Eumungerie Floodplain Risk Management Study

Study and Plan

Dubbo Regional Council

1478-01-F2, 14 April 2022

Report Title	Eumungerie Floodplain Risk Management Study
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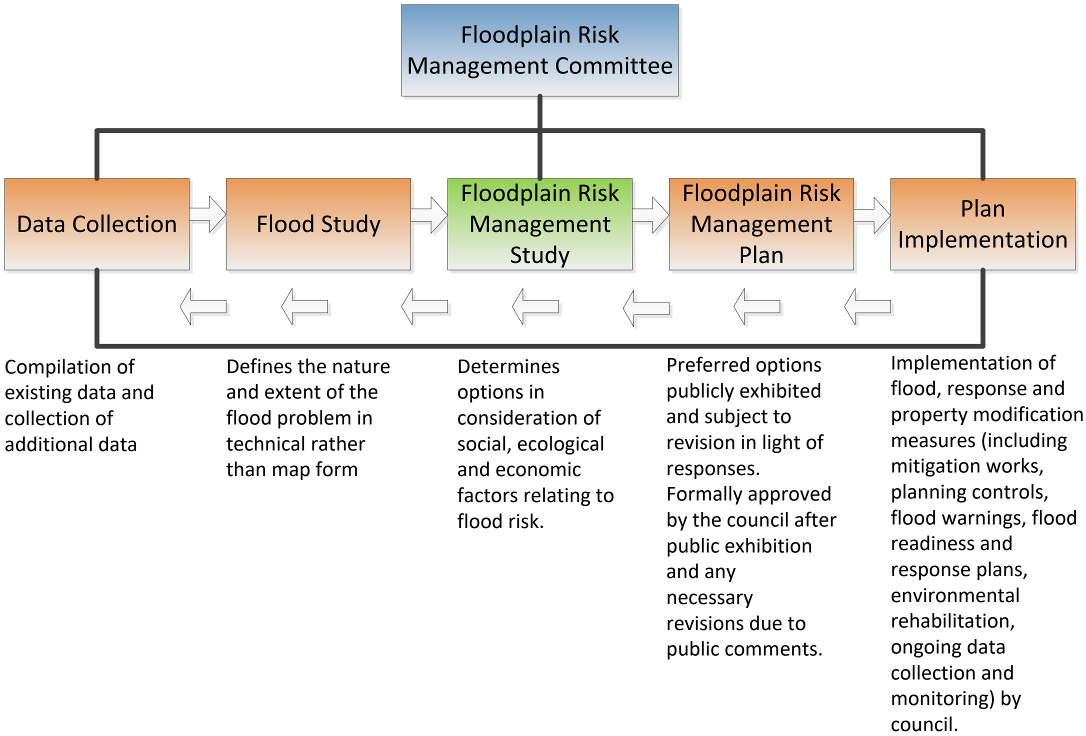
NOTE: This report has been prepared on the assumption that all information, data and reports provided to us by our client, on behalf of our client, or by third parties (e.g. government agencies) is complete and accurate and on the basis that such other assumptions we have identified (whether or not those assumptions have been identified in this advice) are correct. You must inform us if any of the assumptions are not complete or accurate.

Foreword

The NSW Government's Flood Prone Land Policy provides a framework for managing development on the floodplain. The primary objective of the policy is to develop sustainable strategies for managing human occupation and use of the floodplain using risk management principles. Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The NSW Government's Floodplain Development Manual (2005) (the Manual) has been prepared to support the NSW Government's Flood Prone Land Policy. The Manual provides Council's with a framework for implementing the policy to achieve the policy's primary objective. The framework is shown below.



The Eumungerie Floodplain Risk Management Study constitutes the third stage of the Floodplain Risk Management process to define and assess potential options to manage the flood risk. A draft plan for approval by council has also been prepared. It has been prepared by consultants WRM Water & Environment Pty Ltd for Dubbo Regional Council.

Acknowledgements and limitations

This project was prepared with financial assistance from the NSW Government's Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

While all due effort has been made to ensure the reliability of flood model results, all models have limitations (Ball et al, 2019). The accuracy of any model is a function of the quality of the data used in the model development including topographical data, drainage structure data and calibration data. Modelling is by nature a simplification of very complex systems and results of flood model simulations should be considered as a best estimate only. There is, therefore, an unknown level of uncertainty associated with all model results that should be considered when utilising the outputs from this study.

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1 Introduction

1.1 OVERVIEW

Eumungerie is a village in central west New South Wales (NSW) located approximately 37 kilometres north of the regional centre of Dubbo (see Figure 1.1). The village is located in the Drillwarrina Creek catchment, which drains in a southerly direction immediately to the west of Eumungerie. Drillwarrina Creek is a tributary of Coolbaggie Creek, which drains in a westerly direction about 3 km to the south of Eumungerie. Coolbaggie Creek is a tributary of the Macquarie River.

Dubbo Regional Council commissioned WRM Water & Environment Pty Ltd (WRM) to prepare a Flood Study Update and Floodplain Risk Management Study and Plan for the village of Eumungerie in accordance with the NSW Flood Prone Land Policy. This report presents the findings of the floodplain risk management and draft plan components of the study. The flood study update was completed by WRM in 2020.

1.2 THE FLOOD PROBLEM

The study has been undertaken in accordance with the NSW Government's Floodplain Development Manual (2005) (the Manual), which has been prepared to support the NSW Government's Flood Prone Land Policy. The Manual recognises three separate flood problems: the existing problem, the future problem and the continuing problem.

- The **existing problem** refers to existing properties that are liable to flooding and flood damage.
- The **future problem** refers to those properties, which upon development or redevelopment, become flood-liable and susceptible to significantly higher levels of flood damage.
- The **continuing problem** refers to the risk of flooding and flood damage that remains when all adopted floodplain management measures have been implemented. The continuing flood risk and associated damage can only be eliminated by designing for the probable maximum flood (PMF). In general, design for the PMF is either economically or practically infeasible.

The existing problem was defined as part of the Eumungerie Flood Study (WRM, 2020). Computer models were developed to calculate peak flood levels (based on equations of flow) from design rainfall prepared by the Commonwealth Bureau of Meteorology (BOM). The BOM calculates design rainfalls based on long term rainfall records. The computer model accuracy was improved by calibrating the model to the January 1993 event, which inundated much of the village.

Different flood management options were assessed in this study for each flood problem.

- **Structural measures**, e.g. levees and house raising were investigated to reduce damage, hazard and disruption associated with the existing problem.
- **Planning measures**, such as zoning and building controls (e.g. minimum floor levels) were reviewed to reduce damage, hazard and disruption associated with the future problem.
- **Emergency response measures**, such as flood warning, evacuation and recovery, were reviewed to reduce damage, hazard and disruption associated with the continuing problem.

This report describes and assesses the potential measures to address each of the flood problems for Eumungerie and provides recommendations to manage the flood risk.

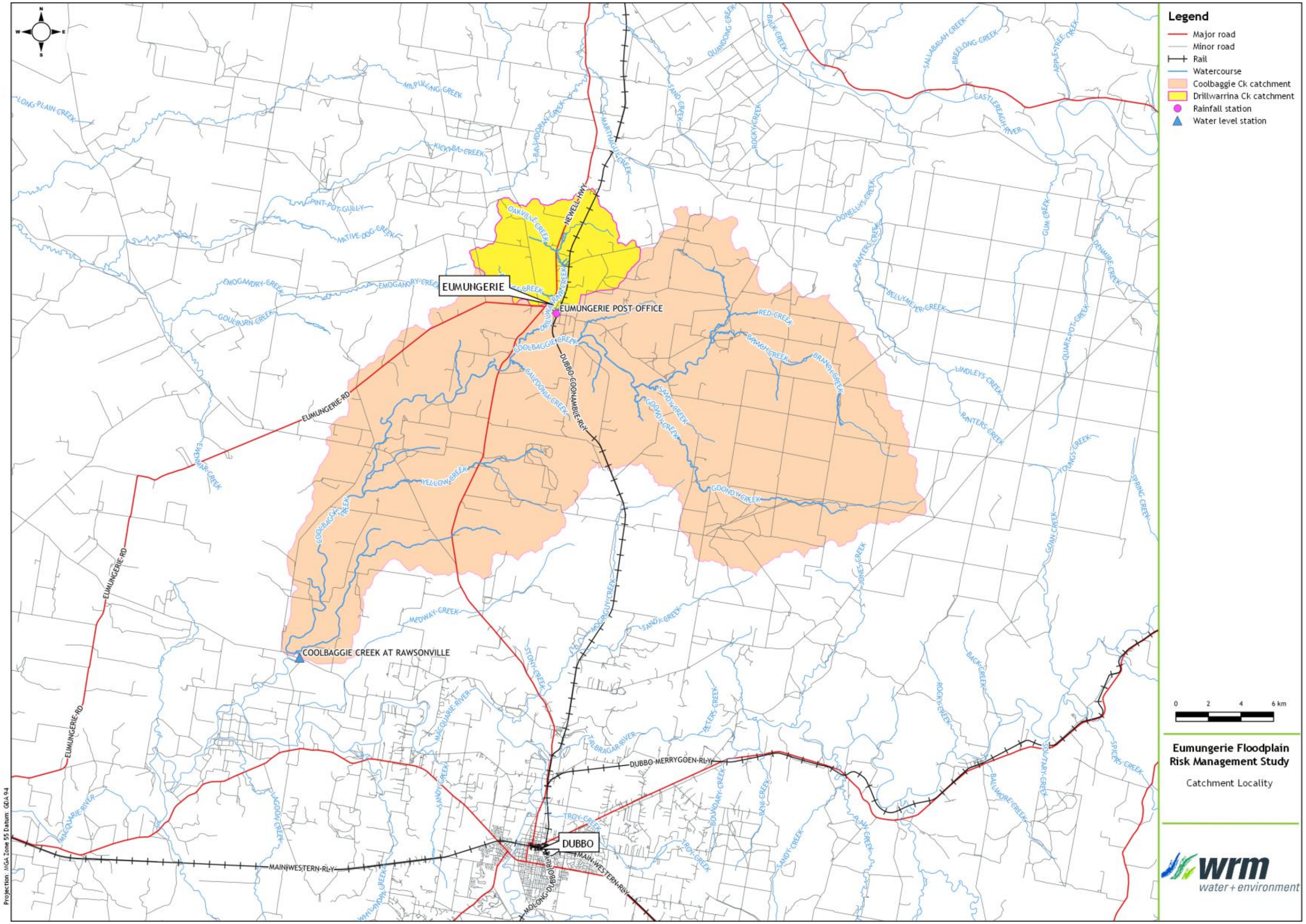

Figure 1.1 – Locality Plan

1.3 REPORT STRUCTURE

The report is structured as follows:

- Section 2 describes the existing landuse zonings, the environmental constraints and social characteristics of Eumungerie:
- Section 3 describes the existing flood behaviour and presents flood hazard mapping for the community;
- Section 4 describes the methodology to estimate the flood damages and presents the tangible flood damage costs for existing conditions;
- Section 5 presents the results of the hydraulic modelling used to support emergency management activities;
- Section 6 provides an assessment of potential structural options to mitigate the existing flood risk in Eumungerie;
- Section 7 provides an assessment of potential non-structural options to mitigate the existing, future and continuing flood risk om Eumungerie;
- Section 8 summarises the findings of the study.
- Section 10 is a list of relevant terms used throughout this study.
- Section 11 is a list of references.

Two appendices are attached.

- Appendix A provides flood hazard maps for Eumungerie based on the hydraulic modelling;
- Appendix B provides flood impact maps for the proposed structural mitigation measure.

2 Background

2.1 STUDY AREA DRAINAGE

The main drainage feature at Eumungerie is Drillwarrina Creek. Drillwarrina Creek drains in a southerly direction to the west of the village centre and joins with Coolbaggie Creek around 3 km downstream of Cobboco Road. Drillwarrina Creek catchment is approximately 50 km^2 to Cobboco Road. A number of local tributaries including Dohnts Creek and Oakville Creek flow into Drillwarrina Creek upstream of Cobboco Road. Local catchment runoff from the east of the Dubbo Coonamble Railway also drains through the village of Eumungerie to Drillwarrina Creek.

Coolbaggie Creek drains in a westerly direction to the south of Eumungerie. It has a catchment area of 367 km^2 to the Drillwarrina Creek confluence and its main tributaries include Drillwarrina Creek, Branch Creek, Goondy Creek, Red Creek, Sandy Creek and Eumunden Creek. The catchment area of Coolbaggie Creek to the Rawsonville gauge (GS421055) is 609 km^2. The catchment boundaries of Drillwarrina and Coolbaggie creeks and their principal tributaries are shown in Figure 1.1.

2.2 LANDUSE

Figure 2.1 shows the land use zones within the study area identified in the local environment plan (LEP). The village has been zoned RU5 (village) with lot sizes limited to 2000 m^2. Areas to the west of the village have been zoned R5 (large lot residential) with a minimum lot size of 8 ha. The surrounding areas are RU1 (primary production) with minimum lot sizes of 800 ha.

2.3 ENVIRONMENT

Figure 2.2 shows an extract of the Dubbo LEP (2011) biodiversity mapping for Eumungerie. There are two predominant vegetation communities within the study area. The Drillwarrina Creek corridor consists predominantly of River Red Gum woodland whereas the Newell Highway corridor is predominantly Pilliga Box - White Cypress Pine. The vegetation communities are identified as having 'high terrestrial biodiversity' in the Dubbo LEP (2011). The Newell Highway corridor has also been identified as a travelling stock reserve for sustainable conservation. It also has suitable Koala habitat. There are no Critically Endangered Ecological Communities within the vicinity of Eumungerie.

Five properties have been identified with heritage value on the LEP including;

- Eumungerie Church;
- Bakers shop & cottage;
- Cottage at 23 Railway Street;
- Eumungerie Hall; and
- Cottage at 6 Moonal St

Soils within the area consist of Balimore - Curban Red Soils (Red Chromosols and Sodosols) suitable for cropping and grazing.

The Eumungerie village does not have a reticulated sewer with on-site septic systems used to manage sewage waste. The individual systems at each property have not been inspected. However, it is likely that all of the on-site systems are prone to flooding and downstream contamination when inundated.

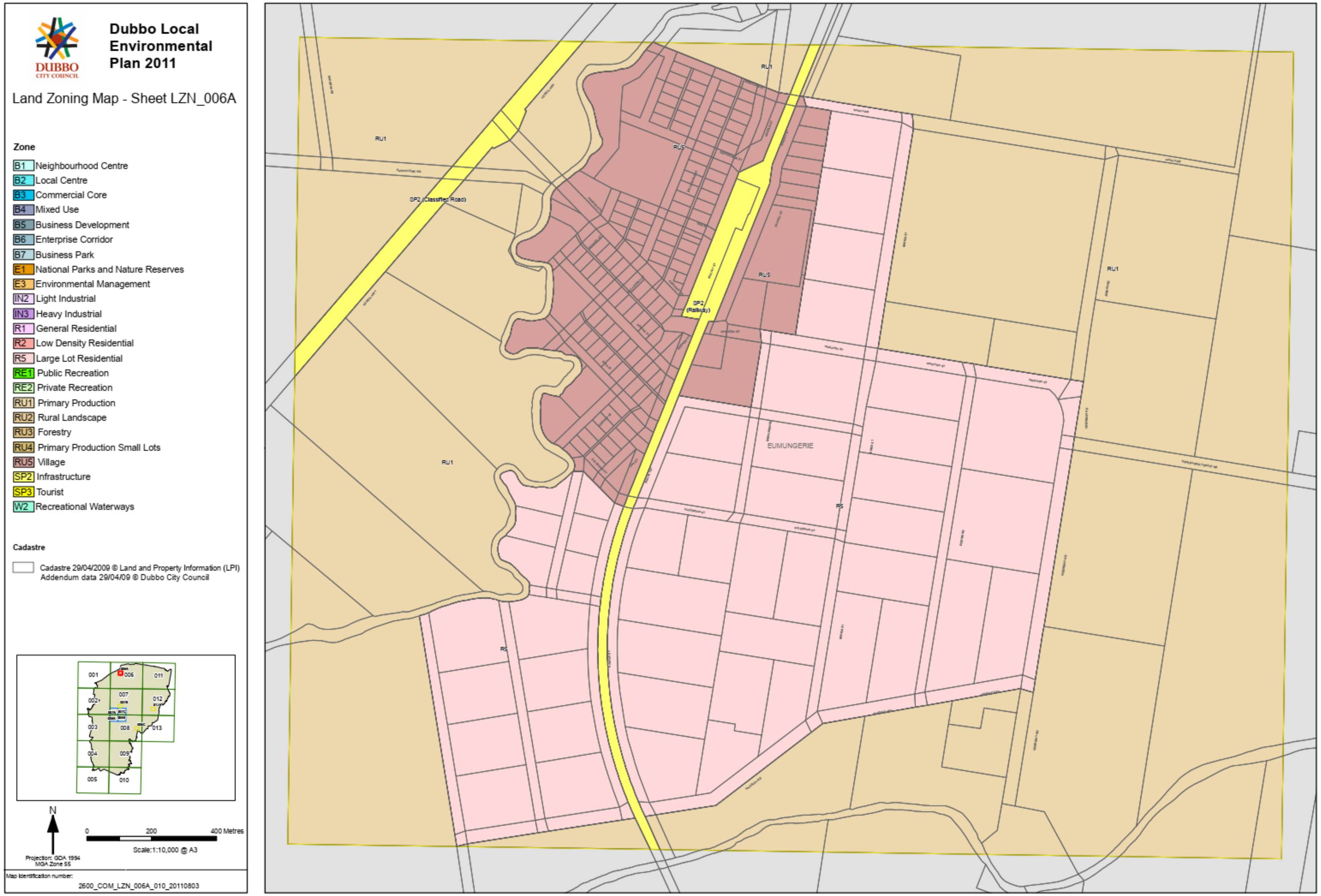

Figure 2.1 – Eumungerie land zoning map

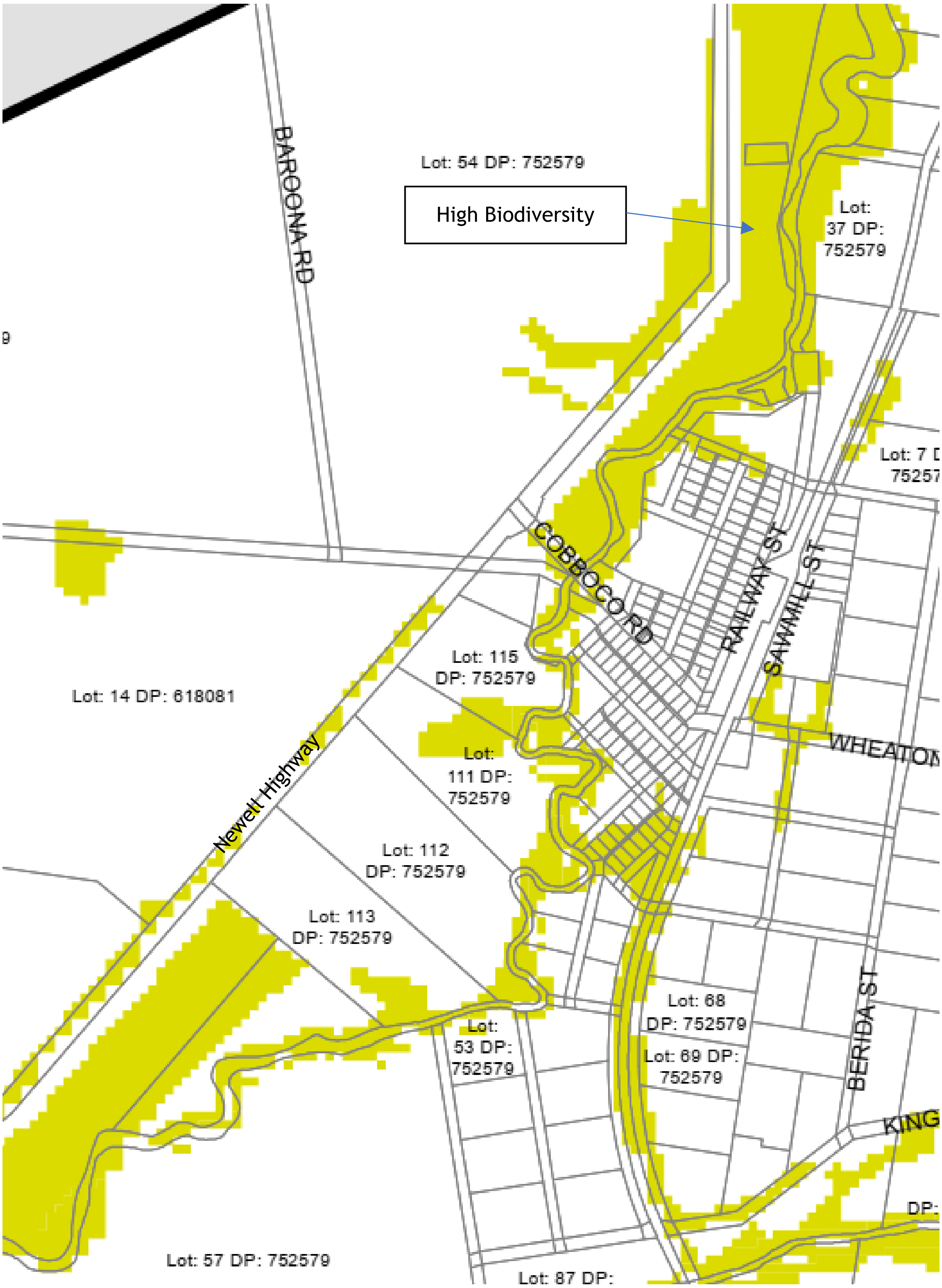

Figure 2.2 – Dubbo LEP 2011 Natural Resource – Biodiversity Map extract of Eumungerie

2.4 SOCIAL CHARACTERISTICS

Eumungerie is located within the ABS Statistical Area Level 1(SAL1) code 1110316 of the Dubbo region. It covers the village of Eumungerie and the surrounding rural areas. Statistical data for the village of Eumungerie only was not available.

In the 2016 Census, there were 411 people in SAL1 1110316. Of these, 54.4% were male and 45.6% were female. Aboriginal and/or Torres Strait Islander people made up 7.1% of the population. The median age was 49 years, which is 11 years higher than the median age across NSW. Some 19.3% of the population were aged over 65, which is higher than the state and national medians. 84% of people were born in Australia and 89% of the population speak english at home.

The unemployment rate was lower than the state rate with the most common occupations Managers 20.4%, Technicians and Trades Workers 18.8%, Clerical and Administrative Workers 15.5%, Sales Workers 11.0%, and Labourers 11.0%. Some 16% of people work from home, which is over three times the rate across the remainder of NSW. 70.7% of households had at least one person access the internet from the dwelling, which is lower than across the state.

All of the private dwellings (150) were separate houses with 90.9% of private dwellings occupied and 9.1% were unoccupied. The houses are generally larger than the state average with most dwellings having 3 to 4 bedrooms.

2.5 PREVIOUS STUDIES

The Eumungerie Flood Study (PPK Consultants, 1995) details the flooding issues experienced in the village of Eumungerie during the January 1993 event. Drillwarrina Creek catchment rainfall and peak water level data was collected from the local residents for this event. The data was used to calibrate computer based models to determine design discharges and peak flood levels from Drillwarrina Creek.

The report goes on to propose a number of mitigation measures to reduce the impact of Drillwarrina Creek flooding on Eumungerie. It was found that the configuration of Cobboco Road significantly contributed to flooding in Eumungerie during the 1993 event. The road level has since been reduced as recommended by the PPK study.

3 Flood behaviour

3.1 OVERVIEW

The principal objective of the Eumungerie Flood Study Update (WRM, 2020) was to define the existing flood behaviour across the study area. For that study, a TUFLOW two-dimensional hydraulic model was developed to define the flood levels, depths, extents and flows across the study area for a range of small to extreme flood events. The model was calibrated to the 1993 flood event.

This section describes the flood behaviour across the study area based on the results of the flood study, including an assessment of:

- the probability of flooding;
- flow conveyance and storage functions of the floodplain; and
- the variation in, and the drivers and degree of, flood hazard and flood risk within the floodplain.

3.2 DESIGN FLOOD LEVELS, DEPTHS AND EXTENTS

The results of the flood modelling presented in the flood study (WRM, 2020) are summarised as follows:

- The dominant flooding mechanisms at Eumungerie occur from Drillwarrina Creek overflows and from stormwater inundation from the catchment to the east of the rail. Coolbaggie Creek does not cause flooding in Eumungerie with the exception of the PMF. The most frequent flooding occurs from stormwater inundation.
- For the 20% and 10% annual exceedance probability (AEP) events, some overbank flooding would occur within Eumungerie to the north of Coolbaggie Street and to the west of Balladoran Street. These shallow flows are generated from the local catchment to the east of the rail line. Some of the flows generated to the east of the rail are diverted southwards by the rail eventually draining across the rail to the south of Eura Street. The public school grounds would be inundated by the 10% AEP event from these local catchment flows.
- For the 5% AEP event, Drillwarrina Creek would overflow to the north of Breelong Street in Eumungerie to combine with the overland flows from the east of the rail. The combined flows would inundate the yards of properties to the east of Balladoran Street. Floodwater would also build up behind Cobboco Road to inundate properties to the east of Balladoran Street.
- Cobboco Road remains a moderate constriction to the floodplain flows potentially increasing upstream flood levels for all events greater than and equal to the 5% AEP event.
- For the larger events, Drillwarrina Creek flood levels increase to inundate most of the yards of properties within Eumungerie.
- Substantial inundation would occur for the probable maximum precipitation flood (PMP Flood), which has been adopted in this study as the PMF.

3.3 PROVISIONAL HAZARD MAPPING

Provisional flood hazards have been defined using the depth and velocity of the floodwaters calculated using the flood model determined in accordance with Figure 3.1 as given in Appendix L of the NSW Floodplain Development (NSW Government, 2005).

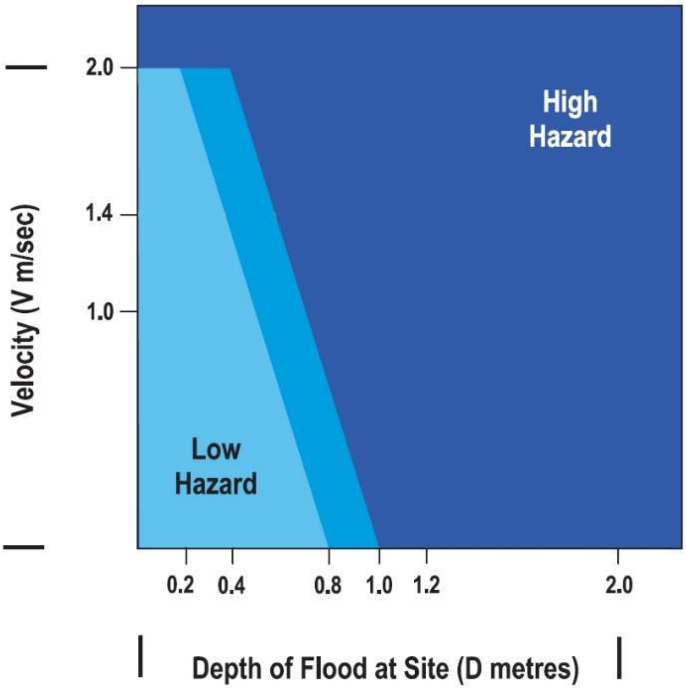

Figure 3.1 – Provisional hazard categories (Source: NSW Government, 2005)

Figure 3.2 presents the provisional hazard map within the study area for the 1% AEP design flood event. Hazard categories for the other design event are given in the flood study (WRM,2020) and show that the urban areas of Eumungerie are generally located in the 'low' hazard part of the floodplain. Areas of 'intermediate' hazard occur immediately upstream of Cobboco Road where higher flood depths occur because of the Cobboco Road constriction.

3.4 HYDRAULIC HAZARD

The Australian Disaster Resilience Guideline 7-3 Flood Hazard (AIDR, 2017) recommends grouping the floodplain into six hazard categories using flood depth, flood velocity and the depth-velocity product in accordance with Figure 3.3. This figure closely resembles Figure L1 in the Manual (NSW Government, 2005) but further delineates the floodplain based on recent research undertaken on the trafficability of vehicles and the safety of people during flood events.

Figure 3.4 shows the hydraulic hazard within the study area for the 1% AEP design flood event, using the flood hazard vulnerability curve shown in Figure 3.3 (AIDR, 2017). For the 1% AEP design flood event, the H6 (most hazardous) areas are generally confined to the Coolbaggie Creek waterway corridors. The H5 areas include the Drillwarrina Creek waterway corridors, as well as additional area along the Coolbaggie Creek (H6) waterway corridors. According to the flood hazard vulnerability curve in Figure 3.3, hazards H5 and H6 define areas where structures become vulnerable to failure. No buildings in Eumungerie are found within these hazard zones for the 1% AEP design flood. The extent of the H5 and H6 areas would correspond to the 'floodway' hydraulic category from the Manual (NSW Government, 2005).

The H4 and H3 hydraulic hazard areas for the 1% AEP design event cover areas along both Drillwarrina Creek and Coolbaggie Creek waterway corridors and areas between the north of Cobboco Road and the south of Emu Street. According to the flood hazard vulnerability curve in Figure 3.3 (AIDR, 2017) hazards H3 and above are unsafe for children and the elderly, and H4 and above are unsafe for all people.

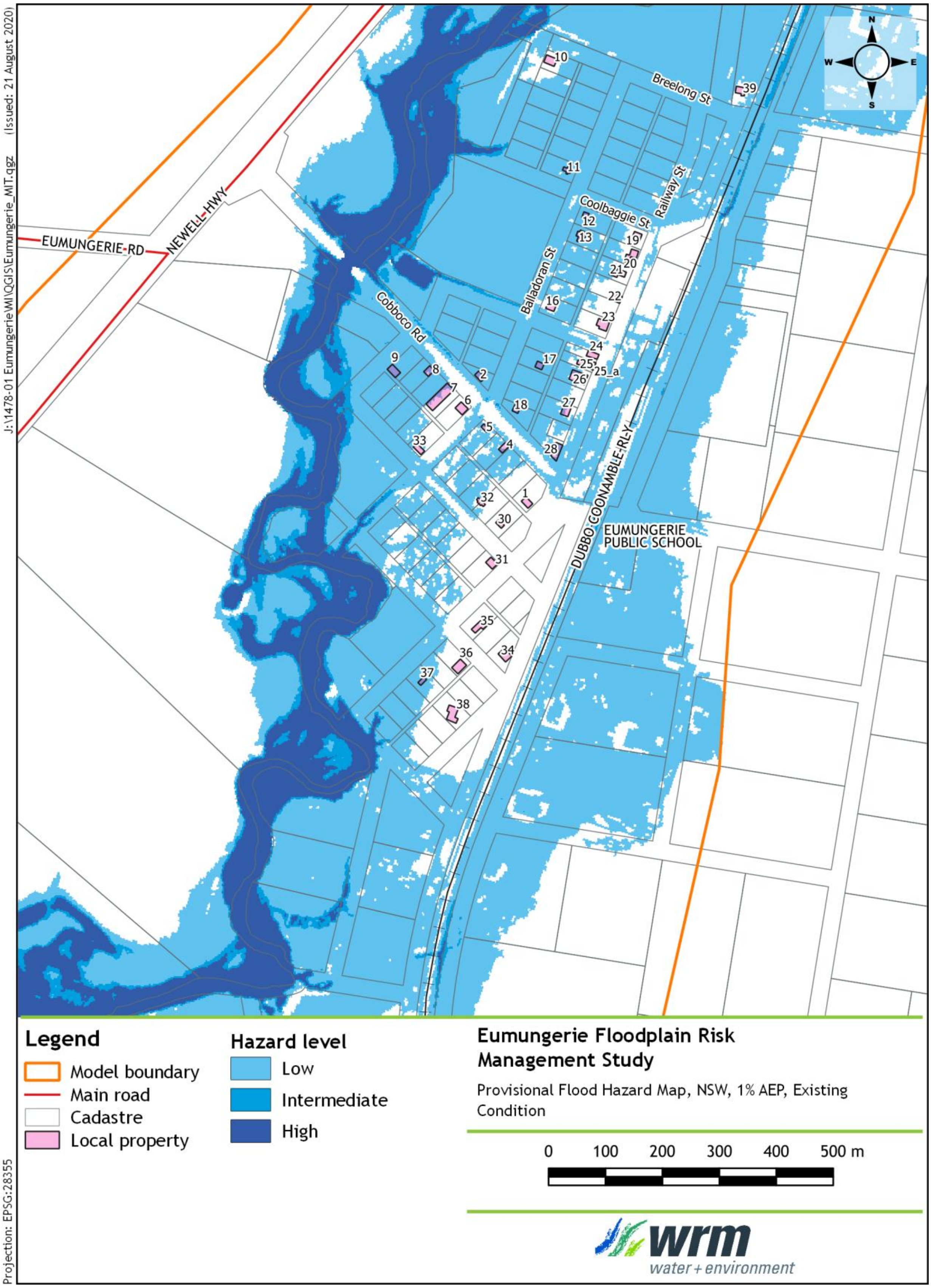

Figure 3.2 – Provisional flood hazard, 1% AEP design flood, existing condition

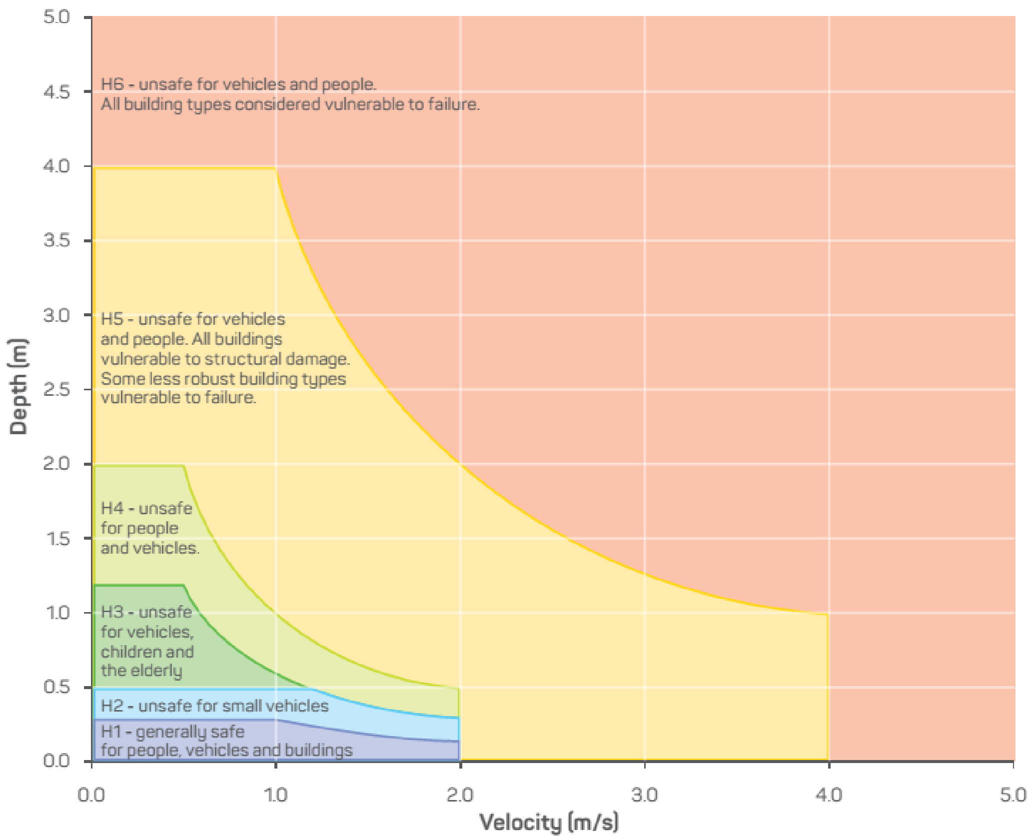

Figure 3.3 – Flood hazard vulnerability curve (source: AIDR, 2017)

Hydraulic hazard mapping for other design flood events is provided in Appendix A. Table 3.1 details the number of existing buildings within each hydraulic hazard zone for each modelled design flood event.

Table 3.1 - Existing building count in each hydraulic hazard zone

Flood Event	Number of buildings per hydraulic hazard zone*					
	H1	H2	H3	H4	H5	H6
20% AEP	3	0	0	0	0	0
10% AEP	8	0	0	0	0	0
5% AEP	12	0	0	0	0	0
2% AEP	14	3	0	0	0	0
1% AEP	17	2	1	0	0	0
0.5% AEP	19	5	3	0	0	0
0.2% AEP	14	13	3	0	0	0
PMF	0	0	0	2	31	3

* number of buildings is the count of buildings in each zone, it does not correspond to the count of flooded buildings

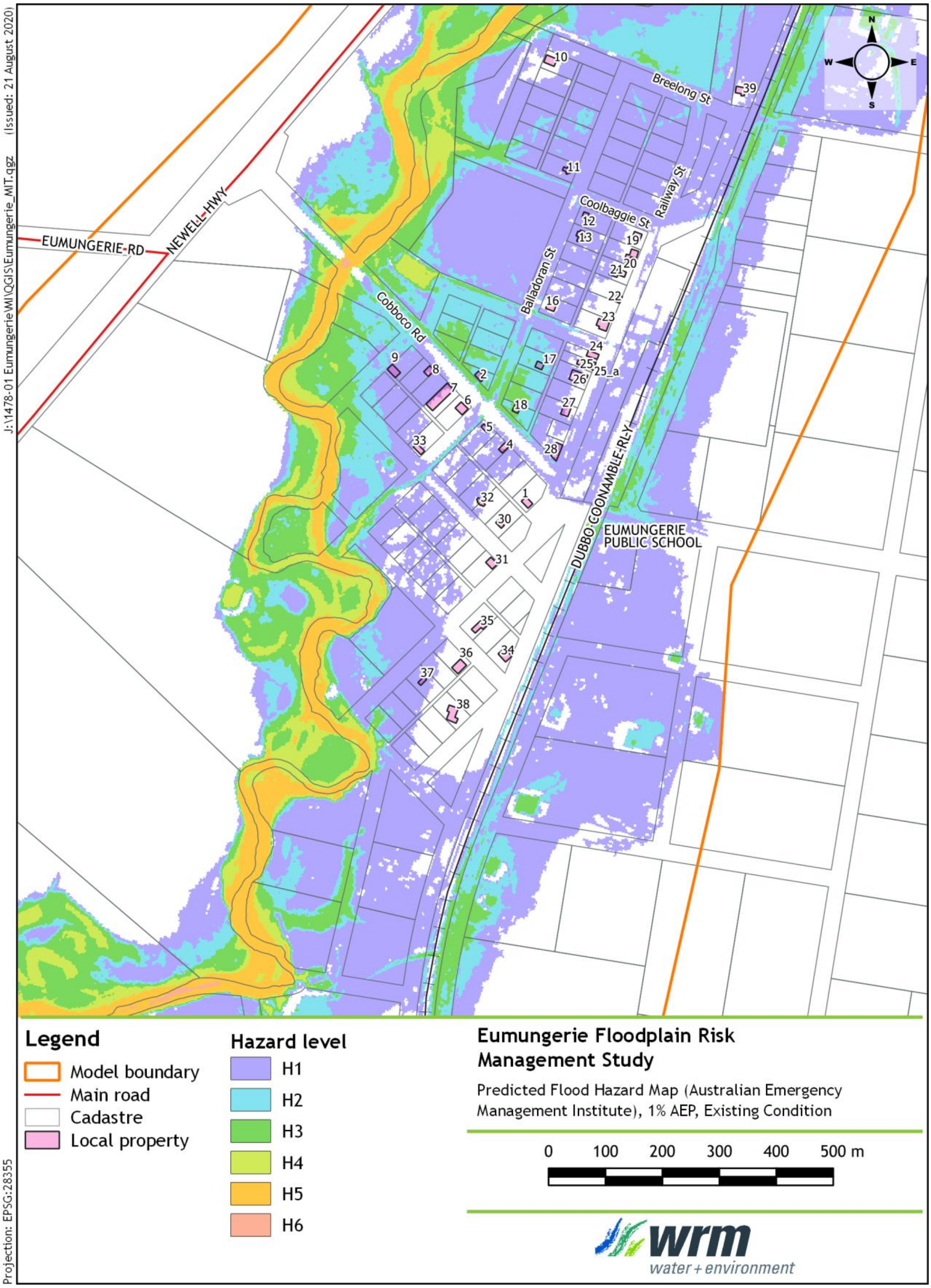

Figure 3.4 – AIDR (2017) hydraulic hazard, 1% AEP design flood

3.5 FLOOD RISK

3.5.1 Overview

The flood risk to a community is measured in terms of both the scale of consequence, and the likelihood of that consequence. Previous sections have described the flooding within and around Eumungerie for a range of design flood events to define the likelihood of flooding.

It is also necessary to investigate the consequences of flooding throughout Eumungerie to define a flood risk map that is independent of flood event magnitude (i.e. a single risk map rather than a risk map for each design flood event). This map can then be used as a decision-making tool as it concisely demonstrates where flood risk management strategies need to be enacted.

The Australian Disaster Resilience Guideline 7-6 (AIDR, 2017) was used as a guide for assessing the flood risk across Eumungerie. The guideline suggests the use of a qualitative risk matrix, an example of which is shown in Table 3.2, to define the level of flood consequence to the community and in particular people, economy, environment, public administration and social settings.

Table 3.2 - Example qualitative risk matrix (source: AIDR, 2017)

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Low	Medium	High	Extreme	Extreme
Unlikely	1 to 10	Low	Low	Medium	High	Extreme
Rare to very rare	0.01 to 1	Very low	Low	Medium	High	High
Extremely rare	<0.01	Very low	Very low	Low	Low	High

Risk: Very low Low Medium High Extreme
AEP = annual exceedance probability

The AIDR hydraulic hazard vulnerability zones have been used to define the level of consequence to people, economy, public administration and social settings. The vulnerability of the community and assets in each hydraulic hazard zone is as follows:

- Hydraulic hazard H1 – generally safe for people, vehicles and buildings;
- Hydraulic hazard H2 – unsafe for small vehicles;
- Hydraulic hazard H3 – unsafe for vehicles, children and the elderly;
- Hydraulic hazard H4 – unsafe for people and vehicles;
- Hydraulic hazard H5 – unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure; and
- Hydraulic hazard H6 – unsafe for vehicles and people. All building types considered vulnerable to failure.

The level of consequence to the environment cannot be assessed purely on hydraulic hazard but can be qualitatively assessed.

Table 3.3 provides an assessment of the consequences in each hydraulic hazard zone for each modelled design flood, including the number of existing buildings in each zone. Based on this information a risk rating has also been provided for each zone, which is then used to define the flood risk matrix for Eumungerie.

Table 3.3 – Level of consequence in each hazard zone and adopted flood risk

Row number	Design event	Hydraulic hazard	Number of existing buildings	Level of consequence	Risk
1	20% AEP	H1	3	Minor – hydraulic hazard is generally safe, but the frequent likelihood of inundation poses other threats (stress from repeated inundation etc.)	Medium
2	20% AEP	H2 & H3	0	Minor to Moderate – hydraulic hazard begins to become unsafe for certain people and the frequent likelihood of inundation poses other threats (stress from repeated inundation etc.)	High
3	20% AEP	H4 - H6	0	Major to Catastrophic – hydraulic hazard is unsafe for people and there is a frequent likelihood of inundation	Extreme
4	10% AEP	H1	8	Per row 1	Medium
5	10% AEP	H2 & H3	0	Per row 2	High
6	10% AEP	H4 - H6	0	Per row 3	Extreme
7	5% AEP	H1	12	Minor – hydraulic hazard is generally safe	Low
8	5% AEP	H2 & H3	0	Moderate – hydraulic hazard begins to become unsafe for certain vehicles and people	Medium
9	5% AEP	H4	0	Major – hydraulic hazard is unsafe for people	High
10	5% AEP	H5 & H6	0	Major to Catastrophic – hydraulic hazard is unsafe for all vehicles and people	Extreme
11	2% AEP	H1 & H2	17	Minor to Moderate – hydraulic hazard begins to become unsafe for certain vehicles	Low
12	2% AEP	H3	0	Moderate – hydraulic hazard begins to become unsafe for certain people and all vehicles	Medium
13	2% AEP	H4 & H5	0	Major – hydraulic hazard is unsafe for people and structures	High
14	2% AEP	H6	0	Major to Catastrophic – hydraulic hazard is unsafe for all vehicles, people and buildings	Extreme
15	1% AEP	H1	17	Minor - hydraulic hazard is generally safe.	Very Low
16	1% AEP	H2	2	Moderate – hydraulic hazard begins to become unsafe for certain vehicles	Low
17	1% AEP	H3 & H4	1	Major – hydraulic hazard is unsafe for vehicles and either becoming unsafe or totally unsafe for people	Medium

Row number	Design event	Hydraulic hazard	Number of existing buildings	Level of consequence	Risk
18	1% AEP	H5	0	Major - hydraulic hazard is unsafe for people and vehicles and structures become vulnerable	High
19	1% AEP	H6	0	Per row 14	Extreme
20	0.5% AEP	H1 & H2	24	Minor - hydraulic hazard is generally safe. A large existing population is exposed	Very Low
21	0.5% AEP	H3	3	Moderate to Major - hydraulic hazard begins to become unsafe for vehicles and certain people	Low
22	0.5% AEP	H4	0	Major - hydraulic hazard is unsafe for people and vehicles and a large existing population is exposed	Medium
23	0.5% AEP	H5	0	Major - hydraulic hazard is unsafe for people and vehicles and structures become vulnerable	High
24	0.5% AEP	H6	0	Major to Catastrophic - hydraulic hazard is unsafe for all vehicles, people and buildings	Extreme
25	0.2% AEP	H1 - H3	30	Minor to Moderate - hydraulic hazard is beginning to become unsafe for some people. A large existing population is exposed	Very Low
26	0.2% AEP	H4	0	Moderate to Major - hydraulic hazard is unsafe for vehicles and people and a very large existing population is exposed	Low
27	0.2% AEP	H5	0	Major - hydraulic hazard is unsafe for people and vehicles and structures become vulnerable	Medium
28	0.2% AEP	H6	0	Major to Catastrophic - hydraulic hazard is unsafe for all vehicles, people and buildings	High
29	Extreme flood event	H1 - H3	0	Minor - hydraulic hazard is beginning to become unsafe for some population but for an extreme event	Very Low
30	Extreme flood event	H4	2	Moderate - hydraulic hazard is unsafe for vehicles and people and a large existing population is exposed	Low
31	Extreme flood event	H5	31	Major - hydraulic hazard is unsafe for people and vehicles and structures become vulnerable for the majority of the population	Medium
32	Extreme flood event	H6	3	Catastrophic - hydraulic hazard is unsafe for all vehicles, people and buildings.	Medium

3.5.2 Flood risk matrix

Table 3.4 provides the qualitative flood risk matrix for Eumungerie, which in effect is a summary of the consequence assessment provided in Table 3.3. The matrix defines six zones of flood risk on the Eumungerie floodplain:

- Z1 - land free from flooding for all design flood events; and
- Z2 (very low risk) to Z6 (extreme risk)

Table 3.4 - Flood risk matrix

Design Flood	Flood risk per hydraulic hazard category					
	H1	H2	H3	H4	H5	H6
20% AEP	Z4	Z5	Z5	Z6	Z6	Z6
10% AEP	Z4	Z5	Z5	Z6	Z6	Z6
5% AEP	Z3	Z4	Z4	Z5	Z6	Z6
2% AEP	Z3	Z3	Z4	Z5	Z5	Z6
1% AEP	Z2	Z3	Z3	Z4	Z5	Z6
0.5% AEP	Z2	Z2	Z3	Z4	Z5	Z6
0.2% AEP	Z2	Z2	Z2	Z3	Z4	Z5
Extreme Event	Z2	Z2	Z2	Z3	Z3	Z4

3.5.3 Flood risk map

Figure 3.5 shows the flood risk map derived from the flood risk matrix. The flood risk map shows that:

- Risk zone Z6 (extreme flood risk) is limited to the Drillwarrina Creek channels;
- Risk zone Z5 (high flood risk) surrounds the Z6 zones and includes all major flood-runners and flow paths;
- Risk zone Z4 (medium flood risk) surrounds the Z5 zones and includes areas west of Balladoran Street and between Breelong Street and Coolbaggie Street;
- Risk zone Z3 covers the most urban area in Eumungerie between Balladoran Street and Railway Street. This highlights the relatively low risk posed by flooding to the residents of Eumungerie;
- Risk zone Z2 (very low flood risk) cover limited land, generally outside of the current urban extent of Eumungerie.

Figure 3.5 – Flood risk map

The approximate number of existing buildings located within each flood risk zone are provided below:

- Risk zone Z6 (extreme flood risk) – 0 buildings;
- Risk zone Z5 (high flood risk) – 0 buildings;
- Risk zone Z4 (medium flood risk) – 7 buildings;
- Risk zone Z3 (low flood risk) – 29 buildings;
- Risk zone Z2 (very low flood risk) – 0 buildings; and
- Risk zone Z1 (flood free land) – 0 buildings.

3.6 FLOOD PLANNING AREA

Section 7.1 of the Dubbo LEP 2011 outlines generic flood planning provisions for managing development on the floodplain. The clauses in the LEP apply to land at or below the flood planning level, which is defined as the level of a 1% AEP flood event plus 0.5 metre freeboard. The extent of inundation defined by the flood planning level is shown in Figure 3.6.

The choice of event and the nominated freeboard is consistent with recommendations given in the Manual (NSW Government, 2005). The 1% AEP event is the typical design event upon which residential flood planning levels are set. A freeboard is added to this event to account for various uncertainties that may include (NSW Government, 2005):

- uncertainties in modelling;
- localised water level differences;
- wave action;
- climate change; and
- cumulative effects of future developments.

Note that the Eumungerie Flood Study (WRM, 2020) found that climate change could increase peak 1% AEP flood levels up to 0.35 m throughout much of the urban areas of Eumungerie to the west of the rail. On this basis, a freeboard of 0.5 m would appear appropriate.

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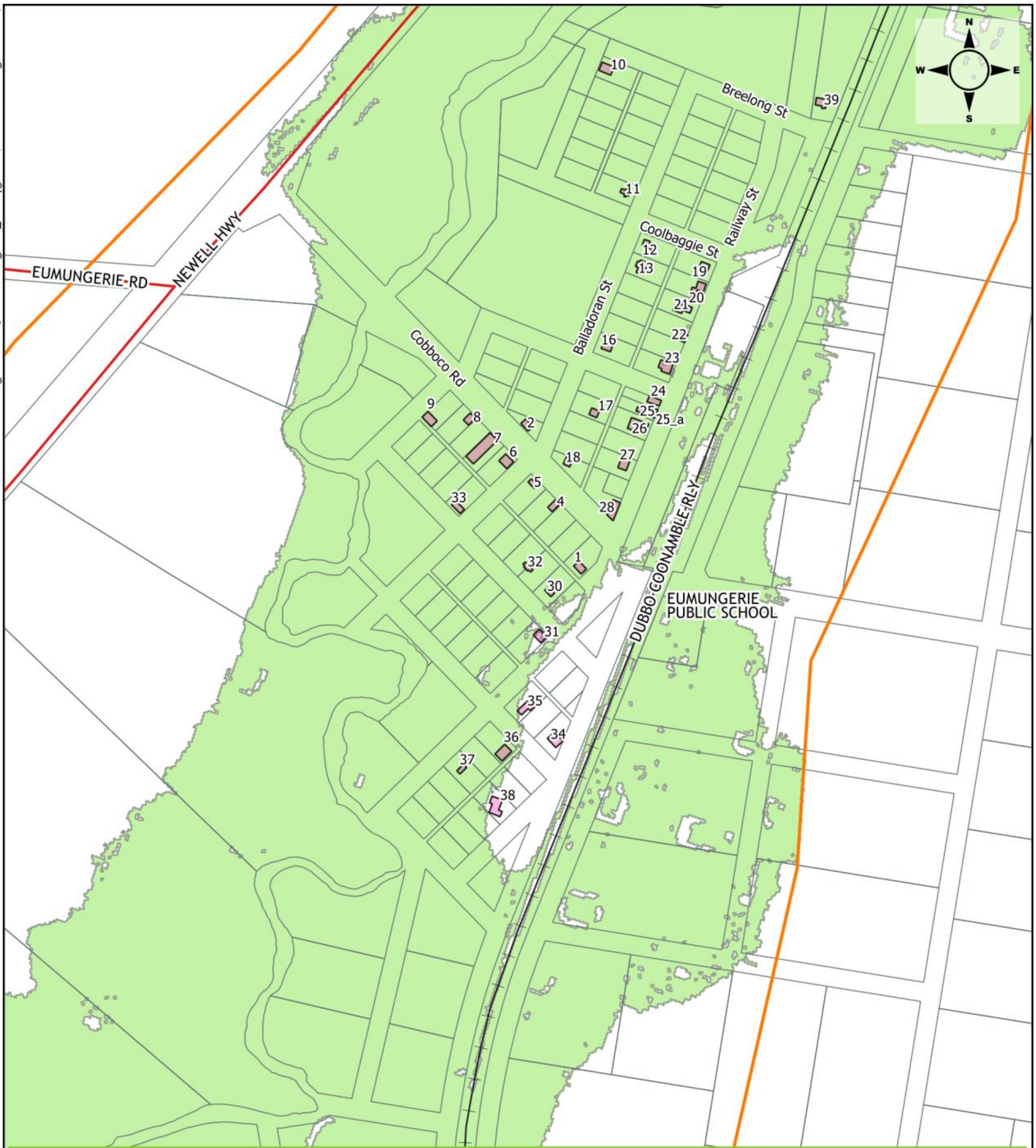

Legend

- Model boundary
- Main road
- Cadastre
- Local property
- Flood extent (1% AEP + 0.5 m freeboard)

Eumungerie Floodplain Risk Management Study

Flood Planning Area

0 100 200 300 400 500 m

wrm water + environment

Projection: EPSG:28355

Figure 3.6 – Eumungerie Flood Planning Area

4 Flood damage estimation

4.1 TYPES OF FLOOD DAMAGE

The Floodplain Development Manual (NSW Government, 2005) defines the various types of damage caused by flooding, with these damages shown graphically in Figure 4.1. Flood damage can be divided into two major categories: tangible and intangible damages. Tangible damages are the financial costs of flooding and are quantified in dollar terms, while intangible damages are the social and environmental costs of flooding and are reflected in increased levels of emotional stress and psychological and physical illness.

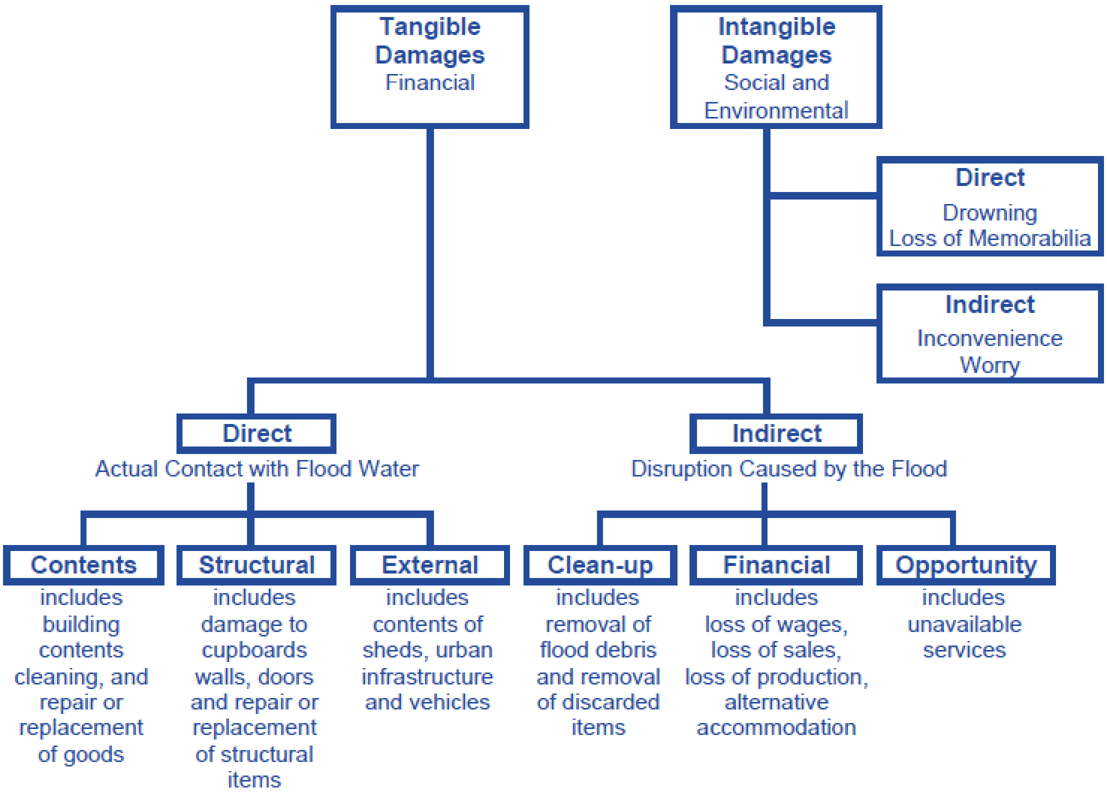

Figure 4.1 – Types of flood damage (Source: NSW Government, 2005)

4.1.1 Tangible damages

Tangible damages can be separated into two major sub-categories:

- direct damage - the loss in value of an object or piece of property caused by direct contact with floodwater; and
- indirect damage - the loss in production or revenue caused by a flood, e.g. the loss of wages, additional accommodation and living expenses and any other extra outlays that occur as a consequence of flood.

Indirect damages are additional to ordinary pre-flood living costs. Indirect damages are typically incurred in the post-flood recovery phase.

4.1.1.1 Direct damage

Direct damage can be incurred either as:

- a replacement cost if a flood-damaged item is discarded;
- a repair cost if the item is repaired; or
- a loss in value if the item is neither discarded nor repaired (repaired items also suffer a loss in value).

In the first case, the direct damage is either the pre-flood value or the replacement cost of the item. In the second case, the damage is the cost of repairs (plus any loss in value). In the third case, the damage is simply the loss in value.

Direct damage is divided into three categories: contents damage, external damage and structural damage (see Figure 4.1):

- contents damage refers to damage to the contents of the main building(s) on a property;
- external damage refers to damage to items external to the main building, e.g. motor vehicles, fences, gardens, the contents of sheds or outbuildings, etc.; and
- structural damage refers to the damage sustained by the fabric of a building (foundations, floors, walls, doors, windows, etc.) and the damage sustained by permanent fixtures in the building, such as built-in cupboards, benches, etc.

4.1.1.2 Indirect damages

Indirect damage is also divided into three categories:

- indirect financial damage refers to the loss of income or increased expenditure caused by a flood;
- clean-up cost refers to the cost of labour and materials required to clean out a flooded building. Typical clean-up activities include the hosing down of walls and floors to remove silt, the taking up of flooded carpets, the removal and discarding of irreparably damaged items, the drying of rooms, etc.; and
- opportunity costs which arise from direct damage to public assets. Because of this damage, a period elapses when the public is not provided with these services or is provided with a reduced level of service.

It is difficult to realistically evaluate opportunity costs. On the one hand, opportunity costs can be estimated in terms of the total operating cost of the facility (wages, maintenance, interest on capital assets, etc.). Society is prepared to pay this cost to provide the services; thus their absence must be worth a corresponding amount. On the other hand, during the aftermath of a flood, public employees often undertake non-duty tasks useful to society when not providing public services (e.g. clean-up operations). For reasons of convenience, opportunity costs are often estimated as the wages cost over the period public facilities are not operating.

4.1.1.3 Potential versus actual damage

Potential damage refers to the damage that would be sustained if no actions were taken by householders, or others, in an attempt to reduce flood damage, i.e. the damage that would occur if the entire population was absent when a flood occurred.

The actual damage sustained at a property is always less than the potential damage. Notwithstanding the shortness or absence of flood warnings, people will attempt to save items by lifting them onto benches or shelves, by shifting motor vehicles, by evacuating their possessions, etc.

Potential and actual damage costs are the same for structural damage, as it is generally impossible to reduce structural damage to buildings in the onset of a flood.

4.1.2 Intangible damages

Intangible damage is difficult to measure and impossible to meaningfully quantify in dollar terms. Nevertheless, it is a very real, significant and often enduring 'cost' that emerges during the recovery phase of a disaster.

The social impacts of flooding include:

- the loss of irreplaceable items, such as family photographs;
- the stress induced by the flood itself;
- temporary evacuation of the home whilst the damage is repaired;
- the disruption caused by the flood to the life of the individual household and to the community as a whole; and
- the effect of floods upon the physical and mental health of those affected.

Research in the past has shown that social impacts can be more important to the victims of floods than the financial losses that they suffer.

4.2 TANGIBLE FLOOD DAMAGE ESTIMATION METHODOLOGY

4.2.1 Overview

Many factors affect flood damage (e.g. depth of inundation, flow velocity, duration of inundation, time of occurrence, debris/sediment loads, water quality etc.). However, other than the depth of inundation, very little guidance and information is available on how to take the relevant factors into account when estimating flood damage.

In most studies, flood damages are related to only the depth of inundation because the other factors are heterogeneous in space and time, difficult to predict, and there is limited information on their quantitative effects (Merz et al., 2010). As a result, flood stage-damage curves are typically used to estimate flood damages. However, accurate flood damage estimates cannot be made without stage-damage curves that are accurate and locally relevant.

Flood damage estimates made from stage-damage cures require the following information:

- property data;
- floor level data;
- ground level data;
- flood level data; and
- stage-damage curves.

4.2.2 Property and floor level data

A property floor level survey was conducted by Dubbo Regional Council on May 2019. All properties within the study area that were within the local Drillwarrina Creek catchment PMF extent.

The floor level survey included relevant property data, such as:

- unique building ID;
- building floor level
- building coordinates; and
- miscellaneous comments.

Building size was mapped based on aerial photographs and building type (commercial/ residential) was assigned based on street view information.

4.2.3 Ground level and flood level data

The ground level at each property was assigned based on available LiDAR topographic data (captured in December 2015). Design flood levels at each property were assigned by inspecting the building coordinates captured during the property survey against flood surfaces produced above.

4.2.4 Residential stage-damage curves

Flood stage-damage curves (flood damage curves) relate the depth of flooding at a residential property to an estimate of the corresponding flood damage.

For this study, the residential stage-damage curves described in the Residential Flood Damages flood risk management guideline (NSW Government, 2007) have been used to estimate tangible residential flood damages. The NSW Government approach uses a typical damage curve, which allows damages to be estimated for individual dwellings on the basis of the property type. The use of these curves provides a consistent basis for calculation of flood damage between different projects across NSW whilst allowing consideration for local variation through the scale of a typical house and the value of its contents.

The parameters used to define the residential stage-damage curves are given in Table 4.1. Figure 4.2 graphically shows the residential stage-damage curves adopted for the study.

Table 4.1 – Residential flood damage curve values, NSW Government method

Parameter	Value
Regional cost variation factor (from Rawlinsons, 2020)	1.08
Post late 2001 adjustments (AWE adjustment*)	1.866
Post flood inflation factor (No. flooded properties > 700)	1.45
Typical duration of immersion	8 hours
Building damage repair limitation factor	0.75
Typical house size	240 m^2
Average content relevant to site	$62,500
Contents damage repair limitation factor	0.75
Level of flood awareness	Low
Effective warning time	0 hours
Likely time in alternative accommodation	3 weeks

*AWE = Average Weekly Earning

4.2.5 Commercial and industrial stage-damage curves

Although commercial and industrial damage can be a significant component of overall flood damage, to date there has been limited research on non-residential stage-damage curves other than residential stage-damage curves. A possible reason for this is that it is very difficult to provide accurate estimates given that the costs can vary significantly between each commercial property type and use.

For this study, flood damage curves developed by researchers at Australian National University (CRES, 1992) in the 1980's (ANUFLOOD) have been used. In ANUFLOOD, the commercial and industrial damage is defined on the basis of building size and business type. Three building sizes (small/medium/large) and five classes of building value category (1/2/3/4/5) are combined for a total of fifteen different building categories.

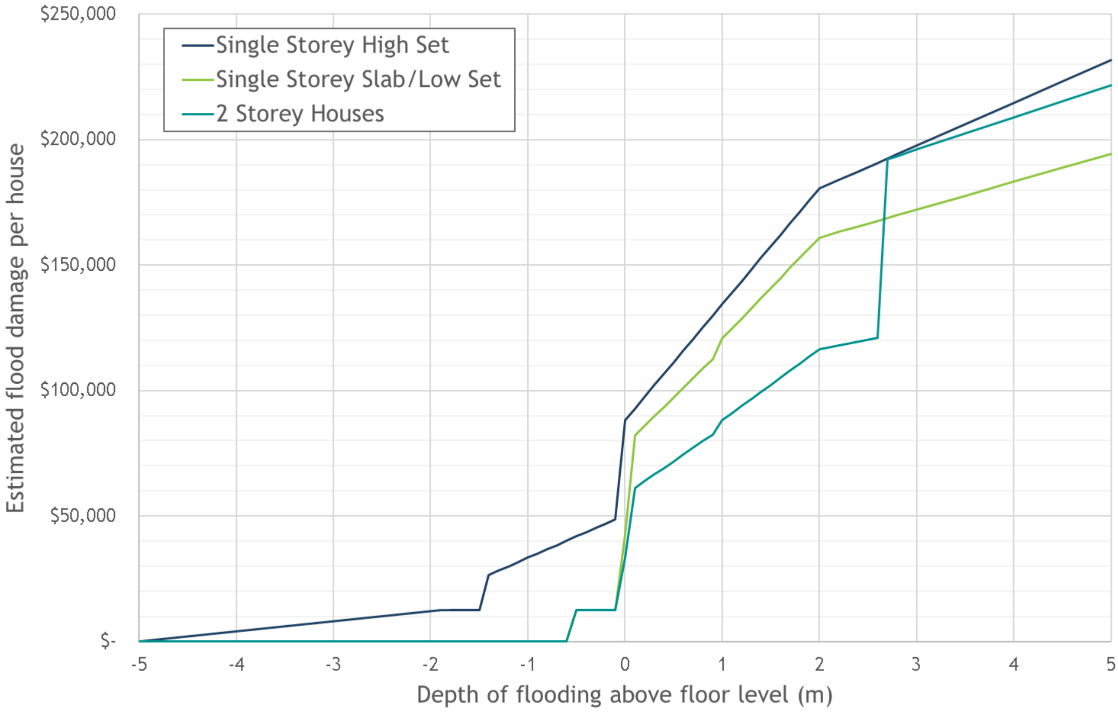

Figure 4.2 – Residential stage-damage curves

In applying these curves, the type of business/industry can be defined on the basis of Australia & New Zealand Standard Industrial Classification Code (ANZIC) (ABS, 2013). The ANZIC value class is assessed from 1 (low value) to 5 (high value). The value class is a subjective estimate of the likely loss that would be sustained if the building was inundated by floodwaters.

Table 4.2 shows ANUFLOOD commercial/industrial stage-damage curves updated to March 2020 prices using changes in the Consumer Price Index (CPI). For each non-residential property, damage is also dependent on the size of the building. ANUFLOOD defines three building size ranges:

- small properties (floor area <186m^2);
- medium properties (floor area 186 - 650m^2); and
- large properties (floor area >650m^2).

For small and medium size properties damage is specified in total dollar values. Damage for large properties is specified as a dollar value per unit floor area. It is not clear what damage components are included and/or excluded in the ANUFLOOD damage values. It appears that damage estimates include structural damages. However, it does not appear that these damage curves include external damages.

The stage-damage curves given in Table 4.2 are potential stage-damage curves. The NSW Government methodology used for the residential stage-damage curves converted potential damages to actual damages, hence a similar conversion was required for the commercial stage-damage curves.

The ratio of actual to potential flood damages was varied depending on the depth of flooding, the available warning time and level of flood awareness. This methodology is more realistic than a simpler constant ratio methodology and is consistent with the residential stage-damage methodology.

Table 4.2 - Stage-damage curves for commercial properties (Source: CRES 1992)

Depth of Flooding Above Floor Level (m)	Potential Direct Damage (March 2020 Dollar Values)				
	Value Class				
	1 Very Low	2 Low	3 Medium	4 High	5 Very High
Small Properties (Floor Area <186m²)			($)		
≤ 0.00	0	0	0	0	0
0.25	5,115	10,232	20,461	40,921	81,845
0.75	12,789	25,575	51,153	102,306	204,612
1.25	19,181	38,367	76,728	153,459	306,916
1.75	21,313	42,626	85,255	170,510	341,018
≥ 2.00	22,591	45,186	90,370	180,739	361,479
Medium Properties (Floor Area 186-650m²)			($)		
≤ 0.00	0	0	0	0	0
0.25	16,201	32,397	64,794	129,586	259,175
0.75	39,217	78,433	156,869	313,738	627,473
1.25	59,677	119,357	238,712	477,489	954,852
1.75	66,069	132,146	264,289	528,579	1,057,158
≥ 2.00	70,334	140,673	281,340	562,681	1,125,362
Large Properties (Floor Area >650m²)			($/m²)		
≤ 0.00	0	0	0	0	0
0.25	16.26	34.84	74.33	141.7	283.4
0.75	90.59	181.2	357.7	715.4	1,438
1.25	188.1	376.3	757.2	1,507	3,013
1.75	306.6	620.2	1,238	2,474	4,945
≥ 2.00	369.3	738.6	1,477	2,954	5,911

4.2.6 Actual to potential damages

For Drillwarrina Creek catchment flood events, the available warning time is negligible so the actual damages would likely approach potential damages. Hence, for local catchment flooding the adopted actual to potential damage ratios were based on Figure 4.3 with flood depths of 0.5 m or less assigned an actual to potential damage ratio of 0.8, while flood depths of 2.0 m or greater were assigned a ratio of 0.9, with the ratio for depths in between linearly interpolated.

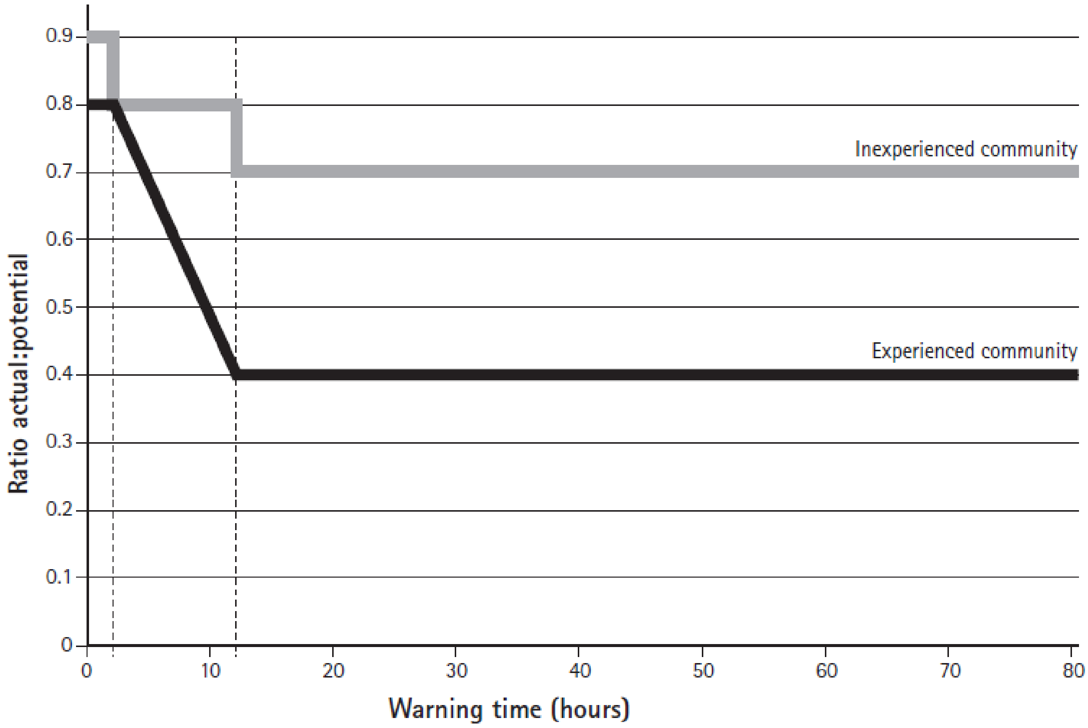

Figure 4.3 - Actual to potential damage ratio relationship (Source: VDNRE, 2000)

4.2.7 Public authority buildings and public utilities

Direct damage to public and community owned buildings and assets must also be considered when estimating overall flood damage. These include:

- hospitals, schools, police and fire stations, and other government owned buildings;
- parks and recreational facilities;
- sporting facilities; and
- communication, electricity, water supply, sewerage and drainage systems.

Ideally, damage to these properties should be estimated on a case by case basis. In the absence of better data, damage to these properties was evaluated using the stage-damage curves given for commercial/industrial damage in Section 4.2.5.

4.2.8 Roads and bridges

Flooding can cause significant damage to roads and bridges. The use of generalised damage rates to calculate road and bridge damage is not applicable as the cost is often closely related to the distance required to travel to access suitable materials (quarries and depots). In the absence of available information, costs due to damage to roads and bridges are not included in this study.

4.2.9 Average annual damage

Over a long period of time, a flood liable community will be subject to a succession of floods. In many years, no floods may occur or the floods may be too small to cause damage. In some years, the floods will be large enough to cause damage, but the damage will generally be small because the floods are of small to medium size. On rare occasions, major floods will occur and cause great damage.

The average annual damage (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 (assuming that the population and development situation does not change over the period of analysis). By estimating the damage caused by floods of different severity, e.g. the 20%, 10%, 5%, 2%, 1%, 0.2% and 0.5% AEP and extreme flood events from this study, it is possible to combine the likelihood of a flood occurring, with the damage it causes, and so estimate the AAD.

4.3 INTANGIBLE FLOOD DAMAGE ESTIMATION METHODOLOGY

For this study, intangible damages have been defined on a qualitative basis by comparing the relative flood mitigation benefits of each option to the existing scenario (refer Section 6). Though intangible damages have only been qualitatively assessed it should be remembered that intangible flood damages represent a not insignificant component of overall flood damage.

4.4 TANGIBLE FLOOD DAMAGE ESTIMATE

Table 4.3 shows the estimated number of properties flooded above and below floor level and the estimated residential and non-residential building damages for each design flood event (in March 2020 dollar values). The estimated AAD is also shown. A total of 36 buildings are located within the study area. Of the 36 buildings, 30 buildings are residential buildings and the remaining 6 are commercial. The spatial distribution of flood affected properties is shown in Figure 3.5.

Table 4.3 – Estimated number of flood affected buildings and flood damage, existing conditions

Parameter	Event (AEP)							
	20%	10%	5%	2%	1%	0.5%	0.2%	PMPF
No. residential buildings flooded AGL	2	6	9	12	15	21	24	30
No. residential buildings flooded AFL	-	-	-	1	2	2	5	29
Total residential damages ($K)	$0.0	$37.5	$105	$176	$273	$390	$609	$4,494
No. non-residential buildings flooded AGL	1	2	2	5	5	6	6	6
No. non-residential buildings flooded AFL	-	-	-	-	-	-	-	6
Total non-residential damages ($K)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$112.5
Building average annual damage	**$133,500**							

AGL – above ground level (count includes buildings flooded above both ground level and floor level)
AFL - above floor level

With respect to the 1% AEP flood, the results show that:

- there are 20 flood affected buildings. Of these:
  - two residential buildings would be inundated above floor level;
  - no non-residential buildings would be inundated above floor level; and
- the total flood damage costs would be in the order of $273,000 (excluding road, bridge and agricultural flood damages).

From the tabulated results it can be seen that:

- significant ‘yard’ flooding occurs for the more frequent events (from stormwater runoff);

- residential buildings in the study area start to be inundated above floor level for the 2% AEP and rarer design flood events;
- commercial buildings in the study area would only be inundated above building floor level for the PMP flood event;
- 29 out of 30 residential buildings would be inundated above building floor level for the PMP flood event;
- total building average annual flood damage for existing conditions is approximately $133,500.

5 Emergency response planning

5.1 OVERVIEW

The flood model results have been analysed to provide flood related information that may assist the SES during an event. This information may be incorporated into any future updates to the Dubbo City Local Flood Plan (SES, 2013). A further discussion of flood emergency planning is given in Section 0.

5.2 ACCESS ROAD INUNDATION

Figure 5.1 shows the locations of roads/streets within Eumungerie estimated to be inundated by more than 0.3 m for more than one hour in the 1% AEP design flood event. It should be noted that each individual flood event is unique, and the design flood modelling has only been calibrated to 1993 flood event, inundated areas and duration could vary on different individual flood events, hence Figure 5.1 should be used as a guide only.

The results show that parts of Balladoran Street south of Emu Street, running northeast to southwest in the centre of urban area in Eumungerie would be likely to be cut for a duration up to 1 hour for the 1% AEP design flood event. Evacuation from property ID17 (see Figure 5.1) would be restricted for this event.

Parts of Cobboco Road west of Balladoran Street would be inundated for up 11 hours. Egress from Eumungerie to the Newell Highway would remain trafficable for the 2% AEP flood but would not be possible for the 1% AEP event.

The primary evacuation route from the community, should an extreme event occur, would be via Wheaton St to the east. Flood modelling shows that local catchment stormwater would inundate Wheaton Street to depths less than 0.1 m for all floods except the PMP flood and would therefore remain trafficable.

5.3 EMERGENCY RESPONSE PLANNING COMMUNITIES

Using the Flood Emergency Response Planning Classification Of Communities flood risk management guideline (NSW Government, 2007), the village of Eumungerie would be classified as an area with Rising Road Access (RRA). RRA areas are those in which access roads rise uphill and away from the rising flood waters. In these places the community is not completely isolated before a flood reaches its maximum and evacuation can take place by vehicle or on foot along the road as flood water advances.

5.4 FLOOD WARNING

There is currently no flood warning system available for Eumungerie. The only nearby stream gauge is located on Coolbaggie Creek at Rawsonville, which is not relevant for the short duration flooding that would occur at Eumungerie.

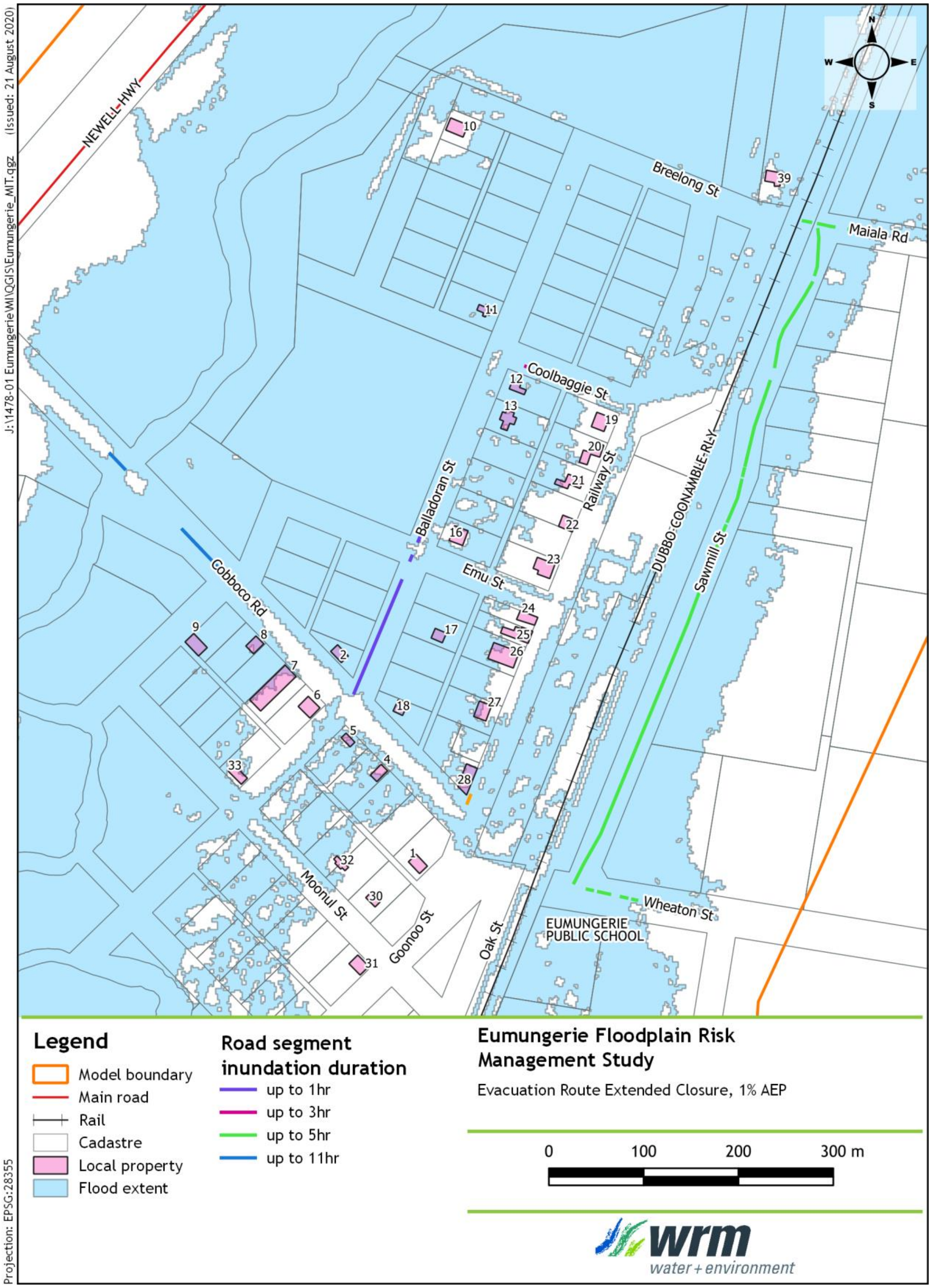

Figure 5.1 –Access roads inundated by 0.3 m for more than one hour, 1% AEP event

6 Structural flood management options

6.1 OVERVIEW

Three structural flood management options have been investigated for Eumungerie. The investigated options have been based on a review of the flood risk zones, with the primary aim of structural management options being, either:

- mitigation: reducing the existing flood risk, and/or
- management: providing greater flood emergency response and evacuation options.

The investigated structural flood mitigation options have included:

- voluntary purchase and house raising programs;
- upgrading the existing private levee to the north of Breelong Street;
- a new levee and diversion channel, including:
    - levee (or raised road) on Coolbaggie Street and Balladoran Street; and
    - excavated drainage channel along the Dubbo Coonamble Rail.

This section describes the proposed measures and outlines the tangible and intangible benefits.

6.2 AIM OF STRUCTURAL FLOOD MANAGEMENT

The aim of any structural flood management option is to reduce the exposure of the community to flood risk, and/or improve emergency response during a flood event. The flood risk map presented in Section 3.5.3 is a key tool in assessing the effectiveness of each structural flood management option, as this map identifies the existing flood risk across Eumungerie.

Figure 3.5 shows that no buildings are present in risk zone Z6 (extreme risk) or risk zone Z5 (high risk) and approximately 6 residential dwelling near flood risk zone Z4 (medium risk) along Balladoran Street and Cobboco Road. The structural flood mitigation options were directed at mitigating the flood risk for these properties without causing impacts to other properties.

6.3 VOLUNTARY PURCHASE AND HOUSE RAISING

6.3.1 Purpose

A voluntary purchase and house raising program for flood prone properties in Eumungerie was considered. The primary objectives of a voluntary purchase and house raising Program would be to:

- reduce the impact of flooding;
- reduce flood liability on individual owners and occupiers of flood prone property; and
- reduce private and public losses resulting from floods.

The voluntary purchase component could be restricted to the most at risk properties, i.e. those in risk zones Z5 and Z6 (high and extreme risk), which there are none. The house raising component could then be targeted at residential properties able to be raised (i.e. not slab-on-ground properties) with an existing floor level below the flood planning level (1% AEP + 0.5 m).

6.3.2 Considerations

There are no existing buildings currently in risk zones Z5 and Z6 (high and extreme risk) and therefore voluntary purchase of properties within Eumungerie would not be appropriate.

Under the current government legislation and practical considerations, a proposed house raising program would likely only apply to:

- residential properties constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government;
- single storey residential buildings located outside of high or extreme flood risk zones (Z5 and Z6). Note: a separate floodplain risk management measure (voluntary purchase) is recommended for properties in high flood risk zones;
- residential buildings structurally able to be raised (i.e. buildings on stumps, not slab-on-ground); and
- residential buildings where the floor level of the residence is below the adopted residential flood planning level (1% AEP flood level + 0.5 m). Any house raising should result in the new floor level being, as a minimum, at the flood planning level.

Given the above criteria, a total number of 7 residential properties are potentially eligible for house raising (noting that no investigation of building age has been undertaken, so the actual number of eligible properties will be less than this). Some flood prone properties have been constructed with a slab-on-ground and therefore cannot be raised.

Subject to Government agreement, funding for the program could potentially be provided at ratio of $2 from the State Government for every $1 provided by the property owner (or council), in accordance with the NSW Government's Floodplain Management Program for voluntary house raising schemes.

6.3.3 Tangible benefits

Table 6.1 shows the number of properties flooded above and below floor level and the estimated residential and commercial damages (in March 2020 dollar values) assuming all potentially eligible residential properties have been raised. The estimated building average annual damage (AAD) under the fully implemented scenario is also shown.

With respect to the 1% AEP flood and comparing to existing conditions (see Table 4.3), the results show that:

- the number of flood affected residential properties above the floor level would reduce from 2 to 0;
- the total local catchment flooding residential flood damages would reduce by approximately $110,000 (from $273,000 under existing conditions).

The total building average annual damage from flooding, assuming complete uptake of a voluntary house raising program, is $124,000. This is approximately $10,000 less than existing conditions.

6.3.4 Estimated cost

The cost of house raising can vary widely depending upon the size of the house and the availability of suitable contractors. In South East Queensland, house raise quotations typically range from $15,000 to $50,000. Molino Stewart (2014) estimated the cost of house raising in Moree to be $80,000 per structure. For this assessment, a cost of $88,200 per structure was assumed for this study (the Molino Stewart estimate was factored using CPI as an indicator of price rise).

Table 6.1 - Number of properties flooded and flood damage costs, fully implemented house raising program

Parameter	Event (AEP)							
	20%	10%	5%	2%	1%	0.5%	0.2%	Extreme
No. residential buildings flooded AGL	2	6	9	12	15	21	24	30
No. residential buildings flooded AFL	-	-	-	-	-	-	-	29
Total residential damages ($K)	$0.0	$25.0	$25.0	$37.5	$163	$200	$263	$4,403
No. non-residential buildings flooded AGL	1	2	3	5	5	6	6	6
No. non-residential buildings flooded AFL	-	-	-	-	-	-	-	6
Total non-residential damages ($K)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$112.5
Building average annual damage	**$124,250**							

AGL - above ground level (count includes buildings flooded above both ground level and floor level)
AFL - above floor level

6.3.5 Economic evaluation

Table 6.2 shows an economic evaluation of the voluntary house raising component of the program. The reduction in average annual damage was calculated assuming that the two highest priority houses were raised to the flood planning level every year. The net present value of the savings was then determined for discount rates of 4%, 7% and 10%, which was compared to the cost of the raising to determine the benefit cost ratio. The total building AAD each year was then calculated as the sum of AAD for regional flooding and AAD for local catchment flooding.

At all discount rates, none of the rounds of raising properties yield a positive benefit cost ratio, which means the program is not economically viable in any years.

Table 6.2 - Economic evaluation of the proposed house raising program

Yr	Total building AAD after each year	AAD savings	NPV Savings over 20 years			Cost of year	Benefit Cost Ratio		
			@ 4%	@ 7%	@ 10%		@4%	@7%	@10%
	$133,493	-							
1	$126,606	$6,887	$93,597	$72,961	$58,633	$176,400	0.53	0.41	0.33
2	$125,465	$1,141	$15,503	$12,085	$9,712	$176,400	0.09	0.07	0.06
3	$124,516	$949	$12,903	$10,058	$8,083	$176,400	0.07	0.06	0.05
4	$124,254	$262	$3,564	$2,779	$2,233	$176,400	0.02	0.02	0.01

6.3.6 Environmental impacts

There are negligible environmental impacts associated with a voluntary purchase and house raising program. There are however potentially positive, but minor, impacts on flooding due to a less obstructed floodplain.

6.3.7 Social impacts

A voluntary purchase and house raising program would have potential positive social impacts on the Eumungerie community. Potential positive social impacts of the program include:

- reduced community impact during rare flood events; and
- reduced stress towards flooding for house owners who participate in the program.

Potential negative social impacts of the program include:

- house owner's financial pressure of partly funding house raising;
- house owner's pressure of moving house if opting for voluntary purchase; and
- inequity for residents who own properties that are ineligible or unsuitable for house raising.

6.4 UPGRADE OF THE PRIVATE LEVEE ALONG BREELONG ST

6.4.1 Purpose

There is a private levee located to the north of Breelong Street. It is understood the levee was constructed after the January 1993 flood to protect property ID 10 on Balladoran Street (see Figure 6.1). The raising of the levee would potentially reduce Drillwarrina Creek flooding.

6.4.2 Considerations

A review of the flood modelling results showed that the existing levee would be overtopped by the 5% AEP event and outflanked by the 20% AEP event. Site observations indicate that it would be very difficult to extend the levee around house ID39 on Breelong Street to prevent the levee from being outflanked. Unless the levee was extended to the south, the levee would not prevent the inundation of Eumungerie for the larger floods. It would also not prevent inundation of local stormwater inundation from the east of the rail.

Given these constraints, the upgrading of the private levee along Breelong Street has not been considered further.

Notwithstanding this, consideration should be given should the owner of property ID10 wish to raise the levee around the house to provide personal protection. This would likely be at the owner's expense.

6.5 LEVEE AND CHANNEL SCHEME

6.5.1 Purpose

During moderate to large flow events, Drillwarrina Creek overflows drain south to inundate a number of properties along Balladoran Street. Balladoran Street also experiences stormwater inundation from the local catchments draining through the rail from the east.

The objective of the levee and channel scheme would be to reduce the flood risk in this area from both of these sources. It would also reduce the stormwater flooding at Eumungerie Public School.

6.5.2 Considerations

Figure 6.1 shows the locations of the proposed mitigation measures, which includes the following:

- A 640 m long levee (or road raise) to prevent Drillwarrina Creek flooding in the urban areas in Eumungerie. The levee would follow Coolbaggie Street before turning southwest following Balladoran Street. The optimal configuration for the levee would potentially be by raising the existing road to the 1% AEP design flood level.
- A 910 m long, 10 m wide constructed drainage channel to divert the local catchment flows from the east of the Dubbo Coonamble Railway away from Eumungerie to the south. The drainage channel would formalise the existing flow path located between the Dubbo Coonamble Railway and Sawmill St and would extent from Coolbaggie Street to the north and Eura Street to the south.

- Culverts under the rail at Wheaton St (RL02 and RL03) and at the grain terminal (RL04) would be blocked to prevent water from draining into Eumungerie; and
- New box culverts (2 X 0.9 mH &1.2 mW) would be constructed on the constructed drainage channel across Wheaton Street.

Note that the community identified stormwater ponding along Balladoran Street was a significant issue and the flood study identified that the most frequent inundation occurred from stormwater runoff. These measures would reduce the catchment and therefore flows draining to this area. It would not however prevent ponding from local rainwater runoff generated between Coolbaggie Street and Cobboco Road. This area would drain via the existing road table drains.

There is opportunity to raise the levee/road to provide a higher level of immunity. However, it would potentially be difficult to raise the road much higher and maintain suitable access to each property and therefore a new structure, potentially on private land would be required. The above levee and channel concept could potentially be located on easement and therefore not require further land acquisition or easements on privately held land.

6.5.3 Concept hydraulic modelling

The hydraulic model was used to test the effectiveness of the above mitigation measures for a range of design flood events from the 20% AEP to the PMP flood. Impact mapping from the hydraulic modelling results is presented in Appendix B.

The hydraulic model results show the following:

- For design flood events up to 1% AEP,
  - properties between Coolbaggie Street, Balladoran Street and Railway Street would not be inundated by overflows from Drillwarrina Creek or from stormwater runoff from the catchment to the east of the rail;
  - significant reductions in flooding would occur for properties to the south of Cobboco Road;
  - the Eumungerie Public School would not be inundated;
  - a minor reduction in flood level would occur to the property ID 2 and a minor increase at property ID 11 (the church); and
  - peak flood levels at other properties would not change.
- For events rarer than 1% AEP, a clear reduction in flood levels would occur for properties located along Balladoran Street and for properties to the south of Cobboco Road. No properties with the exception of property ID 11 (the church) would experience increased flood levels.
- Increased flooding would occur along the rail to the south of Eumungerie due to the diverted stormwater. No investigations have been undertaken to mitigate this increase. However, it is possible additional culverts through the rail would be required.

6.5.4 Tangible benefits

Table 6.3 presents a high-level quantification of the tangible benefits of the Levee and Channel Scheme configured as per Figure 6.1.

For the 1% AEP event, six properties would be inundated above ground level, reduced from 15 in the existing condition. One property would be inundated above floor level, reduced from two previously. The estimated flood damage cost for the 1% AEP event would be $130,000, a reduction of approximately $140,000. The average annual damage is reduced by $10,000 to approximately $125,000.

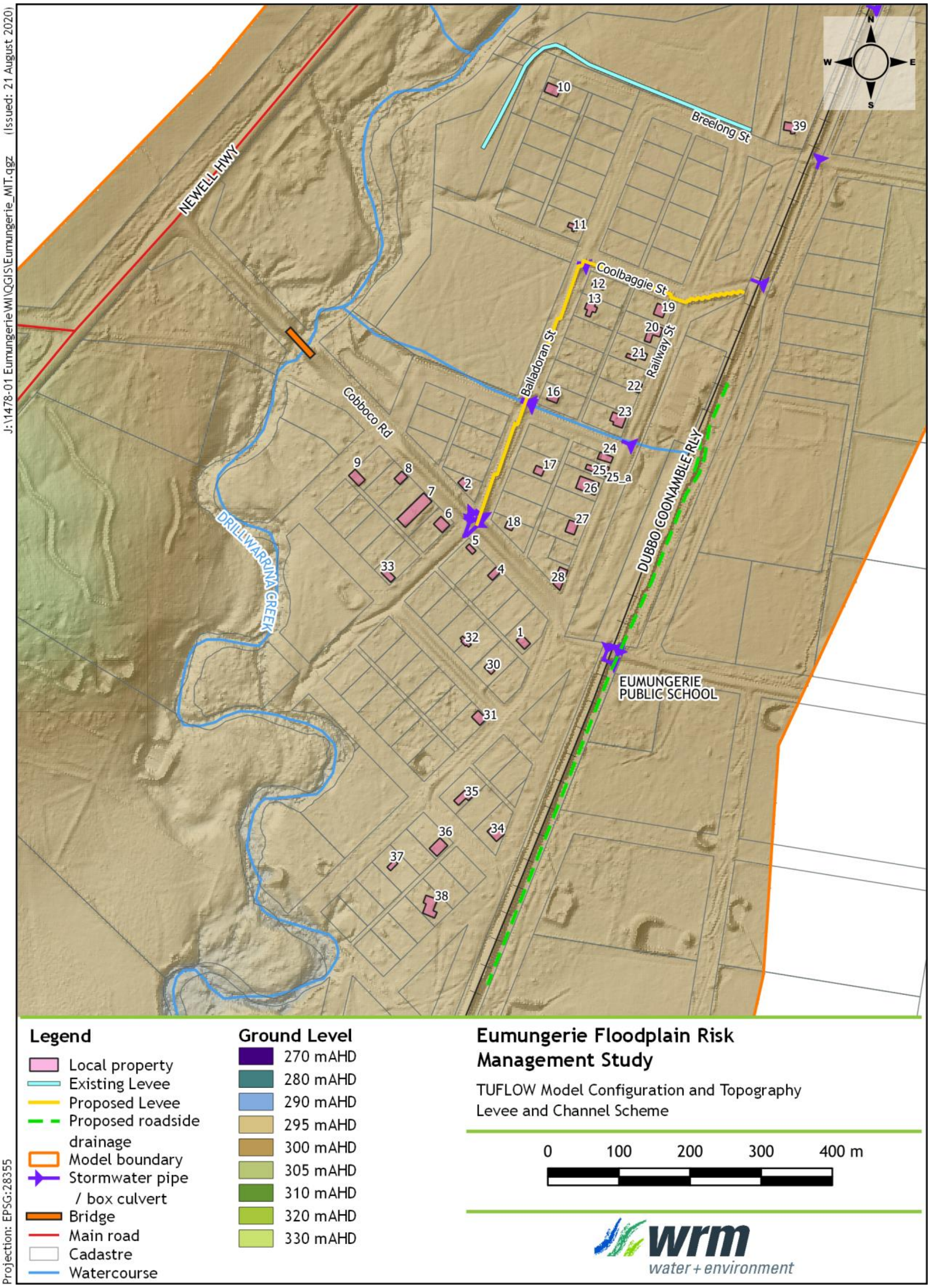

Figure 6.1 – Levee and channel scheme concept

Table 6.3 – Number of properties flooded and flood damage costs, Levee and Channel scheme flood mitigation option

Parameter	Event (AEP)							
	20%	10%	5%	2%	1%	0.5%	0.2%	Extreme
No. residential buildings flooded AGL	-	1	3	5	9	16	24	30
No. residential buildings flooded AFL	-	-	-	-	1	2	5	29
Total residential damages ($K)	$0.0	$12.5	$25	$63	$130	$332	$596	$4,492
No. non-residential buildings flooded AGL	1	1	2	3	3	5	6	6
No. non-residential buildings flooded AFL	-	-	-	-	-	-	-	5
Total non-residential damages ($K)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$112.5
Building average annual damage	**$125,229**							

AGL - above ground level (count includes buildings flooded above both ground level and floor level)
AFL - above floor level

From the results of the hydraulic modelling and the flooded property analysis it is apparent that the levee and channel scheme would benefit the majority of property owners, with the exception of property ID 11 (the church) which would remain not flooded above floor level by the 1% AEP event.

6.5.5 Estimated cost

Table 6.4 provides indicative costings of the levee (road upgrade) and drainage channel. The costs have been determined using unit rates of fill as well as road and culvert construction composite rates based on the Australian Construction Handbook (Rawlinsons, 2020). The costs been developed to assist in broad-scale planning and should be regarded as indicative only. A 25% contingency cost has also been included. However, the costing is suitable for the comparative preliminary benefit cost analysis undertaken for this study.

Table 6.4 - Costing of proposed levee and road raise

Item	Unit Cost	Unit	Quantity	Estimate
Raising Coolbaggie and Balladoran streets				
Strip	$1.85	m^2	2700	$4,995
Fill	$17.2	m^3	1340	$23,048
Gravel road surface	$1.85	m^2	2700	$4,995
Total				**$33,038**
Constructed channel				
Channel excavation	$12	m^3	6,000	$69,300
Channel revegetation	$10,900	ha	1.27	$10,900
Wheaton St Culvert	$51,250	Item	1	$51,250
Total				**$131,450**
25% Contingency				$41,122
Total				**$205,610**

Cost that was **not** considered in the cost estimate include:

- Cost of any new rail infrastructure to the south of Eumungerie; and

- maintenance and repair of the structures.

6.5.6 Economic evaluation

Table 6.5 shows an economic evaluation of the proposed scheme. The net present value of the savings has been determined for discount rates of 4%, 7% and 10%, which has been compared to the cost of the levee scheme to determine the benefit cost ratio. The results show that the costs outweigh the benefits for all discount rates. Further work to reduce the estimated cost could be undertaken to improve the benefit cost ratio. The inclusion of the intangible benefits would also improve the evaluation.

Table 6.5 – Economic evaluation of the proposed levee and channel

Yr	Total AAD	AAD savings	NPV Savings over 20 years			Cost	Benefit Cost Ratio		
			@ 4%	@ 7%	@ 10%		@4%	@7%	@10%
	$133,493	-							
1	$125,229	$8,265	$177,542	$114,058	$81,942	$205,610	0.86	0.55	0.4

6.5.7 Environmental impacts

The proposed levee and channel are not expected to have a detrimental environmental impact because:

- the proposed levee (raised road) would be located on an existing road easement;
- Drillwarrina Creek flooding behaviour would not change; and
- The proposed drainage channel along the rail would be formalising an existing flow path, albeit artificially created by the rail.

Careful consideration of the alignment of the diversion channel during detailed would be required to minimise or eliminate the need for the removal of vegetation. Proper consideration to erosion protection would also be required.

6.5.8 Social impacts

A levee and channel scheme would have an overall positive social impact on the Eumungerie community. Potential positive social impacts of the scheme include:

- reduced community impact during frequent to rare flood events;
- reduced flood impacts at Eumungerie Public School; and
- increase the accessibility of Cobboco Road – Wheaton Street as an evacuation access during major flood events.

Potential negative social impacts of the scheme include:

- impacts to the local church at the intersection of Balladoran Street and Coolbaggie Street; and
- increased ponding extents east of Dubbo Coonamble Railway, between Wheaton Street and Kingsley Road.

6.6 RECOMMENDED STRUCTURAL MITIGATION OPTION

The comparison of the proposed structural flood mitigation options would suggest that the proposed road raise/levee and channel scheme is the most viable for Eumungerie, although the costs generally outweigh the benefits.

The social benefits of the levee scheme would be significant by reducing local stormwater inundation that frequently occurs in the area. Although the damage caused by the local stormwater inundation is not significant, the lack of drainage in the area means that water would pond for extended periods.

It is recommended to undertake further investigation into the scheme. The investigation should:

- Consult with the community on the suitability of the option;
- Engage with ARTC on the use of the rail easement; and
- Refine the design and costings to improve the benefit cost ratio.

Should the further investigations demonstrate that the levee scheme is feasible and has community acceptance, the floodplain management study should be updated with the revised flood levels once it has been constructed.

7 Non-structural flood management options

7.1 OVERVIEW

Dubbo Regional Council currently manage the development of flood prone land via land use zoning within the LEP (refer Figure 2.1) and development requirements specified in the Dubbo Development Control Plan (2013).

The LEP defines the flood planning area for Dubbo City but has not defined the area for Eumungerie. The proposed flood planning area for Eumungerie is shown in Figure 3.6, which has been derived from the extent of flooding for the 1% AEP event plus 0.5 m.

The LEP stipulates that:

Development consent must not be granted to development on land to which this clause applies (land within the flood planning area) *unless the consent authority is satisfied that the development:*

> *(a) is compatible with the flood hazard of the land, and*
>
> *(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
>
> *(c) incorporates appropriate measures to manage risk to life from flood, and*
>
> *(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
>
> *(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

The DCPs set standards for new developments and modifications to existing developments within the flood planning area. The LEP and DCP have been reviewed to determine whether the controls are appropriate for Eumungerie.

7.2 LAND USE PLANNING - LAND USE ZONING

7.2.1 Purpose

The application of land use zoning is an effective and long-term means of controlling development in flood affected areas. The Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning (AIDR, 2017) recommends “limiting the growth in flood risk because of new land uses and development in the floodplain”. Land use zoning is therefore key to restricting or preventing incompatible development on flood prone land.

7.2.2 Considerations

Land use zonings over flood prone land should be based on an objective assessment of flood hazard and risk, environmental and social factors including:

- the NSW Governments Flood Prone Land Policy;
- whether the land is in a high flood risk area;
- the potential for future development to have an adverse impact on flood behaviour and thereby negatively impact existing development;
- whether adequate access is available during floods;

- whether certain activities should be excluded because of additional or special risk to their users, e.g. accommodation for aged people, hospitals etc.; and
- existing planning controls.

7.2.3 Proposed strategy

A review of the land use zoning map and the flood risk map presented in Section 3.5 shows that the majority of the RU5 lots within Eumungerie have a Z3 (low) or Z4 (medium) flood risk. There is only one undeveloped freehold RU5 lot located within the Z5 (high) and Z6 (extreme) flood risk zone. The location of this lot together with the extent of the Z5 and Z6 flood risk zone is shown in Figure 7.1. The remaining RU5 lots within the Z5 and Z6 zone, also shown in Figure 7.1, are listed as crown land and therefore would not be developed.

It is unlikely that any of these lots within the high flood risk area would be developed in the future as it would not comply with the LEP requirement to be '*compatible with the flood hazard of the land*'. These lots have also been identified on the Natural Resource Biodiversity map as having high biodiversity, which would further limit development.

The R5 lots adjacent to Drillwarrina Creek to the south of Eumungerie are generally within Z3 and Z4 zones and are therefore zoned appropriately.

Although there is a low chance that the lots identified in Figure 7.1 could be developed, it is recommended that Council undertake consultation with the owners of the lots to understand their current use and to articulate the flood hazard of the land. This consultation will be with a view to inclusion of the lots in Council's strategic planning processes for potential rezoning in the future, having regard to the significant flood hazard and the likely constraints of the land to further development.

7.3 LAND USE PLANNING – BUILDING AND DEVELOPMENT CONTROLS

7.3.1 Purpose

The DCP is the primary instrument for managing development on the floodplain to ensure development is compatible with the prevailing flood situation and that the overall level of potential flood risk is not increased.

7.3.2 Considerations

A summary of the key flood development controls within the Dubbo DCP and a discussion on their implications to development within Eumungerie are listed below.

Residential

- Ground floors of residences are located at or above the 'flood planning level' to provide protection to life and property in accordance with the accepted level of risk. (A7.1 – Stormwater management)
- Flood free access is provided for driveway and access points (A3.1 in Vehicular access and car parking)
- Where Council sewerage services are not available, an approved effluent disposal system is installed and located so it is not: - Situated on flood-affected land (A3.4 – Infrastructure)

Given the existing flooding constraints in Eumungerie, it is unlikely that any of the existing (undeveloped) RU5 lots would satisfy the flood free requirements for driveway and access points because the majority of public roads to which they would connect, themselves are not flood free.

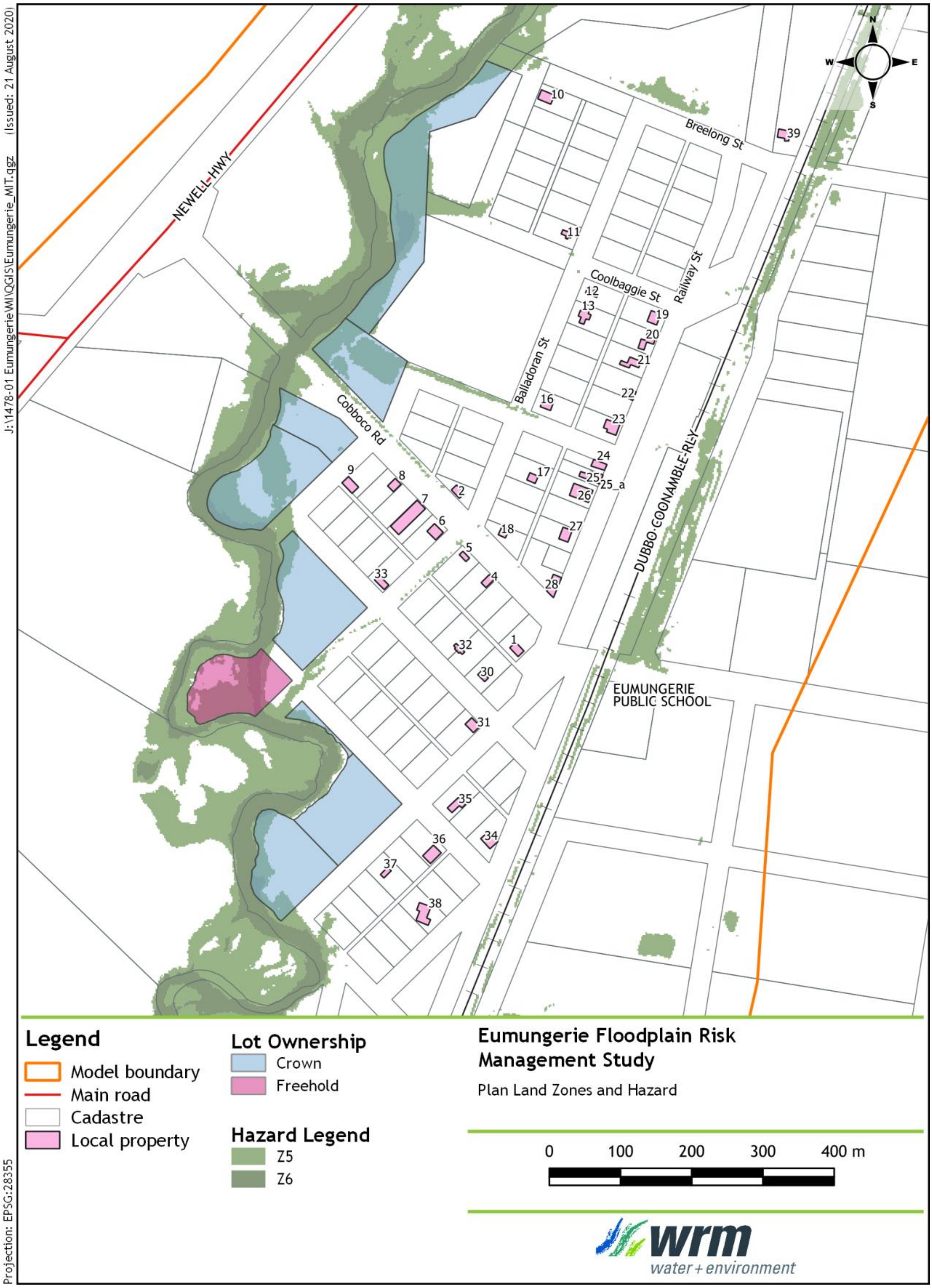

Figure 7.1 – High and extreme flood risk allotments within the RU5 zone

Whilst the term "*flood free*" is not defined in the DCP, it would notionally relate to the PMF under the NSW Floodplain Development Manual. However, in the context of flooding behaviour in Eumungerie where flood events would be expected to rise and fall in hours and the community has a rising road access as defined by the Flood Emergency Response Planning Classification of Communities, temporary isolation may be acceptable, and thus having a flood free access up to the PMF flood standard would not be expected to be an imperative.

For major events which would involve over floor flooding and thus likely necessitate evacuation, the public road system would be inundated, and thus the relevance of having a flood-free access within the property itself becomes mute. Under such circumstances the ability for heavy vehicles to access and depart the site to facilitate evacuations, becomes more relevant, being a consideration of the flood depth, velocity and trafficability of the adjacent road surface.

The sewerage constraints would also potentially restrain future residential development within Eumungerie as it would be required to minimise future contamination of the waterway.

Rural development

- Buildings on R5 not sited near obvious depressions and watercourses or on flood-prone land (A5.2 in Site integration)
- Evacuation and alternative evacuation paths from natural hazards are clearly identified and constructed prior to development (A5.3 in Site integration)
- Access is flood-free to allow safe transit during and after periods of heavy rain (P3 and associated AS's in Access).
- Development is located away from watercourses and flood-prone land and does not adversely impede the flow of flood waters (P1 and associated AS's in flooding).
- A Flood Evacuation Plan has been prepared (P2 and A2.1 in flooding).

With respect to the study area, the R5 zoned land between Drillwarrina Creek and the rail to the south of Eumungerie would not satisfy the Site Integration and Access and Flooding conditions of the DCP due to its flooding constraints. Given that the subject R5 zoned land is undeveloped 'rural' land with no current servicing, no formed public road access, and subject to other natural hazards (i.e. bushfire), the opportunity exists for Council to undertake consultation with the landowners with a view for the inclusion of that area into Council's strategic planning processes for potential rezoning in the future, having regard to the significant flood hazard and the likely constraints of the land to further development.

Commercial

- Ground floors of commercial buildings are located above the 1% AEP flood level to provide protection to property in accordance with the accepted level of risk (P3.2 of Soil, water quality and noise management).

The above development control would appear to be consistent with the LEP and best practice floodplain management.

Cumulative impacts of filling

Although the current development demand is low, there would appear to be about 100 RU5 lots within Eumungerie that could incorporate a residential dwelling at some time in the future. Most of these would require a fill pad to meet the floor level requirements, unless constructed on stumps.

The minimum lot size within the RU5 zone is 2,000 m^2 with all but the 10 lots to the south of Cobboco Road and to the west of Balladoran Street exceeding this area. The hydraulic model was used to assess the hypothetical future scenario where all RU5 lots contained a fill pad of 300 m^2 above the 1% AEP flood level including the existing properties. The results of the impact assessment showing the impact of the hypothetical filled scenario compared to existing conditions is shown in Figure 7.2.

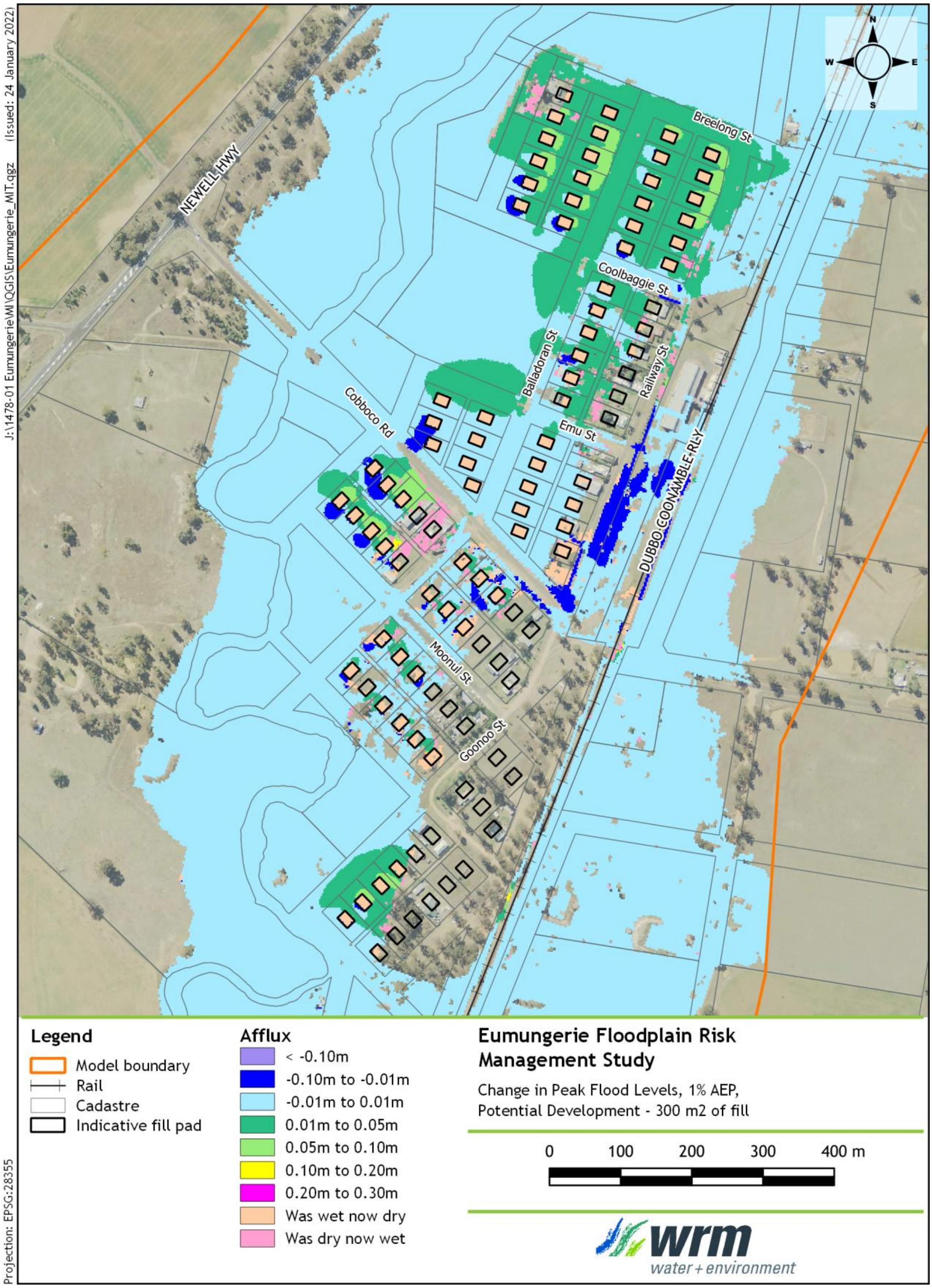

Figure 7.2 – Flood level impacts for filling each RU5 lot by 300m², 1% AEP event.

The results of the assessment show that peak 1% AEP flood levels would increase by:

- up to 0.01 m for the existing dwellings along Railway and Balladoran streets;
- up to 0.09 m for the existing dwellings/commercial properties along Cobboco Road to the west of Balladoran Street;
- up to 0.06 m for the undeveloped lots to the north of Coolbaggie Street.

The greatest flood impact would occur at the existing dwellings/commercial properties along Cobboco Road. The impacts would appear very localised around each fill pad. None of the existing buildings would be inundated above floor level by the 1% AEP event if the fill occurred according to these hypothetically filled areas.

7.3.3 Proposed strategy

7.3.3.1 Terminology

The DCP refers to terms such as 'flood prone land' and 'flood free', neither of which are defined within the DCP dictionary. Consideration should be given to defining these terms within the DCP dictionary.

- **Flood prone** land should be consistent with the Floodplain Development Manual (NSW Government, 2005) as *land susceptible to flooding by the PMF event*.
- **Flood free** should relate to a specific flood event and this may vary across the LGA depending upon location. For Eumungerie, flood free access could refer to being trafficable during a 1% AEP event.

7.3.3.2 Cumulative impacts of filling

The DCP should include provisions for managing the filling within the floodplain. The development standards should be consistent with Division 5 of the NSW House Code. However, further acceptable solutions could be considered to take advantage of the assessment undertaken above. Possible acceptable solutions for fill within the floodplain within the RU5 zone include:

- A fill pad on each lot should not exceed 300 m^2 at the ground surface;
- The minimum fill pad level should be the 1% AEP event plus 0.3 m; and
- Any fill pad exceeding 300 m^2 would need a flood study to demonstrate that there would be no adverse impacts on adjacent property

7.4 FLOOD EMERGENCY PLANNING

7.4.1 Purpose

The existing Dubbo City Local Flood Plan (SES, 2013) covers issues such as preparedness, response and recovery for flood events within the Dubbo LGA including for Eumungerie. The plan details clear lines of responsibility for managing flood events with particular focus on large river flooding from the Macquarie and Talbragar rivers in Dubbo. An assessment of the response measures in the plan for Eumungerie is given below.

7.4.2 Considerations

7.4.2.1 Flood warning

The flood study showed that major flooding at Eumungerie from Drillwarrina Creek would occur from rainfall events of about 6 hours. For these events, the flood peaks were predicted to peak within about 6 hours of the commencement of the storm and the onset of overbank flooding would occur within about 4 hours. This suggests that there would be very little time between the heaviest rainfall occurring and the onset of overbank flooding. Note that the January 1993 flood, which resulted from a 1 hour storm, peaked within 3 hours of the storm commencing with overbank flooding occurring within an hour.

There are no flood gauges or rainfall alert stations within the catchment that provide early warning for an impending flood. The broad nature of the catchment would also suggest that the establishment of a flood warning system would not be of significant benefit.

At the peak of the event, the village would also be isolated from Dubbo due to Cobboco Road being inundated by Drillwarrina Creek and Mogriguy Road being inundated by Coolbaggie Creek and potentially at other locations.

Given the above, it is unlikely that SES staff in Dubbo could respond to an event prior to the flood peak. A local SES unit member trained in flood and stormwater response operations would be required to manage any response.

7.4.2.2 Shelter in place

The flood study showed that above floor flooding would not commence until the 2% AEP event (for one dwelling) and only five properties would be inundated for the 0.2% AEP event. It is likely that most residents would remain in their properties for most flood events and only evacuate once yard or above floor flooding commenced. Given the lack of warning, this may be unavoidable.

Given that the roads within Eumungerie rise away from Drillwarrina Creek towards the rail, residents should be able to safely evacuate as the floodwaters arrive. Vulnerable residents would likely need assistance.

7.4.2.3 Evacuation centres

The Dubbo City Local Flood Plan (SES, 2013) identified two evacuation centres for Eumungerie:

- the Eumungerie Hall (Railway Street), and
- Eumungerie Primary School (Wheaton Street).

The Eumungerie Hall would experience yard flooding for the 1% AEP event and above floor flooding for the PMF event. It would not be safe during a PMF. The Eumungerie Primary School would experience yard flooding from local stormwater for the 10% AEP event to shallow depths. Peak flood depths for the PMF would generally be less than 0.4 m.

On this basis, the Eumungerie Primary School should be the favoured evacuation centre.

7.4.3 Proposed Strategy

The Dubbo City Local Flood Plan (SES, 2013) would appear to cover the key issues. However, consideration should be given to training local SES unit members in flood and stormwater response operations specific to Eumungerie as it would be unlikely that the Dubbo SES could respond until after the event had passed.

The additional and updated information provided in Section 5 can be used to update the Local Flood Plan and/or prepare a Local Flood Policy. In particular, the information on the locations of road inundation depths for the various events could assist prioritisation of evacuations for regional flood events.

7.5 PUBLIC AWARENESS, COMMUNITY CONSULTATION AND EDUCATION

7.5.1 Purpose

Appropriate and timely public response during flooding is related to the level of understanding in the community of the nature, frequency and extent of flooding, the rate of rise of floodwaters and the degree of risk. Therefore, public awareness of the potential risk should be an integral and ongoing part of managing flood affected areas.

7.5.2 Considerations

Significant flood events have been rare in Eumungerie with local stormwater problems more prominent to the local community. Given the infrequent flooding, a continuing public education programme is recommended on the basis that a well-prepared community will suffer less damage and other flood related problems during a significant flood event.

Public education is relatively inexpensive and has the potential to reduce the risk to life and property. Significant flood events are infrequent. Therefore, a programme of public information must be ongoing and sustained if it is to be effective.

7.5.3 Proposed strategy

The following public awareness strategies are proposed:

- Publishing the Eumungerie Flood Study (WRM, 2020) and the Eumungerie Floodplain Risk Management Study and Plan (WRM 2020) on the Dubbo Regional Council website.
- Flood related property information made available to anyone enquiring through Dubbo Regional Council, including:
    - property ground level and floor levels;
    - design flood levels; and
    - the flood planning level.
- A flier sent to the residents annually, potentially as part of the rates notice reminding residents of the flood risk (as well as other hazards) and to be prepared. The flier could highlight Eumungerie's exposure to all of the hazards, identify nominated evacuation centres and provide information on emergency response numbers.

8 Public consultation

A draft version of this report was placed on public exhibition for a period of 4 weeks from 7 March to 4 April 2022 on Council's website and link to the report provided on Council's Facebook page. A letter was sent to all community members advising them that the report was on public display and inviting them to provide a written response to the report directly or via an on-line survey.

During the exhibition period, an information session was held on 30 March at the Eumungerie Hall to respond to any questions raised by the community. No written responses were received on the draft report. However, the information session provided an opportunity to discuss the measures assessed and gain feedback on the levee and channel scheme and the potential changes to the Development Control Plan to provide guidance on filling for future developments.

The filling guidance recommendation within the DCP was generally well received and the attendees thought the levee and channel scheme was a good idea but questioned its viability. There were not revisions or updates required for the study but adjustments were made to the draft Plan following consultation with council.

9 Conclusions and recommendations

This floodplain risk management study has highlighted the existing flood risk in Eumungerie. The results of hydraulic modelling from the flood study have been used to assess the flood hazard assessment has then been summarised into a single flood risk map, independent of flood severity.

The existing flood risk analysis has been complemented with a comprehensive building flood damage assessment. The total average annual damage to buildings in Eumungerie has been estimated at $133,500.

The existing problem, future problem and residual flood problem has been analysed with structural measures, planning measures and emergency response measures considered to address these problems.

Following consideration of hydraulic, environmental, economic and social issues, a selection of structural flood risk management measures have been ranked for implementation as part of Floodplain Management Plan of this study. The measures in order of highest priority to lowest priority are given in Table 9.1.

Table 9.1 – Recommended floodplain risk management measures for Eumungerie

Priority	Measure	Recommendation	Responsibility and expected date of completion
High	1. Levee and channel scheme	• Refine the concept design • Examine financial feasibility and consider funding strategy	• Dubbo Regional Council • December 2023
Medium	2. Land use planning	• Incorporate flood planning area map into the LEP • Consider rezoning land currently located in Z5 and Z6 hazard areas	• Dubbo Regional Council • December 2023
Medium	3. Building and development controls	• Updating DCP to include flood risk measures to improve terminology • Updating DCP to include assessment of filling impacts	• Dubbo Regional Council • December 2023
Medium	4. Local flood policy	• Prepare a Local Flood Policy to incorporate information on flood risks to properties and additional information on road inundation and flood warning. Communicate the contents of the Local flood Policy to the community.	• Dubbo Regional Council and State Emergency Services • December 2023
Medium	5. Flood education plan	• Develop and implement an ongoing flood education plan.	• Dubbo Regional Council and State Emergency Services • December 2023

10 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. (see ARI)
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average recurrence interval (ARI)	the long-term average number of years between the occurrence of a flood as big as or larger than the selected 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.
discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
effective warning time	the time available after receiving advice of an impending flood and before 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.
emergency management	a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
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 awareness	an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
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 susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms

	the basis for physical works to modify the impacts of flooding.
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 a 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 includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined 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 area	the area of land below the FPL and thus subject to flood related development controls.
flood planning levels (FPLs)	are the combinations 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.
flood proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
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 the 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.
hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the Floodplain Development Manual (2005).
historical flood	a flood which has actually occurred.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
mathematical / computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood (PMF)	the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event.
probable maximum precipitation (PMP)	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.

probability	a statistical measure of the expected chance of flooding (see annual exceedance probability).
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 streamflow, also known as rainfall excess.
stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
MIKE-FLOOD	a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.
velocity	the speed or rate of motion (distance per unit of time, e.g., metres per second) in a specific direction at which the flood waters are moving
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time

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Appendix A- Hazard category mapping

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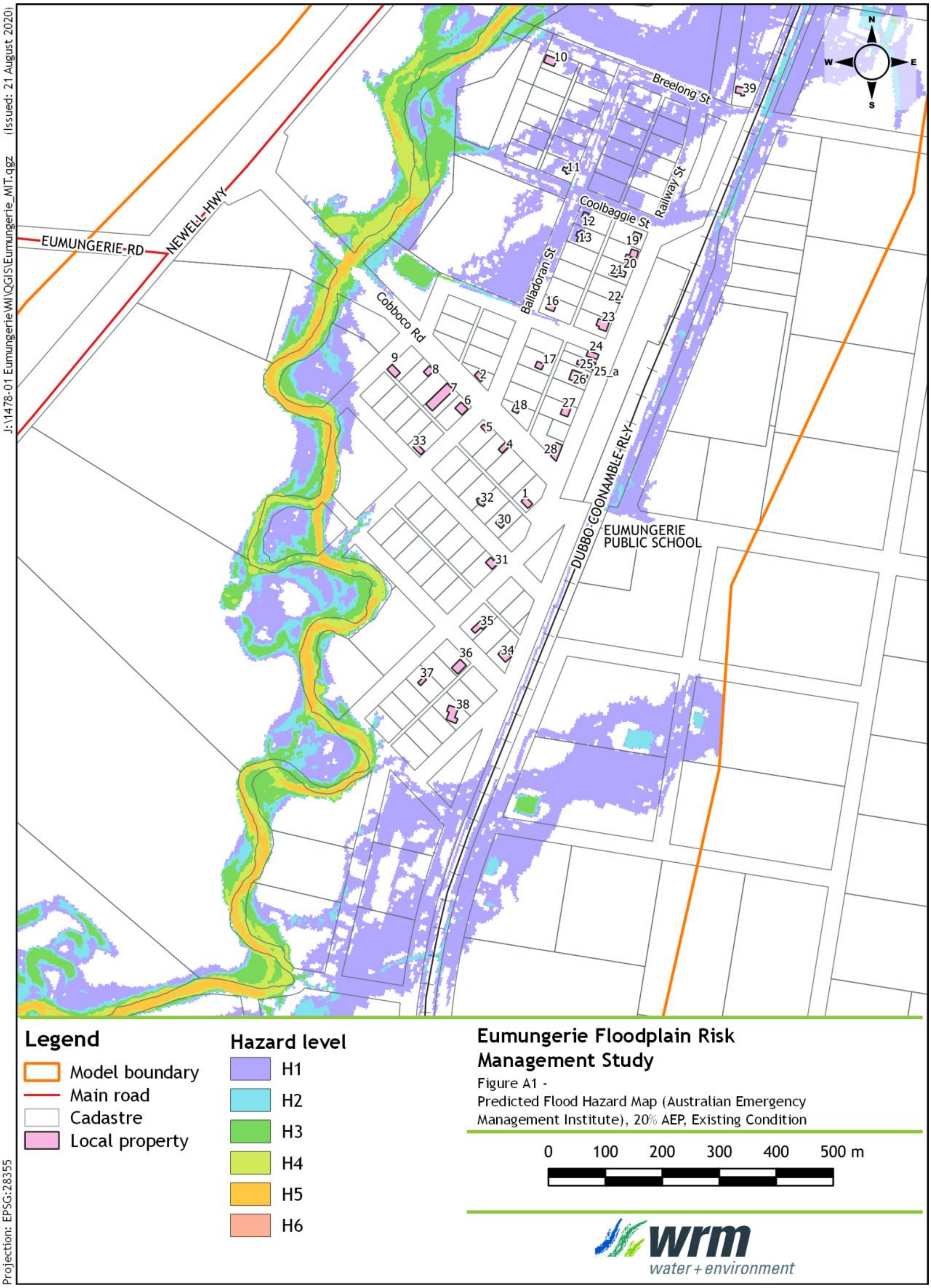

Figure A 1 - AIDR (2017) hydraulic hazard, 20% AEP design flood

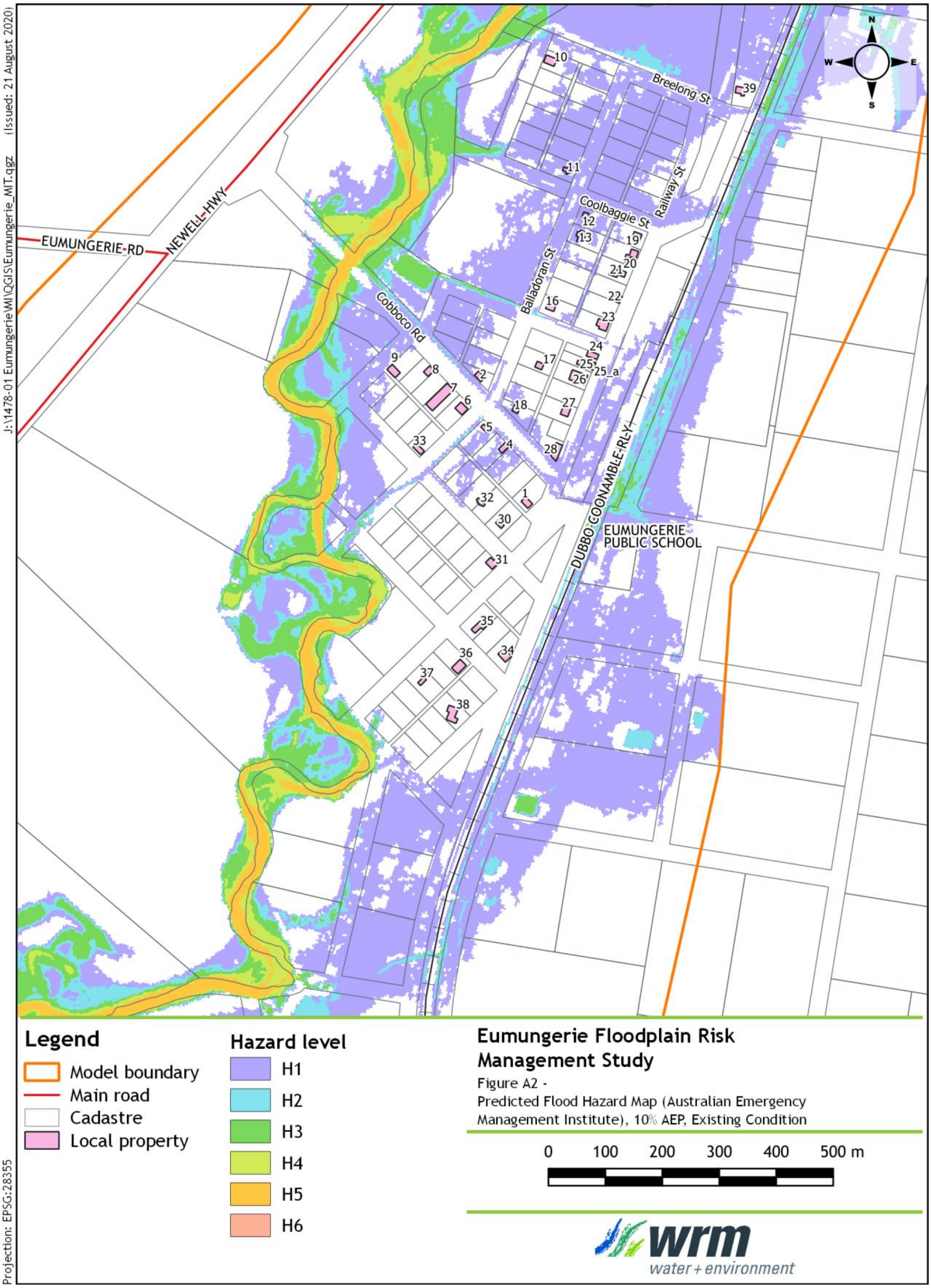

Figure A 2 - AIDR (2017) hydraulic hazard, 10% AEP design flood

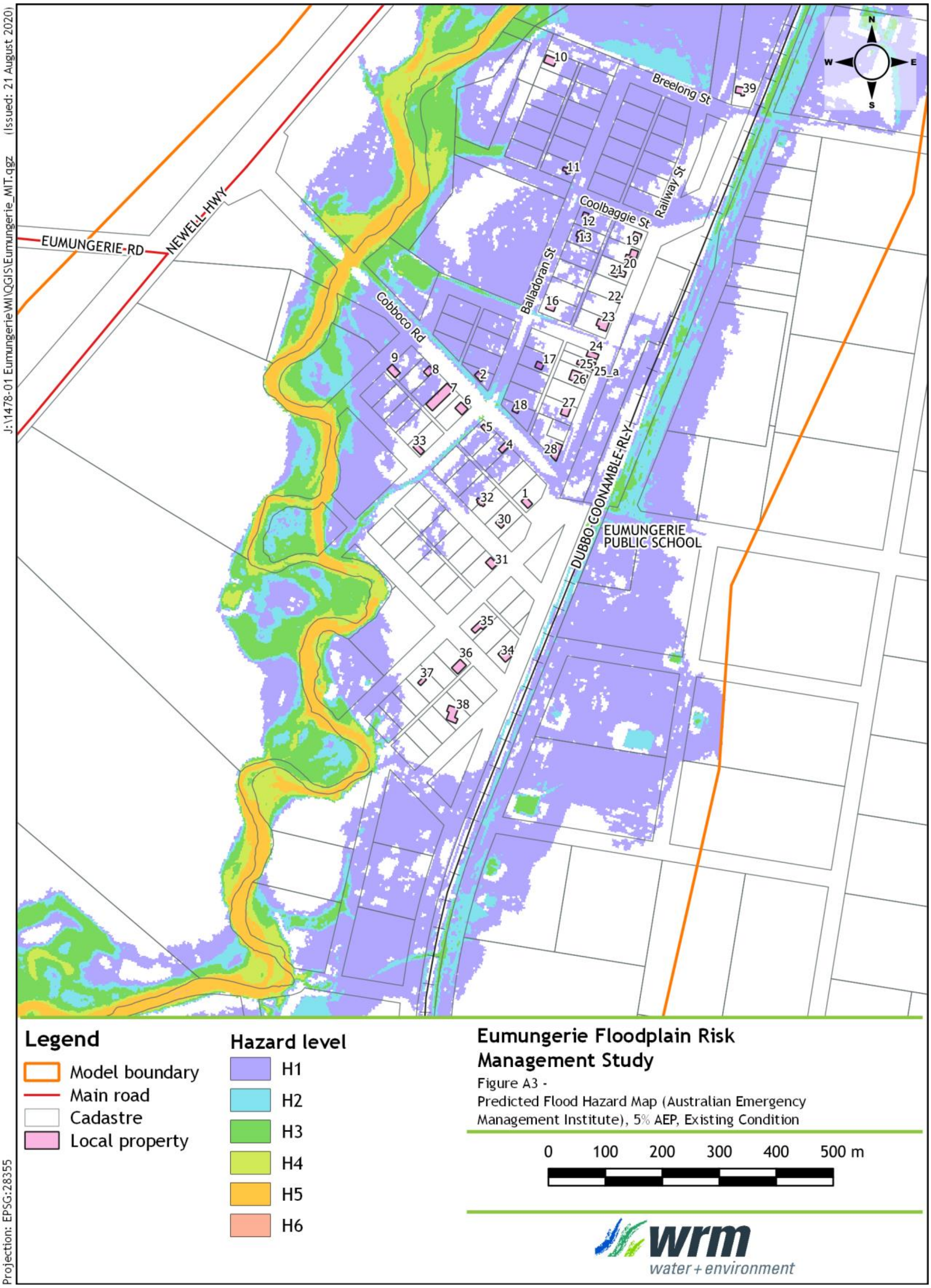

Figure A 3 - AIDR (2017) hydraulic hazard, 5% AEP design flood

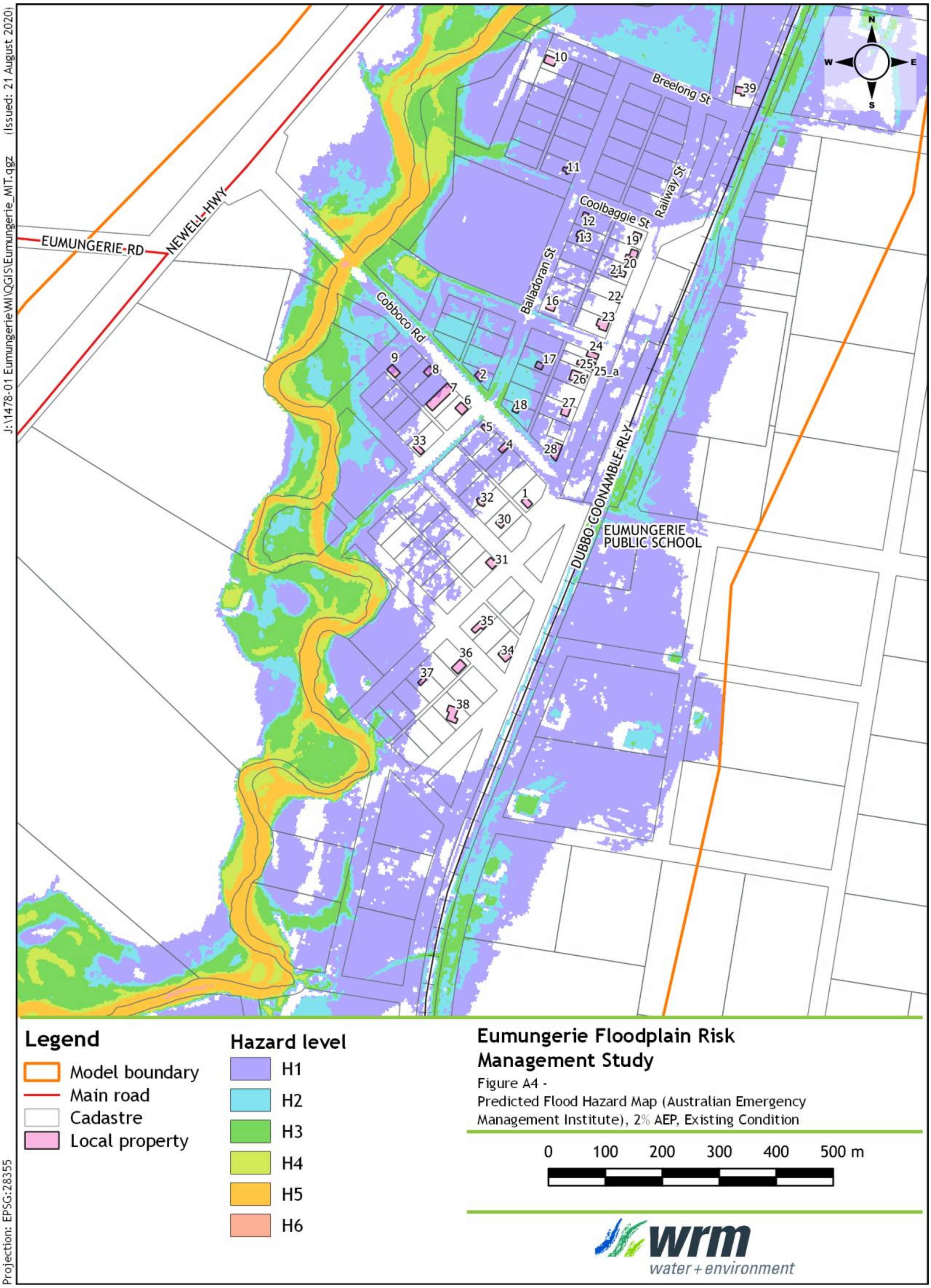

Figure A 4 - AIDR (2017) hydraulic hazard, 2% AEP design flood

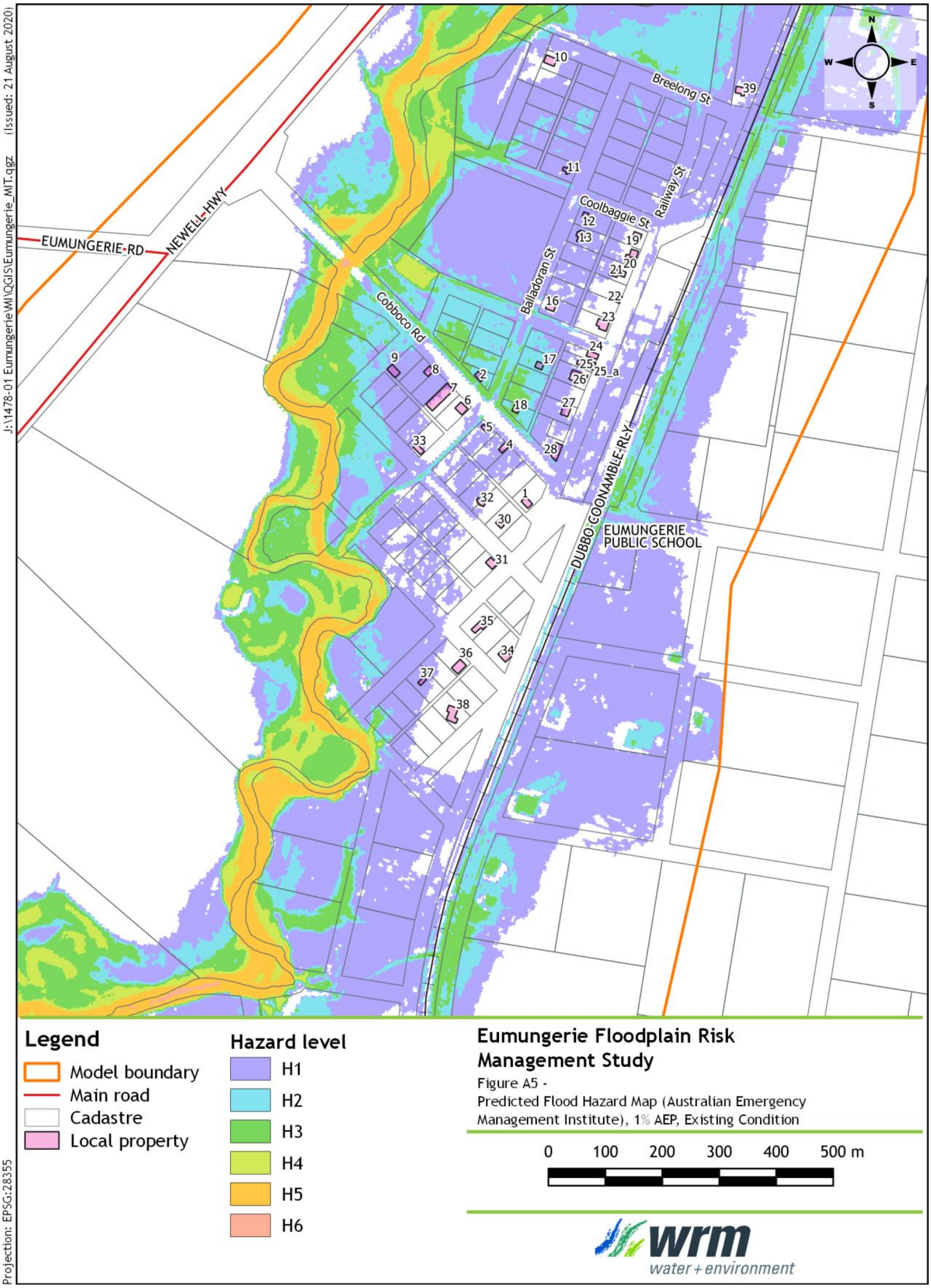

Figure A 5 - AIDR (2017) hydraulic hazard, 1% AEP design flood

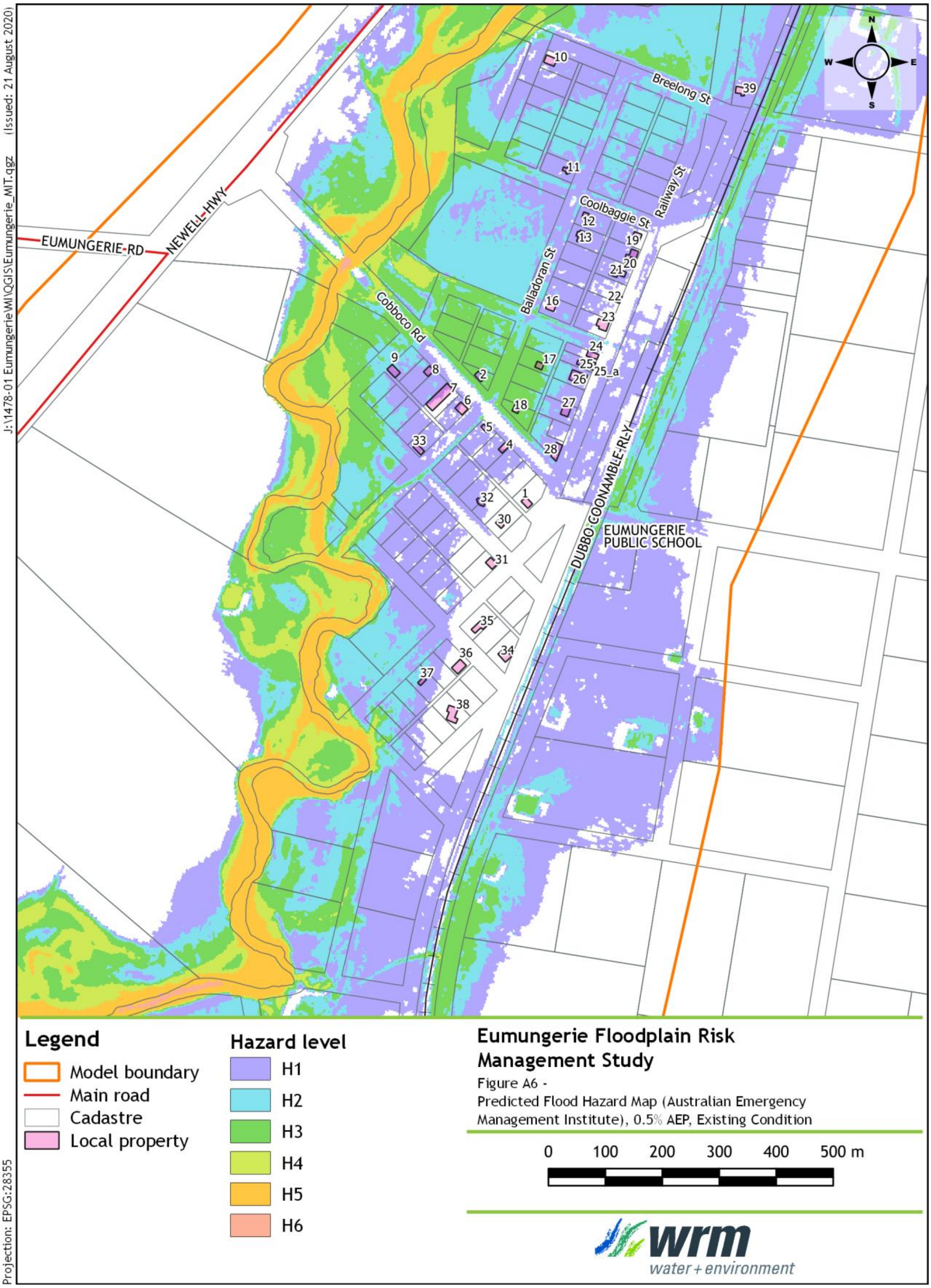

Figure A 6 - AIDR (2017) hydraulic hazard, 0.5% AEP design flood

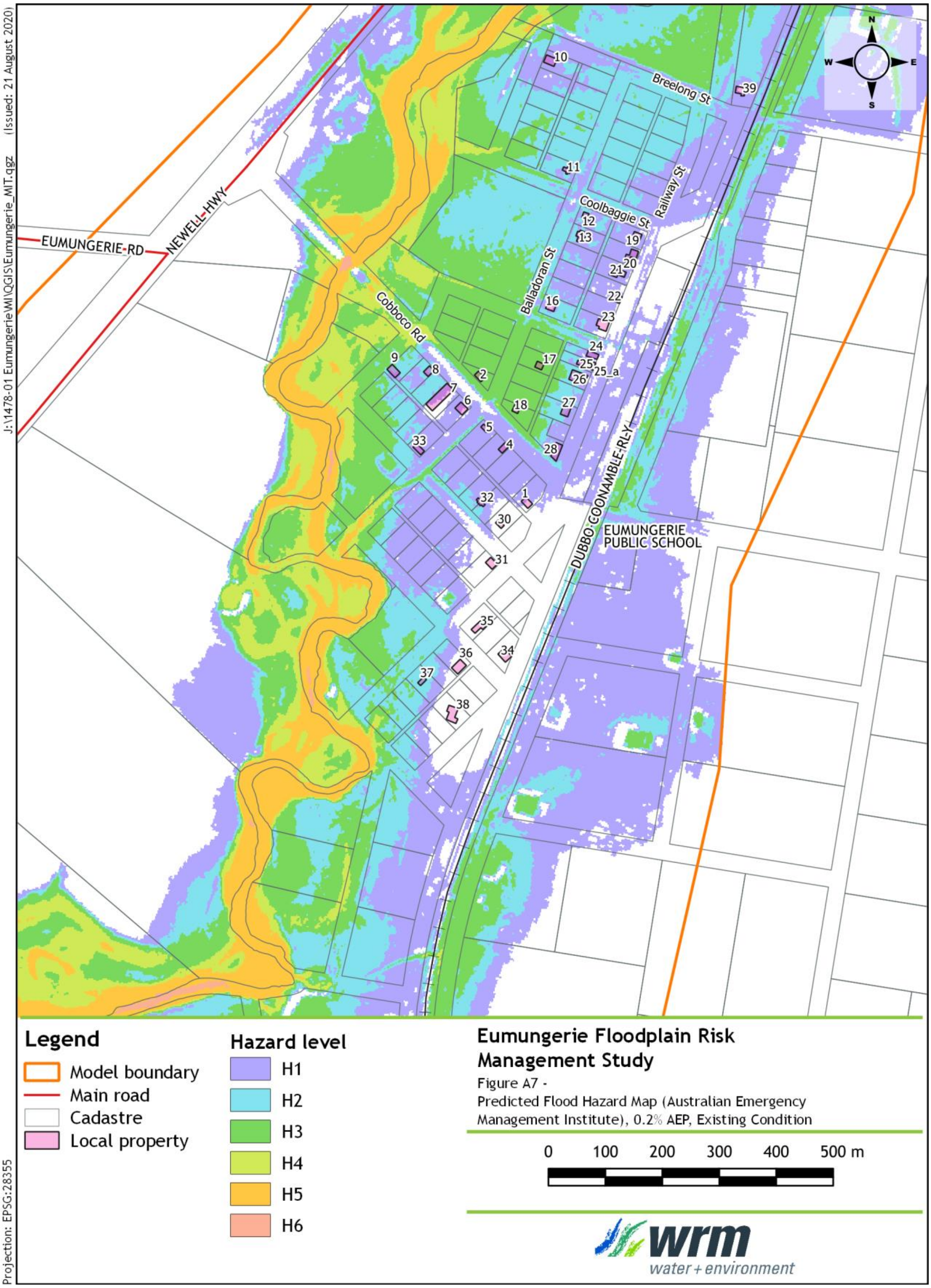

Figure A 7 - AIDR (2017) hydraulic hazard, 0.2% AEP design flood

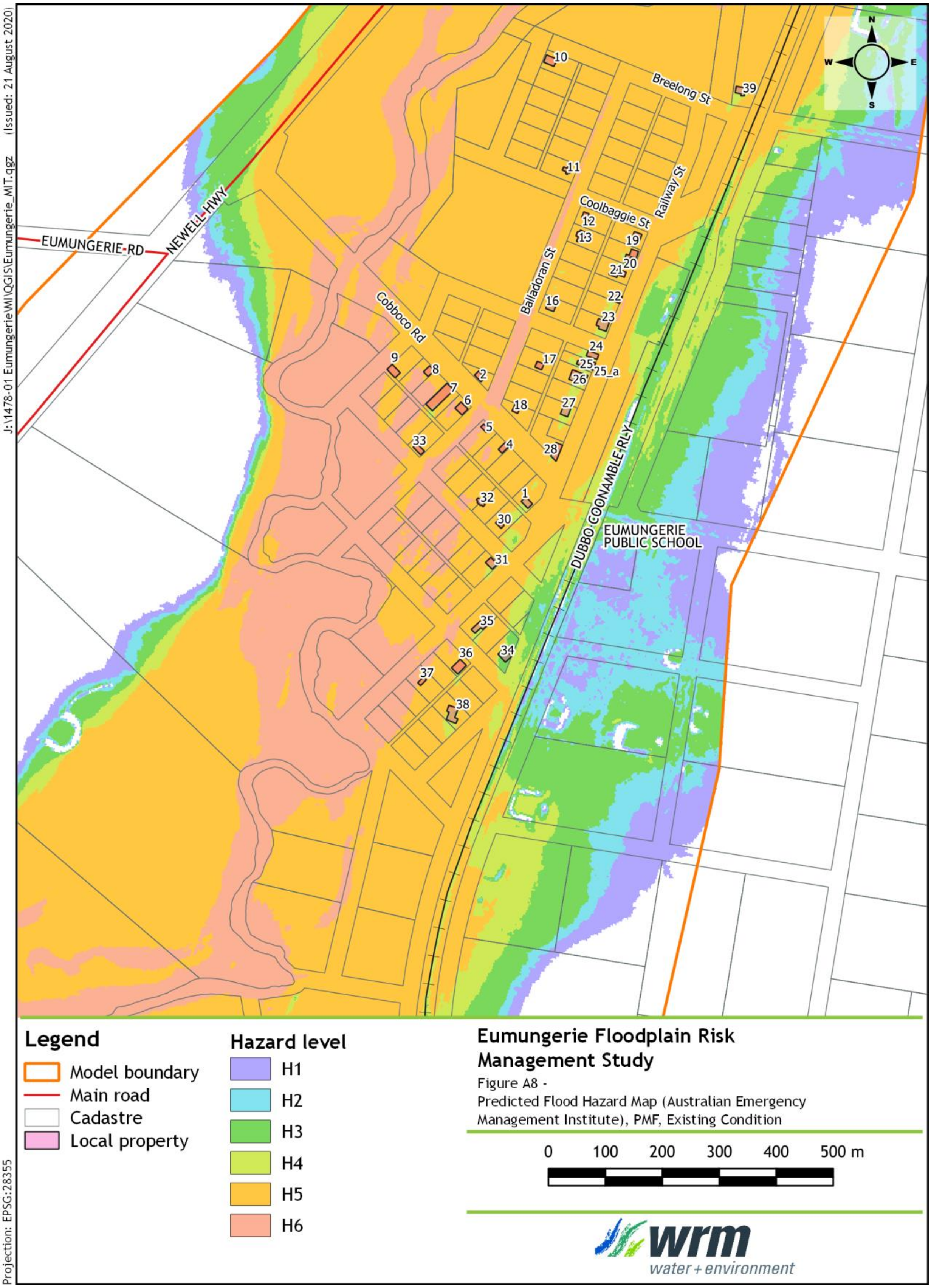

Figure A 8 - AIDR (2017) hydraulic hazard, PMF design flood

Appendix B - Levee and channel scheme flood impact mapping

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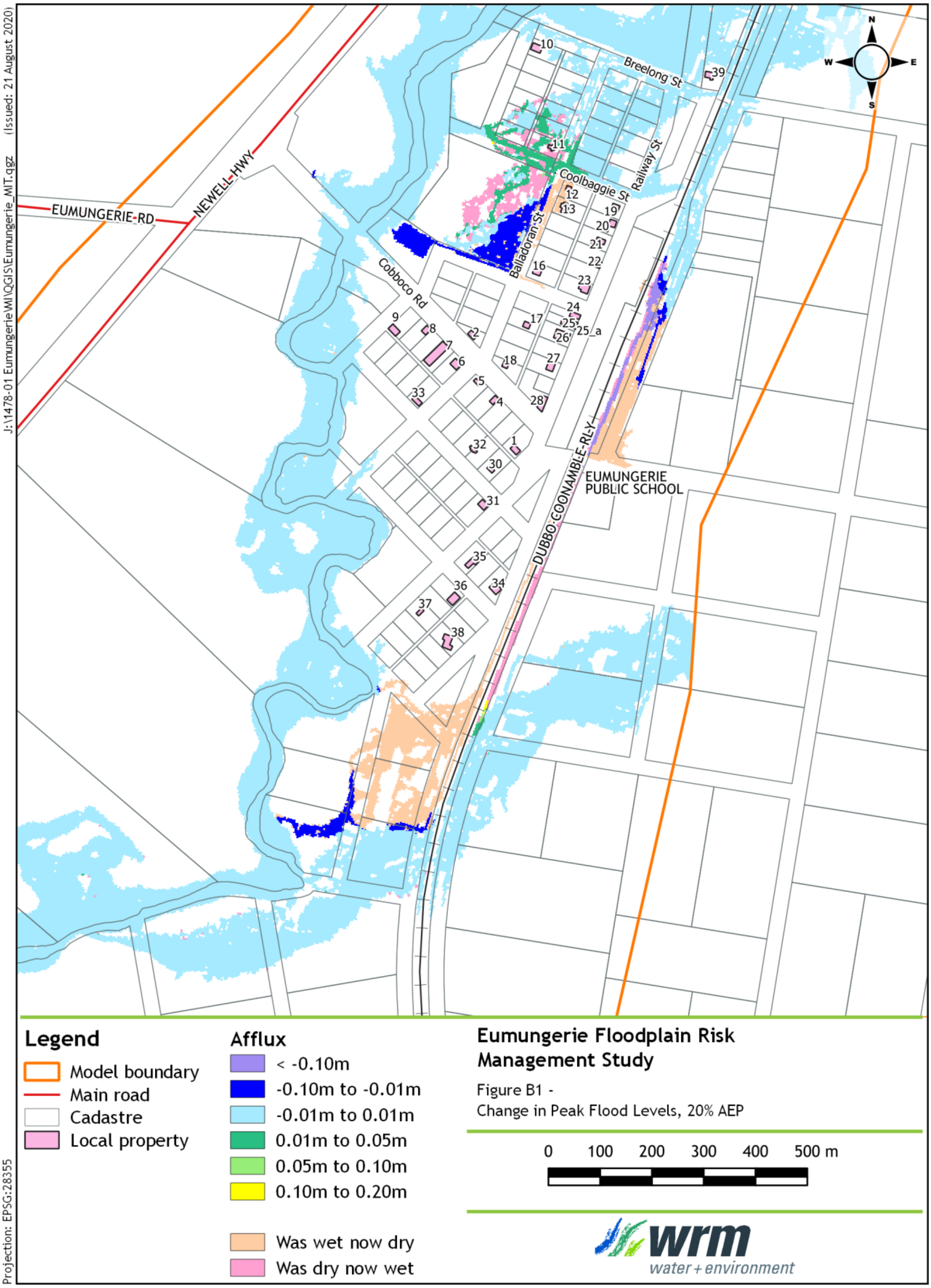

Figure B 1 – Proposed levee and channel scheme flood level impacts, 20% AEP flood

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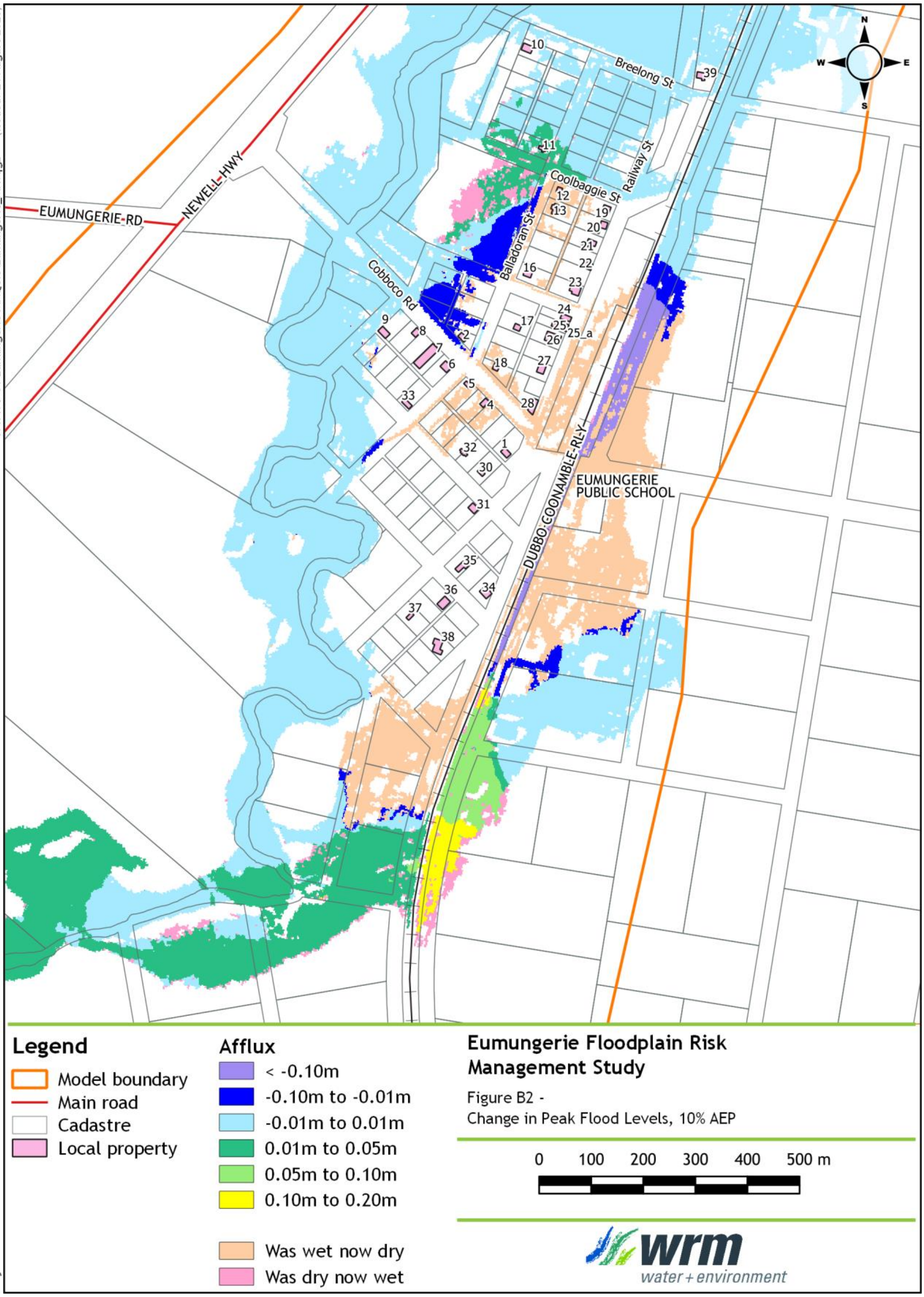

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Figure B 2 – Proposed levee and channel scheme flood level impacts, 10% AEP flood

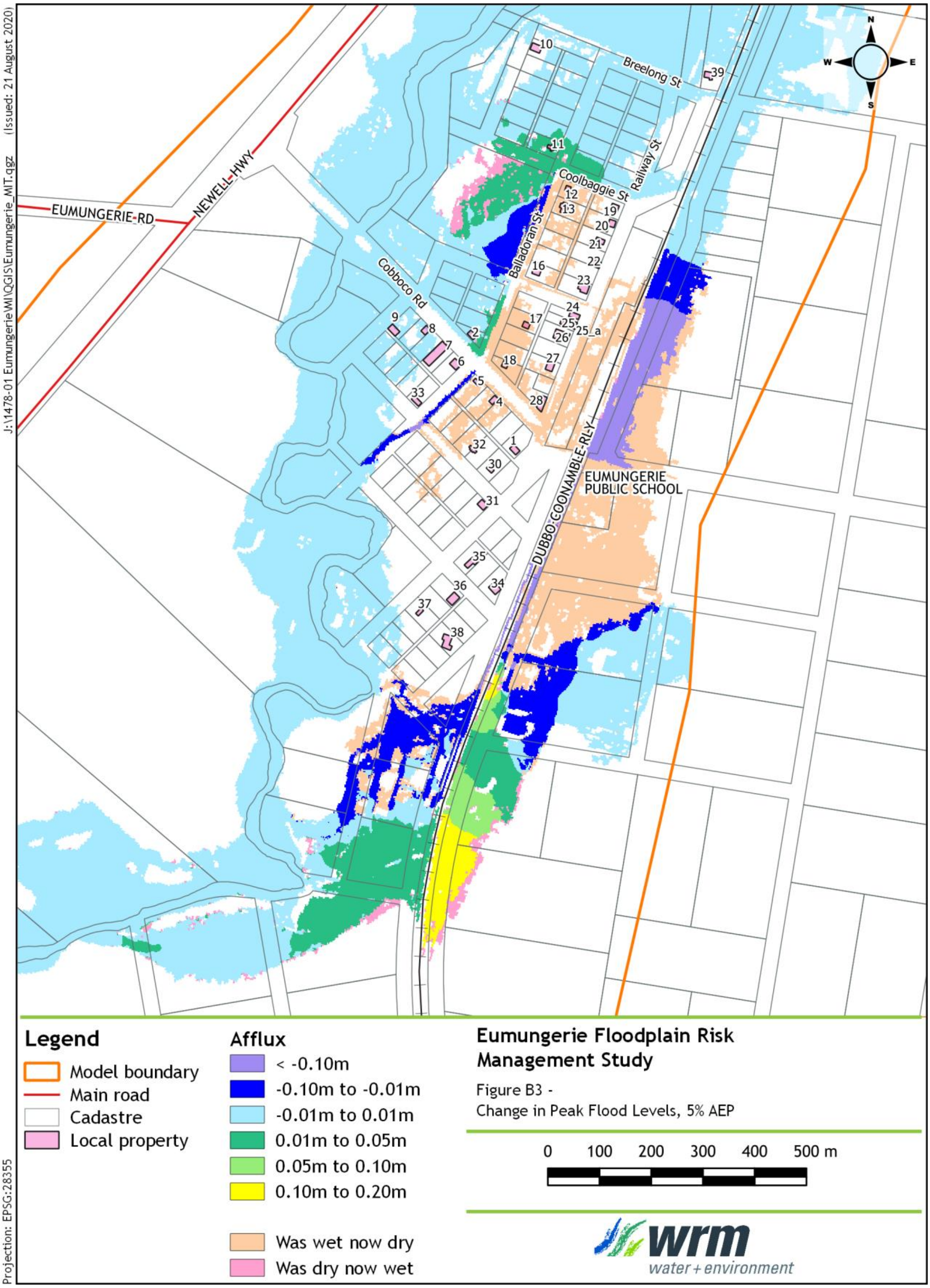

Figure B 3 – Proposed levee and channel scheme flood level impacts, 5% AEP flood

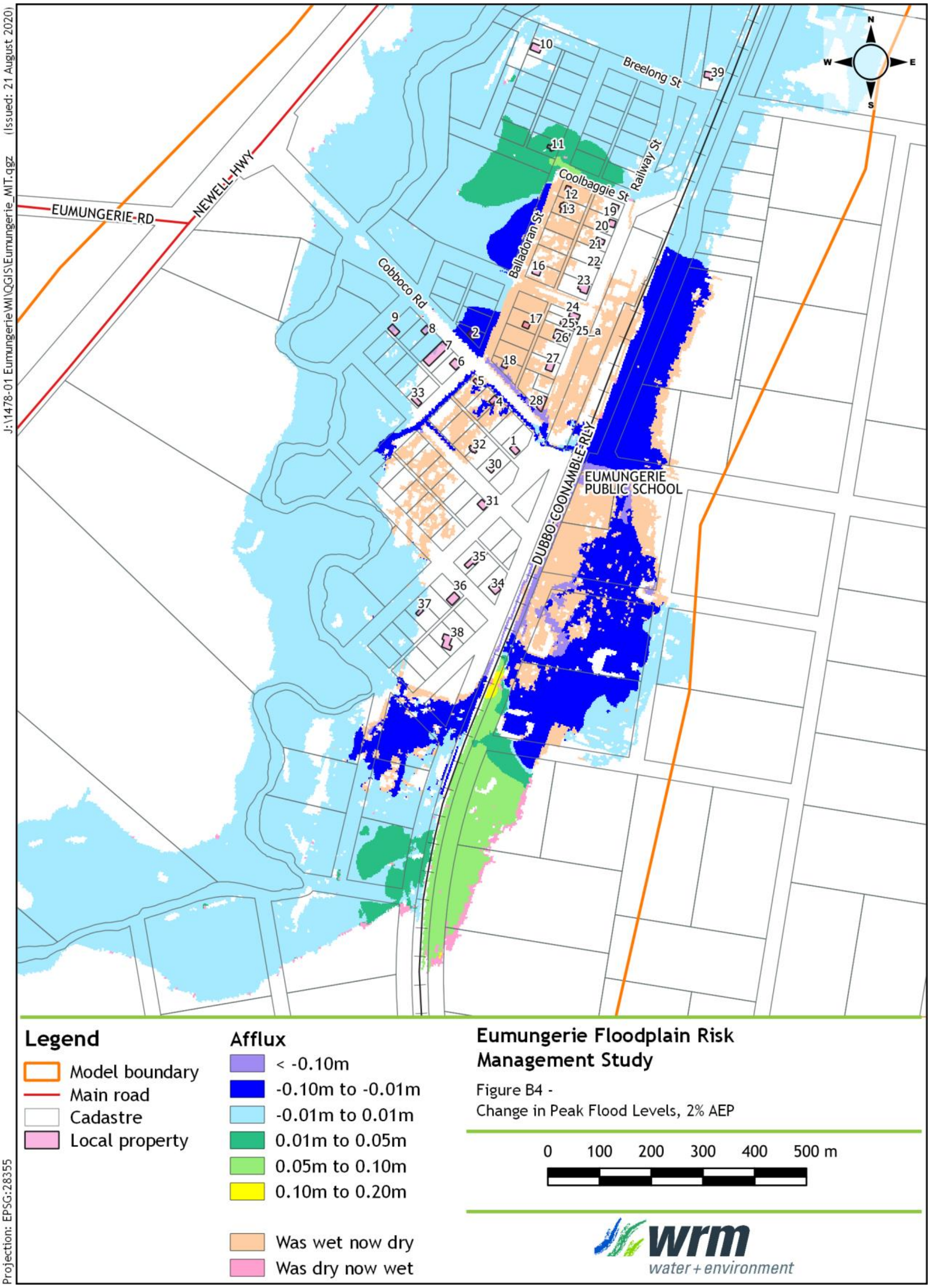

Figure B 4 – Proposed levee and channel scheme flood level impacts, 2% AEP flood

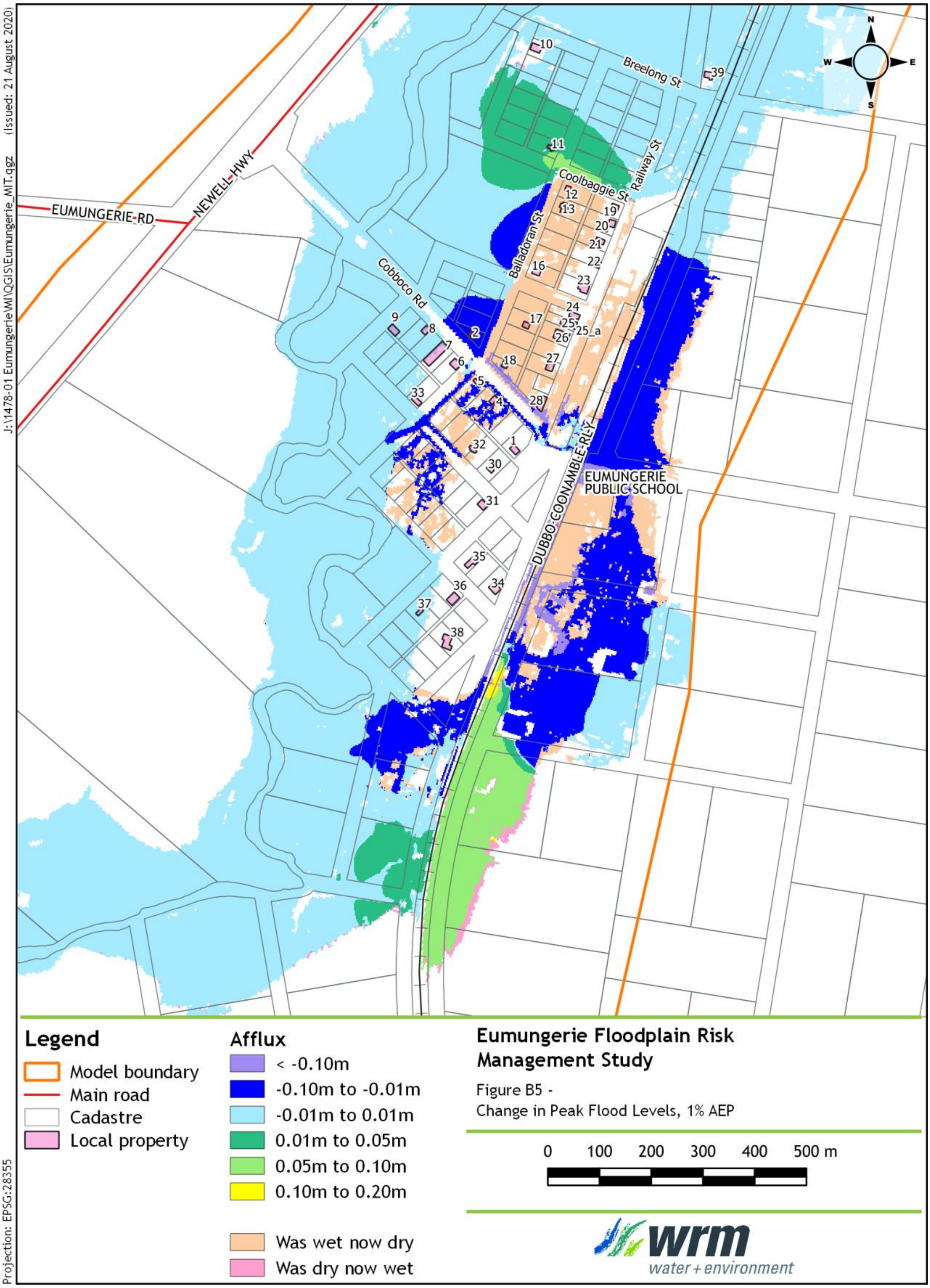

Figure B 5 – Proposed levee and channel scheme flood level impacts, 1% AEP flood

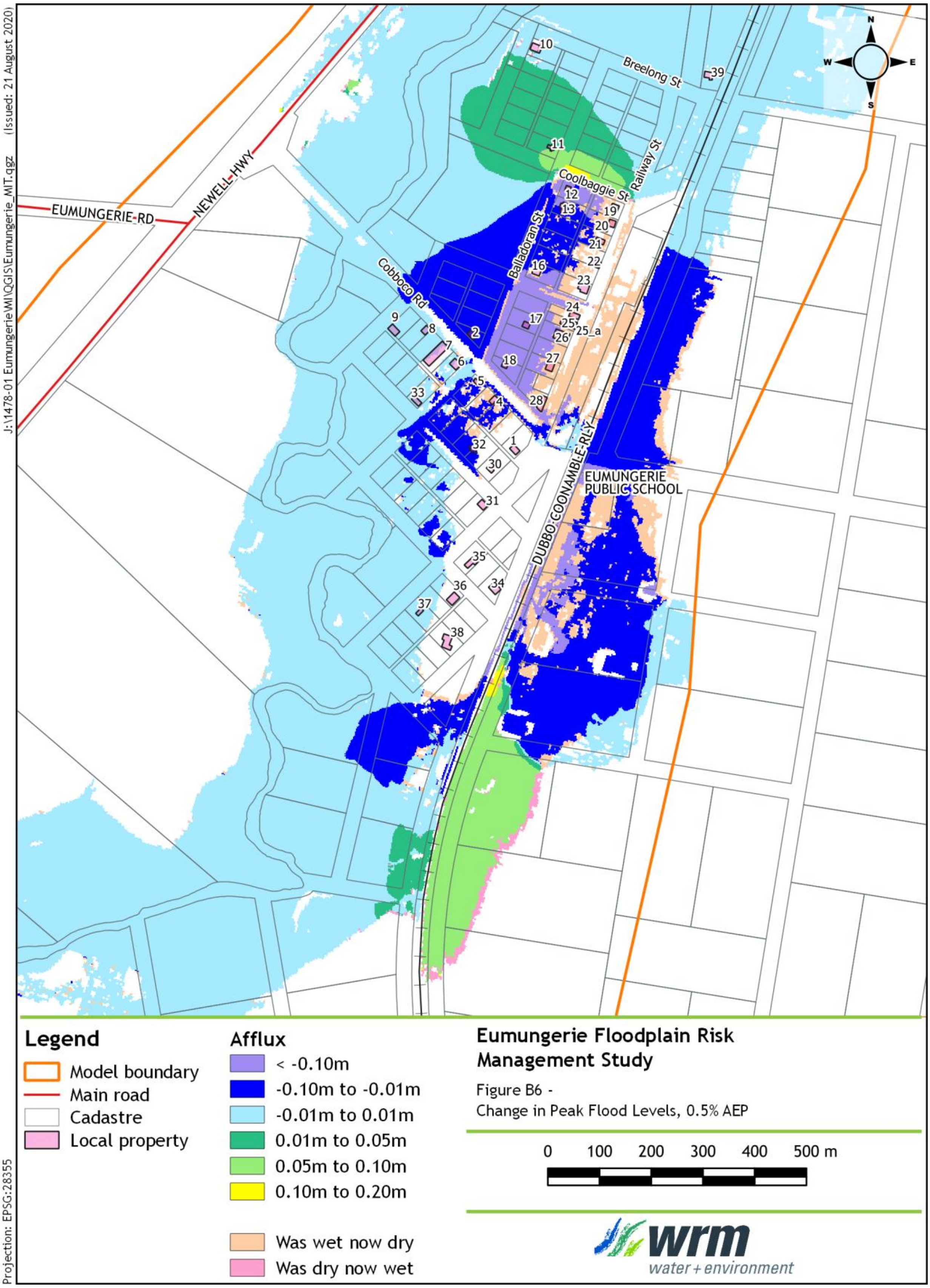

Figure B 6 – Proposed levee and channel scheme flood level impacts, 0.5% AEP flood

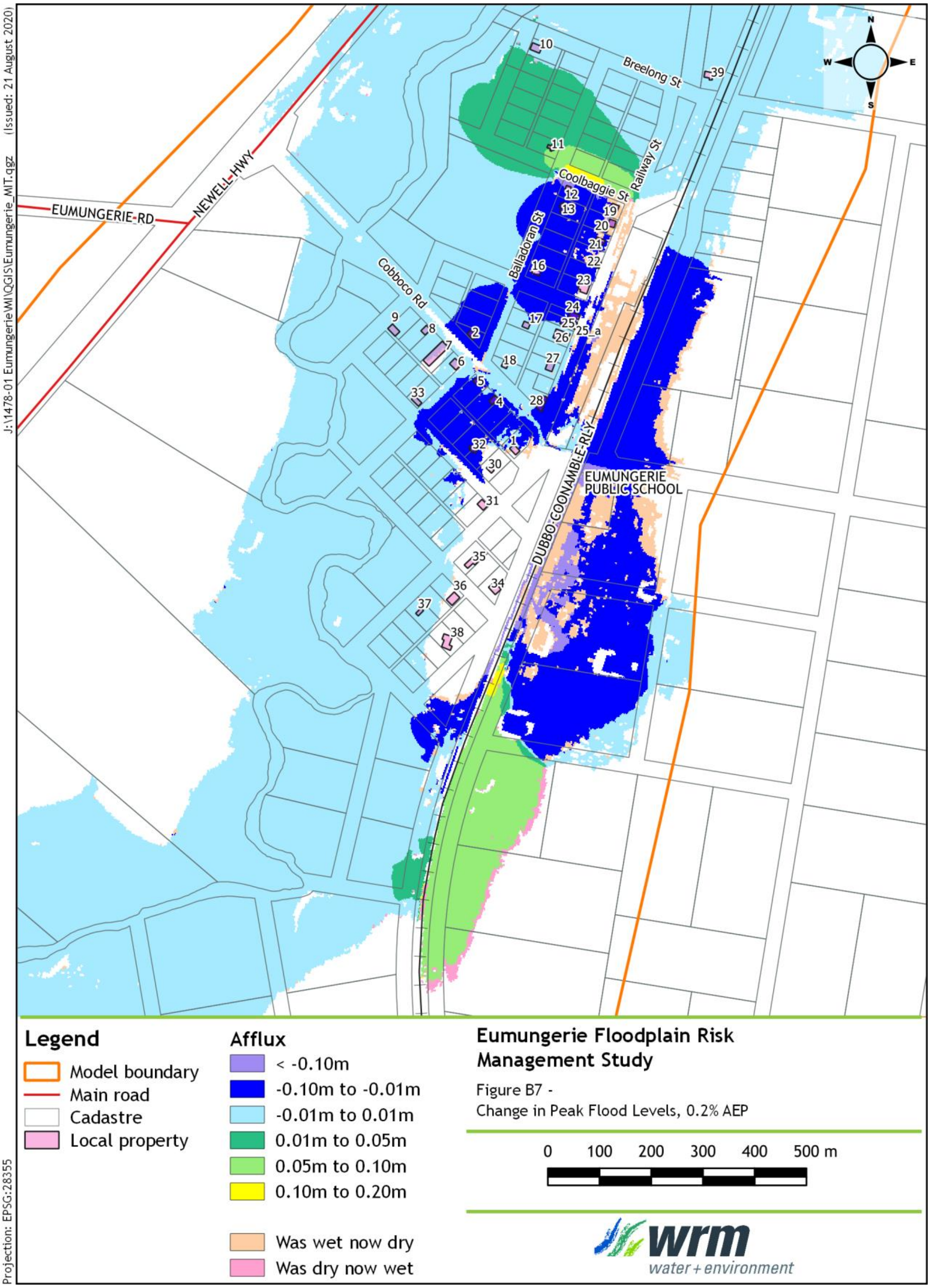

Figure B 7 – Proposed levee and channel scheme flood level impacts, 0.2% AEP flood

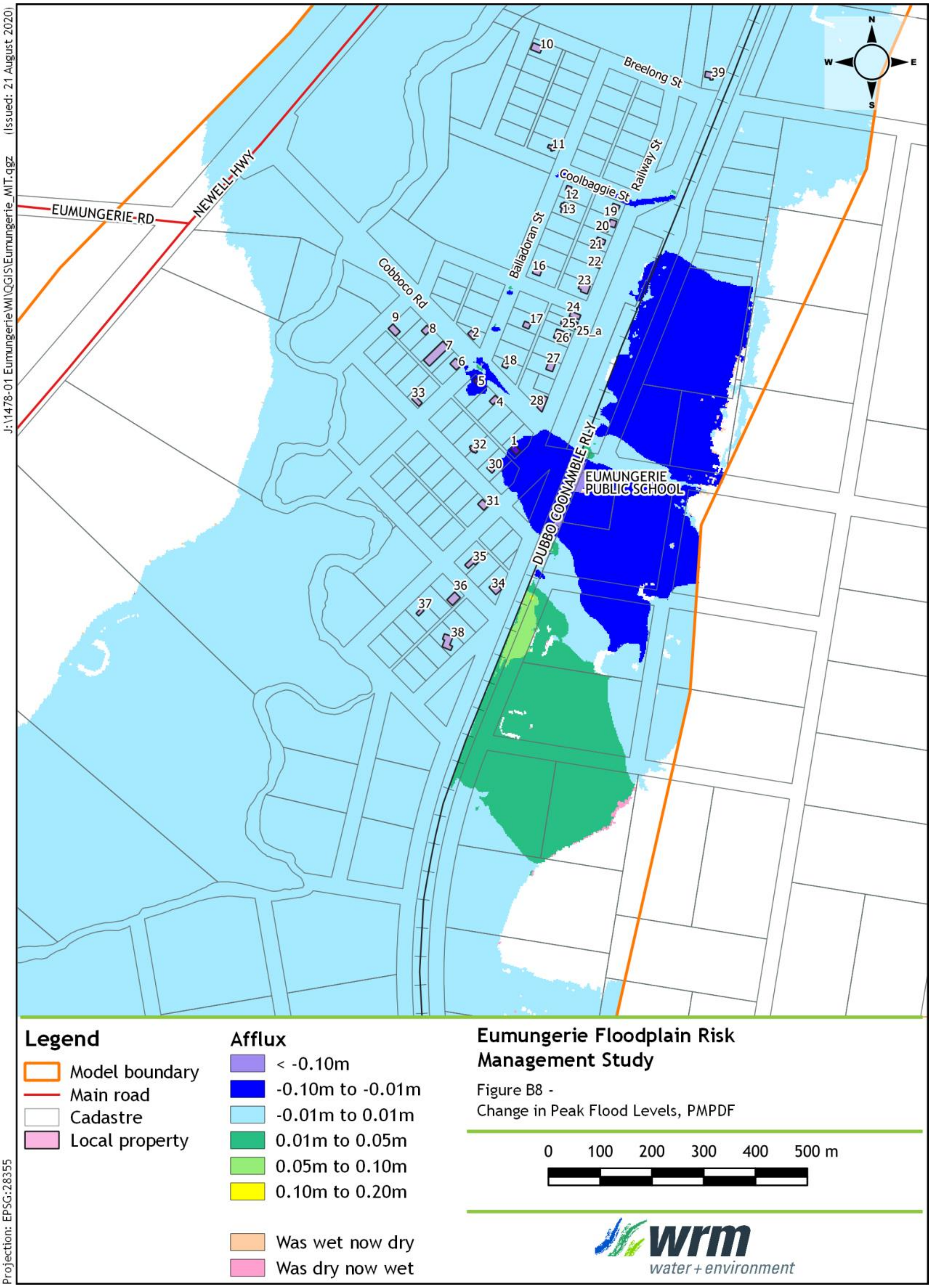

Figure B 8 – Proposed levee and channel scheme flood level impacts, PMF