains, with the majority of the Lower Macleay floodplain experiencing flood level increases of 0.3 – 0.5m in 2050 and 0.7 – 1m in 2100.

In the lower reaches of the Macleay and up Macleay Arm and Yarrahapinni Wetlands flood levels increase by up to 0.6m in 2050 and up to 1.2m as a result of the increased flood flows in combination with sea level rise. The long section flood profiles indicate the effect of the increased outflows and ocean levels decreases with distance from the outlet to Seven Oaks.

At Hat Head, Crescent Head and in the Maria River floodplain the flood levels are 0.4 – 0.5m higher in the 2050 scenario, while they are about 0.9m higher in Crescent Head, over 1m higher at Hat Head and around 1m higher in the Maria River floodplain in the 2100 scenario.

In the local creeks and minor watercourses the flood levels are generally 0.1 – 0.2m higher in the 2050 scenario and 0.2 – 0.4m higher in the 2100 scenario.

Given the sensitivity of flooding conditions in the climate change scenarios, Council has resolved to incorporate climate change impacts into planning controls for development of the Lower Macleay floodplain. This will be undertaken by adopting the maximum envelope of the flood planning level (based on current climate 1% AEP flood level plus 0.5m freeboard) and the year 2100 climate change scenario 1% AEP flood level.

The estimates of the PMF in this study are based on current climatic conditions. While there are limited studies on the predicted effects of climate change on the PMF, recent research estimates that probable maximum precipitation (PMP) would increase by 13% for a Shared Socioeconomic Pathway (SSP) scenario SSP1 – 2.6 (assuming low level projections of greenhouse gas emissions) and 33% for scenario SSP5 – 8.5 (assuming higher level projections of greenhouse gas emissions) in the year 2100, compared to current climate PMP (Visser et al, 2022). The implication is that the increased PMP rainfall intensities would result in increased PMF flows and flood levels.

Impacts to the Community

Flooding conditions in the Lower Macleay towns and villages and impacts to key access roads, critical facilities and sensitive properties is characterised in the FRMS.

Flood damages and numbers of properties affected by the different scale design floods are summarised in Table 3 and Table 4 for residential and non-residential and commercial properties, respectively. Average annual damages (AAD) are also estimated.

Table 3: Estimated tangible flood damages for residential properties

Event	Number of properties affected	Number of properties flooded above floor level	Estimated Flood Damage	Contribution to AAD
20% AEP	244	30	$7,827,980	$1,174,197
10% AEP	409	105	$19,753,795	$1,379,089
5% AEP	662	247	$42,641,008	$1,559,870
2% AEP	1192	600	$105,478,116	$2,221,787
1% AEP	1633	1149	$190,620,456	$1,480,493
0.5% AEP	2162	1805	$326,317,982	$1,292,346
0.2% AEP	2454	2145	$440,506,484	$1,150,237
PMF	4756	4569	$1,252,648,544	$1,684,689
AAD				**$11,942,708**

Table 4: Estimated tangible flood damages for non-residential and commercial properties

Event	Number of properties affected	Number of properties flooded above floor level	Estimated Flood Damage	Contribution to AAD
20% AEP	2	2	$56,169	$8,425
10% AEP	51	51	$5,686,285	$287,123
5% AEP	103	103	$20,384,461	$651,769
2% AEP	173	173	$51,595,780	$1,079,704
1% AEP	212	212	$74,172,796	$62,8843
0.5% AEP	273	273	$110,510,042	$46,1707
0.2% AEP	320	320	$133,124,624	$365,452
PMF	597	597	$311,320,442	$442,223
AAD				**$3,925,245**

Agricultural flood damages were estimated based on a post-flood event survey undertaken on behalf of Kempsey Shire Council following the 2001 flood event, as summarised in Table 5.

Table 5: Estimated agricultural flood damages

Event	Inundated rural-zoned area (ha)	Estimated Flood Damage	Contribution to AAD
20% AEP	32,584	$48,484,287	$12,410,304
10% AEP	36,519	$54,340,746	$5,141,252
5% AEP	38,288	$56,972,749	$2,782,837
2% AEP	39,871	$59,328,349	$1,744,516
1% AEP	40,848	$60,782,245	$600,553
0.5% AEP	41,867	$62,298,730	$307,702
0.2% AEP	42,530	$63,284,198	$188,374
PMF	47,105	$70,092,739	$132,710
AAD			**$18,170,588**

Review of Existing Emergency Planning

The Kempsey Flood Emergency Sub-Plan 2017 (SES, 2017) is a sub-plan of the NSW State Flood Plan (SES, 2018a) outline the specific arrangements for management of flood events within the Kempsey Council area. Roles and responsibilities for agencies including regional and local SES, Police, Council, Rural Fire Service, BOM, WaterNSW, DPE etc. and operators of facilities (schools, pre-schools, caravan parks) community groups and community members, among others, and pre-, during and post-flood procedures are defined.

Flooding impacts to the communities in the Lower Macleay and other parts of Kempsey LGA are described, including flood behaviour/characteristics, floodplain categorisation (e.g. low flood island, etc), levees and their overtopping AEPs, at risk facilities etc. Flood extent mapping, design flood levels at the various villages and other information may be superseded by outcomes from this FRMS.

Upon completion of this current floodplain risk management study and plan, it is recommended that the Sub-Plan be updated with consideration of the information and findings of this FRMS on the flooding behaviour for Lower Macleay.

Kempsey Shire Council operates a total flood warning system with support from agencies including Manly Hydraulics Laboratory (MHL). At its simplest, a total flood warning system is based on the following six components (Attorney-General's Department, 2009).

1) Prediction - detecting changes in the environment that lead to flooding and predicting river levels during the flood.
2) Interpretation - identifying in advance the impacts of the predicted flood levels on communities at risk.
3) Message construction - devising the content of the message that will warn people of impending flooding.
4) Communication - disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood.
5) Response - generating appropriate and timely actions from the threatened community and from the agencies involved.
6) Review - examining the various aspects of the system with a view to improving its performance.

During a flood event, Council and SES monitor rainfall and flooding conditions via online gauges in addition to conditions on ground, such as flooding relative to levee levels and road low points. Flood status updates are posted on Council's website and Council and SES social media (Facebook, Twitter (now called "X")) and direct to resident text messaging to relay information on key information such as roads which are cut off, roads remaining

open at the time, evacuation orders, services and facilities affected, emergency response activities being undertaken, evacuation centres open etc. This messaging is supplementary to BOM's flood warnings and aim to provide near real-time local level information on conditions as the flood event progresses. The live rainfall and water level data and flood camera imagery are also available to the public (https://mhlfit.net/users/KempseyShireCouncil/) with a link via Council's flood web page (https://www.kempsey.nsw.gov.au/Your-Valley/Disaster-emergency/Flood-information-cameras).

Known locations where the key access routes become first cut by flooding are summarised below:

- **Kempsey:** Forth Street, Eden Street, Wide Street, Macleay Valley Way (Kempsey/Frederickton), Kemp Street, Spooners Avenue, South West Rocks Road (Austral Eden), Crescent Head at Rudders Lagoon.
- **Smithtown:** Smithtown Road (first point of breach near Macleay Valley Way intersection), South West Rocks Road (breaches between Kinchela and Hat Head turnoff)
- **Frederickton:** Macleay Valley Way (Kempsey/Frederickton), Macleay Valley Way (Between Frederickton and Smithtown Road intersection), Macleay Valley Way at Frederickton - trunk drainage channel inundation.
- **Hat Head:** Hat Head Road (start of national park),
- **Crescent Head:** Rudders Lagoon, The Corduroy (immediately west of Crescent Head).
- **South West Rocks:** Plummers Lane (multiple location), South West Rocks Road (multiple locations)
- **Lower Macleay – Belmore:** Left and Right Bank Roads
- **Lower Macleay – Kinchela:** Left and Right Bank Roads.
- **Stuarts Point:** Stuarts Point Road opposite Grassy Head Road (local flooding).

The flood modelling indicates that durations of inundation of these roads in the design events would be around 1 week. Experience from historic floods indicates that inundation duration would continue for in excess of 1-2 weeks generally.

Most of these roads pass across the floodplain for long distances and it may take up to an hour to drive to higher ground on the rural roads, with longer travel times expected due to heavier traffic if evacuation orders are in place and during peak holiday times. Consultation with residents indicates that flooding can rise extremely rapidly based on historic flood experience, resulting in the access routes becoming cut off suddenly and with highly hazardous flow conditions. Adequate warning time is therefore critical for arranged and self evacuation, which places a high emphasis on the importance of the flood warning system and dissemination of accurate real-time flood information during an event.

Assessment of Flood Risk Management Measures

A range of flood risk management measures were assessed, consisting of Flood Modification, Property Modification and Response Modification measures. These were considered for their appropriateness and potential effectiveness for managing flood risk in the Lower Macleay and for inclusion in the Floodplain Risk Management Plan.

A number of potential mitigation works options were initially identified for consideration based on review of the existing flooding behaviour and impacts, consultation with Council staff and previous consultation with the community during the Lower Macleay Flood Study (Jacobs, 2019). The initial list of options was then workshopped with the Flooding Reference Group and the community providing input and feedback, with a finalised list of 17 options selected for detailed assessment based on this consultation. Note that the finalised list of options only nominates the options for assessment of their benefits and costs and does not guarantee that all the options will be recommended for implementation.

Table 6 provides a summary of the 17 options that were assessed including their advantages, benefits, constraints and impacts.

Table 6: Summary of assessed options – Description, benefits and constraints

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
Option 1	Raise Crescent Head Road to 3.2m AHD + no drainage upgrade	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is substantially reduced.	• Requires implementation in combination with Option 1B to realise full benefit (road would remain cut at Rudders Lagoon) • Traffic impacts during construction phase • Potential works in and adjacent to environmentally sensitive areas (E2 Environmental Conservation zoning, koala management plan area) • Impacts to existing underground and above ground utilities • Likely acid sulfate soils and challenging geotechnical conditions.	• Improved road flood immunity from less than 50% AEP to 10% AEP • Reduced duration that road is cut in 5% and 1% AEP events by 170hrs • *Increase in peak flood levels of 0.2m in the 20% AEP event, up to 0.35m in the 5% AEP event and up to 0.1m in the 1% AEP event.* • *Increases in peak flood levels of 0.04 – 0.1m in the 20% AEP event extend to Kinchela.* • *Increases in peak flood levels of 0.04 – 0.07m in the 5% AEP event and up to 0.02m in the 1% AEP event extend across the Lower Macleay floodplain, up to Stuarts Point* • *Increased duration of flooding on properties by up to 24 hrs* • *Up to 14 residential buildings and one commercial building newly flooded above floor in 1% AEP event. Increased duration of flooding on properties by up to 24 hours.* • Reductions in peak flood levels to the south of the road of up to 0.06m in the 20% and 1% AEP events and up to 0.2m in the 5% AEP event
Option 1A	Raise Crescent Head Road to 3.2m AHD + 1000m of viaduct	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is substantially reduced. • Provision of viaduct allows floodwaters to drain across Crescent Head Road more freely compared to existing case and to Option 1.	• Requires implementation in combination with Option 1B to realise full benefit (road would remain cut at Rudders Lagoon) • Traffic impacts during construction phase • Potential works in and adjacent to environmentally sensitive areas (E2 Environmental Conservation zoning, koala management plan area) • Impacts to existing underground and above ground utilities • Likely acid sulfate soils and challenging geotechnical conditions requiring management during construction.	• Improved road flood immunity from less than 50% AEP to 5% AEP • Reduced duration that road is cut in 5% and 1% AEP events by 200hrs • Minor increase in peak flood levels of less than 0.01m in the 20% AEP event and 0.02 – 0.03m in the 10% and 1% AEP events. • *Increase in peak flood levels of up to 0.06m in the 5% AEP event* • Reductions in peak flood levels to the south of the road of up to 0.06m in the 20% and 1% AEP events and up to 0.2m in the 5% AEP event • Reduced durations of flooding by 8 – 10hrs • No change to numbers of residential and commercial buildings with above floor flooding
Option 1B	New emergency access from Crescent Head Road to Pacific Highway	• Provide new on and off ramps on Pacific Highway to Crescent Head Road to bypass flooding of Crescent Head Road at Rudders Lagoon. Local road roundabout on Crescent Head Road to allow traffic to turn around at flooded section of road • Operate as emergency access during flood events only • Improve road access flood immunity from less than 50% AEP to at least 5% AEP and potentially up to 1% AEP • Good potential for financial contribution from Transport for NSW for construction of option	• Traffic impacts on Pacific Highway during construction phase • Property acquisitions • Road geometry of on/off ramps likely to require reduced speed limits on Pacific Highway during operation in flood events. Fully compliant road geometry with no requirement of reduced speed limit on highway could be investigated although cost of option likely to be increased. • Requires further consultation with TfNSW to confirm design and operational details, permissibility of works.	• Nil impacts to flooding. Option 1B is outside of flood extent and would not change flood behaviour. • No change to numbers of residential and commercial buildings with above floor flooding
Option 2A	Raise Hat Head Road to 2.3m AHD + 200m culverts/floodway	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is reduced. • Improved conveyance of floodwaters across Hat Head Road in small flood events	• Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Potential impact to internal access road for the private property	• Improve road flood immunity from less than 20% AEP to about 10% AEP. • In the 1% AEP event, the duration of flooding of the road would decrease from 150 hours in the existing case to 100 hours with Option 2A.*Increase in peak flood levels of 0.35m in low-lying areas to the north of Hat Head Road in the 20% AEP event with corresponding increase in duration of flooding exceeds 100 hours.* • Negligible increases in peak flood levels to the north of Hat Head Road in the 10%, 5% and 1% AEP events, although the *duration of flooding*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
				increases by about 10 hours in the 1% AEP event and up to 24 hours in the 10% AEP event. • To the south of Hat Head Road, peak flood levels decrease by up to 0.1m in the 20% AEP event and up to 0.01m in the 10% AEP event. Duration of flooding decreases by 10 – 24 hours. • No change to numbers of residential and commercial buildings with above floor flooding
Option 3	Disconnect Korogoro and Killick Creek	• Closing of the existing floodgates on Korogoro Creek and Killick Creek, with additional bunding earthworks on the creek banks and raising of existing drainage structures to prevent floodwaters overtopping in 1% AEP event. • Reduced/eliminated risk of blackwater events and fish kills in the creeks due to floodplain drainage • Reduced flood levels in parts of Hat Head and Crescent Head villages.	• Potential impacts to depth of creek entrances and navigability due to reduced tidal scouring needs to be considered.	• *Flood levels increase by up to 0.07m in the 10% AEP event and 0.1 – 0.15m in the 5% and 1% AEP events. Increases in flooding extend across much of the Lower Macleay floodplain. The greatest increases in peak flood levels occur around Crescent Head Road at The Corduroy.* • *Increase in duration of flooding on Macleay floodplain by 8 – 15 hours* • Flood levels are reduced in Hat Head village by typically more than 0.05m (up to 0.16m on some properties) in the 5% AEP event and 0.05 – 0.13m in the 1% AEP event • Properties along Killick Creek in Crescent Head would experience reductions in peak flood levels of 0.05m in the 1% AEP event. *Increases of 0.15m on properties in the western portion of village* • Up to 49 individual residential buildings, mainly in Hat Head and Crescent Head, would no longer be flooded above floor in the 1% AEP event. • *However, up to 23 individual residential buildings and one commercial building would experience new above floor flooding in the 1% AEP event. These buildings are located on the Macleay floodplain.*
Option 4	Widen Loftus Road Ryans Cut crossing	• Doubled flow capacity at Loftus Road crossing at Ryans Cut reduces peak flood levels and duration of flooding on parts of Macleay southern floodplain	• Works required in Hat Head National Park • Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Unlikely to result in increased risk of blackwater event and fish kills in Ryans Cut lagoon, but may require further investigation.	• Reduces duration of by 13 – 30 hours in parts of the southern Macleay floodplain for the 10%, 5% and 1% AEP events. Durations are reduced by 6 – 30 hours in the 20% AEP event. • Reduction in peak flood levels by 0.02 – 0.06m on the southern floodplain in the 10% AEP event, and by 0.02 – 0.04m over the broader Lower Macleay floodplain area in the 5% and 1% AEP events. • *Localised increases in peak flood levels of 0.2 – 0.3m in the 5% and 1% AEP events east of Loftus Road and north of Crescent Head, but these increases in peak flood levels do not affect any buildings.* • Up to 13 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 4b	Widen Loftus Road Ryans Cut crossing and extend Ryans Cut to Belmore River	• Doubled flow capacity at Loftus Road crossing at Ryans Cut reduces peak flood levels and duration of flooding on parts of Macleay southern floodplain • Additional low-level drainage of low areas around Belmore River • Some additional drainage capacity of Macleay River via direct connection from Ryans Cut to Belmore River (minor).	• Works required in Hat Head National Park • Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Unlikely to result in increased risk of blackwater event and fish kills in Ryans Cut lagoon, but may require further investigation. • Effects on risk of blackwater events around Belmore River uncertain. • Increased drainage capacity of Macleay River direct to Ryans Cut is constrained by the natural form of Belmore River, which	• Reduces duration of by 15 – 38 hours in parts of the southern Macleay floodplain for the 10%, 5% and 1% AEP events. Durations are reduced by 15 – 31 hours in the 20% AEP event. • Reduction in peak flood levels by 0.02 – 0.1m on the southern floodplain in the 10% AEP event, and by 0.02 – 0.04m over the broader Lower Macleay floodplain area in the 5% and 1% AEP events. • *Increase in flood levels and extents on about 10 properties along Belmore River in the 20% and 10% AEP events.* • *Localised increases in peak flood levels of 0.2 – 0.3m in the 5% and 1% AEP events east of Loftus Road and north of Crescent Head, but these increases in peak flood levels do not affect any buildings.*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
			narrows with distance upstream of the headworks. The proposed widened Loftus Road crossing is also a constraint.	• Up to 12 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 5	Increased Floodplain Drainage Capacity	• Has potential to reduce durations of inundation on the Macleay floodplain	• Requires modification to numerous aging drainage structures and floodgates. Condition assessment required. • High potential for increased risk and frequency of occurrence of floodplain acid runoff, blackwater events in receiving waterways and fish kills. Requires further investigation and identification of mitigation strategies.	• Negligible changes to peak flood levels • Negligible change to duration of flooding on most of the floodplain • Reductions in duration of flooding of around 20 hours in parts of the floodplain in Summer Island, however, the area experiencing benefits is small.
Option 6	Reinstate Rowes Cut	• Diverts floodwater outflows through new outlet to the ocean • Reduces flooding in Hat Head village • Potential to reduce/eliminate blackwater runoff through Hat Head village due to new outlet	• Works required in Hat Head National Park • No direct road access for construction and maintenance but access could be made via beach from Hat Head village • Ongoing maintenance required to maintain the channel profile.	• Peak flood levels in Hat Head village are reduced by up to 0.04m in the 5% AEP event and 0.07m in the 1% AEP event. • Reductions in flood levels of up to 0.1m occur in Korogoro Creek and vegetated areas • Minor reduction in durations of flooding of 9 – 16 hours for the 10%, 5% and 1% AEP events on parts of Macleay southern floodplain • Up to 47 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 7	Enlarge headworks on Belmore and Kinchela	• Has potential to reduce durations of inundation on the Macleay floodplain	• High potential for increased risk and frequency of occurrence of floodplain acid runoff, blackwater events in receiving waterways and fish kills. Requires further investigation and identification of mitigation strategies.	• Negligible changes to peak flood levels in the 10%, 5% and 1% AEP events • In the 20% AEP event, there are increases in peak flood levels of 0.01 – 0.05m in areas downstream of Kinchela
Option 8A	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads	• Potential to reduce flooding on Macleay southern floodplain • Raising of roads would improve flood access along Belmore River and Kinchela Creek banks • Opportunity to upgrade the Belmore River and Kinchela Creek flood control structures to be operated remotely	• Condition assessment required for existing flood control structures • Impacts to property access from raised roads. Property acquisition may be required	• Reductions in flood levels of up to 0.1m on the southern floodplain in the 20% AEP event • *Increased flood levels in Belmore River, Kinchela Creek and the Macleay River, resulting in increased river overflows and increased flood levels by up to 0.1m elsewhere in the 20% AEP event.* • *In the 10% and 5% AEP events the reductions and increases in flood levels on the floodplain are generally less than +/-0.05m, but there are remaining increases in flood levels in Belmore River and Kinchela Creek which affect the properties along the banks of those waterways.* • Minimal change in peak flood levels in the 1% AEP event. • One individual residential building would no longer be flooded above floor in the 20% AEP event. No change in other events.
Option 8B	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads and SWR Road + additional levee	• Potential to reduce flooding on Macleay southern floodplain • Additional road raising and levees would further reduce overflows onto floodplain • Raising of roads would improve flood access along Belmore River and Kinchela Creek banks and parts of South West Rocks Road • Opportunity to upgrade the Belmore River and Kinchela Creek flood control structures to be operated remotely	• Condition assessment required for existing flood control structures • Impacts to property access from raised roads and levees. Property acquisition may be required	• Reductions in flood levels of over 0.1m in the 20% AEP event and 0.2m in the 10% and 5% AEP events on the southern floodplain. Reductions in flood levels are typically less than 0.02m in the 1% AEP event • *Increases in peak flood levels of over 0.4m in locations on the northern floodplain including around Kempsey CBD in all flood events assessed. Flood impacts extend upstream of Kempsey* • Up to 12 individual residential buildings would no longer be flooded above floor in up to the 1% AEP event. • *However, up to 22 individual residential buildings and 24 commercial building would experience new above floor flooding in up to the 1% AEP event.*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
Option 9A	Raise and Extend Smithtown Levee to protect from 20% AEP flood	• Raising and extending the existing levee including filling in existing low points in the levee would eliminate floodwaters overflowing into the village in the 20% AEP event. • Upgraded levee would be raised to the 20% AEP flood level plus 0.3m freeboard • Improved flood protection provided by levee from less than 20% AEP event to over 20% AEP event	• Combination of sections of earth levee and, in the vicinity of private properties ad buildings, concrete retaining wall levee • Raising of a section of Croads Esplanade to be incorporated into part of the levee system would be required. • Works on private property likely required. Structural assessment for impact to existing buildings may be required • Potential impacts to existing utilities • Further review of Smithtown levee audit report and a condition assessment may be required.	• Prevents overtopping of levee in 20% AEP event • No mainstream flooding inside levee in the 20%, 10% and 5% AEP events. Reductions in flood levels of 0.07m in 1% AEP event. • Outside Smithtown village, peak flood levels on the northern floodplain are reduced typically by up to 0.03m in the 20%, 10% and 5% AEP events and by up to 0.1m immediately north of Smithtown village. Negligible change in 1% AEP event. • On southern floodplain, generally minor increases in flood levels of 0.02m in the 20%, 10% and 5% AEP events. *Localised increases of less than 0.1m in the 20% AEP event*. Negligible change in 1% AEP event. • Up to 33 individual residential buildings and three commercial buildings would no longer be flooded above floor in up to the 5% AEP event.
Option 9B	Raise and Extend Smithtown Levee to protect from 5% AEP flood	• Raising and extending the existing levee including filling in existing low points in the levee would eliminate floodwaters overflowing into the village in the 5% AEP event. • Upgraded levee would be raised to the 5% AEP flood level plus 0.3m freeboard • Improved flood protection provided by levee from less than 20% AEP event to over 5% AEP event	• Combination of sections of earth levee and, in the vicinity of private properties ad buildings, concrete retaining wall levee • Raising of a section of Croads Esplanade to be incorporated into part of the levee system would be required. • Works on private property likely required. Structural assessment for impact to existing buildings may be required • Works in and around Nestle factory required. Detailed constructability assessment has not been undertaken to date and will be required. Alternatively, the levee could go around the east of the factory. • Potential impacts to existing utilities • Further review of Smithtown levee audit report and a condition assessment may be required.	• Prevents overtopping of levee in 5% AEP event • Flood levels inside the levee are reduced by 0.1m in the 20%, 10% and 5% AEP events. Negligible change in 1% AEP event. • Outside Smithtown village, peak flood levels on the northern floodplain are reduced typically by up to 0.03m in the 20%, 10% and 5% AEP events and by up to 0.1m immediately north of Smithtown village. Negligible change in 1% AEP event. • On southern floodplain, generally minor increases in flood levels of 0.02m in the 20%, 10% and 5% AEP events. *Localised increases of less than 0.1m in the 20% AEP event*. Negligible change in 1% AEP event. • Up to 35 individual residential buildings and four commercial buildings would no longer be flooded above floor in up to the 5% AEP event. • Up to eight individual residential buildings and one commercial building would no longer be flooded above floor in the 1% AEP event.
Option 11	Dredging of Macleay River	• Significant increase in drainage capacity of the Macleay River	• Very high capital and maintenance costs. • Potential hydrodynamic impacts to everyday tidal flows and flushing of the river. Potential resultant impacts to riverbank stability and structures (bridges) stability • Highly unlikely to receive environmental approvals and funding • Potential to sell off dredge spoil for industrial and construction uses, but further materials and market analysis would be required to confirm a viable downstream market.	• Widespread reductions in flood levels of up to 0.2 – 0.4m in the 10% and 5% AEP events. Up to 0.14m in the 1% AEP event. • Localised reductions of 0.7m on the floodplain around Kinchela. • *Minor increases of 0.05m around Seven Oaks in the 5% and 1% AEP event.* • Localised reductions in durations of inundation on the floodplain of up to 48 hours at Kinchela north of Hat Head Road in the 10% AEP event and in Clybucca near Plummers Lane in the 20% AEP event. Mainly minor reductions in durations of around half a day. • Up to 50 individual residential buildings and 12 commercial buildings would no longer be flooded above floor in the 5% AEP event. • Up to 125 individual residential buildings and seven commercial building would no longer be flooded above floor in the 1% AEP event.
Option 12	Additional ocean outlet for Macleay River	• Significant increase in drainage capacity of the Macleay River lower reaches.	• Likely hydrodynamic impacts to everyday tidal flows and flushing of the river. Following a flood event, the scoured secondary outlet may become semi-permanent. Potential impacts including shoaling up of the main river entrance channel.	• Substantial reductions in peak flood levels in lower reaches of 0.7m in the 5% AEP and 1.4m in the 1% AEP event. Reductions of 0.2m at Kinchela and. Improvements to peak flood levels are around 0.14m on the northern floodplain and 0.07 – 0.15m on the southern floodplain including Belmore River and Kinchela Creek.

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
			• Potential resultant impacts to riverbank stability, ocean wave damage to shoreline, infrastructure and property. Damages value not quantified. • Highly unlikely to receive environmental approvals and funding • Potential to sell off excavated material for industrial and construction uses, but further materials and market analysis would be required to confirm a viable downstream market.	• Reductions in flood levels of 0.1 – 0.2m in 20% and 10% AEP events. • While peak flood levels are reduced, the reductions in duration of inundation on the floodplain are minimal to minor. Durations are reduced at Swan Pool by less than one day. • Up to nine individual residential buildings and one commercial building would no longer be flooded above floor in the 5% AEP event. • Up to 131 individual residential buildings and one commercial building would no longer be flooded above floor in the 1% AEP event.
Option 13	Levee system remediation – Filling levee low points	• Restore proper functioning of existing levee system,	• Some residents' houses reportedly built on the existing levees.	• Reduced risk of floodwater overtopping during frequent flood events.

The options were evaluated using a multi-criteria analysis which considered in a wholistic overview the hydraulic effects, cost-benefits (including savings in property and agricultural flood damages and benefits based on improved flood access) and other aspects relating to the assessed options including effects on flood risk, environment/ecologic systems, social effects, effects on emergency management and administrative and asset management aspects. Favourable options are included in the floodplain risk management plan.

Floodplain Risk Management Plan

The Floodplain Risk Management Plan, which outlines an implementation program for the proposed measures, is provided in Table 7. The Plan can be progressively implemented with an anticipated timeframe of 3-5 years for high priority options and 5-10 years for medium priority options. Estimated costs and responsibilities for implementation are indicated. The timing of the proposed works will be dependent on Council's overall budgetary commitments and the availability of funding from external sources.

Council and the Flood Reference Group have provided feedback which has been incorporated into the Plan. Community consultation including public exhibition has been undertaken on the FRMSP prior to adoption of the Plan by Council.

Table 7: Lower Macleay River Floodplain Risk Management Plan

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
FM1	**Option 9A/9B** Raising and extending Smithtown levee	Council	Up to ~$18M	Not costed	• Raising and extending Smithtown levee to 20% AEP flood level or to 5% AEP flood level. • Feasibility study should be undertaken to assess optimal option for the levee raising and extension	Medium priority Option to be further investigated following feasibility assessment (Measure FM1A).
FM1A	Feasibility study for Option 9A/9B – Raising and extending Smithtown levee	Council	$200K	N/A	• A feasibility study should be undertaken to assess in further detail the technical aspects of raising and extending Smithtown levee. • The study would include consultation with Nestle factory in Smithtown to identify and select the optimal design for extending the levee through the property. • Consider technical and design requirements for levee internal stormwater pumping station. • Update of cost estimates. • Provide inputs for potential design/construction commissioning.	High – feasibility assessment should be undertaken in the near future to further develop and optimise Measure FM1
FM2	**Option 1B** Emergency flood access ramps at Crescent Head Road/Pacific Highway	Council, TfNSW	$3.14M	Not costed	• Construction of new traffic ramps from/to Crescent Head Road and Pacific Highway. • The new traffic ramps would be for emergency flood access only. • Council to advocate TfNSW for funding/ implementation of this option.	High – would significantly improve flood immunity in the surrounding area.
FM3	**Option 13** Remediation of existing levees	Council	Part of maintenance program	Low cost	• Council to undertake remediation of existing levees including filling of low points which have developed in the existing levees. • Works are to be undertaken as a part of Council's asset maintenance program.	Medium priority – ongoing program
FM4	Maintenance of existing drainage assets for flood drainage	Council	Part of maintenance program	Part of maintenance program	Council to incorporate into their asset maintenance program as priority works: • Cleaning and maintenance of Council floodplain drains • Protection of drainage assets from becoming damaged or degraded from construction works and roadworks – ensure effective construction phase earthworks planning and erosion and sediment control is implemented to prevent mobilised sediment during construction works from clogging up drains. • Investigate replacement of older floodgate flaps with newer lighter weight gate flaps. • Clearing and maintenance of sediment and vegetation at upstream end of Ryans Cut and at Big Hill Creek outlet structure.	Medium priority – ongoing program
FM5	Investigation into Hat Head Control Levee increase	Council	Up to $200K	N/A	• A feasibility study is recommended to assess design options for raising the Hat Head village levees to provide a 1% AEP flood protection level. • Prepare a concept design for potential options. • Flood modelling to identify potential flood impacts and confirm options performance. • Options costings, flood damages assessment, cost-benefit assessment, input into business case.	Medium priority

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
FM6	Flood Mitigation Environmental Projects	Council, NSW Govt environmental agencies	Uncosted	N/A	• Undertake feasibility study/s to identify proposed environmental projects that would provide no detrimental flooding impacts, or, identify further mitigations which would assist in reducing or eliminating the flooding impacts of those environmental projects • Utilise the findings on potential options flood impacts from this FRMS to help the ongoing design and development of proposed environmental projects. • Consider in broader scope the environmental, social and economic factors, costs and benefits in evaluating proposed environmental and flood mitigation projects.. • Consider varying scenarios and combinations of environmental works (such as separate disconnection of Killick Creek and Korogoro Creek from the floodplain) as a part of feasibility study with the aim of maximising environmental benefits and optimising flooding, social and economic outcomes.	Medium/High – Pending environmental program scheduling.
FM7	Second Bridge Crossing at Kempsey	Council	Council staff costs	N/A	Council should continue to advocate for a second road bridge crossing at Kempsey, based on completed feasibility by Council/Transport for NSW, to imrpvove traffic conditions on existing routes and provide improved transport connectivity between M1 Pacific Highway/South Kempsey and West Kempsey (including hospital and proposed Emergency Operations Centre) and rural areas to the north and west of Kempsey.	High – ongoing advocacy
FM8	Local catchment flood studies and other focussed assessments	Council	$150K each	N/A	Commission flood modelling and studies with finer model resolution for local catchment flooding problem areas not assessed in detail in this FRMS. Potential locations of interest include Stuarts Point – Grassy Head, and Frederickton.	Medium
FM9	Replacement of Rudders Lagoon bridge with high level bridge	Council	Uncosted	N/A	Consider replacement of Crescent Head Road bridge at Rudders Lagoon with a higher level bridge and road to improve flood immunity of this road crossing once the existing bridge reaches end-of-life and requires replacement.	Low
PM1	Revise Flood Planning Level/Flood Planning Area	Council	Council staff costs	N/A	Revise Flood Planning Level/Flood Planning Area based on maximum level of: • 1% AEP current climate flood level + 500mm freeboard; and • 1% AEP year 2100 flood level (no freeboard). • At area of overlap of Lower Macleay River FRMSP mapping with Kempsey CBD FRMSP mapping area, refer to Kempsey CBD FRMSP Flood Planning Level, which is already adopted by Council.	High – ensure planning documents are consistent and utilise the most up to date flood information. It is noted that Council has already resolved to adopt the maximum level of the 1% AEP current day flood level with 500mm freeboard and the 1% AEP year 2100 flood level as the flood planning level.
PM2	Flood Policy	Council	Council staff costs	N/A	• Council to develop Flood Policy.	High – ensure planning documents are consistent and provide clarity and utilize the most up to date flood information.

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
PM3	Amendments to LEP and Section 10.7 certificates	Council	Council staff costs	N/A	• Revise LEP based on outcomes from this FRMSP, including update of Flood Planning Level and Flood Planning Area, and floodway/flood storage mapping. • Section 10.7 certificates to notate properties which are affected by flooding as identified in this FRMSP. • Reissue Section 10.7 certificates to all affected by the revised FPA/FPL.	High – ensure planning documents are consistent and utilize the most up to date flood information.
PM4	Amendments to DCP	Council	Council staff costs	N/A	• Update DCP 2013 include the floodway/flood storage mapping presented in this FRMS. • The flood mapping, design flood levels and other outputs from this Lower Macleay FRMS are to be used as the basis for all flood planning and development controls in the Lower Macleay area, superseding info from previous studies. • Given the projected increases in peak flood levels in the Lower Macleay due to ongoing and future climate change, define the flood planning level as the maximum level of the 1% AEP current day flood level with 500mm freeboard and the 1% AEP year 2100 flood (already adopted by Council as policy as of drafting of this FRMP). • Council should consider whether climate change flooding conditions should be adopted for the various other development controls. • Update of DCP 2013 could consider reference to the AIDR flood hazard categories and the flood hazard mapping that are presented in this FRMS. The current DCP refers to velocity – depth product as an indication of hydraulic hazard conditions. • Restricting new development to areas of H4 flood hazard and lower in the 1% AEP event would be generally consistent with the development conditions relating to hydraulic hazard in the current DCP 2013. • Review whether Bellimbopinni and Seven Oaks floodway area should be retained in the DCP, as it does not match flooding conditions in this FRMS. If retained, consideration should be made for extending the floodway are further east to include areas of higher flood hazard as identified in this FRMS. • Review the requirement in the DCP for a separate detailed flood study for proposed development on specified lots in the South West Rocks New Entrance floodway area. The modelling and flood mapping outputs from this FRMS could be referenced for these lots. • "Flood prone land" as defined in DCP 2013 refers to the land which is inundated during a 1% AEP flood. This definition should be updated to refer to the land which is inundated in the PMF, that is, land which would be subject to inundation by the full range of flood magnitudes. This latter definition would be consistent with that provided in the Flood Risk Management Manual 2023. • Continue to provide requirements for flood proofing and flood compatible design of individual buildings as development controls in the DCP	High – ensure planning documents are consistent and provide clarity and utilize the most up to date flood information.
PM5	Voluntary purchase of high hazard properties	Council (with grant funding)	$500+ per property approx.	Minimal costs	• Aims to reduce population at risk to high hazard flooding and damage to property by voluntary purchase of dwellings affected by high hazard flooding in 1% AEP event. Subject to property eligibility and DCEEWW grant funding application. • Council should continue with its voluntary purchase of high hazard properties program with guidance from the flood modelling and mapping outcomes from this FRMS. Update of register of eligible properties. • Preliminary estimate of 421 dwellings potentially eligible. To be confirmed with review of specific dwellings for eligibility.	High – ongoing continuation of existing program

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• Council should develop a policy or strategy as to how this action might be funded in respect to Council's contribution, including prioritisation of any properties to be acquired and how the land will be used in the future. • Review the ongoing feasibility of the scheme, citing historic and ongoing property price increases. • Sources of funding forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored	
PM6	Voluntary house raising	Council and property owners (with grant funding)	$100K per dwelling approx.		• Aims to reduce flood damages due to over-floor flooding by voluntary raising of habitable floors of dwellings affected by low hazard flooding in 1% AEP event. Subject to property eligibility and DCCEEW grant funding application. • Council should continue with its voluntary house raising program with guidance from the flood modelling and mapping outcomes from this FRMS. Update of register of eligible properties. • Preliminary estimate of 777 dwellings potentially eligible. To be confirmed with review of specific dwellings for eligibility. • Additional sources of funding such as those potentially forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored.	High – ongoing continuation of existing program
RM1	Flood warning systems	Council, BOM	Transfer of total flood warning gauge network – not costed. Improvements to Council messaging system – staff costs.		• Council investigate the feasibility of and advocate for the transfer of ownership and operation of the total flood warning gauge network to BOM. • If ownership and operation of the total flood warning system gauges is transferred to BOM, Council and local SES should remain as a key stakeholder in the operation of the total flood warning system. • Investigate opportunities to improve the efficiency of Council's total flood warning system messaging and reduce the lag between the reporting of on-ground activities/conditions and communications. • Consider improvements to social media and SMS flood messaging system including checks of gaps in mobile coverage and investigate improvements in coverage gaps, and regular update of flood message recipients list. • Consider improvements to the live flood monitoring webcams including installing/ reinstating Turners Flat Bridge Webcam and Bellbrook Bridge Webcam. • Maintain Council's flooding website and its links to real-time flood information and warnings, and Council's own flood messaging system.	High – maintain existing program and planned additional gauge sites; review and improve flood warning messaging system. Medium priority for investigating and implementing total flood warning system gauge network to BOM.
RM2	Relocation of emergency services facilities	Council, SES, NSW RFS	Feasibility studies, development and relocation activities not costed	N/A	• Council should continue to investigate the viability of a new dedicated Emergency Operations Centre (EOC), to be co-located with the existing Kempsey FCC/SES at North Street/River Street • The new EOC would serve as a purpose-built centre for both flooding and bushfire emergency management activities, where currently there are separate fire and flooding emergency management facilities. • Funding to investigate the option may be available through NSW Reconstruction Authority. • Cost of constructing the development and relocation of services is to be confirmed during feasibility studies.	Medium – Ongoing investigation and design including consultation with SES, RFS etc.

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
RM3	Stock refuge mounds and other land shaping	Landowners, Council administration	Low costs for Council administration	Ongoing program	• Areas of artificially elevated ground to be used as temporary evacuation for communities / stock / assets in minor flood events. Suitable for locations in the floodplain up- and down-stream of Kempsey clear of floodways and major flow paths. • Council should continue with its policy of requiring property owners wishing to build stock flood refuge mounds to prove that the mound will not impact on surrounding properties. • Council should consider whether flood impact and mitigation assessments should be undertaken for agricultural land shaping on rural properties.	Low – ongoing program
RM4	Flood depth markers and flood signs	Council	Static depth indicator and warning signs $600 per depth marker, assume up to 40	N/A	• Flood depth markers at key road low points and low area access points. • The depth markers serve as depth indicators and warning of flooding ahead during a flood event to reduce occurrences of people driving into floodwaters, in addition as a passive reminder of flooding risk. • Flood warining signs (fixed signage) are recommended at selected locations to indicate that the road ahead is cut by flooding. Key locations include Crescent Head Road east of The Corduroy and west of Rudders Lagoon, and Hat Head Road west of the village.	High – aims to directly modify driver response to flood hazard during a flood event. Static signs are a low cost measure which also improves flood safety and flood awareness at each location.
RM5	Update of current emergency management planning	SES	SES costs	SES costs	• Kempsey Flood Emergency Sub-Plan should be updated incorporating the findings of this study on flood behaviour and hazards.	High – incorporate into the 5 yearly review cycle of the Flood Plan (due 2027).
RM6	Flood education and awareness program	Council, SES	$50K	Staff costs	Continue to promote flood awareness and readiness in the community. Measures may include: • Promotion of FloodSafe brochures to help residents understand the flood risk and prepare their property and personal plans for a flooding event. ▪ Continue to undertake community flooding and emergency planning education events in coordination with SES • Maintain Council's flooding website with flood education, awareness and readiness information. • Regular updates of flood information and messaging recipients list. • Consider future requirement in the flood planning instruments for flood awareness and education materials such as flood information posters/brochures outlining Lower Macleay flood risks, evacuation routes, template flood emergency plan (similar to bushfire plan) key organisation (SES, emergency services) phone numbers, Council flood website and other flood info sources, to be displayed at high risk premises including temporary visitor accommodation and for distribution to new permanent residents. Council would prepare the standard information posters/brochures in consultation with SES. • Mail-out of flooding information packages to new residents to maintain flood awareness and minimise gaps in disseminating communications to the community. • Update the interactive mapping portal with latest flood mapping when these are updated and become available.	High – community awareness is likely to significantly improve flood preparedness, reduce flood damages and reduce flood response and risk to people.

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• Develop and maintain a flood education and awareness program to plan out various flood education and awareness activities. Review implementation and effectiveness of program on regular (e.g. 2 – 5 year) cycle	

1. Introduction

1.1 Background

The Lower Macleay River floodplain (refer to Figure 1-1) occupies approximately 500km^2 of coastal floodplain downstream of Kempsey, to the Macleay River's main outlet at South West Rocks. The floodplain drains a catchment area of 11,500km^2, has several secondary outlets to the ocean at Hat Head and Crescent Head and a hydraulic link to the Hastings River to the south, all owing to improved channel linkages constructed during implementation of historic flood mitigation schemes between 1955 and mid-1970s. The river's historic outlet to the ocean was at Grassy Head, to the north of its current outlet, until a major flood in 1893 cut an entrance at its current location. River training walls have been constructed to stabilise the current river course.

The floodplain is generally low lying and contains numerous watercourses including Belmore River, Kinchela Creek, Collombatti Creek and Clybucca River, in addition to a number of wetland areas. The towns and villages of Smithtown, Gladstone, Kinchela, Jerseyville, Fishermans Reach and Stuarts Point are situated in the floodplain, with South West Rocks, Hat Head and Crescent Head accessed by roads through the floodplain.

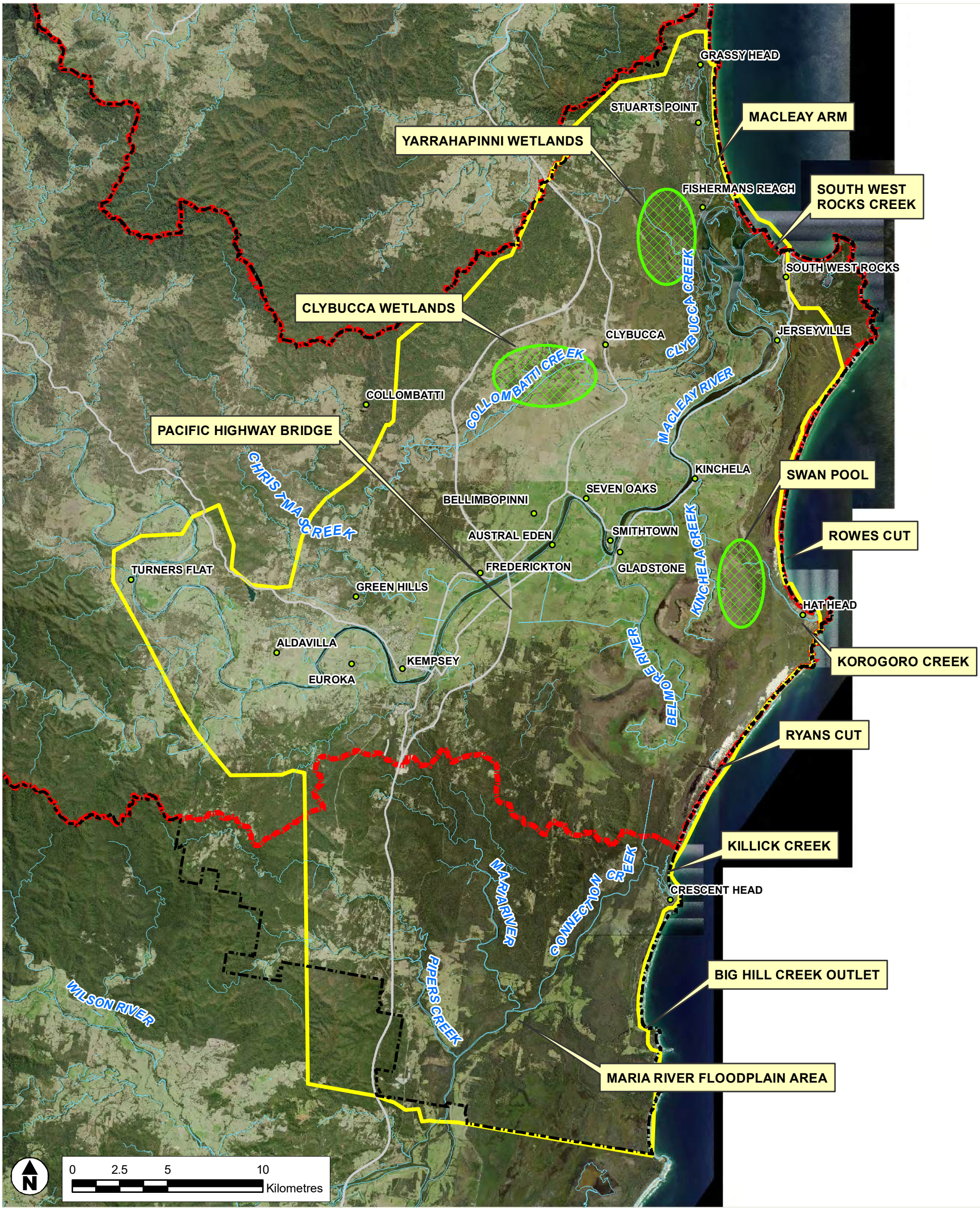
Significant floods occurred in the valley in 1838, 1893, 1949, 1950, 1963, 2001, 2009, 2011 and 2013. A major flood mitigation scheme was implemented from 1955 to the mid-1970s consisting of numerous flood gates, drainage channels and levees to help protect Kempsey township and the agricultural area, and to provide flood warning and improved drainage. Recent infrastructure works in the floodplain include the Pacific Highway Kempsey Bypass, which crosses the river and floodplain via a 3.2km bridge to the east of Kempsey.

Kempsey Shire Council engaged Jacobs to undertake the Lower Macleay River Floodplain Risk Management Study and Plan. The study will build on the previous Lower Macleay Flood Study Update (Jacobs, 2022) which provided information on flood behaviour in the Lower Macleay floodplain based on detailed hydraulic modelling developed for this Floodplain Risk Management Study (FRMS) project. This report is the Floodplain Risk Management Study and Plan report which defines the flooding behaviour and its impact on the community, identifies and appraises potential management measures to reduce existing and future flood risk. Based on the study findings, a list of prioritised measures recommended for implementation by Council is included in the Floodplain Risk Management Plan (FRMP) within this report.

1.2 Study objectives

Key objectives of this study are summarised below.

- Update of previous flood study modelling including extension of TUFLOW hydraulic model upstream to Turners Flat and southward to the Kempsey LGA boundary to include the Maria River floodplain. utilising revised main catchment hydrologic modelling and update local catchment hydrologic modelling to Australian Rainfall and Runoff (ARR) 2019. Redefine design flood conditions.
- Understanding of impacts and consequences of flooding on the community. This includes knowledge of properties (numbers of properties, flood damages), roads, infrastructure and critical services impacted by current and future flooding conditions, which will inform town planning, emergency management and evaluation of feasibility of mitigation works.
- Develop a list of recommended and prioritised physical works and strategic planning flood risk mitigation measures to improve current and future flood risk.
- Assistance with development of guidelines to manage future and proposed developments on the floodplain.



GIS MAP file : IA252400_R03_RevB_Fig1-1_StudyArea_02

Legend

- Study Area
- Macleay River Catchment
- Kempsey Local Government Area
- Main Road
- Drainage

Jacobs

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Study Area

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	Figure 1-1	1	1
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1.3 Floodplain risk management

Council is responsible for managing the existing, continuing and future flood risk for its Local Government Area (LGA). The floodplain risk management planning process, as set out in the *Flood Risk Management Manual* (NSW Government, 2023) has a number of steps which are illustrated in Figure 1-2.

Figure 1-2 Floodplain Risk Management Process

1.4 Structure of this report

This report is structured accordingly:

- Section 2 – Summary of the physical setting, history of flooding and social, environmental and heritage aspects of the catchment.
- Section 3 –Previous studies and relevant available information and data on flooding and hydrology in the catchment.
- Section 4 – Summary of consultation activities undertaken for the study.
- Section 5 – Describes existing flood behaviour and flood hazard.
- Section 6 – Impacts of flooding on the community including high hazard properties, flood damages, land use compatibility, evacuation considerations.
- Section 7 – Summary of relevant State and local government policies and planning framework.
- Section 8 – Overview of existing flood emergency planning.
- Section 9 – Outline of management measure types and review of property and response modification measures.
- Section 10 – Assessment of shortlisted mitigation options and evaluation of options.
- Section 11 – The Draft Final Floodplain Risk Management Plan.
- Section 12 – Acknowledgements.
- Section 13 – Literature cited in this report.
- Section 14 – Definition of terms used in this report

2. Background on the Study Area

2.1 Description of Study Area

This study focusses on the Lower Macleay River floodplain, which covers an area of approximately 500km^2 downstream of Kempsey. The key watercourses within the floodplain are the Macleay River, Macleay Arm, Clybucca Creek/Collombatti Creek, Kinchela Creek, Belmore River and Christmas Creek. The catchment upstream of upstream of Kempsey, covers an area of approximately 11,500km^2, stretching up to the Northern Tablelands region to townships including Armidale, Guyra and Walcha. The catchment generally drains to the east where a significant portion of the middle catchment is dominated by gorge country. The upper and lower ends of the catchment are relatively flat, while the central two-thirds are extremely mountainous and rugged. Catchment elevations range from near sea level at Kempsey to over 1,000m AHD on the Northern Tablelands.

The catchment is of a fan-shaped form, where the central catchment area is fed by a sprawling network of tributaries. The main tributaries include the Apsley, Muddy and Chandler Rivers, fed by numerous smaller streams from very steep gorge country. These watercourses converge to the Macleay River around 35km upstream of Kempsey. In this area the catchment shape funnels down to a narrow valley. The shape and generally steep terrain of the catchment tends to concentrate flood runoff from the upstream sub-catchments, influencing flood behaviour and producing floods with typically rapid rates of rise in the lower valley. Beyond Kempsey, the floodplain broadens as the Lower Macleay River meanders towards the coast.

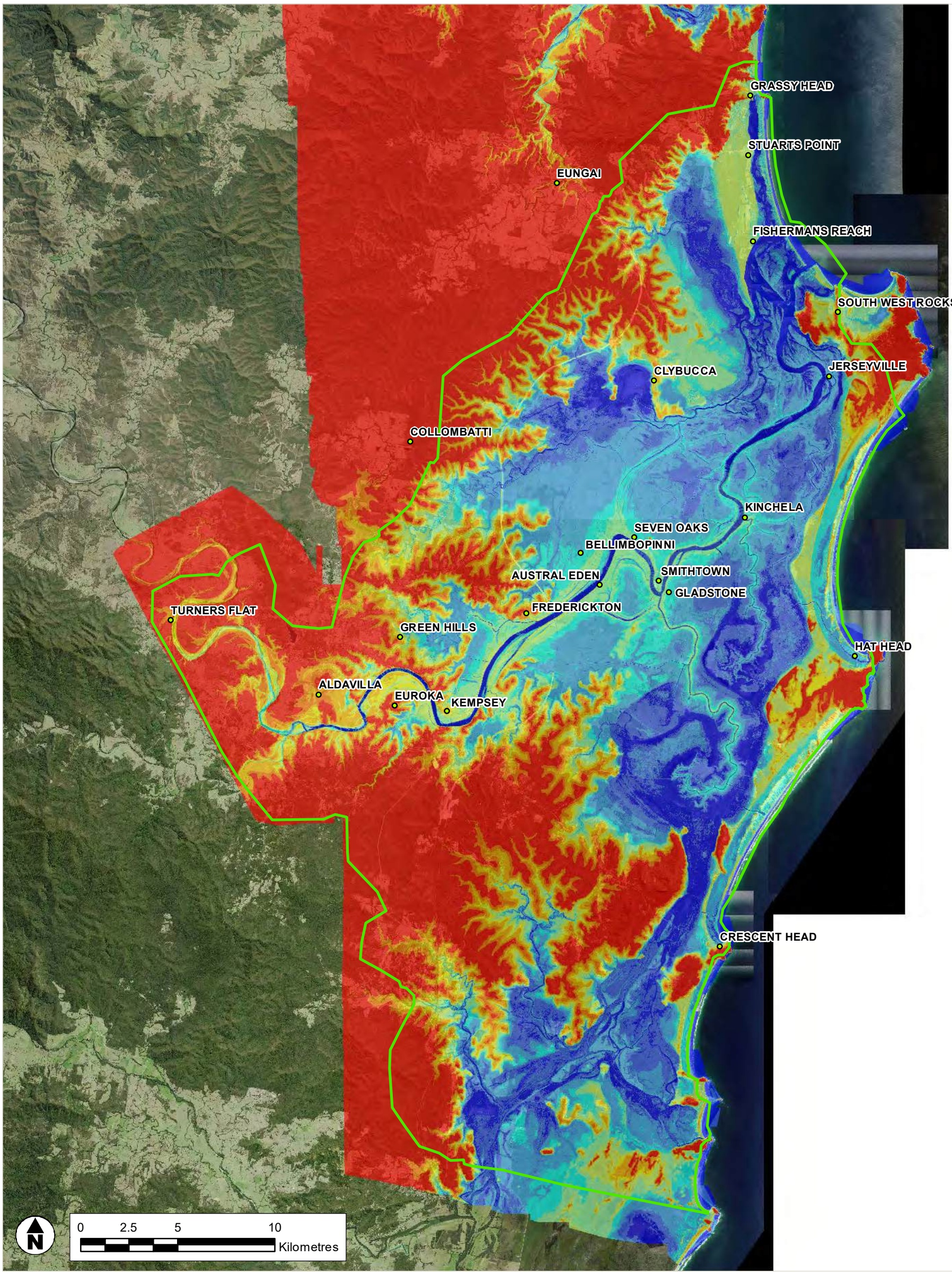
The general topography of the floodplain (refer to Figure 2-1) includes well defined natural riverbank levees up to 7m AHD along the rivers and creeks formed by deposition of alluvial sediments over the course of numerous historic floods. The terrain grades down to low-lying areas typically less than 1m AHD, and down to 0m AHD. The main floodplain and wetland areas are located at Clybucca Wetlands in the north and Belmore River and Kinchela Creek swamp areas, including Swan Pool. There are a number of other wetland areas connected to the estuary including the Yarrahapinni Wetlands.

Collombatti Creek, which drains into Clybucca Creek, and Christmas Creek are the main local watercourses with a contributing catchment area which produces flows into the watercourses. Belmore River and Kinchela Creek are both lowland waterways which historically transferred tidal and river flood flows into the attached coastal backswamp areas, with freshwater outflows only occurring following main river floods overflowing into the swamps.

The Macleay River currently discharges to the ocean at South West Rocks via a fully trained river entrance. Historically the river discharged to the ocean at Grassy Head, approximately 10km to the north, until the 1893 flood broke out and formed a new entrance at the existing location. During flood events floodwaters may discharge to the ocean via secondary outlets including Korogoro Creek and Rowes Cut at Hat Head, Killick Creek and Ryans Cut at Crescent Head, and South West Rocks Creek at South West Rocks.

The floodplain in the vicinity of Belmore River and Kinchela Creek (broadly referred to in this report as the "southern floodplain"), to the south of the main river, are hydraulically connected to the Hastings River floodplain to the south, with flows occurring between the Macleay floodplain and the Hastings floodplain via Connection Creek and the Maria River. A floodgate on Connection Creek and the raised Crescent Head Road embankment are low-level barriers to this interflow. These are overtopped when floodwaters reach approximately 1.2m AHD, which may occur during frequent flood events.

The floodplain area to the north of the river, adjoining Collombatti Creek/Clybucca Creek, including the Clybucca Wetlands and Seven Oaks Drain, is broadly referred to in this report as the "northern floodplain". Floodwaters flow in these watercourses through the Menarcobrinni flood gates in Clybucca before joining Andersons Inlet and then Macleay Arm at Fishermans Reach.



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Legend

Ground Elevation (m AHD)

- < 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 8
- 8 - 10
- 10 - 15
- 15 - 20
- > 20

Limit of Mapping

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Study Area Terrain

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE 2-1	1	1
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2.2 Existing Development and Land Use

Land use in the Lower Macleay is predominantly rural and agricultural, made up mostly of pastural and grazing lands with some pockets of cropping land. Within the rural landscape are areas of forest, wetlands and other environmentally significant lands.

Within the floodplain are a number of small urban centres and villages, including Smithtown, Gladstone, Frederickton, Kinchela, Jerseyville, Fishermans Reach and Stuarts Point, which are located primarily on the banks of the Macleay River. Smithtown and Gladstone, supports a large milk product factory ("Nestle factory") and further downstream the village of Jerseyville is a centre of the local fishing industry.

Other developed centres include South West Rocks, Crescent Head and Hat Head, which are situated along the coast and are directly and indirectly affected by flooding in the Lower Macleay by having transport, communications and services cut-off during flood events.

The greatest number of businesses in Kempsey Shire are in agriculture, comprising 27% of total registered businesses. In the 2021 Census, the reported economic output of agriculture, forestry and fishing industries in the Lower Macleay (downstream of Turners Flat) was $41.7 Million in the 2020-21 financial year (Source: https://economy.id.com.au/kempsey/employment-locations?EconSpace=1&Indkey=23001).

The land zoning map is shown on Figure 2-2.

2.3 Flood Behaviour

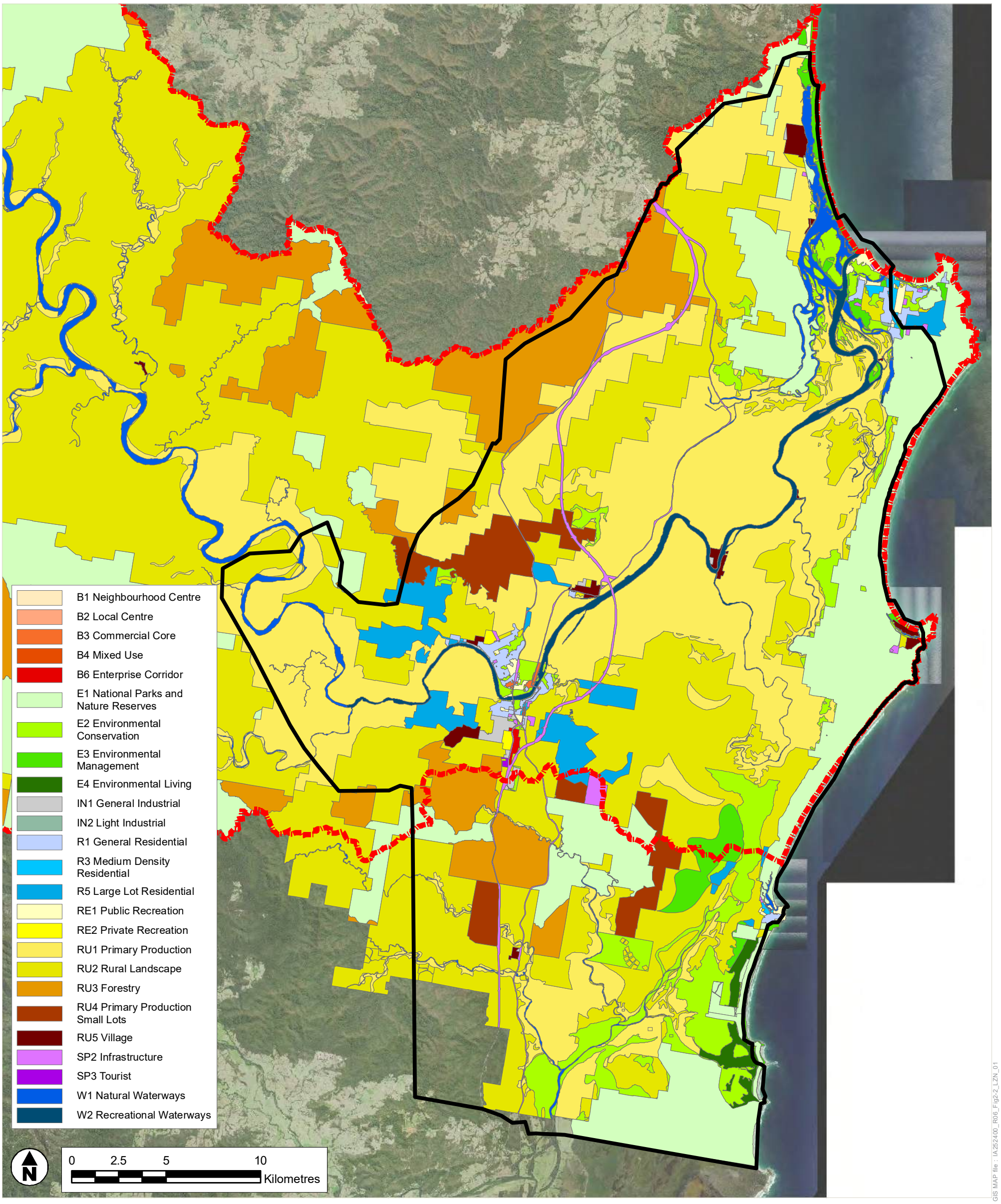
The configuration of the Macleay catchment is practically suited to the production of high peak flood flows. The major tributaries join the main stem of the river within a small distance of each another causing a rapid concentration of floodwater in the main stream below their confluences, and the large upstream catchment funnels to a narrow bottleneck upstream of Kempsey. Following major rain storms the Macleay River at Kempsey may rise from a normal dry weather discharge of about 56m^3/sec to 12,000m^3/sec (the estimated discharge of the August 1949 flood) within a 30 hour period.

The main river flows are the dominant cause of flooding in the study area. Floodwaters tend to overflow from the river particularly between Kempsey and Smithtown, filling the adjacent floodplain areas. Floodwaters slowly drain through the floodplain, flowing in parallel to the main river, conveyed in natural and man-made floodplain channels and watercourses, converging on the main river in the lower reaches of the catchment.

During flood events floodwaters may break out to the ocean at a number of minor creek outlets as mentioned in Section 2.1. There is also potential for overtopping of the coastal beach foredune system at a number of locations in rare flood events, which may scour out additional discharge points in such events.

It is quite likely that there would be coinciding flooding in the adjacent Hastings River to the south of the Macleay, in addition to other river systems during a regional flooding event. Depending on the relative size of flood events in the Macleay River floodplain and Hastings River floodplain, floodwaters may flow into the Macleay floodplain or out to the Hastings floodplain via the low-lying area connecting the two floodplains to the south-west of Crescent Head. Flows may occur in both directions over the course of particular flood events.

Flooding can also occur in tributary watercourses and creeks such as Christmas Creek, Euroka Creek, Dungay Creek, Collombatti Creek, Maria River and Pipers Creek among others. This flooding may coincide with riverine flooding in the Macleay River. Local flooding can also occur in minor local catchments and gullies, of which there are several in urban areas in Kempsey and Frederickton, and inside levee systems such as in Kempsey, Smithtown and Hat Head.



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Legend

Study Area

Macleay River Catchment

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Land Use Zoning

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	Figure 2-2	1	1
CHECK AH	DATE 1/05/2024			

2.4 History of Flooding

The Macleay valley has a history of flooding. The first recorded flood to cause damage was in 1838. As mentioned earlier the 1893 flood event significantly changed the course of the river in the lower reaches the breakout of a new river entrance at its current location.

Winter floods in 1949 where water levels recorded at Kempsey Traffic Bridge reached 8.52m AHD resulting in the loss of six (6) lives and more than 7,000 head of stock and 600 buildings damaged or destroyed. Winter floods again in 1950 recorded peak water levels at the Kempsey Traffic Bridge of 8.31m AHD. Based on new flood frequency analysis of recorded flood levels at Kempsey Traffic Bridge, the 1949 event was estimated as larger than a 0.5% (1 in 200) Annual Exceedance Probability (AEP) event, while the 1950 flood was estimated as an approximately 1% (1 in 100) AEP event.

The March 2001 flood event is the largest flood event in the valley in recent years and was the largest to occur since the 1963 event. Over 1,000 residents were evacuated by air from the floodplain urban centres. The estimated rural flood damages for that event have been assessed at greater than $12 million dollars (Webb McKeown and Associates, 2002). This flood event was estimated at 5% (1 in 20) AEP.

The March 2001 flood event followed a minor flood in early February 2001. Most upper river rain stations received 30 to 50mm on both 31 January and 1 February, with mid and lower catchment stations receiving 50 to 100mm on those two days. A low pressure system formed on 5 March with Bureau of Meteorology issuing wet weather alerts. Significant rainfall fell on an already wet upper catchment between 5 and 12 March, as summarised on Table 2-1.

Table 2-1 Rainfall on the Macleay River Catchment 5 – 11 March 2001

Location	Daily rainfall (mm)							
	Mon 5th	Tues 6th	Wed 7th	Thurs 8th	Fri 9th	Sat 10th	Sun 11th	TOTAL
Pt Lookout	15	84	71	233	170	78	23	674
Guyra	12	4	15	42	8	1	8	90
Blue Nobby	8	13	25	86	8	2	9	151
Walcha	1	4	1	4	21	4	2	37
Wollomombi	2	21	12	57	43	11	1	147
Tia	0	14	97	30	5	11	0	157
Boonanghi	1	66	31	72	105	72	25	372
Millbank	2	65	26	108	151	50	8	410
Bellbrook	2	52	22	104	144	27	8	359
Turners Flat	1	72	14	79	93	45	13	317
Wittitrin	1	3	3	2	9	5	4	27
Kempsey	4	122	30	80	42	11	3	292
Seven Oaks	1	24	4	31	18	2	1	81
Seale Road	12	81	12	49	25	7	1	187

Flooding peaked at Kempsey on 12 March at 7.44m AHD on the Kempsey Traffic Bridge gauge, overtopping a number of levees in the CBD (both Eden Street and First Lane/Cochrane Street levees overtopped, with the Eden Street levee overtopping first in this particular event) in addition to rural levees in the lower floodplain. Extensive inundation of the lower floodplain occurred. Gladstone, Smithtown, South West Rocks, Hat Head, Crescent Head and many upstream and downstream rural areas were isolated. Many food drops, or evacuation for medical reasons, were organised. The sewerage treatment system at Smithtown/ Gladstone was overloaded by floodwaters and surcharging occurred. Council staff were unable to bring the system back online until late

Tuesday. Both villages were voluntarily evacuated of some residents until the sewer was fully functional (reference: Kempsey Shire Council Report on Macleay Flood of March, 2001 River Levels, Rainfall and Recovery).

Significant flooding also recently occurred during February 2013. The flood peaked on 24 February at 7.11m AHD at the Kempsey Traffic Bridge gauge, slightly lower than the March 2001 event. Floodwaters overtopped First Lane/Cochrane Street levee at Kempsey causing inundation of parts of the CBD. Widespread flooding was experienced in the Lower Macleay floodplain including inundation of Smithtown and Gladstone, among other villages. This event was smaller than a 5% AEP event.

Widespread flooding occurred on the Mid-North Coast of NSW during the second half of March 2021. In Kempsey local government area (LGA), flooding in the Macleay River reached the highest levels since the February 2013 flood event, with impacts experienced due to inundation of rural lands, numerous roads and bridges being cut-off for over one week and communities within the floodplain inundated and isolated. Flood levels peaked at Kempsey Traffic Bridge gauge at 6.50m AHD, about 0.6m below the overtopping level of the RSL levee and 0.7m below overtopping level of Eden Street levee. Flood levels at Smithtown gauge exhibited a peak of 4.04m AHD on 20 March, before subsiding and then peaking a second time at 4.06m AHD on 22 March, causing overtopping of the levee at the low point on Jeffery Street.

The March 2021 flood was estimated as a 15% AEP event based on rating at Kempsey Traffic Bridge. Although rainfall event probabilities of rarer than 1% AEP were experienced at and downstream of Kempsey, the prevalence of lower rainfall depths with event AEPs of 0.5 – 0.2EY across the majority of the upstream catchment limited the resultant flood AEP. The limited penetration of rainfall further inland from coastal areas, and the absence of more intense rainfall at the shorter 1 and 2 day event durations reduced the potential for a larger/rarer probability event in the Macleay River at Kempsey.

Photos from historic floods are presented below (source: Kempsey Shire Council).

Figure 2-3 View of the floodplain looking downstream of Kempsey after the 1949 flood

Figure 2-4 Floodwaters overtopping the Eden Street levee in Kempsey CBD in the 2001 flood

Figure 2-5 Aerial photo of Smithtown and Gladstone, looking downstream, in the 2013 flood

Figure 2-6 Kempsey Bypass and new Pacific Highway bridge over Lower Macleay floodplain, 2013 flood

Figure 2-7 Belmore River Flood Control Structure discharging flood water from the Belmore River into the Belmore floodplain, 2013 flood

Figure 2-8 Kinchela Creek Left Bank Flood Control Structure discharging flood water from Kinchela Creek into the west Kinchela area, 2013 flood

Figure 2-9 Ryans Cut - Ocean floodwater outlet discharging flood water from the Belmore area into the ocean, 2013 event

Figure 2-10 Killick Creek - floodwater discharging into the ocean at Crescent Head, 2013 event

2.5 Lower Macleay Flood Mitigation Scheme

Following the severe flood events in 1949 and 1950 there was significant community reaction which demanded action to mitigate the impacts of flooding on the Lower Macleay Floodplain. This led to the formation of the Macleay Valley Flood Mitigation Committee which formulated a basis of the flood problem and developed options for the Lower Macleay Flood Mitigation Scheme, a series of works to address flooding problems (McDonald, 1967). The product of this assessment was the "Jacka Report" (Macleay Valley Flood Mitigation Committee, 1953) which documented the assessment and recommendations for the Scheme.

Works on the Scheme commenced in 1955 and were progressively implemented until the mid-1970's that included the construction of 47 flood-gated structures (of various sizes), 116km of drainage channels and 180km of levee.

The stated aims of the flood mitigation scheme were:

1) Protection of the Kempsey township up to a 1 in 10 year flood event;
2) Protection for the lower Macleay agricultural area from a 1 in 2.5 year flood event;
3) Allow for rapid drainage of floodwaters;
4) Provide for erosion protection;
5) Improve flood mapping, proofing and data; and
6) Provision of flood warning.

Focussing on the Lower Macleay downstream of Kempsey CBD, a significant feature of the Scheme includes the system of levees, flood gates and flood control structures on the southern floodplain, including the areas of Upper Belmore and Upper Kinchela and wetland areas of Swan Pool. Extensive levees along both banks of Belmore River and Kinchela Creek are linked with on-stream floodgates in the upper sections of each watercourse. The structures aim to prevent floodwaters from the Macleay River spilling into the southern

floodplain and inundating the large tracts of productive agricultural land in minor flood events. Large off-line (lateral) flood control structures and floodways on Belmore River left bank and Kinchela Creek left and right banks can be opened to allow controlled flow of floodwaters into the floodplain in slightly larger flood events to help mitigate flooding to downstream villages. These parts of the Scheme are likely to be overtopped with minimal influence on flooding behaviour in moderate and major flood events.

Works related to the Scheme on the southern floodplain also include constructed drainage link channels between the floodplain and to a number of coastal creeks to assist with drainage of floodwaters following a flood event. These creeks included Korogoro Creek at Hat Head and Killick Creek at Crescent Head, and the coastal lagoon at Ryans Cut, to the north of Crescent Head. Each of these waterways were naturally separated from the southern floodplain by sand dune systems. Floodgate headworks and an excavated channel through the beach dune system were also constructed at Rowes Cut, on Korogoro Creek just north of Hat Head, as an additional coastal outlet. However, Rowes Cut land ownership was handed to National Parks limiting the ability for Council to freely operate and maintain. Accordingly, it was eventually filled in by the beach dune system.

At the southern extremity of the southern floodplain a connecting channel (Connection Creek) and floodgates were constructed, linking the southern Lower Macleay floodplain to the Maria River and Hastings River floodplains to the south. An additional ocean outlet was constructed at Big Hill, connecting the Maria River floodplain to the ocean.

On the northern floodplain, Collombatti Creek/Clybucca Creek naturally drained the low-lying areas in this region. Drainage channels including Seven Oaks Drain and Andersons Inlet were constructed to improve floodwater drainage. Major headworks at Clybucca floodgates, were constructed on Clybucca Creek to prevent saltwater intrusion into the northern floodplain area to improve agricultural potential.

Numerous flood mitigation works were also implemented in and around Kempsey CBD, which is not the focus of this study. Refer to WMAwater (2016, 2017) for details.

2.6 Population

2.6.1 Social profile

Social characteristics of the study area are a key consideration for the floodplain risk management study. The census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population, movement of people into and from the area all of which can be useful to understand and have implication of flood risk management. Information has been extracted from the 2021 census (Australian Bureau of Statistics, https://www.abs.gov.au/census/find-census-data/community-profiles/2021/LGA14350) for Kempsey local government area (LGA). The study area covers the majority of the population centres in Kempsey LGA and population statistics and trends for the LGA are expected to be closely reflected in the study area. Kempsey LGA has a residential population of 30,688 comprising over 14,000 dwellings. Population growth has been 10% overall since 2011.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer period of time will have a better understanding of flooding issues affecting them than those who have recently moved to the area. In the last 5 years 19% have moved into Kempsey LGA from outside the LGA. A large percentage of the population would have been residents within Kempsey at the time of the most recent floods. These people are likely to have an understanding of the flood issues affecting them in Kempsey LGA. About 48% of the population are over the age of 50 years, and are likely to have experienced significant floods including the 1963, 2001, 2013 events, among others. The majority of the population are likely to have experienced the recent 2021 flood event.

It is also useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and to have put measures in place to reduce them. Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risks unless they have been there for enough time to have

experienced flooding or have been sufficiently informed by their landlords. The number of rented properties in Kempsey LGA is 23%. The number of privately owned or mortgaged properties is 68%.

The languages spoken by the population is also useful to consider as it can have implication on providing flood information to the public. In the study area greater than 95% of the population speak English at home.

2.6.2 Population centres

There are a number of population centres in the Lower Macleay, including Kempsey. The populations at these localities are summarised in Table 2-2.

Table 2-2: Population in Lower Macleay towns and villages

Locality	Population	Number of dwellings
Kempsey (including South Kempsey and West Kempsey)	7,630	3,515
Frederickton	1,452	562
Smithtown	625	272
Gladstone	437	177
South West Rocks	5,058	3,057
Kinchela	286	119
Jerseyville	132	57
Fishermans Reach	144	104
Stuarts Point	766	481
Hat Head	365	381
Crescent Head	1,163	871

Source: https://profile.id.com.au/kempsey/locality-snapshots. Based on Census 2021.

2.7 Environment

Key environmental features and environmentally sensitive areas within the study area include the following:

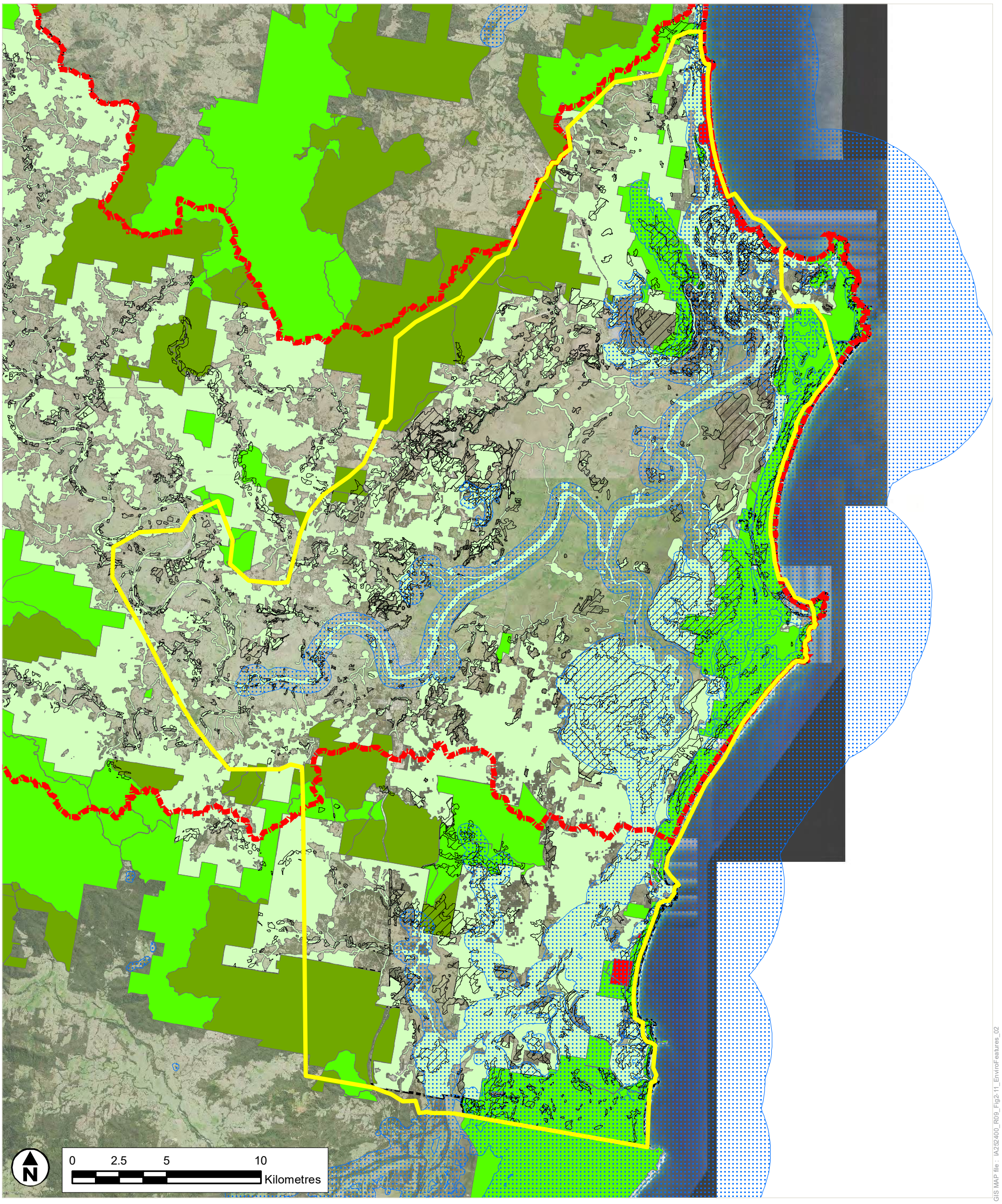
- National Parks and State Forests including
  - Hat Head National Park
  - Yarrahapinni Wetlands National Park
  - Yarriabini National Park
  - Arakoon National Park
  - Maria National Park
  - Limeburners Creek National Park
  - Goolawah National Park
  - Cooperabung Creek National Park
  - Tamban State Forest
  - Way Way State Forest
  - Ballengara State Forest
  - Kalateenee State Forest
  - Old Station State Forest
  - Maria River State Forest
- Areas covered by NSW Coastal Management State Environmental Planning Policy (SEPP)

- Environmental Protected Reserves
- Potential Endangered Ecological Communities
- High Environmental Value Land.

Any potential flood mitigation works proposed in this FRMSP would need to consider these environmentally sensitive areas and constraints. Development consent is required prior to any works being undertaken in the vicinity of the identified environmental areas. Any development within or near these areas must be considered for the impact it might have on the environment, and whether or not impacts of the proposal are avoidable, before consent is granted. Refer to Figure 2-11 for mapping of the environmental features and sensitive areas.

Generally, floodplain mitigation works have fulfilled their design intentions but since the 1980's it has been thought that the levees, drains or control structures have some adverse environmental effects including fish kills and black water. These environmental impacts have caused the community to question the sustainability of the works and their operation policies. However recent evidence suggests that major kills have occurred prior to the construction of the works. Over time significant settlement in the Macleay River has allowed the floodplain vegetation to change from plants preferring wet conditions to those more tolerable of dry conditions. During a flood, the dry tolerable vegetation becomes covered with flood water and dies off then begins to decompose, which deoxygenates the flood water causing the black water effect. With the advent of flood mitigation in the 1950s the proliferation of dry tolerable plant species expanded on the Lower Macleay exacerbating an existing problem (WMAwater, 2017).

The historic floodplain drains have also had the effect of lowering the water table in many parts of the floodplain, exposing potential acid sulfate soils that discharge acidic waters (pH ~3) and resulting in degradation of the landscape. Parts of the northern floodplain around Clybucca Wetlands was historically some of the most degraded acid sulfate soil areas on the NSW North Coast. In recent years, Transport for NSW purchased a large area of low-lying land on the Collombatti-Clybucca floodplain for biodiversity offsets as part of the Pacific Highway upgrade project. These areas were identified for rehabilitation to improve the wetland habitats of the floodplain and improve, with implementation of rehabilitation works commencing in 2020 to help restore the area as a freshwater wetland to saturate the acid sulphate scalded lands and reduce acid runoff. Potential mitigation measures identified in this FRMSP would need to avoid impacting on this project or otherwise consider the objectives of this environmental rehabilitation project.



GIS MAP file : IA252400_R09_Fig2-11_EnviroFeatures_02

Legend

- Coastal Management SEPP
- Environmental Protection Reserves
- Potential Endangered Ecological Communities
- National Parks
- State Forest
- High Environmental Value Land
- Study Area
- Macleay River Catchment

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Environmental Features

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	Figure 2-11	1	1
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3. Relevant previous studies

3.1 Lower Macleay Flood Study and Flood Study Update

Detailed discussion of the data and information available and collected during the flood study is provided in the Lower Macleay Flood Study Update (Jacobs, 2022) report. Review of that information is not repeated in this report except as relevant, refer sections below.

3.2 Kempsey CBD Floodplain Risk Management Study and Plan (WMAwater, 2017)

Builds on the flood study documented in Kempsey Hydraulic Model TUFLOW Update Final Report (WMAwater, 2016). Flood modelling is based on the now superseded *Australian Rainfall and Runoff 1987* (Engineers Australia, 1987) guidelines. Design flood levels are slightly higher than those defined in the Lower Macleay Flood Study Update (Jacobs, 2022), discussed above, as the design flood flow rates have been revised.

The Kempsey CBD FRMSP outlines the existing flooding problem in Kempsey CBD to Frederickton area including hydraulic and hazard characterisation, flood damages, flood planning level; the catchment context (planning, social, environmental); and identifies and assesses a number of floodplain management measures. The currently adopted flood planning information adopted by Council for Kempsey CBD down to Frederickton is based on this study.

3.3 Lower Macleay Floodplain Management Study (Webb McKeown & Associates 1997)

This study investigates the flooding issues in the Lower Macleay floodplain at that time and presents options to improve the performance of the area during and after flooding and in non-flood periods. Hydraulic modelling was undertaken of the floodplain downstream of Kempsey in RUBICON which is a one-dimensional hydraulic model, originally developed by Webb McKeown and Associates (1989).

The study and modelling was updated in the Lower Macleay Floodplain Management Plan, Supplementary Report covering the Floodplain between Kempsey and Frederickton – Final (Webb McKeown & Associates, 2004a). Design flood levels and velocities were estimated for the entire floodplain from Kempsey to South West Rocks, including the ocean outlets at Hat Head and Crescent Head. The majority of information used by Council for flood planning purposes in the Lower Macleay (prior to formal adoption of this current study) is based on the Webb McKeown & Associates (2004a) study.

3.4 NSW Flood Inquiry

The eastern states of Australia experienced multiple significant floods over the 2020, 2021 and 2022 multi-year La Nina event. On the NSW North Coast, catchments to the north and south of the Macleay incurred major flood events of 1% AEP magnitude and larger during this period.

The NSW Government established an independent flood inquiry to examine and report on the causes of, preparedness for, response to and recovery from the 2022 catastrophic flood event. The inquiry was tasked with examining and reporting on:

- Causes of and factors contributing to the frequency, intensity, timing and location of floods
- Preparation and planning by agencies and the community for floods in NSW
- Responses to floods, particularly measures to protect life, property and the environment
- The transition from incident response to recovery
- Recovery, including housing, clean-up, financial support, community engagement and longer-term community rebuilding.

The Inquiry was asked to consider and, if warranted, make recommendations on matters, including:

- The safety of emergency services and community first responders

- Current and future land use planning and management and building standards in flood prone locations across NSW
- Appropriate action to adapt to future flood risks to communities and their surrounds
- Coordination and collaboration between all levels of government.

Kempsey Shire Council made a formal submission to the Inquiry with regard to the above matters.

There were 28 recommendations made by the Inquiry. A number of these are related to improving organisational capacity within agencies to better manage the planning, response and recovery phases of flood emergencies. Key recommendations relevant to the Macleay, Kempsey Shire Council and this FRMS include:

- Improve the rain and river gauge network by:
  - implementing the Bureau's proposed New Policy Proposal for rain and river gauges in NSW
  - working to transfer ownership and maintenance responsibility for as many of the river and rain gauges as possible in NSW to the Bureau of Meteorology
  - upgrading and ensuring there is a maintenance program across NSW for those gauges that remain in state and local government ownership
- Risk-based Approach to Calculating Flood Planning Level, utilising knowledge of climate change effects on flooding and incorporating this into flood planning level calculations for planning purposes. Revision of flood planning levels should occur within 3 years for NSW's high risk catchments.
- Relocating Communities Most At Risk With Good Homes and Amenities.

The NSW Government's response to the Inquiry can be accessed online here https://www.nsw.gov.au/sites/default/files/noindex/2022-08/NSW_Government_Reponse.pdf (accessed 10/08/2023).

The parent website for the Flood Inquiry can be accessed by this link https://www.nsw.gov.au/nsw-government/projects-and-initiatives/floodinquiry (accessed 10/08/2023).

The NSW Reconstruction Authority (NSWRA) has been established by the NSW Government with the responsibility of facilitating disaster prevention, preparedness, recovery, reconstruction, and adaptation to the effects of natural disasters in NSW. NSWRA will be the primary agency for managing, coordinating and implementing many of the recommendations of the Flood Inquiry, and is otherwise a key stakeholder in other recommended actions of the Inquiry.

4. Community Consultation

4.1 Overview

Community consultation is an important part of the flood study and floodplain risk management study process. Its objectives are to inform the community about the study, gather information on experiences of flooding in the study area and provide an opportunity for the community to communicate their concerns about flooding issues.

4.2 Consultation with Flooding Reference Group

The Flooding Reference Group was formed in early 2024 to provide steering for the Lower Macleay River FRMS. The Reference Group was comprised of councillors, Council officers, agency officers (SES, NSW Reconstruction Authority), community groups and community members. Meetings to present the findings of this study to the Reference Group were held including:

- 14 March 2024: Options Identification. Outline the identified options for further investigation and identification of additional options for assessment.
- 18 April 2024: Options Assessment. Discussion of flood modelling of options and the hydraulic benefits and impacts, cost benefit analysis and multi-criteria analysis. Feedback was sought on aspects of the assessment methodology. A key piece of feedback was the view that the agricultural damages and savings in damages would be important in the economic and multi-criteria assessment of the options.
- 30 May 2024: Draft Flood Risk Management Plan Meeting. Provided information on the updated agricultural damages and savings assessment to the Reference Group. Provided an overview of the Draft Floodplain Risk Management Plan.

4.3 Community workshops

A community workshop was held at Smithtown Hall on 15 March 2024 to outline the flooding impacts and the initial list of options for further investigation and seek feedback on the options and additional options for consideration.

4.4 Community Feedback

Following the 15 March 2024 community workshop, a summary of Draft Options was placed on Council's Your Say Macleay community feedback webpage. A total of 187 user views were made and 19 submissions on the proposed options were received which supported the workshop and Reference group feedback.

4.5 Direct engagement with stakeholders

SES were consulted over the course of the project on subjects including projected urban and population growth in the study area, engagement with the community on flood messaging, the existing flood warning system and flooding of key evacuation routes. Mapping of the key evacuation routes and gauge levels at time of routes being cut off were prepared for SES.

4.6 Public exhibition

The Final Draft FRMSP was placed on public exhibition in July-August 2024 on Council's website. Submissions on the FRMSP have been considered in the finalising of this report.

5. Existing Flood Environment

5.1 Flood Mapping

Flood mapping for all design flood events is provided in the Lower Macleay Flood Study Update report (Jacobs, 2022). Depth, flood level, velocity and flood hazard are presented. Mapping is provided for the broader study area in addition to zoomed in views of urban areas and villages at Kempsey, South West Rocks, Jerseyville, Fishermans Reach, Stuarts Point, Frederickton, Smithtown, Gladstone, Kinchela, Crescent Head and Hat Head. The flow directions are indicated on the zoomed in village maps of the depth and velocity. Flood depth and flood level mapping for the 1% AEP and PMF events is reproduced in Appendix A of this report.

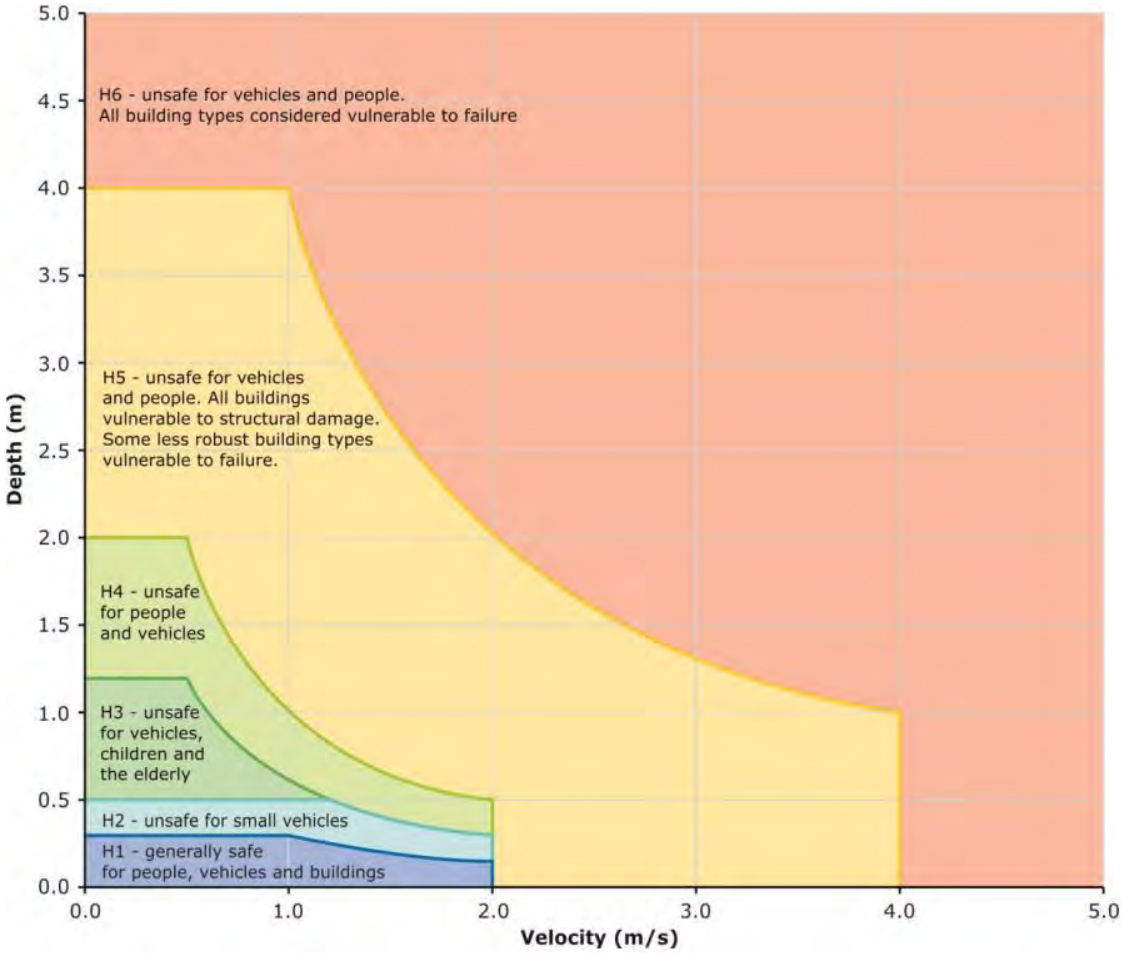
Note that the flood mapping shows the flood conditions over the ground surface beneath bridges crossing the floodplain, including the Pacific Highway bridge crossing the Macleay floodplain. This does not necessarily mean that the bridge is overtopped. Note that the Kempsey CBD area was incorporated into the current modelling and flood mapping is presented for this area.

Flood hazard mapping was prepared based on the latest guidelines and the hydraulic modelling results. Recent research has been undertaken into the hazard that flooding poses and the vulnerability of the public and assets when interacting with floodwaters. A combined flood hazard classification is presented in *Flood hazard, Flood risk management guideline FB03* (DPE, 2023), *Australian Disaster Resilience Handbook 7. Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017a) and *Guideline 7-3 Flood Hazard* (AIDR, 2017c) based on this research, and is illustrated in Figure 5-1. The flood hazard categories according to the AIDR definition are:

- H1 – Generally safe for people, vehicles and buildings;
- H2 – Unsafe for small vehicles;
- H3 - Unsafe for vehicles, children and the elderly;
- H4 - Unsafe for people and vehicles;
- H5 - Unsafe for people and vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

The flood hazard mapping for the 1% AEP and PMF events is provided in Appendix A.

Figure 5-1 General flood hazard vulnerability curves



5.2 Design flood levels

Design flood levels are summarised at key locations throughout the study area in Table 5-1.

Table 5-1 Design Flood Levels at Selected Locations (m AHD)

Event AEP	AEP								
	50%	20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Turners Flat	17.13	19.94	21.42	23.13	25.81	27.19	28.86	29.36	38.87
Greenhill	4.61	7.87	9.17	10.29	11.82	12.69	13.76	14.49	23.23
Kempsey Rail Bridge (upstream)	4.05	6.49	7.36	8.19	9.22	9.90	10.84	11.54	19.75
Kempsey Traffic Bridge (upstream)	3.96	6.24	6.90	7.39	8.04	8.42	8.95	9.31	14.90
Frederickton	3.61	5.48	5.90	6.12	6.38	6.53	6.73	6.87	9.87
Smithtown (Nestle)	3.14	4.47	4.56	4.62	4.86	5.04	5.48	5.86	9.28
Smithtown (Gauge)	2.94	4.14	4.22	4.27	4.47	4.77	5.37	5.79	9.18
Kinchela Creek Entrance	2.32	3.30	3.35	3.47	4.07	4.61	5.30	5.74	9.11
Jerseyville	1.43	1.83	1.94	2.58	3.67	4.31	5.09	5.55	8.89
South West Rocks (Gauge)	1.14	1.17	1.28	1.80	3.19	3.88	4.68	5.17	8.26
Fishermans Reach	1.05	1.14	1.31	1.91	3.19	3.86	4.65	5.12	8.02
Stuarts Point	1.02	1.15	1.34	1.92	3.19	3.85	4.64	5.11	7.04
Collombatti D/S of Pacific Highway	1.66	2.00	2.86	3.30	4.05	4.64	5.35	5.78	9.21
Clybucca Floodgates	1.04	1.85	2.56	3.03	3.94	4.53	5.25	5.69	9.04
Upper Belmore	1.17	2.23	2.98	3.67	4.28	4.71	5.34	5.76	9.08
Upper Kinchela	1.03	2.04	2.61	3.42	4.22	4.69	5.35	5.77	9.14
Hat Head	1.14	1.14	1.18	1.34	2.43	2.65	3.18	3.91	7.11

Event AEP	AEP								
	50%	20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Crescent Head	1.13	1.13	1.15	1.43	2.45	2.67	2.77	3.35	5.22
Big Hill	1.60	1.99	2.43	2.85	3.14	3.46	3.85	4.35	6.60
Maria River	2.11	2.33	2.60	2.84	3.21	3.59	3.97	4.42	6.84

5.3 Flood classification

Flood warning classifications are locally defined flood levels developed by SES to give an indication of the severity of the impact of expected flooding. These impacts are defined as Minor, Moderate and Major. Definitions for Minor, Moderate and Major are provided below (SES, 2019):

- **Minor Flooding**. Flooding which causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.
- **Moderate Flooding**. In addition to Minor Flooding, flooding which inundates low-lying areas, requiring removal of stock and/or evacuation of some houses. Main traffic routes may be flooded. In addition to the effects of minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required
- **Major Flooding**. In addition to Moderate Flooding, flooding which causes inundation of extensive rural areas, with properties, villages and towns isolated and/or appreciable urban areas flooded. Evacuation of flood affected areas may be required. Utility services may be impacted.

The flood levels relating to Minor, Moderate and Major Floods are defined for Kempsey and Smithtown gauges in Table 5-2.

Table 5-2: Flood classification levels at gauges in the Lower Macleay

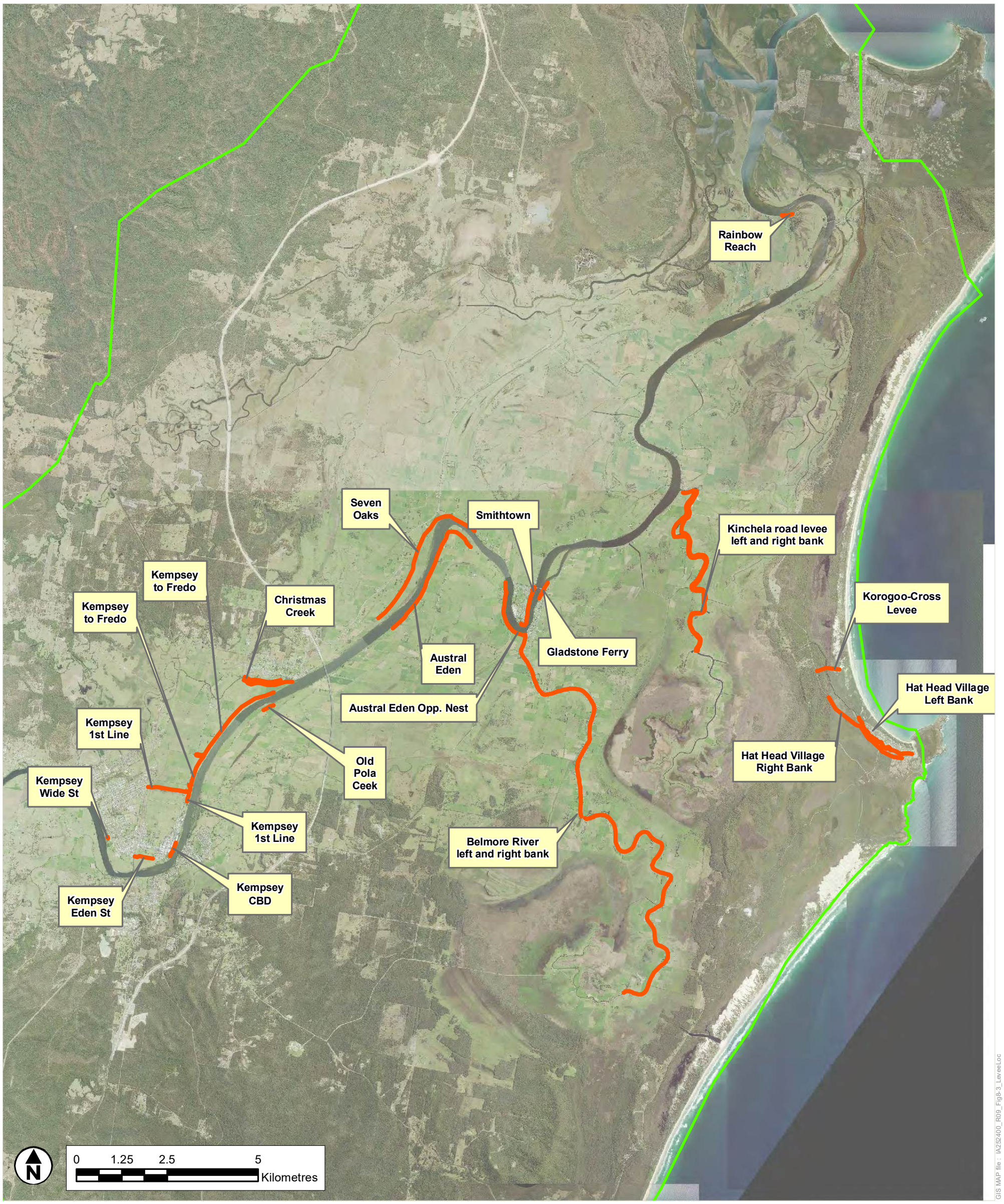
Flood Classification	Flood level at gauge (m AHD)	
	Kempsey	Smithtown
Minor	4.5	3.4
Moderate	5.7	4.0
Major	6.6	4.2

5.4 Overtopping of levees

The flood mapping was reviewed at constructed levees and the overtopping flood AEP identified, refer to Table 5-3. The levee locations are mapped on Figure 5-2. As discussed in WMAwater (2016) either Eden Street levee or First Lane levee may overtop first depending on the individual flood event. Floods with a faster rate of rise are more likely to overtop Eden Street levee first, while floods with a slow rate or rise but with longer duration and larger flood volume will fill downstream floodplains and cause floodwater to back up, leading to overtopping of First Lane levee first.

Table 5-3: Overtopping AEP of levees

Levee ID	Name	Overtopping AEP
CL07	Kempsey CBD	10% - 5% AEP
CL09	Kempsey Wide St	1% AEP
EL01	Rainbow Reach	< 50% AEP
EL02	Smithtown	< 20% AEP
EL03	Seven Oaks	< 20% AEP
EL04	Kempsey to Fredo	< 20% AEP
EL05	Christmas Creek	< 20% AEP
EL06	Kempsey 1st Lane	10% AEP
EL08	Kempsey Eden St	10% AEP
EL10	Old Pola Creek	< 50% AEP
EL11	Austral Eden	20% AEP
EL12	Austral Eden Opp. Nestle	20% AEP
EL13	Gladstone Ferry	< 20% AEP
-	Belmore River Left and Right Bank	< 20% AEP
EL16	Korogoro-Cross Levee	1% AEP
EL18	Hat Head Village right bank	5% AEP, due to local catchment flooding from behind the levee overflowing into Korogoro Creek
RL14, RL15	Kinchela (road levee) left and right bank	< 20% AEP
RL17	Hat Head Village left bank	2% AEP



Legend

- Levee
- TUFLOW Model Extent

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Location of Levees for Overtopping Review		
PROJECT	Lower Macleay River Floodplain Risk Management Study		
DRAWN CC	PROJECT # IA252400	MAP # FIGURE 8-3	REV 1 VER 1
CHECK LC	DATE 25/10/2024		

5.5 Dominant Flooding Source

The dominant flooding sources, causing peak flooding, from the different flood mechanisms are summarised below for the 1% AEP.

- Macleay River flooding is the dominant mechanism in the majority of the study area.
- From 3.5km south of Crescent Head Road, flooding from the Maria River/Hastings River system is the dominant mechanism.
- In minor watercourses, local catchment flood flows cause peak flooding at elevations generally above 5m AHD.

5.6 Timing of flood peak

Based on the design 1% AEP flood modelling, flooding at Turners flat peaks around 2.5 days after the start of the storm. Kempsey Traffic Bridge peaks about 3 hours after Turners Flat based on the flood modelling, which was generally reflected by the recorded flood levels in the historic March 2001, February 2013 and March 2021 events.

The flood modelling estimates that the flood peak at Smithtown gauge would occur about 14 hours after Kempsey gauge. This differs from the timing indicated in the Kempsey flood plan of 1 – 4 hours. During the March 2001, flooding at Smithtown gauge peaked 3 hours *before* Kempsey gauge. During the February 2013 event, Smithtown peaked 45 minutes after Kempsey, and in March 2021 Smithtown gauge peaked 2 hours after Kempsey. It is noted that the flood level hydrograph at Smithtown, both recorded and modelled, exhibits a flat profile near the flood peak, such that at 4 hours after the peak at Kempsey (i.e. 10 hours before the precise peak at Smithtown) the modelled flood levels are only 0.14m lower than the peak. For emergency planning purposes, it can be assumed that flooding at Smithtown gauge would peak up to 4 hours after Kempsey.

Downstream of Smithtown, the timing of the flood peak is expected to be highly influenced by timing of storm surge levels and tides. The modelling suggests that peak flooding at South West Rocks gauge in the design 1% AEP event would occur 21 hours after Kempsey gauge. This timing would vary depending on actual tide and storm surge timing.

5.7 Hydraulic categorisation

Hydraulic categories classify areas of the floodplain based on its hydraulic function. The three flood hydraulic categories identified in the *Flood Risk Management Manual* (NSW Government, 2023) are:

- Floodway, where the main body of flow occurs and blockage could cause redirection of flows. Generally characterised by relatively high flow rates; depths and velocities;
- Flood storage, characterised by deep areas of floodwater and low flow velocities. Floodplain filling of these areas can cause adverse impacts to flood levels in adjacent areas; and
- Flood fringe, areas of the floodplain characterised by shallow flows at low velocity.

There is no firm guidance on hydraulic parameter values for defining these hydraulic categories, and appropriate parameter values may differ from catchment to catchment. For the Lower Macleay, the criteria outlined in Table 5-4 was employed and the criteria are similar to that derived in the Kempsey CBD FRMS (WMAwater, 2017). The categorisation appears to represent the broad hydraulic behaviour of flooding in the study area.

Other categorisation approaches adopted in studies for similar river systems including the Richmond River, Manning River, Hastings River, Murrumbidgee River at Narrandera and Nepean River were trialled for application on the Lower Macleay, however, these were considered to give too broad a spatial definition for floodways (i.e. floodway hydraulic areas appear in many locations, some with low flow characteristics) or conversely too narrow a definition, with limited identification of floodway zones..

Table 5-4 Hydraulic Categories Criteria

Hydraulic Category	Criteria
Floodway	Initially based on the following criteria for the 1% AEP event: • Flood hazard ≥ H5 rating; and • Velocity x depth ≥ 2; and • Velocity ≥ 0.5. Gaps between the identified areas filled in to provide a contiguous floodway area, where appropriate. Permanent watercourse extents also incorporated into the floodway extent.
Flood Storage	Area within the 1% AEP flood extent, outside the Floodway, where depth > 1m.
Flood Fringe	Area within the 1% AEP flood extent outside the Floodway and Flood Storage areas.

The hydraulic categories are mapped for the 1% AEP event for the current climate and for the year 2050 and 2100 future climate change scenarios in Appendix B.

5.8 Flood emergency response

Areas within the study area have been classified based on floodplain risk management *Guideline 7-2 Flood Emergency Response Classification of the Floodplain* (AIDR, 2017b). The classification indicates the relative vulnerability of different areas of the catchment and considers the ability to evacuate certain parts of the community.

The categories are identified as per the definitions in Table 5-5. In summary, these include:

- FEO – Flooded area, with an Exit Route via Overland Escape
- FER – Flooded area, with an Exit Route via Rising Road
- FIE – Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS – Flooded Area, Isolated and Fully Submerged

The guideline in AIDR (2017b) recommends classification of the floodplain for the PMF only. However, due to the large variation in flooding between the 1% AEP and PMF events and the spatial uniformity of the classification in the PMF, the classification has been prepared for the 1% AEP as well. Mapping of the classification is provided in Appendix B.

Table 5-5 Flood emergency response classifications

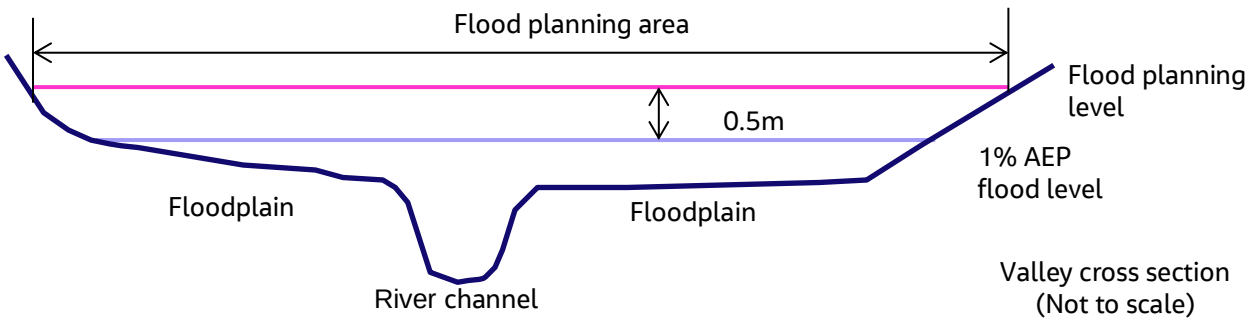
Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
Flooded (F)	The area is flooded in the flood event of interest*	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/ or impossible terrain as waters rise during a flood event. These areas are likely to lose electricity, gas, water, sewerage and telecommunications during a flood.	Submerged (**FIS**)	Where all the land in the isolated area will be fully submerged in the flood event of interest after becoming isolated.
				Elevated (**FIE**)	Where there is a substantial amount of land in isolated areas elevated above the flood event of interest.
		Exit Route (E)	Areas that are not isolated in the flood event of interest and have an exit route to community evacuation facilities (located on flood-free land)	Overland Escape (**FEO**)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.
				Rising Road (**FER**)	Evacuation routes from the area follow roads that rise out of the floodplain.

5.9 Flood planning area and flood planning level

The flood planning area (FPA) is defined by the extent of the area below the flood planning level (FPL; usually the 1% AEP flood plus freeboard) and delineates the area and properties where flood planning controls are proposed, for example, minimum floor levels to ensure that there is sufficient freeboard of building habitable floor levels above the 1% AEP flood. Other controls may be considered, such as policies on fence construction or rezoning.

A freeboard of 0.5m is often applied for defining the flood planning level on mainstream floodplains, including the study area. This flood planning level is then extended until it intersects with the ground. This defines the flood planning area. An illustration of this is provided below. The provisional flood planning area map is shown in Appendix B, and is based on the existing climate 1% AEP flood.

Mainstream flooding



5.10 Climate Change Assessment

5.10.1 Effects on the 1% AEP flood event

Assessment was undertaken to estimate the potential impact of climate change on flooding in the Lower Macleay. Key elements of future climate change including sea level rise, increased storm rainfall intensity and resulting increased flood runoff, and their combined effects on flooding. Previous guidance from the NSW Government recommended considering a 0.4m rise in sea level from current (1990) levels for the year 2050, and 0.9m rise for the year 2100 in assessing the impact of climate change on flooding. These projections are based on research by the Intergovernmental Panel on Climate Change (IPCC) and were refined for the Australian region.

Australian Rainfall and Runoff 2019 provides interim climate change factors for a range of climate change impact increase scenarios up to the year 2090. For climate change sensitivity assessment, in the year 2050 and the year 2090 an increase in rainfall depth and intensity of 9.7%[1] and 19.7%, respectively, was adopted. Hydrologic modelling for the Macleay River and local catchments represented the increased rainfall intensities and the resultant inflows were input into the TUFLOW hydraulic model.

The combined sea level rise and increased rainfall/runoff scenarios assessed in the sensitivity assessment were:

- Year 2050: Sea level rise of +0.4m and a 9.7% increase in rainfall/runoff; and
- Year 2100: Sea level rise of +0.9m and a 19.7% increase in rainfall /runoff.

The results from the climate change flooding assessment for the Lower Macleay are mapped on Figures C-1 and C-2 in Appendix C for the year 2050 and 2100, respectively.

Flooding conditions in the 2050 scenario include increase of 0.5 – 0.8m from Greenhill to Kempsey, while the 2100 scenario sees increases of over 1m. At Turners Flat the increases are 0.9m in 2050 and 1.7m in 2100. At Frederickton the increases are up to 0.2m in 2050 and 0.4m in 2100. These increases are due mainly to the increase in flood flows in the river.

Between Frederickton and Seven Oaks the change in flood levels drop as a result of the river channel hydraulics. Increases at Seven Oaks are up to 0.1m in 2050 and 0.3m in 2100. The constrained flow capacity of the river in this section results in the limited increase in flood levels. Consequently, the increased river flood flows spill out onto the floodplains, with the majority of the Lower Macleay floodplain experiencing flood level increases of 0.3 – 0.5m in 2050 and 0.7 – 1m in 2100.

In the lower reaches of the Macleay and up Macleay Arm and Yarrahapinni Wetlands flood levels increase by up to 0.6m in 2050 and up to 1.2m as a result of the increased flood flows in combination with sea level rise. The long section flood profiles indicate the effect of the increased outflows and ocean levels decreases with distance from the outlet to Seven Oaks.

At Hat Head, Crescent Head and in the Maria River floodplain the flood levels are 0.4 – 0.5m higher in the 2050 scenario, while they are about 0.9m higher in Crescent Head, over 1m higher at Hat Head and around 1m higher in the Maria River floodplain in the 2100 scenario.

In the local creeks and minor watercourses the flood levels are generally 0.1 – 0.2m higher in the 2050 scenario and 0.2 – 0.4m higher in the 2100 scenario.

Given the sensitivity of flooding conditions in the climate change scenarios, Council has resolved to incorporate climate change impacts into planning controls for development of the Lower Macleay floodplain. This will be undertaken by adopting the maximum envelope of the flood planning level (based on current climate 1% AEP flood level plus 0.5m freeboard) and the year 2100 climate change scenario 1% AEP flood level.

[1] ARR 2019 projection is for a 9.0% increase to storm rainfall intensity and depth for the year 2050. The Macleay River inflows for the 2050 climate change scenario were provided assuming a slightly conservative 9.7% rainfall increase and this was adopted for the sensitivity assessment.

5.10.2 Effects on the probable maximum flood

The estimates of the PMF in this study are based on current climatic conditions. While there are limited studies on the predicted effects of climate change on the PMF, recent research estimates that probable maximum precipitation (PMP) would increase by 13% for a Shared Socioeconomic Pathway (SSP) scenario SSP1 – 2.6 (assuming low level projections of greenhouse gas emissions) and 33% for scenario SSP5 – 8.5 (assuming higher level projections of greenhouse gas emissions) in the year 2100, compared to current climate PMP (Visser et al, 2022). The projected increases in rainfall may change as the research and industry guidance becomes further developed and finalised. The implication is that the increased PMP rainfall intensities would result in increased PMF flows and flood levels.

6. Impacts of flooding on the community

6.1 Flooding of towns and villages

Flood behaviour at the towns and villages in the Lower Macleay based on modelling of the design flood events is summarised below for the following urban areas:

- Kempsey – refer to Table 6-1
- Frederickton – refer to Table 6-2
- Smithtown – refer to Table 6-3
- Gladstone – refer to Table 6-4
- South West Rocks – refer to Table 6-5
- Jerseyville – refer to Table 6-6
- Stuarts Point – refer to Table 6-7
- Fishermans Reach – refer to Table 6-8
- Kinchela – refer to Table 6-9
- Hat Head – refer to Table 6-10
- Crescent Head – refer to Table 6-11.

With respect to the timing of flooding, this is described as the hours following exceedance of the Minor Flood Level at Kempsey (4.5m on Kempsey gauge) at which flooding of the lowest dwelling due to rising floodwaters occurs at the subject village. The rate of rise is described for the main part of the rising limb of the flood. Durations of flooding are based on the design flood events. Actual flood events may differ in behaviour and durations of flooding may be 1 – 2 weeks based on historic floods.

Table 6-1: Description of flooding - Kempsey

Item	Comments
General description	Kempsey is affected by flooding primarily from the Macleay River. Floodwaters overtop Eden Street levee and flow through the CBD floodway in the 10% AEP event and larger. The First Lane levee is also overtopped in the 10% AEP event. Flooding also occurs in Christmas Creek and Collombatti Creek and local gullies in Kempsey due to backwater from the Macleay River in addition to local catchment flows. Flooding in South Kempsey occurs due to main river flooding in addition to in local watercourses and gullies. Backwater flooding from the Macleay River in the local watercourses is restricted by existing flood gate systems. Flow velocities exceed 2m/s in the 1% AEP event in the main active flow path in the CBD floodway, and up to 1.5m/s in other flow paths such as in roadways in the CBD. Flooding in Lower Macleay generally peaks about 2 days after the start of the flood at Kempsey.
Flood depth	Typical flood depths are up to 2m in 50% AEP and up to 4.5m in the 20% AEP within local watercourses. Flooding begins to affect existing properties and buildings in the 10% AEP event due to overtopping of levees, with depths of 1 – 2m at properties in the CBD. Maximum depths are up to 5m in local watercourses. Typical flood depths in 5% and 1% AEP and PMF events are between 2 to 6m, 4 to 6.5m, and 4 to 11m, respectively. Maximum flood depths in 5% and 1% AEP and PMF events are around 5.5m, 6.6m, and 11.6m, respectively.

Flood hazard	Typical flood hazard category in 50% AEP is H3 and H5. In the 20%, 5% and 1% AEP events, flood hazard generally increases to H5 and H6 in the town (An extreme pattern is identified in the PMF events, in which H6 is the dominant hazard level across the whole area). Maximum flood hazard by zAEM1 category in 50%, 20%, 5%, 1% AEP, and PMF, are around category H5, H6, H6, H6, and H6, respectively.
Rate of rise – River	The average rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.6m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.3m/hr and 0.9m/hr, respectively.
Duration of inundation	The lowest building in Kempsey is at a ground level of 4.1m AHD and has the duration of inundation of around 60, 95, 130, and 150 hours in 20%, 5%, 1% AEP, and PMF events, respectively.
Timing of flooding	Flooding of the lowest dwelling around Kempsey occurs up to 3 hours before the Minor Flood Level of 4.5m is reached. The subject property is a rural property to the northeast of town.
Isolation issues	Roads within and around Kempsey can be cut by floodwaters. Parts of Kempsey would become isolated from evacuation centres e.g. Kempsey Showground.

Table 6-2: Description of flooding - Frederickton

Item	Comments
General description	Frederickton is affected by flooding from the Macleay River as well as from two gullies in the east and north of the village. Both gullies drain to the Clybucca Wetlands and the northern floodplain. Flood gates under the Pacific Highway interchange prevent/minimise backwater flooding from the Macleay River northern floodplain back into the village. There is also flooding in Christmas Creek in the west of the village, mainly caused by backwater from the Macleay River. Most of the village is flood-free in up to the 0.2% AEP event. In the southeast of the village, properties experience yard flooding in the 20% AEP event from the river, and up to two properties are affected by flooding in the eastern gully. In the 5% AEP, the river overtops its bank in the vicinity of Frederickton Hotel and causes flooding of properties to depths of 0.5m. Backwater flooding in the eastern gully causes property flooding of 0.5 - 1m. Flow velocities on properties are generally up to 0.5m/s in up to the 0.2% AEP event and exceed 2m/s in some locations in the PMF. Some properties in Frederickton may also be affected by overland flooding in the gullies running through the village; however, this was not a focus of this study, and the overland flooding is not shown on the flood mapping.
Flood depth	Typical flood depths in 50% and 20% AEP events are up to 2m in Christmas Creek on the south side of the town. In the 5% and 1% AEP events, flood depths are up to 2m from the eastern gully, while the deeper depths of up to 4m are identified in the southeast area of town by Christmas Creek. These depths are in open space areas and properties are generally not affected. In PMF events, the flood water levels generally range from 4 to 7m in the lower elevated parts of the village. Maximum flood depth in the 1% AEP event is around 4m in in low areas next to Christmas Creek, while PMF events reach up to 8m depth.

Flood hazard	In flood events up to 1% AEP, the flood hazard rating generally ranges from H3 to H5. In the PMF events, the flood hazard rating is up to H5 and H6.
Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.4m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.4m/hr and 0.7m/hr, respectively.
Duration of inundation	The lowest building here is at the ground level of 4.15m AHD and has the duration of inundation of around 55, 90, 120, and 150 hours in 20%, 5%, 1% AEP, and PMF events, respectively.
Timing of flooding	Flooding of the lowest dwelling around Frederickton occurs around 1 hour after the Minor Flood Level of 4.5m at Kempsey is reached.
Isolation issues	While most of Frederickton is flood-free, direct access to Kempsey via Macleay Valley Way is cut in frequent flood events including the 20% AEP event, and the village will become isolated from evacuation centres e.g. Kempsey Showground. There is road access to the Pacific Highway from most of the village, but this access within the village may also be affected during flood events. The Pacific Highway is expected to be generally accessible in up to events rarer than the 1% AEP flood.

Table 6-3: Description of flooding - Smithtown

Item	Comments
General description	Smithtown is affected in the 20% AEP event, with the Macleay River overtopping the village levees and riverbanks at several locations, including on the western side north of Jeffery Street, at the southern end of the village and along the eastern side of the village. Flood depths are greatest in the middle of the village, where there is a natural low point, where floodwaters generally flow northward on the floodplain. The highest flow velocities and hazard are due to the river breakout on the western side of the village, where velocities are 1.5m/s in the 20% AEP and 5% AEP events, and over 2m/s in the 1% and 0.2% AEP events. High flow velocities are also present as floodwaters flow northward over the Smithtown Road embankment. Flow velocities exceed 2.5m/s in the PMF.
Flood depth	In 50% AEP, the flood water is well contained in the channel of the Macleay River, and the town is not affected by flooding. Shallow flood water spreads in the 20% AEP event across the town, and the depths generally range from 0.2 to 1m. Typical flood depths in 5% AEP are in a range of 0.2 – 2m, while the depths increase to 1 – 2.4m in the 1% AEP event. In the PMF events, the entire Smithtown village, sitting in the Macleay River floodplain, generally has 5 – 6.5m flood depths. In a 50% and 20% AEP event, the town has maximum flood depth values of up to 1m. Maximum flood depth in 5%, 1%, and PMF events are around 1.6m, 2.4m and 6.7m, respectively.
Flood hazard	In 20%, 5% and 1% AEP events, the typical flood hazard rating ranges from H1 to H3, H3 and H4, and H4 and H5, respectively. In PMF, the entire area of Smithtown is affected by H6 flood hazard. Maximum flood hazard rating in 20%, 5%, 1% AEP, and PMF events are around H3, H4, H5, and H6.

Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.3m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.4m/hr and 0.5m/hr, respectively.
Duration of inundation	The lowest building here is at the ground level of 2.28m AHD and has a duration of inundation of around 80 and 115 hours in 20% and 5% AEP events, respectively. The duration of inundation of the same building is greater than 140 and 165 hours in 1% AEP and PMF events, respectively.
Timing of flooding	Floodwaters begin to overtop the existing levee and natural riverbanks about 5 – 8 hours after the Minor Flood Level of 4.5m is reached in Kempsey for events up to and including the 1% AEP event. In the PMF, the timing of flooding overtopping the levee and riverbanks is around 2 hours after the Minor Flood Level is reached at Kempsey. The Smithtown river gauge has a Minor Flood Level of 3.4m AHD assigned. In the 1% AEP event the Minor Flood Level at Smithtown is reached approximately 2 hours after the Minor Flood Level at Kempsey is exceeded.
Isolation issues	Smithtown is located on the floodplain and road access over the floodplain via South West Rocks Road and Macleay Valley Way to evacuation centres becomes cut in frequent flood events. Smithtown village is mostly inundated in the 20% AEP flood and becomes virtually fully inundated in the 10% AEP flood.

Table 6-4: Description of flooding - Gladstone

Item	Comments
General description	Gladstone is affected by bank overflows from the Macleay River. Depths of this bank overflow flooding are shallow in the 20% AEP event, less than 0.2m, although there are areas with depths up to 0.5m. In the 5% AEP, the bank overflows are also relatively shallow on the higher ground along the village's west side, with greater depths of around 1m as backwater from the floodplain to the east begins to contribute to flooding. Flood depths are up to 2m in the 1% AEP, up to 3m in the 0.2% AEP and over 5m in the PMF. The highest point of the eastern approach ramp of Smithtown bridge is above the 0.2% AEP flood level. Flow velocities in the village are generally low (less than 0.25m/s) in up to the 5% AEP, with velocities in flow paths and roads around 1 - 1.5m/s. The maximum flow velocities in the 1% and 0.2% AEP are up to 2m/s. PMF velocities are 1 - 2m/s. Floodwaters tend to flow from the river towards the east onto the floodplain in all events.
Flood depth	In 50% AEP event, floodwaters are well contained in the channel of the Macleay River, and the village is not affected by flooding. The bank overflow flooding is shallow in the 20% AEP event, less than 0.2m. The overflow flooding spread throughout the town in 5%, 1% and PMF events. Typically, flood depths are up to 1m in the 5% AEP, 2m in the 1% AEP, and over 5m in the PMF. Typically, maximum flood depth in 20%, 5%, 1% AEP, and PMP events are approximately up to 0.5, 1, 2.5 and 7.5m. No flooding is in the town in 50% AEP. A few farmhouses are scattered east of the main town area, where the greatest flood depths of this area are found. Flood depths at this location are up to 1.4, 2.6, and 7.1m in 5%, 1% and PMF events, although they only occur locally around the properties.
Flood hazard	Typical flood hazard ratings in 20%, 5%, 1% AEP, and PMF events are around categories H1, H1 and H3, H3 and H4, and H6, respectively.

	Maximum flood hazard ratings in the 20%, 5%, 1% AEP, and PMF, are around category H2, H4, H5, and H6, respectively.
Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.3m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.4m/hr and 0.5m/hr, respectively.
Duration of inundation	The lowest building here is at the ground level of 2.64m AHD and has a duration of inundation of around 70, 105, 135, and 165 hours in 20%, 5%, 1% AEP, and PMF events, respectively.
Timing of flooding	Floodwaters begin to overtop the Macleay riverbank about 5 – 8 hours after the Minor Flood Level of 4.5m is reached in Kempsey for events up to and including the 1% AEP event. In the PMF, the timing of flooding overtopping the riverbank is around 2 hours after the Minor Flood Level is reached at Kempsey.
Isolation issues	Gladstone is located on the floodplain and road access over the floodplain via South West Rocks Road and Macleay Valley Way to evacuation centres becomes cut in frequent flood events. Flooding of the village to shallow depths may occur in the 10% AEP and becomes of more substantial depths of 1m in the 5% AEP and rarer.

Table 6-5: Description of flooding - South West Rocks

Item	Comments
General description	South West Rocks is affected by flooding from the Macleay River, South West Rocks Creek and Spencers Creek. Property yard flooding occurs along the river in the 5% AEP event and the Riverside Tavern, built on a filled pad, becomes surrounded by floodwaters but not submerged. Properties along South West Rocks Creek are not flood-affected in the 20% AEP event as flood levels are dictated mainly by ocean tide levels in up to the 5% AEP event. Flooding in Saltwater Creek, to the east of the town, and local overland flooding in South West Rocks (including west of Gregory Street) was not assessed in this study.
Flood depth	In up to 5% AEP event, no significant flooding on buildings is found in the town of South West Rocks. The floodwater is limited in the channel of South West Rocks Creek. In 1% AEP, typical flood depths are 3-4m, affecting vegetated and wetland/mangrove areas. Riverside Tavern is affected by depths of 1-2m. In the PMF event, higher depths up to approximately 7.5m are found along Souths West Rocks Creek. Maximum flood depths in the 20%, 5% and 1% AEP and PMF events are around 0.6m, 0.9m, 3m, and 7.5m, respectively.
Flood hazard	Typical flood hazard ratings in the 20%, 5% and 1% AEP events are H2 and H3, H3, H3 to H5, respectively, affecting mostly vegetated and wetland/ mangrove areas. In the 1% AEP event, hazard ratings of H1 to H3 affect the Ingenia Holiday South West Rocks and its proximity, and higher hazards (H4 to H5) are around Riverside Tavern. Maximum flood hazard ratings in the 20%, 5%, 1% AEP, and PMF events are around category H3, H3, H5, and H6, respectively.
Rate of rise - River	The average rate of floodwater level rise in 1% AEP and PMF are 0.1m/hr and 0.4m/hr, respectively. The maximum rate of floodwater level rise in 1% AEP and PMF are 0.2m/hr and 0.5m/hr, respectively.

Duration of inundation	The lowest building is at a ground level of 1.24m and has the duration of inundation of around 105 and 140 hours in 1% AEP and PMF event, respectively. No flooding inundation of buildings in South West Rocks due to riverine flooding is identified in the 20% and 5% AEP events.
Timing of flooding	Flooding of the lowest dwelling in South West Rocks in the 1% AEP event occurs around 30 hours after the Minor Flood Level of 4.5m at Kempsey is reached. In the PMF event it occurs around 18 hours after the Minor Flood Level at Kempsey is reached.
Isolation issues	South West Rocks is mostly flood-free, but road access over the floodplain via South West Rocks Road becomes cut in frequent flood events and the town may be isolated for up to 1-2 weeks based on experience from historic major flood events.

Table 6-6: Description of flooding - Jerseyville

Item	Comments
General description	In Jerseyville, due to the low-lying nature of the properties, the village is inundated in the 20% AEP event to depths of up to 1m, and 1 - 2m in the 5% AEP. Flood depths exceed 2m in the 1% AEP. Flooding occurs due to rising floodwaters in the Macleay River and Spencers Creek.
Flood depth	Buildings are not flooded in the 50% AEP event. Typical flood depths in 20% and 5% AEP events are up to around 1.5m. Up to around 3m depths is generally experienced in the 1% AEP event, while depths of up to 8m occur in the PMF event.
Flood hazard	Typical flood hazard rating in the 20%, 5% and 1% AEP and PMF events are H3, H3 to H4, H5, and H6, respectively.
Rate of rise - River (or floodplain)	The average rate of flood water level rise in 1% AEP and PMF are 0.1m/hr and 0.4m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.5m/hr, respectively.
Duration of inundation	The lowest dwelling in Jerseyville is at the ground level of 1.19m AHD and has the duration of inundation of around 55, 95, and 130 hours in 20%, 5%, and 1% AEP events, respectively. The duration of inundation of the same building is greater than 162 hours in the PMF event.
Timing of flooding	The lowest dwelling could be inundated by elevated ocean levels and storm surge prior to flooding commencing at Kempsey, depending on the actual meteorological conditions during a storm/flood event. A peak ocean level of at least 1.25m AHD was assumed in the design flood modelling. Other dwellings in Jerseyville and Main Street are at about 1.5m AHD and 1.4m AHD, respectively. These could become inundated in the 1% AEP event approximately 5 hours before the Minor Flood Level at Kempsey is exceeded, due to elevated ocean levels and high tides. There may be periods when tide levels recede following initial inundation, allowing evacuation from the village, prior to the main riverine flood arriving at the village.
Isolation issues	Jerseyville is on the floodplain and becomes inundated in the 20% AEP event. The access route out of the floodplain to South West Rocks evacuation centre is short, whereby the Jerseyville residents may be isolated for up to 1-2 weeks based on experience from historic flood events.

Table 6-7: Description of flooding - Stuarts Point

Item	Comments
General description	Flooding begins to affect Stuarts Point village in the 5% AEP when the caravan park becomes inundated to over 0.5m depth, with up to 2m flooding depths in the 1% AEP. The majority of the village is flood-free up to the 0.2% AEP event and is affected by depths of 1 - 2m in the PMF. Flow velocities are generally up to 0.5m/s in the PMF in the village, with areas in roadways experiencing up to 2m/s velocities. Flooding around Stuarts Point is dictated by backwater flooding from the Macleay River backing up northward up Macleay Arm. There is also localised flooding in the low points between the dune features to the west of the village, which affects some properties there in the 5% AEP and rarer. Note that while groundwater and local stormwater flooding is an existing issue in Stuarts Point, these aspects are beyond the scope of this study, which focusses on mainstream flooding. It is noted that parts of Grass Head, as an extension of Stuarts Point village, includes a number of overland flow paths which cause property flooding and can cut road access for short periods. Further detailed overland flow modelling during subsequent Council flood studies would be undertaken to quantify the overland flood behaviour.
Flood depth	Stuarts Points is not affected by events up to and including the 20% AEP. The village is mostly flood-free in up to and including the 0.2% AEP event, with only low-lying properties along the foreshore affected. Typical flood depths are up to around 2.5m in the 5% and 1% AEP events, affecting the foreshore area along the Macleay Arm, including the Stuarts Point Holiday Park. There is also inundation of the road and adjacent land at the Stuarts Point Road and Grassy Head Road intersection due to local runoff. Maximum depths are around 1m on vegetated areas and about 0.3 – 0.4m on the road in the 1% AEP In PMF events, flood water widely spreads throughout the whole town, up to around 5.5m in the Stuarts Point Holiday Park near the Macleay Arm. Maximum flood depths in 20%, 5% and 1% are around 0.9m, with depths of to 5.4m in the PMF event.
Flood hazard	Typical flood hazard rating in the 5%, 1% AEP and PMF events are around H1 to H2, H1 and H4 to H5, and H4 to H6, respectively. There is no significant hazard in 50% and 20% AEP events. Maximum flood hazard by zAEM1 category in 5%, 1% AEP, and PMF events are around H2, H5 and H6, respectively.
Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF are 0.1m/hr and 0.4m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.5m/hr, respectively.
Duration of inundation	The lowest building here is at the ground level of 1.46m and has the duration of inundation of around 20 hours and 100 hours in 5% and 1% AEP events, respectively. The duration of inundation of the same building is greater than 137 hours in PMF event. No inundation of any buildings in the village is identified in 20% AEP event.
Timing of flooding	Flooding of the lowest dwelling in Stuarts Point in the 5% and 1% AEP events occurs around 45 hours and 30 hours, respectively, after the Minor Flood Level of 4.5m at Kempsey is

	reached. In the PMF event it occurs around 20 hours after the Minor Flood Level at Kempsey is reached.
Isolation issues	Most of Stuarts Point is above the 1% AEP flood and becomes fully inundated in the PMF. Parts of Grassy Head are affected by backwater flooding from Macleay Arm in addition to local flooding, which may remain for extended periods due to poor drainage conditions. Road access along Stuarts Point Road to the Pacific Highway becomes cut at a number of gully crossings due to local catchment flooding in the 1% AEP event, which is expected to be of relatively short duration. Inundation of the road around the Stuarts Point Road and Grassy Head Road intersection to the west of the village may remain for extended durations due to poor drainage conditions of local low points, although depths on the road are indicated to be shallow by the flood modelling. Road access via Grassy Head Road and Scotts Head Road to the north to the Pacific Highway at Macksville is reported by residents to become cut off at Warrell Creek, outside of the Lower Macleay study area, for periods of around 3 days (personal communication, Stuarts Point and District Community Organisation) and potentially longer in major floods. Roads around Grassy Head are also reported to be affected by local flooding originating from a number of gullies in the area.

Table 6-8: Description of flooding - Fishermans Reach

Item	Comments
General description	Flooding is contained in the watercourse in up to the 5% AEP event, and overflows the banks affecting property in the 1% AEP generally to 0.5m depth with areas up to 2m. Depths are generally 2m in the 0.2% AEP and up to 4m in the PMF. Flooding around Fishermans Reach is dictated by backwater flooding from the Macleay River backing up northward up Macleay Arm. Flow velocities are generally benign in the 1% AEP, around 0.25m/s with areas up to 0.5m/s. In the PMF, velocities are typically 0.5m/s with localised areas at 1m/s or more.
Flood depth	Fishermans Reach is not affected by flooding in up to and including the 5% AEP event. In the 2% and 1% AEP event, flooding from Macleay Arm occurs with typical depths of 1 – 2m on properties. Flood depths are up to around 6.5m in PMF events. Maximum flood depth in the 1% AEP and PMF events are around 2.5m and 6.5m, respectively.
Flood hazard	Typical flood hazard rating in flood-affected parts of the village in the 1% AEP and PMF events are H3 to H4, and H4 to H6, respectively. Maximum flood hazard rating in the 1% AEP, and PMF events are around H5 and H6, respectively.
Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF are 0.1m/hr and 0.4m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF are 0.2m/hr and 0.5m/hr, respectively.
Duration of inundation	The lowest building here is at the ground level of 1.95m AHD and has a duration of inundation of around 70 and 130 hours in 1% AEP and PMF event, respectively. No flooding inundation on buildings is identified in 20% and 5% AEP event.

Timing of flooding	Flooding of the lowest dwelling in Fishermans Reach in the 1% AEP event occurs around 45 hours after the Minor Flood Level of 4.5m at Kempsey is reached. In the PMF event it occurs around 20 hours after the Minor Flood Level at Kempsey is reached.
Isolation issues	Fishermans Reach is accessed by road from Stuarts Point. Additional to the access and isolation issues to Stuarts Point, road access just north of Fishermans Reach village is affected by inundation in frequent flood events due to flooding in local low points, which may be for extended durations due to poor drainage conditions.

Table 6-9: Description of flooding - Kinchela

Item	Comments
General description	Flooding in Kinchela is caused by bank overflows from the Macleay River and Kinchela Creek. Flood flows pond and builds up against South West Rocks Road and Hat Head Road before overflowing onto the wider floodplain to the east. The junction area of South West Rocks Road and Hat Head Road is above the 1% AEP flood, while the highest points of the bridge approach over the Kinchela Creek entrance are above the 0.2% AEP flood. Flow velocities in the village are less than 0.5m/s in up to the 1% AEP. Higher flow velocities are presented where floodwaters overtop and spill over the road embankments and river levees. Velocities exceed 2m/s in the 0.2% AEP and the PMF to the east of the village where flows break out of Kinchela Creek.
Flood depth	Typically, flood depths at dwellings are up to around 0.5m in the 20% AEP event, with most dwellings located above the 20% AEP flood. In 5%, 1% AEP and PMF events, typical flood depths at dwellings reach around 1m, 2m and 5m, respectively. Maximum flood depths in the 50%, 20%, 5%, 1% AEP and PMF events are around 0.6m, 1.1m, 2.6m, 4m, and 7.1m, respectively.
Flood hazard	Typical flood hazard rating in the 20%, 5%, 1% AEP and PMF events are H1 to H3, H3 to H4, H3 to H5, and H6, respectively. Maximum flood hazard rating in the 20%, 5%, 1% AEP and PMF events are H3, H4, H5, and H6, respectively.
Rate of rise - River	The average rate of flood water level rise in 1% AEP and PMF events are 0.1m/hr and 0.2m/hr, respectively. The maximum rate of flood water level rise in 1% AEP and PMF events are 0.3m/hr and 0.4m/hr, respectively.
Duration of inundation	The lowest dwelling in Kinchela village is at a ground level of 3m AHD and has the duration of inundation of around 42 hours and 76 hours in 20% and 5% AEP, respectively. The duration of inundation of the same building is greater than 112 and 157 hours in 1% AEP and PMF events, respectively.
Timing of flooding	Inundation of the lowest dwelling in Kinchela village occurs around 4 – 8 hours after the Minor Flood Level of 4.5m at Kempsey is reached in events up to the 1% AEP event. During the PMF, inundation of the lowest dwelling in Kinchela village occurs around 2 hours after the Minor Flood Level of 4.5m at Kempsey is reached. Several rural dwellings in Kinchela outside the village are located at low elevations of 1.8m AHD where the ground may become inundated several hours before the Minor Flood Level of 4.5m at Kempsey is reached in events up to the 1% AEP event.

Isolation issues	Kinchela is located on the floodplain and access along South West Rocks Road is cut in frequent flood events such as the 20% AEP event. Flooding in the village is isolated in the 10% AEP event and becomes widespread in the 5% AEP event, with full inundation in the 2% AEP event.

Table 6-10: Description of flooding - Hat Head

Item	Comments
General description	Hat Head is affected by flooding in Korogoro Creek, influenced by flows from the southern floodplain into the creek and elevated ocean levels at the creek entrance. Levees along the creek's northern and southern sides protect village areas. The levees are overtopped in events rarer than the 5% AEP event. Local catchment runoff contributes to flooding of the levee-protected areas on either side of Korogoro Creek. These flows pond in the low-lying area behind the levee on both sides of the creek. This is the dominant source of flooding in the village in up to and including the 5% AEP event, when the levees are not overtopped from Korogoro Creek and mainstream floodwaters are contained in the creek. During the 5% AEP event, local catchment flooding behind the levee on the southern side of the creek overtops the levee into the creek. Flows into Korogoro Creek from the southern Lower Macleay floodplain are limited in up to the 0.2% AEP event due to the constriction of the hydraulic connection through the sand hills between the floodplain and the head of the creek, to the north of the village. There are significant overflows over the sand hills separating the floodplain and Korogoro Creek which entirely fills the creek floodplain between the sand hills and the coastal beach dunes. The narrow creek outlet abutting Korogoro Point headland is the only outlet for these floodwaters. Most of the village is inundated in the PMF, with some properties to the south of the creek located on high ground above the PMF. Flow velocities on the floodplain and through properties are low in up to the 1% AEP, generally less than 0.5m/s in the streets. These velocities increase to 0.75m/s in the 0.2% AEP. In the PMF, maximum flow velocities are generally above 1m/s with higher velocities near Hat Head Road crossing where flows break out of the creek and near the boat ramp where there are steeper ground slopes and flows re-enter the creek. There are also high velocities where floodwaters spill over the sand dunes onto the beach.
Flood depth	Some properties to the south of the creek are affected by flooding to depths of up to 0.8m in the 20% AEP event and up to 1m in the 5% AEP in the low points of properties due to local catchment flooding. Depths of flooding in the drainage low points in the village area to the north of the creek are generally shallow, up to 0.2m in the 20% AEP event and up to 0.3m in the 5% AEP event, due to local flooding. The levee protecting the village area to the north of Korogoro Creek (left bank levee) begins to be overtopped from creek floodwaters in the 2% AEP event. In the 1% AEP event, the village on both sides of the creek are inundated typically to depths 0.6 - 1m and localised areas over 1m. Depths in the village increase to over 2m in the 0.2% AEP. This is predominantly due to floodwaters overtopping the levee and causing flooding of the village areas in both of these events. Flood depths in the PMF are 4 - 5m in the village.
Flood hazard	There are areas of H1 to H3 flood hazard in the southern part of the village in the 20% AEP event. The northern part of the village is mainly not flooded in this event with only some nuisance flooding in low points. In the 5% AEP event, the flood hazard is generally rated H3 in flood-affected areas in the southern part of the village. The hazard rating increases to H3 in

	the northern part of the village in the 1% AEP event and is rated up to H4 in the southern side of the village. Flood hazard is very high (H5) in the 0.2% AEP and extreme (H6) in the PMF.
Rate of rise	The rate of floodwater level rise in Korogoro Creek in 1% AEP and PMF are both around 0.3m/hr. The rate of rise in events up to and including the 0.2% AEP event is caused mainly by the ocean tidal signal during the rising limb of the flood event. Rates of rise of local catchment flooding behind the southern (right bank) levee are up 0.5m/hr during short duration (e.g. 2 hours) storms during the 1% AEP event.
Duration of inundation	The lowest building here is at the ground level of 1.40m AHD and has the duration of inundation of around 75 and 130 hours in 1% AEP and PMF event, respectively.
Timing of flooding	In the 1% AEP and PMF events, floodwater from Korogoro Creek begins to overtop the northern (left bank) levee around 42 hours and 22 hours, respectively, after the Minor Flood Level of 4.5m at Kempsey is exceeded.
Isolation issues	Access to Hat Head becomes cut as South West Rocks Road and Hat Head Road at Kinchela become inundated in frequent flood events such as the 20% AEP event. Periods of isolation may be 1-2 weeks based on historic major flood events.

Table 6-11: Description of flooding - Crescent Head

Item	Comments
General description	Crescent Head is affected by flooding from the Lower Macleay southern floodplain, on the village's western side, in addition to flooding in Killick Creek, which is influenced by flows from the southern floodplain into the creek combined with elevated ocean levels entering the creek entrance. In the 20% AEP event, Killick Creek flooding is influenced mainly by high ocean tides with a minor contribution of flows from the southern floodplain into the head of the creek. A few properties experience shallow yard flooding. In the 5% AEP event, floodplain inflows into Killick Creek increase and properties along the creek are flooded to depths of 0.5 - 1m. Flooding in the southern floodplain begins to encroach on the properties in the western side of town. Depths increase to 1 - 2m in the 1% AEP event along Killick Creek properties and up to 0.5m on western side properties. Floodwater begins to overflow from the southern floodplain to Killick Creek through properties. In the 0.2% AEP event, maximum flood depths on Killick Creek properties are over 2m and 1 - 2m on western side properties. The southern floodplain overflows at two locations. In the PMF, depths on affected properties of 3 - 4m are common, with overflows from the southern floodplain to depths of over 2m through the town. The southern half of the town is located on elevated ground above the PMF. Active flows are contained mainly in Killick Creek with velocities over 2m/s in the 5% AEP event and rarer. Flow velocities in the southern floodplain are generally low, less than 0.5m/s, affecting the western side of town in up to the 0.2% AEP event. There are localised higher velocity flows in streets in the 0.2% AEP event. In the PMF, there are numerous locations where velocities exceed 1.5m/s due to overflows from the southern floodplain.
Flood depth	Generally, in events up to 1% AEP, flood depths up to around 1.5m are in the town of Crescent Head. In PMF events, up to approximately 4m flood depths on buildings close to Pacific Street adjacent to Killick Creek.

	Maximum flood depth in 5%, 1% AEP, and PMF events are around 0.2m, 1.5m and 4.1m, respectively.
Flood hazard	Flood hazard is generally rated H1 to H2 on affected properties in the 1% AEP, with some low-lying properties along Killick Creek with high hazard H4. The extent of H1 to H2 hazard increases through the centre of the village in the 0.2% AEP, with maximum hazard on properties increasing to very high (H5). In the PMF, there are extensive areas of very high to extreme (H5 - H6) hazards throughout the town. The sewage treatment plant to the north of the town appears to be mostly unaffected by the 0.2% AEP flood.
Rate of rise - River (or floodplain)	The rate of rise of floodwaters in the 1% AEP and PMF is up to 0.3m/hr.
Duration of inundation	The lowest building in Crescent Head is at the ground level of 1.39m AHD and has the duration of inundation time of around 74 and 127 hours in 1% AEP and PMF events, respectively.
Timing of flooding	The lowest dwelling, at 1.4m AHD ground level, could be inundated by elevated ocean levels, storm surge and wave setup prior to flooding commencing at Kempsey, depending on the actual meteorological conditions during a storm/flood event. A peak ocean level of at least 1.25m AHD (High High Water Spring tide) was assumed in the design flood modelling. High ocean wave conditions and resultant wave setup water levels could cause further increased water levels in Killick Creek. Other dwellings in Crescent Head are above 2m AHD. Floodwaters would reach 2m AHD in the 1% AEP event approximately 20 hours after the Minor Flood Level at Kempsey is exceeded, noting that flooding in Killick Creek is significantly influenced by concurrent elevated ocean levels. During the PMF, flooding originating from the Macleay floodplain affects Crescent Head 20 hours after the Minor Flood Level at Kempsey is exceeded, although there may be coastal inundation occurring on high tides prior to the Macleay floodwaters arriving.
Isolation issues	Access to Crescent Head becomes cut as Crescent Head Road becomes cut at The Corduroy as well as at Rudders Lagoon in South Kempsey in the 50% AEP event. Periods of isolation may be 1-2 weeks based on historic major flood events.

6.2 Flooding of roads

The flood immunity of key roads in the Lower Macleay were assessed to determine the flood event at which they become first inundated at various low points. The key roads for assessment were selected in consultation with Council and SES and are comprised of main access and evacuation routes through the floodplain. Some of the key roads are relatively long and hence a number of locations where the road would first be cut-off were identified.

Where possible, the coinciding flood levels at monitored river gauges in the Lower Macleay were identified for the smallest road overtopping flood event at each road cut-off location. This may indicate whether the road would become cut-off if a flood of a particular height (gauge level) is forecast to occur.

The coincident flood gauge levels were identified based on the design flood events simulated in the hydraulic model, and the timing of flooding at the gauges and the road cut-off locations can differ between the design events and actual flood events. Actual flood events may be of longer duration and slower to rise, or shorter duration with greater peak, compared to the design events. Hence, the indicative coinciding gauge flood levels may also differ. There may also be reduced or low correlation between flooding at the gauges and the road cut-off locations for the locations which are in backwater areas of the floodplain or in locations which are dominated

by local catchment flooding. High correlation to gauge levels is expected for road cut-off locations situated adjacent to the Macleay River, such as Plummers Lane, Smithtown Road and parts of South West Rocks Road.

Refer to Figure D-1 in Appendix D for mapping of the road locations. Table D-1 in Appendix D summarises the flood AEP when the key roads become cut, and the corresponding flood gauge level when cut, for the design flood events.

In summary, the key roads on the floodplain generally become cut in frequent events including the 50% and 20% AEP events. There are several locations where key roads are cut in the 10% AEP event, including one location on South West Rocks Road near Kinchela and Forth Street in Kempsey CBD, which is located behind the levee system. One location on Macleay Valley Way near Frederickton is cut only in the PMF.

The upgraded Pacific Highway was designed and constructed with a relatively high level of flood immunity, generally 1% AEP or greater. There are two locations where the highway may be overtopped by local catchment flooding in less than a 1% AEP event.

Other key access roads affected by flooding include:

- Crescent Head Road: Cut at The Corduroy and Rudders Lagoon in the 50% AEP event
- Hat Head Road: Cut first at Kinchela in the 20% AEP event
- Stuarts Point Road: Affected by local gully flooding at a number of locations in the 50% AEP event. Expected to be short duration effects. Affected by local inundation around the Stuarts Point Road and Grassy Head Road intersection potentially for extended periods (not shown on the Appendix D maps).
- Grassy Head Road: Affected by shallow local inundation between Stuarts Point Road and Grassy Head potentially for extended periods due to poor drainage of local ponding in addition to local gully flooding combined with backwater flooding from Macleay Arm (not shown on the Appendix D maps).
- Access outside of the study area: Road access from Grassy Head to the north to the Pacific Highway at Macksville via Grassy Head Road and Scotts Head Road becomes cut off at Warrell Creek, outside of the Lower Macleay study area, for periods of around 3 days or longer (not shown on the Appendix D maps).

6.3 Flooding of services and sensitive facilities

Sensitive properties and critical infrastructure were identified in the study area. Certain types of properties may require specific evacuation considerations due to the vulnerability of its occupants, such as schools and pre-schools, and aged care facilities. Critical infrastructure (water supply systems and distribution systems, wastewater systems and sewer distribution facilities, electricity substations, etc.) and evacuation and emergency services centres (SES, police, fire stations, hospitals, ambulance centres, etc.) impacted by flooding may have effects on response, recovery and functioning of the community during and following a flood event.

The sensitive properties and critical infrastructure identified in the study area are mapped on Figure D-2 in Appendix D. The flood hazard in the PMF event is mapped on the figure. A summary of the flood-affectation of services and sensitive facilities is provided below:

- There are a number of primary schools and preschools which are affected by frequent to moderate floods (e.g. 20% AEP to 5% AEP events) including those in Smithtown, Gladstone, Kinchela and Kempsey. However, the large majority of preschools, primary schools and high schools have a high flood immunity and are flood-affected in events rarer than the 0.2% AEP event.
- Similarly, emergency services and facilities (fire and police, SES) located in Smithtown and Gladstone are flood-affected in frequent events due to the location of those villages on the floodplain. The police station and fire station in Kempsey are affected by flooding in rare events, larger than the 1% AEP and 0.5% AEP, respectively.
- South West Rocks SES depot is affected in the 0.2% AEP event and larger. However, access between SES and main part of South West Rocks town along Gordon Young Drive could be affected by local catchment flooding, which was not assessed in detail in this study.

- Rural fire brigade (RFB) depots have varied flood immunity. Hat Head and Smithtown-Gladstone RFB are affected by the 20% and 10% AEP events, respectively. Others have a higher flood immunity.
- Aged care facilities typically have a high flood immunity with one centre (Cedar Place Aged Care, Kempsey) affected in rarer than the 0.2% AEP flood event. Other centres are not flood affected in the PMF.
- Designated or potential evacuation locations are commented on below:
  - Crescent Head Bowling Club: Not flood-affected in the PMF.
  - Kempsey Showground: Affected in rarer than the 0.2% AEP event.
  - South West Rocks Country Club: Outside of modelled area, but appears unaffected by Macleay River PMF.
  - Hat Head Bowling and Recreation Club: Affected by the 2% AEP event and larger. Potentially on a low flood island and would be affected by overtopping of Hat Head left bank levee.
  - Gladstone Oval: Affected by the 20% AEP event. Suitable as an initial mustering area for subsequent evacuation but not considered suitable by SES for an evacuation area. Primarily an RFS Neighbourhood Safe Space.
  - Joe Donavon Sporting Complex, Stuarts Point: Affected in events rarer than the 0.2% AEP event. Primarily an RFS Neighbourhood Safe Space.
- Council water and wastewater system assets have varied flood immunity. Minimum flood immunity of 20% - 10% AEP flood.
- Main electricity substations: Mostly not flood-affected in PMF. Two of six are flood- affected, including Smithtown (20% AEP flood immunity) and South Kempsey adjacent to railway (rarer than 0.5% AEP).

6.4 Buildings flood damages assessment

6.4.1 Overview

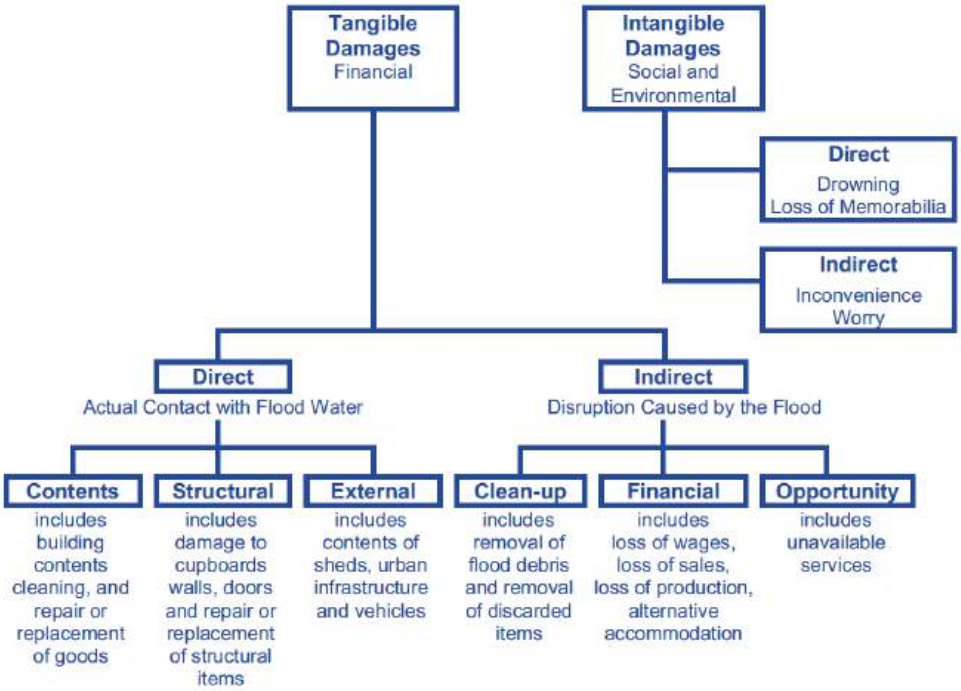
Flood events may cause damage to property with significant costs to property owners and insurers. The damage may occur due to floodwaters affecting the building façade and interior (weatherboard exterior, gyprock interior walls, carpets), electrical wiring and building contents and other property outside the dwelling (vehicles, contents of sheds and garages, etc). Structural damage to the dwelling can also occur due to extreme flood hazard conditions.

The cost of flooding is estimated to identify the magnitude of the event to a community, and subsequently provide a benchmark for the viability of potential measures for mitigating the impacts of flooding. This section describes the estimation of flood damage costs in the study area, focussing on residential and commercial properties.

6.4.2 Flood damages categories

The type of damages associated with floods is shown in Figure 6-1 (*Flood Risk Management Manual¸ NSW Government 2023*). The cost of damage caused by floods may include tangible and intangible components. Tangible damage costs include the direct material damage and rebuilding costs to existing homes, property and infrastructure, and also the indirect costs associated with the social disruption of the floods, such as: clean-up; lost income during and after the flood event; and the cost of alternative accommodation for people displaced by the floods. A monetary value can be readily placed on the direct damages, which are the focus of this assessment.

Figure 6-1 Types of Flood Damage



Other social and environmental damages to which a monetary value cannot be placed are intangible damages, which include emotional stress of the flood event, injury and loss of life. While these damages cannot readily be incorporated into an economic feasibility assessment of mitigation options, it is still important to consider the potential for these intangible damages, particularly if there is an elevated risk of loss of life.

6.4.3 Estimation of direct tangible flood damage costs

6.4.3.1 Residential property damages

Residential flood damages guidelines and a calculation spreadsheet was developed by the NSW Office of Environment and Heritage (OEH, 2016; now named Department of Climate Change, Energy, Environment and Water, "DCCEEW"). The calculation spreadsheet includes a representative stage-damage curve derived for typical house types in the study area to estimate structural, contents and external damage. The amount of damage is based on the flood inundation depth, for a suite of annual exceedance probability events ranging from the 20% AEP event up to the PMF. These values are then summed to provide a total damage for each flood event analysed. The AEP of the PMF in the study area is assumed to be 1 in 100,000.

Various input parameters are used to define the flooding and location characteristics which derive a location specific damage curve. The parameters adopted for the study area are presented in Table 6-12.

The OEH stage-damage curves within the spreadsheet were originally derived for late 2001 dollar values, and have been updated using an Average Weekly Earnings (AWE) factor to the current day values.

Table 6-12 Input parameters for damage calculations

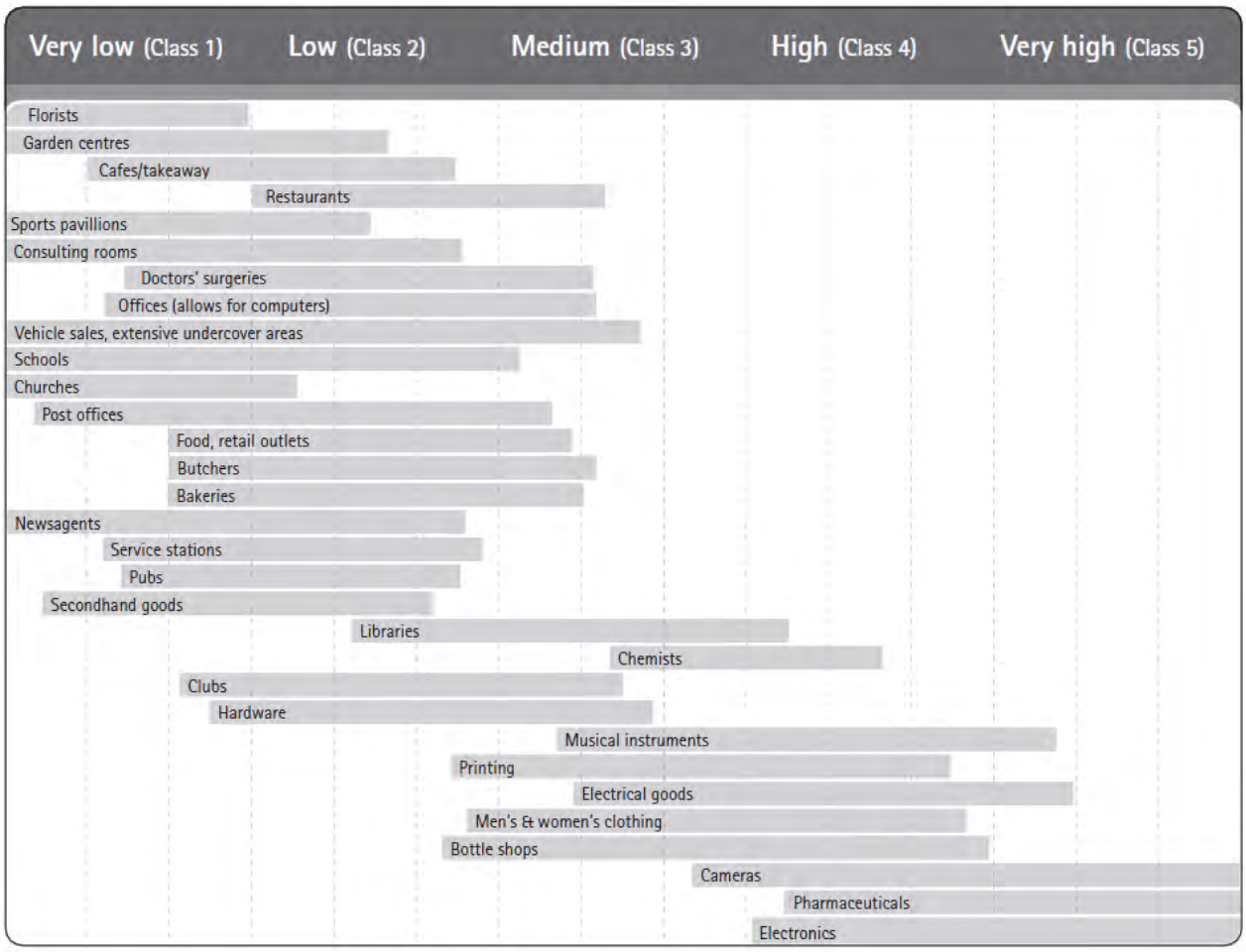
Parameter	Value	Comment
Regional Cost Variation Factor	1.1	
Post flood inflation factor	1.5	Upper bound value recommended by the guideline.
Typical duration of immersion	24 hours	

Parameter	Value	Comment
Building damage repair limitation Factor	1.0	Upper bound value recommended by the guideline, for longer duration flooding.
Typical free-standing house size	240m^2	
Contents damage repair limitation Factor	0.9	Upper bound value recommended by the guideline, for longer duration flooding.
Effective warning time (hrs)	24	Target warning lead time for Moderate flooding at Kempsey in Provisions of and Requirements for Flood Warning – Supplementary Document to the State Flood Plan. (NSW State Emergency Service, 2018)
Level of flood awareness	High	Generally high awareness of flooding in the community given the setting on major floodplain and with consideration of recent flooding events. Sensitivity analysis assuming "Low" flood awareness in the community indicates a 7% increase in flood damages.

6.4.3.2 Commercial and non-residential property damages

No information on commercial property flood damage costs in NSW was found during a literature search. The most relevant information obtained was published in the Queensland Government Natural Resources and Management Department's *Guidance on the Assessment of Tangible Flood Damages* (2002). This document contains flood damage curves for commercial properties over a range of property footprint areas and degrees of susceptibility to flooding and is based on information published in *ANUFLOOD: A Field Guide* (Centre for Resource and Environmental Studies (Australian National University), 1992). Different types of commercial and non-residential properties were assigned a susceptibility rating, as illustrated in Figure 6-2.

Figure 6-2 Damage categories for commercial properties



* From *Guidance on the Assessment of Tangible Flood Damages* (Qld. Government, 2002)

The stage-damage data were factored up by a value of 2.62 from late 2001 dollars to current values based on Average Weekly Earnings (AWE), similar to the approach adopted for the residential flood damages.

An additional multiplication factor of 1.6 was applied based on guidance in *Rapid-Appraisal Method (RAM) for Floodplain Management* (Victorian Government Natural Resources and Environment, 2000), which suggests that the ANUFLOOD values are underestimated and should be increased by 60%.

A commercial damages class of 2 was assumed for each commercial property in the damages assessment. The results of the commercial and non-residential property flood damages assessment are provided in Section 6.4.3.5.

6.4.3.3 Sheds

For the purposes of this flood damages assessment, sheds (including residential yard sheds and garages and rural sheds) were excluded. It is expected that many rural sheds in this study area are likely to house extensive high value equipment, however, no specific data for average value of rural shed contents is available. Hence these were excluded from the assessment.

6.4.3.4 Damages to utilities and infrastructure

Utilities and infrastructure in the study area which may be damaged by flooding include roads, rail, water and sewage treatment plants, sewage pumping stations, electrical transformer boxes, etc. The costs of damage to

infrastructure are difficult to quantify. For the purpose of this study these have not been included in the flood damages assessment.

6.4.3.5 Damage assessment results

The most convenient way to express flood damage for a range of flood events is by calculating the Annual Average Damage (AAD). The AAD is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. The AAD for the existing case then provides a benchmark by which to assess the merit of flood management options.

The AAD value is determined by multiplying the damages that can occur in a given flood by the probability of that flood actually occurring in a given year and then summing across a range of floods. This method allows smaller floods, which occur more frequently to be given a greater weighting than the rarer catastrophic floods. The 50% AEP flood event is nominally assumed to have zero flood damage cost.

Table 6-13 and Table 6-14 summarises the residential damages and the commercial/non-residential damages, respectively. The residential and commercial property flood damages include direct damages to property such as structural, external and contents damage, and indirect damages such as clean up costs and accommodation/ loss of rent costs. Infrastructure damage, vehicular damage and intangible damages are not included.

The flood damages here are "potential flood damages", which may be reduced with increased flood awareness and preparedness in the community. The Net Present Value of the flood damages assumes a 7% discount rate over a 50 year life, as per the OEH (2016b) guidelines. The damages are in 2022 dollar values.

Table 6-13 Estimated tangible flood damages for residential properties

Event	Number of properties affected	Number of properties flooded above floor level	Estimated Flood Damage	Contribution to AAD
20% AEP	244	30	$7,827,980	$1,174,197
10% AEP	409	105	$19,753,795	$1,379,089
5% AEP	662	247	$42,641,008	$1,559,870
2% AEP	1192	600	$105,478,116	$2,221,787
1% AEP	1633	1149	$190,620,456	$1,480,493
0.5% AEP	2162	1805	$326,317,982	$1,292,346
0.2% AEP	2454	2145	$440,506,484	$1,150,237
PMF	4756	4569	$1,252,648,544	$1,684,689
AAD				**$11,942,708**

Table 6-14 Estimated tangible flood damages for non-residential and commercial properties

Event	Number of properties affected	Number of properties flooded above floor level	Estimated Flood Damage	Contribution to AAD
20% AEP	2	2	$56,169	$8,425
10% AEP	51	51	$5,686,285	$287,123
5% AEP	103	103	$20,384,461	$651,769
2% AEP	173	173	$51,595,780	$1,079,704
1% AEP	212	212	$74,172,796	$62,8843
0.5% AEP	273	273	$110,510,042	$46,1707
0.2% AEP	320	320	$133,124,624	$365,452
PMF	597	597	$311,320,442	$442,223
AAD				**$3,925,245**

6.4.4 Summary

Flood damages in the study area is primarily attributed to residential dwellings in urban and rural areas. The number of commercial and industrial properties is limited and hence they have a small contribution to the AAD.

Although the flood damages to rural sheds, utilities and infrastructure are difficult to quantify and were excluded from the assessment, it is expected that these could substantially increase the overall flood damage costs.

While flood damage estimates for the study area are indicative only, they are useful in the evaluation of flood management options, aimed at reducing flood damage estimates while being economically viable to implement.

6.5 Agricultural flood damages

Agricultural flood damages were estimated based on a post-flood event survey undertaken on behalf of Kempsey Shire Council following the 2001 flood event to gather information on actual flood damages resulting from the event. A total of 9 landowners/operators were surveyed to estimate rural flood damages, which are summarised in Table 6-15. The Lower Macleay agricultural sector is predominantly cattle grazing (beef/dairy) and hence the flood damages estimates are dominated by costs relating to grazing operations.

Table 6-15: Reported actual flood damages from 2001 flood event (2004 dollar values)

Location	Inundation		Agistment/Feed			Stock, Infra-structure, Equipment, etc.	Loss of Sales or Production	Fencing	Pasture
	Area (ha)	Duration (days)	Freight	Period (weeks)	Cost				
Austral Eden	52	2	$1200	3	$200	nil	$2000	$4000	-
Austral Eden	75	2	-	-	?	$900	$12000	nil	$4000
Kinchela Ck	180	?	$1240	20	$4700	$2000	?	a lot	$6000
Kinchela Creek	200	10	-	-	$42000	$4000	$300000	$10000	$50000
East Frederickton	164	7-14	$4000	20	$16500	$2000	$5400	$2000	$9000
Belmore River	110	7-10	$2500	28	$53500	$1000	$38300	nil	$17500
Belmore River	160	14-28	$6000	?	$3000	nil	$10000	nil	$7500
Belmore River	225	10-14	$9000	28	$28000	$8300	$6000	$2000	$18000
Belmore River	?	?	?	?	?	$26000	?	?	?
TOTAL	1166		$23940		$147900	$44200	$373700	$18000	$112000

Reference: Macleay River Flood March 2001 – Flood Damages Data Collection. Webb McKeown & Associates (2004).

6.5.1 Flood damages on areal basis

The survey suggests an average damages value of $620/hectare of inundation in 2004 dollars, or equivalent present day dollar value of $1488/hectare with scaling based on Australian Bureau of Statistics information on average weekly earnings. It is acknowledged that this is a generalised cost value as the specific costs are expected to vary between individual operators and depends on the property size, location on the floodplain, specifics of their operations, costs of production etc. Additionally, the impacts to operators would vary for different flood events due to the differing flood behaviour.

Flooding event costs to farmers on the Lower Macleay were obtained during this study based on 2013, 2021 and 2022 flood events. Information was provided by landowners with costs of around $350-1,010/ha (present day values) estimated based on two methods of estimation. This is substantially lower than the estimates based on the post-2001 flood survey. In relation to the lower estimate, it was noted by one landowner that their cattle were able to be moved to another of their properties that was flood-free, hence various costs such as agistment and feed could be reduced or avoided.

For the purposes of this study the areal rate of $1488/ha was adopted to assess the agricultural flood damages.

6.5.2 Agricultural average annual damages

The potential agricultural flood damages for each AEP flood event, based on the inundated rural-zoned area, and the agricultural AAD is summarised in Table 6-16. The agricultural AAD is about 50% higher than the residential buildings AAD due to the large area of inundation in the more frequent flood events such as the 20% and 10% AEP events. Additionally, the AAD is considered an upper-limit estimate as it assumes full stocking of all rural-zoned land for grazing.

Table 6-16 Estimated agricultural flood damages

Event	Inundated rural-zoned area (ha)	Estimated Flood Damage	Contribution to AAD
20% AEP	32,584	$48,484,287	$12,410,304
10% AEP	36,519	$54,340,746	$5,141,252
5% AEP	38,288	$56,972,749	$2,782,837
2% AEP	39,871	$59,328,349	$1,744,516
1% AEP	40,848	$60,782,245	$600,553
0.5% AEP	41,867	$62,298,730	$307,702
0.2% AEP	42,530	$63,284,198	$188,374
PMF	47,105	$70,092,739	$132,710
AAD			**$18,170,588**

7. Flood Policies and Planning Controls

7.1 Background

This section provides an overview on the NSW flood risk management framework, and existing policies and planning controls applicable to the study area and recommends additional controls to be considered for the study area.

7.2 NSW flood risk management framework

7.2.1 Objectives and approach

The primary objective of the NSW Flood Risk Management (FRM) framework, as expressed within the NSW Flood Prone Land Policy (Flood Risk Management Manual (FRMM) 2023), is as follows:

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

Within the scope of this report, the relevance of the above objective is primarily to ensure that future redevelopment within the study area does not lead to increased flood risk to property and persons, and that the planning controls proposed to achieve this outcome form part of a consistent and coordinated strategy to reduce flood risk.

7.2.2 NSW FRM policy and guidelines

The NSW Flood Prone Land Policy, as identified within Section 1.1 of the FRMM, places the primary responsibility for flood risk management on local councils. This provides the opportunity for FRM to be integrated within council's normal planning processes.

The NSW Flood Prone Land Policy and the FRMM provide a platform for the management of floodplains following a risk management approach. The FRMM provides guidance on how to implement the NSW Flood Prone Land Policy. The FRMM requires the level of flood risk acceptable to the community to be determined through a process overseen by a committee comprised of local elected representatives, community members and state and local Government officials (including the SES).

The ultimate outcome is the preparation of a Floodplain Risk Management Plan (FRMP), which is a plan formally adopted by a local council in accordance with the NSW Flood Prone Land Policy. FRMPs should have an integrated mix of management measures that address existing, future and continuing risk.

7.2.3 2021 Flood Prone Land Package

The flood-prone land package, including updated Planning Circular (PS 21-006) was released by the NSW Government on 14 July 2021 and provides advice to councils on considering flooding in land-use planning. It updated and replaced the Planning Circular (PS 07-003), dated 31 January 2007, and its provisions for flood planning. Significant flood events, like those in Brisbane in 2011 and those more recently in NSW show the importance of managing flood risk up to and beyond the 1% AEP flood and considering flood risks up to the probable maximum flood level. This will build resilience in communities located on floodplains and reduce the extent of property damage and potential loss of life from severe to extreme flooding throughout NSW. The updated guidance supports:

- better management of flood risk beyond the 1% annual exceedance probability
- best management practices in managing and mitigating severe to extreme flood events
- greater resilience built into communities in floodplains and reduces potential property damage and loss of life in recognition of increasing extreme flood events throughout NSW.

The flood planning level (FPL) is the main provision in LEPs and DCPs to administer planning controls on development in NSW. Whilst the flood used to define the residential FPL is a decision for local councils, FRMM highlights that FPLs for typical residential development would be based around the 1% AEP, or a historic flood of similar scale, plus an appropriate freeboard (typically 0.5m).

With the 2021 flood-prone land package, Special Flood Considerations apply to sensitive and hazardous development in areas between the FPL and up to the probable maximum flood (PMF) and to land that may cause a particular risk to life and other safety considerations that require additional controls. These controls relate to the management of risk to life and the risk of hazardous industry/hazardous storage establishments to the community and the environment in the event of a flood.

7.2.4 Relationship with EP&A Act

Planning in NSW is primarily governed by two pieces of legislation:

- Environmental Planning and Assessment Act 1979 (EP&A Act)
- Environmental Planning and Assessment Regulation 2000 (EP&A Regulation).

This legislation is in turn supported by other statutory documents. Of particular relevance to this study are State Environmental Planning Policies (SEPPs) and Local Environmental Plans (LEPs). SEPPs deal with matters of State or regional environmental planning significance and outline the NSW Government's approach to dealing with particularly planning issues. LEPs are an integral part of the NSW planning system. They are created by local Councils in consultation with their community to control the form and location of new development, along with protecting open space and environmentally sensitive area. LEPs guide planning decisions for local government area.

The plan-making processes under the EP&A Act, such as for the preparation of Local Environmental Plans (LEPs) and Development Control Plans (DCPs), operate independently of the preparation of FRMPs under the FDM. While these two processes could be overlapped, it has been the usual practice to undertake the processes separately. Ultimately the planning recommendations of the FRMP will need to be reflected in planning instruments and policies brought into force in accordance with the EP&A Act.

7.3 Existing policies and planning controls

The imposition of planning controls can be an effective means of managing flood risks associated with future development (including redevelopment). Such controls might vary from prohibiting certain land uses to specifying development controls such as minimum floor levels and building materials.

In principle, the degree of restriction that is imposed on development due to flooding relates to the level of risk that the community is prepared to accept after balancing economic, environmental and social considerations. In practice, the planning controls that may ultimately be imposed are influenced by a complex array of considerations including state-imposed planning policy and directions, existing local planning strategies and policies and ultimately the acceptability of conditions that could be imposed through the development application process.

The following provides an outline of policy that is potentially relevant because it either directs the FRM planning controls that could be adopted or affects the way flood risk is identified in the planning controls.

7.3.1 State Environmental Planning Policies

State Environmental Planning Policies (SEPPs) are planning policies which deal with State wide matters of environmental planning significance. They are prepared in accordance with the EP&A Act by the NSW Department of Planning and Environment and approved by the Minister. Clause 1.19 of the Exempt and Complying Development Codes SEPP has been amended so that land identified as 'flood control lot' is no longer excluded from the application of the General Housing Code. Instead, specified development and development standards have been added to the General Housing Code in Clause 3.36 of the Exempt and Complying Development Codes SEPP (2008) for development on flood control lots. The development standards have been

designed to ensure that complying development is not allowed on those parts of flood control lots which are defined as being floodways, flood storage areas, a flow path, a high flood hazard area or high flood risk area.

7.3.2 Section 9.1(2) Directions

Ministerial directions pursuant to section 9.1(2) of the EPA Act specify matters which local councils must take into consideration in the preparation of LEPs. Direction 4.1, as currently applies (20 February 2023) , deals specifically with flood prone land and has the following two objectives:

(a) To ensure that the development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual, 2005.[2]

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

The Direction applies to all relevant planning authorities that are responsible for flood prone land when preparing a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land:

1) *A planning proposal must include provisions that give effect to and are consistent with:*
    a) *the NSW Flood Prone Land Policy,*
    b) *the principles of the Floodplain Development Manual 2005,*
    c) *the Considering flooding in land use planning guideline 2021, and*
    d) *any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manual 2005 and adopted by the relevant council.*
2) *A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront or Special Purpose Zones.*
3) *A planning proposal must not contain provisions that apply to the flood planning area which:*
    a) *permit development in floodway areas,*
    b) *permit development that will result in significant flood impacts to other properties,*
    c) *permit development for the purposes of residential accommodation in high hazard areas,*
    d) *permit a significant increase in the development and/or dwelling density of that land,*
    e) *permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,*
    f) *permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,*
    g) *are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or*

[2] The Flood Risk Management Manual 2023 was recently released and supersedes the Floodplain Development Manual 2005. It is expected that the wording in the section 9.1(2) directions will be updated in due course to reflect the updated guidance document.

h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

4) A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply which:

a) permit development in floodway areas,

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

c) permit a significant increase in the dwelling density of that land,

d) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

e) are likely to affect the safe occupation of and efficient evacuation of the lot, or

f) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

5) For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

7.3.3 Local Environmental Plan 2013

The *Kempsey Local Environmental Plan 2013* (LEP 2013) provides land use controls for the Kempsey local government area and has been developed to be consistent with the FDM. Part 5.21 of the LEP 2013 addresses flood planning. Excepts of this clause are provided below:

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.*

The LEP 2013 contains a number of land use zones, shown on Figure 2-2. For each land use zone, the LEP specifies development which may be carried out with or without consent, prohibited development and objectives for development.

7.3.4 Development Control Plan 2013

Kempsey Development Control Plan 2013 (DCP 2013) provides detailed guidelines to guide the design and assessment of development applications for land covered by LEP 2013. Chapter B7 of DCP 2013 addresses Flood Hazard Area Management. Provisions related to flooding are made for different types of development and land use.

The objectives of Chapter B7 are:

a) *To ensure that development on flood prone land is consistent with:*

   i. *Kempsey Local Environmental Plan 2013;*

   ii. *Council's adopted Floodplain Risk Management Plans;*

   iii. *NSW Government's Floodprone Lands Policy; and*

   iv. *NSW Government's Floodplain Development Manual.*

b) *To ensure that new development on flood prone land is compatible with the degree of flood hazard and that adequate flood risk management measures are incorporated in the design of the development thereby minimising the possibility of loss of life and damage to property.*

c) *To encourage the re-development of existing flood prone lands in a manner that will minimise the chance of loss of life and damage to property by future flooding.*

d) *To prevent the creation of any 'new area' of urban development on flood prone lands.*

e) *To prevent any extension of existing urban zoned areas into flood prone lands.*

f) *To seek the eventual clearance of the Kempsey CBD Floodway Number 1 and its re-development for recreational, agricultural and limited commercial uses which will only have a minimal effect on the free flow of floodwaters and minimal risk of causing loss of life or damage to property, e.g. sporting fields, picnic grounds, nurseries, recreation facilities with minimal permanent buildings and no residential facilities.*

The DCP 2013 specifies the development controls which are applicable to the different land use zonings and floodplain areas. For example, restrictions on new development and subdivisions in floodway areas. The requirements for flood proofing of developments is also stipulated, by means of earth mounds, elevated buildings, electrical installations and suitable building materials.

Discussion on key aspects of DCP 2013 are provided below.

Flood planning level

DCP 2013 sets minimum habitable floor levels based on the flood planning level, that is, the 1% AEP flood level plus 0.5m freeboard, for residential and rural residential development. For new commercial development, Council will seek the provision of part of the floor level of the building to be 500mm above the 1% AEP flood level to facilitate the storage of goods during time of flood.

Given the projected increases in peak flood levels in the Lower Macleay due to ongoing and future climate change, it would be prudent to re-define the flood planning level in future revisions of the DCP based on the design 1% AEP flood level under climate change scenario. This would be consistent with recommendations made in the NSW Flood Inquiry (refer Section 3.4 of this report). Some other local councils (e.g. Port Stephens Council) have adopted flood planning levels with incorporation of climate change flooding estimates.

Council has resolved to adopt the FPL as being the maximum of the 1% AEP existing climate flood level plus 500mm freeboard, and the 1% AEP year 2100 climate flood level.

Flood prone land

"Flood prone land" as defined in DCP 2013 refers to the land which is inundated during a 1% AEP flood. This definition should be updated to refer to the land which is inundated in the PMF, that is, land which would be subject to inundation by the full range of flood magnitudes. This latter definition would be consistent with that provided in the Flood Risk Management Manual 2023.

Requirements for structural design of buildings

Comments on current provisions for structural design in DCP 2013:

- For several development types referred to in DCP 2013, construction will not be permitted "unless it can be shown that the product of the depth and velocity of flow of water during a 1% AEP flood is equal to, or less than, one (1)". This hydraulic definition is mostly consistent with AIDR flood hazard rating system for H4 category maximum limits, although the H4 category also employs a maximum depth threshold of 2m and velocity threshold of 2m/s. Refer to Section 5.1. Update to the DCP could be considered such that it refers to AIDR flood hazard categories and the flood hazard mapping presented in this FRMS. Note that restricting development to areas of H4 flood hazard and lower, and excluding development from H5 hazard areas in the 1% AEP flood would preclude development from the large majority of the Lower Macleay floodplain, refer to flood hazard mapping in Appendix A.
- For several development types referred to in DCP 2013, "support structures below PMF level must be capable of withstanding flood forces (water flow, debris impact, and buoyancy) and continuous submergence for up to *one* week, requiring an engineering certification". As modelled durations of inundation may exceed one week particularly for the PMF, and observed durations in historic events have also been reported as exceeding one week and been up to two weeks, consideration could be made for extending the design duration of submergence beyond one week. However, it is acknowledged that this may result in overly-onerous design requirements.

Designated floodway and flood storage areas

DCP 2013 defines a number of floodway and flood storage areas, within which certain development conditions apply. Future update to the DCP should incorporate the floodway and flood storage area mapping that is presented in this FRMS.

The DCP 2013 also refers to the Bellimbopinni and Seven Oaks floodway area. It is unclear on how this floodway area was identified, although this location is a pinch-point in the Macleay River channel where flow breakouts occur. However, hydraulic modelling undertaken for this FRMS does not identify particularly high flows or hydraulically classify the area as a floodway (as per the adopted categorisation method discussed in Section 5.3) and there are other locations in the study area with higher flow rates. Consideration should be made whether the designated Bellimbopinni and Seven Oaks floodway area should be retained in the DCP, noting that velocity x

depth product values do exceed a value of 1.0 in this area. If it is to be retained, consideration should be made to extending the designated floodway area towards the east to cover additional areas of flow breakout. Renaming it a "flood development conditions" area or similar would also reduce confusion with the floodway areas hydraulically defined in this FRMS.

Conditions on development are placed on former Lots 5 and 6, DP 1022342 and Lot 851 DP790816 at New Entrance, South West Rocks, which are considered to be within a probable "floodway". DCP 2013 requires that any development proposal for this land will require a detailed flood study to be undertaken. The modelling undertaken for this FRMS identifies flow breakout through this area and a floodway has been mapped through these lots. The requirement for a separate detailed flood study for proposed development on these lots could be lifted.

The *Kempsey CBD Floodplain Risk Management Study* (WMAwater, 2017) provided a review of relevant development controls specific to the CBD Floodway and other floodways in the Kempsey township area. The discussion in that review is not repeated in this Lower Macleay FRMS.

Design flood levels

DCP 2013 specifies design flood levels and climate change flood level increase allowances for the basis of development applications in the Lower Macleay. This design flood information is based on previous hydraulic modelling dated circa 2004. Updates to the DCP should incorporate the design flood levels, with and without climate change as appropriate.

It is noted that there would be increases in the design 1% AEP flood level particularly in the lower reaches of the Macleay. The current flood modelling included updated river bed and floodplain survey, assessment of river entrance bed scoured levels and updated guidance on coincident design ocean levels. These factors contribute to the different design flood levels estimated in this study.

7.3.5 Section 10.7(2) Certificates

Kempsey Shire Council, under the provisions of Section 10.7 of the Environmental Planning and Assessment Act 1979 issue Section 10.7(2) Certificates which are also known as planning certificates. These indicate whether the land may be impacted by flooding and subject to flood related development controls. The Certificates suggest that contact should be made with Council in respect to possible flooding matters. They are usually required upon the sale or purchase of a property.

8. Local Emergency Planning Context

8.1 Kempsey Flood Emergency Sub-Plan

The Kempsey Flood Emergency Sub-Plan 2017 (SES, 2017) is a sub-plan of the NSW State Flood Plan (SES, 2018a) outline the specific arrangements for management of flood events within the Kempsey Council area. Roles and responsibilities for agencies including regional and local SES, Police, Council, Rural Fire Service, BOM, WaterNSW, DPE etc. and operators of facilities (schools, pre-schools, caravan parks) community groups and community members, among others, and pre-, during and post-flood procedures are defined.

Flooding impacts to the communities in the Lower Macleay and other parts of Kempsey LGA are described, including flood behaviour/characteristics, floodplain categorisation (e.g. low flood island, etc), levees and their overtopping AEPs, at risk facilities etc. Flood extent mapping, design flood levels at the various villages and other information may be superseded by outcomes from this FRMS.

Review of the Sub-Plan indicated the following, which may require update:

- The Sub-Plan describes flood events up to the 2013 flood and design flood info is based on the Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017) and there appear to be some differences in reported design flood levels and behaviour. For example, the PMF level reported in the Sub-Plan for Kempsey is 13.89m AHD, while the current FRMS estimate is 14.9m AHD. Other details on design floods may also need update. Recent flood events including March 2021 and others should be listed.
- The emergency classification of communities terminology has changed since the Sub-Plan publication.
- There are population and demographic data for the population centres which are based on Census 2011 and need updating.
- ARI/AEP rating of various historic events need to be updated based on recent flood frequency analysis conducted for Kempsey Traffic Bridge gauge data.
- The periods of isolation for villages which are indicated in the local flood plan appear lengthy (e.g. greater than 20 days for Crescent Head in the 1% AEP) compared to the current FRMS flood modelling (approximately 10 days). This difference could be driven by assessment of historic flood events for the flood plan information.
- There are various maps and diagrams which would require update with the currently modelled flood extents and other details.

Upon completion of this current floodplain risk management study and plan, the Sub-Plan should be updated with consideration of the information and findings of this study on the flooding behaviour for Lower Macleay.

Revision of the Sub-Plan and preparation of new responsibilities, systems and procedures should be undertaken with input from all key stakeholders. Any organisational and responsibility changes forthcoming from the NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be incorporated into future revisions of the Sub-Plan.

8.2 Current Flood Forecasting and Warning Systems

8.2.1 Bureau of Meteorology flood messages

The Bureau of Meteorology (BOM) provides an Australia-wide Flood Warning Service Program with its primary function being the provision of an effective flood forecasting and warning service in each Australian State/Territory, in cooperation with State/Territory emergency management agencies, water authorities and local Councils and other stakeholders. Flood messages may include either qualitative or quantitative predictions or may include a statement about future flooding that is more generalised. The type of prediction provided depends on the quality of real-time rainfall and river level data, the capability of rainfall and hydrological forecast models and the level of service required.

"Flood Watch" messages are issued by BOM ahead of actual flood events when weather forecasts and modelling indicate that flooding is expected to occur in a region. The warnings are provided for separate river catchments about the locations along river valleys where flooding is expected, the likely class of flooding and when it is likely to occur. Predictions of expected water levels and the timing of flood peaks are provided at key forecast locations based on flood forecast modelling and real-time monitoring of rainfall and river levels. This information is published on the BoM's web site www.bom.gov.au, and is incorporated into NSW SES Flood Bulletins for distribution to media outlets

During a flood event, BOM may issue specific "Flood Warning" messages to advise that flooding is occurring or expected to occur in a geographical area, including whether Minor, Moderate or Major flooding is expected in areas where the BOM has specialised warning systems, including the Macleay catchment. They provide advanced warning about the locations along river valleys where flooding is expected, the likely class of flooding and when it is likely to occur. Predictions of expected water levels and the timing of flood peaks are provided at key forecast locations.

At present, BOM undertakes flood forecasting using computer hydrologic models for the Macleay River catchment utilising real-time rainfall and river water level data as inputs, with flood warnings provided at Armidale (Stephens Bridge), Georges Creek, Bellbrook, Kempsey and Smithtown (refer to Table 1 in SES, 2019).

Issues with the BOM flood warnings were experienced in the lead up to the March 2021 and March 2022 flood events, whereby BOM issued an initial Flood Watch for river valleys to the north and south of the Macleay, yet the Macleay remained without a Flood Watch. With an already wet catchment due to preceding very wet weather conditions, exclusion of the Macleay from the Flood Watch was a potential cause for complacency within the community (Kempsey Shire Council, pers. comm.).

It is noted that for both March 2022 events moderate flood levels were reached for the majority of the Macleay River catchment, thereby demonstrating that a 'flood watch' was warranted to assist in warning the community to commence enacting flood plans and preparations, in particular for those with rural land holdings who require more time to be prepared.

Timeliness of warnings were also a concern on multiple occasions in the Kempsey Shire during flooding events in 2021 and 2022, where river levels reached flooding warning levels at the same time the warning has been issued. This has a considerable impact on the ability for the community to prepare and the combat agency and Emergency Operations Centre to respond appropriately. In addition, this results in a lack of trust of emergency authorities by the community.

Both the issues above point to the high priority for adequate resourcing of BOM teams responsible for flood forecasting and warning, particularly during multi-region flood events such as that in the March 2021 event.

8.2.2 Macleay Valley total flood warning system

Kempsey Shire Council operates a total flood warning system with support from agencies including Manly Hydraulics Laboratory (MHL). At its simplest, a total flood warning system is based on the following six components (Attorney-General's Department, 2009).

1) Prediction - detecting changes in the environment that lead to flooding and predicting river levels during the flood.
2) Interpretation - identifying in advance the impacts of the predicted flood levels on communities at risk.
3) Message construction - devising the content of the message that will warn people of impending flooding.
4) Communication - disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood.
5) Response - generating appropriate and timely actions from the threatened community and from the agencies involved.
6) Review - examining the various aspects of the system with a view to improving its performance.

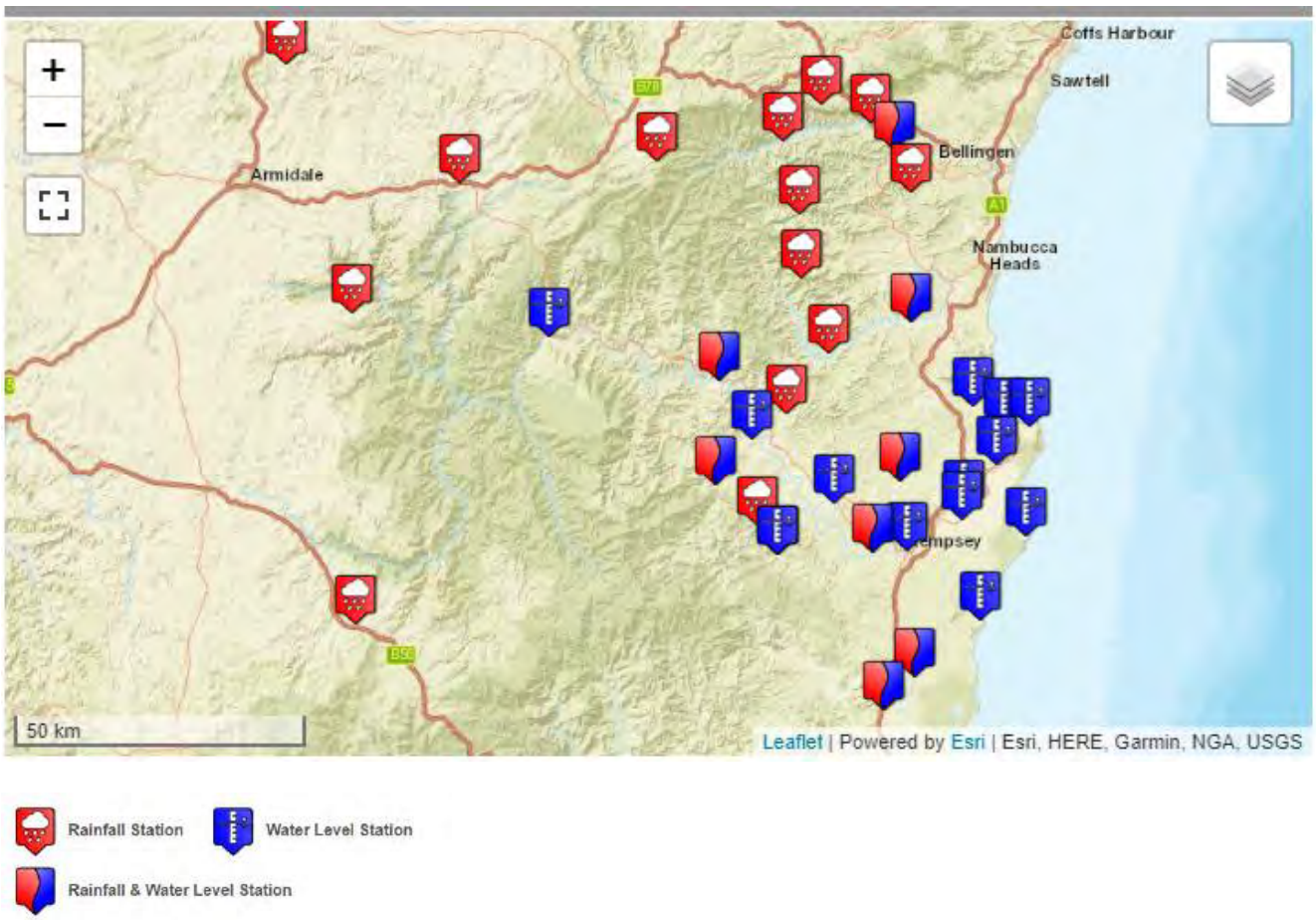
Within the Kempsey Shire there are various gauge owners and over 50% of the Macleay River catchment is within other local government areas. Kempsey Shire Council maintains or contributes to the provision of gauges outside of the local government area as up-river catchment information is critical to flood planning within the Kempsey Shire. Rainfall and water level gauge owners in the Macleay catchment include Kempsey Shire Council, BOM, Department of Planning and Environment, WaterNSW and MHL. Gauge locations are shown on Figure 8-1. Currently there are gaps shown in the gauge network in the central and upper catchment, although additional gauges have since been installed to provide coverage in these gaps (Kempsey Shire Council, pers. comm.). These include:

- River Level Gauges: Frederickton (Reinstated) & Third Lane Kempsey.
- Rainfall Gauges: East Kunderang, Buddsmare Campground (Walcha) and Kookaburra School Hut (Yarrowitch)

A number of surveillance cameras are also installed to visually monitor flooding at key road bridges including Sherwood Bridge and Kempsey Traffic Bridge.

Figure 8-1: Rainfall and water level monitoring in Macleay Valley total flood warning system

(https://mhlfit.net/users/KempseyShireCouncil/)



During a flood event, Council and SES monitor rainfall and flooding conditions via online gauges in addition to conditions on ground, such as flooding relative to levee levels and road low points. Flood status updates are posted on Council's website and Council and SES social media (Facebook, Twitter (now called "X")) and direct to resident text messaging to relay information on key information such as roads which are cut off, roads remaining open at the time, evacuation orders, services and facilities affected, emergency response activities being undertaken, evacuation centres open etc. This messaging is supplementary to BOM's flood warnings and aim to provide near real-time local level information on conditions as the flood event progresses. The live rainfall and water level data and flood camera imagery are also available to the public (https://mhlfit.net/users/

KempseyShireCouncil/) with a link via Council's flood web page (https://www.kempsey.nsw.gov.au/Your-Valley/Disaster-emergency/Flood-information-cameras).

There were 50 flood status updates issued by Council over the 8 days of the March 2021 flood event. At various stages of the event, there were reports by residents on the Council Facebook page that certain information was out of date at the time, such as flood status update reports of certain roads being open/closed when the conditions were the opposite on ground. This could be the case due to quickly-changing flooding conditions and Council staff deployed elsewhere not being able to closely monitor road flooding conditions. There may also be lags in the communication chain as messages from operational teams need to pass through the communications team for official posting as a flood status update. Opportunities for improvement in the total flood warning system and messaging should be investigated.

8.3 Flood evacuation and emergency access considerations

As a part of this study, mapping of known road flooding points (first locations where the key roads become cut) overlaid on flood depth mapping has been prepared for around Kempsey, Smithtown/Gladstone and Kinchela and provided to SES. These maps are included in Appendix E. The known locations where the key access routes become first cut are summarised below:

- **Kempsey:** Forth Street, Eden Street, Wide Street, Macleay Valley Way (Kempsey/Frederickton), Kemp Street, Spooners Avenue, South West Rocks Road (Austral Eden), Crescent Head at Rudders Lagoon.
- **Smithtown:** Smithtown Road (first point of breach near Macleay Valley Way intersection), South West Rocks Road (breaches between Kinchela and Hat Head turnoff)
- **Frederickton:** Macleay Valley Way (Kempsey/Frederickton), Macleay Valley Way (Between Frederickton and Smithtown Road intersection), Macleay Valley Way at Frederickton - trunk drainage channel inundation.
- **Hat Head:** Hat Head Road (start of national park),
- **Crescent Head:** Rudders Lagoon, The Corduroy (immediately west of Crescent Head).
- **South West Rocks:** Plummers Lane (multiple location), South West Rocks Road (multiple locations)
- **Lower Macleay – Belmore:** Left and Right Bank Roads
- **Lower Macleay – Kinchela:** Left and Right Bank Roads.
- **Stuarts Point:** Stuarts Point Road opposite Grassy Head Road (local flooding).

The flood modelling indicates that durations of inundation of these roads in the design events would be around 1 week. Experience from historic floods indicates that inundation duration would continue for in excess of 1-2 weeks generally.

Most of these roads pass across the floodplain for long distances and it may take up to an hour to drive to higher ground on the rural roads, with longer travel times expected due to heavier traffic if evacuation orders are in place and during peak holiday times. Consultation with residents indicates that flooding can rise extremely rapidly based on historic flood experience, resulting in the access routes becoming cut off suddenly and with highly hazardous flow conditions. Adequate warning time is therefore critical for arranged and self evacuation, which places a high emphasis on the importance of the flood warning system and dissemination of accurate real-time flood information during an event.

9. Floodplain Risk Management Measures

9.1 Overview

One of the objectives of this Floodplain Risk Management Study is to identify and compare various floodplain risk management options to deal with existing and future flood risk in the study area, considering and assessing their social, economic, ecological and cultural impacts and their ability to mitigate flood impacts.

The *Flood Risk Management Manual* (NSW Government, 2023) describes floodplain risk management measures in three broad categories as described below:

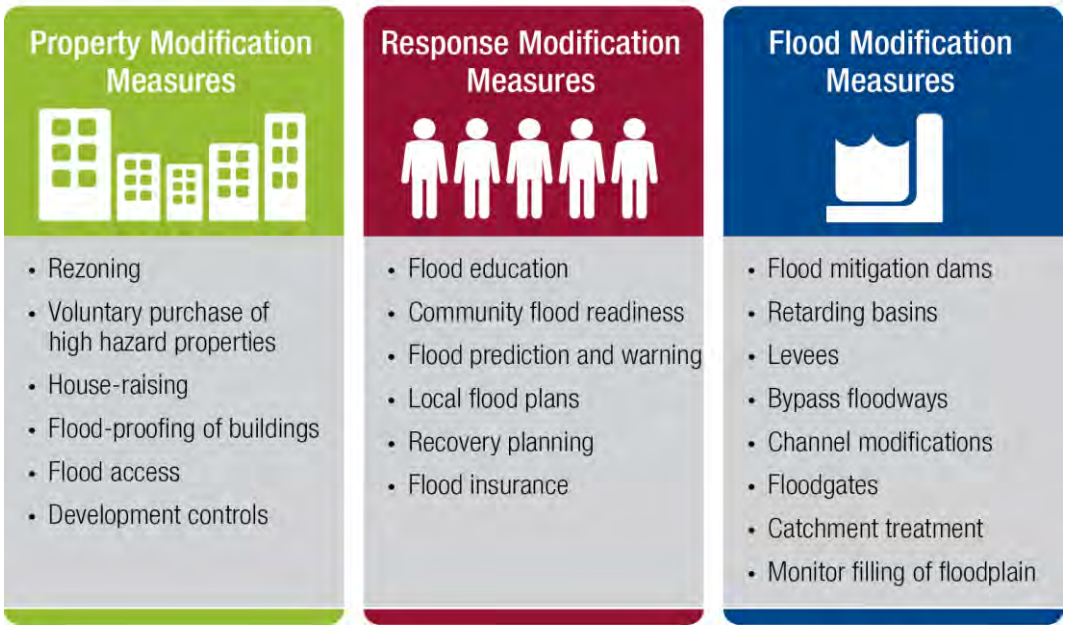
- Property modification measures involve modifying existing properties (for example, house-raising) and/or imposing controls on new property and infrastructure development (for example, floor height restrictions);
- Response modification measures involve modifying the response of the population at risk to better cope with a flood event (for example improving community flood readiness); and
- Flood modification measures involve modifying the behaviour of the flood itself (for example, construction of a levee to exclude floodwaters from an area or flood retarding/detention basins to store floodwaters and reduce peak outflows).

Examples of measures falling under the three categories are outlined in Figure 9-1. Some of these measures may or may not be appropriate in a particular catchment, depending on factors such as the flooding behaviour and patterns of development.

A description and evaluation of potentially suitable works-based options for specific locations, nominated for further detailed modelling assessment, is provided in this section. These consist of works-based options with the aim of improving flooding conditions or improving flood access. Refer to Section 9.4 for details. Other response and property modification measures are addressed in this section.

Figure 9-1 Examples of Floodplain Risk Management Measures

(Source: Flood Risk Management Manual, 2023)



9.2 Property modification measures

9.2.1 Voluntary purchase of high hazard properties

Voluntary purchase of high flood hazard properties may be considered in order to eliminate the potentially high risk of loss of life and damage to property from these areas by physically removing the dwellings at risk to hazardous flood conditions. DPE previously prepared Guidelines for Voluntary Purchase Schemes (OEH, 2013b). This describes the eligibility criteria for NSW Government funding for VP schemes, which include:

- no other feasible flood risk management options are available to address the risk to life at the property;
- residential properties and not commercial and industrial properties;
- buildings were approved and constructed prior to 1986;
- properties are located either 1) within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them, 2) within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain, or 3) within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected.

The *Kempsey CBD FRMS* (WMAwater, 2017) acknowledges that the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

It is not uncommon for the uptake of voluntary purchase properties to slow right down once most of the owner occupied housing stock has been purchased. This can create fragmented neighbourhoods where it is common for the remaining housing to be dominated by rental properties and visually unappealing businesses. The voluntary purchase zoning can encourage rental investors to hold on to properties.

Land swap schemes can also help accelerate the clearance of the floodway such as that undertaken in Grantham, Lockyer Valley, Queensland following the January 2011 floods. Through such a scheme, people who own land within the floodway would be offered deeds for another parcel of land outside of the floodway in return for their current property to be returned to Council for demolition and clearance.

Recent experience after the Lismore 2022 floods indicates that some residents may not agree with the nomination of their homes as being within high flood hazard areas and eligible for voluntary purchase, citing that their homes are sufficiently flood-proofed (https://www.abc.net.au/news/2023-03-19/lismore-flood-resident-rejects-buyback-calls-for-house-raising/102110120). Consultation from Council needs to include community education on the factors considered in the flood hazard rating of buildings, for example, that a raised habitable floor may not be sufficient to mitigate flood risk and that structural integrity and stability of the building could be threatened due to the flow of floodwaters. However, consultation should also highlight that property buyback is completely voluntary and at the discretion of the landowner.

A preliminary count of dwellings affected by high hazard (considered to be H5 or higher for this purpose) flooding in the 1% AEP event or within a floodway zone indicates that there are **421** dwellings which could be eligible for voluntary purchase within the study area, which includes Kempsey CBD and up to Turners Flat. There are limits to the funding available for a voluntary purchase program and additional eligibility criteria may apply.

Further assessment of the eligibility of individual dwellings for VHP should be undertaken as applications are received by Council.

Kempsey Shire Council currently has a voluntary purchase scheme. Given historic and ongoing property price increases across Australia, the ongoing feasibility of the scheme needs to be reviewed, although there should be a view to continue with the scheme as it is an effective way to reduce flood risk in the floodplain. Sources of funding forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored. The Macleay Valley is likely to be considered a "high risk" catchment area which would be an initial target for flood risk management by NSW RA.

Recommendation

Council should continue with its voluntary purchase of high hazard properties program with guidance from the flood modelling and mapping outcomes from this FRMS, although review of ongoing feasibility of the scheme, citing historic and ongoing property price increases. Sources of funding forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored.

9.2.2 Voluntary house raising

Voluntary house raising has long been a traditional response to flooding in New South Wales, as demonstrated by the number of raised houses in frequently flooded urban areas such as Lismore and Fairfield (*Floodplain Development Manual*, NSW Government, 2005). There are advantages associated with house raising which are noted as follows (Frost & Rice, 2003):

- A reduction of flood damages due to personal items being stored above the nominated flood level
- A reduction in danger to personal safety and a reduction in the cost of potentially needing to evacuate residents
- Potentially cost-effective alternative to voluntary purchase, with positive social outcomes (i.e. home owners who have strong sentimental value on their properties can remain in the same location).

Some of the disadvantages include:

- Residents' concern over security and privacy due to an open, exposed ground floor
- Accessibility issues for the elderly or people with a disability
- Following raising, residents may develop a false sense of security from impacts. This can result in a belief that they will not be impacted by flooding or reluctance to evacuate when required.
- Over time and when flooding has not occurred, residents may be inclined to utilise the ground floor and converting it to a habitable area.

The NSW Government previously prepared *Guidelines for Voluntary House Raising Schemes* (OEH, 2013a). This describes the eligibility criteria for NSW Government funding of VHR schemes including:

- not located in floodways
- limited to areas of low flood hazard
- the suitability of individual houses for raising
- residential properties and not commercial and industrial properties
- buildings were approved and constructed prior to 1986
- properties cannot be benefiting substantially from other floodplain mitigation measures
- VHR should generally return a positive net benefit in damage reduction relative to its cost (benefit–cost ratio greater than 1).

Inclusion of a property in a voluntary house raising scheme places no obligation on the owner to sell the property or on the council or NSW Government to fund the purchase of the property. Owner participation in the scheme is voluntary and there are limitations on the availability of funding.

A preliminary count of dwellings affected by a flood hazard of H4 or lower rating and with above-floor flooding indicates that there are about **777** dwellings which could be eligible for voluntary house raising within the study area, which includes Kempsey CBD and up to Turners Flat. Note that WMAwater (2017) indicates that some properties have already been raised in the past. Further raising of some properties may be in conflict with maximum building heights specified in LEP 2013. There are limits to the funding available for a voluntary purchase program and additional eligibility criteria may apply. Further assessment of the eligibility of individual dwellings for VHR should be undertaken as applications are received by Council.

WMAwater (2017) states that for the floodplain downstream of Kempsey, Council has determined a list of the 100 most flood prone rural properties that are suitable for house raising (WMAwater, 2008b). These properties are on a list for a voluntary house raising scheme, subject to funding, where the owner and Government both contribute to the cost of house raising. Council regularly contacts and reviews this list. This list does not cover all rural properties within the study area and should be extended to cover the remaining properties. Council should continue to periodically contact those on the list for rural voluntary house raising and review the list periodically.

Recommendation

Council should continue with its voluntary house raising program with guidance from the flood modelling and mapping outcomes from this FRMS. Additional sources of funding such as those potentially forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored.

9.2.3 Flood proofing and flood compatible design of individual buildings

Flood compatible design refers to the design and construction of buildings with appropriate water-resistant materials such that flood damage to the building itself (structural damage) and possibly its contents, is minimised should the building be inundated. These include structural and architectural design and building materials, in addition to design considerations such as setting of electrical equipment above flood levels to reduce risk of their damage. A list of suitable flood-compatible building materials is provided in DCP2013. Further promotion of types of flood proofing measures could also be undertaken as a part of flood awareness and readiness improvement programs (refer Section 9.3.8).

DCP 2013 also addresses other methods of flood proofing including use of elevated earth mounds to raise buildings above the surrounding floodplain, raised/elevated buildings to provide habitable floor spaces on second storeys and requirements to locate electrical switchboards and fixed electrical installations at a minimum level of 500mm above the 1% AEP flood level.

Recommendation

- Continue to provide requirements for flood proofing and flood compatible design of individual buildings as development controls in the DCP
- Promotion of flood proofing measures should also be included in flood education and awareness programs.

9.2.4 Planning and development controls

Land use planning and development controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Planning controls including flood planning levels, flood related development control plans and restrictions on permissible types of development in different parts of the floodplain are recommended to ensure that development in the study area occurs in an appropriate manner in relation to flooding.

Key proposed updates on planning and development controls include:

- Development of a new standalone Flood Policy document that will replace Section B7 in the DCP. The standalone Flood Policy will allow for more detailed definition of the flood related development controls. Site-specific controls for the various villages could be outlined, based on outcomes from this Lower Macleay FRMS.
- Flood mapping, design flood levels, flood planning levels/areas and climate change flooding information developed in this Lower Macleay FRMS is proposed to be adopted for the whole Lower Macleay area to update the LEP, DCP and Flood Policy:
  - It is a floodplain-wide dataset, while the current LEP 2013 and DCP 2013 utilise a range of datasets from different previous flood studies. Using the floodplain-wide dataset will allow consistency in the design flood levels and flood planning levels and avoid potential ambiguity when applying the design flood information from the previous patchwork of flood studies and mapping.
  - The previous flooding datasets are based on the superseded Australian Rainfall and Runoff (ARR) 1987 hydrologic guidelines and design flood flows, while this Lower Macleay FRMS design flooding dataset is based on the current ARR 2019 hydrologic guidelines and updated design flood flows in the Macleay River. Hence, the Lower Macleay FRMS design flood levels have been defined based on the current flood analysis guidance.
  - Flooding conditions in the year 2100 future and ongoing climate change scenario are defined by this Lower Macleay FRMS, which will be used to guide flood planning in the Lower Macleay. The previous studies relied on by LEP 2013 and DCP 2013 did not utilise the current guidance on climate change impacts to flooding.
- Note that the recommended actions and measures in currently adopted studies including the Kempsey CBD FRMS (WMAwater, 2017) would remain valid.

With respect to the review of the existing Council policies and planning controls in Section 7.3, a number of updates to LEP 2013, DCP 2013 and Section 10.7(2) Certificates are recommended below.

Recommendation

- Develop Flood Policy for development types. The amended DCP will refer to the new Flood Policy standalone document.
- Update LEP 2013 to include the floodway/flood storage and flood planning level mapping presented in this FRMS.
- Update DCP 2013 to include the floodway/flood storage mapping presented in this FRMS.
- Update the DCP 2013 to include the flood planning levels and flood planning area mapping presented in this FRMS,
- The flood mapping, design flood levels and other outputs from this Lower Macleay FRMS are to be used as the basis for all flood planning and development controls in the Lower Macleay area, given that it provides a spatially continuous dataset based on the current ARR 2019 hydrologic guidelines and design flood flows in the Macleay River. Retaining the currently adopted flood planning datasets means utilising outdated information of a patchwork nature, which may lead to difficulties in administering the flood planning controls. Given the projected increases in peak flood levels in the Lower Macleay due to ongoing and future climate change, it is recommended for Council to re-define the flood planning level in future revisions of the DCP based on the design 1% AEP flood level under climate change scenario. The area covered by the flood planning level under a climate change scenario will be larger than that for the existing climate flooding conditions. It is noted that Council has already resolved to adopt the maximum level of the 1% AEP current day flood level with 500mm freeboard and the 1% AEP year 2100 flood level as the flood planning level.
- Update of DCP 2013 could consider reference to the AIDR flood hazard categories and the flood hazard mapping that are presented in this FRMS. The current DCP refers to velocity – depth product as an indication of hydraulic hazard conditions.

- Restricting new development to areas of H4 flood hazard and lower in the 1% AEP event would be generally consistent with the development conditions relating to hydraulic hazard in the current DCP 2013.
- Council should consider whether climate change flooding conditions should be adopted for the various development controls.
- Remove the currently defined Bellimbopinni and Seven Oaks floodway area from the DCP, as these appear to be based on historic anectodal reports and do not match flooding conditions in this FRMS.
- Review the requirement in the DCP for a separate detailed flood study for proposed development on specified lots in the South West Rocks New Entrance floodway area. The modelling and flood mapping outputs from this FRMS could be referenced for these lots.
- "Flood prone land" as defined in DCP 2013 refers to the land which is inundated during a 1% AEP flood. This definition should be updated to refer to the land which is inundated in the PMF, that is, land which would be subject to inundation by the full range of flood magnitudes. This latter definition would be consistent with that provided in the Flood Risk Management Manual 2023.

9.2.5 Rezoning

Review of the current land zoning in the study area indicates that there are no floodway areas which have been defined for the existing climate flooding conditions occurring on incompatible land use zones including residential (except floodways for some tributary watercourses and fringe of Macleay River floodway on R5 zoning), commercial or industrial. Floodways typically occur on land zoned rural, recreational, environmental conservation or other compatible land uses.

Land within the Kempsey CBD Floodway no.1 which currently has historic residential and commercial development has previously been rezoned E2 Environmental Conservation, as a part of the ongoing floodway clearance program.

For the year 2100 climate change scenario floodway areas, there would be some residential and commercial zoned properties that become affected by the floodway around Verge Street and Eden Street, adjoining the currently defined Kempsey CBD floodway.

Based on the above, no further rezoning of land for flooding compatibility is recommended with respect to current climate flooding conditions. Rezoning may be considered in the future to account for increased flood hazard and flood risk due to future and ongoing climate change.

9.2.6 Relocation of neighbourhoods

One of the recommendations of the NSW Flood Inquiry was for facilitating the relocation of communities most at risk from flooding to lower risk locations with good homes and amenities. This action has been conducted following the 2011 Queensland floods with the relocation of 90 households from Grantham, and is under planning for relocation of around 400 dwellings in East Lismore, NSW, following the 2022 flood event. The objective of relocating neighbourhoods and villages is to reduce populations at risk of highly hazardous flooding from the floodplain, hence reducing potential loss of life and property flood damages. This would involve a coordinated scheme of voluntary purchase of existing properties and establishment of new settlements outside of the floodplain. A suitable site for a new settlement would need to be identified for such a scheme.

Smithtown would be the most likely candidate in the Lower Macleay for village relocation based on its location and exposure to flooding, although most of the village is not subject to high velocity flood flows and flood warning times are in the range of 12 – 24 hours rather than rapid-rising flash flooding. At this stage, the village is not considered further for village relocation.

9.3 Response modification measures

9.3.1 Flood warning systems

BOM flood forecasting and warning system

The Macleay catchment currently has a flood forecasting and warning system administered by BOM that issues Flood Watch and Flood Warning messages for the catchment, refer to Section 8.2.1. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided by the BOM (who then prepare and provide flood forecasts) to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods). Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BOM (refer flood awareness in Section 9.3.8).

Kempsey Shire Council – Macleay Catchment total flood warning system

Council also operates a total flood warning system which is based on rainfall and flood level data from numerous recording gauges in the catchment upstream of Kempsey, refer to Section 8.2.2. This provides a finer detail warning system that is more closely tailored to the local catchment and emergency management setting with Council and SES. The gauges are owned and operated by a number of different agencies and hence there is potential for inconsistency in upkeep of maintenance of the gauges and telemetry systems. The NSW flood Inquiry 2022 made the recommendation:

> *"That, to provide more accurate and complete data for flood threat identification, warning and modelling systems, Government through the proposed new NSW Reconstruction Authority (NSWRA) work with the Australian Government to improve the rain and river gauge network by … working to transfer ownership and maintenance responsibility for as many of the river and rain gauges as possible in NSW to the Bureau of Meteorology".*

There would be benefit to transfer ownership and operation of all rainfall and water level gauges in the Macleay Catchment total flood warning system to BOM. Consistency in the type/technology and quality of equipment used, the frequency of updating data on the BOM website and consistency in implementation of maintenance programs are important considerations. Consistency of application across the state also means the community have confidence in the level of service provided, as do forecasting and responding agencies irrespective of the catchment they are looking at. A single responsible authority is essential and a consistent whole of catchment-based approach implemented across NSW.

If ownership and operation of the total flood warning system gauges is transferred to BOM, Council and local SES should remain as a key stakeholder in the operation of the total flood warning system.

Flash flood warning system

While the flood risk in the Lower Macleay is dominated by riverine flooding, there are a number of local watercourses in the study area which may contribute to local catchment or flash flooding. Flash flood catchments are those defined as catchments in which less than six hours may elapse between heavy rainfall and flooding. Flash flooding usually results from relatively short intense bursts of rainfall, commonly from thunderstorms. This is problematic in urban areas where drainage systems may not cope. Flash floods tend to be quite local and it may be difficult to provide effective warning because of their rapid onset. The local watercourses in the study area include Christmas Creek, Collombatti Creek, Maria River, Smiths Creek and Pipers Creek, among others.

A flash flood warning system has been implemented in Dungog township, NSW, in response to the April 2015 flood event during which three residents lost their lives due to flash flooding from Myall Creek, adjacent to the town. The system is based on a water level gauge installed in 2020 in the town, which sends alerts to emergency services as water levels rise and sounds a siren when water levels reach the first house to be flooded. The siren

may sound earlier if water is rising quickly. In April 2015, flood levels rose at rates of 3m per hour (https://www.dungog.nsw.gov.au/Build/Flood-Plain-Management/Dungog-Township-Flood-Warning-System).

While further hydrologic investigation would be required to confirm the need for and feasibility of a flash flood warning system for local watercourses in the Lower Macleay, initial assessment indicates that such a system is not required:

- There are no concentrated settlements or villages located adjacent to the high flood hazard areas of the Lower Macleay local watercourses. The watercourses generally flow through rural or open space areas. A siren system would need to be spread out to service a dispersed population.
- Existing dwellings along the local watercourses appear to generally be outside the 1% AEP flood extent.

Hence, a flash flood warning system for local watercourses in the Lower Macleay is not recommended at this stage.

Flood warning messaging and communications

The Council flood information webpage provides links to latest information on rainfall and water level on the BOM websites, and Council latest news and information on emergencies including near real-time flood bulletins during flood events. This communication channel forms a part of the total flood warning system.

The Macleay total flood warning system operates by Council technical and operations officers reviewing relevant information of flooding conditions, road closures and conditions etc, and then preparing flood bulletin messages for dissemination. These draft messages are sent to the communications officers who then post the flood bulletins to Council website and social media and other channels. During the March 2021 flood event it was observed that on some occasions there were inconsistencies between the flood bulletin messages and conditions on the ground, such as road closures. This is not unexpected when conditions are rapidly changing during the course of a flood event, however, it is recommended that opportunities should be investigated to improve the efficiency of flood update messaging and reduce the lag between on-ground activities and communications.

Use of social media and SMS text messaging to mobile phones of residents for flood updates is currently undertaken by Council. Checks for gaps in mobile coverage in the study area and opportunities considered to improve coverage, where necessary, should be undertaken.

Council should update their flood message recipients list regularly, particularly to include any new residents to the study area who are not likely to be familiar with the flooding behaviour and flood messaging system. Inclusion onto the recipients list is currently voluntary. Council should review their lists of new ratepayers/ property owners or other relevant lists and send out invitations to join their flood message recipients list.

Council's flood information and cameras webpage (https://www.kempsey.nsw.gov.au/Your-Valley/Disaster-emergency/Flood-information-cameras. Accessed 15/04/2024) includes webcams of Kempsey Traffic Bridge and Sherwood Bridge that provide visual updates of flooding at these locations at 30 minute or hourly intervals. In flood events, the last daylight image will stay on the web page until the first image is captured on the following day. A webcam was also previously set up for Turners Flat Bridge, but is currently inactive.

Recommendations

- It is recommended that Council advocate for the transfer of ownership and operation of the total flood warning gauge network to BOM. If ownership and operation of the total flood warning system gauges is transferred to BOM, Council and local SES should remain as a key stakeholder in the operation of the total flood warning system.
- Opportunities should be investigated to improve the efficiency of Council's total flood warning system messaging and reduce the lag between the reporting of on-ground activities/conditions and communications.

- Consider improvements to social media and SMS flood messaging system including checks of gaps in mobile coverage and investigate improvements in coverage gaps, and regular update of flood message recipients list.
- Consider improvements to the live flood monitoring webcams including installing/reinstating Turners Flat Bridge Webcam and Bellbrook Bridge Webcam.
- Maintain Council's flooding website and its links to real-time flood information and warnings, and Council's own flood messaging system.

9.3.2 Stock refuge mounds and other landform shaping considerations

A review of the applicability of stock refuge mounds as a flood risk mitigation measure was undertaken for the Macleay in the *Kempsey CBD Flooplain Risk Management Study* (WMAwater, 2017), and is discussed here. Flood refuge mounds are used as an effective means of reducing losses during a flood and are useful as a last resort evacuation for communities and stock during a flood. They are widely used on floodplains in New South Wales and can provide some benefit for isolated areas and the rural farming properties situated on the Macleay River.

Flood refuge mounds should only be considered for stock where access to high ground can be cut early or is far away. Flood refuge mounds can cause localised flow diversions or increases in flood levels. Flood refuge mounds should therefore be located as much as possible in line with the flow path (minimising any obstructions to flow paths) and utilise existing high ground. Flood refuge mounds should not be constructed in floodway zones. For large rural properties it is unlikely these impacts would extend far enough to affect neighbouring properties. However, in accordance with Council policy this should be confirmed for all proposed flood mounds.

Flood mounds are not built to the PMF level and so some residual risk exists. Flood mounds should be treated as a back-up plan not a primary evacuation plan. If an event turns out to be larger than expected, then evacuation would be required.

The cost to construct the mounds depends entirely upon the availability of fill material. Funding under the NSW Floodplain Management Program is unlikely to be available for these works and they are usually funded by the individual proponent.

Flood refuge mounds for stock only are suitable mitigation options for the rural floodplain upstream and downstream of Kempsey. A number of stock mounds were built downstream of Kempsey as mitigation measures for the Kempsey Bypass. These were built to the 5% AEP flood level. Given the depth of floodwaters on the floodplain the mounds would need to be over 3m high, if provided on higher points on the floodplain, to provide refuge in a 1% AEP event.

Flood refuge mounds are suitable mitigation options for stock only for the floodplain upstream and downstream of Kempsey. Stock flood mounds should be treated as a back up plan not a primary evacuation plan. In accordance with Council policy the impact of flood mounds on neighbouring properties should be confirmed for all proposed flood mounds.

Other land filling and agricultural land shaping on rural lands also has the potential to affect flood behaviour with resultant impacts to adjacent properties. Council should consider whether flood impact and mitigation assessments should be undertaken for agricultural land shaping on rural properties.

Recommendation

Council should continue with its policy of requiring property owners wishing to build stock flood refuge mounds to prove that the mound will not impact on surrounding properties.

Council should consider whether flood impact and mitigation assessments should be undertaken for agricultural land shaping on rural properties.

9.3.3 Improvements to flood access routes

Many of the flood access routes in the Lower Macleay are low-lying and become cut in frequent flooding events. Improving the flood immunity of existing flood access routes has been considered, and detailed assessment of selected routes is discussed in Appendix F.2, Appendix F.3 and Appendix F.4. Routes selected for assessment in this study include Crescent Head Road and Hat Head Road. The previous *Kempsey CBD FRMS* (WMAwater, 2017) also considered raising of South West Rocks Road.

9.3.4 Kempsey Second Bridge Crossing

A separate body of work, including preparation of concept design and business case, has been completed in tandem investigating the potential of a second bridge crossing of the Macleay River. The proposed second bridge would cross the Macleay River upstream of the existing railway bridge, connecting Queen Street on the southern bank to Tozer Street or River Street on the northern bank.

A problem which would be addressed by this proposal is the existing traffic congestion around the Kempsey Traffic Bridge. It would also provide better connectivity between West and South Kempsey along with added benefit of addressing flood risk by providing critical linkages in times of flooding including for emergency services via the proposed relocated Emergency Operations Centre (refer to Section 9.3.6) and the hospital. The new access route would provide flood-free access in moderate to major flood events between the M1 Pacific Highway, South Kempsey and West Kempsey by bypassing Kempsey CBD and the CBD floodway, which would be flooded in major flood events. The new route would link up with River Road and Spooners Avenue, providing a flood-free route during flooding for rural landowners and agricultural farmers based to the north and west of Kempsey.

The proposed second bridge crossing is within the Kempsey CBD Flood Risk Management Plan study area (WMAwater, 2017), however, it was out of scope at the time of that study. Council should continue to advocate state for a second bridge crossing to improve flood immunity and flood access.

Recommendation

Council should continue to advocate for the Second Bridge Crossing.

9.3.5 Flood depth marker and signs

Flood depth marker signs are recommended for key road low points primarily to warn drivers of the flood hazard during a flood event and reduce occurrences of people driving into floodwaters. Flood depth signage also acts as a passive reminder to residents of the potential for flooding in their neighbourhood streets. Figure D-1 in Appendix D identifies 37 key road low points in the study area which become first flooded along those stretches of roads in the 50% to 10% AEP flood events. It is recommended that flood depth marker signs be installed in these locations at a minimum.

Residents in the study area also reported that a number of previously installed flood depth marker signs on some key roads had gone missing. Council should investigate the locations of these missing old flood depth signs and reinstall signs in the same locations.

During recent flood events it was also reported that residents and visitors had attempted to drive out of the study area villages including Crescent Head, travelling some distance down the road only to encounter the road being cut by flooding. It is likely there was difficulty in performing U-turns to return to the village due to narrow road widths and traffic. There are a number of locations which would benefit from new flood signs with messaging to indicate that the road access out of the village is cut by flooding.

Recommendation

It is recommended for flood depth marker signs to be installed at keyroad low points.

It is also recommended that flood signs be installed at selected locations to indicate that the road ahead is cut by flooding. Key locations include Crescent Head Road east of The Corduroy and west of Rudders Lagoon, and Hat Head Road west of the village.

9.3.6 Relocation of emergency services facilities

Emergency management in Kempsey is run out of two main centres as follows:

- **Emergency Operations Centre**
  Co-located with Kempsey Police Station
  5 Elbow Street
  West Kempsey NSW 2440
- **Kempsey Fire Control Centre**
  Co-located with Kempsey SES
  North Street/River Street
  West Kempsey NSW 2440

The current EOC is in the vicinity of the CBD area and has a 1% AEP flood immunity while the Kempsey Fire Control Centre is located above the PMF level. Council is currently investigating options to co-locate the EOC within the FCC/SES property. This would make the EOC flood-free and would substantially improve the operability of the EOC during flood events. It is proposed that the EOC would be the combined centre for flood and fire emergency management in the Macleay. Placing them on the same premises would promote improvements in cross-agency communication and coordination during flooding and bushfire emergencies.

Recommendation

Council should continue to investigate options and the viability of co-locating the Emergency Operations Centre (EOC) with the Kempsey Fire Control Centre/SES at its site on North Street/ River Street, West Kempsey.

. The EOC would serve as the centre for both flooding and bushfire emergency management activities. Relocating the EOC to the FCC site would significantly improve the flood immunity and operability of the centre during flood events.

9.3.7 Update of Emergency Planning and Management

As discussed in Section 8.1, flood emergency planning is currently addressed in the Kempsey Flood Emergency Sub-Plan. Upon completion of this current floodplain risk management study and plan, the Sub-Plan should be updated with consideration of the information and findings of this study on the flooding behaviour for Lower Macleay.

Revision of the Sub-Plan and preparation of new responsibilities, systems and procedures should be undertaken with input from all key stakeholders. Any organisational and responsibility changes forthcoming from the NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be incorporated into future revisions of the Sub-Plan.

Recommendation

It is recommended that Kempsey Flood Emergency Sub-Plan be updated incorporating the findings of this study.

9.3.8 Flood education, awareness and readiness

Flood education and awareness should continue to be promoted throughout the study area. Measures may include promotion of NSW SES FloodSafe brochures and website (https://www.ses.nsw.gov.au/disaster-tabs-header/flood/). Council's website already promotes the flood education, awareness and readiness information with links to the SES website.

Council and SES already run community workshops within the Macleay to help residents learn how they can prepare their property for floods and storms, including hands-on skills and resources from the Kempsey Shire SES unit to help in preparing for emergencies.

Community consultation during this study indicated that while many landowners in the study area are long term residents who have experienced previous floods and are generally familiar with flood behaviour in their area, there are newly arrived residents who have recently moved into both rural and urban areas of the study area. These new residents typically did not have knowledge of the flooding conditions and generally relied on established neighbours to understand the flooding issues. Council should investigate opportunities for flood education and promote flood awareness with new residents, such as mail-out of information packages that provide links to key flooding information:

- Council flooding website
- Overview of available sources of flood information before/during a flood (BOM, SES, Council flood bulletins, Council email, SMS and social media recipients lists)
- Overview of resources for flood awareness, readiness and post-event recovery available from Council and other agencies
- Invitation and details to join relevant flood mailing lists.

As previously discussed, it is recommended Council regularly update of flood message recipients list to minimise gaps in disseminating communications to the community.

Council should consider future inclusion of a requirement in the flood planning instruments for flood awareness and education materials such as flood information posters/brochures outlining Lower Macleay flood risks, evacuation routes, template flood emergency plan (similar to bushfire plan) key organisation (SES, emergency services) phone numbers, Council flood website and other flood info sources, to be displayed at high risk premises including temporary visitor accommodation and for distribution to new permanent residents. Council would prepare the standard information posters/brochures in consultation with SES.

Council should update the flood mapping extents shown on their interactive mapping portal to present the latest available information. As at mid-April 2024, the portal was already being updated with latest flood mapping (https://kempsey.maps.arcgis.com/apps/webappviewer/index.html?id=1e06f4bc67744a36961b6886b010d296. Accessed 17/04/2024).

A flood education and awareness program is recommended to be developed/maintained by Council which outlines and schedules various flood education methods to be implemented (e.g. brochures, news articles highlighting previous flooding, SES events, Council web pages etc.). The program should be reviewed on a regular (e.g. 2 – 5 year) cycle to assess the effectiveness of the program, reinvigorate flood awareness in the community and plan the roll-out of new flood information as it becomes available.

Recommendation

In general, continue to promote flood awareness and readiness in the community. Measures may include:

- Promotion of SES FloodSafe brochures to help residents understand the flood risk and prepare their property and personal plans for a flooding event.
- Continue to undertake community flooding and emergency planning education events in coordination with SES

- Consider future inclusion of a requirement in the flood planning instruments for flood awareness and education materials such as flood information posters/brochures outlining Lower Macleay flood risks, evacuation routes, template flood emergency plan (similar to bushfire plan) key organisation (SES, emergency services) phone numbers, Council flood website and other flood info sources, to be displayed at high risk premises including temporary visitor accommodation and for distribution to new permanent residents. Council would prepare the standard information posters/brochures in consultation with SES.
- Maintain Council's flooding website with flood education, awareness and readiness information.
- Regular updates of flood information and messaging recipients list.
- Mail-out of flooding information packages to new residents to maintain flood awareness and minimise gaps in disseminating communications to the community.
- Update the interactive mapping portal with latest flood mapping when these are updated and become available.
- Develop and maintain a flood education and awareness program to plan out various flood education and awareness activities. Review implementation and effectiveness of program on regular (e.g. 2 – 5 year) cycle.

9.4 Flood modification measures

9.4.1 Location-based mitigation works

A range of location-based mitigation measures have been assessed. Refer to Section 10 for details.

9.4.2 Maintenance of existing drainage assets

Identified key drainage asset maintenance issues include:

- Cleaning and maintenance of floodplain drains under Council's ownership is required to ensure the drains function properly at the end of a flood event to discharge of remaining water on the floodplain.
- Roadworks and earthworks should be undertaken so as not to degrade the capacity of drains due to misplacement of earth spoil.
- Some floodgates may be old and towards end of life, with flap gates prone to debris blockage or otherwise not sealing properly and allowing saltwater to back up into drains and the floodplain. Some flaps are heavy metal build which require higher headwater to open them. These may require replacement with newer lighter weigh plastic flaps for more efficient drainage.
- Clearing of vegetation and accumulated sediment at the upstream end of Ryans Cut is currently required to reinstate efficient drainage of Upper Belmore floodplain.
- More frequent clearing of beach sand from Big Hill Creek outlet is required to ensure it drains freely during a flood event. Sand buildup on the beach side of the outlet can prevent the culvert flap gates from opening.
- However, it should be recognised that the minor creek outlets are relatively small and have a flow capacity of only a minor portion of the total flood flows in the Macleay. While maintenance of the creek outlets will help to drain remaining flooding at the end of a flood event, maintaining their full flow capacity would not mitigate peak flood levels in the Lower Macleay, compared to a less maintained condition.

Council's drainage maintenance program should continue to ensure priority maintenance of key assets for flood management.

Recommendation

Council continue to complete maintenance of Flood Mitigation Structures and gain state funding to support mainteance programs where applicable.

10. Assessment of location-based mitigation measures

10.1 Overview

A number of potential mitigation measures were initially identified for consideration based on review of the existing flooding behaviour and impacts, consultation with Council staff and previous consultation with the community during the Lower Macleay Flood Study (Jacobs, 2019). The initial list of options was then workshopped with the Flooding Reference Group and the community providing input and feedback, with a finalised list of 17 options selected for detailed assessment based on this consultation. Note that the finalised list of options only nominates the options for assessment of their benefits and costs and does not guarantee that all the options will be recommended for implementation.

Following the selection of the finalised list of options for detailed assessment, the following assessments were undertaken:

- Testing in the TUFLOW hydraulic model to estimate changes in flood conditions (increases and decreases in flood levels and durations of flooding)
- Estimate of building flood damages with the options, and savings in building flood damages compared to the base case
- Count of individual buildings which become no longer flooded or newly flooded with the options
- Estimate of savings in agricultural damages
- Estimate of other economic benefits of the options
- Cost estimates for implementation of the options
- Cost estimates of options
- Economic appraisal of benefits and impacts including cost-benefit assessment over the life of the options
- Multi-criteria analysis of options.

Recommended options were selected based on the above assessment outcomes.

The focus of the identified potential options is on the Lower Macleay floodplain. The Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017) primarily considered options for mitigating flood risk around the CBD, and it is not the focus of this current study to revisit these CBD-area options.

10.2 Description, benefits and constraints of assessed options

Most of the assessed options are aimed at reducing the time to drain the floodplain following a flood peak. Two large-scale options aim to reduce peak flooding in the Macleay. Some options consider improvements to flood access, with hydraulic modelling undertaken to assess potential resultant impacts.

Table 10-1 provides a summary of the 17 options that were assessed including their advantages, benefits, constraints and impacts. Modelling of the options was undertaken in the TUFLOW model to identify the beneficial changes to flooding, or any impacts to flooding. Appendix F provides detailed description and illustration of each of the options, discussion on constraints in addition to the flood modelling results (changes in flood levels and durations) and effects on flooding of buildings.

Discussion on the cost estimates is provided in Section 10.3.1. The economic appraisal is discussed in Section 10.3.2. Multi-criteria assessment and the overall results of the assessment including constraints, impacts and benefits are provided in Section 10.3.4. A summary of the assessment is provided in Section 10.7. A number of options that were not considered further are outlined in Section 10.5 and Section 10.6.

Table 10-1: Summary of assessed options – Description, benefits and constraints

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
Option 1 Refer Appendix F.2	Raise Crescent Head Road to 3.2m AHD + no drainage upgrade	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is substantially reduced.	• Requires implementation in combination with Option 1B to realise full benefit (road would remain cut at Rudders Lagoon) • Traffic impacts during construction phase • Potential works in and adjacent to environmentally sensitive areas (E2 Environmental Conservation zoning, koala management plan area) • Impacts to existing underground and above ground utilities • Likely acid sulfate soils and challenging geotechnical conditions.	• Improved road flood immunity from less than 50% AEP to 10% AEP • Reduced duration that road is cut in 5% and 1% AEP events by 170hrs • *Increase in peak flood levels of 0.2m in the 20% AEP event, up to 0.35m in the 5% AEP event and up to 0.1m in the 1% AEP event.* • *Increases in peak flood levels of 0.04 – 0.1m in the 20% AEP event extend to Kinchela.* • *Increases in peak flood levels of 0.04 – 0.07m in the 5% AEP event and up to 0.02m in the 1% AEP event extend across the Lower Macleay floodplain, up to Stuarts Point* • *Increased duration of flooding on properties by up to 24 hrs* • *Up to 14 residential buildings and one commercial building newly flooded above floor in 1% AEP event. Increased duration of flooding on properties by up to 24 hours.* • Reductions in peak flood levels to the south of the road of up to 0.06m in the 20% and 1% AEP events and up to 0.2m in the 5% AEP event
Option 1A Refer Appendix F.2	Raise Crescent Head Road to 3.2m AHD + 1000m of viaduct	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is substantially reduced. • Provision of viaduct allows floodwaters to drain across Crescent Head Road more freely compared to existing case and to Option 1.	• Requires implementation in combination with Option 1B to realise full benefit (road would remain cut at Rudders Lagoon) • Traffic impacts during construction phase • Potential works in and adjacent to environmentally sensitive areas (E2 Environmental Conservation zoning, koala management plan area) • Impacts to existing underground and above ground utilities • Likely acid sulfate soils and challenging geotechnical conditions requiring management during construction.	• Improved road flood immunity from less than 50% AEP to 5% AEP • Reduced duration that road is cut in 5% and 1% AEP events by 200hrs • Minor increase in peak flood levels of less than 0.01m in the 20% AEP event and 0.02 – 0.03m in the 10% and 1% AEP events. • *Increase in peak flood levels of up to 0.06m in the 5% AEP event* • Reductions in peak flood levels to the south of the road of up to 0.06m in the 20% and 1% AEP events and up to 0.2m in the 5% AEP event • Reduced durations of flooding by 8 – 10hrs • No change to numbers of residential and commercial buildings with above floor flooding
Option 1B Refer Appendix F.3	New emergency access from Crescent Head Road to Pacific Highway	• Provide new on and off ramps on Pacific Highway to Crescent Head Road to bypass flooding of Crescent Head Road at Rudders Lagoon. Local road roundabout on Crescent Head Road to allow traffic to turn around at flooded section of road • Operate as emergency access during flood events only • Improve road access flood immunity from less than 50% AEP to at least 5% AEP and potentially up to 1% AEP • Good potential for financial contribution from Transport for NSW for construction of option	• Traffic impacts on Pacific Highway during construction phase • Property acquisitions • Road geometry of on/off ramps likely to require reduced speed limits on Pacific Highway during operation in flood events. Fully compliant road geometry with no requirement of reduced speed limit on highway could be investigated although cost of option likely to be increased. • Requires further consultation with TfNSW to confirm design and operational details, permissibility of works.	• Nil impacts to flooding. Option 1B is outside of flood extent and would not change flood behaviour. • No change to numbers of residential and commercial buildings with above floor flooding
Option 2A Refer Appendix F.4	Raise Hat Head Road to 2.3m AHD + 200m culverts/floodway	• Road flood immunity is increased from existing case • In flood events where the raised road is flooded, the duration of flooding is reduced. • Improved conveyance of floodwaters across Hat Head Road in small flood events	• Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Potential impact to internal access road for the private property	• Improve road flood immunity from less than 20% AEP to about 10% AEP. • In the 1% AEP event, the duration of flooding of the road would decrease from 150 hours in the existing case to 100 hours with Option 2A.*Increase in peak flood levels of 0.35m in low-lying areas to the north of Hat Head Road in the 20% AEP event with corresponding increase in duration of flooding exceeds 100 hours.* • Negligible increases in peak flood levels to the north of Hat Head Road in the 10%, 5% and 1% AEP events, although the *duration of flooding*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
				increases by about 10 hours in the 1% AEP event and up to 24 hours in the 10% AEP event. • To the south of Hat Head Road, peak flood levels decrease by up to 0.1m in the 20% AEP event and up to 0.01m in the 10% AEP event. Duration of flooding decreases by 10 – 24 hours. • No change to numbers of residential and commercial buildings with above floor flooding
Option 3 Refer Appendix F.5	Disconnect Korogoro and Killick Creek	• Closing of the existing floodgates on Korogoro Creek and Killick Creek, with additional bunding earthworks on the creek banks and raising of existing drainage structures to prevent floodwaters overtopping in 1% AEP event. • Reduced/eliminated risk of blackwater events and fish kills in the creeks due to floodplain drainage • Reduced flood levels in parts of Hat Head and Crescent Head villages.	• Potential impacts to depth of creek entrances and navigability due to reduced tidal scouring needs to be considered.	• *Flood levels increase by up to 0.07m in the 10% AEP event and 0.1 – 0.15m in the 5% and 1% AEP events. Increases in flooding extend across much of the Lower Macleay floodplain. The greatest increases in peak flood levels occur around Crescent Head Road at The Corduroy.* • *Increase in duration of flooding on Macleay floodplain by 8 – 15 hours* • Flood levels are reduced in Hat Head village by typically more than 0.05m (up to 0.16m on some properties) in the 5% AEP event and 0.05 – 0.13m in the 1% AEP event • Properties along Killick Creek in Crescent Head would experience reductions in peak flood levels of 0.05m in the 1% AEP event. *Increases of 0.15m on properties in the western portion of village* • Up to 49 individual residential buildings, mainly in Hat Head and Crescent Head, would no longer be flooded above floor in the 1% AEP event. • *However, up to 23 individual residential buildings and one commercial building would experience new above floor flooding in the 1% AEP event. These buildings are located on the Macleay floodplain.*
Option 4 Refer Appendix F.6	Widen Loftus Road Ryans Cut crossing	• Doubled flow capacity at Loftus Road crossing at Ryans Cut reduces peak flood levels and duration of flooding on parts of Macleay southern floodplain	• Works required in Hat Head National Park • Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Unlikely to result in increased risk of blackwater event and fish kills in Ryans Cut lagoon, but may require further investigation.	• Reduces duration of by 13 – 30 hours in parts of the southern Macleay floodplain for the 10%, 5% and 1% AEP events. Durations are reduced by 6 – 30 hours in the 20% AEP event. • Reduction in peak flood levels by 0.02 – 0.06m on the southern floodplain in the 10% AEP event, and by 0.02 – 0.04m over the broader Lower Macleay floodplain area in the 5% and 1% AEP events. • *Localised increases in peak flood levels of 0.2 – 0.3m in the 5% and 1% AEP events east of Loftus Road and north of Crescent Head, but these increases in peak flood levels do not affect any buildings.* • Up to 13 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 4b Refer Appendix F.7	Widen Loftus Road Ryans Cut crossing and extend Ryans Cut to Belmore River	• Doubled flow capacity at Loftus Road crossing at Ryans Cut reduces peak flood levels and duration of flooding on parts of Macleay southern floodplain • Additional low-level drainage of low areas around Belmore River • Some additional drainage capacity of Macleay River via direct connection from Ryans Cut to Belmore River (minor).	• Works required in Hat Head National Park • Traffic impacts during construction phase • Impacts to existing underground and above ground utilities • Potential property acquisitions • Likely acid sulfate soils at this location requiring management during construction • Unlikely to result in increased risk of blackwater event and fish kills in Ryans Cut lagoon, but may require further investigation. • Effects on risk of blackwater events around Belmore River uncertain. • Increased drainage capacity of Macleay River direct to Ryans Cut is constrained by the natural form of Belmore River, which	• Reduces duration of by 15 – 38 hours in parts of the southern Macleay floodplain for the 10%, 5% and 1% AEP events. Durations are reduced by 15 – 31 hours in the 20% AEP event. • Reduction in peak flood levels by 0.02 – 0.1m on the southern floodplain in the 10% AEP event, and by 0.02 – 0.04m over the broader Lower Macleay floodplain area in the 5% and 1% AEP events. • *Increase in flood levels and extents on about 10 properties along Belmore River in the 20% and 10% AEP events.* • *Localised increases in peak flood levels of 0.2 – 0.3m in the 5% and 1% AEP events east of Loftus Road and north of Crescent Head, but these increases in peak flood levels do not affect any buildings.*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
			narrows with distance upstream of the headworks. The proposed widened Loftus Road crossing is also a constraint.	• Up to 12 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 5 Refer Appendix F.8	Increased Floodplain Drainage Capacity	• Has potential to reduce durations of inundation on the Macleay floodplain	• Requires modification to numerous aging drainage structures and floodgates. Condition assessment required. • High potential for increased risk and frequency of occurrence of floodplain acid runoff, blackwater events in receiving waterways and fish kills. Requires further investigation and identification of mitigation strategies.	• Negligible changes to peak flood levels • Negligible change to duration of flooding on most of the floodplain • Reductions in duration of flooding of around 20 hours in parts of the floodplain in Summer Island, however, the area experiencing benefits is small.
Option 6 Refer Appendix F.9	Reinstate Rowes Cut	• Diverts floodwater outflows through new outlet to the ocean • Reduces flooding in Hat Head village • Potential to reduce/eliminate blackwater runoff through Hat Head village due to new outlet	• Works required in Hat Head National Park • No direct road access for construction and maintenance but access could be made via beach from Hat Head village • Ongoing maintenance required to maintain the channel profile.	• Peak flood levels in Hat Head village are reduced by up to 0.04m in the 5% AEP event and 0.07m in the 1% AEP event. • Reductions in flood levels of up to 0.1m occur in Korogoro Creek and vegetated areas • Minor reduction in durations of flooding of 9 – 16 hours for the 10%, 5% and 1% AEP events on parts of Macleay southern floodplain • Up to 47 individual residential buildings would no longer be flooded above floor in the 1% AEP event.
Option 7 Refer Appendix F.10	Enlarge headworks on Belmore and Kinchela	• Has potential to reduce durations of inundation on the Macleay floodplain	• High potential for increased risk and frequency of occurrence of floodplain acid runoff, blackwater events in receiving waterways and fish kills. Requires further investigation and identification of mitigation strategies.	• Negligible changes to peak flood levels in the 10%, 5% and 1% AEP events • In the 20% AEP event, there are increases in peak flood levels of 0.01 – 0.05m in areas downstream of Kinchela
Option 8A Refer Appendix F.11	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads	• Potential to reduce flooding on Macleay southern floodplain • Raising of roads would improve flood access along Belmore River and Kinchela Creek banks • Opportunity to upgrade the Belmore River and Kinchela Creek flood control structures to be operated remotely	• Condition assessment required for existing flood control structures • Impacts to property access from raised roads. Property acquisition may be required	• Reductions in flood levels of up to 0.1m on the southern floodplain in the 20% AEP event • *Increased flood levels in Belmore River, Kinchela Creek and the Macleay River, resulting in increased river overflows and increased flood levels by up to 0.1m elsewhere in the 20% AEP event.* • *In the 10% and 5% AEP events the reductions and increases in flood levels on the floodplain are generally less than +/-0.05m, but there are remaining increases in flood levels in Belmore River and Kinchela Creek which affect the properties along the banks of those waterways.* • Minimal change in peak flood levels in the 1% AEP event. • One individual residential building would no longer be flooded above floor in the 20% AEP event. No change in other events.
Option 8B Refer Appendix F.11	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads and SWR Road + additional levee	• Potential to reduce flooding on Macleay southern floodplain • Additional road raising and levees would further reduce overflows onto floodplain • Raising of roads would improve flood access along Belmore River and Kinchela Creek banks and parts of South West Rocks Road • Opportunity to upgrade the Belmore River and Kinchela Creek flood control structures to be operated remotely	• Condition assessment required for existing flood control structures • Impacts to property access from raised roads and levees. Property acquisition may be required	• Reductions in flood levels of over 0.1m in the 20% AEP event and 0.2m in the 10% and 5% AEP events on the southern floodplain. Reductions in flood levels are typically less than 0.02m in the 1% AEP event • *Increases in peak flood levels of over 0.4m in locations on the northern floodplain including around Kempsey CBD in all flood events assessed. Flood impacts extend upstream of Kempsey* • Up to 12 individual residential buildings would no longer be flooded above floor in up to the 1% AEP event. • *However, up to 22 individual residential buildings and 24 commercial building would experience new above floor flooding in up to the 1% AEP event.*

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
Option 9A Refer Appendix F.12	Raise and Extend Smithtown Levee to protect from 20% AEP flood	• Raising and extending the existing levee including filling in existing low points in the levee would eliminate floodwaters overflowing into the village in the 20% AEP event. • Upgraded levee would be raised to the 20% AEP flood level plus 0.3m freeboard • Improved flood protection provided by levee from less than 20% AEP event to over 20% AEP event	• Combination of sections of earth levee and, in the vicinity of private properties ad buildings, concrete retaining wall levee • Raising of a section of Croads Esplanade to be incorporated into part of the levee system would be required. • Works on private property likely required. Structural assessment for impact to existing buildings may be required • Potential impacts to existing utilities • Further review of Smithtown levee audit report and a condition assessment may be required.	• Prevents overtopping of levee in 20% AEP event • No mainstream flooding inside levee in the 20%, 10% and 5% AEP events. Reductions in flood levels of 0.07m in 1% AEP event. • Outside Smithtown village, peak flood levels on the northern floodplain are reduced typically by up to 0.03m in the 20%, 10% and 5% AEP events and by up to 0.1m immediately north of Smithtown village. Negligible change in 1% AEP event. • On southern floodplain, generally minor increases in flood levels of 0.02m in the 20%, 10% and 5% AEP events. *Localised increases of less than 0.1m in the 20% AEP event*. Negligible change in 1% AEP event. • Up to 33 individual residential buildings and three commercial buildings would no longer be flooded above floor in up to the 5% AEP event.
Option 9B Refer Appendix F.12	Raise and Extend Smithtown Levee to protect from 5% AEP flood	• Raising and extending the existing levee including filling in existing low points in the levee would eliminate floodwaters overflowing into the village in the 5% AEP event. • Upgraded levee would be raised to the 5% AEP flood level plus 0.3m freeboard • Improved flood protection provided by levee from less than 20% AEP event to over 5% AEP event	• Combination of sections of earth levee and, in the vicinity of private properties ad buildings, concrete retaining wall levee • Raising of a section of Croads Esplanade to be incorporated into part of the levee system would be required. • Works on private property likely required. Structural assessment for impact to existing buildings may be required • Works in and around Nestle factory required. Detailed constructability assessment has not been undertaken to date and will be required. Alternatively, the levee could go around the east of the factory. • Potential impacts to existing utilities • Further review of Smithtown levee audit report and a condition assessment may be required.	• Prevents overtopping of levee in 5% AEP event • Flood levels inside the levee are reduced by 0.1m in the 20%, 10% and 5% AEP events. Negligible change in 1% AEP event. • Outside Smithtown village, peak flood levels on the northern floodplain are reduced typically by up to 0.03m in the 20%, 10% and 5% AEP events and by up to 0.1m immediately north of Smithtown village. Negligible change in 1% AEP event. • On southern floodplain, generally minor increases in flood levels of 0.02m in the 20%, 10% and 5% AEP events. *Localised increases of less than 0.1m in the 20% AEP event*. Negligible change in 1% AEP event. • Up to 35 individual residential buildings and four commercial buildings would no longer be flooded above floor in up to the 5% AEP event. • Up to eight individual residential buildings and one commercial building would no longer be flooded above floor in the 1% AEP event.
Option 11 Refer Appendix F.13	Dredging of Macleay River	• Significant increase in drainage capacity of the Macleay River	• Very high capital and maintenance costs. • Potential hydrodynamic impacts to everyday tidal flows and flushing of the river. Potential resultant impacts to riverbank stability and structures (bridges) stability • Highly unlikely to receive environmental approvals and funding • Potential to sell off dredge spoil for industrial and construction uses, but further materials and market analysis would be required to confirm a viable downstream market.	• Widespread reductions in flood levels of up to 0.2 – 0.4m in the 10% and 5% AEP events. Up to 0.14m in the 1% AEP event. • Localised reductions of 0.7m on the floodplain around Kinchela. • *Minor increases of 0.05m around Seven Oaks in the 5% and 1% AEP event.* • Localised reductions in durations of inundation on the floodplain of up to 48 hours at Kinchela north of Hat Head Road in the 10% AEP event and in Clybucca near Plummers Lane in the 20% AEP event. Mainly minor reductions in durations of around half a day. • Up to 50 individual residential buildings and 12 commercial buildings would no longer be flooded above floor in the 5% AEP event. • Up to 125 individual residential buildings and seven commercial building would no longer be flooded above floor in the 1% AEP event.
Option 12 Refer Appendix F.14	Additional ocean outlet for Macleay River	• Significant increase in drainage capacity of the Macleay River lower reaches.	• Likely hydrodynamic impacts to everyday tidal flows and flushing of the river. Following a flood event, the scoured secondary outlet may become semi-permanent. Potential impacts including shoaling up of the main river entrance channel.	• Substantial reductions in peak flood levels in lower reaches of 0.7m in the 5% AEP and 1.4m in the 1% AEP event. Reductions of 0.2m at Kinchela and. Improvements to peak flood levels are around 0.14m on the northern floodplain and 0.07 – 0.15m on the southern floodplain including Belmore River and Kinchela Creek.

Option	Description	Advantages	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*
			• Potential resultant impacts to riverbank stability, ocean wave damage to shoreline, infrastructure and property. Damages value not quantified. • Highly unlikely to receive environmental approvals and funding • Potential to sell off excavated material for industrial and construction uses, but further materials and market analysis would be required to confirm a viable downstream market.	• Reductions in flood levels of 0.1 – 0.2m in 20% and 10% AEP events. • While peak flood levels are reduced, the reductions in duration of inundation on the floodplain are minimal to minor. Durations are reduced at Swan Pool by less than one day. • Up to nine individual residential buildings and one commercial building would no longer be flooded above floor in the 5% AEP event. • Up to 131 individual residential buildings and one commercial building would no longer be flooded above floor in the 1% AEP event.
Option 13 Refer Appendix F.15	Levee system remediation – Filling levee low points	• Restore proper functioning of existing levee system,	• Some residents' houses reportedly built on the existing levees.	• Reduced risk of floodwater overtopping during frequent flood events.

10.3 Evaluation of options

10.3.1 Options cost estimates

To enable the options evaluation, cost estimates were prepared for each option. Preliminary cost estimates for construction of options were made based on unit rates in Rawlinsons Australian Construction Handbook (Rawlinsons, 2023) and other relevant sources.

A summary of costings for assessed options is provided in Appendix G. Costings cover the basic design and construction costs and do not include the cost for excavation and disposal of contaminated or acid sulphate soils. Nominal costs are provisioned for relocation of existing utilities during the construction.

10.3.2 Economic appraisal of benefits and impacts

The cost savings of benefits provided by the options were considered, including:

- Savings in flood damages to buildings (avoided average annual damages, "AAD"). Flood damages were estimated for residential and commercial buildings based on NSW Government guidelines and calculation spreadsheets (OEH, 2016).
- Avoided intangible costs. These include damages to heritage assets, psychological impacts and damages to flora and fauna which may be difficult to quantify but nonetheless have significant social costs.
- Avoided costs of resupply of isolated communities.
- Avoided costs of cancelled vehicle trips on roads affected by flooding.
- Avoided rural damages, based on post-event survey of 2001 flood (Webb McKeown & Associates, 2004b).

The costs of the above items were estimated for the existing "Do Nothing" case and with the mitigation options, and the difference in costs input into the economic assessment. Where the costs or damages were increased with the mitigation options, for example due to increased flood levels, these were accounted for in the assessment.

A cost-benefit analysis was undertaken for each option. The costs of the options, net change in flood damages (due to increases or decreases in flood damages at individual properties) and economic savings to emergency management activities (resupply, etc) are summed over the life of the option. These are presented in terms of the reduction in Net Present Value (NPV) of the damages from the base case to the with-option. The NPV was calculated by discounting the value of the average annualised costs/savings during each successive year after the present year for the design life of the proposed mitigation measures. In this study a design life of 50 years and a discount rate of 7% have been assumed. Details of the economic assessment are provided in Appendix H.

Several options including Option 11 and Option 12 have an elevated risk of resultant environmental and social costs from potential large-scale changes to the Macleay River system. There is uncertainty about the overall scale of potential impacts and quantification of resultant damages has not been undertaken and is not accounted for in the economic assessment.

10.3.3 Savings of agricultural flood damages

10.3.3.1 Savings in agricultural flood damages on areal basis

The savings in agricultural flood damages on an areal basis offered by the flood mitigation options were estimated using a rate of $1488/ha of rural land inundated. Refer to Section 6.5 for background on this estimated areal damages rate. The savings in agricultural flood damages was calculated by applying the areal damages rate by the change in area of inundated rural lands with each of the mitigation options.

10.3.3.2 Savings in agricultural flood damages on duration of inundation basis

Aside from rural damages being a function of the area affected by flooding, the duration of flooding is another consideration due to die-off of pasture and damage from waterlogging of soils. Common pasture species such as

kikuyu die-off if inundated by floodwaters for a period of 3-4 days. Costs related to flood damage occur due to need for agistment of grazing stock, supplementary feed and re-establishment of damaged pastures etc.

The flood modelling indicates that reductions in durations of inundation are generally negligible for the assessed mitigation options. The best performing options including increasing drainage capacity at Ryans Cut result in only 0.5 – 1.5 days reduction in flood duration, mainly in the Upper Belmore to Swan Pool areas. The dredging option provided 1-2 days reductions in flooding in localised areas of the floodplain around Kinchela and Upper Belmore. Given the existing durations of flooding indicated by the flood modelling of at least 5 days, and historic flooding durations reported as typically 1-2 weeks (and up to 4 weeks in low-lying areas), it is expected that the reductions in the duration of inundation offered by the mitigation options would not be sufficient to significantly reduce the area of pasture die-off. Those areas of the floodplain where some pasture die-off could be avoided would be in areas with shallow depths of flooding, and these areas benefitting are already accounted for in the estimated reduced flood extents.

Note that while pasture die-off and subsequent recovery/re-establishment is only one aspect of rural flood damages relating to flooding duration. Consultation with landowners indicates that:

1) Regrowth of pastures can take from 3 months to 6 depending on inundation time, time of year, amount of silt coverage on the plants etc.
2) Recently flooded land cannot be grazed as the cattle 'pug' it up (trampling and tearing up the soil's structure) and the cattle refuse to eat grass that has a covering of silt.
3) Essentially, inundated pastures are not available for a minimum of 3+ months.

Therefore, regardless of whether there is pasture die-off, cattle herds are likely to be relocated in any case so that the pasture and floodplain can recover.

10.3.3.3 Inclusion of rural flood damages in economic assessment

Based on the above, the savings in areal rural flood damages were accounted in the economic assessment. If there were any increased flooding extent resulting from the assessment mitigation options, these were included as additional costs and damages. Table 10-2 summarises the change in the area of rural lands (zoned R1 and R2) for each assessed option in the 20%, 10%, 5% and 1% AEP events, including areas no longer flooded (now dry) and new areas flooded (now wet) and the net change in flood extent area. The savings in flood damages based on the adopted areal rate of $1488/ha are indicated. Compared to the total area of rural lands flooded without any mitigation options of 40,800ha in the 1% AEP event, the change in flooding extent on rural lands with the mitigation options is minor.

Potential agricultural flood damages savings due to reductions in duration of inundation were not considered further, as the reductions in durations were found to be generally negligible compared to the overall duration of inundation, and because stock were likely required to be moved from inundated pasture in any case to allow the pasture and floodplain to recover. Hence, the costs of stock relocation would not be avoided.

Table 10-2: Areal changes in flood extents and savings in rural flood damages for options

Option	20% AEP				10% AEP			
	Rural lands Now Dry (hectares)	Rural lands Now Wet (hectares)	Rural lands Net Change in Flood Extent (hectares)*	Rural Damages Savings*	Rural lands Now Dry (hectares)	Rural lands Now Wet (hectares)	Rural lands Net Change in Flood Extent (hectares)	Rural Damages Savings
1	7.9	54.7	46.7	($69,519)	16.9	80.2	63.3	($94,149)
1A	4.0	0.6	-3.4	$5,085	2.4	1.9	-0.5	$761
2A	26.1	420.0	393.9	($586,171)	5.4	0.8	-4.6	$6,812
3	0.4	46.7	46.3	($68,870)	0.4	32.4	31.9	($47,537)
4	10.5	0.6	-9.9	$14,739	20.3	0.6	-19.7	$29,289
4B	69.9	16.3	-53.6	$79,781	30.4	11.4	-19.0	$28,331
6	1.8	1.1	-0.7	$1,049	0.2	3.1	2.9	($4,375)
8A	76.1	125.8	49.7	($73,980)	9.7	30.4	20.7	($30,815)
8B	135.3	197.3	61.9	($92,180)	179.1	241.9	62.8	($93,433)
9A	30.1	28.9	-1.2	$1,785	13.6	17.5	3.8	($5,710)
9B	29.9	28.9	-1.1	$1,565	14.5	17.6	3.2	($4,735)
11	2451.7	35.5	-2416.2	$3,595,292	1054.6	7.6	-1047.0	$1,557,930
12	29.9	6.4	-23.5	$34,956	49.3	0.7	-48.6	$72,379

Option	5% AEP				1% AEP			
	Rural lands Now Dry (hectares)	Rural lands Now Wet (hectares)	Rural lands Net Change in Flood Extent (hectares)	Rural Damages Savings	Rural lands Now Dry (hectares)	Rural lands Now Wet (hectares)	Rural lands Net Change in Flood Extent (hectares)	Rural Damages Savings
1	23.3	40.1	16.8	($24,992)	6.9	10.7	3.8	($5,671)
1A	3.0	3.6	0.6	($917)	0.7	0.9	0.2	($334)
2A	0.5	0.4	-0.2	$247	0.2	0.1	-0.1	$102
3	0.9	29.0	28.1	($41,846)	0.5	32.8	32.2	($47,963)
4	9.4	0.3	-9.1	$13,573	10.9	0.3	-10.5	$15,688
4B	12.4	0.6	-11.8	$17,601	10.1	0.4	-9.7	$14,457
6	0.9	0.3	-0.6	$841	1.6	0.1	-1.5	$2,173
8A	1.8	2.8	1.1	($1,612)	0.5	0.2	-0.3	$399
8B	84.2	95.6	11.4	($16,965)	9.6	10.4	0.8	($1,223)
9A	2.9	8.3	5.4	($8,075)	0.1	0.9	0.8	($1,201)
9B	3.7	9.2	5.5	($8,223)	0.0	1.1	1.0	($1,504)
11	300.7	3.5	-297.3	$442,340	117.8	0.3	-117.5	$174,810
12	28.7	2.0	-26.7	$39,759	229.9	0.3	-229.6	$341,597

* Positive value change in flood extent represents increase in flood extent. Negative value in Rural damages savings (in brackets) represents increased damages; positive value represents reduced damages i.e. savings.

10.3.4 Results of options evaluation

Table 10-3 summarises the evaluation of potentially feasible options including likely constraints, hydraulic performance (changes to flooding conditions as estimated in the hydraulic model), savings in property flood damages and other economic benefits, cost of works or increase in net flood damages if there are unintended flood impacts from the options, and economic appraisal. Savings in agricultural damages are included. The flood damages are presented in terms of the reduction in Net Present Value (NPV) of the damages from the base case to the mitigation case.

Comparison of the benefits to the cost of the mitigation option and resultant flood impacts, if any, provides a basis for evaluating the economic feasibility of an option, whereby the reduction in NPV ("Benefit") are divided by the capital cost ("Cost"). A benefit-cost ratio greater than 1.0 would indicate that the capital cost of the works would be less than the savings in flood damages over the life of the works, and vice-versa for a ratio less than 1.0. A negative value benefit-cost ratio means that the option results in increased flood damages compared to the base case.

10.3.5 Multi-criteria assessment

The multi-criteria analysis considers in a wholistic overview the hydraulic effects, cost-benefits and other aspects relating to the assessed options including effects on flood risk, environment/ecologic systems, social effects, effects on emergency management and administrative and asset management aspects.

The multi-criteria assessment is based on a scoring system, with scores from -3 (strongly negative) to +3 (strongly positive) with 0 being a neutral score, for a range of aspects and issues relating to implementation of the mitigation options. The scoring system matrix is shown on Table 10-4.

A summary evaluation table of the mitigation options is presented in Table 10-5. Each option is given a relative rating for each criterion and is given a total score for further consideration by Council. For some criteria, all options provide a neutral or near neutral score because there is minimal change from existing conditions, for example, impact on risk to life and impact to SES, as there is only minor reduction in high flood hazard areas as a result of the options.

Note that Option 1 and Option 1A, involving improvement of access on Crescent Head Road at The Corduroy where the road currently comes cut during frequent flood events, have been assessed as singular options and not in conjunction with Option 1B, which removes a second road cut-off location at Rudders Lagoon. Option1 and Option 1A provide minimal benefit to improvement to access on their own, as traffic which can pass The Corduroy would only make it to Rudders Lagoon before road access is again cut. Therefore, to realise the full benefits of Option 1 and Option 1A, these must be implemented in combination with Option 1B. However, the high costs of implementing Option 1A and the increased flood damages from Option 1 would mean that a combined Option 1/1A + Option 1B scheme would not appear economically feasible.

Table 10-3 Mitigation options economic appraisal summary

Option	Description	Total Benefits (50 years life, 7% Discount Factor)	Total Costs incl. CAPEX	Benefit Cost Ratio (BCR)
Option 1	Raise Crescent Head Road to 3.2m AHD + no drainage upgrade	-$ 4.69M	$ 13.39M	-0.35
Option 1A	Raise Crescent Head Road to 3.2m AHD + 1000m of viaduct	$ 0.29M	$ 43.17M	0.01
Option 1B	New emergency access from Crescent Head Road to Pacific Highway	$ 5.09M	$ 3.14M	1.62
Option 2A	Raise Hat Head Road to 2.3m AHD + 200m culverts/floodway	-$2.70M	$ 10.84M	-0.25
Option 3	Disconnect Korogoro and Killick Creek	-$1.81M	$ 0.20M	-9.03
Option 4	Widen Loftus Road Ryans Cut crossing	$2.10M	$ 6.43M	0.33
Option 4b	Widen Loftus Road Ryans Cut crossing and extend Ryans Cut to Belmore River	$3.30	$15.49	0.21
Option 5	Increased Floodplain Drainage Capacity	Negligible hydraulic benefits. Costings and economic assessment not undertaken.		
Option 6	Reinstate Rowes Cut	$2.99M	$ 3.85M	0.78
Option 7	Enlarge headworks on Belmore and Kinchela	Negligible hydraulic benefits. Costings and economic assessment not undertaken.		
Option 8A	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads	-$1.82M	$ 12.15M	-0.15
Option 8B	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads and SWR Road + additional levee	-$35.23M	$ 28.21M	-1.25
Option 9A	Raise and Extend Smithtown Levee to protect from 20% AEP flood	$27.66M	$ 7.30M	3.79
Option 9B	Raise and Extend Smithtown Levee to protect from 5% AEP flood	$29.81M	$ 14.76M	2.02

Option	Description	Total Benefits (50 years life, 7% Discount Factor)	Total Costs incl. CAPEX	Benefit Cost Ratio (BCR)
Option 11	Dredging of Macleay River	$89.57M	$568.44M (NPV) including initial dredging and periodic maintenance dredging	0.16
Option 12	Additional ocean outlet for Macleay River	$17.79M (excludes potential environmental, social and property damages and impacts – benefits would be reduced or negated)	$3.14M	5.66 (excludes potential environmental, social and property damages and impacts – benefits would be reduced or negated)
Option 13	Levee system remediation – Filling levee low points	Economic assessment not conducted – Option to be recommended as a part of Council maintenance and asset management program.		

Table 10-4 Options scoring system matrix

Aspect	Score						
	-3	-2	-1	0	1	2	3
	Negative			Neutral	Positive		
Impact on Flood Levels	> 200mm increase	50 – 200mm increase	< 50mm increase	Neutral, or benefits countered by negative impacts	< 50mm decrease	50 – 200mm decrease	> 200mm decrease
Impact on Duration of Flooding	> 24hr increase	8 – 24hr increase	< 8hr increase	Neutral	< 8hr decrease	8 – 24hr decrease	> 24hr decrease
Number of Properties Benefited – above floor flooding	>20 properties negatively impacted	10-20 properties negatively impacted	< 10 properties negatively impacted	Neutral, or benefits countered by negative impacts	<10 properties benefitted	10-20 benefitted	>20 properties benefitted
Technical Feasibility	Significant issues (unproven, high risk)	Some issues (complex, some difficulty)	Minor issues	Neutral	Moderately straightforward	Straightforward	No issues (proven, well established, no risk)
Economic Merit (benefit/cost ratio)	Very low (<0.4)	Low (0.4-0.6)	Slightly low (0.6-0.8)	Neutral (0.8-1.2)	Slightly high (1.2-1.5)	High (1.5-2)	Very high (>2)
Financial Feasibility (funding, Government assistance & grants)	Very unlikely to receive funding	-	Unlikely to receive funding	Neutral	Likely to receive funding	-	Very likely to receive funding
Environmental and Ecological Benefits	Significant disbenefits	Some disbenefits	Minor disbenefits	Neutral	Minor benefits	Some benefits	Significant benefits
Impact on Risk to Life	Significant increase in risk to life	Some increase in risk to life	Minor increase in risk to life	Neutral	Minor decrease in risk to life	Some decrease in risk to life	Significant decrease in risk to life
Impacts on SES including flood access	Significant disbenefit to SES	-	Some disbenefit to SES	Neutral	Some benefit to SES	-	Significant benefit to SES
Long-term Performance (design life & climate change)	Significant reduction	Some reduction	Slight reduction	Neutral	Slight increase	Some increase	Significant increase
Legislative & Permissibility Requirements (including political & administrative	Significant issues affecting implementation	-	Some issues affecting implementation	Minor issues affecting implementation	Negligible issues affecting implementation	-	No issues affecting implementation
Social Impact / Community Acceptance	Large majority against	Most against	Some against	Neutral	Some for	Most for	Large majority for

Table 10-5 Multi Criteria Assessment of Options

Option	Impact on flood behaviour[1] (flood levels; duration)	Number of properties benefited (above floor flooding)	Technical feasibility	Economic merit (benefit/cost ratio)	Financial feasibility (cost, funding, Government assistance & grants)	Environmental and ecological benefits[2]	Impact on risk to life	Impacts on SES incl. flood access	Long-term performance (design life & climate change)	Legislative & permissibility requirements (including political & administrative)	Social impact / community acceptance	Total score	Rank[5]
1	-3; -2	-3	-1	-3[3]	-1	0	1	2	1	0	2	-7	**13**
1A	-1; 1	0	-2	-3[3]	-3	0	1	2	1	0	2	-2	**10**
1B	0; 0	0	1	2	3	0	1	3	3	-1	3	15	**3**
2A	0; 0	0	-1	-3	-1	0	0	2	1	0	2	0	**8**
3	-1; -1	2	3	-3	1	2	0	0	2	1	1	7	**5**
4	1; 1	2	1	-3	1	0	0	0	2	-1	2	6	**6**
4B	1; 1	2	-1	-3	0	0	0	0	2	-1	2	3	**7**
5	0; 0	0	-1	Not assessed	1	-2	0	0	0	0	-1	Not recommended due to minimal hydraulic benefit	
6	1; 2	3	3	-1	3	-1	2	0	2	-1	2	15	**4**
7	-1; 0	0	1	Not assessed	1	-2	0	0	0	0	-1	Not recommended due to minimal hydraulic benefit	
8A	-1; 0	0	-2	-3	0	0	0	2	1	0	0	-3	**12**
8B	-3; 0	-3	-3	-3	0	0	0	2	1	0	-2	-11	**14**
9A	2; 2	3	-1	3	2	0	1	2	1	0	2	17	**1**
9B	3; 3	3	-3	3	1	0	2	2	1	0	2	17	**2**
11	3; 1	3	-3	-3	-3	-3	2	2	-2	-3	2	-4	**11**
12	3; 1	3	-2	1[6]	-1	-3	1	1	-2	-3	1	0	**9**
13	**Not included in assessment – to be recommended as part of Council asset management program**												

1. Neutral or fairly neutral score adopted if no significant change in flood behaviour
2. Potential environmental and ecologic impacts from construction of works assumed neutral if appropriate management measures implemented during construction.
3. The economic merit of Option 1 and Option 1A could be improved if implemented in combination with Option 1B. In the current assessment, the full benefits of Option 1 and Option 1A are not fully realised as Crescent Head Road would still be cut-off at Rudders Lagoon.
4. Sensitivity options comprising raising of South West Rocks Road and Plummers Lane not included in options evaluation.
5. Where options receive an equal score, higher priority/ranking is given for lower cost/higher benefit-cost ratio/options not listed as Internal – For Council Information only.
6. Economic merit of Option 12 (new ocean outlet) marked down due to uncertainty about resultant environmental/social/property damages and impacts, damages not quantified but could be substantial.

10.4 Climate change considerations in the Mitigation Options Assessment

Parts of the study area are highly constrained by low elevations, where sea level rise is likely to impact on the future performance of the mitigation options. Increased rainfall and runoff with climate change would also have an impact on hydraulic performance but to a lesser degree. The impact of climate change on the long-term performance of the options is considered in the evaluation matrix.

All assessed options are located at low elevations within the floodplain and would be affected by increased flooding resulting from climate change, including increased rainfall and flood flows and sea level rise. Options involving improved flood immunity and flood protection (road raising, levees etc) could be expected to have their flood immunity and protection levels (in terms of AEP) reduced by climate change-induced increases in flooding. However, the interventions offered by any implemented options would provide an elevated level of protection compared to a climate change scenario with no interventions.

10.5 Options not considered in detail

The following potential options were initially identified but were subsequently excluded from further detailed assessment:

- Raise Crescent Head Road crossing at The Corduroy by 0.1m and 0.3m height – excluded due to minimal improvements to vehicle access.
- Raise Crescent Head Road crossing at Rudders Lagoon including upgraded bridge. several scenarios of raising Rudders Lagoon bridge and Crescent Head Road to achieve various levels of flood immunity. In summary:
  - In minor flood events such as a 20% (1 in 5) annual exceedance probability (AEP) event, it was identified that the road would need to be raised by approximately 0.8m for a length of 350m of road.
  - In the 1% (1 in 100) AEP event the bridge and road would need to be raised by up to 2.9m over a length of 500m of road.

  The road and bridge raising options represent high-cost options and were ruled out as feasible options in the study. Substituted with Option 1B new emergency access on and off ramps from Pacific Highway.
- Increased floodplain drainage capacity – Clybucca floodplain and drainage capacity at Macleay Valley Way. Minimal flood gradient across the road and unlikely to have sufficient hydraulic head to provide a reasonable conveyance of flows through a proposed culvert and floodway system.
- Removal of Clybucca headworks – separate studies indicate that removal of the headworks would result in saltwater intrusion onto upstream pastures, which would be detrimental to pasture health and landowners (Rayner et al, 2020).
- Raising of roads across the floodplain – While there are a number of key access routes across the Lower Macleay which are flood-affected in frequent floods, raising of these roads to improve flood access has not been considered as the required heights of several metres above existing levels are significant and would result in significant flooding impacts across the floodplain. It is not feasible to provide cross-drainage to convey flows under the roads as the structures would be excessively large and extremely high in construction costs.

10.6 Options excluded from this assessment

The following options were previously assessed as a part of the Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017). It is proposed not to reassess these options as a part of this study.

- Raise South West Rocks Road, Red Hill to Austral Eden. It is understood that modelling assessment of raising the road by up to 300mm was previously undertaken for Council.
- South Kempsey Levee
- West Kempsey – Gladstone Street floodgate

- Kempsey – raise/repair levees. Raise Belgrave Street.

10.7 Summary of options evaluation

High priority options

- Options 9A and 9B (raising Smithtown levee for 20% AEP and 5% AEP flood protection, respectively) are ranked 1 and 2. Both have high BCR of 3.79 and 2.02, respectively.
- Option 9A receives a higher rank due to lower cost, higher BCR and expected less technically challenging construction compared to Option 9B, which would require more extensive works in the Nestle factory property.
- Option 9B, however, does provide for a higher level of flood protection and also with consideration of increased flooding with climate change.
- Option 1B (new on/off ramps to Pacific Highway from Crescent Head Road) is also ranked highly at 3 and with a high BCR of 1.62. It has relatively low construction cost of $3.14M. While it does not reduce the existing case flood damages costs, it would provide road access during flood events to an existing community of over 1300 people residing between South Kempsey and Crescent Head, who would otherwise be cut-off by flooding on Crescent Head Road at Rudders Lagoon. The number of residents benefitting is expected to increase due to future land rezoning.
- Options 9A/9B and 1B are recommended for further consideration in the Floodplain Risk Management Plan.
- Option 13 remediation of existing levees (filling of levee low points) is recommended for implementation as a part of Council's asset management program.

Low priority or not recommended

- Option 12, although shown to have a high BCR of 5.52, is marked down due to high risk of uncertain hydrodynamic, environmental, social and property impacts resulting from formation of a new major ocean outlet for the Macleay River. Based on theses potential impacts, it is also unlikely to receive approvals from relevant authorities to proceed.
- Option 11 results in significant reductions in flood levels and numbers of properties flood affected from dredging of the Macleay River. However, such a large-scale dredging project is unlikely to receive environmental approvals to proceed and the high costs are unlikely to be fulfilled by agency funding. It has a low BCR value.
- The remaining assessed options are low priority or are not recommended for further consideration. This is due to the options having low BCR significantly below 1.0, have high construction cost/low economic feasibility and/or result in adverse flood impacts and increased flood damages.
- Options 1 and 1A (raising Crescent Head Road, without and with viaduct), while locally improving road access during flood events to the permanent and temporary holiday population in Crescent Head village, do not realise the full benefit of the improved access if implemented on their own. Vehicle traffic which can pass The Corduroy would still be impeded by flooding at Rudders Lagoon, assuming Option 1B is not implemented in combination.

If Option 1/1A were to be implemented in combination with Option 1B, it is expected that the economic feasibility of the combined options would remain low and similar to Option 1/1A. This is due to the relatively low dollar benefit from improving the access compared to the high cost of implementing Option 1 or 1A. Additionally, Option 1 would also incur increased flood damages due to its impact on peak flood levels on properties.

10.8 Cumulative effects of recommended options on flooding

There are not expected to be any cumulative effects on flooding by the proposed options. Only one of Option 9A or 9B will be eventually selected for implementation, and Option 1B is outside the PMF extent and hence its works do not interact with flooding in the Lower Macleay. Option 13 consisting of filling in rural levee low points is not expected to significantly affect the levees' influence in floods which overtop them (particularly 10% AEP and larger).

10.9 Recommendation for Further Works

In undertaking the flood modelling and options analyses in this FRMS, opportunities for further mitigation measures were identified to address existing vulnerabilities in the Flood Mitigation Scheme:

- Investigate through a feasibility study the raising of Hat Head village levee/s to provide flood protection to Hat Head village in up to the 1% event, without Rowes Cut functioning. The current emergency management documentation indicates that the Hat Head levees provide 1% AEP flood protection, which is not consistent with the findings in this FRMS. The feasibility study would include flood modelling and assessment of resulting flood impacts and benefits to properties, consider various options for the proposed measure, concept design, flood damages assessment, options costing, cost-benefit analysis etc. Investigate providing a hardstand (concrete) walking track on top of the levee to provide erosion protection.
- A number of proposed environmental projects and interventions which aim to improve water quality and ecologic outcomes (such as reducing risks of fish kills during flood events) were observed to result in potential flooding impacts. Based on available studies and research commissioned by the NSW Government's Coastal Management Program, undertake investigations to identify those environmental projects that would provide no detrimental flooding impacts, or, identify further mitigations which would assist in reducing or eliminating the flooding impacts of those environmental projects. The Lower Macleay flood model developed in this study could be utilised to help develop solutions. Additionally, the findings from this FRMS on potential options flood impacts could be used to help the ongoing design and development of proposed environmental projects.
- Further studies could more broadly consider environmental, social and economic factors, costs and benefits in evaluating proposed environmental and flood mitigation projects. Varying scenarios and combinations of environmental works (such as separate disconnection of Killick Creek and Korogoro Creek from the floodplain) could be assessed.
- The regional flood model developed for this FRMS focusses primarily on mainstream and regional flooding in the Macleay River, although tributary and floodplain catchment flooding was also considered in the flood model. Some local catchment flooding is represented in the model but generally a detailed assessment of these minor flow paths is outside the limitations and the technical capability of this regional-based flood model. Detailed, finer resolution flood modelling studies should be considered for key local catchment flooding areas, including around Stuarts Point/Grassy Head and Frederickton.
- While the raising of Crescent Head Road and bridge at Rudders Lagoon was excluded as an option in this FRMS due to large magnitude of works and high cost, the raising of the bridge and road should be considered in the future once the bridge nears end-of-life and requires replacement. The design of the future bridge replacement should consider the merits and feasibility of providing a high flood immunity level bridge.

These recommended further works and assessments are included in the Draft Final FRMP.

11. Floodplain risk management plan

11.1 Purpose of the Plan

The Floodplain Risk Management Plan provides input into the strategic and statutory planning roles of Council. It provides a steering document to enable Council to effectively manage flood liable land moving forward. It also suggests an implementation plan based on priorities of floodplain risk management measures and availability of funding.

The Plan, consisting of proposed floodplain risk management measures, are provided in Table 11-1 and were developed from the recommendations made in the Floodplain Risk Management Study documented in the preceding sections of this report. consultation with the community, Council and the Flooding Reference Group on the recommendations and the preliminary proposed measures was undertaken.

11.2 Funding and Implementation

11.2.1 Estimated Costs

Costs have been estimated for structural and non-structural measures. The costs of planning, policy, administrative and organisational non- structural measures are largely unknown to the consultant. The timing of the proposed works will be dependent on Council's overall budgetary commitments and the availability of funding from external sources. The Plan can be progressively implemented with an anticipated timeframe of 3-5 years for high priority options and 5-10 years for medium priority options.

11.2.2 Alternative Funding sources

There are a number of funding sources, which Council could consider applying to for supplementary funds. The Department of Climate Change, Energy, Environment and Water (DCCEEW) offer support to local Councils through Floodplain Management Grants. Assistance under this Program is usually $2 from government for every $1 from Council.

The Protecting Our Communities (Disaster Resilience) Program is a Commonwealth administered program that aims to deliver important disaster resilience projects across Australia that have been identified by communities to improve their disaster resilience and preparedness for further disasters at the local level.

The Federal Government has also established the Disaster Ready Fund (DRF). The DRF is providing up to one billion dollars over the five years from 1 July 2023, to improve Australia's resilience and reduce risk to natural disasters. Applications for funding under this program are made through NSW Reconstruction Authority.

In addition to State and Federal Government, Council could approach other organisations (for example Transport for NSW, SES) to assist with funding of measures.

11.3 On-going Review of Plan

This Floodplain Risk Management Plan should be regarded as a robust document, which requires review and amendments to be made over time. At a minimum, it is recommended that the Plan be reviewed every 10 years to ensure it remains relevant to the requirements of the area. In addition to scheduled reviews, the Plan should be reviewed following flood events, any change in State or Local Government legislation or alterations to funding availability. Implementation of the Plan should be monitored by the Flooding Reference Group. The local community should continue to be informed of progress through Newsletters available via the Council website or displayed at Council offices.

Table 11-1 Lower Macleay River Floodplain Risk Management Plan

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
FM1	**Option 9A/9B** Raising and extending Smithtown levee	Council	Up to ~$18M	Not costed	• Raising and extending Smithtown levee to 20% AEP flood level or to 5% AEP flood level. • Feasibility study should be undertaken to assess optimal option for the levee raising and extension	Medium priority Option to be further investigated following feasibility assessment (Measure FM1A).
FM1A	Feasibility study for Option 9A/9B – Raising and extending Smithtown levee	Council	$200K	N/A	• A feasibility study should be undertaken to assess in further detail the technical aspects of raising and extending Smithtown levee. • The study would include consultation with Nestle factory in Smithtown to identify and select the optimal design for extending the levee through the property. • Consider technical and design requirements for levee internal stormwater pumping station. • Update of cost estimates. • Provide inputs for potential design/construction commissioning.	High – feasibility assessment should be undertaken in the near future to further develop and optimise Measure FM1
FM2	**Option 1B** Emergency flood access ramps at Crescent Head Road/Pacific Highway	Council, TfNSW	$3.14M	Not costed	• Construction of new traffic ramps from/to Crescent Head Road and Pacific Highway. • The new traffic ramps would be for emergency flood access only. • Council to advocate TfNSW for funding/ implementation of this option.	High – would significantly improve flood immunity in the surrounding area.
FM3	**Option 13** Remediation of existing levees	Council	Part of maintenance program	Low cost	• Council to undertake remediation of existing levees including filling of low points which have developed in the existing levees. • Works are to be undertaken as a part of Council's asset maintenance program.	Medium priority – ongoing program
FM4	Maintenance of existing drainage assets for flood drainage	Council	Part of maintenance program	Part of maintenance program	Council to incorporate into their asset maintenance program as priority works: • Cleaning and maintenance of Council floodplain drains • Protection of drainage assets from becoming damaged or degraded from construction works and roadworks – ensure effective construction phase earthworks planning and erosion and sediment control is implemented to prevent mobilised sediment during construction works from clogging up drains. • Investigate replacement of older floodgate flaps with newer lighter weight gate flaps. • Clearing and maintenance of sediment and vegetation at upstream end of Ryans Cut and at Big Hill Creek outlet structure.	Medium priority – ongoing program
FM5	Investigation into Hat Head Control Levee increase	Council	Up to $200K	N/A	• A feasibility study is recommended to assess design options for raising the Hat Head village levees to provide a 1% AEP flood protection level. • Prepare a concept design for potential options. • Flood modelling to identify potential flood impacts and confirm options performance. • Options costings, flood damages assessment, cost-benefit assessment, input into business case.	Medium priority

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
FM6	Flood Mitigation Environmental Projects	Council, NSW Govt environmental agencies	Uncosted	N/A	• Undertake feasibility study/s to identify proposed environmental projects that would provide no detrimental flooding impacts, or, identify further mitigations which would assist in reducing or eliminating the flooding impacts of those environmental projects • Utilise the findings on potential options flood impacts from this FRMS to help the ongoing design and development of proposed environmental projects. • Consider in broader scope the environmental, social and economic factors, costs and benefits in evaluating proposed environmental and flood mitigation projects.. • Consider varying scenarios and combinations of environmental works (such as separate disconnection of Killick Creek and Korogoro Creek from the floodplain) as a part of feasibility study with the aim of maximising environmental benefits and optimising flooding, social and economic outcomes.	Medium/High – Pending environmental program scheduling.
FM7	Second Bridge Crossing at Kempsey	Council	Council staff costs	N/A	Council should continue to advocate for a second road bridge crossing at Kempsey, based on completed feasibility by Council/Transport for NSW, to imrpvove traffic conditions on existing routes and provide improved transport connectivity between M1 Pacific Highway/South Kempsey and West Kempsey (including hospital and proposed Emergency Operations Centre) and rural areas to the north and west of Kempsey.	High – ongoing advocacy
FM8	Local catchment flood studies and other focussed assessments	Council	$150K each	N/A	Commission flood modelling and studies with finer model resolution for local catchment flooding problem areas not assessed in detail in this FRMS. Potential locations of interest include Stuarts Point – Grassy Head, and Frederickton.	Medium
FM9	Replacement of Rudders Lagoon bridge with high level bridge	Council	Uncosted	N/A	Consider replacement of Crescent Head Road bridge at Rudders Lagoon with a higher level bridge and road to improve flood immunity of this road crossing once the existing bridge reaches end-of-life and requires replacement.	Low
PM1	Revise Flood Planning Level/Flood Planning Area	Council	Council staff costs	N/A	Revise Flood Planning Level/Flood Planning Area based on maximum level of: • 1% AEP current climate flood level + 500mm freeboard; and • 1% AEP year 2100 flood level (no freeboard). • At area of overlap of Lower Macleay River FRMSP mapping with Kempsey CBD FRMSP mapping area, refer to Kempsey CBD FRMSP Flood Planning Level, which is already adopted by Council.	High – ensure planning documents are consistent and utilise the most up to date flood information. It is noted that Council has already resolved to adopt the maximum level of the 1% AEP current day flood level with 500mm freeboard and the 1% AEP year 2100 flood level as the flood planning level.
PM2	Flood Policy	Council	Council staff costs	N/A	• Council to develop Flood Policy.	High – ensure planning documents are consistent and provide clarity and utilize the most up to date flood information.
PM3	Amendments to LEP and Section 10.7 certificates	Council	Council staff costs	N/A	• Revise LEP based on outcomes from this FRMSP, including update of Flood Planning Level and Flood Planning Area, and floodway/flood storage mapping. • Section 10.7 certificates to notate properties which are affected by flooding as identified in this FRMSP. • Reissue Section 10.7 certificates to all affected by the revised FPA/FPL.	High – ensure planning documents are consistent and utilize the most up to date flood information.

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
PM4	Amendments to DCP	Council	Council staff costs	N/A	• Update DCP 2013 include the floodway/flood storage mapping presented in this FRMS. • The flood mapping, design flood levels and other outputs from this Lower Macleay FRMS are to be used as the basis for all flood planning and development controls in the Lower Macleay area, superseding info from previous studies. • Given the projected increases in peak flood levels in the Lower Macleay due to ongoing and future climate change, define the flood planning level as the maximum level of the 1% AEP current day flood level with 500mm freeboard and the 1% AEP year 2100 flood (already adopted by Council as policy as of drafting of this FRMP). • Council should consider whether climate change flooding conditions should be adopted for the various other development controls. • Update of DCP 2013 could consider reference to the AIDR flood hazard categories and the flood hazard mapping that are presented in this FRMS. The current DCP refers to velocity – depth product as an indication of hydraulic hazard conditions. • Restricting new development to areas of H4 flood hazard and lower in the 1% AEP event would be generally consistent with the development conditions relating to hydraulic hazard in the current DCP 2013. • Review whether Bellimbopinni and Seven Oaks floodway area should be retained in the DCP, as it does not match flooding conditions in this FRMS. If retained, consideration should be made for extending the floodway are further east to include areas of higher flood hazard as identified in this FRMS. • Review the requirement in the DCP for a separate detailed flood study for proposed development on specified lots in the South West Rocks New Entrance floodway area. The modelling and flood mapping outputs from this FRMS could be referenced for these lots. • "Flood prone land" as defined in DCP 2013 refers to the land which is inundated during a 1% AEP flood. This definition should be updated to refer to the land which is inundated in the PMF, that is, land which would be subject to inundation by the full range of flood magnitudes. This latter definition would be consistent with that provided in the Flood Risk Management Manual 2023. • Continue to provide requirements for flood proofing and flood compatible design of individual buildings as development controls in the DCP	High – ensure planning documents are consistent and provide clarity and utilize the most up to date flood information.
PM5	Voluntary purchase of high hazard properties	Council (with grant funding)	$500+ per property approx.	Minimal costs	• Aims to reduce population at risk to high hazard flooding and damage to property by voluntary purchase of dwellings affected by high hazard flooding in 1% AEP event. Subject to property eligibility and DCEEWW grant funding application. • Council should continue with its voluntary purchase of high hazard properties program with guidance from the flood modelling and mapping outcomes from this FRMS. Update of register of eligible properties. • Preliminary estimate of 421 dwellings potentially eligible. To be confirmed with review of specific dwellings for eligibility. • Council should develop a policy or strategy as to how this action might be funded in respect to Council's contribution, including prioritisation of any properties to be acquired and how the land will be used in the future. • Review the ongoing feasibility of the scheme, citing historic and ongoing property price increases.	High – ongoing continuation of existing program

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• Sources of funding forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored	
PM6	Voluntary house raising	Council and property owners (with grant funding)	$100K per dwelling approx.		• Aims to reduce flood damages due to over-floor flooding by voluntary raising of habitable floors of dwellings affected by low hazard flooding in 1% AEP event. Subject to property eligibility and DCCEEW grant funding application. • Council should continue with its voluntary house raising program with guidance from the flood modelling and mapping outcomes from this FRMS. Update of register of eligible properties. • Preliminary estimate of 777 dwellings potentially eligible. To be confirmed with review of specific dwellings for eligibility. • Additional sources of funding such as those potentially forthcoming from the 2022 NSW Flood Inquiry and establishment of NSW Reconstruction Authority should be explored.	High – ongoing continuation of existing program
RM1	Flood warning systems	Council, BOM	Transfer of total flood warning gauge network – not costed. Improvements to Council messaging system – staff costs.		• Council investigate the feasibility of and advocate for the transfer of ownership and operation of the total flood warning gauge network to BOM. • If ownership and operation of the total flood warning system gauges is transferred to BOM, Council and local SES should remain as a key stakeholder in the operation of the total flood warning system. • Investigate opportunities to improve the efficiency of Council's total flood warning system messaging and reduce the lag between the reporting of on-ground activities/conditions and communications. • Consider improvements to social media and SMS flood messaging system including checks of gaps in mobile coverage and investigate improvements in coverage gaps, and regular update of flood message recipients list. • Consider improvements to the live flood monitoring webcams including installing/ reinstating Turners Flat Bridge Webcam and Bellbrook Bridge Webcam. • Maintain Council's flooding website and its links to real-time flood information and warnings, and Council's own flood messaging system.	High – maintain existing program and planned additional gauge sites; review and improve flood warning messaging system. Medium priority for investigating and implementing total flood warning system gauge network to BOM.
RM2	Relocation of emergency services facilities	Council, SES, NSW RFS	Feasibility studies, development and relocation activities not costed	N/A	• Council should continue to investigate the viability of a new dedicated Emergency Operations Centre (EOC), to be co-located with the existing Kempsey FCC/SES at North Street/River Street • The new EOC would serve as a purpose-built centre for both flooding and bushfire emergency management activities, where currently there are separate fire and flooding emergency management facilities. • Funding to investigate the option may be available through NSW Reconstruction Authority. • Cost of constructing the development and relocation of services is to be confirmed during feasibility studies.	Medium – Ongoing investigation and design including consultation with SES, RFS etc.
RM3	Stock refuge mounds and other land shaping	Landowners, Council administration	Low costs for Council administration	Ongoing program	• Areas of artificially elevated ground to be used as temporary evacuation for communities / stock / assets in minor flood events. Suitable for locations in the floodplain up- and down-stream of Kempsey clear of floodways and major flow paths.	Low – ongoing program

Measure ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• Council should continue with its policy of requiring property owners wishing to build stock flood refuge mounds to prove that the mound will not impact on surrounding properties. • Council should consider whether flood impact and mitigation assessments should be undertaken for agricultural land shaping on rural properties.	
RM4	Flood depth markers and flood signs	Council	Static depth indicator and warning signs $600 per depth marker, assume up to 40	N/A	• Flood depth markers at key road low points and low area access points. • The depth markers serve as depth indicators and warning of flooding ahead during a flood event to reduce occurrences of people driving into floodwaters, in addition as a passive reminder of flooding risk. • Flood warining signs (fixed signage) are recommended at selected locations to indicate that the road ahead is cut by flooding. Key locations include Crescent Head Road east of The Corduroy and west of Rudders Lagoon, and Hat Head Road west of the village.	High – aims to directly modify driver response to flood hazard during a flood event. Static signs are a low cost measure which also improves flood safety and flood awareness at each location.
RM5	Update of current emergency management planning	SES	SES costs	SES costs	• Kempsey Flood Emergency Sub-Plan should be updated incorporating the findings of this study on flood behaviour and hazards.	High – incorporate into the 5 yearly review cycle of the Flood Plan (due 2027).
RM6	Flood education and awareness program	Council, SES	$50K	Staff costs	Continue to promote flood awareness and readiness in the community. Measures may include: • Promotion of FloodSafe brochures to help residents understand the flood risk and prepare their property and personal plans for a flooding event. ▪ Continue to undertake community flooding and emergency planning education events in coordination with SES • Maintain Council's flooding website with flood education, awareness and readiness information. • Regular updates of flood information and messaging recipients list. • Consider future requirement in the flood planning instruments for flood awareness and education materials such as flood information posters/brochures outlining Lower Macleay flood risks, evacuation routes, template flood emergency plan (similar to bushfire plan) key organisation (SES, emergency services) phone numbers, Council flood website and other flood info sources, to be displayed at high risk premises including temporary visitor accommodation and for distribution to new permanent residents. Council would prepare the standard information posters/brochures in consultation with SES. • Mail-out of flooding information packages to new residents to maintain flood awareness and minimise gaps in disseminating communications to the community. • Update the interactive mapping portal with latest flood mapping when these are updated and become available. • Develop and maintain a flood education and awareness program to plan out various flood education and awareness activities. Review implementation and effectiveness of program on regular (e.g. 2 – 5 year) cycle	High – community awareness is likely to significantly improve flood preparedness, reduce flood damages and reduce flood response and risk to people.

12. Acknowledgements

This study has been undertaken by Jacobs on behalf of Kempsey Shire Council. Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Infrastructure and Environment.

A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- The Lower Macleay Flooding Reference Group;
- Residents of the study area;
- Council officers;
- WMAwater;
- Transport for NSW;
- SES;
- Manly Hydraulics Laboratory; and
- NSW Department of Climate Change, Environment, Energy and Water (DCCEEW).

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14. Glossary

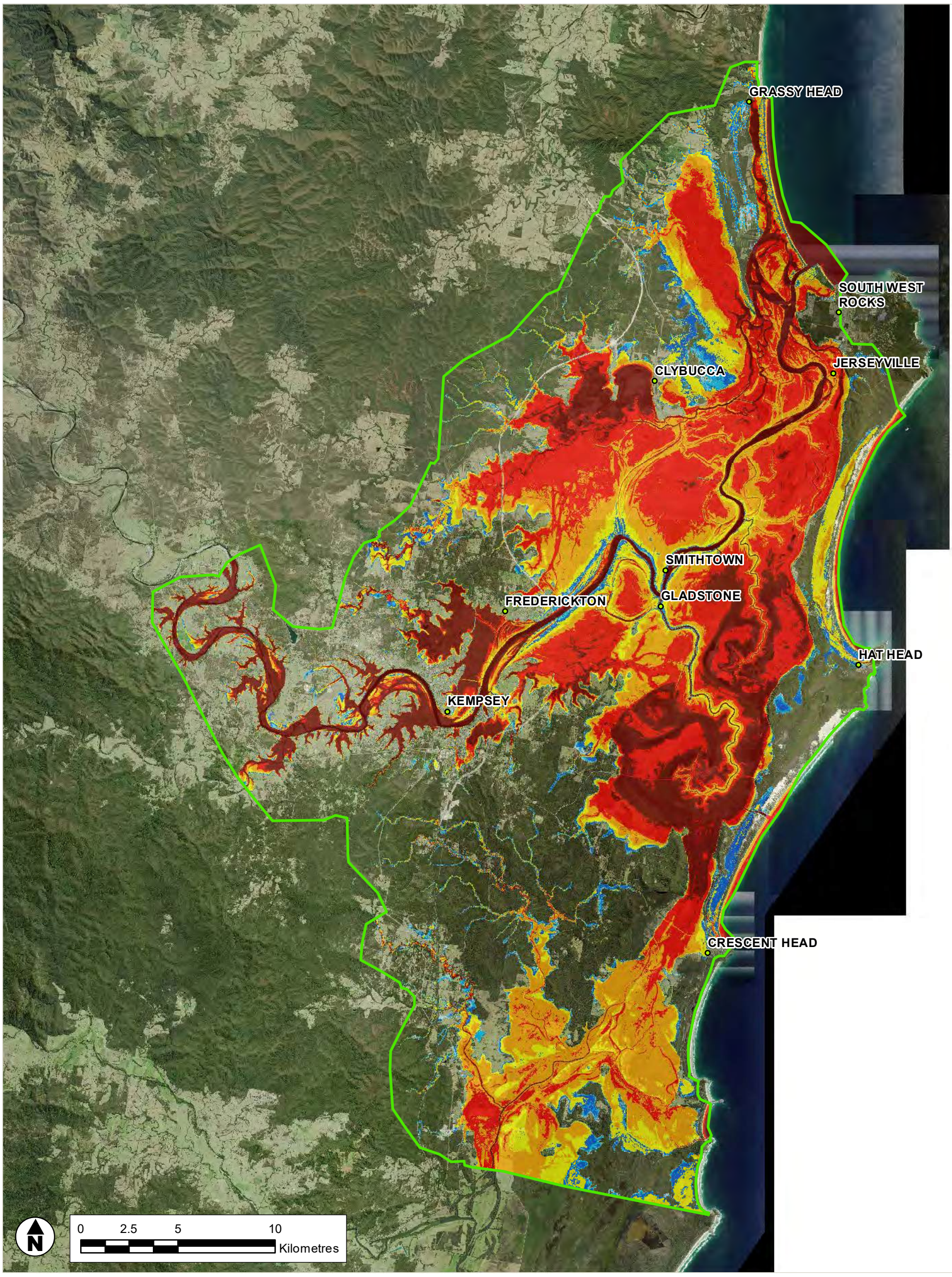
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 100 year ARI (ie. 1% AEP) events was derived from 1987 Australian Rainfall and Runoff. Hence the flowing relationship between AEP and ARI applies to this study. 20% AEP = 5 year ARI; 10% AEP = 10 year ARI; 5% AEP = 20 year ARI; 2% AEP = 50 year ARI; 1% AEP = 100 year ARI.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Development	Is defined in Part 4 of the EP&A Act In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
DRAINS	DRAINS is a hydrologic and hydraulic modelling computer program which is used to simulate catchment rainfall-runoff and stormwater drainage systems and is widely used across Australia.
Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood liable land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.

	Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
Habitable room	As defined in Kempsey DCP 2013, includes any living rooms and any rooms intended or adaptable for sleeping, eating or cooking but not including laundry and toilet. “Habitable floor level” refers to the floor elevation (in m AHD) of those habitable rooms.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Overland flow path	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.

Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation,1986). It is the primary input to PMF estimation.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
WBNM	WBNM is a hydrologic modelling computer program which is used to simulate catchment rainfall-runoff and is widely used across Australia.

Appendix A. Design event flood mapping



GIS MAP file : IA252400_R03_FigD6_1pAEP_d_001

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4
- Limit of Mapping

Jacobs

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A3

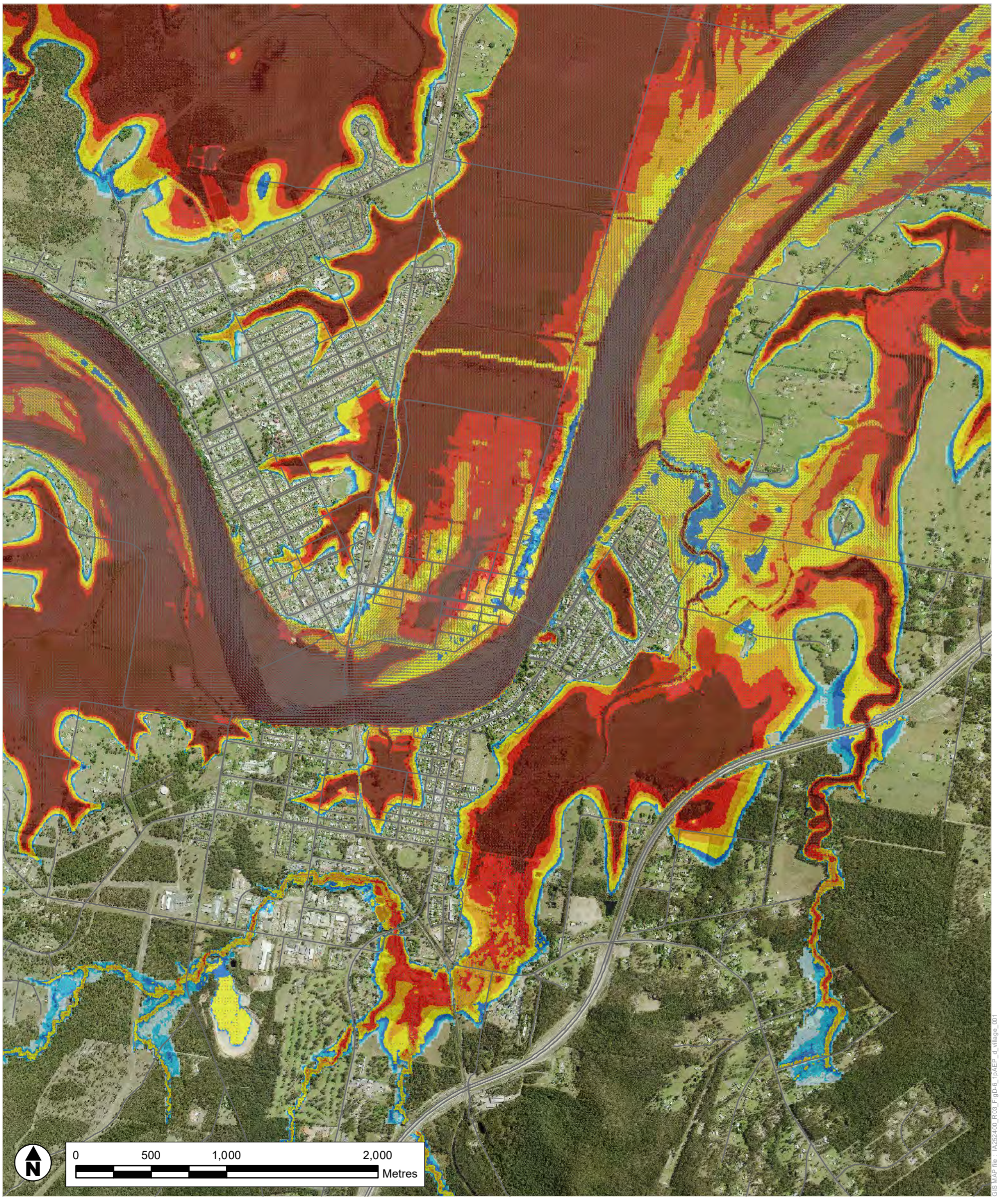
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Depth

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-1	1	1
CHECK AH	DATE 29/09/2022			



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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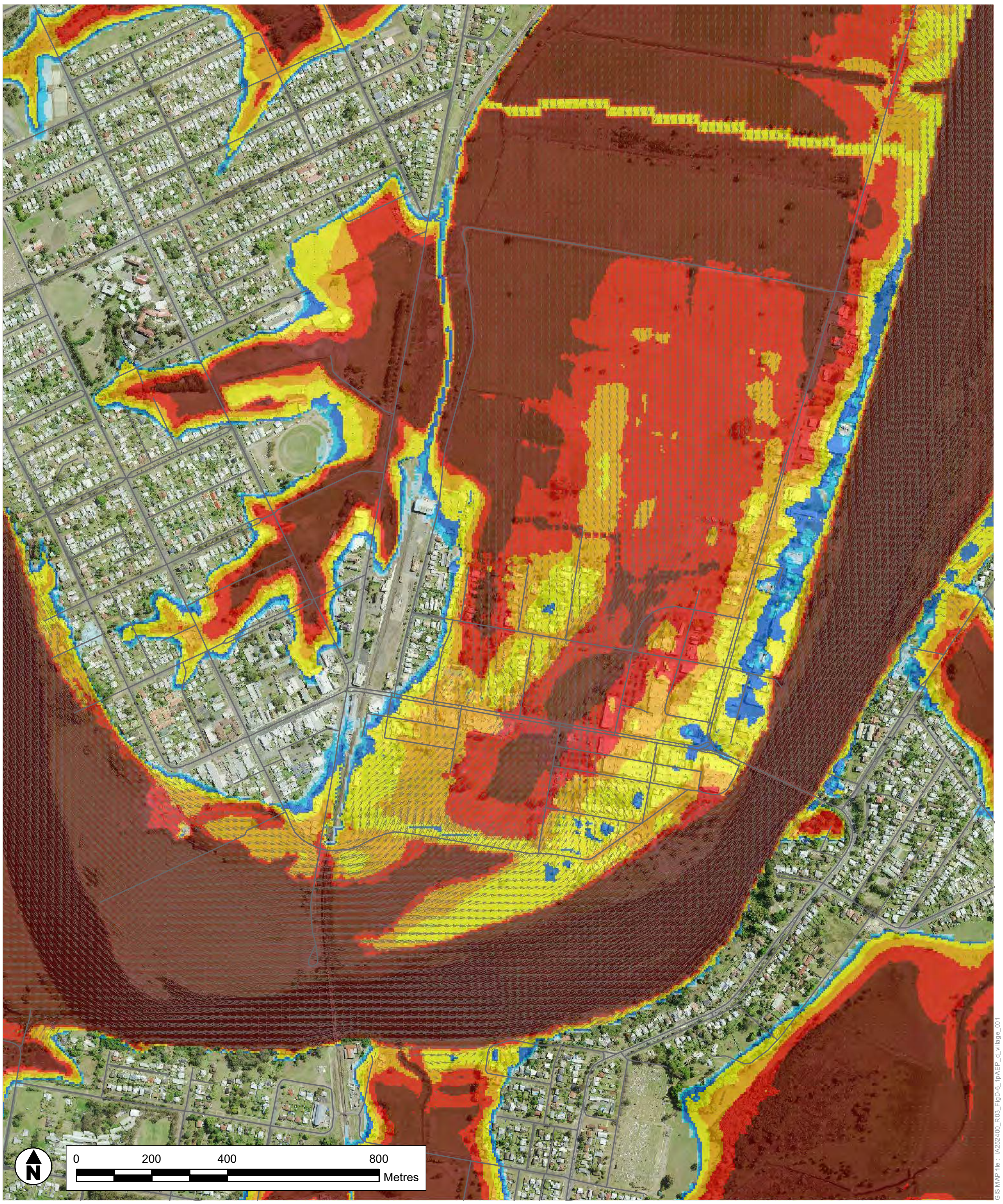
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(A)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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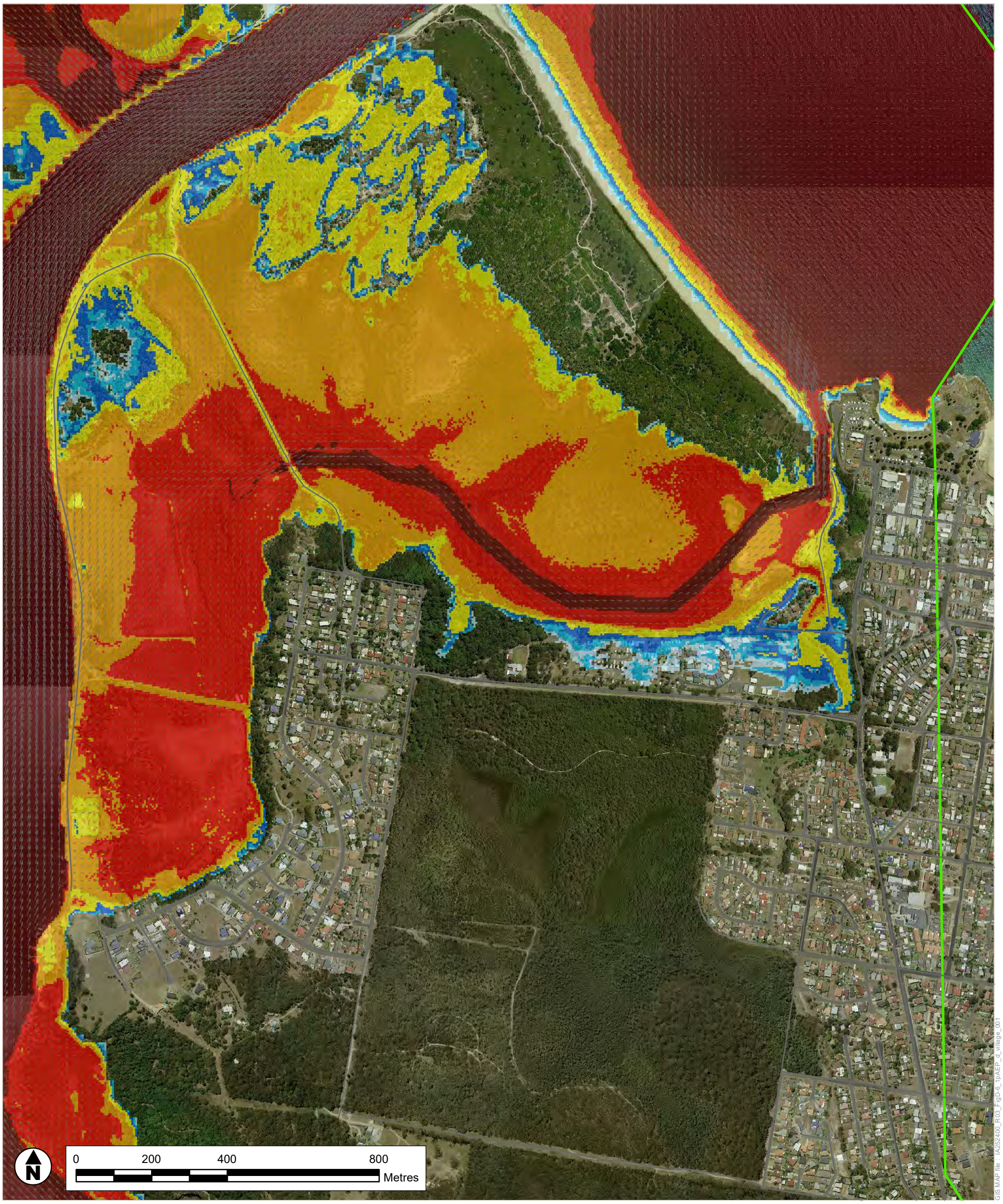
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(B)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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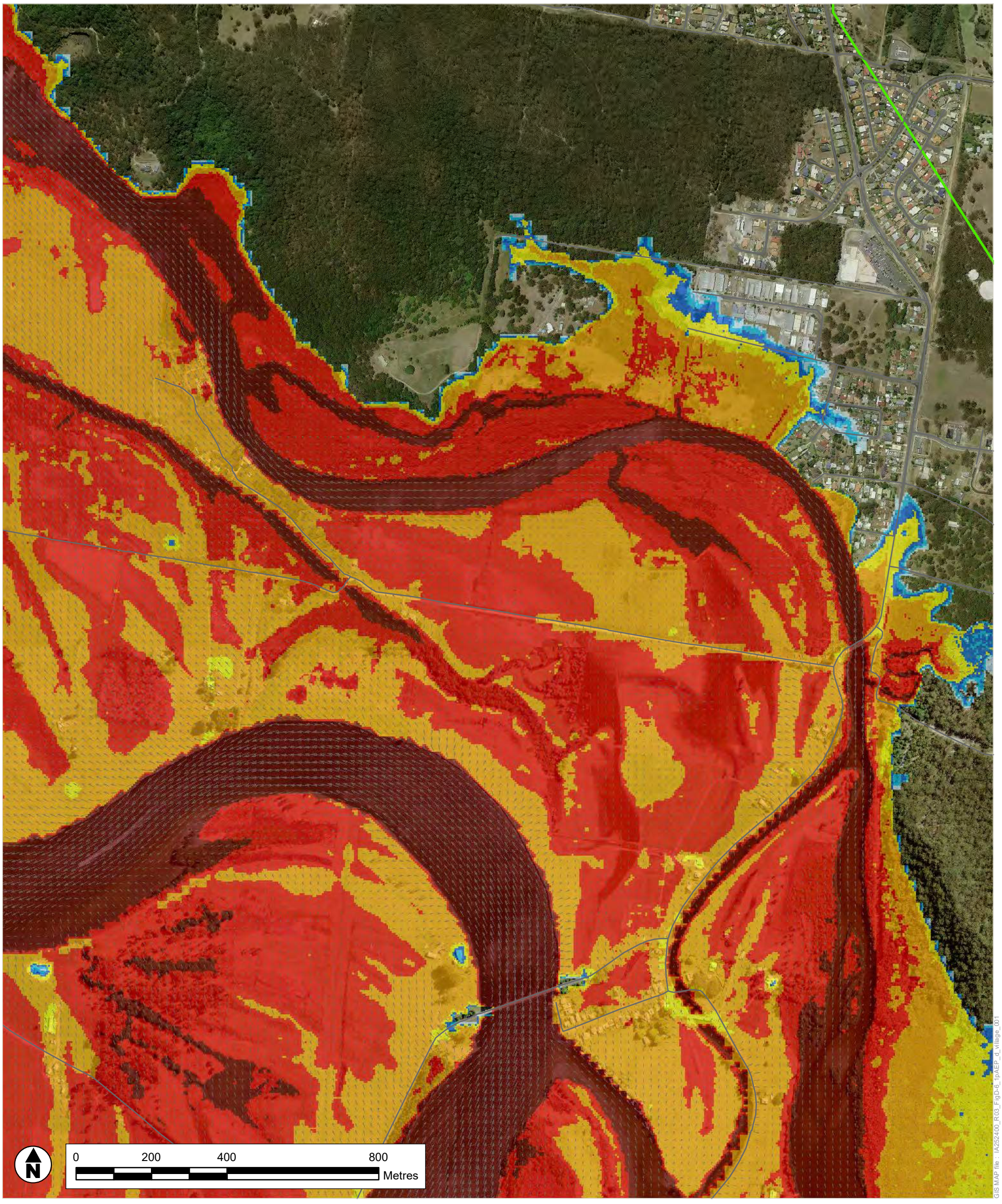
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-1(C)
CHECK AH	DATE 30/09/2022	



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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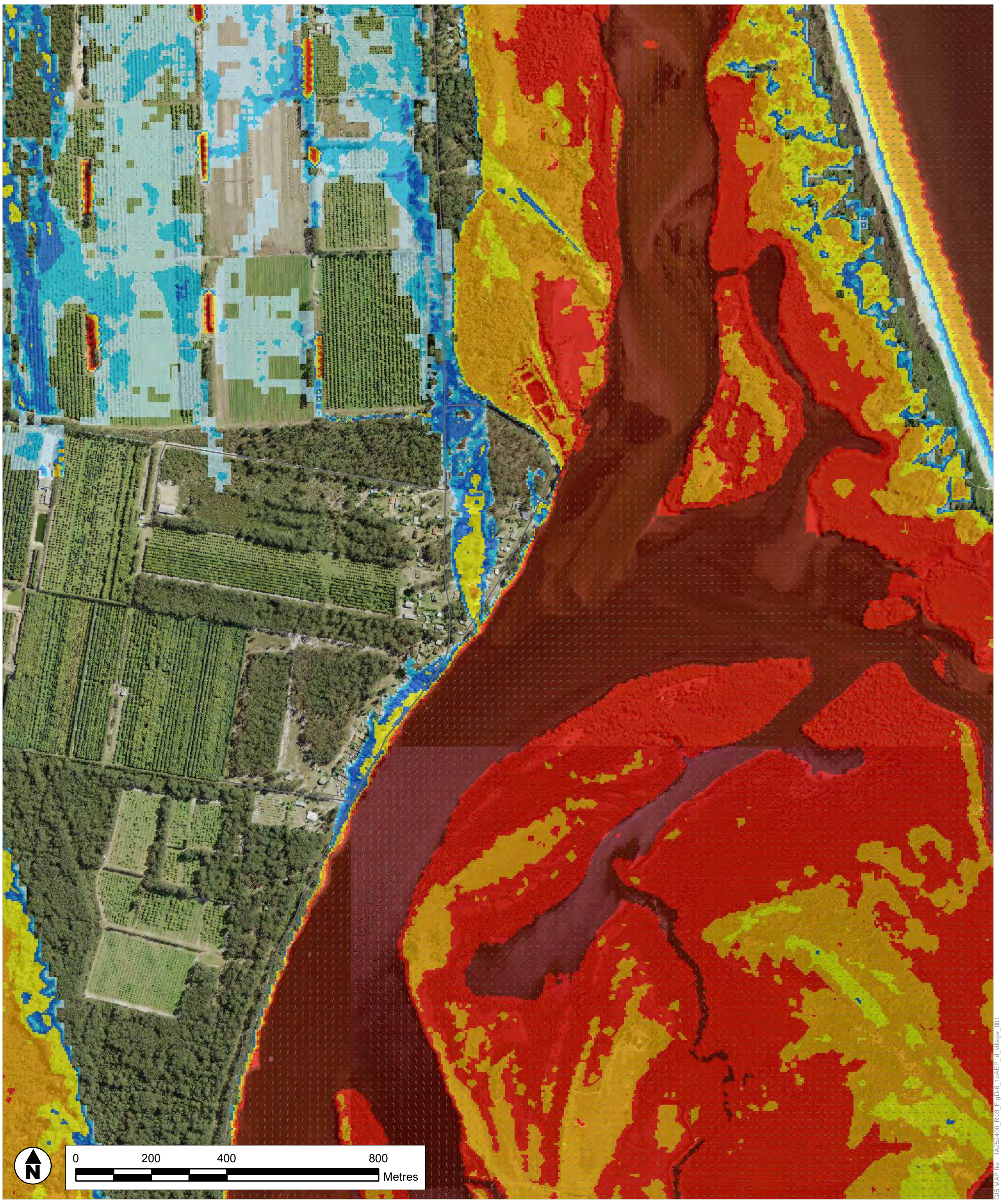
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(D)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

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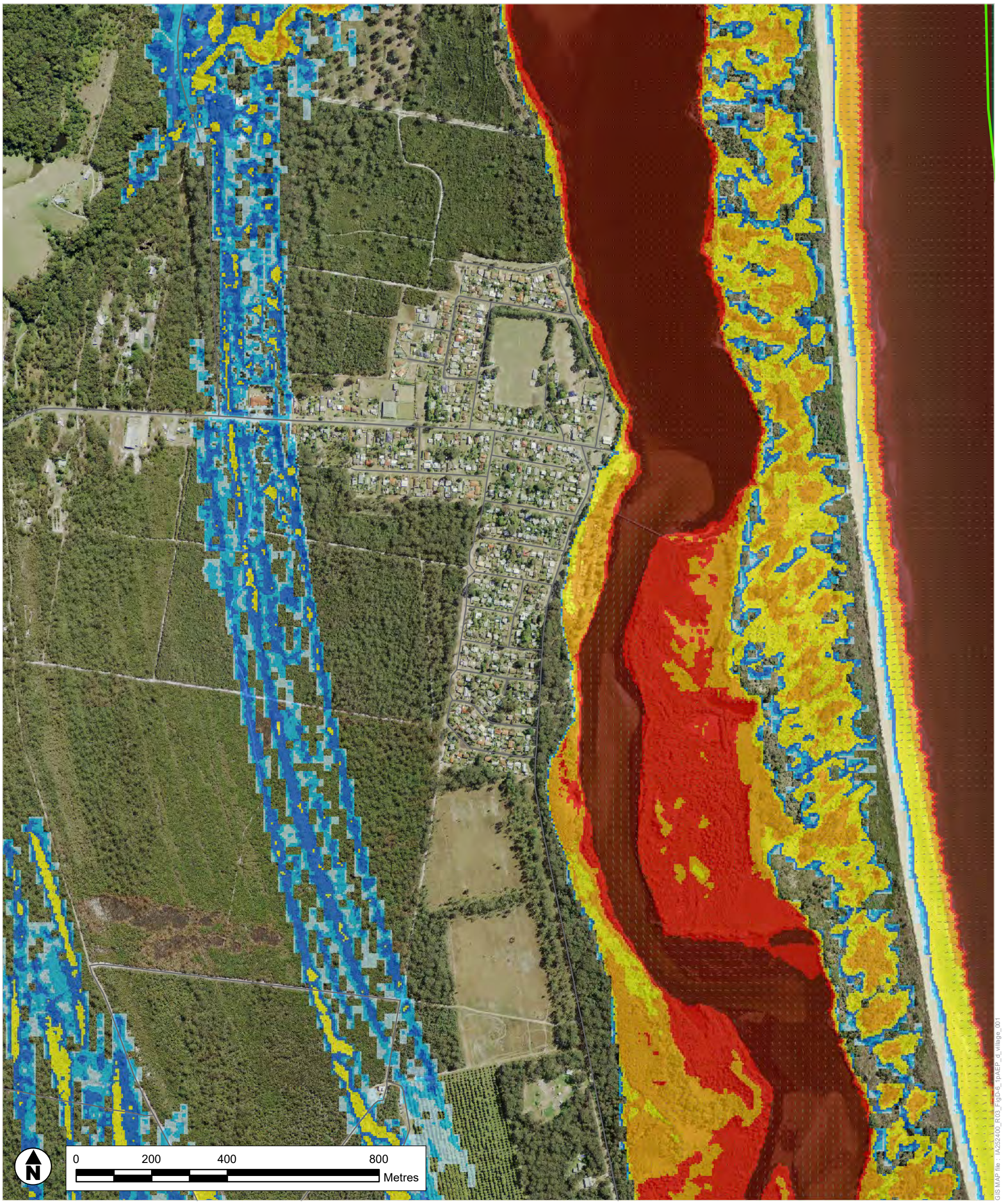
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(E)



Legend

Depth (m)

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- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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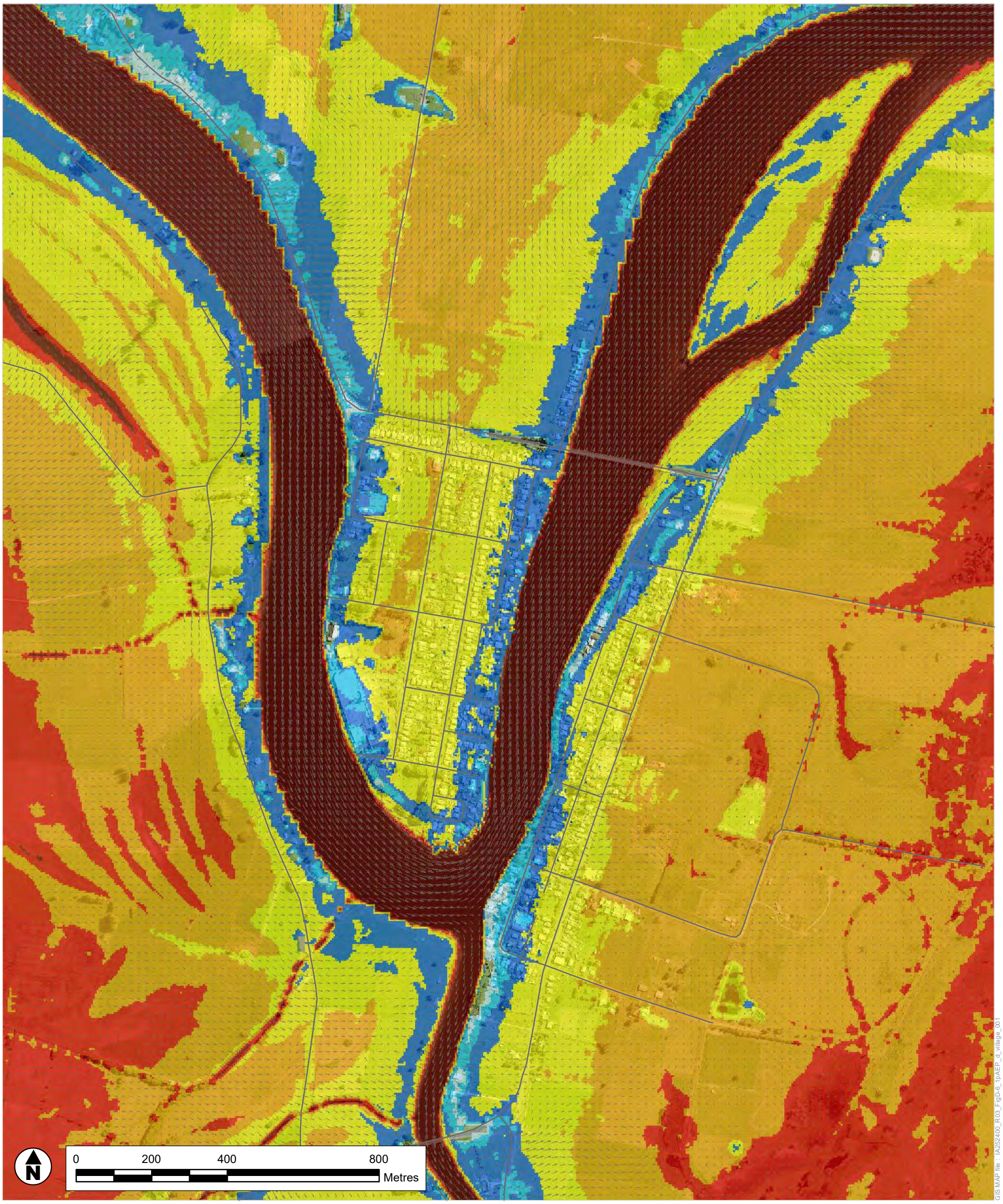
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(F)



Legend

Depth (m)

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- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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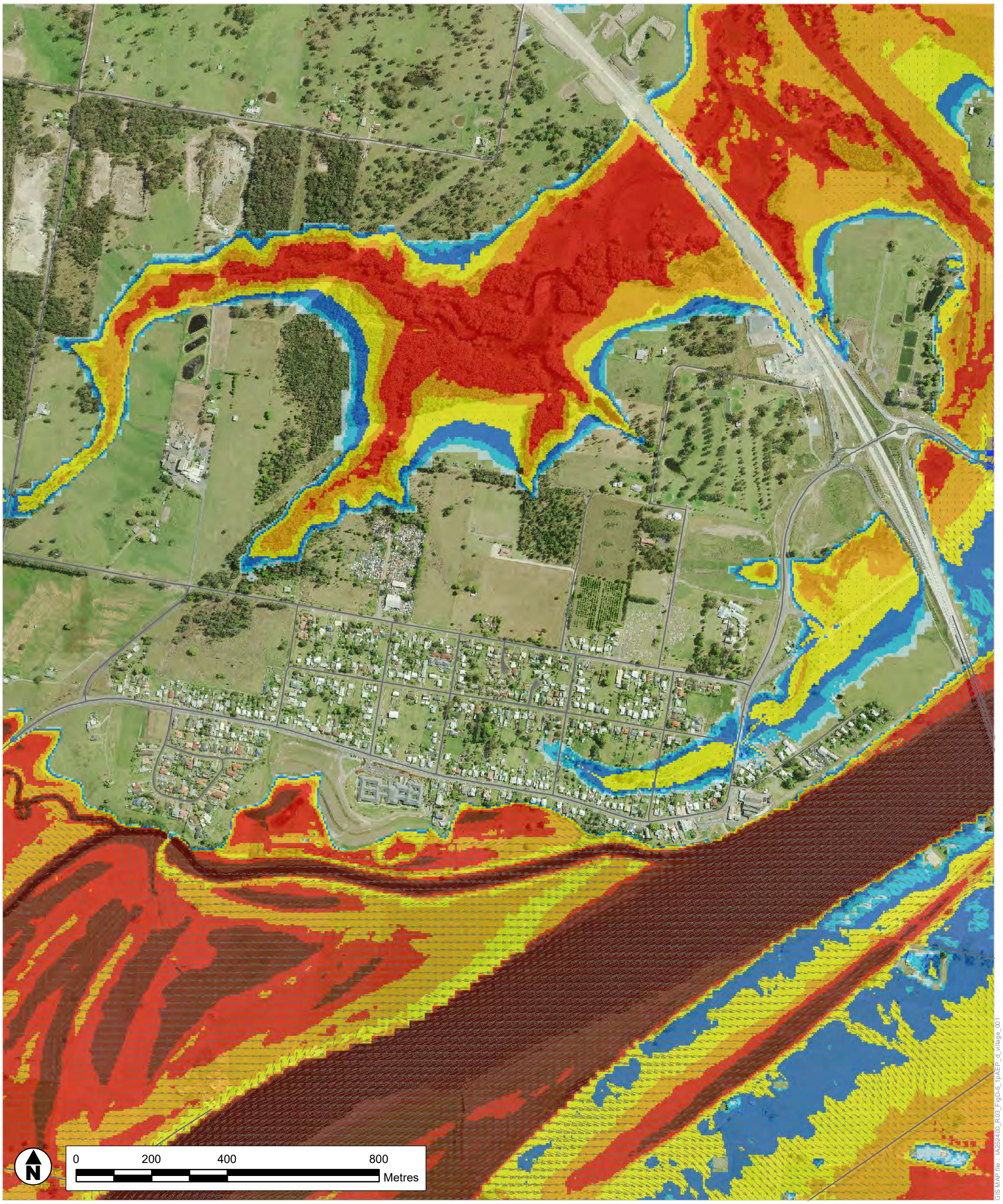
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(G)



Legend

Depth (m)

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- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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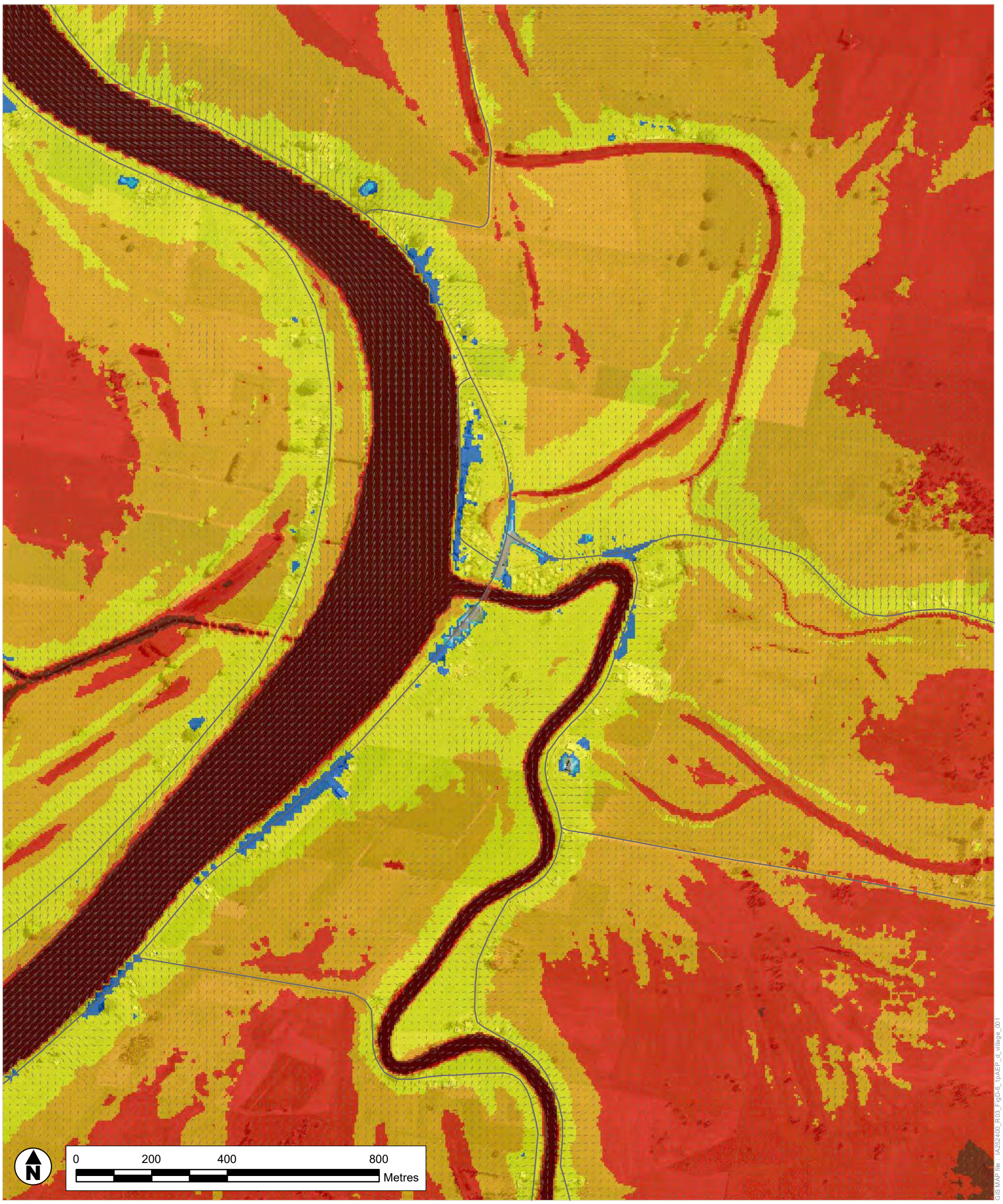
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Frederickton	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(H)



Legend

Depth (m)

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- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

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A3

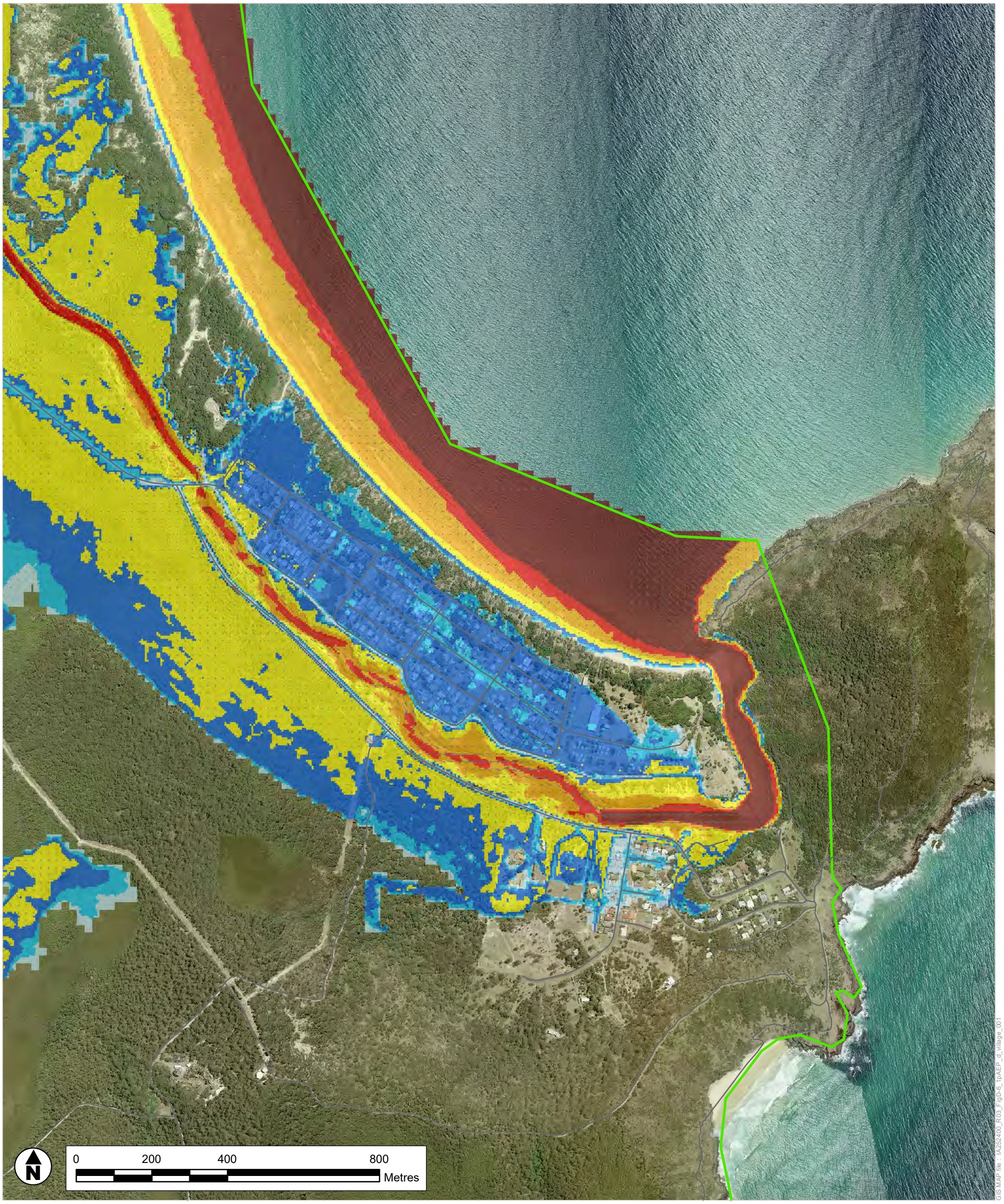
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Depth
Kinchela

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-1(I)
CHECK AH	DATE 30/09/2022	



Legend

Depth (m)

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- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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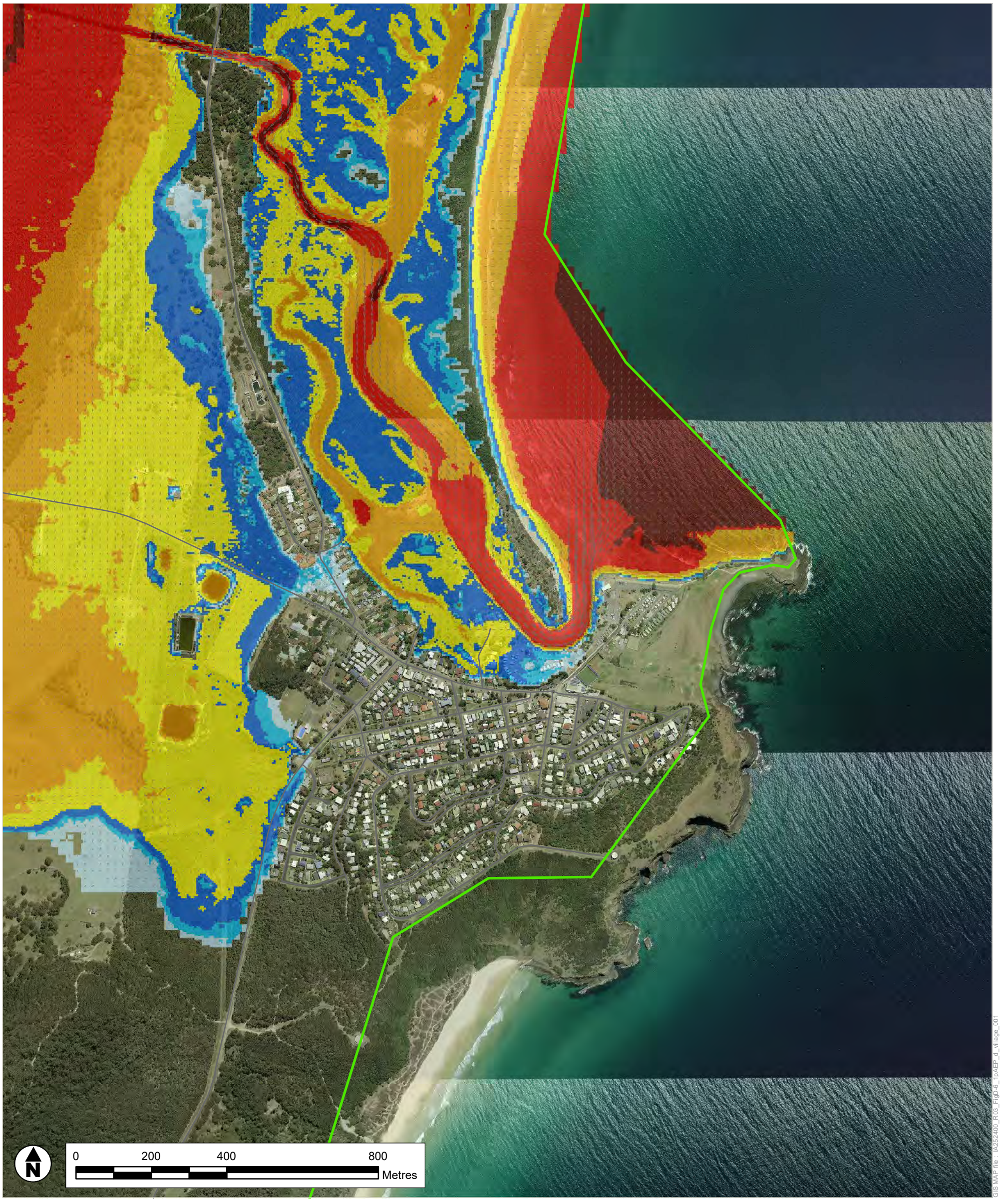
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(J)

GIS MAP file : IA252400_R03_FigD-6_1pAEP_d_village_001



Legend

Depth (m)

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- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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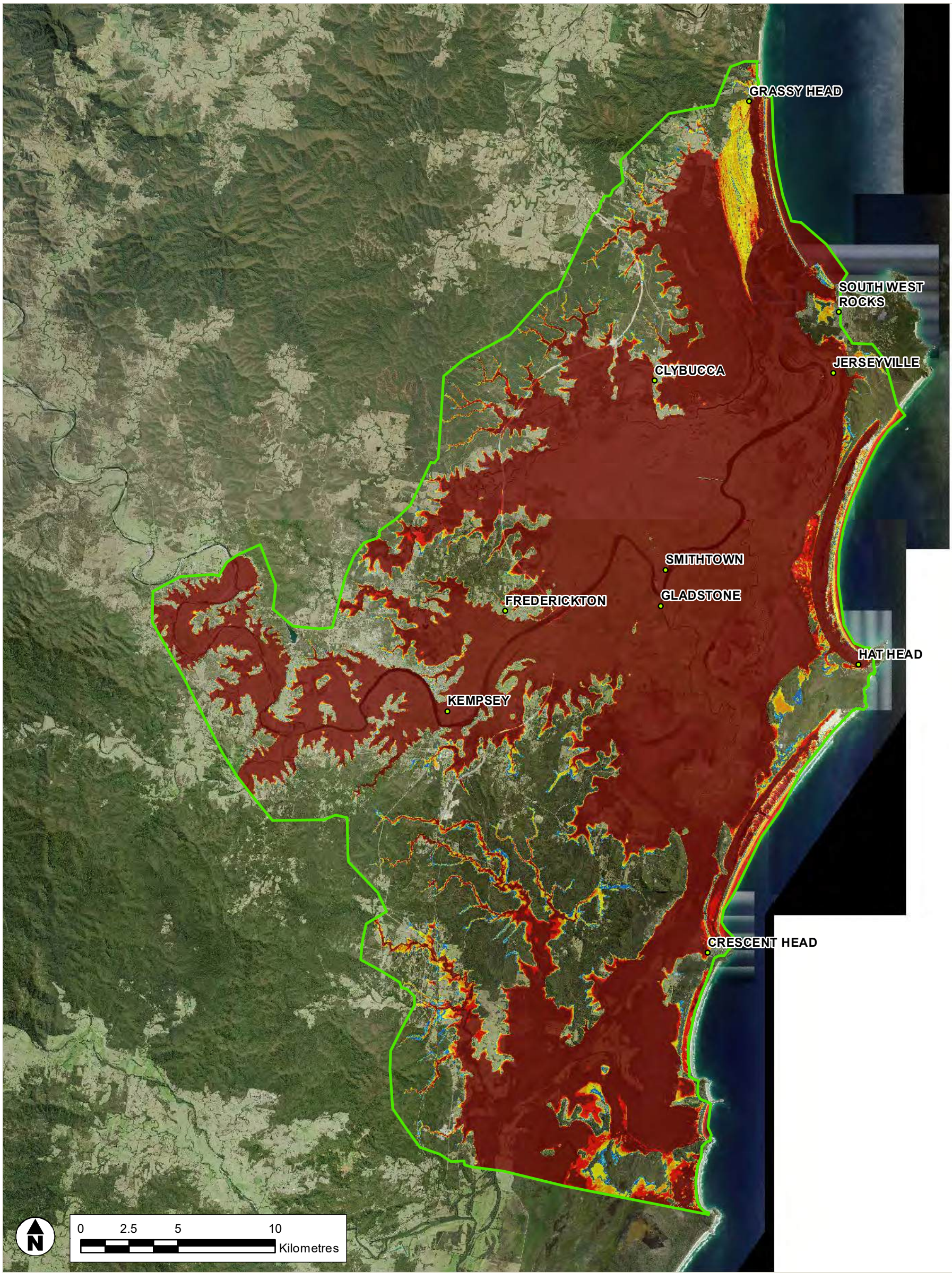
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 30/09/2022	FIGURE A-1(K)



GIS MAP file : IA252400_R03_FigD-9_PMF_d_001

Legend

Depth (m)

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- 2 - 3
- 3 - 4
- > 4
- Limit of Mapping

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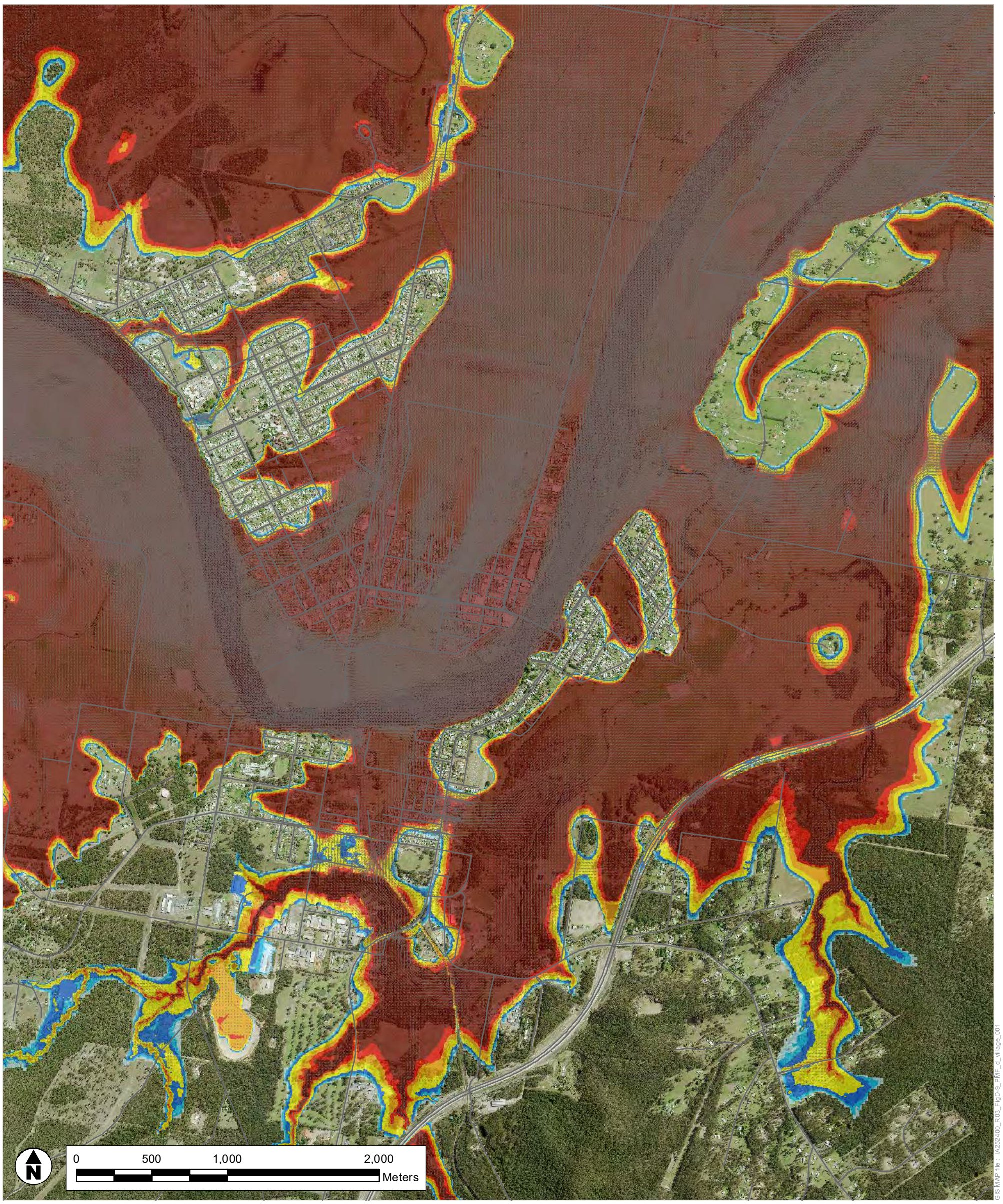
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-2	1	1
CHECK	DATE			
LC	7/10/2022			



Legend

Depth (m)

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- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-2(A)
CHECK AH	DATE 7/10/2022	

Legend

Depth (m)

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- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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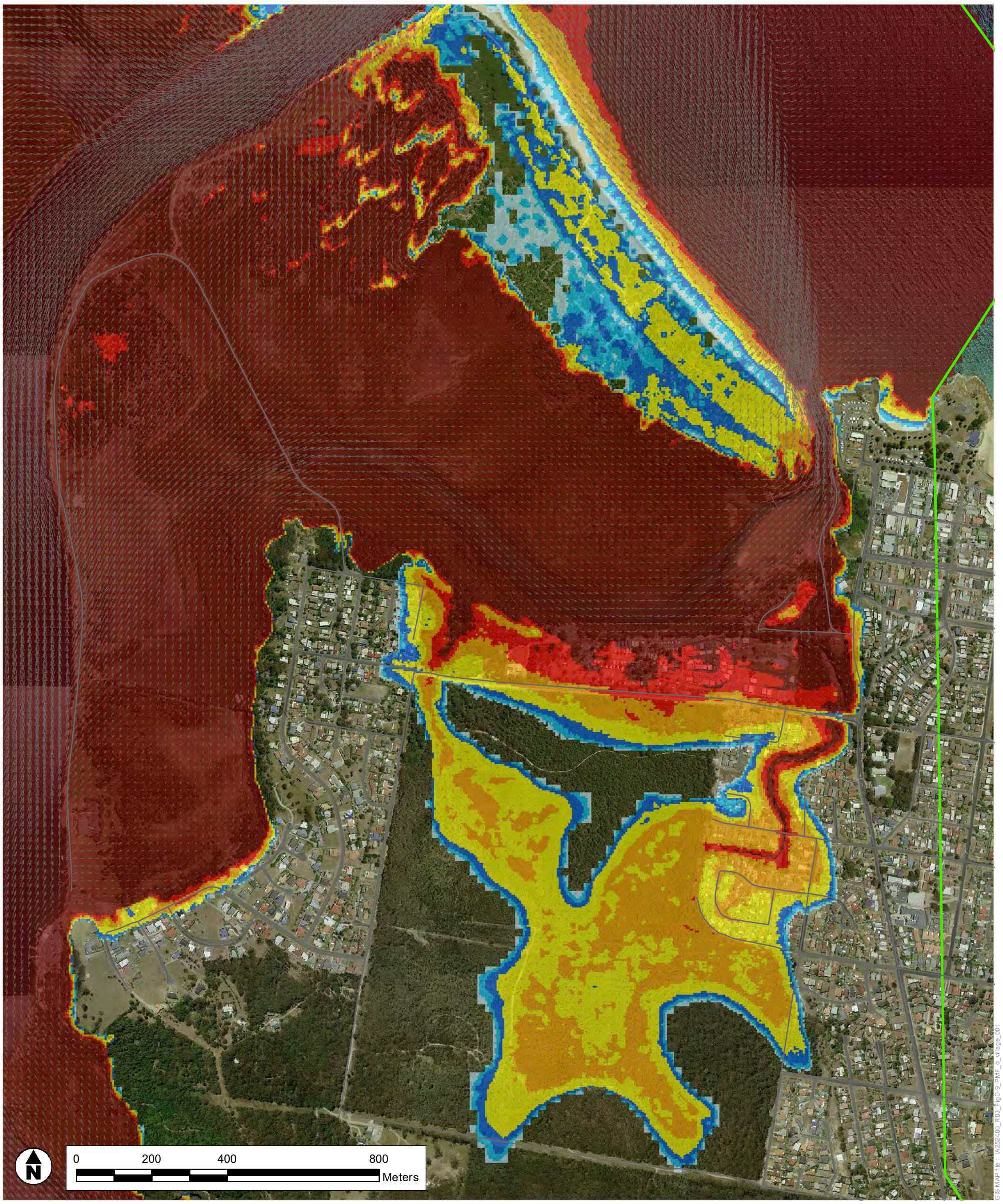
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-2(B)
CHECK AH	DATE 7/10/2022	



Legend

Depth (m)

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- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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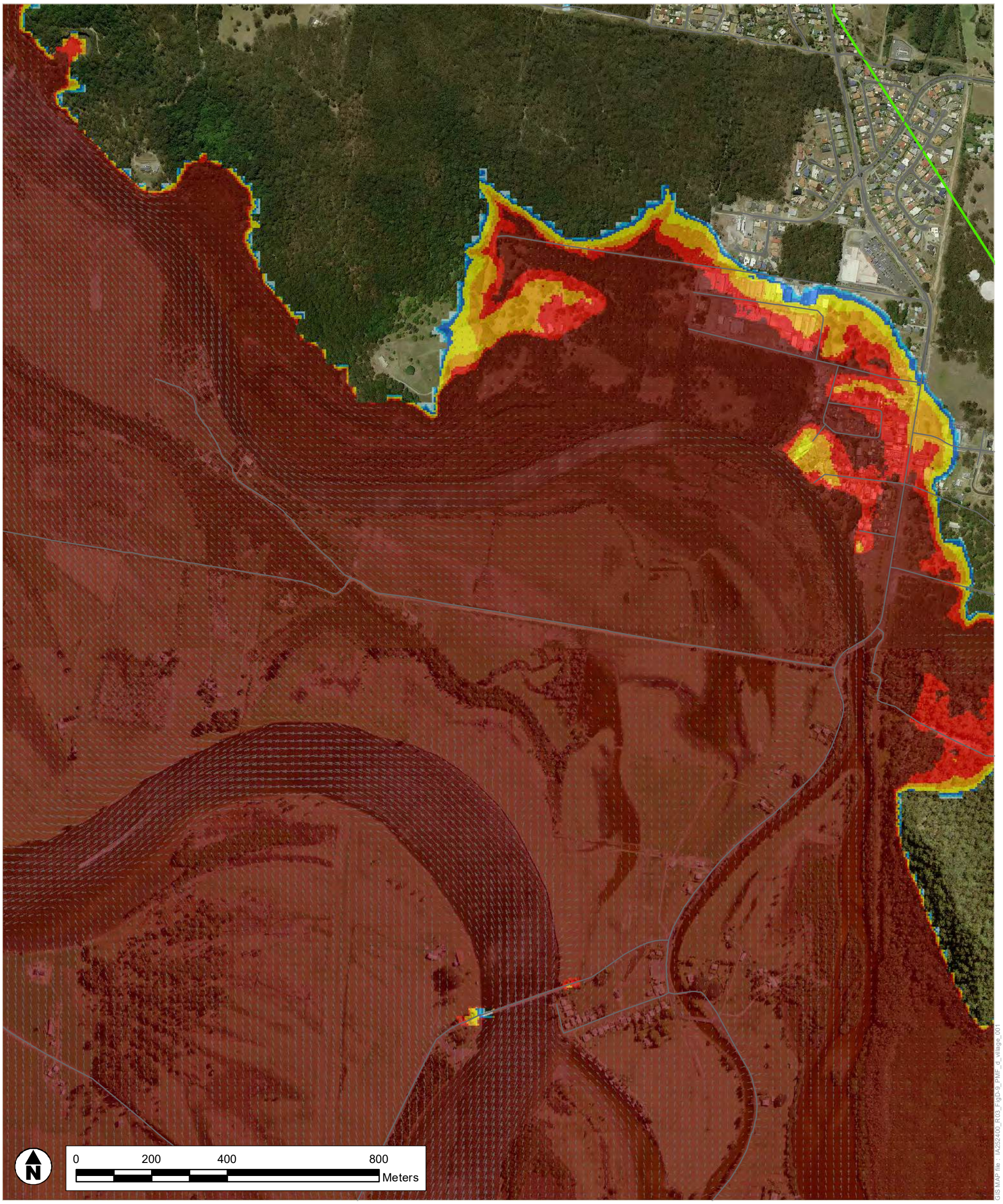
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-2(C)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

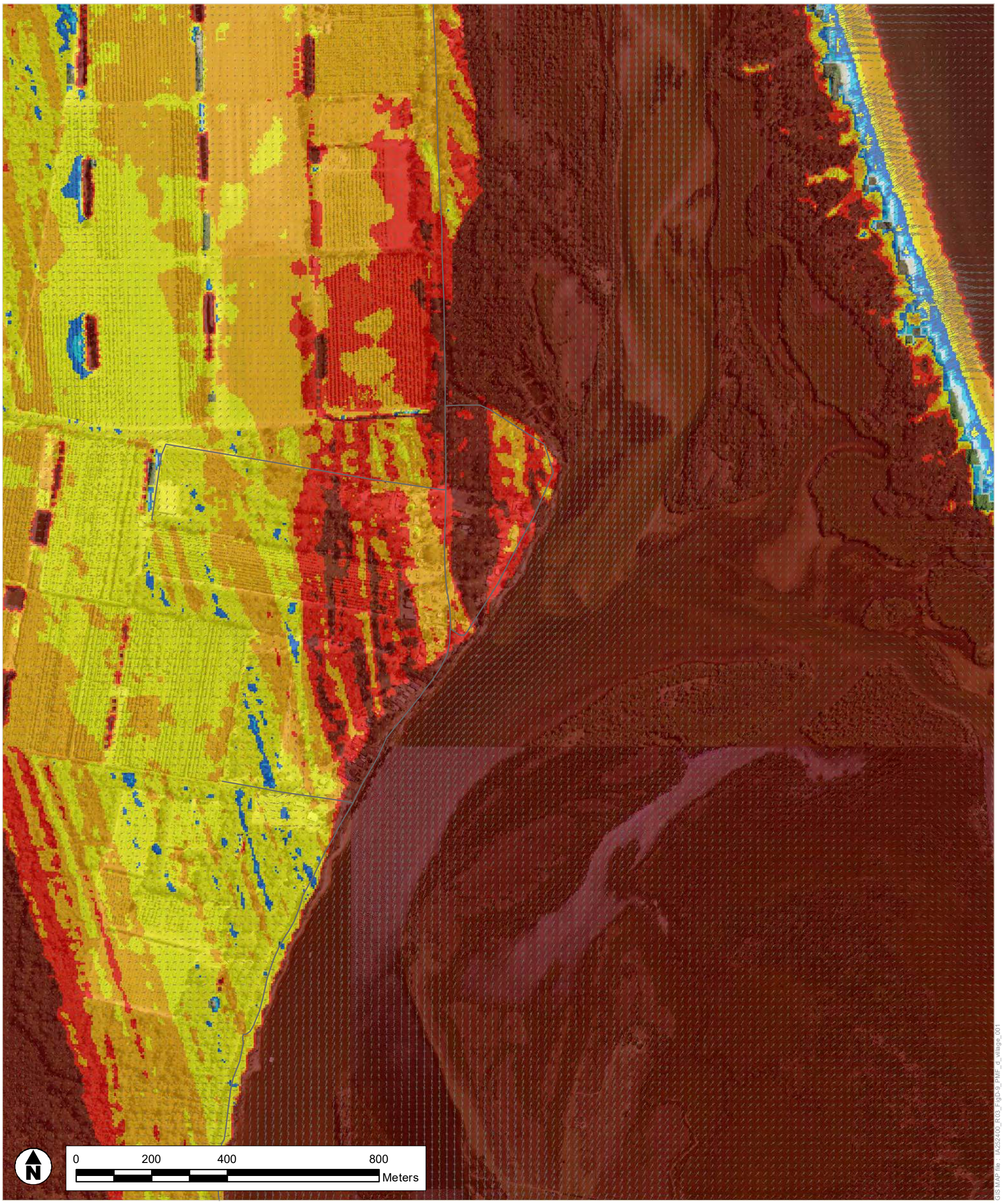
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-2(D)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

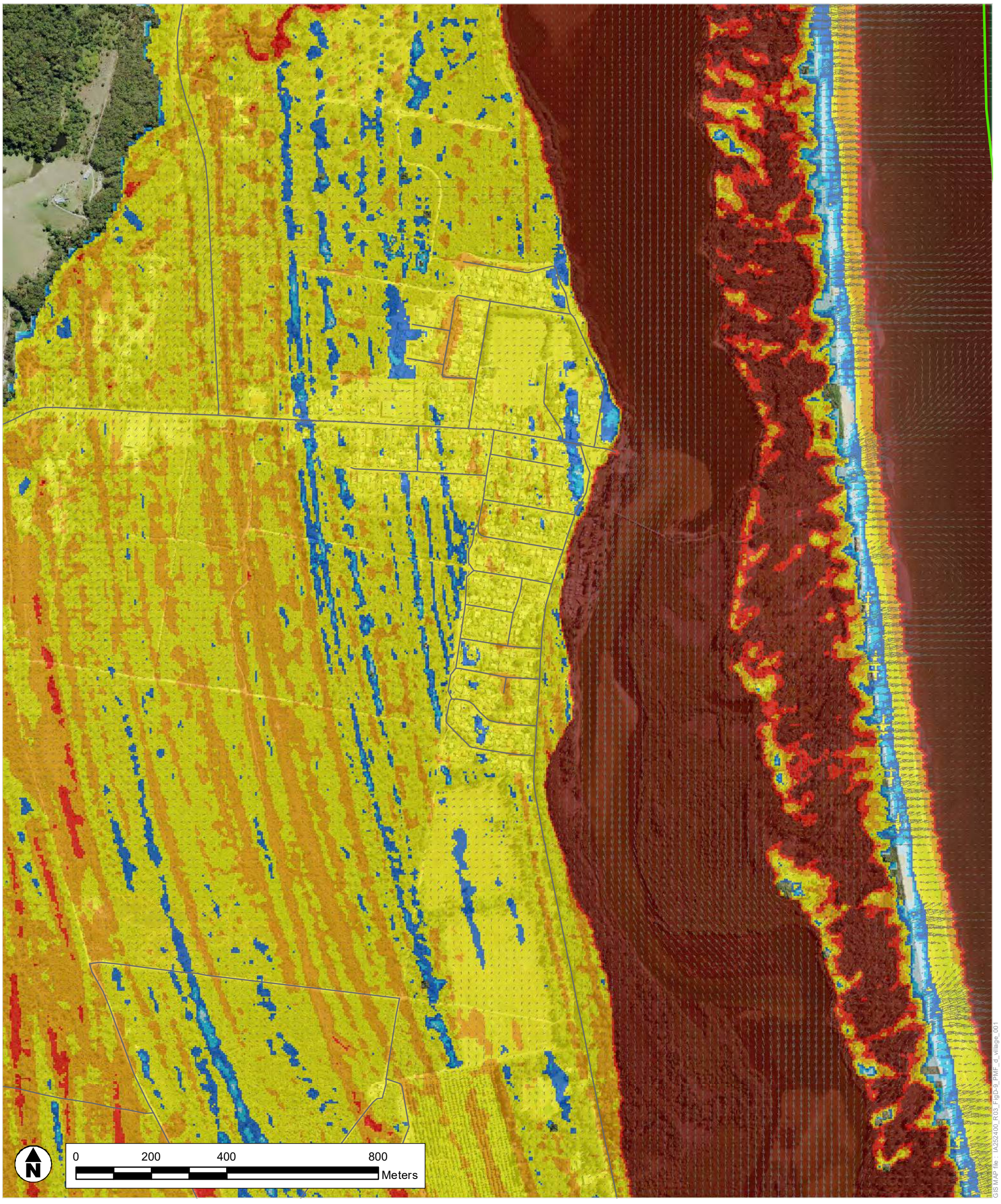
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Depth
Fishermans Reach

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-2(E)
CHECK AH	DATE 7/10/2022	



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-2(F)

GIS MAP file : IA252400_R03_FigD-9_PMF_d_village_001

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

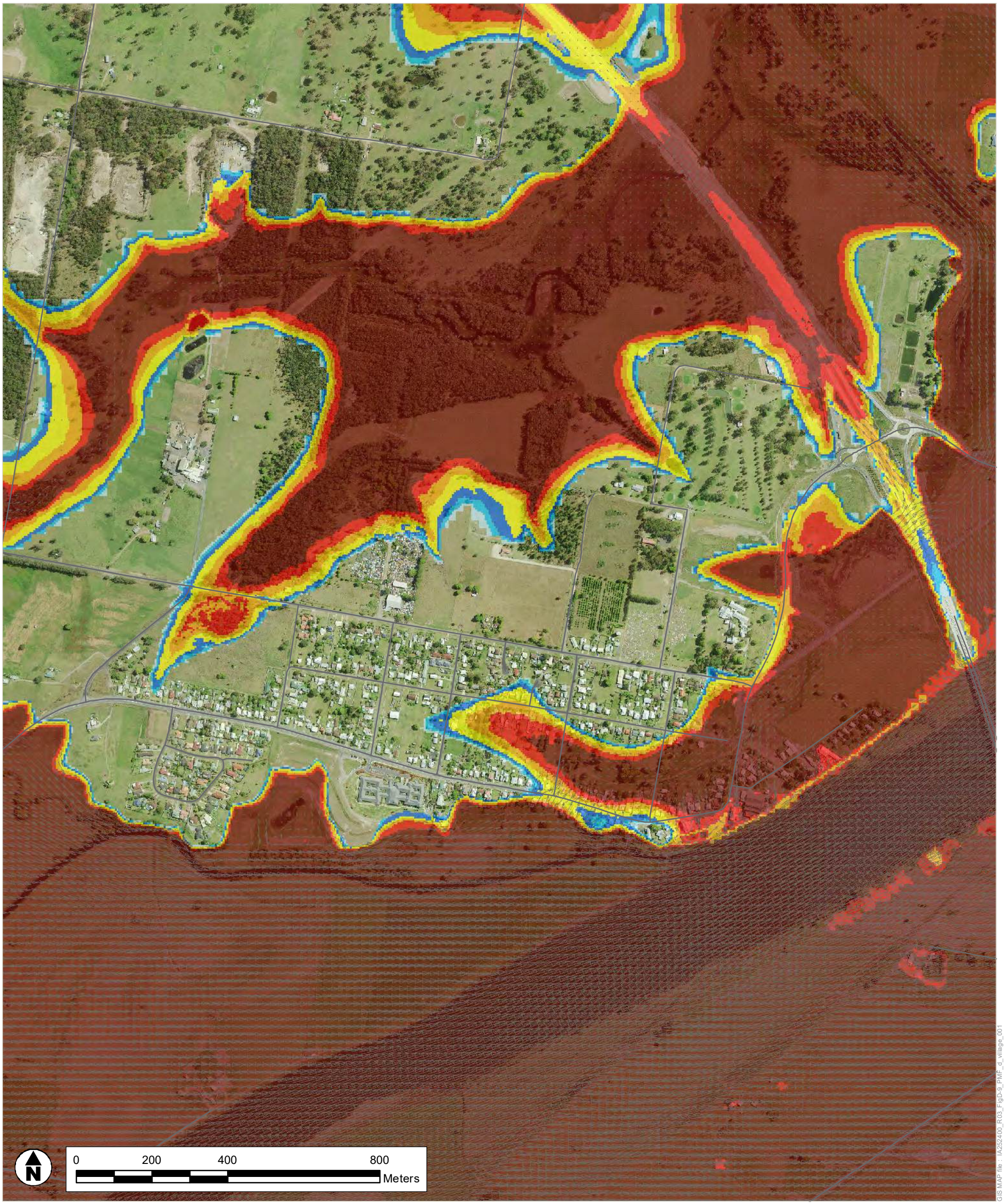
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Depth
Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-2(G)
CHECK AH	DATE 7/10/2022	



GIS MAP file : IA252400_R03_FigD-9_PMF_d_village_001

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Depth
Frederickton

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-2(H)
CHECK AH	DATE 7/10/2022	

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

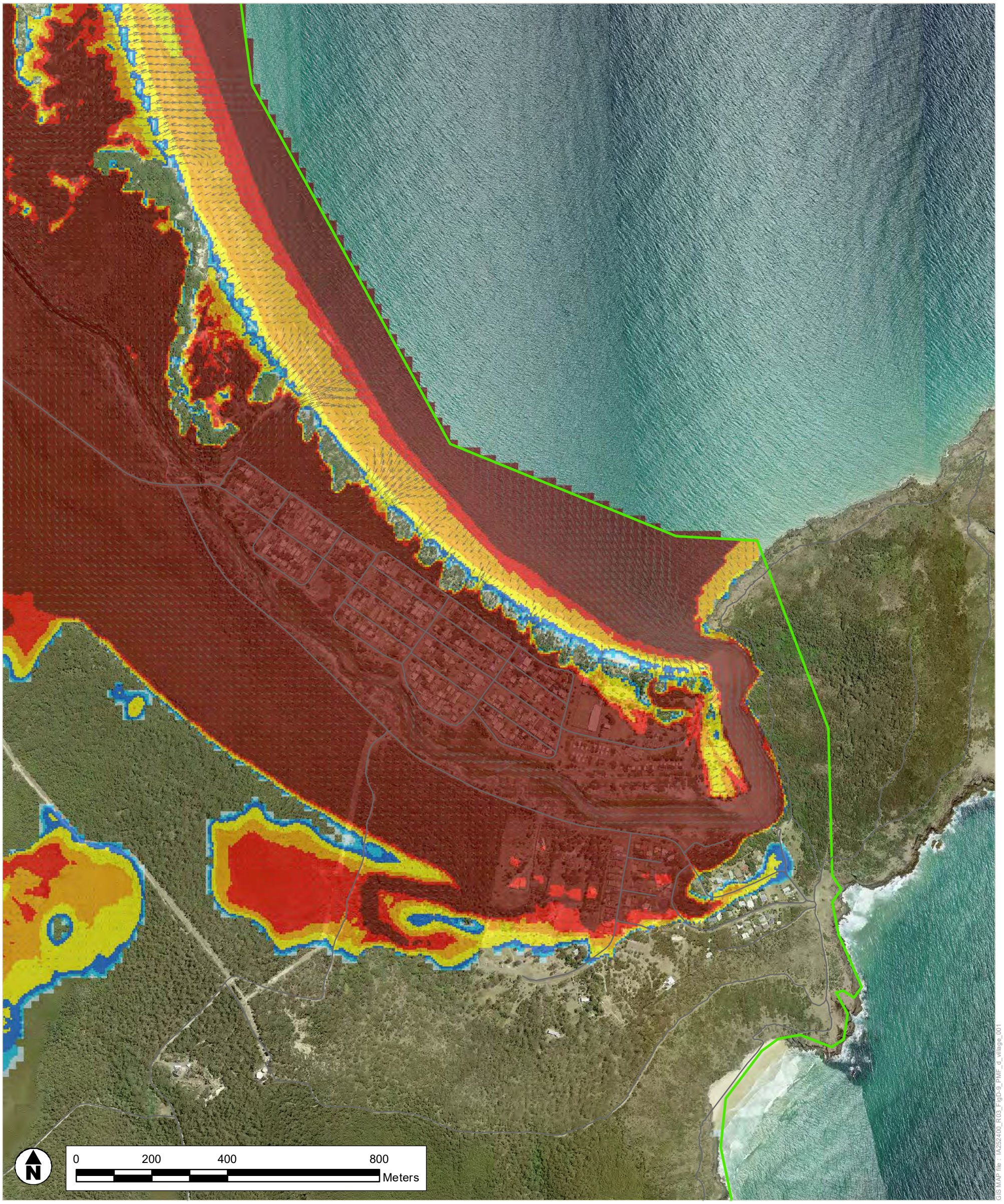
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-2(I)



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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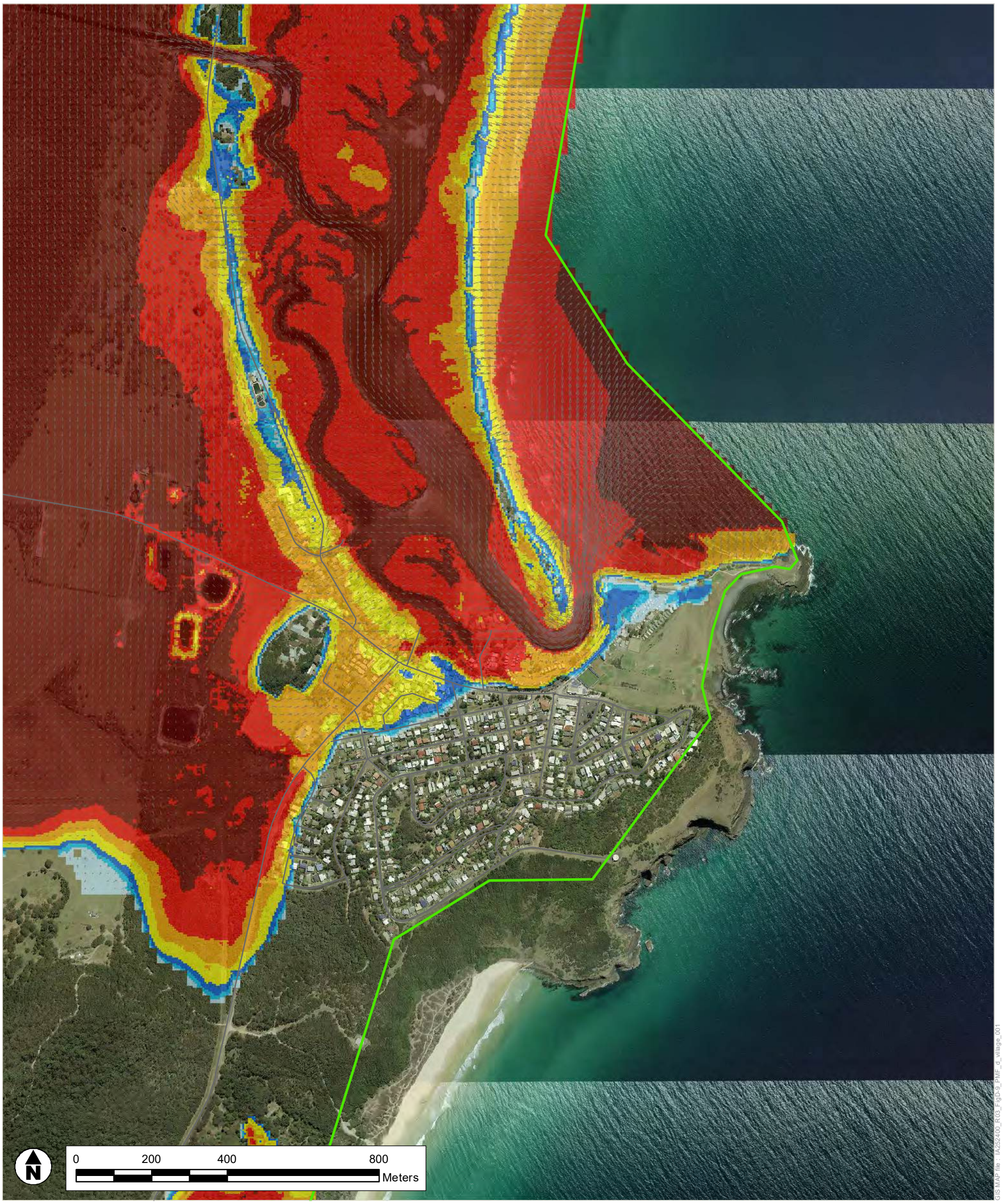
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Depth Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-2(J)

GIS MAP file : IA252400_R03_FigD-9_PMF_d_village_001



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

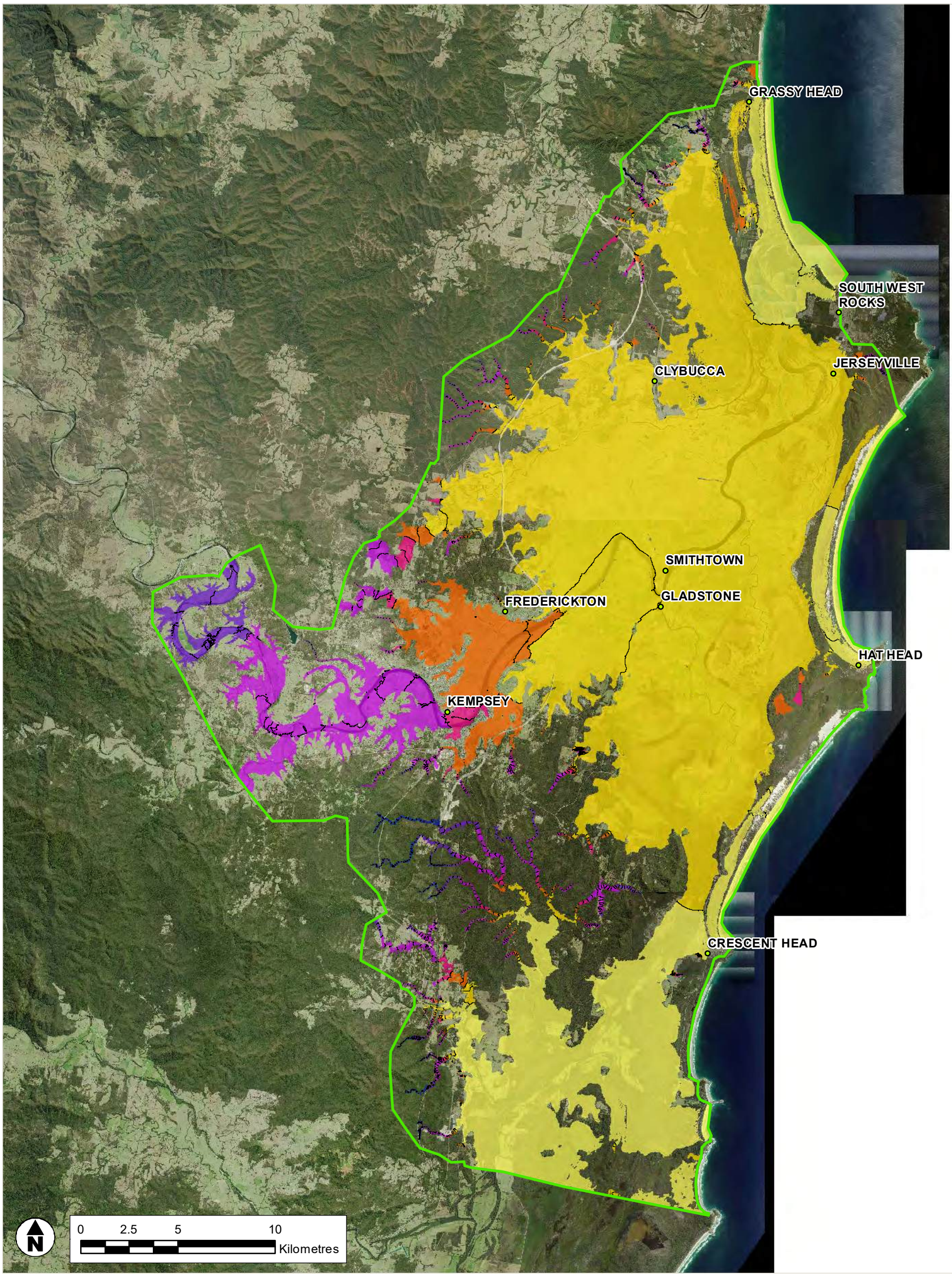
GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Depth
Crescent Head

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-2(K)
CHECK AH	DATE 7/10/2022	

GIS MAP file : IA252400_R03_FigD-9_PMF_d_village_001



GIS MAP file : IA252400_R06_FigA-3_1pAEP_h_001

Legend

Flood Level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

Flood Level 1m Contour (m AHD)

Limit of Mapping

Jacobs

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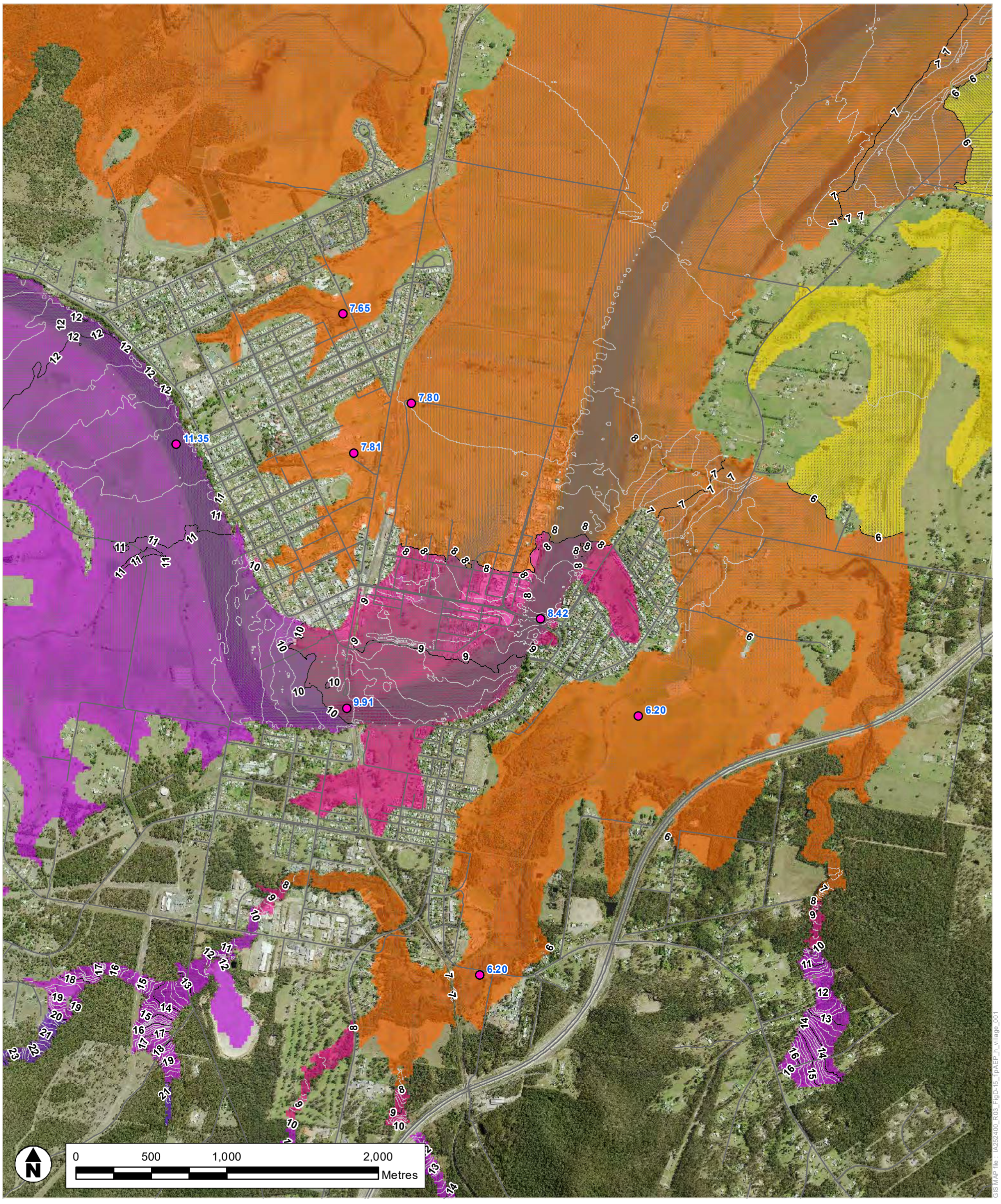
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Level

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-3	1	1
CHECK AH	DATE 3/04/2024			



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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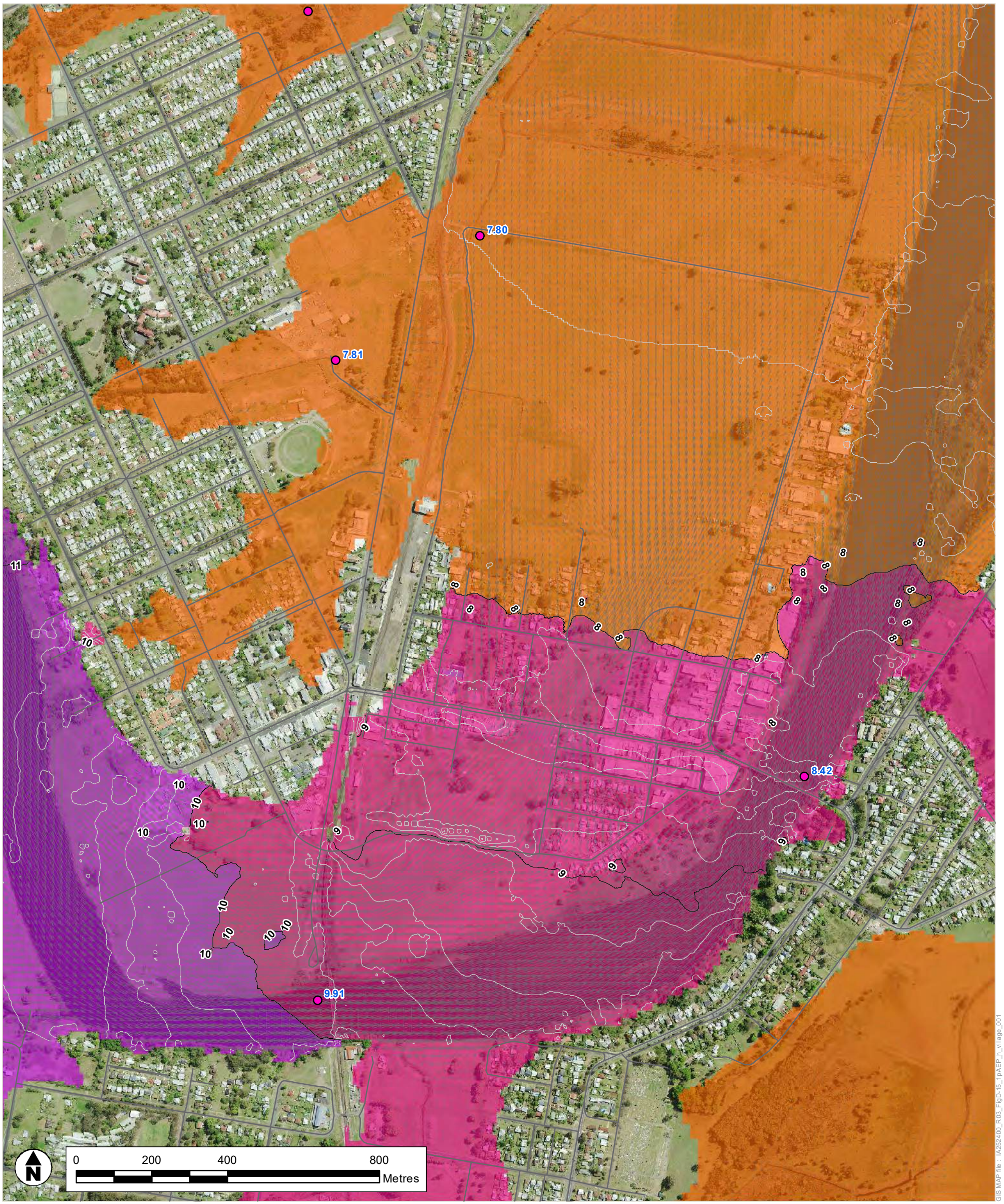
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-3(A)

GIS MAP file : IA252400_R03_FigD-15_fpAEP_h_village_001



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Level Kempsey CBD

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-3(B)
CHECK AH	DATE 10/10/2022	

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-3(C)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1
	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level South West Rocks (S) and Jerseyville
PROJECT	Lower Macleay River Floodplain Risk Management Study
DRAWN	LC
PROJECT #	IA252400
CHECK	AH
DATE	10/10/2022
MAP #	FIGURE A-3(D)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Level
Fishermans Reach

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-3(E)
CHECK AH	DATE 10/10/2022	

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-3(F)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Level
Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-3(G)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-15_1pAEP_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

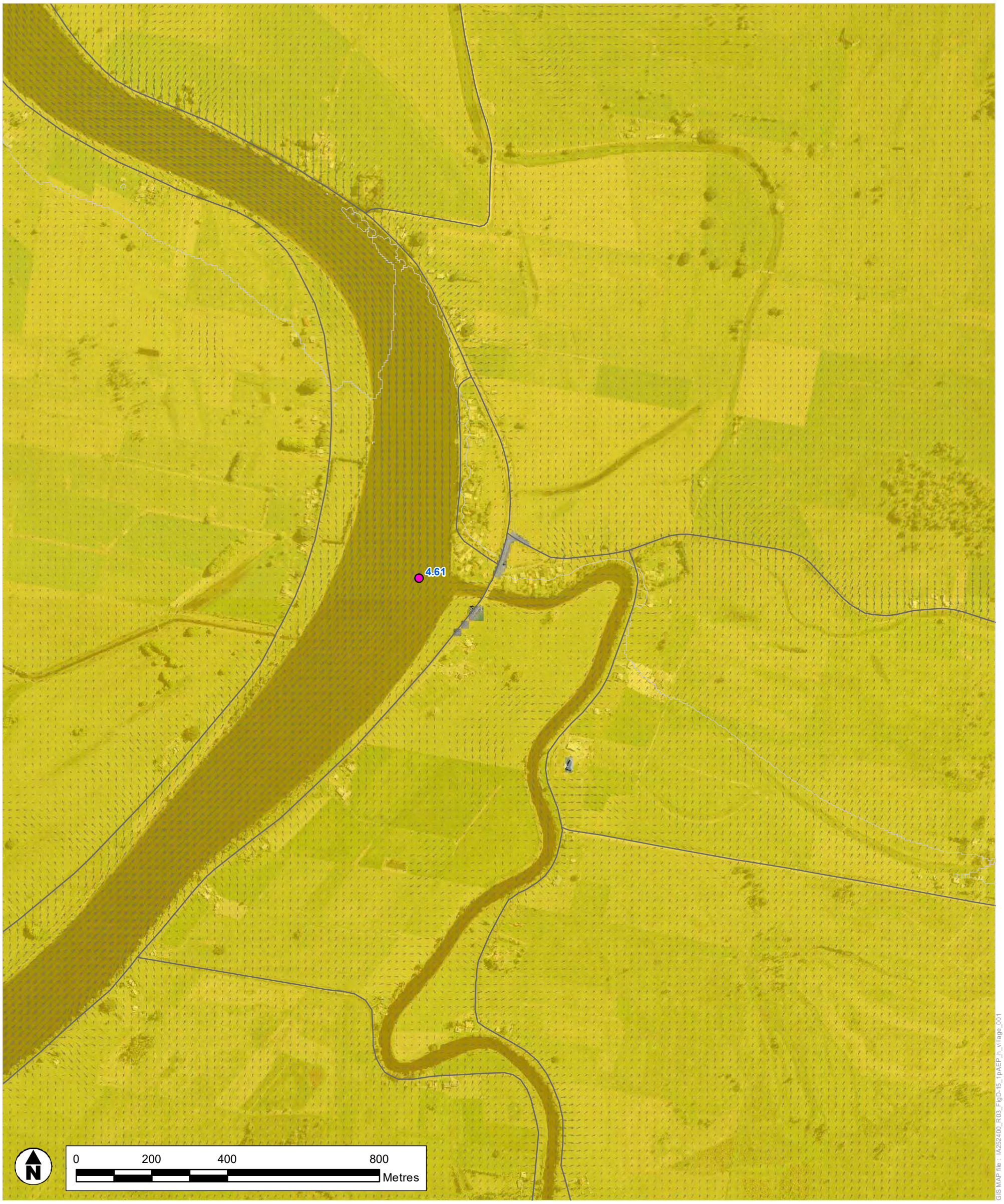
GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Level Frederickton

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-3(H)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-15_1pAEP_h_village_001



GIS MAP file : IA252400_R03_FigD-15_1pAEP_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-3(I)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Level
Hat Head

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-3(J)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-15_1pAEP_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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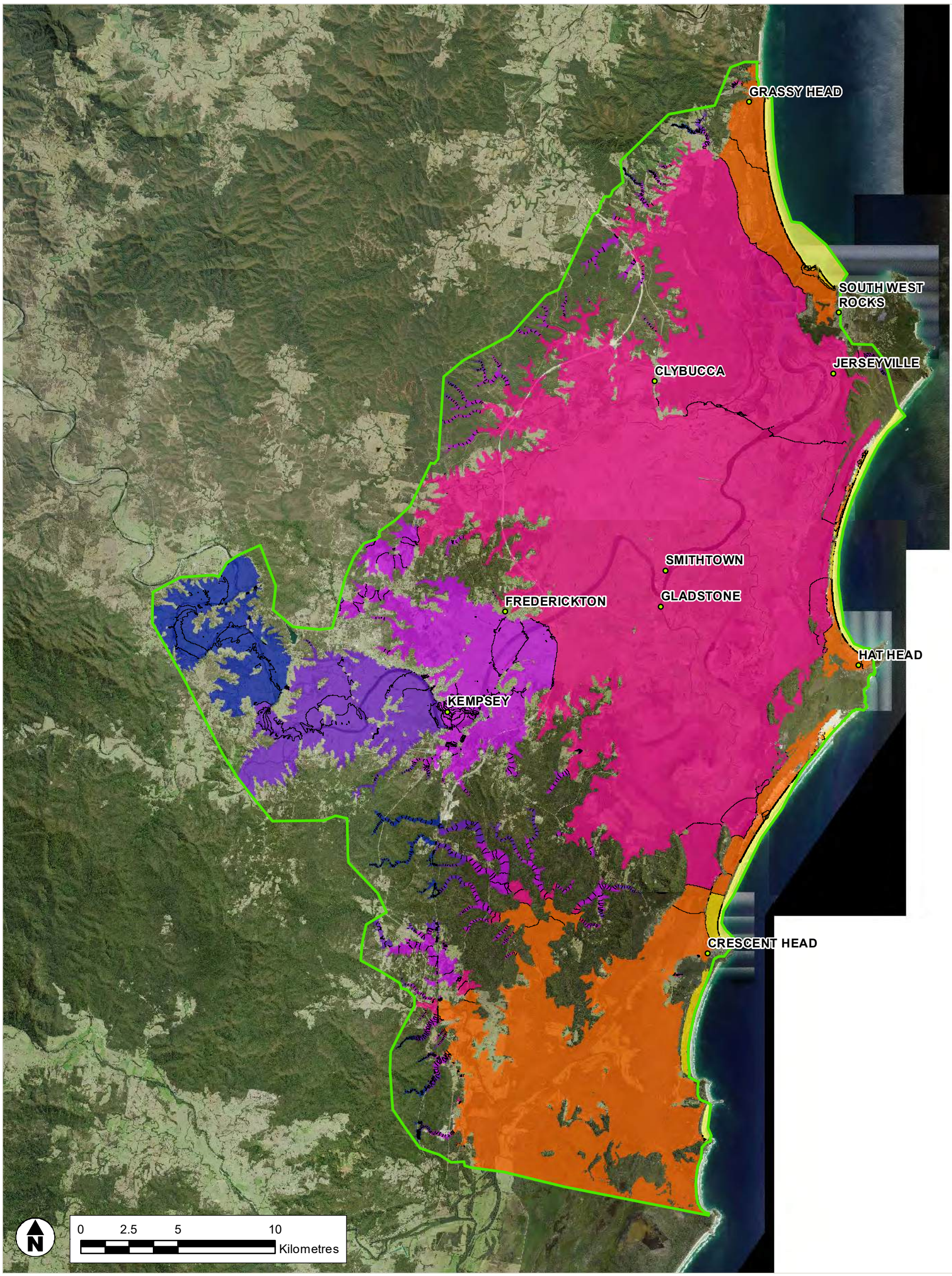
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Level Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-3(K)

GIS MAP file : IA252400_R03_FigD-15_1pAEP_h_village_001



GIS MAP file : IA252400_R06_FigA4_PMF_h_001

Legend

Flood Level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

Flood Level 1m Contour (m AHD)

Limit of Mapping

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A3

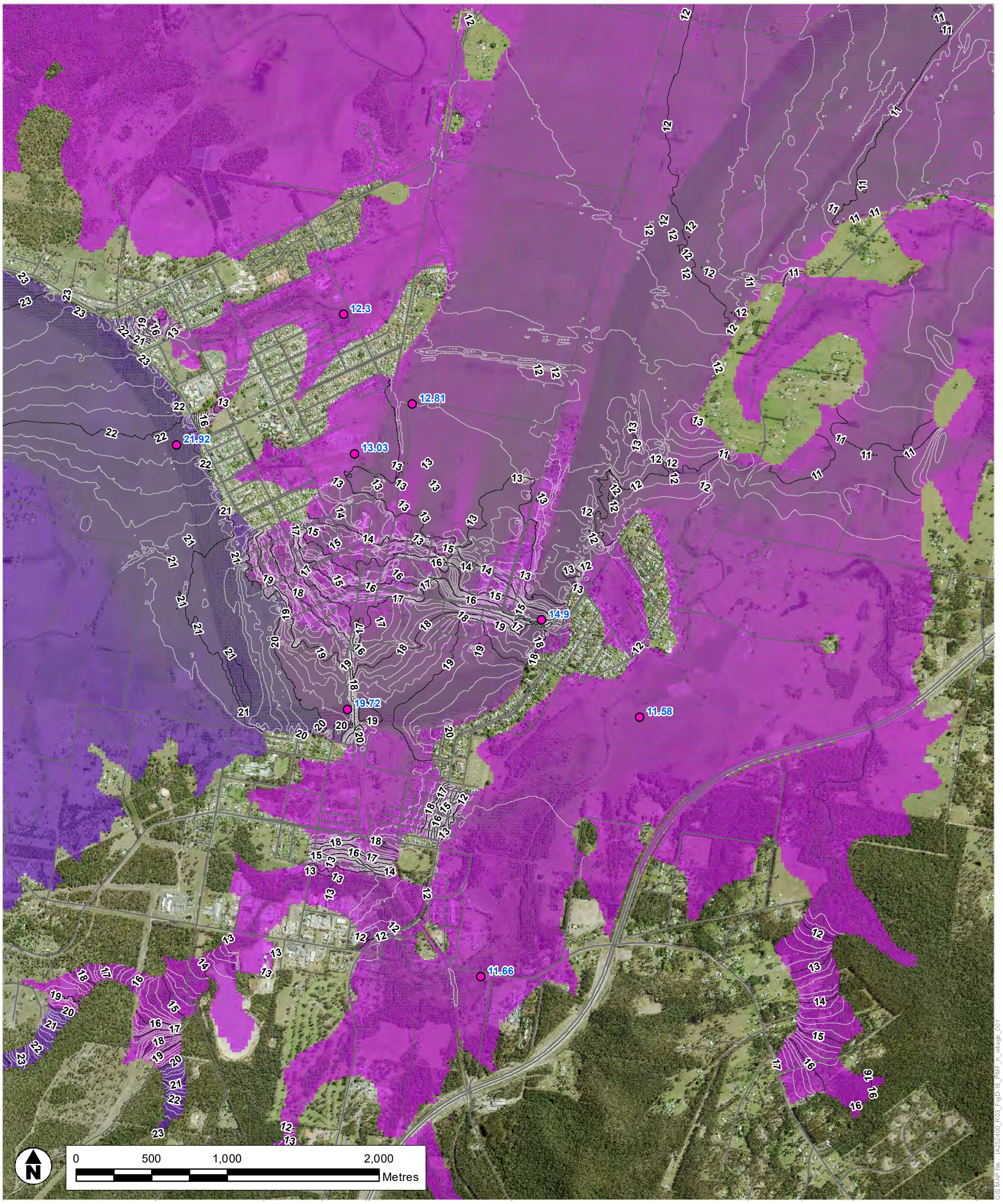
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Level

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-4	1	1
CHECK AH	DATE 3/04/2024			



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Level Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-4(A)

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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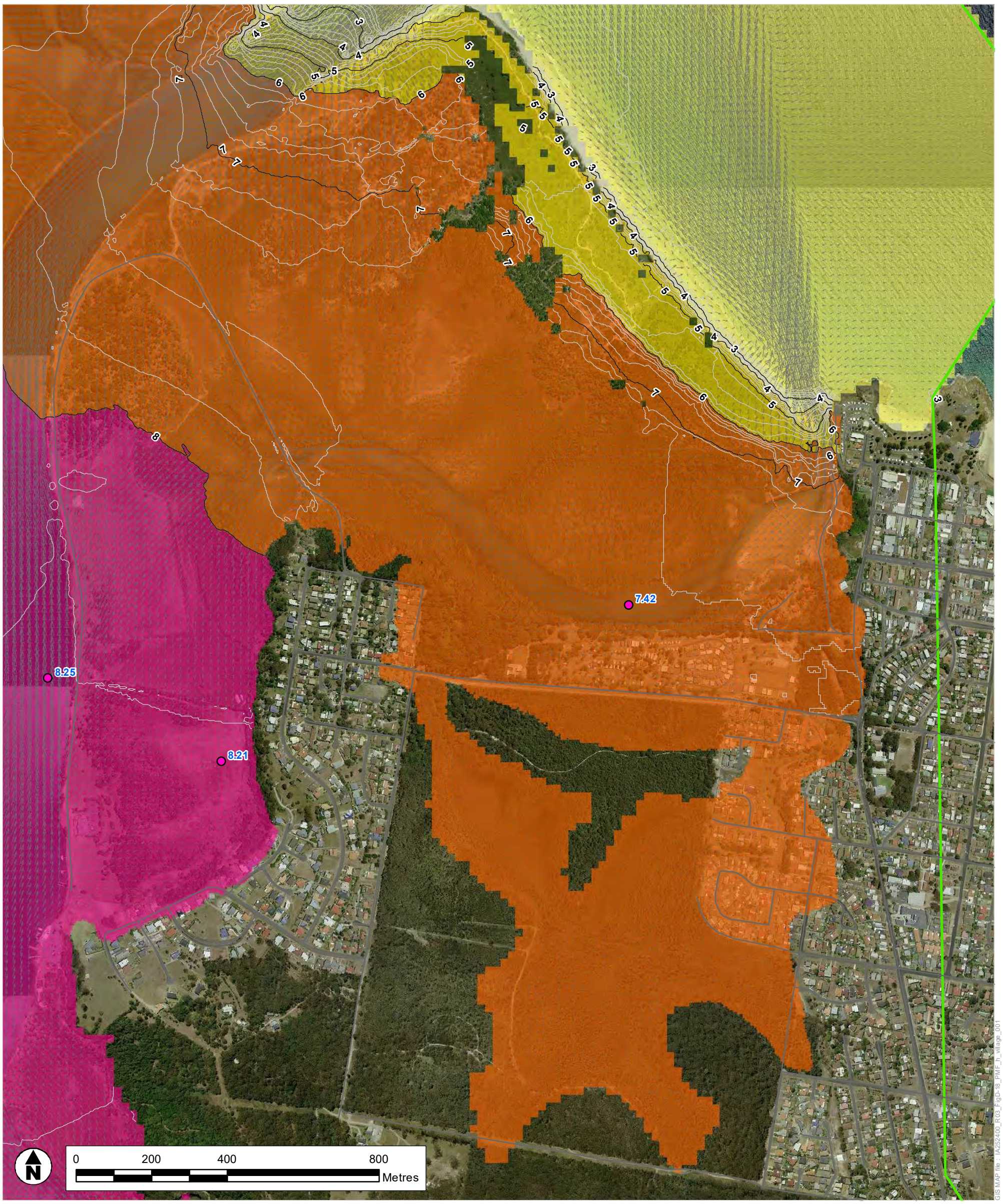
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Level Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-4(B)

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

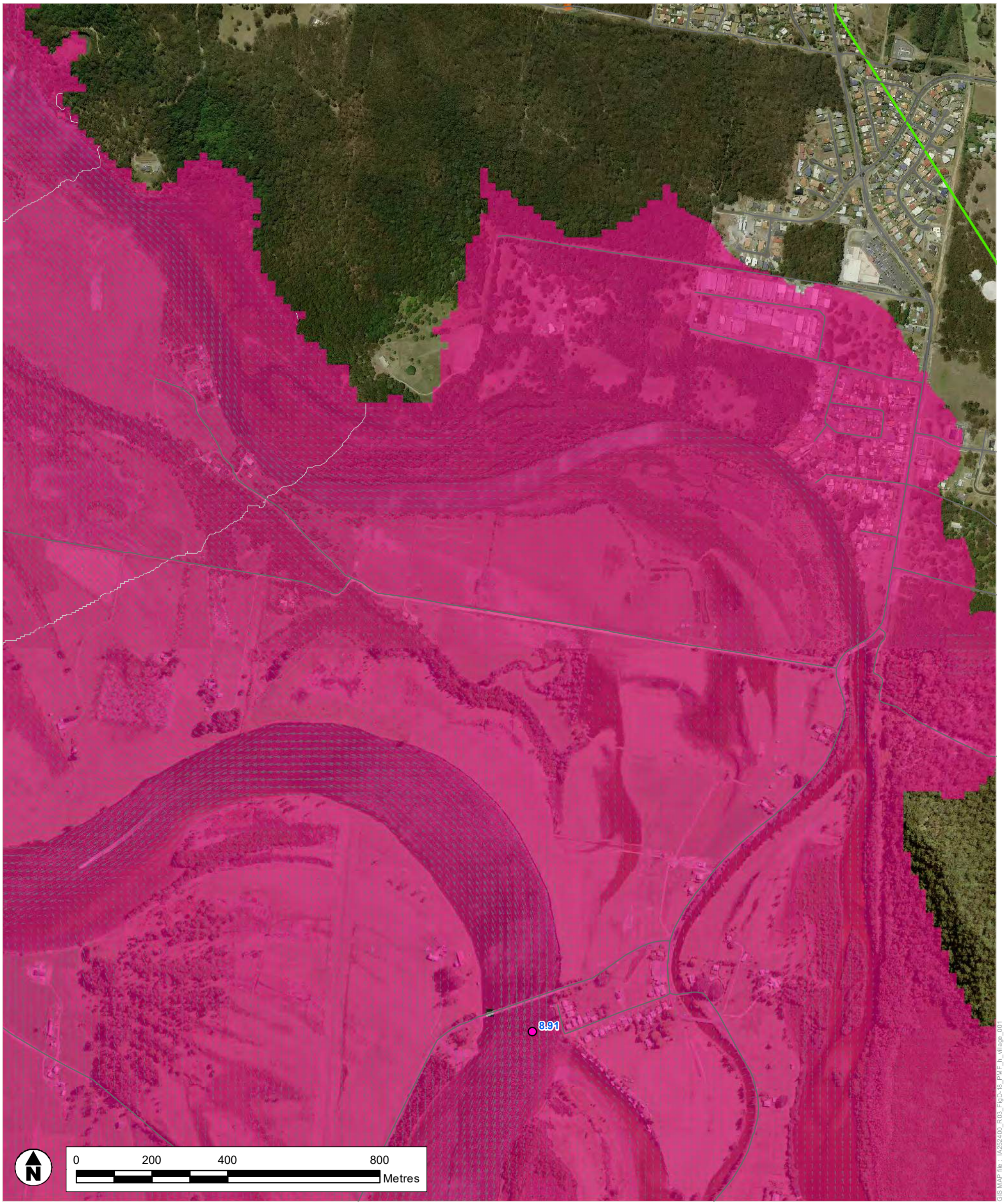
GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Level South West Rocks (N)

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(C)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

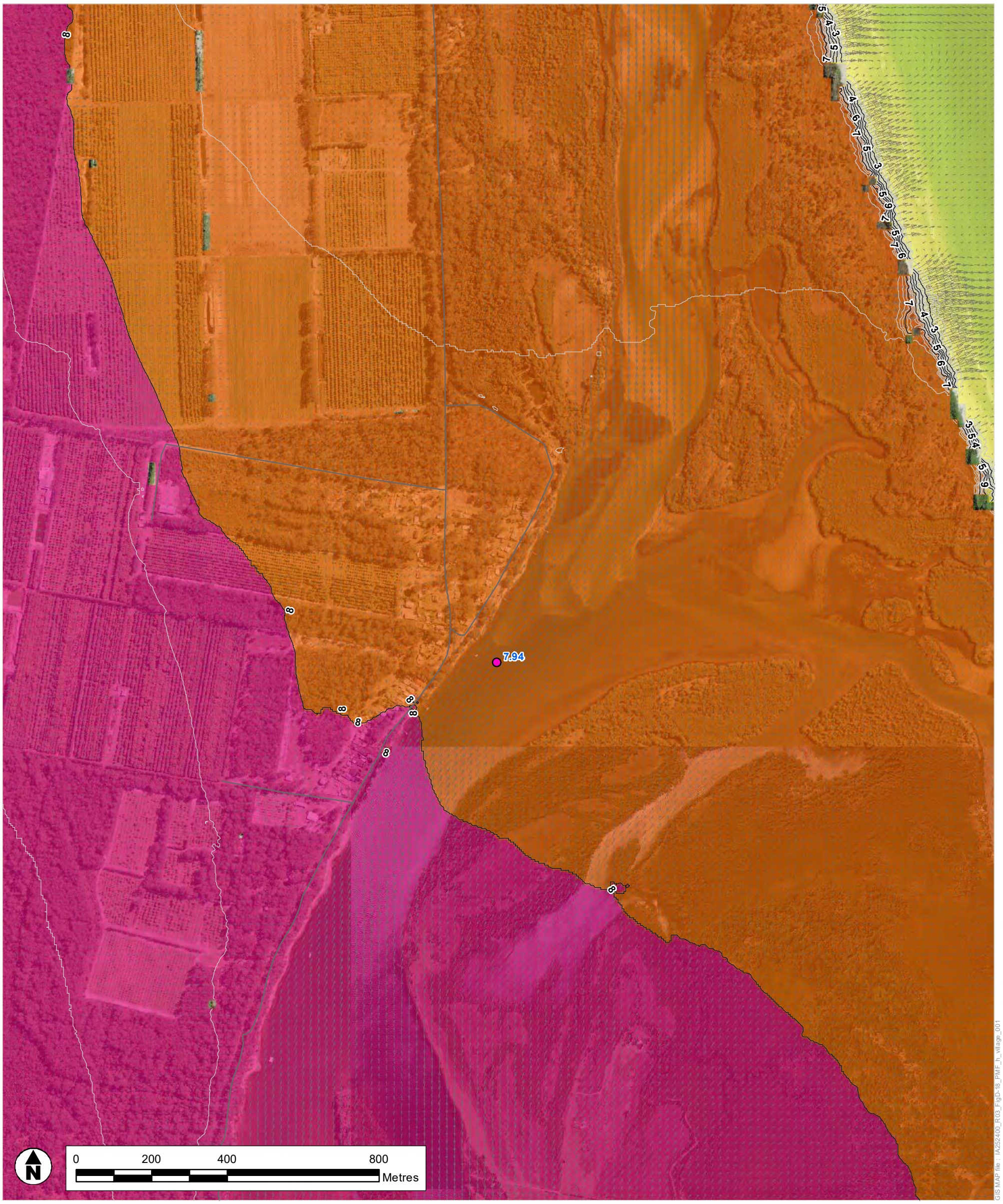
- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Level South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-4(D)
CHECK AH	DATE 10/10/2022	



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Level Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-4(E)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Level
Stuarts Point

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(F)
CHECK AH	DATE 10/10/2022	

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

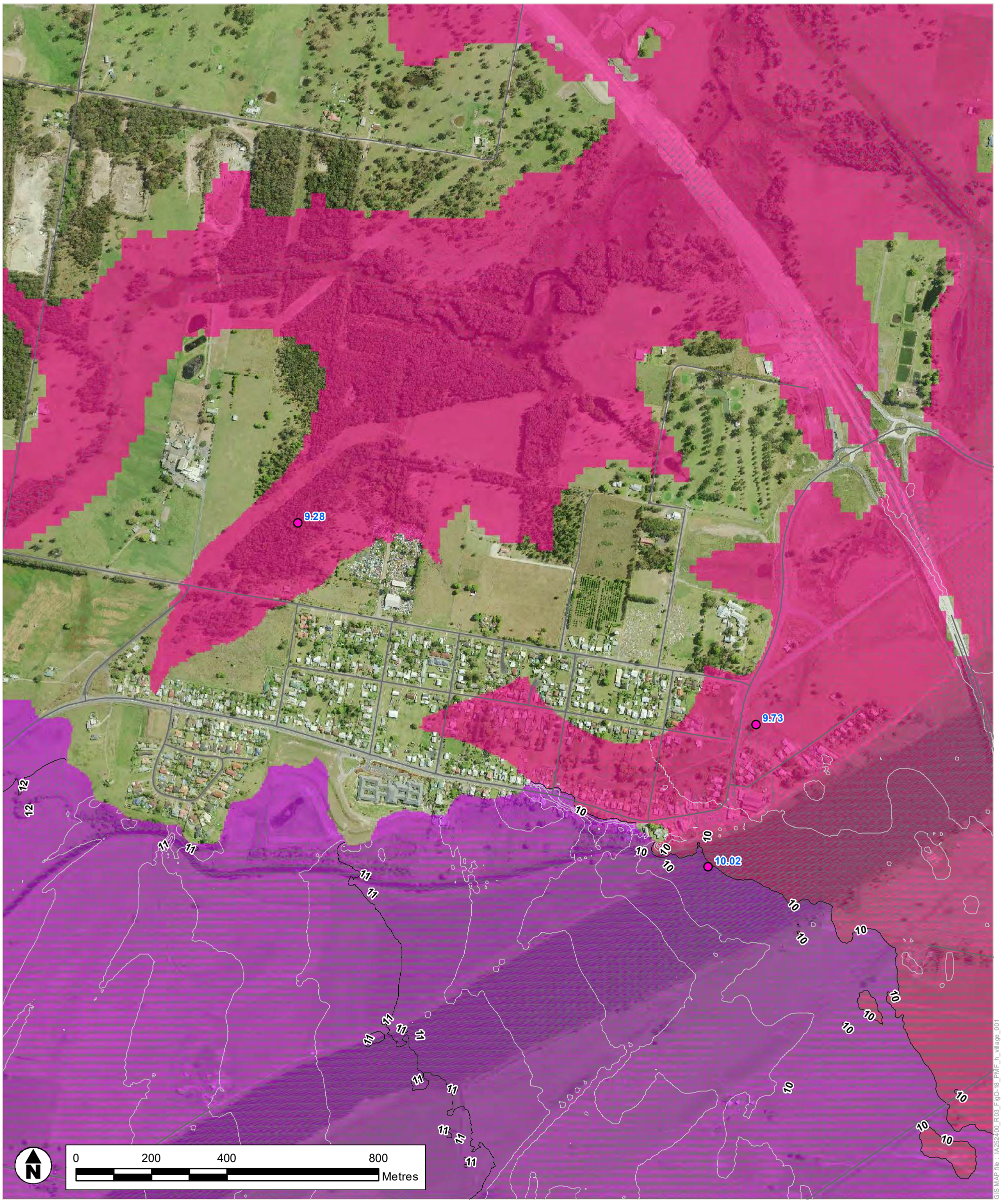
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Level Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(G)
CHECK AH	DATE 10/10/2022	



Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Level Frederickton

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(H)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Level Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 10/10/2022	FIGURE A-4(I)

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event
Flood Level
Hat Head

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(J)
CHECK AH	DATE 10/10/2022	

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001

Legend

Flood level (m AHD)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

- Flood Level 1m Contour (m AHD)
- Flood Level 0.2m Contour (m AHD)
- 5.50 Peak Flood Level (m AHD) at Point
- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

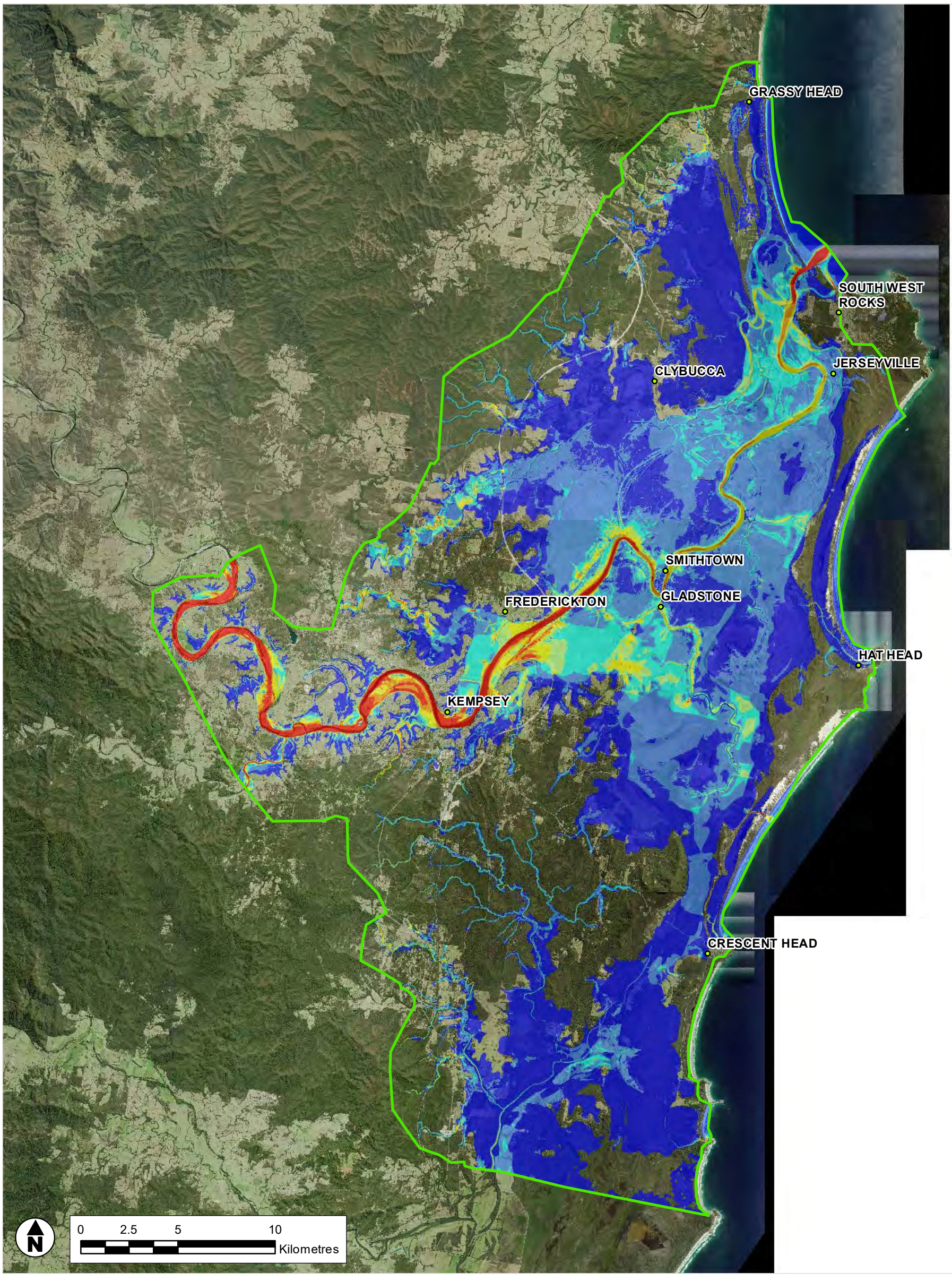
GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Level Crescent Head

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-4(K)
CHECK	DATE	
AH	10/10/2022	

GIS MAP file : IA252400_R03_FigD-18_PMF_h_village_001



GIS MAP file : IA252400_R03_FigD-24_1pAEP_v_001

Legend

Flow velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0
- Limit of Mapping

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A3

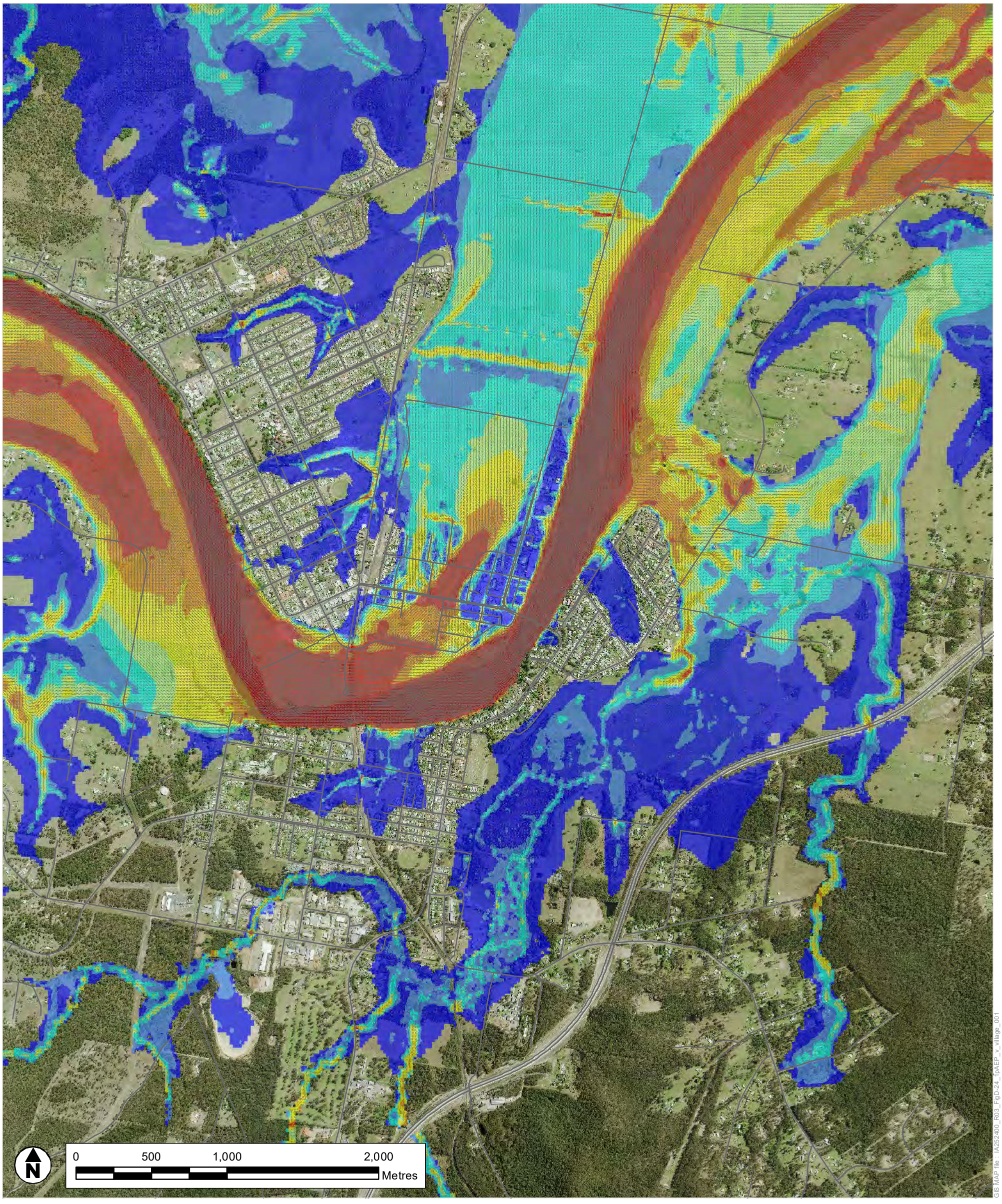
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flow Velocity

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-5	1	1
CHECK LC	DATE 29/09/2022			



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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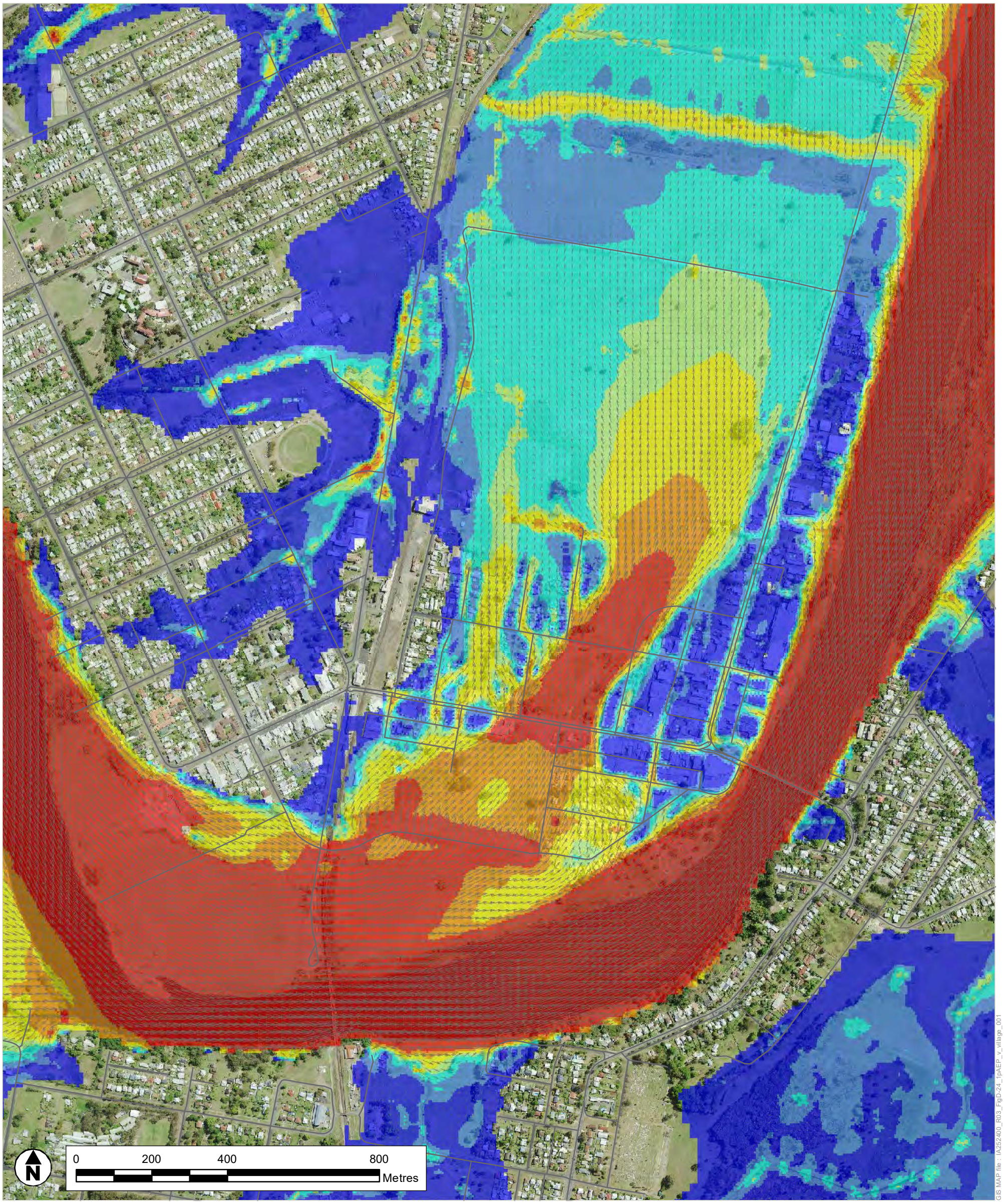
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(A)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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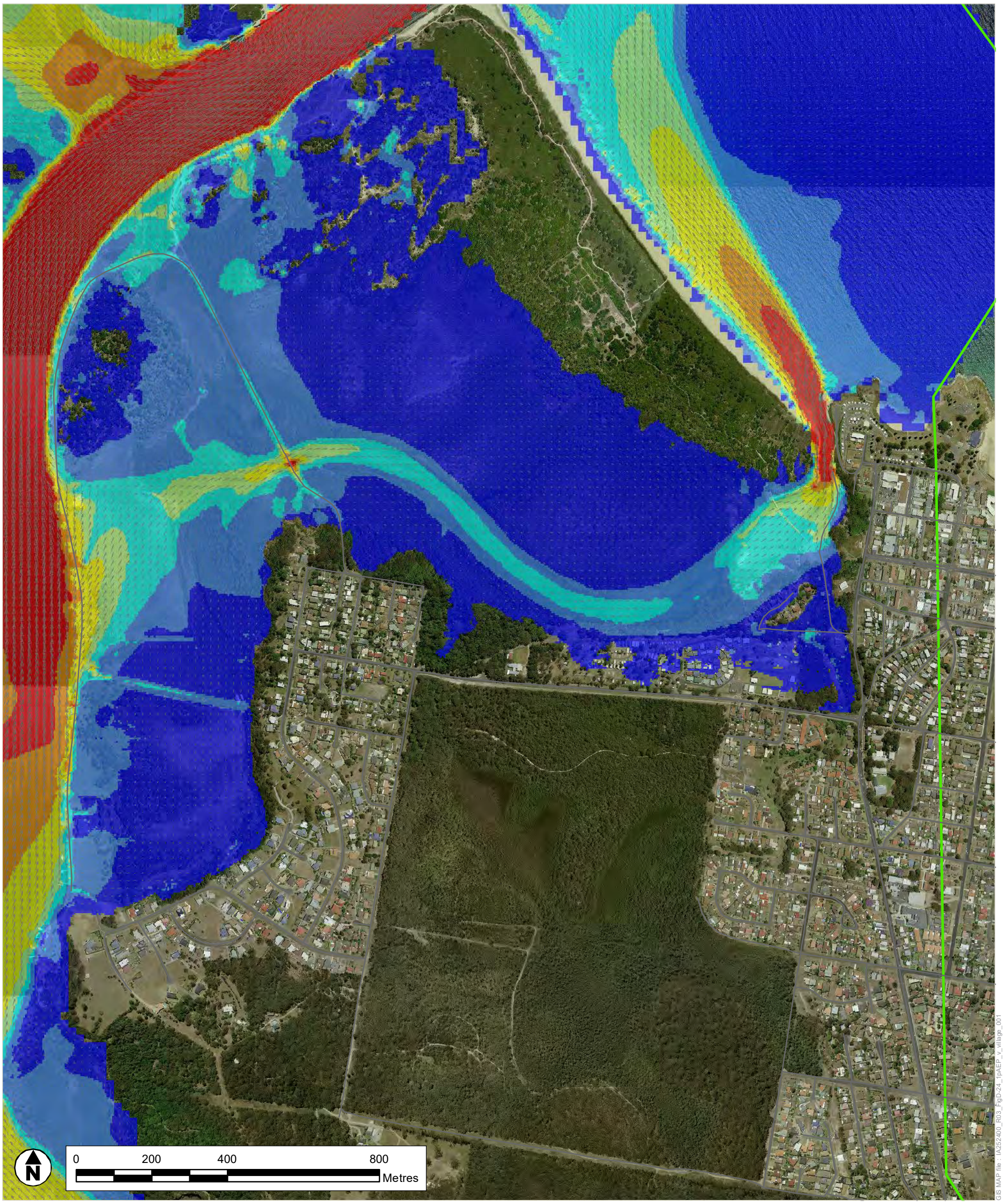
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(B)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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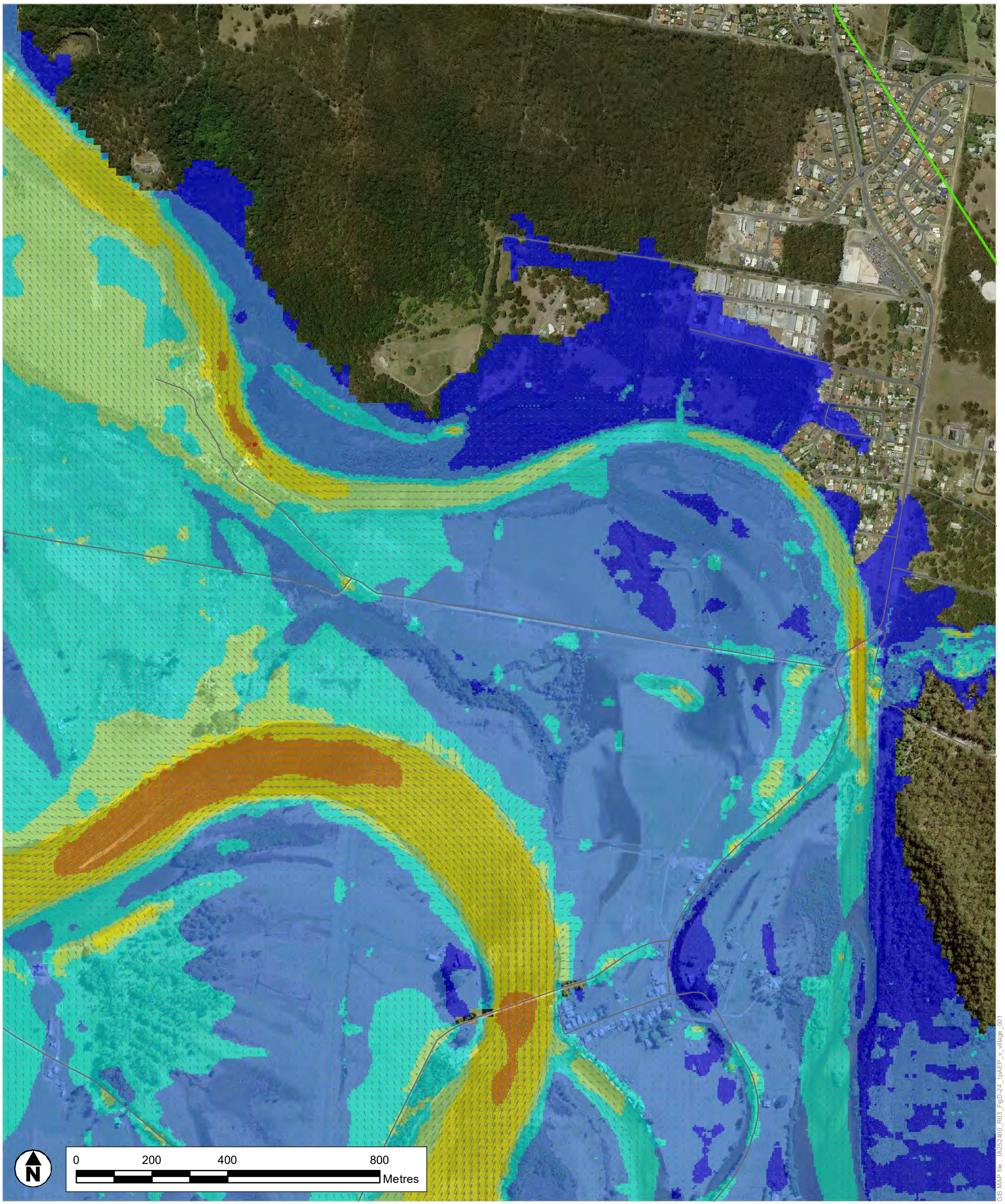
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(C)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

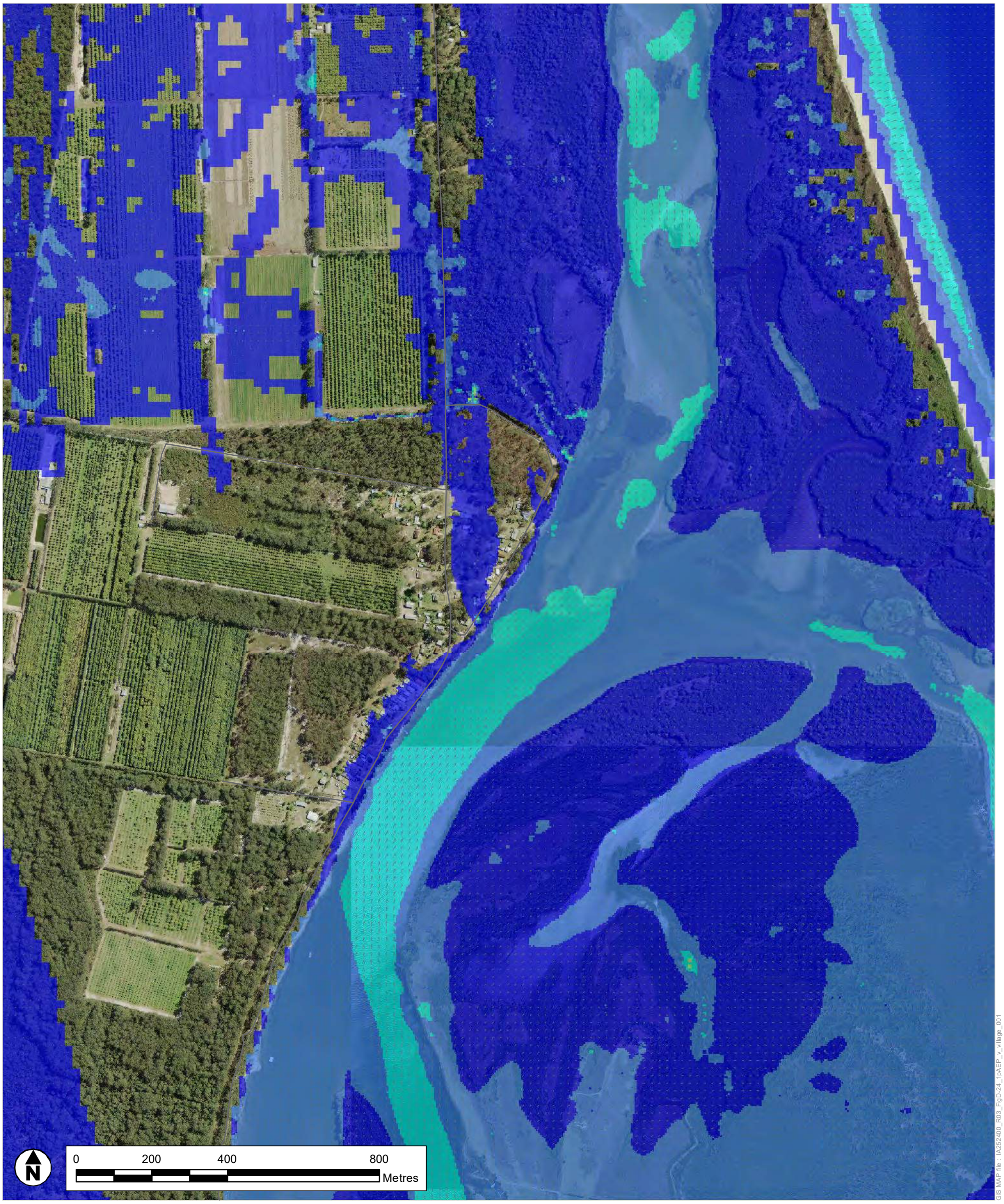
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(D)



GIS MAP file : IA252400_R03_FigD-24_1pAEP_v_village_001

Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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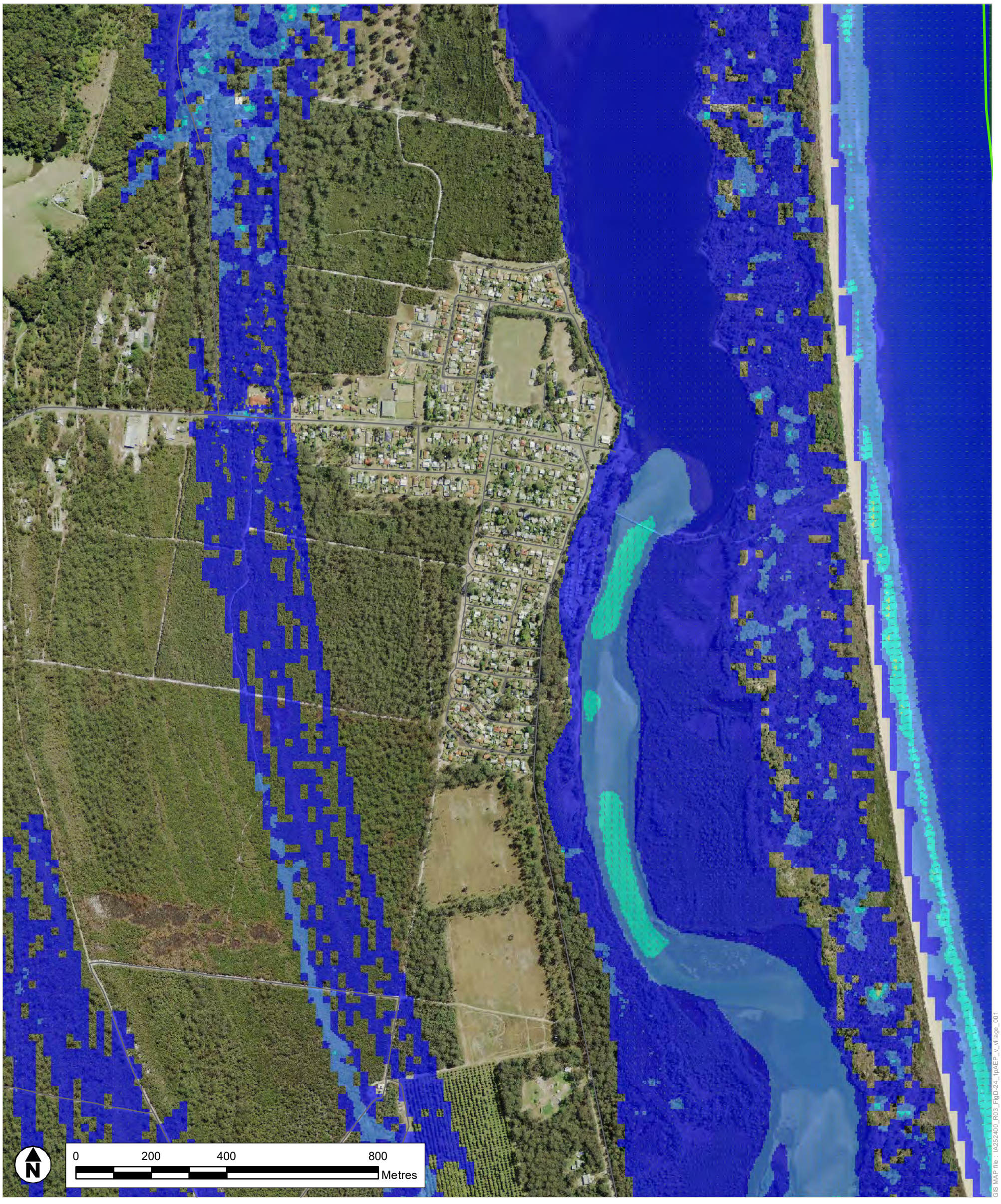
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(E)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

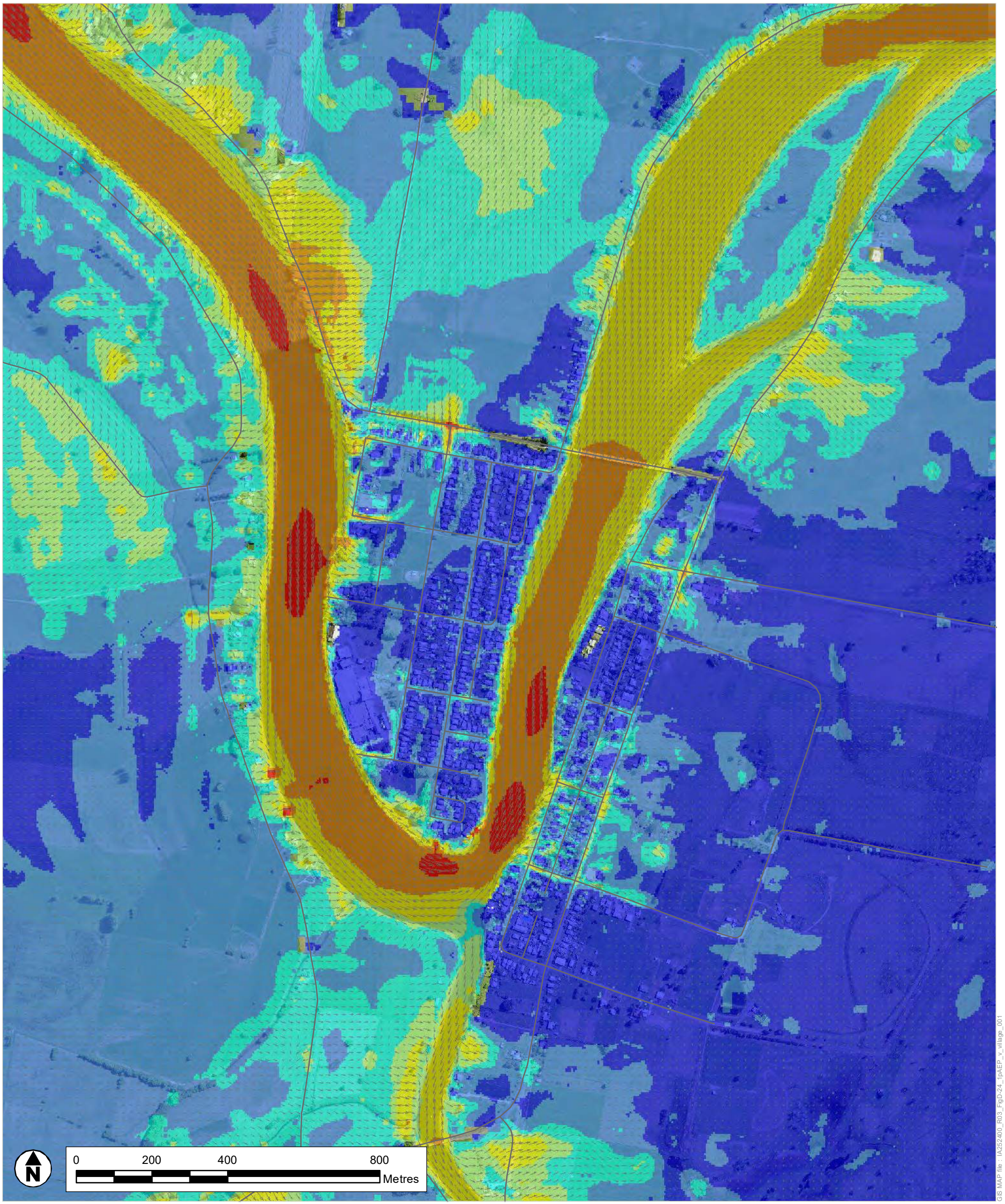
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(F)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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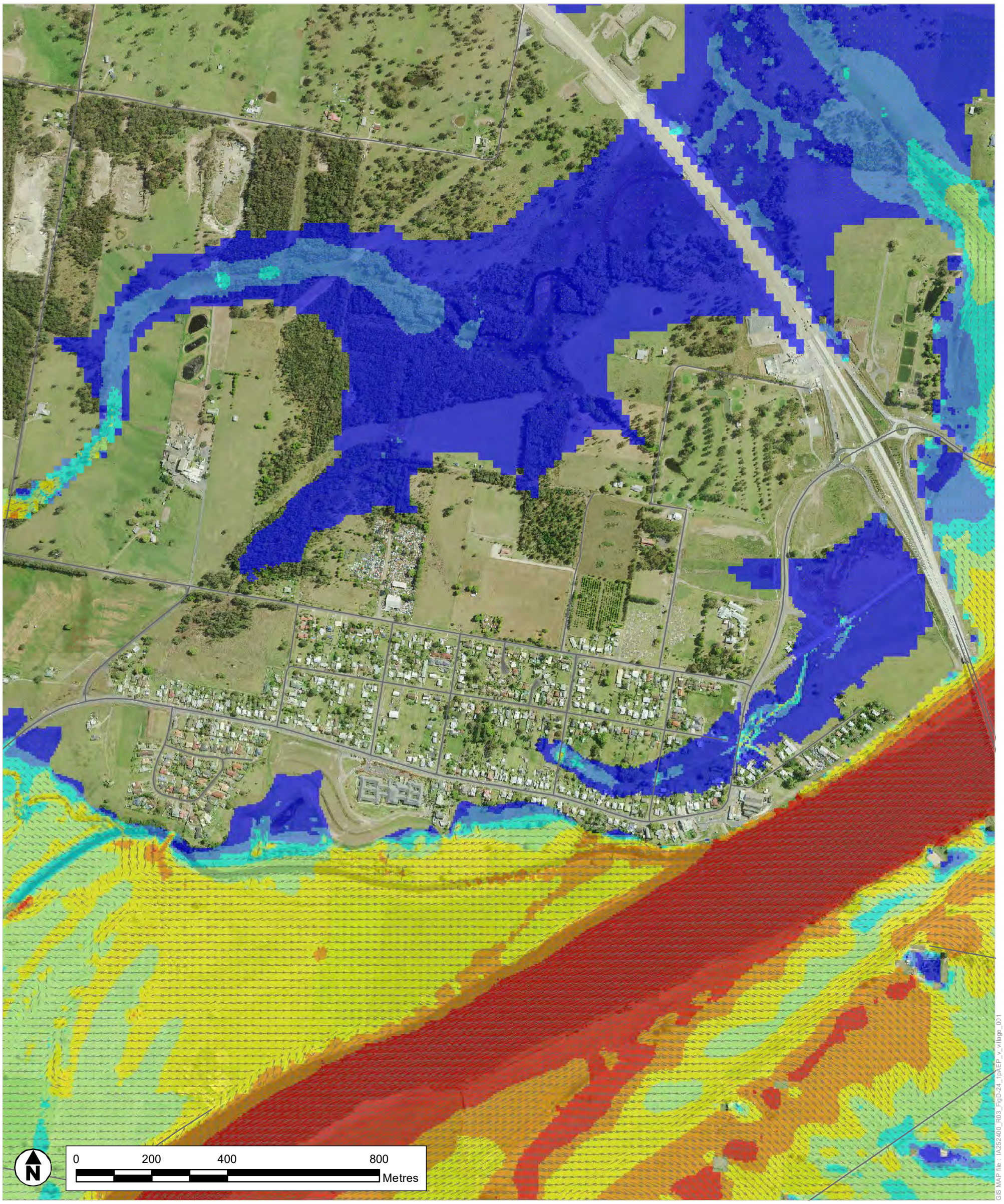
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(G)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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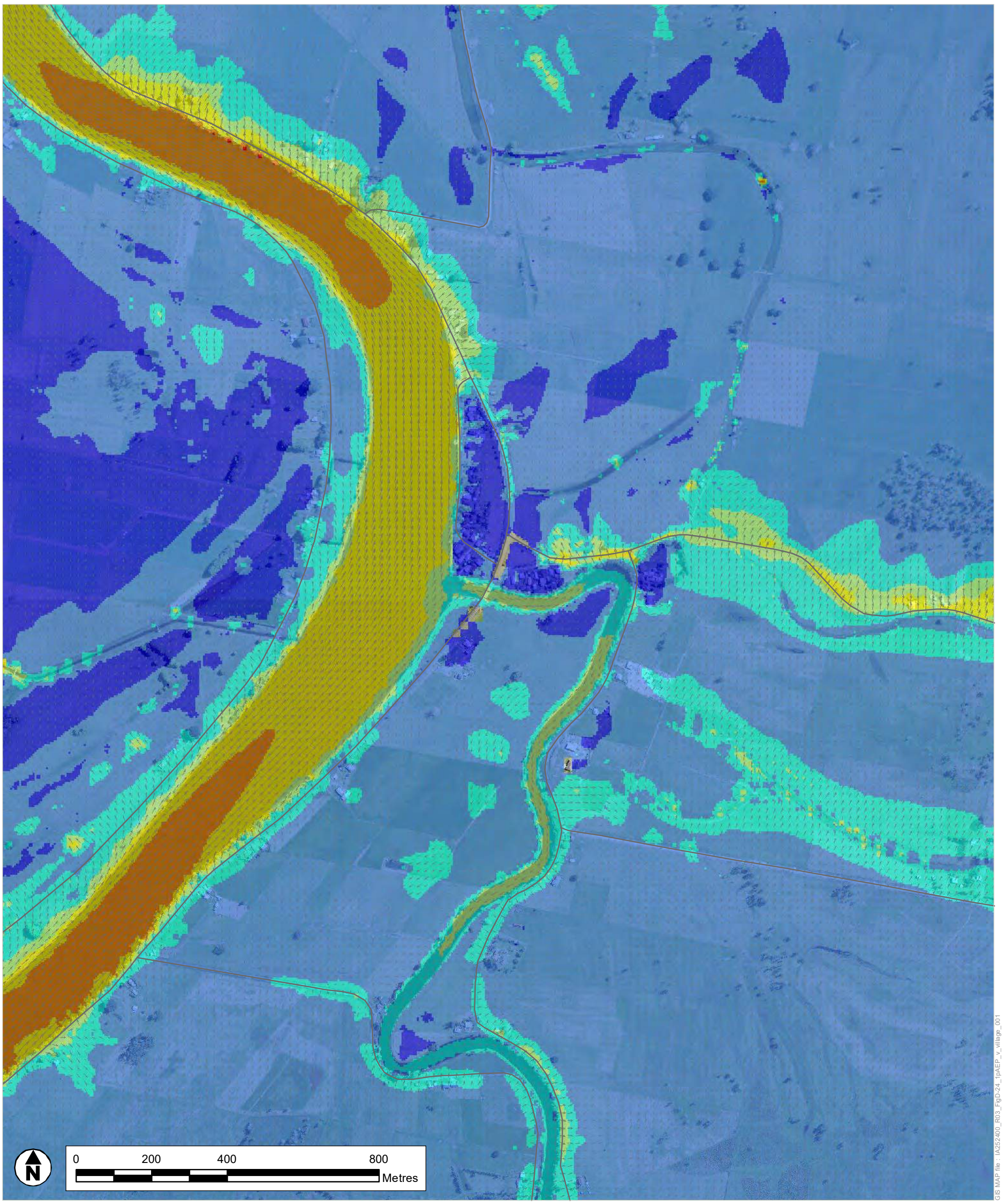
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Frederickton	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(H)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

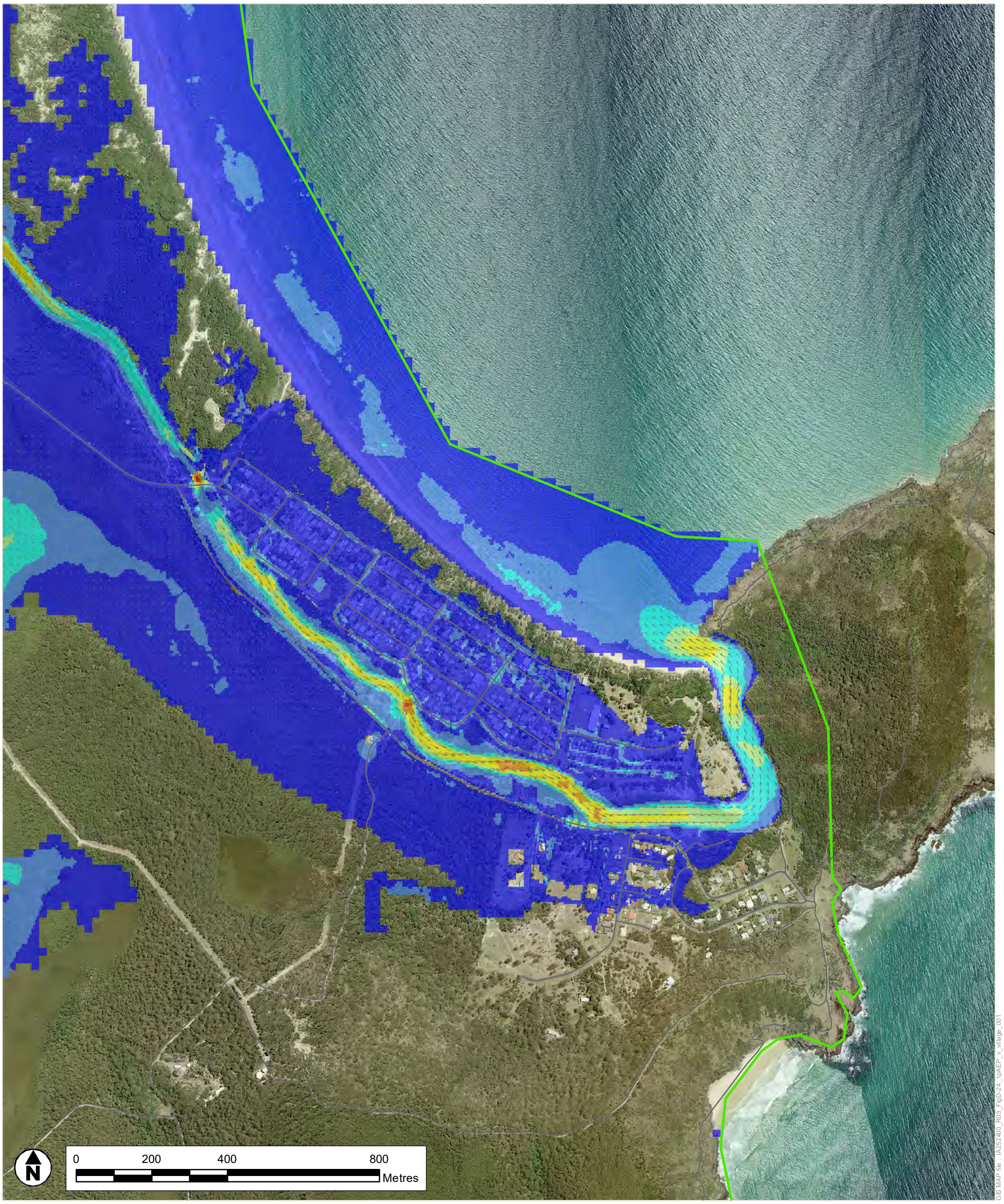
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(I)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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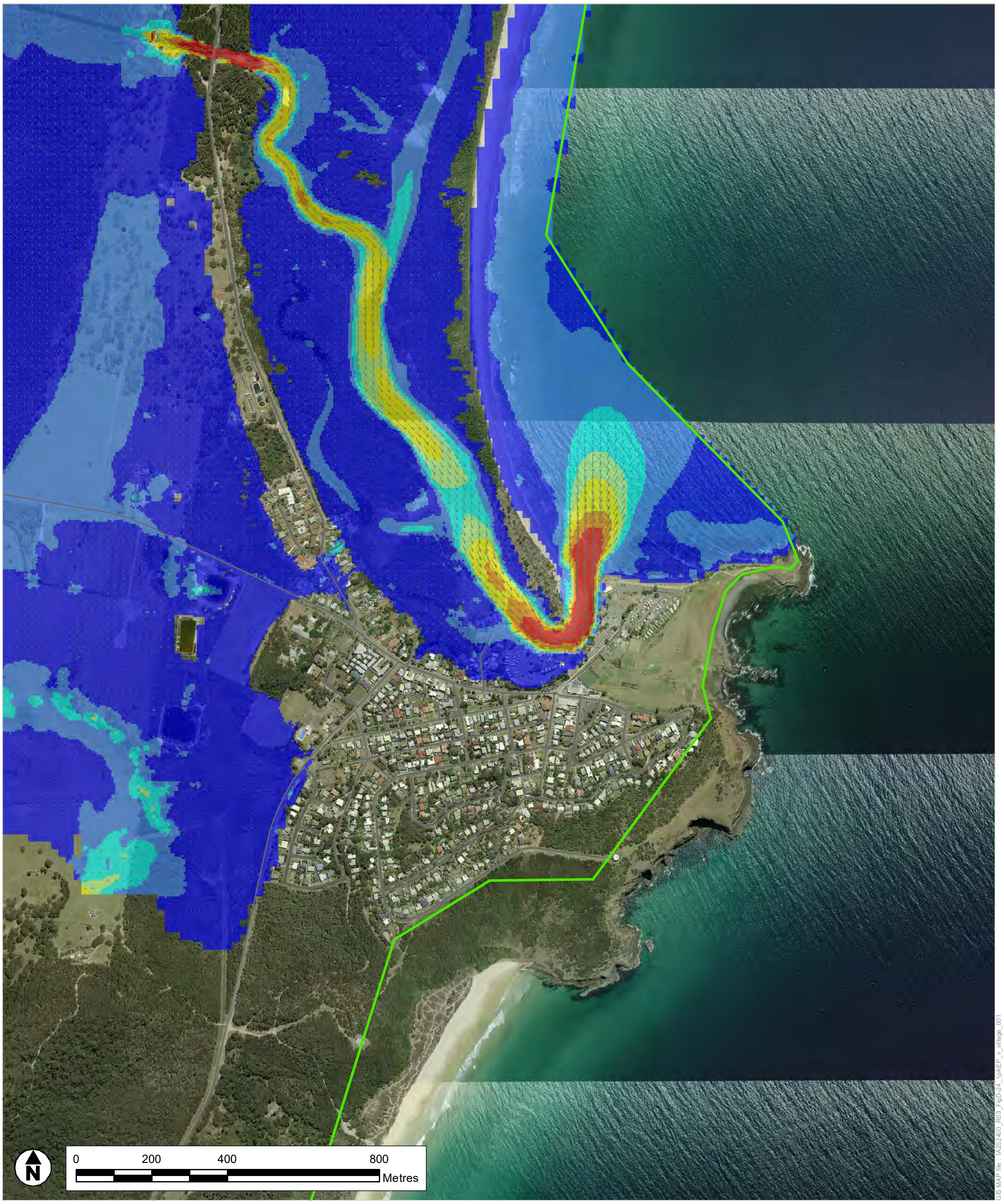
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(J)

GIS MAP file : IA252400_R03_FigD-24_1pAEP_v_village_001



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

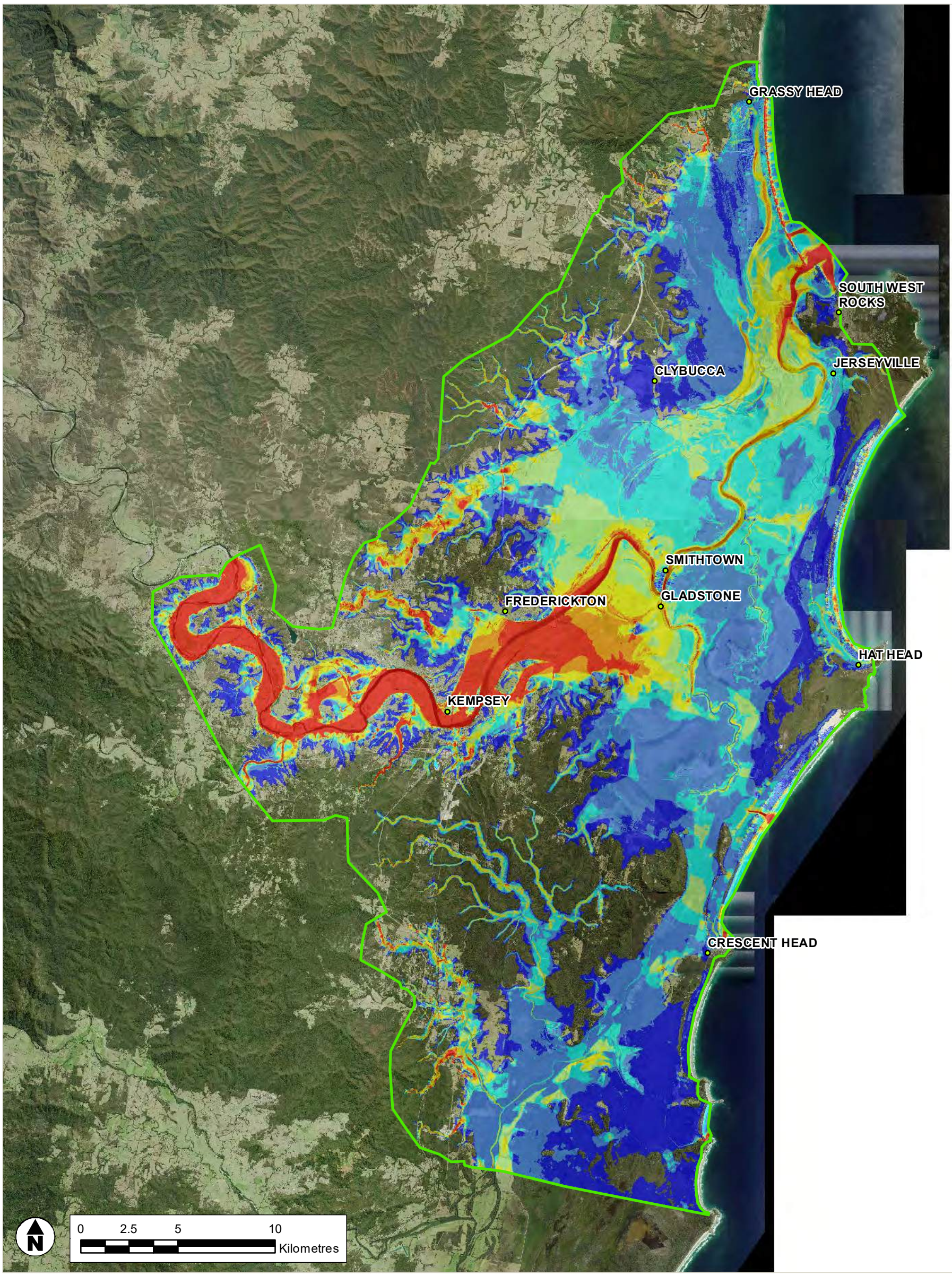
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flow Velocity Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 1/10/2022	FIGURE A-5(K)



GIS MAP file : IA252400_R03_FigD-27_PMF_v_001

Legend

Flow velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0
- Limit of Mapping

Jacobs

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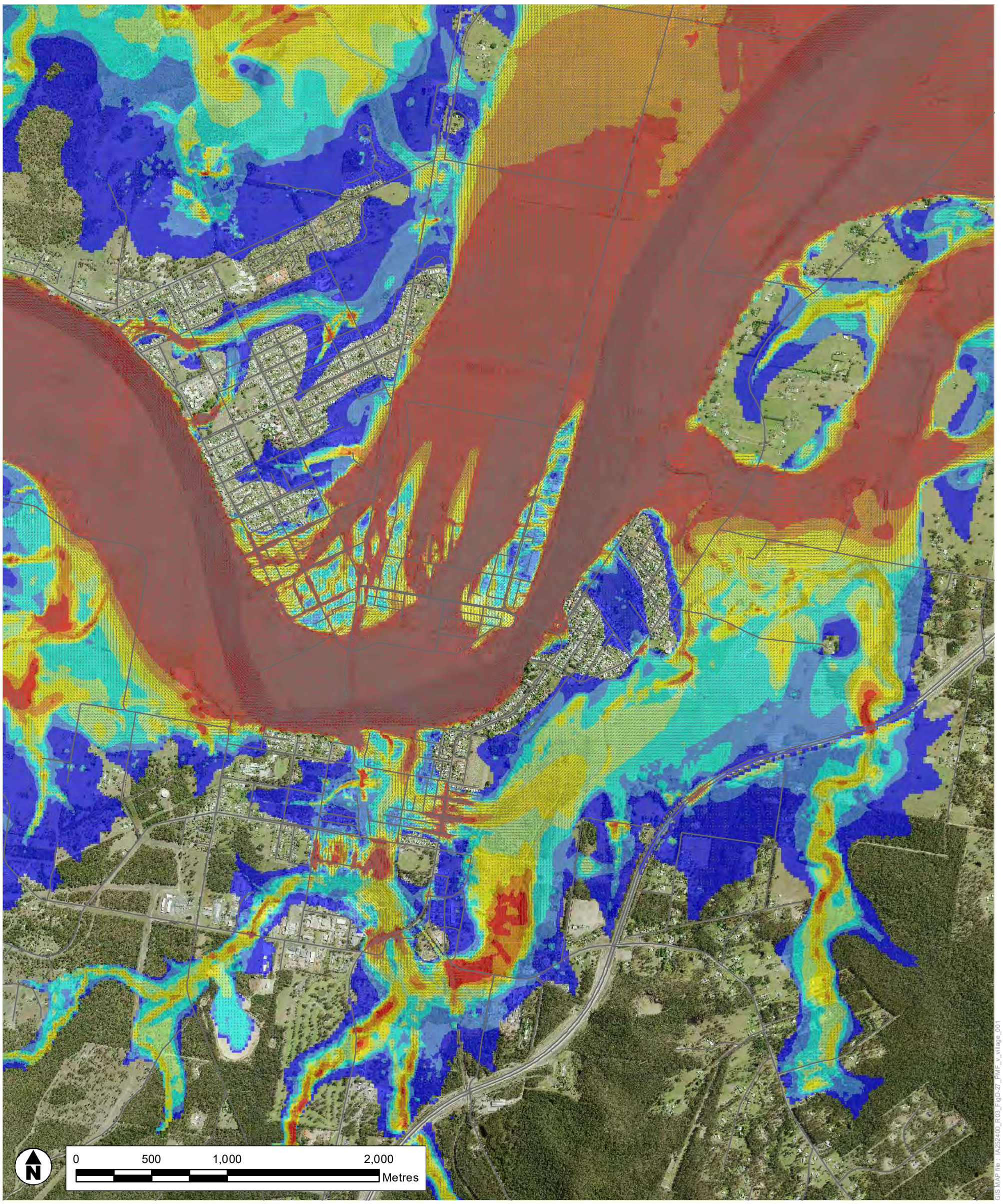
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-6	1	1
CHECK	DATE			
LC	7/10/2022			



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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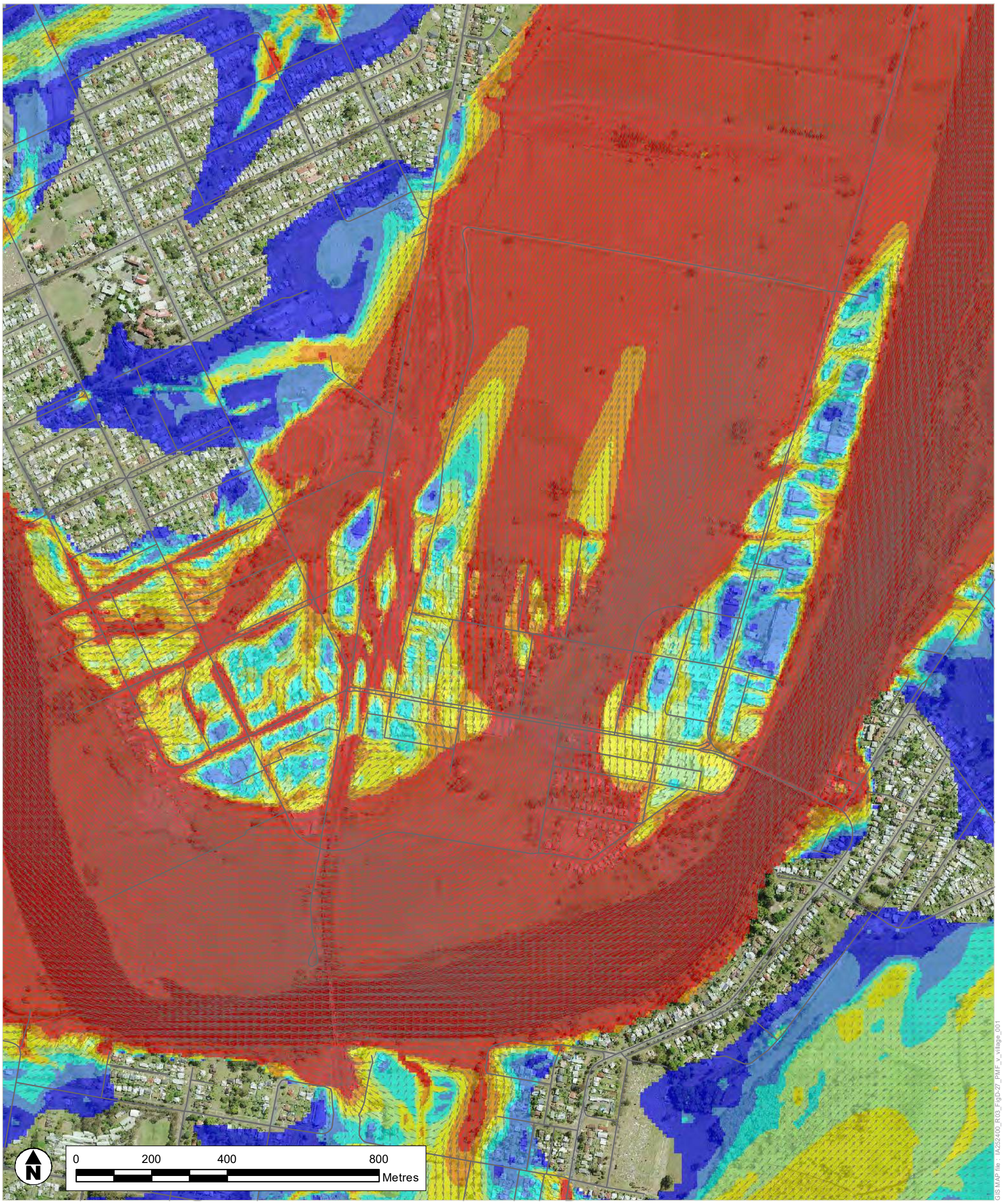
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-6(A)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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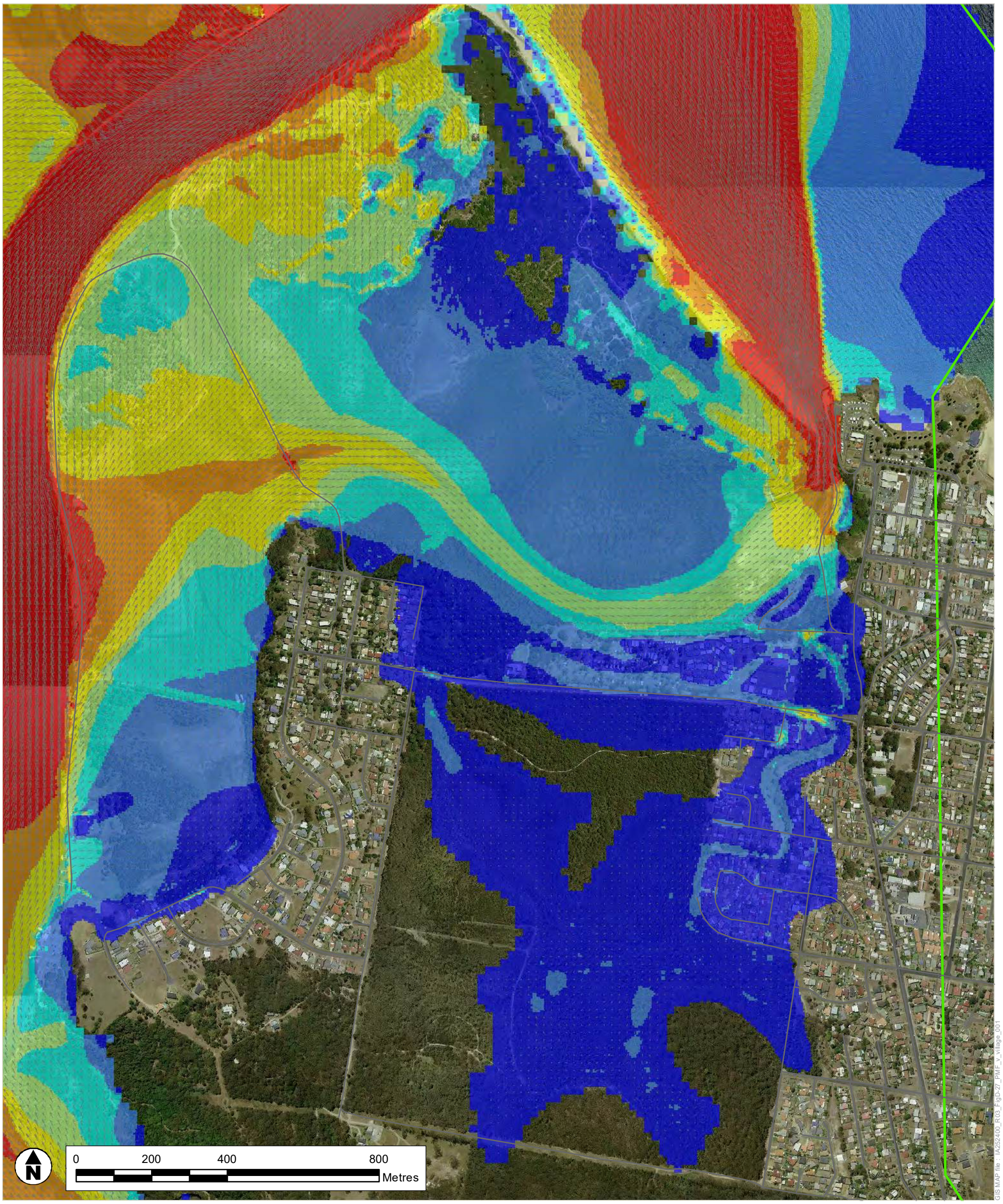
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-6(B)
CHECK AH	DATE 7/10/2022	



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

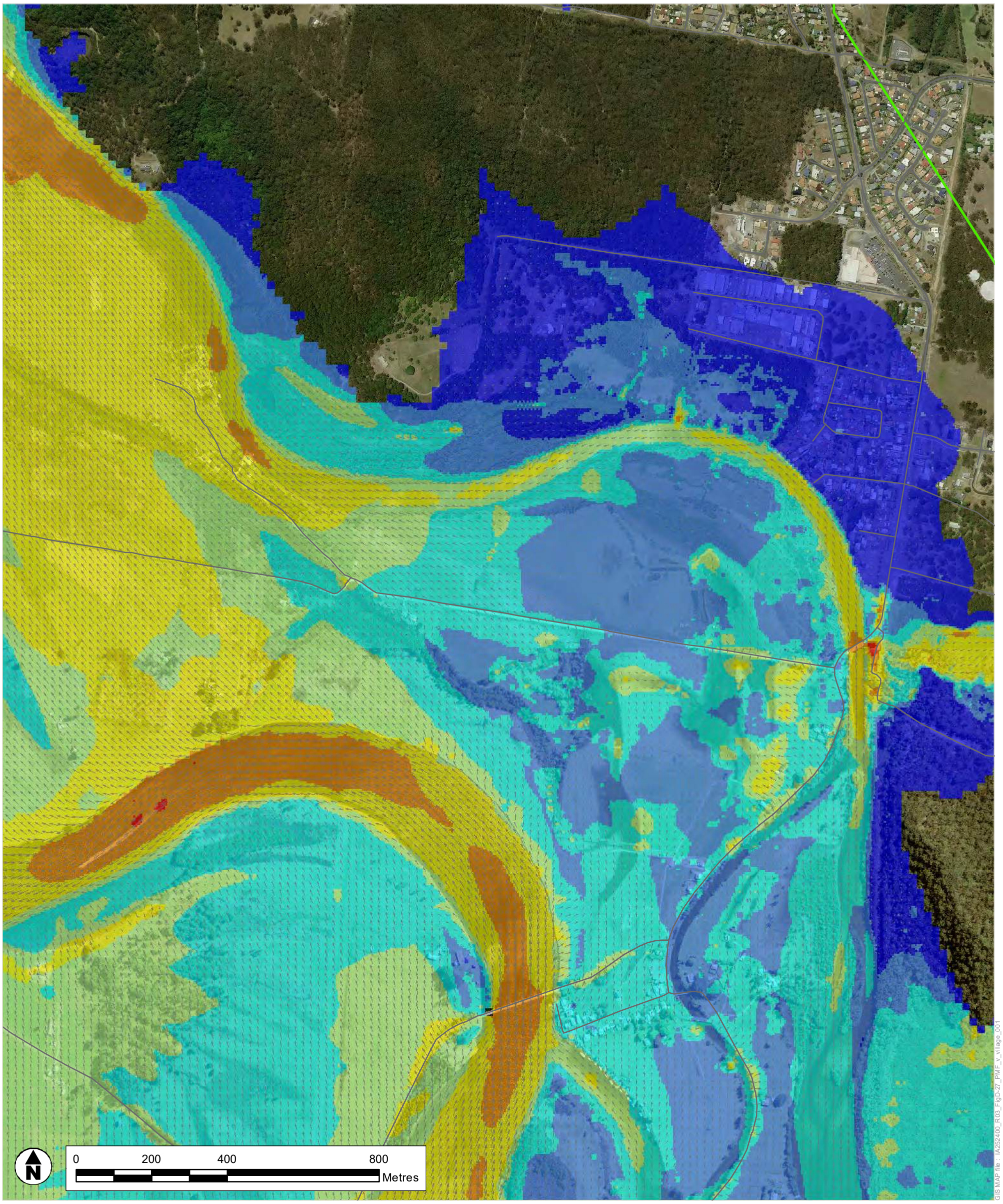
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-6(C)
CHECK AH	DATE 7/10/2022	



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

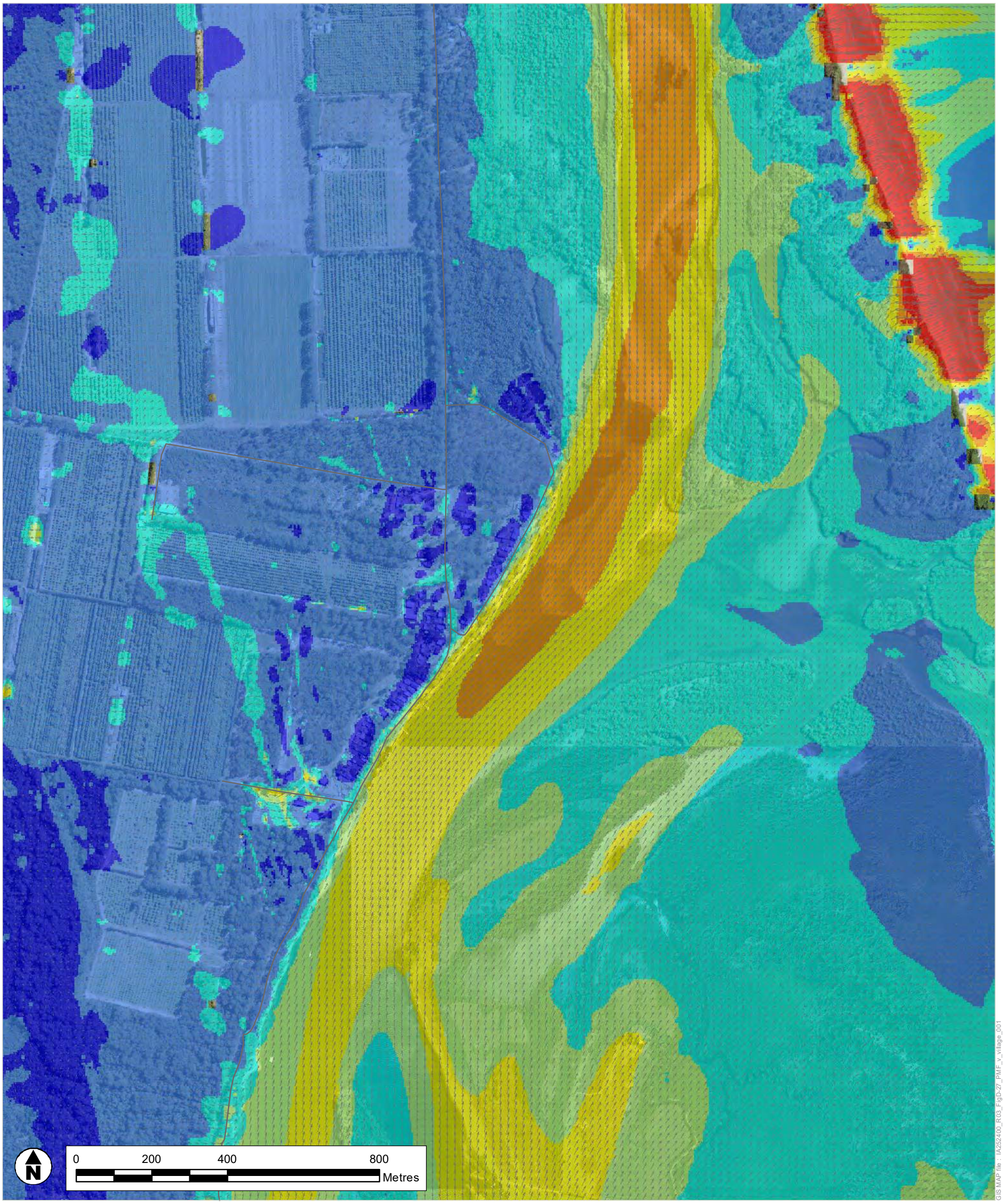
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-6(D)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

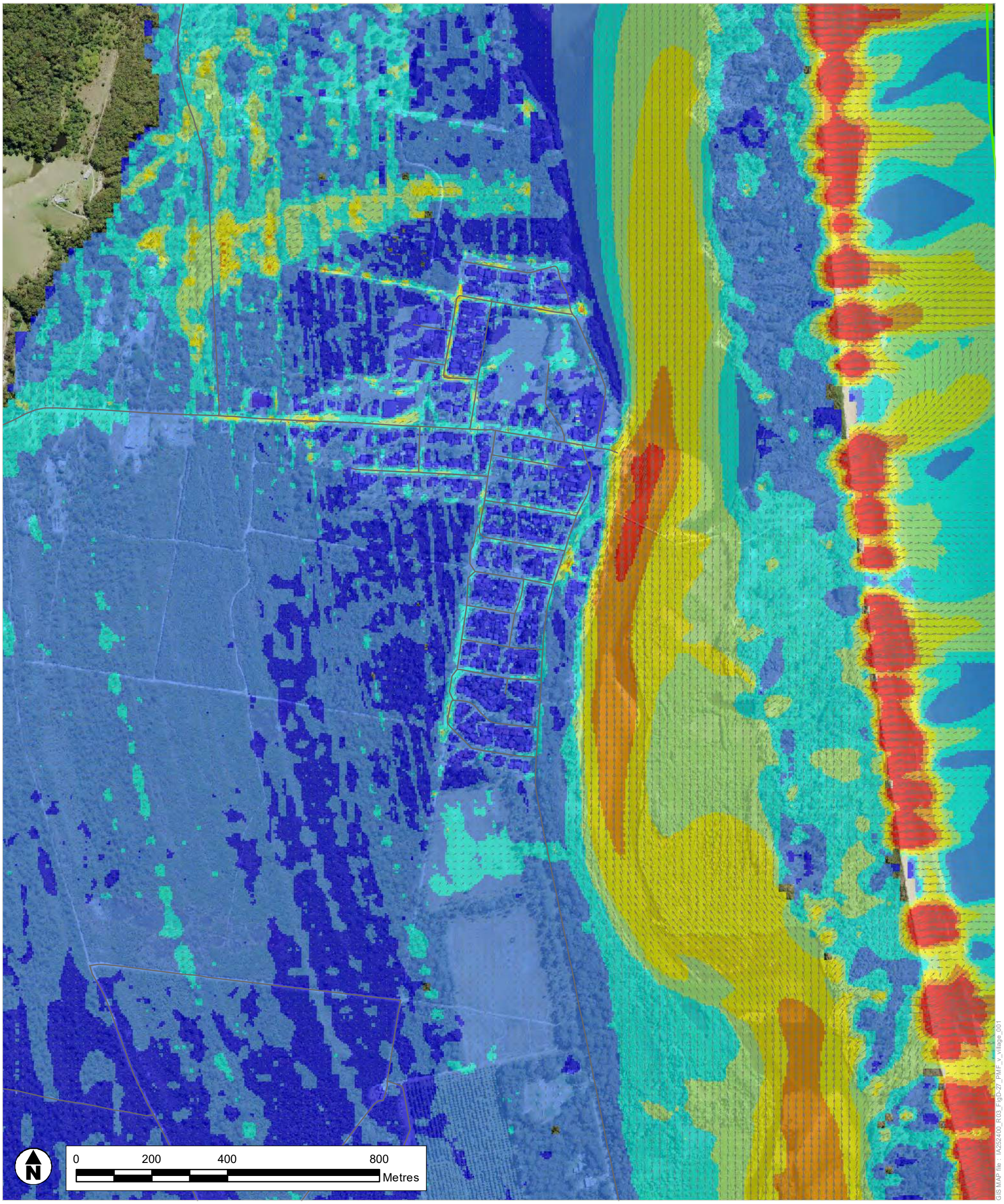
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-6(E)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

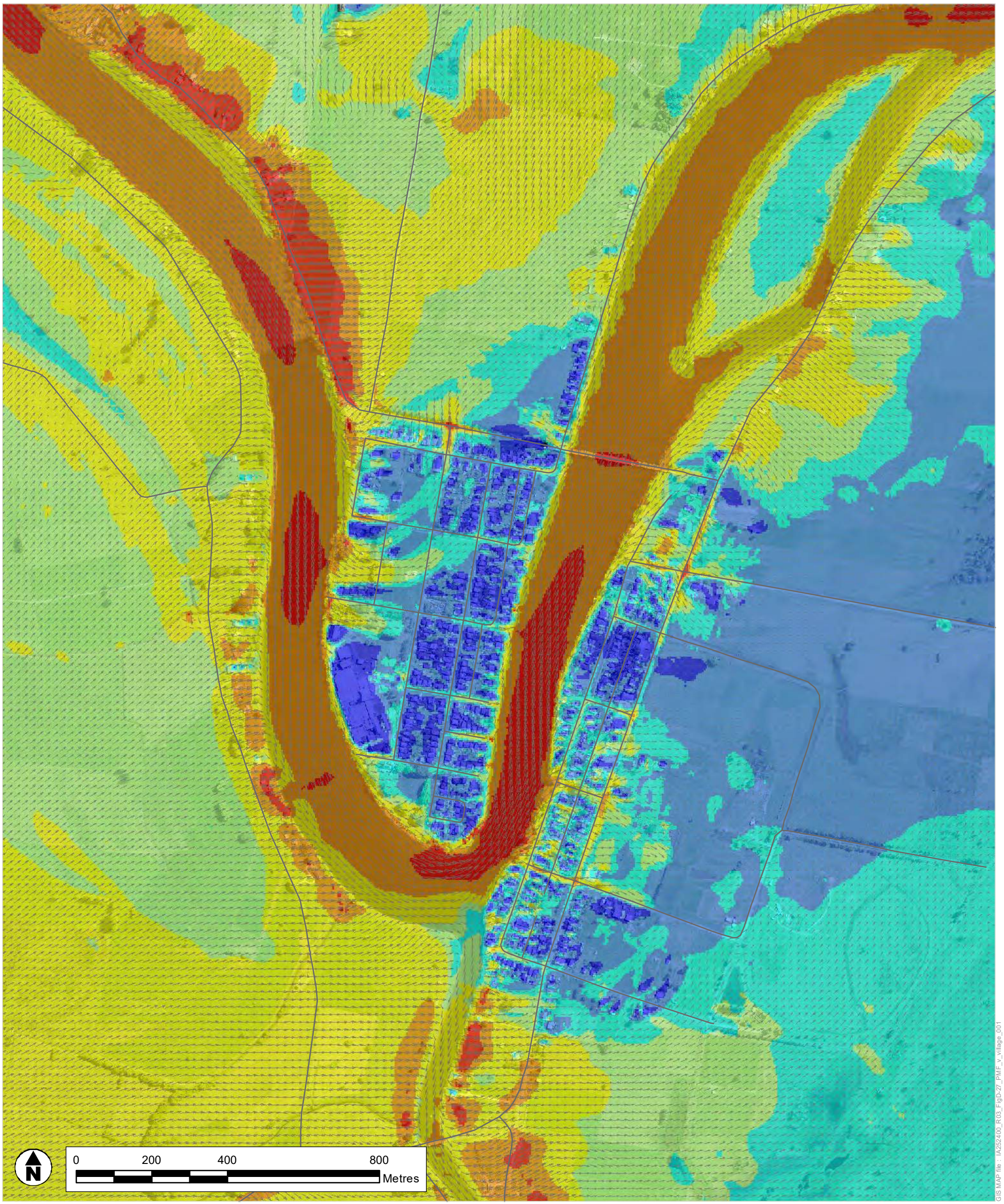
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-6(F)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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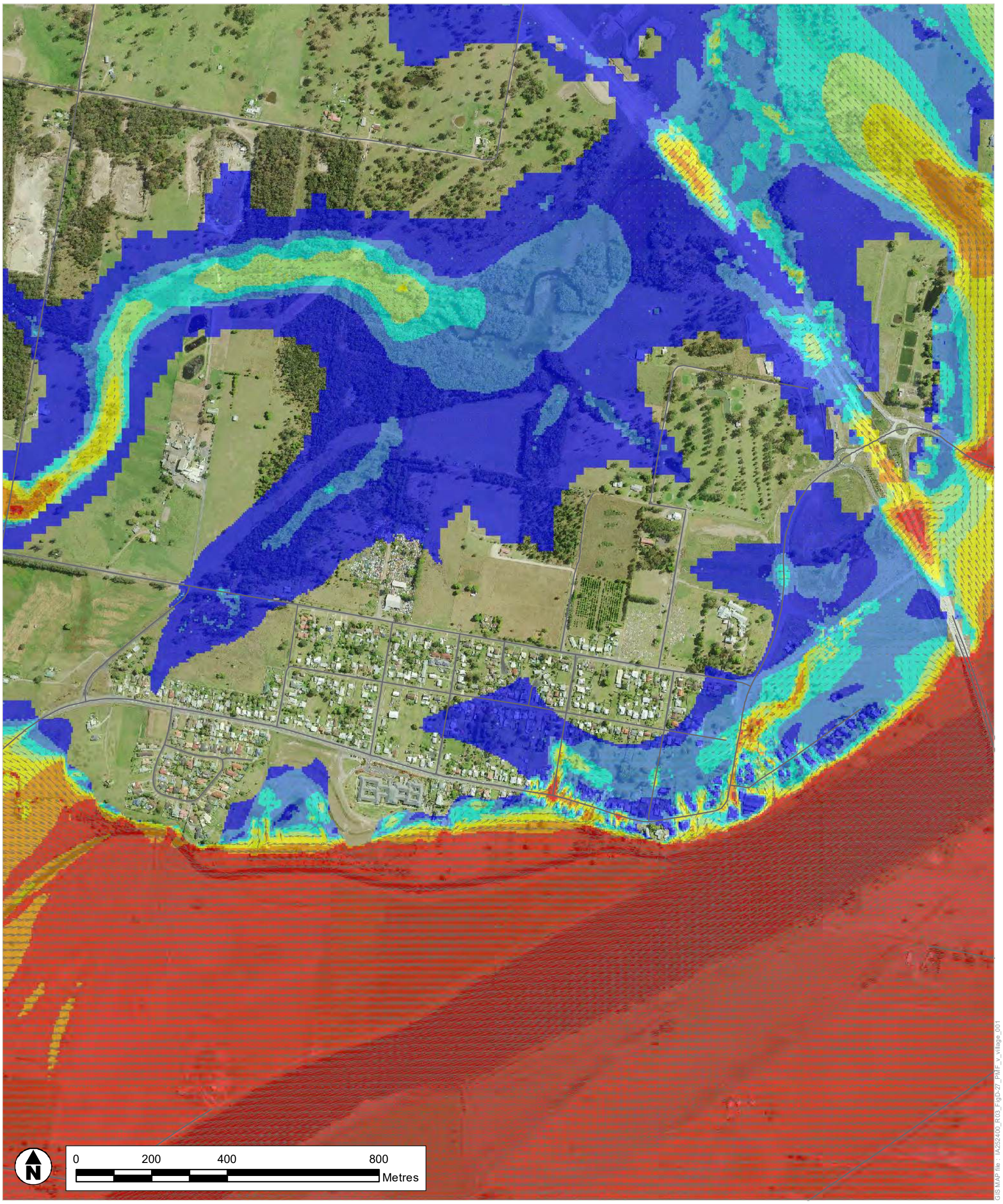
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-6(G)
CHECK AH	DATE 7/10/2022	



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

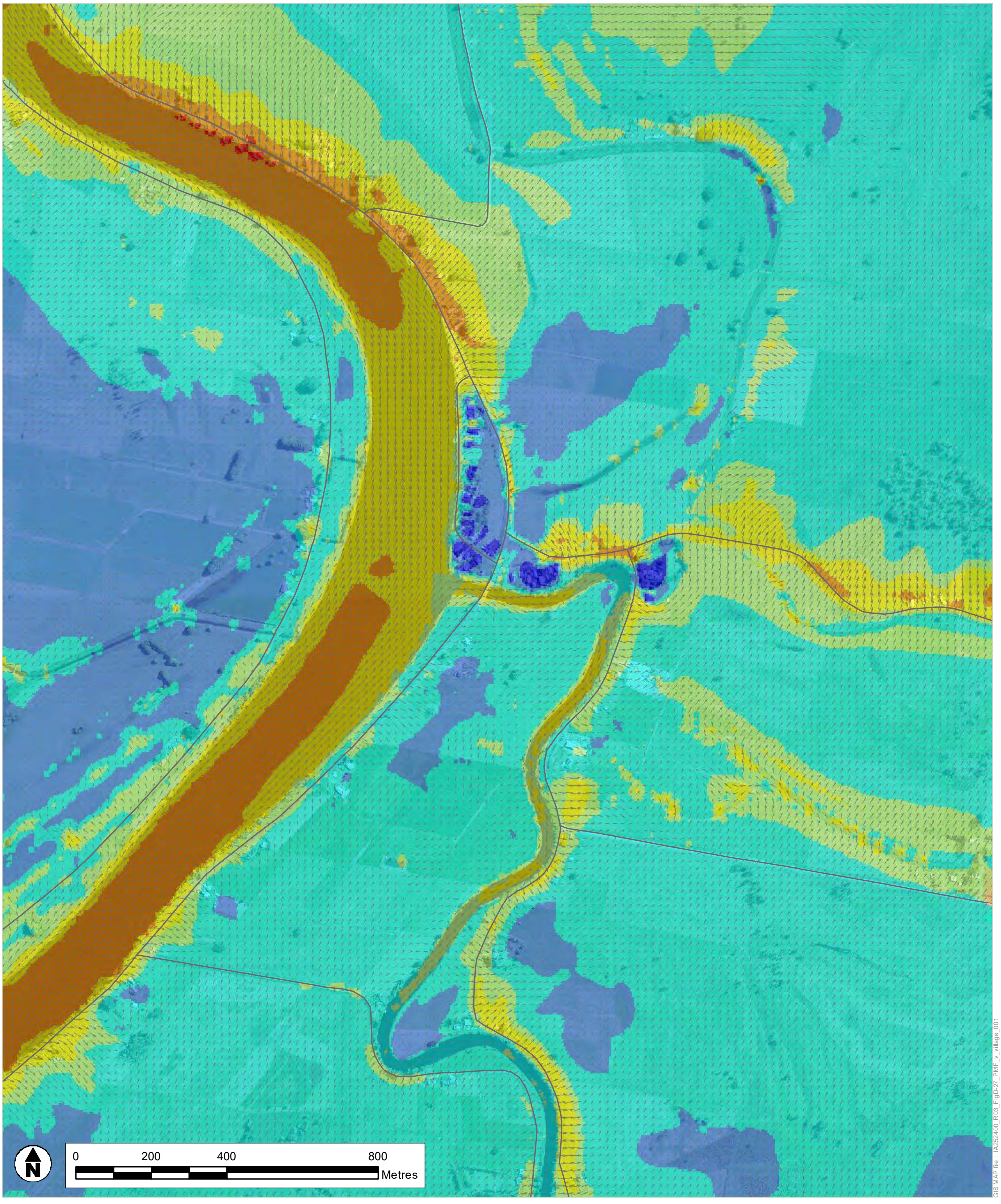
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Frederickton	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-6(H)



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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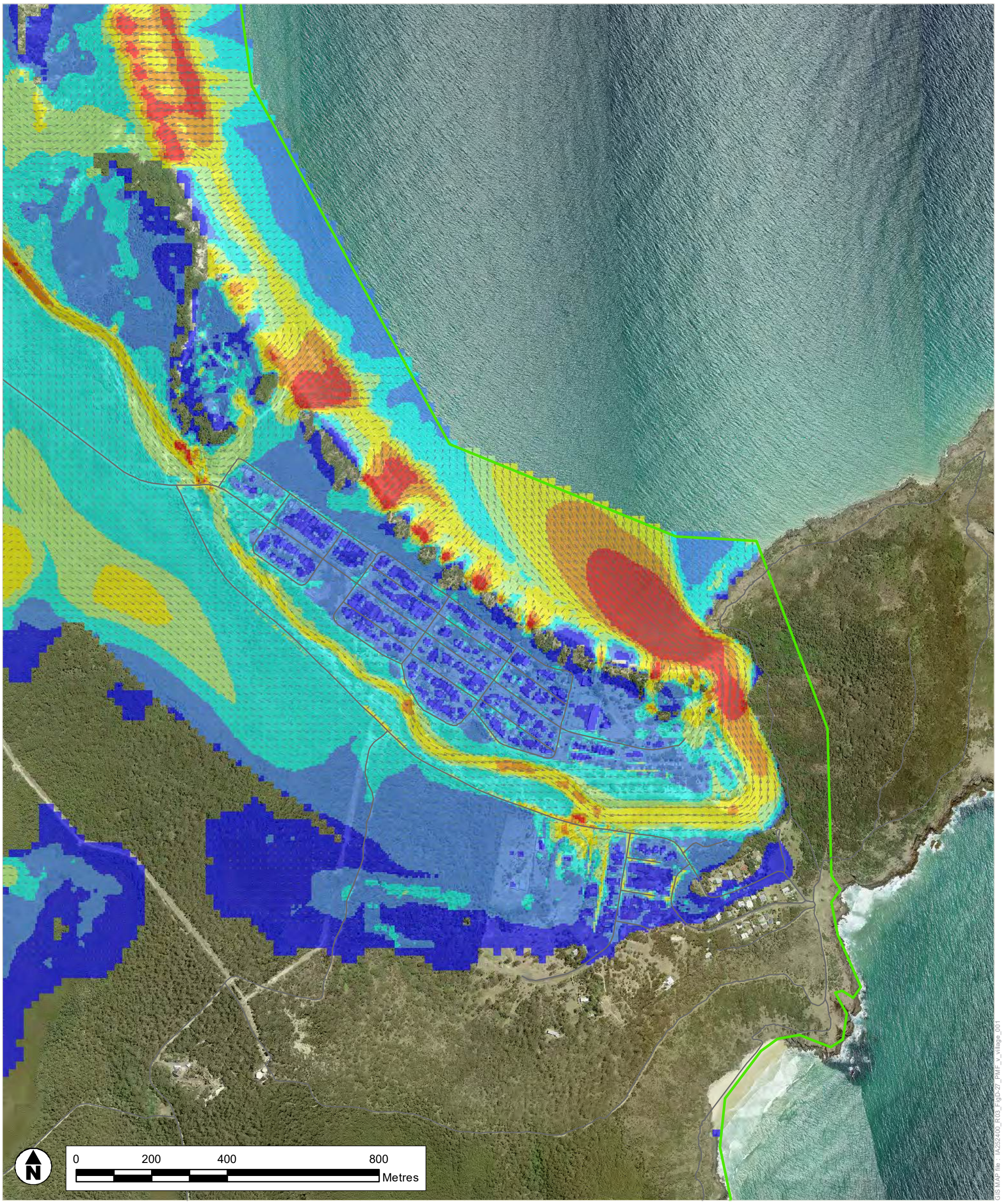
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-6(I)
CHECK AH	DATE 7/10/2022	



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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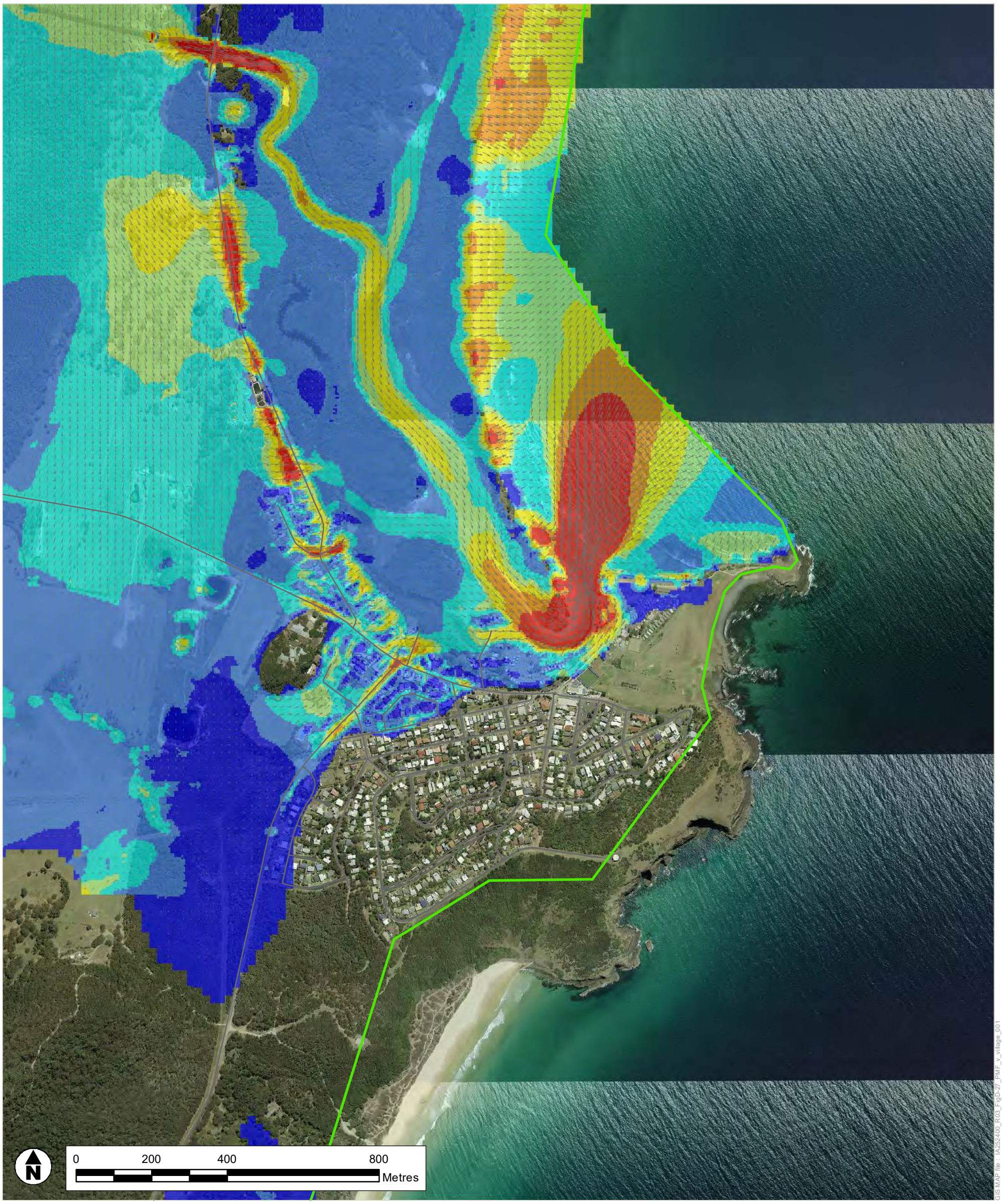
A3

SHEET	1 of 1
	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Hat Head
PROJECT	Lower Macleay River Floodplain Risk Management Study
DRAWN	LC
PROJECT #	IA252400
CHECK	AH
DATE	7/10/2022
MAP #	FIGURE A-6(J)

GIS MAP file : IA252400_R03_FigD-27_PMF_v_village_001



Legend

Flow Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Road
- Limit of Mapping

Jacobs

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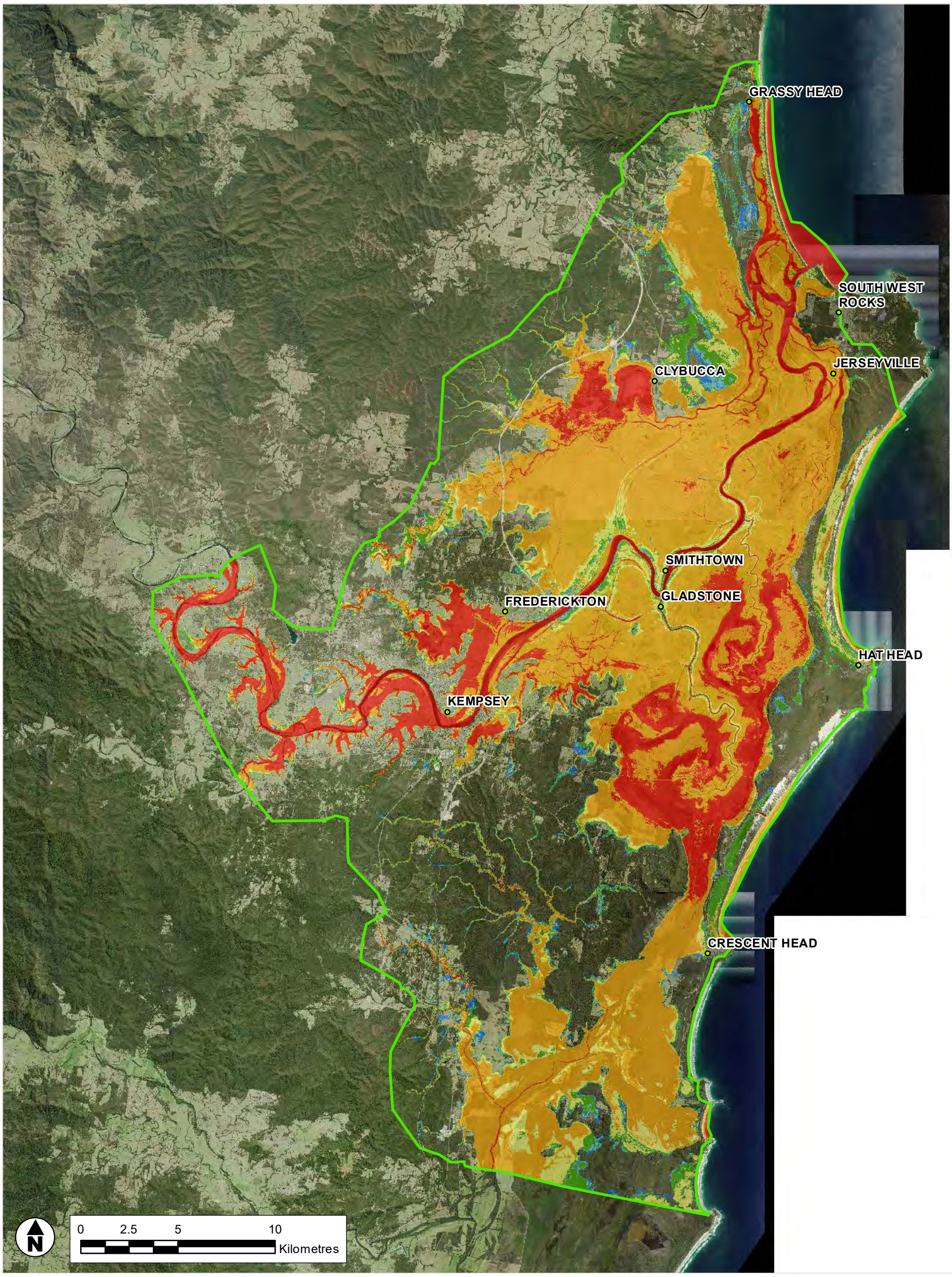
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flow Velocity Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-6(K)
CHECK AH	DATE 7/10/2022	

GIS MAP file : IA252400_R.03_FigD-27_PMF_v_village_001



GIS MAP file : IA252400_R03_FigD-33_1pAEP_haz_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

Limit of Mapping

Jacobs

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A3

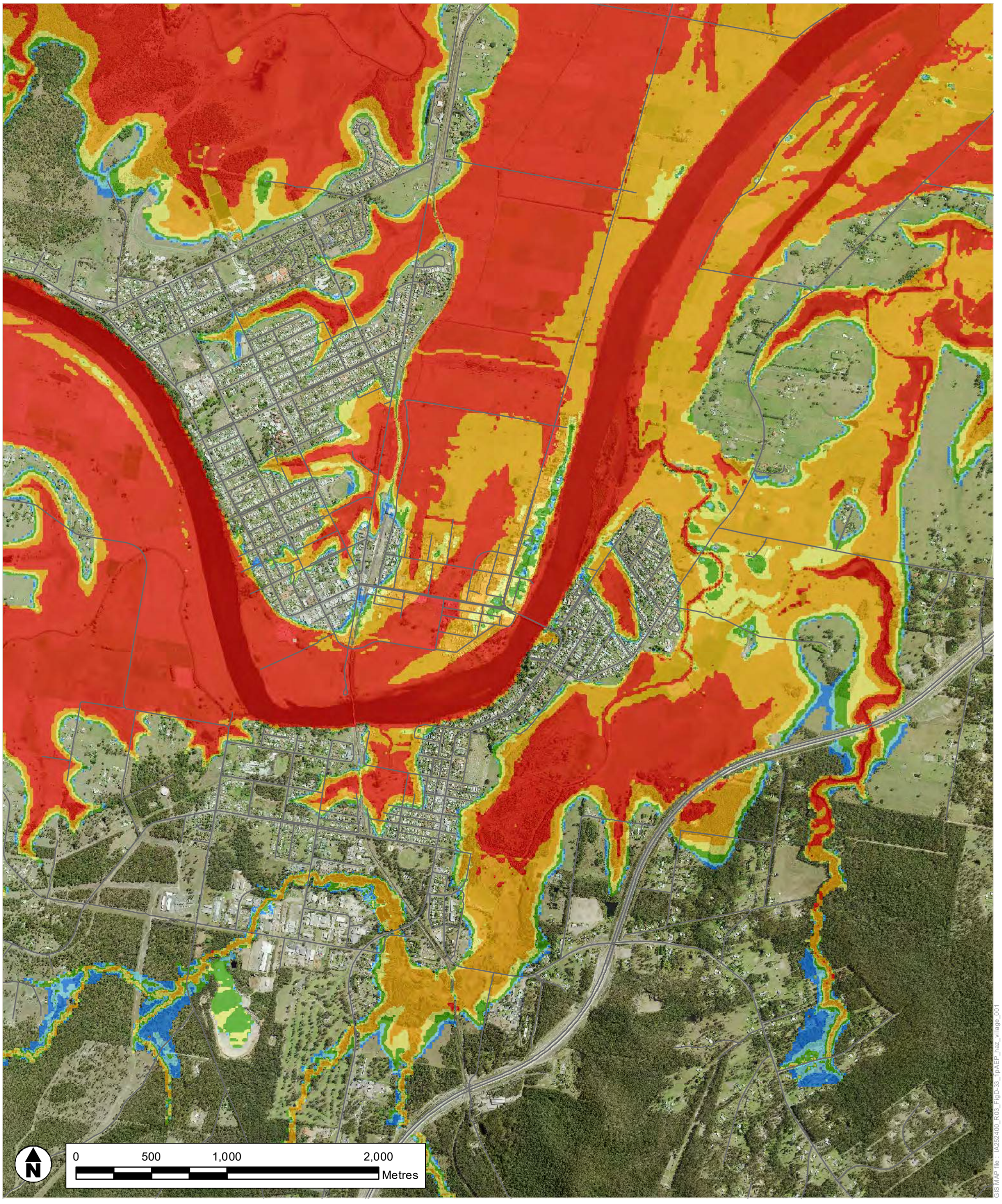
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Hazard

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-7	1	1
CHECK LC	DATE 29/09/2022			



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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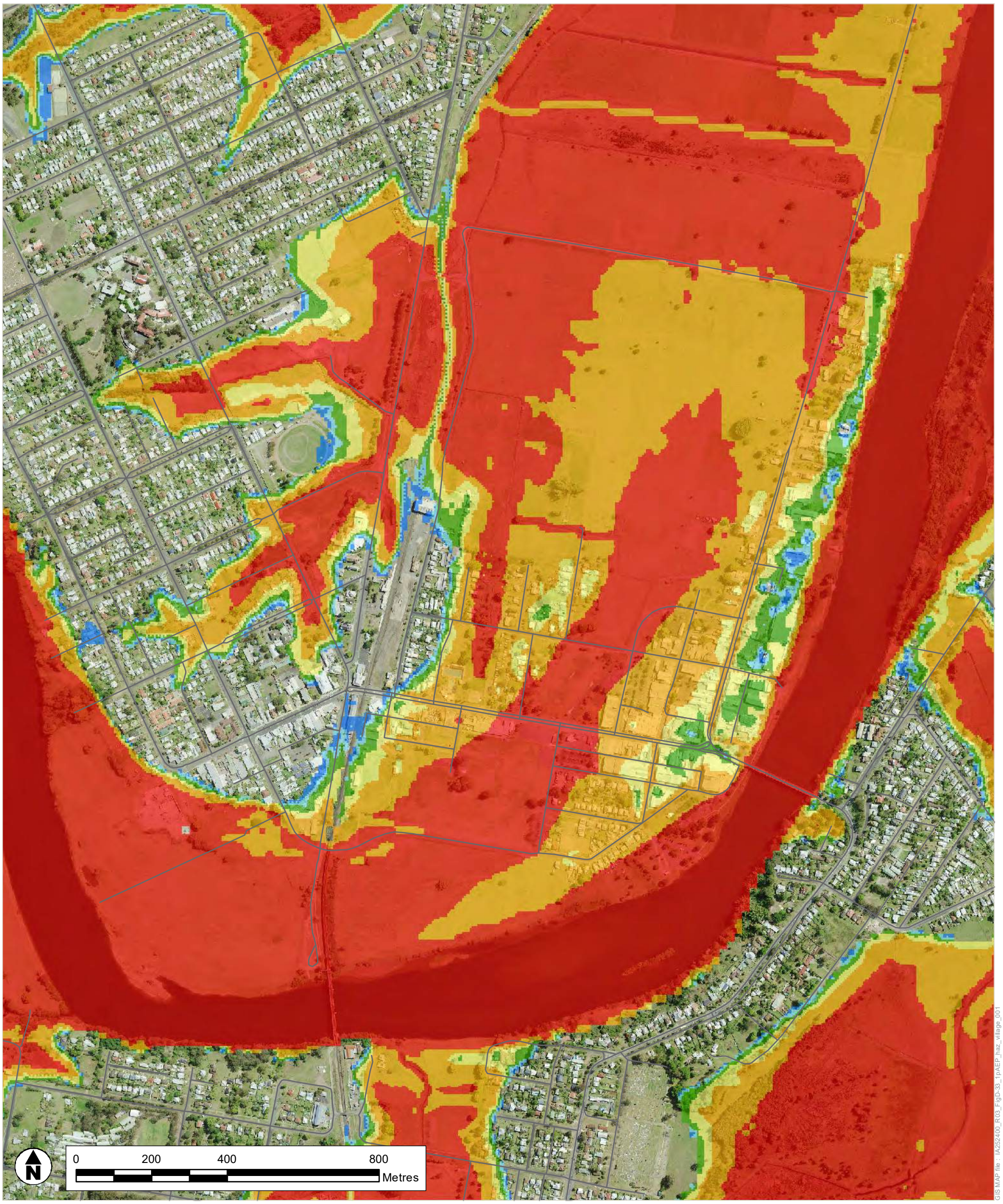
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(A)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

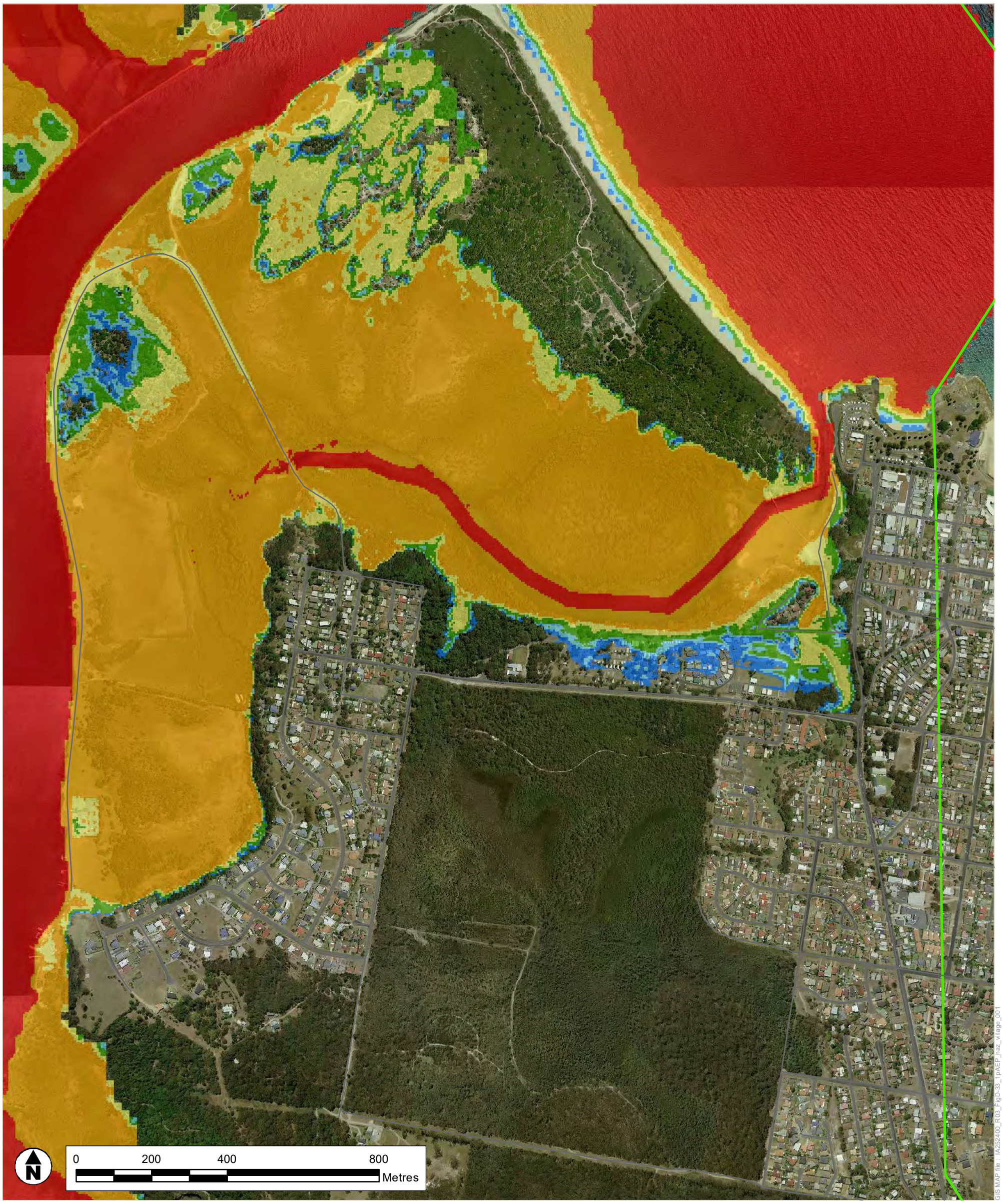
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Hazard Kempsey CBD

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-7(B)
CHECK AH	DATE 2/10/2022	



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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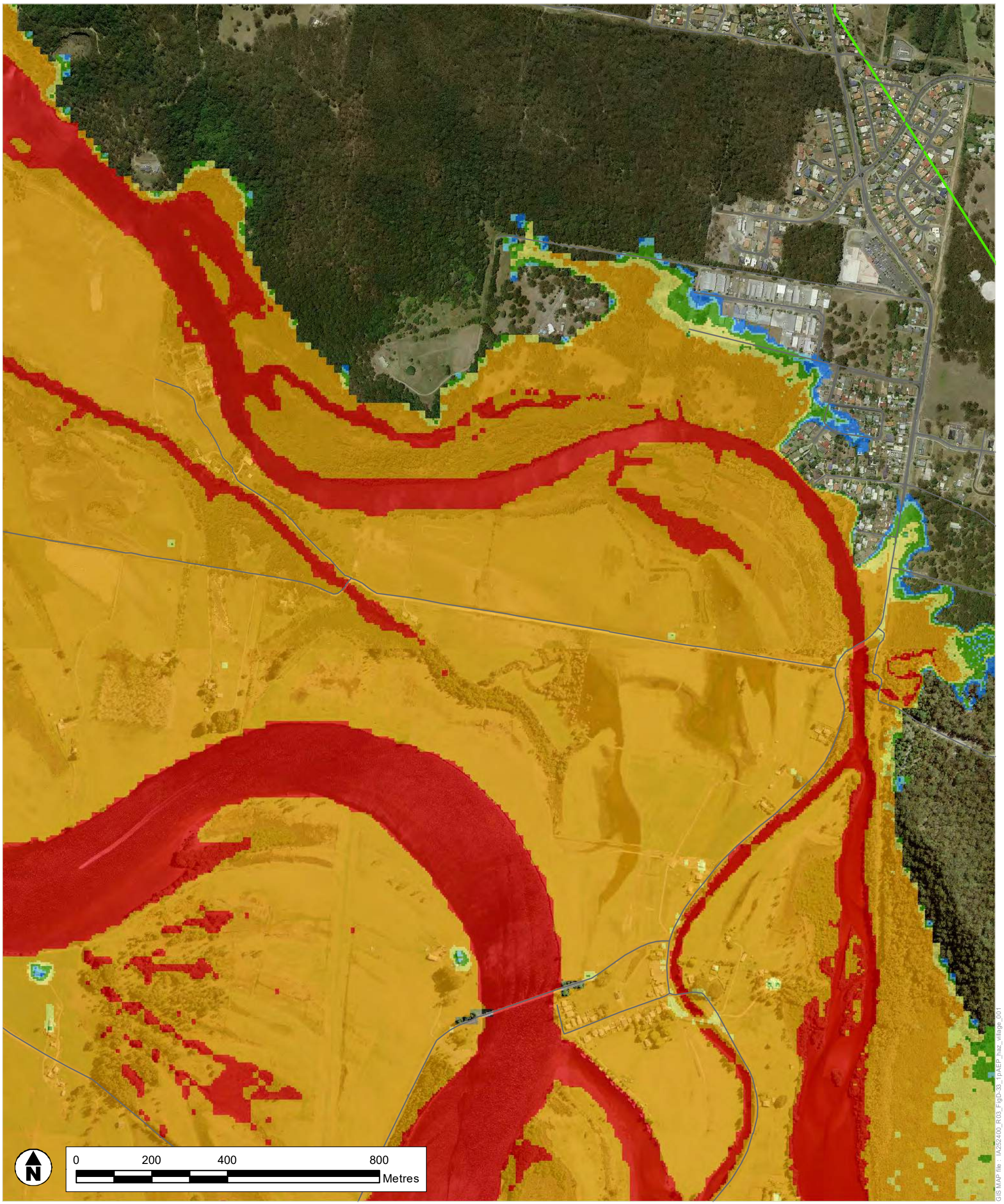
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(C)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

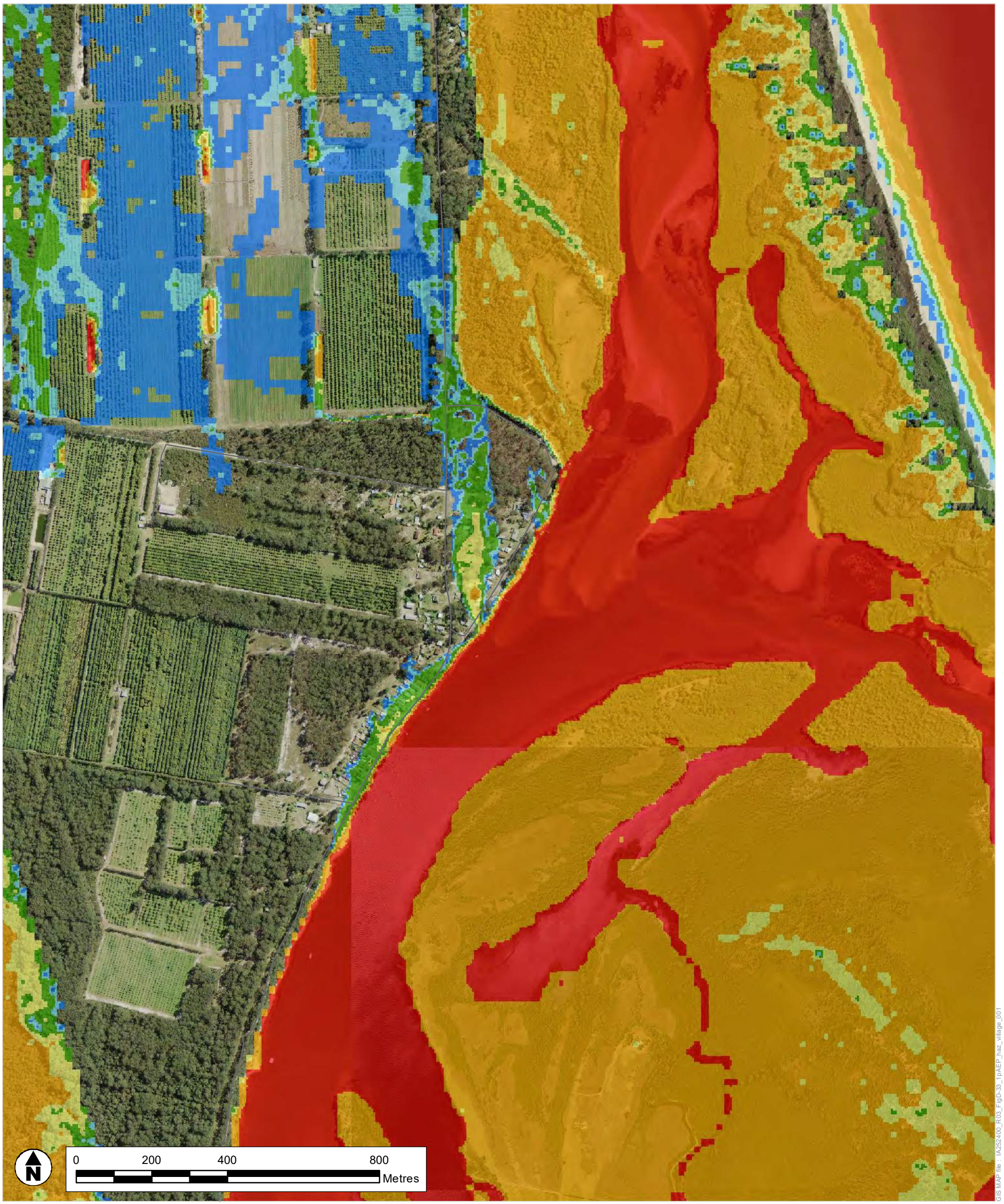
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Hazard
South West Rocks (S) and Jerseyville

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-7(D)
CHECK AH	DATE 2/10/2022	



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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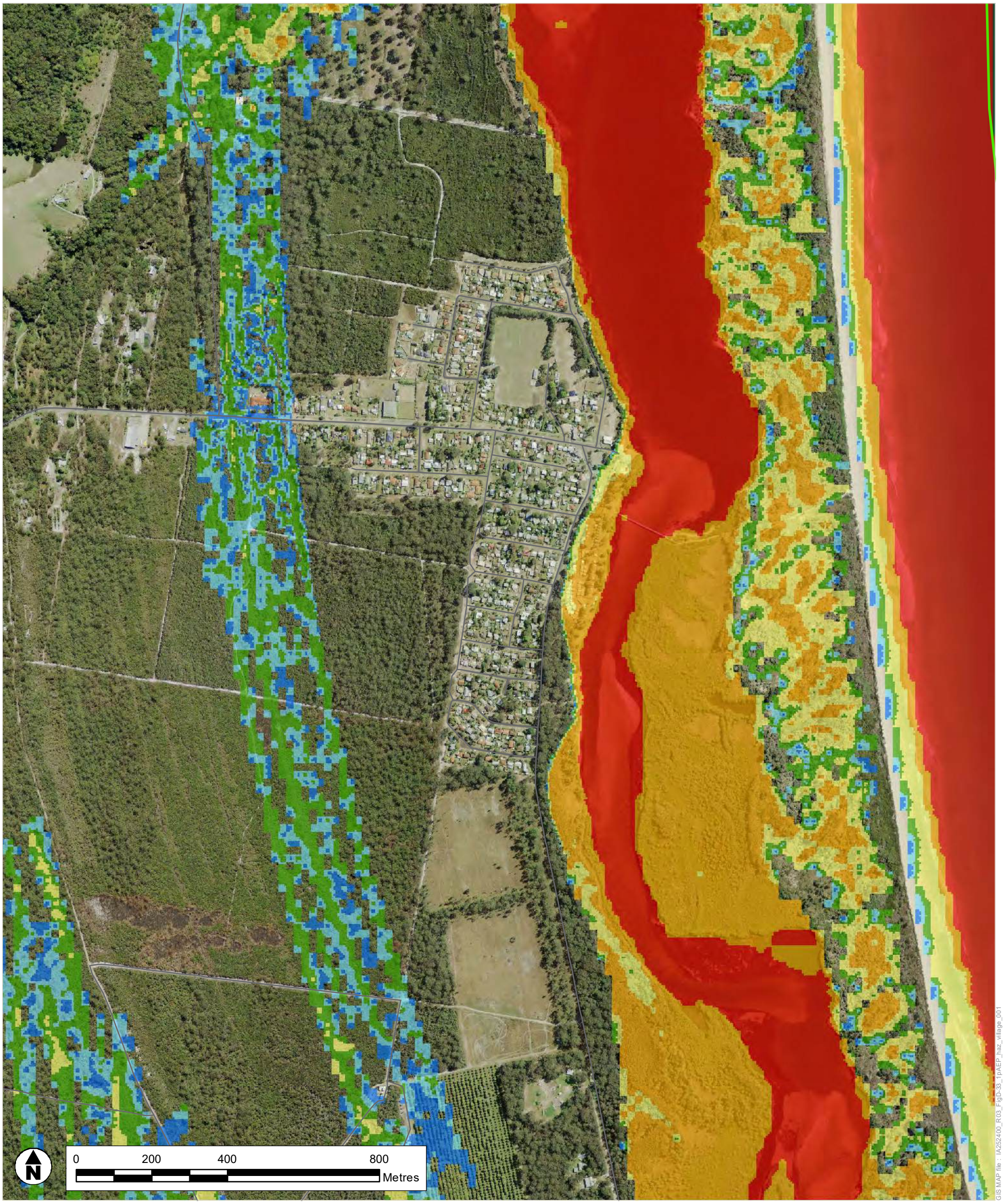
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(E)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

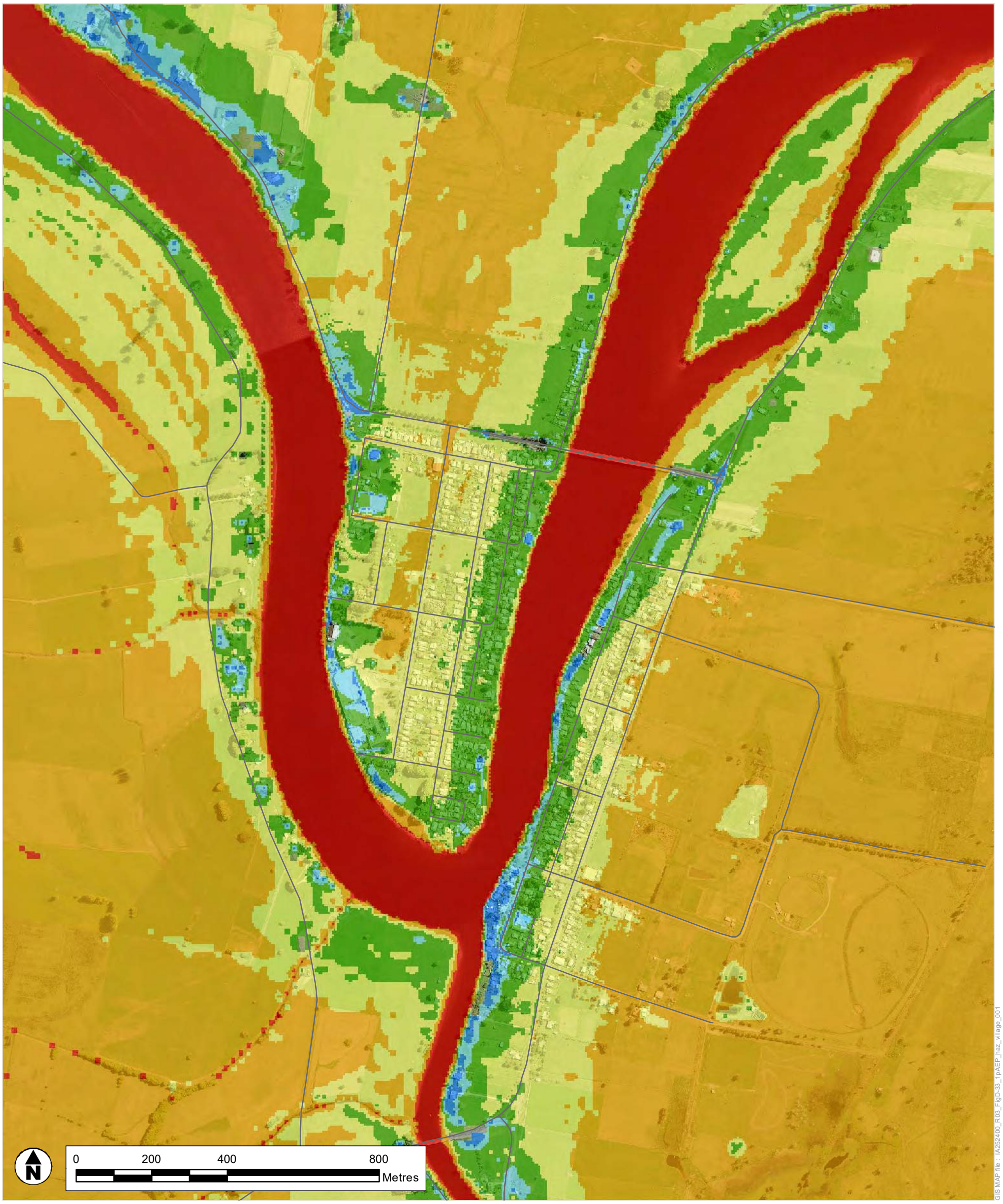
- Road
- Limit of Mapping

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(F)



GIS MAP file : IA252400_R03_FigD-33_1pAEP_haz_village_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

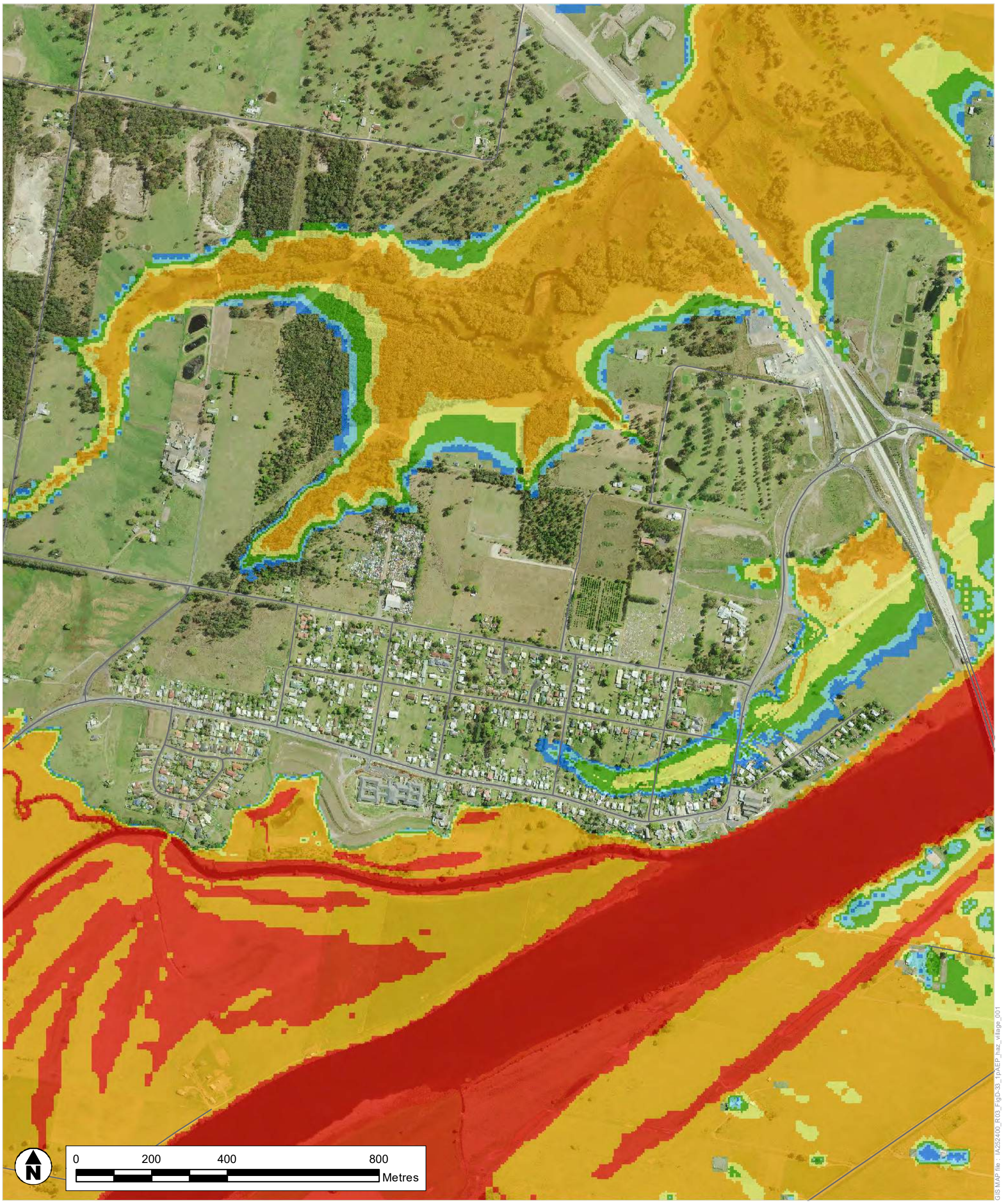
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Flood Hazard
Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-7(G)
CHECK AH	DATE 2/10/2022	



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Frederickton	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(H)

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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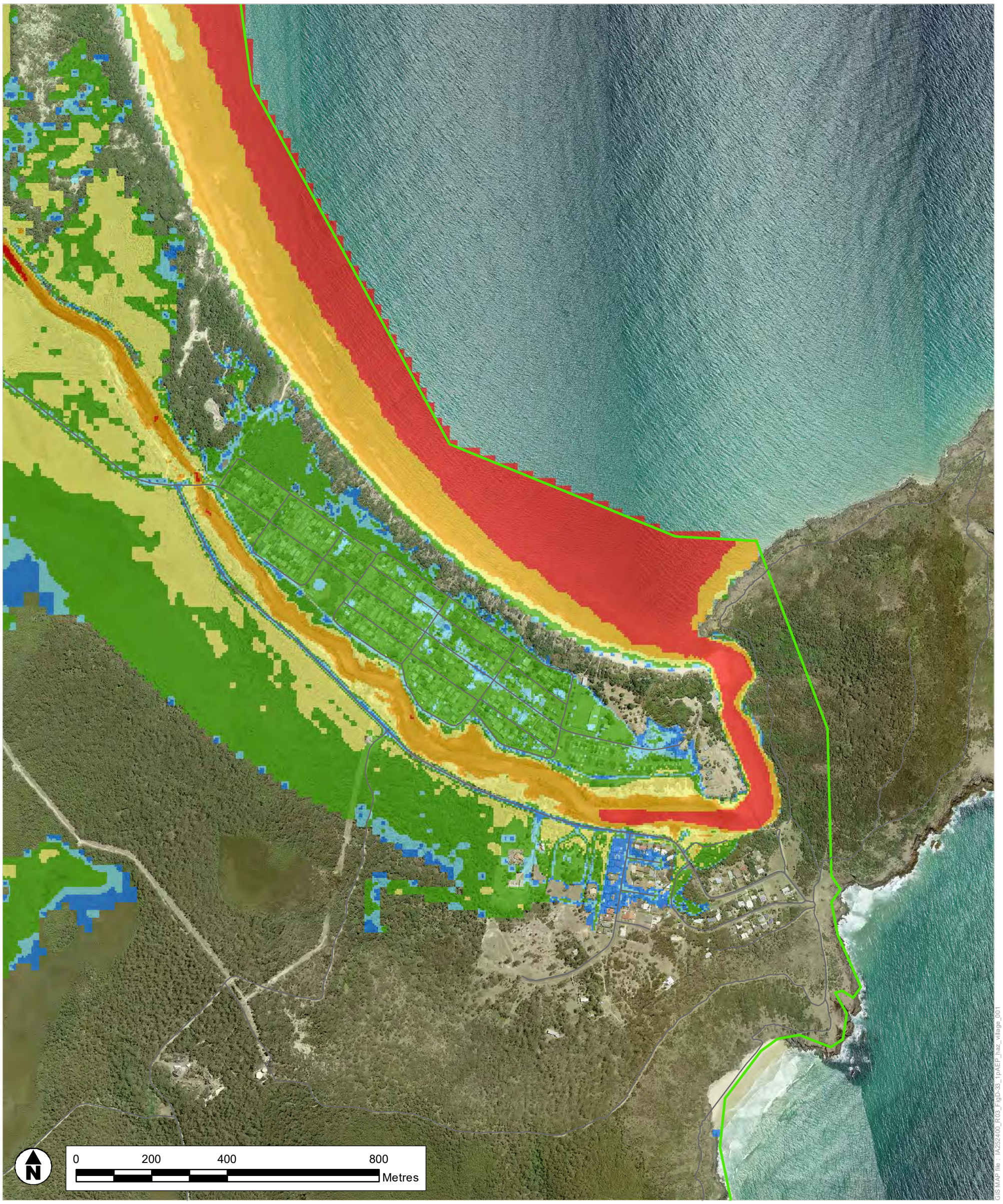
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(I)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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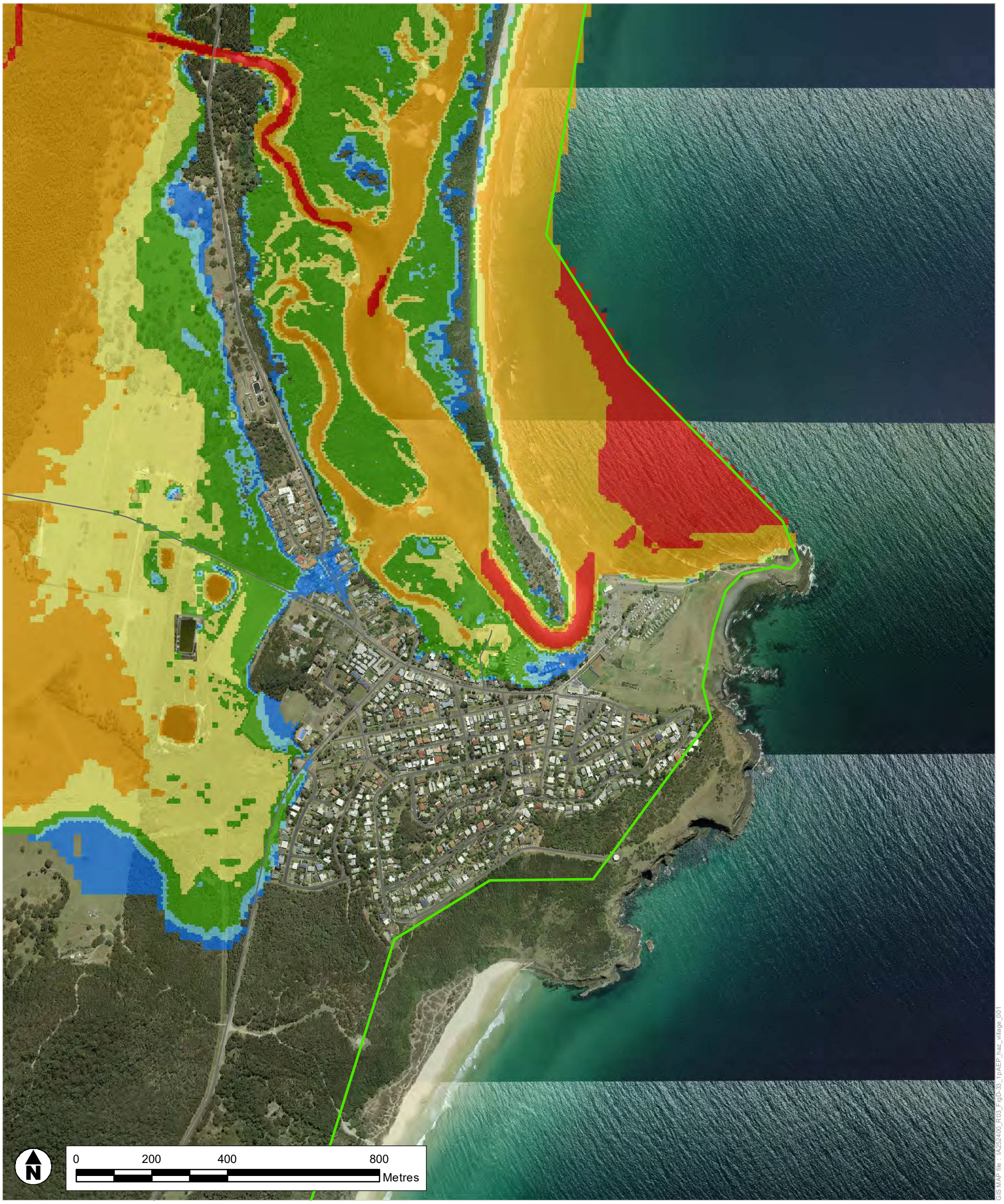
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Hazard Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 2/10/2022	FIGURE A-7(J)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

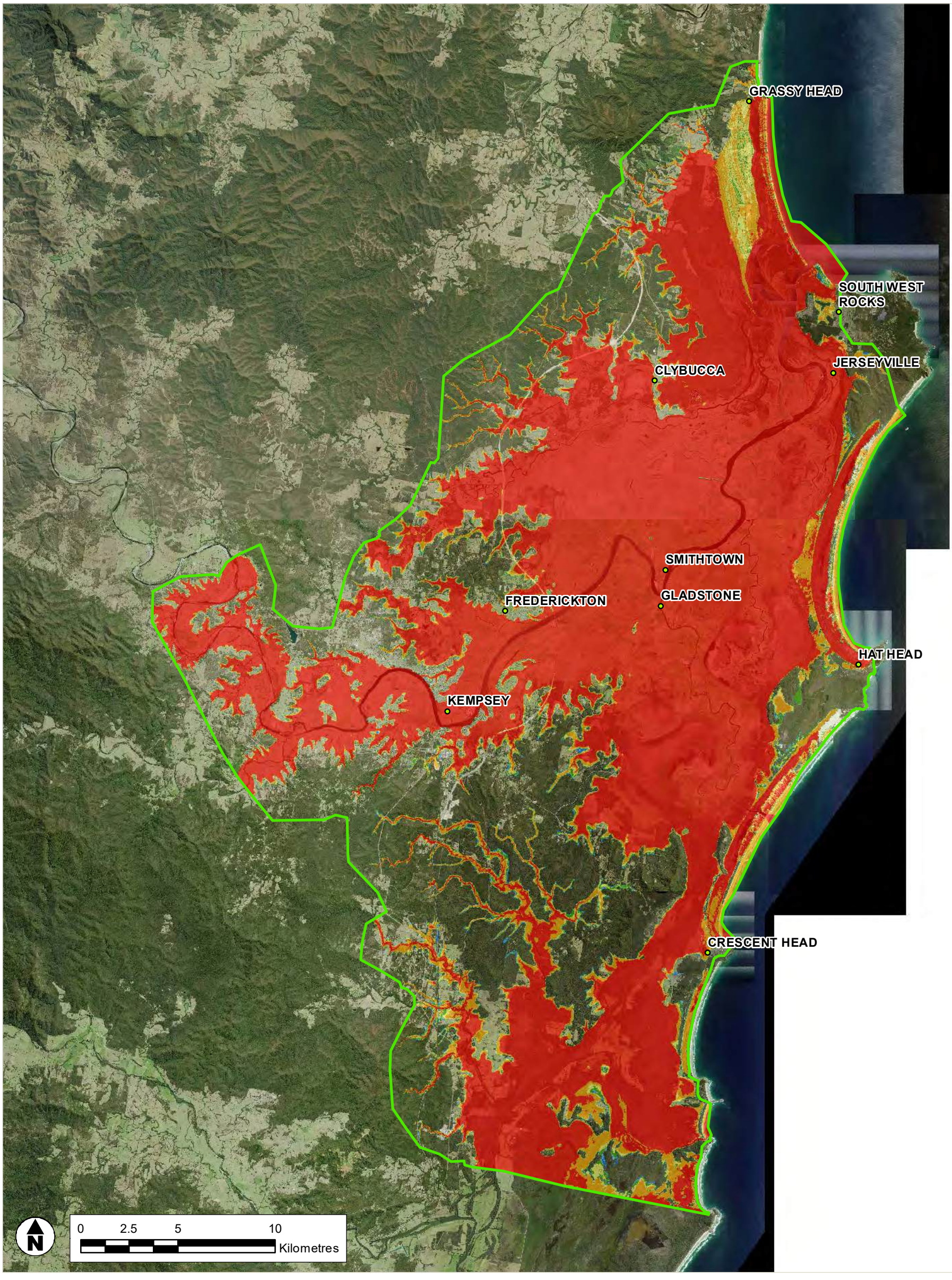
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event Flood Hazard Crescent Head

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-7(K)
CHECK AH	DATE 2/10/2022	



GIS MAP file : IA252400_R03_FigD-36_PMF_haz_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

Limit of Mapping

Jacobs

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A3

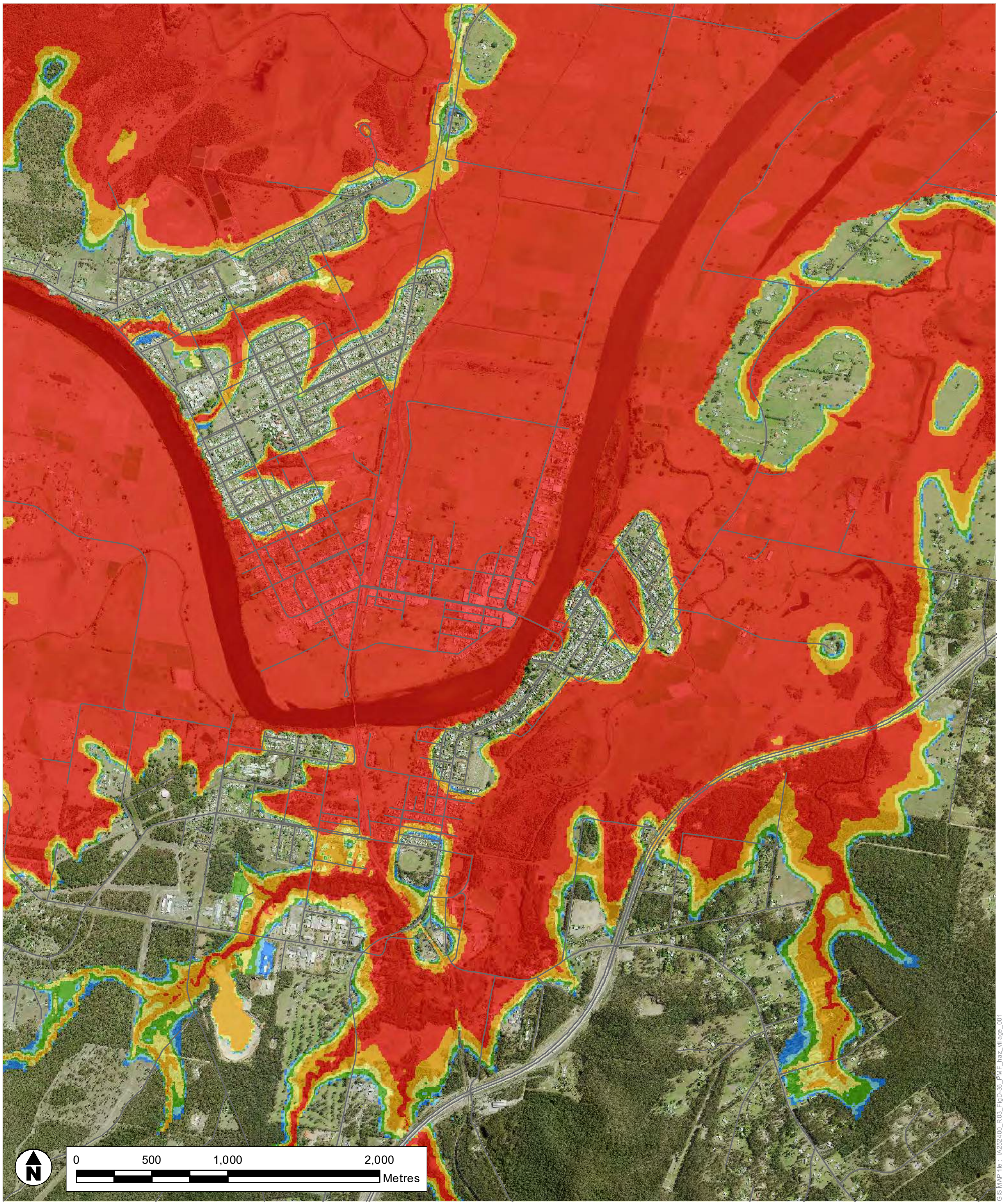
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Hazard

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE A-8	1	1
CHECK LC	DATE 7/10/2022			



GIS MAP file : IA252400_R03_FigD-36_PMF_haz_village_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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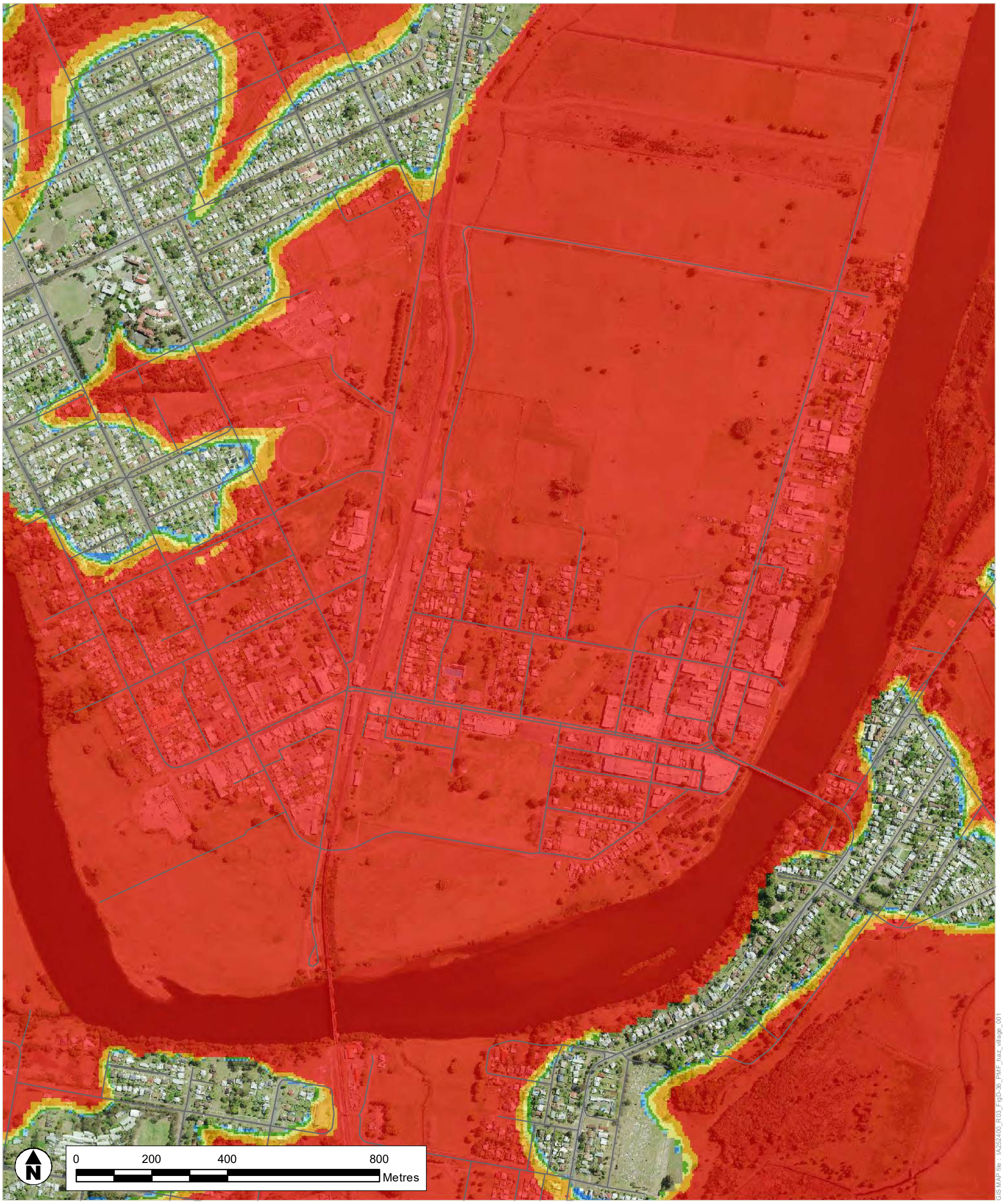
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(A)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE A-8(B)
CHECK AH	DATE 7/10/2022	

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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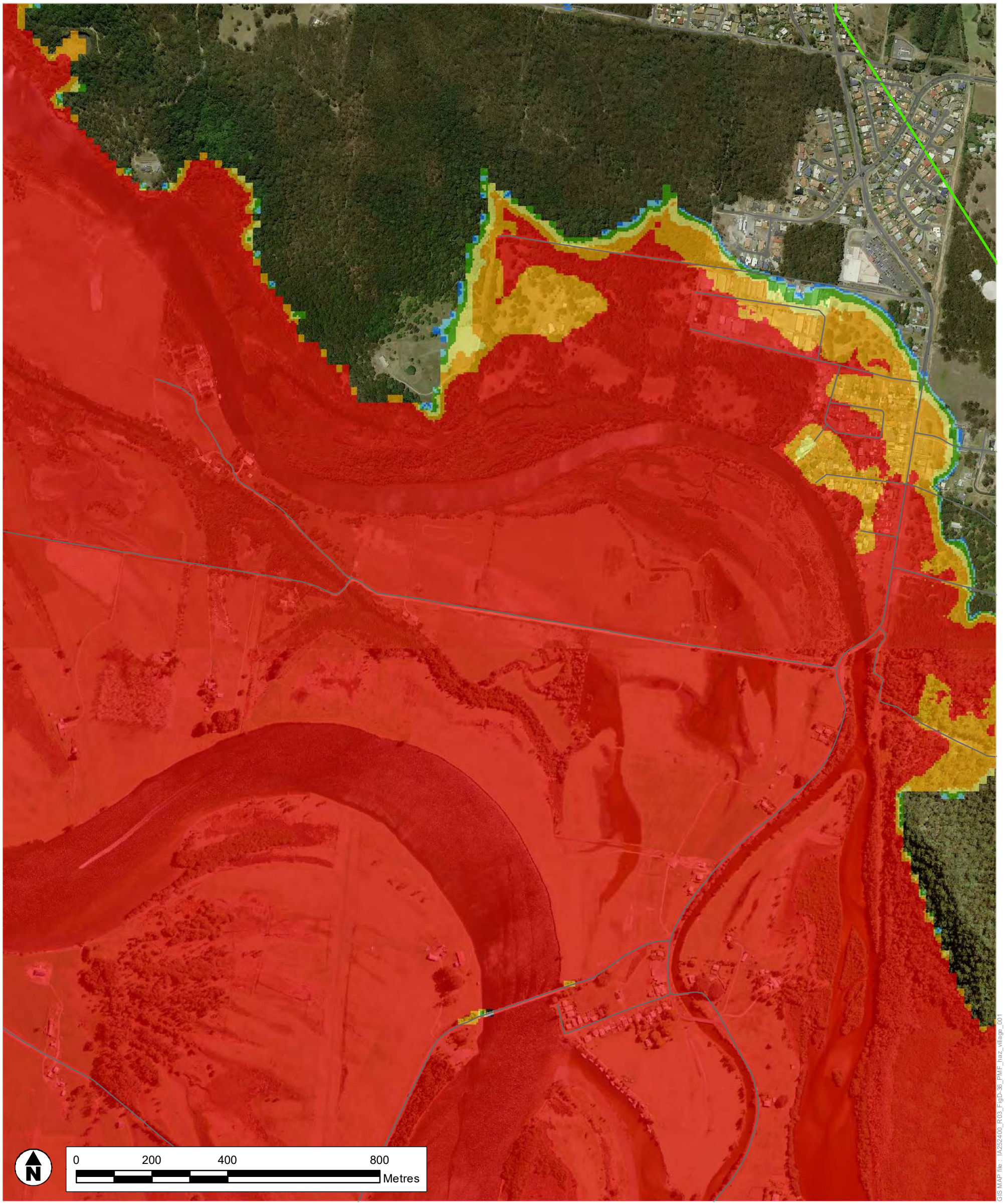
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(C)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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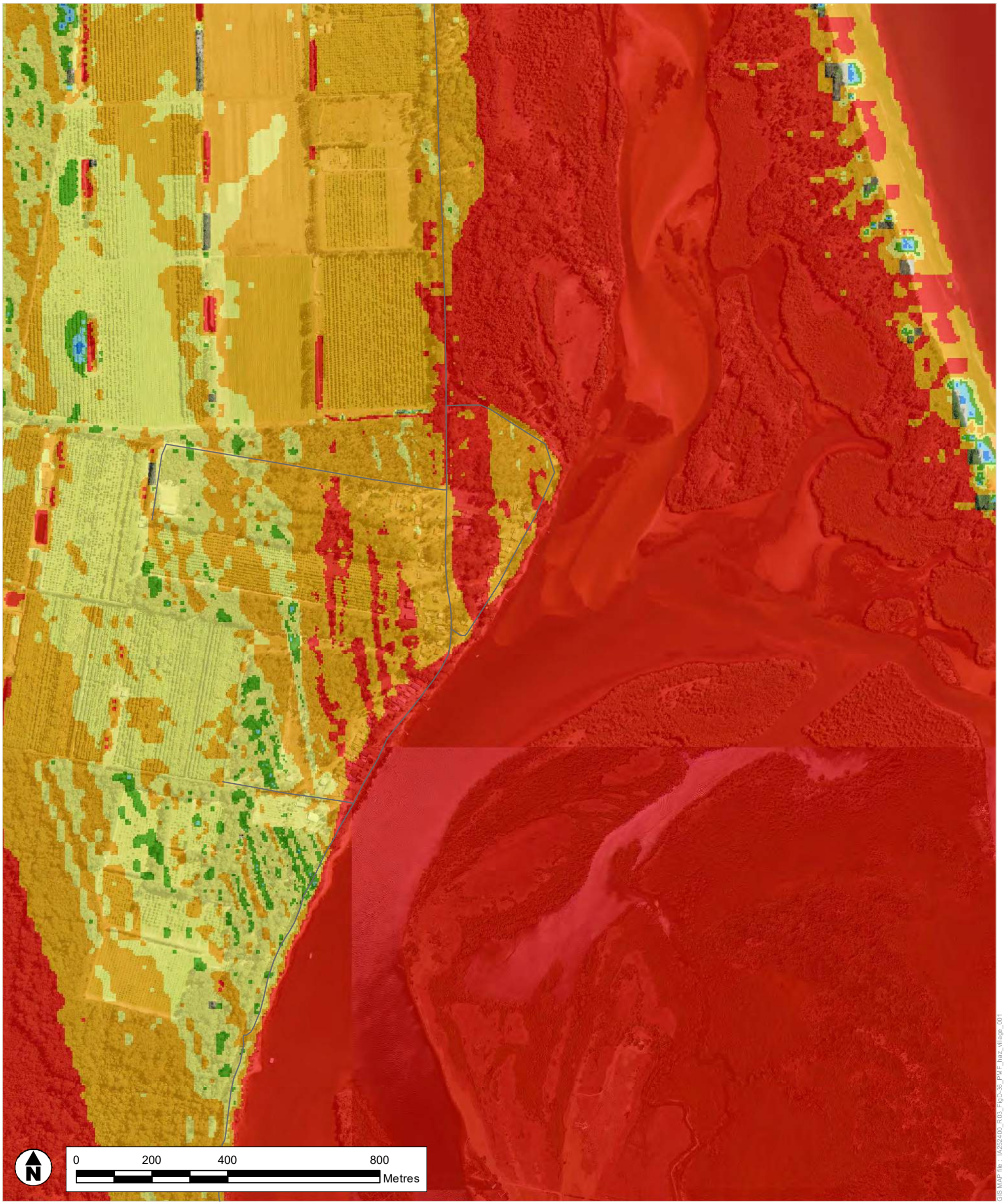
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(D)



GIS MAP file : IA252400_R03_FigD-36_PMF_haz_village_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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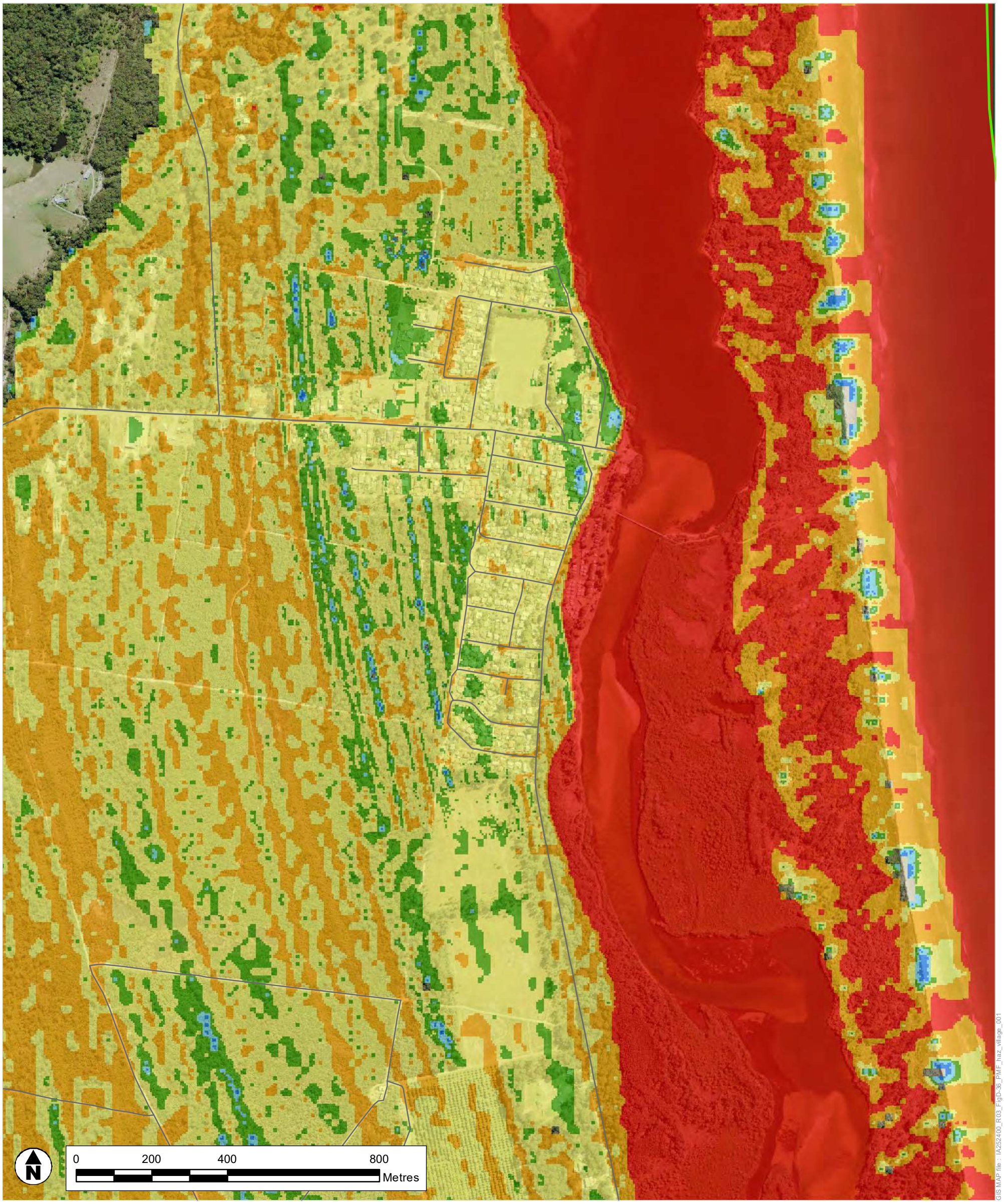
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(E)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(F)

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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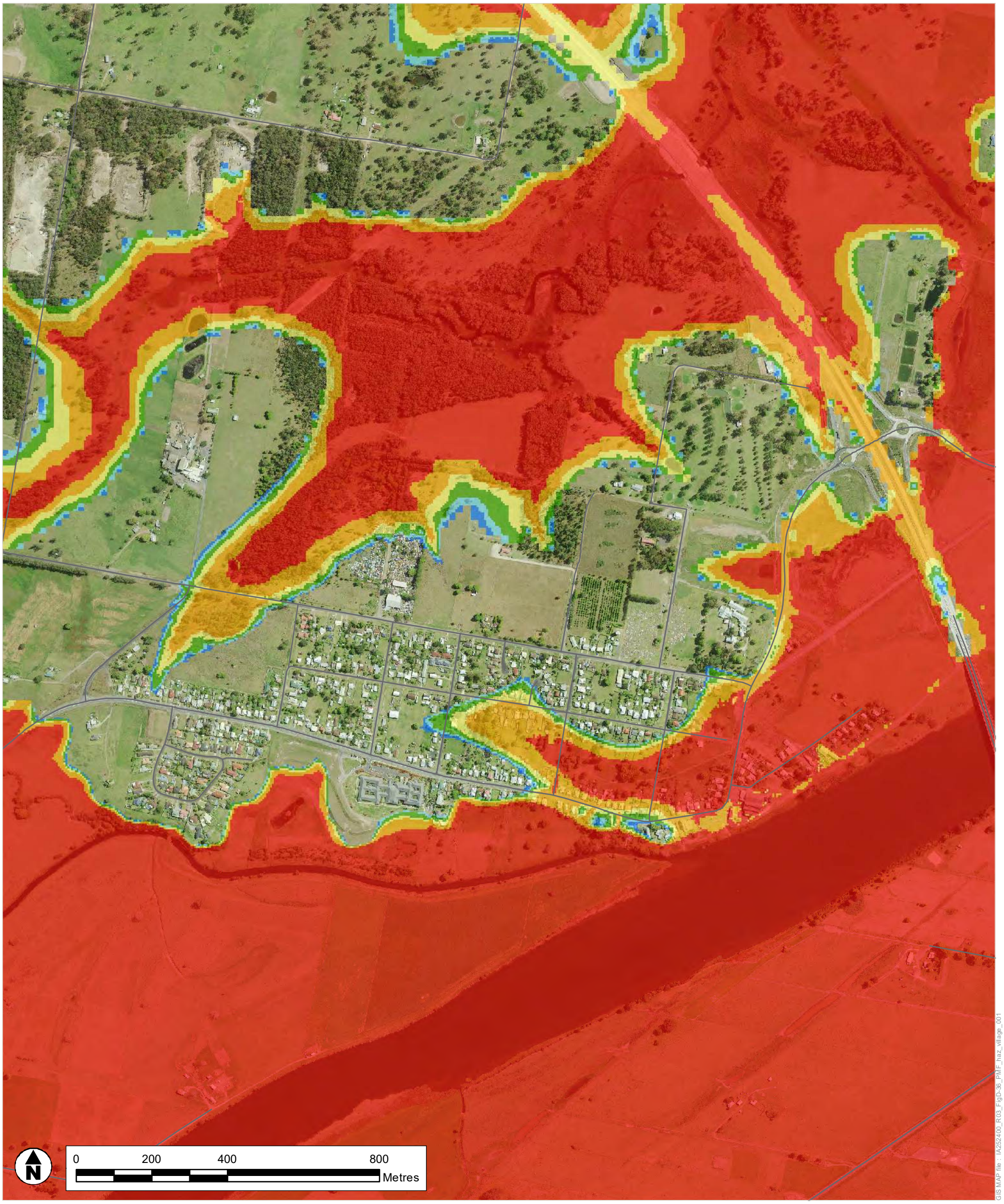
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(G)



GIS MAP file : IA252400_R03_FigD-36_PMF_haz_village_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Flood Hazard Frederickton

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE A-8(H)
CHECK AH	DATE 7/10/2022	

GIS MAP file : IA252400_R03_FigD-36_PMF_haz_village_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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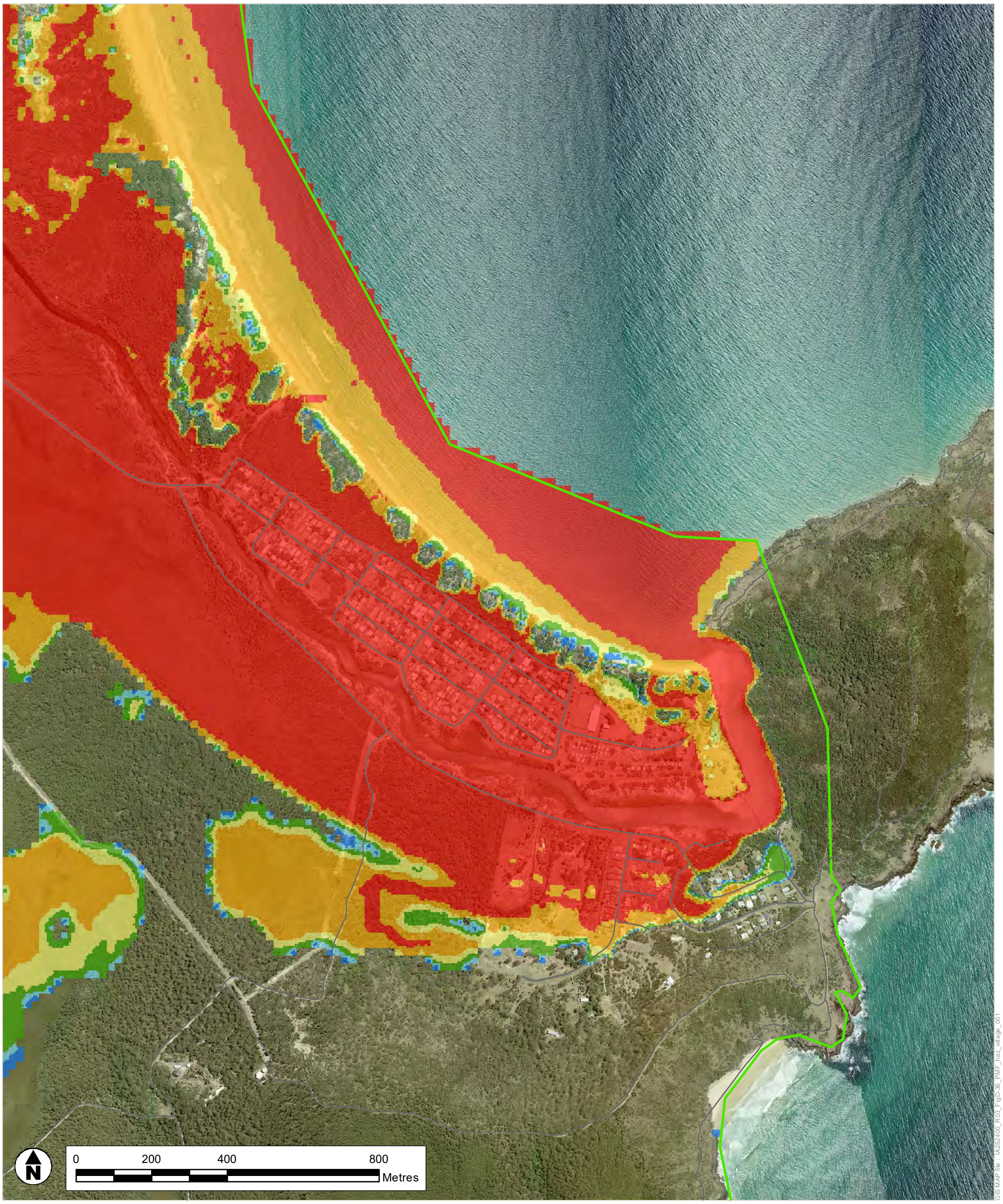
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(I)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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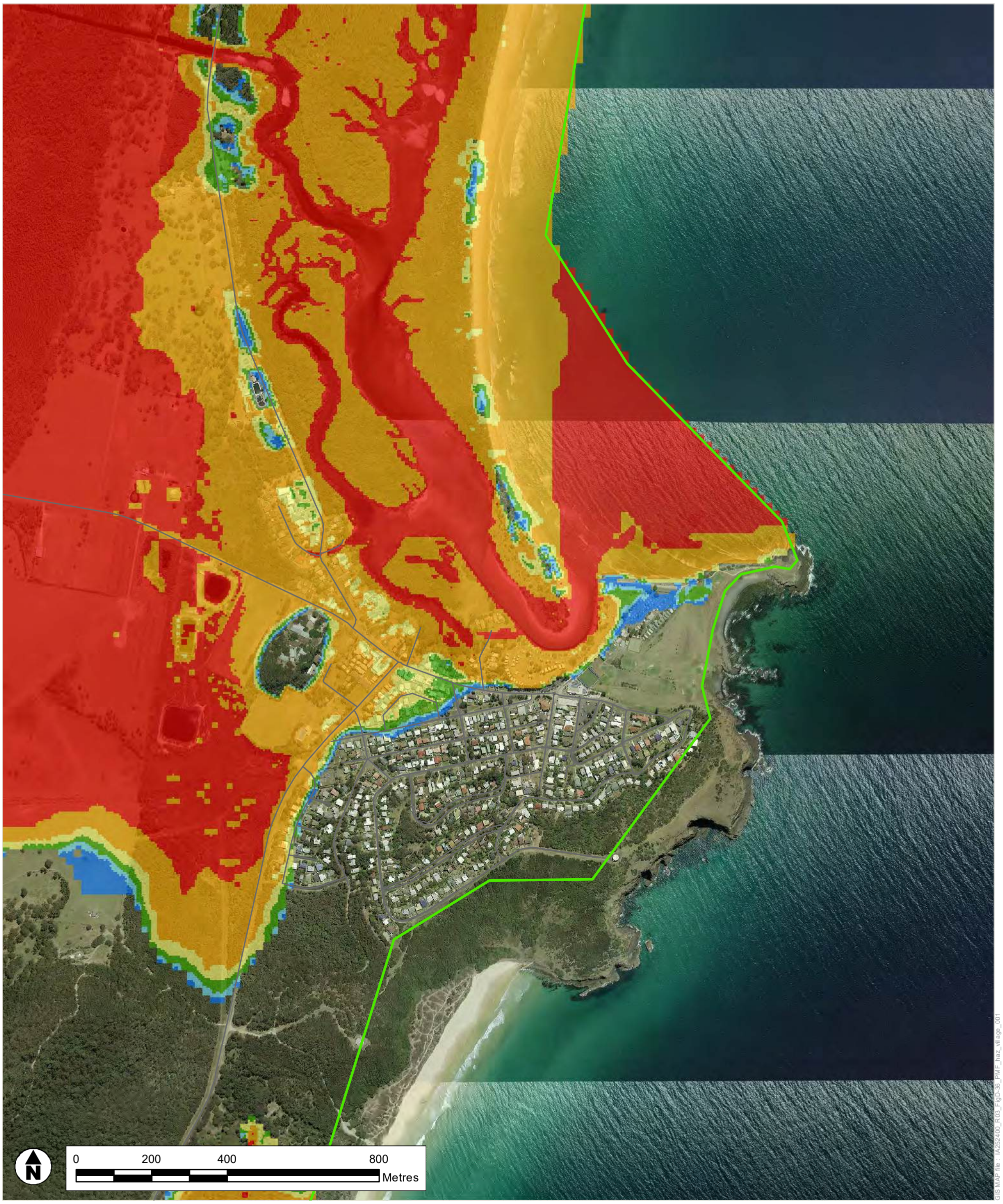
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(J)



Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

- Road
- Limit of Mapping

Jacobs

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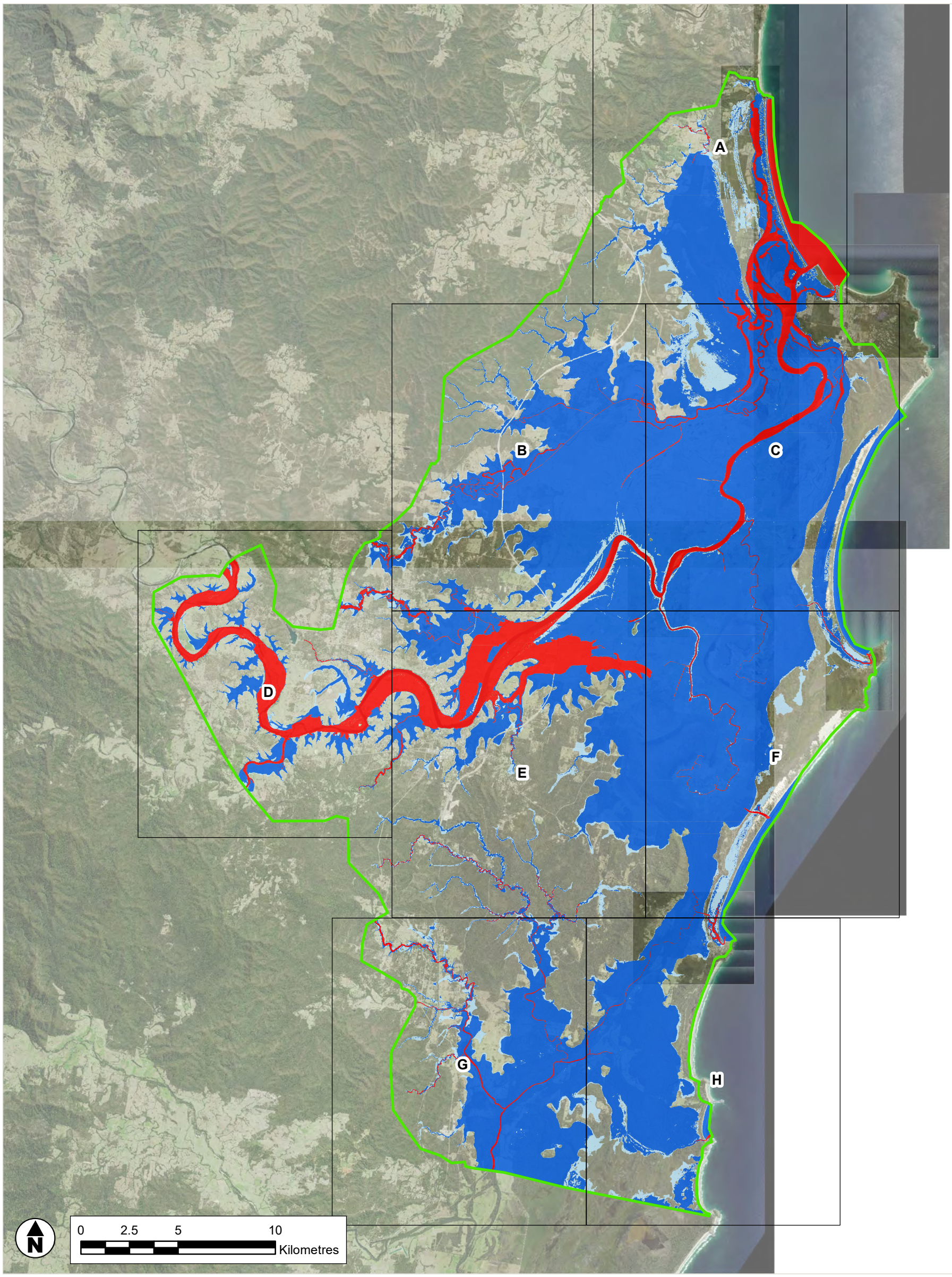
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Flood Hazard Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 7/10/2022	FIGURE A-8(K)

GIS MAP file : IA252400_R03_FigD-36_PMF_haz_village_001

Appendix B. Flood planning mapping



GIS MAP file : IA252400_R04_FigA-1_HydCat_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping
- Inset Map Frame - Refer following map sheets

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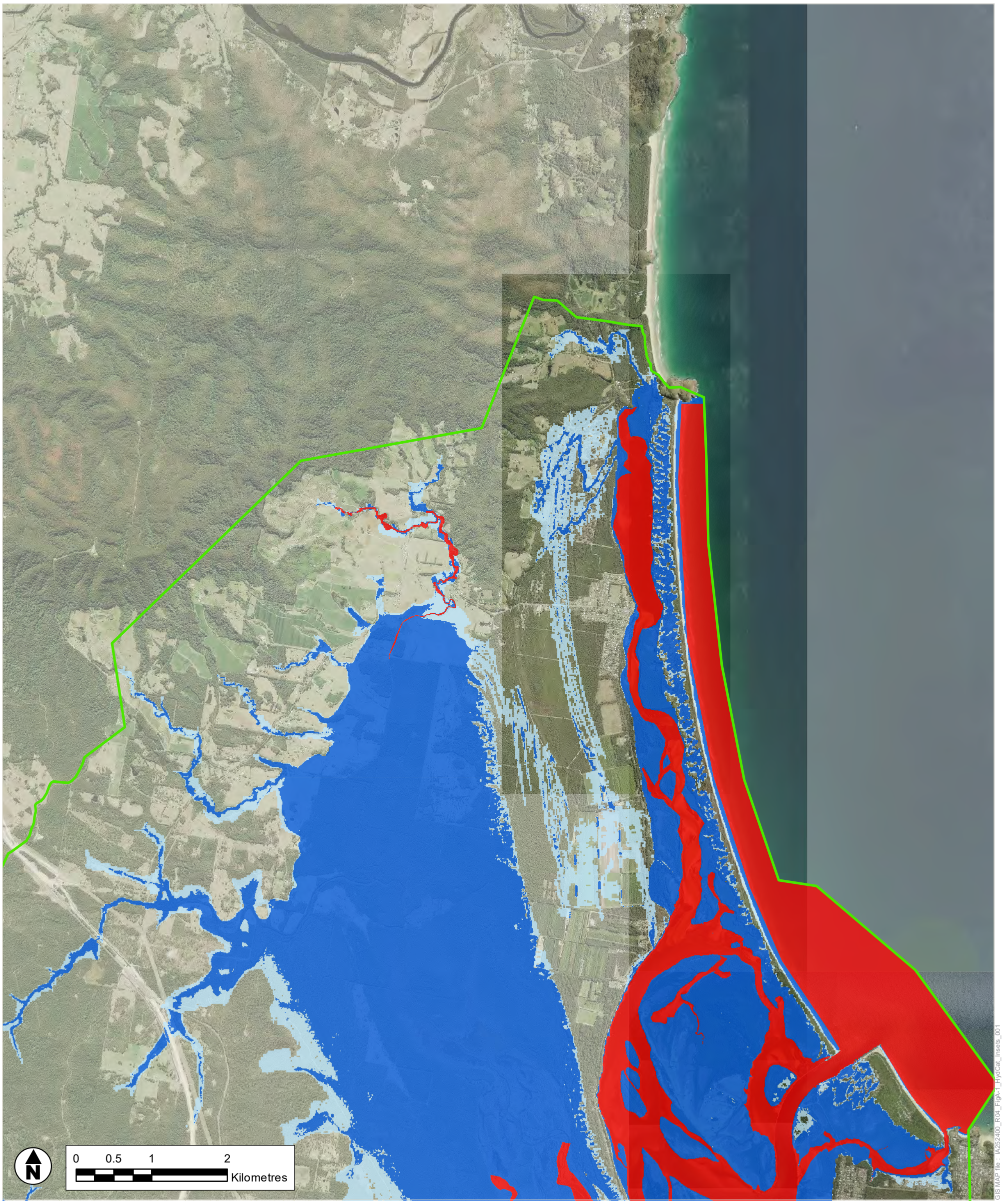
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-1	1	1
CHECK AH	DATE 14/02/2023			



GIS MAP file : IA252400_R04_FIgA-1_HydCat_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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A3

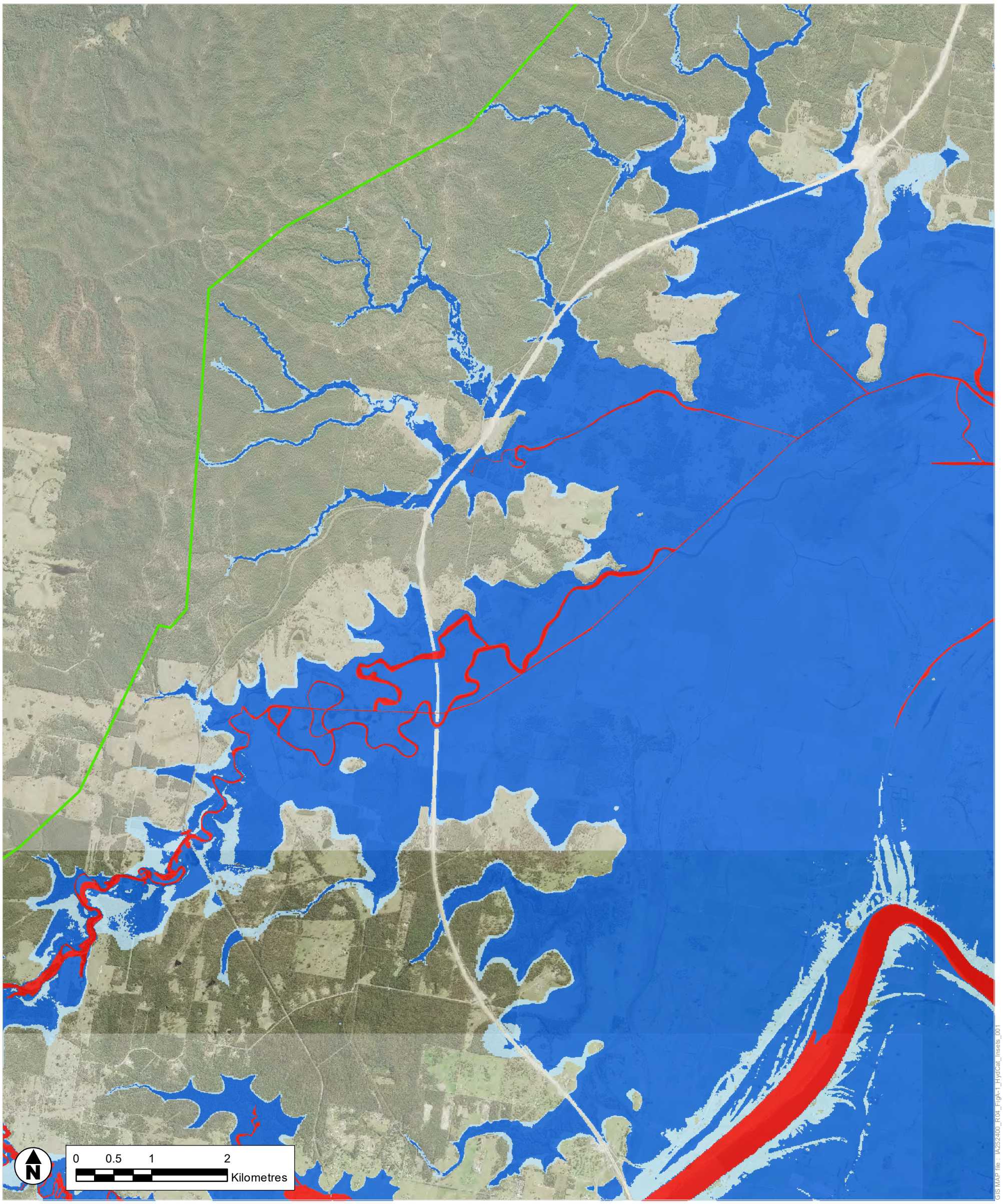
INSET # 1 of 8

GDA 1994 MGA Zone 56

TITLE 1% AEP Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(A)	1 1
CHECK AH	DATE 14/02/2023		



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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INSET # 2 of 8

GDA 1994 MGA Zone 56

TITLE 1% AEP Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(B)	1 1
CHECK AH	DATE 14/02/2023		

GIS MAP file : IA252400_R04_Fig4-1_HydCat_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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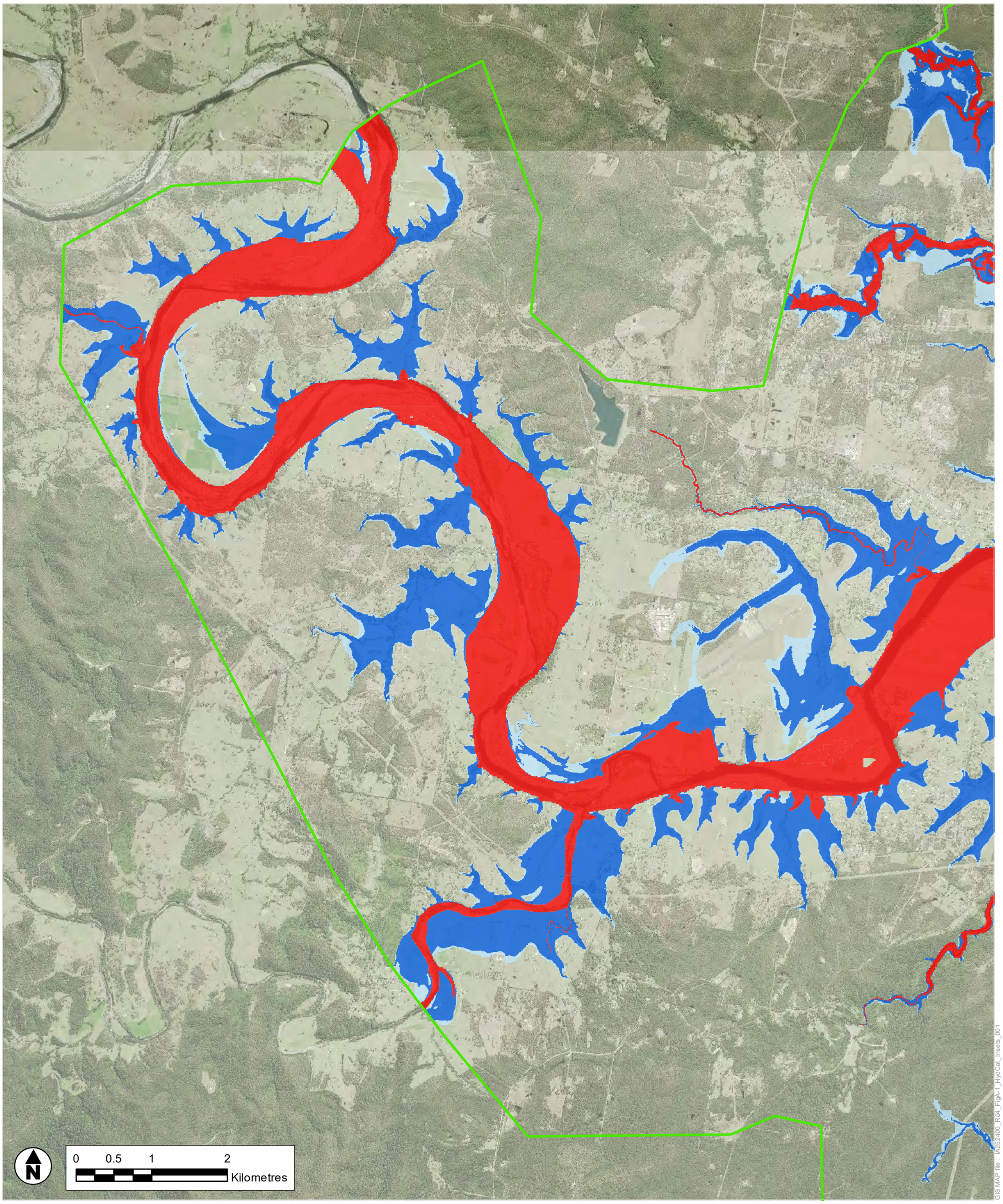
A3

INSET #	3 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-1(C) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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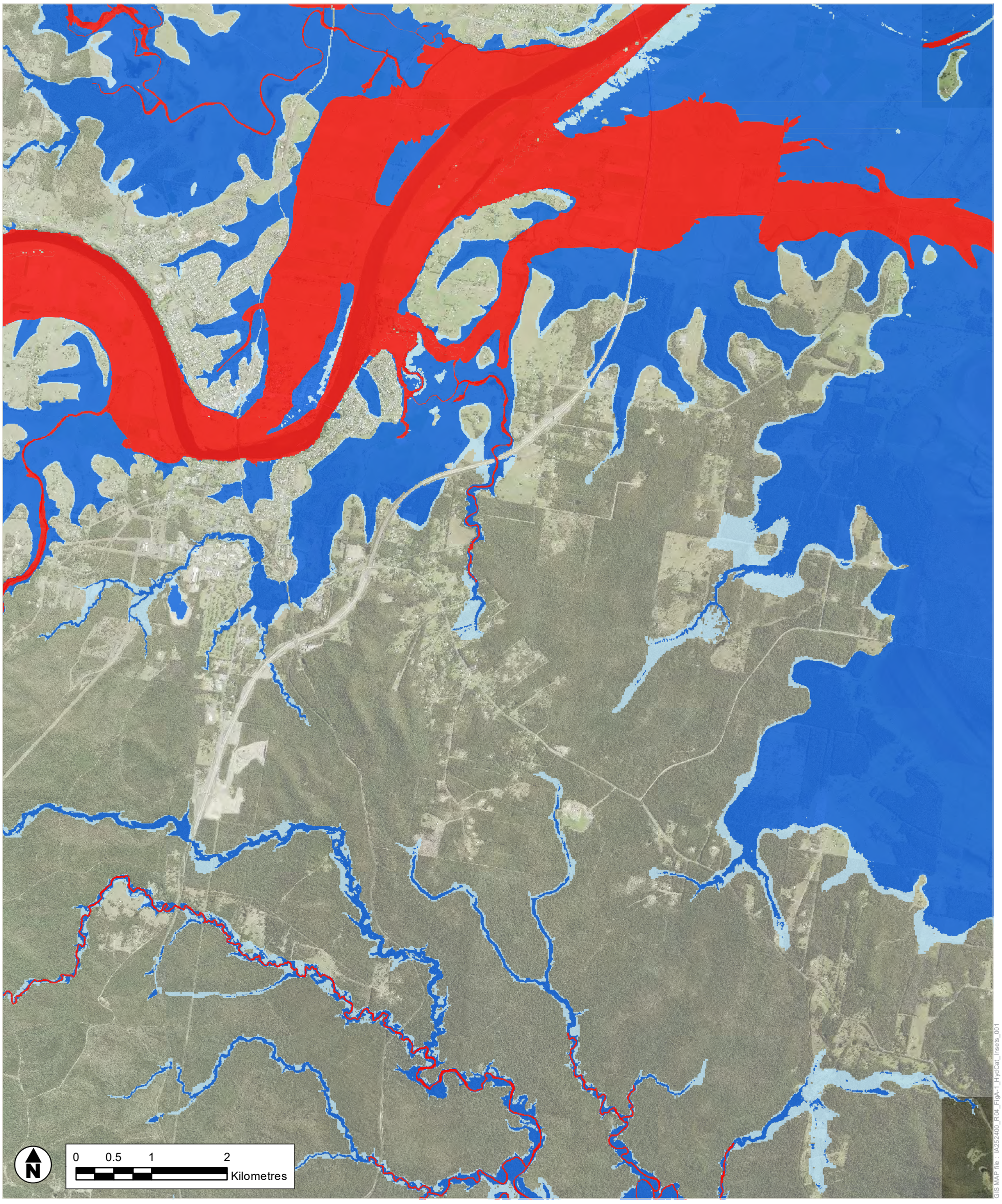
INSET # 4 of 8

GDA 1994 MGA Zone 56

TITLE 1% AEP
Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(D)	1 1
CHECK AH	DATE 14/02/2023		



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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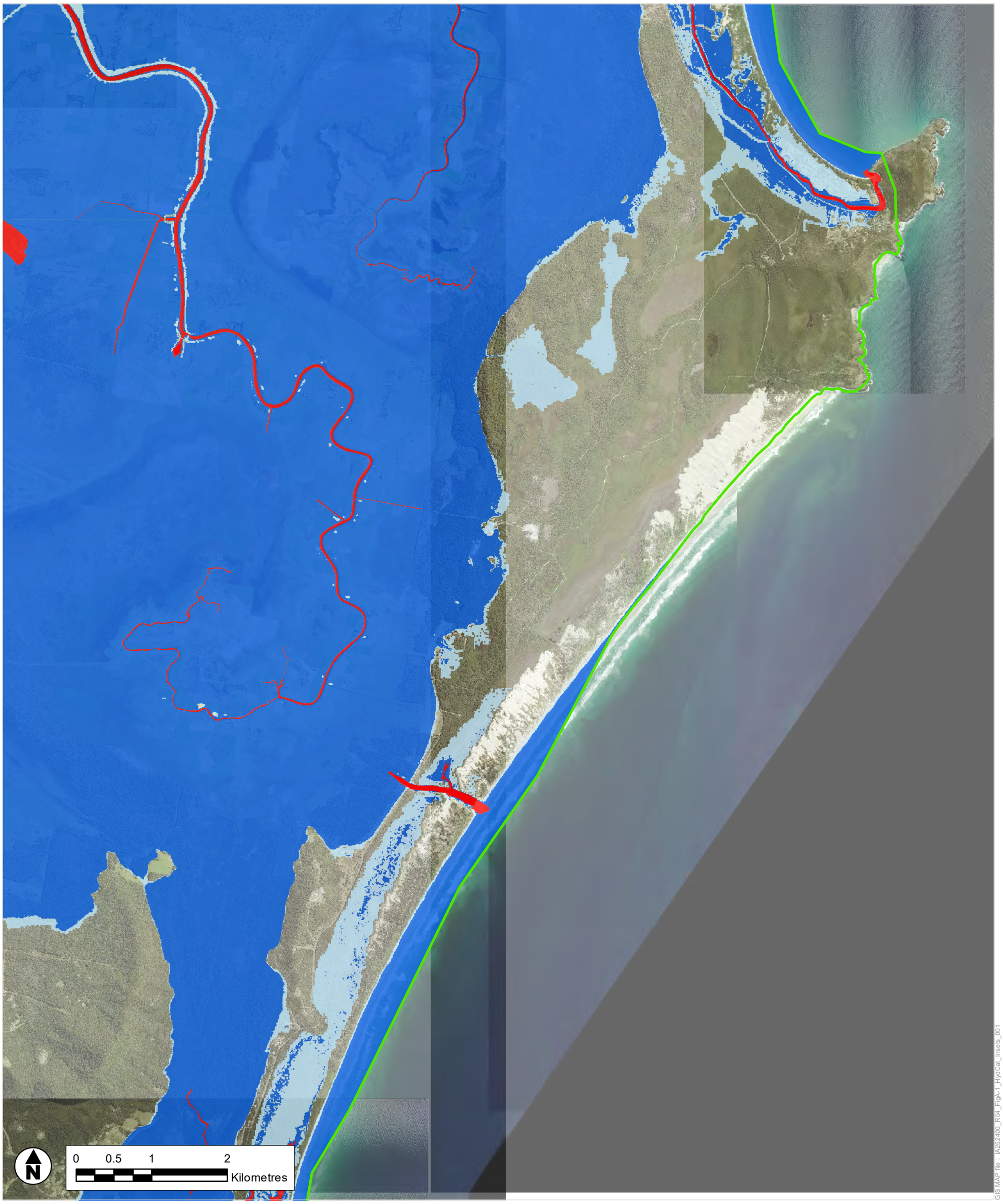
INSET # 5 of 8

GDA 1994 MGA Zone 56

TITLE 1% AEP
Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-1(E)	1	1
CHECK AH	DATE 14/02/2023			



GIS MAP file : IA252400_R04_FigA-1_HydCat_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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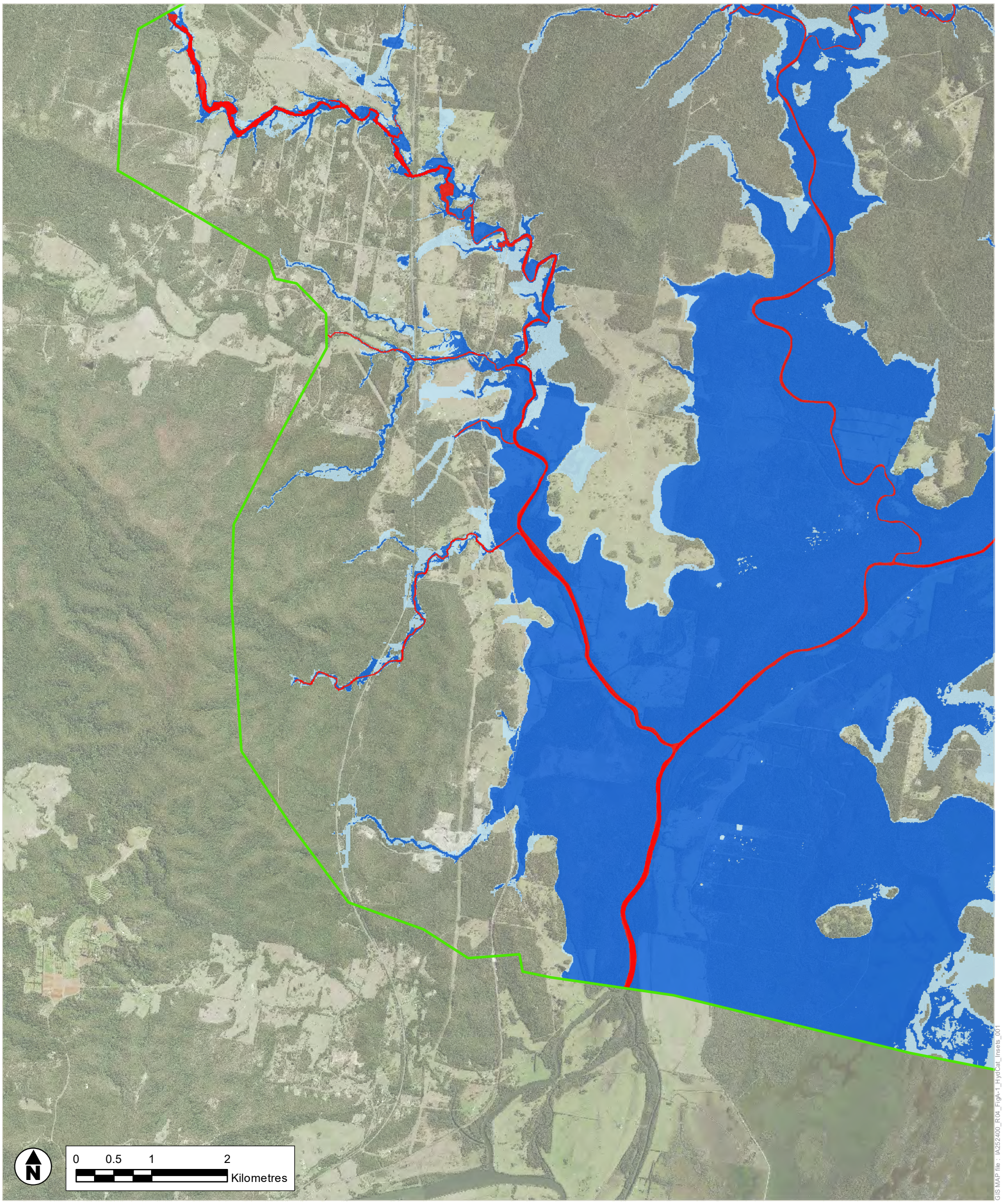
INSET #	6 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-1(F) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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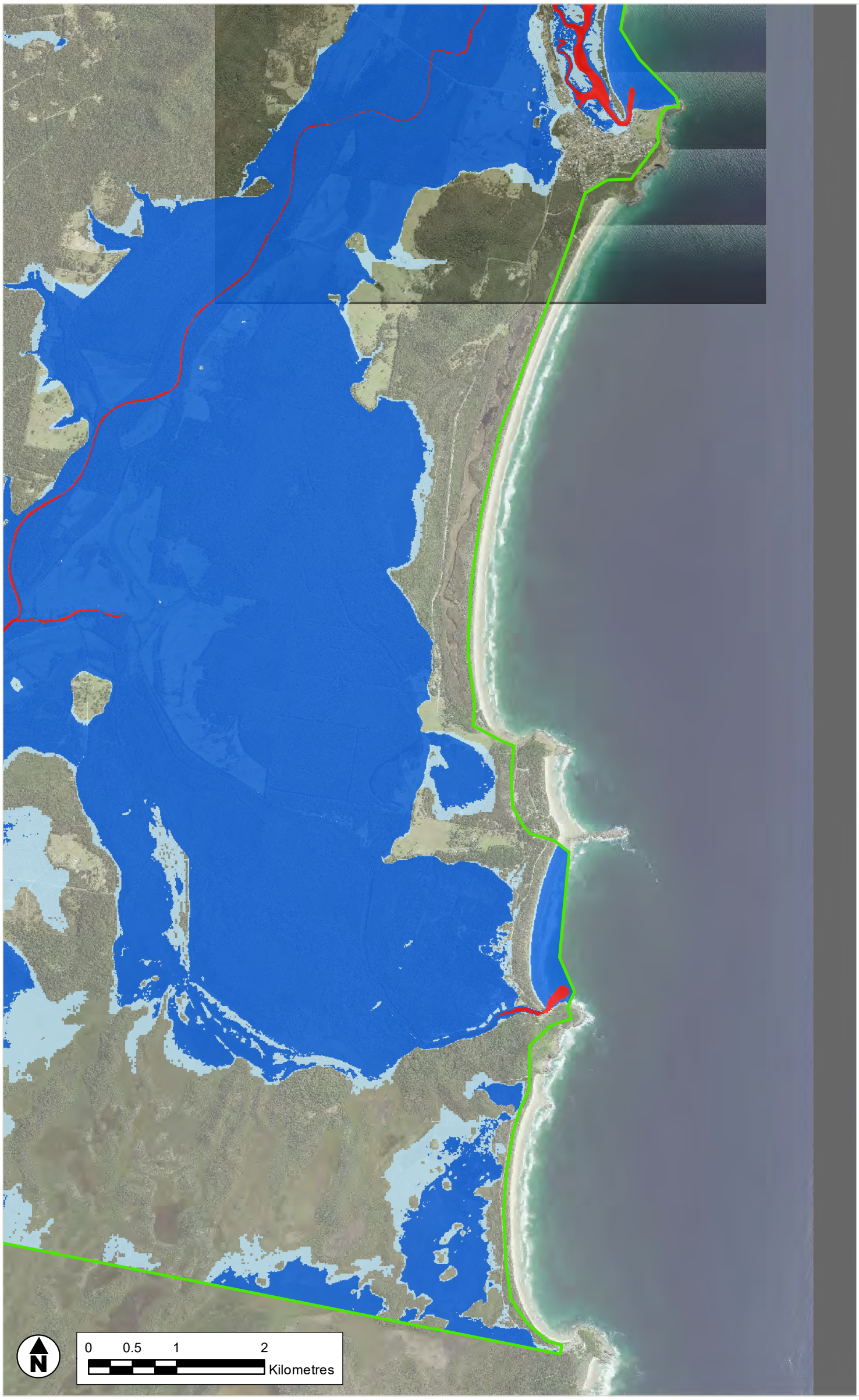
INSET #	7 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-1(G) REV VER 1 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-1_HydCat_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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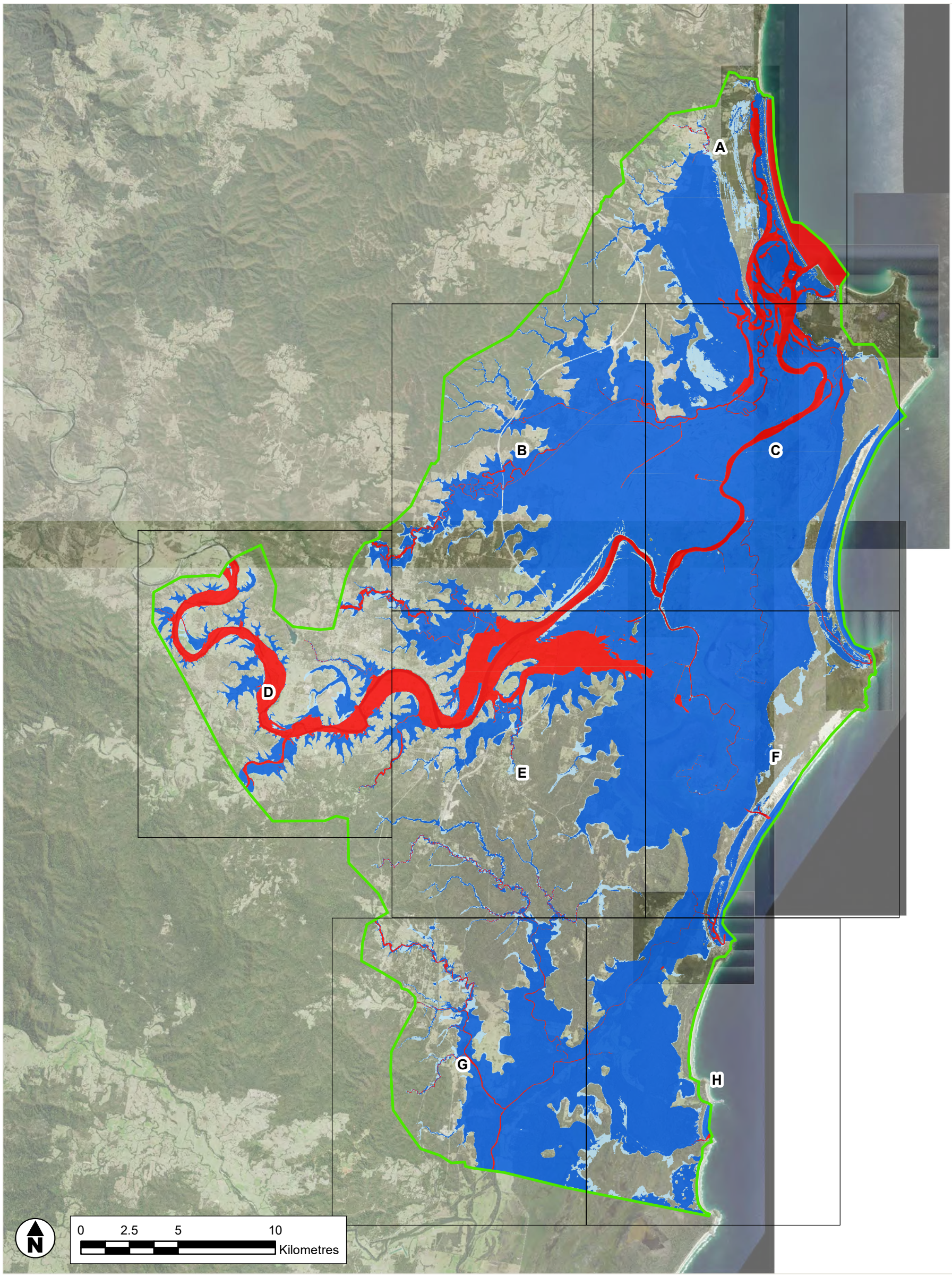
INSET #	8 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-1(H) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-2_HydCat_CC2050_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping
- Inset Map Frame - Refer following map sheets

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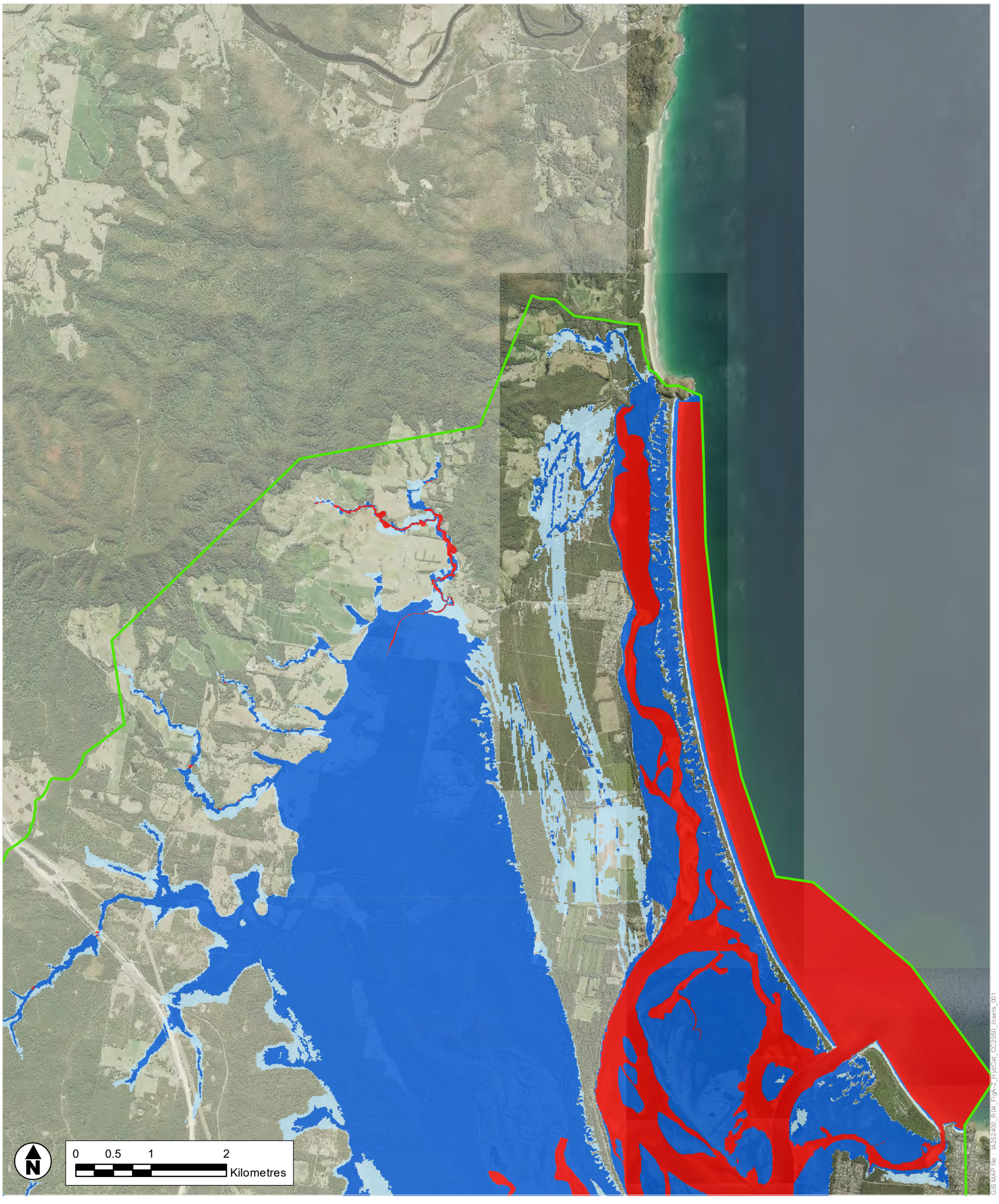
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP
Climate Change Year 2050 Scenario
Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-2	1	1
CHECK	DATE			
AH	14/02/2023			



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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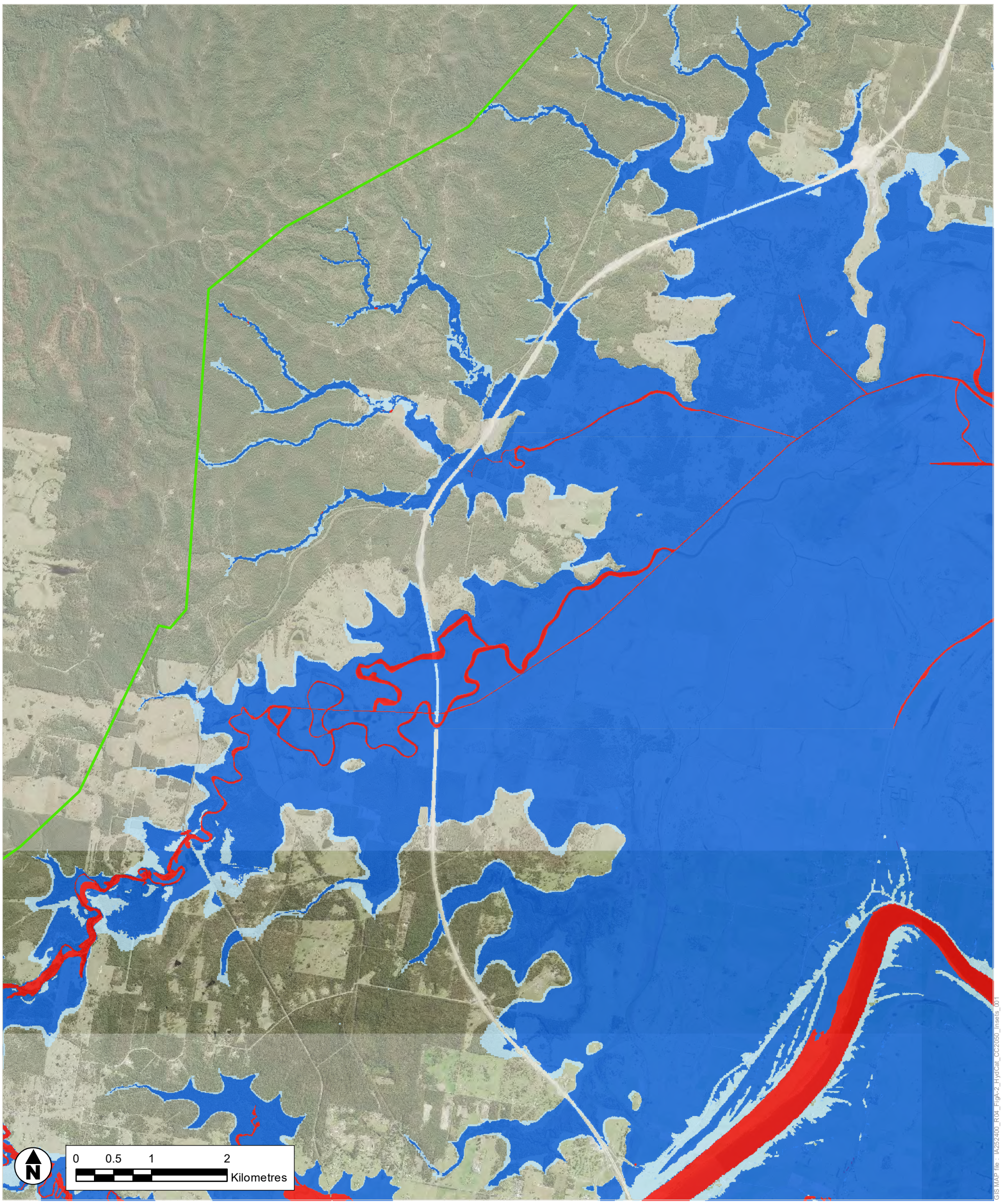
INSET #	1 of 8
	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories
PROJECT	Lower Macleay River Floodplain Risk Management Study
DRAWN	LC
PROJECT #	IA252400
MAP #	FIGURE B-2(A)
REV	1
VER	1
CHECK	AH
DATE	14/02/2023

GIS MAP file : IA252400_R04_Fig4-2_HydCat_CC2050_Insets_001



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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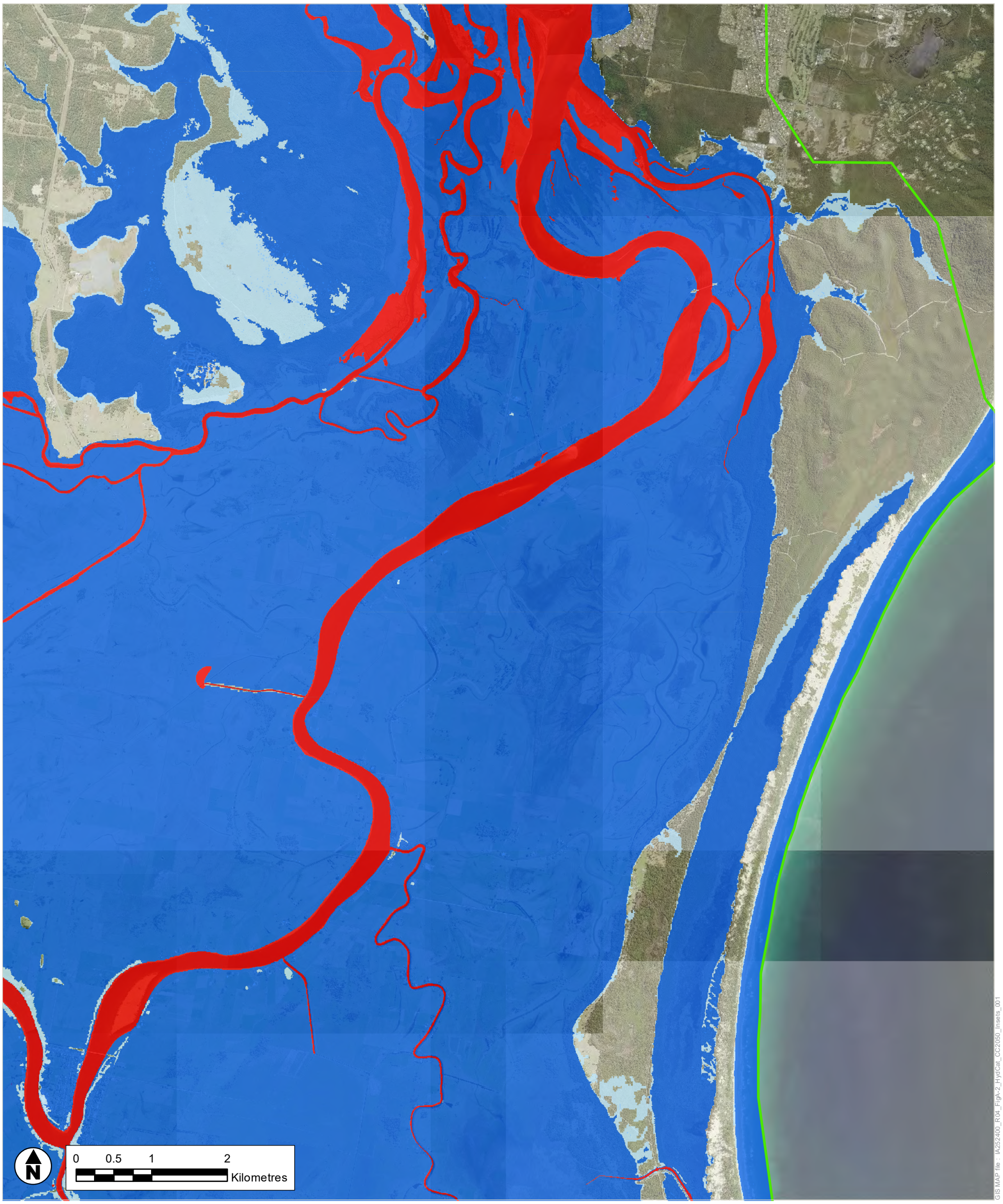
A3

INSET #	2 of 8	GDA 1994 MGA Zone 56	
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories		
PROJECT	Lower Macleay River Floodplain Risk Management Study		
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(B)	REV 1 VER 1
CHECK AH	DATE 14/02/2023		



GIS MAP file : IA252400_R04_FigA-2_HydCat_CC2050_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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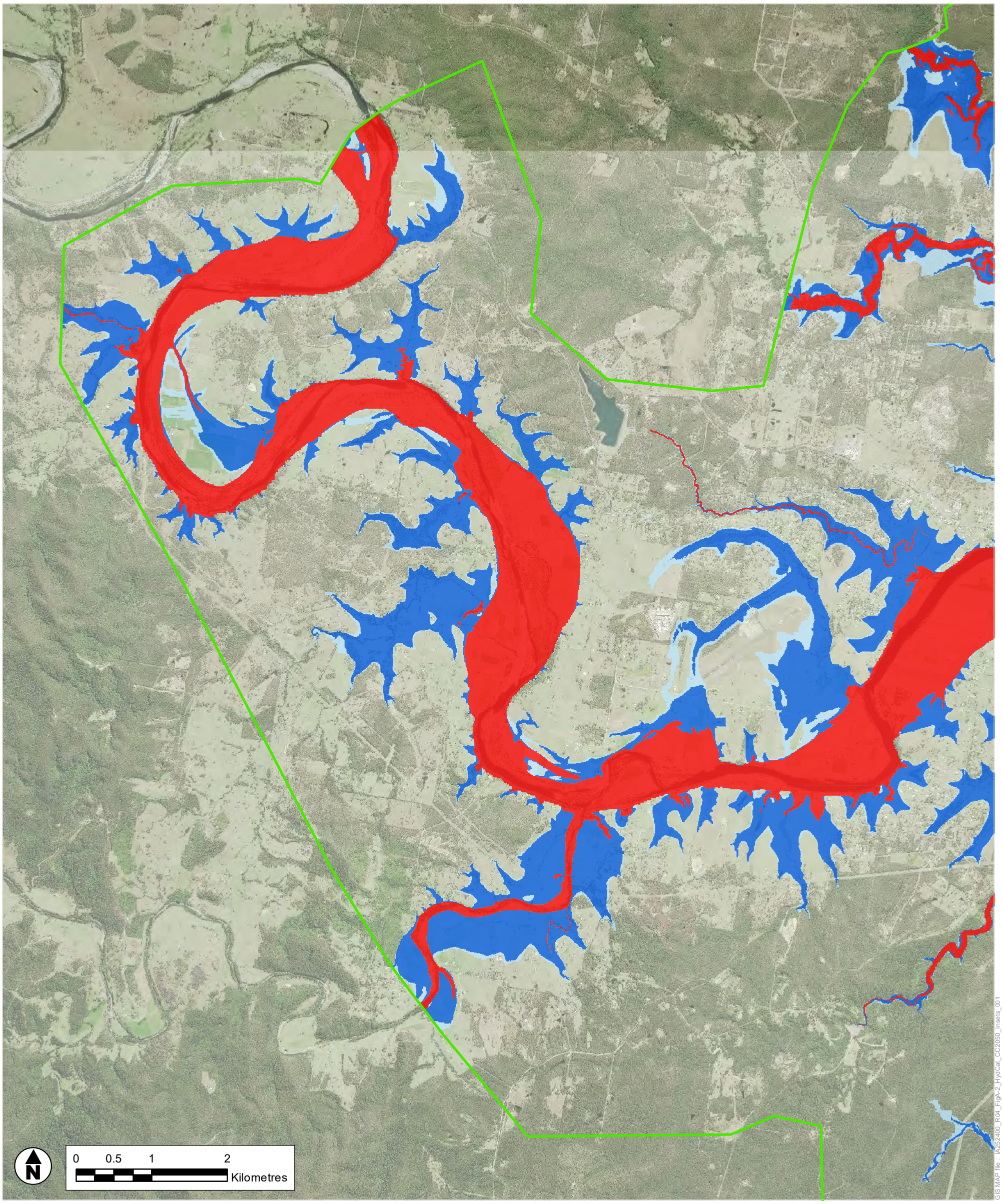
A3

INSET #	3 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(C) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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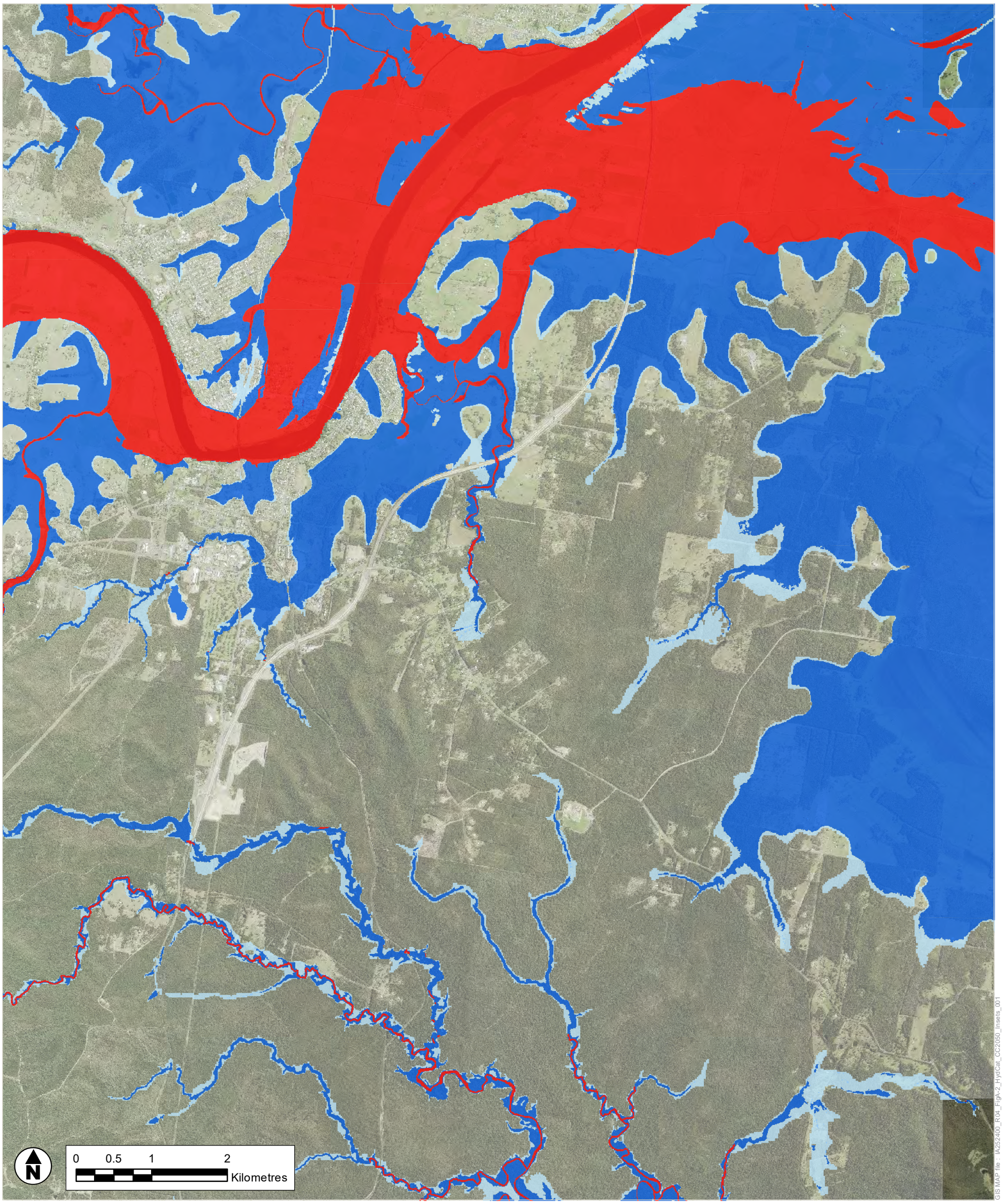
A3

INSET #	4 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(D) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_Fig4-2_HydCat_CC2050_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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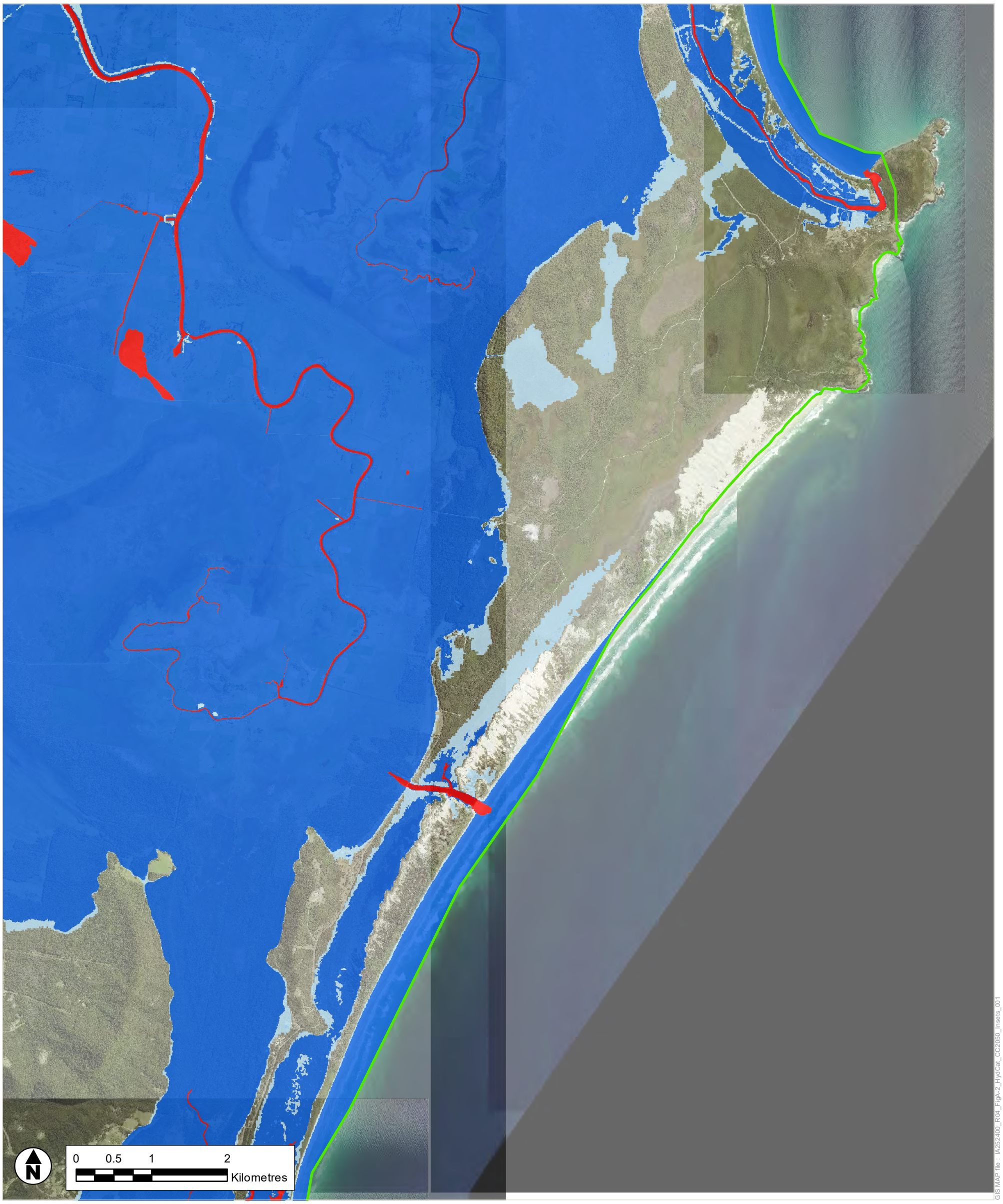
INSET #	5 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-2(E)	1	1
CHECK	DATE			
AH	14/02/2023			



GIS MAP file : IA252400_R04_FigA-2_HydCat_CC2050_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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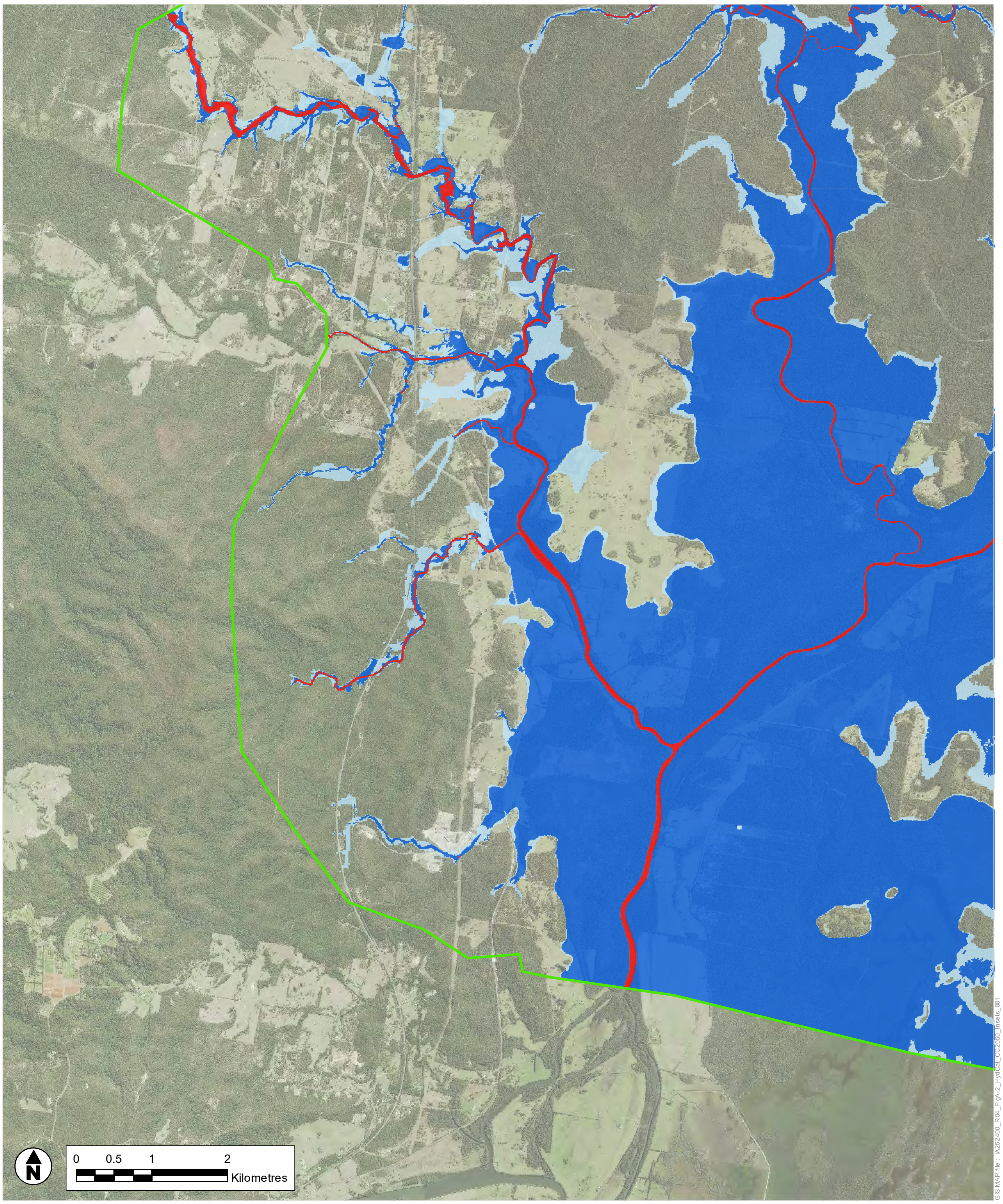
A3

INSET #	6 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(F) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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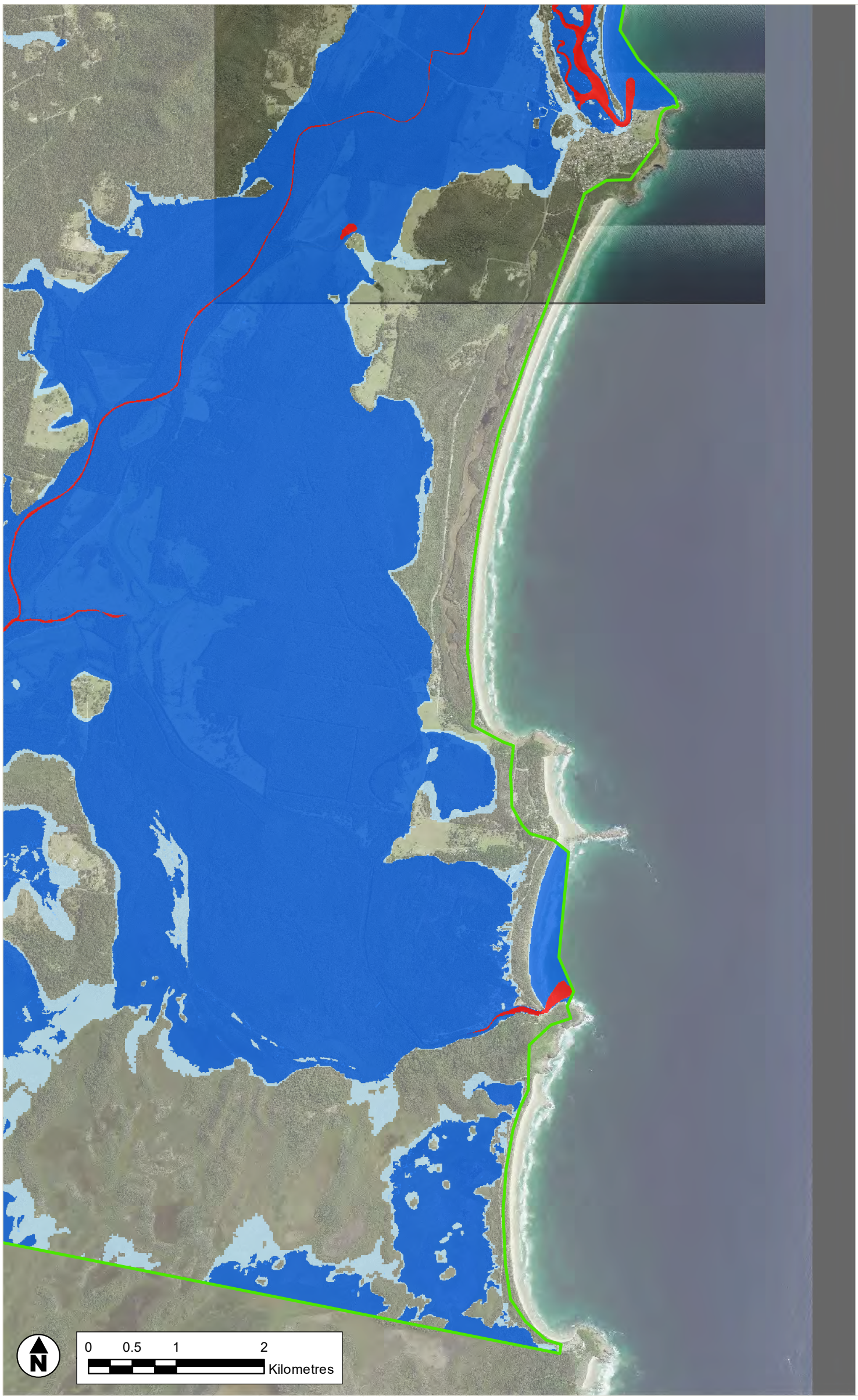
A3

INSET #	7 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(G) REV VER 1 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-2_HydCat_CC2050_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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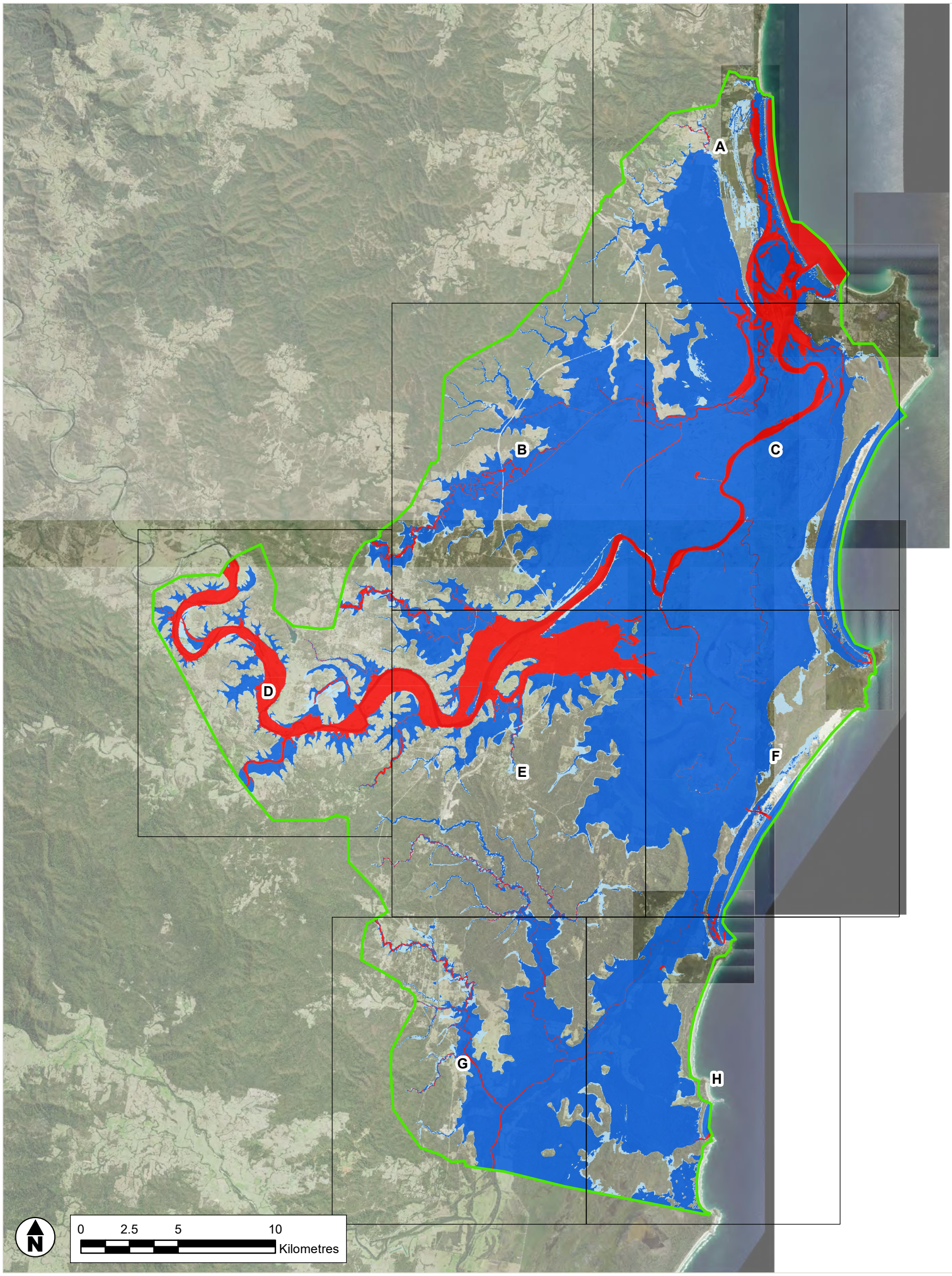
A3

INSET #	8 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2050 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-2(H) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-3_HydCat_CC2100_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping
- Inset Map Frame - Refer following map sheets

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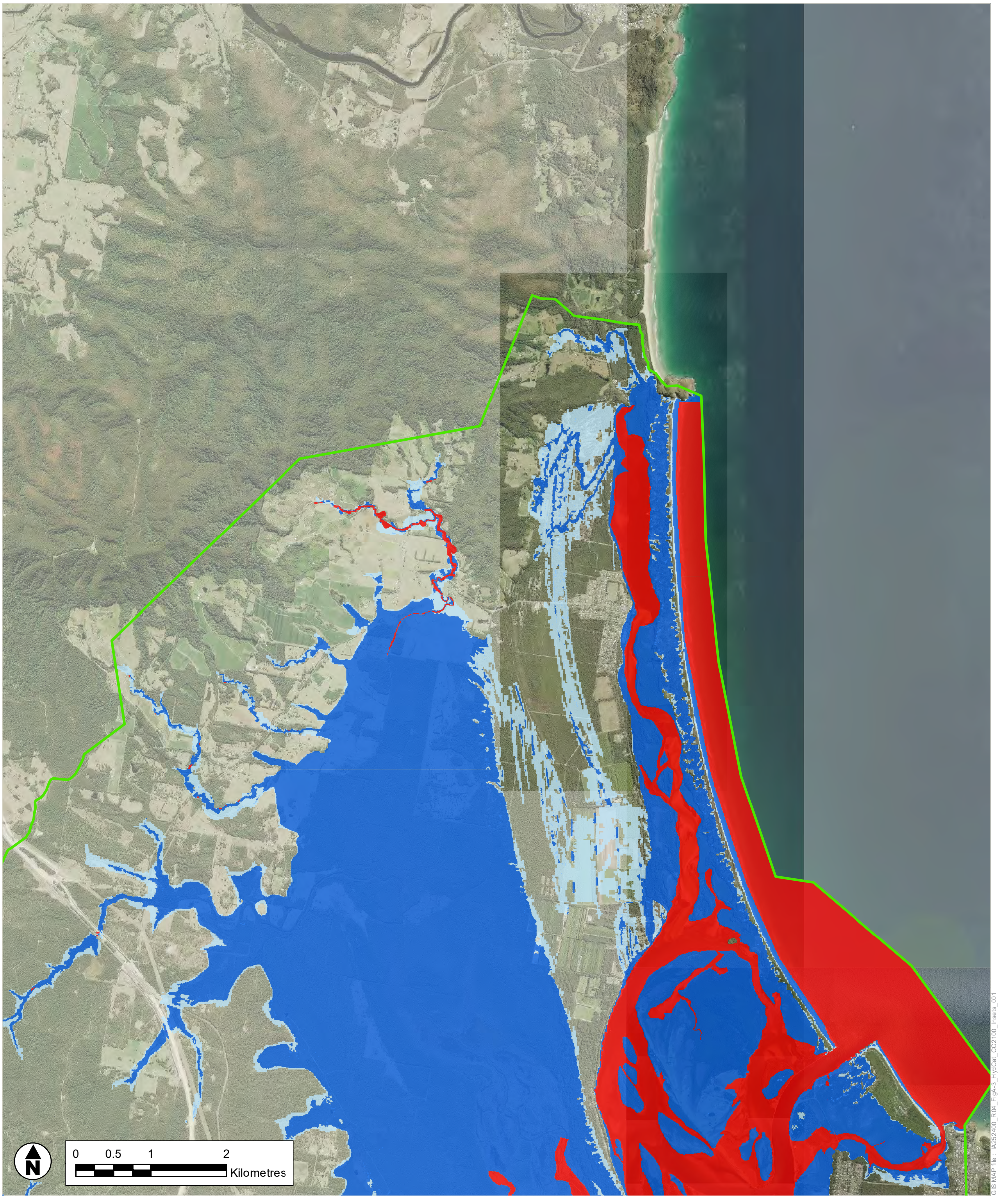
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP
Climate Change Year 2100 Scenario
Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-3	1	1
CHECK AH	DATE 14/02/2023			



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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A3

INSET # 1 of 8

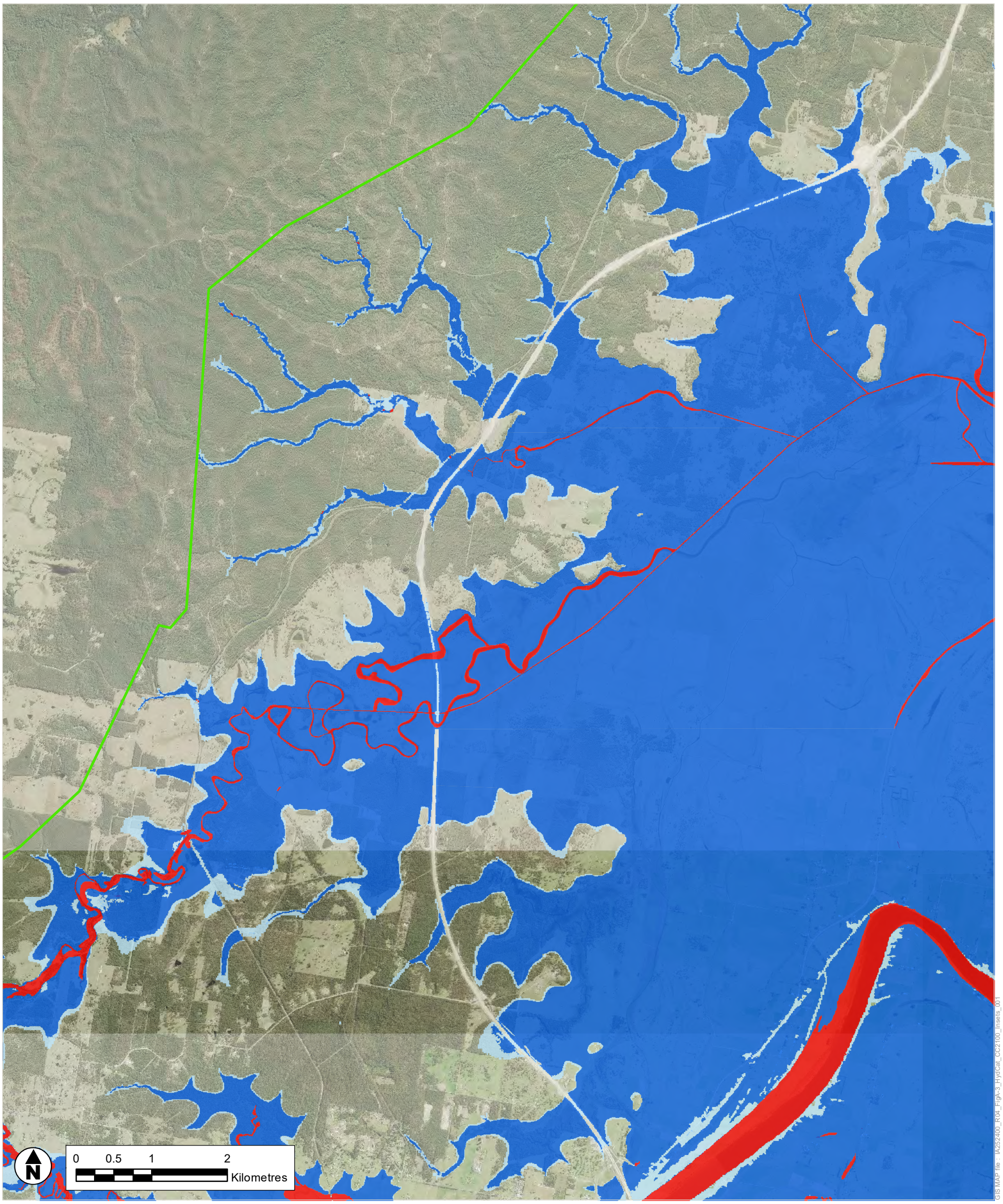
GDA 1994 MGA Zone 56

TITLE 1% AEP
Climate Change Year 2100 Scenario
Hydraulic Categories

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-3(A)	1	1
CHECK AH	DATE 14/02/2023			

GIS MAP file : IA252400_R04_Fig4-3_HydCat_CC2100_Insets_001



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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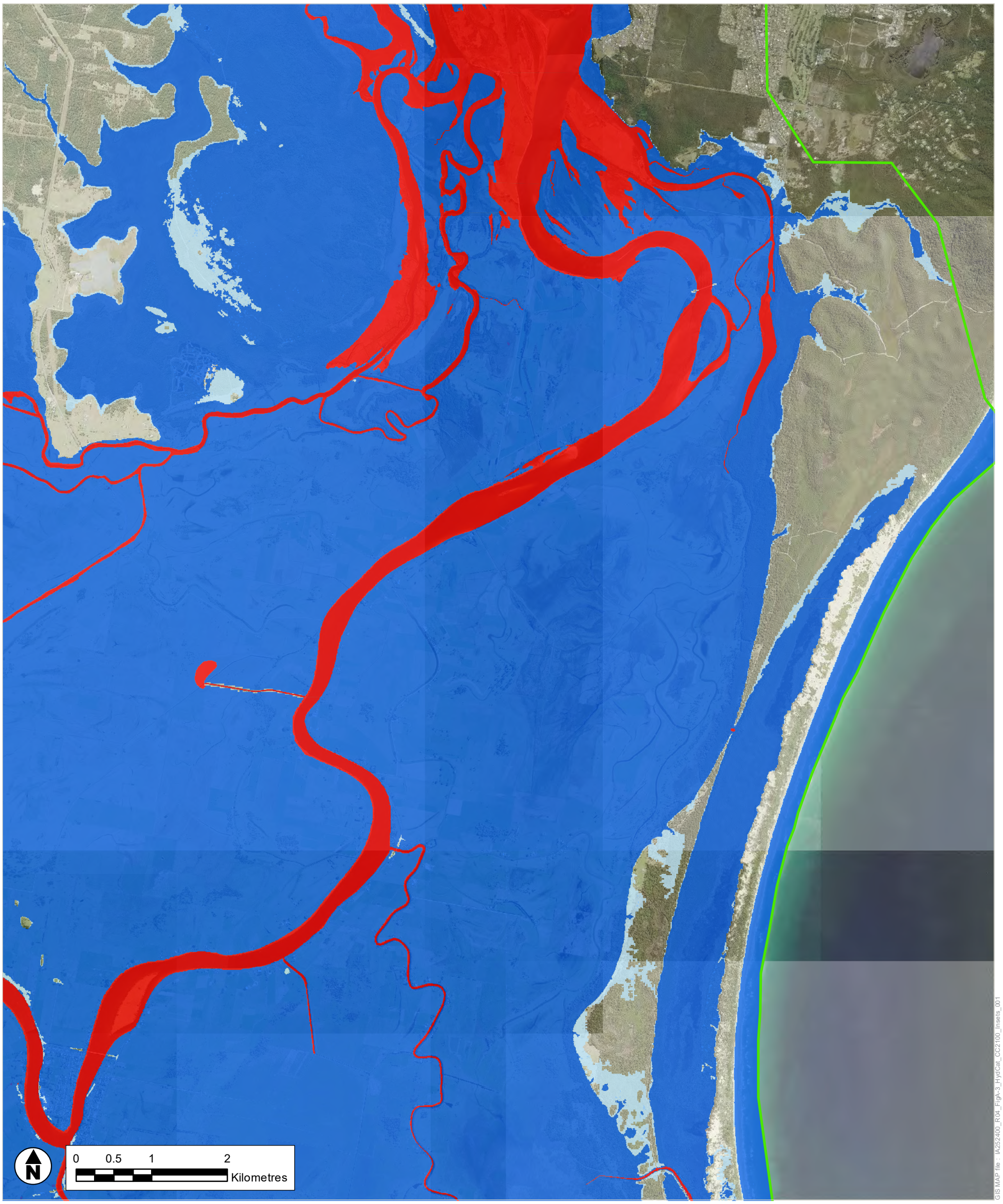
INSET #	2 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-3(B)	1 1
CHECK AH	DATE 14/02/2023		

GIS MAP file : IA252400_R04_FIgA-3_HydCat_CC2100_Insets_001



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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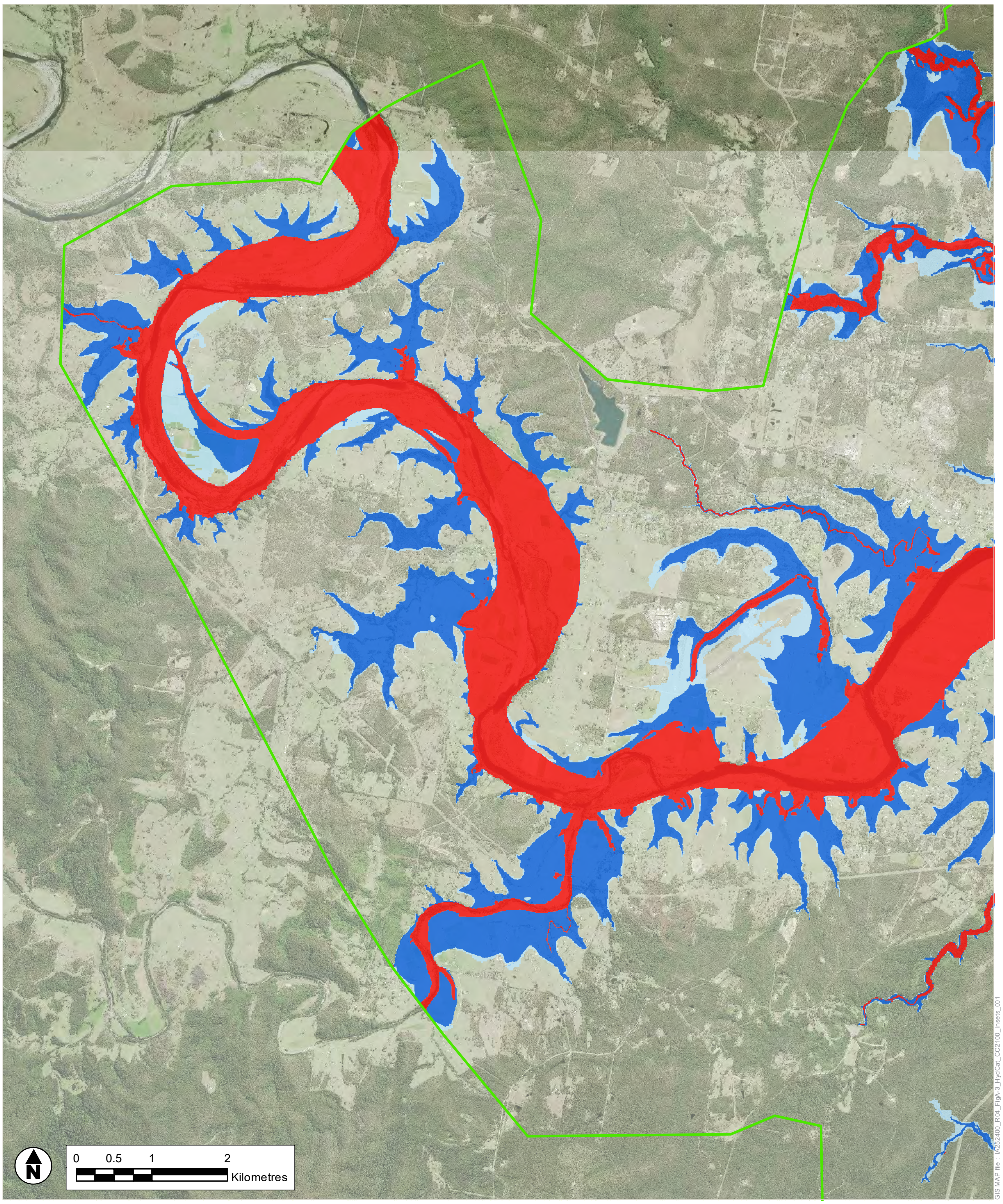
A3

INSET #	3 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-3(C) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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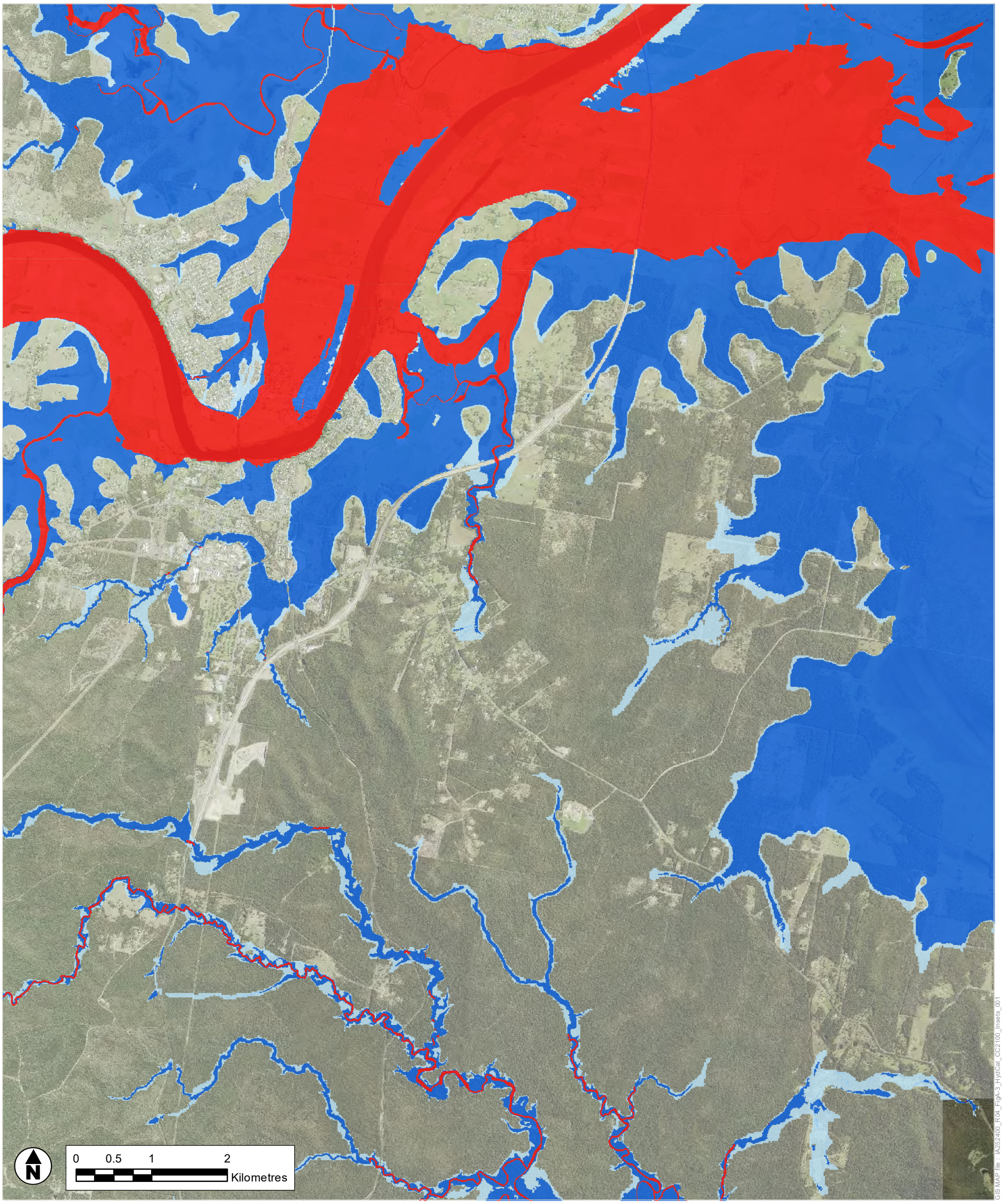
A3

INSET #	4 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-3(D) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_Fig4-3_HydCat_CC2100_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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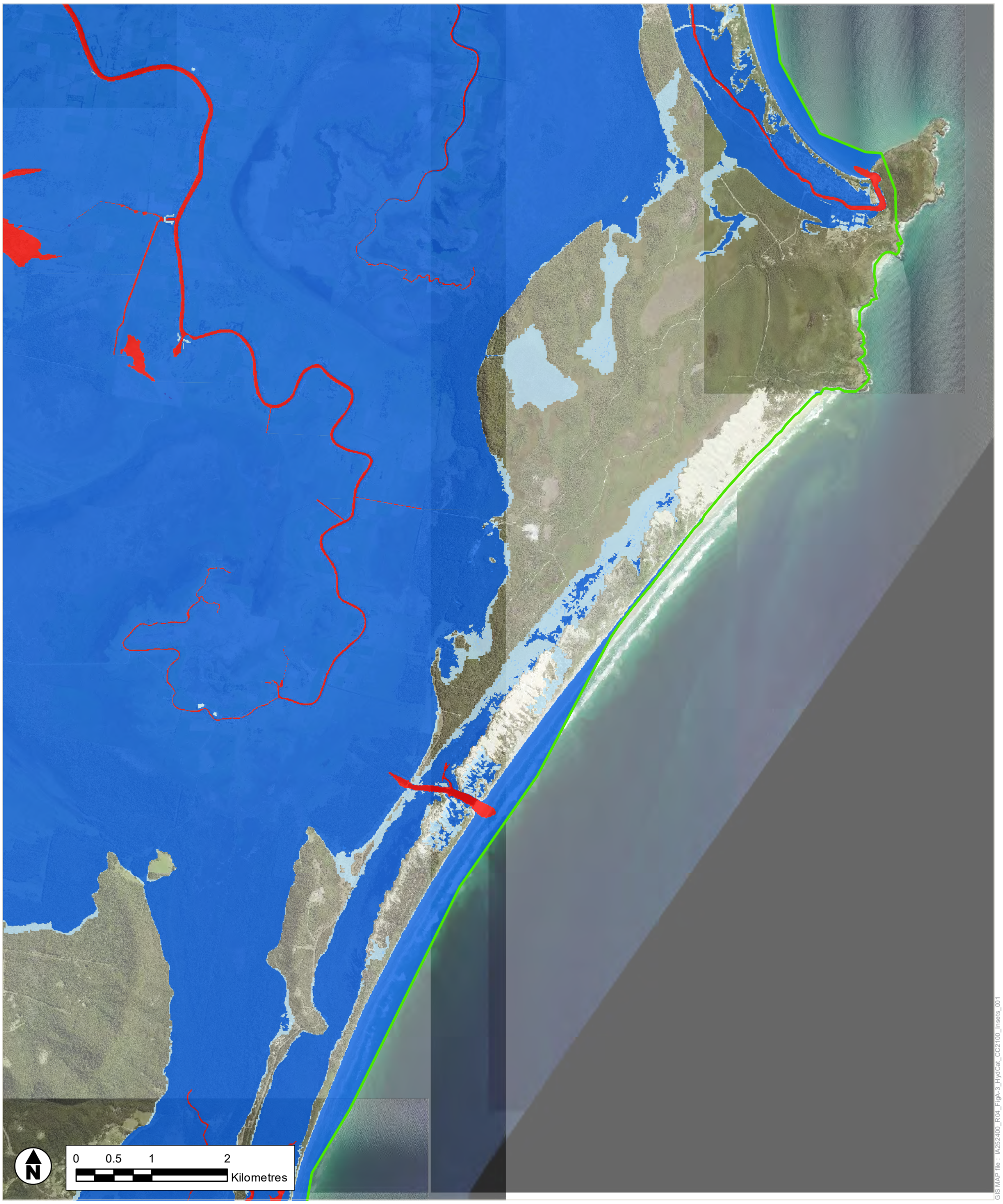
INSET #	5 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-3(E)	1 1
CHECK AH	DATE 14/02/2023		



GIS MAP file : IA252400_R04_FigA-3_HydCat_CC2100_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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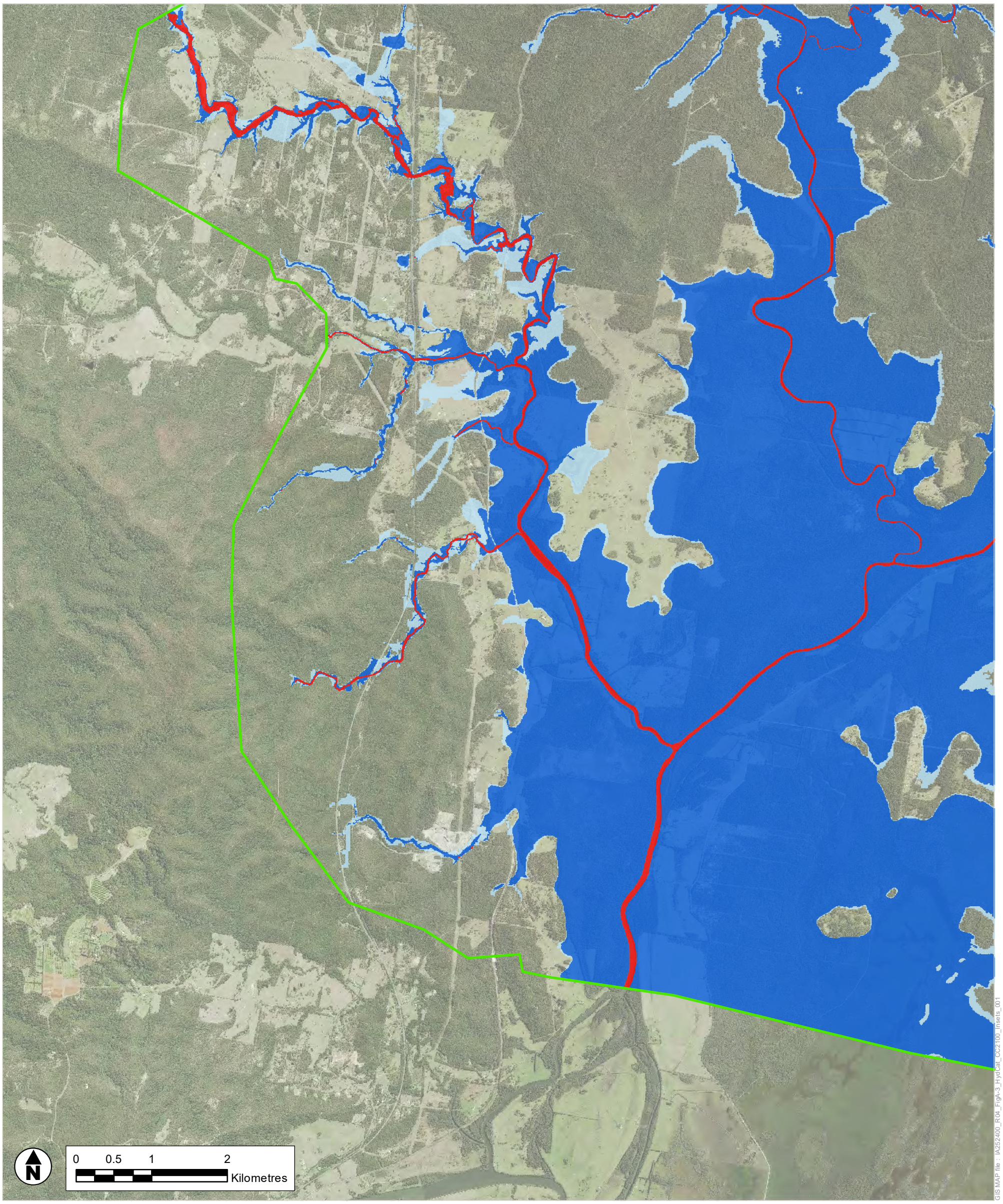
A3

INSET #	6 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-3(F) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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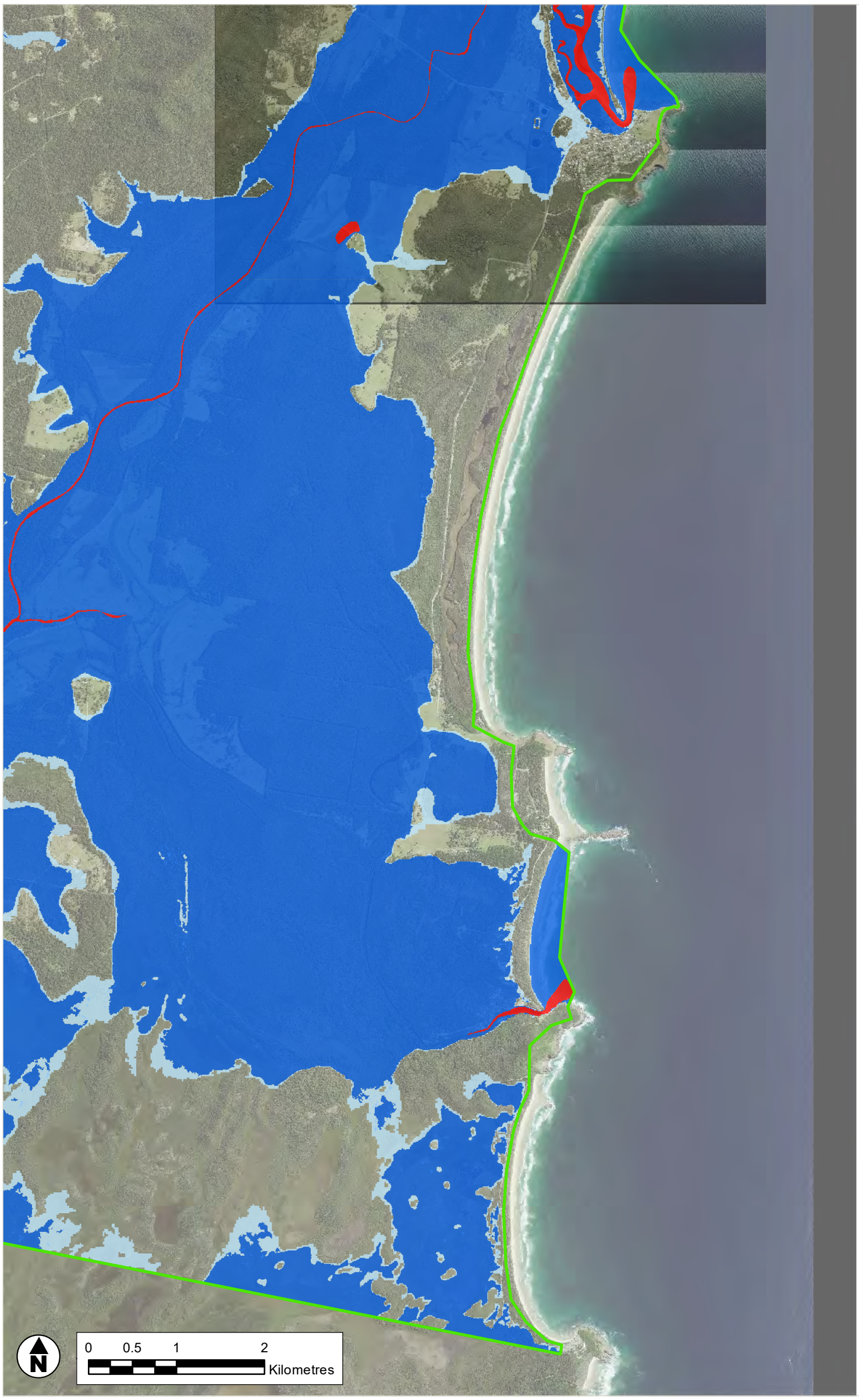
A3

INSET #	7 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-3(G) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-3_HydCat_CC2100_Insets_001

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Limit of Mapping

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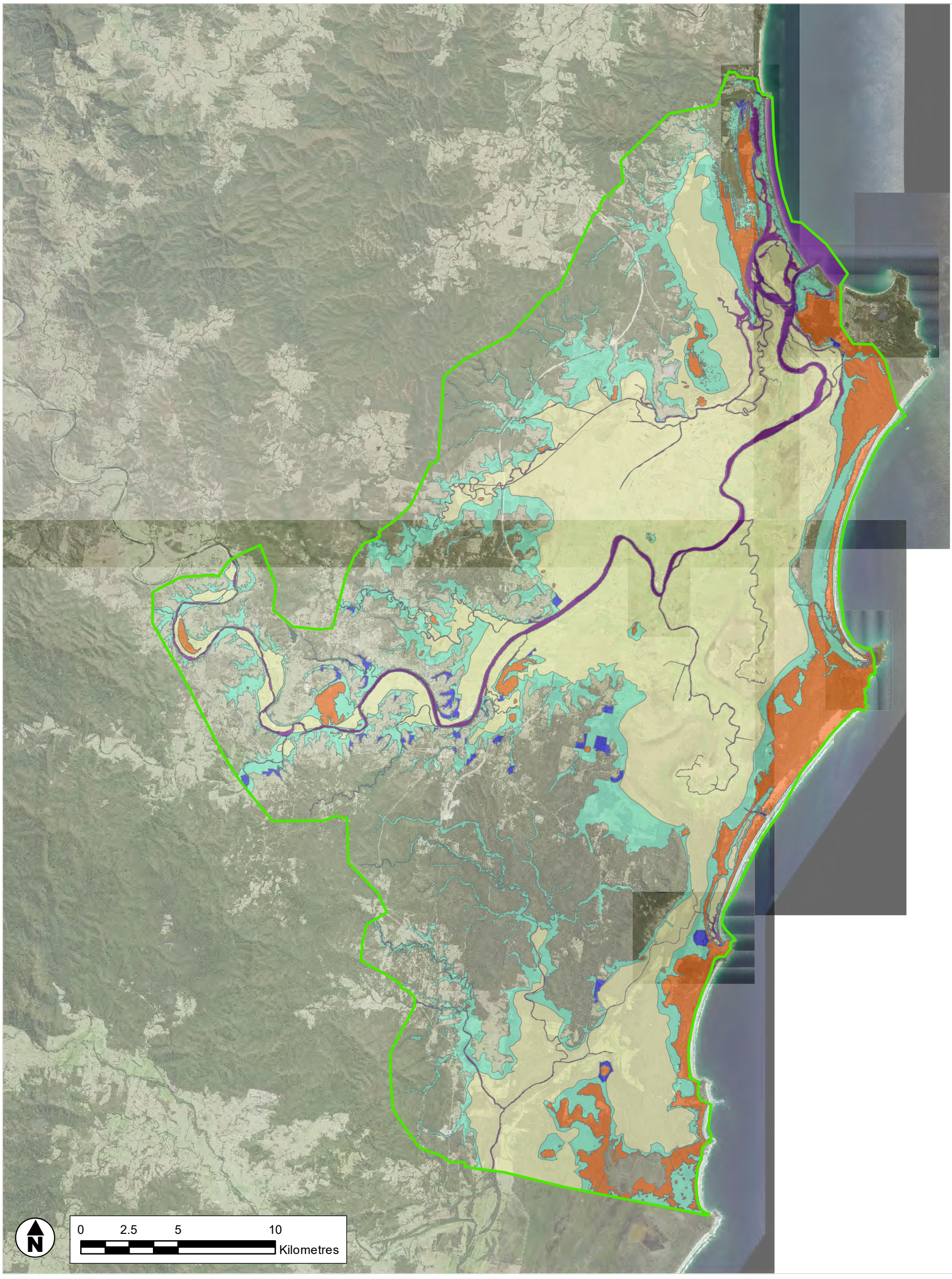
A3

INSET #	8 of 8	GDA 1994 MGA Zone 56
TITLE	1% AEP Climate Change Year 2100 Scenario Hydraulic Categories	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-3(H) REV 1 VER 1
CHECK AH	DATE 14/02/2023	



GIS MAP file : IA252400_R04_FigA-4_1pAEP_EmClass_001

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

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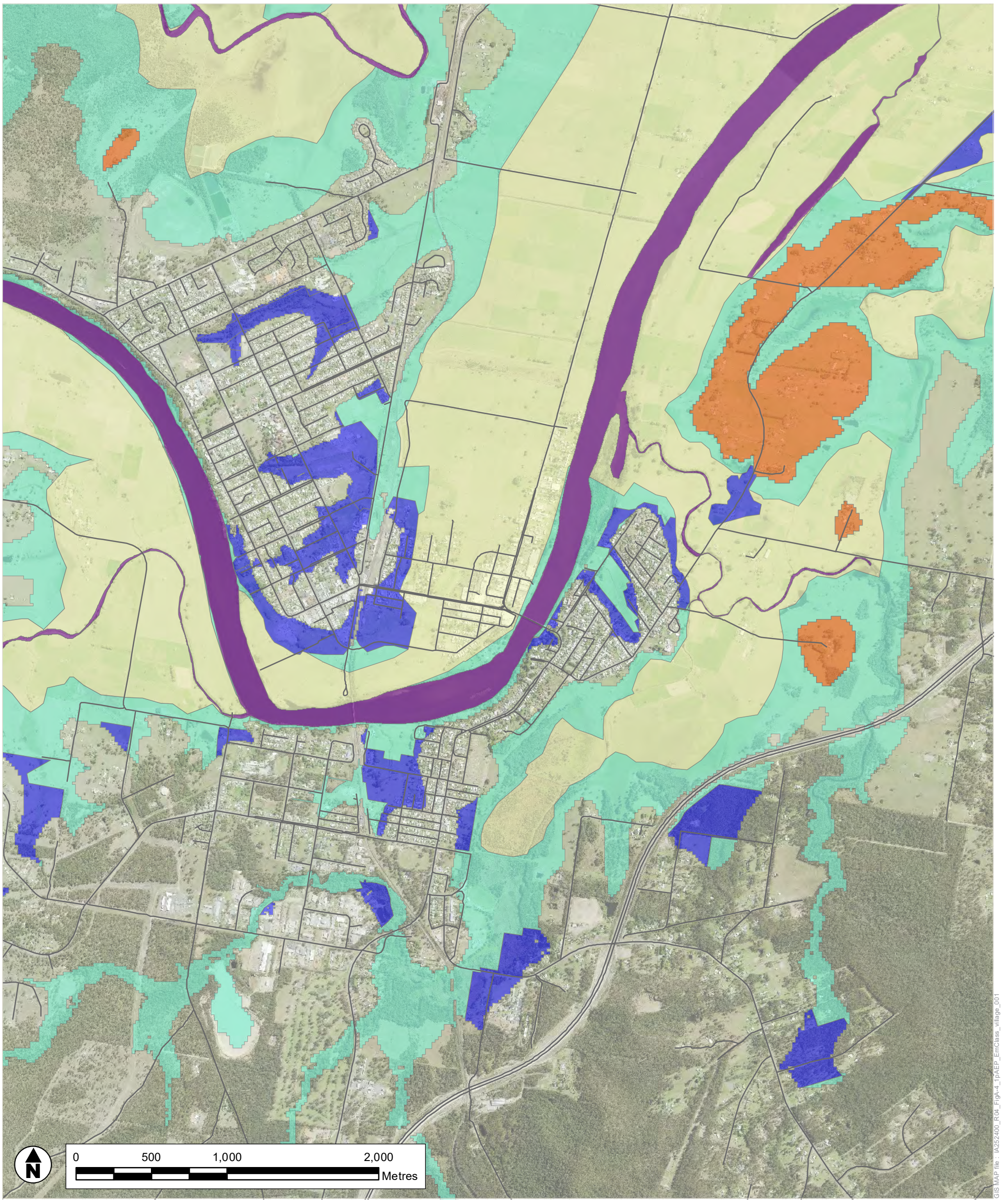
SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-4	1	1
CHECK	DATE			
AH	15/02/2023			



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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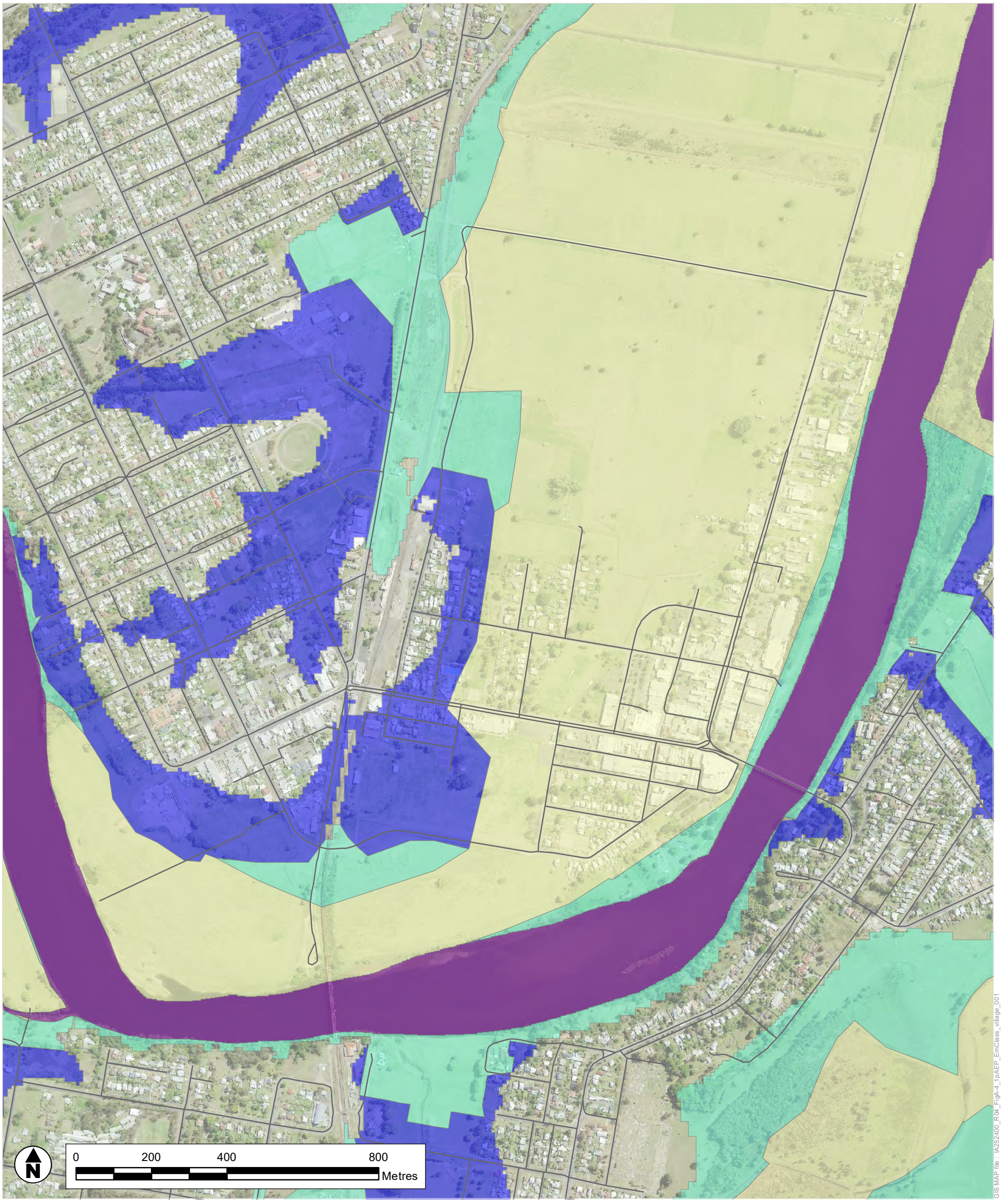
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(A)



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP
Emergency Response Classification
Kempsey CBD

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE B-4(B)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

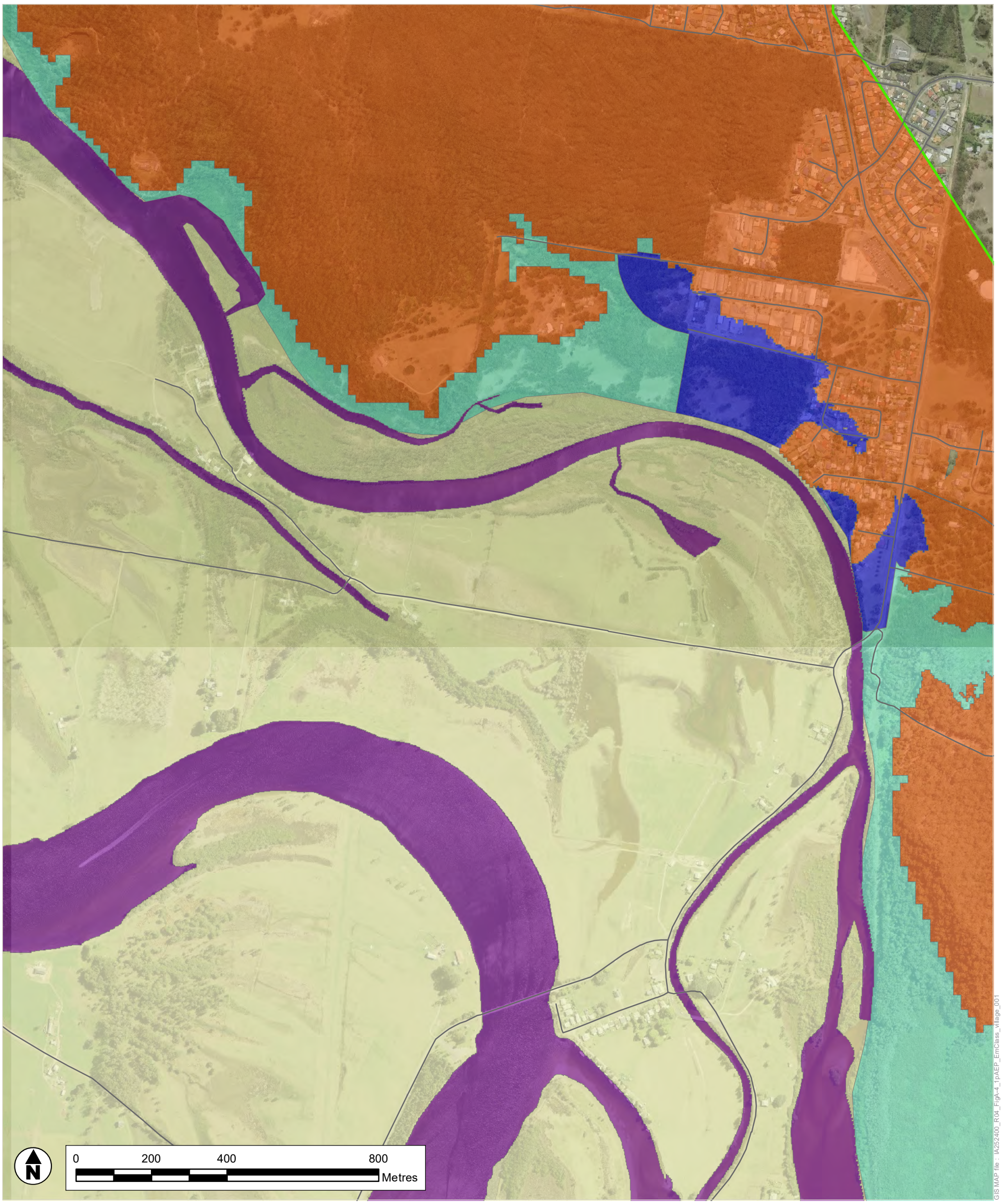
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP
Emergency Response Classification
South West Rocks (N)

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE B-4(C)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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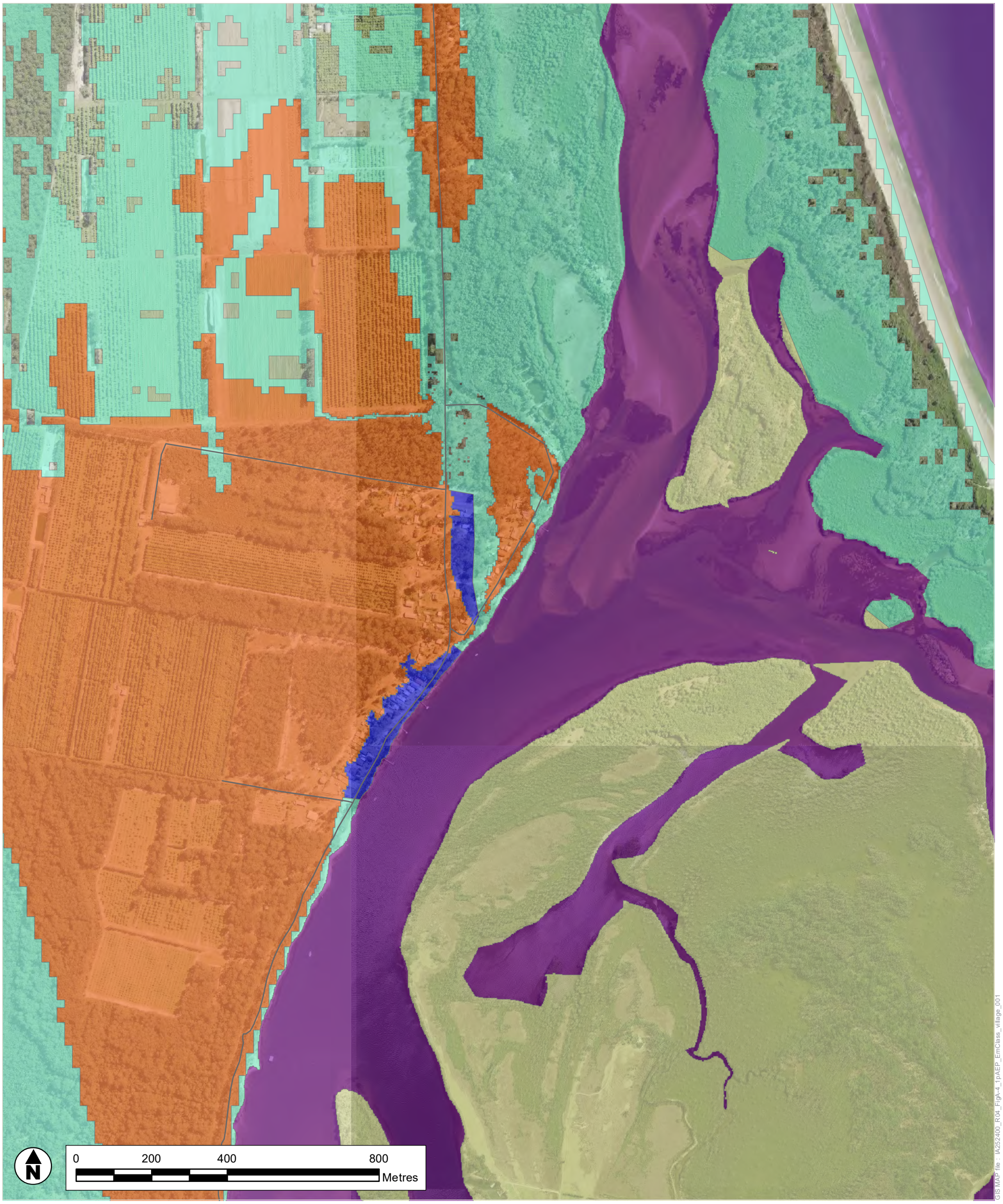
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(D)



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(E)

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(F)

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

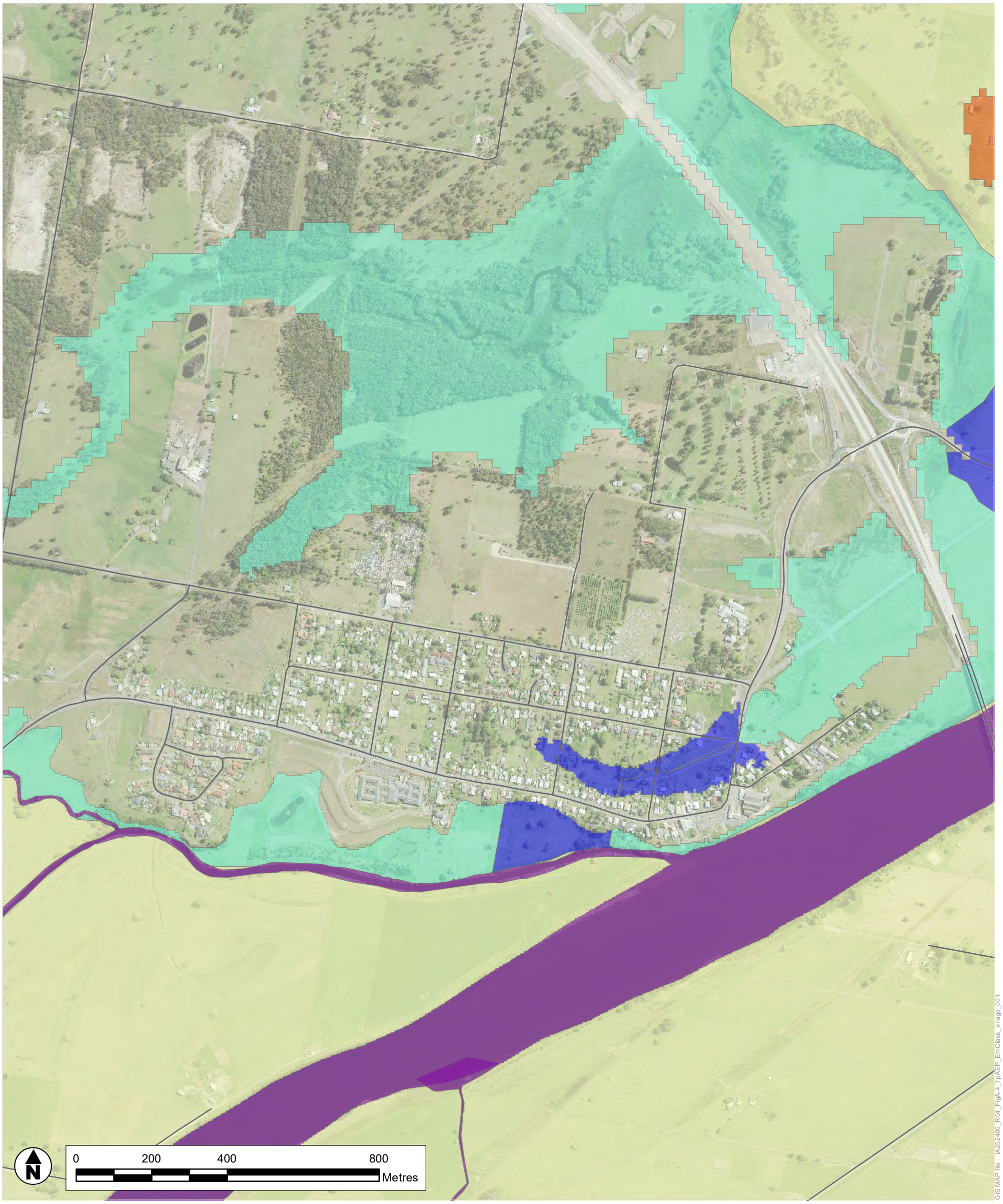
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP
Emergency Response Classification
Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE B-4(G)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1
	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Frederickton
PROJECT	Lower Macleay River Floodplain Risk Management Study
DRAWN	LC
PROJECT #	IA252400
CHECK	AH
DATE	15/02/2023
MAP #	FIGURE B-4(H)

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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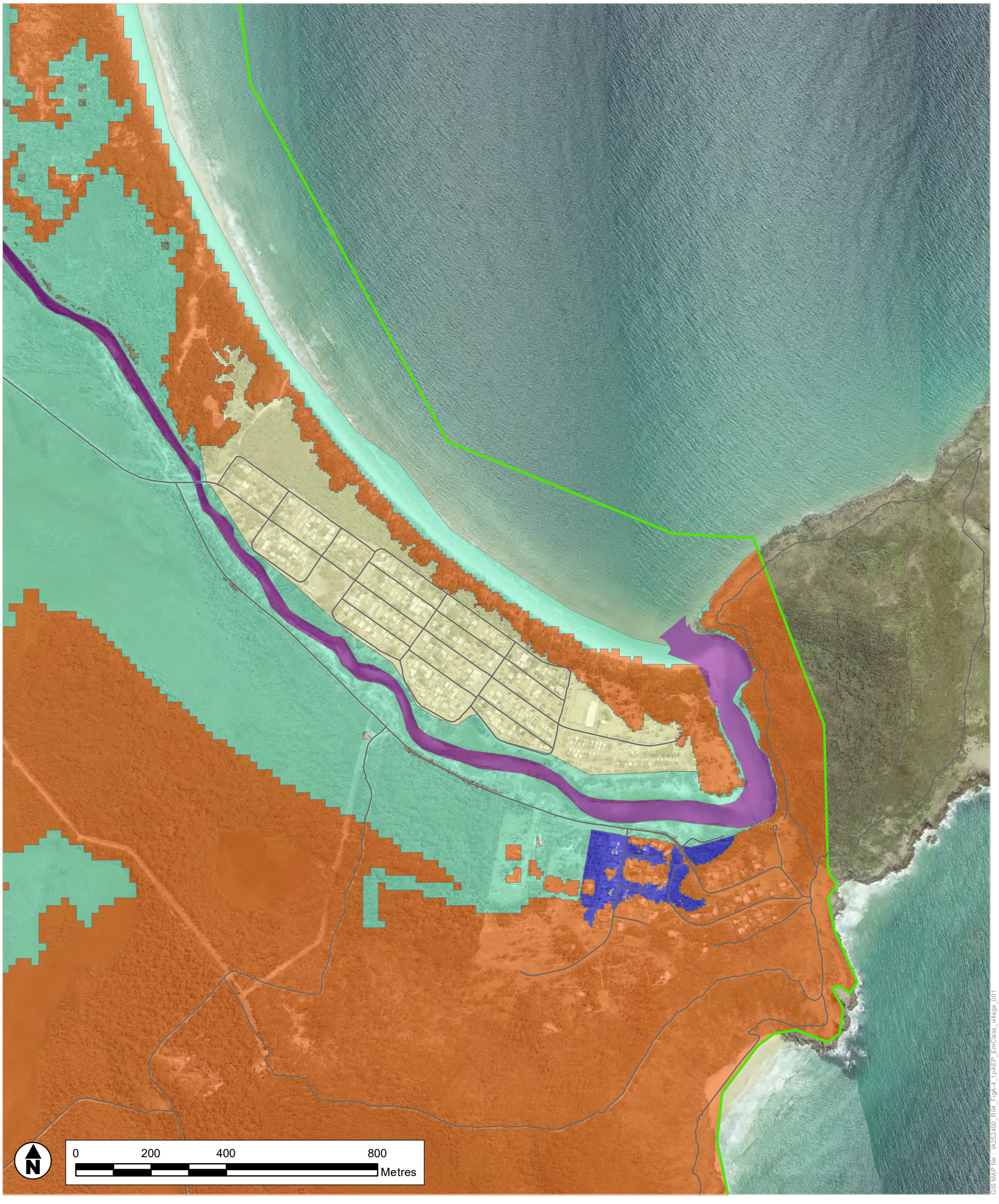
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(I)



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(J)

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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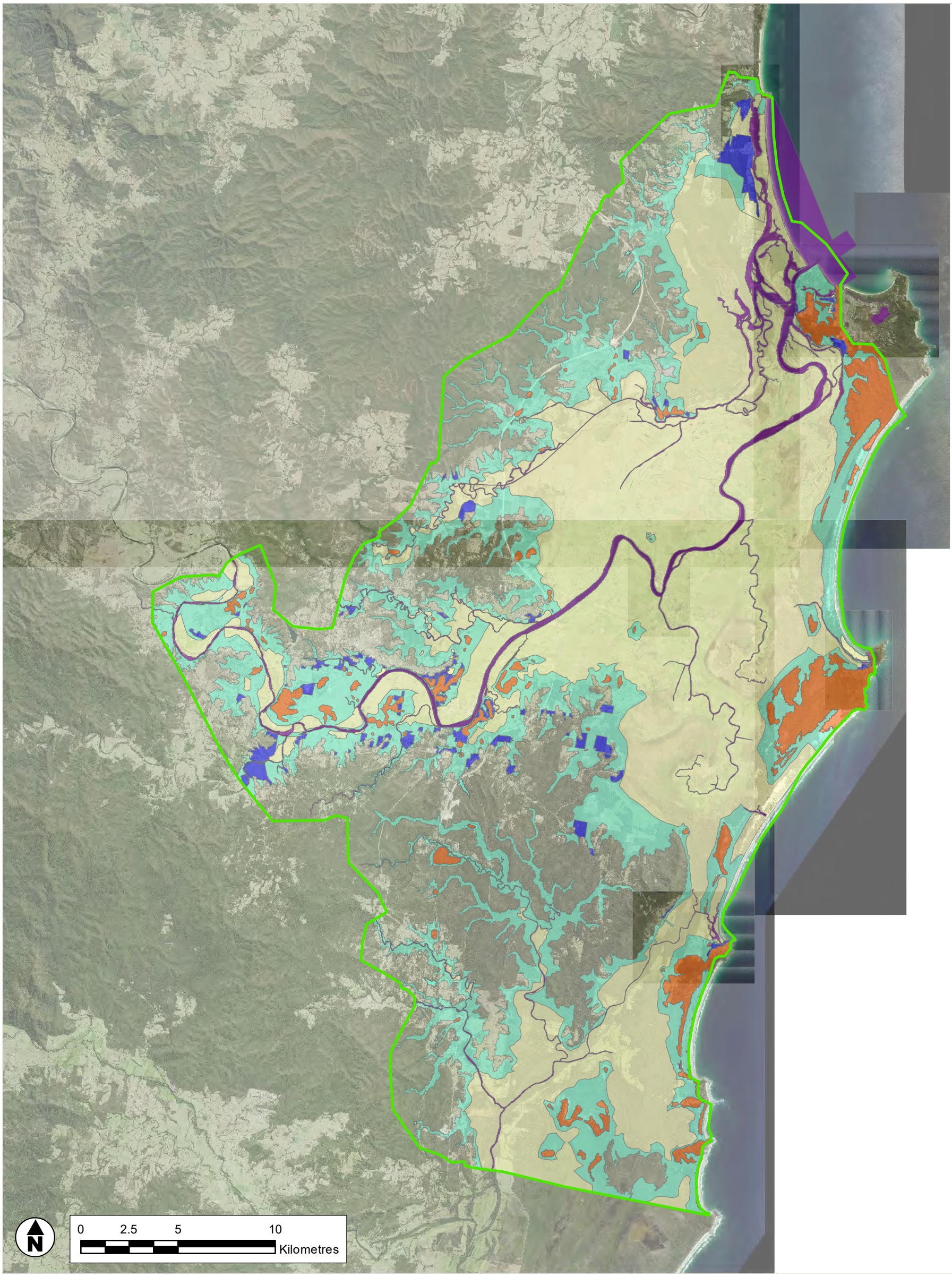
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Emergency Response Classification Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 15/02/2023	FIGURE B-4(K)



GIS MAP file : IA252400_R04_FigA-5_PMF_EmClass_001

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

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A3

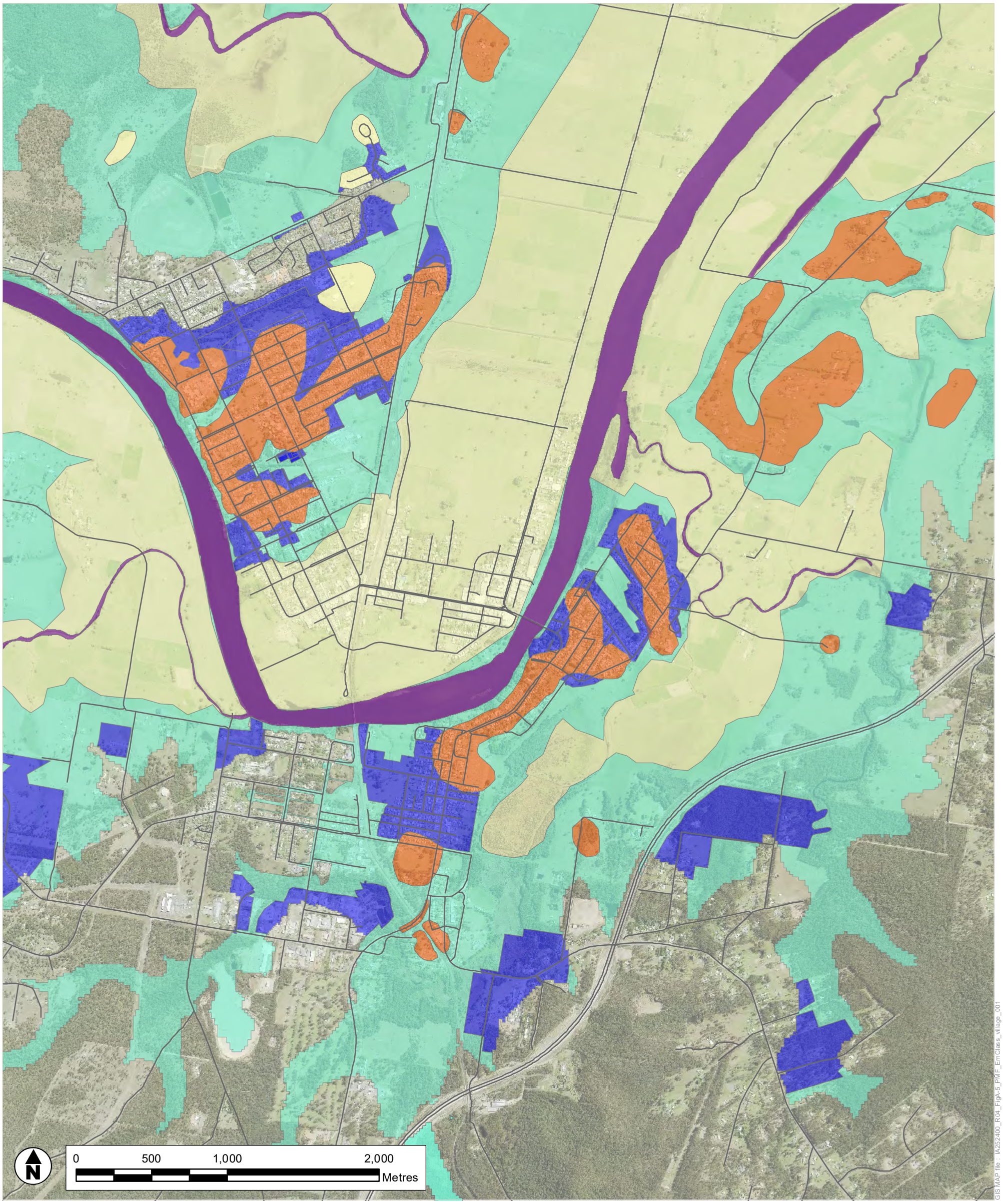
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Emergency Response Classification

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-5	1	1
CHECK AH	DATE 15/02/2023			



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

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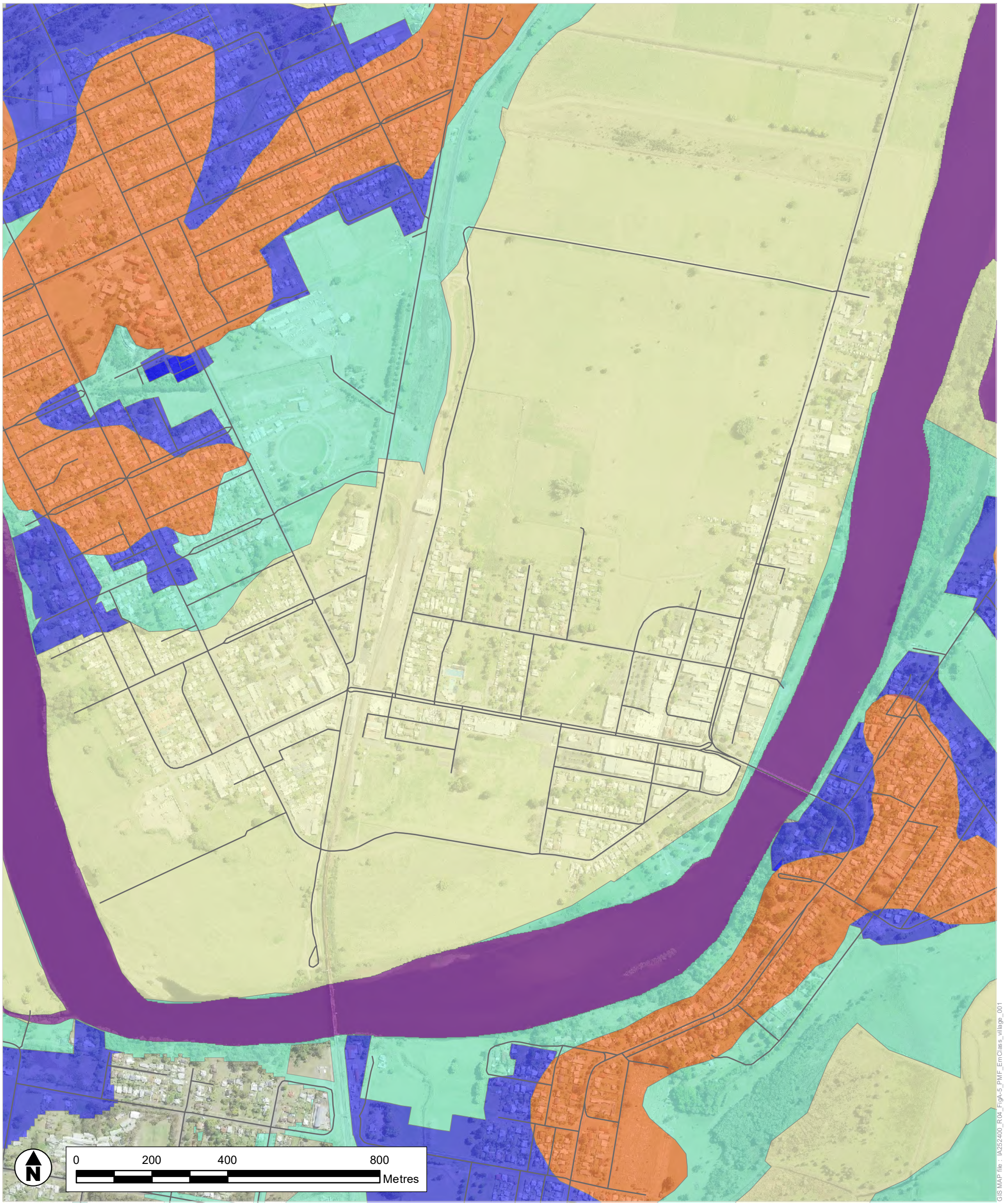
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(A)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Kempsey CBD	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(B)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

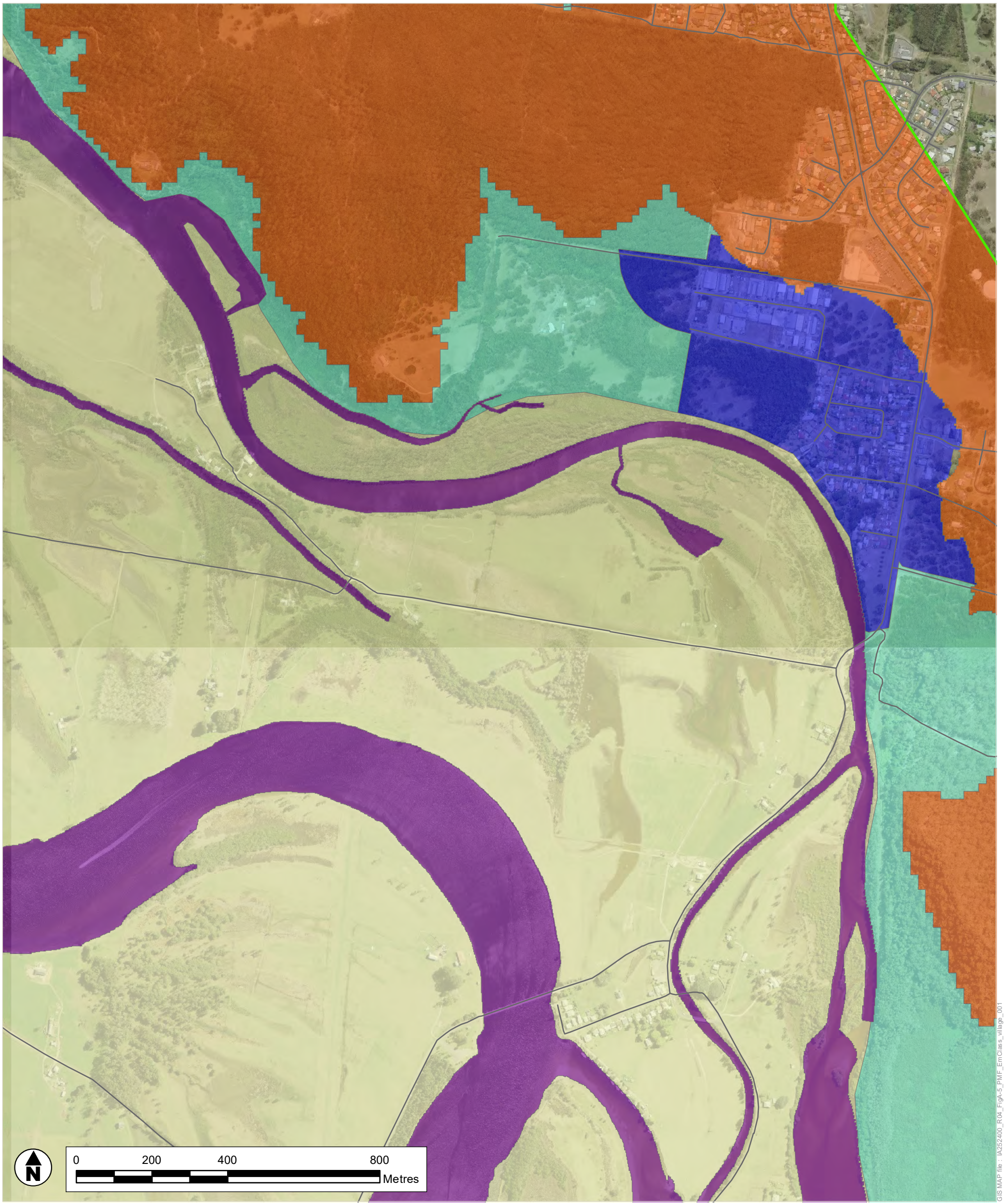
- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification South West Rocks (N)	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(C)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification South West Rocks (S) and Jerseyville	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(D)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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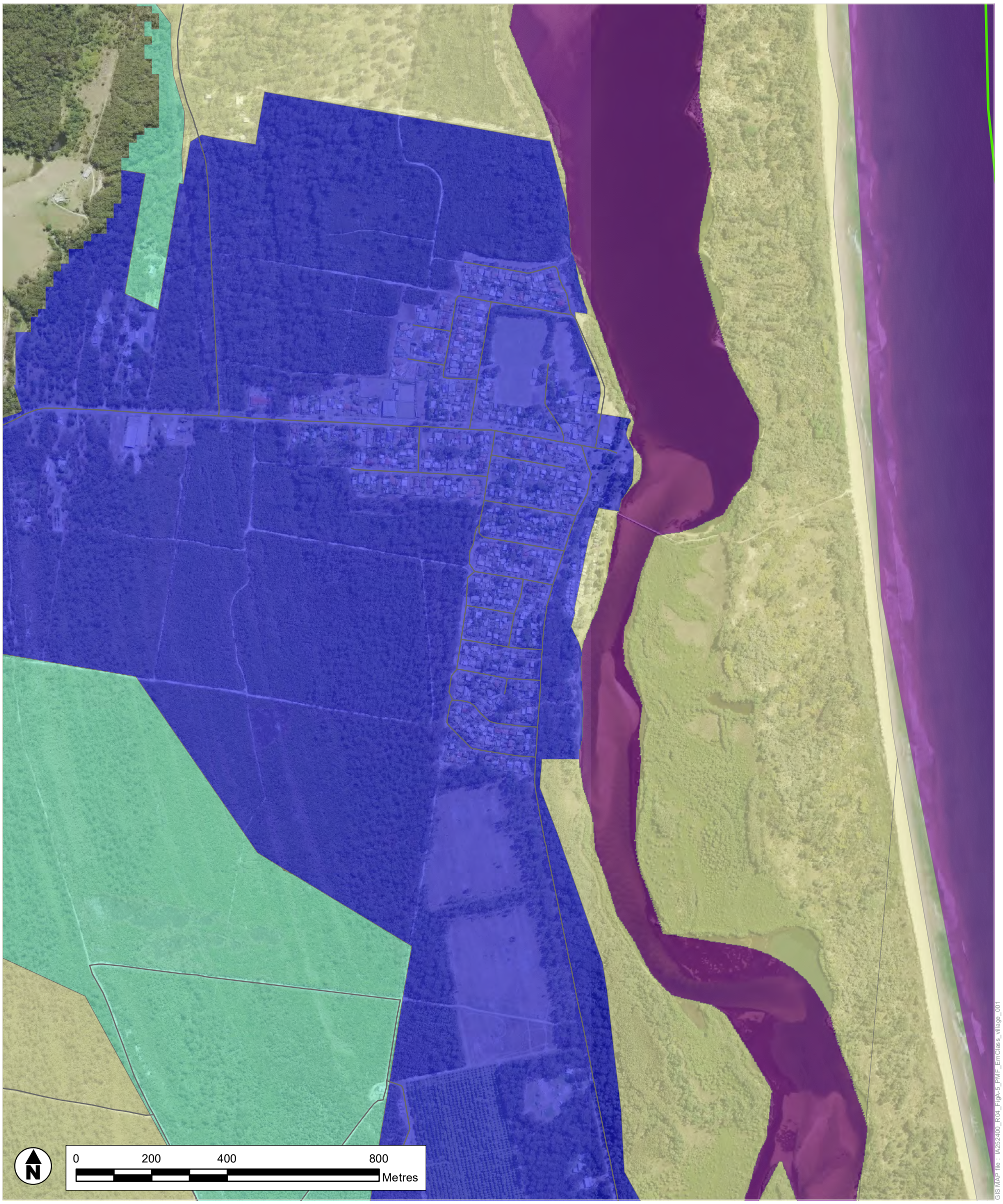
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Fishermans Reach	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(E)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Stuarts Point	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(F)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

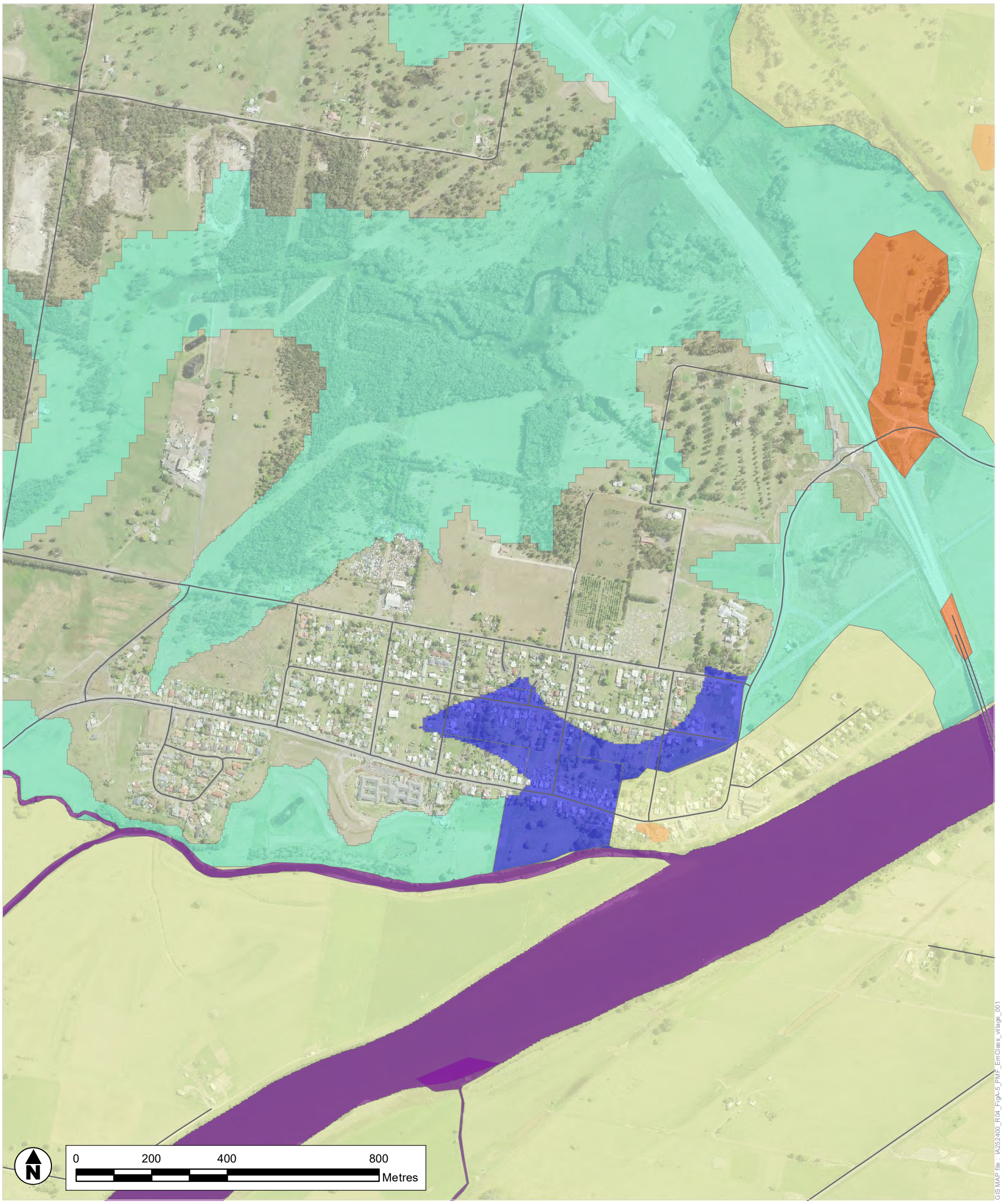
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Probable Maximum Flood Event Emergency Response Classification Smithtown and Gladstone

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE B-5(G)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Frederickton	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(H)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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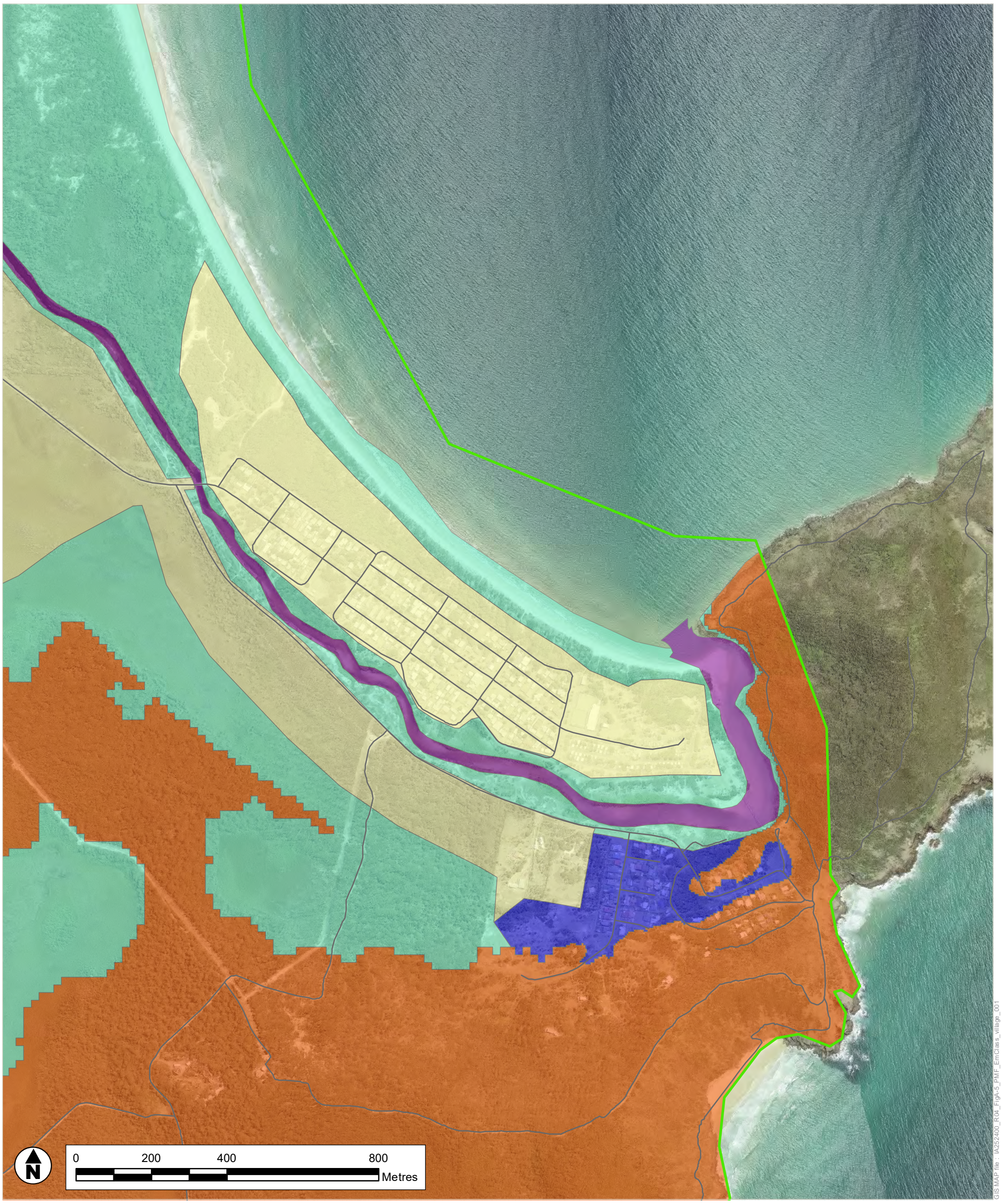
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Kinchela	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(I)
CHECK AH	DATE 15/02/2023	



Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
- FIS - Flooded Area, Isolated and Fully Submerged
- Watercourse
- Limit of Mapping
- Road

Jacobs

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Hat Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(J)
CHECK AH	DATE 15/02/2023	

Legend

Emergency Response Classification

- FEO - Flooded area, with an Exit Route via Overland Escape
- FER - Flooded area, with an Exit Route via Rising Road
- FIE - Flooded Area, Isolated with an Area Elevated Above flood event of interest
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- Watercourse
- Limit of Mapping
- Road

Jacobs

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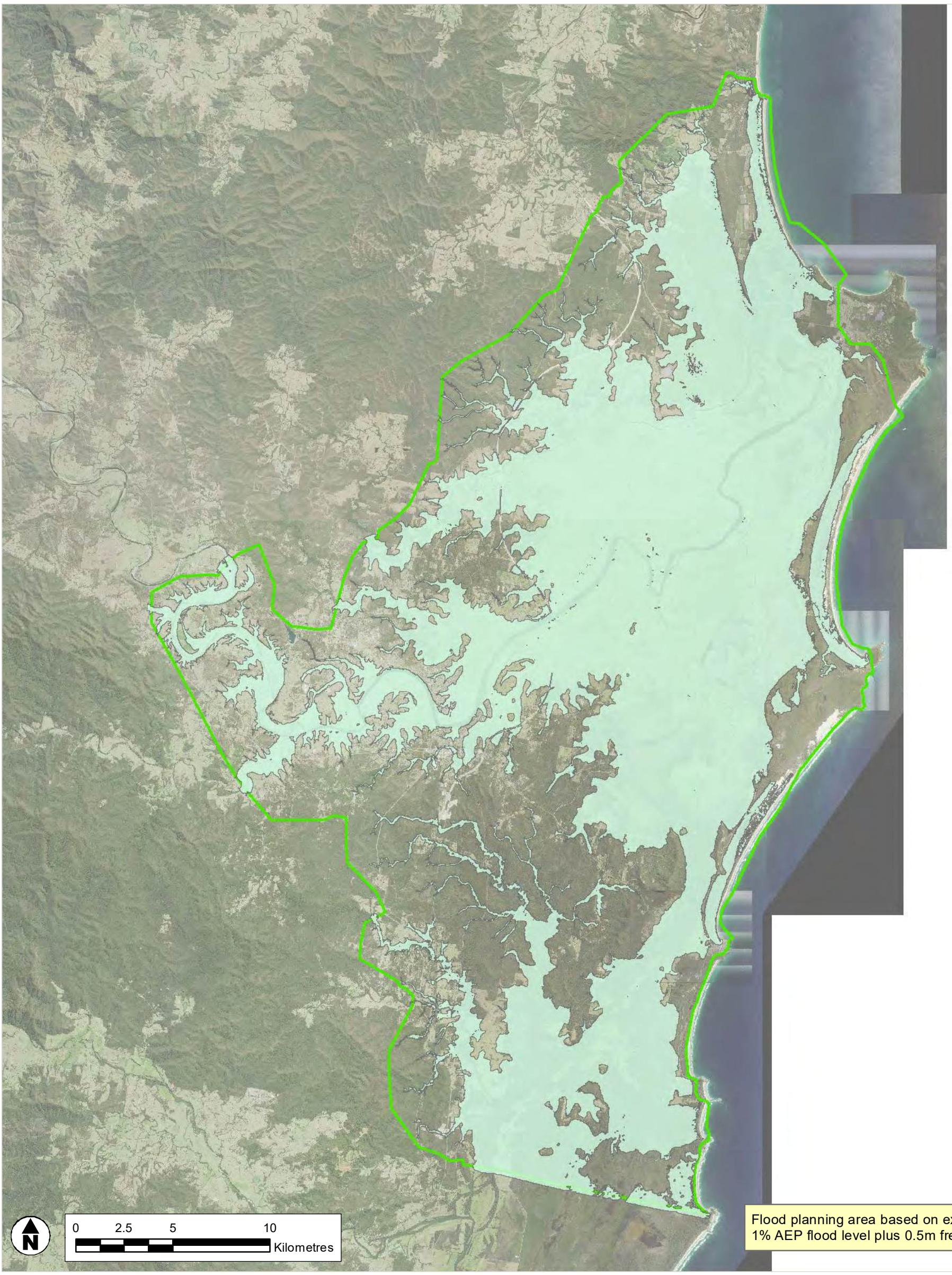
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Probable Maximum Flood Event Emergency Response Classification Crescent Head	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-5(K)
CHECK AH	DATE 15/02/2023	



GIS MAP file : IA252400_R06_FigA-6_FPA_003

Legend

- Flood Planning Area
- Limit of Mapping

Jacobs

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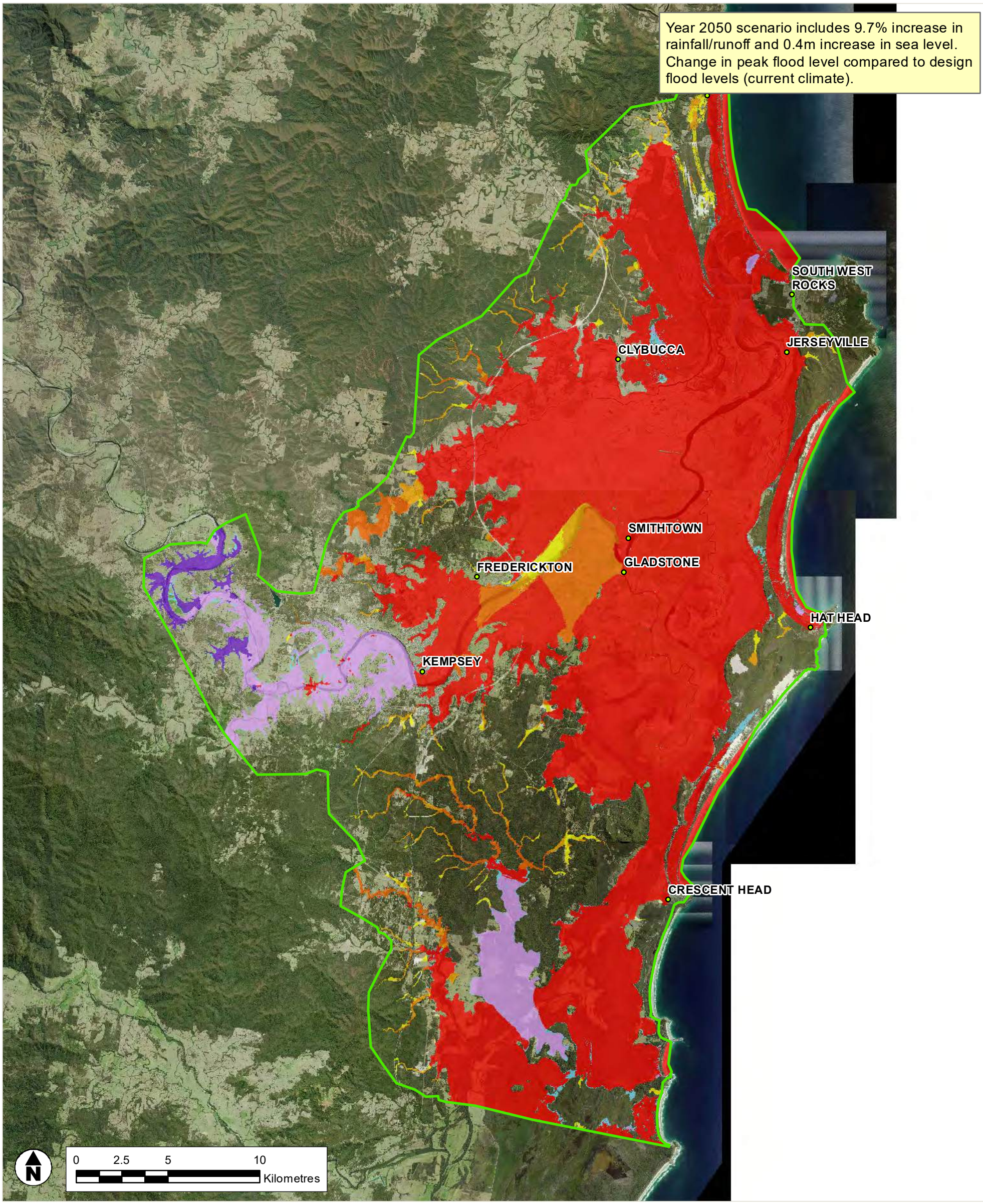
SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Flood Planning Area		
PROJECT	Lower Macleay River Floodplain Risk Management Study		
DRAWN LC	PROJECT # IA252400	MAP # FIGURE B-6	REV 1 VER 1
CHECK AH	DATE 8/07/2024		

Appendix C. Climate change flood mapping



GIS MAP file : IA252400_R03_FigF-1_CC2050_1pAEP_001

Legend

Change in Flood Level (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

- New Areas Flooded
- Limit of Mapping

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A3

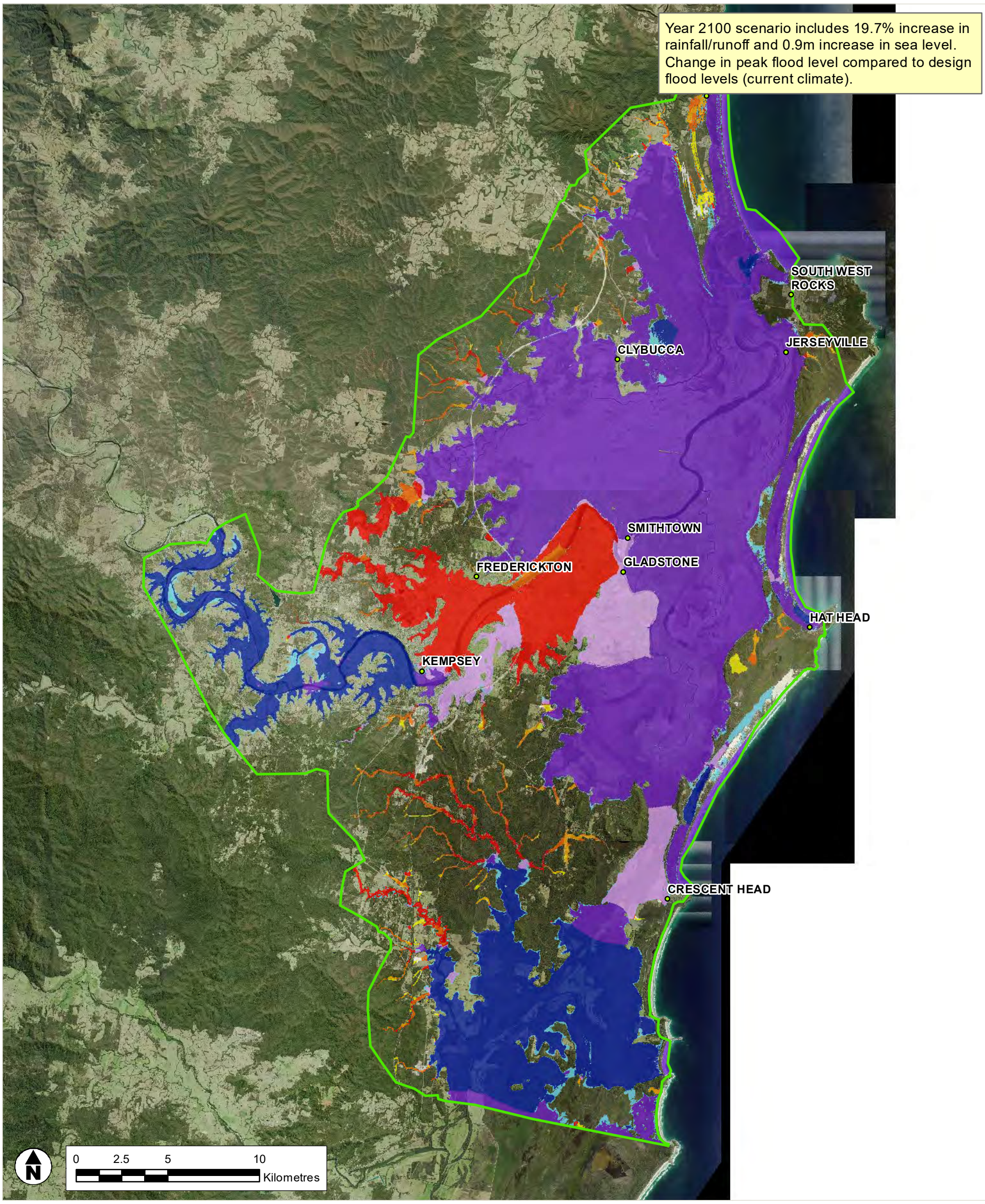
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Impacts
Year 2050 Scenario

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-1	1	1
CHECK AH	DATE 8/10/2022			



GIS MAP file : IA252400_R03_FigF-2_CC2100_1pAEP_001

Legend

Change in Flood Level (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

- New Areas Flooded
- Limit of Mapping

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A3

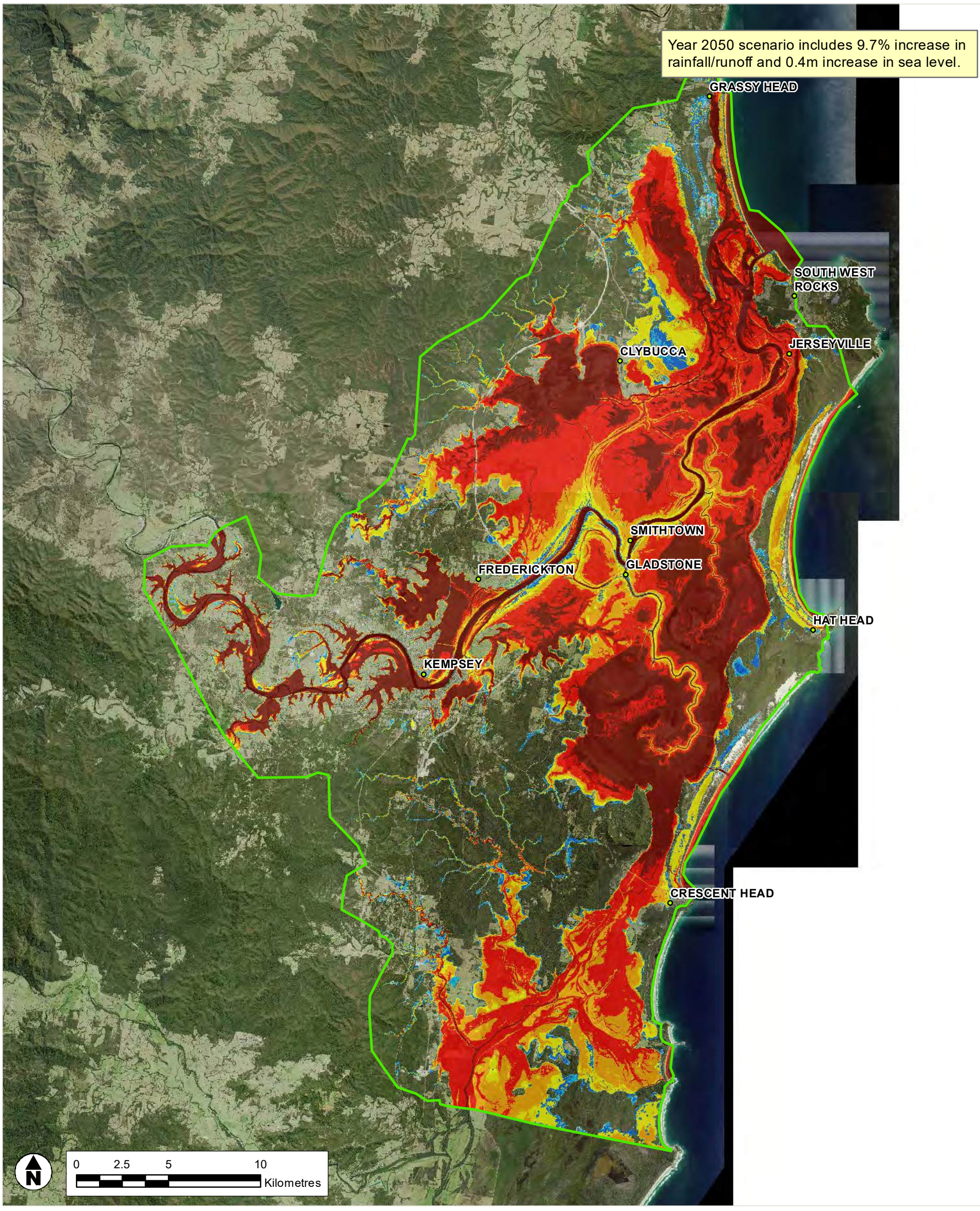
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Impacts
Year 2100 Scenario

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-2	1	1
CHECK AH	DATE 10/10/2022			



GIS MAP file : IA252400_R03_FigF-3_1pAEP_CC2050_d_001

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4
- Limit of Mapping

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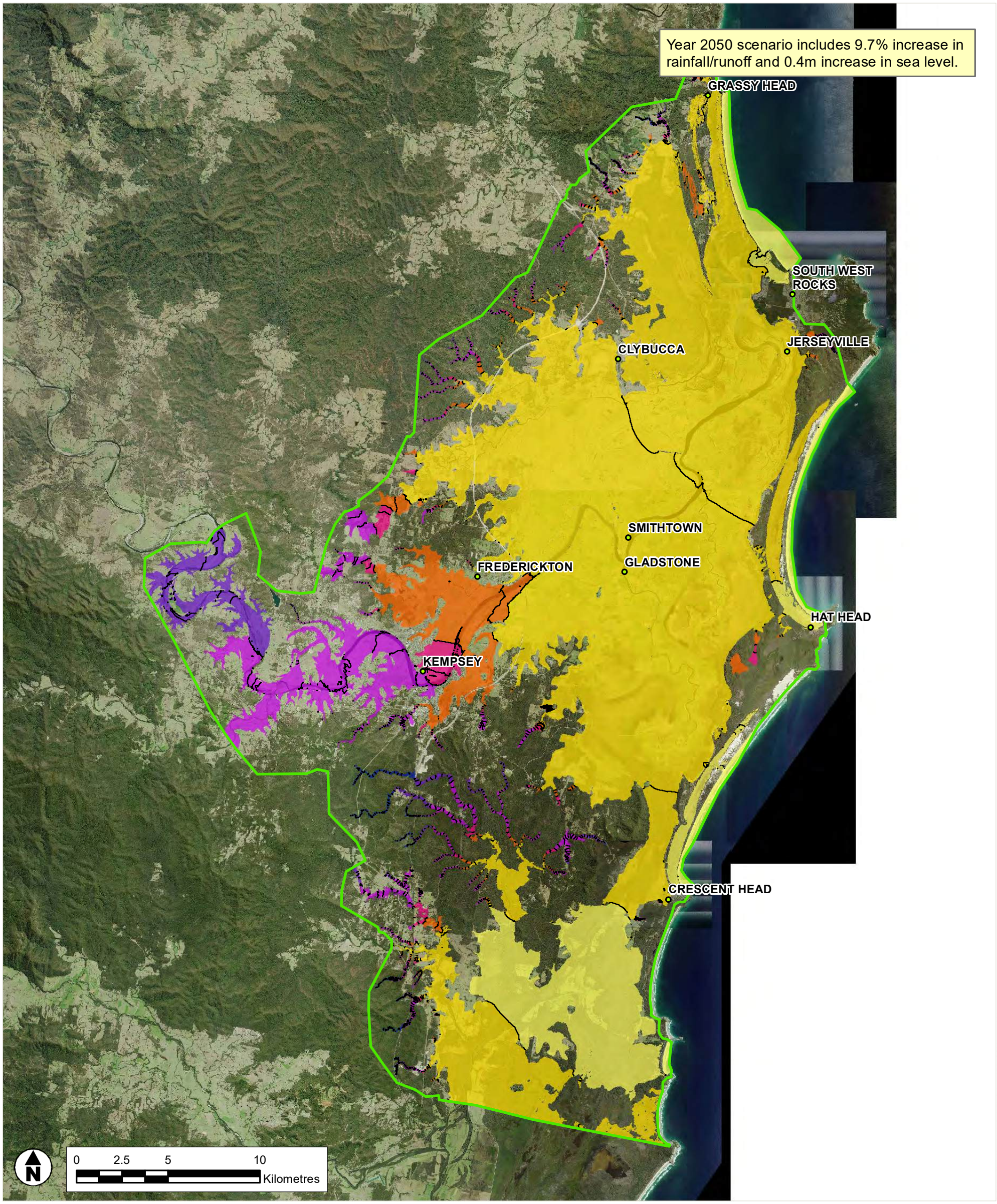
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Climate Change Year 2050 Flood depth	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-3	1	1
CHECK LC	DATE 8/10/2022			



GIS MAP file : IA252400_R08_FigC-4_1pAEP_CC2050_h_001

Legend

Level (m)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

Flood Level 1m Contour (m AHD)

Limit of Mapping

Jacobs

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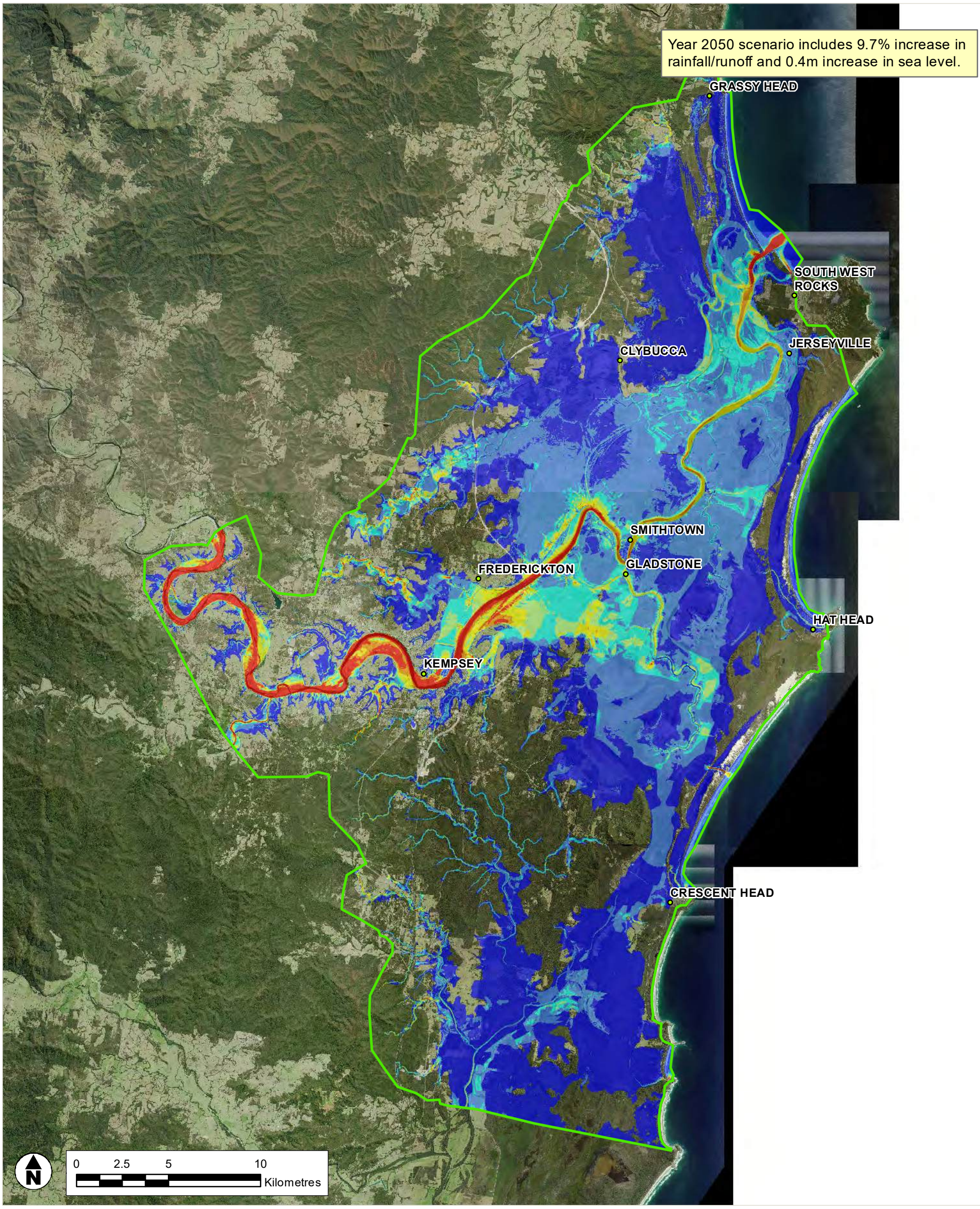
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Year 2050
Flood Level

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-4	1	1
CHECK	DATE			
AH	16/12/2024			



GIS MAP file : IA252400_R03_FigF-5_1pAEP_CC2050_v_001

Legend

Flow velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0
- Limit of Mapping

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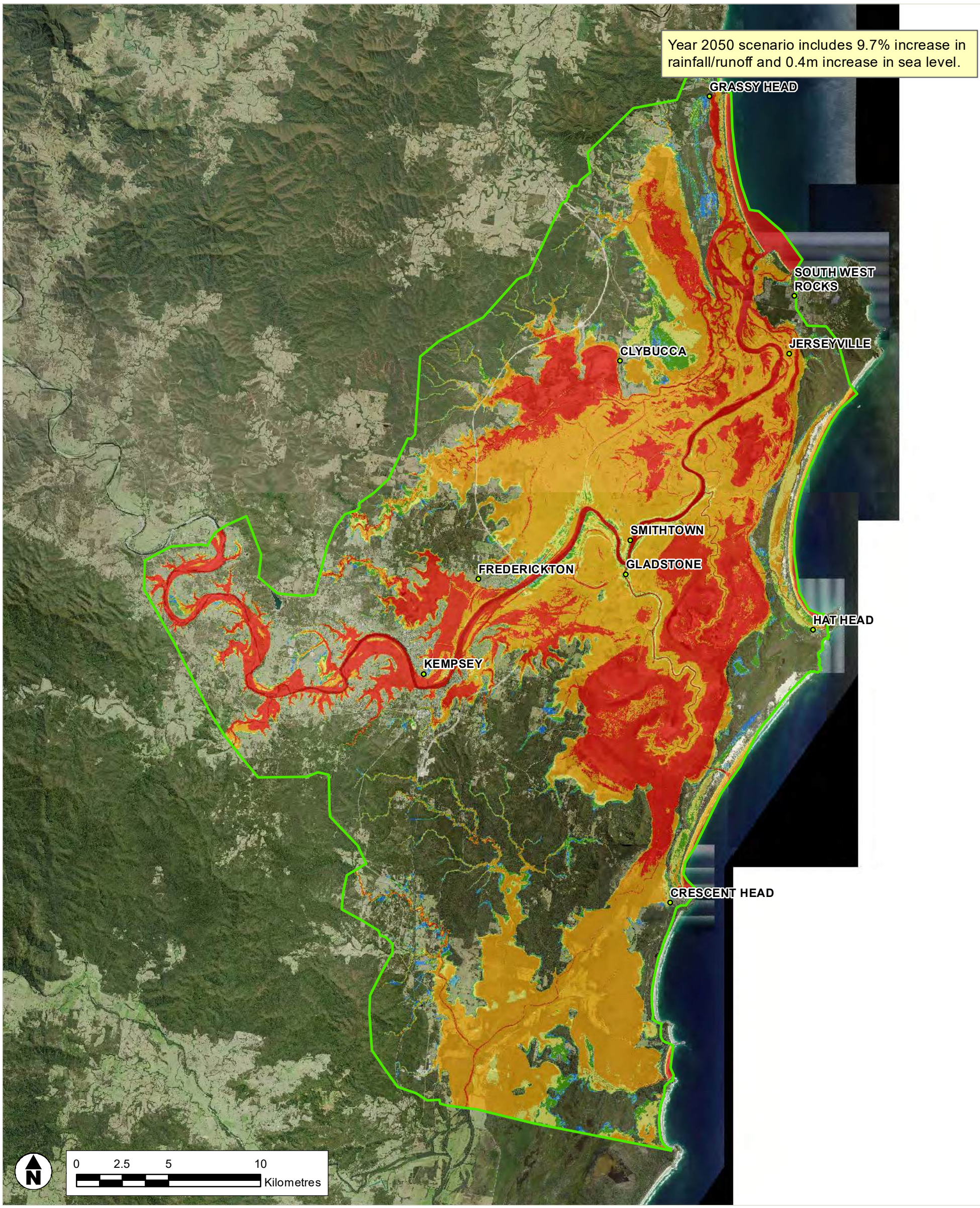
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Climate Change Year 2050 Flow Velocity	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-5	1	1
CHECK LC	DATE 8/10/2022			



GIS MAP file : IA252400_R03_FigF-6_1pAEP_CC2050_haz_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

Limit of Mapping

Jacobs

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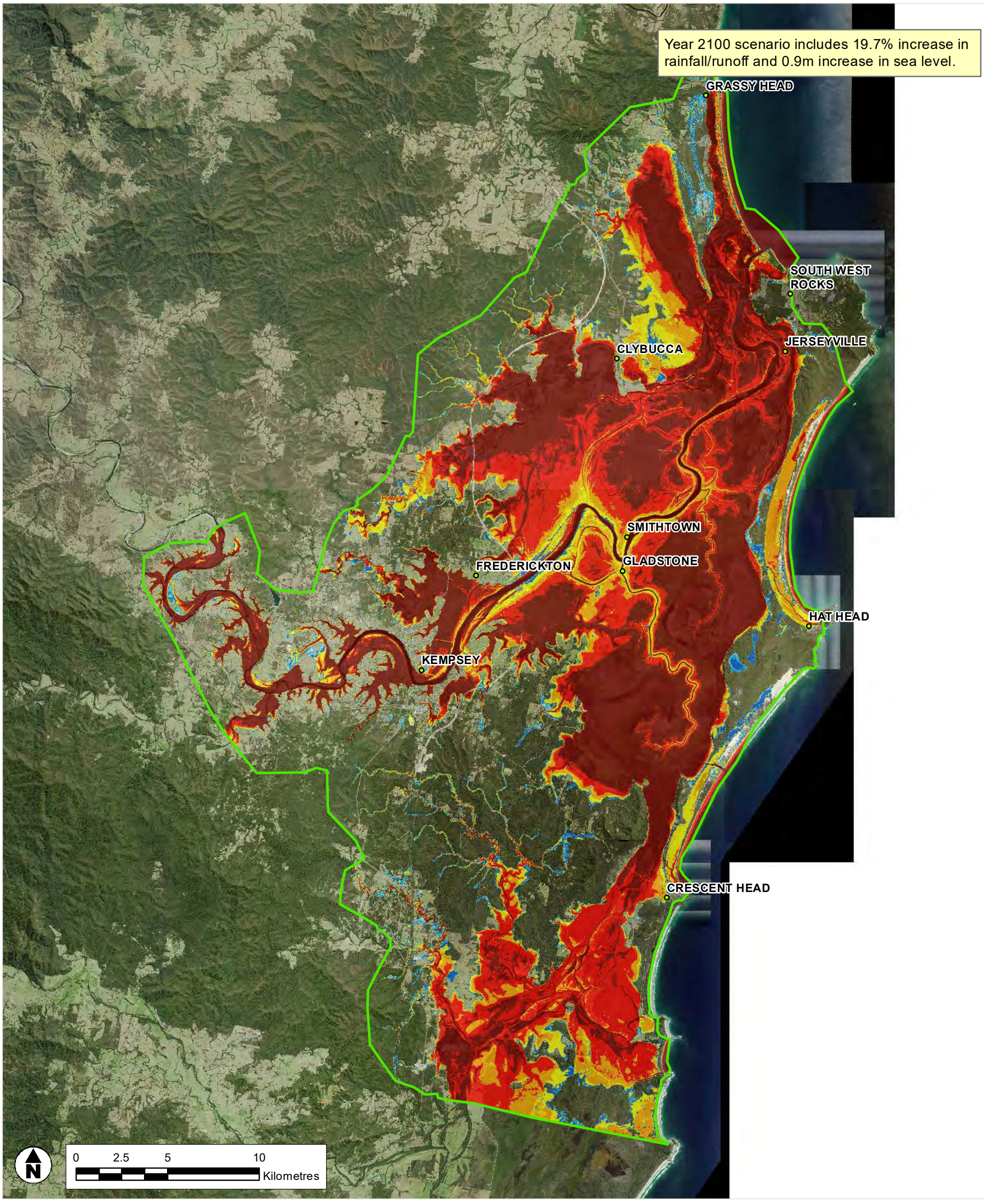
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Year 2050
Flood Hazard

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-6	1	1
CHECK LC	DATE 8/10/2022			



GIS MAP file : IA252400_R03_FigF-7_1pAEP_CC2100_d_001

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4
- Limit of Mapping

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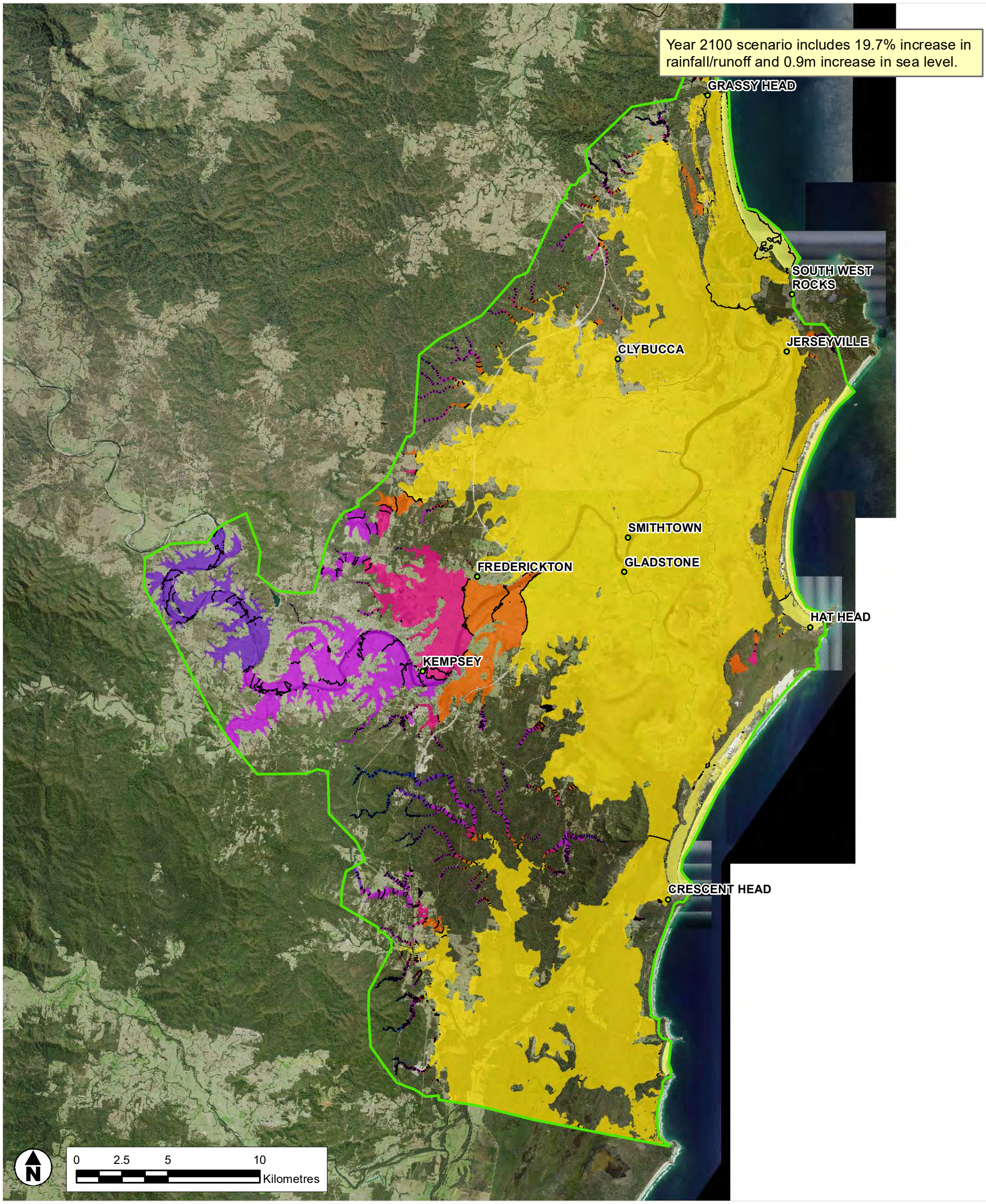
SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Climate Change Year 2100 Flood depth	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-7	1	1
CHECK LC	DATE 8/10/2022			



GIS MAP file : IA252400_R03_FigC-8_1pAEP_CC2100_h_001

Legend

Level (m)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 20
- 20 - 30
- > 30

Flood Level 1m Contour (m AHD)

Limit of Mapping

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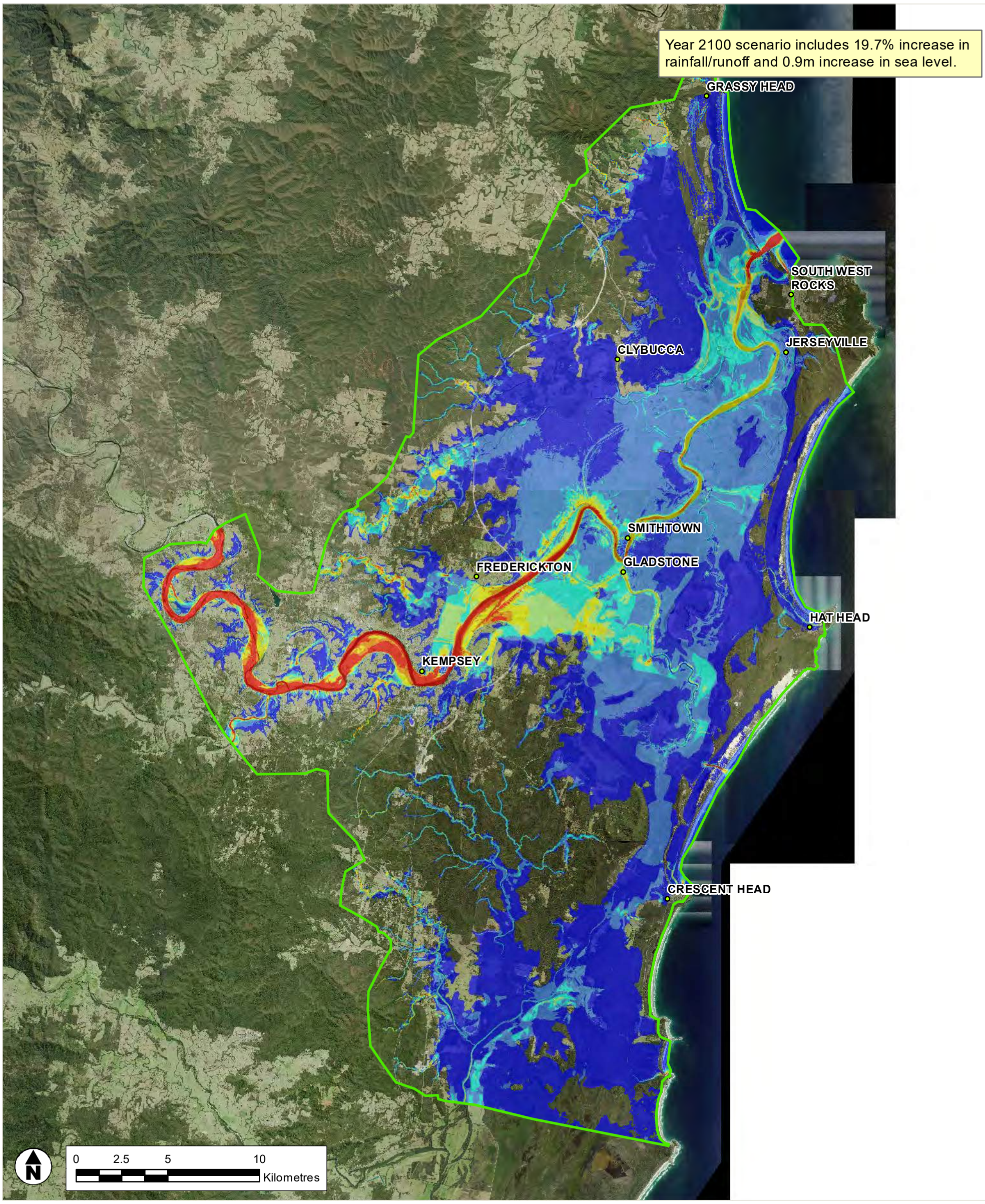
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Climate Change Year 2100 Flood Level	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-8	1	1
CHECK	DATE			
LC	16/12/2024			



GIS MAP file : IA252400_R03_FigF-9_1pAEP_CC2100_v_001

Legend

Flow velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0
- Limit of Mapping

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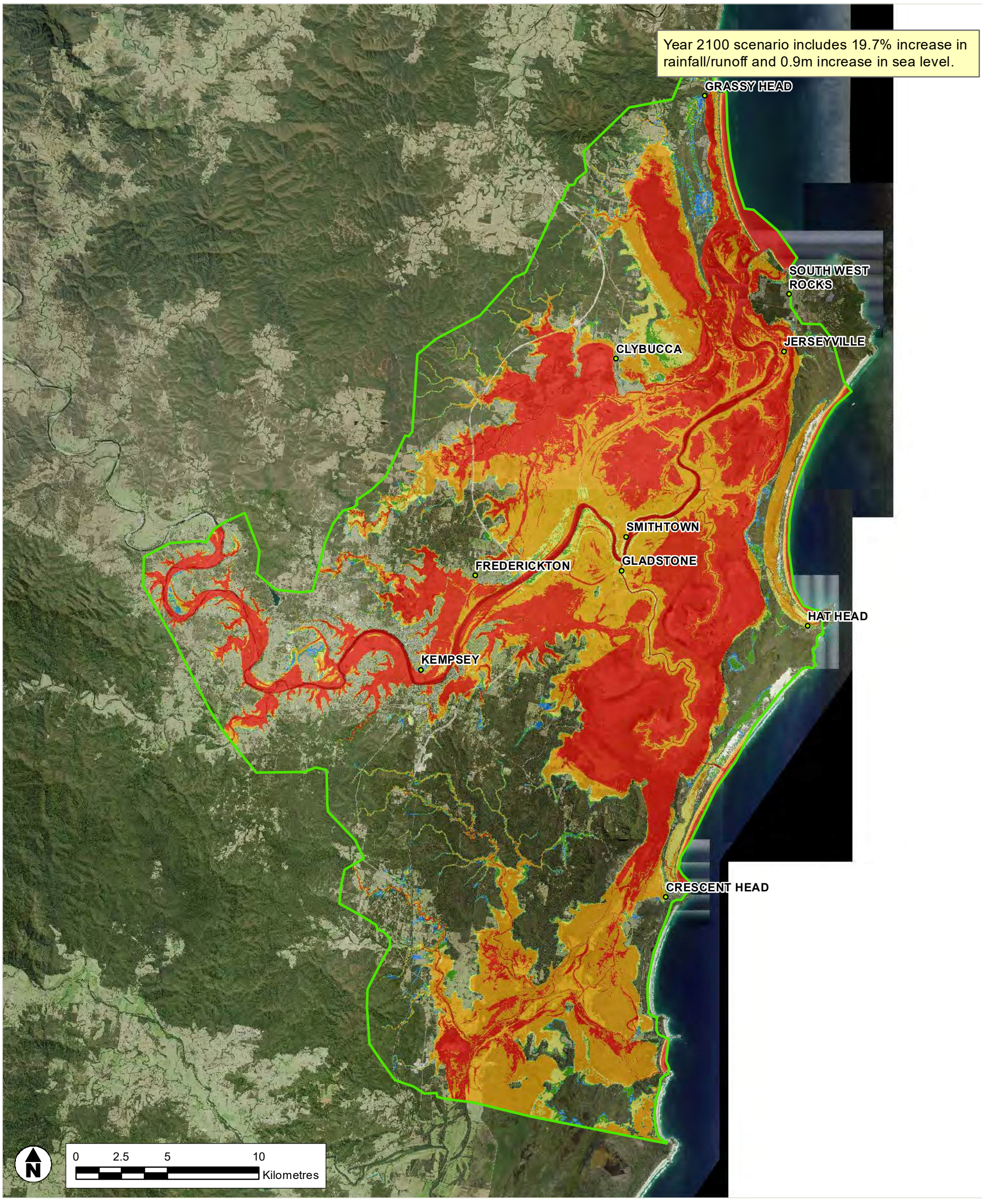
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Year 2100
Flow Velocity

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-9	1	1
CHECK LC	DATE 8/10/2022			



GIS MAP file : IA252400_R03_FigF-10_1pAEP_CC2100_haz_001

Legend

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for all vehicles, children and the elderly.
- H4 - Unsafe for all people and all vehicles.
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
- H6 - Unsafe for Vehicles and people. All building types considered vulnerable to failure.

Limit of Mapping

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SHEET 1 of 1

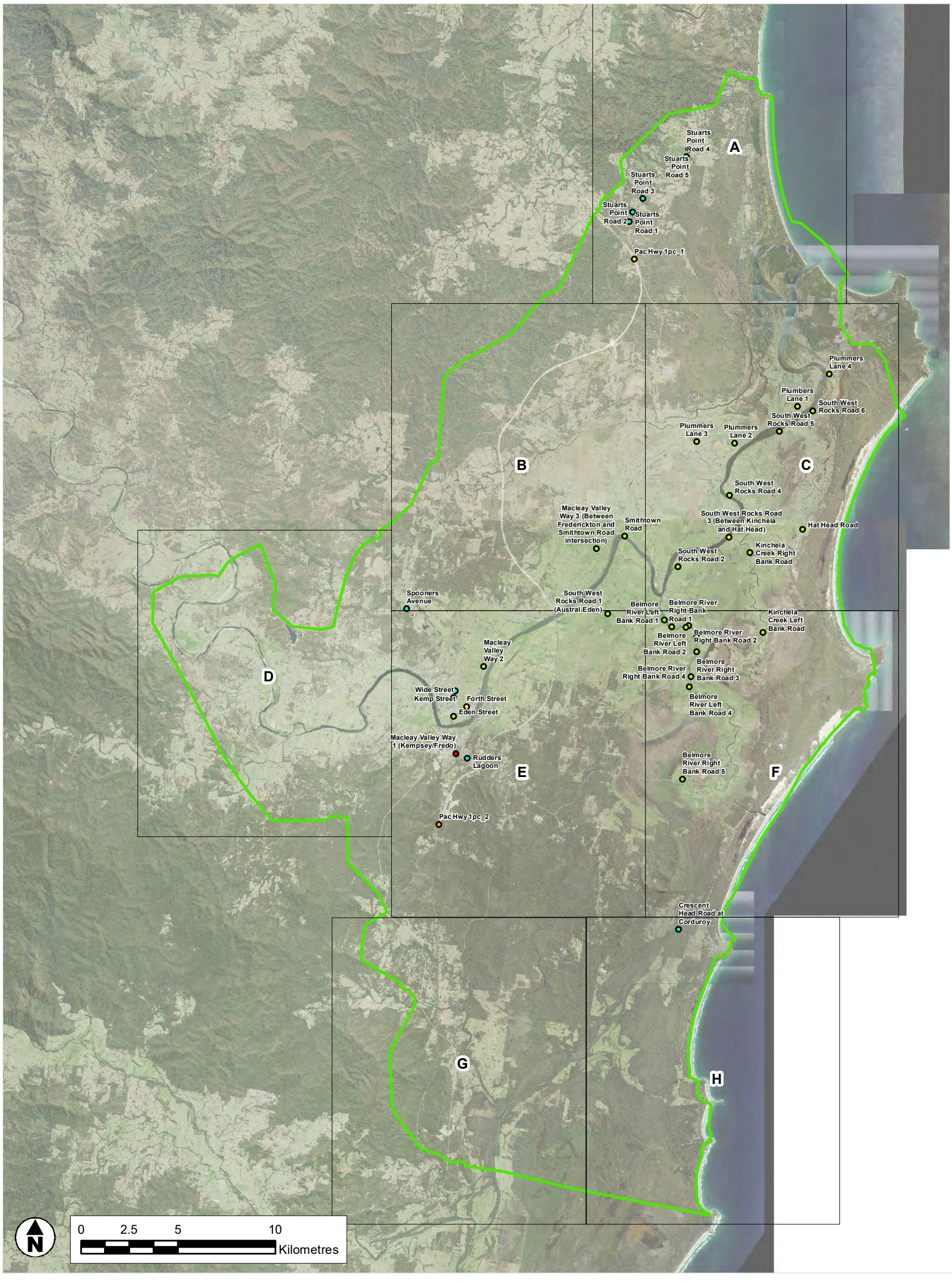
GDA 1994 MGA Zone 56

TITLE 1% AEP Event
Climate Change Year 2100
Flood Hazard

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE C-10	1	1
CHECK LC	DATE 8/10/2022			

Appendix D. Flood immunity of roads and sensitive facilities



GIS MAP file : IA252400_R08_FigD-1_RoadCutoff_001

Legend

Minimum AEP Event

- 50%
- 20%
- 10%
- 2% AEP
- PMF

Limit of Mapping

Inset Map Frame - Refer following map sheets

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE D-1	1	1
CHECK AH	DATE 21/10/2024			

Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

- Main Access Road
- Limit of Mapping
- PMF Event Extent

0 0.5 1 2 Kilometres

N

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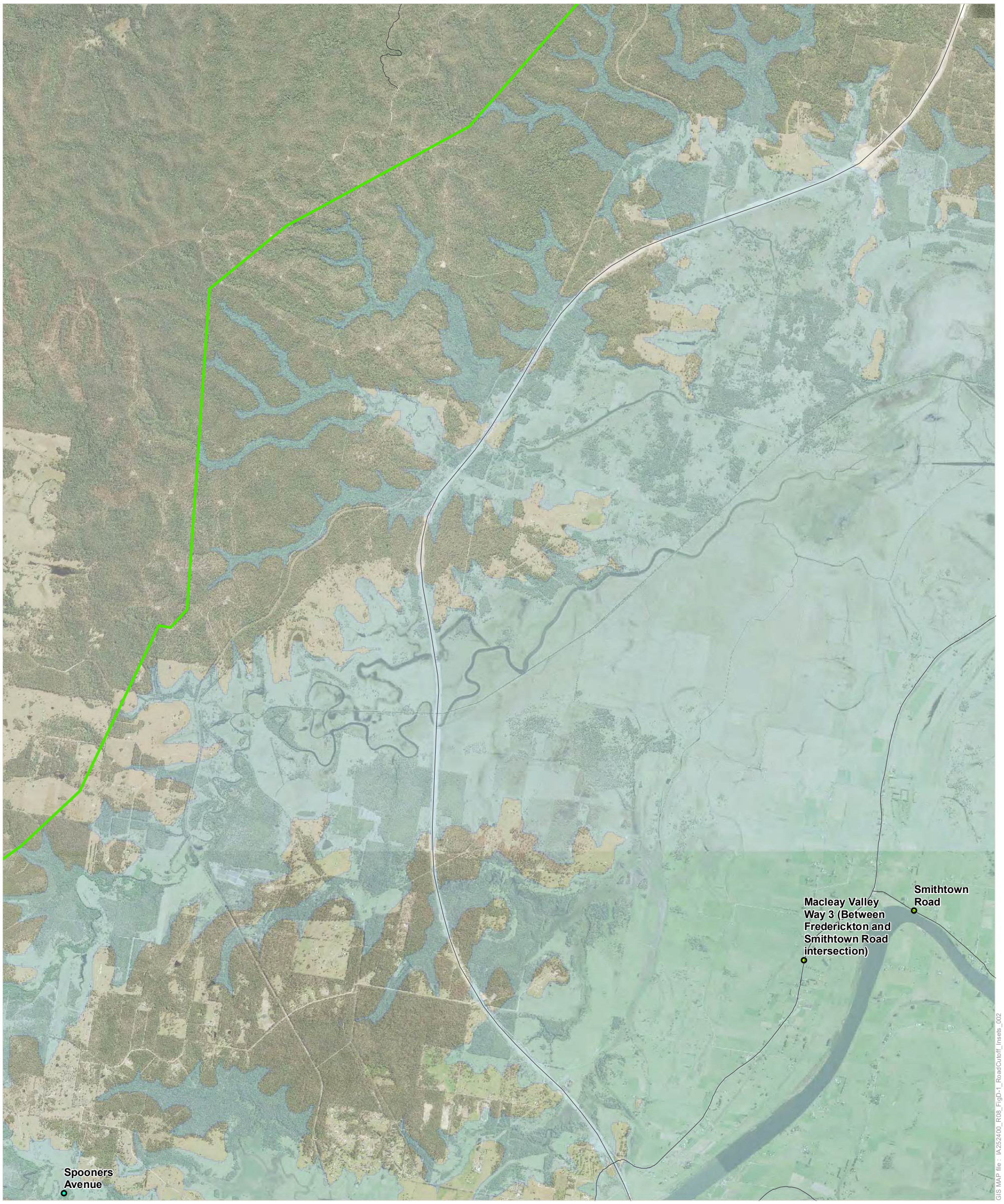
INSET # 1 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(A)	1 1
CHECK AH	DATE 21/10/2024		



Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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INSET # 2 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE B-1(B)	1	1
CHECK	DATE			
AH	21/10/2024			

Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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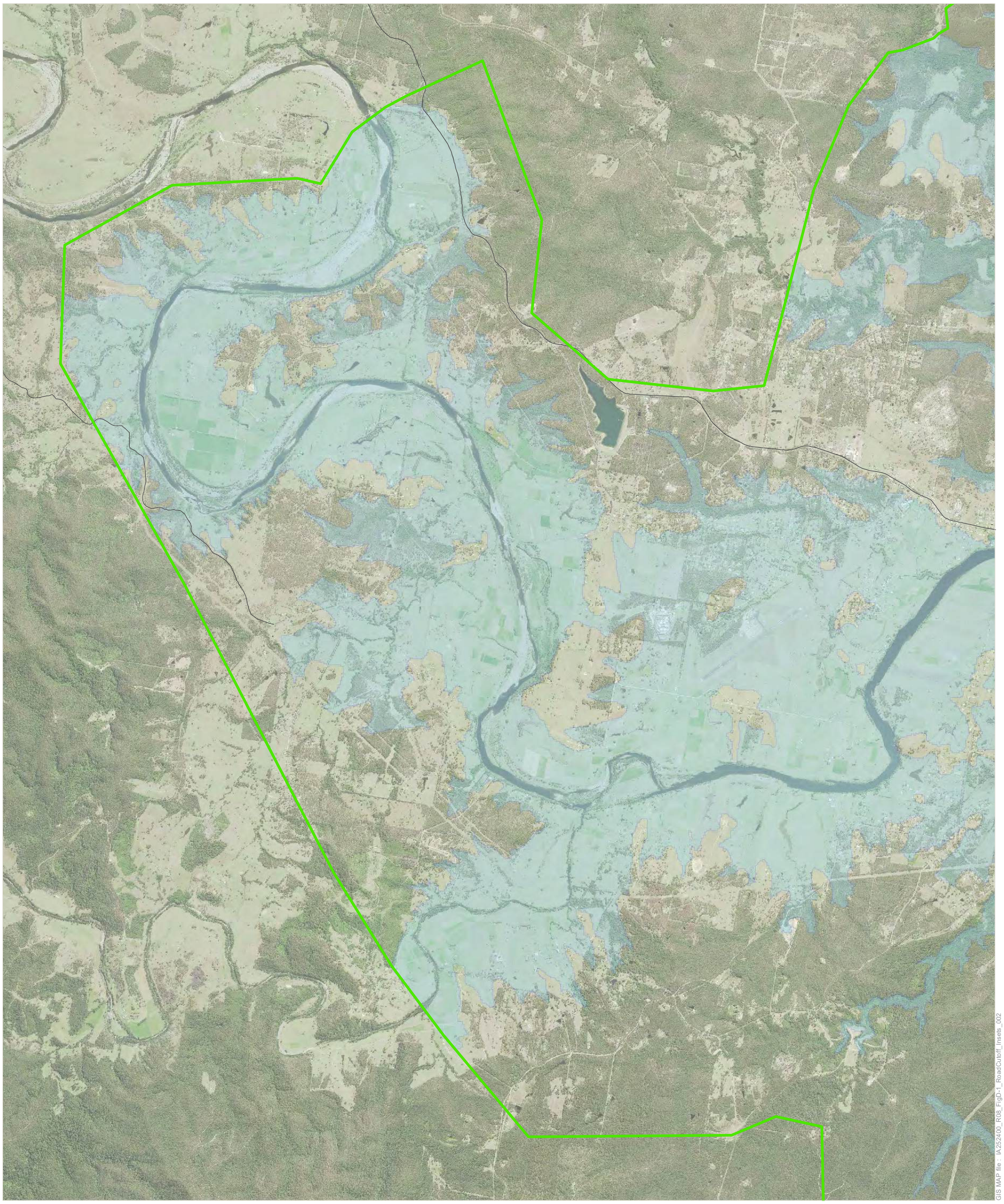
INSET # 3 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(C)	1 1
CHECK AH	DATE 21/10/2024		



Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

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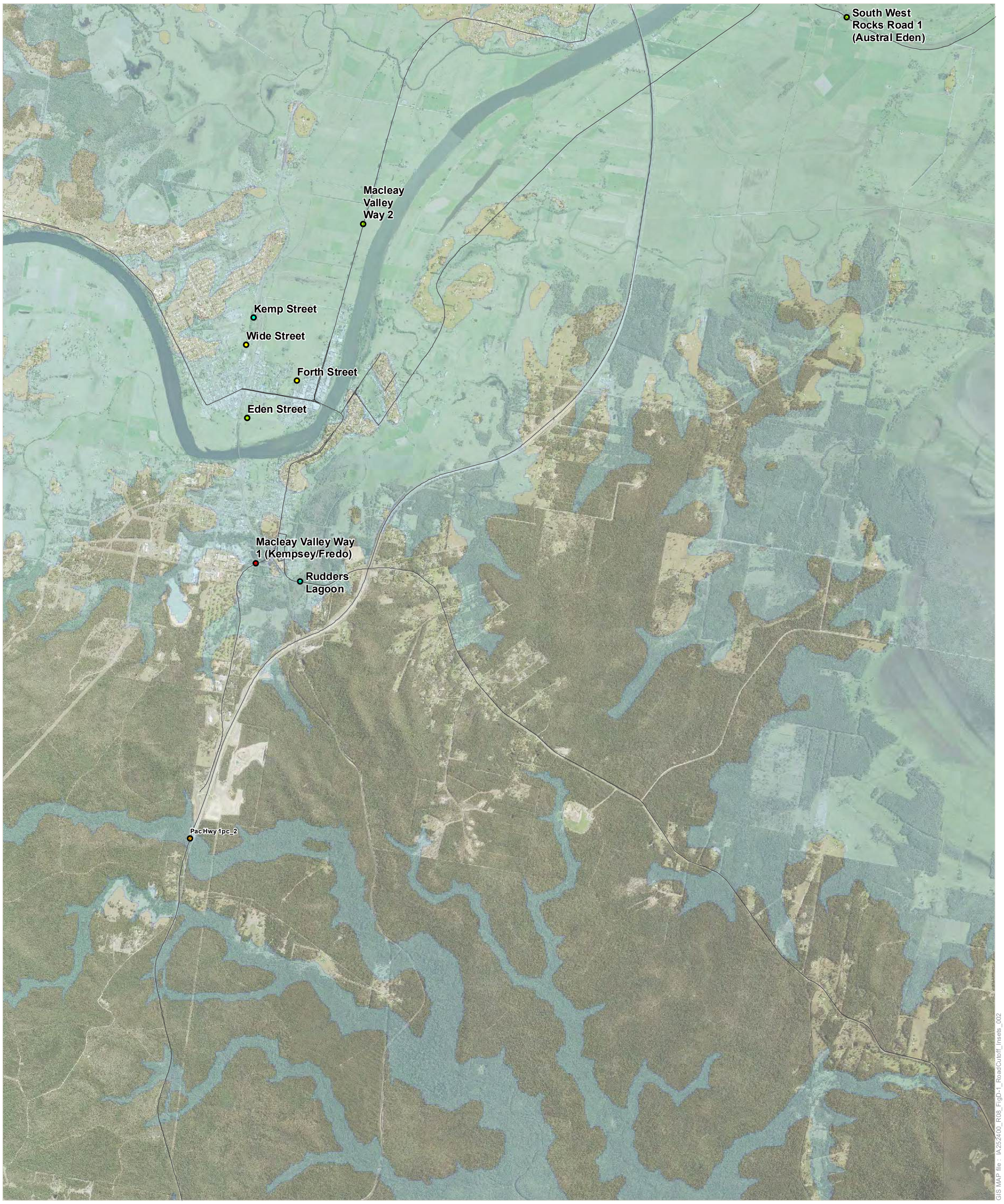
INSET # 4 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(D)[1]	1
CHECK AH	DATE 21/10/2024		



Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

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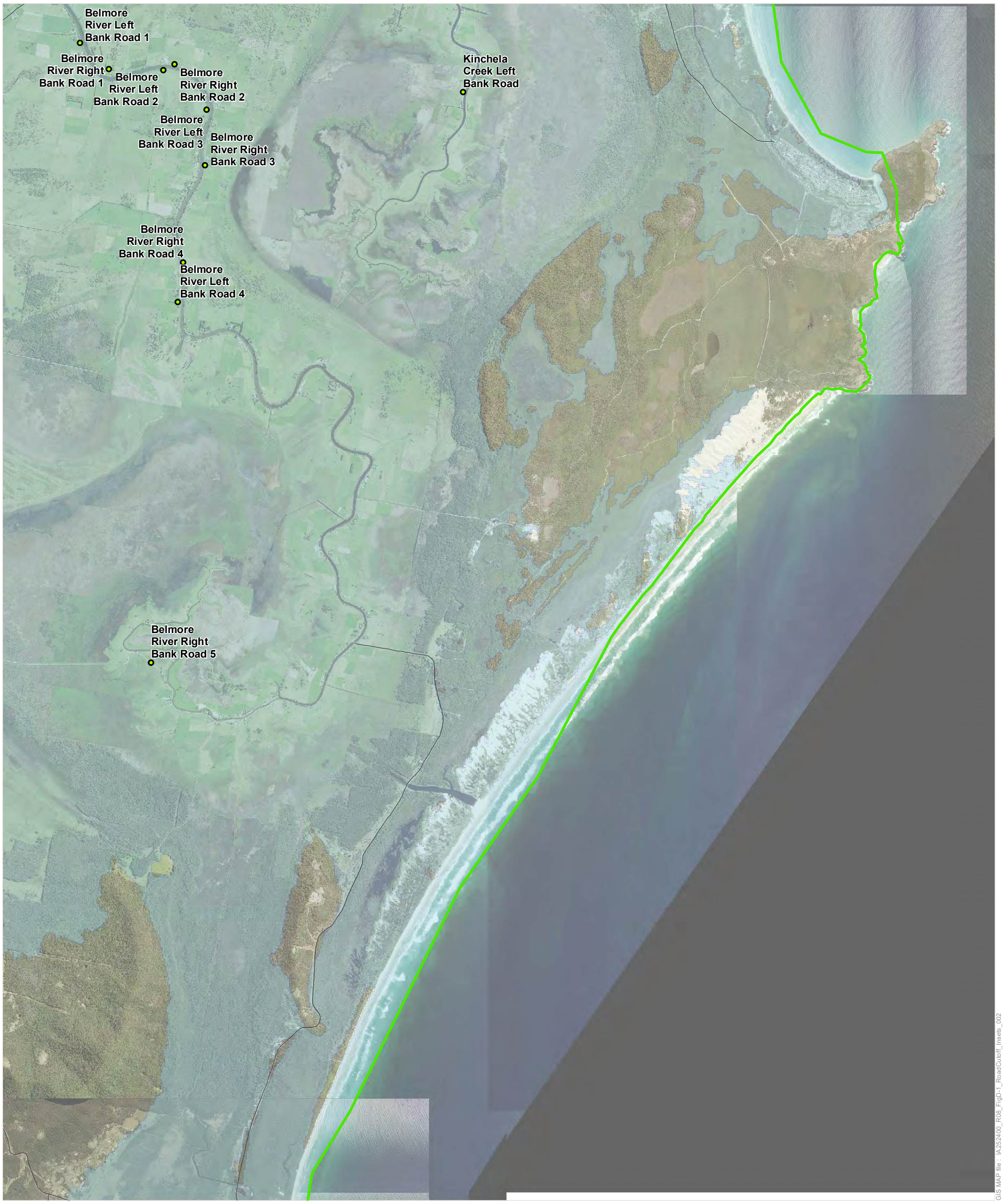
INSET # 5 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(E)	1 1
CHECK AH	DATE 21/10/2024		



GIS MAP file : IA252400_R08_FigD-1_RoadCutoff_Insets_002

Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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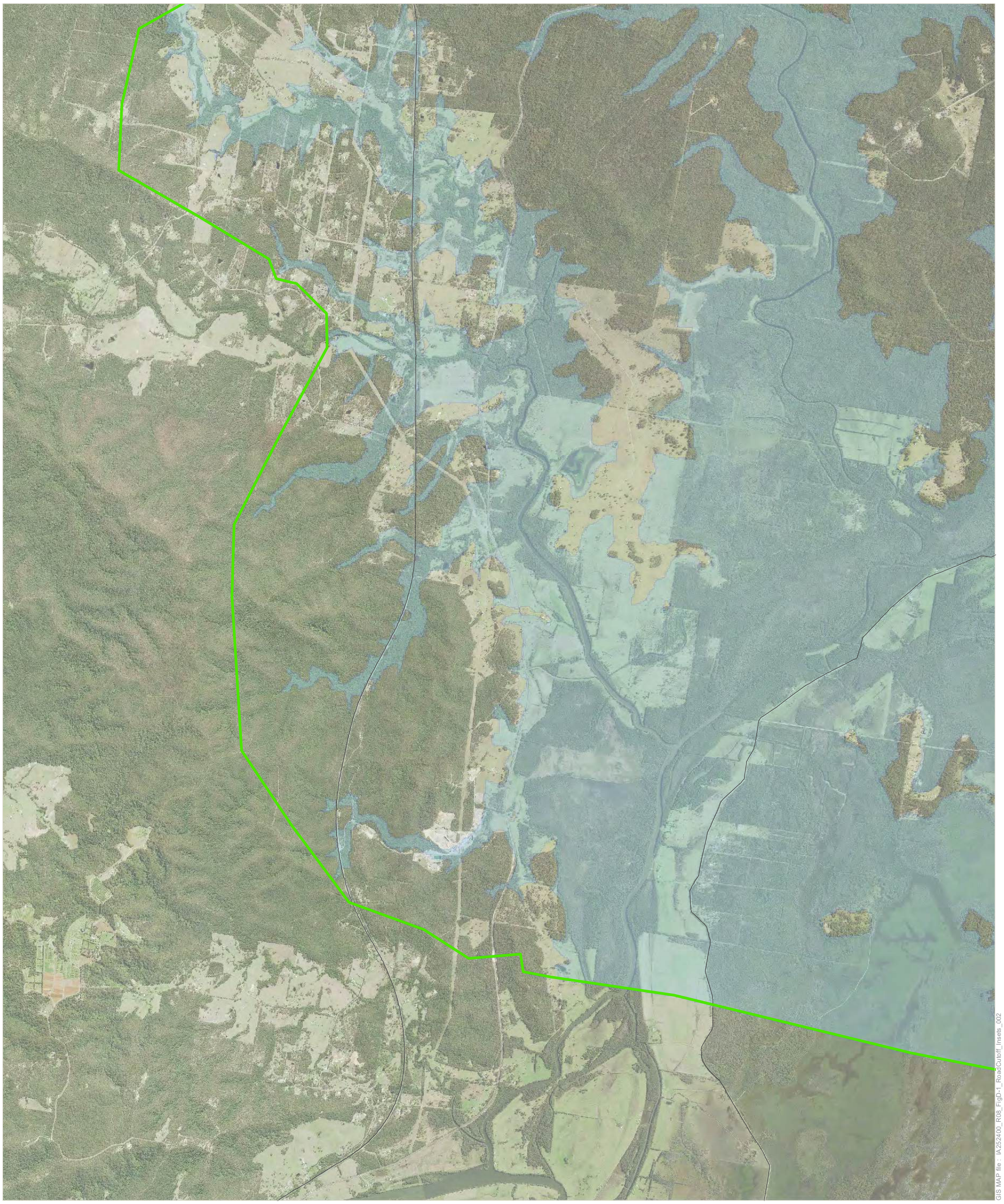
INSET # 6 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(F)	1 1
CHECK AH	DATE 21/10/2024		



Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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INSET # 7 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(G)[1]	1
CHECK AH	DATE 21/10/2024		

GIS MAP file : IA252400_R08_FigD-1_RoadCutoff_Insets_002

Legend

Minimum AEP Event

- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- PMF

Main Access Road

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

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INSET # 8 of 8

GDA 1994 MGA Zone 56

TITLE Road Cutoff

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE B-1(H)	1 1
CHECK AH	DATE 21/10/2024		

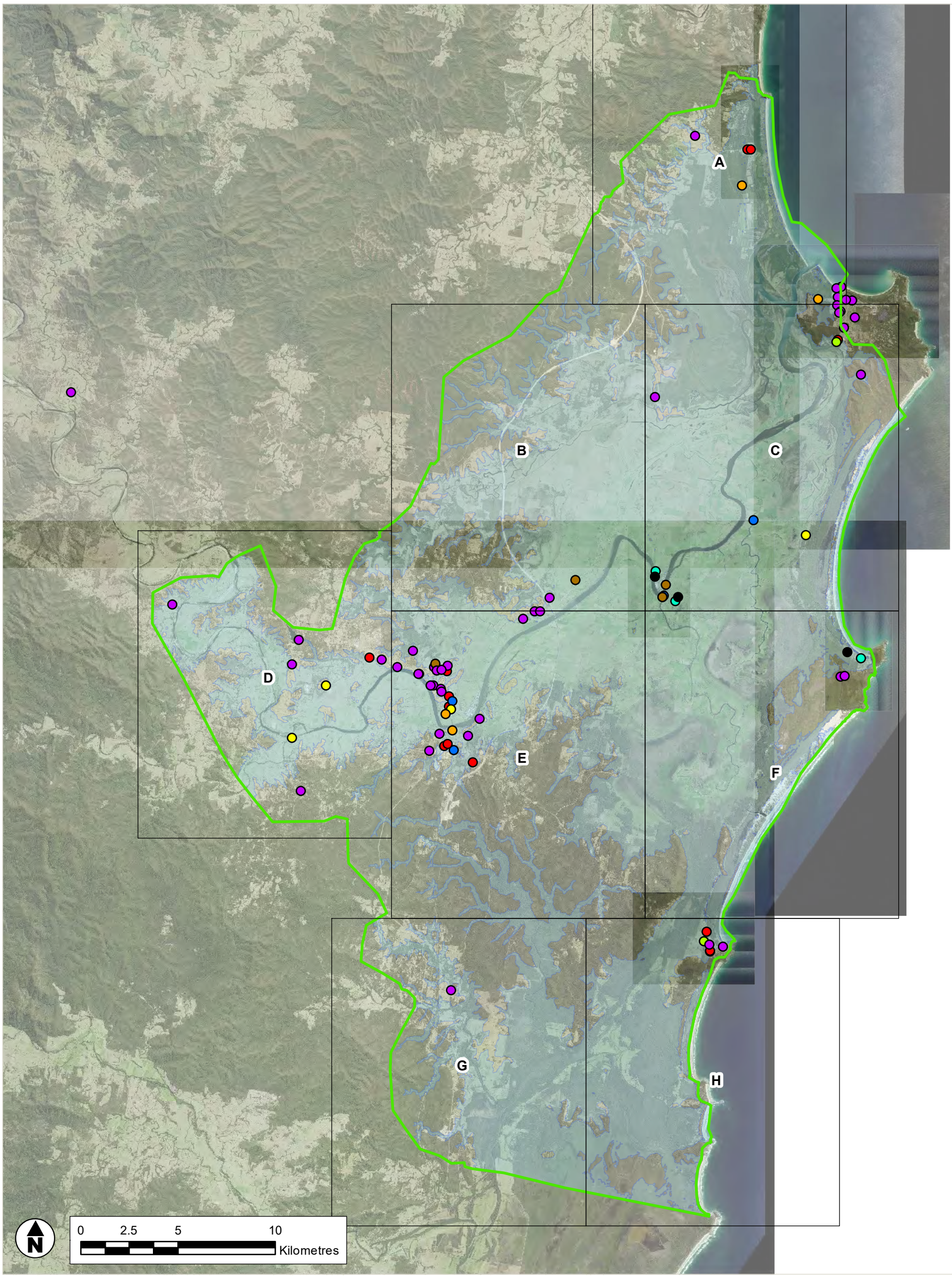
Table D-1: Flood immunity and corresponding river gauge levels at road cut off locations

Road Names	Flood immunity	Minimum Flood AEP when cut	Road Level (m AHD)	Flood Level in minimum flood AEP (m AHD)	Concurrent gauge height when road first becomes cut off (in minimum flood AEP or otherwise stated). Gauge height is relative to AHD.
Belmore River Left Bank Road 1	50% - 20% AEP	20% AEP	4.12	4.28	3.87m on Smithtown gauge
Belmore River Left Bank Road 2	50% - 20% AEP	20% AEP	4.10	4.14	4.03m on Smithtown gauge
Belmore River Left Bank Road 3	50% - 20% AEP	20% AEP	3.75	3.97	3.50m on Smithtown gauge
Belmore River Left Bank Road 4	50% - 20% AEP	20% AEP	3.65	3.75	3.42m on Smithtown gauge
Belmore River Right Bank Road 1	50% - 20% AEP	20% AEP	3.64	3.70	3.30m on Smithtown gauge
Belmore River Right Bank Road 2	50% - 20% AEP	20% AEP	4.13	4.16	4.12m on Smithtown gauge
Belmore River Right Bank Road 3	50% - 20% AEP	20% AEP	3.81	3.95	3.82m on Smithtown gauge
Belmore River Right Bank Road 4	50% - 20% AEP	20% AEP	3.73	3.81	3.72m on Smithtown gauge
Belmore River Right Bank Road 5	50% - 20% AEP	20% AEP	1.04	2.20	4.1m on Smithtown gauge
Crescent Head Road at Corduroy	<50% AEP	50% AEP	1.45	1.49	1.45m on Green Valley gauge (Maria River) 6.11m on Kempsey gauge on the falling limb. 9hrs after peak of 6.25m in 20% AEP event 7.37m on KTB 5% AEP 72hr, rising Low correlation to KTB
Eden Street	50% - 20% AEP	20% AEP	6.39	6.51	6.19m on Kempsey gauge
Forth Street	20% - 10% AEP	10% AEP	3.92	5.99	6.90m on Kempsey gauge
Hat Head Road	50% - 20% AEP	20% AEP	1.87	1.98	4.18m - falling limb. 38hrs after 20% AEP peak of 6.25m AHD on Kempsey gauge

Road Names	Flood immunity	Minimum Flood AEP when cut	Road Level (m AHD)	Flood Level in minimum flood AEP (m AHD)	Concurrent gauge height when road first becomes cut off (in minimum flood AEP or otherwise stated). Gauge height is relative to AHD.
					3.11m - falling limb.24hrs after 20% AEP peak of 4.13m AHD on Kempsey gauge
Kemp Street	<50% AEP	50% AEP	2.77	2.85	Due to local flow in 50% AEP. No correlation to Kempsey gauge
					6.24m in 20% AEP event on Kempsey gauge
Kinchela Creek Left Bank Road	50% - 20% AEP	20% AEP	1.89	2.04	4.18m - falling limb. 38hrs after 20% AEP peak of 6.25m AHD on Kempsey gauge
					3.11m - falling limb.24hrs after 20% AEP peak of 4.13m AHD
Kinchela Creek Right Bank Road	50% - 20% AEP	20% AEP	2.91	3.02	5.79m on Kempsey gauge
					4.01m on Smithtown gauge
Macleay Valley Way 1 (Kempsey/Fredo)	0.2% AEP - PMF	PMF	10.39	11.75	13.69m PMF 48hr on Kempsey gauge
					13.47m PMF 72hr on Kempsey gauge
Macleay Valley Way 2	50% - 20% AEP	20% AEP	3.90	5.44	6.2m on Kempsey gauge
Macleay Valley Way 3 (Between Frederickton and Smithtown Road intersection)	50% - 20% AEP	20% AEP	3.20	3.55	5.85m on Kempsey gauge
Plummers Lane 1	50% - 20% AEP	20% AEP	1.45	1.72	5.96m on Kempsey gauge
					4.10m on Smithtown gauge
Plummers Lane 2	50% - 20% AEP	20% AEP	1.94	2.23	6.16m on Kempsey gauge
					4.13m on Smithtown gauge
Plummers Lane 3	50% - 20% AEP	20% AEP	2.13	2.29	6.16m on Kempsey gauge
					4.13m on Smithtown gauge
Plummers Lane 4	50% - 20% AEP	20% AEP	1.83	1.90	

Road Names	Flood immunity	Minimum Flood AEP when cut	Road Level (m AHD)	Flood Level in minimum flood AEP (m AHD)	Concurrent gauge height when road first becomes cut off (in minimum flood AEP or otherwise stated). Gauge height is relative to AHD.
Crescent Head Road at Rudders Lagoon	<50% AEP	50% AEP	3.96	3.98	Local catchment flooding in up to 20% AEP, no correlation with Kempsey gauge 6.49m in 10% AEP event on Kempsey gauge Peak flood level 5% AEP 5.12m AHD; 1% AEP 6.2m AHD
Smithtown Road	50% - 20% AEP	20% AEP	4.25	4.82	5.22m on Kempsey gauge 3.53m on Smithtown gauge
South West Rocks Road 1 (Austral Eden)	50% - 20% AEP	20% AEP	3.55	3.96	6.16m on Kempsey gauge 4.13m on Smithtown gauge
South West Rocks Road 2	50% - 20% AEP	20% AEP	3.91	4.04	5.79m on Kempsey gauge 4.01m on Smithtown gauge
South West Rocks Road 3 (Between Kinchela and Hat Head)	20% - 10% AEP	10% AEP	3.42	3.42	6.42m on Kempsey gauge 4.16m on Smithtown gauge
South West Rocks Road 4	50% - 20% AEP	20% AEP	3.05	3.02	6.02m on Kempsey gauge 4.12m on Smithtown gauge
South West Rocks Road 5	50% - 20% AEP	20% AEP	2.17	2.39	5.79m on Kempsey gauge 4.01m on Smithtown gauge
South West Rocks Road 6	50% - 20% AEP	20% AEP	1.85	2.08	5.79m on Kempsey gauge 4.01m on Smithtown gauge
Spooners Avenue	50% - 20% AEP	20% AEP	5.90	5.94	Local flooding dominant in 20% AEP - no correlation to gauge levels 6.89m in 10% AEP
Stuarts Point Road 1	<50% AEP	50% AEP	5.14	5.36	Local flooding - no correlation to gauge levels
Stuarts Point Road 2	<50% AEP	50% AEP	5.57	5.71	Local flooding - no correlation to gauge levels

Road Names	Flood immunity	Minimum Flood AEP when cut	Road Level (m AHD)	Flood Level in minimum flood AEP (m AHD)	Concurrent gauge height when road first becomes cut off (in minimum flood AEP or otherwise stated). Gauge height is relative to AHD.
Stuarts Point Road 3	<50% AEP	50% AEP	10.66	11.11	Local flooding - no correlation to gauge levels
Stuarts Point Road 4	<50% AEP	50% AEP	3.48	3.88	Local flooding - no correlation to gauge levels
Stuarts Point Road 5	<50% AEP	50% AEP	5.80	5.82	Local flooding - no correlation to gauge levels
Wide Street	20% - 10% AEP	10% AEP	2.83	5.99	6.88m on Kempsey gauge
Pac Hwy 1pc_1	20% - 10% AEP	10% AEP	8.15	8.36	Local flooding - no correlation to gauge levels
Pac Hwy 1pc_2	5% - 2% AEP	2% AEP	29.92	30.12	Local flooding - no correlation to gauge levels



GIS MAP file : IA252400_R04_FigB-2_FloodImmunity_002

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF
- Limit of Mapping
- PMF Event Extent
- Inset Map Frame - Refer following map sheets

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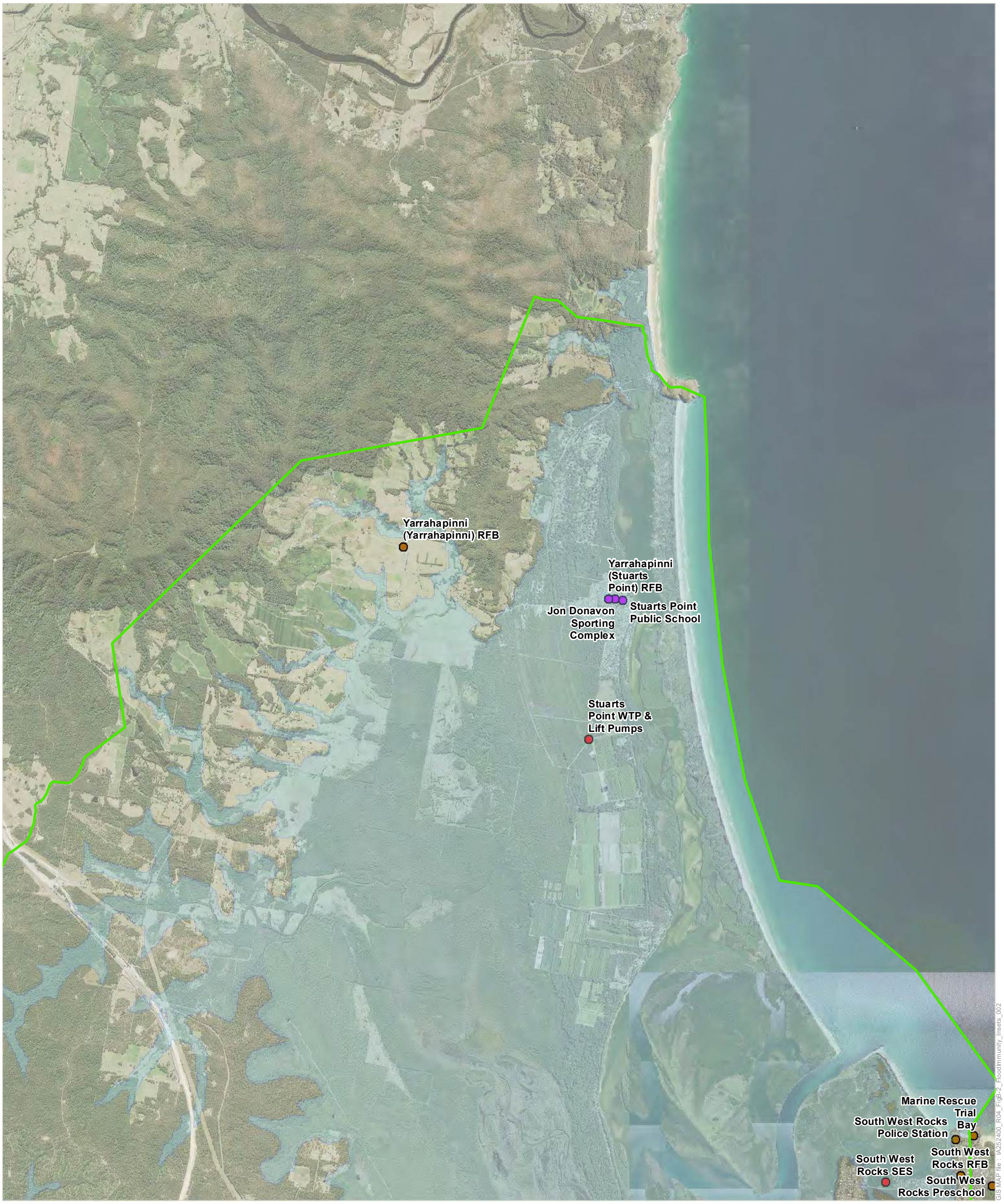
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE D-2	1	1
CHECK	DATE			
AH	16/02/2023			



Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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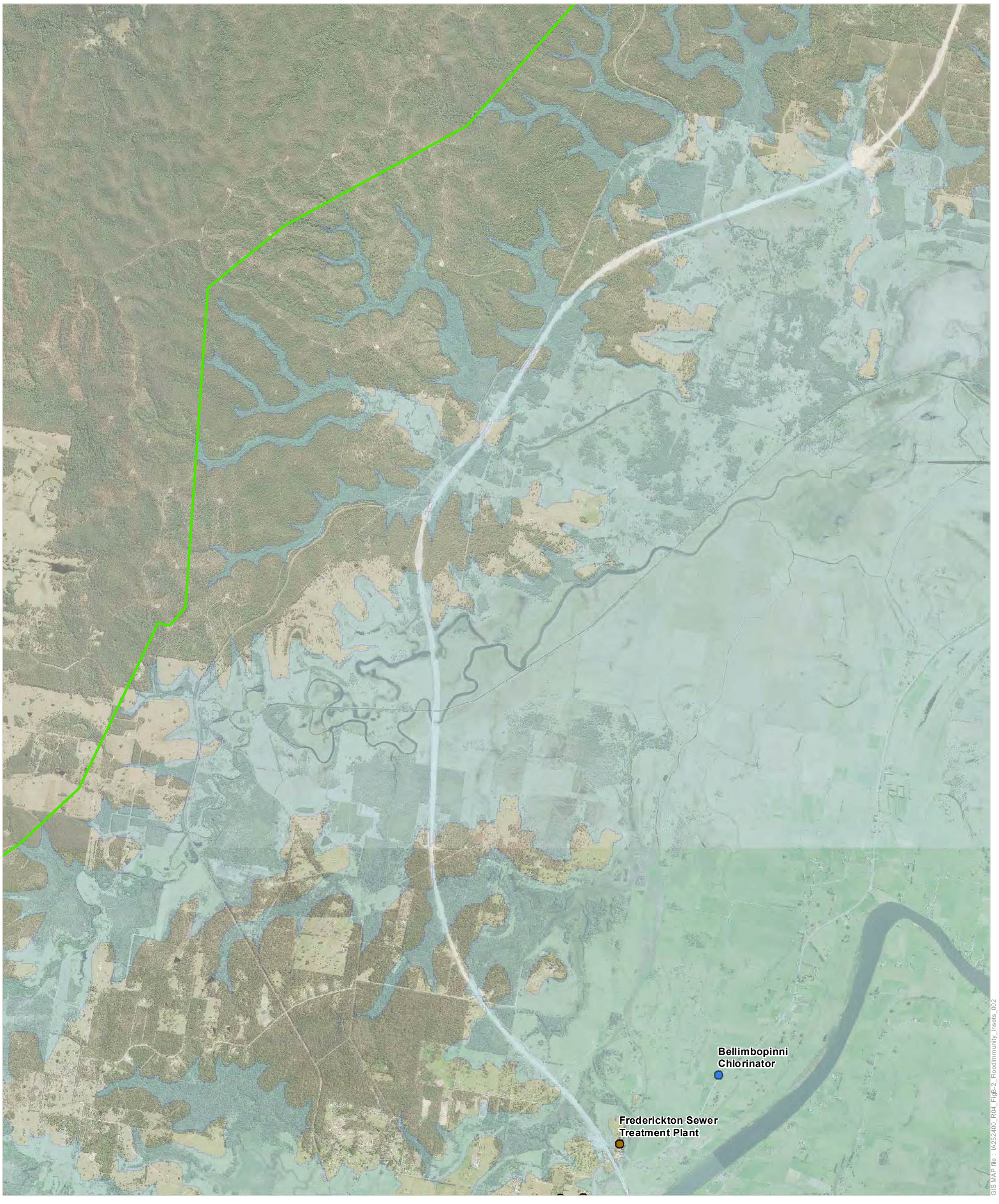
INSET # 1 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(A)	1 1
CHECK AH	DATE 16/02/2023		



Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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INSET # 2 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA252400	FIGURE D-2(B)	1	1
CHECK	DATE			
AH	16/02/2023			

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

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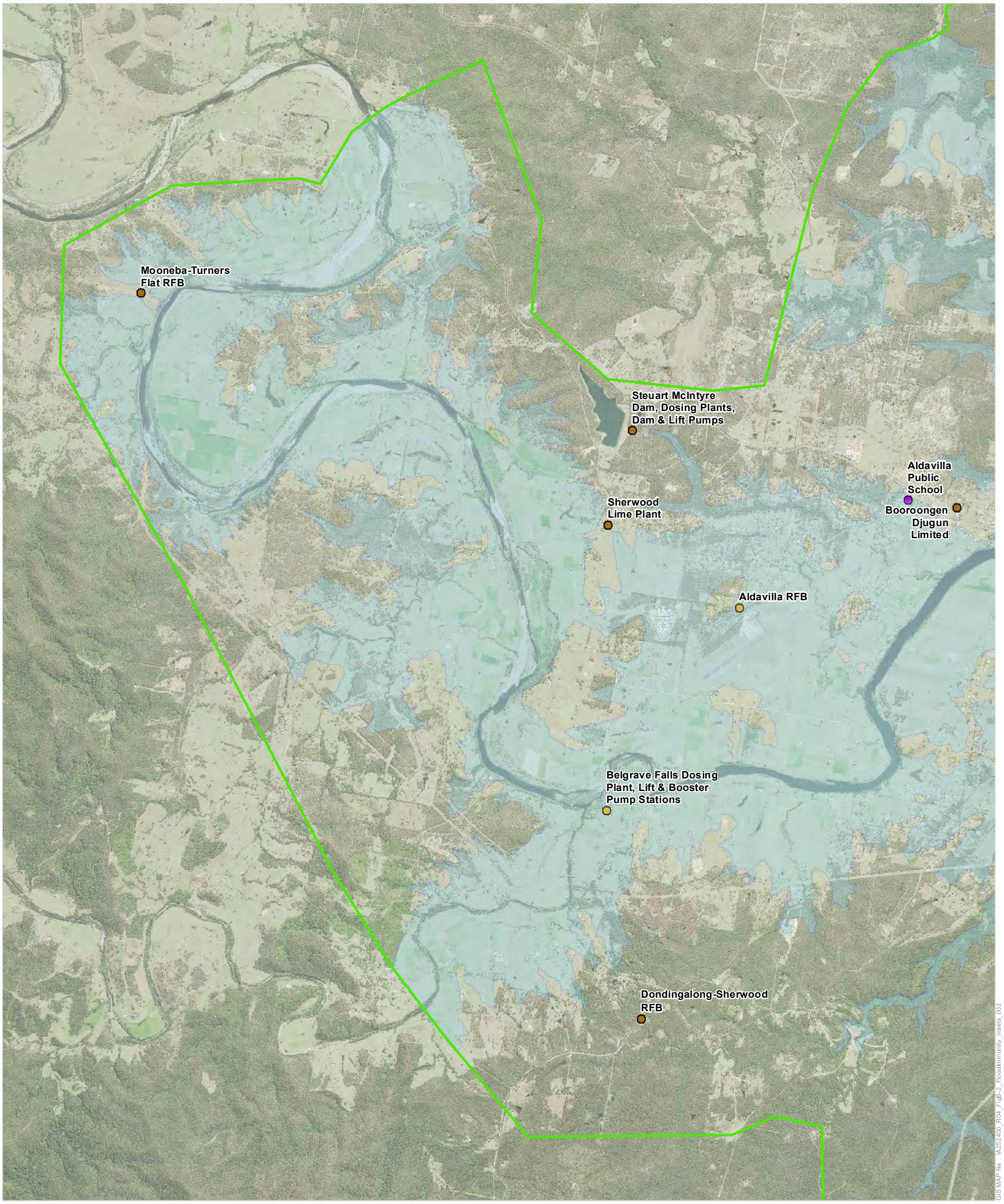
INSET # 3 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(C)	1 1
CHECK AH	DATE 16/02/2023		



Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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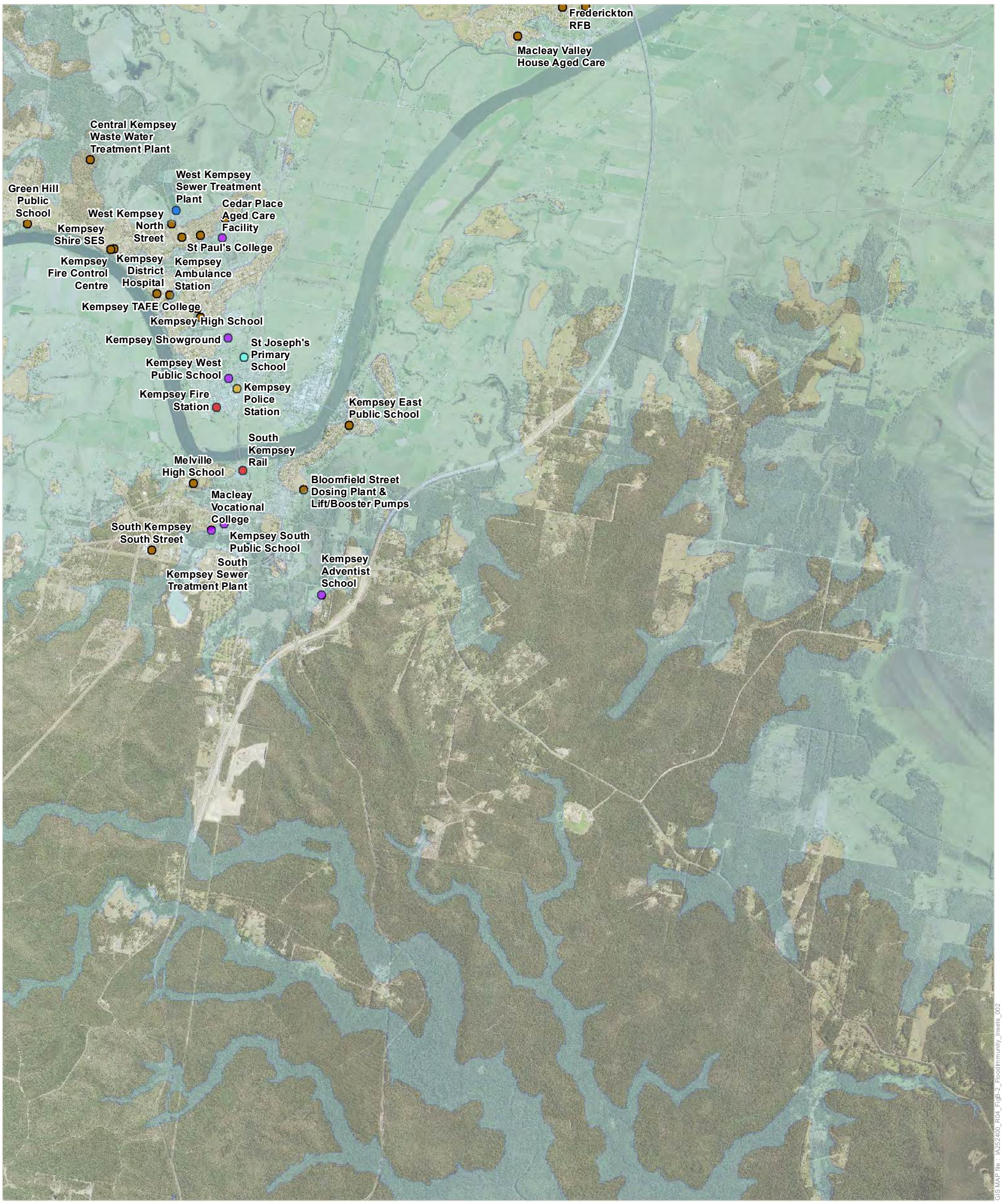
INSET # 4 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(D)	1 1
CHECK AH	DATE 16/02/2023		



GIS MAP file : IA252400_R04_FigB-2_FloodImmunity_Insets_002

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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A3

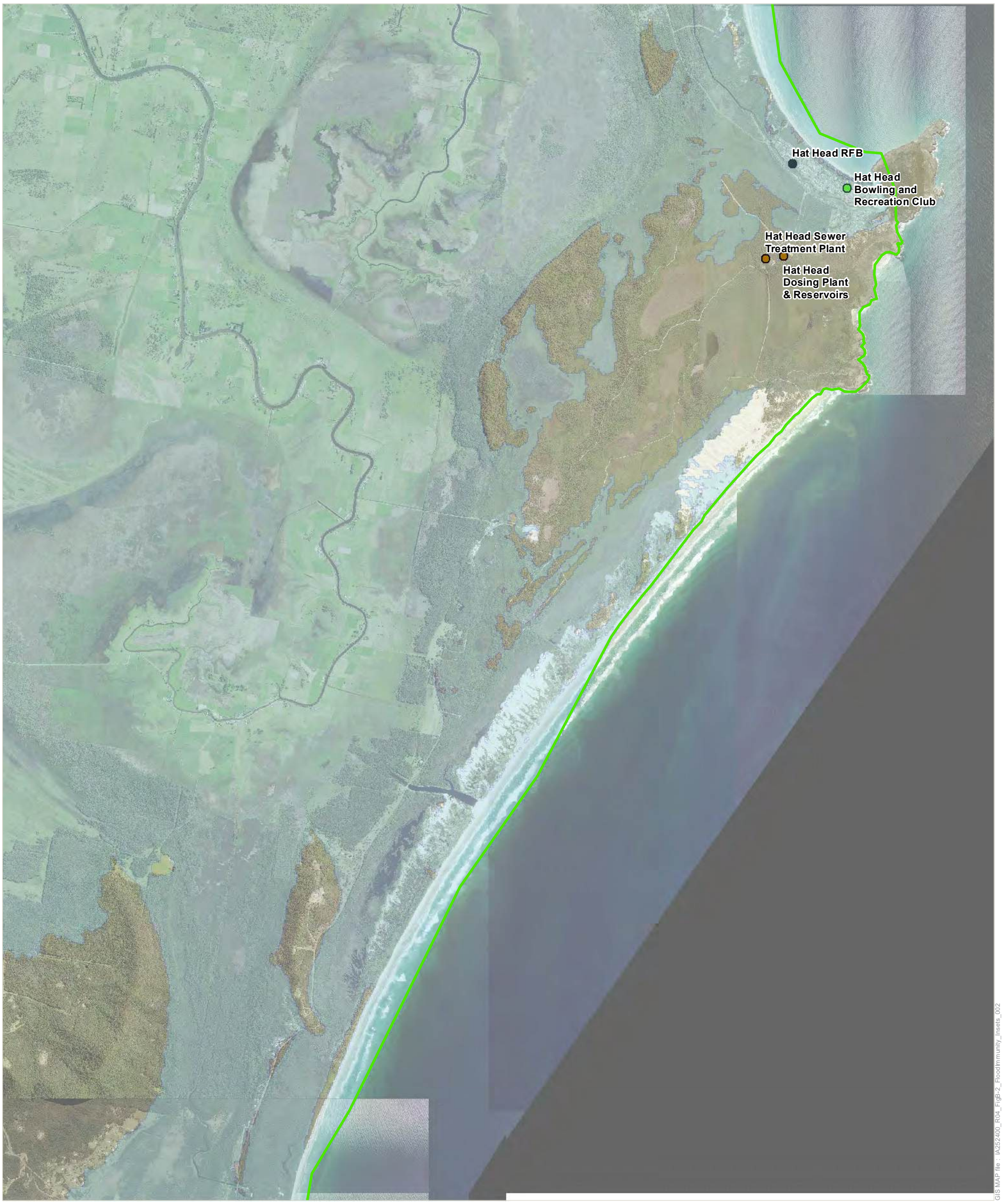
INSET # 5 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(E)	1 1
CHECK AH	DATE 16/02/2023		



GIS MAP file : IA252400_R04_FigB-2_FloodImmunity_Insets_002

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

- Limit of Mapping
- PMF Event Extent

0 0.5 1 2 Kilometres

N

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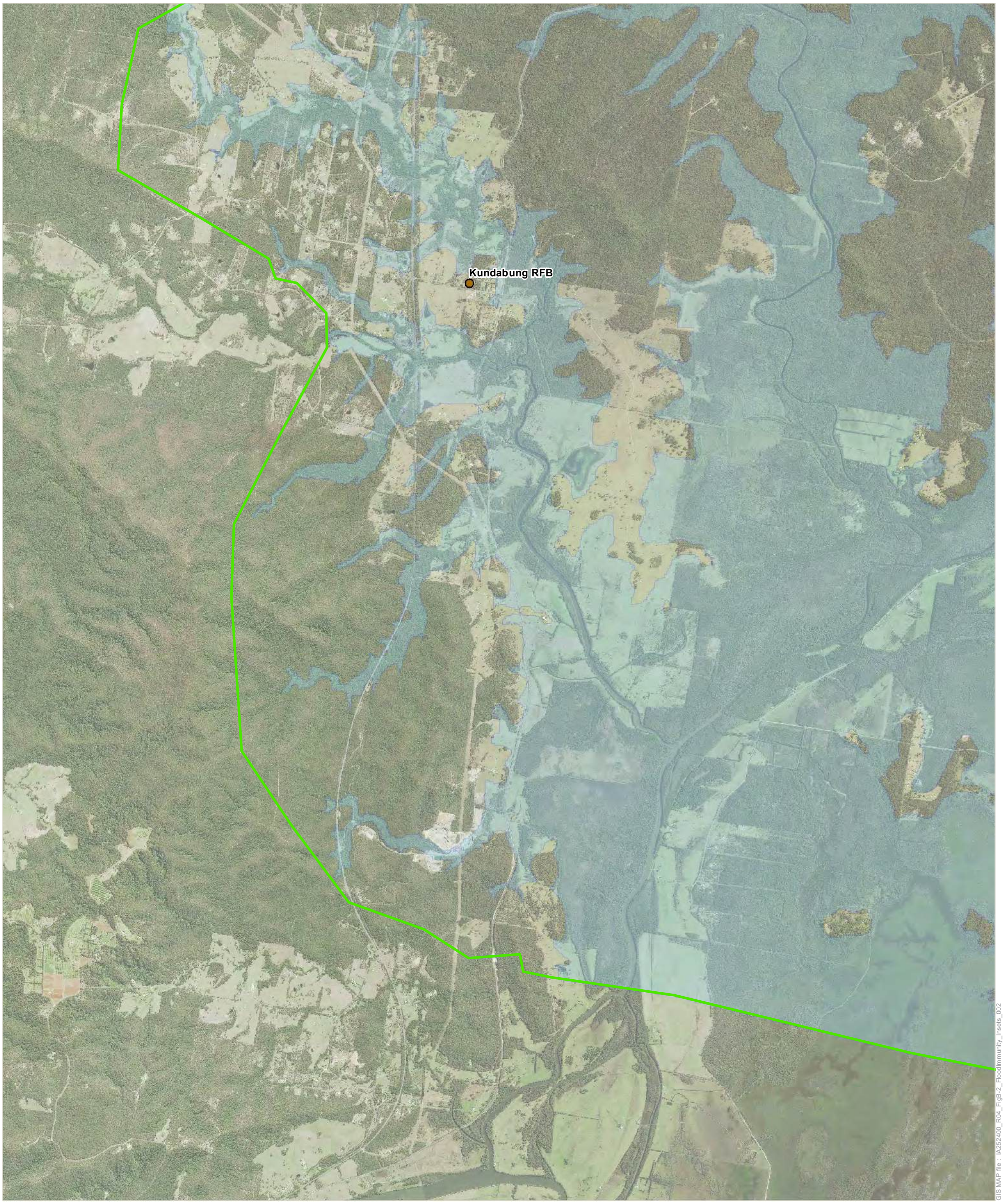
INSET # 6 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(F)	1 1
CHECK AH	DATE 16/02/2023		



GIS MAP file : IA252400_R04_FigB-2_FloodImmunity_Insets_002

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

Limit of Mapping

PMF Event Extent

0 0.5 1 2 Kilometres

N

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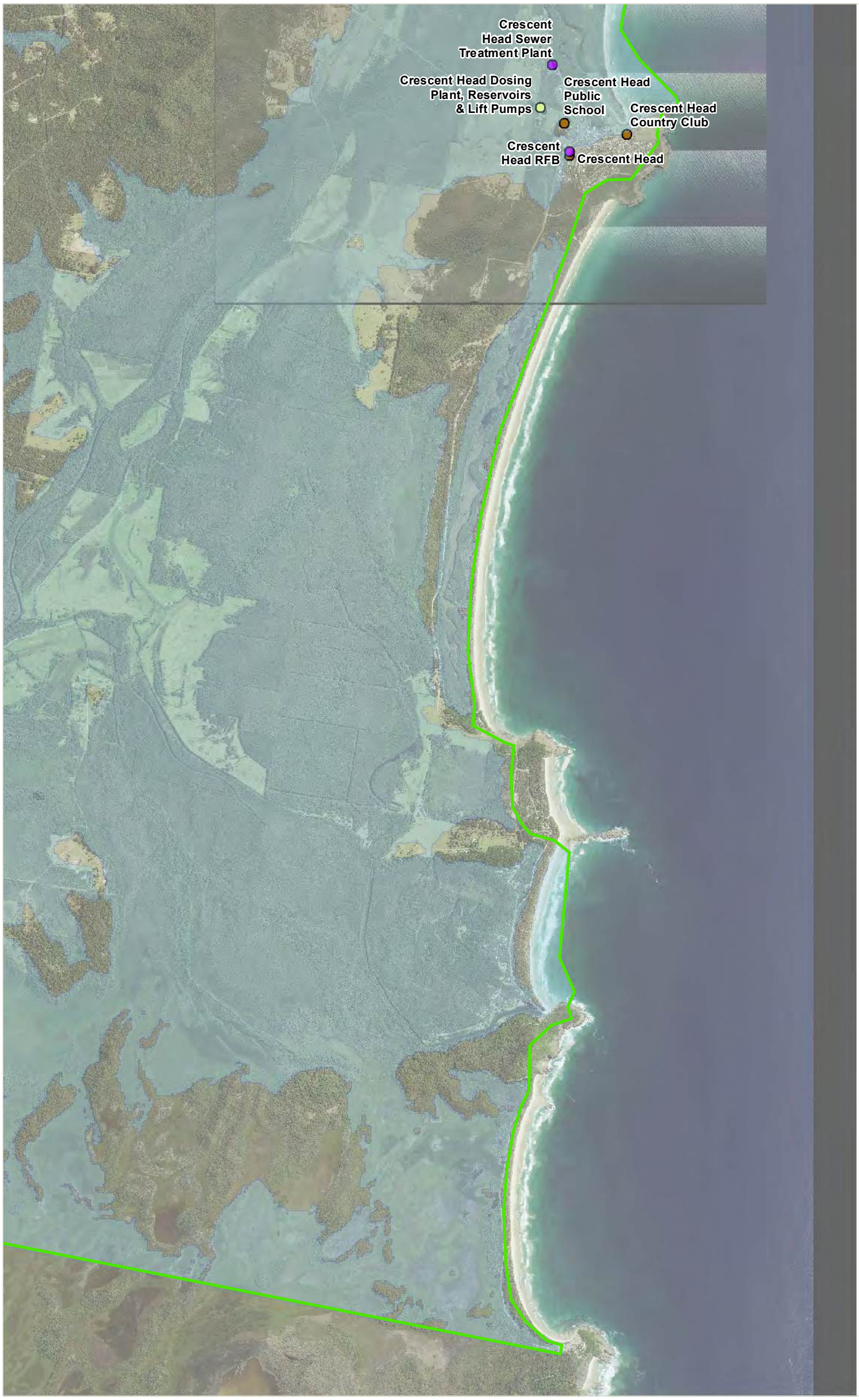
INSET # 7 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(G)[1]	1
CHECK AH	DATE 16/02/2023		



GIS MAP file : IA252400_R04_FigB-2_FloodImmunity_Insets_002

Legend

Flood immunity

- 50% - 20% AEP
- 20% - 10% AEP
- 10% - 5% AEP
- 5% - 2% AEP
- 2% - 1% AEP
- 1% - 0.5% AEP
- 0.5% - 0.2% AEP
- 0.2% AEP - PMF
- PMF

- Limit of Mapping
- PMF Event Extent

0 0.5 1 2 Kilometres

N

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INSET # 8 of 8

GDA 1994 MGA Zone 56

TITLE Flood Immunity Of Sensitive Properties

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #	REV VER
LC	IA252400	FIGURE D-2(H)	1 1
CHECK AH	DATE 16/02/2023		

Table D-2: Flood levels and flood immunity at sensitive facilities

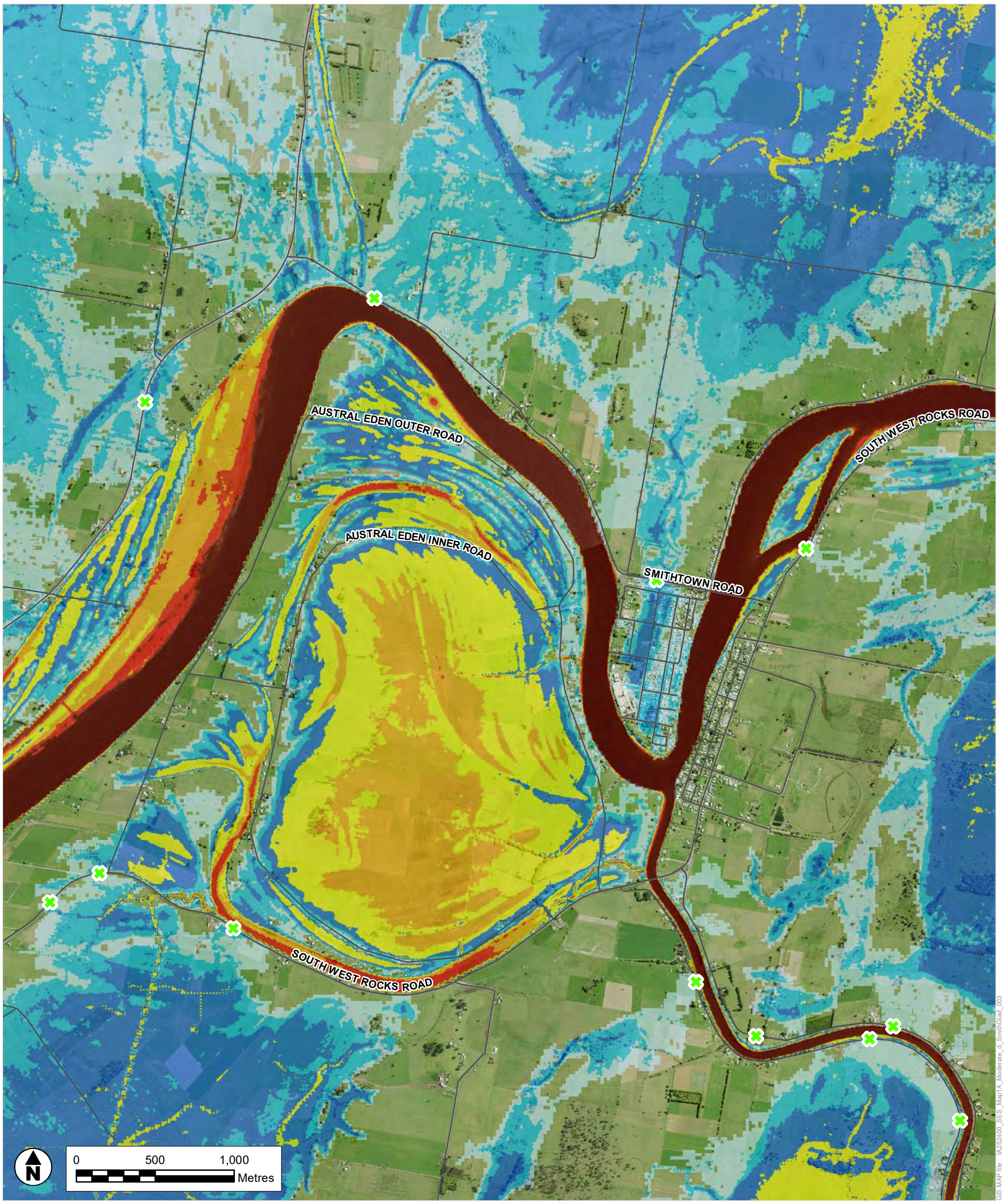
id	Description	Comment	Flood immunity (event when flooding commences)	Flood level (m AHD)										
				PMF	0.2%	0.5%	1% Climate change 2050	1% Climate change 2100	1%	2%	5%	10%	20%	50%
Emergency Facilities, Schools, Aged Care														
1	Crescent Head RFB		0.5% AEP - PMF	6.62										
2	Dondingalong-Sherwood RFB		PMF											
3	Mooneba-Turners Flat RFB		PMF											
4	Kundabung RFB		PMF											
5	Hat Head RFB		50% - 20% AEP	7.31	4.08	3.40	3.15	3.81	2.63	2.11	2.09	2.07	2.03	
6	Gladstone-Smithtown RFB		20% - 10% AEP	9.18	5.79	5.37	5.08	5.50	4.72	4.29	4.17	4.13		
7	Willawarrin RFB	Outside model domain	n/a											
8	Bellbrook RFB	Outside model domain	n/a											
9	South West Rocks RFB		PMF											
10	Collombatti RFB	Outside model domain	n/a											
11	Clybucca RFB		PMF											
12	Yarrahapinni (Yarrahapinni) RFB		PMF											
13	Eungai RFB	Outside model domain	n/a											
14	Warrell Creek RFB	Outside model domain	n/a											
15	Scotts Head RFB	Outside model domain	n/a											
16	Frederickton RFB		PMF											
17	Yarrahapinni (Stuarts Point) RFB		0.5% AEP - PMF	6.78										
18	Kempsey Fire Control Centre		PMF											
19	Wittitrin RFB	Outside model domain	n/a											
20	Kempsey Ambulance Station		PMF											
21	Scotts Head Public School	Outside model domain	n/a											
22	Medlow Public School	Outside model domain	n/a											
23	Bellbrook Public School	Outside model domain	n/a											
24	Bellbrook Police Station	Outside model domain	n/a											
25	Frederickton Public School		PMF											
26	Kempsey West Public School		0.5% AEP - PMF	15.03										
27	Willawarrin Public School	Outside model domain	n/a											

id	Description	Comment	Flood immunity (event when flooding commences)	Flood level (m AHD)										
				PMF	0.2%	0.5%	1% Climate change 2050	1% Climate change 2100	1%	2%	5%	10%	20%	50%
28	Eungai Public School	Outside model domain	n/a											
29	St Joseph's Primary School		10% - 5% AEP	13.41	8.64	8.31	8.06	8.30	7.81	7.42	6.73			
30	Kempsey Police Station		1% - 0.5% AEP	15.88	9.64	9.54	9.47	9.54						
31	Eungai Pre-School	Outside model domain	n/a											
32	Kempsey Fire Station		0.5% - 0.2% AEP	18.29	11.57									
33	Aldavilla Public School		0.5% AEP - PMF	23.73										
34	Kempsey High School		PMF											
35	St Paul's College		PMF											
36	Kempsey District Hospital		PMF											
37	Green Hill Public School		PMF											
38	Kempsey TAFE College		PMF											
39	Macleay Vocational College		0.5% AEP - PMF	13.00										
40	Kempsey East Public School		PMF											
41	Kempsey South Public School		0.5% AEP - PMF	15.02										
42	Melville High School		PMF											
43	Kempsey Adventist School		0.5% AEP - PMF	11.67										
44	Crescent Head Public School		PMF											
45	South West Rocks Public School		PMF											
46	Kinchela Public School		10% - 5% AEP	9.09	5.72	5.28	4.98	5.42	4.58	4.03	3.40			
47	Gladstone Public School		10% - 5% AEP	9.20	5.79	5.37	5.07	5.50	4.70	4.19	3.82			
48	Smithtown Public School		50% - 20% AEP	9.25	5.84	5.45	5.19	5.56	4.89	4.63	4.44	4.41	4.36	
49	Gladstone SES		2% - 1% AEP	9.25	5.81	5.40	5.11	5.52	4.81					
50	Gladstone Police Station		20% - 10% AEP	9.24	5.81	5.39	5.11	5.52	4.77	4.53				
51	Marine Rescue Trial Bay		PMF											
52	South West Rocks Preschool		PMF											
53	South West Rocks Police Station		PMF											
54	South West Rocks Ambulance Station		PMF											
55	Stuarts Point Public School		0.5% AEP - PMF	6.72										
56	Kempsey Shire SES		PMF											
57	South West Rocks SES	Could be affected by increased flooding due to future climate change. Access along Gordon Young Drive could be cut-off by local	0.5% - 0.2% AEP	7.45	4.67			4.42						

id	Description	Comment	Flood immunity (event when flooding commences)	Flood level (m AHD)										
				PMF	0.2%	0.5%	1% Climate change 2050	1% Climate change 2100	1%	2%	5%	10%	20%	50%
		flooding (not assessed in this study)												
58	South West Rocks Fire Station		2% - 1% AEP	8.90	5.55	5.09	4.76	5.25	4.31					
59	Aldavilla RFB		1% - 0.5% AEP	24.21	16.05	15.32	14.54	15.30						
60	Cedar Place Aged Care Facility		0.5% AEP - PMF	12.30										
61	BUPA Kempsey Aged Care		PMF											
62	Vincent Court Aged Care		PMF											
63	Japara The Mariner Aged Care		PMF											
64	Macleay Valley House Aged Care		PMF											
65	Temagog RFB	Outside model domain	n/a											
66	Booroongen Djugun Limited		PMF											
Evacuation Centres, Council Assets														
1	Crescent Head Sewer Treatment Plant		0.5% AEP - PMF	6.67										
2	Frederickton Sewer Treatment Plant		PMF											
3	Gladstone Sewer Treatment Plant		5% - 2% AEP	9.16	5.78	5.35	5.06	5.48	4.69	4.19				
4	Hat Head Sewer Treatment Plant		PMF											
5	South Kempsey Sewer Treatment Plant		10% - 5% AEP	12.68	8.59	8.09	7.94	8.33	7.53		7.19			
6	South West Rocks Sewer Treatment Plant	Outside model domain	PMF											
7	West Kempsey Sewer Treatment Plant		20% - 10% AEP	12.17	8.33	8.03	7.81	8.03	7.59	7.25	6.68	6.24		
8	Central Kempsey Waste Water Treatment Plant		PMF											
9	Crescent Head Country Club		PMF											
10	Kempsey Showground		0.2% AEP - PMF	13.32										
11	Willawarrin Showground	Outside model domain	PMF											
12	South West Rocks Country Club	Outside model domain	PMF											
13	Hat Head Bowling and Recreation Club		5% - 2% AEP	7.04	3.88	3.14	3.05	3.65	2.64	2.20				
14	Gladstone Oval		50% - 20% AEP	9.16	5.78	5.35	5.06	5.48	4.69	4.19	3.41	2.61	2.04	
15	Jon Donavon Sporting Complex		0.2% AEP - PMF	6.76										
16	Hat Head Dosing Plant & Reservoirs		PMF											
17	South West Rocks WTP & Lift Pumps		0.2% AEP - PMF	8.90										
18	South West Rocks Balance Tank & Lift Pump Station		PMF											
19	Stuarts Point WTP & Lift Pumps		0.5% - 0.2% AEP	7.55	5.89									
20	Kinchela Emergency WTP & Lift Pumps		1% - 0.5% AEP	9.08	5.72	5.28		5.42						
21	Sherwood Lime Plant		PMF											

id	Description	Comment	Flood immunity (event when flooding commences)	Flood level (m AHD)										
				PMF	0.2%	0.5%	1% Climate change 2050	1% Climate change 2100	1%	2%	5%	10%	20%	50%
22	Steuart McIntyre Dam, Dosing Plants, Dam & Lift Pumps	Above flood model domain but may be exposed to dam overflows	PMF											
23	Willawarrin Dosing Plant	Outside model domain	n/a											
24	Bellbrook WTP	Outside model domain	n/a											
25	Crescent Head Dosing Plant, Reservoirs & Lift Pumps		2% - 1% AEP	6.65	4.71	4.37	4.18	4.54	3.87					
26	Belgrave Falls Dosing Plant, Lift & Booster Pump Stations		1% - 0.5% AEP	25.80	17.76	17.28	16.95	17.28						
27	Bloomfield Street Dosing Plant & Lift/Booster Pumps		PMF											
28	Bellimbopinni Chlorinator		20% - 10% AEP	9.29	5.84	5.40	5.08	5.54	4.69	4.14	3.87	3.80		
29	South West Rocks Recycled WTP	Outside model domain	n/a											
30	Thunggutti Dosing Plant	Outside model domain	n/a											
Main Electrical Substations														
1	South Kempsey South Street		PMF											
2	Smithtown		5% - 2% AEP	9.23	5.84	5.44	5.17	5.56	4.86	4.50				
3	Crescent Head		PMF											
4	South Kempsey Rail		0.5 - 0.2% AEP	18.74	11.18									
5	West Kempsey North Street		PMF											
6	South West Rocks		PMF											

Appendix E. SES Access Routes flood cut locations



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

✖ Key road first flooded location in Moderate Flood

Road

Flood event shown is the Moderate Flood at Kempsey (5.7m at Kempsey gauge).

The map indicates the locations where key roads become flooded in Minor or Moderate Flood events or early in larger flood events. Other road locations may become flooded as flood magnitude increases.

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Flood Depth Moderate Flood at Kempsey Gauge Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 13/02/2023	FIGURE E-1

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Key road first flooded location in Moderate Flood

Road

Flood event shown is the Moderate Flood at Kempsey (5.7m at Kempsey gauge).

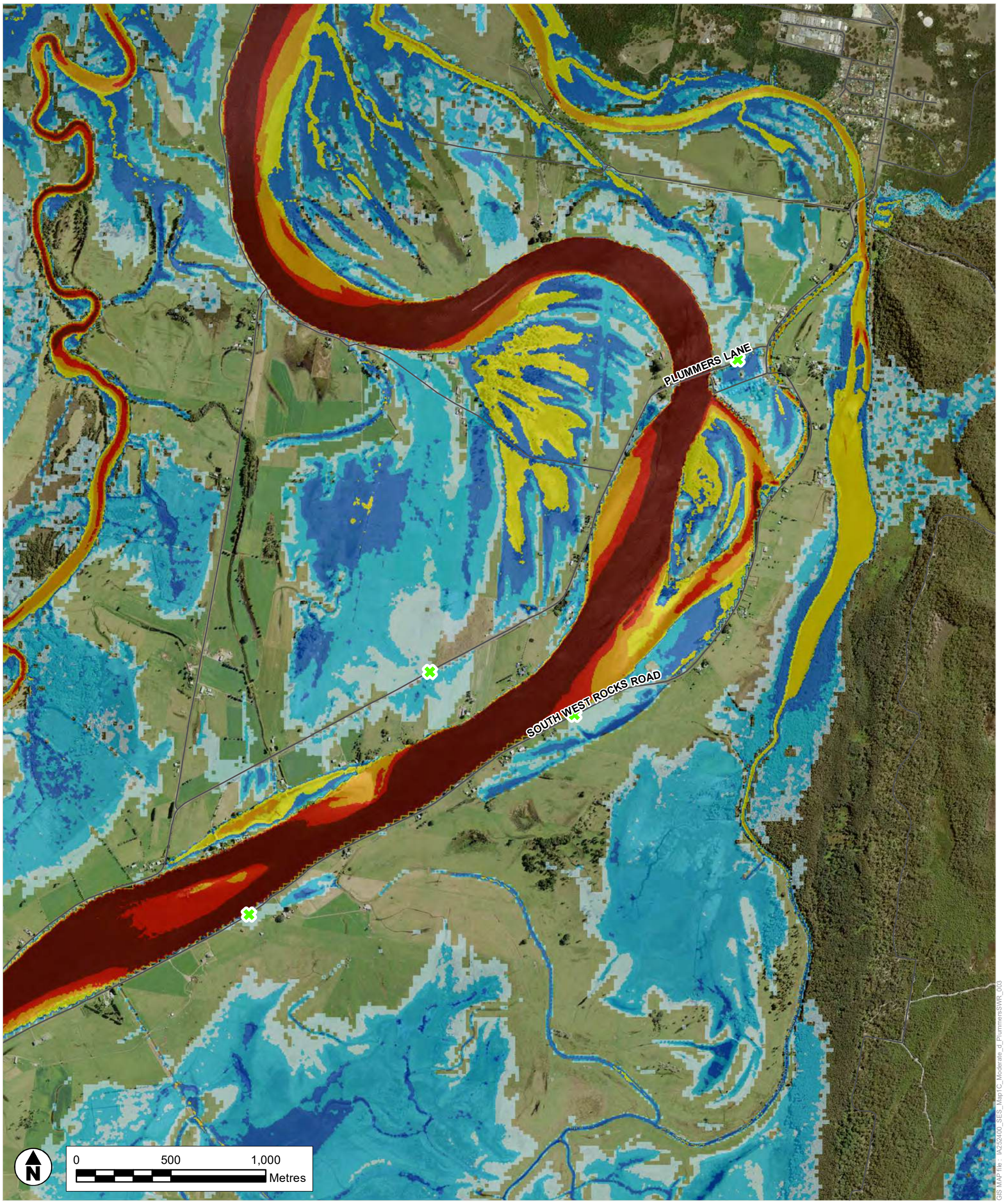
The map indicates the locations where key roads become flooded in Minor or Moderate Flood events or early in larger flood events. Other road locations may become flooded as flood magnitude increases.

Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Flood Depth Moderate Flood at Kempsey Gauge Kinchela		
PROJECT	Lower Macleay River Floodplain Risk Management Study		
DRAWN LC	PROJECT # IA252400	MAP #	
CHECK AH	DATE 13/02/2023	FIGURE E-2	



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

✖ Key road first flooded location in Moderate Flood

Road

Flood event shown is the Moderate Flood at Kempsey (5.7m at Kempsey gauge).

The map indicates the locations where key roads become flooded in Minor or Moderate Flood events or early in larger flood events. Other road locations may become flooded as flood magnitude increases.

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A3

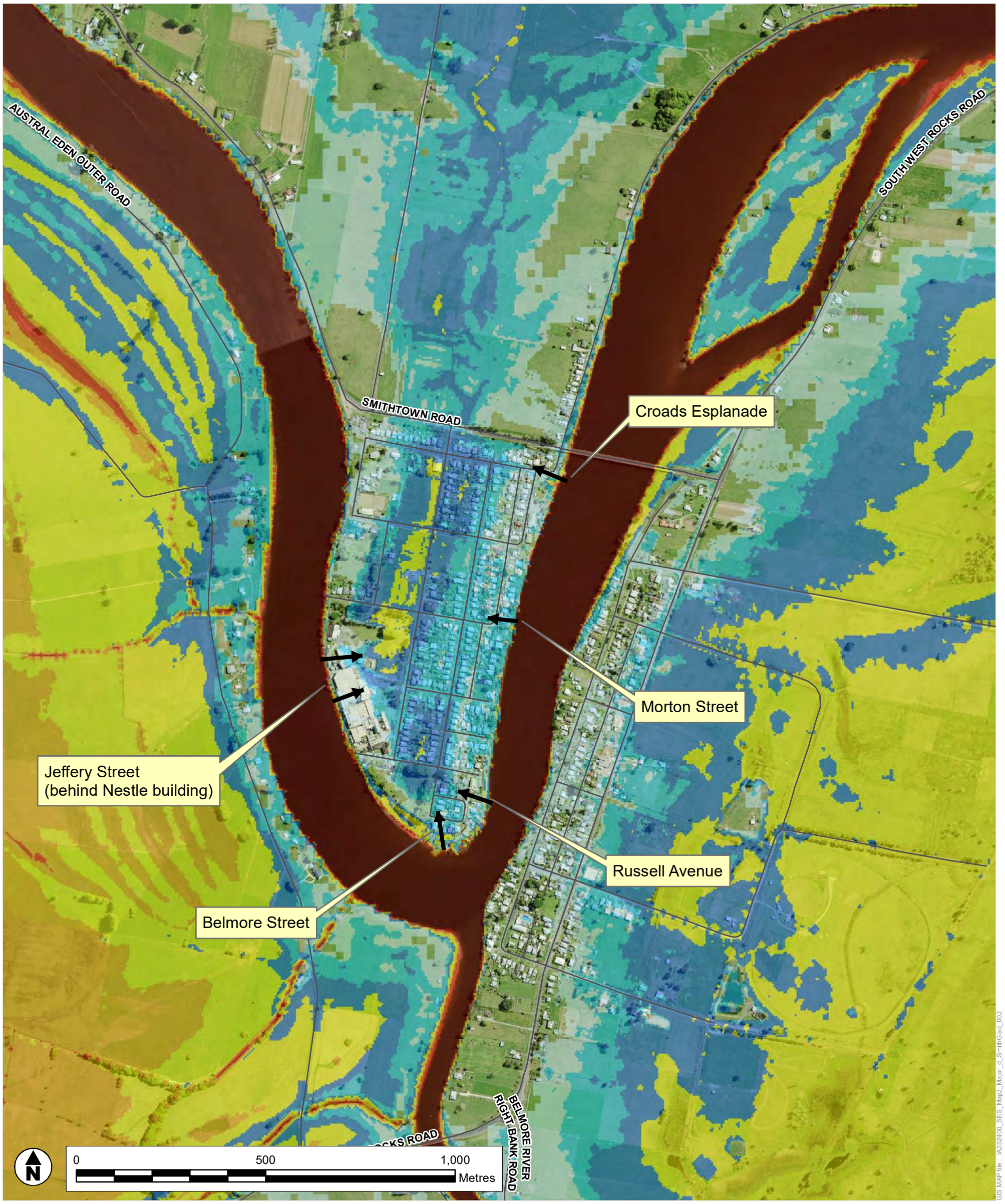
SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE Flood Depth
Moderate Flood at Kempsey Gauge
Plummers Lane and SWR Road

PROJECT Lower Macleay River Floodplain Risk Management Study

DRAWN	PROJECT #	MAP #
LC	IA252400	FIGURE E-3
CHECK AH	DATE 13/02/2023	



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Locations of first flood overflows into Smithtown

Road

Flood event shown is the Major Flood at Kempsey (6.6m at Kempsey gauge).

Jacobs

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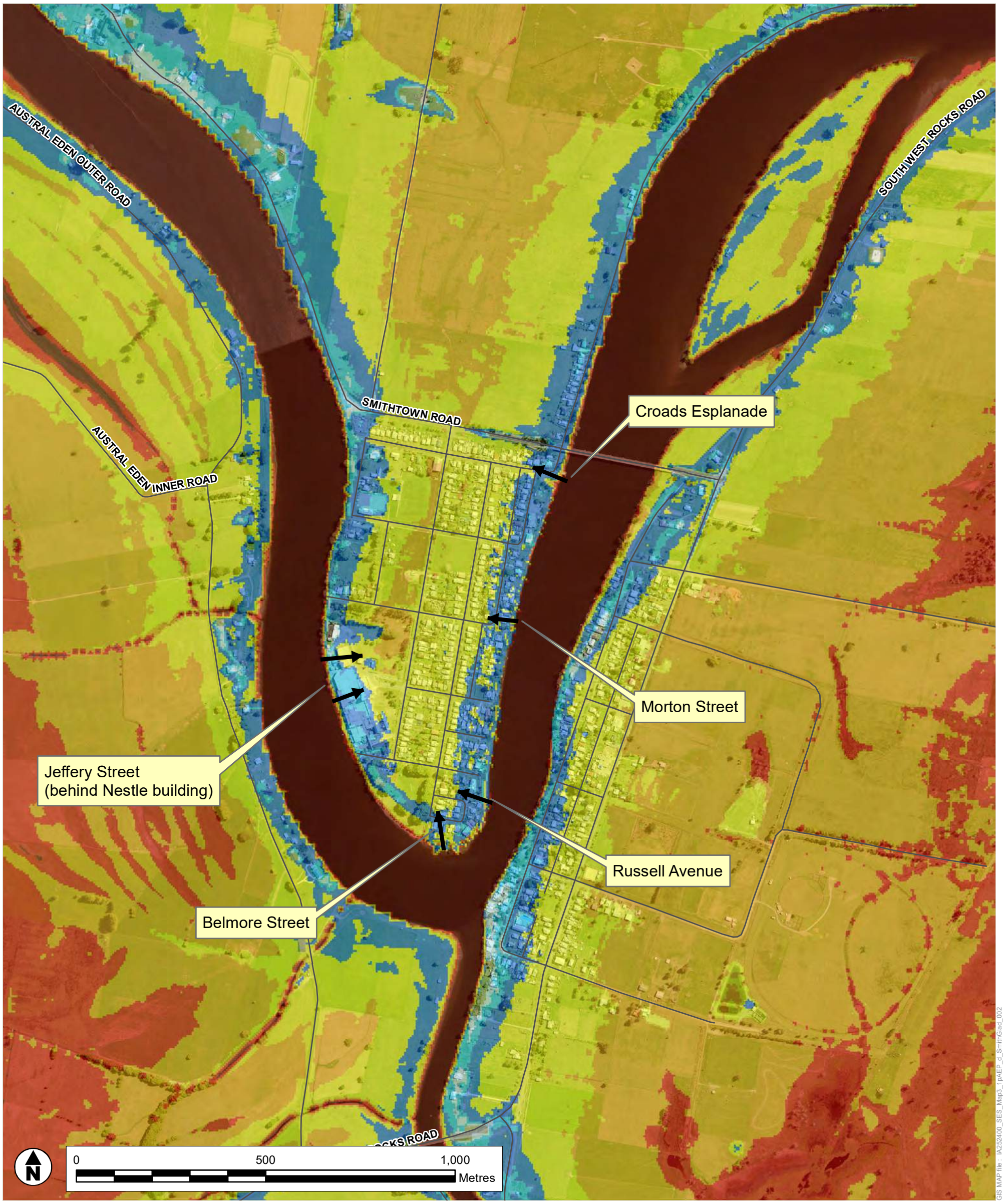
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Flood Depth Major Flood at Kempsey Gauge Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 13/02/2023	FIGURE E-4



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Locations of first flood overflows into Smithtown Road

Flood event shown is the 1% AEP design flood event (8.42m at Kempsey gauge).

Jacobs

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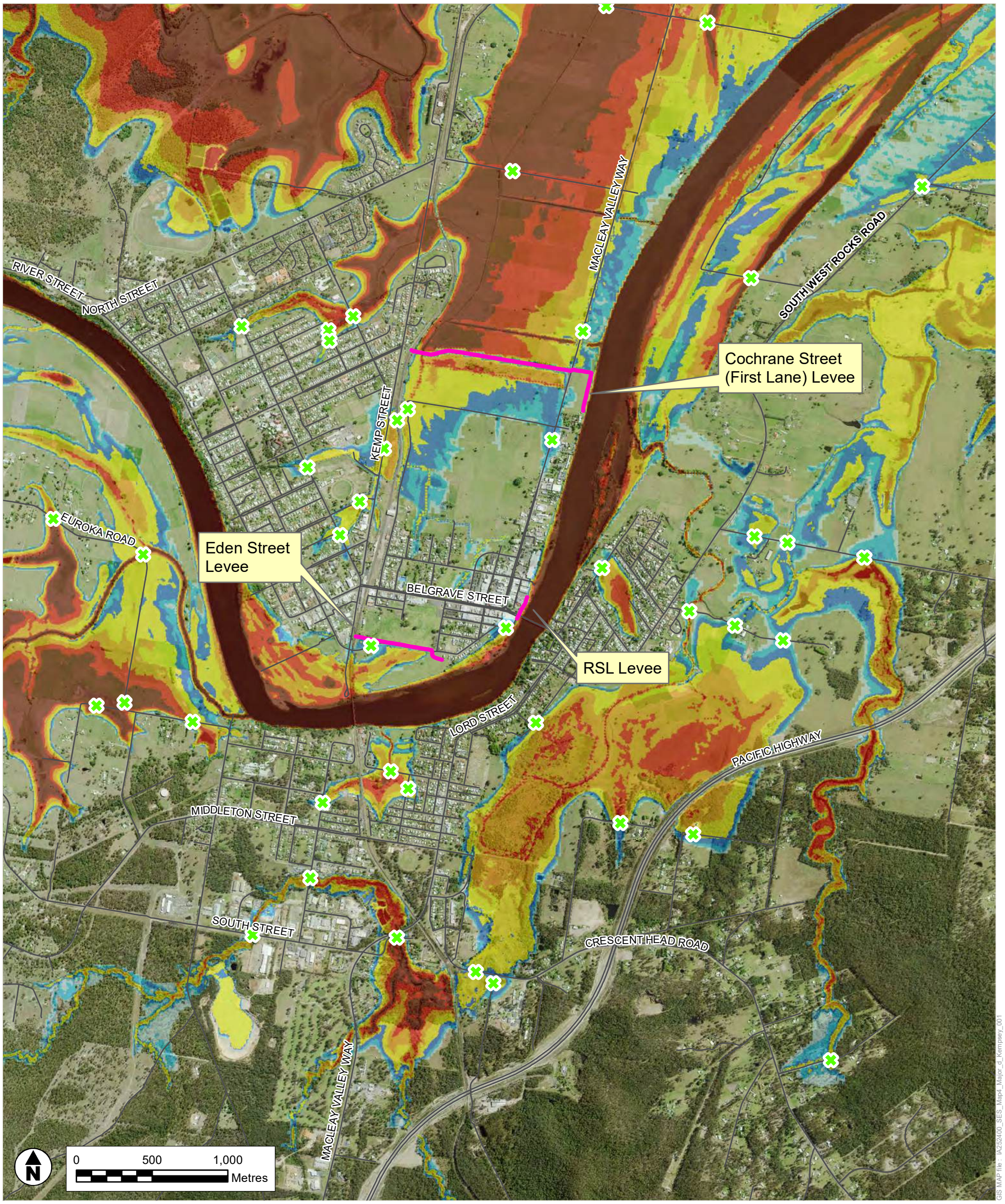
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Flood Depth 1% AEP Flood Smithtown and Gladstone	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 13/02/2023	FIGURE E-5

GIS MAP file : IA252400_SES_Map3_1pAEP_d_SmithGlad_002



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Levee

Road

Road cut location

Flood event shown is the Major Flood at Kempsey (6.6m at Kempsey gauge).

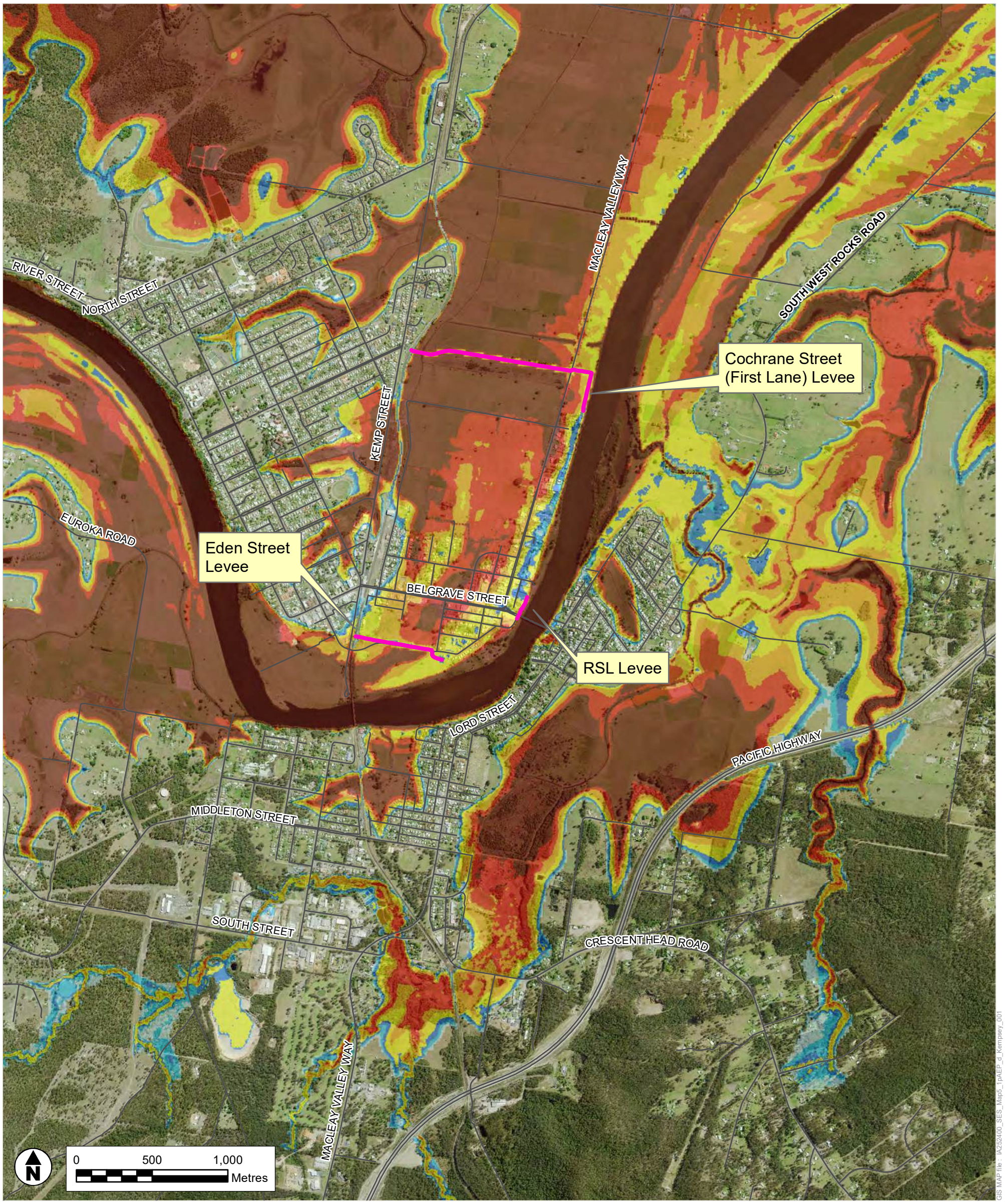
Jacobs

LIMITATIONS: This mapping is based on data and assumptions identified in the Lower Macleay Flood Study prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy ofinformation contained in this map.

A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Flood Depth Major Flood at Kempsey Gauge Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP #
CHECK AH	DATE 29/11/2022	FIGURE E-6

GIS MAP file : IA252400_SES_Map4_Major_d_Kempsey_001



Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Levee
- Road

Flood event shown is the 1% AEP design flood event (8.42m at Kempsey gauge).

Jacobs

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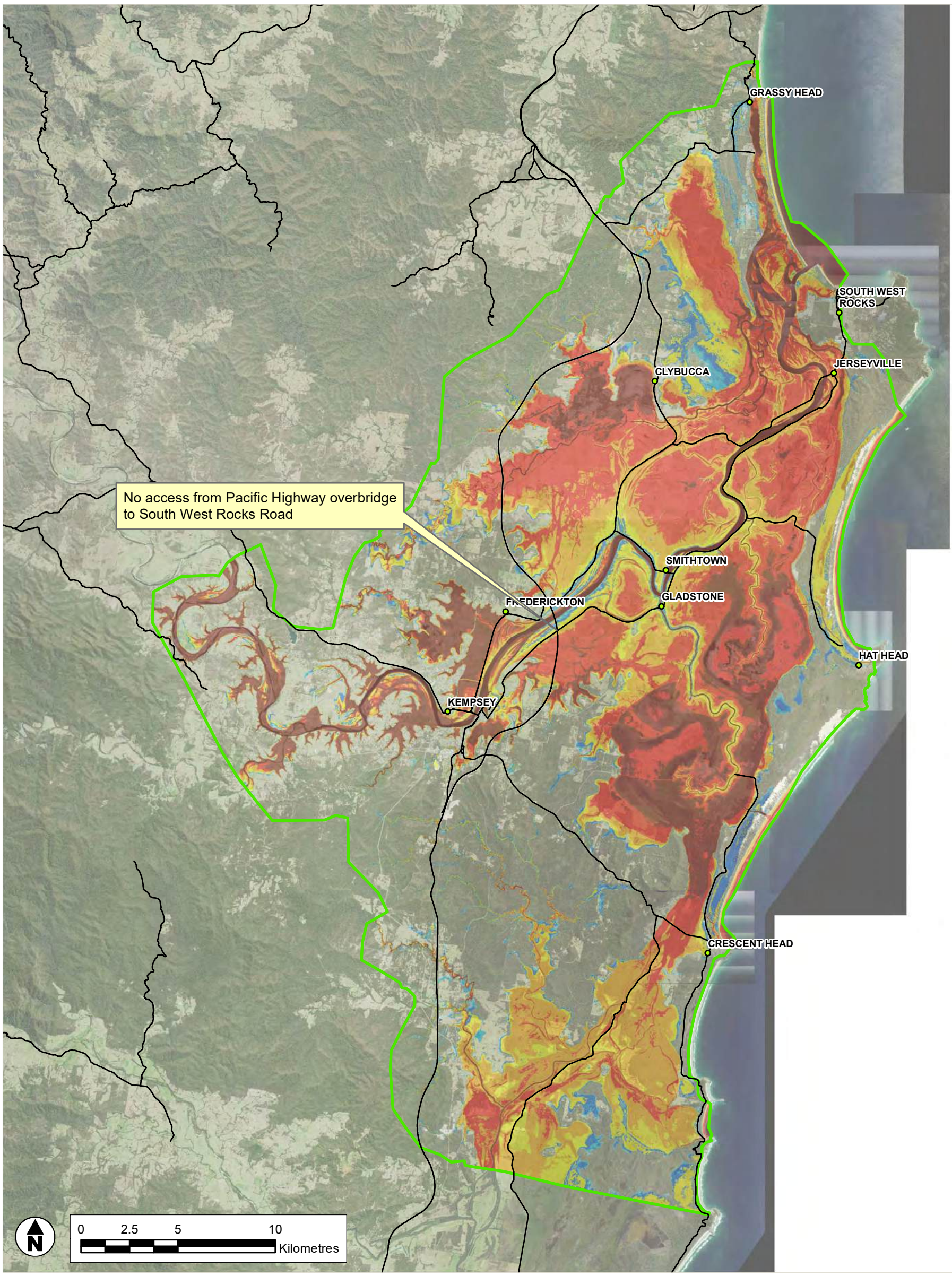
A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Flood Depth 1% AEP Flood Kempsey	
PROJECT	Lower Macleay River Floodplain Risk Management Study	
DRAWN LC	PROJECT # IA252400	MAP # FIGURE E-7
CHECK AH	DATE 29/11/2022	

GIS MAP file : IA252400_SES_Map5_1pAEP_d_Kempsey_001



GIS MAP file : IA252400_SES_Map6_1pAEP_d_KeyRoadsNoLabel_002

Legend

Depth (m)

- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

- Main Access Road
- Limit of Mapping

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A3

SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	1% AEP Event Flood Depth and Key Access Roads	
PROJECT	Lower Macleay River Floodplain Risk Management Study	

DRAWN	PROJECT #	MAP #	REV	VER
CC	IA252400	FIGURE E-8	1	1
CHECK	DATE			
LC	15/02/2023			

Appendix F. Mitigation options flood modelling and constraints assessment

F.1 Options assessment

A number of potential flood modification measures were identified for consideration in the Flood Impacts and Flood Planning Report (Jacobs, 2023) based on review of the existing flooding impacts, consultation with Council staff and previous consultation with the community during the Lower Macleay Flood Study (Jacobs, 2019). The focus of the identified potential options is on the Lower Macleay floodplain. The Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017) primarily considered options for mitigating flood risk around the CBD, and it is not the focus of this current study to revisit these CBD options.

Most of the identified options are aimed at reducing the time to drain the floodplain following a flood peak. It is acknowledged that it is not feasible to significantly reduce peak flooding in the Macleay, particularly in major events. Some options consider improvements to flood access, with modelling to assess potential resultant impacts recommended. There are a range of floodplain environmental management issues relevant to the Lower Macleay and it is outside the scope of this study to specifically address these in detail, although assessment of the identified options makes consideration of these environmental constraints and issues at a broad level.

The following sections describe the options and effects on flooding. Changes in peak flood levels and durations of flooding were estimated for each option in the TUFLOW model. The 1%, 5%, 10% and 20% AEP events for the critical durations (96 hour duration for 5% AEP; 72 hour duration for the other events) were assessed. Reductions in flooding, or conversely resultant increases in flooding, due to the options were noted.

Refer to the main body of this FRMSP report for discussion on the following aspects of the options assessment:

- Cost estimates of options
- Economic appraisal of benefits and impacts including cost-benefit assessment over the life of the options
- Multi-criteria assessment, considering non-economic factors.

F.2 Option 1 and 1A – Raising Crescent Head Road at The Corduroy

Discussion

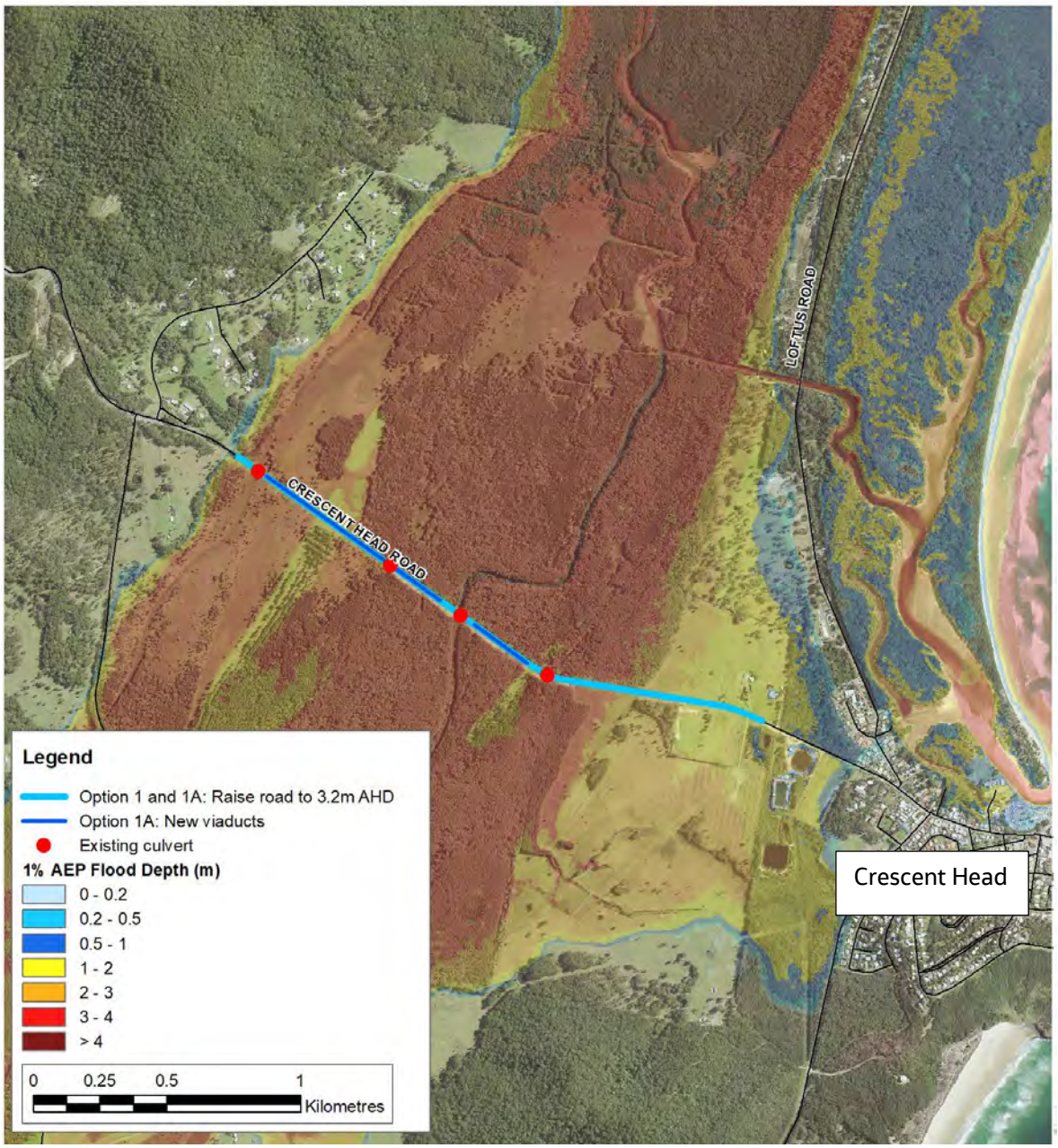
Several options for raising Crescent Head Road at The Corduroy, on the Connection Creek floodplain to the west of Crescent Head, have been assessed in the TUFLOW model. The existing road has an elevation of about 1.5m AHD at its low point and is susceptible to becoming inundated and cutting off Crescent Head during flood events.

Options of raising the road by 0.1m, 0.3m and 0.6m and to an elevation of 3.2m AHD have previously been considered. Raising the road to 3.2m AHD would involve an increase in height of the road by up to 1.7m, to approximately 0.1m above the existing 5% AEP flood level. This was assessed as per the following:

- Option 1 – raising the road to 3.2m AHD with no improvement to existing transverse drainage across the road
- Option 1A – raising the road to 3.2m AHD and replacing the existing transverse drainage as required with viaducts totalling 1km long.

Figure F-1 illustrates the extent of road raising and of proposed viaducts.

Figure F-1: Option 1 and 1A Raise Crescent Head Road at The Corduroy



The existing road is overtopped in the 50% AEP design flood. Peak flow rates from the Macleay River floodplain to the Hastings River floodplain at Crescent Head Road during flood events range from 116m^3/s in the 20% AEP event, to 697m^3/s in the 5% AEP event and 1405m^3/s in the 1% AEP event. Only a small portion of this flow is conveyed by the existing transverse drainage, with the majority overflowing over the road. With a raised road option, significant upgrade of the transverse drainage capacity would be required to maintain peak flood levels near existing levels.

Effects on flooding – Option 1 Raise road with no drainage upgrades

Raising Crescent Head Road to 3.2m AHD without upgrades to transverse drainage results in flood impacts of up to 0.2m in the 20% AEP event, up to 0.35m in the 5% AEP event and up to 0.1m in the 1% AEP event. Increases in peak flood levels of 0.04 – 0.1m in the 20% AEP event extend to Kinchela. Increases in peak flood levels of 0.04 – 0.07m in the 5% AEP event and up to 0.02m in the 1% AEP event extend across the Lower Macleay floodplain, up to Stuarts Point. There are reductions in peak flood levels to the south of the road of up to 0.06m in the 20% and 1% AEP events and up to 0.2m in the 5% AEP event. Refer to Figure F-2 to Figure F-4.

Figure F-5 indicates reductions of 170 hours in the duration that Crescent Head Road is cut off by flooding in the 5% and 1% AEP events, with the duration reducing from 210 - 250 hours with the existing road to about 40 - 80 hours with the road raising. Additionally, the road becomes flood-free in up to and including the 10% AEP event with the road raising, while it is flooded in the 20% AEP event in the existing case. However, durations of flooding to areas and properties to the north of Crescent Head Road would be increased by up to 24 hours in the 20% AEP event with Option 1.

Figure F-2: Option 1 – Change in peak flood level from existing case – 20% AEP event

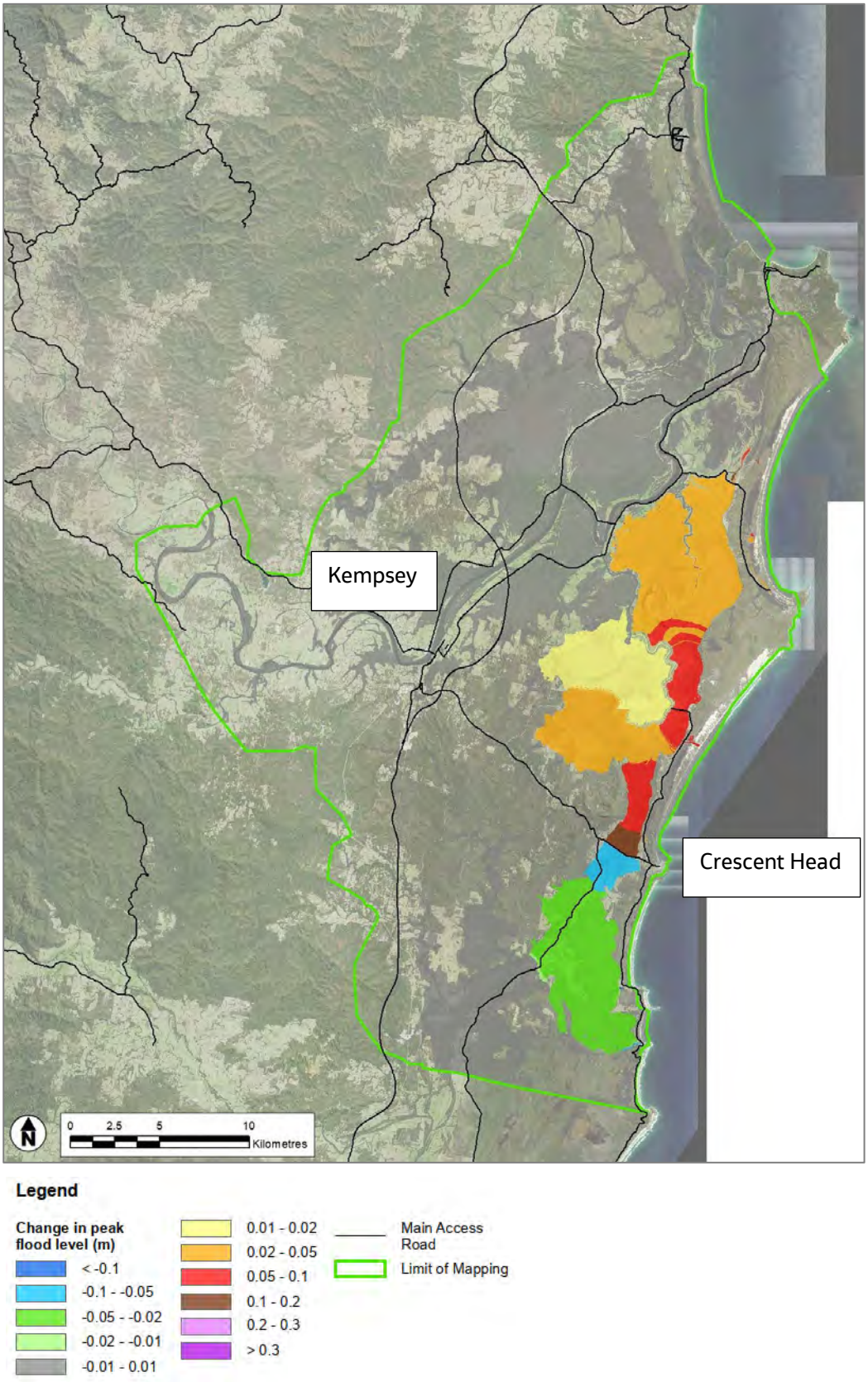


Figure F-3: Option 1 – Change in peak flood level from existing case – 5% AEP event

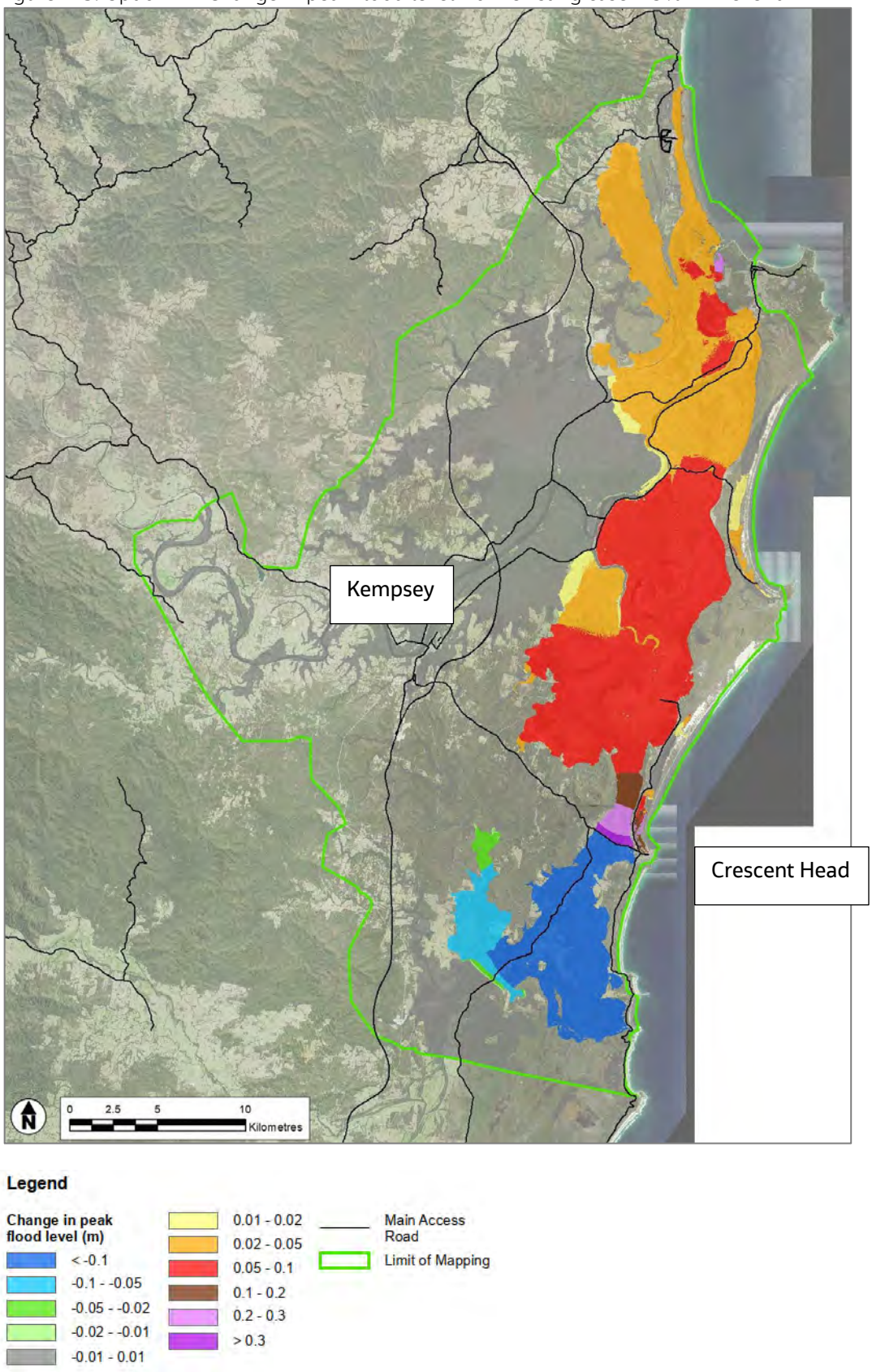


Figure F-4: Option 1 – Change in peak flood level from existing case – 1% AEP event

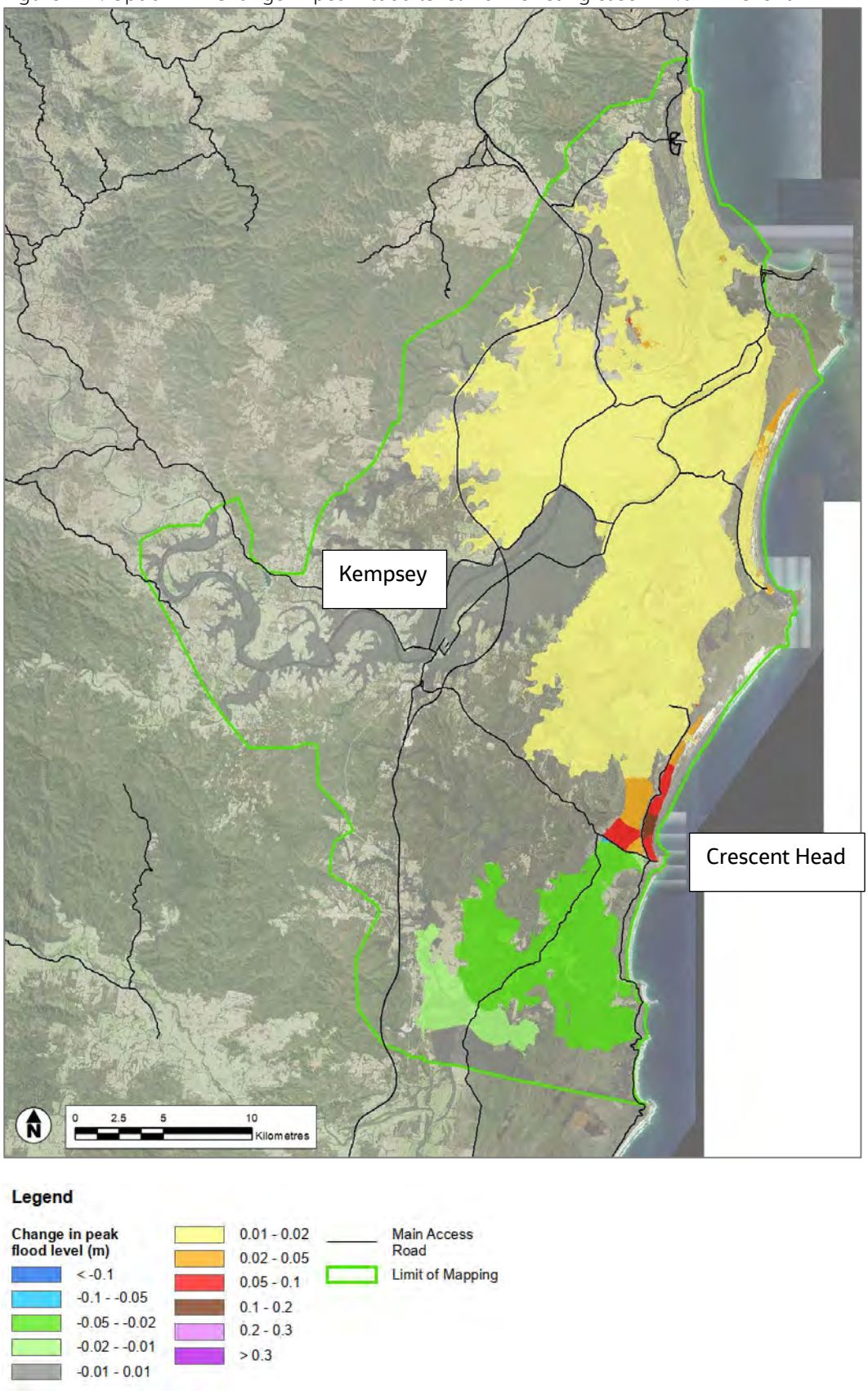
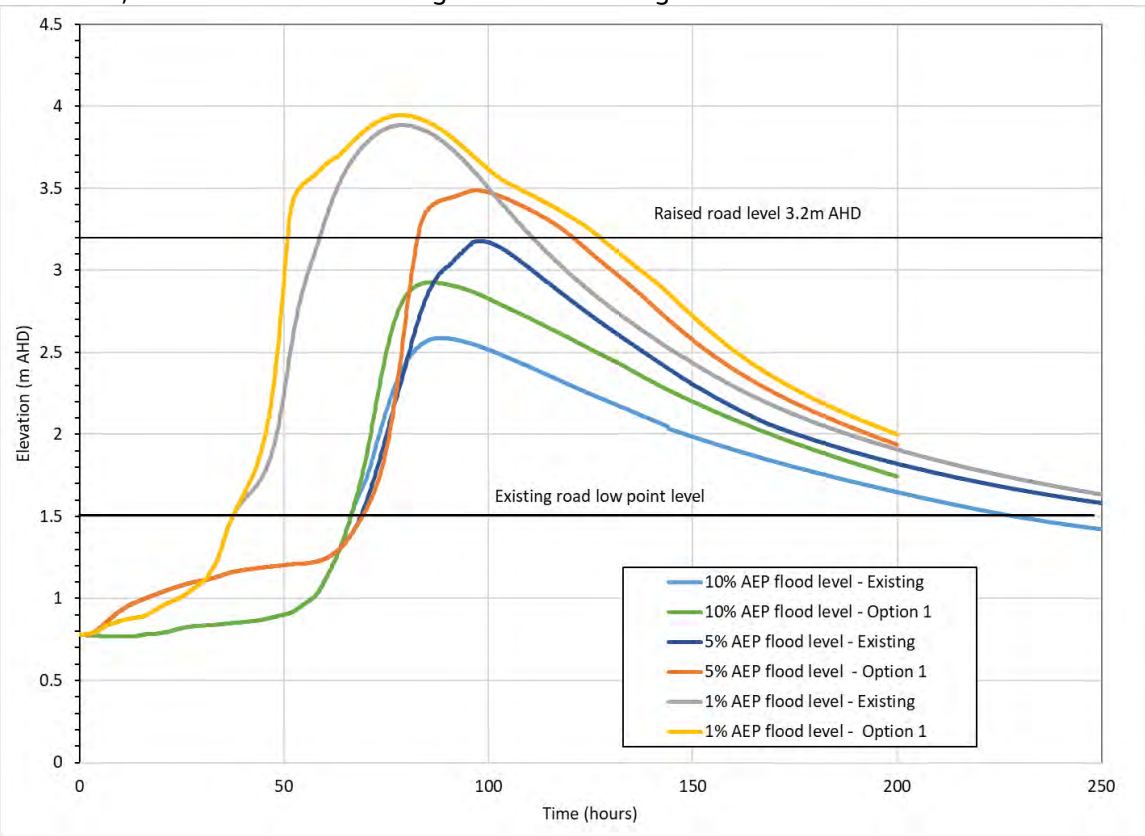


Figure F-5: Option 1 – Flood levels versus time at Crescent Head Road, Existing road compared with raising to 3.2m AHD, no modification to existing transverse drainage

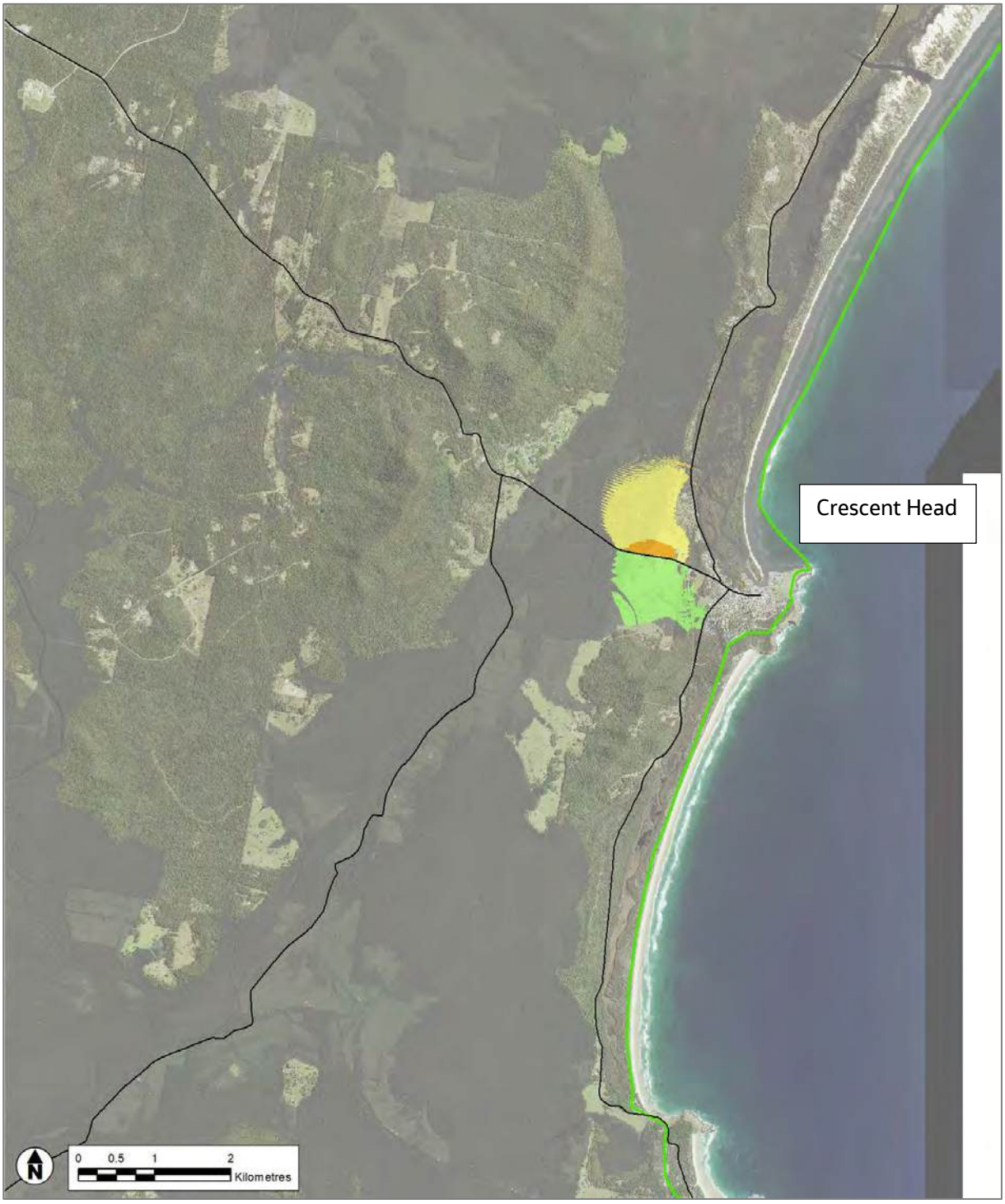


Effects on flooding – Option 1A Raise road with viaducts

Flooding impacts for Option 1A are lower than for Option 1 due to the viaducts conveying flood flows across the raised road. Changes in flood levels are negligible to minor, less than 0.01m in the 20% AEP event and 0.02 – 0.03m in the 10% and 1% AEP events to the north of Crescent Head Road. Flood level increases are up to 0.06m in the 5% AEP event, affecting several properties and buildings, and limited to 4km from Crescent Head Road. The change in flood levels are mapped for the 10%, 5% and 1% AEP events on Figure F-6 to Figure F-8, respectively.

Figure F-9 shows reductions of around 200 hours in the duration that Crescent Head Road is cut off by flooding in the 5% and 1% AEP events, with the duration reducing from 210 - 250 hours with the existing road to 4 hours in the 5% AEP event and 54 hours in the 1% AEP event with the road raising. Additionally, the road becomes flood-free in up to and including the 10% AEP event with the road raising, while it is flooded in the 20% AEP event in the existing case. Additionally, there are minor reductions in the duration of flooding of 8 – 10 hours for the 10%, 5% and 1% AEP events as the viaduct allows floodwaters to flow to the south more freely compared to the existing road embankment.

Figure F-6: Option 1A – Change in peak flood level from existing case – 10% AEP event



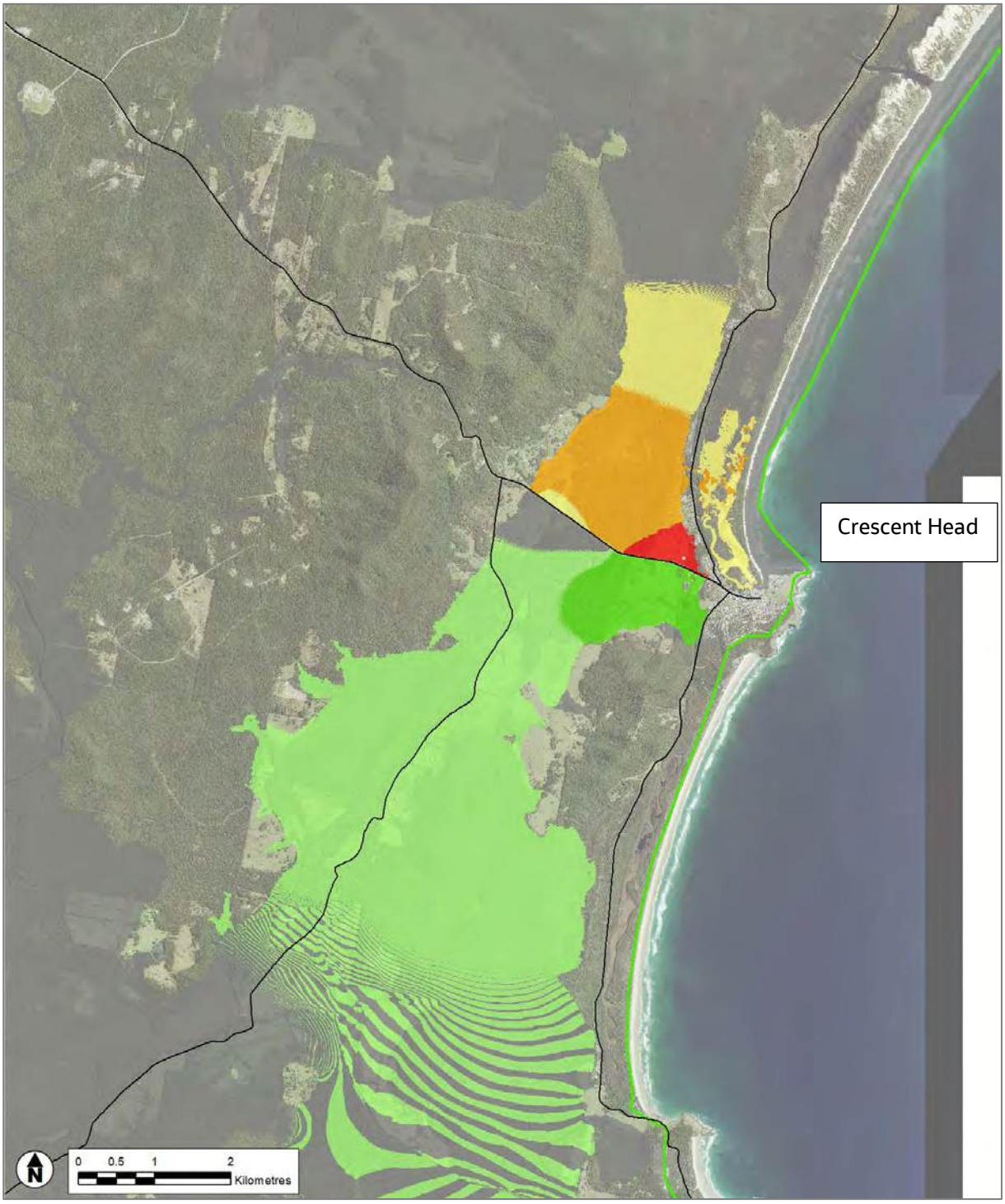
Legend

Change in peak flood level (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3

- Main Access Road
- Limit of Mapping

Figure F-7: Option 1A – Change in peak flood level from existing case – 5% AEP event



Legend

Change in peak flood level (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3

- Main Access Road
- Limit of Mapping

Figure F-8: Option 1A – Change in peak flood level from existing case – 1% AEP event

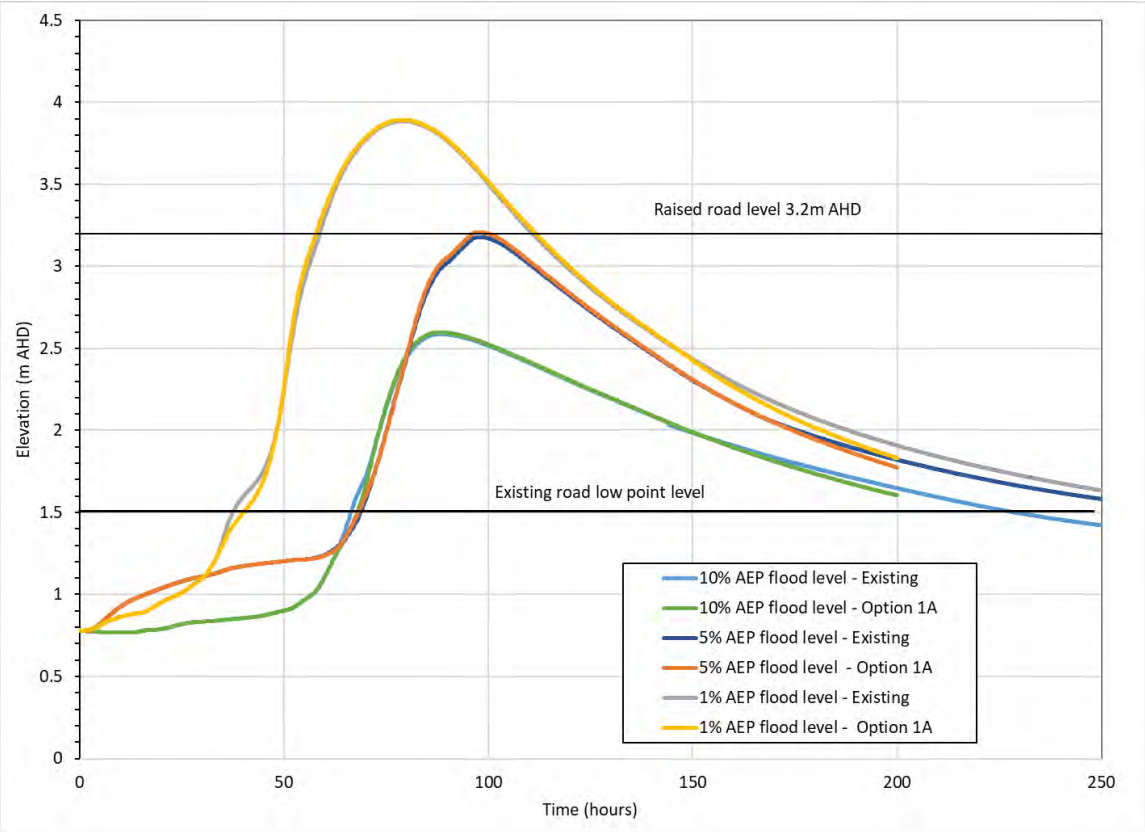
Legend

Change in peak flood level (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3

- Main Access Road
- Limit of Mapping

Figure F-9: Option 1A – Flood levels versus time at Crescent Head Road, Existing road compared with raising to 3.2m AHD and viaducts



Improvement to road access

With Option 1, flood immunity of the road at The Corduroy is improved from 50% AEP in the existing case to 10% AEP. In the 1% AEP event, the duration of flooding of the road would decrease from over 200 hours in the existing case to 80 hours with Option 1.

With Option 1A, flood immunity of the road at The Corduroy is improved from 50% AEP in the existing case to 5% AEP. In the 1% AEP event, the duration of flooding of the road would decrease from over 200 hours in the existing case to 50 hours with Option 1A.

Limitations of Option 1 and 1A

While Options 1 and 1A would improve road access through the floodplain at The Corduroy, Crescent Head Road may still remain cut by flooding at Rudders Lagoon, at South Kempsey. Additional works would be required near Rudders Lagoon to provide access along all of Crescent Head Road. Refer to Section F.3 for Option 1B, which mitigates against the road being cut-off by flooding at Rudders Lagoon.

F.3 Option 1B – New emergency access from Crescent Head Road to Pacific Highway

Discussion

The Crescent Head Road crossing of Rudders Lagoon, in South Kempsey, becomes flooded in frequent flood events. The duration that the road was cut at this location in the March 2021 event was approximately 7 days, isolating communities to the east of Rudders Lagoon and preventing access to Kempsey and other major regional centres.

This option would allow vehicle access from Crescent Head Road to the Pacific Highway, and would involve:

- A new on ramp from Crescent Head Road to the Pacific Highway southbound carriageway,
- New off ramp from the Pacific Highway northbound carriageway to Crescent Head Road.
- Local road modifications including a new roundabout on Crescent Head Road at Yabsleys Lane would allow vehicles to turn around on Crescent Head Road if the road is flooded at Rudders Lagoon.

There is currently a population of approximately 1300 residing between South Kempsey and Crescent Head village and The Corduroy who would benefit from this option. There is also expected to be population growth in this area resulting from rezoning of rural properties to rural residential land use and consolidation of existing vacant lots, thus permitting about 100 more dwellings in the area.

The on and off ramps would permit access to Kempsey (via Macleay Valley Way interchange, about 3.7km south of Crescent Head Road) and Port Macquarie. Vehicles on the highway approaching from the north including Coffs Harbour could pass Crescent Head Road and then turn around at Macleay Valley Way interchange to go northbound and exit onto Crescent Head Road. Similarly, vehicles entering the highway from Crescent Head Road could turn around at the Macleay Valley Way interchange to go northbound.

The new on and off ramps could be operated as an emergency access during flood events only. Reduced speed limits and closed left lane could be enacted on the highway to allow safe vehicle movement during flood events and emergency access conditions.

Effects on flooding

Option 1B is outside the PMF extent and would have no resulting flood impacts. In contrast, an alternative option of raising Crescent Head Road at Rudders Lagoon to improve flood access is expected to result in flooding impacts in South Kempsey upstream of the crossing.

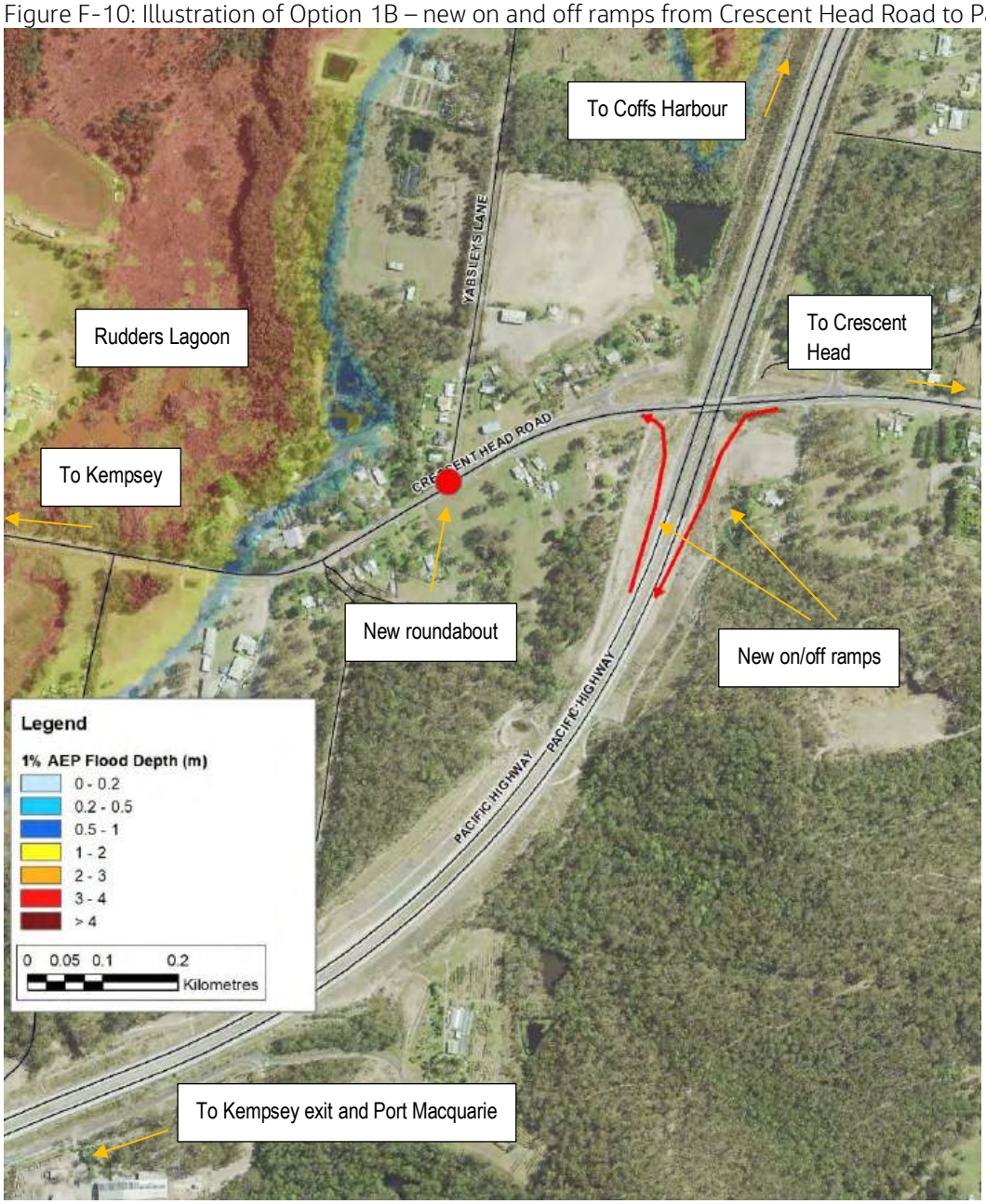
Improvement to road access

The Pacific Highway has a minimum 1% AEP flood immunity from mainstream flooding in the Macleay floodplain, although noting that there are two locations where the highway may be overtopped by local catchment flooding in less than a 1% AEP event. This is a substantial improvement in flood immunity of Crescent Head Road at Rudders Lagoon, which is cut in a 50% AEP event.

Although parts of Kempsey CBD would be affected by flooding in about a 10% AEP event, highway access to Port Macquarie and Coffs Harbour for resupply is expected to be available in at least up to a 5% AEP event, although further investigation is required to confirm this level of flood immunity.

Hence, road access via Crescent Head Road at or around Rudders Lagoon during flood events would be maintained in at least the 5% AEP event and potentially up to the 1% AEP event, compared to the road being cut at Rudders Lagoon in a 50% AEP event.

Figure F-10: Illustration of Option 1B – new on and off ramps from Crescent Head Road to Pacific Highway



F.4 Option 2A – Raise Hat Head Road and install floodway

Discussion

Hat Head Road at Kinchela appears to act as a barrier to water on the floodplain draining more freely to the north. There are a number of minor pipe crossings but these appear to be small in size with limited flow conveyance. Additionally, the road becomes flooded at this location in a 20% AEP event. Figure F-11 shows the ponding of water to the south of Hat Head Road in the 20% AEP event with reduced inundation on the floodplain to the north. It also indicates a low point in the road which is overtopped in the 20% AEP event. The low point is proposed to be to improve flood access in the 20% AEP event and a bank of culverts (160m total width) installed to allow floodwaters to discharge to the north, thereby reducing inundation times to the south of the road. The water flows would return to the Macleay River via the floodplain drainage and Saltwater Creek at Jerseyville.

There is about 0.8m difference in peak water level between south and north of the road in the 20% AEP event which would help with flow conveyance.

Ground levels upstream and downstream of the road would need to be lowered down by 0.5-0.6m to 1-1.2m AHD to form a floodway channel into and out of the culvert bank. The road level is currently at 2.0 – 2.3m AHD and would need to be raised by up to 0.5m to 2.5m AHD to provide sufficient cover over the proposed culverts. The proposed culverts would be 2.4m wide x 0.9m height. Figure F-12 illustrates the option.

Note that substantial raising of the road would be required to provide a higher level of flood immunity. For a 10% AEP flood immunity, a total 2km length of road would need to be raised.

There could be impact to internal access road for the private property to the north of Hat Head Road at this location. There would be ongoing asset maintenance issues for this option, such as clearing of debris after flood events and mowing and vegetation maintenance in the floodway.

Figure F-11: Hat Head Road at Kinchela obstructing flow towards the north. 20% AEP flood depths shown.

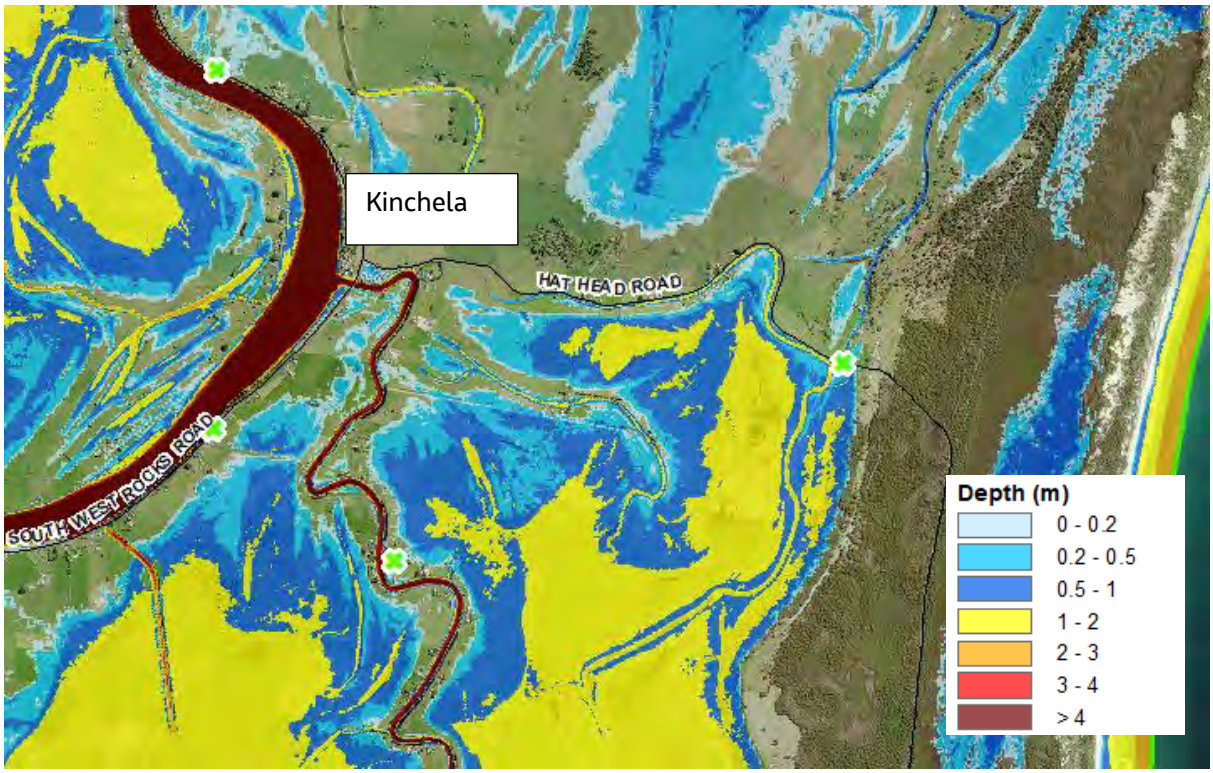
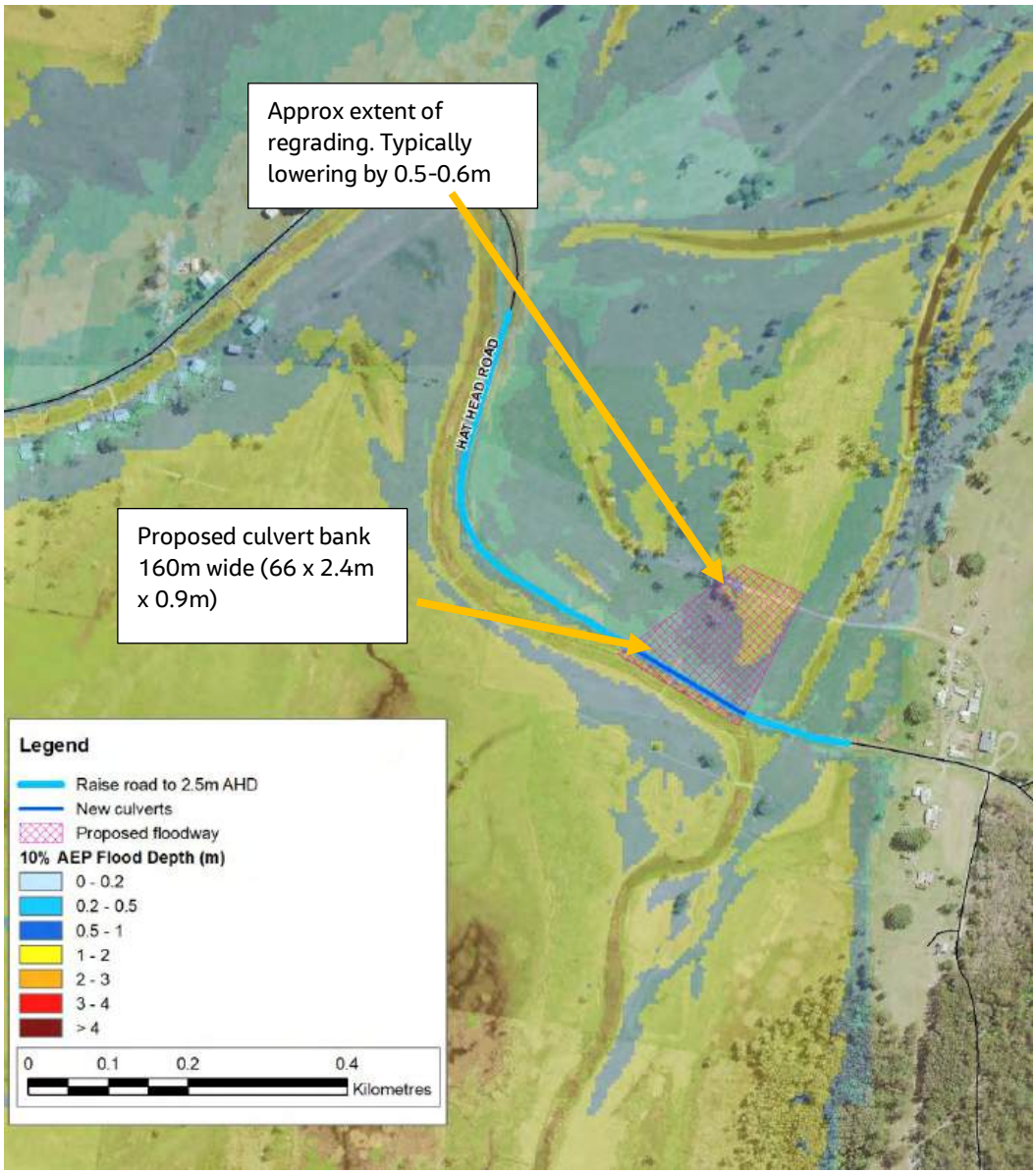


Figure F-12: Illustration of Hat Head Road floodway option

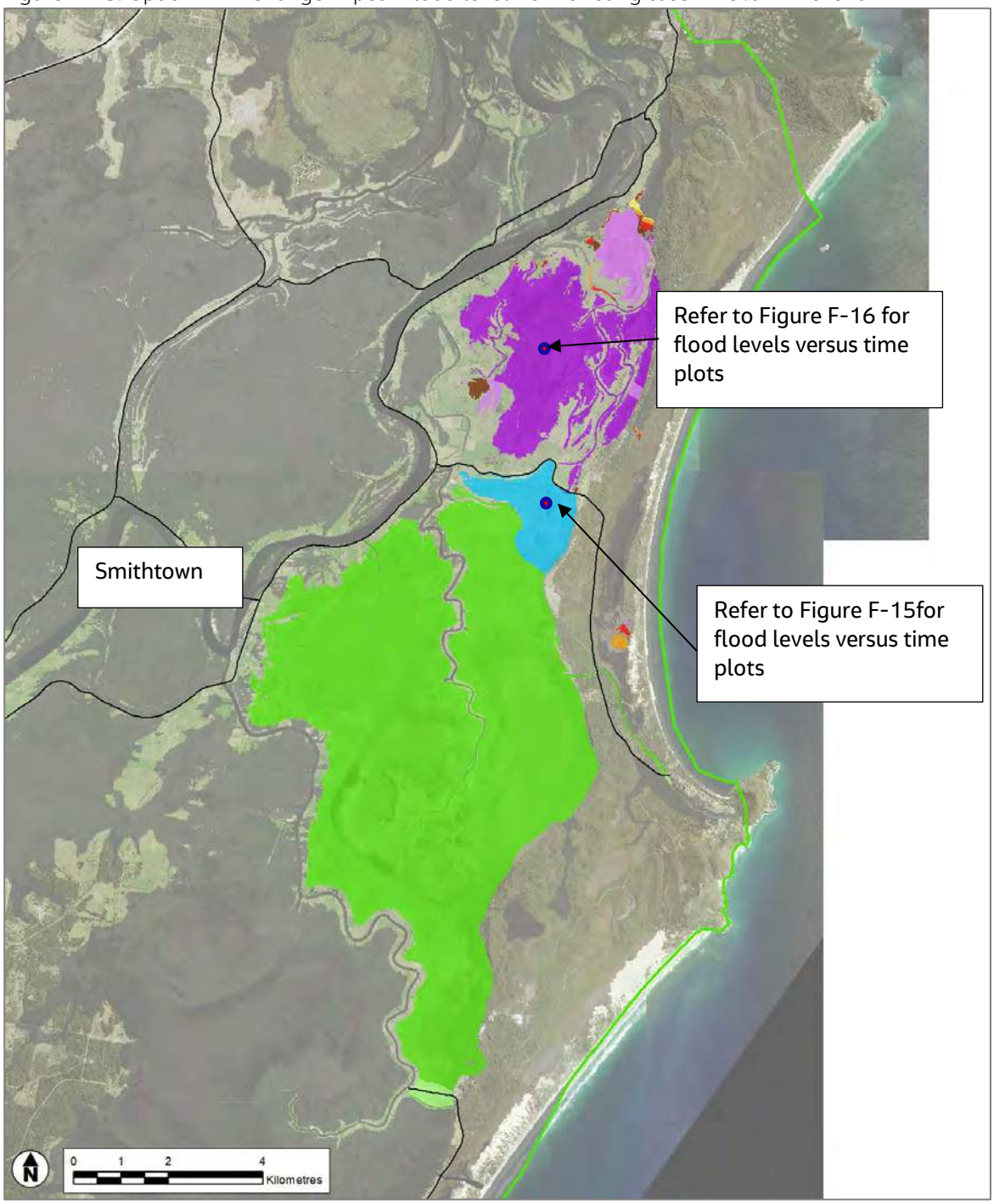


Effects on flooding

Figure F-13 and Figure F-14 present the change in peak flood levels for the 20% and 10% AEP events, respectively, with Option 2A. Change in peak flood levels are negligible for the 5% and 1% AEP events and hence mapping is not shown.

Figure F-15 and Figure F-16 present the flood levels versus time north and south of Hat Head Road, respectively, for the 20%, 10%, 5% and 1% AEP events. Locations where the flood levels are sampled are shown on Figure F-13.

Figure F-13: Option 2A – Change in peak flood level from existing case – 20% AEP event



Legend

Change in peak flood level (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3

- Main Access Road
- Limit of Mapping

Figure F-14: Option 2A – Change in peak flood level from existing case – 10% AEP event

Legend

Change in peak flood level (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3

- Main Access Road
- Limit of Mapping

Figure F-15: Option 2A – Flood levels versus time south of Hat Head Road, Existing road compared with raising to 2.5m AHD and culverts

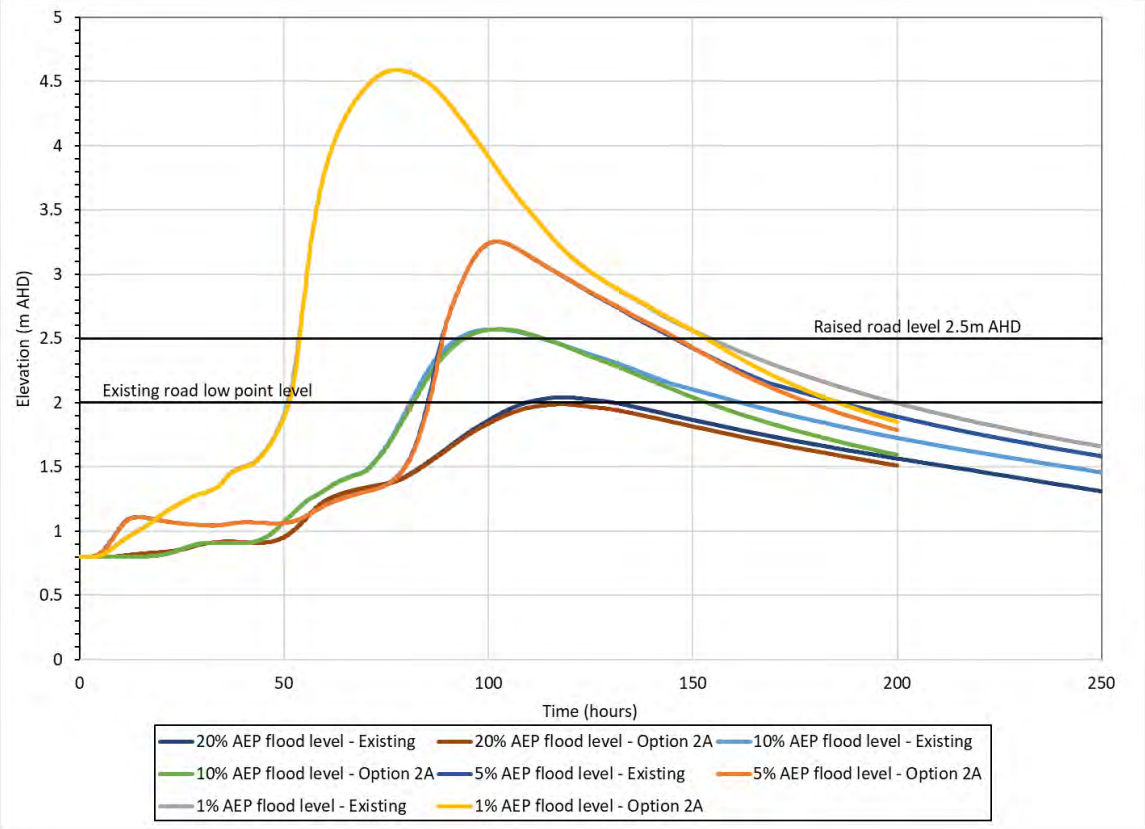
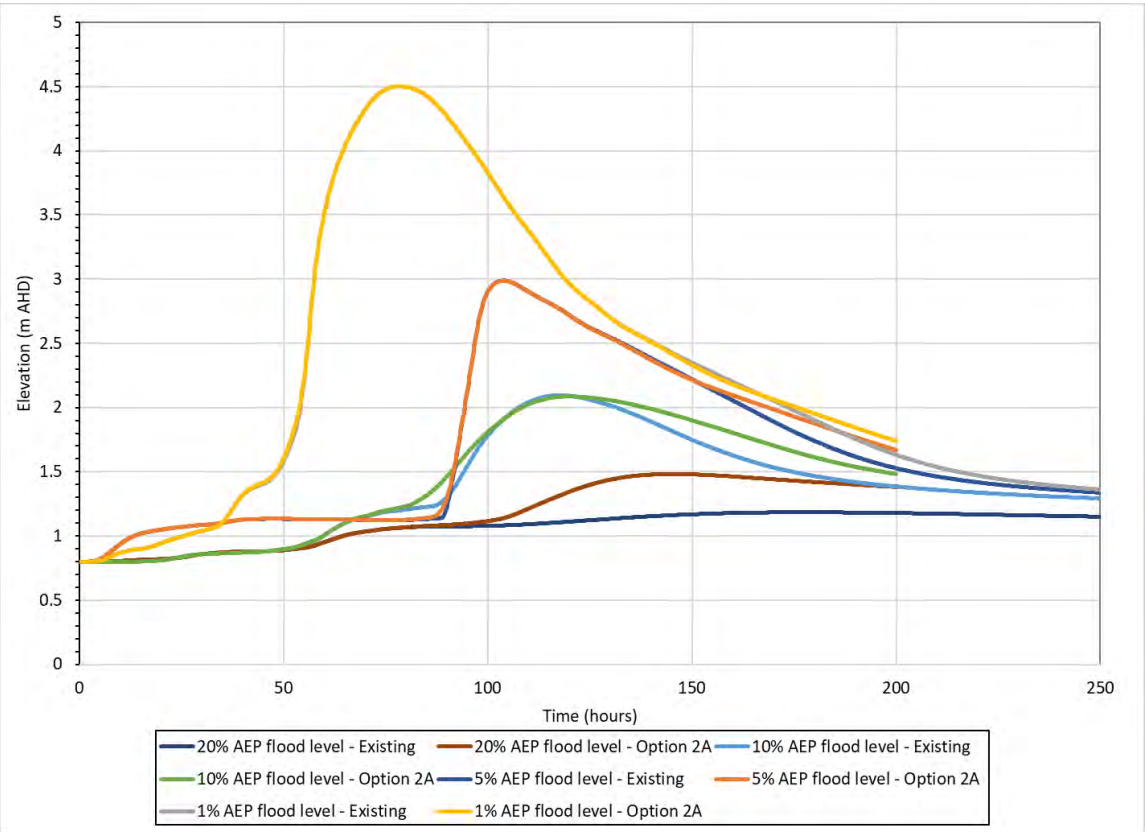


Figure F-16: Option 2A – Flood levels versus time north of Hat Head Road, Existing road compared with raising to 2.5m AHD and culverts



The modelling indicates a 0.35m increase in peak flood levels in low-lying areas to the north of Hat Head Road in the 20% AEP event due to increased drainage from south to north through the new culverts and floodway. The corresponding increase in duration of flooding exceeds 100 hours.

There are negligible increases in peak flood levels to the north of Hat Head Road in the 10%, 5% and 1% AEP events due to overtopping of the road, although the duration of flooding increases by about 10 hours in the 1% AEP event and up to 24 hours in the 10% AEP event.

To the south of Hat Head Road, peak flood levels decrease by up to 0.1m in the 20% AEP event and up to 0.01m in the 10% AEP event. Duration of flooding decreases by 10 – 24 hours.

Improvement to road access

Figure F-15 indicates that Option 2A would improve the road flood immunity from 20% AEP to about 10% AEP. In the 1% AEP event, the duration of flooding of the road would decrease from 150 hours in the existing case to 100 hours with Option 2A.

F.5 Option 3 – Disconnect Korogoro Creek and Killick Creek

Discussion

The option of disconnecting Korogoro Creek and Killick Creek from the Lower Macleay floodplain has been considered, with the objective of this option would be to reduce or eliminate the drainage of floodwaters with degraded water quality through the creek estuaries and causing blackwater fish kill events in the creeks. This option on its own would not improve flooding conditions in the Lower Macleay.

Option 3 assumes closing of the existing floodgates on Korogoro Creek at Hat Head Road (upstream end of the creek) and on Killick Creek upstream of Loftus Road, with additional bunding earthworks on the creek banks and raising of existing drainage structures to prevent floodwaters overtopping in up to and including the 1% AEP event.

Disconnecting the creeks from the floodplain should occur at or close to the existing headworks to maintain the creek tidal prism tidal flushing, and minimise the potential of the creek entrances closing up due to reduced tidal scouring.

Effects on flooding

Figure F-17 to Figure F-19 present the change in peak flood levels for the 10%, 5% and 1% AEP events, respectively, due to disconnecting Killick Creek and Korogoro Creek from the Lower Macleay floodplain. Flood levels increase by up to 0.07m in the 10% AEP event and 0.1 – 0.15m in the 5% and 1% AEP events. Increases in flooding extend across much of the Lower Macleay floodplain. The greatest increases in peak flood levels occur around Crescent Head Road at The Corduroy.

Figure F-17: Option 3 – Change in peak flood level from existing case – 10% AEP event

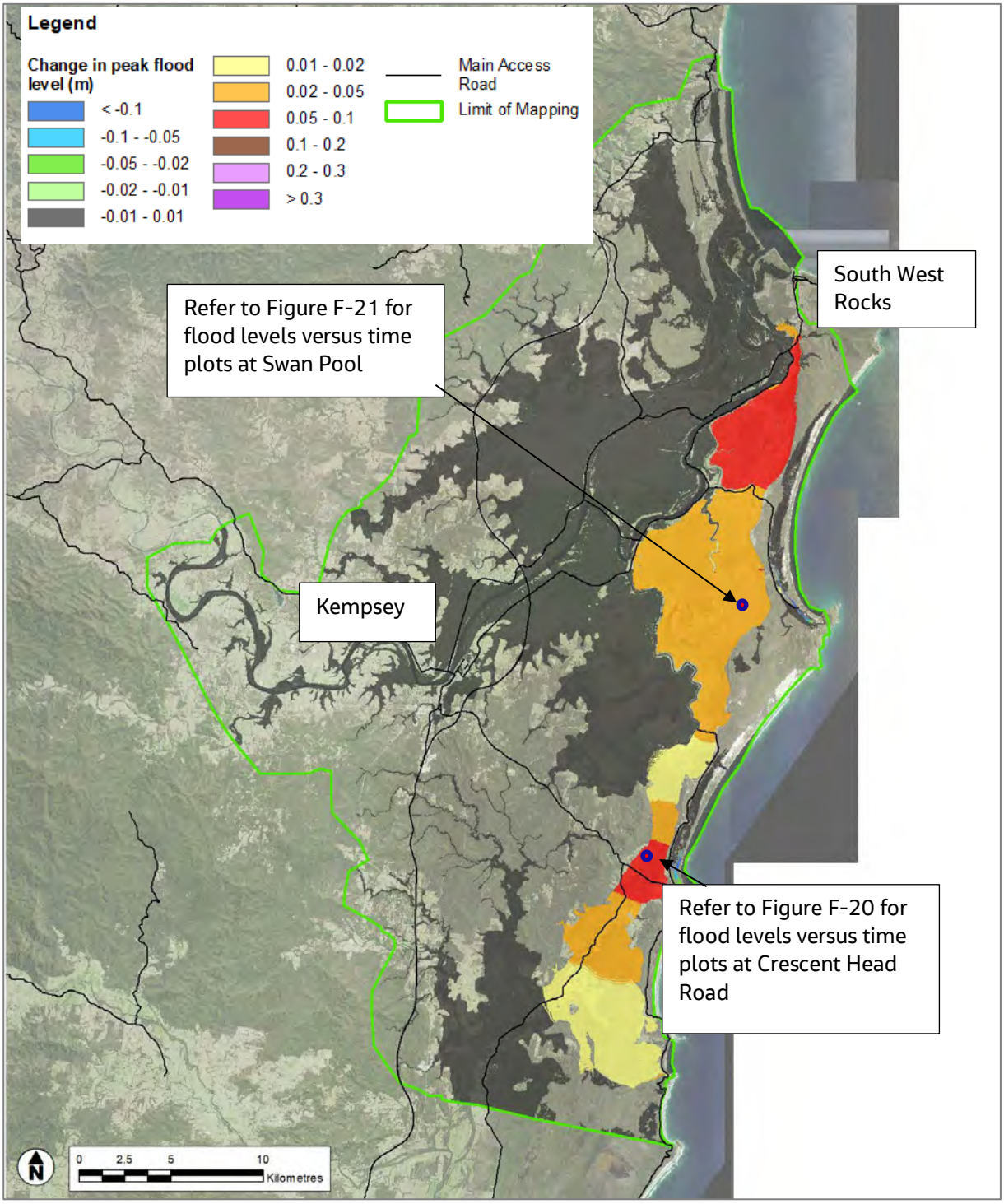


Figure F-18: Option 3 – Change in peak flood level from existing case – 5% AEP event

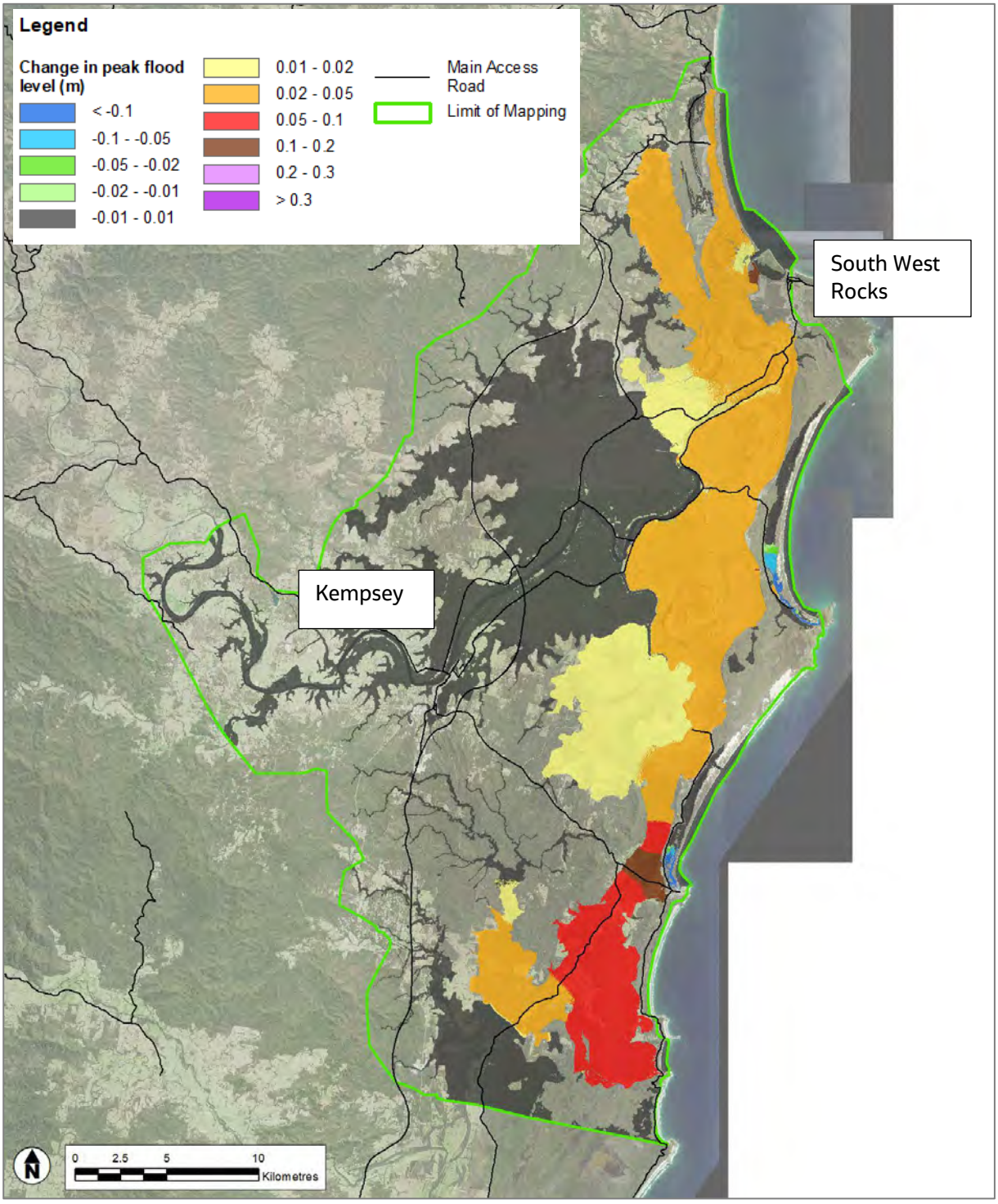


Figure F-19: Option 3 – Change in peak flood level from existing case – 1% AEP event

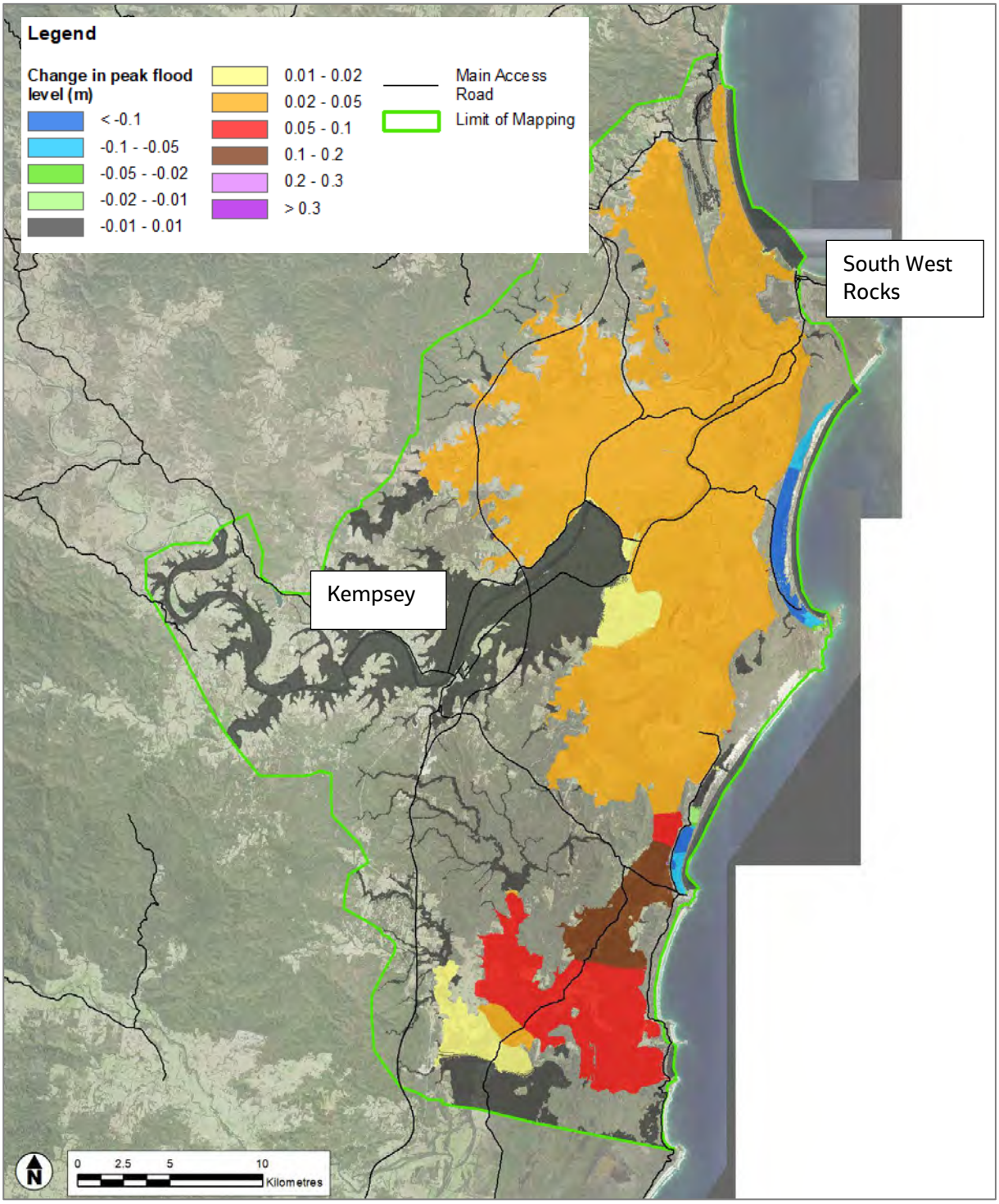


Figure F-20 and Figure F-21 present the flood levels versus time north of Crescent Head Road and at Swan Pool, respectively. The locations where flood level results were sampled are shown on Figure F-17. The figures indicate that durations of flooding would increase by up to 8 to 15 hours for the 20%, 10%, 5% and 1% AEP events.

Figure F-20: Option 3 – Flood levels versus time at Crescent Head Road, existing case compared with disconnecting Killick Creek and Korogoro Creek

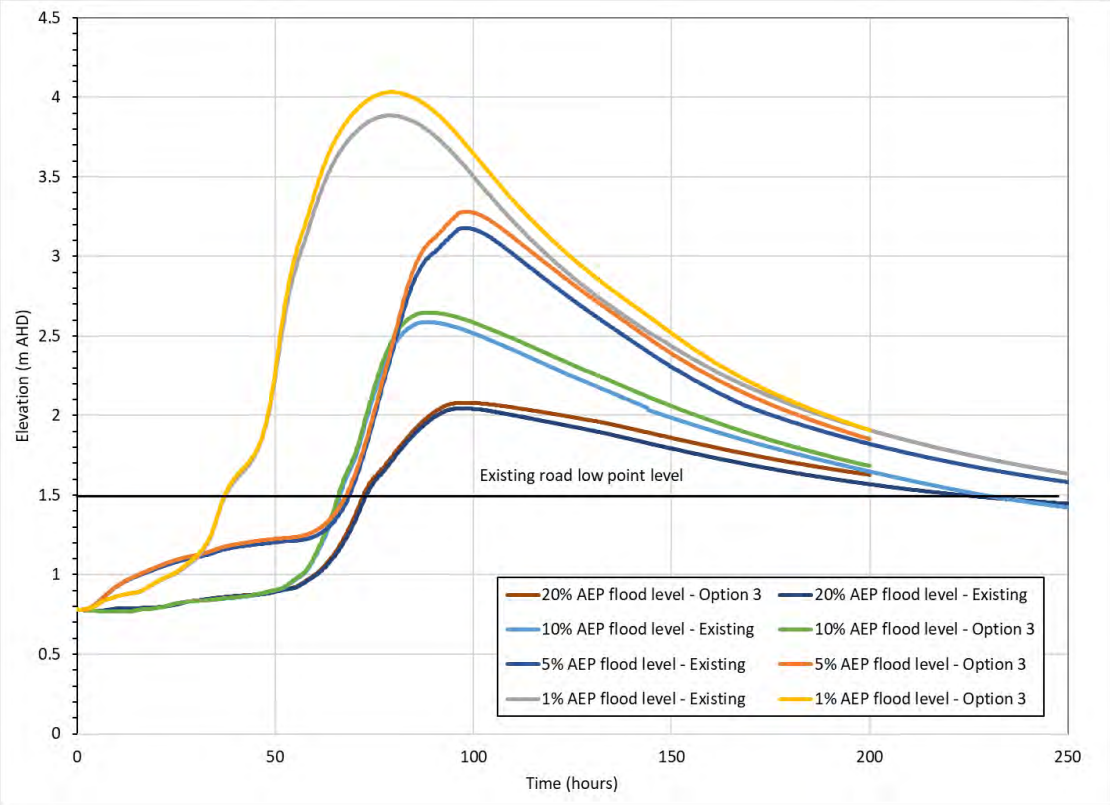
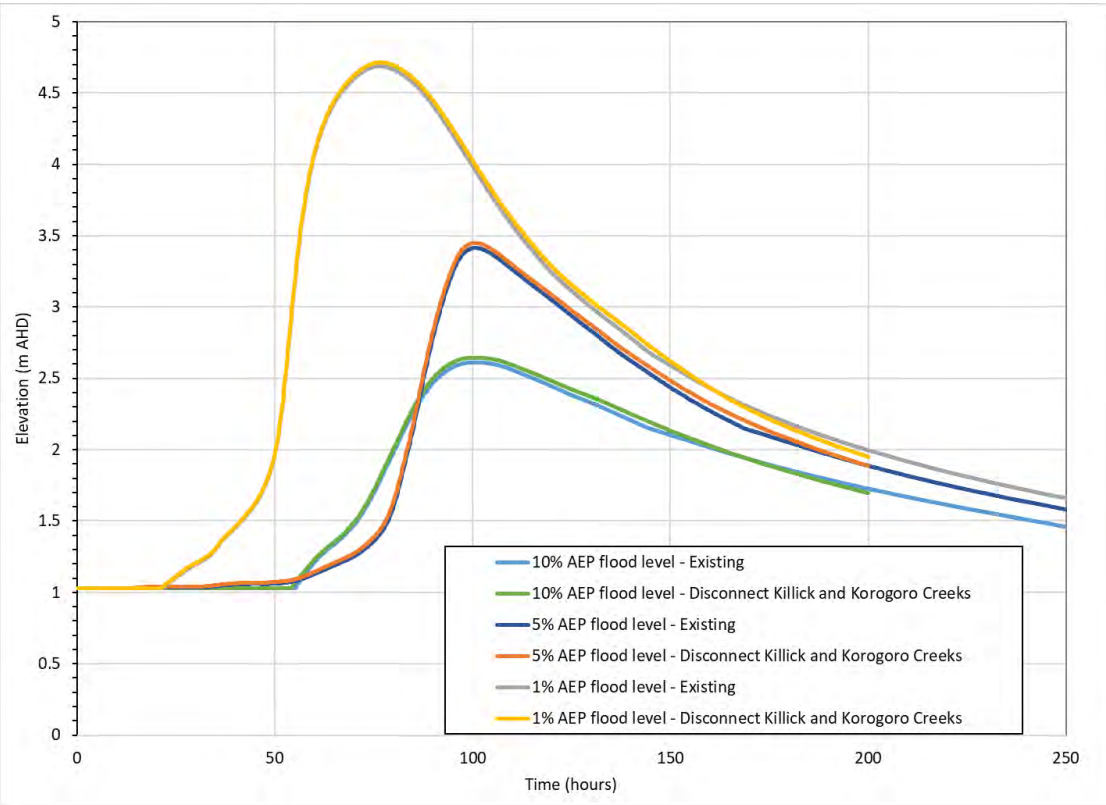


Figure F-21: Option 3 – Flood levels versus time at Swan Pool, existing case compared with disconnecting Killick Creek and Korogoro Creek



Peak flood levels are reduced in Hat Head village by typically more than 0.05m (up to 0.16m on some properties) in the 5% AEP event and 0.05 – 0.13m in the 1% AEP event. There are no changes in flooding in the village in the 10% and 20% AEP events as the levee is not overtopped in these events.

In Crescent Head village, properties along Killick Creek would experience reductions in peak flood levels of 0.05m in the 1% AEP event, but those in the western portion of the village affected by flooding in Connection Creek would experience flood level increases of 0.15m. Similar effects occur in the 5% AEP event.

Figure F-22: Change in 1% AEP peak flood level with Option 3 at Hat Head

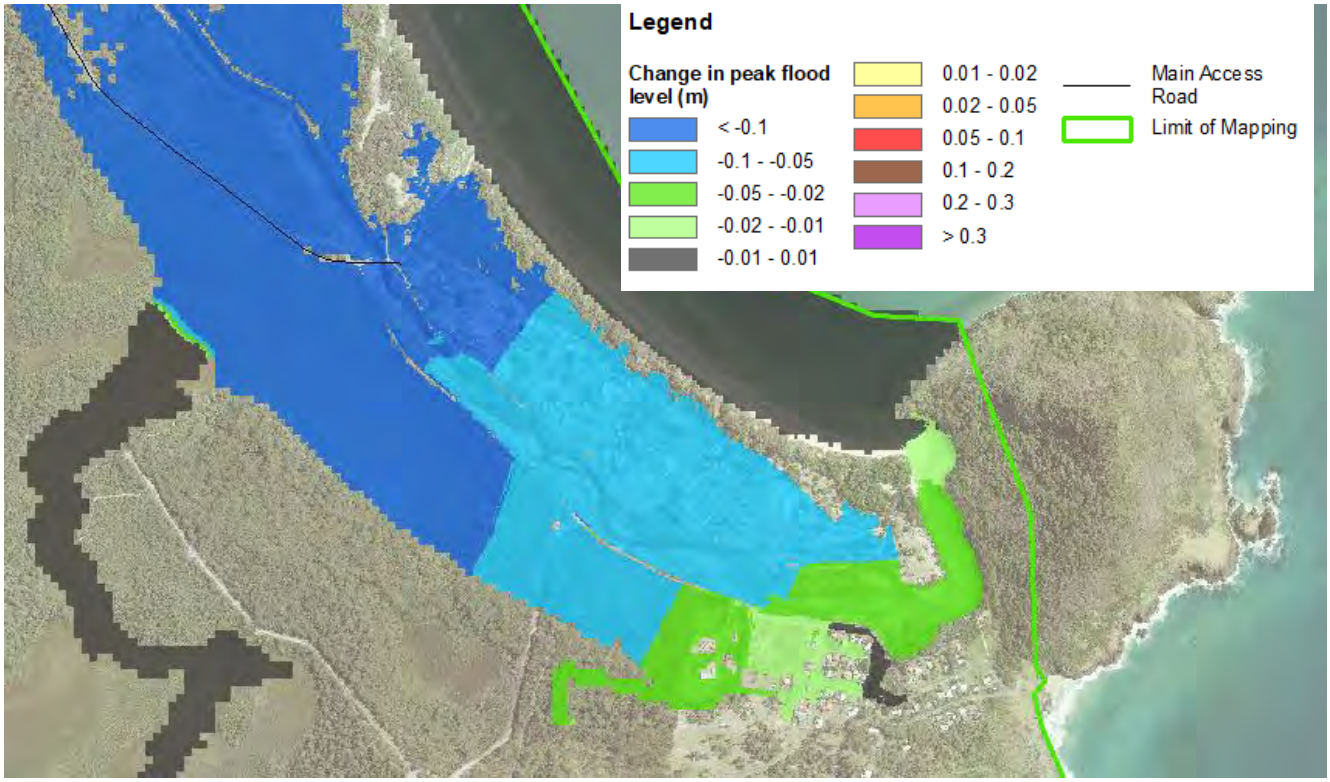
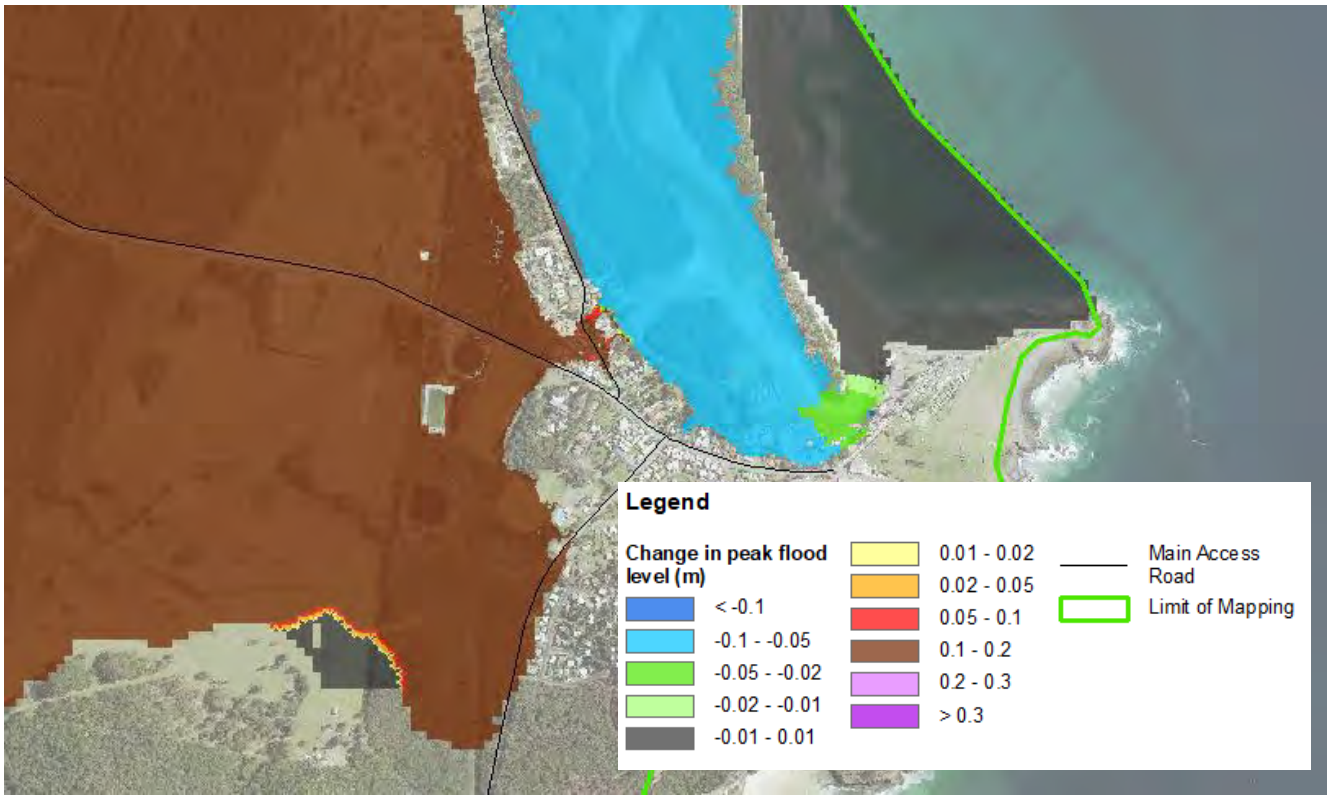


Figure F-23: Change in 1% AEP peak flood level with Option 3 at Crescent Head



F.6 Option 4 – Increase flow capacity at Ryans Cut

Discussion

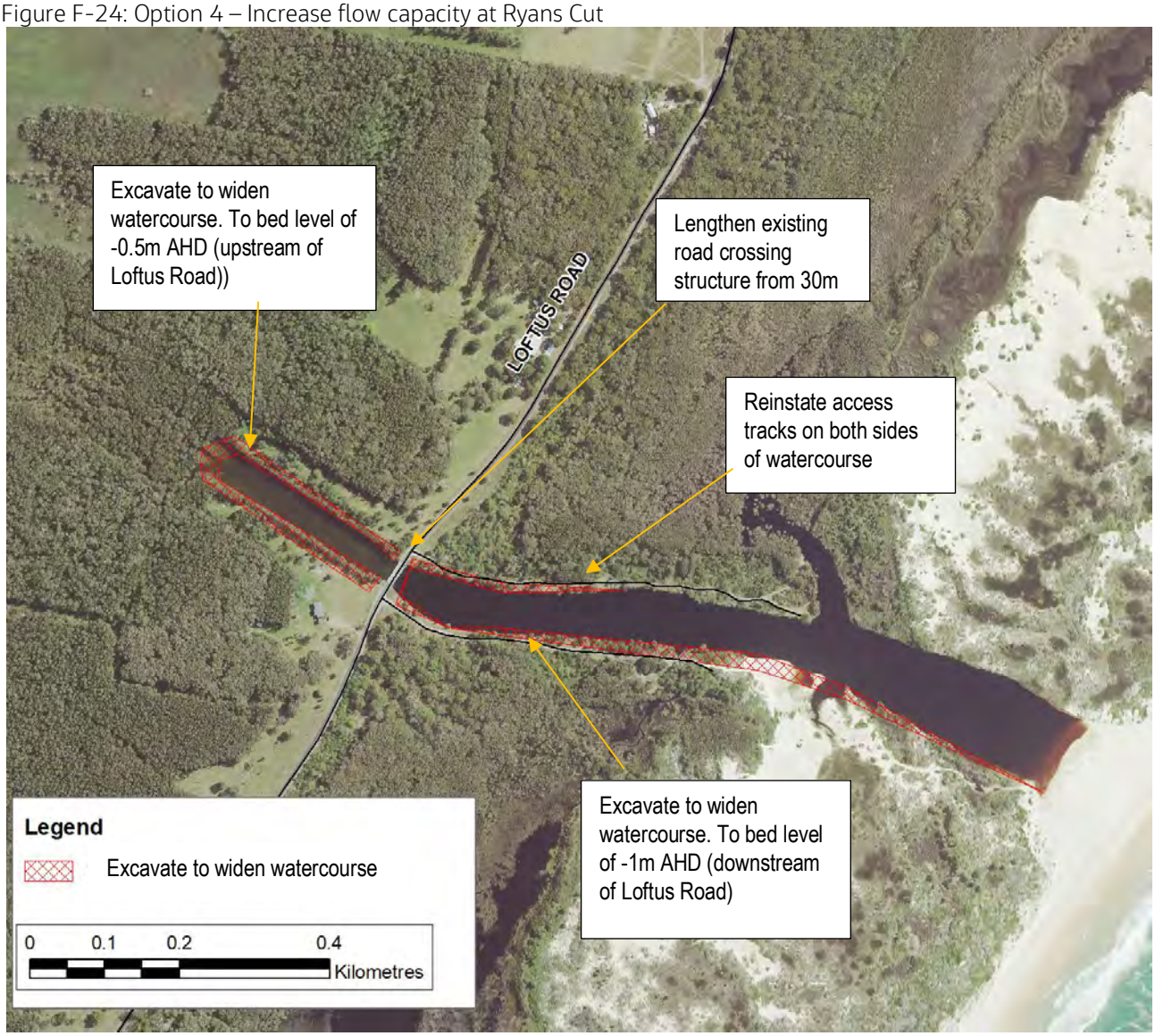
Discharge of floodwater through Ryans Cut to the ocean is currently limited by the capacity of the floodgate crossing at Loftus Road and potentially the width of the open channel upstream and immediately downstream of the crossing. The current crossing is 32m long and the current peak discharge rates are about 140m^3/s in the 10% AEP event and 260m^3/s in the 5% AEP event. Doubling the length and capacity of the crossing could improve drainage times for the southern floodplain. Peak flood levels are unlikely to be significantly improved. Option 4 was modelled by doubling the crossing length and assuming excavation of the existing banks of the lagoon channel to widen the channel.

The risk of a large blackwater fish kill at Ryans Cut with Option 4 is not expected to be significantly greater than the existing case, as the lagoon is small and currently becomes flushed out during flood events. Further environmental assessment would need to be undertaken in the detailed assessment to confirm risks.

Widening the crossing and channel would have impacts to adjacent properties and existing utilities (overhead power line, possibly underground utilities). Works downstream of Loftus Road would be in Hat Head National Park.

There are utilities along the road as underground assets and above ground powerlines.

Figure F-24: Option 4 – Increase flow capacity at Ryans Cut



Effects on flooding

Figure F-25 to Figure F-26 show the change in peak flood levels with Option 4 for the 10%, 5% and 1% AEP events. Peak flood levels reduce by 0.02 – 0.06m on the southern floodplain in the 10% AEP event, and by 0.02 – 0.04m over the broader Lower Macleay floodplain area in the 5% and 1% AEP events. There are increases in peak flood levels of 0.2 – 0.3m in the 5% and 1% AEP events as there are increased flows which overflow from Ryans Cut lagoon into the area between Loftus Road and the beach foredune area to the north of Crescent Head, but these increases in peak flood levels do not affect any buildings.

Changes in peak flood levels in the 20% AEP event are less than 0.02m, and are not mapped in this report.

Figure F-25: Option 4 – Change in peak flood level from existing case – 10% AEP event

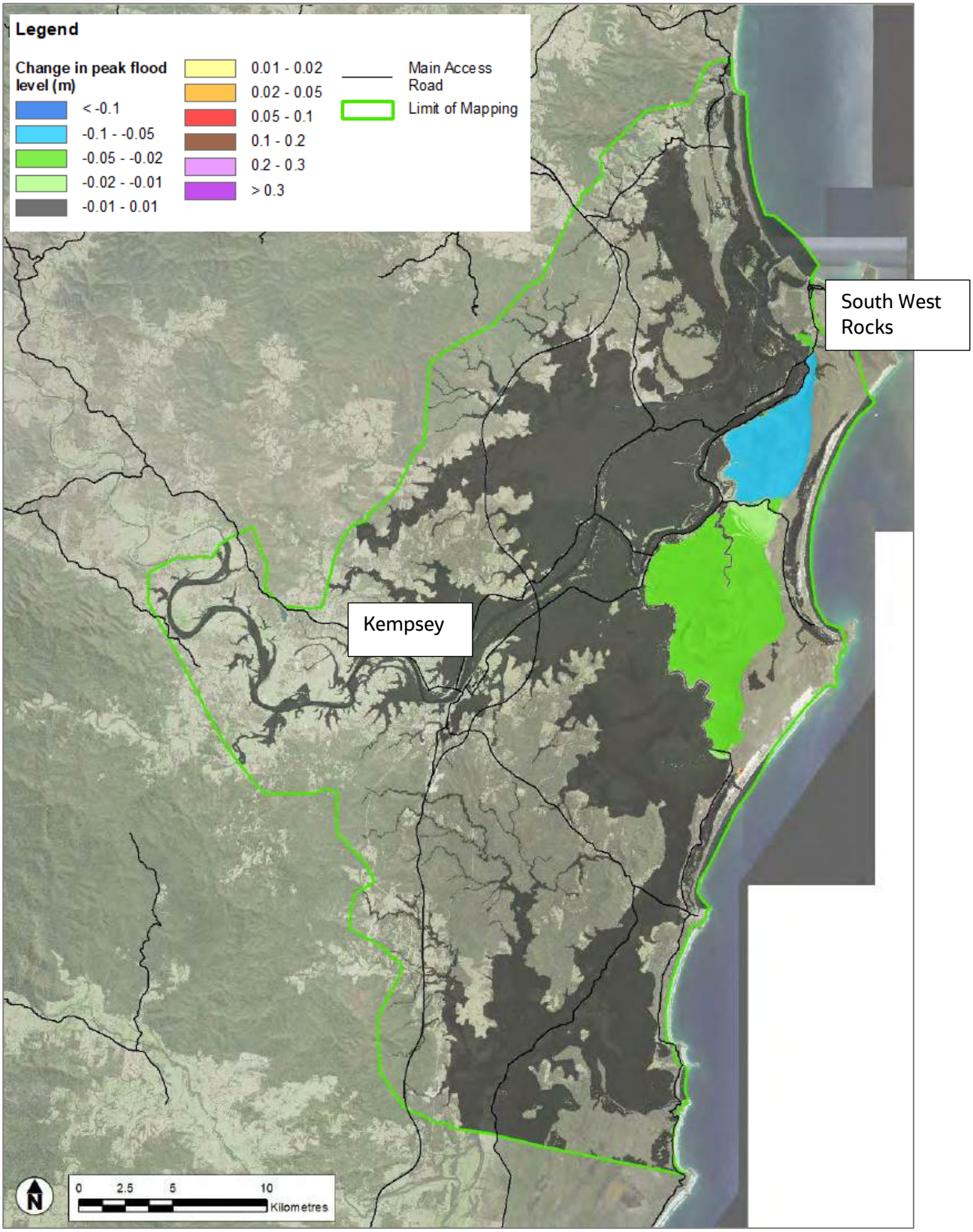


Figure F-26: Option 4 – Change in peak flood level from existing case – 5% AEP event

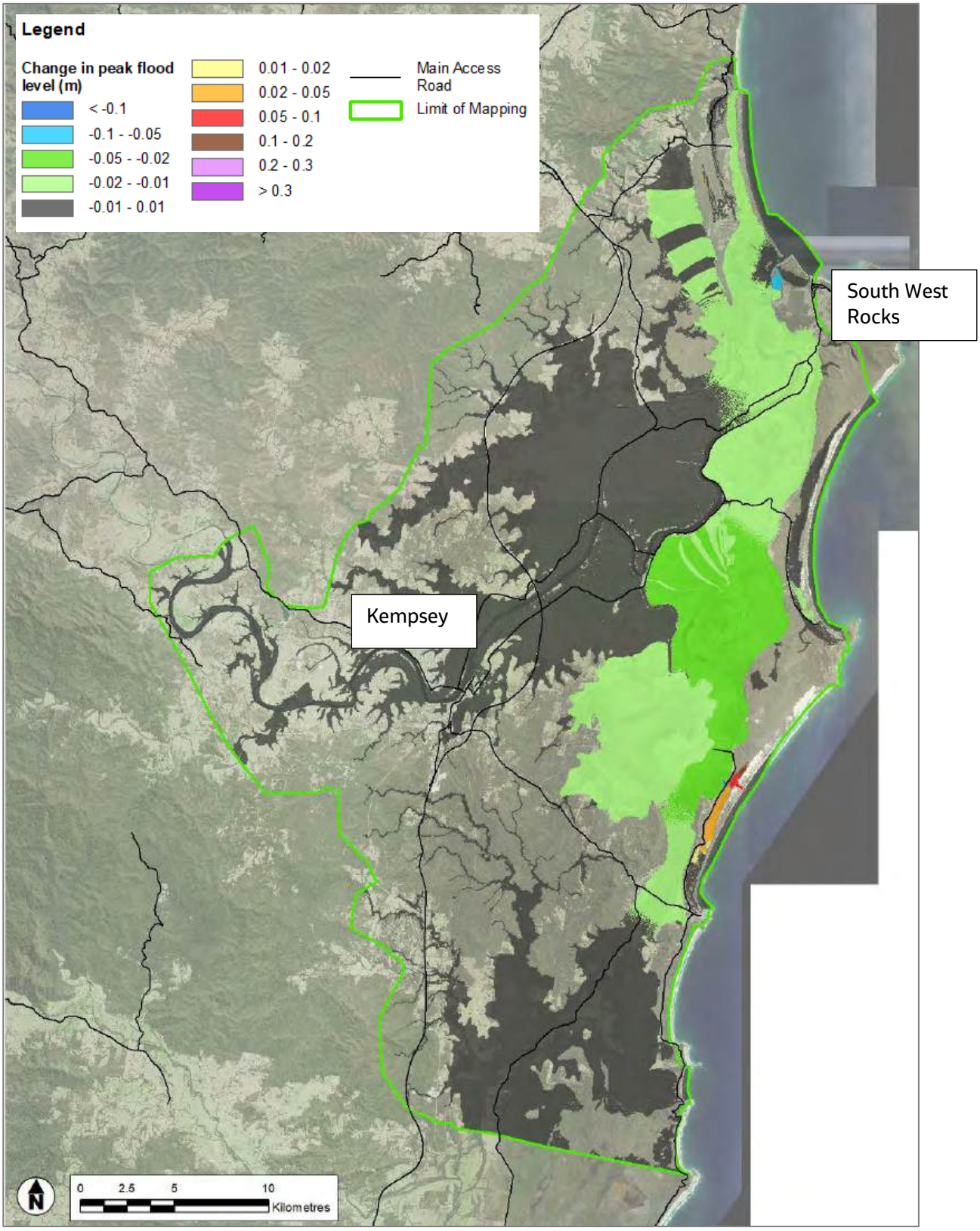


Figure F-27: Option 4 – Change in peak flood level from existing case – 1% AEP event

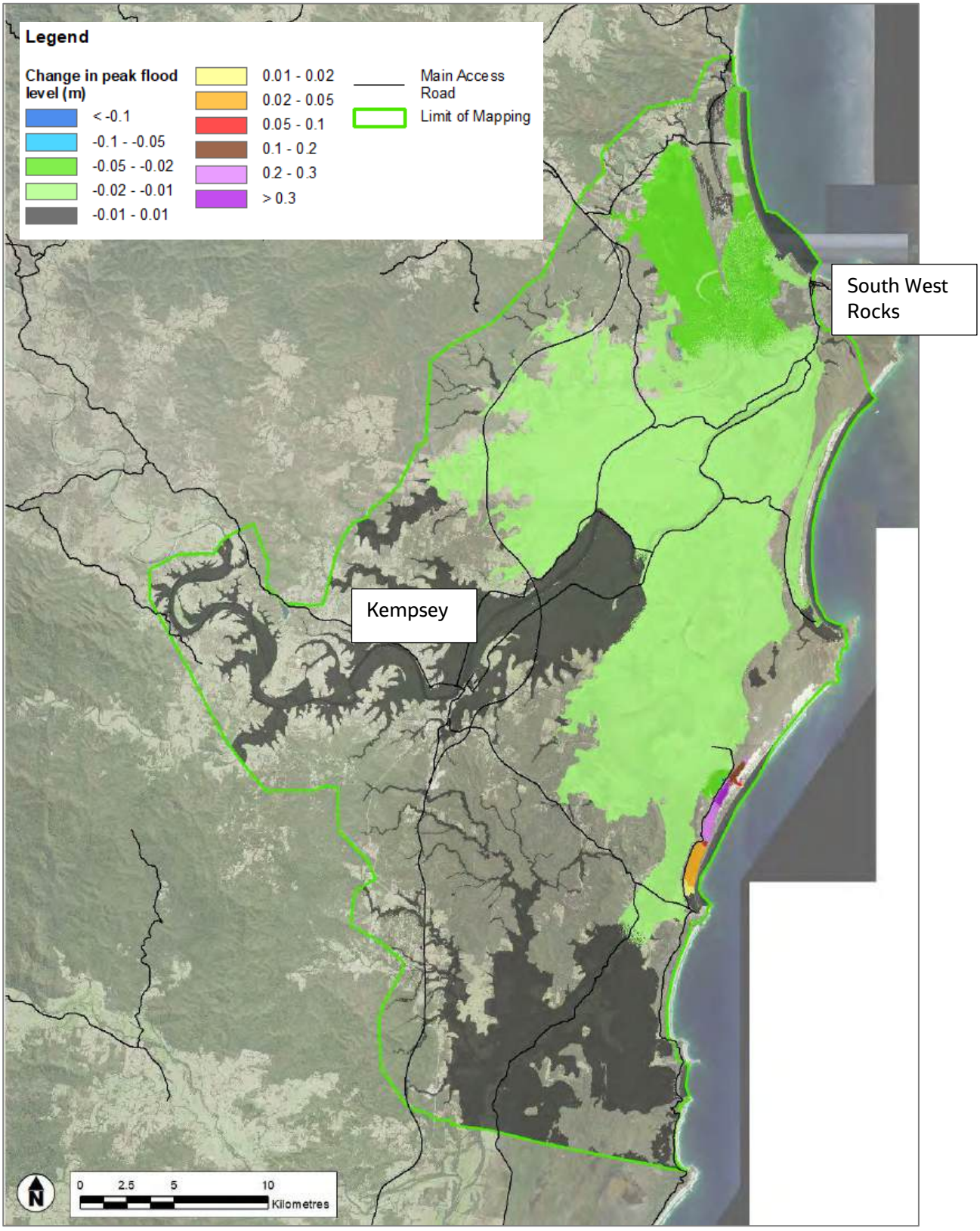


Figure F-28 to Figure F-30 show the flood levels versus time north of Crescent Head Road, Upper Belmore and at Swan Pool, respectively, for the 20%, 10%, 5% and 1% AEP events. Durations of flooding are reduced by 13 to 30 hours at both locations for the 10%, 5% and 1% AEP events, which is typical for the southern floodplain to the east of Belmore River. Durations are reduced by 30 hours at Swan Pool and by 6 hours north of Crescent Head Road in the 20% AEP event.

There are negligible changes to duration of flooding for areas to the west of Belmore River and north of Hat Head Road at Kinchela.

Figure F-28: Flood levels versus time north of Crescent Head Road, Existing compared with Option 4

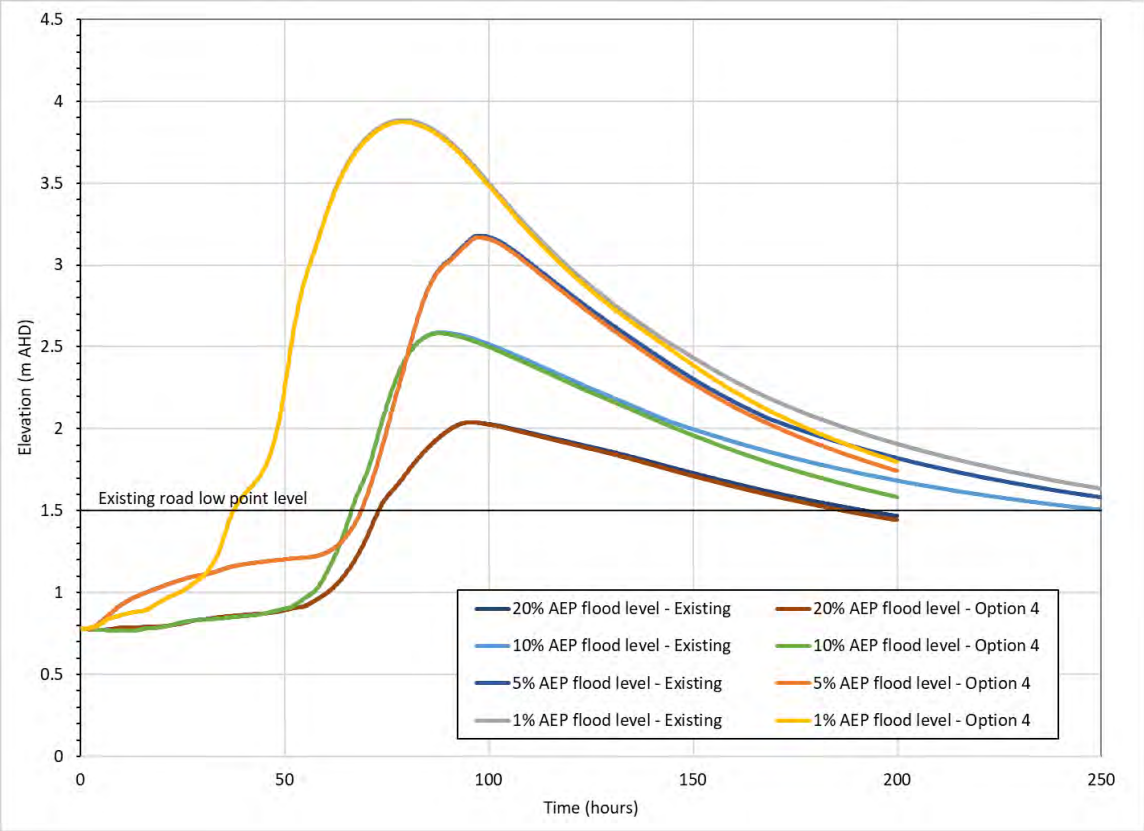


Figure F-29: Flood levels versus time at Upper Belmore, Existing compared with Option 4

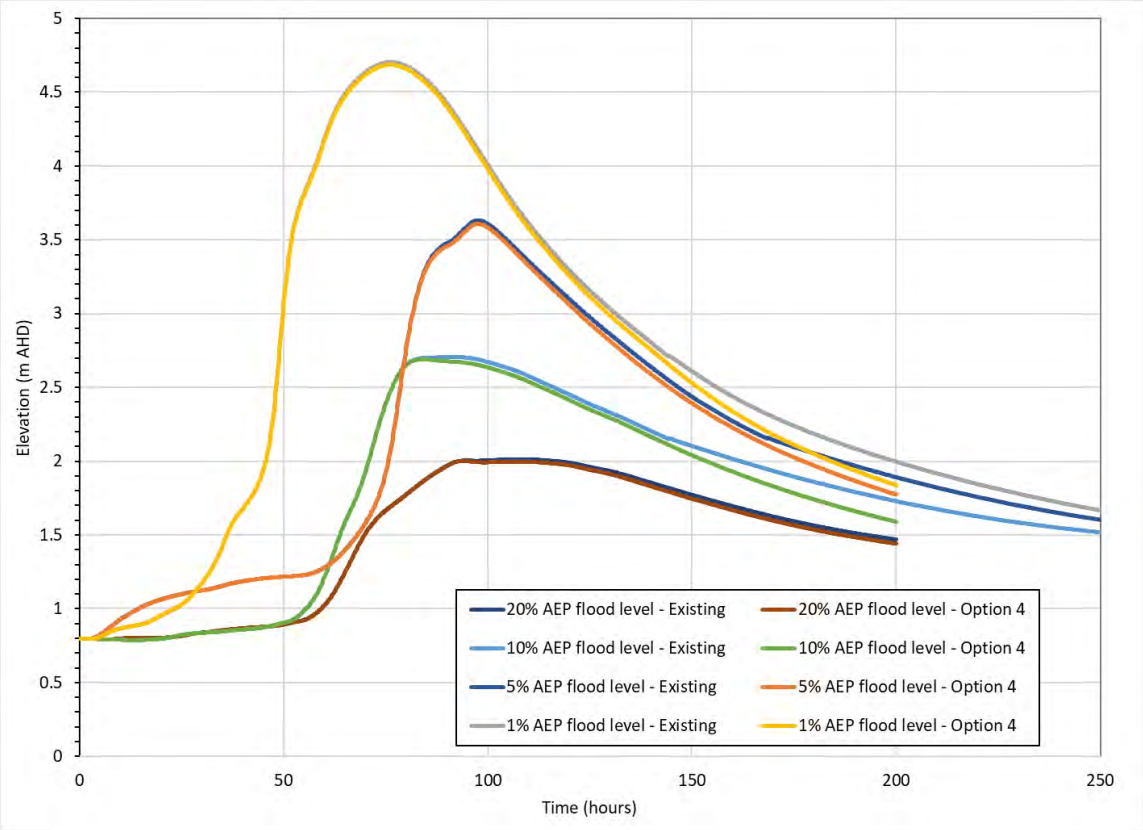
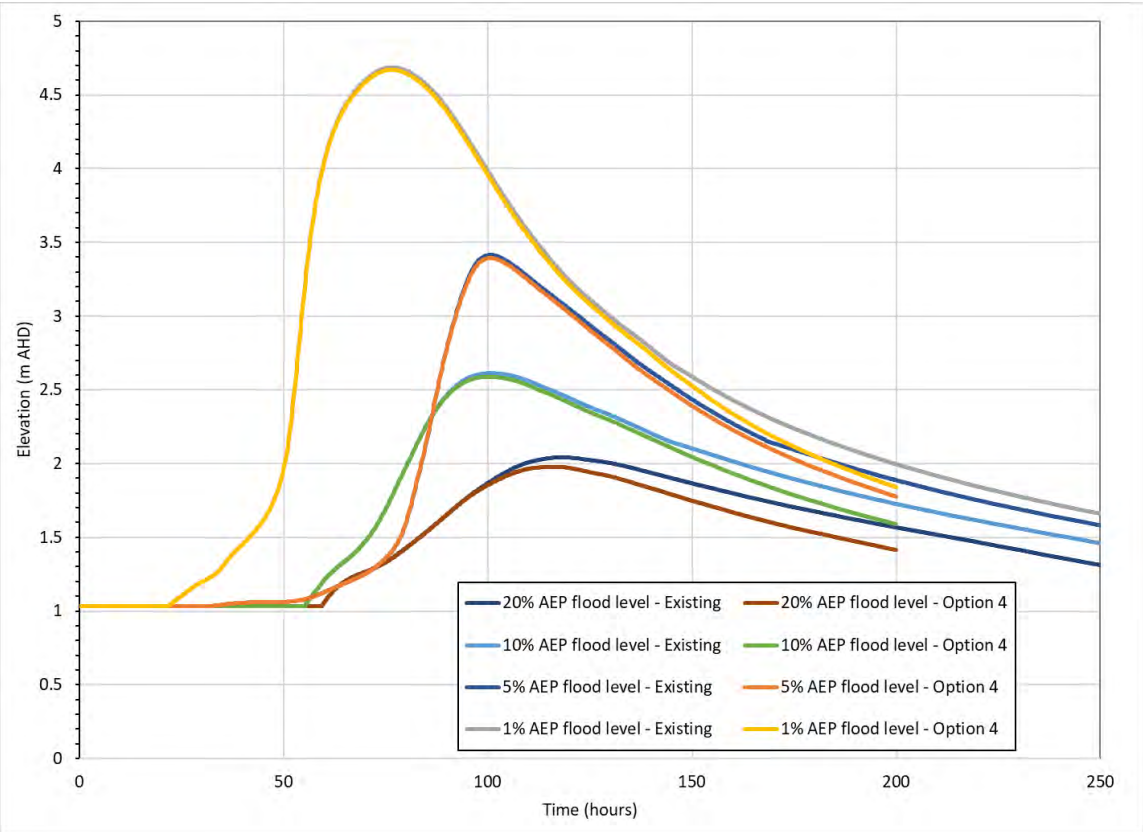


Figure F-30: Flood levels versus time at Swan Pool, Existing compared with Option 4



F.7 Option 4B – Increased flow capacity at Ryans Cut plus extension of Ryans Cut to Belmore River

Discussion

Initial consultation on the increased Ryans Cut flow capacity (Option 4) indicated that some community and Reference Group members viewed an extension of Ryans Cut to connect to Belmore River could be beneficial for flood drainage of the Lower Macleay. This option would include the following:

- Widening of Loftus Road crossing and Ryans Cut waterway as per Option 4
- Extend Ryans Cut via Upper Belmore swamps to Belmore River with a 70-90m wide (approx.) channel at 0m AHD, lowering existing ground levels by 0.2 – 0.5m. This would require Belmore River Right Bank Road bridge over Worthings Drain and a number of other bridges to be reconstructed. See Figure F-31
- Modify the cross-levee at Belmore River headworks by lowering the earth embankment by about 4m height to 0.5m AHD. See Figure F-32
- Allow Belmore River headworks to remain open during flood.

This option is intended to work by allowing flooding in the Macleay River to back up the Belmore River freely, then exit the floodplain via the direct connection to Ryans Cut and the ocean. This option should also allow the floodplain to drain more freely following a flood due to the higher ground between existing Ryans Cut and the Upper Belmore swamps being removed.

The extended works as a part of Option 4B (compared to Option 4) would be on private property.

Figure F-31: Option 4B – Channel extension of Ryans Cut to Belmore River

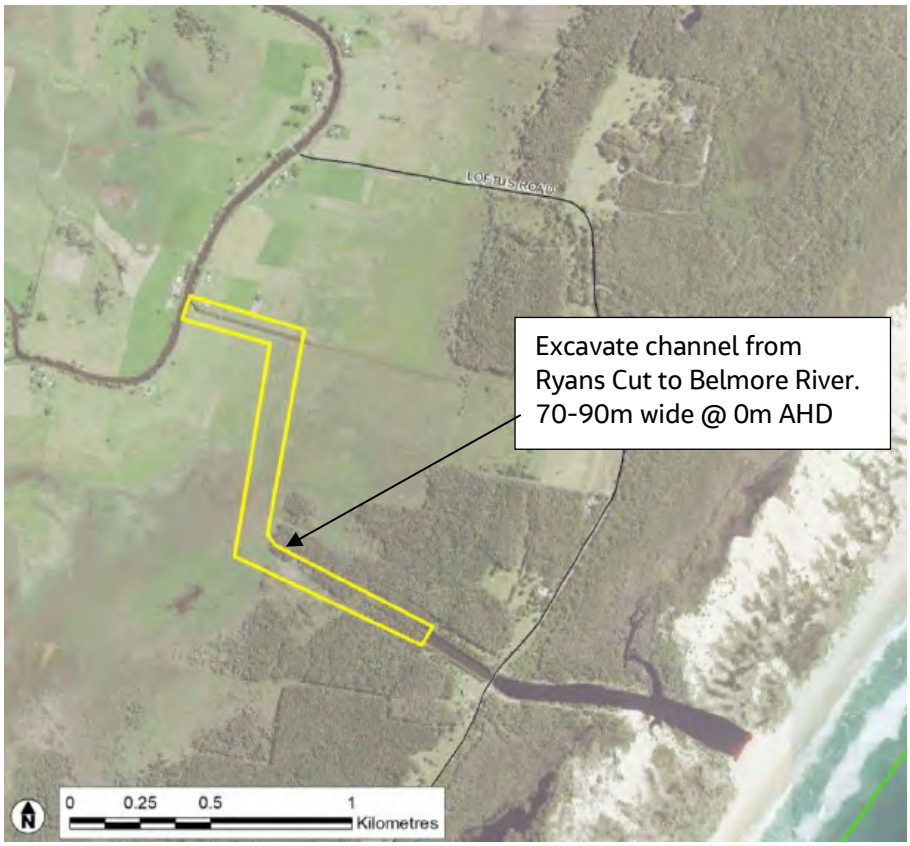
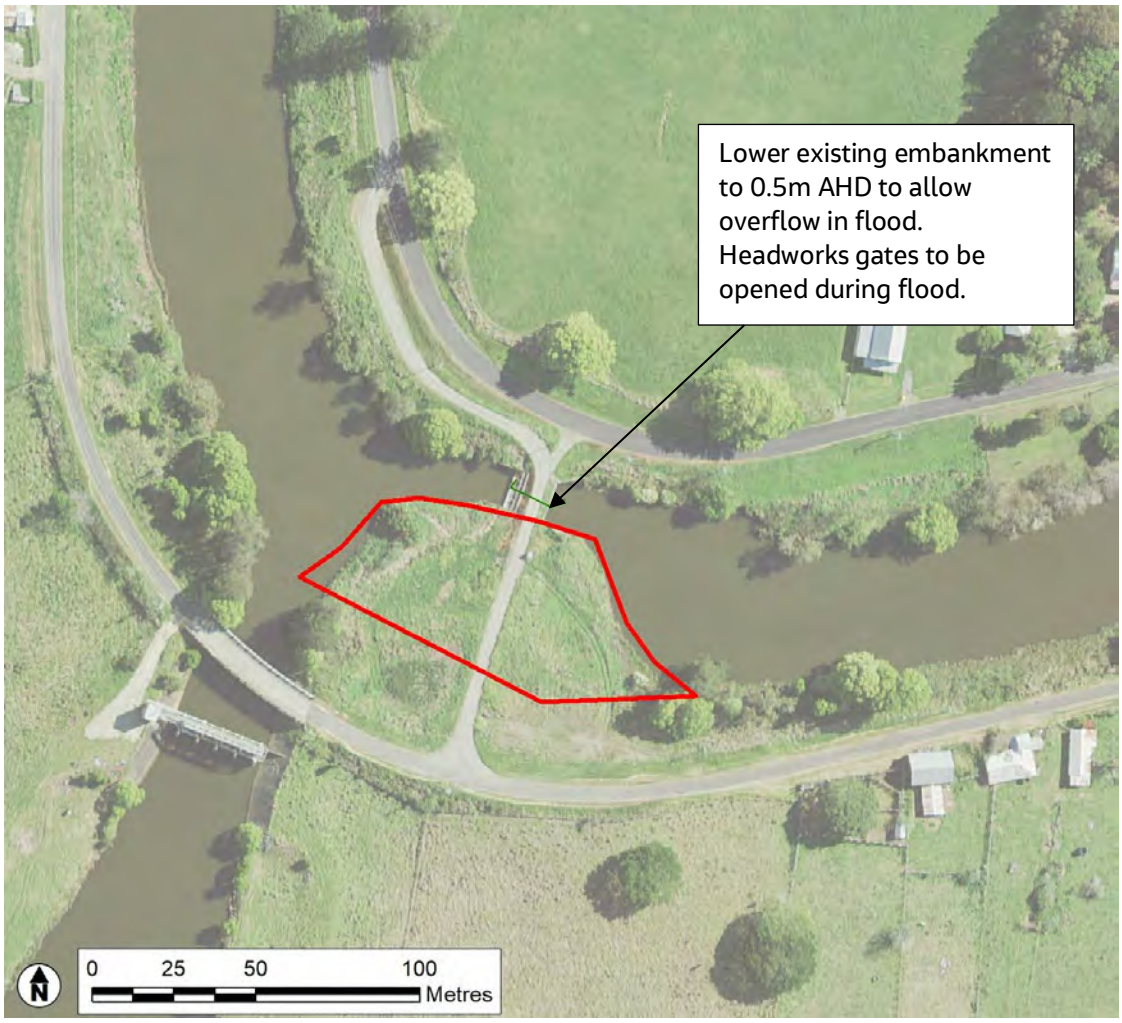


Figure F-32: Option 4B – Modification to Belmore River headworks



Effects on flooding

Figure F-33 to Figure F-36 show the change in peak flood levels with Option 4B for the 20%, 10%, 5% and 1% AEP events. In the 20% AEP event peak flood levels reduce by 0.02 to 0.1m around Pola Creek to Belmore River as overflows onto the floodplain are reduced, due to floodwaters being allowed to back up Belmore River through the headworks. Peak flood levels in Belmore River channel downstream of the headworks reduce by 0.13m, but increase by up to 1m upstream of the headworks, reducing with distance upstream. There are about 10 properties affected by increased flood levels or flood extents in the 20% AEP event

In the 10%, 5% and 1% AEP events peak flood levels reduce by 0.01 – 0.03m on the southern floodplain due to the increased drainage capacity at Ryans Cut. Peak flood levels in Belmore River channel downstream of the headworks reduce by 0.1m in the 10% AEP event, and increase by up to 0.4m upstream of the headworks, reducing with distance upstream. There are about 10 properties affected by increased flood levels or flood extents in the 10% AEP event. There is negligible change in the Belmore River channel peak flood levels in the 5% and 1% AEP events.

There are increases in peak flood levels of 0.2 – 0.3m in the 1% AEP event as there are increased flows which overflow from Ryans Cut lagoon into the area between Loftus Road and the beach foredune area to the north of Crescent Head, but these increases in peak flood levels do not affect any buildings.

Figure F-33: Option 4B – Change in peak flood level from existing case – 20% AEP event

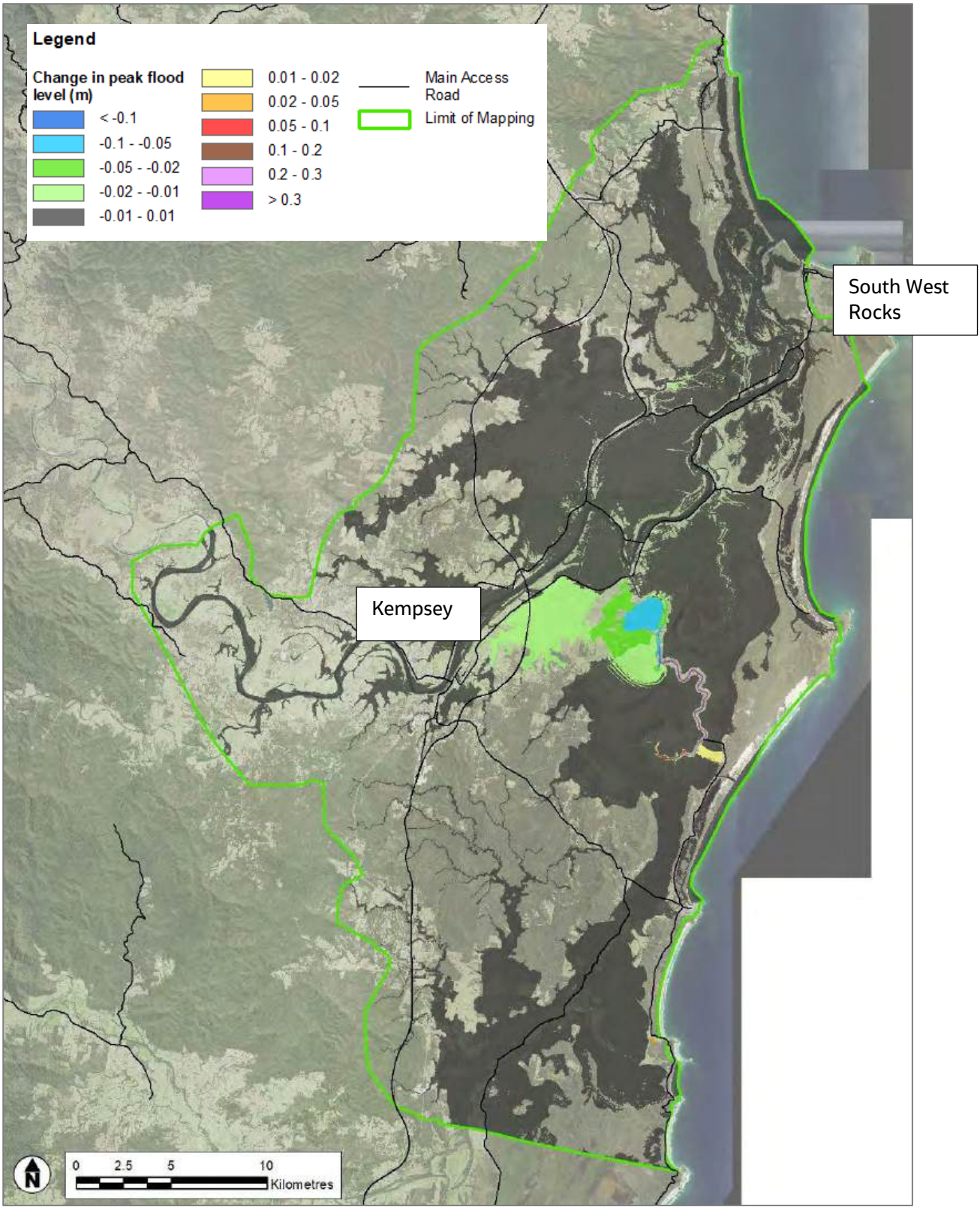


Figure F-34: Option 4B – Change in peak flood level from existing case – 10% AEP event

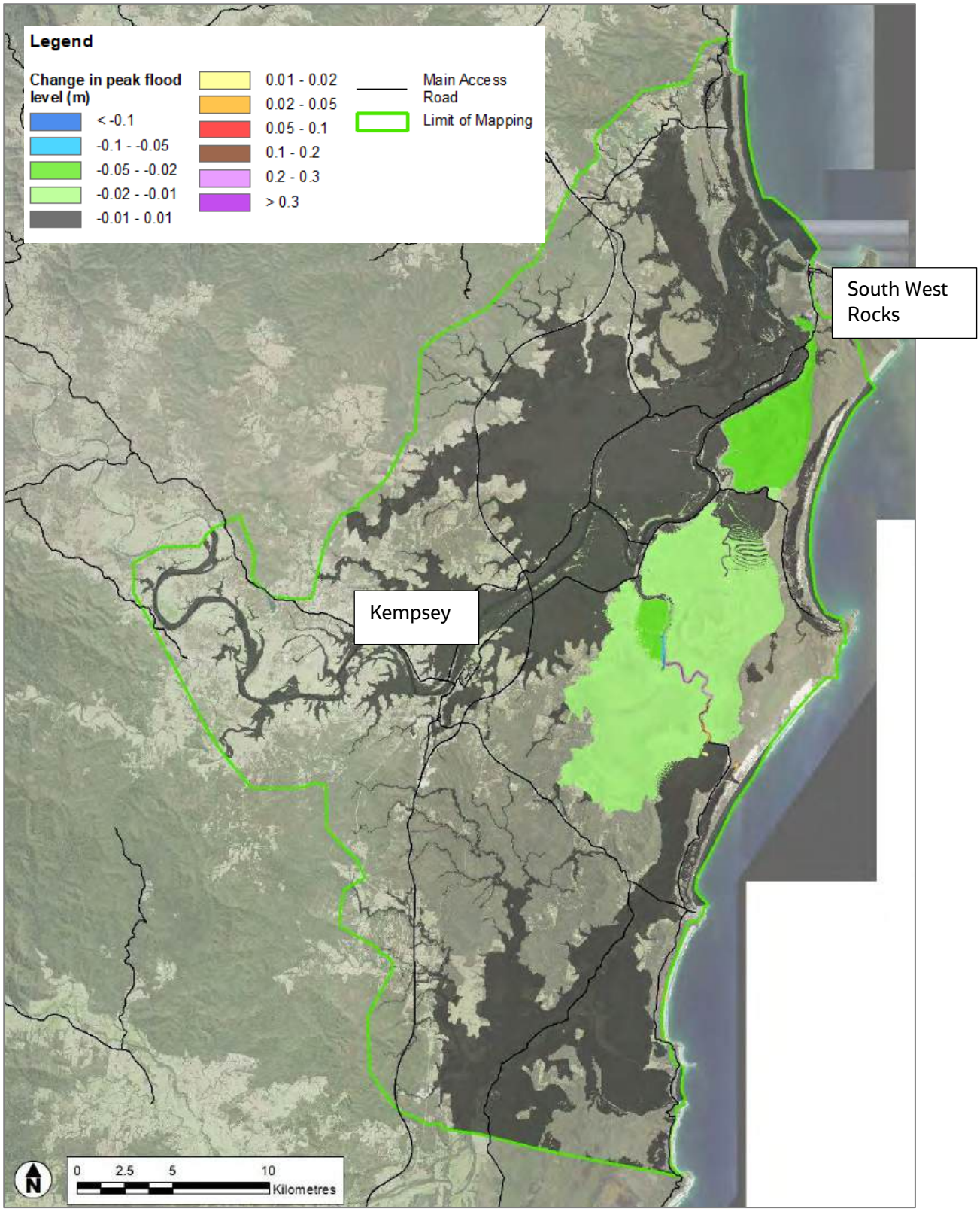


Figure F-35: Option 4B – Change in peak flood level from existing case – 5% AEP event

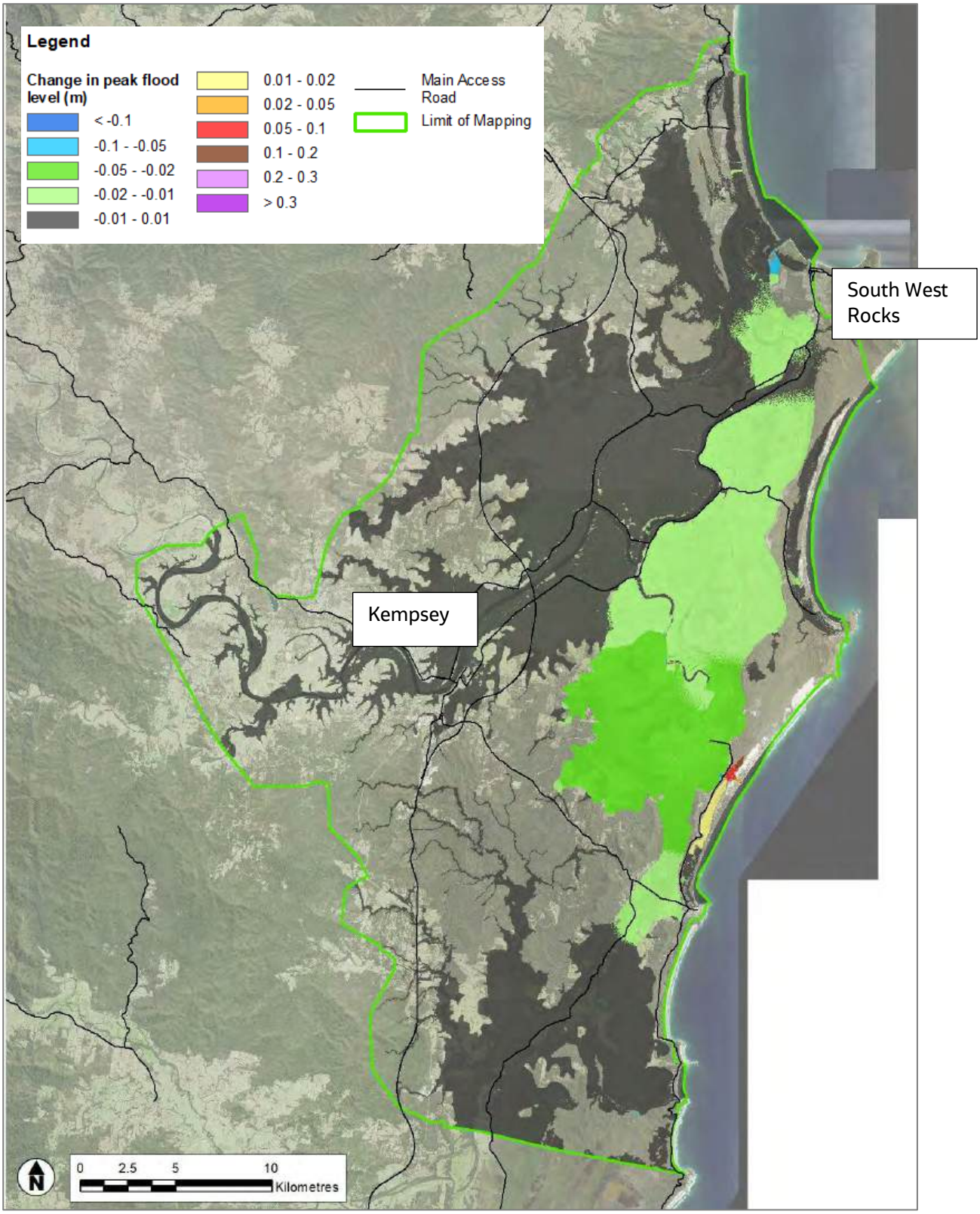


Figure F-36: Option 4B – Change in peak flood level from existing case – 1% AEP event

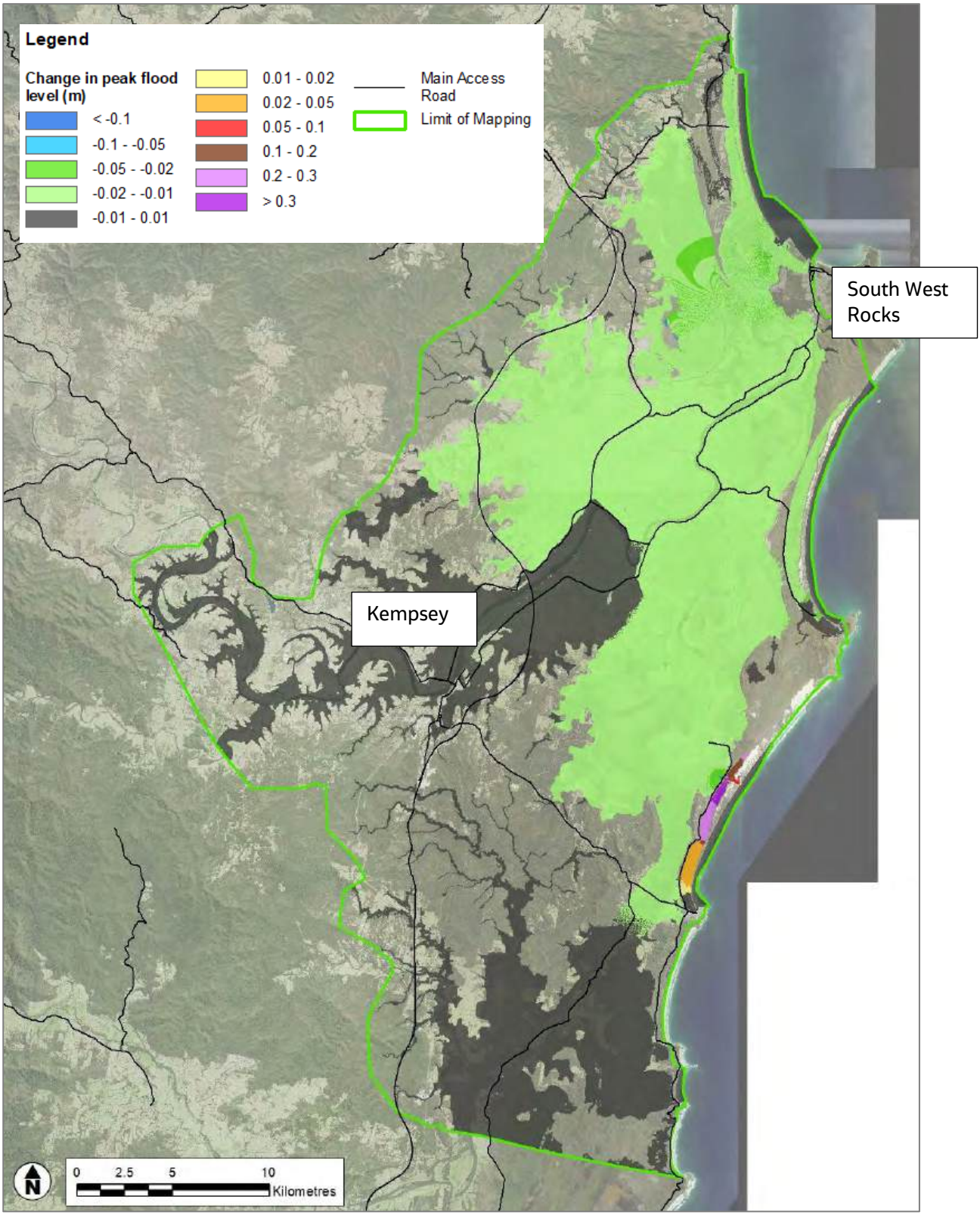


Figure F-37 and Figure F-38 show the flood levels versus time at Upper Belmore and at Swan Pool, respectively, for the 20%, 10%, 5% and 1% AEP events. Durations of flooding are reduced by 15 to 38 hours at both locations for the 10%, 5% and 1% AEP events, which is typical for the southern floodplain to the east of Belmore River. The reductions in durations are slightly greater than for Option 4. There are negligible changes to duration of flooding for areas to the west of Belmore River and north of Hat Head Road at Kinchela.

Figure F-37: Flood levels versus time at Upper Belmore, Existing compared with Option 4B

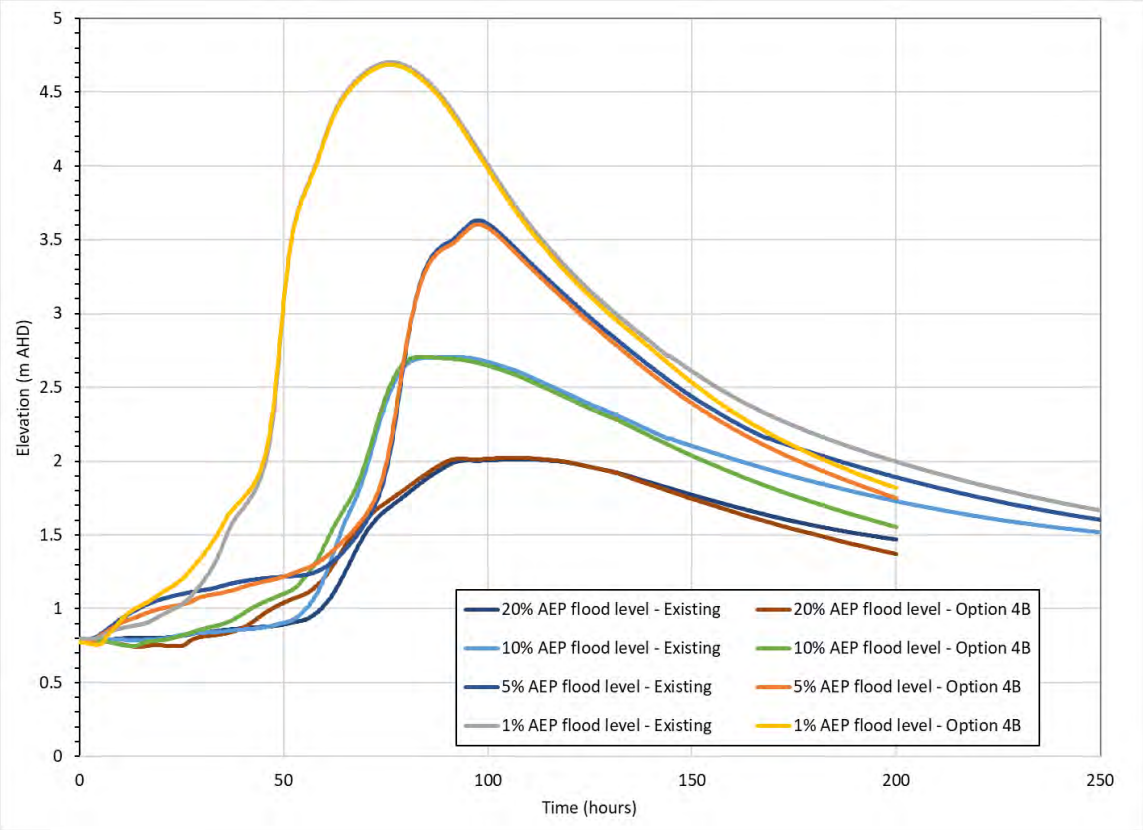
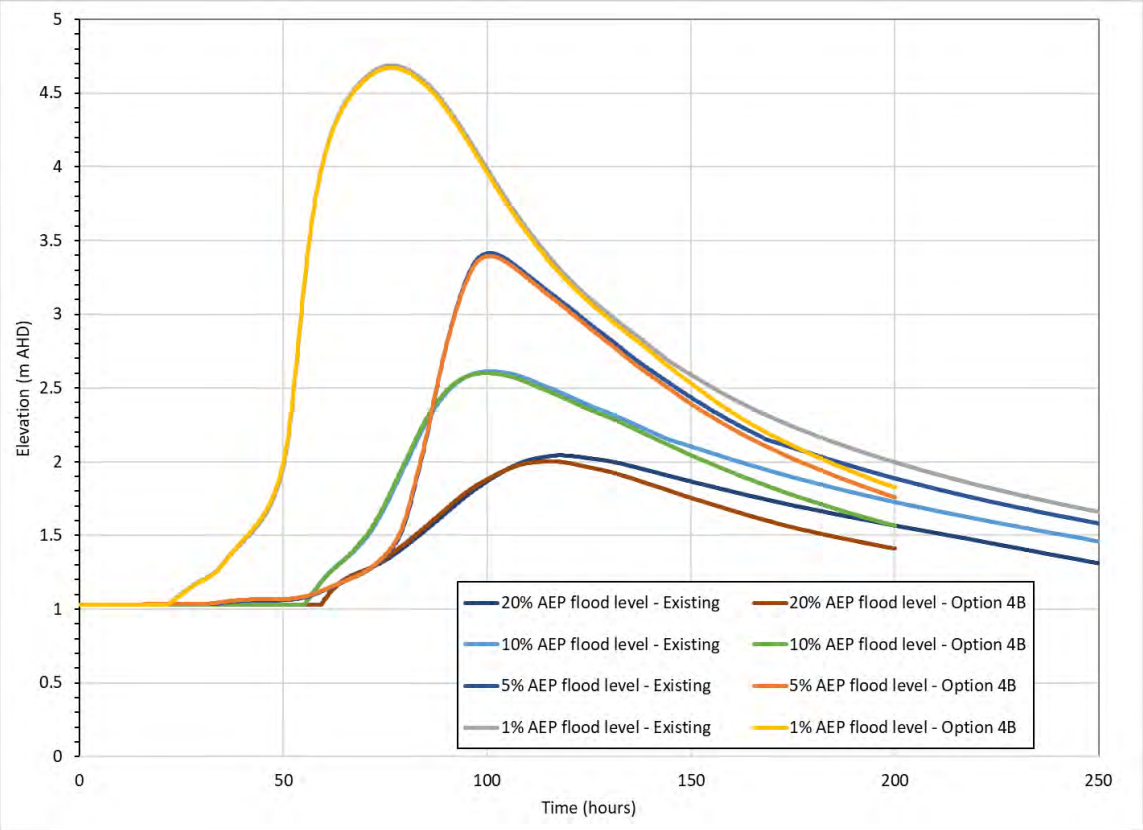


Figure F-38: Flood levels versus time at Swan Pool, Existing compared with Option 4B



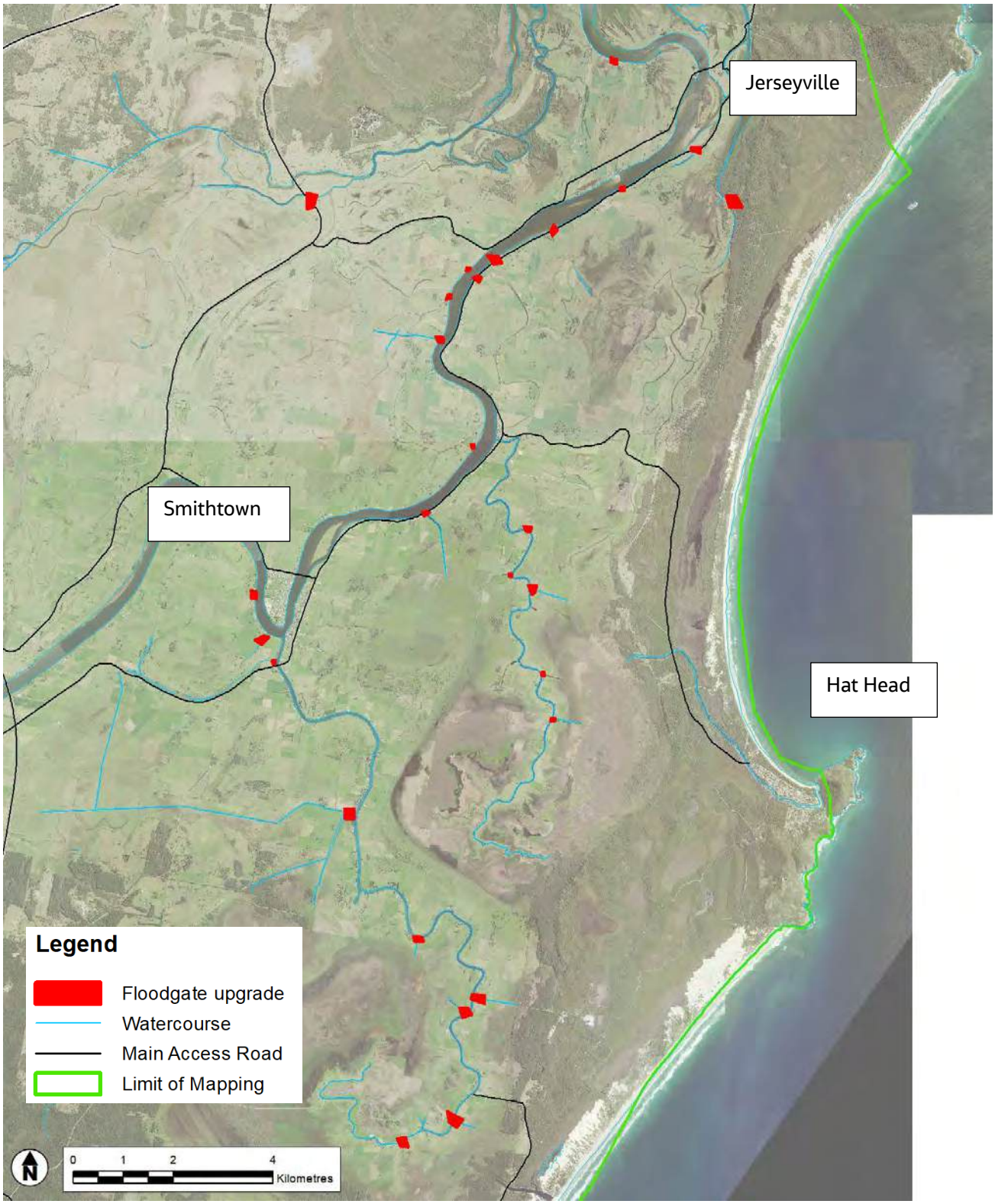
F.8 Option 5 – Increased floodplain drainage capacity – floodgates and drains

Discussion

The floodplain is drained by numerous drains and floodgates to the Macleay River and main tributaries including Belmore River, Kinchela Creek and Clybucca Creek. Increasing the size and capacity of the drains and floodgates may help to improve the drainage times on the floodplain following a flood event. Option 5 has been tested by nominally doubling the capacity of the floodgate structures within the TUFLOW model, shown on Figure F-39. Where required, drainage channels were also widened to suit the upgraded floodgate structures.

The existing drains and floodgates on the Lower Macleay, in addition to other floodplains on the NSW North Coast, have been associated with poor water quality outcomes and aquatic ecology impacts due to acid sulfate runoff, lowered water table and increased risks of blackwater events. Increasing drainage capacity at drains and floodgates may worsen these impacts. Further environmental studies would be required to help quantify the risk of reduced water quality impacts and identify any mitigation strategies.

Figure F-39: Locations of assessed floodgate capacity upgrades, Option 5



Effects on flooding

Option 5 results in negligible changes in peak flood levels from the existing case for the 20%, 10%, 5% and 1% AEP events.

Figure F-40 to Figure F-42 plot the flood levels with time for the 20%, 10%, 5% and 1% AEP events at Swan Pool, Upper Belmore and Summer Island which are representative locations for reporting the change in duration of flooding with Option 5 compared to existing. Figure F-43 shows the locations where the flood levels are reported. Option 5 provides negligible changes to the duration of flooding in the southern floodplain (Swan Pool and Upper Belmore).

There are reductions in duration of flooding of around 20 hours in all events in parts of Summer Island, however, the area of the floodplain experiencing benefits is small, as shown on figure F-43. Option 5 could be further considered based on floodgate and drainage upgrades limited to around Summer Island and Clybucca.

Figure F-40: Flood levels versus time at Swan Pool, Existing compared with Option 5

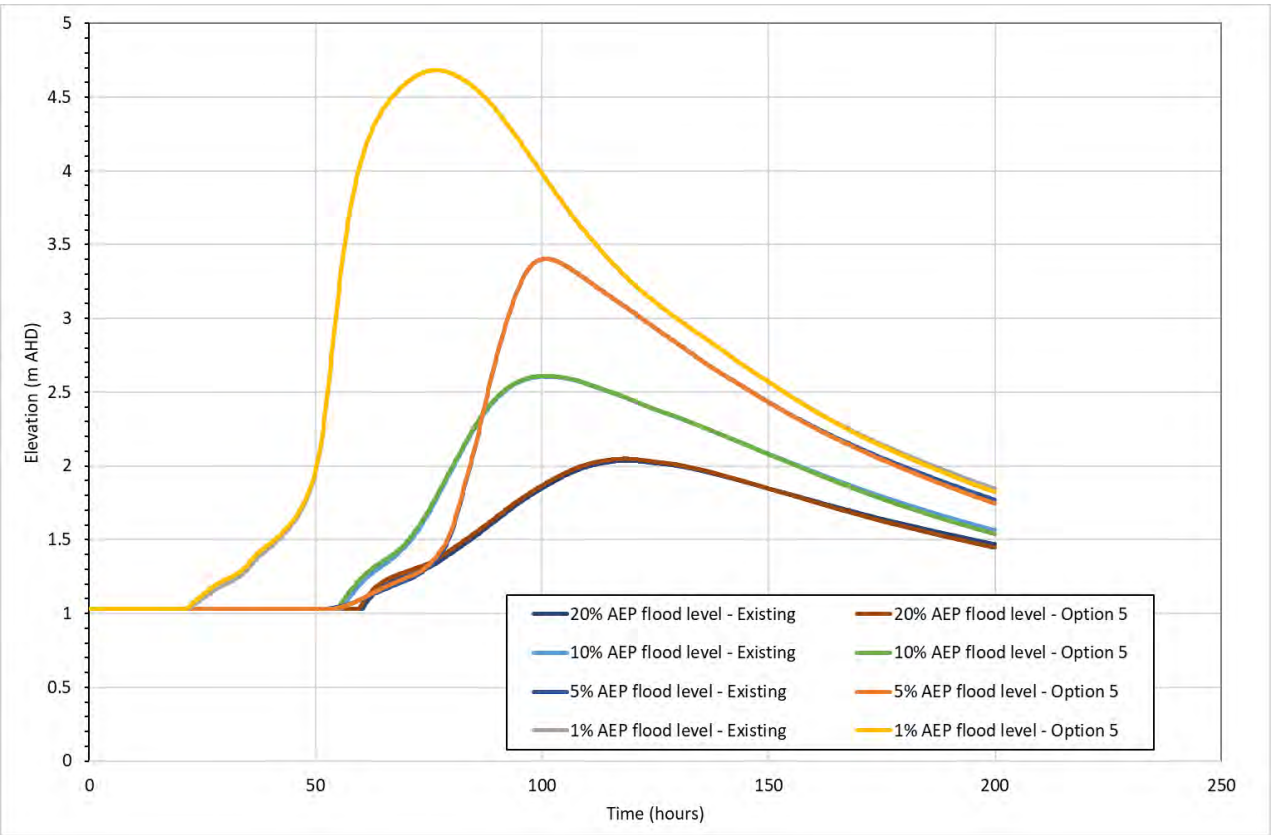


Figure F-41: Flood levels versus time at Upper Belmore, Existing compared with Option 5

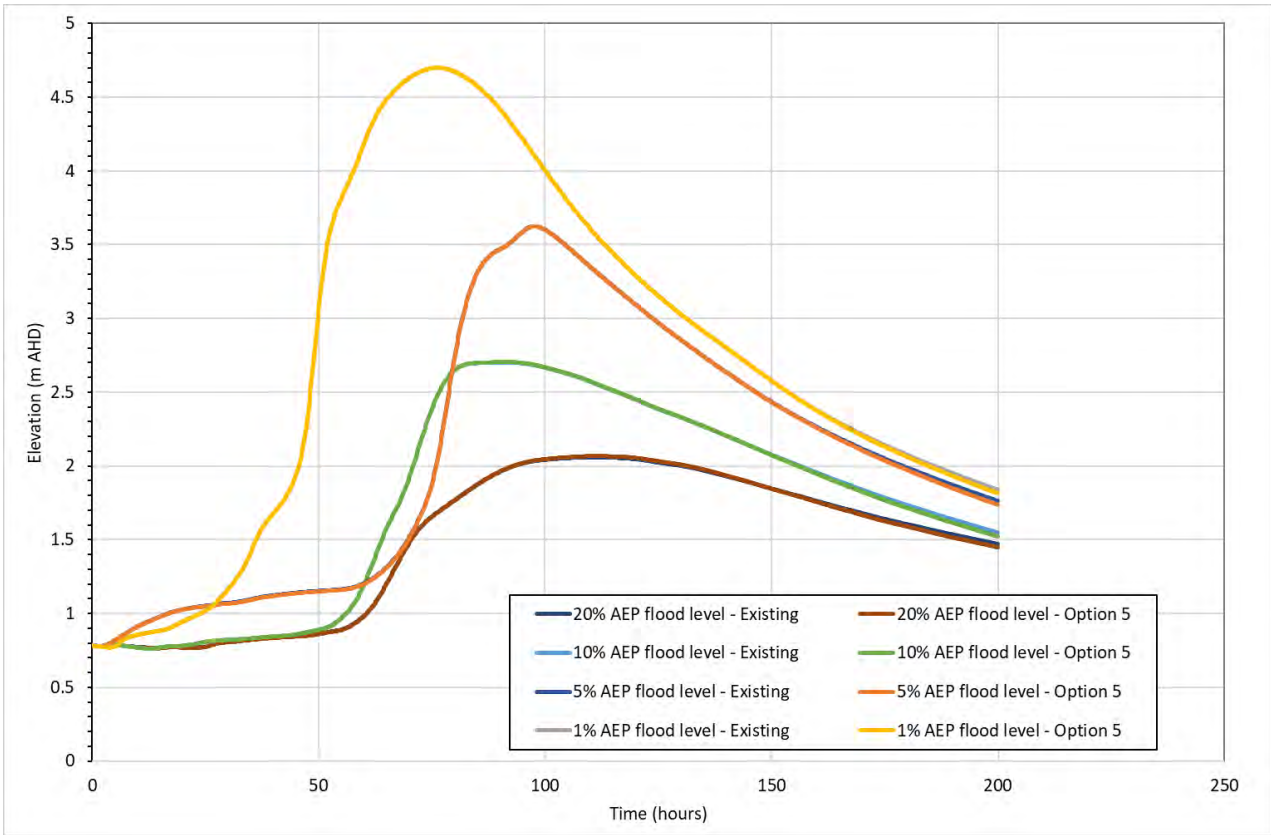


Figure F-42: Flood levels versus time at Summer Island, Existing compared with Option 5

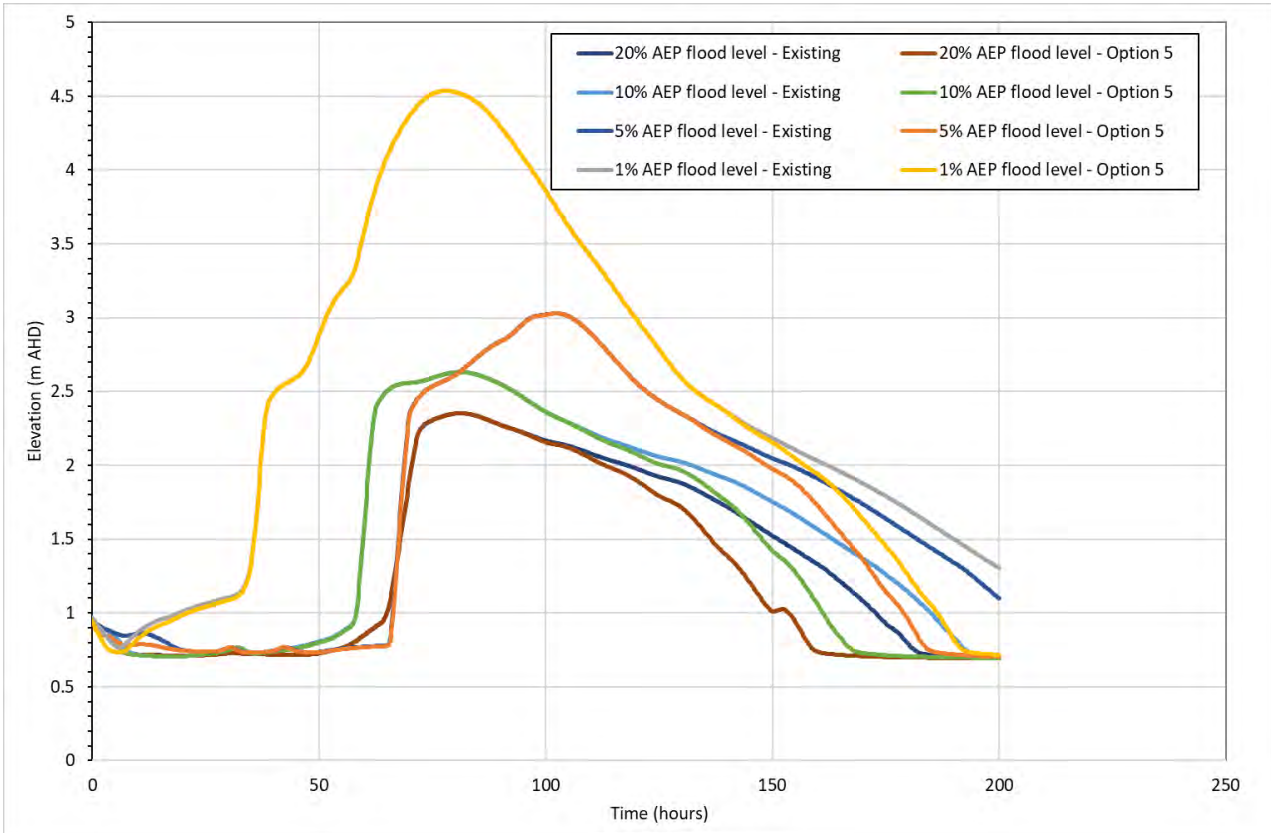
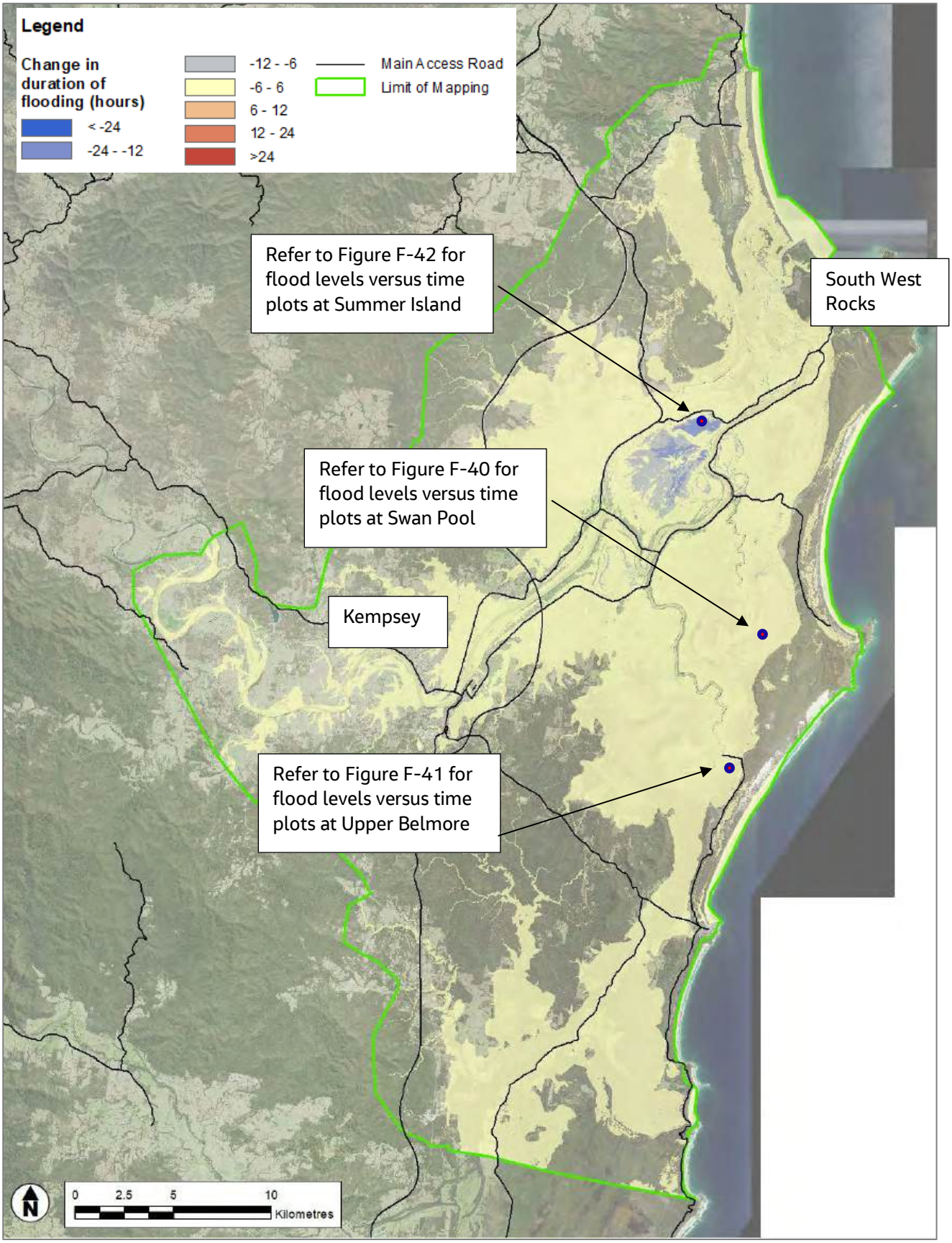


Figure F-43: Flood level with time reporting locations and 5% AEP event change in duration of flooding, Option 5



F.9 Option 6 – Reinstate Rowes Cut

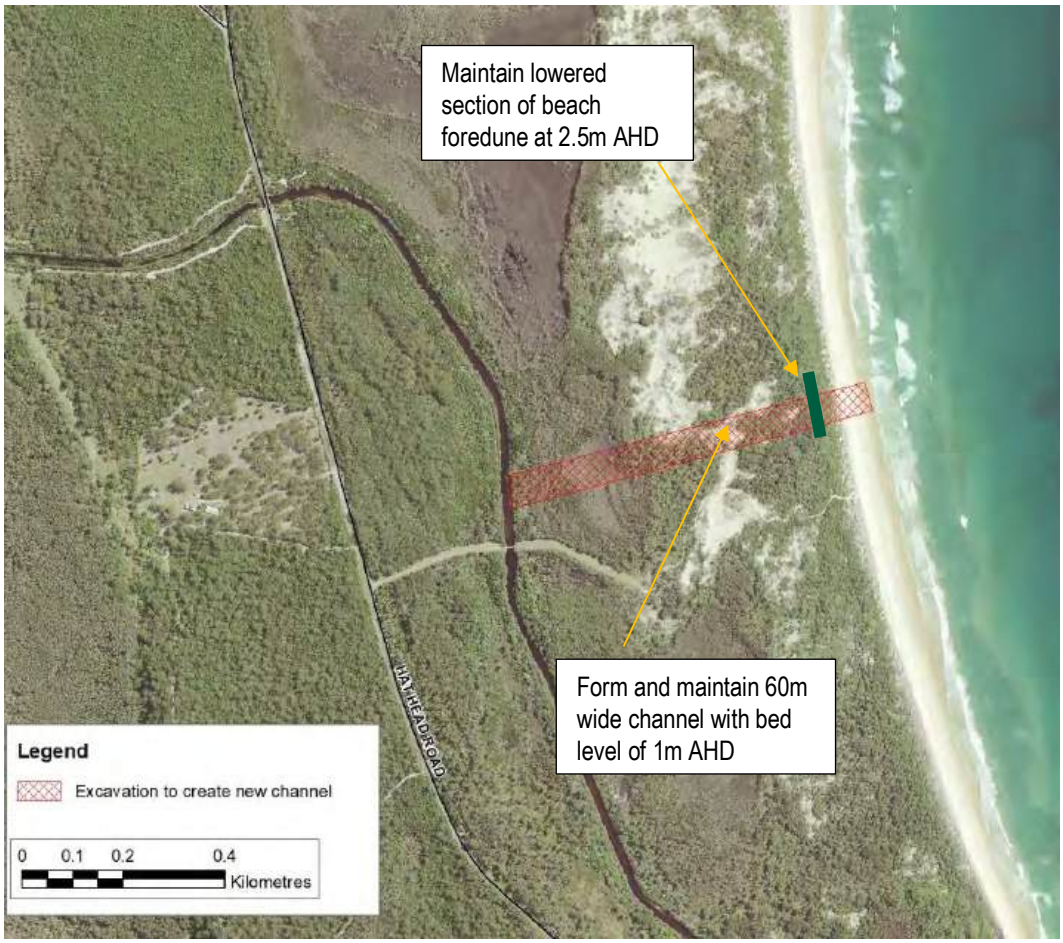
Discussion

Option 6 would involve earthworks and vegetation clearing to reinstate Rowes Cut as an ocean outlet for floodplain discharge, which may help reduce inundation times in the Lower Macleay floodplain. Rowes Cut is currently in an unmaintained condition with the dune system filling the Cut and vegetation becoming re-established.

The assessed option includes clearing of vegetation and excavation to create and maintain a new channel 60m wide to 1m AHD base elevation. At the beach foredune area, a lowered section of the dunes (to 2.5m AHD) would be maintained which would be washed out by flows during a flood event. Channel sides would be stabilised with cellular matrix proprietary products which would allow vegetation to grow through the matrix layer while holding the topsoil layer together. Refer to Figure F-44.

Works associated with this option would occur within Hat Head National Park, which would require additional environmental permits and approvals. Periodic maintenance of the Cut would be required to maintain the lowered dune profile and manage vegetation.

Figure F-44: Option 6 – Reinstate Rowes Cut north of Hat Head



Effects on flooding

Figure F-45 and Figure F-46 present the change in peak flood levels for the 5% and 1% AEP events, respectively, with reinstatement of Rowes Cut. The changes in peak flood levels are not mapped for the 10% and 20% AEP events as the changes are minimal.

Figure F-45: Option 6 – Change in peak flood level from existing case – 5% AEP event

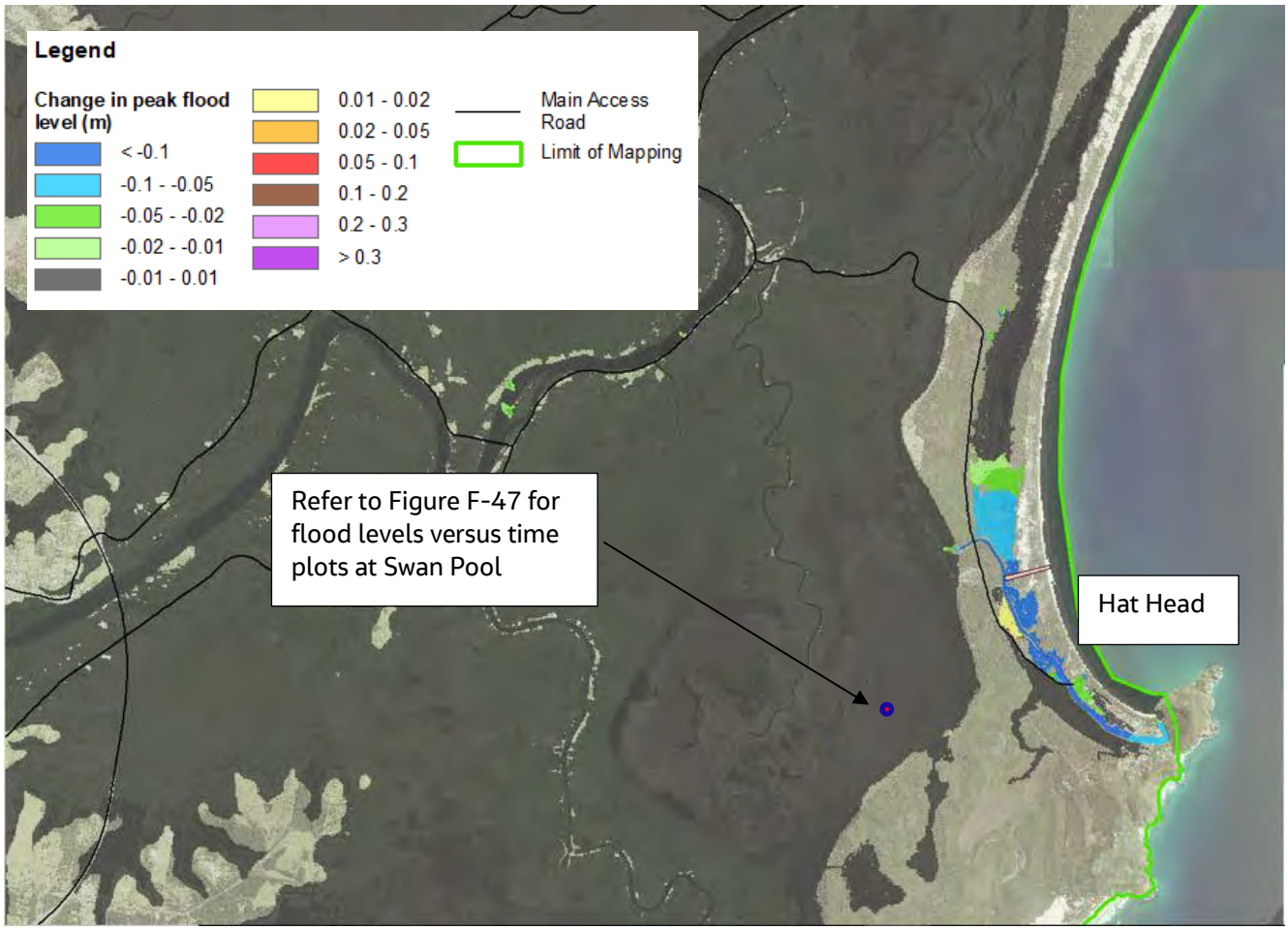
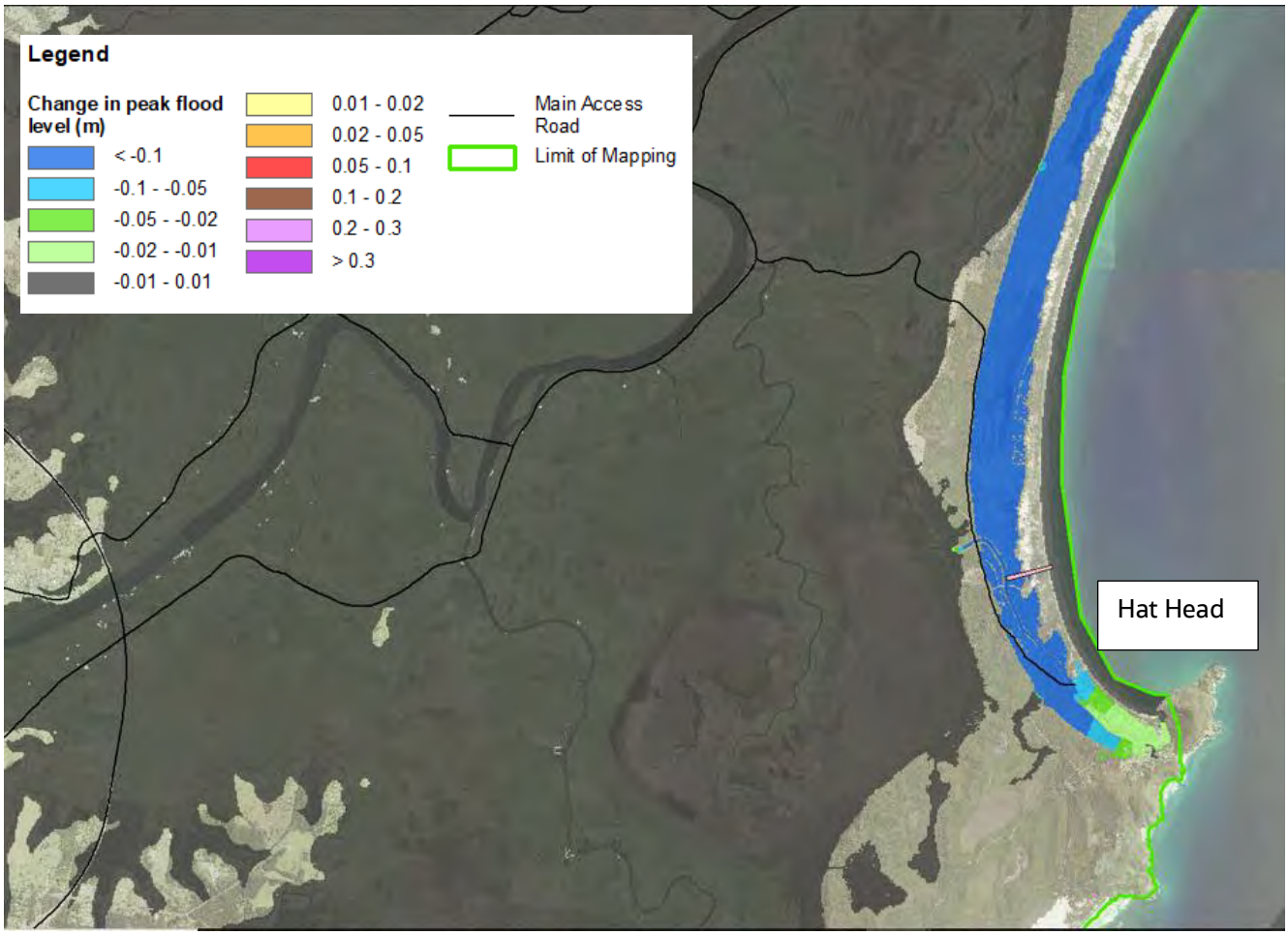


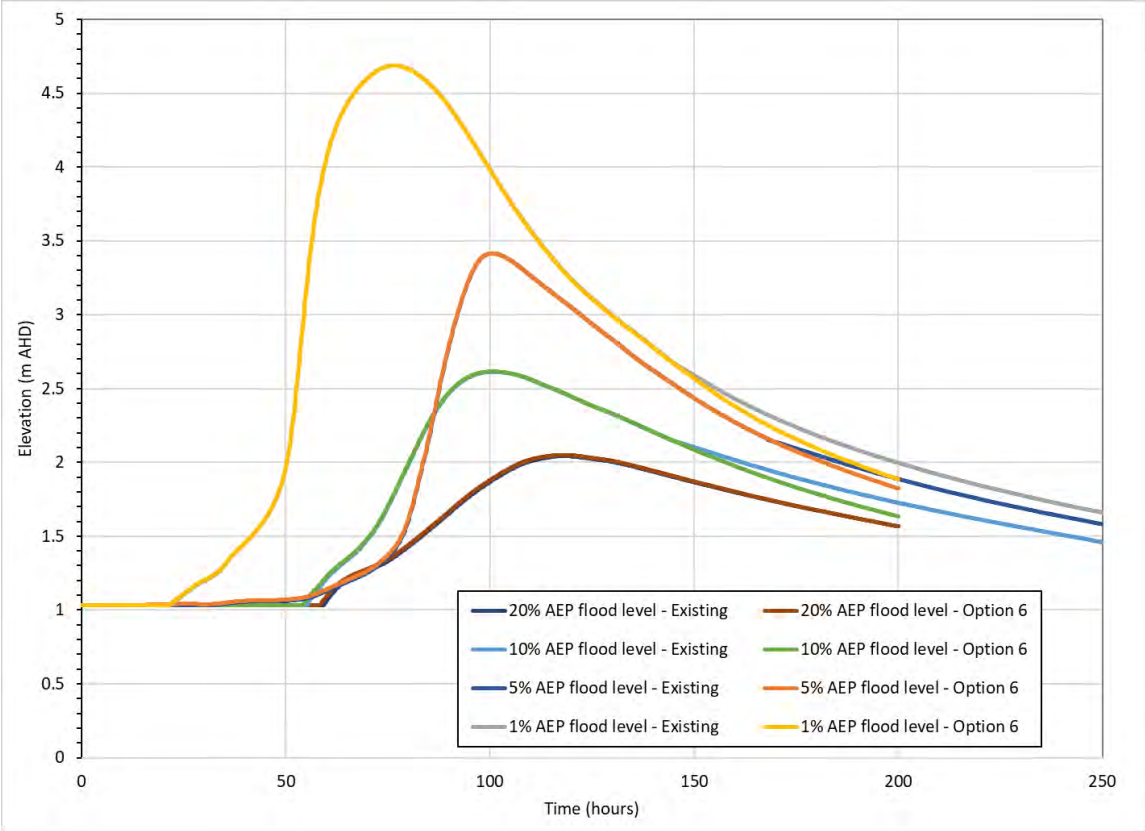
Figure F-46: Option 6 – Change in peak flood level from existing case – 1% AEP event



Peak flood levels in Hat Head village are reduced by up to 0.04m in the 5% AEP event and 0.07m in the 1% AEP event. Reductions in flood levels of up to 0.1m occur in Korogoro Creek and vegetated areas.

Figure F-47 plots the flood levels versus time for the 20%, 10% 5% and 1% AEP events for the existing case and with Option 6 at Swan Pool, The reporting location is shown on Figure F-45. Durations of flooding are reduced by 9 to 16 hours for the 10%, 5% and 1% AEP events, which is considered a minor improvement. The reductions in duration are limited to the area in the southern floodplain between Hat Head Road and Crescent Head Road and east of Belmore River.

Figure F-47: Flood levels versus time at Swan Pool, Existing compared with Option 6



F.10 Option 7 – Enlarged headworks on Belmore River and Kinchela Creek

Discussion

The existing headworks on the Belmore River and Kinchela Creek are relatively small compared to the width of the waterways. For example, the width of the headworks on Belmore River is about 12m compared to a channel width of 45m at that location, with a discharge rate of 64m^3/s during the recession in the 1% AEP event. On Kinchela Creek the headworks are 6m wide compared to a 35m channel width, with a 1% AEP event peak discharge rate of 20m^3/s. Option 7 was therefore tested for the potential to reduce inundation times in the southern floodplain, involving an increase in the numbers of floodgates at the Belmore and Kinchela headworks. Refer to Figure F-48 and Figure F-49 for illustration.

Figure F-48: Option 7 – Enlarged headworks at Belmore River

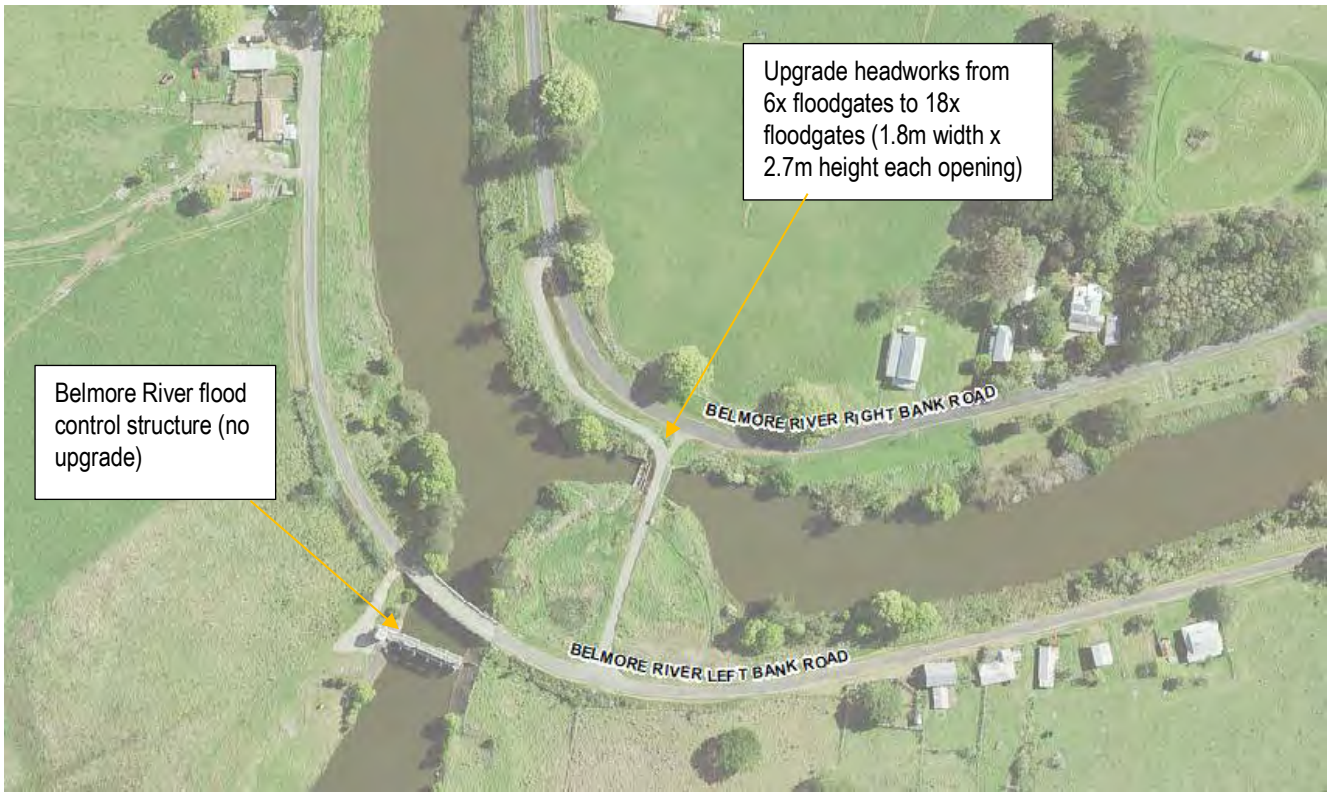
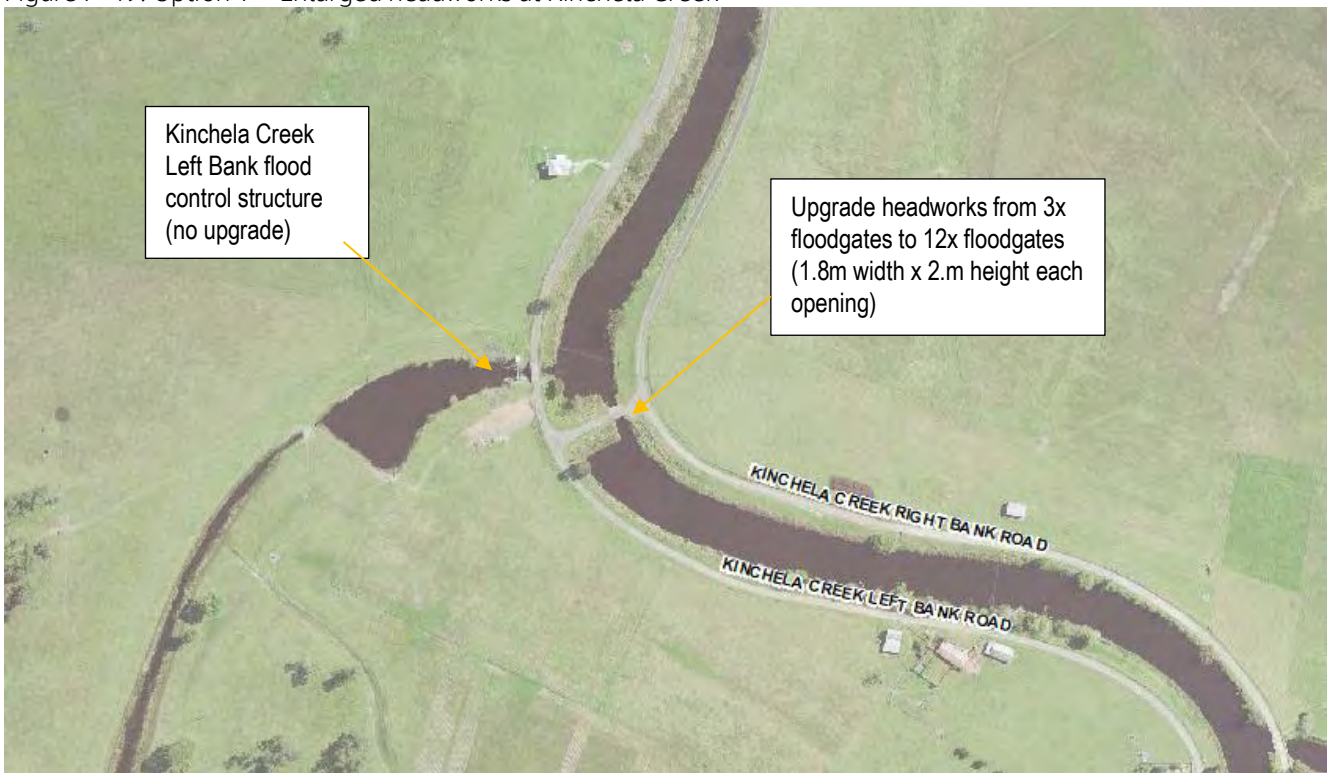


Figure F-49: Option 7 – Enlarged headworks at Kinchela Creek



The Belmore River and Kinchela Creeks have previously been described as "fish traps" (refer Lower Macleay Floodplain Management Study, Webb McKeown & Associates, 1997) where by during a flood event fish take

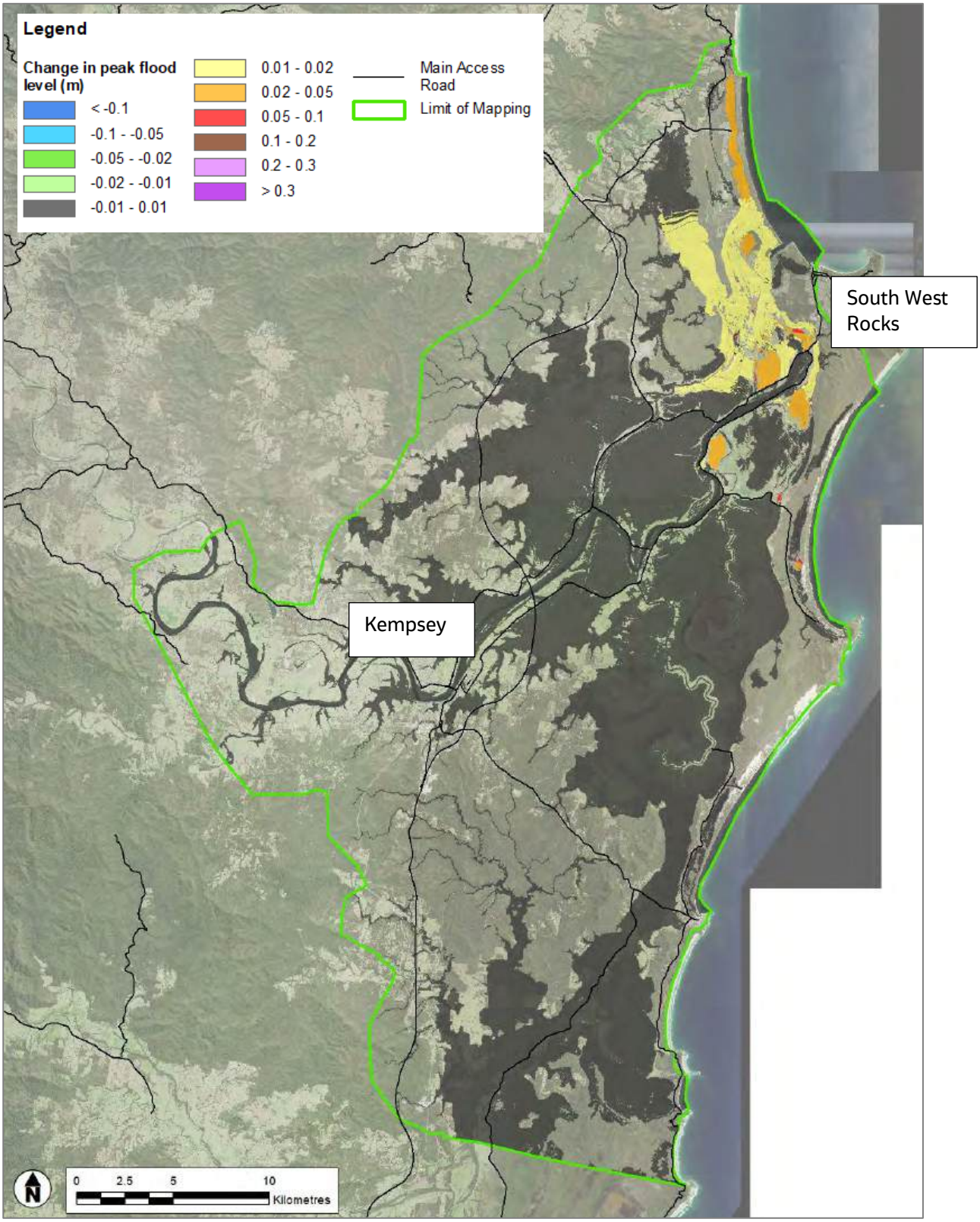
refuge in the creeks out of highly turbid water in the main river. They become trapped by the turbid river water, poor water quality (low dissolved oxygen or pH) discharged by floodplain drains in the lower reaches of the creeks as well as through the headworks, eventually succumbing to a fish kill event as the pocket of better water quality diminishes by the increased floodplain drainage. This option has the potential to increase the risk of this phenomenon. Further environmental studies would be required to confirm such risks.

Effects on flooding

Option 7 has generally negligible impact on peak flood levels or durations of inundation. The change in peak flood levels were less than 2mm for the 10%, 5% and 1% AEP events and change in durations of inundation less than 1 hour. In the 20% AEP event, there are increases in peak flood levels of 0.01 – 0.05m in areas downstream of Kinchela. Refer to Figure F-50.

While peak flows through the upgraded headworks are increased with Option 7, the increases in flows are impeded by relatively high tailwater levels. For example, the existing discharge rate of 64m^3/s at Belmore River headworks during the recession in the 1% AEP event is only increased to 75m^3/s with Option 7, due to a 0.1m water level difference across the headworks limiting outflow. The existing floodgates draining to the creeks upstream of the headworks may also be a constraint on system drainage.

Figure F-50: Option 7 – Change in peak flood level from existing case – 20% AEP event



F.11 Option 8A and 8B – Modify opening regime of flood control structures with supplementary road and levee raising

Discussion

The flood control structures at Belmore River and Kinchela Creek are assumed to open when flood levels at the creek entrances reach 3.8m AHD and 3.0m AHD, respectively, under the current operation of the structures. This is when flooding is expected to start overtopping the levees on these watercourses and is about 0.3m below the 20% AEP flood level at the creek entrances. It is to be noted the actual levels at which the structures are open may vary between actual flood events and availability of Council staff to man the structures, given that they are currently opened manually.

The flood control structures have been tested to open at the 10% AEP flood level, with the objective of reducing inundation on the southern floodplain. The levees and roads along the Belmore River and Kinchela Creek currently overtop at some locations during the 20% AEP event. Hence, modified opening supplementary raising of the roads and levees was assessed as described below:

- Option 8A: Opening of flood control structures at the 10% AEP flood level (4.44m AHD at Belmore River entrance and 3.35m AHD at Kinchela Creek entrance) plus raising of Belmore River Left Bank and Right Bank Roads/Kinchela Creek Left Bank and Right Bank Roads to above 10% AEP flood level (typically raised by 0.1 – 0.4m; localised sections up to 0.6m).
- Option 8B: As per Option 8A, plus raising of sections of South West Rocks Road through Austal Eden and Gladstone to Kinchela (typically raised by 0.1 – 0.4m; sections up to 1.2m raised through Austral Eden) and new/raised earth levee (0.7 – 1m height) between East Kempsey and Pola Creek. The purpose of these additional works are to prevent overflows from the Macleay River at these locations into the southern floodplain in the 10% AEP event.

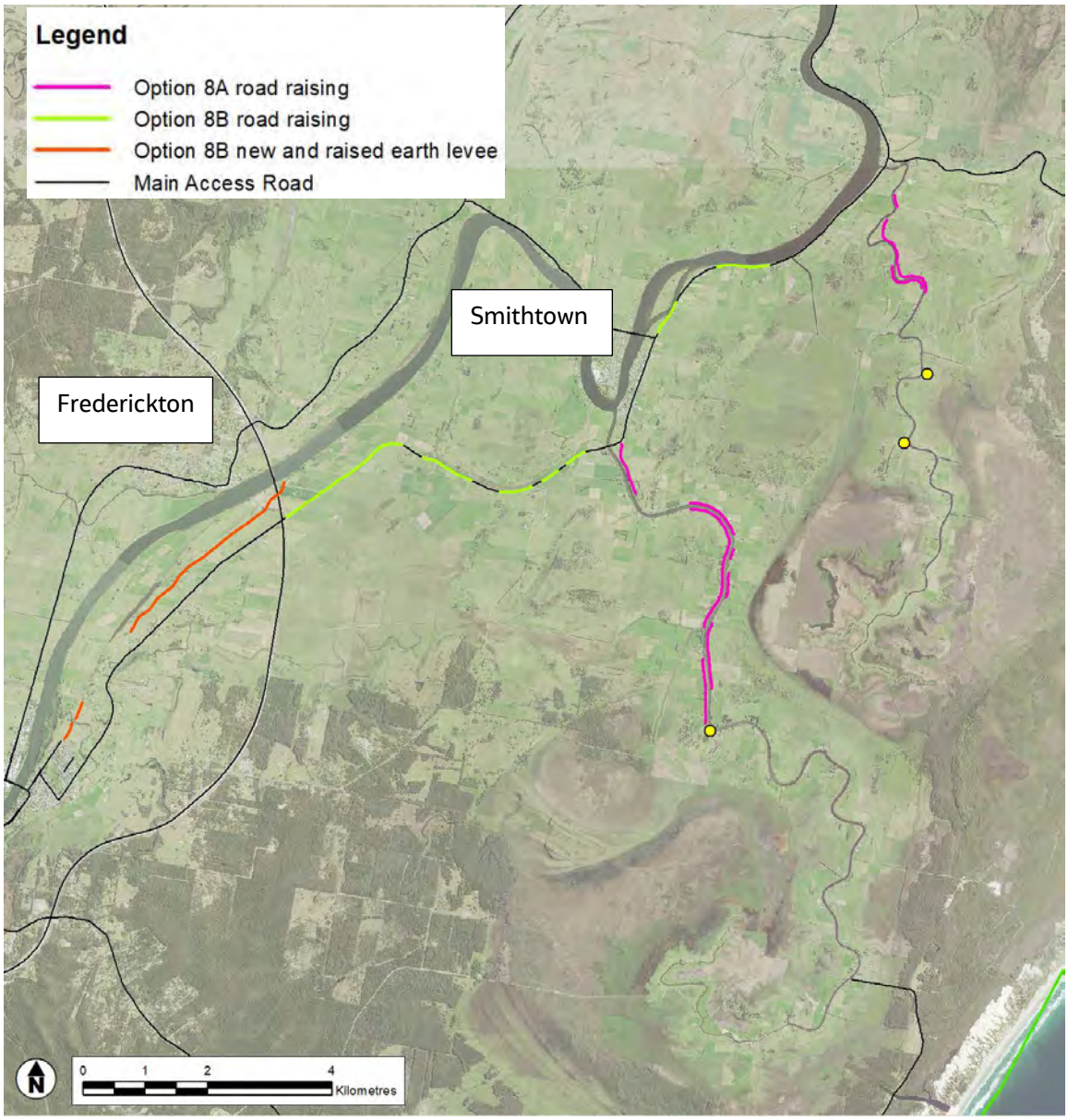
Refer to F-51 for illustration of locations where roads would be raised and new levees provided as a part of Option 8A and Option 8B.

Options of modifying the flood control structures to open at the 5% and the 1% AEP flood levels, plus supplementary road and levee raising works, was not considered in detail as there is significant overtopping of floodwaters over the existing roads and levees into the southern floodplain under current conditions. Substantial raising of roads and levees would be required, which would result in flooding impacts.

Opening the structures at the 10% AEP flood level would translate to opening them at approximately 0.4m higher flood level than currently. In the 10% AEP event the overflows from the river are significantly greater than in the 20% AEP (1009m^3/s in the 10% AEP event compared to 86m^3/s in the 20% AEP event. The effect on floodplain inundation of changing the opening stage of the flood control structures is likely to be minimal in the 10% AEP event and larger.

The Belmore River flood control structure conveys about 250m^3/s into the floodplain during the 20% AEP event, which is about 12% of the flow in the river at Smithtown gauge. Delaying opening the structure may result in increased overflow of the river into Smithtown and other locations in the 20% AEP event.

Figure F-51: Illustration of road raising and new levees locations for Options 8A and 8B



Effects on flooding – Option 8A

Figure F-52 to Figure F-55 show the change in peak flood level for the 20%, 10%, 5% and 1% AEP events from existing case to with Option 8A. There are reductions in flood levels of up to 0.1m on the southern floodplain in the 20% AEP event due to reduced flow through the flood control structures, but the option results in increased flood levels in Belmore River, Kinchela Creek and the Macleay River, resulting in increased river overflows and increased flood levels by up to 0.1m elsewhere. In the 10% and 5% AEP events the reductions and increases in flood levels on the floodplain are generally less, but there are remaining increases in flood levels in Belmore River and Kinchela Creek which affect the properties along the banks of those waterways. There is minimal change in flood levels in the 1% AEP event with Option 8A.

Figure F-52: Option 8A – Change in peak flood level from existing case – 20% AEP event

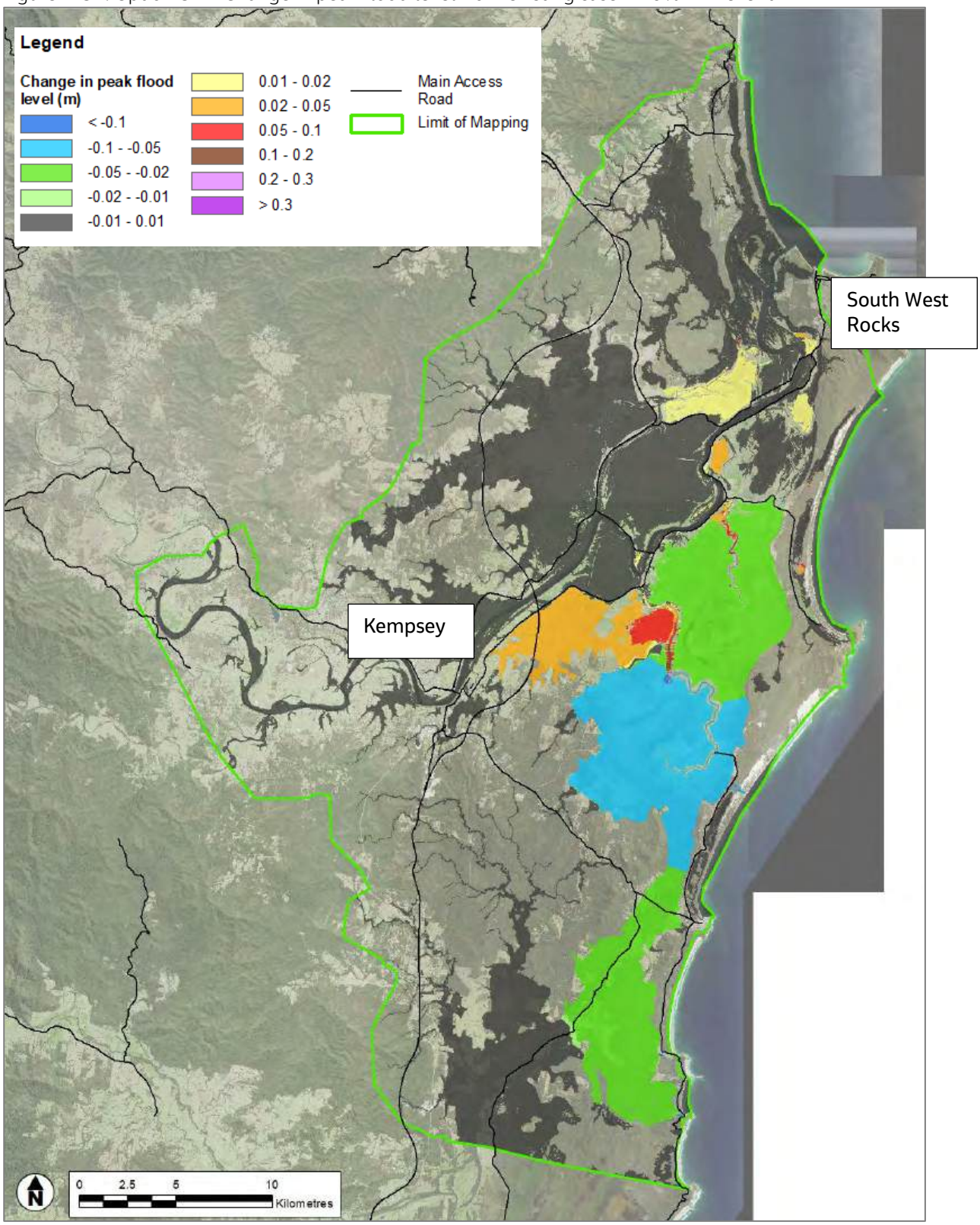


Figure F-53: Option 8A – Change in peak flood level from existing case – 10% AEP event

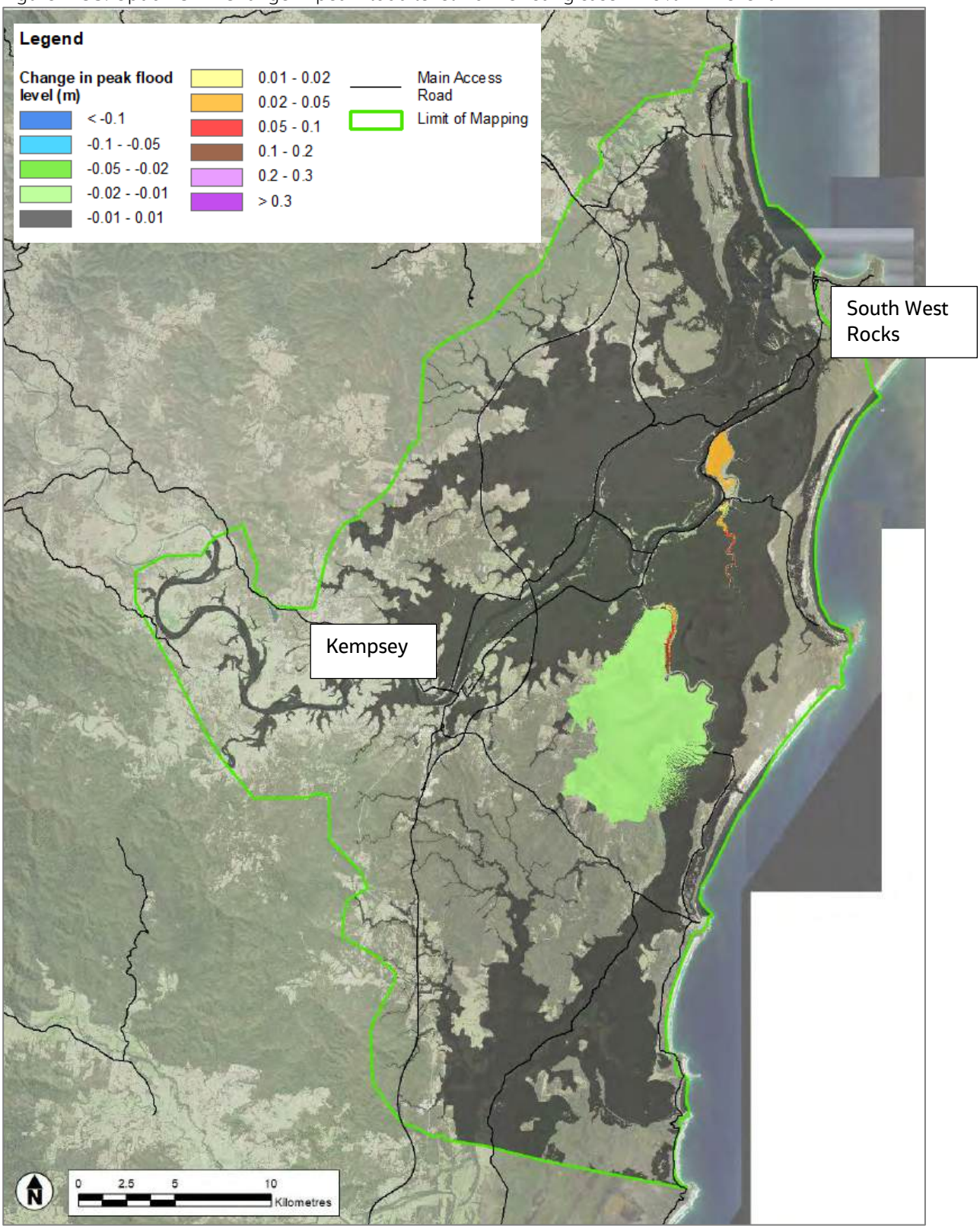


Figure F-54: Option 8A – Change in peak flood level from existing case – 5% AEP event

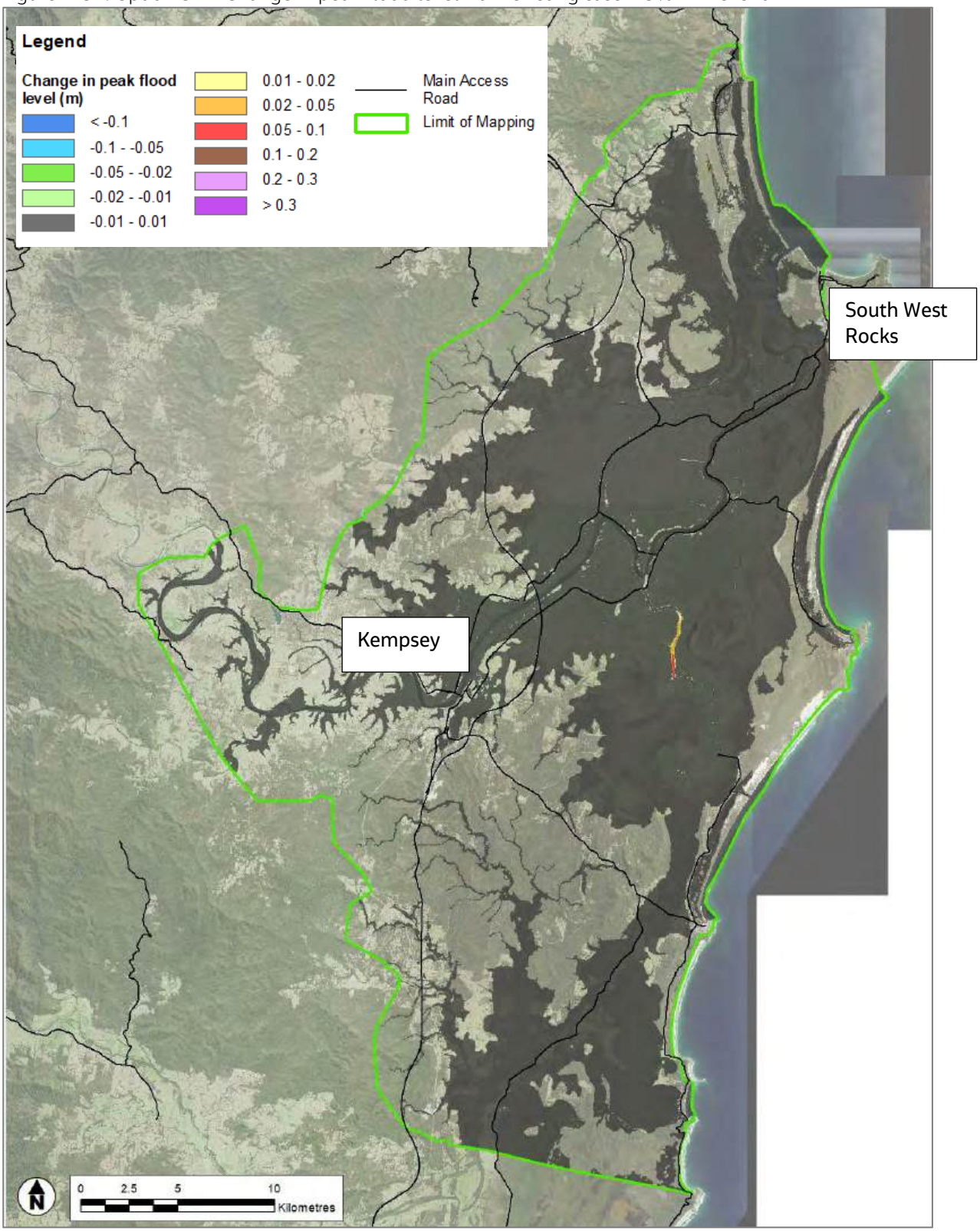
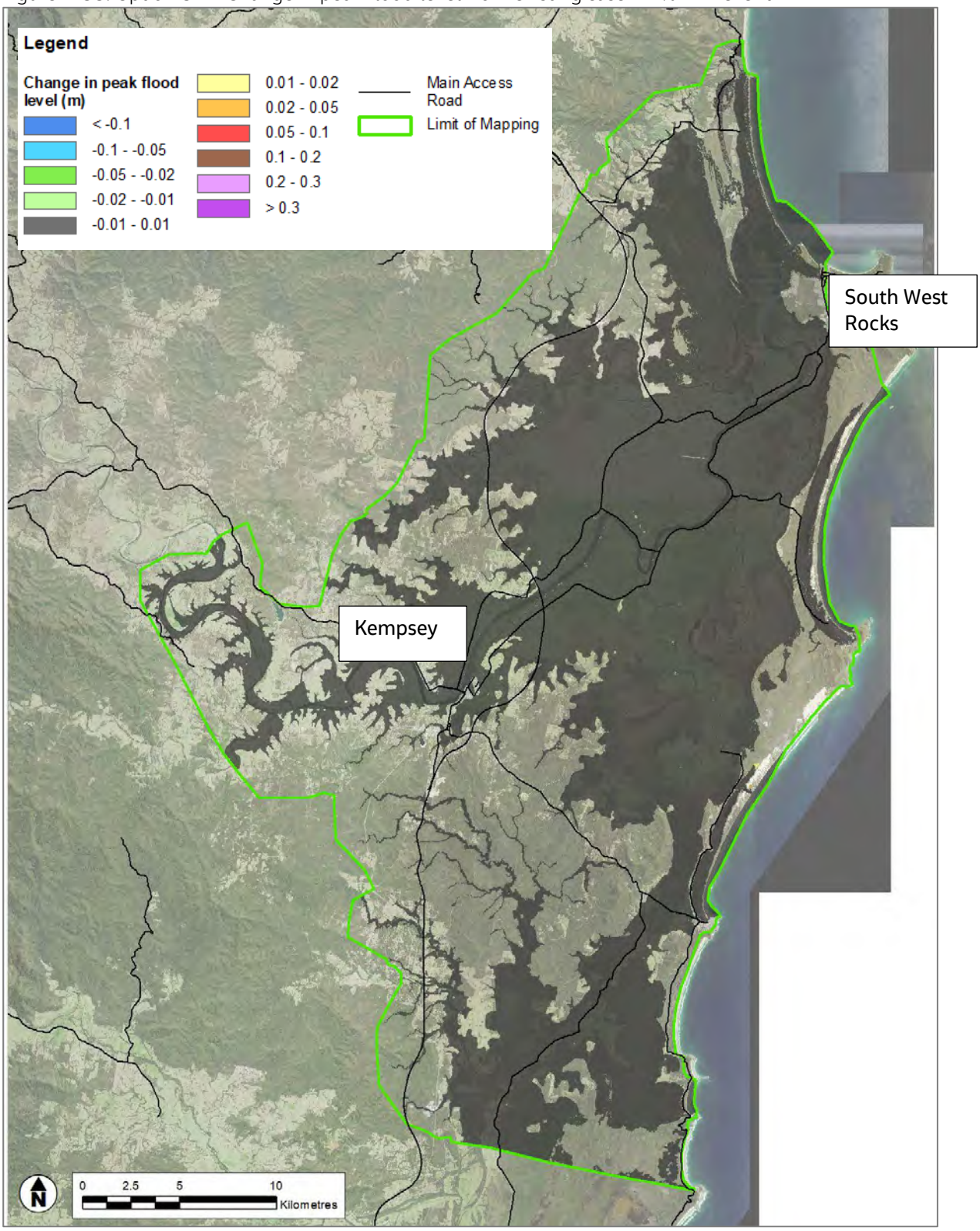


Figure F-55: Option 8A – Change in peak flood level from existing case – 1% AEP event



Effects on flooding – Option 8B

Figure F-56 to Figure F-59 show the change in peak flood level for the 20%, 10%, 5% and 1% AEP events from existing case to with Option 8B. The reductions in peak flood levels on the southern floodplain are greater than with Option 8A, due to the additional raised roads and levees reducing overflows from the Macleay River and onto the southern floodplain. There are reductions in flood levels of over 0.1m in the 20% AEP event and 0.2m in the 10% and 5% AEP events on the southern floodplain. Reductions in flood levels are typically less than 0.02m in the 1% AEP event. However, the additional road raising and levees with Option 8B results in greater

flood level increases elsewhere, with increases in peak flood levels of over 0.4m experienced in a number of locations on the northern floodplain including around Kempsey CBD in all flood events assessed. Flood impacts extend upstream of Kempsey.

Figure F-56: Option 8B – Change in peak flood level from existing case – 20% AEP event

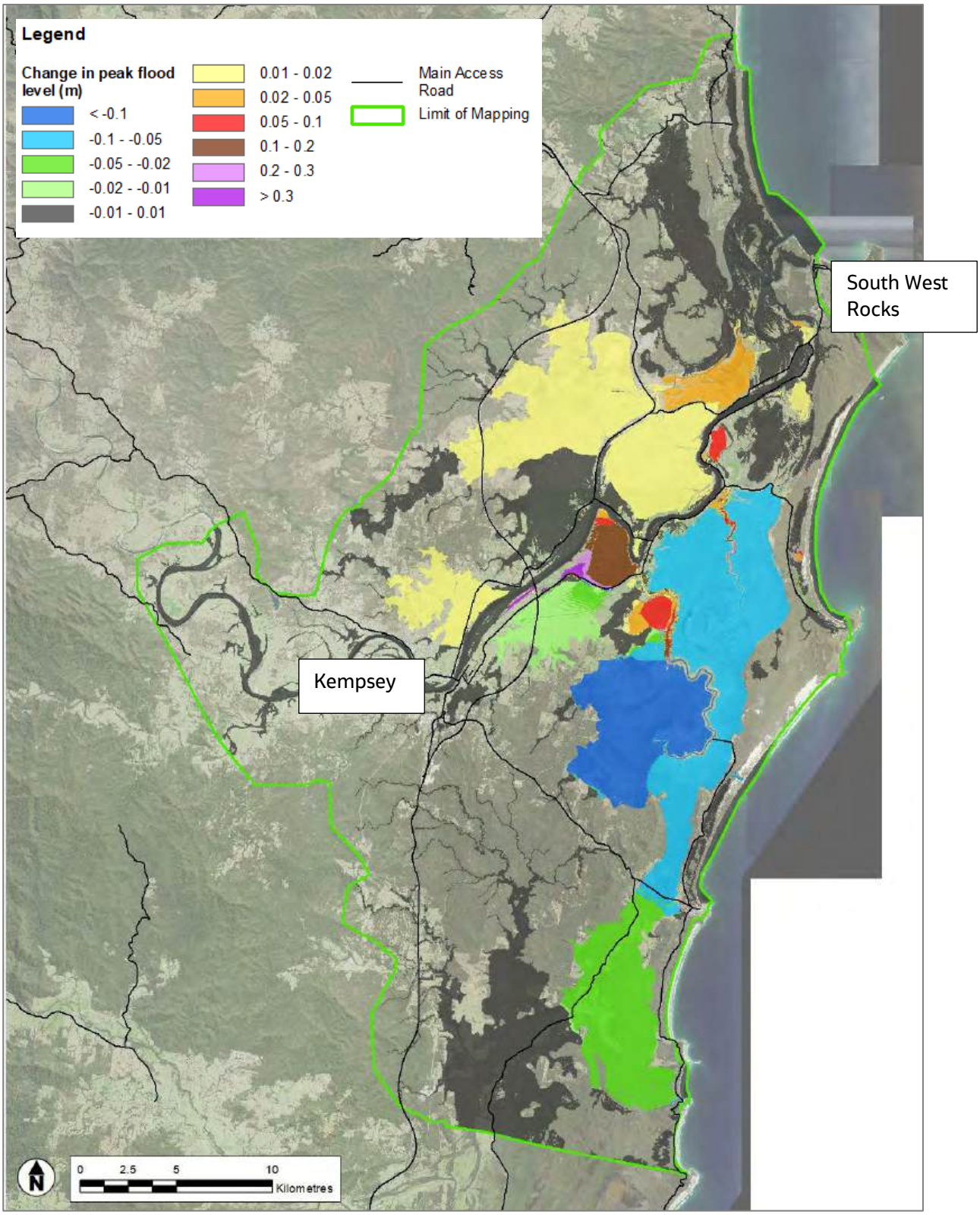


Figure F-57: Option 8B – Change in peak flood level from existing case – 10% AEP event

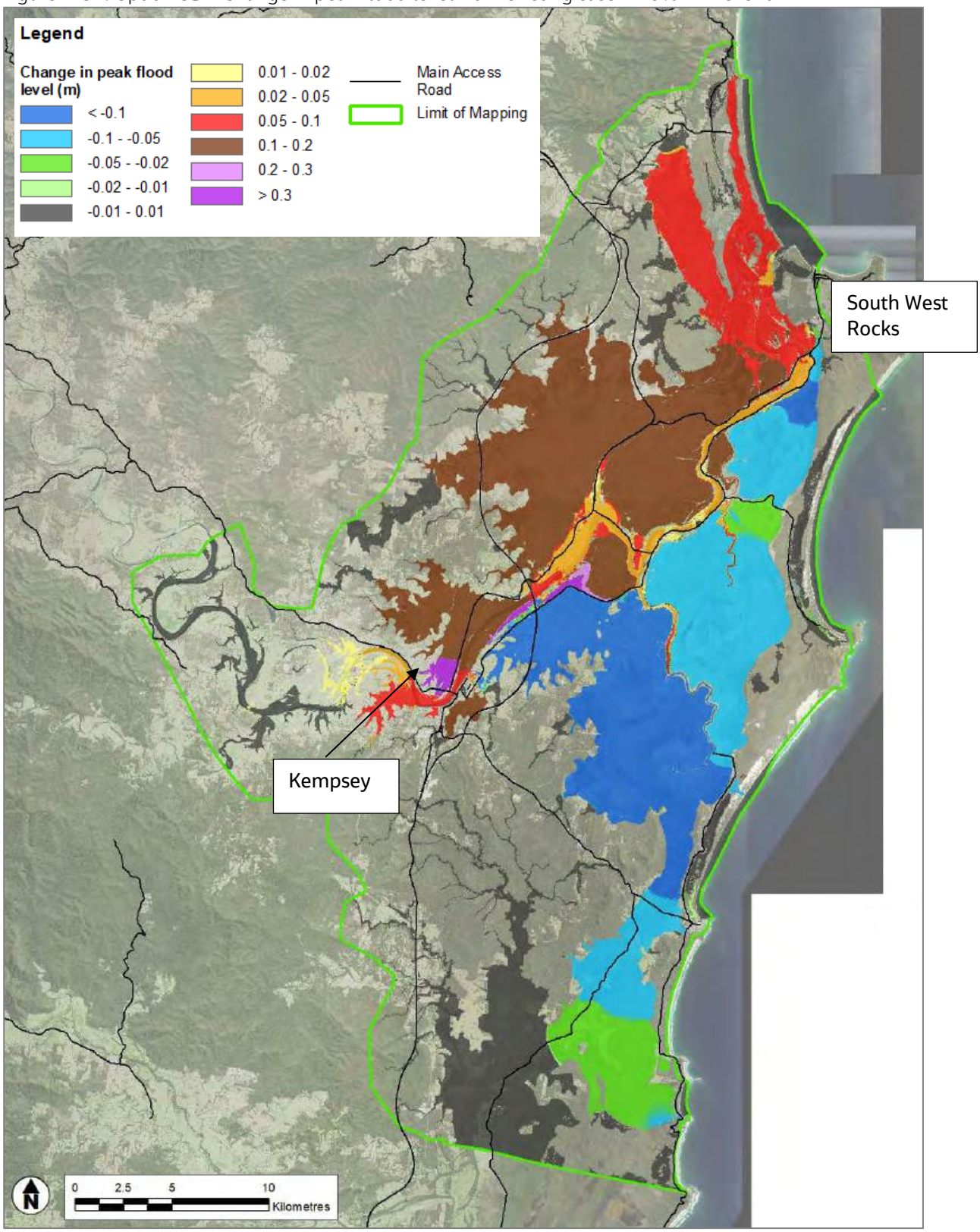


Figure F-58: Option 8B – Change in peak flood level from existing case – 5% AEP event

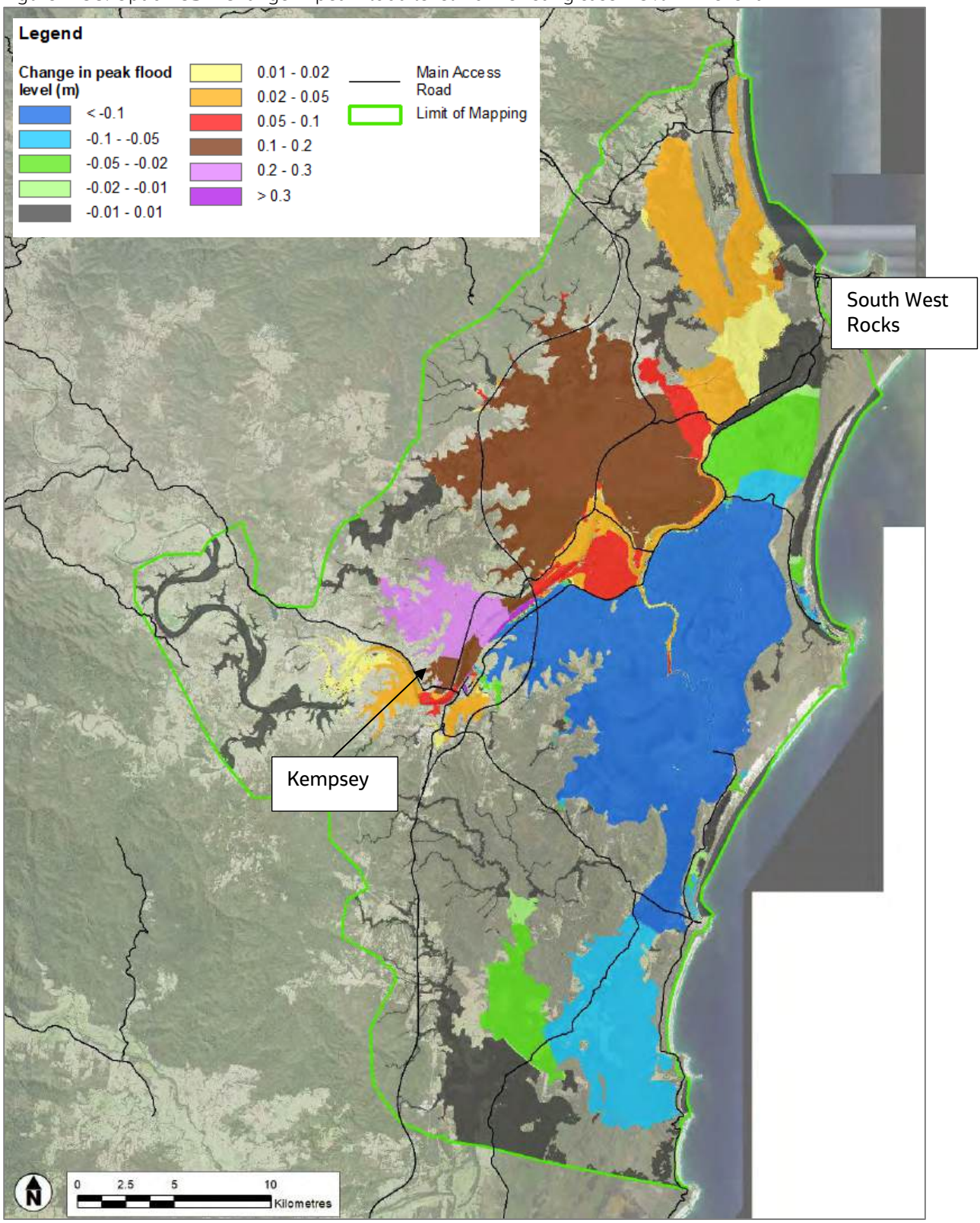
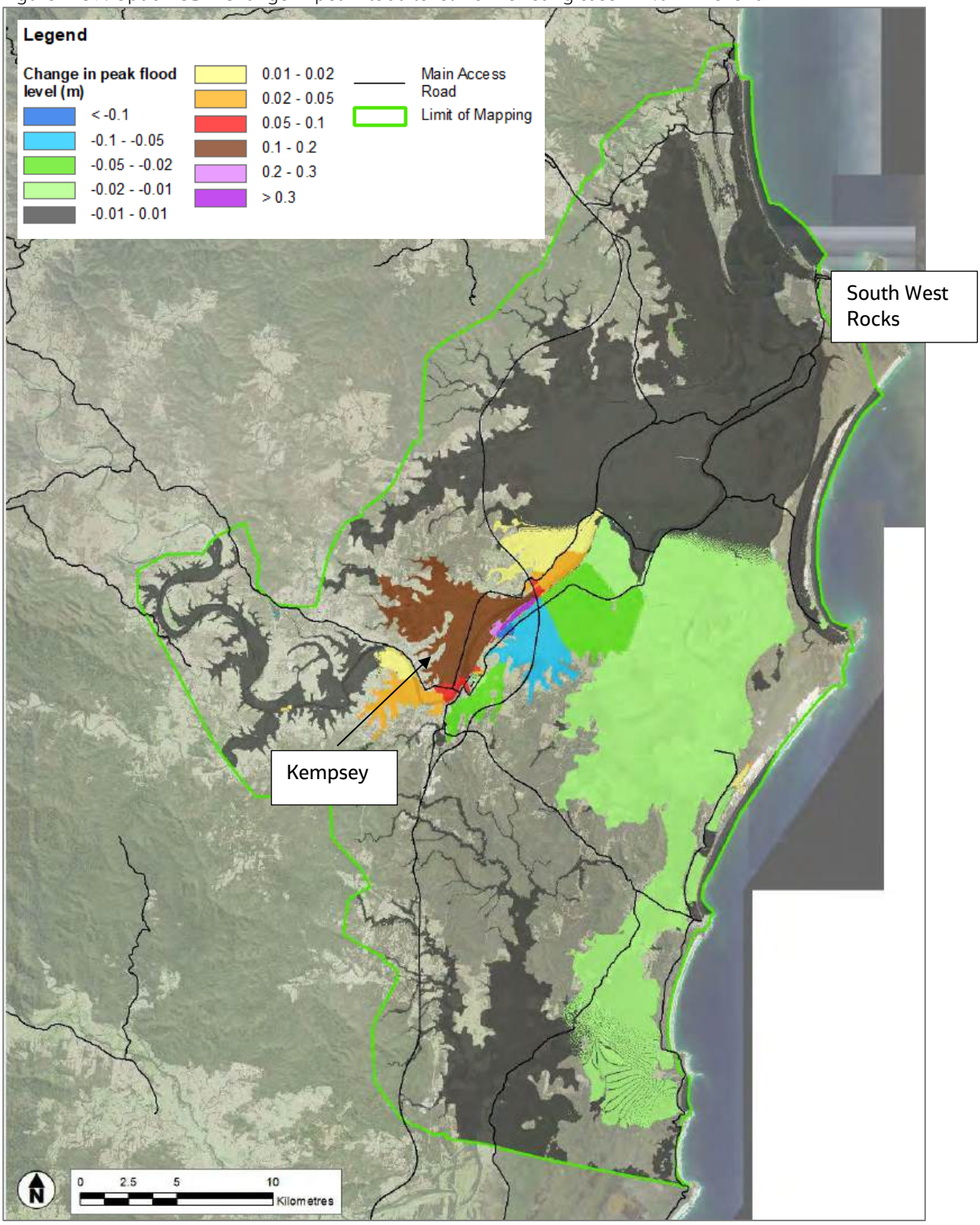


Figure F-59: Option 8B – Change in peak flood level from existing case – 1% AEP event



Remote operation of flood control structures

The flood control structures are currently opened and closed manually by Council staff. Delaying the opening of the flood control structures to a higher river level would mean about 6 – 10 hours less time for Council staff on ground to evacuate from the floodplain after opening the structures. In any case, given that there is only one road access route to and from the flood control structures, the current operational procedures with manual opening/closing mean that the Council staff are already put at risk of being caught in floodwaters in the existing situation with no mitigation works. Costs to upgrade the existing flood control structures to ones which could be operated remotely from a Council office or depot were therefore investigated in order to manage this current health and safety risk.

Cost estimates for operation of the flood control structures remotely from Council depot offices were obtained, based on costings for various Sydney Water projects, and are summarised below combined for the Belmore River, Kinchela Creek Left Bank and Kinchela Creek Right Bank structures.

- SCADA $800,000
- Power & control outdoor kiosks $300,000
- Cabling $100,000
- Conduits and cable ladders $100,000
- Instrumentations $150,000
- CCTV $100,000
- 10% allowance for design - $155,000
- 20% allowance for installation - $310,000
- **Total cost estimate: $2,015,000.**

F.12 Option 9A and 9B – Raise and extend Smithtown levee

Discussion

An audit of Smithtown village levee was prepared on behalf of Council in 2015 (Kempsey Shire Council, 2015). The Smithtown levee is typically less than 0.5m in height above the natural surface level, although a section of levee approximately 80m in length at the Southern end of the levee is approximately 1.5m high on the protected side and up to approximately 2.5m high (above the natural surface level) on the river side. The crest is generally 1.7m to 2.5m wide, but with some localised wider sections. The shoulders generally are graded between 1V:2H and 1V:9H. The design crest level of the levee ranges from 4.43m AHD at its southern end to 4.32m AHD at its northern end.

A topographic survey showed that the existing crest level of the levee is on average 0.2m below the original levee crest design level, with the typical range being 0.1 – 0.4m below design level. Note that the existing levee is about 1m lower than design levels at the southern end, and about 0.5m at the eastern end of Jeffery Street. No evidence was found to suggest why the levee was constructed to the level. A number of undulating sections of levee were also identified, typically located in the yards of residential properties. The undulations appear to have been caused by localised erosion levee crest or as a result of garden beds and trees being planted on the levee.

Raising the existing levee to design levels would involve increasing the height by typically 0.1 – 0.4m, with localised raising of 0.5 to 1m. The levee is constructed close to existing buildings at a number of locations, including at the southern end where the levee is lower than design level by 1m. If proposed, the footprint of an earth levee in this and similar locations would encroach on existing buildings.

Comparing the current design flood level estimates to the design levee levels indicates that the Smithtown levee would be overtopped in the 10% AEP event at the southern end of the levee.

The existing levee extends along the eastern side of the village. There are several locations not covered by the existing levee which are overtopped in the 20% and 10% AEP events, refer to Figure F-60 and Figure F-61, respectively.

Figure F-60: 20% AEP flood extent at Smithtown showing breakouts at areas not covered by existing levee (marked X)

Figure F-61: 10% AEP flood extent at Smithtown showing breakouts at areas not covered by existing levee (marked X)

Description of proposed options

Two separate options for levee raising have been assessed:

- Option 9A: Raise and extend the existing levee to the 20% AEP flood level plus 0.3m freeboard. The levee crest level would range from 4.8m AHD around the western side of the village, 4.6 – 4.7m AHD around the southern end of the village and down to 4.43m AHD at the north-eastern end of the village. The height would be typically 0.2 – 0.4m, and up to 0.6m in some locations, above existing ground levels. Total length of levee works around 1700m. Around 32 and up to 36 properties would be affected.
- Option 9B: Raise and extend the existing levee to the 5% AEP flood level plus 0.3m freeboard. The levee crest level would range from 5.0m AHD at the north-western end of the village, around 4.7 – 4.8m AHD around the southern end of the village and down to 4.56m AHD at the north-eastern end of the village. The height would be typically 0.3 – 0.5m, and up to 0.7m in some locations, above existing ground levels. Total length of levee works around 2500m. Around 34 and up to 38 properties would be affected.

The levee works for both options would pass through private properties in the village. A free-standing concrete retaining wall is proposed where the levee passes through private property in order to minimise the footprint of the levee. The retaining wall works would include foundations down to about 3m below ground surface.

In open space areas, an earth levee with 1:4 side slopes is proposed, including sub-surface works to key the new levee core into the existing ground.

The Option 9B levee would pass through the Nestle factory. Further site investigation would be required to confirm details of the levee through this property. Detailed constructability assessment has not been undertaken to date and will be required. Alternatively, the levee could go around the east of the factory.

At the north-eastern corner of Smithtown village, the levee would need to cross Croads Esplanade around the Smithtown Road overbridge and tie in with the overbridge abutment. Hence, a section of Croads Esplanade

would be raised to form part of the levee. The freeboard above design flood level would be reduced to 0.1m to minimise the impact to the road geometry.

The extent of the works for Options 9A and 9B are shown on Figure F-62 and Figure F-63, respectively. The extent of existing levees as shown in Council's asset database is also shown. Exact alignment of proposed levee works would be determined through future feasibility investigations.

A pumping station/s to dispose of levee internal catchment stormwater should be considered further in future feasibility assessment these options. Siting and hydraulic design of the pumping station/s needs to be considered and costing of pumping stations has not been undertaken at this stage.

Figure F-62: Extent of levee raising works at Smithtown, Option 9A

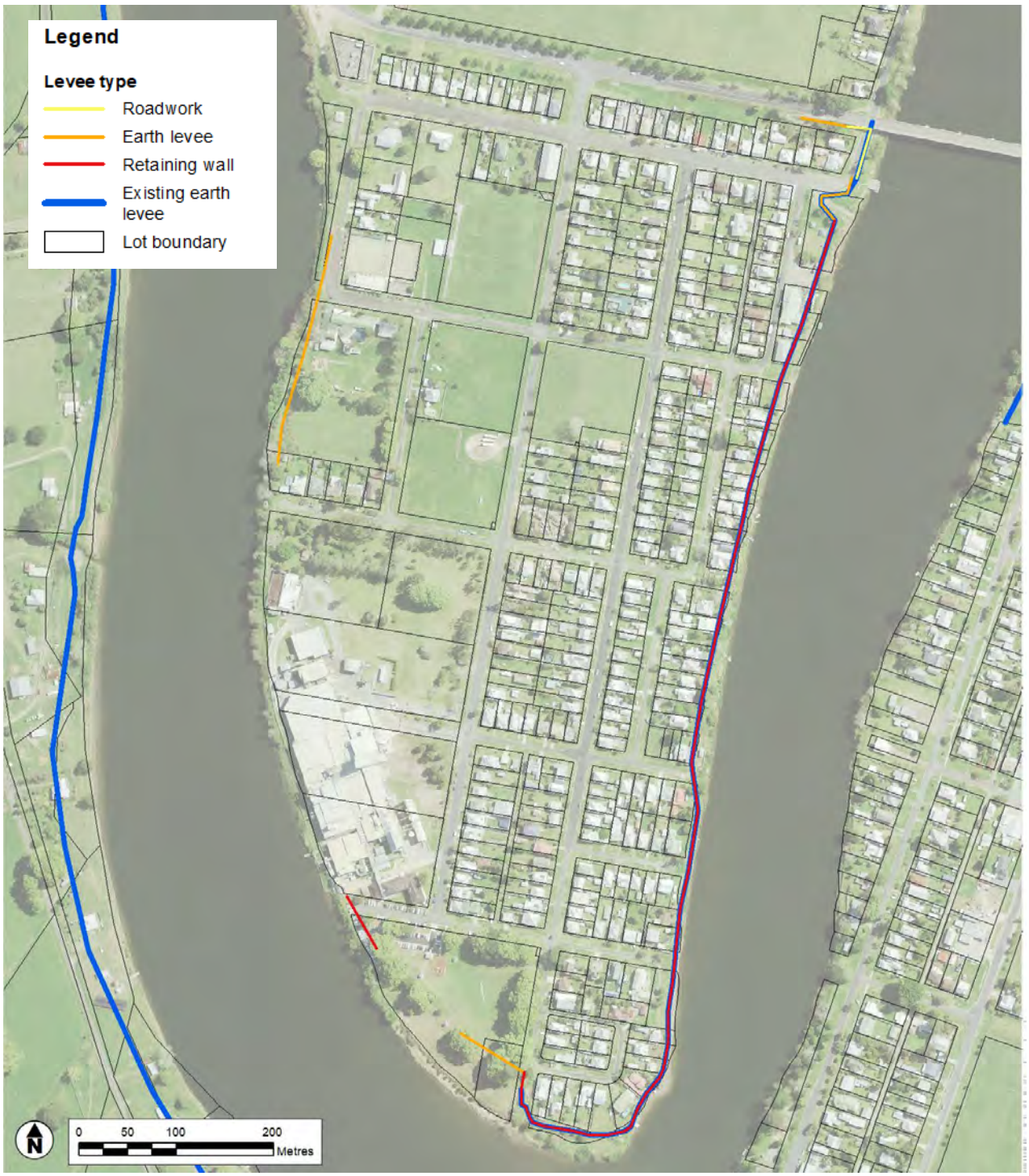
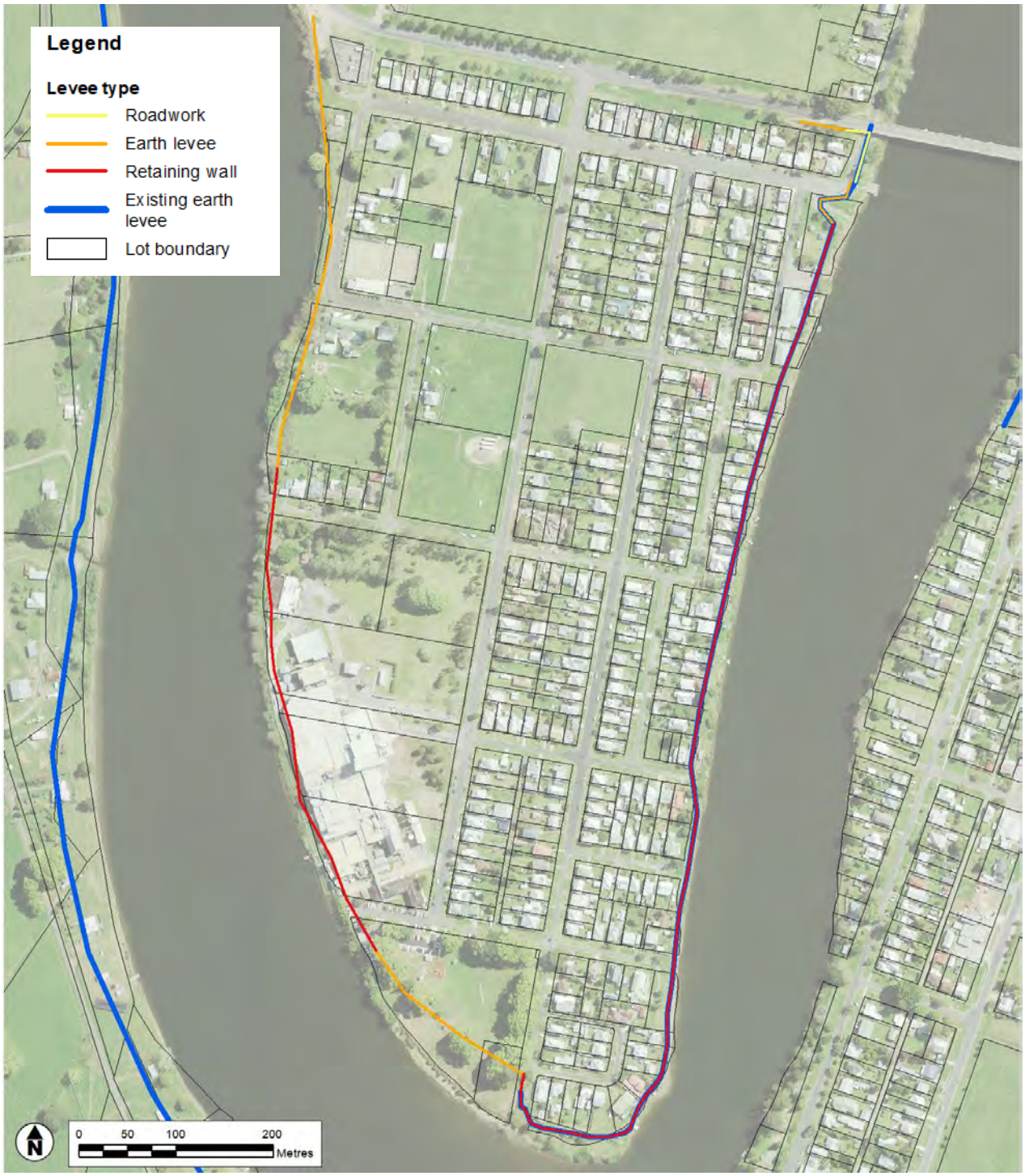


Figure F-63: Extent of levee raising works at Smithtown, Option 9B



Effects on flooding – Option 9A

Figure F-64 to Figure F-67 show the change in peak flood level for the 20%, 10%, 5% and 1% AEP events from existing case to with Option 9A. The raised Smithtown levee to the 20% AEP flood level plus 0.3m freeboard results in prevention of floodwaters overflowing from the Macleay River in the 20% AEP event, noting that there is likely to still be local flooding from rain falling directly into the area inside the levee. There would be substantial reductions in overflows over the levee in the 10% and 5% AEP events. Flood levels inside the levee are reduced by 0.1m in the 20%, 10% and 5% AEP events. There is negligible change in peak flood levels in the 1% AEP event.

Outside Smithtown village, peak flood levels on the northern floodplain are reduced typically by up to 0.03m in the 20%, 10% and 5% AEP events and by up to 0.1m immediately north of Smithtown village, as the reduced flood overflows over the levee result in lower floodplain flow rates and depths. This also results in increased overflows onto the southern floodplain with generally minor increases in flood levels of 0.02m in the 20%, 10% and 5% AEP events. There are localised increases in flood levels of less than 0.1m on the southern floodplain in the 20% AEP event. There is negligible change in peak flood levels in the 1% AEP event.

Effects on flooding – Option 9B

The spatial patterns of the changes in flood levels with Option 9B for the areas outside the Smithtown levee are very similar to those described above for Option 9A and hence the change in flood level mapping is not shown for Option 9B.

Inside the levee, the raised Smithtown levee to the 5% AEP flood level plus 0.3m freeboard results in prevention of floodwaters overflowing from the Macleay River in up to and including the 5% AEP event, noting that there is likely to still be local flooding from rain falling directly into the area inside the levee. In the 1% AEP event, peak flood levels in Smithtown village inside the levee are reduced by up to 0.07m.

Figure F-64: Option 9A – Change in peak flood level from existing case – 20% AEP event

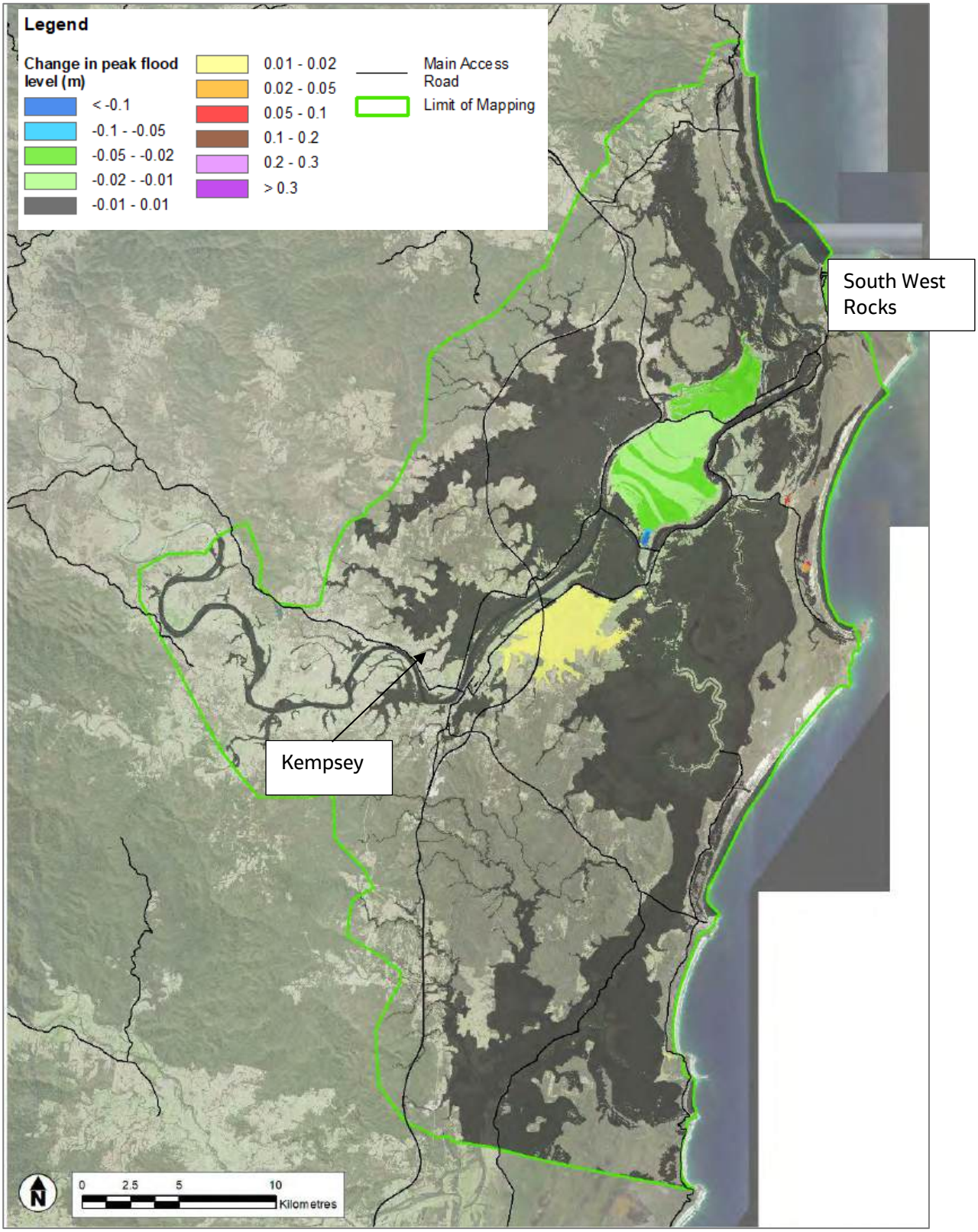


Figure F-65: Option 9A – Change in peak flood level from existing case – 10% AEP event

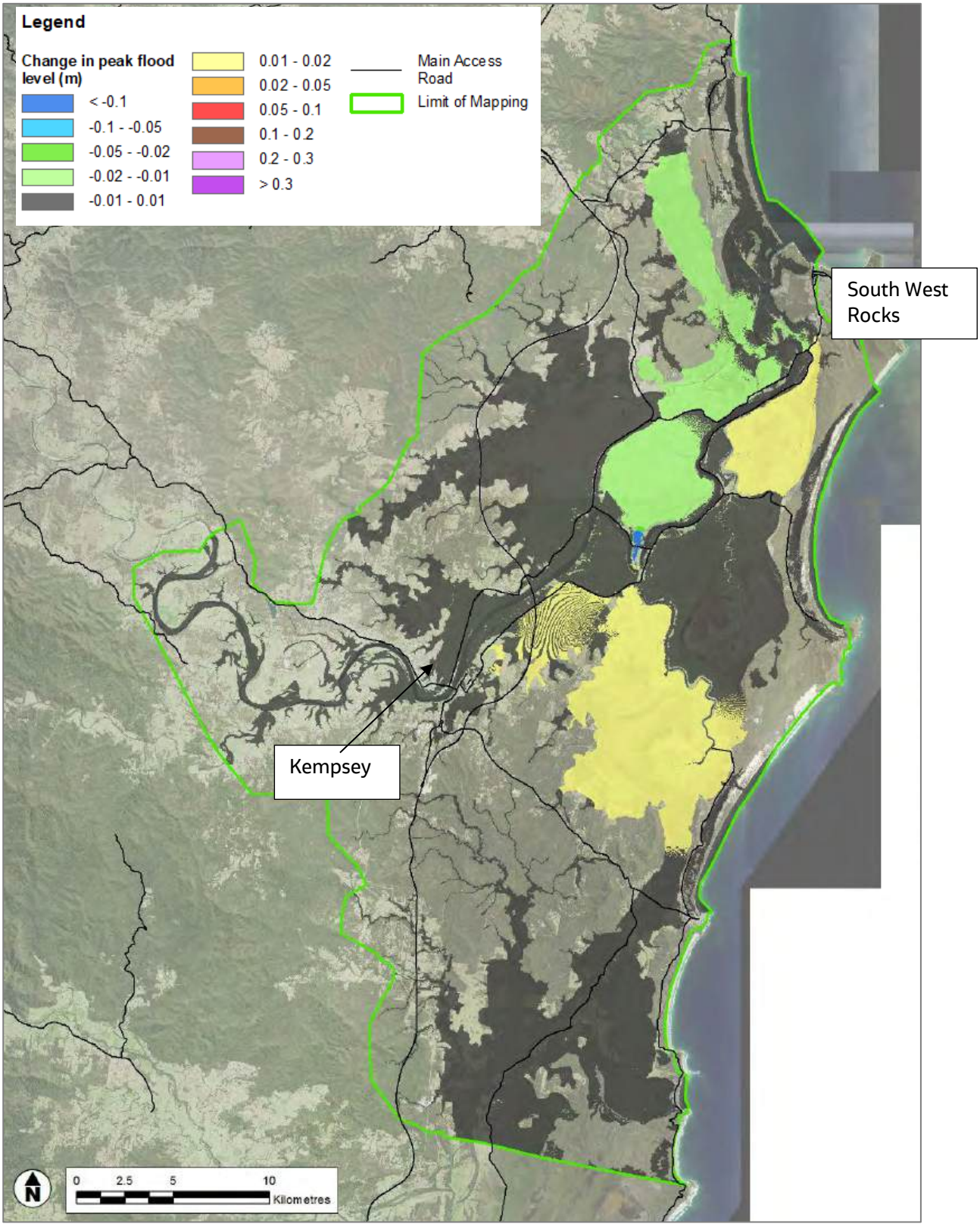


Figure F-66: Option 9A – Change in peak flood level from existing case – 5% AEP event

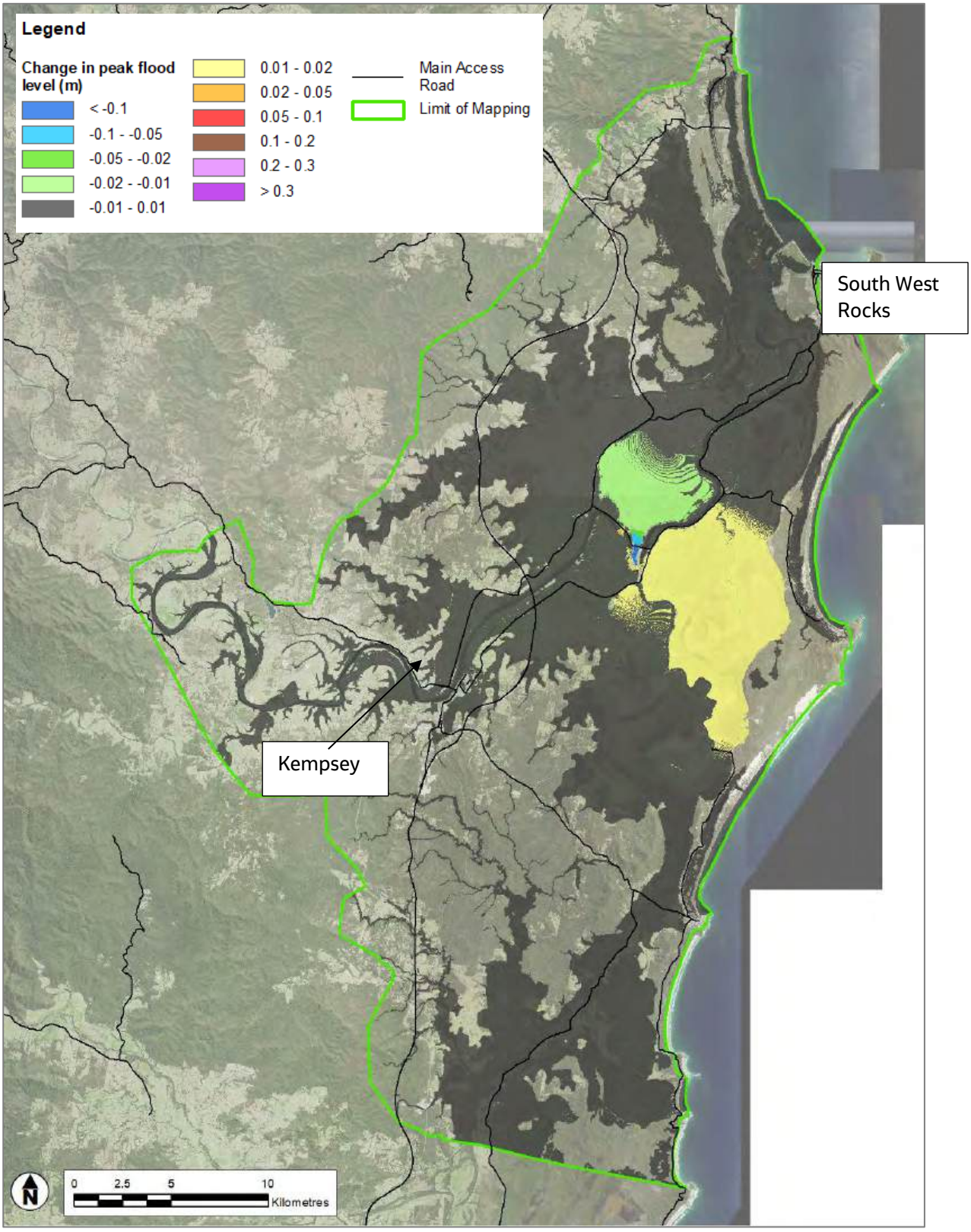
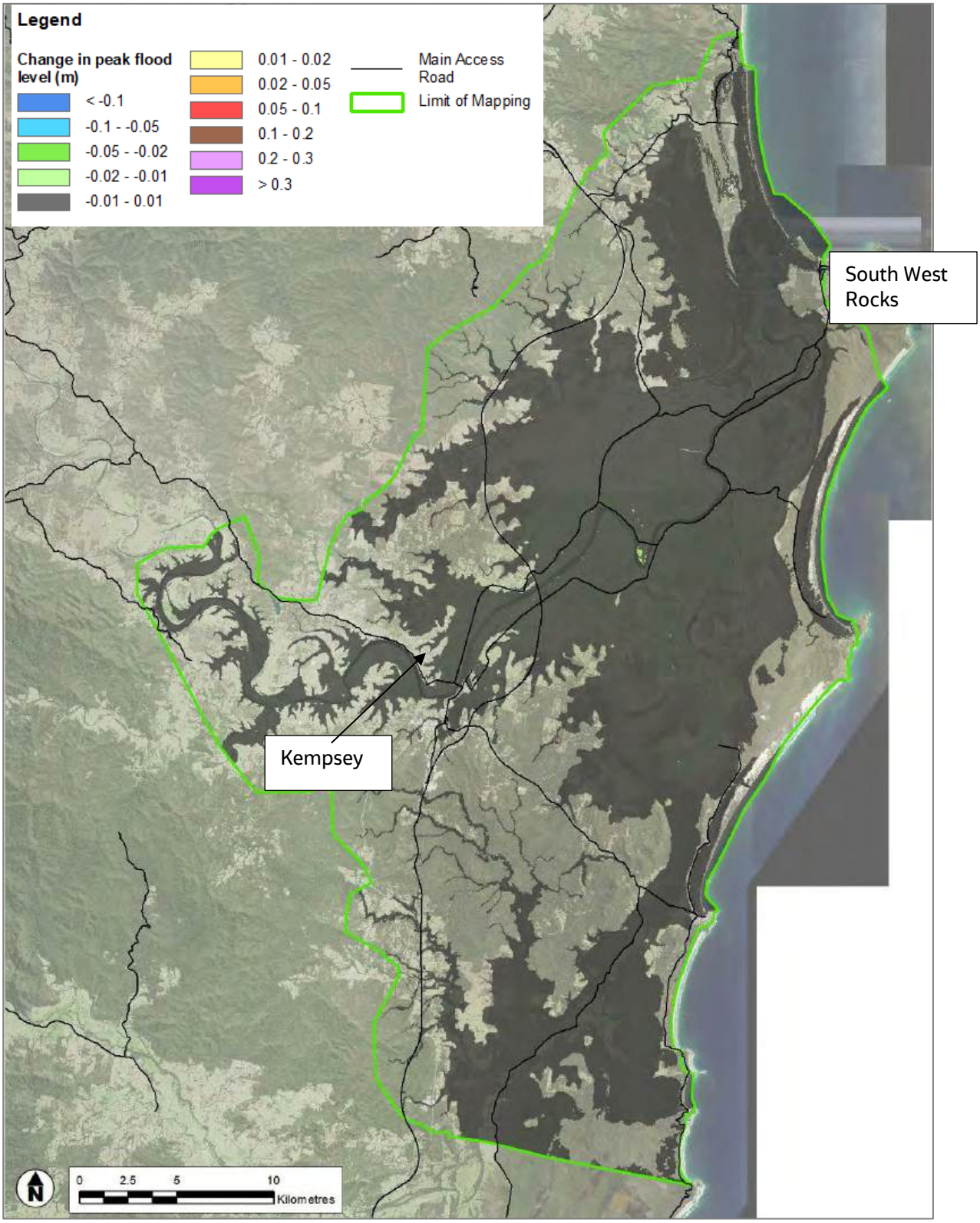


Figure F-67: Option 9A – Change in peak flood level from existing case – 1% AEP event



F.13 Option 11 – Dredging of Macleay River

Discussion

Dredging of sections of the Macleay River was raised as an option for consideration by members of the community during consultation for this current FRMS and during the 2019 flood study. Certain sections of the river are reported to have become shallow particularly around Jerseyville, Rainbow Reach and Kinchela with several shoals having developed and which are exposed on some tides. Community members reported that the river used to be dredged during the mid-20th century, most likely to maintain navigability of the river to Kempsey. Members of the community held the view that these areas could be dredged which would improve flow conveyance and flood conditions. They proposed that the dredged material could be sold for construction material, although further investigation is required to confirm whether the sediment composition is suitable.

There are a number of sand bars and shoals between Kinchela and South West Rocks which are as shallow as 1 to 2m depth (bed level -1 to -2m AHD) or less. The deeper holes on the bends of the river are at bed level -6m AHD or lower.

The dredging scheme assessed in the TUFLOW model involved lowering the riverbed by 2m between upstream of Frederickton to the river entrance, a distance of 36km. The section of river between Frederickton and Seven Oaks is where a significant volume of floodwater overflows from the channel and onto the floodplain. The extent of dredging would result in the deepening of the river through the currently shallow sections between Kinchela and downstream of Jerseyville. Refer to Figure F-68 for the extent of the assessed dredging option.

Dredging as an option was assessed in the Lower Macleay Floodplain Management Study (Webb McKeown & Associates, 1997) as not being a practical flood mitigation option due to high costs and environmental impacts. The 1997 study states that "modelling has shown that to have any real impact on flood levels the bed would need to be lowered by between 0.5 m and 1.0 m over a significant length. This would cost between $50M and $100M (in 1997 dollars) and would need to be regularly repeated". Cost estimates of the assessed dredging scheme in this study are based on an initial dredged volume of 15,320,000m^3 over the 36km length of river assessed for dredging. Based on coastal waterways dredging projects around NSW (Tuggerah Lakes, Myall River) a cost rate of $20/m^3 is assumed, assuming minimal cartage distances. This results in an initial dredging cost of $459.6 Million (2022 dollars), including contingencies. For costing purposes, maintenance dredging is assumed every 10 years at a 20% portion of the initial volume, or $91.92 Million every 10 years. It would be expected for Council for co-fund 50% of the costs, with State Government funding of the remainder, if the dredging option were to be successful in funding grant application.

Dredging around Jerseyville bridge could affect the structural stability of the bridge. Numerous riverbank rock protection works and unprotected banks could also be impacted by changed bed profiles and tidal current patterns. Environmental approvals for dredging projects are generally difficult to obtain in recent times. Funding of such large costs is highly unlikely to be granted and Council reported that previous requests for funding for river dredging were not successful.

Figure F-68: Extent of assessed dredging Option 11

Effects on flooding

Figure F-69 to Figure F-71 show the change in peak flood level for the 10%, 5% and 1% AEP events from existing case to with Option 11. On the southern floodplain around Belmore River and Kinchela Creek there are typical reductions in peak flood levels of 0.3 – 0.4m in the 10% AEP, 0.3m in the 5% AEP and 0.14m in the 1% AEP event. Flood level reductions are up to 0.7m on the floodplain in Kinchela north of Hat Head Road in the 10% AEP event.

On the northern floodplain there are reductions in peak flood levels of 0.1 – 0.2m in the 10% AEP, 0.05 – 0.4m in the 5% AEP and 0.13m in the 1% AEP event. Reductions in flood levels extend upstream of Kempsey. There are increases in peak flood levels of 0.05 – 0.1m in the lower reaches of the Macleay River and Macleay Arm in the 10% AEP event and localised increases of 0.05m around Seven Oaks in the 5% and 1% AEP events resulting from the increased flow efficiency of the river conveying increased flows to various parts of the system.

Figure F-69: Option 11 – Change in peak flood level from existing case – 10% AEP event

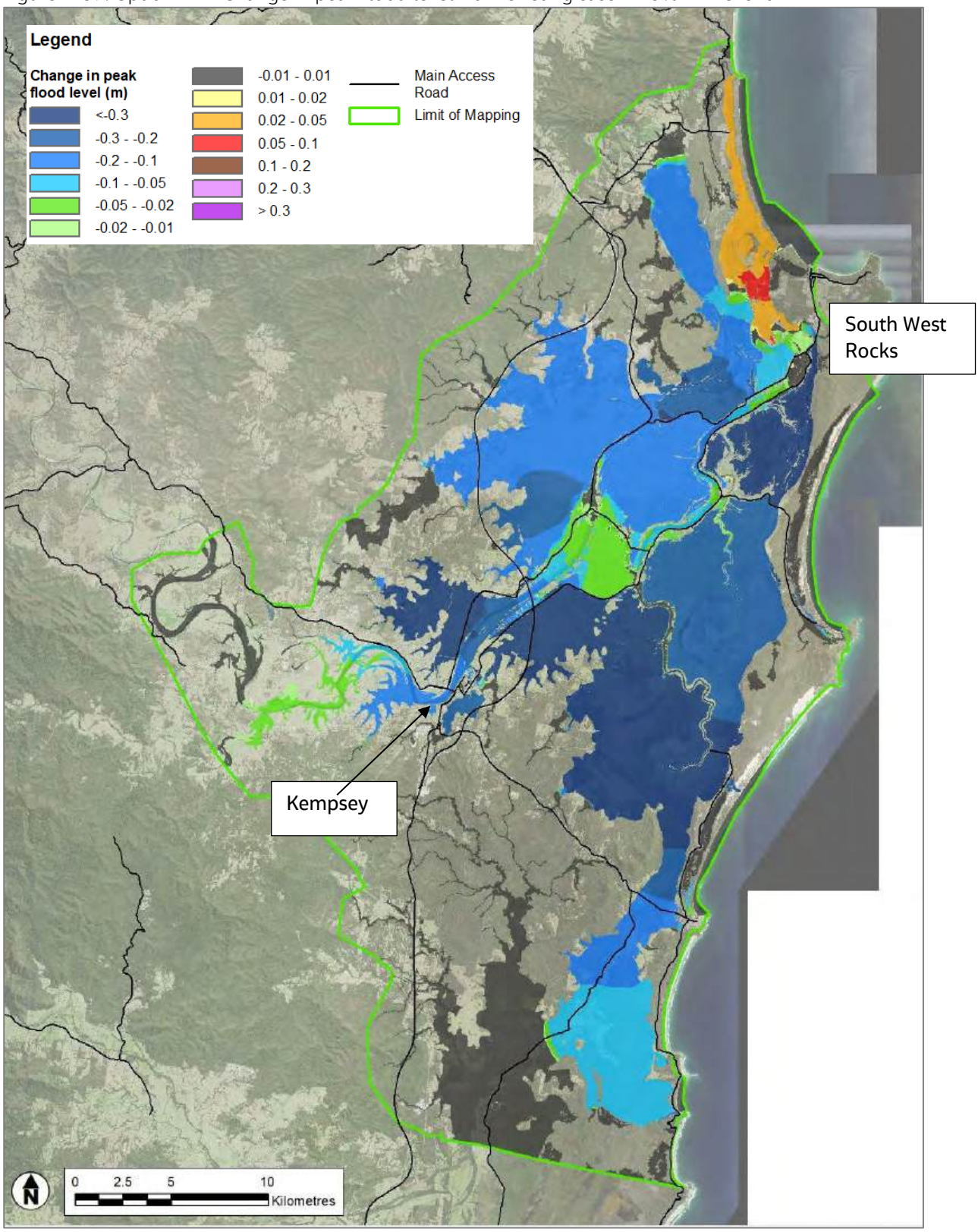


Figure F-70: Option 11 – Change in peak flood level from existing case – 5% AEP event

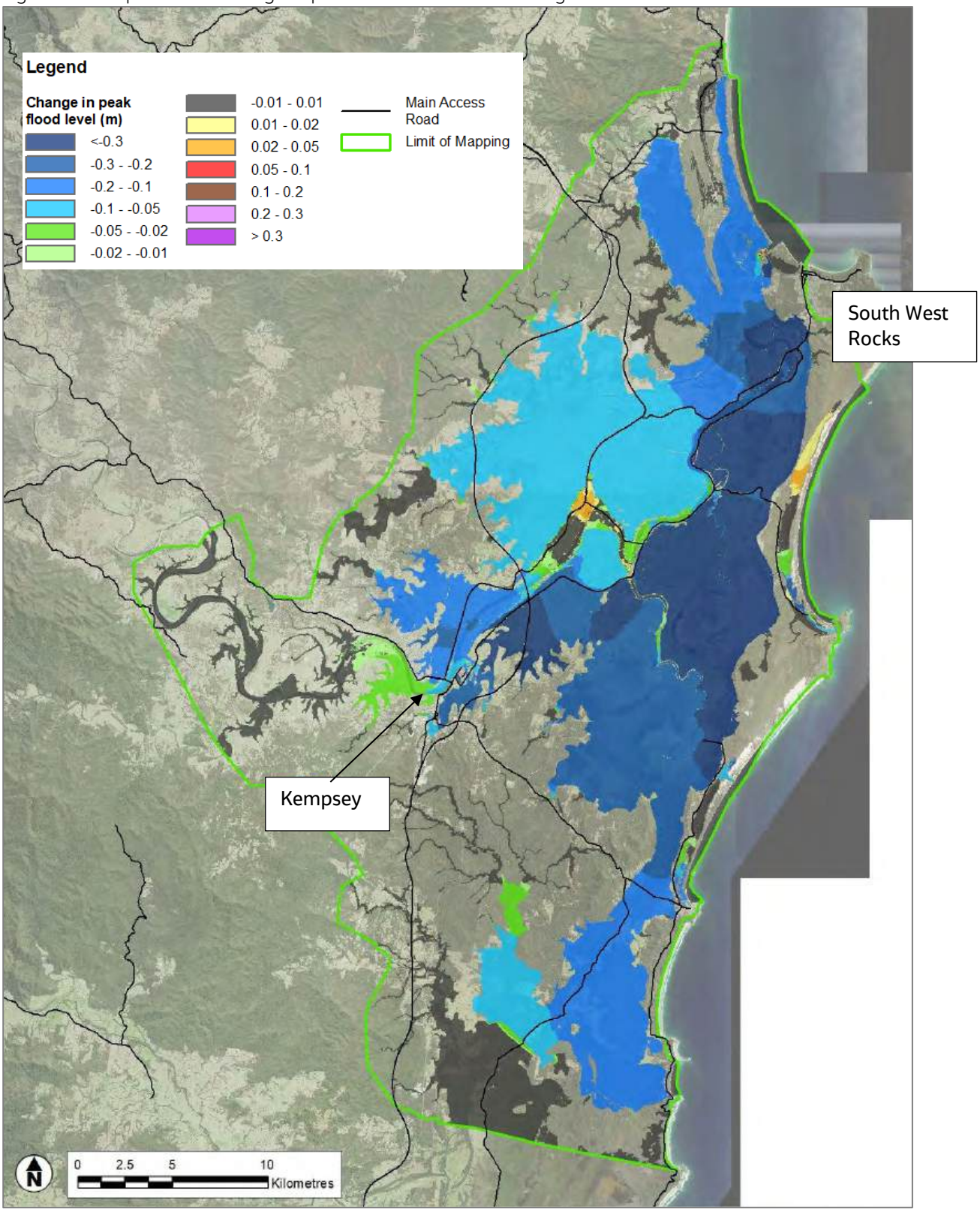


Figure F-71: Option 11 – Change in peak flood level from existing case – 1% AEP event

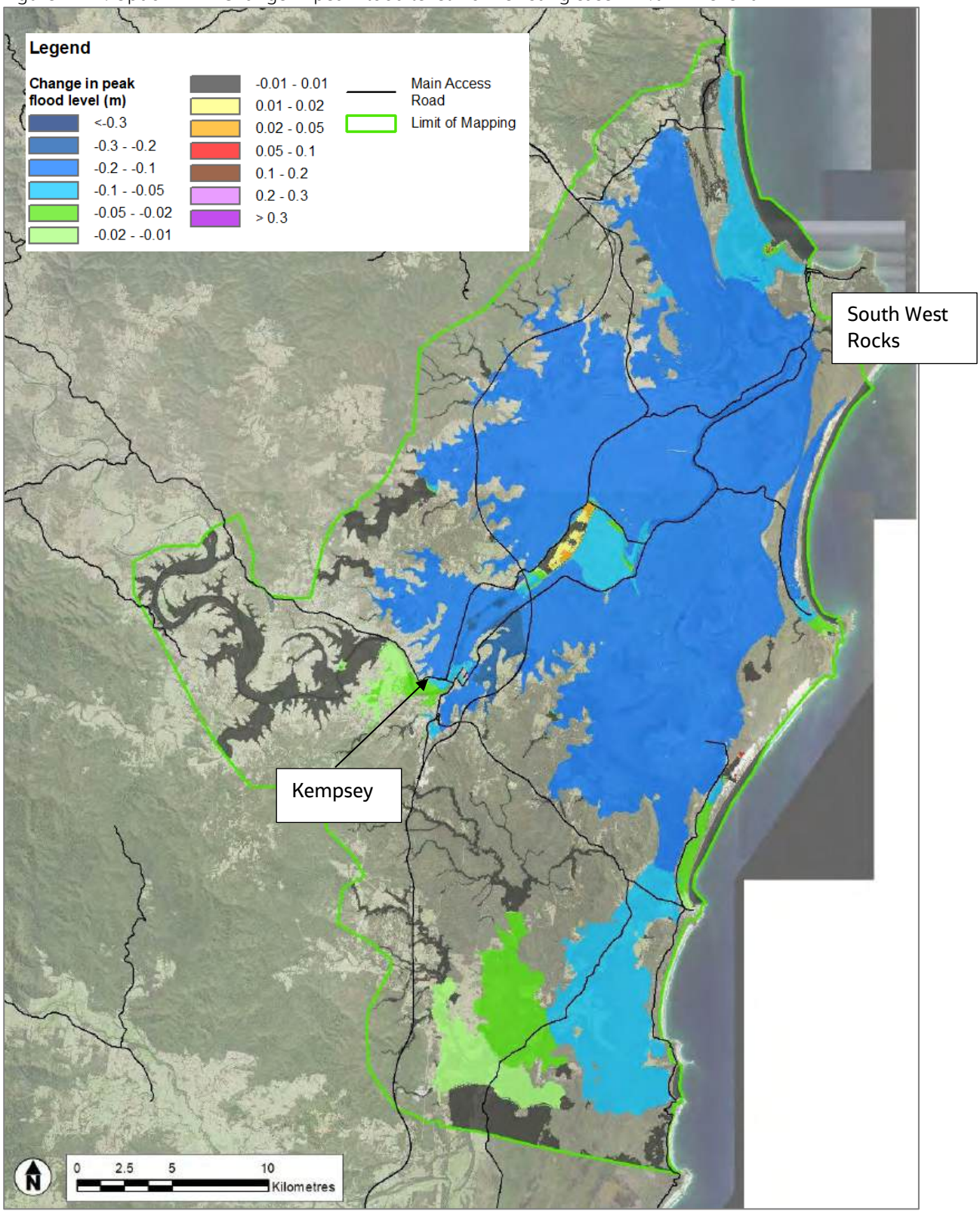


Figure F-72 to Figure F-75 plots the flood levels versus time for the 20%, 10% 5% and 1% AEP events for the existing case and with Option 11 at Upper Belmore, Swan Pool, Kinchela north of Hat Head Road, and Clybucca near Plummers Lane.

Upper Belmore would experience reductions in durations of inundation of around a day for each event. There are some reductions in durations of inundation of up to 48 hours at Kinchela north of Hat Head Road in the 10% AEP event and in Clybucca near Plummers Lane in the 20% AEP event. However, these reductions in durations appear to be fairly specific to those AEP flood events as they are related to flood overspill from the river channel in those events, and the reductions in durations are minor (less than half a day) for other flood AEPs. Additionally, those larger reductions in durations are localised in those reported locations and are not widespread. The reductions in durations are relatively minor (typically around half a day) in other parts of the Macleay floodplain, as shown at Swan Pool.

Figure F-72: Flood levels versus time at Upper Belmore, Existing compared with Option 11

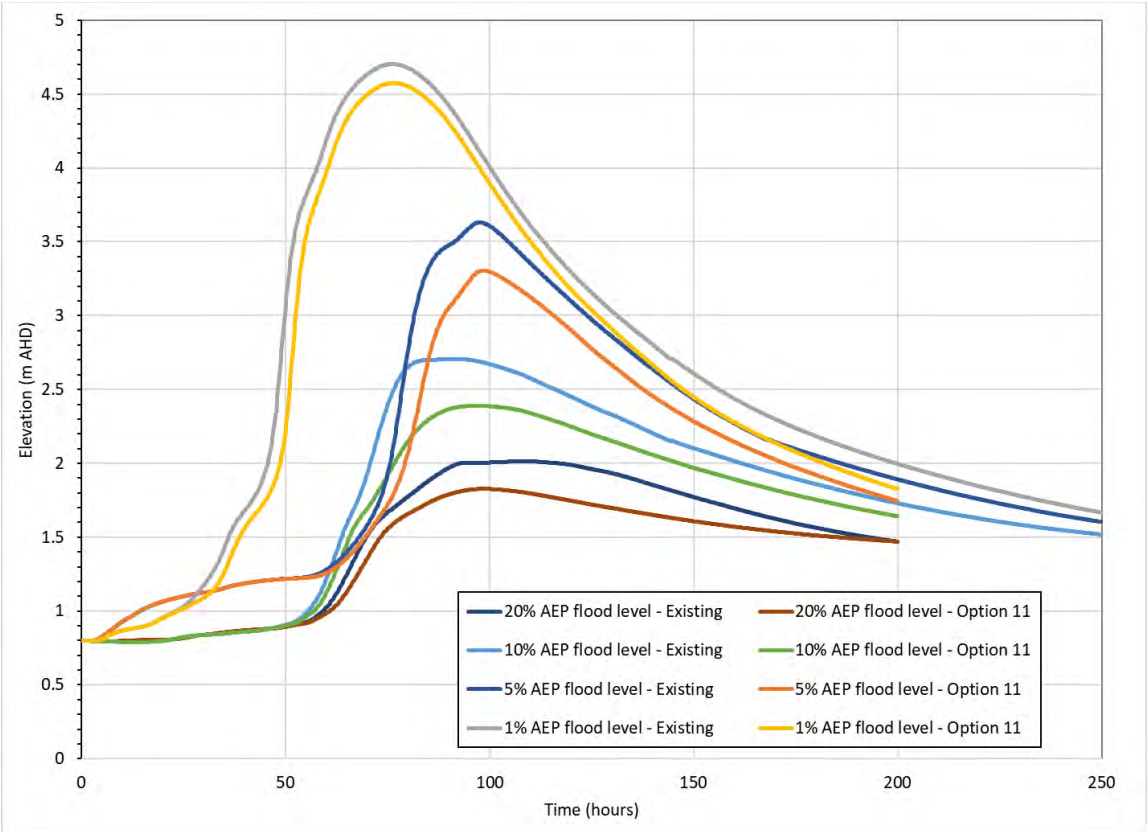


Figure F-73: Flood levels versus time at Swan Pool, Existing compared with Option 11

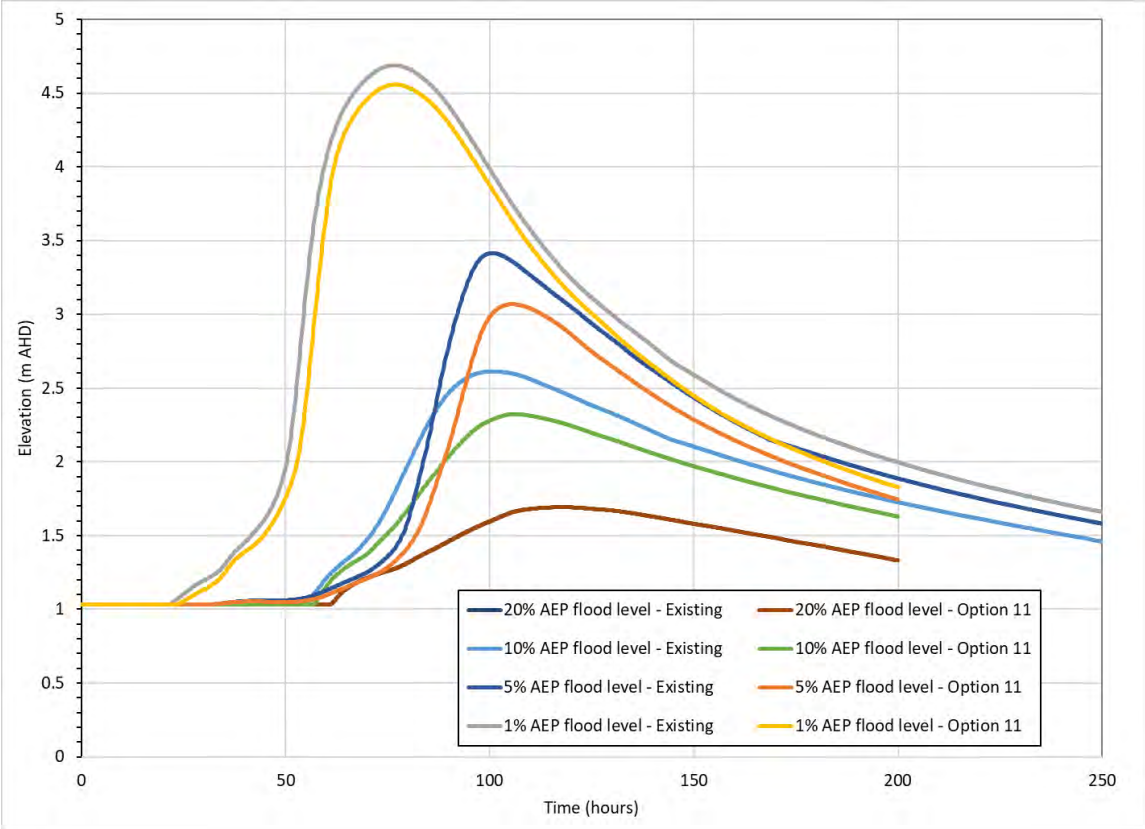


Figure F-74: Flood levels versus time north of Hat Head Road, Existing compared with Option 11

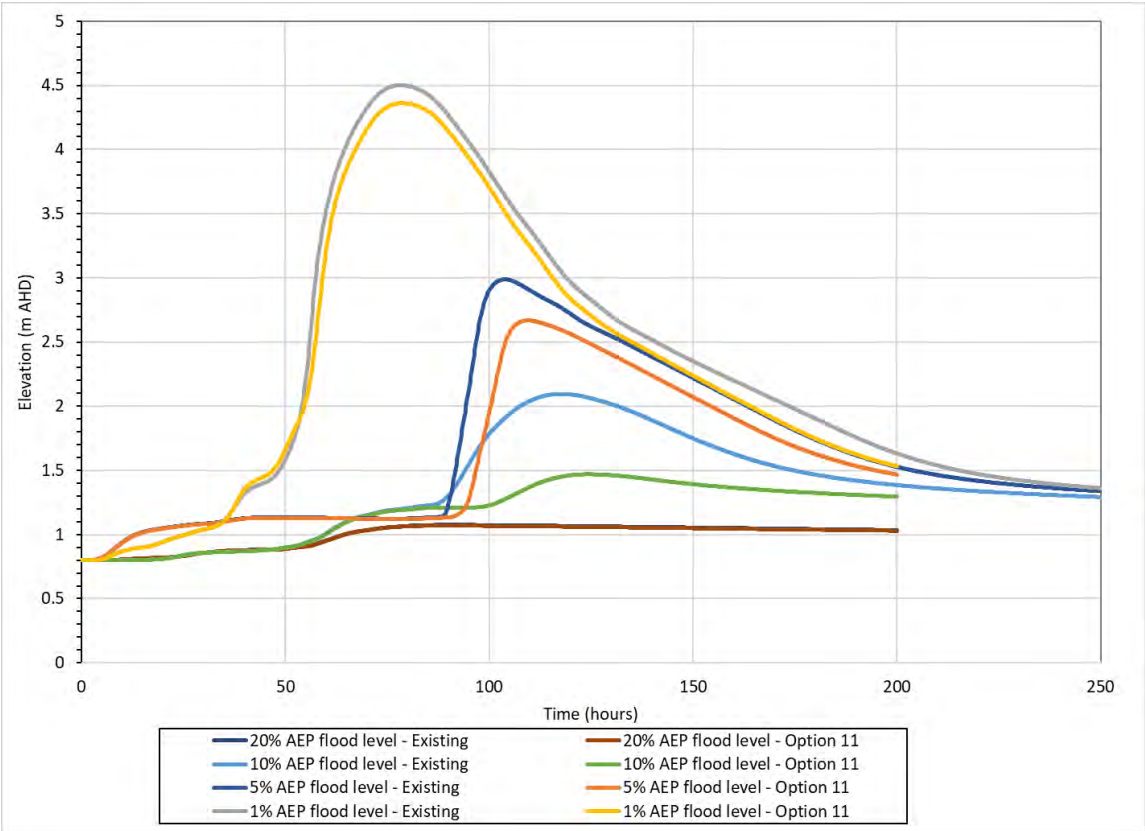
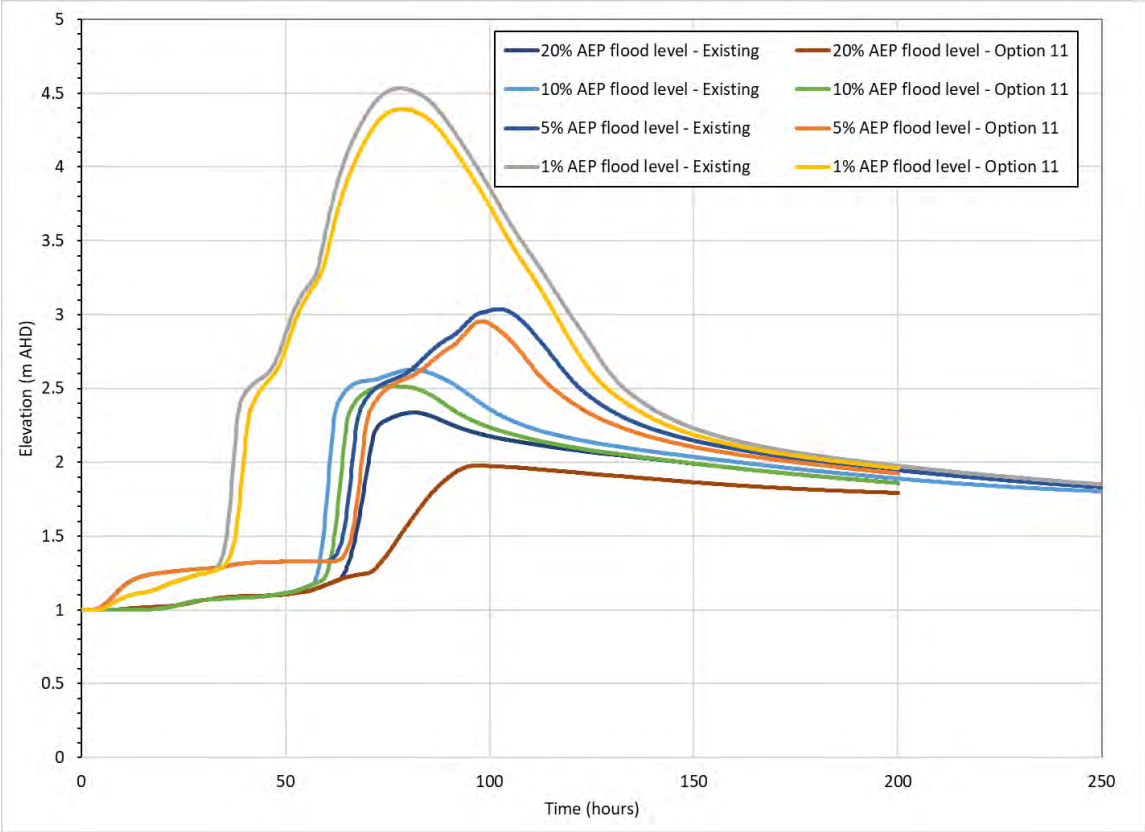


Figure F-75: Flood levels versus time at Clybucca near Plummers Lane, Existing compared with Option 11



F.14 Option 12 – Additional ocean outlets for the Macleay River

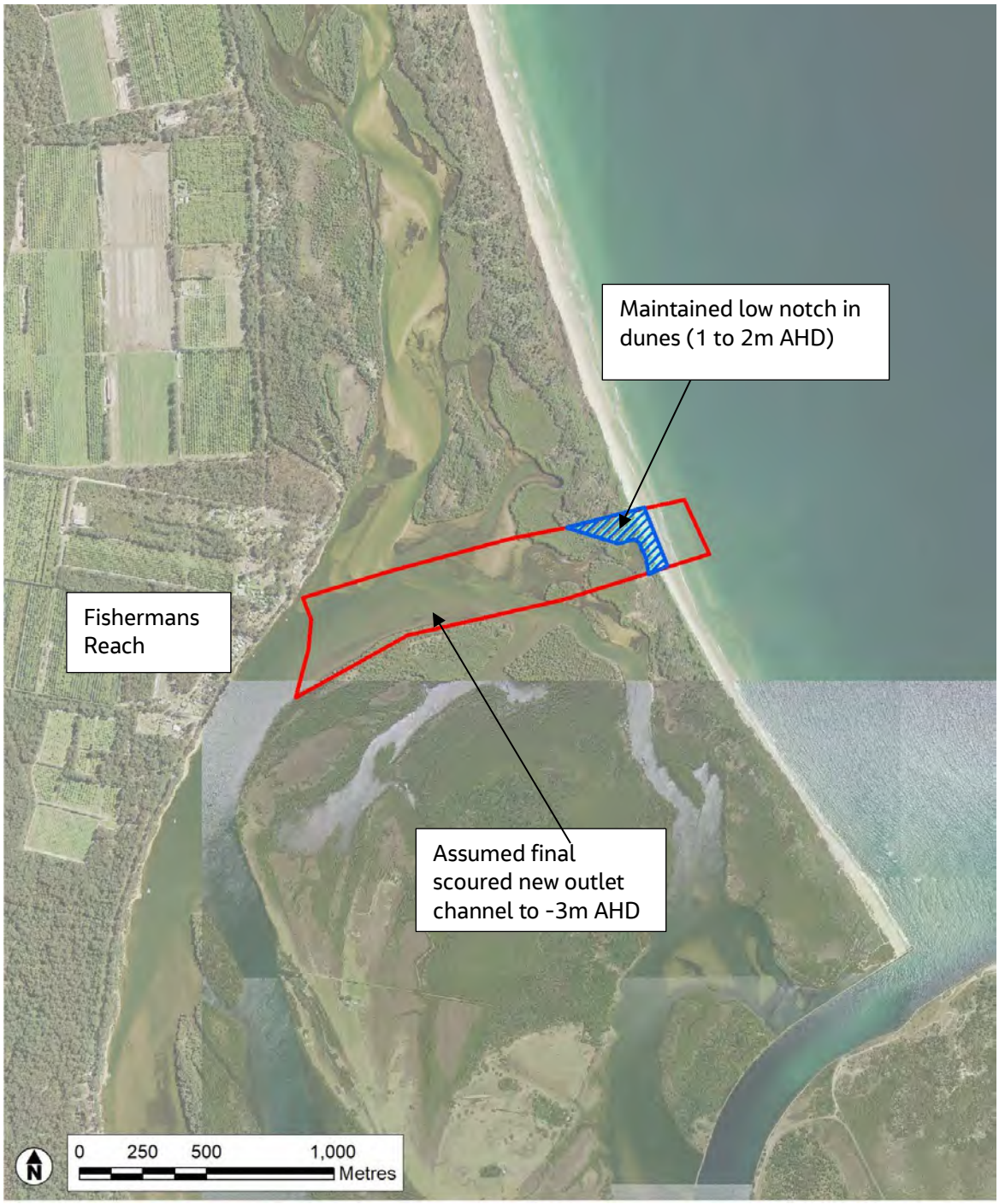
Discussion

Additional ocean outlets would increase the discharge capacity for the river to the ocean, with reductions in peak flood levels and durations of inundation expected in the lower reaches. There are several locations between the Macleay River entrance and Grassy Head which would overtop in the 0.2% AEP event. The dunes at one or more of these locations could be lowered and maintained at a reduced height to wash out during flood events to form new ocean outlet/s and help drain the Lower Macleay at a quicker rate post-flood. At 2m AHD, the lowered dune section would overtop in larger than 5% AEP event. The 5% AEP flood level at Fishermans Reach is approximately 1.9m AHD.

This option was assessed as a single new outlet with a maintained low notch about 220m wide in the sand dunes opposite Fishermans Reach. This is assumed to scour out to a bed level of -3m AHD and a final width of 270m, limited by the existing Macleay Arm channel width and depth at this location. A single new ocean outlet was assessed rather than several smaller outlets along the dune system between the Macleay entrance and Grassy Head, due to the greater hydraulic efficiency of a single outlet at the lower end of the Macleay Arm, where the waterway is wider and deeper. The waterway becomes significantly shallower further north along the Macleay Arm, hence drainage of floodwaters through new outlets north of Fishermans Reach would be less efficient. Works done for Option 12 would be on Crown land. Refer to Figure F-76

This option has the risk of the new outlet/s eroding wider than planned, with potential changes to the hydrodynamics of the Lower Macleay estuary system. Rock protection works to fix the opening width would be costly. At present there is no road access for maintenance activities, with vehicle access being limited to the beach. With the assessed option, the new outlet is likely to scour out to substantial depths and remain open to the ocean for long periods of time, allowing ocean swells to enter the estuary, with potential wave erosion of the shoreline at Fishermans Reach and wave damage to existing jetties, oyster leases and other property and infrastructure. There is a risk that the new outlet becomes semi-permanent, reducing the tidal flushing and scouring of the main entrance which would result in sand bars and the entrance bar becoming shallower thus impacting on navigability of the main entrance.

Figure F-76: Assessed new ocean outlet at Fishermans Reach Option 12



Effects on flooding

Figure F-77 to Figure F-79 show the change in peak flood level for the 10%, 5% and 1% AEP events from existing case to with Option 12. In the 10% AEP event the reductions in flood levels are a maximum of 0.1 – 0.2m in the lower reaches including around Fishermans Reach, Stuarts Point/Macleay Arm and parts of South West Rocks. The improvements in flooding dissipate to nil around Rainbow Reach/Jerseyville.

In the 5% AEP event the reductions in flood levels are a maximum of 0.7m in the lower reaches. The improvements in flooding dissipate to nil around Kinchela.

In the 1% AEP event the reductions in flood levels are a maximum of 1m around the western side of South West Rocks and 1.4m in Macleay Arm including Fishermans Reach and Stuarts Point. The improvements in flooding

reduce with distance upstream to 0.2m at Kinchela and nil near Smithtown. Improvements to peak flood levels are around 0.14m on the northern floodplain and 0.07 – 0.15m on the southern floodplain including Belmore River and Kinchela Creek.

Figure F-77: Option 12 – Change in peak flood level from existing case – 10% AEP event

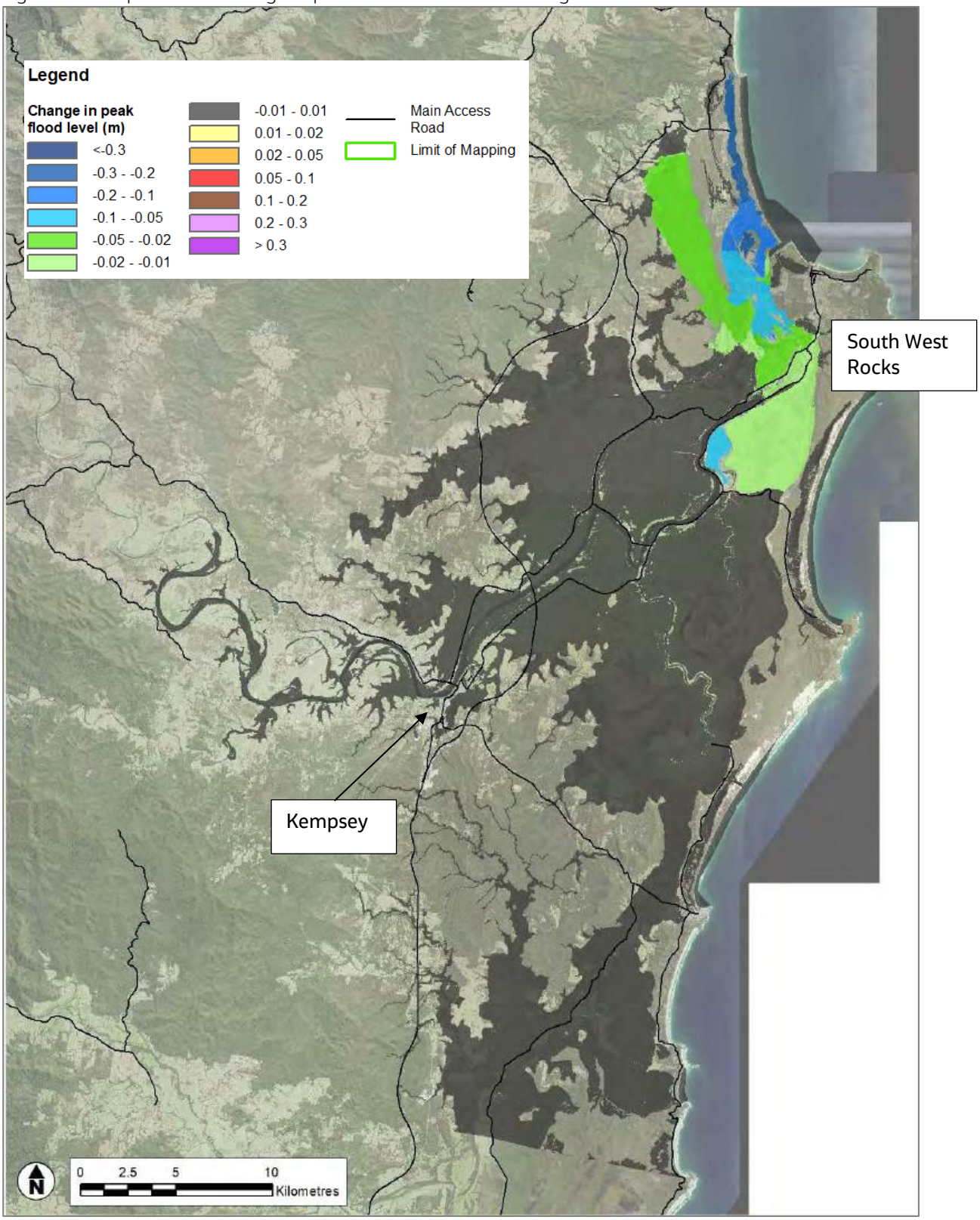


Figure F-78: Option 12 – Change in peak flood level from existing case – 5% AEP event

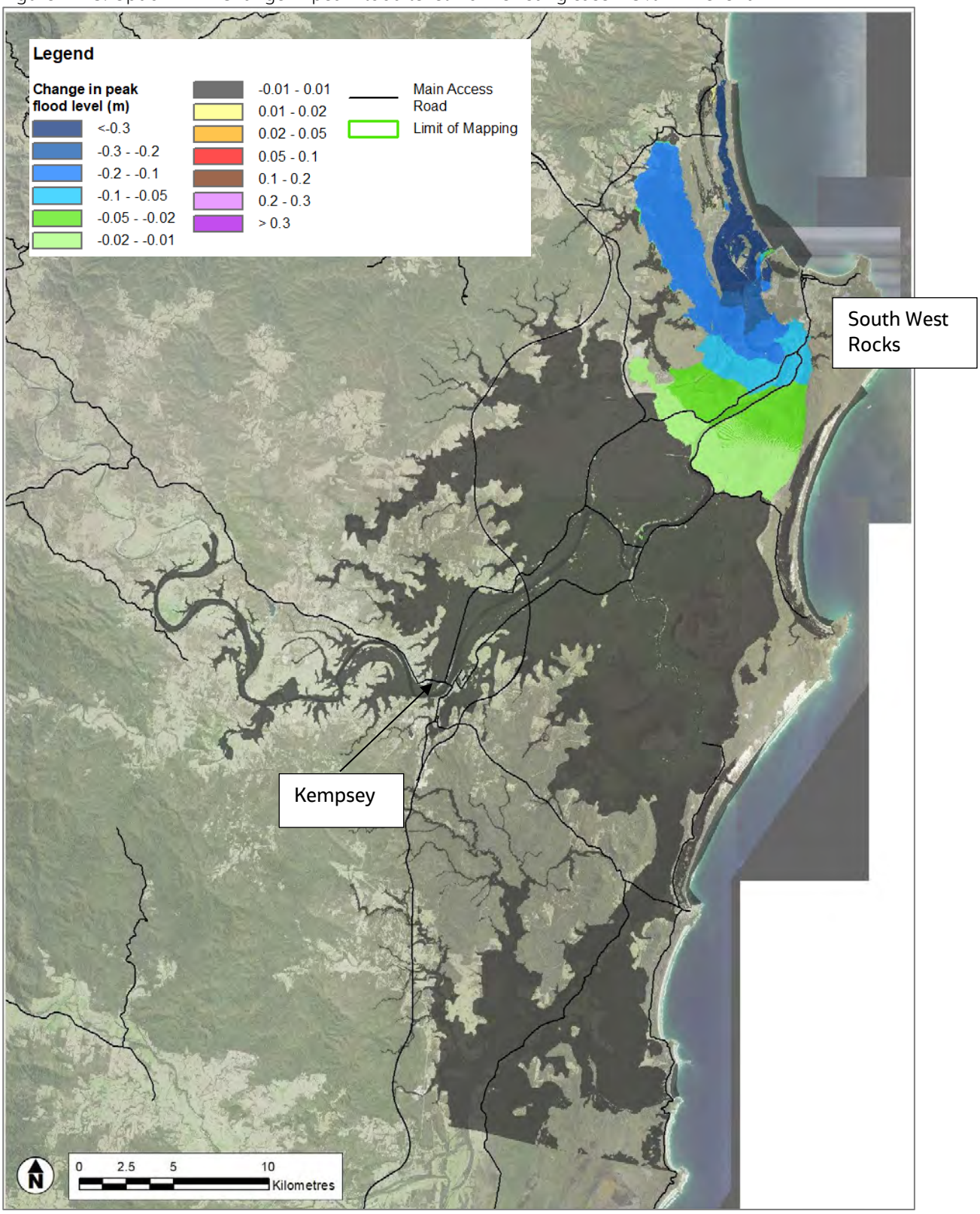


Figure F-79: Option 12 – Change in peak flood level from existing case – 1% AEP event

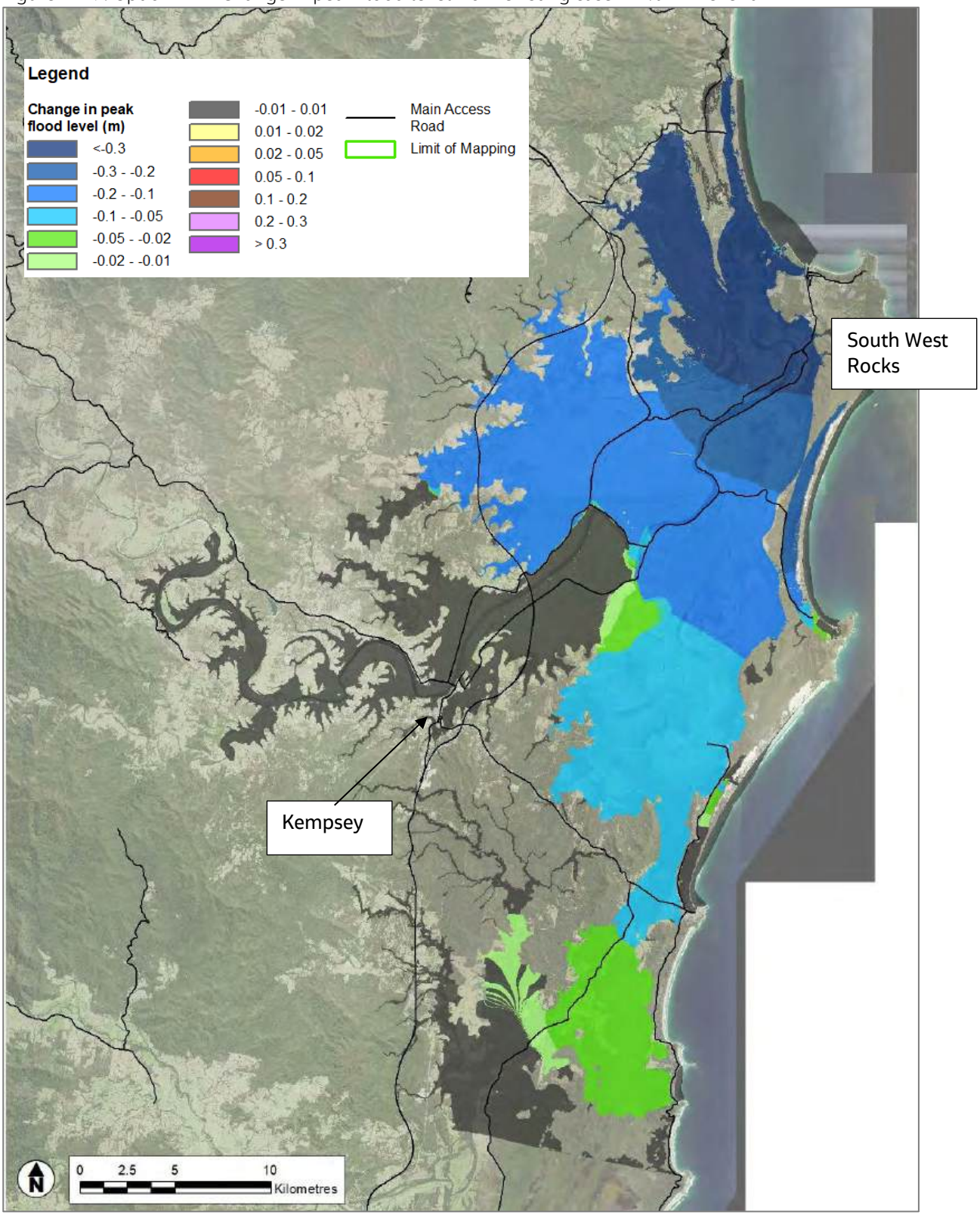


Figure F-80 to Figure F-82 plots the flood levels versus time for the 20%, 10% 5% and 1% AEP events for the existing case and with Option 12 at Swan Pool, Kinchela north of Hat Head Road, and Clybucca near Plummers Lane. The figures show that while peak flood levels are reduced, the reductions in duration of inundation are minimal to minor. Durations are reduced at Swan Pool by less than one day.

Figure F-80: Flood levels versus time at Swan Pool, Existing compared with Option 12

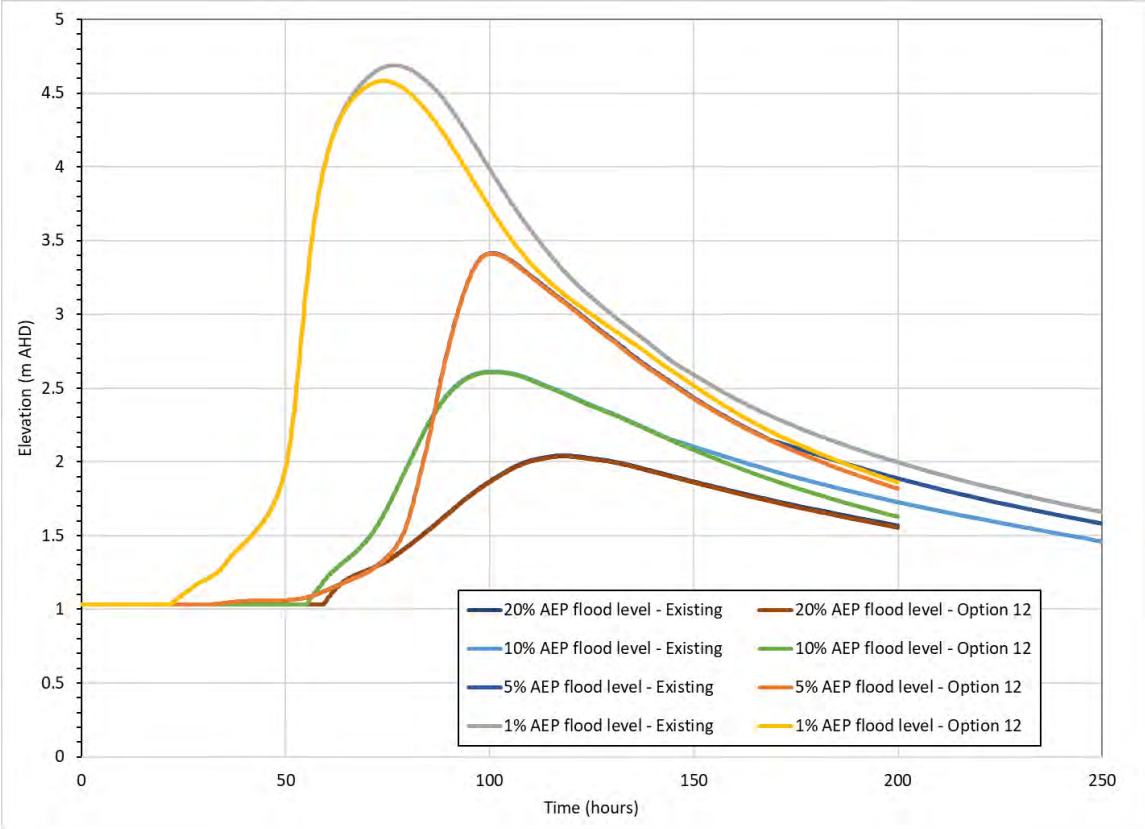


Figure F-81: Flood levels versus time north of Hat Head Road, Existing compared with Option 12

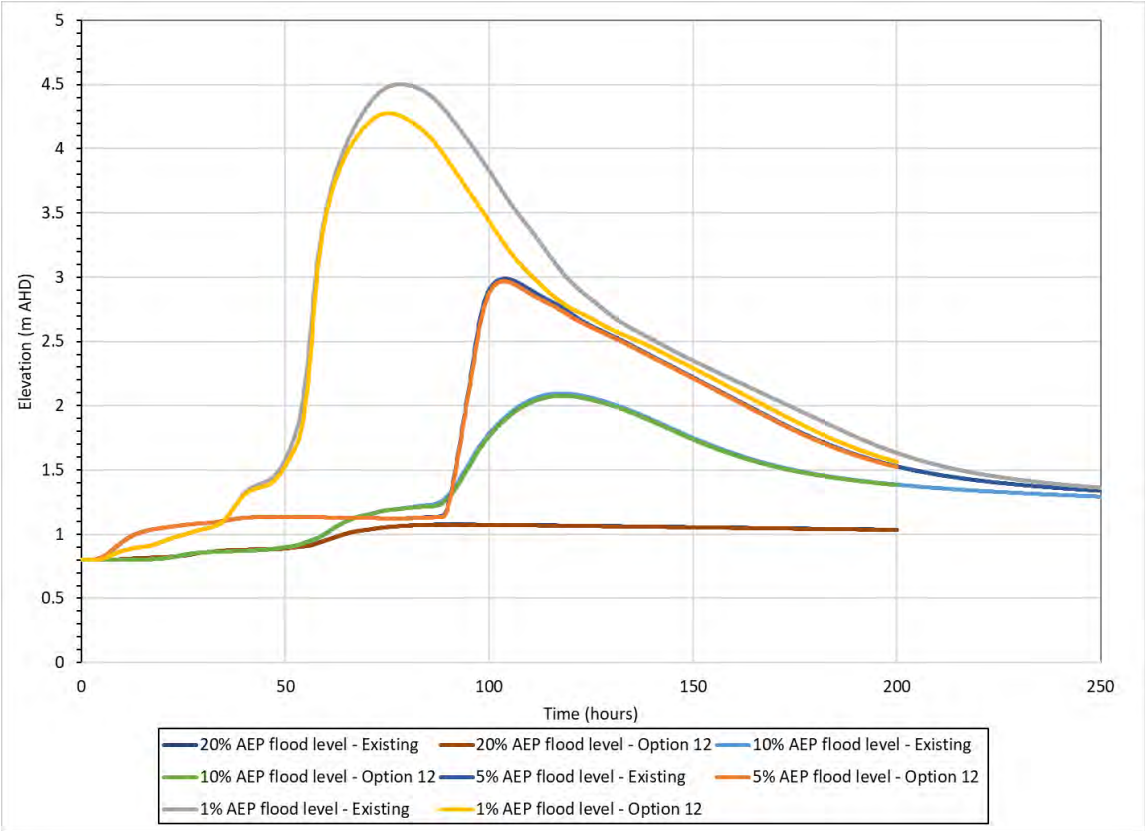
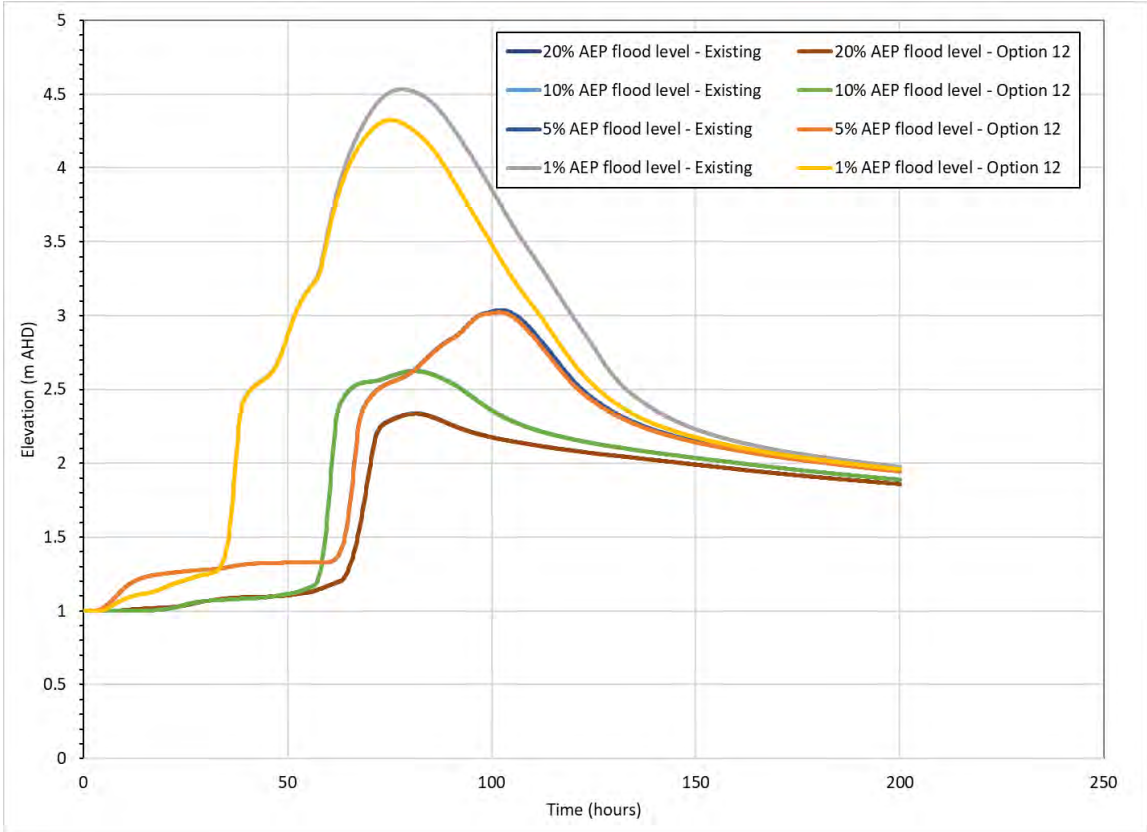


Figure F-82: Flood levels versus time at Clybucca near Plummers Lane, Existing compared with Option 12



F.15 Option 13 – Filling of low points in the levee system

Discussion

Council commissioned audits of main levees in the Macleay around 2015, which identified that the levees are lower than their design crest level at a number of locations due to erosion or wearing down by cattle traffic. In some locations there are localised low points in the levees. The Rainbow Reach levee audit report found that for approximately 50% of the length of the levee the surveyed crest level is approximately 200mm below the design crest level. The Frederickton to Smithtown levee audit reported that the crests of the levees appear to have eroded with undulations and cattle tracks identified over the entire lengths of most of the levees, typically ±50-100mm in size.

The flood mapping from this current study indicates that most of the levees are overtopped by the 20% AEP event or smaller, as summarized in Table 8-5 in the Flood Study Update report (Jacobs, 2022). Noting that the objectives of the Macleay Flood Mitigation Scheme, as stated on Council's flood management web page, was to provide "Protection for the lower Macleay agricultural area from a 1 in 2.5 year flood event", overtopping of the levees in the 20% AEP event (approximately 1 in 4 to 1 in 5 year event) could be considered acceptable and within the objectives of the Scheme.

The levee audit reports recommend remediation of the defects (including low points and sections below design crest levels) be undertaken. The height of raising the levees above existing levels to design level varies. There are sections along Frederickton to Smithtown requiring up to 0.5m raising. The levees at design level would likely still overtop in the 20% AEP event, so the benefits may be difficult to quantify.

Effects on flooding

Remediation of existing low points in the levee system would provide improved protection of properties in the areas local to the repaired sections. Given the low design flood protection of the majority of rural levees, flood

protection and any resultant flood impacts are unlikely to be significant for overtopping floods including the 20% AEP event and larger.

The recommendation is for remediation of levee low points to be undertaken by Council as a part of maintenance of existing flood protection assets.

F.16 Property flood benefits and impacts from assessed options

An assessment of the benefits and impacts of the proposed short-term flood modification options tested in the TUFLOW model was conducted, which included a count of individual properties where above-floor flooding was removed as a result of the option, and where new above-floor flooding was resultant from the options.

Table F-1 summarises the changes in numbers of residential and commercial buildings which experience above-floor flooding in the existing case to the mitigation cases. This provides a better understanding of the effects of the mitigation options at individual buildings compared to the net effects which are reflected by a count of the number of buildings affected by floor flooding. Buildings with less than +/- 0.01 change in flood level have been filtered out as these are considered to be negligible changes.

Table F-1: Changes to above floor flooding of buildings with assessed mitigation options*

Option	Description	No Longer Flooded Above Floor				Now Flooded Above Floor				Comment
		AEP				AEP				
		1%	5%	10%	20%	1%	5%	10%	20%	
Residential										
Option 1	Raise Crescent Head Road to 3.2m AHD + no drainage upgrade	0	0	1	0	14	5	3	0	Increases north of Crescent Head Road, decreases south for Crescent Head Road.
Option 1A	Raise Crescent Head Road to 3.2m AHD + 1000m of viaduct	0	0	0	0	0	0	0	0	
Option 1B	New emergency access from Crescent Head Road to Pacific Highway	Not assessed – No influence on peak flood levels								
Option 2A	Raise Hat Head Road to 2.3m AHD + 200m culverts/floodway	0	0	0	0	0	0	0	0	
Option 3	Disconnect Korogoro and Killick Creek	49	0	0	0	23	4	2	0	Decreases in Hat Head village. Increases elsewhere on the southern floodplain.
Option 4	Widen Loftus Road Ryans Cut crossing	13	1	0	0	0	0	0	0	Decreases occur on the southern floodplain
Option 4B	Widen Loftus Road Ryans Cut crossing and extend Ryans Cut to Belmore River	12	2	0	1	0	0	0	0	
Option 5	Increased Floodplain Drainage Capacity	Not assessed - Negligible change in peak flood levels								
Option 6	Reinstate Rowes Cut	47	0	0	0	0	0	0	0	Decreases in Hat Head village.
Option 7	Enlarge headworks on Belmore and Kinchela	Not assessed - Negligible change in peak flood levels								
Option 8A	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads	0	0	0	1	0	0	0	0	
Option 8B	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads and SWR Road + additional levee	8	12	3	1	16	20	22	1	Refer to the change in peak flood level maps on Figure F-56 to Figure F-59 for indication of where increases and decreases in numbers of buildings with above-floor flooding would occur.
Option 9A	Raise and Extend Smithtown Levee to protect from 20% AEP flood	0	33	29	10	0	0	0	0	Decreases within Smithtown village
Option 9B	Raise and Extend Smithtown Levee to protect from 5% AEP flood	8	35	30	10	0	0	0	0	Decreases within Smithtown village
Option 11	Dredging of Macleay River	125	50	40	10	0	0	0	0	Substantial reductions in number of above floor flooded residential buildings as a result of reductions in peak flood levels.
Option 12	Additional ocean outlet for Macleay River	131	9	1	0	0	0	0	0	Substantial reductions in number of above floor flooded residential buildings as a result of reductions in peak flood levels.
Option 13	Filling levee low points	Not assessed								Minor improvement to property flooding expected behind affected levees. Option not assessed in flood model.
Commercial										
Option 1	Raise Crescent Head Road to 3.2m AHD + no drainage upgrade	0	0	0	0	0	1	0	0	Increases north of Crescent Head Road, decreases south for Crescent Head Road.
Option 1A	Raise Crescent Head Road to 3.2m AHD + 1000m of viaduct	0	0	0	0	0	0	0	0	
Option 1B	New emergency access from Crescent Head Road to Pacific Highway	Not assessed – No influence on peak flood levels								

Option	Description	No Longer Flooded Above Floor				Now Flooded Above Floor				Comment
		AEP				AEP				
		1%	5%	10%	20%	1%	5%	10%	20%	
Option 2A	Raise Hat Head Road to 2.3m AHD + 200m culverts/floodway	0	0	0	0	0	0	0	0	
Option 3	Disconnect Korogoro and Killick Creek	0	0	0	0	0	1	0	0	Decreases in Hat Head village. Increases elsewhere on the southern floodplain.
Option 4	Widen Loftus Road Ryans Cut crossing	0	0	0	0	0	0	0	0	
Option 4B	Widen Loftus Road Ryans Cut crossing and extend Ryans Cut to Belmore River	0	0	0	0	0	0	0	0	
Option 5	Increased Floodplain Drainage Capacity	Not assessed - Negligible change in peak flood levels								
Option 6	Reinstate Rowes Cut	0	0	0	0	0	0	0	0	
Option 7	Enlarge headworks on Belmore and Kinchela	Not assessed - Negligible change in peak flood levels								
Option 8A	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads	0	0	0	0	0	0	0	0	
Option 8B	Modify Opening Regime of Flood Control Structures - 10% AEP + raise Belmore and Kinchela Left/Right Bank Roads and SWR Road + additional levee	0	0	0	0	5	11	24	0	Refer to the change in peak flood level maps on Figure F-56 to Figure F-59 for indication of where increases and decreases in numbers of buildings with above-floor flooding would occur.
Option 9A	Raise and Extend Smithtown Levee to protect from 20% AEP flood	0	3	4	1	0	0	0	0	Decreases within Smithtown village
Option 9B	Raise and Extend Smithtown Levee to protect from 5% AEP flood	1	4	4	1	0	0	0	0	Decreases within Smithtown village
Option 11	Dredging of Macleay River	7	12	47	1	0	0	0	0	Relatively high reductions in number of above floor flooded commercial buildings as a result of reductions in peak flood levels.
Option 12	Additional ocean outlet for Macleay River	1	1	0	0	0	0	0	0	
Option 13	Filling levee low points	Not assessed								Minor improvement to property flooding expected behind affected levees. Option not assessed in flood model.

* Excludes buildings with less than +/-0.01m change in flood level

Appendix G. Mitigation options cost estimate summaries

Option 1 - Raise Crescent Head Road to 3.2m AHD with no drainage capacity upgrade

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	58422	sqm	$ 2.00	$ 116,844.00	
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	70585	cum	$ 93.20	$ 6,578,522.00	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	15729	sqm	$ 32.10	$ 504,900.90	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	15729	sqm	$ 30.50	$ 479,734.50	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	2247	m	$ 135.50	$ 304,468.50	
Extend existing culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	25	20	m	$ 1,885.00	$ 942,500.00	Assumption (Needs further analysis to determine the size)
SUB TOTAL						$ 8,926,969.90	

Adding 10% miscellaneous expenses	$ 892,696.99	
Adding 40% contingencies	$ 3,570,787.96	
TOTAL	**$ 13,390,454.85**	

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width: 7m
- Batter Slope for existing road 3:1
- Batter Slope for new road 3:1
- Traffic Management and Alternate Road not considered
- Assuming existing embankment is not demolished
- Utility relocation fees not included

Option 1A - Raise Crescent Head Road to 3.2m AHD with 1000m of new viaduct

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	58422	sqm	$ 2.00	$ 116,844.00	
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	6802	cum	$ 93.20	$ 633,946.40	Assuming the cut will be used as fill
Earthwork Cut	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	22495	cum	$ 14.85	$ 334,050.75	
Bridge Works	Two lane 11m wide: Conventional (Price are for reinforced concrete single span bridges including safety rails, balustrades but excluding approach works, abutments and piling)	-	13200	sqm	$ 1,970.00	$ 26,004,000.00	Excluding price of approach work, abutments, and piling
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	15729	sqm	$ 32.10	$ 504,900.90	

Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	15729	sqm	$ 30.50	$ 479,734.50	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	1047	m	$ 135.50	$ 141,868.50	
Extend existing culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	15	20	m	$ 1,885.00	$ 565,500.00	Assumption (Needs further analysis to determine the size)

SUB TOTAL	$ 28,780,845.05	
Adding 10% miscellaneous expenses	$ 2,878,084.51	
Adding 40% contingencies	$ 11,512,338.02	
TOTAL	**$ 43,171,267.58**	

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width: 7m
- Batter Slope for existing road 3:1
- Batter Slope for new road 3:1
- Traffic Management and Alternate Road not considered
- Piling cost not included due to uncertainty in ground conditions
- Utility relocation fees not included

Option 1B - New emergency access from Crescent Head Road to Pacific Highway

Exit Ramp

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	5200	sqm	$ 2.00	$ 10,400.00	Assuming 20m wide strip needs to be cleared. Tree removal cost not accounted as exact road aliment is unknown and road geometry is not carried out
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	1448.57	cum	$ 93.20	$ 135,006.72	Assuming the cut will be used as fill. Retaining structure / soil stabilisation may be required at some sections.
Earthwork Cut	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	919.15	cum	$ 14.85	$ 13,649.38	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	910	sqm	$ 32.10	$ 29,211.00	

Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	910	sqm	$ 30.50	$ 27,755.00	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	260	m	$ 135.50	$ 35,230.00	
TOTAL						$ 251,252.10	

Entry Ramp

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	8300	sqm	$ 2.00	$ 16,600.00	Assuming 20m wide strip needs to be cleared. Tree removal cost not accounted as exact road aliment is unknown and road geometry is not carried out
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	16958.88	cum	$ 93.20	$ 1,580,567.62	Assuming the cut will be used as fill. Retaining structure / soil stabilisation may be required at many sections.

Earthwork Cut	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	525.375	cum	$ 14.85	$ 7,801.82	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	1452.5	sqm	$ 32.10	$ 46,625.25	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	1452.5	sqm	$ 30.50	$ 44,301.25	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	415	m	$ 135.50	$ 56,232.50	
TOTAL						$ 1,752,128.43	

Roundabout

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	1500	sqm	$ 2.00	$ 3,000.00	Assuming 1500sqm
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	1000	sqm	$ 32.10	$ 32,100.00	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	1000	sqm	$ 30.50	$ 30,500.00	

Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	200	m	$ 135.50	$ 27,100.00	
TOTAL						$ 92,700.00	

TOTAL COST INCLUDING EXIT RAMP, ENTRY RAMP AND ROUNDABOUT

SUB TOTAL	$ 2,096,080.54	
Adding 10% miscellaneous expenses	$ 209,608.05	
Adding 40% contingencies	$ 838,432.21	
TOTAL	**$ 3,144,120.80**	

Assumption:

- Land acquisition cost not considered.
- Road geometry design not carried out
- pavement width: 3.5m
- Batter Slope for new road 3:1
- Traffic Management and Alternate Road not considered
- Utilities relocation not considered

Option 2A - Raise Hat Head Road to 2.3m AHD with 200m new culverts and floodway

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	81742	sqm	$ 2.00	$ 163,484.00	Tree removal cost not accounted
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	14717	cum	$ 93.20	$ 1,371,624.40	
Earthwork Cut (Road)	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	1988	cum	$ 14.85	$ 29,521.80	Assuming the cut will be used as fill
Earthwork Cut (Floodway)	Excavate to reduce levels and deposit in spoil heaps within clay. Cartage 20km		6451.86	cum	$ 20.40	$ 131,617.94	
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowing free growth of vegetation	-	23320	sqm	$ 13.00	$ 303,160.00	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	6300	sqm	$ 32.10	$ 202,230.00	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	6300	sqm	$ 30.50	$ 192,150.00	

Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	900	m	$ 135.50	$ 121,950.00	
Culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	125	20	m	$ 1,885.00	$ 4,712,500.00	Assumtion (Needs further analysis to determine the size)
SUB TOTAL						$ 7,228,238.14	
Adding 10% miscellaneous expenses						$ 722,823.81	
Adding 40% contingencies						$ 2,891,295.26	
TOTAL						**$ 10,842,357.22**	

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width: 7m
- Batter Slope for existing road 3:1
- Batter Slope for new road 3:1
- Traffic Management and Alternate Road not considered
- Assuming existing pavement/earthwork is not demolished
- Utilities relocation not considered

Option 4 - Widen Loftus Road crossing at Ryans Cut

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	35089.91	sqm	$ 2.00	$ 70,179.82	Tree removal cost not accounted
Earthwork Cut (Floodway)	Excavate to reduce levels and deposit in spoil heaps within clay. Cartage 20km		63664.84	cum	$ 20.40	$ 1,298,762.74	
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowing free growth of vegetation	-	23546.1	sqm	$ 13.00	$ 306,099.30	
Roadwork Base Course Track Road	Crushed rock /blue metal: 100mm	-	6300	sqm	$ 13.20	$ 83,160.00	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	420	sqm	$ 32.10	$ 13,482.00	
Roadwork Paving Track road	Prime and sprayed bitumen sealing two coats	-	6300	sqm	$ 8.60	$ 54,180.00	

Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	420	sqm	$ 30.50	$ 12,810.00	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	60	m	$ 135.50	$ 8,130.00	
Culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	28	10	m	$ 3,715.00	$ 1,040,200.00	Assumption (Needs further analysis to determine the size) (Cost is interpolated from Rawlinsons)
Floodgate	Floodgate – nominal allowance	-	28	no	$50,000.00	$ 1,400,000.00	Assumption (Needs further analysis to determine the size)
SUB TOTAL						$ 4,287,003.86	
Adding 10% miscellaneous expenses						$ 428,700.39	
Adding 40% contingencies						$ 1,714,801.54	
TOTAL						**$ 6,430,505.78**	

Assumptions:

- Land acquisition cost not considered.
- Environmental approvals cost not considered.
- Traffic Management and Alternate Road not considered
- Utilities relocation not considered

Option 4b - Widen Loftus Road crossing at Ryans Cut + Extend to Belmore river

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetable soil average 150mm deep and spread and level on site	-	269263.9	sqm	$ 2.00	$ 538,527.82	Tree removal cost not accounted
Earthwork Cut (Floodway)	Excavate to reduce levels and deposit in spoil heaps within clay. Cartage 20km		224374.8	cum	$ 20.40	$ 4,577,246.74	
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowig free growth of vegetation	-	28964.1	sqm	$ 13.00	$ 376,533.30	
Reestablish pasture	Reseed floodway with grass	-	228756	sqm	$ 0.40	$ 91,502.40	Based on hydromulch costs in Rawlinsons and cross-checked with Macleay 2001 flood rural damages costs
Roadwork Base Course Track Road	Crushed rock /blue metal: 100mm	-	6300	sqm	$ 13.20	$ 83,160.00	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	1080	sqm	$ 32.10	$ 34,668.00	

Roadwork Paving Track road	Prime and sprayed bitumen sealing two coats	-	6300	sqm	$ 8.60	$ 54,180.00	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	1080	sqm	$ 30.50	$ 32,940.00	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	60	m	$ 135.50	$ 8,130.00	
Culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	28	10	m	$ 3,715.00	$ 1,040,200.00	Assumtion (Needs further analysis to determine the size) (Cost is interpolated from Rawlinsons)
Culverts	Floodgate Duckbill type	-	28	no	$50,000.00	$ 1,400,000.00	Assumtion (Needs further analysis to determine the size)
Bridges	Replace road bridge around Belmore River	1	630	sqm	$2,400.00	$ 1,512,000.00	
Bridges	Replace access track bridges	2	240	sqm	$1,200.00	$ 576,000.00	Assumed 2

SUB TOTAL		$ 10,325,088.26	
Adding 10% miscellaneous expenses		$1,032,508.83	
Adding 40% contingencies		$ 4,130,035.30	
TOTAL	**$ 15,487,632.38**	**$ 15,487,632.38**	

Assumptions:

- Land acquisition cost not considered.
- Environmental approvals cost not considered.
- Traffic Management and Alternate Road not considered
- Utilities relocation not considered

Option 6 – Reinstate Rowes Cut

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	45658.97	sqm	$ 2.00	$ 91,317.94	Tree removal cost not accounted
Earthwork Cut (Floodway)	Excavate to reduce levels and deposit in spoil heaps within clay. Cartage 20km		92202.87	cum	$ 20.40	$ 1,880,938.55	
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowing free growth of vegetation	-	45658.97	sqm	$ 13.00	$ 593,566.61	Assuming channel lining not required. If channel lining required further analysis required.
SUB TOTAL						$ 2,565,823.10	
Adding 10% miscellaneous expenses						$ 256,582.31	
Adding 40% contingencies						$ 1,026,329.24	
TOTAL						$ 3,848,734.65	

Assumptions:

- Land acquisition cost not considered.
- Environmental approvals cost not considered.
- Traffic Management and Alternate Road not considered
- Utilities relocation not considered

Option 8A - Modify Opening Regime of Flood Control Structures to 10% AEP flood level, with raising of Belmore and Kinchela Left/Right Bank Roads

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	109008	sqm	$ 2.00	$ 218,016.00	
Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	19762	cum	$ 93.20	$ 1,841,818.40	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	54504	sqm	$ 32.10	$ 1,749,578.40	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	54504	sqm	$ 30.50	$ 1,662,372.00	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	9084	m	$ 135.50	$ 1,230,882.00	Optional
Culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	5	6	m	$ 1,885.00	$ 56,550.00	Assumption (Needs further analysis to determine the size)

SUB TOTAL						$ 6,759,216.80	
Adding 10% miscellaneous expenses						$ 675,921.68	
Adding 40% contingencies						$ 2,703,686.72	
TOTAL						$ 10,138,825.20	

Upgrade Belmore and Kinchela Flood Control Structures for Remote Operation

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
SCADA		-	1	-	$800,000	$800,000	
Power & control outdoor kiosks		-	1	-	$300,000	$300,000	
Cabling		-	1	-	$100,000	$100,000	
Conduits and cable ladders		-	1	-			
Instrumentations		-	1	-	$150,000	$150,000	
CCTV		-	1	-	$100,000	$100,000	

Project design	10% allowance	-	1	-	$155,000	$155,000	
Installation	20% allowance	-	1	-	$310,000	$310,000	
TOTAL						$ 2,015,000.00	

TOTAL COST INCLUDING ROAD RAISING AND UPGRADE TO FLOOD CONTROL STRUCTURES

TOTAL	$ 12,153,825.20

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width Option 8A: 6m
- Batter Slope for existing road 3:1
- Traffic Management and Alternate Road not considered
- Assuming existing embankment is not demolished
- Utility relocation fees not included
- Costs for upgrade to existing flood control structures based on previous cost estimates on various Sydney Water projects.

Option 8B - Modify Opening Regime of Flood Control Structures to 10% AEP flood level, with raising of Belmore and Kinchela Left/Right Bank Roads and Parts of South West Rocks Road and additional levees

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	109008	sqm	$ 2.00	$ 218,016.00	

Earthwork Fill	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	19762	cum	$ 93.20	$ 1,841,818.40	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	54504	sqm	$ 32.10	$ 1,749,578.40	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	54504	sqm	$ 30.50	$ 1,662,372.00	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	9084	m	$ 135.50	$ 1,230,882.00	Optional
Culverts	Precast concrete box culvert laid on the ground including minimal excavation size 1200 x 1200 mm	5	6	m	$ 1,885.00	$ 56,550.00	Assumtion (Needs further analysis to determine the size)
Additional Items							
Site Preparation (Road)	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	96650	sqm	$ 2.00	$ 193,300.00	
Site Preparation (Levee)	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	34649	sqm	$ 2.00	$ 69,298.00	

Earthwork Fill (Road)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	48846	cum	$ 93.20	$ 4,552,447.20	
Earthwork Fill (Levee)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	21957	cum	$ 93.20	$ 2,046,392.40	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	48325	sqm	$ 32.10	$ 1,551,232.50	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	48325	sqm	$ 30.50	$ 1,473,912.50	
Crash and Guard Rails	Galvanised steel double corrugated guard rail with bolts and splice plates	-	6041	m	$ 135.50	$ 818,555.50	Optional
SUB TOTAL						$ 17,464,354.90	
Adding 10% miscellaneous expenses						$ 1,746,435.49	
Adding 40% contingencies						$ 6,985,741.96	
TOTAL						$ 26,196,532.35	

Upgrade Belmore and Kinchela Flood Control Structures for Remote Operation							
Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
SCADA		-	1	-	$800,000	$800,000	
Power & control outdoor kiosks		-	1	-	$300,000	$300,000	
Cabling		-	1	-	$100,000	$100,000	
Conduits and cable ladders		-	1	-			
Instrumentations		-	1	-	$150,000	$150,000	
CCTV		-	1	-	$100,000	$100,000	
Project design	10% allowance	-	1	-	$155,000	$155,000	
Installation	20% allowance	-	1	-	$310,000	$310,000	
TOTAL						$ 2,015,000.00	

TOTAL COST INCLUDING ROAD RAISING, LEVEEES AND UPGRADE TO FLOOD CONTROL STRUCTURES

TOTAL	$ 28,211,532.35

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width Option 8A: 6m
- Batter Slope for existing road 3:1
- Traffic Management and Alternate Road not considered
- Assuming existing embankment is not demolished
- Utility relocation fees not included
- Costs for upgrade to existing flood control structures based on previous cost estimates on various Sydney Water projects.

Option 9A - Raise and Extend Smithtown Levee to 20% AEP flood level plus 0.3m freeboard

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	3618	sqm	$ 2.00	$ 7,236.00	Tree removal cost not accounted
Earthwork Fill (Leeve)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	642.50	cum	$ 93.20	$ 59,881.00	
Earthwork Cut	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	49.38	cum	$ 14.85	$ 733.29	Foundation of retaining wall
Retaining Wall	Precast concrete wall panels with a smooth off-form finish	-	329.18	sqm	$ 580.00	$ 190,924.40	Construction subjective to actual site conditions
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowig free growth of vegetation	-	3618	sqm	$ 13.00	$ 47,034.00	

Sheet Steel Piling (Retaing Wall & Earth Leeve)	Sheet steel piling including all supports: Permanent - 74.0kg/m	-	5819	sqm	$ 775.00	$ 4,509,725.00	(Sheet piles are inserted 3m deep below the ground)
Site Preparation (Road)	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	1400	sqm	$ 2.00	$ 2,800.00	Tree removal cost not accounted
Earthwork Fill (Road)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	4	cum	$ 93.20	$ 372.80	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	1400	sqm	$ 32.10	$ 44,940.00	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	1400	sqm	$ 30.50	$ 42,700.00	
SUB TOTAL						$ 4,863,646.49	
Adding 10% miscellaneous expenses						$ 486,364.65	
Adding 40% contingencies						$ 1,945,458.60	
TOTAL						$ 7,295,469.74	

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width: 10m
- New longitudinal slope for the elevated road 1:12
- Width of levee at the road: 2m
- Batter Slope for earth levee 3:1
- Depth of sheet pile: 3m
- Traffic Management and Alternate Road not considered
- Assuming existing levee is not demolished
- Utility relocation fees not included
- Drainage not considered

Option 9B - Raise and Extend Smithtown Levee to 5% AEP flood level plus 0.3m freeboard

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	6693	sqm	$ 2.00	$ 13,386.00	Tree removal cost not accounted
Earthwork Fill (Leeve)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	1294.49	cum	$ 93.20	$ 120,646.47	
Earthwork Cut	Excavate from borrow pit and deposit as fill within 1km including compaction to 90% in Clay	-	403.55	cum	$ 14.85	$ 5,992.72	Foundation of retaining wall
Retaining Wall	Precast concrete wall panels with a smooth off-form finish	-	2690.36	sqm	$ 580.00	$ 1,560,408.80	Construction cost may differ to actual site conditions
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowig free growth of vegetation	-	6693	sqm	$ 13.00	$ 87,009.00	
Sheet Steel Piling (Retaing Wall & Earth Leeve)	Sheet steel piling including all supports: Permanent - 74.0kg/m	-	10250	sqm	$ 775.00	$ 7,943,750.00	(Depth of Sheet Pile 3m below the ground)

Site Preparation (Road)	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	1710	sqm	$ 2.00	$ 3,420.00	Tree removal cost not accounted
Earthwork Fill (Road)	Crushed rock filling laid and consolidated in 150mm layers (81$/cum) cartage, per additional 20km ($12.8/cum)	-	6	cum	$ 93.20	$ 559.20	
Roadwork Base Course	Crushed rock /blue metal: 300mm	-	1710	sqm	$ 32.10	$ 54,891.00	
Roadwork Paving	Hot bituminous concrete including tack coat: 40mm plus prime coat emulsion and crushed rock/blue metal chips	-	1710	sqm	$ 30.50	$ 52,155.00	
SUB TOTAL						$ 9,842,218.19	
Adding 10% miscellaneous expenses						$ 984,221.82	
Adding 40% contingencies						$ 3,936,887.27	
TOTAL						$ 14,763,327.28	

Assumptions:

- Land acquisition cost not considered.
- Existing pavement width: 10m
- New longitudinal slope for the elevated road 1:12
- Width of levee at the road: 2m
- Batter Slope for earth levee 3:1

- Depth of sheet pile: 3m
- Traffic Management and Alternate Road not considered
- Assuming existing levee is not demolished
- Utility relocation fees not included
- Drainage not considered
- Further detailed assessment of design through Nestle factory property required.

Option 11 – Dredging of Macleay River

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Dredging – composite cost	Dredging 36km Macleay River, lowering by 2m. Dispose spoil within 200m	-	15,320,000	m3	$ 20.00	$ 306,400,000.00	Based on coastal waterways dredging (Tuggerah Lakes, Myall River) budgeted rates.
SUB TOTAL						$ 306,400,000.00	
Adding 10% miscellaneous expenses						$30,640,000.00	
Adding 40% contingencies						$122,560,000.00	
TOTAL						**$ 459,600,000.00**	

Assumptions:

- Assumes clean sand, excludes disposal of unsuitable fill material/acid sulphate soils etc.
- Cost of environmental studies and approvals excluded.
- Offset of costs from potential sale of dredged sand and other material not accounted for – requires feasibility and market assessment.

Option 12 – New ocean outlet

Line Item	Description	No	Quantity	Unit	Rate	Total	Remarks
Site Preparation	Excavate to remove vegetated soil average 150mm deep and spread and level on site	-	35480	sqm	$ 2.00	$ 70,960.00	Tree removal cost not accounted
Earthwork Cut	Excavate to reduce levels and deposit in spoil heaps . Cartage 20km		76600	cum	$ 20.40	$ 1,562,640.00	
Erosion and Sediment Control	Cellular confinement system comprising interconnected cells designed to prevent soil movement on steep slopes and batter, whilst allowing free growth of vegetation	-	35480	sqm	$ 13.00	$ 461,240.00	Assuming channel lining not required. If channel lining required further analysis required.
SUB TOTAL						$ 2,094,840.00	
Adding 10% miscellaneous expenses						$209,484.00	
Adding 40% contingencies						$837,936.00	
TOTAL						**$ 3,142,260.00**	

Assumptions:

- Assumes clean sand, excludes disposal of unsuitable fill material/acid sulphate soils etc.
- Cost of environmental studies and approvals excluded.
- Offset of costs from potential sale of dredged sand and other material not accounted for – requires feasibility and market assessment.

Appendix H. Economic assessment of mitigation options

Lower Macleay FRMS - Economic assessment of mitigation options

Date: 18 July 2023
Updated 25 April 2024
Project name: Lower Macleay River Floodplain Risk Management Study
Project no: IA252400
Attention: Lih Chong
Company: Jacobs
Prepared by: Ngcebo Gwebu

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Introduction

Jacobs has been undertaking a flood risk management study to Kempsey Shire Council for a variety of flood mitigations works for the Macleay River catchment. For this project, Jacobs has developed flood modelling scenarios and cost estimates. In order to inform a value for money assessment of the various options, Jacobs has undertaken an economic assessment which will compare the costs and benefits of each option.

The flood mitigation options assessed as part of the economic assessment are outlined below. The options assessed include upgrading levees and raising key roads.

Table 1 Options assessed

Option name	Brief description	Capex
1	Raise Crescent Head Road to 3.2m AHD + no drainage update	$ 13.39 m
1A	Raise Crescent Head Road to 3.2m AHD + bridge crossing	$ 43.17 m
1B	New on ramp to Pacific Highway from Crescent Head Road	$ 3.14 m
2A	Raise Hat Head Road to 2.3m AHD + new culverts and floodway	$ 10.84 m
3	Disconnect Korogoro and Killick Creek	$ 0.20 m
4	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut	$ 6.43 m
4B	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut + Extension to Belmore River	$15.49 m
6	Reinstate Rowes Cut	$ 3.85 m
8A	Modified opening regime Flood Control Structures	$ 12.15 m
8B	Modified opening regime Flood Control Structures + levees	$ 28.21 m

9A	Raise Smithtown levee 20% AEP	$ 7.30 m
9B	Raise Smithtown levee 5% AEP	$ 14.76 m
11	Dredging of Macleay River. 36km by 2m deepening	$ 459.6 m initial + $108.84 m NPV of periodic maintenance dredging (50yrs) = $568.84 m
12	New ocean outlet	$3.14 m

Approach

The economic assessment has been completed through a Cost Benefit Analysis (CBA). The costs and benefits of the options assessed have been calculated relative to a 'Do Nothing' base case. The CBA is underpinned by the following parameters:

- Discount rate of 7%
- Assessment period of 2024 – 2074
  - Construction: FY2024
  - Operations period of 50 years: FY2025 – FY2074
- Direct average residential and commercial buildings annual damages (AAD) based on NSW OEH Curves and Jacobs flood modelling
- Indirect and intangible damages monetised through a literature review and Jacobs flood modelling on isolation durations
- No escalation over the assessment period of damages

Benefits for each option are simply the difference between the base case damages and the respective project case damages. This represents avoided damages that mean an increase in economic welfare for the local community and industry. Table 2 also outlines how the damages are calculated.

Table 2 Economic benefits approach

Benefit	Description	Calculation	Inputs
Avoided AAD	Combined AAD from direct damages to residential and commercial buildings.	$Combined\ AAD_{Base\ case} - Combined\ AAD_{\ Project\ case}$	▪ Jacobs Flood modelling ▪ NSW OEH AAD Calculator
Avoided Intangibles costs	Intangible damages refer to flood damages that do have a market price but nonetheless represent a significant social cost. Examples include damages to heritage assets, psychological impacts and damages to flora and fauna. Melbourne water research indicates that intangible represents 100% of direct damage costs.	$Avoided\ AAD\ \times Intangibles\ factor$ Where: Intangibles factor = 100%	▪ Intangibles factor sourced from Melbourne Water Flood Risk Reduction Literature Review
Avoided Isolation Supply Cost	During periods of isolation, the local community has to fly in food supplies and other necessities. Research indicates that rental rates for an emergency helicopter is roughly $1,600 per hour.	$\Delta Isolation\ hours \times Helicopter\ rental\ rate$ Where: $\Delta Isolation\ hours$ = Change in community isolation between base case and project case Plane rental rate = $1600	▪ Isolation hours obtained Jacobs flood modelling ▪ helicopter rental rate obtained from internet search
Avoided cancelled trips	During period of isolation, local residents and industry are forced to cancel planned trips. This is loss of economic welfare as it can be assumed that the trip was beneficial, whether it be for commuting to work, a business trip or delivering produce.	$\Delta Isolation\ hours \times AADT\ \times VOT$ Where: Trip time : average trip time to Kempsey AADT = impacted daily traffic VOT = Value of time	▪ Trip time sourced from Google maps ▪ AADT sourced from council data ▪ VOT sourced from Transport for NSW Wales economic parameters guidelines

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Rural damages	Based on post-2001 flood event survey of rural land owners in the Lower Macleay. Comparison made to flood damages info from Lower Macleay residents for 2013, 2021 and 2022 floods	Refer to discussion below.	▪ Jacobs flood modelling ▪ Damage $ rates on post-2001 flood event survey of rural land owners in the Lower Macleay.

Consideration of savings in rural damages

A post-flood event survey was undertaken on behalf of Kempsey Shire Council following the 2001 flood event to gather information on actual flood damages resulting from the event. A total of 9 landowners/operators were surveyed to estimate rural flood damages, which are summarised in Table 3. While the sample size of 9 is relatively small, this is the best estimate available for rural damages local to the Lower Macleay.

Table 3 Reported actual flood damages from 2001 flood event (2004 dollar values)

Location	Inundation		Agistment/Feed			Stock, Infra-structure, Equipment, etc.	Loss of Sales or Production	Fencing	Pasture
	Area (ha)	Duration (days)	Freight	Period (weeks)	Cost				
Austral Eden	52	2	$1200	3	$200	nil	$2000	$4000	-
Austral Eden	75	2	-	-	?	$900	$12000	nil	$4000
Kinchela Ck	180	?	$1240	20	$4700	$2000	?	a lot	$6000
Kinchela Creek	200	10	-	-	$42000	$4000	$300000	$10000	$50000
East Frederickton	164	7-14	$4000	20	$16500	$2000	$5400	$2000	$9000
Belmore River	110	7-10	$2500	28	$53500	$1000	$38300	nil	$17500
Belmore River	160	14-28	$6000	?	$3000	nil	$10000	nil	$7500
Belmore River	225	10-14	$9000	28	$28000	$8300	$6000	$2000	$18000
Belmore River	?	?	?	?	?	$26000	?	?	?
TOTAL	1166		$23940		$147900	$44200	$373700	$18000	$112000

Reference: Macleay River Flood March 2001 – Flood Damages Data Collection. Webb McKeown & Associates (2004).

Flood damages on areal basis

The survey suggests an average damages value of $620/hectare of inundation in 2004 dollars, or equivalent 2022 dollar value of $1488/hectare based on Australian Bureau of Statistics information on average weekly earnings. It is acknowledged that this is a generalised cost value as the specific costs are expected to vary between individual operators and depends on the property size, location on the floodplain, specifics of their operations, costs of production etc. Additionally, the impacts to operators would vary for different flood events due to the differing flood behaviour.

Flooding event costs to farmers on the Lower Macleay were obtained during this study based on 2013, 2021 and 2022 flood events. Information was provided by one landowner with costs of around $350/ha estimated. This is substantially lower than the estimates based on the post-2001 flood survey, however, it was noted by the landowner that their cattle were able to be moved to another of their properties that was flood-free, hence various costs such as agistment and feed could be reduced or avoided.

For the purposes of this study the areal rate for flood damages on the Lower Macleay of $1488/ha was adopted to assess the savings in rural flood damages offered by the flood mitigation options.

Flood damages on duration of inundation basis

Aside from rural damages being a function of the area affected by flooding, the duration of flooding is another consideration due to die-off of pasture and damage from waterlogging of soils. Common pasture species such as kikuyu die-off if inundated by floodwaters for a period of 3-4 days. Costs related to flood damage occur due to need for agistment of grazing stock, supplementary feed and re-establishment of damaged pastures etc.

The flood modelling indicates that reductions in durations of inundation are generally negligible for the assessed mitigation options. The best performing options including increasing drainage capacity at Ryans Cut result in only 0.5 – 1.5 days reduction in flood duration, mainly in the Upper Belmore to Swan Pool areas. The

dredging option provided 1-2 days reductions in flooding in localised areas of the floodplain around Kinchela and Upper Belmore. Given the existing durations of flooding indicated by the flood modelling of at least 5 days, and historic flooding durations reported as typically 1-2 weeks (and up to 4 weeks in low-lying areas), it is expected that the reductions in the duration of inundation offered by the mitigation options would not be sufficient to significantly reduce the area of pasture die-off. Those areas of the floodplain where some pasture die-off could be avoided would be in areas with shallow depths of flooding, and these areas benefitting are already accounted for in the estimated reduced flood extents.

Note that while pasture die-off and subsequent recovery/re-establishment is only one aspect of rural flood damages relating to flooding duration. Consultation with landowners indicates that:

- Regrowth of pastures can take from 3 months to 6 depending on inundation time, time of year, amount of silt coverage on the plants etc.
- Recently flooded land cannot be grazed as the cattle 'pug' it up and the cattle refuse to eat grass that has a covering of silt.
- Essentially, inundated pastures are not available for a minimum of 3+ months.

Therefore, regardless of whether there is pasture die-off, cattle herds are likely to be relocated in any case so that the pasture and floodplain can recover.

Inclusion of rural flood damages in economic assessment

Based on the above, the savings in areal rural flood damages were accounted in the economic assessment. If there were any increased flooding extent resulting from the assessment mitigation options, these were included as additional costs and damages.

Potential rural flood damages savings due to reductions in duration of inundation were not considered further, as the reductions in durations were found to be generally negligible compared to the overall duration of inundation, and because stock were likely required to be moved from inundated pasture in any case to allow the pasture and floodplain to recover. Hence, the costs of stock relocation would not be avoided.

Summary results

Table 4 below outlines the CBA results for each options. The table shows the following high level findings:

- Option 1B, 9A and 9B generate positive net present values (NPVs) and benefit cost ratios (BCR) above 1, which indicates positive economic viability
- Option 12 also generates positive net present values (NPVs) and benefit cost ratios (BCR) above 1, however, resultant environmental/social/property damages and impacts have not been quantified and are excluded from the economic assessment. These would have the effect of reducing or negating the economic benefits.
- Avoided AAD and intangibles are the largest drivers of economic viability for all options
- Option 1B generates as a positive net present value purely through its reduction of isolation related economic costs.
- Options 1, 3, 8A and 8B generate negative avoided AAD benefits. This means that these options actually generate an increase in flood damage costs , relative to the base case.

Figure 1 below illustrates the composition of benefits for each option.

Table 4 CBA summary results (7% discount rate)

Options	1	1A	1B	2A	3	4	4B	6	8A	8B	9A
Costs											
Capital costs	$ 13.39 m	$ 43.17 m	$ 3.14 m	$ 10.84 m	$ 0.20 m	$ 6.43 m	$15.49 m	$ 3.85 m	$ 12.15 m	$ 28.21 m	$ 7.30 m
Maintenance costs (NPV over 50yrs)											
Benefits											
Avoided AAD	-$ 2.41 m	-$ 0.19 m		$ 0.09 m	-$ 0.67 m	$ 0.96 m	$ 1.38 m	$ 1.49 m	-$ 0.70 m	-$ 17.32 m	$ 14.91 m
Avoided Intangibles costs	-$ 2.41 m	-$ 0.19 m	-	$ 0.09 m	-$ 0.67 m	$ 0.96 m	$ 1.38 m	$ 1.49 m	-$ 0.70 m	-$ 17.32 m	$ 13.83 m
Avoided Isolation Supply Cost	$ 0.63 m	$ 0.65 m	$ 1.61 m	$ 0.14 m	-	$ 0.05 m	$ 0.07 m	-			
Avoided cancelled trips			$ 3.48 m								
Avoided rural damages	-$ 0.48 m	$ 0.03 m	-	-$ 3.03 m	-$ 0.46 m	$ 0.12 m	$ 0.46 m	$ 0.00 m	-$ 0.42 m	-$ 0.59 m	-$ 0.00 m
Total benefits	-$ 4.69 m	$ 0.29 m	$ 5.09 m	-$ 2.70 m	-$ 1.81 m	$ 2.10 m	$ 3.30 m	$ 2.99 m	-$ 1.82 m	-$ 35.23m	$ 27.66 m
Viability metrics											
NPV	-$ 18.08m	-$ 42.88m	$ 1.95 m	-$ 13.54m	-$ 2.01 m	-$ 4.33 m	-$ 12.19m	-$ 0.86 m	-$ 13.98m	-$ 63.44m	$ 20.36 m
BCR	-0.35	0.01	1.62	-0.25	-9.03	0.33	0.21	0.78	-0.15	-1.25	3.79

Options	9B	11	12
Costs			
Capital costs	$ 14.76 m	$ 459.60 m	$ 3.14 m
Maintenance costs (NPV over 50yrs)		$ 108.84 m	
Benefits			
Avoided AAD	$ 14.91 m	$ 34.42 m	$ 8.68 m
Avoided Intangibles costs	$ 14.91 m	$ 34.42 m	$ 8.68 m
Avoided Isolation Supply Cost			
Avoided cancelled trips			
Avoided rural damages	-$ 0.00 m	$ 20.72 m	$ 0.43 m
Total benefits	$ 29.81 m	$ 89.57 m	$ 17.79 m
Viability metrics			
NPV	$ 15.04 m	-$ 478.87 m	$ 14.65 m
BCR	2.02	0.16	5.66

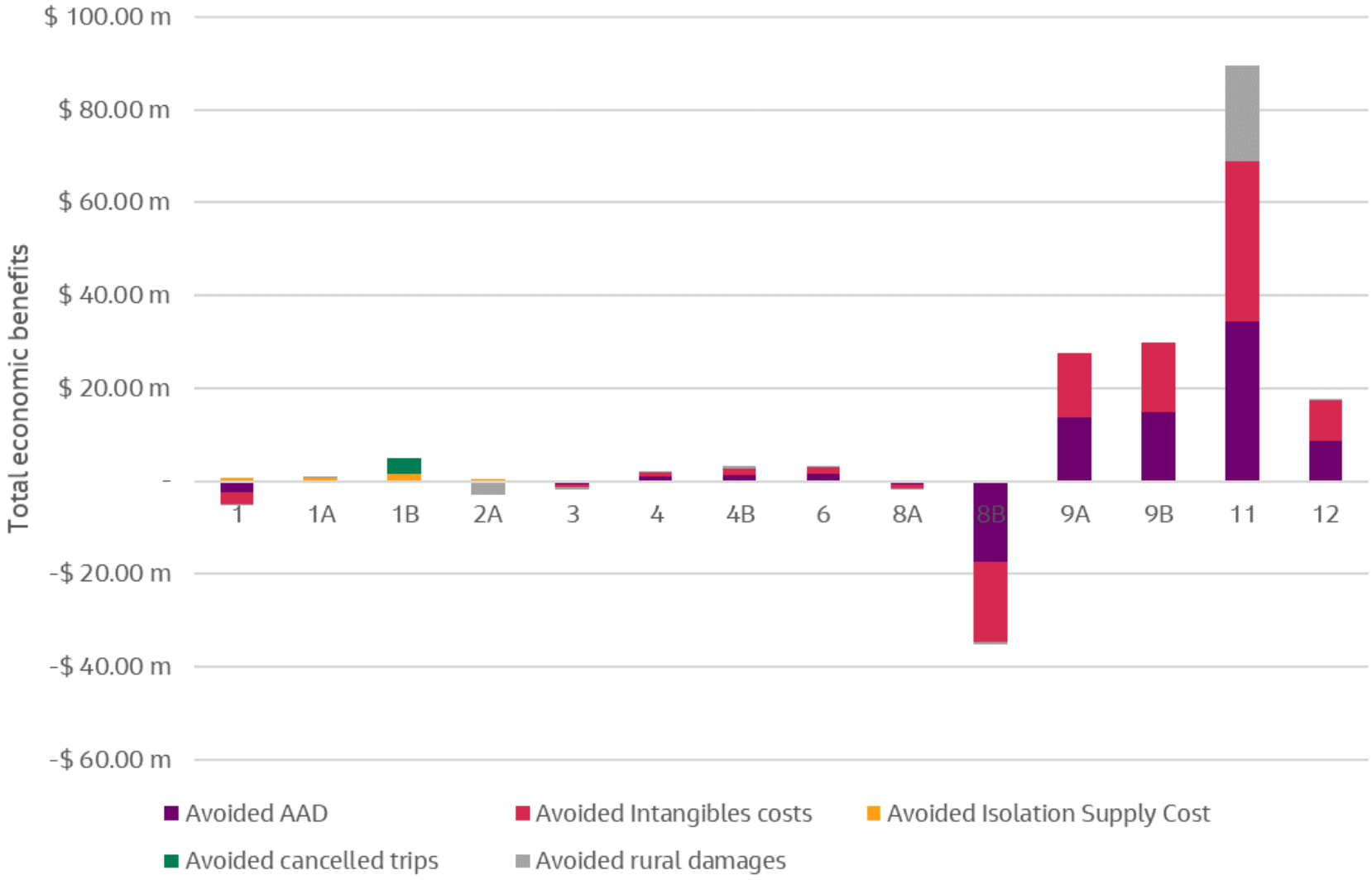

Figure 1 Total economic benefits

Economic assumptions

Lower Macleay Flooding Study Economic Assessment

AAD - Assumptions

Options	Description	Commercial AAD	Residential AAD	Combined AAD
Base case	No project	$4,016,618.8	$12,591,643.1	$16,608,261.8
1	Raise Crescent Head Road to 3.2m AHD + no drainage update	$4,023,046.9	$12,760,099.0	$16,783,145.9
1A	Raise Crescent Head Road to 3.2m AHD + bridge crossing	$4,017,058.2	$12,604,899.8	$16,621,958.0
1B	New on ramp to Pacific Highway from Crescent Head Road	$4,016,618.8	$12,591,643.1	$16,608,261.8
2A	Raise Hat Head Road to 2.3m AHD + new culverts and floodway	$4,016,497.5	$12,584,979.3	$16,601,476.8
3	Disconnect Korogoro and Killick Creek	$4,023,193.0	$12,633,882.8	$16,657,075.8
4	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut	$4,013,008.5	$12,519,801.1	$16,532,809.5
4B	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut + Extend to Ryans Cut	$4,005,022.0	$12,497,584.1	$16,502,606.1
6	Reinstate Rowes Cut	$4,016,497.5	$12,483,599.7	$16,500,097.3
8A	Modified opening regime Flood Control Structures	$4,025,081.5	$12,634,081.4	$16,659,162.9
8B	Modified opening regime Flood Control Structures + levees	$4,786,331.0	$13,076,851.3	$17,863,182.3
9A	Raise Smithtown levee 20% AEP	$3,989,182.3	$11,616,850.7	$15,606,033.1
9B	Raise Smithtown levee 5% AEP	$3,974,560.8	$11,553,666.4	$15,528,227.2
11	Dredge Macleay River	$3,300,625.2	$10,813,314.1	$14,113,939.3
12	New ocean outlet	$3,992,769.1	$11,986,669.4	$15,979,438.4
Base case for Option 4	No project	$4,016,618.8	$12,585,927.6	$16,602,546.4

Damages parameters - Assumptions

Parameter	Factor
Indirect damages	20.0%
Intangibles	100.0%

Source: Melbourne Water

Isolation parameters - Assumptions

		Isolation Hours - Baseline					Isolation Hours - Project				
Options	Description	50% AEP	20% AEP	10% AEP	5% AEP	1% AEP	50% AEP	20% AEP	10% AEP	5% AEP	1% AEP
1	Raise Crescent Head Road to 3.2m AHD + no drainage update	-	150	163	208	254	-	-	-	37	76
1A	Raise Crescent Head Road to 3.2m AHD + bridge crossing	-	150	163	208	254	-	-	-	4	54
1B	New on ramp to Pacific Highway from Crescent Head Road	150	180	200	250	250	-	-	-	-	-
2A	Raise Hat Head Road to 2.3m AHD + new culverts and floodway	-	19	81	101	149	-	-	19	57	99
3	Disconnect Korogoro and Killick Creek										
4	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut	-	150	163	208	254	-	144	139	195	237
4B	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut + Extend to Ryans Cut	-	150	163	208	254	-	137	132	192	235
5	Increased Floodplain Drainage Capacity - double floodgate capacity										
6	Reinstate Rowes Cut										
11	Dredge Macleay River										
12	New ocean outlet										
Base case	No project										

		Isolation Hours - Baseline					Isolation Hours - Project						
Options	Description	50% AEP average annual hours	20% AEP average annual hours	10% AEP average annual hours	5% AEP average annual hours	1% AEP average annual hours	50% AEP average annual hours	20% AEP average annual hours	10% AEP average annual hours	5% AEP average annual hours	1% AEP average annual hours	Baseline average	project average
1	Raise Crescent Head Road to 3.2m AHD + no drainage update	-	30.0	16.3	10.4	2.5	-	-	-	1.9	0.8	59.2	2.6
1A	Raise Crescent Head Road to 3.2m AHD + bridge crossing	-	30.0	16.3	10.4	2.5	-	-	-	0.2	0.5	59.2	0.7
1B	New on ramp to Pacific Highway from Crescent Head Road	75.0	36.0	20.0	12.5	2.5	-	-	-	-	-	146.0	-
2A	Raise Hat Head Road to 2.3m AHD + new culverts and floodway	-	3.8	8.1	5.1	1.5	-	-	1.9	2.9	1.0	18.4	5.7
3	Disconnect Korogoro and Killick Creek	-	-	-	-	-	-	-	-	-	-	-	-
4	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut	-	30.0	16.3	10.4	2.5	-	28.8	13.9	9.8	2.4	59.2	54.8
4B	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut + Extend to Ryans Cut	-	30.0	16.3	10.4	2.5	-	27.4	13.2	9.6	2.4	59.2	52.6
5	Increased Floodplain Drainage Capacity - double floodgate capacity	-	-	-	-	-	-	-	-	-	-	-	-
6	Reinstate Rowes Cut	-	-	-	-	-	-	-	-	-	-	-	-
11	Dredge Macleay River	-	-	-	-	-	-	-	-	-	-	-	-
12	New ocean outlet	-	-	-	-	-	-	-	-	-	-	-	-
Base case	No project	-	-	-	-	-	-	-	-	-	-	-	-

		Avoided isolation hours					
Options	Description	50% AEP average annual hours	20% AEP average annual hours	10% AEP average annual hours	5% AEP average annual hours	1% AEP average annual hours	Total average annual hours
1	Raise Crescent Head Road to 3.2m AHD + no drainage update	-	30.0	16.3	8.6	1.8	56.6
1A	Raise Crescent Head Road to 3.2m AHD + bridge crossing	-	30.0	16.3	10.2	2.0	58.5
1B	New on ramp to Pacific Highway from Crescent Head Road	75.0	36.0	20.0	12.5	2.5	146.0
2A	Raise Hat Head Road to 2.3m AHD + new culverts and floodway	-	3.8	6.2	2.2	0.5	12.7
3	Disconnect Korogoro and Killick Creek	-	-	-	-	-	-
4	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut	-	1.2	2.4	0.7	0.2	4.4

Economic assumptions

Lower Macleay Flooding Study Economic Assessment

4B	Increased Floodplain Drainage Capacity –Floodplain and Drainage Capacity at Ryans Cut + Extend to Ryans Cut	-	2.6	3.1	0.8	0.2	6.7
5	Increased Floodplain Drainage Capacity - double floodgate capacity	-	-	-	-	-	-
6	Reinstate Rowes Cut	-	-	-	-	-	-
11	Dredge Macleay River	-	-	-	-	-	-
12	New ocean outlet	-	-	-	-	-	-
Base case	No project	-	-	-	-	-	-

AEP- ARI Conversion - Assumptions

	50% AEP	20% AEP	10% AEP	5% AEP	1% AEP
ARI	0.5	0.2	0.1	0.1	0.0

Economic assumptions

Lower Macleay Flooding Study Economic Assessment

Isolation services costs

	Cost
Emergency flights Isolation resupply cost per hour	$1,600.0
Percentage of hours required to supply	50.0%

Isolation cancelled trips travel assumptions

Note: Cancelled trips only apply to Option 1B as advised by Jacobs flood modellers

Option 1B:

AADT

Crescent Head Road AADT	4,400.0
AADT benefiting from Option 1b	1,400.0
Percentage of commercial vehicles	12.8%
Percentage of business trips	10.0%
Percentage of cars	71.4%
Percentage of commuting car trips	28.7%
Trip trime to Kempsey (hours)	0.5
Impacted AADT car tips	999
Impacted commuting car trips AADT	286
Impacted business car trips AADT	100
Impacted freight vehicle trips AADT	401
Hours in a day	24.0
Even rate of needing to drive during isolation	50.0%

Value of time per vehicle hour

Car commuter trips	$33.1
Business trips	$81.9
Heavy vehicle trips	$54.3

Discount rates

	Rate
Core discount rate	7.0%
Lower discount rate	5.0%

Appraisal period

Start year	2024
Operations period	50.0
Last year of appraisal	2073

Option	20% AEP				10% AEP			
	AreaRural NowDry (hectares)	AreaRural NowWet (hectares)	AreaRural NetChangeExtent (hectares)	RuralDamages Savings	AreaRural NowDry (hectares)	AreaRural NowWet (hectares)	AreaRural NetChangeExtent (hectares)	RuralDamages Savings
1	7.9	54.7	46.7	($69,519)	16.9	80.2	63.3	($94,149)
1A	4.0	0.6	-3.4	$5,085	2.4	1.9	-0.5	$761
2A	26.1	420.0	393.9	($586,171)	5.4	0.8	-4.6	$6,812
3	0.4	46.7	46.3	($68,870)	0.4	32.4	31.9	($47,537)
4	10.5	0.6	-9.9	$14,739	20.3	0.6	-19.7	$29,289
4B	69.9	16.3	-53.6	$79,781	30.4	11.4	-19.0	$28,331
6	1.8	1.1	-0.7	$1,049	0.2	3.1	2.9	($4,375)
8A	76.1	125.8	49.7	($73,980)	9.7	30.4	20.7	($30,815)
8B	135.3	197.3	61.9	($92,180)	179.1	241.9	62.8	($93,433)
9A	30.1	28.9	-1.2	$1,785	13.6	17.5	3.8	($5,710)
9B	29.9	28.9	-1.1	$1,565	14.5	17.6	3.2	($4,735)
11	2451.7	35.5	-2416.2	$3,595,292	1054.6	7.6	-1047.0	$1,557,930
12	29.9	6.4	-23.5	$34,956	49.3	0.7	-48.6	$72,379

Option	5% AEP				1% AEP				NPV
	AreaRural NowDry (hectares)	AreaRural NowWet (hectares)	AreaRural NetChangeExtent (hectares)	RuralDamages Savings	AreaRural NowDry (hectares)	AreaRural NowWet (hectares)	AreaRural NetChangeExtent (hectares)	RuralDamages Savings	7% discount factor
1	23.3	40.1	16.8	($24,992)	6.9	10.7	3.8	($5,671)	($483,715)
1A	3.0	3.6	0.6	($917)	0.7	0.9	0.2	($334)	$26,433
2A	0.5	0.4	-0.2	$247	0.2	0.1	-0.1	$102	($3,028,747)
3	0.9	29.0	28.1	($41,846)	0.5	32.8	32.2	($47,963)	($457,987)
4	9.4	0.3	-9.1	$13,573	10.9	0.3	-10.5	$15,688	$124,637
4B	12.4	0.6	-11.8	$17,601	10.1	0.4	-9.7	$14,457	$462,665
6	0.9	0.3	-0.6	$841	1.6	0.1	-1.5	$2,173	$2,073
8A	1.8	2.8	1.1	($1,612)	0.5	0.2	-0.3	$399	($418,343)
8B	84.2	95.6	11.4	($16,965)	9.6	10.4	0.8	($1,223)	($593,059)
9A	2.9	8.3	5.4	($8,075)	0.1	0.9	0.8	($1,201)	($2,986)
9B	3.7	9.2	5.5	($8,223)	0.0	1.1	1.0	($1,504)	($3,269)
11	300.7	3.5	-297.3	$442,340	117.8	0.3	-117.5	$174,810	$20,723,573
12	28.7	2.0	-26.7	$39,759	229.9	0.3	-229.6	$341,597	$434,503