Harcourt Flood Study Summary Report

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Prepared for: North Central Catchment Management Authority

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Acknowledgments

The project team would like to acknowledge the contributions of the members of the Project Reference Group who help guide the successful completion of the Harcourt Flood Study with their valuable knowledge and insights. The members of the Project Reference Group include:

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- Bryan Balmer – Community Representative
- Jarrod Coote – Community Representative
- John Baldock – Community Representative
- Paul Diss – Mount Alexander Shire Council
- Glenn Deaker – Mount Alexander Shire Council
- Lauren Watt – Mount Alexander Shire Council
- Nathan Lord – Mount Alexander Shire Council
- Nick Butler – North Central CMA
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- Rebecca McDonald – VICSES
- Bob Pratt – VICSES
- Pearl Elgindy – Bureau of Meteorology
- Jarrod Threlfall – Coliban Water
- Lucas Arnup – Coliban Water
- Danny Moloney – Department of Transport and Planning

Definitions

Annual Exceedance Probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood level of 8 m has an AEP of 10%, it means that there is a 10% chance (i.e. a 1 in 10 chance) of a peak flood level of 8 m been equalled or exceeded in any one year (also see average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding to about mean sea level.
Catchment	The area of land that drains to a particular point.
Critical duration	The critical duration is the storm duration for a given event magnitude that provides for the peak flood conditions at the location of interest.
Design flood	A theoretical flood representing a specific likelihood of occurrence (for example the 1% AEP flood).
Flash flooding	Flooding occurring within about six hours of rain, usually the result of intense local rain and characterised by rapid rises in water-levels.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flood depth	The height or elevation of floodwaters above ground level.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum).
Flood model	The model developed for this Study inclusive of both the RORB hydrologic and TUFLOW hydraulic models
Hydraulics	The study of water flow in rivers, estuaries and coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The study of the rainfall-runoff process in catchments.
LiDAR	Remote (aerial) sensing method that uses light in the form of a pulsed laser to measure distance to the Earth. This is used to generate detailed 3D topographical information across an area.
Peak flood level, flow or velocity	Rainfall-runoff routing computer model for hydrologic analysis of catchment runoff.
Probable Maximum Flood	The largest flood that could theoretically be expected to occur at a particular location.
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.

Velocity	The speed at which the floodwaters are moving.

Abbreviations

AGCD	Australian Gridded Climate Data
AHD	Australian Height Datum
AWAP	Australian Water Availability Project
BoM	Bureau of Meteorology
Council	Mount Alexander Shire Council
CFA	Country Fire Authority
DELWP	Department of Environment, Land, Water and Planning
DEM	Digital Elevation Model
DoT	Department of Transport
FSL	Full Supply Level
ICCF	Interim Climate Change Factor
IFD	Intensity-Frequency-Duration
North Central CMA	North Central Catchment Management Authority
PMF	Probable Maximum Flood
PRG	Project Reference Group
RCP	Representative Concentration Pathway
Study	Harcourt Flood Study
TFWS	Total Flood Warning System
The Study	Harcourt Flood Study
The Catchment	The Barkers Creek Catchment to the Study Area downstream boundary
VicSES	Victoria State Emergency Service
WMIS	Water Management Information System

1 Introduction

This report provides a summary of the Harcourt Flood Study (the Study). This information summarised in this report is detailed in the supporting technical reports:

- Data Review Report (Venant Solutions 2022)
- Flood Modelling Report (Venant Solutions 2024a)
- Flood Mapping Report (Venant Solutions 2024b)
- Flood Warning Assessment Report (Venant Solutions 2024c)

The reporting is supported by Investigation deliverables including:

- Calibrated and validated RORB hydrologic and TUFLOW hydraulic models and results
- GIS flood mapping and Spatial Data Specification outputs
- Draft planning scheme overlay mapping
- Municipal Flood Emergency Plan updates

1.1 Background

Harcourt is a township of 1,038 people, as of the 2021 Census that has been identified as a town that can accommodate growth in the Mount Alexander Shire Council (Council) region (Council 2018).

Despite recent flood events in 2010, 2011, 2016 and 2022 little information currently exists defining the flood risk in Harcourt. It was identified by the North Central Catchment Management Authority (North Central CMA) in the North Central Regional Floodplain Management Strategy 2018–2028 (North Central CMA 2018) that addressing this gap in knowledge through a flood mapping project and updating planning controls for Harcourt are regional priorities.

In response Council has received funding from the Victorian and Commonwealth Governments through the Risk and Resilience Grants Program, and in partnership with North Central CMA have engaged Venant Solutions to undertake the Harcourt Flood Study.

The purpose of this Study is to identify areas of flood risk and increase community resilience to flooding by achieving the following objectives:

- Define flood related controls in the Mount Alexander Planning Scheme
- Develop flood intelligence products and inform emergency response planning
- Assist in the preparation of community flood awareness and education products
- Assess feasibility for improved flood warning arrangements
- Provide information for the assessment of flood risk

1.2 Study Area and catchment description

Harcourt is located approximately 10 km north-east of Castlemaine and approximately 25 km south of Bendigo (Figure 1-1). The Harcourt township and most of its residences are primarily located on the eastern bank of Barkers Creek (Figure 1-2). However, the Study Area (Figure 1-1) extends from the Barkers Creek Reservoir in the north to Merrifield Street in the south covering rural and semi-rural areas of North Harcourt, Harcourt, Barkers Creek and the northern outskirts of Castlemaine. The Study Area includes important primary and secondary transport links including the Calder Freeway, Midland Highway, Harmony Way and the Bendigo railway line.

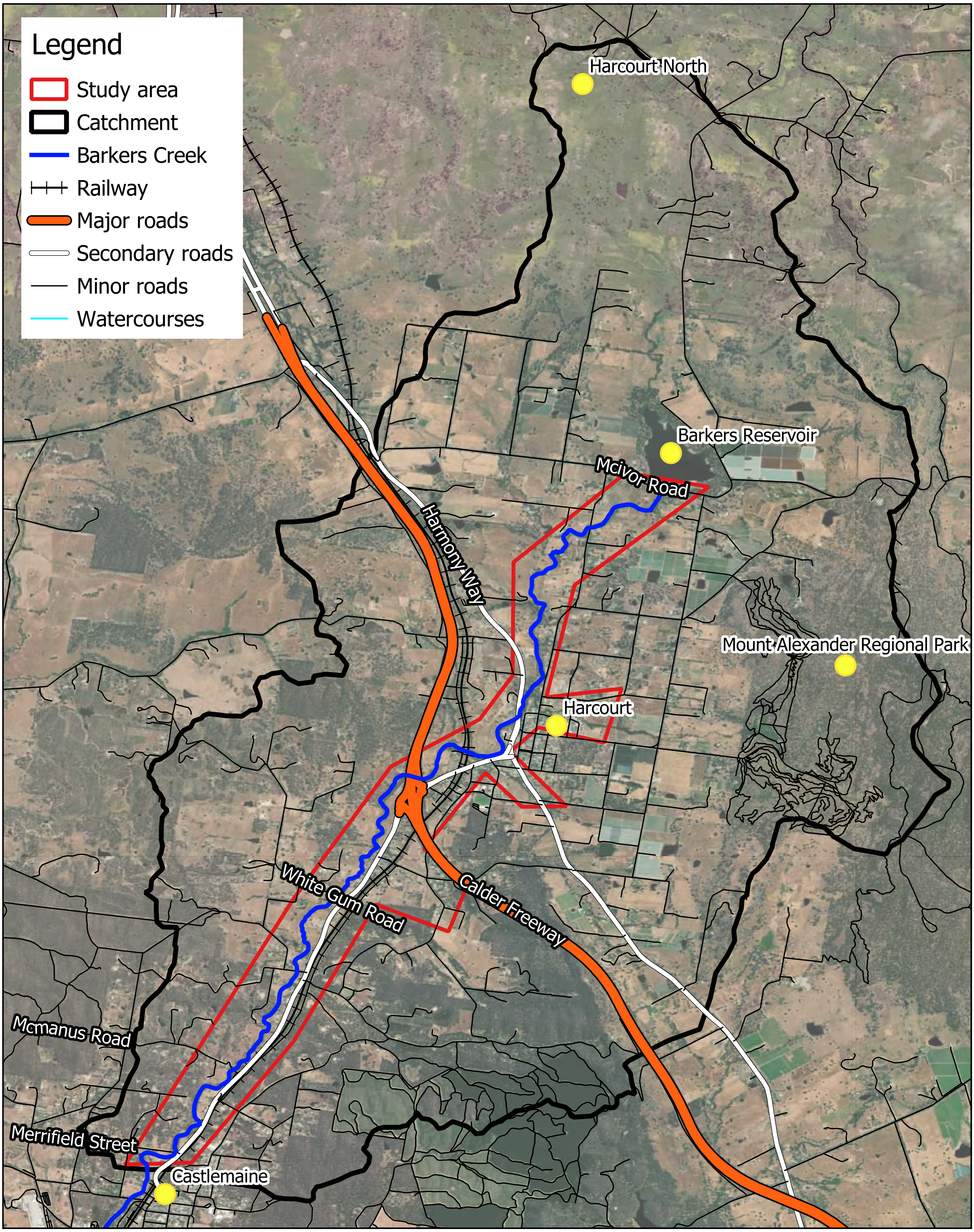
The Barkers Creek catchment (the Catchment) (Figure 1-1) is generally well defined as it is located in the hills of the Great Dividing Range. The Catchment flows in a generally southerly direction towards and through

Castlemaine before flowing into Campbells Creek and the Loddon River. From the upstream to the downstream extent of the Study Area the Catchment has an area of 67 km^2.

The primary land use within the Catchment beyond the residential and commercial areas of Harcourt itself is agriculture though it includes conservation areas such as the large Mount Alexander Regional Park as well as many smaller nature and bushland reserves.

The Barkers Creek Reservoir operated by Coliban Water for irrigation water supply purposes is located in the upper reaches of Barkers Creek (Figure 1-2), with a contributing catchment of approximately 13 km^2 or 20% of the Catchment.

Generally, the waterways and gullies in the Catchment are well defined. However, in the Harcourt township itself between Harmony Way and the Calder Freeway the channel is relatively undefined. Through Harcourt and in some areas upstream, the Barkers Creek main channel is densely vegetated, while downstream of the Calder Freeway the channel is relatively clear with dense vegetation along the banks. There are two tributaries that flow into Barkers Creek in Harcourt; Eagles Channel and Picnic Gully Creek.



Title: Harcourt Flood Study
Catchment and Study Area Layout

Figure:	Rev:	Scale		By: JS
1-1	A	1 0 1 km	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Feb 2024

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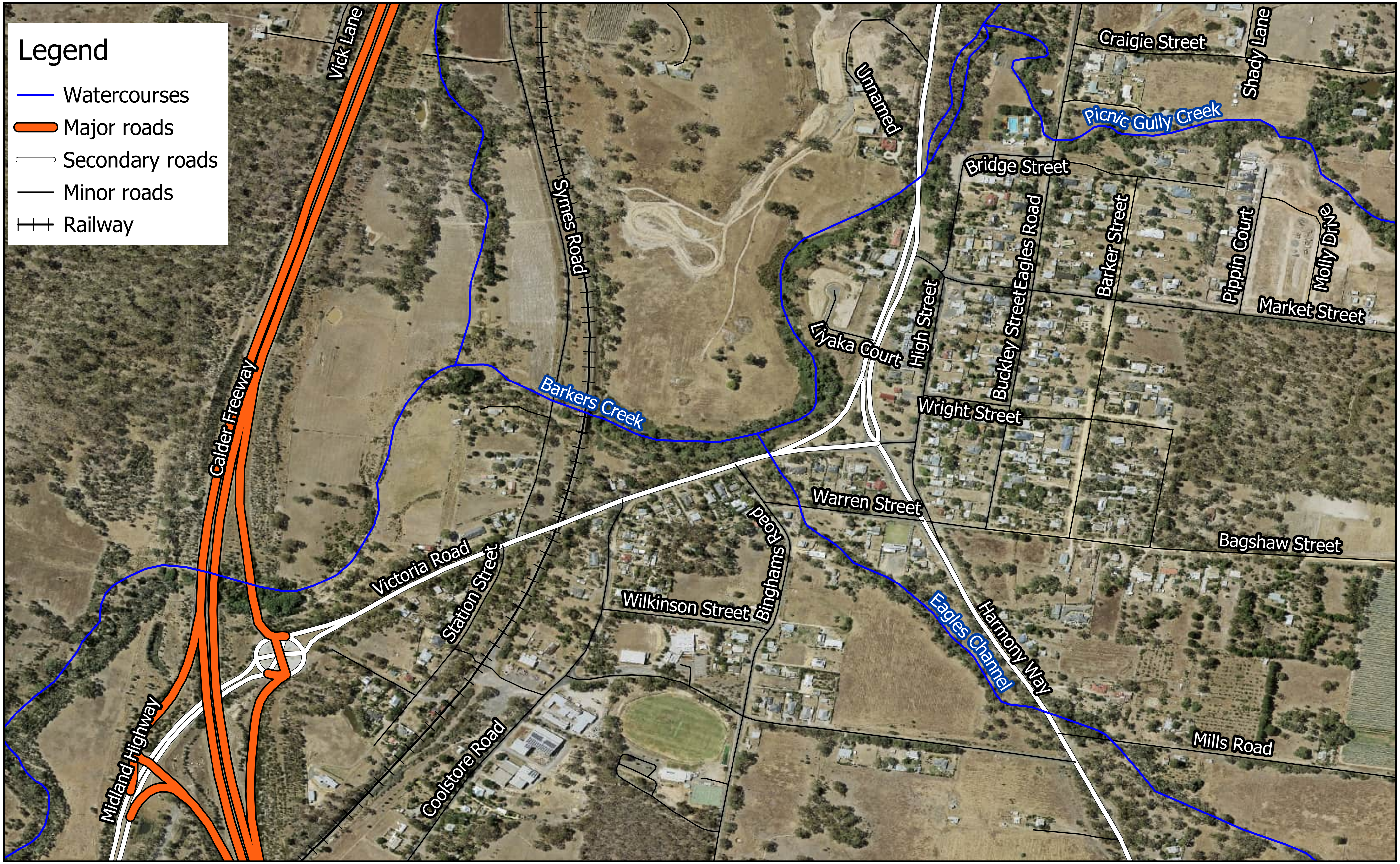

Title: Harcourt Flood Study
Harcourt Township Layout

Figure: 1-2

Rev: A

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This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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By: JS

Date: Feb 2024

2 Stakeholder engagement

The local knowledge provided was invaluable to the successful completion of this Study by providing data inputs to, and validating the outputs of, the flood modelling, and identifying potential structural mitigation and flood warning options for assessment.

2.1 Project Reference Group (PRG)

To support the Study team (Council, North Central CMA and Venant Solutions) in completing the Study a Project Reference Group (PRG) was established including representatives from the local community, Council, North Central CMA, Harcourt Progress Association, Coliban Water, Bureau of Meteorology (BoM), Department of Energy, Environment and Climate Action (DEECA), Victorian State Emergency Service (VICSES) and Department of Transport (DoT).

Two PRG meetings were held during the Study as summarised below with a third scheduled following the completion of the Study to present the final outcomes:

- **PRG Meeting 1 (19 August 2022) -** The first PRG meeting was held in Harcourt on 19 August 2022. The purpose of this meeting was to provide an overview of the Study tasks, gather information and discuss aspects of the Study of particular relevance to the local community. During this meeting the following information was provided:
    - Broken culvert near ANA Hall in Harcourt causing flooding
    - The swimming pool popped out of ground due to flooding from Picnic Gully Creek (1972?)
    - There are no known arterial road closures as a result of flooding in the area
- **PRG Meeting 2 (29 August 2023) -** The second PRG meeting was held in Harcourt on 29 August 2023. The purpose of this meeting was to present the model calibration results and draft flood mapping, and confirm the next steps.

2.2 Community sessions and display of draft mapping

The local knowledge provided by the PRG was complimented by information provided by the local community at three sessions as summarised below with a fourth scheduled following the completion of the Study to present the final outcomes:

- **Community Session 1 (3 August 2022) -** The first community session was held at the Castlemaine Farmers Market on 3 August 2022 to introduce the Study to the community and request historic flood information. During this session the following information was provided:
    - Flood photos throughout the Study Area taken on 4 September 2010
    - The waterway that runs behind the bowls club has been historically altered and now is cut off by several dams east of Harmony Way
- **Community Session 2 (19 August 2022) -** The second community session was held at the Harcourt Produce and General Store on 19 August 2022 to introduce the Study to the community and request historic flood information. During this meeting the following information were provided:
    - Identification of the 2016 flood extent behind the Harcourt Produce and General Store
- **Community Session 2 (25 October 2023)** – The third community session was held at the Harcourt Recreation Reserve on 25 October 2023 to present the model calibration results and draft flood mapping. Unfortunately there were no attendees at this session.

The draft 2016 and 2022 calibration event, and 1% Annual Exceedance Probability (AEP) RCP 8.5 year 2100 climate change flood mapping was also presented on Council's web mapping portal for comment where five submissions were received.

3 Data review

A comprehensive set of data was collected and reviewed for the Study from a broad range of resources including Council, North Central CMA, DEECA, DoT, BoM and publicly available datasets such the Water Measurement Information System (WMIS), Victorian spatial data online portal and the National Library of Australia's Trove newspaper online library. This data was supplemented by data provided the PRG and the local community along with data captured during the site visits and field survey. Table 3-1 provides a summary of the data collected and reviewed, while a full description of the data review tasks is provided in the Data Review Report (Venant Solutions 2022).

Table 3-1 Data review summary

Data	Description
Previous studies	No detailed flood studies of Barkers Creek in the Harcourt area have previously been undertaken, however the following relevant previous studies have been identified: • North Central Regional Floodplain Management Strategy 2018-2028 (North Central CMA 2018) • Castlemaine, Campbells Creek and Chewton Flood Management Plan (GHD 2015)
Historic flood data	In addition to the community information, the following historic flood data has been collected: • Photos of the September 2010 flood event showing the Merrifield Street floodway depth indicator • Photography of the past 4 major floods (2007, 2010, 2016, 2022). Additional photography was sourced from newspaper articles and other media • Surveyed flood marks of the October 2022 flood event • Newspaper articles and other media
Topographical data	The following digital elevation models (DEM) datasets were obtained: • 2020 North Central Riparian LiDAR • 2009-10 ISC Rivers LiDAR • VicMap Elevation DTM 10m Verification of the vertical accuracy of the LiDAR data against permanent survey marks and spot heights captured during the field survey confirmed that LiDAR accuracy and coverage is appropriate for use in the flood model.
Rainfall data	Historic daily and sub-daily rainfall data was sourced from a number of locations: • Daily total rainfall records from the Bureau of Meteorology (BoM) Climate Data Online portal • BoM sub-daily (pluviograph) rainfall records • Sub-daily (pluviograph) rainfall records for gauges not operated by BoM accessed via the WMIS • Rainfall records from private rain gauges accessed via the Weather Underground website Verification of the rainfall data available for each selected historic event was undertaken.

<table>
<tr><td>Barkers Creek Reservoir data</td><td>Coliban Water provided data for the Barkers Creek Reservoir including:
Report for Barkers Creek Reservoir Dam Break Analysis (GHD 2012) which includes the storage-discharge relationship
Spillway plan details
Records of reservoir volume and water level from 2004 to 2022</td></tr>
<tr><td>Hydraulic structures</td><td>Hydraulic structures, including culverts and bridges, are located on waterway crossings throughout the Catchment and are managed by various authorities. The following information on the various bridges and culverts has been obtained:
Location and attribute spreadsheet of council managed road bridges and culverts
Plans of bridges and culverts along major roads were provided by DoT
Details and photos of railway bridges and culverts were provided by V/Line
Field survey of key structures
Inspections and measurements of structures along the key watercourses and roads undertaken by Venant Solutions staff</td></tr>
<tr><td>GIS data</td><td>GIS data was sourced from the Victorian Spatial Datamart online portal. The GIS data sourced includes:
Planning Zones and Overlays - Used to define catchment landuse to aid in determining catchment fraction imperviousness and surface roughness
Property Parcels - Used to populate flood intelligence outputs and undertake economic flood damages assessment
Watercourse - Used to identify and present waterways for mapping products</td></tr>
<tr><td>Site visit</td><td>Venant Solutions, accompanied by the North Central CMA undertook site visits on 22 June 2022 and 19 August 2022. Areas of interest were visited including the hydraulic structures along key waterways and roads.</td></tr>
<tr><td>Field survey</td><td>Survey was commissioned to obtain the following:
Details of six bridge and culvert crossings
Details of the drainage through the ANA Hall reserve
Staff gauge levels at Symes Road and Merrifield Street
Two October 2022 flood marks in Liyaka Court
Road centreline levels at six locations
Floor level survey of 79 buildings</td></tr>
</table>

4 Flood modelling

A RORB hydrologic and TUFLOW hydraulic flood model have been developed for this Study. The purpose of the RORB model is to convert rainfall to runoff for a given probability to provide catchment flow rates and timing. The purpose of the TUFLOW model is to represent the physical characteristics of the flow such as flood extent, level and velocity across the Study Area. The flood model has been developed in accordance with the guidance and parameters provided in the 2019 release of Australian Rainfall and Runoff (ARR 2019) (Ball, et al. 2019).

As there are no stream gauges located on Barkers Creek, calibration of the RORB model to recorded stream flows was not possible. Rather, a joint calibration and validation of the RORB and TUFLOW models was undertaken to flood marks and photography available for the September 2010, January 2011, September 2016 and October 2022 flood events as summarised in Section 4.3.

Design event modelling has been defined by ensemble simulation in the TUFLOW hydraulic model to select the critical storm duration and mean temporal patterns.

Flood modelling was undertaken to produce mapping and flood intelligence outputs of the following design events:

- 20% Annual Exceedance Probability (AEP)
- 10% AEP (including RCP 4.5 and 8.5, year 2100 climate change conditions)
- 5% AEP
- 2% AEP
- 1% AEP (including RCP 4.5 and 8.5, year 2100 climate change conditions)
- 0.5% AEP
- 0.1% AEP
- Probable Maximum Flood (PMF)

A detailed description of the flood modelling is provided in the Flood Modelling Report (Venant Solutions 2024a).

4.1 RORB hydrologic modelling

The RORB model covers the entire catchment contributing to Barkers Creek from Harcourt North, draining south-southwest to downstream of Merrifield Street, north of Castlemaine. For this Study delineation into sub-catchments was performed to ensure a minimum of 3-4 sub-catchments upstream of all waterways to be mapped and to provide suitable inflow locations to the TUFLOW model.

Total Impervious Area (TIA) was categorised into three surface types as per ARR 2019: Indirectly Connected Area (ICA), Effectively Impervious Area (EIA), and Pervious Area (PA). TIA values were determined by digitising land use types from planning schemes and aerial photography.

Barkers Creek Reservoir was represented in the RORB model with a storage node using a rating curve, i.e., a water level vs discharge relationship. The drawdown in the reservoir used for design event modelling is 364.50 m AHD. This is equal to the Full Supply Level (FSL) of the reservoir which Coliban Water aims to achieve in its operation of the reservoir.

The RORB model calibrated jointly with the TUFLOW model, as summarised in Section 4.3.

4.2 TUFLOW hydraulic modelling

Details of the model development include a grid size of 2 m with 0.5 m sub-grid sampling, ensuring adequate representation of major waterways while managing model run times. Topography was based on the 2022 North

Central Riparian LiDAR dataset, and was modified using TUFLOW features to rectify channel inconsistencies, reinforce or remove road levels at bridge and culvert crossings and reinforce crest levels of features that control flood behaviour. Surface roughness values were informed by GIS data, aerial imagery, and field inspections. Information used to represent bridges and culverts in the model were obtained from design drawings, site survey, and site inspections. The RORB model was used to generate inflow hydrographs to the hydraulic model and were applied using external QT (flow-time) and internal Sas (source-area) boundaries.

4.3 Joint calibration and validation

With the absence of stream gauges present in the catchment to calibrate the RORB hydrologic model to, a joint calibration and validation process using the TUFLOW hydraulic model was used, to compare the adopted hydrologic and hydraulic parameters to historic flood level marks and photography. Changes were then made to model parameters in an iterative process.

The RORB and TUFLOW models were calibrated to three historic flood events: the September 2010, September 2016, and October 2022 flood events and validated to the January 2011 event. The January 2011 event was selected for validation because there was no flood data available for the event so the models' performance in replicating this event is limited to feedback provided by the community and PRG.

A good fit was achieved to the limited available flood photography and flood level marks for each of the September 2010, September 2016, and October 2022 calibration events confirming:

- The equivalent K_c and *m* RORB model routing parameters adapted from the calibrated Castlemaine, Campbells Creek and Chewton Flood Management Plan (GHD, 2015) are appropriate.
- The initial and continuing losses of 10 mm and 2 mm/hr respectively provide a good fit to all three calibration events (initial loss of 8 mm and continuing loss of 1.7 mm/hr were used for the September 2010 event, used in the September 2010 historic event for the Castlemaine, Campbells Creek and Chewton Flood Management Plan (GHD 2015)).
- The adopted Manning's *n* coefficient over the 2D cells in the TUFLOW model are appropriate.
- The alterations made to the LiDAR DEM in the Barkers Creek channel through Harcourt based on the cross-section survey are appropriate.

Given the good fit to the limited available flood data it is considered that the RORB and TUFLOW models are suitable for design event modelling.

The joint RORB and TUFLOW also identified that the historic flood events with the greatest rainfall magnitudes across the whole storm duration do not necessarily result in the highest flood levels in Study Area where the critical storm durations are 6 hours or less. This is evident by the January 2011 flood event which has the highest total storm event magnitude of approximately 1% AEP. However, the September 2010 and January 2011 events have similar flood depths and extents and both events correlate to approximately a 20% to 10% AEP storm event for the 6 hour event.

4.4 Design event modelling and critical durations

Critical design events were selected by running an ensemble simulation of events from 15 min to 24 hr in the TUFLOW model. Peak flood level for each duration were then mapped based on an average of the 10 temporal patterns. An envelope of the maximum peak flood level for each duration was then created and inspected to select the critical events across the Study Area. The critical events of the results are between 1 to 9 hours in Barkers Creek, 1 to 4.5 hours in Picnic Gully Creek, and 1 to 3 hours in Eagles Channel.

5 Flood mapping and intelligence outputs

Flood depth, level, velocity and hazard mapping outputs were produced for all modelled flood events as listed in Section 4 and presented in the Flood Mapping Report (Venant Solutions 2024b). The following mapping is presented in this report for the 1% AEP and 1% AEP RCP 8.5, year 2100 climate change conditions:

- Figure 5-1 and Figure 5-2: Regional flood depth
- Figure 5-3 and Figure 5-4: Regional flood level
- Figure 5-5 and Figure 5-6: Regional flood velocity
- Figure 5-7 and Figure 5-8: Regional flood hazard
- Figure 5-9 and Figure 5-10: Harcourt township flood depth
- Figure 5-11 and Figure 5-12: Harcourt township flood level
- Figure 5-13 and Figure 5-14: Harcourt township flood velocity
- Figure 5-15 and Figure 5-16: Harcourt township flood hazard

The GIS flood mapping outputs have also been supplied as part of the data handover and have been translated into Spatial Data Specification (SDS) format.

Flood animations have also been produced as part of this Investigation.

The flood mapping is limited to flooding from Barkers Creek and a few smaller tributaries including Picnic Gully Creek and Eagles Channel. Stormwater flooding in Harcourt has not been modelled or mapped.

Flooding in the Study Area is characterised by a narrow flood extent, mostly contained within Barkers Creek and its relatively narrow floodplains. Flood depths greater than 1 m is mostly contained to waterways and farm dams, with the exception of the PMF.

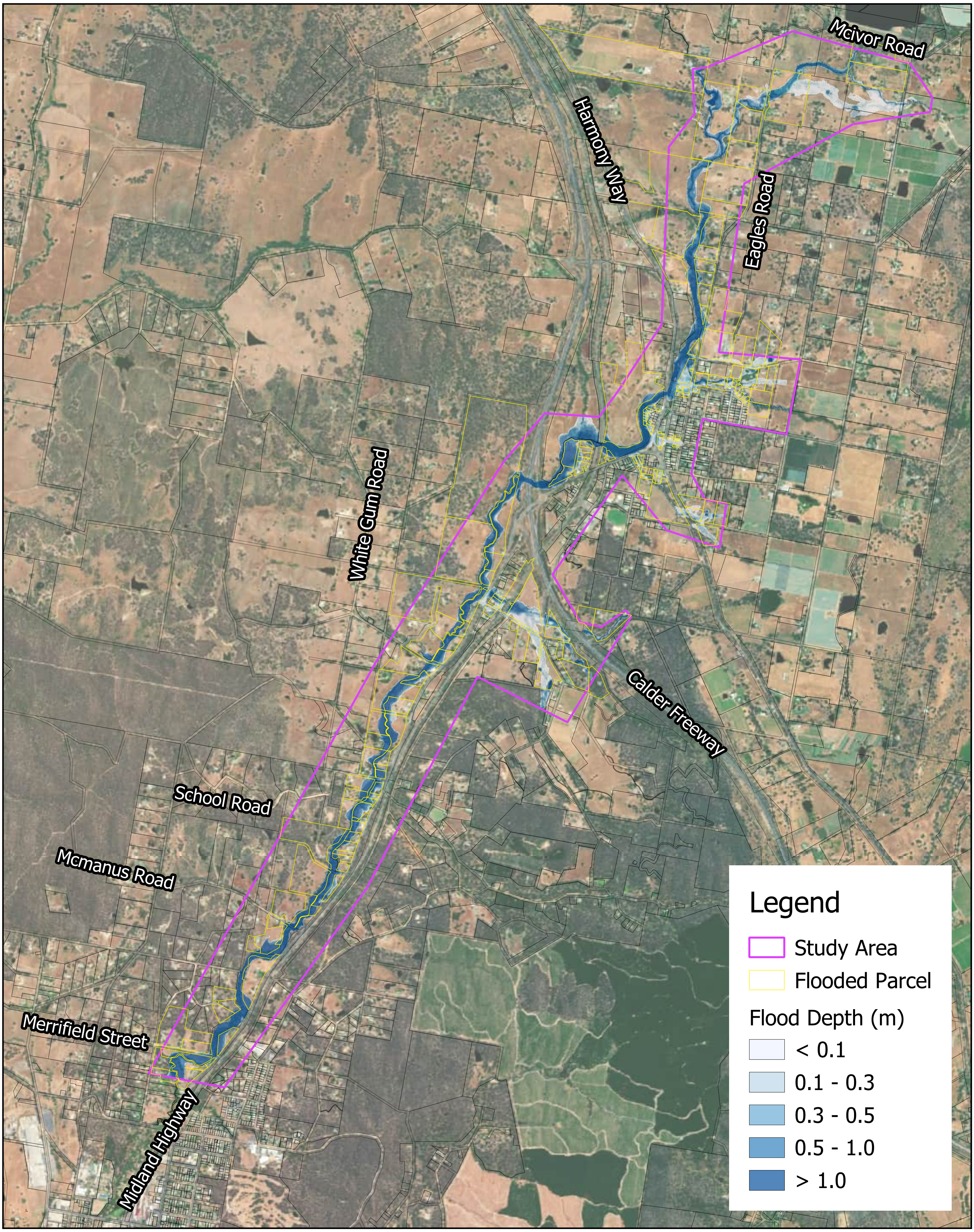
The Harcourt township is largely free from waterway flooding in all events (except the PMF). Inundation of lots between the CFA station and Harcourt Pony Club/Swimming Pool is mainly caused by breakout flow from Picnic Gully Creek. In the 20% AEP event, minor flood depths less than 0.1 m are shown on Harcourt Pony Club/Swimming Pool, while in the 10% AEP event the flood extent begins to increase, including greater flooding of the road reserve and deeper depths on the carpark between Bridge St and Barkers Creek. The depths of breakout flow paths from Picnic Gully Creek to Barkers Creek generally greater than 0.3 m begin to occur from the 2% AEP event. The upgraded Eagles Rd bridge over Picnic Gully Creek is flood immune in the 0.1% AEP event.

Under the 2100 RCP 4.5 climate change scenarios, the 1% AEP event resembles 0.5% AEP current climate event, and the 10% AEP falls approximately halfway between the current climate 10% and 5% AEP events.

Under the 2100 RCP 8.5 climate change scenarios, the 1% AEP event closely resembles the 0.1% AEP current climate event, with flood depths lower by approximately 0.05 m, and the 10% AEP event closely resembles that of the current climate 5% AEP event. Flood levels in the 1% RCP 8.5 climate change event are on average 0.2 m to 0.3 m higher than in existing conditions.

Velocities in Barkers Creek vary, tending to decrease in areas of increased surface roughness and increase in areas where the channel narrows or at flows through blockages such as bridges.

Flood hazard classes above 1 are generally limited to waterways and floodplains. Hazard class of breakout flows are generally low due to low flood depths. The main breakout flow path from Picnic Gully Creek along the CFA building reaches hazard Class 3 (unsafe for vehicles, children and elderly) in the 1% AEP event. High hazards of classes 2-3 also occur on High St/Bridge St outside the CFA building in the 20% AEP event.



Title: Harcourt Flood Study
Peak Flood Depth - 1% AEP

Figure:	Rev:	Scale	Disclaimer	
5-1	A	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: LD Date: Feb 2024

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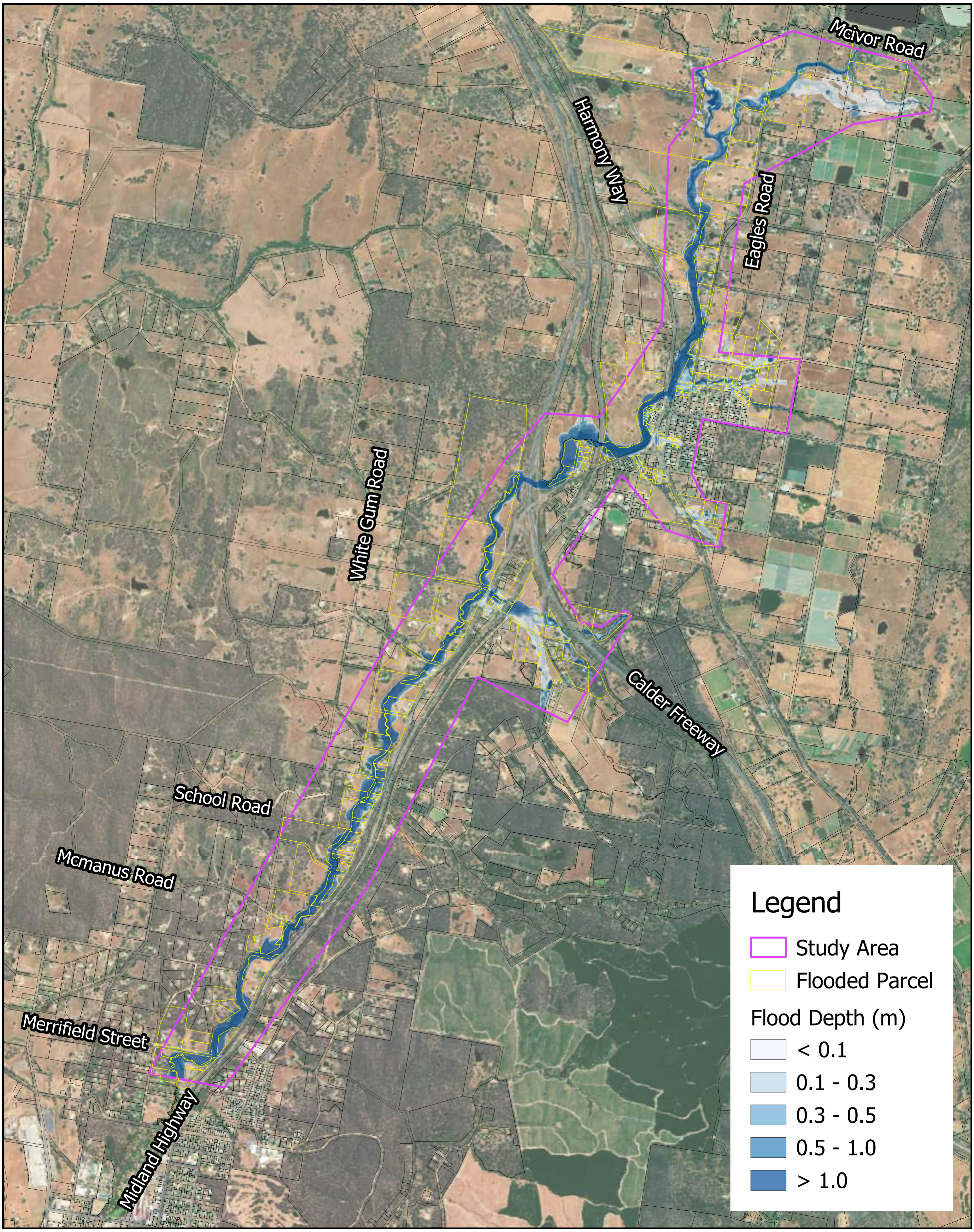

Title:

Harcourt Flood Study
Peak Flood Depth - 1% RCP8.5

Figure:	Rev:			By: LD
5-2	A	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Feb 2024

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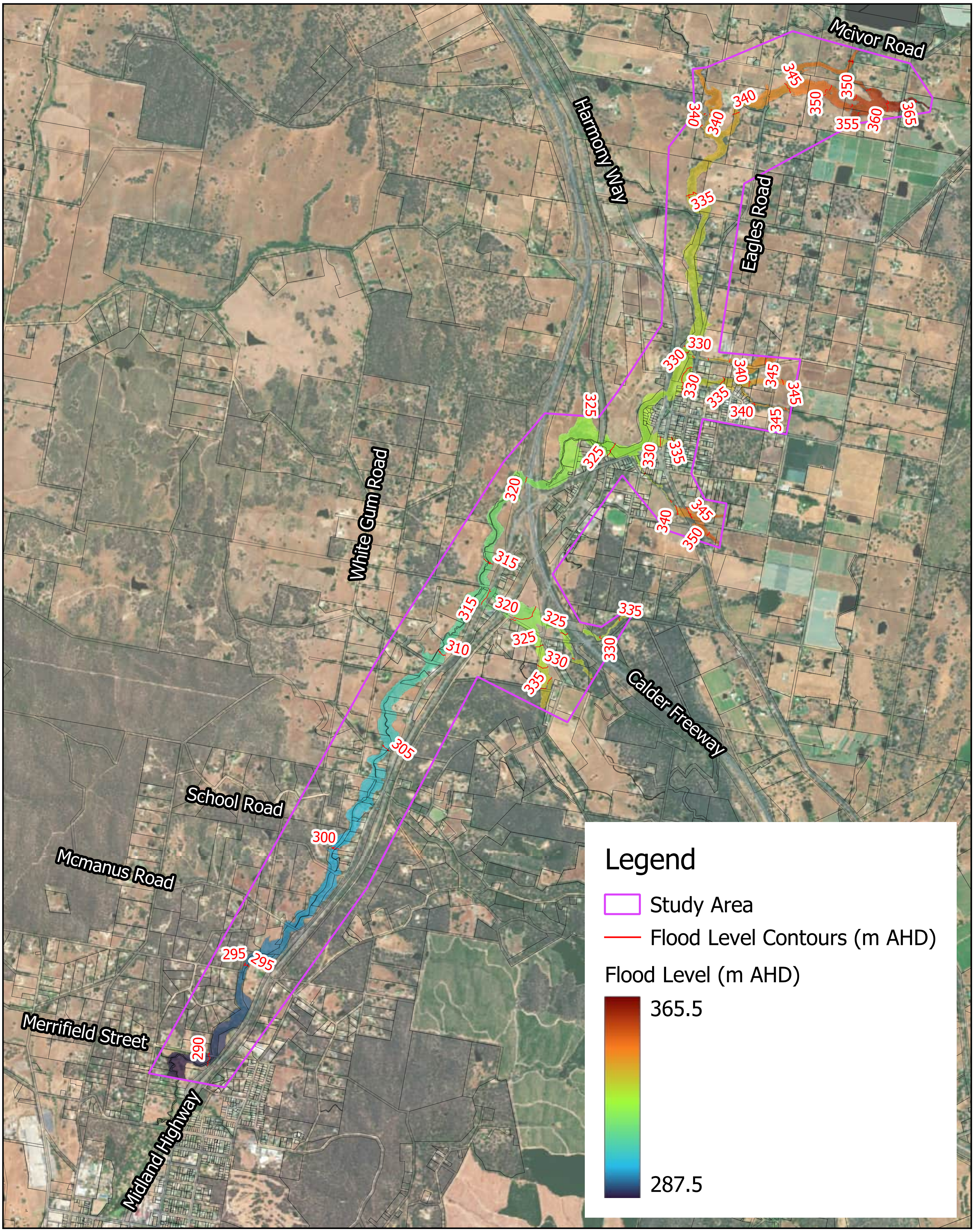

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Harcourt Flood Study
Peak Flood Level - 1% AEP

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5-3	A	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: LD Date: Feb 2024	VENANT SOLUTIONS Mount Alexander Shire Council North Central CMA VICTORIA State Government

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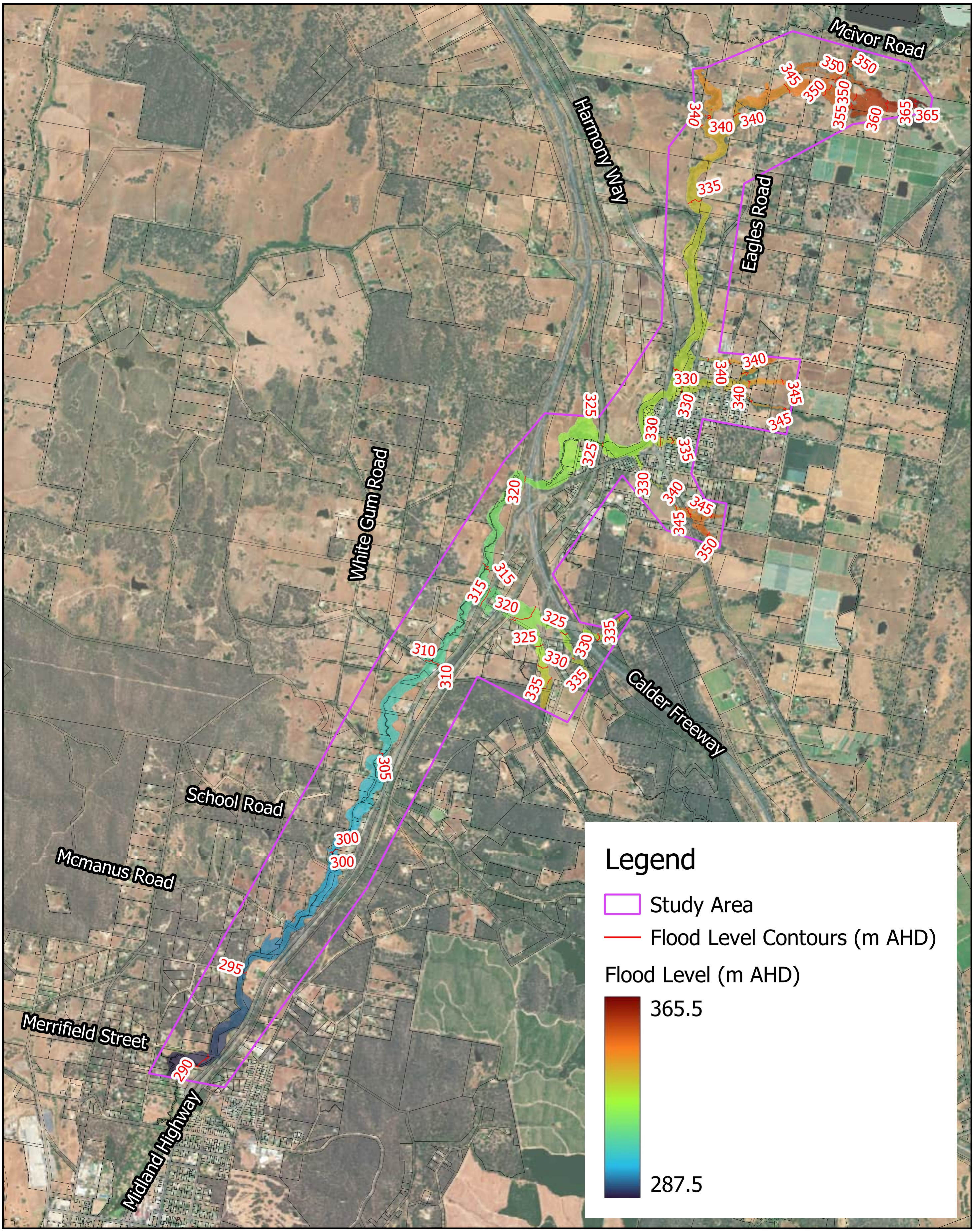

Title:

Harcourt Flood Study
Peak Flood Level - 1% RCP8.5

Figure:	Rev:	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: LD
5-4	A			Date: Feb 2024

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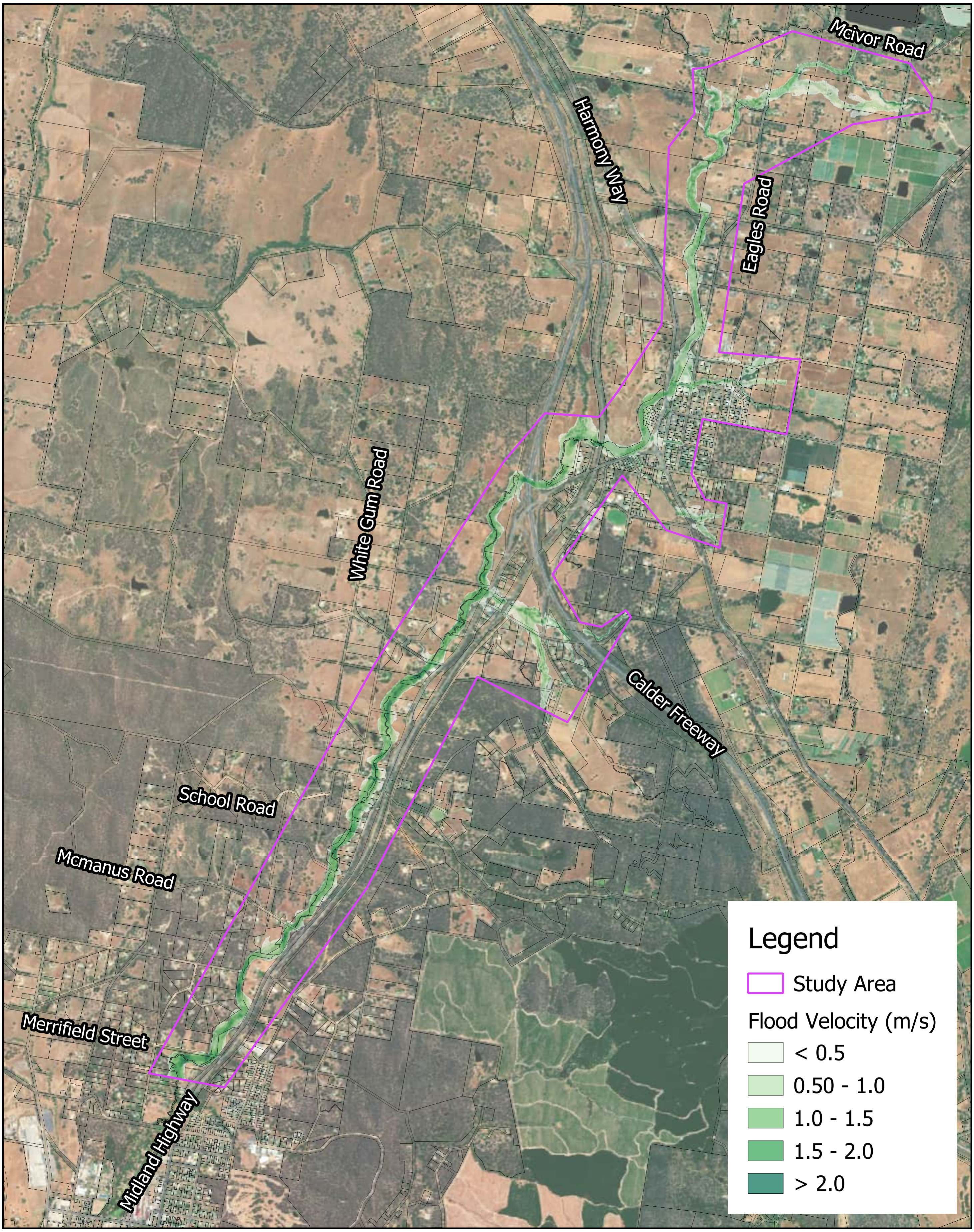

Title: Harcourt Flood Study
Peak Flood Velocity - 1% AEP

Figure:	Rev:	Scale		By: LD
5-5	A	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Feb 2024

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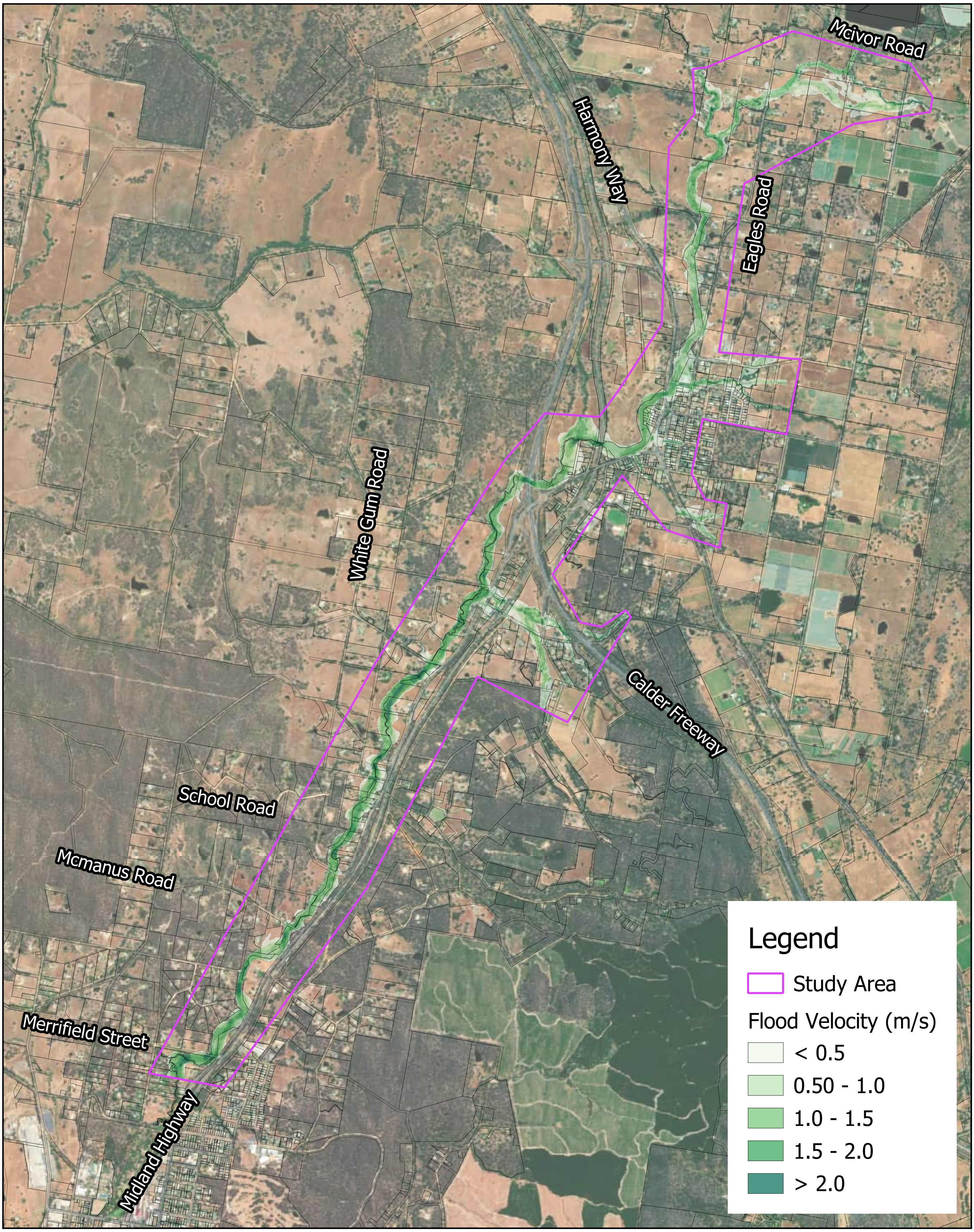
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-5_E01_100y_024_V_max.qgz



Title: Harcourt Flood Study
Peak Flood Velocity - 1% RCP8.5

Figure: 5-6

Rev: A

500 0 500 m

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Date: Feb 2024

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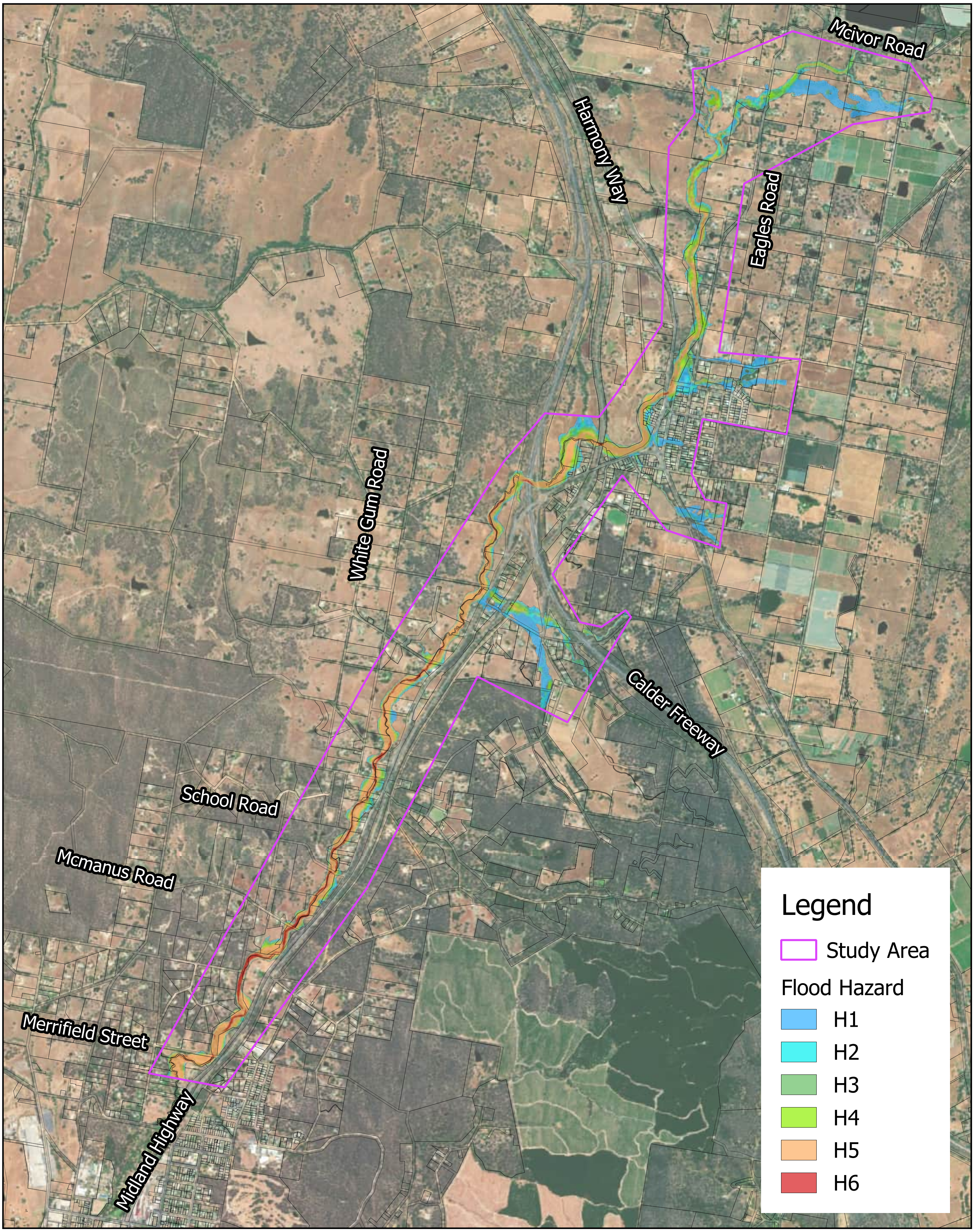

Title:

Harcourt Flood Study
Peak Flood Hazard - 1% AEP

Figure:	Rev:			By: LD
5-7	A	500 0 500 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Feb 2024

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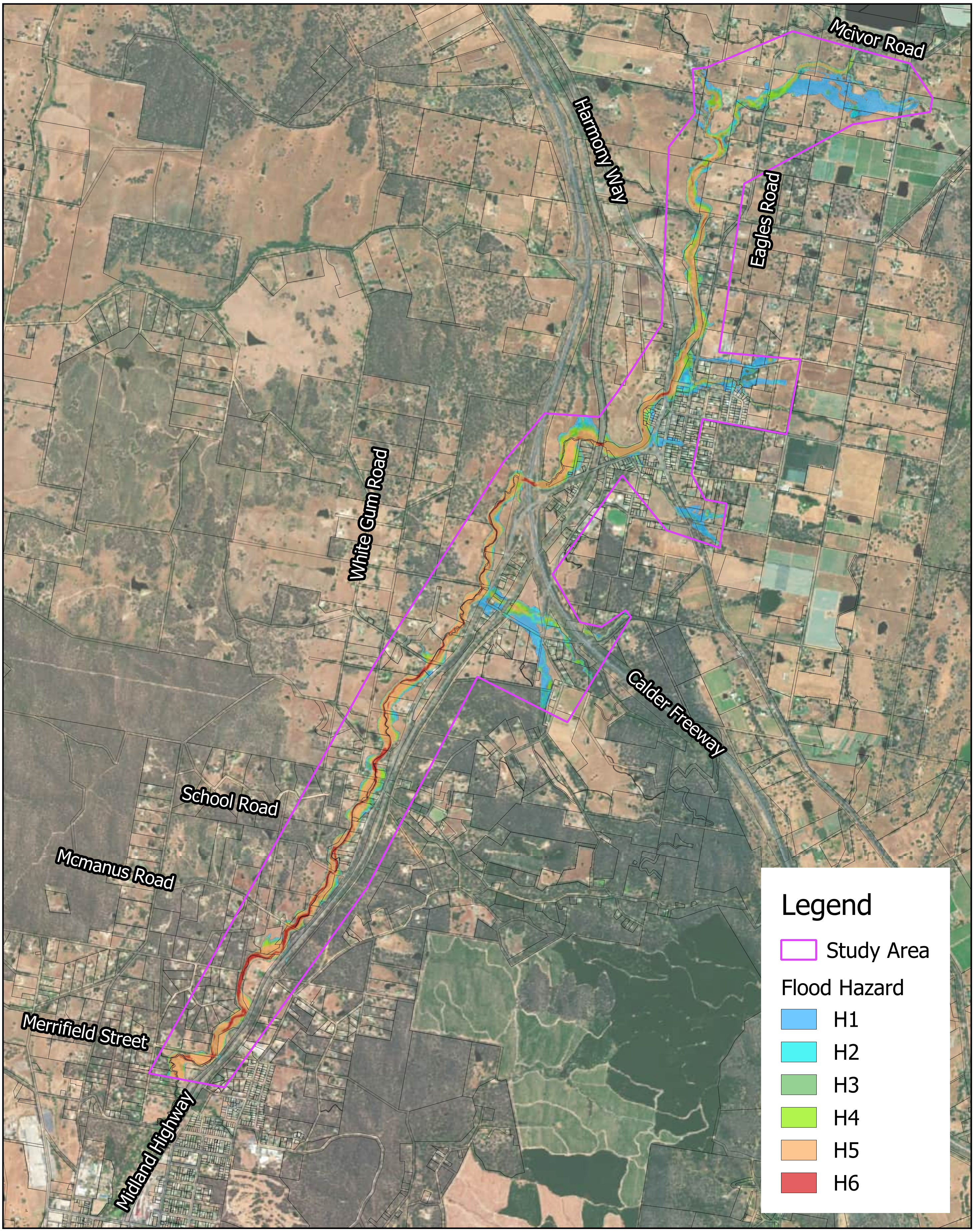

Title:

Harcourt Flood Study
Peak Flood Hazard - 1% RCP8.5

Figure: 5-8

Rev: A

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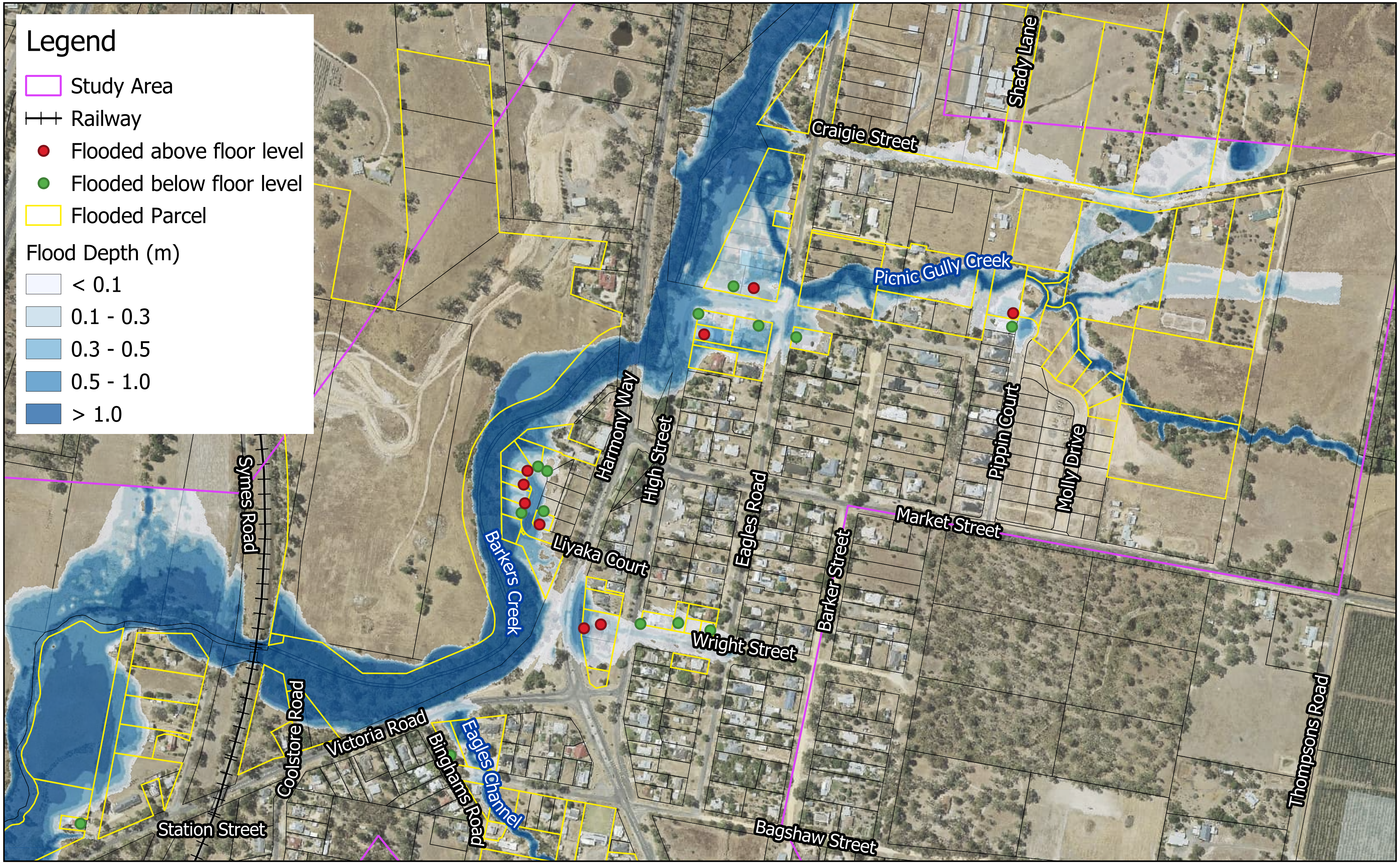
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-8_E01_100yCC2_024_ZAEM1_max.qgz



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Depth - 1% AEP

Figure: 5-9

Rev: A

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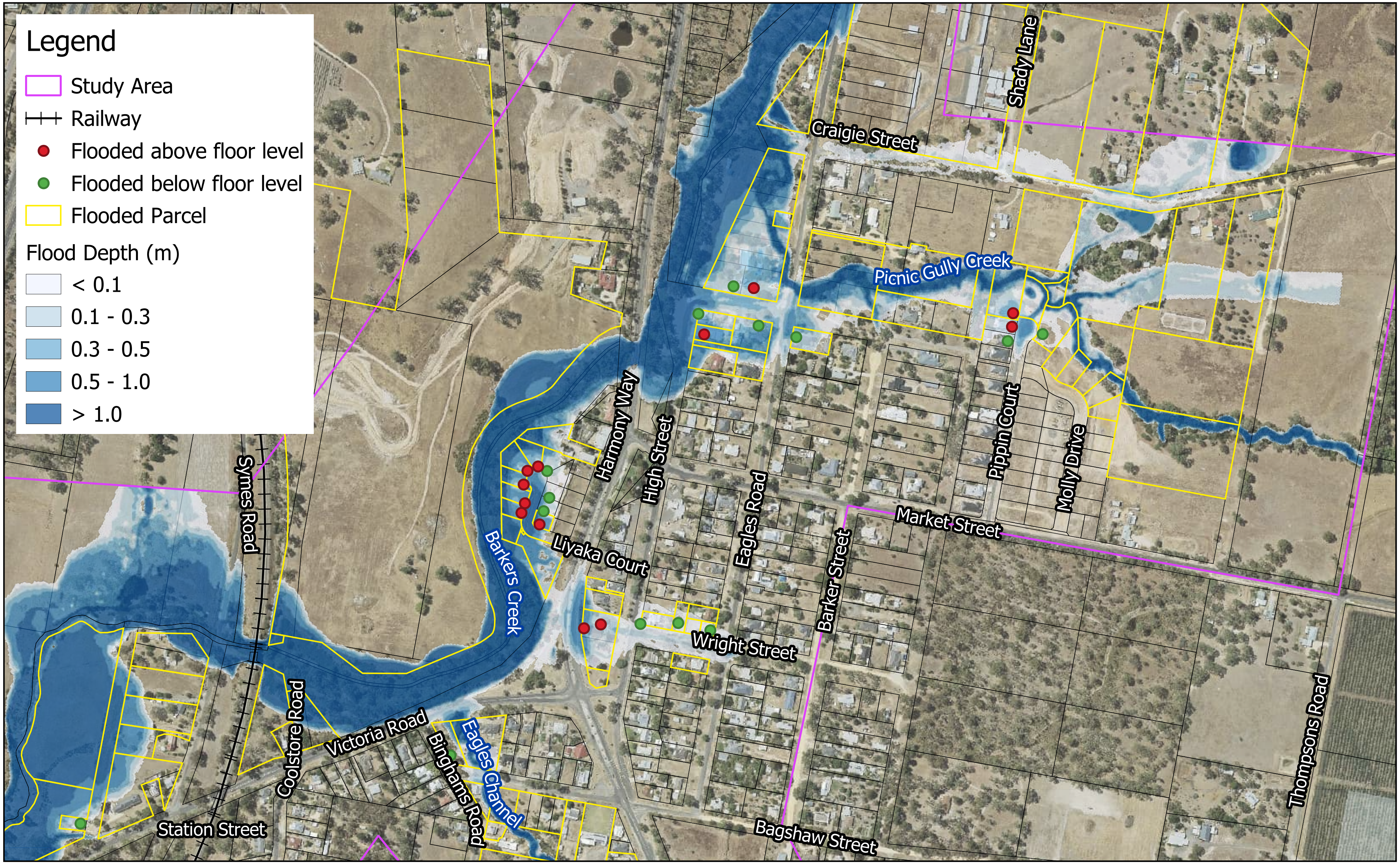
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.01\Fig5-9_E01_100y_024_d_max_Harcourt.qgz

By: JS

Date: Apr 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Depth - 1% AEP (Climate Change RCP8.5)

Figure:	Rev:
5-10	A

100 0 100 m

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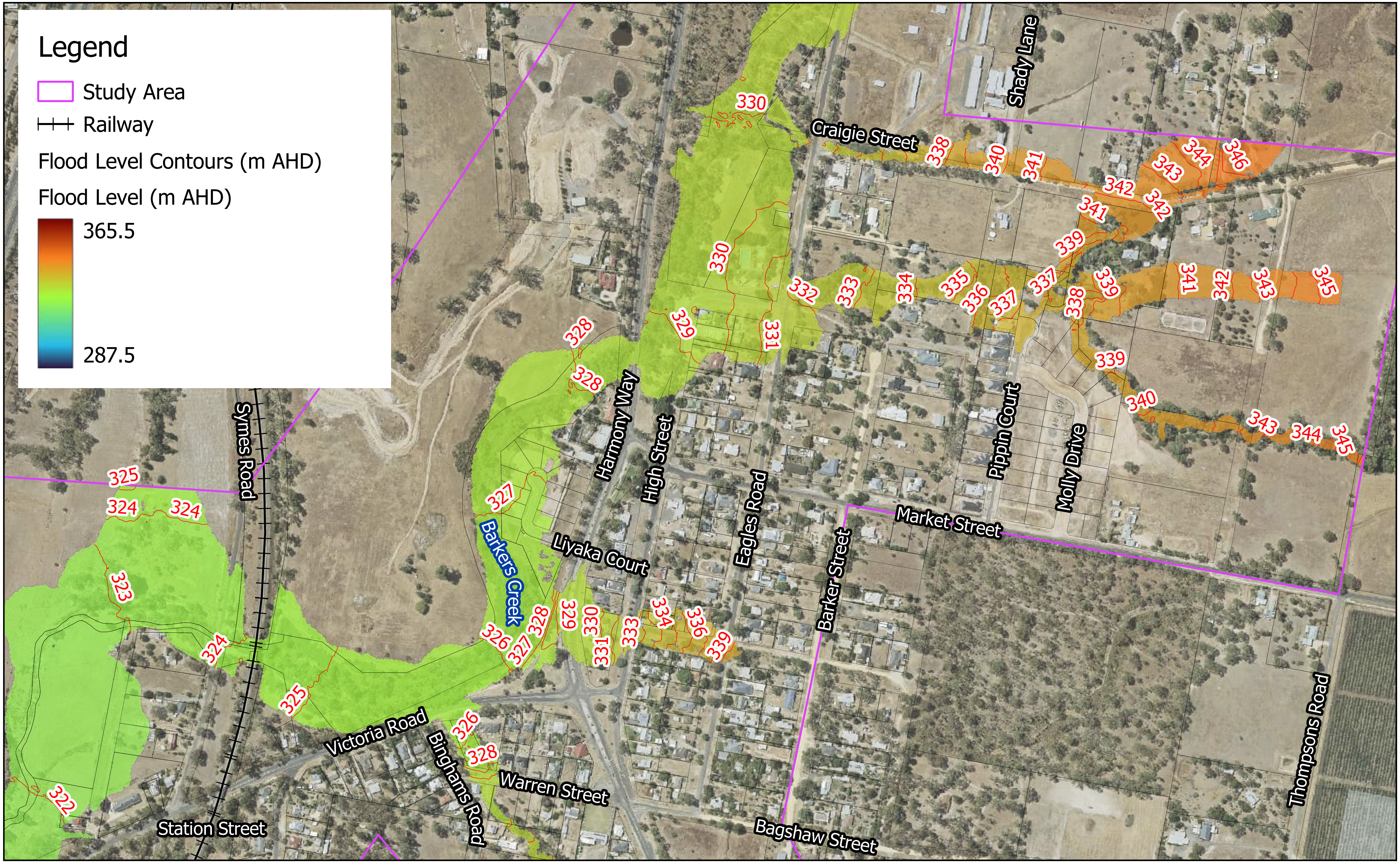
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.01\Fig5-10_E01_100yCC2_024_d_max_Harcourt.qgz

By: JS | Date: Apr 2024



Title: Harcourt Flood Study - Harcourt Township Peak Flood Level - 1% AEP

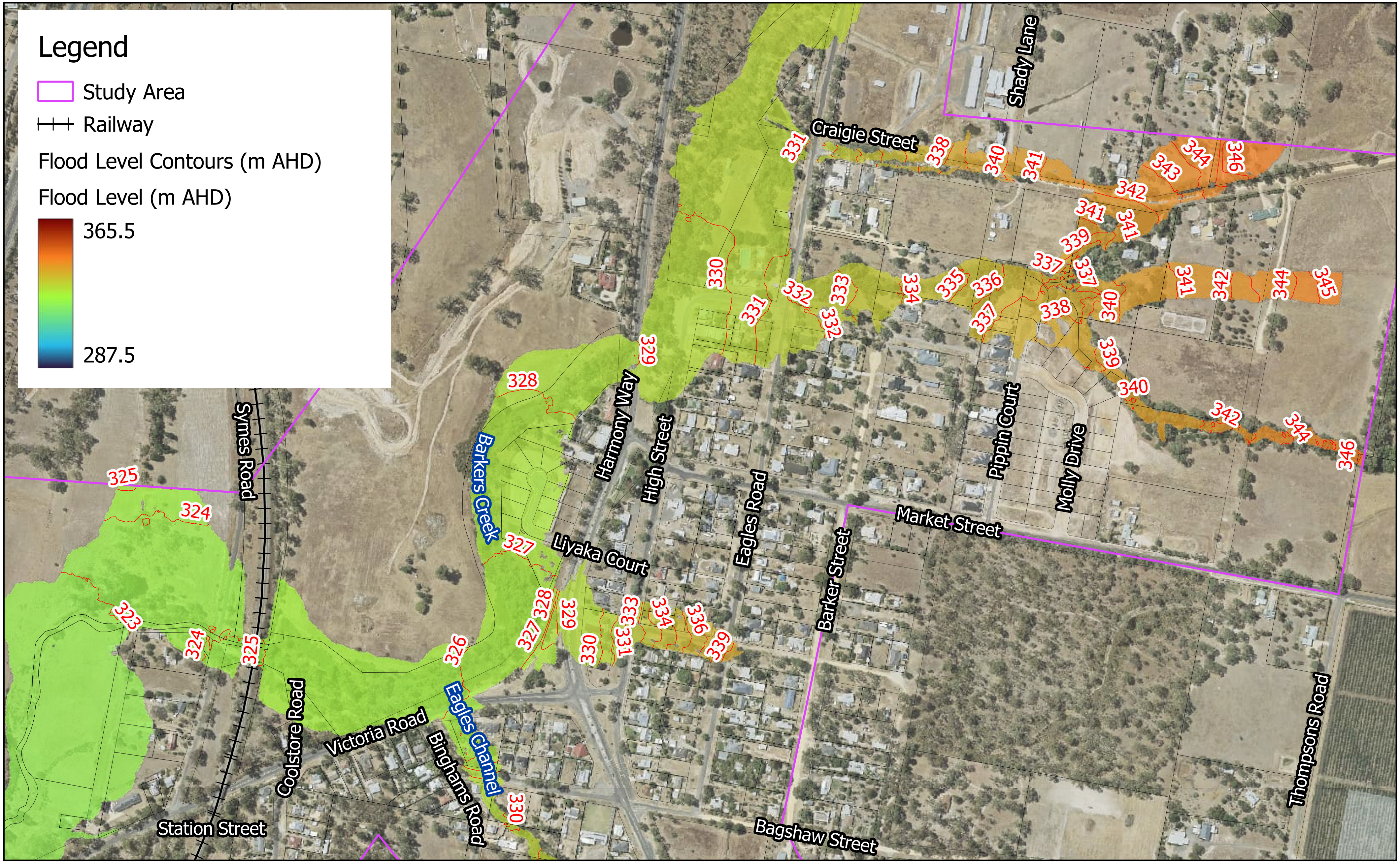
Figure:	Rev:
5-11	A

100 0 100 m

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-11_E01_100y_024_h_max_Harcourt.qgz

By: LD Date: Feb 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Level - 1% RCP8.5

Figure: 5-12

Rev: A

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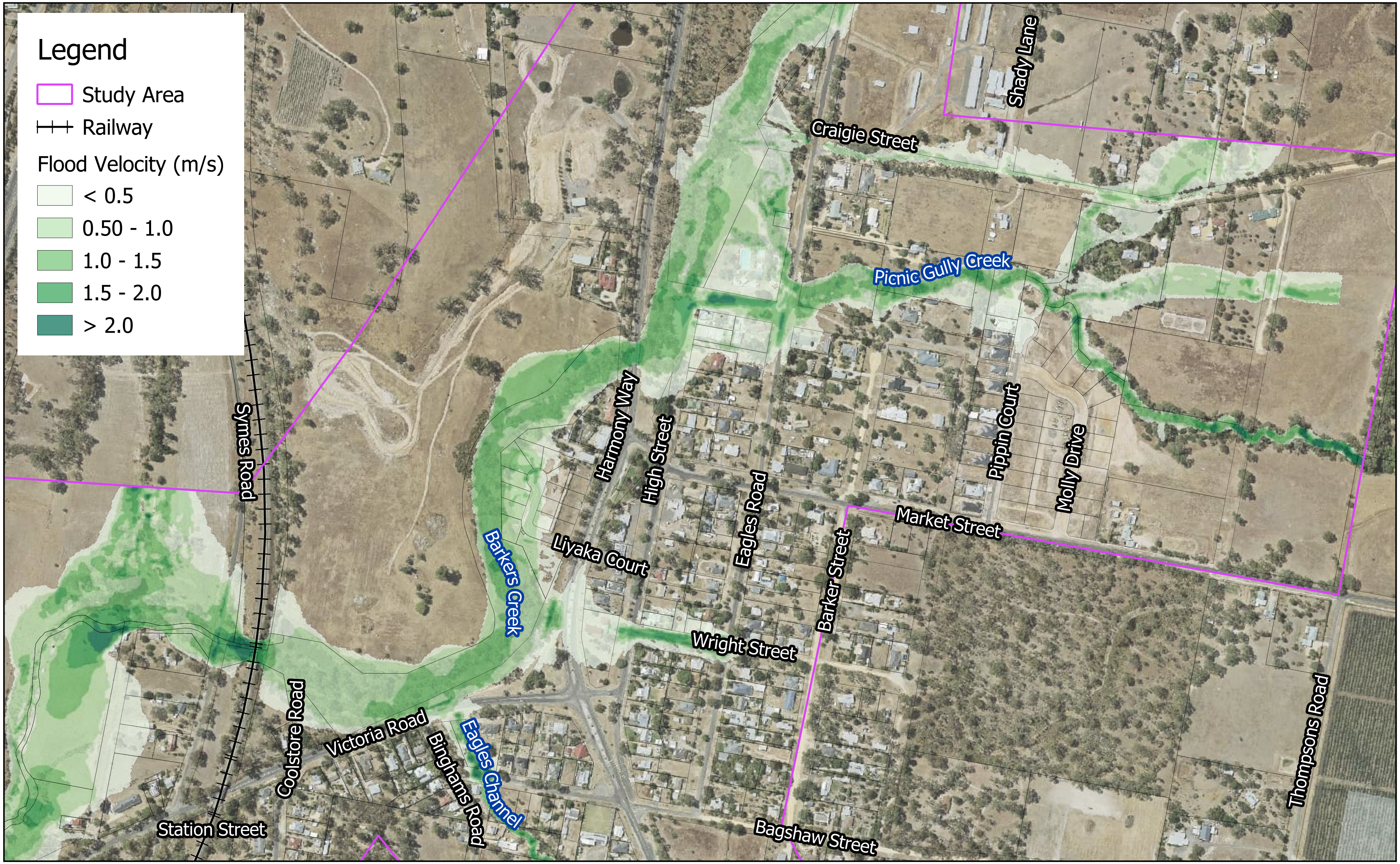
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-12_E01_100yCC2_024_h_max_Harcourt.qgz

By: LD | Date: Feb 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Velocity - 1% AEP

Figure: 5-13

Rev: A

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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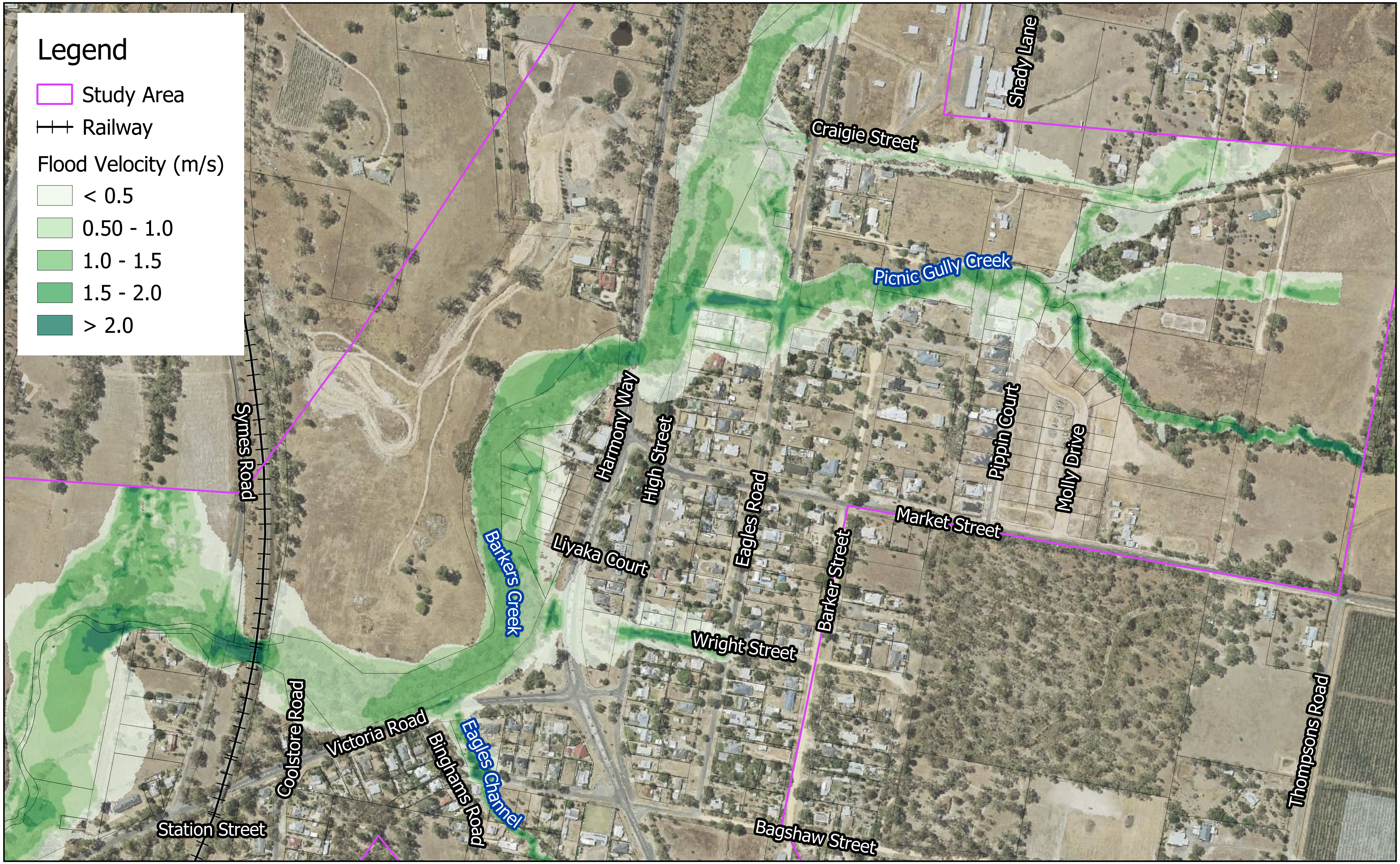
By: LD

Date: Feb 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Velocity - 1% RCP8.5

Figure: 5-14

Rev: A

100 0 100 m

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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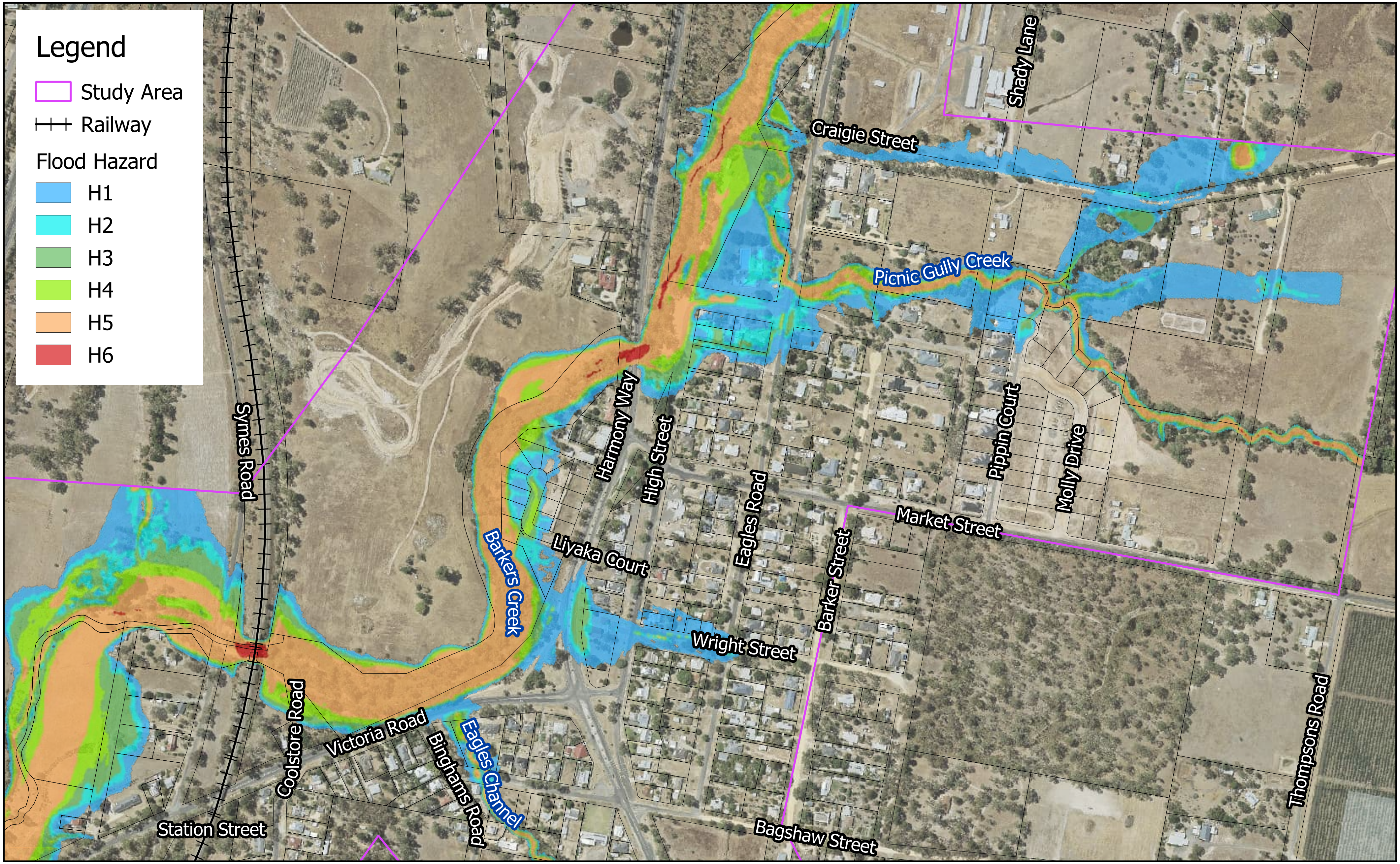
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-14_E01_100yCC2_024_V_max_Harcourt.qgz

By: LD

Date: Feb 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Hazard - 1% AEP

Figure: 5-15

Rev: A

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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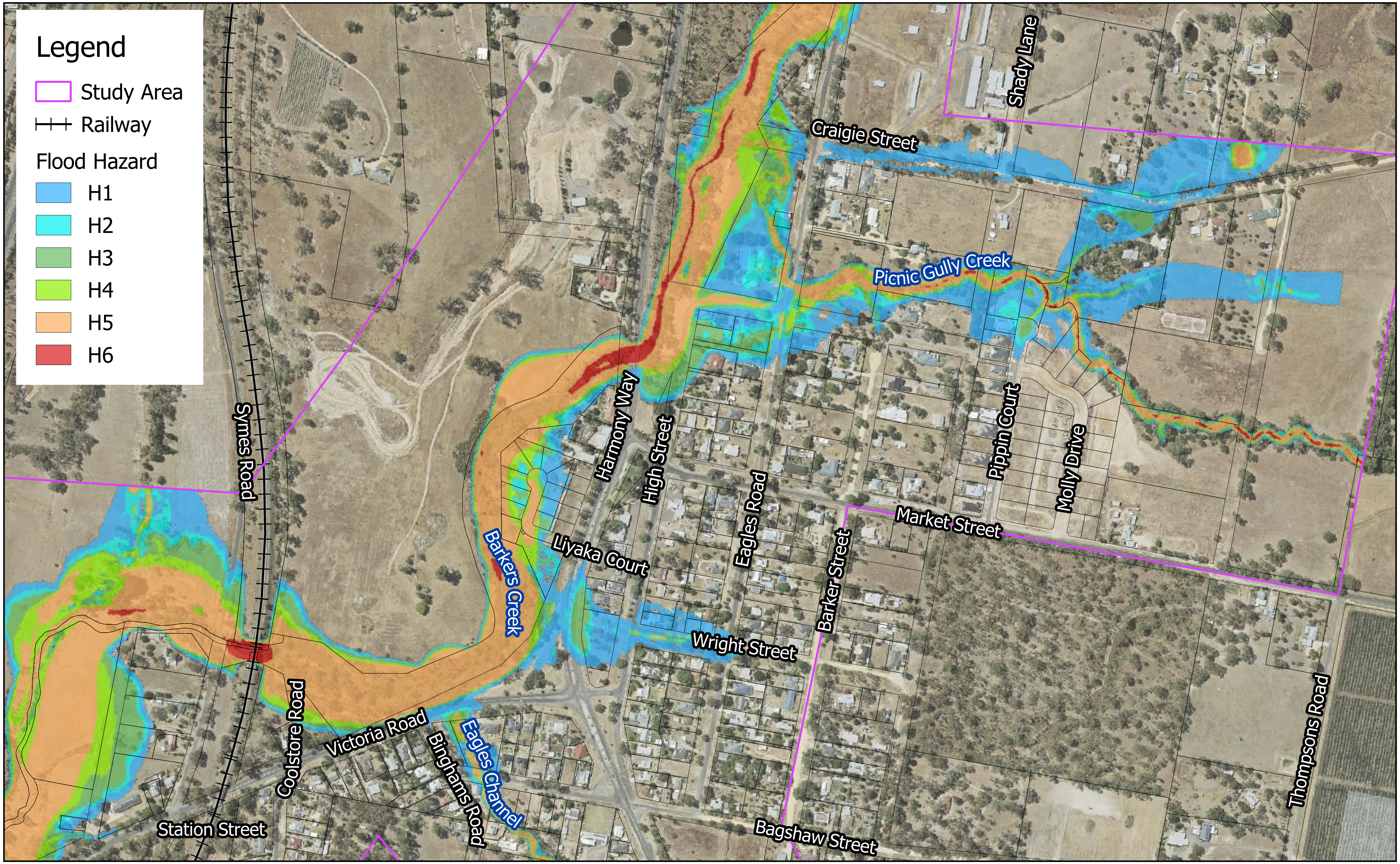
By: LD

Date: Feb 2024



Title: Harcourt Flood Study - Harcourt Township
Peak Flood Hazard - 1% RCP8.5

Figure: 5-16

Rev: A

100 0 100 m

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.00\Fig5-16_E01_100yCC2_024_ZAEM1_max_Harcourt.qgz

By: LD

Date: Feb 2024

5.1 Building and property inundation

Counts of inundated buildings and properties for the study are presented in Table 5-1 and their locations shown on the flood depth mapping presented in Figures D-1 to D-24 in the Flood Mapping Report (Venant Solutions 2024b). Limited floor level survey was captured, resulting in a low estimate of flooded floor levels for the PMF event.

As the flood extent is mostly contained within waterways, inundated properties are mostly limited to lots partially covering Barkers Creek and tributaries. 182 properties are inundated in the 20% AEP event, only increasing by 29 for the 0.1% AEP. The ANA Hall is the only building with floor level lower than the flood level in the 20% AEP event. However, inundation occurs from shallow flow and building landscaping and drainage works may prevent it becoming inundated. The CFA building floor level is inundated in the 10% AEP event.

Table 5-1 Inundated buildings

AEP	Inundated properties	Flood level below floor level	Flood level above floor level
20%	182	7	1
10%	186	10	2
5%	194	16	2
2%	198	23	3
1%	206	18	10
0.50%	209	17	12
0.10%	221	18	14
PMF	305	3	61
10% RCP4.5	189	10	2
10% RCP8.5	194	17	2
1% RCP4.5	210	17	12
1% RCP8.5	218	18	14

5.2 Road inundation

Figure 5-17 to Figure 5-21 show the smallest modelled event in which road sections in the become overtopped. Road inundation depths are presented in Table 5-2 for the locations shown in Figure 5-17 to Figure 5-21. Roads inundated to depths greater than 0.3 m have been highlighted in red.

The Barkers Creek crossing at Merrifield St is the most flood prone road in the Study Area, with a flood depth of 1.5 m predicted in a 20% AEP event. However, the crossing can be avoided via Burnett Road towards the Froomes Road bridge over Barkers Creek.

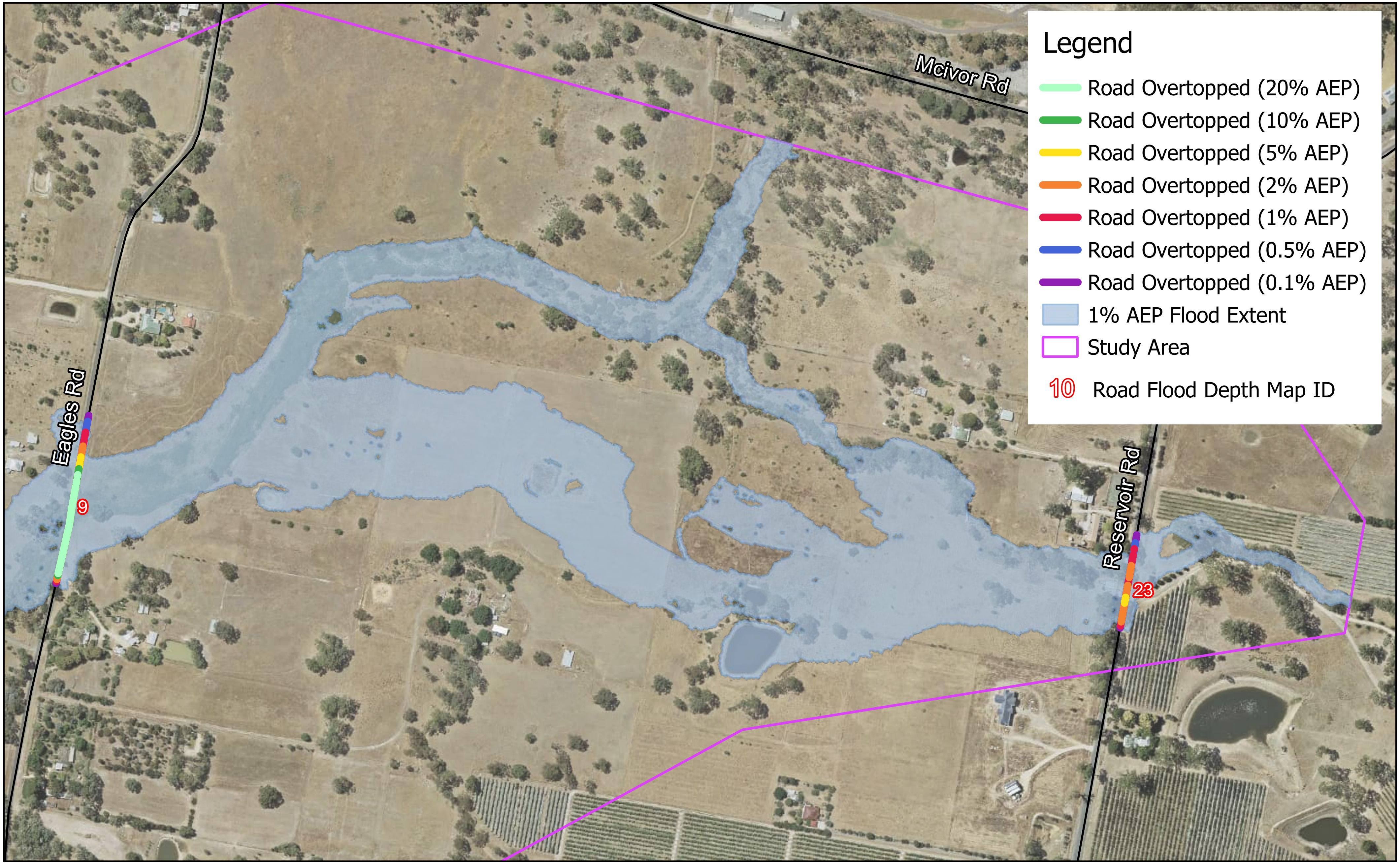
A section of Eagles Road north of Craigie Street is inundated due to spillover from Barkers Creek. Flood hazard Class 2 (unsafe for small vehicles) occurring in the 10% AEP event. Flood hazard Class 5 (unsafe for all vehicles and people) is reached in the 5% AEP at Barkers Creek crossing at Symes Road. Flood depths greater than 0.3 m in the 5% AEP event occurs at Harmony Way near the ANA Hall due to pooling of local floodwaters.

Flood depths of bridge crossings within the study are mostly below 0.3 m, with the exception of the School Road bridge over Barkers Creek, where flood depths greater than 0.3 m occurs in the 10% AEP event.

Table 5-2 Road inundation depths

Map ID	Road Name	Event										
		20%	10%	5%	2%	1%	0.50 %	0.10 %	10% RCP 4.5	10% RCP 8.5	1% RCP 4.5	1% RCP 8.5
1	Blackjack Rd (east of Coolstore Rd)		0.06	0.08	0.09	0.13	0.14	0.16	0.09	0.09	0.14	0.16
2	Blackjack Rd (near Nursery)	0.01	0.02	0.03	0.03	0.03	0.06	0.14	0.02	0.02	0.06	0.13
3	Blackjack Rd (near railway)	0.03	0.08	0.13	0.14	0.15	0.27	0.63	0.10	0.10	0.31	0.57
4	Blackjack Rd (west of Coolstore Rd)	0.07	0.08	0.09	0.11	0.12	0.15	0.17	0.09	0.10	0.15	0.16
5	Bridge St	0.02	0.13	0.31	0.53	0.72	0.81	1.11	0.18	0.32	0.83	1.07
6	Buckley St (near Wright St)	0.07	0.12	0.13	0.15	0.16	0.17	0.18	0.13	0.14	0.16	0.17
7	Coolstore Rd (north of Blackjack Rd)		0.04	0.09	0.14	0.18	0.21	0.27	0.07	0.09	0.22	0.25
8	Craigie St (East of Shady Ln)	0.20	0.22	0.24	0.25	0.26	0.28	0.29	0.24	0.24	0.28	0.29
9	Eagles Rd (Barkers Ck bridge)		0.07	0.13	0.26	0.33	0.37	0.49	0.12	0.17	0.39	0.46
10	Eagles Rd (North of Craigie St)	0.18	0.32	0.51	0.72	0.90	0.98	1.23	0.40	0.51	1.00	1.18
11	Eagles Rd (South of Bridge St)				0.01	0.03	0.06	0.11	0.00	0.00	0.07	0.11

12	Harmony Way (by ANA Hall)	0.46	0.52	0.57	0.57	0.60	0.61	0.63	0.53	0.56	0.61	0.62
13	Harmony Way (north of Mills Rd)			0.02	0.06	0.08	0.08	0.10	0.00	0.03	0.08	0.09
14	High St (by ANA Hall)	0.05	0.08	0.09	0.10	0.12	0.13	0.14	0.08	0.09	0.12	0.13
15	High St (near CFA)	0.07	0.21	0.44	0.71	0.94	1.04	1.38	0.28	0.44	1.06	1.33
16	Liyaka Ct	0.10	0.30	0.58	0.88	1.12	1.20	1.46	0.39	0.57	1.21	1.43
17	McManus Rd (Barkers Ck bridge)			0.23	0.67	1.15	1.23	1.67	0.18	0.26	1.27	1.57
18	Merrifield St (Barkers Ck crossing)	1.50	1.67	1.84	2.10	2.32	2.36	2.58	1.80	1.89	2.38	2.54
19	Midland Hwy (by Merrifield St)					0.02	0.05	0.29	0.00	0.00	0.07	0.24
20	Midland Hwy (north of Blackjack Rd)			0.07	0.17	0.23	0.27	0.34	0.00	0.08	0.28	0.33
21	Midland Hwy (south of Blackjack Rd)			0.01	0.02	0.03	0.06	0.11	0.00	0.00	0.07	0.11
22	Mills Rd	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05
23	Reservoir Rd				0.06	0.12	0.17	0.22	0.00	0.01	0.17	0.17
24	School Rd (Barkers Ck bridge)	0.12	0.38	0.65	0.92	1.15	1.17	1.38	0.56	0.67	1.19	1.34
25	Symes Rd (Barkers Ck crossing)	0.73	0.87	1.03	1.17	1.32	1.36	1.51	0.92	1.02	1.36	1.49
26	Victoria Rd (east of Binghams Rd)				0.10	0.18	0.23	0.29	0.00	0.01	0.23	0.26
27	Warren St				0.01	0.05	0.09	0.13	0.00	0.00	0.09	0.12
28	White Gum Rd (Barkers Ck bridge)					0.23	0.26	0.52	0.00	0.00	0.29	0.48
29	Wright St		0.03	0.04	0.06	0.07	0.09	0.09	0.04	0.05	0.07	0.09



Title: Harcourt Flood Study
Roads Overtopped - Map 1

Figure: 5-17

Rev: A

50 0 50 m

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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By: JS

May 2024

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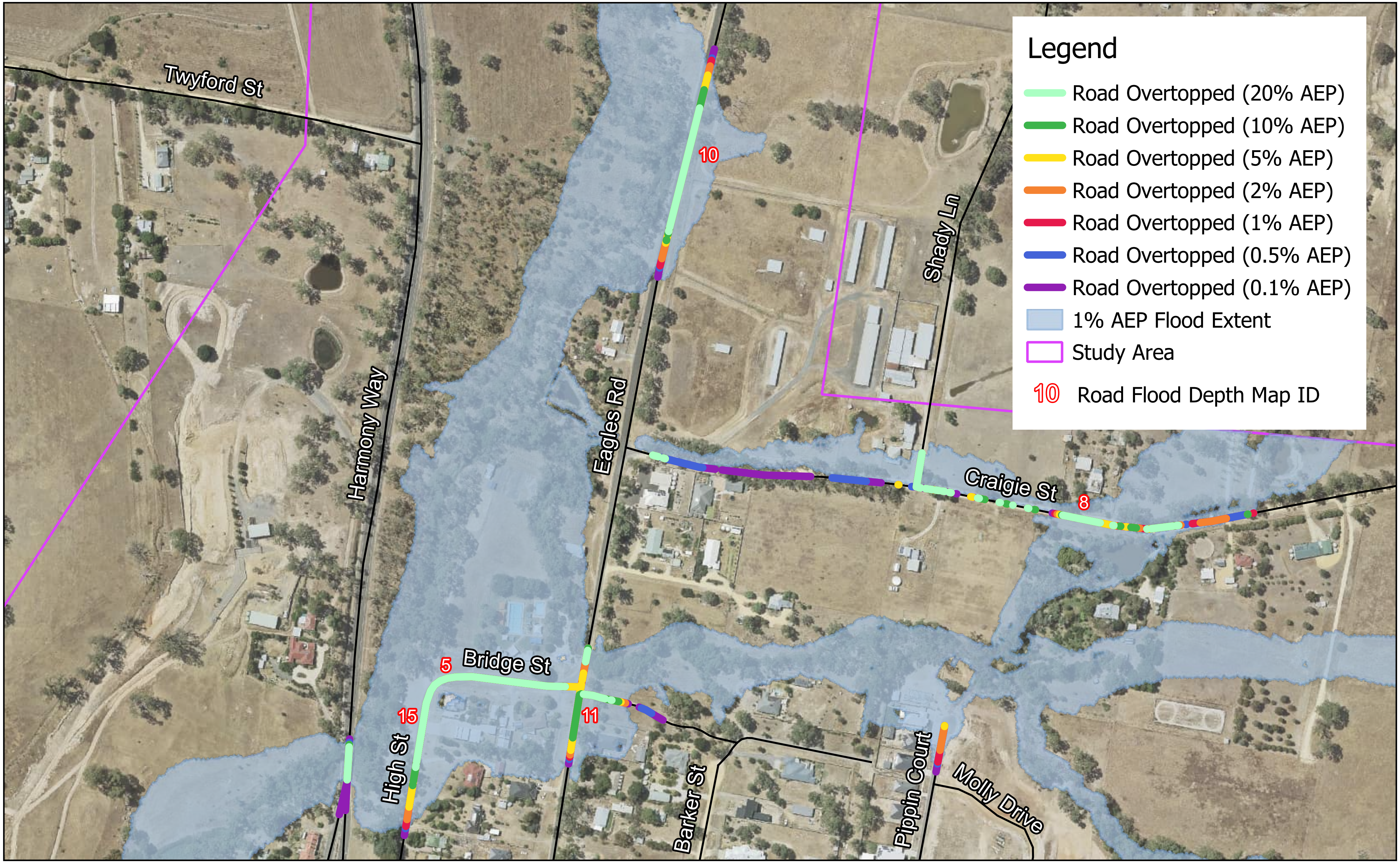
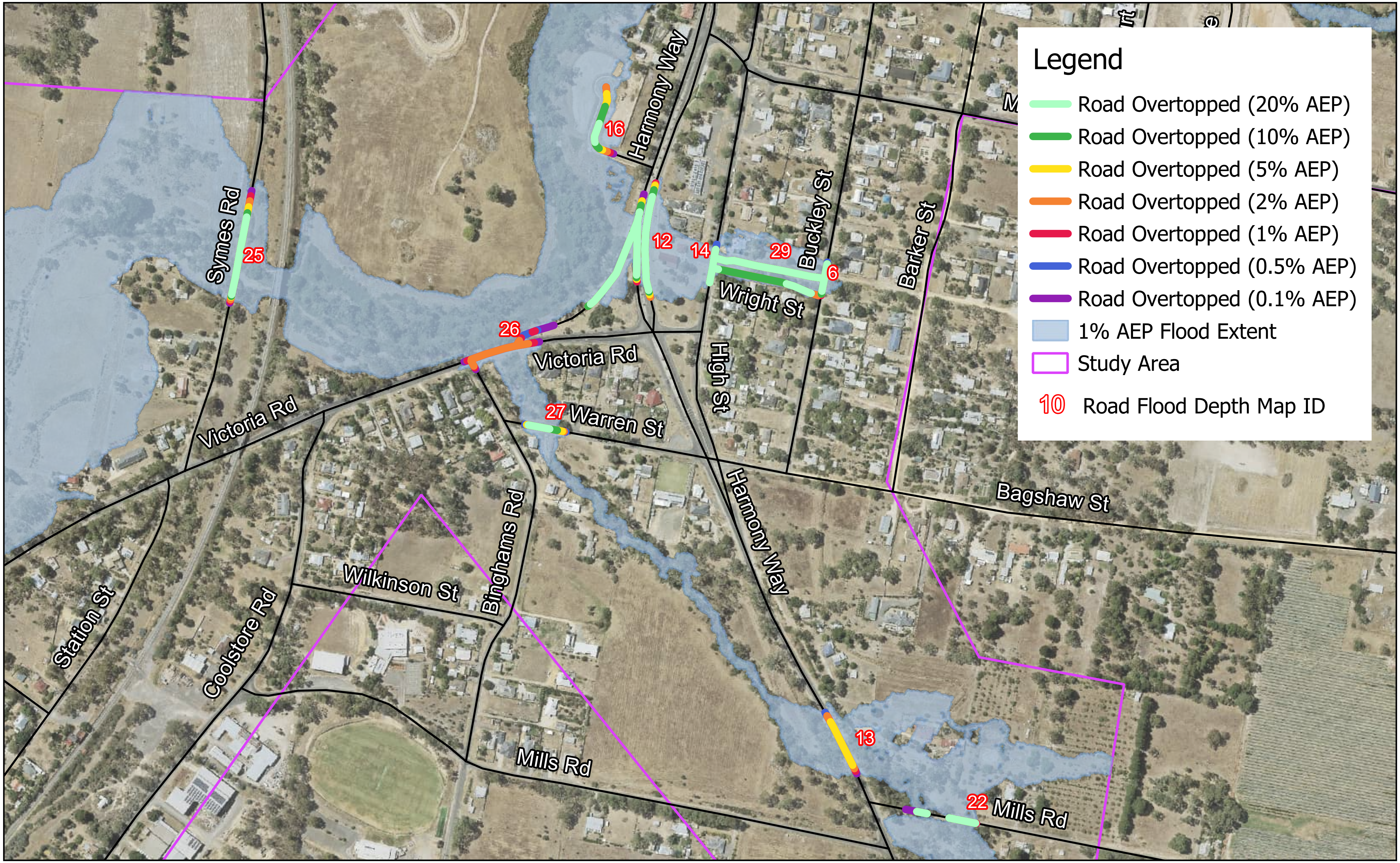


Title: Harcourt Flood Study Roads Overtopped - Map 2	Figure: 5-18	Rev: A	50 0 50 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	VENANT SOLUTIONS
Filename: S:\Projects\M00386.MS.HarcourtFloodStudy\GIS\Drawings\R.M00386.005.02\Fig5-18_Overtopped_roads_Map_2_E01_024.qgz			By: JS	May 2024	www.VenantSolutions.com.au



Title: Harcourt Flood Study
Roads Overtopped - Map 3

Figure:	Rev:
5-19	A

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By: JS | May 2024

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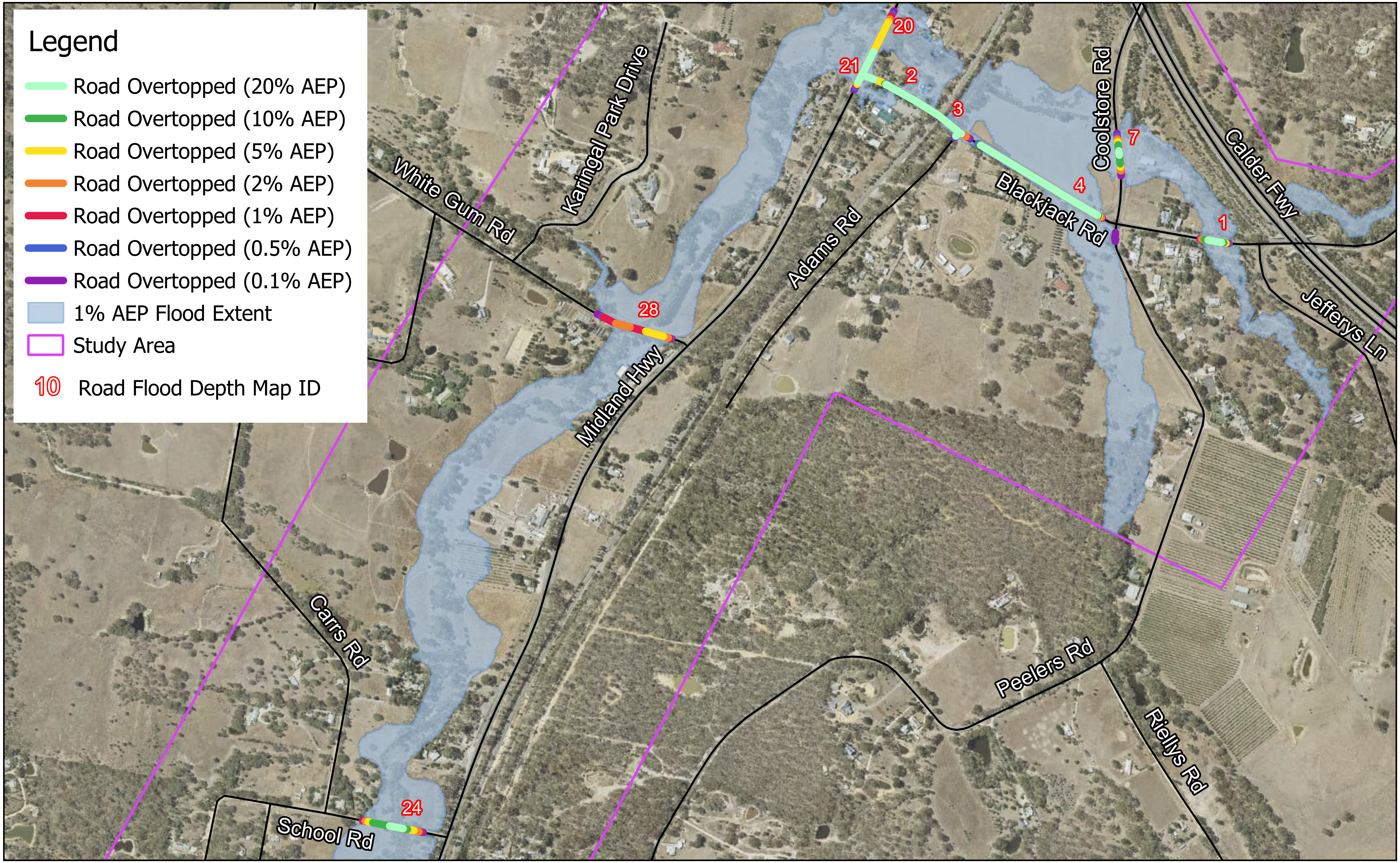

Title: Harcourt Flood Study
Roads Overtopped - Map 4

Figure:	Rev:
5-20	A

150 0 150 m

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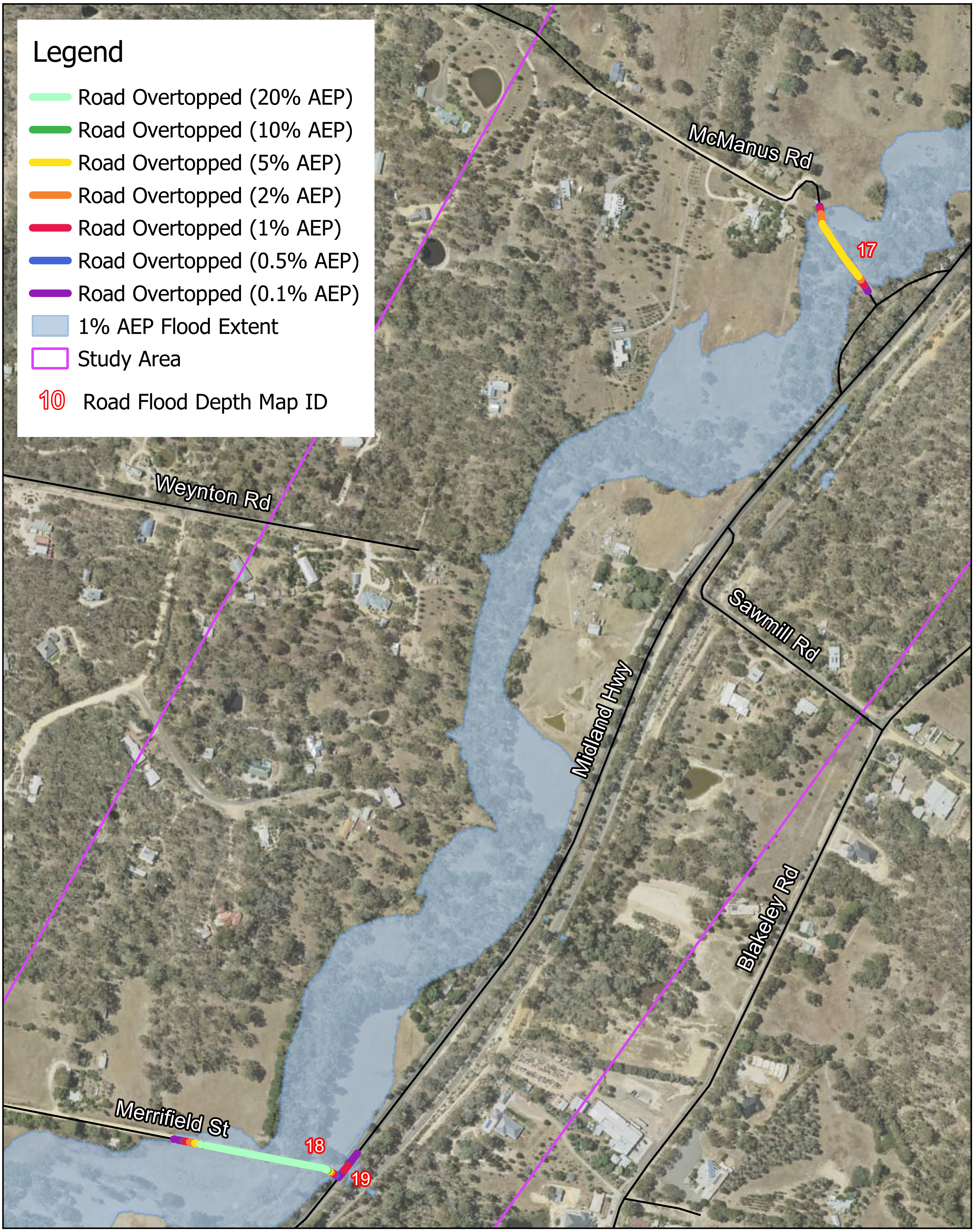

Title: Harcourt Flood Study
Roads Overtopped - Map 5

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Figure:	Rev:	Scale	Disclaimer	By / Date
5-21	A	80 0 80 m	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: JS Date: May 2024

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5.3 Travel times

Critical design event travel times at key locations are shown in Table 5-3.

Travel times are a function of storm duration which varies by design event and reporting location. Please note that travel times can vary significantly for individual flood events as a result of several factors including catchment antecedent (wetness) conditions storm durations, temporal patterns, and spatial patterns.

The travel times presented in Table 5-3 are for the critical events selected based on peak flood level (refer to Section 7.1 in the Flood Modelling Report (Venant Solutions 2024a)) at the location of reporting. This has resulted in longer travel times reported for the 1% AEP event at Harcourt and Picnic Gully Creek Outlet where the 6-hour event is critical. The critical 6-hour event is only 50 mm higher than the 2-hour event at Harcourt which has a start of rise of 0.8 hours and time of peak of 2.3 hours in keeping with the other AEP event travel times.

The critical events for Picnic Gully Creek Outlet and Eagles Channel Outlet are influenced by water levels in Barkers Creek. As such the critical events are likely longer duration storm events than would be expected for local (flash flooding) and travel times are likely overestimated.

Table 5-3 Critical design event travel times

AEP	Harcourt (at Harmony Way bridge)		Picnic Gully Creek Outlet (Harcourt Pony Club)		Eagles Channel Outlet (Victoria Road)		Merrifield Street Crossing	
	Start of Rise (hrs)	Flood Peak (hrs)	Start of Rise (hrs)	Flood Peak (hrs)	Start of Rise (hrs)	Flood Peak (hrs)	Start of Rise (hrs)	Flood Peak (hrs)
20%	2.0	4.3	1.3	3.8	1.7	2.6	2.6	5.5
10%	1.7	3.5	1.1	3.4	0.9	1.7	2.8	5.8
5%	1.4	3.3	1.0	3.3	0.8	1.3	2.0	4.6
2%	0.9	2.6	0.7	2.3	0.3	1.3	2.2	5.3
1%	1.7	4.7	1.2	4.6	0.3	1.0	2.2	5.8
0.50%	0.7	2.3	0.4	2.0	0.3	1.7	2.0	5.1
0.10%	0.5	2.2	0.3	2.0	0.3	1.7	1.7	5.0
PMF	0.3	1.8	0.3	1.9	0.3	1.6	0.3	2.5
10% RCP4.5	1.5	3.9	1.3	3.6	0.8	1.9	3.3	6.8
10% RCP8.5	1.1	2.7	0.6	2.5	0.5	1.3	2.6	6.7
1% RCP4.5	0.5	2.2	0.4	2.0	0.3	1.7	2.0	5.1
1% RCP8.5	0.8	2.4	0.5	2.3	0.4	2.1	1.8	5.0

6 Flood warning feasibility assessment

The Bureau of Meteorology (BoM) does not offer a flood warning service for Harcourt. This is because there are no stream gauges on Barkers Creek and the travel times are less than 6 hours and are classified as flash flooding. With little flood risk information existing prior to the completion of this Study flash flood warning arrangements have not been developed for Harcourt and the only warning information available to the local community are the Severe Thunderstorm or Severe Weather Warnings issued by BoM.

The Total Flood Warning System (TFWS) encompass all the elements needed to maximise the effectiveness of flood responses by the community and emergency response agencies in minimising flood risk. In Harcourt once heavy rainfall begins there is little to no warning time to undertake the Monitoring and Prediction, Interpretation, Message Construction and Communication elements of a TFWS (Figure 6-1) to provide enough warning lead time for meaningful protective behaviour and actions to be undertaken.

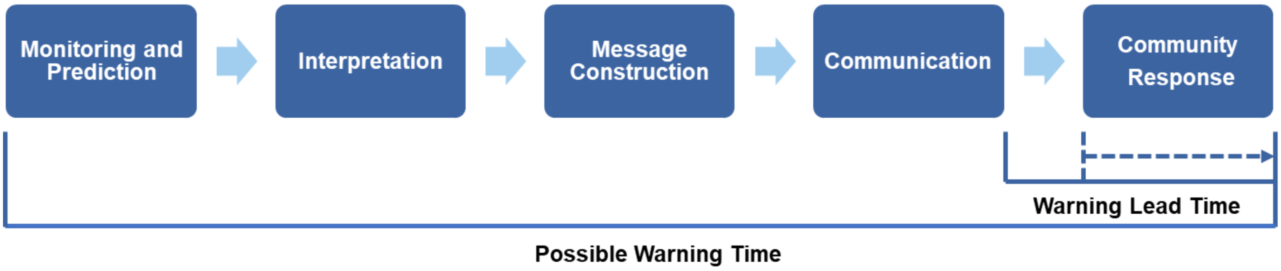

Figure 6-1 TFWS flood warning timeline

To provide sufficient warning lead time, flood warnings based on rainfall forecasts are required as opposed to a system based on observed rainfalls or stream levels. However, thunderstorms can be localised and develop quickly leading to them being hard to predict with the information contained in the warnings likely being too generalised to allow for a predication accuracy commensurate with flood mapping and intelligence data available through this Study. Therefore, the focus of this flood warning feasibility assessment is to build the community's awareness of the flood risk and ongoing flood risk reduction measures (for example permanently parking vehicles outside of the floodplain as opposed to moving once an event is imminent) independent of rainfall forecasts.

The recommended actions as detailed in the Flood Warning Feasibility Assessment Report (Venant Solutions 2024c) are presented in Table 6-1. The recommended actions are categorised as:

Near-term	Actions achievable in the near-term (0 - 1.5 years) using information, services and systems that are currently in place and require minimum investment.
Mid-term	Actions achievable in the mid-term (1.5 – 3 years) requiring a greater level of investment to implement.

Table 6-1 Recommended TFWS actions

TFWS Element	Action	Responsible Lead Agency
Building community resilience to disasters	• Continue flood awareness activities that emphasise personal safety and damage reduction. This includes: ○ Provide links to the Study and flood intelligence documentation (MFEP) on Council's and/or North Central CMA's website ○ Upload the flood mapping onto North Central CMA's Flood Eye online mapping tool	Council, North Central CMA
	• Complete the LFG and make it available to the Harcourt community via a link on the Council website. A flood information poster can also be displayed in prominent locations (flood pole) with a QR Code linking to the LFG	VICSES
	• Install a "flood pole" in a prominent location in Harcourt near Barkers Creek to aid in increasing and maintaining the community's awareness of flooding and to help visualise the design flood levels developed by this study. The flood pole would also make a suitable location to display flood intelligence products such as posters of the LFG.	Council
Monitoring and prediction	• Provide the indicative flood guidance tools and instructions for their use (including limitations) to Council staff, VicSES and local CFA for routine use.	North Central CMA
	• Council, North Central CMA and VICSES agree who will maintain the tools.	Council, North Central CMA, VICSES
	• Make the recordings of the recently Installed rainfall gauge at the Barkers Creek Reservoir publicly assessable in real-time (15 minute or lower intervals), preferably via the Bom website. • As a less preferable alternative to the Barkers Creek Reservoir, the Muckleford North (closest to the catchment) or Redesdale AWS and/or Bendigo AWS recordings publicly available in real-time (15 minute or lower intervals).	Council, Coliban Water, BoM
Interpretation	• The flood mapping and intelligence outputs of this Study and Mount Alexander Shire MFEP Appendices provide detailed information to enable the community and emergency response agencies to determine the likely risks of flooding. This information should be made available.	Council, North Central CMA
Message construction	• Based on the difficulties in proving high accuracy forecasts for Harcourt, the content of messaging to the community should be focused on general flood risk reduction activities rather than focused actions based on specific flood magnitude predictions.	Council

Communication	• Establish a community flood action group and investigate ways that this group can be incorporated into existing community groups such as the Harcourt Progress Association, Harcourt Valley Landcare and the Harcourt CFA brigade	Council
Community Response	• Undertake an awareness and education program to inform the community of their flood risk, the limitations in providing accurate flood warnings and encourage the community members to undertake flood risk reduction measures and develop individual flood response plans.	Council
Continuous review and improvement	• Review and update all aspects of the TFWS including: ○ Ensuring locations and links to flood information are up to date and accessible to the community ○ Additional flood behaviour information and post response review findings following flood events are incorporated ○ Incorporate updated flood mapping and intelligence information if it becomes available ○ Updated monitoring and prediction data, primarily the installation of new rainfall gauges, improved availability of frequent rainfall observations or improvements in the accuracy of storm event rainfall predictions	Council
	• It is recommended that this review be undertaken by Council with input from VicSES, North Central CMA, CFA.	Council

7 Recommendations

This report provides a summary of the Harcourt Flood Study (the Study). For a detailed description of the Study inputs, approach and outcomes the accompanying detailed technical reports should be referred to.

The key recommendations of the Investigation are:

- A good calibration and validation to the limited data available has been achieved for both the RORB hydrologic and TUFLOW hydraulic models through the joint calibration process. The resulting flood mapping is appropriate to be used for floodplain management purposes including:
    - Incorporation of the flood mapping and intelligence outputs into emergency response procedures and actions, including updating of the Municipal Flood Emergency Plan (MFEP)
    - Incorporate the flood mapping into the planning scheme (draft planning scheme overlays have been developed as part of this Investigation)
    - Use of the Study inputs and outputs to further educate/inform the Harcourt community
    - Use of the flood models developed to undertake future assessments
- The possible actions identified in the flood warning feasibility assessment be further investigated by Council, with the support of other relevant authorities as required

8 References

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