Report

Woodend Flood Study

AWE200155 / 304600136



Prepared for
Macedon Ranges Shire Council

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Executive Summary

Overview

Macedon Ranges Shire Council (MRSC) received financial support from the Natural Disaster Resilience Grants Scheme managed by Emergency Management Victoria to undertake a flood study for the Woodend Township. The intention of the project was to have updated and sufficient flood information capable of being used by a variety of stakeholders including authorities and the community for land use planning, flood management planning, emergency response and flooding education. The North Central Regional Floodplain Management Strategy 2018-2028 also requires the land-use planning controls for Woodend to be updated.

Woodend has been subject to a number of heavy rainfall events, which have led to widespread flooding, including in September 1993, November 2010, January 2011 and more recently in 2022. The January 2011 event was the largest flood event in living memory for Woodend. However, the 1993 event still remains an event against which flooding is compared. After the 1993 event, a series of flood levees were constructed along Five Mile Creek in order to increase the level of protection to properties which were inundated during the 1993 event.

Community Consultation and Feedback

A key objective for this study was to engage with the community to ensure their input was considered and incorporated into the study. Despite the limitations of face to face consultation due to COVID-19, it is expected that two rounds of community feedback will have occurred by the completion of the project. The 1st round involved getting community feedback as to where flooding within the community occurs, with the second round seeking public comments on the study's recommendations and findings.

Hydraulic and Hydrological Modelling

As part of this study, a calibrated hydrological RORB model has been developed for the 1993, 2010 and 2011 events with a calibrated hydraulic developed for both the 1993 and 2011 events.

Emergency Response

A key outcome of this study is to provide VICSES with detailed flood information in order to better prepare and respond to flood events within Woodend especially due to flooding along Five Mile Creek.

Next Steps

The Woodend Flood Study has been presented and reviewed by Council with key findings and outcomes from the study being made available to the public in 2023.

Abbreviations

Abbreviation	Name / Definition
AAD	Average Annual Damages
AEP	Annual Exceedance Probability *The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year* *The conversion from ARI to AEP is shown below:* *ARI (years) – equivalent AEP (%)* *1yr ARI – 63% AEP* *2yr ARI – 39% AEP* *5yr ARI – 18% AEP/0.2EY* *10yr ARI – 10% AEP* *20yr ARI – 5% AEP* *50yr ARI – 2% AEP* *100yr ARI – 1% AEP*[1]
ARF	Areal Reduction Factor
ARR1987	Australian Rainfall and Runoff 1987
ARR2019	Australian Rainfall and Runoff 2019 *Best practice for:* *Developing flood management plans for urban and rural communities;* *Flood warnings and flood emergency management; and* *Prediction of extreme flood levels.* *With the release of ARR2019, ARR2016 become superseded (with ARR1987 becoming superseded with the release of ARR2016).*
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EY	Exceedances per Year
DELWP	Department of Environment, Land, Water & Planning
GIS	Geographical Information System
ID	RORB Model Sub-catchment Identifier
IFD	Intensity, Frequency Duration

[1] Bureau of Meteorology, *Glossary*, http://www.bom.gov.au/water/designRainfalls/ifd-arr87/glossary.shtml accessed on 16th June 2022.

LiDAR	Light detection and ranging (LiDAR) data *LiDAR is a remote sensing technology that uses laser light to sample the surface of the earth's surface to produce point cloud datasets that are able to be visualized, shared and used as an input to flood modelling.*
EIA	Effective Impervious Areas *The portion of total impervious area that is hydraulically connected to the formalised drainage system*
FI	Fraction Impervious
FFA	Flood Frequency Analysis
K_c value	Routing parameter used within RORB
ICIA	Indirectly Connected Impervious Areas *Where rainfall runs from an impervious surface across another surface where some continuing losses occur.*
PA	Pervious areas *Where rainfall falls on pervious areas (only to be used for natural undeveloped/forested areas in urban/semi-rural areas).*
PMF	Probable Maximum Flood
RFFE	Regional Flood Frequency Estimation
RORB model	Runoff and streamflow routing program which calculates catchment losses, streamflow hydrographs from rainfall events and other forms of inflows.

Table of Contents

1	Introduction		1
	1.1	Related Documents	1
	1.2	Scenarios to be Assessed	1
2	Background		2
	2.1	Study Area	2
	2.2	Previous Studies	2
	2.3	Relevant Guidelines and References	4
	2.4	Flood Behaviour	6
3	Available Information		9
	3.1	Introduction	9
	3.2	Historical Flood Data	9
	3.3	Data Collection	10
4	Community Consultation		14
	4.1	First Round of Community Consultation	14
	4.2	Second Round of Community Consultation	14
5	Hydrological Analysis		15
	5.1	Model Selection	15
	5.2	Hydrological Model Setup	15
	5.3	Hydrological Model Parameters Selection	21
	5.4	Hydrological Model Calibration	25
	5.5	Hydrological Model Results	31
	5.6	Hydrological Model Validation	34
	5.7	Discussion of The Results	39
	5.8	Critical Storm Events and Associated Temporal Patterns	40
6	Hydraulic Analysis		44
	6.1	Hydraulic Controls	44
	6.2	Model Selection	47
	6.3	Hydraulic Model Setup	47
	6.4	Hydraulic Model Calibration and Validation	53
	6.5	Overall Model Results	61
7	Consequences of Flooding on the Community		64
	7.1	Flood Impacts	64
	7.2	Performance of Hydraulic Control Structures Upstream of the Hydraulic Model Extent	65
	7.3	Hydraulic Model Sensitivity	69
8	Post Processing of Results		79
	8.1	Post processing methodology	79
	8.2	Flood Maps	80
9	Information to Inform Decisions on Activities in the Floodplain and Managing Flood Risk		81

9.1 Emergency Response 81
9.2 Average Annual Damages 100
10 Conclusions 106
11 Recommendations 107
12 Data Hand Over 108
13 Acknowledgements 109
14 References 110

Appendices

Appendix A Figures
Appendix B Sub-Catchment Characteristics
Appendix C ARR Data Hub Information
Appendix D Site Visit Photographs
Appendix E LFCSH Calculations
Appendix F Flood Maps
Appendix G Floor Level Survey

Tables

Table 1-1	Scenarios Modelled	1
Table 2-1	National level Guidelines and References	4
Table 2-2	State level Guidelines and References	5
Table 2-3	Regional level Guidelines and References	5
Table 2-4	Local level Guidelines and References	5
Table 3-1	Rating tables provided by Ventia	12
Table 5-1	Retarding Basin Initial Water Levels within RORB Model	16
Table 5-2	Fraction Impervious Factors Adopted	18
Table 5-3	Fully Developed Permissible Land Use Fraction Impervious Factors Adopted	20
Table 5-4	Assessment of Calculation Method for Future Climate Scenarios	22
Table 5-5	Coefficient of Variation between Rainfall Depths at Three Locations in Woodend Catchment	22
Table 5-6	Comparison of Peak Rainfall Intensities from the 1993 Event to Design Rainfall Intensities	26
Table 5-7	Comparison between Crapper and Cardno (now Stantec's) 1993 Event RORB Calibration	26
Table 5-8	Comparison of Peak Rainfall Intensities from the 2010 Event to Design Rainfall Intensities	27
Table 5-9	Comparison of Peak Rainfall Intensities from the 2011 Event to Design Rainfall Intensities	29
Table 5-10	RORB Calibration Results	30
Table 5-11	Peak Design Flow Rate at Calder Highway Bridge (Monte Carlo Analysis)	34
Table 5-12	Peak Design Flow Rate for Various Storm Lengths – Base Case	34
Table 5-13	Summary of Gauges within Woodend Township	35
Table 5-14	Flood Frequency Analysis Results for Gauge 406269A	35
Table 5-15	Regional Flood Frequency Estimate	36
Table 5-16	Peak Flow Rate at Calder Highway Bridge from Previous Studies	36
Table 5-17	Critical Storm Durations and Temporal Patterns	41
Table 6-1	Invert (based on LiDAR) for formalised Basins and Storages Within the Hydraulic Model	50
Table 6-2	Findings of the Sensitivity Analysis at Calder Highway Bridge	56
Table 6-3	Findings of the Sensitivity Analysis at all Survey Points for the 1993 Flood Event	57
Table 6-4	Findings of the Sensitivity Analysis at All Survey Points For 2011 Flood Event	58
Table 6-5	Hydraulic Model Design Flow Rates	63
Table 7-1	Flood Levels and Depths Over Major Roads	64
Table 7-2	Summary of Results - Calder Highway Bridge over Five Mile Creek	66
Table 7-3	Summary of Results for Culvert 1	67
Table 7-4	Summary of Results for Culvert 2	67
Table 7-5	Summary of Results for Culvert 3	68
Table 7-6	Outcome of the Blockage Assessment	70
Table 8-1	Result Processing Methodology for the 1% AEP Event	79
Table 8-2	Assessed events	80
Table 9-1	Consequences of Flooding	83
Table 9-2	Flood Depths Over Major Roads	90
Table 9-3	Hazard Class over Major Roads	90

Table 9-4 Campaspe Drive Levee 91
Table 9-5 Pyke Street Levee 91
Table 9-6 Retarding Basins 91
Table 9-7 Flood Intelligence Card for Riverine Flooding 93
Table 9-8 Residential Buildings Damages Curve 101
Table 9-9 Commercial Buildings Damages Curve 102
Table 9-10 Industrial Buildings Damages Curve 103
Table 9-11 Vehicle Damages Curve 103
Table 9-12 Road Damages 104
Table 9-13 Expected Damages per AEP 105

Figures

Figure 2-1 Study Area 2
Figure 2-2 1993 Event – Woodend Football Ground (Gilbert Gordon Oval) (Source: North Central Catchment Management Authority) 3
Figure 2-3 1993 Event - Woodend Park Reserve and Bowling Club (Source: North Central Catchment Management Authority) 6
Figure 2-4 1995 Event – Five Mile Creek at Calder Highway (Source: Geoff Crapper) 7
Figure 2-5 2011 Event – Adjacent to Primary School (Source North Central Catchment Management Authority) 8
Figure 3-1 The 1995 Event Upstream of Woodend-Wallan Road (Romsey Road) (Source: Geoff Crapper) 10
Figure 3-2 Floor Level Survey 10
Figure 3-3 1993 Event – South of High Street Bridge (Source North Central Catchment Management Authority) 11
Figure 3-4 Plot of the 9 rating tables 13
Figure 4-1 1993 Event – Near Calder Highway (Source: North Central Catchment Management Authority) 14
Figure 5-1 RORB Layout 15
Figure 5-2 RORB Model 17
Figure 5-3 Effective Impervious Fraction 19
Figure 5-4 Fully Developed Permissible Land Use Effective Impervious Fraction 21
Figure 5-5 Areal Reduction Factors 24
Figure 5-6 1993 Event – Coach Road (From Northern End) (Source: North Central Catchment Management Authority) 27
Figure 5-7 2010 Event RORB Calibration 28
Figure 5-8 2011 Event RORB Calibration 30
Figure 5-9 Monte Carlo Assessment Locations 31
Figure 5-10 Example Monte Carlo Input Sampling (HARC, 2016) 32
Figure 5-11 Deriving the Flood Frequency Curve (HARC, 2016) 33
Figure 5-12 Peak Design Flow Rate at Calder Highway Bridge Plot (Monte Carlo Analysis) 34
Figure 5-13 Comparison of Peak 1% AEP Flow Rates at the Calder Highway Bridge 38
Figure 6-1 Calder Highway Bridge Circa 1934 (Source: State Library of Victoria) and Eastern side of Calder Highway Bridge from the Site Visit. 44
Figure 6-2 Railway Underpass Located at the end of Templeton Street 45
Figure 6-3 Pyke Street Levee 46
Figure 6-4 21 Quarry Road Retarding Basin 47
Figure 6-5 Hydraulic Model Topography 48
Figure 6-6 Hydraulic Model Roughness 49
Figure 6-7 Modelled Stormwater Network and Bridges 52
Figure 6-8 Application of Rainfall and Downstream Boundaries 53
Figure 6-9 1993 TUFLOW Calibration Results 54
Figure 6-10 Flooding from the 1993 Event believed to be at 1 Heron Street (Source: North Central Catchment Management Authority) 54

Figure 6-11 2011 TUFLOW Calibration Results 55
Figure 6-12 Flooding from the 2011 Event Adjacent to Woodend Primary School (Source: North Central Catchment Management Authority) 56
Figure 6-13 Council Hotspots 59
Figure 6-14 Routing within the Hydraulic Model 61
Figure 6-15 Wallan-Woodend Road (Romsey Road) in the 1993 event (Source: North Central catchment Management Authority) 62
Figure 7-1 Assessed Upstream Crossings 66
Figure 7-2 Aerial Imagery of Culvert 3 (Captured 03/04/2021) 68
Figure 7-3 Locations of Blockage Assessment 69
Figure 7-4 5% AEP Blockage Difference Plot 70
Figure 7-5 1% AEP Blockage Difference Plot 71
Figure 7-6 0.1% AEP Blockage Difference Plot 71
Figure 7-7 5% AEP High Hydraulic Roughness Difference Plot 72
Figure 7-8 5% AEP Low Hydraulic Roughness Difference Plot 73
Figure 7-9 1% AEP High Hydraulic Roughness Difference Plot 73
Figure 7-10 1% AEP Low Hydraulic Roughness Difference Plot 74
Figure 7-11 0.1% AEP High Hydraulic Roughness Difference Plot 74
Figure 7-12 0.1% AEP Low Hydraulic Roughness Difference Plot 75
Figure 7-13 5% AEP Downstream Boundary Difference Plot 76
Figure 7-14 1% AEP Downstream Boundary Difference Plot 76
Figure 7-15 0.1% AEP Downstream Boundary Difference Plot 77
Figure 7-16 1% AEP High Flow Difference Plot 78
Figure 9-1 Woodend Rainfall Triggers - Calder Highway at Five Mile Creek 92
Figure 9-2 Types of flood damage (Floodplain Development Manual, NSW Gov, 2005) 100
Figure 9-3 Surveyed Floor Levels Compared to LIDAR 104

1 Introduction

Macedon Ranges Shire Council (Council) with support from the Victorian State Government engaged Cardno (now Stantec) to undertake a detailed hydrological and hydraulic modelling assessment of the Woodend Township. The aim of the study was to provide updated and sufficient flood information capable of being used by a variety of stakeholders including authorities and the community for land use planning, flood emergency planning, emergency response and community education.

This project consisted of a number of stages including:

- Data Review – assessing the data available and determining the most appropriate information to utilise
- Hydrological Modelling – deriving flows which represent flood events so that these can be introduced to the hydraulic model
- Hydraulic Modelling – determining flood risk in the catchment as a result of these flows (for example flood depth, velocity and hazard)
- Flood Mapping – preparing GIS and mapped outputs to illustrate the hydraulic model findings

1.1 Related Documents

The following documents should be referred to in conjunction with this report:

- Data Review report – 28th February 2020 (AWE2000155_DataReview_WoodendFloodStudy.pdf); and
- Modelling Methodology Report – 4th March 2020 (AWE200155_Modelling_Methodology_Report.pdf).

1.2 Scenarios to be Assessed

The modelled scenarios are outlined in Table 1-1.

Table 1-1 Scenarios Modelled

Scenario	AEP						
	0.2EY	10%	5%	2%	1%	0.1%	Historical Events
1A Historical Calibration							√
2B* Base Case (Existing Conditions)	√	√	√	√	√	√	
3 Fully Developed for Permissible Land Uses			√		√	√	
4D Sensitivities to Climate Change (Increased Rainfall Intensities)			√		√	√	
5 Design Events for Levee Assessment (Scenarios to also Include the Design Flood and Events above the Design Flood)	√	√		√	√	√	
7C Model Parameter Sensitivity Analysis			√		√	√	

*Scenario includes scenarios 8 (Design events for assessment of flood hazard) , 9 (Design events for assessment of flood function) & 12 (Design events for developing information to support land use planning activities)

2 Background

2.1 Study Area

The study area is shown in Figure 2-1, which indicates:

- The hydrologic model catchment – this has been developed based on topography
- The Hydraulic model extent which is centred on the Woodend Township as the area of interest for this study
- The Victorian Government defined waterways including Five Mile Creek (NB: Waterways are designated in accordance with section 188 of the Water Act 1989).

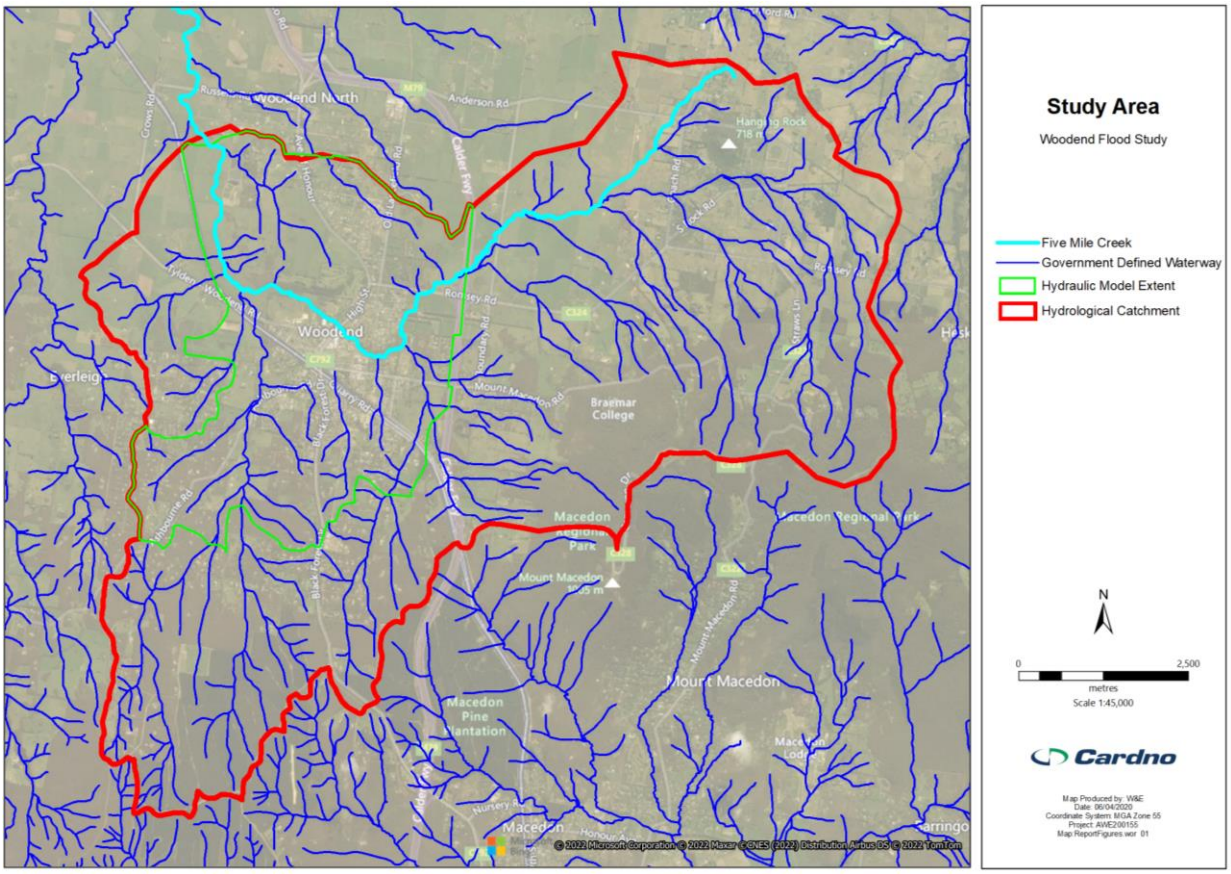


Figure 2-1 Study Area

2.2 Previous Studies

Several previous flood studies have been undertaken along Five Mile Creek in the vicinity of Woodend. As part of this project, the following studies have been supplied to Cardno (now Stantec) as reference material:

- Five Mile Creek Flood Study, Geoff Crapper 1995:
  - This report comprises a RORB and HEC-RAS model calibrated to the 1993 flood event and in turn a 1% AEP design flow rate which had been widely adopted by future studies along Five Mile Creek
  - This report also references earlier studies including:
    - Strategy Plan Report, Scott & Furphy July 1974
    - Flood Study, Clive Steele Partners 1991
    - Shirley Park Flood Study, John Randles & Associates 1993.
- Report on 6th November 1995 Storm Event in Five Mile Creek, Woodend, Geoff Crapper 1995:
  - This report undertakes an assessment of the 6th November 1995 flood event

- An Assessment of Coomes Consulting Group Woodend Township Drainage Study Report for the Shire of Macedon Ranges, Christine Pruneau & Geoff Crapper 1996:
  - This report consists of a review of the Coomes 1997 Study before this study was finalised
- Design Flows for Five Mile Creek at Boundary Road, Woodend, Geoff Crapper 1997:
  - This report undertakes a hydrological assessment to assist in the development of the Woodend Bypass
- Woodend Township Drainage Study (Volume 1 to Volume 3), Coomes 1997:
  - This series of reports determined the 1% AEP flood levels along Five Mile Creek and assesses drainage problems within the Woodend Township, using RORB and HEC-RAS
  - This study relies on key findings of the Crapper (1995) Study
- Woodend Detention Basin Investigations and Woodend Flood Damages Assessment, Lawson Treloar 1998:
  - This study was undertaken as a preliminary investigation into the feasibility and economic viability of a detention storage for flood mitigation purposes on Five Mile Creek
  - This study relies on key findings from the Crapper (1995) Study
- Five Mile Creek at Wallan-Woodend Road, Neil Craigie 1998:
  - This study was undertaken to assist in the geomorphological design of the Woodend Bypass
  - This study relied on key findings from the Lawson Treloar (1998) Study
- 2-4 Davy Street Woodend Development Flood Assessment, Water Technology 2015:
  - This study was undertaken in order to assist the development of 2-4 Davy Street, Woodend using RORB and TUFLOW
  - This study relied on key findings from the Coomes (1997) Study



Figure 2-2 1993 Event – Woodend Football Ground (Gilbert Gordon Oval) (Source: North Central Catchment Management Authority)

2.3 Relevant Guidelines and References

Relevant National, State and Regional level Guidelines and References are detailed below including a description of the application of the reference to this study.

2.3.1 National Level Guidelines and References

Table 2-1 National level Guidelines and References

Reference	Source	Application
Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia	https://knowledge.aidr.org.au/media/3515/adr-guideline-7-2.pdf	▪ Flood Risk Management Framework ▪ Principles of best practice approach to flood risk management ▪ Roles and responsibilities ▪ Flood probabilities, flood function, flood hazard ▪ Flood consequences to the community, built environment ▪ Treating flood risks ▪ Flood study guidance
Guideline 7-2 Flood Emergency Response Classification	https://knowledge.aidr.org.au/media/3515/adr-guideline-7-2.pdf	▪ Emergency management planning for floods ▪ Classification of the floodplain based on flood emergency response classifications ▪ Strategic and development scale land use planning ▪ Assessment of isolation risks
Guideline 7-3 Flood Hazard	https://knowledge.aidr.org.au/media/3518/adr-guideline-7-3.pdf	▪ Quantifying flood hazard ▪ Isolation, warning time, rate of rise and time of day considerations
Guideline 7-5 Flood Information to Support Land-use Planning	https://knowledge.aidr.org.au/media/3519/adr-guideline-7-5.pdf	▪ Flood planning constraint categorisation ▪ Flood extent and flood mapping
Guideline 7-6 Assessing Options and Service Levels for Treating Existing Risk	https://knowledge.aidr.org.au/media/3520/adr-guideline-7-6.pdf	▪ Assessing and optimising treatment options
Australian Disaster Resilience Handbook Collection - Manual 27 Disaster Loss Assessment Guidelines	https://knowledge.aidr.org.au/media/1967/manual-27-disaster-loss-assessment-guidelines.pdf	▪ Framework for disaster loss assessment ▪ Inform approach to calculate Average Annual Damages (AADs)
Australian Rainfall & Runoff (ARR)	http://www.arr-software.org/project-reports.html	▪ Used to inform the hydrological analysis and hydraulic assessment

2.3.2 State level Guidelines and References

Table 2-2 State level Guidelines and References

Reference	Source	Application
Victorian Floodplain Management Strategy	https://www.water.vic.gov.au/managing-floodplains/vfms	▪ The key roles and responsibilities of government, agencies and authorities ▪ The strategic framework for floodplain management in Victoria
State Emergency Response Plan (Flood Sub-Plan)	https://files-em.em.vic.gov.au/public/EMV-web/SERP-StateFloodSub-plan.pdf	▪ The response arrangements for flooding in Victoria
Victorian Flood Data and Mapping Guidelines	https://www.water.vic.gov.au/__data/assets/pdf_file/0027/53757/Victorian-Flood-Data-and-Mapping-FOR-WEB.pdf	▪ The standards for flood mapping and flood data collection
Levee Management Guidelines	https://www.water.vic.gov.au/__data/assets/pdf_file/0010/60013/DEP-8419-Levee-design-construction-and-management-guidelines_FA_web.pdf	▪ Principles for levee management, categories for levees including levee hazard classification, developing a levee management system and guidance on a 'Levee Management Manual'

2.3.3 Regional level Guidelines and References

Table 2-3 Regional level Guidelines and References

Reference	Source	Application
North Central Regional Floodplain Management Strategy (2018-2028)	http://www.nccma.vic.gov.au/sites/default/files/publications/nc_rfms_-_final_for_web.pdf	The regional floodplain management context, the defining of roles and responsibilities, the details of risk treatments and identification of regional floodplain management issues
Melbourne Water Corporation Flood Mapping Projects Guidelines and Technical Specifications Version 10	Melbourne Water (*sourced from Flood Services team*)	Used to inform the hydrological analysis and hydraulic assessment

2.3.4 Local level Guidelines and References

Table 2-4 Local level Guidelines and References

Reference	Source	Application
Macedon Ranges Planning Schemes Online	https://planning-schemes.delwp.vic.gov.au/schemes/macedonranges	Used to guide SES flood emergency plan and hydrological analysis and hydraulic assessment.

2.4 Flood Behaviour

Woodend is prone to flooding due to its proximity to both the Macedon Ranges and to Five Mile Creek and its associated tributaries which run through the centre of the town. Flooding along the waterways surrounding Woodend including along Five Mile Creek is primarily caused by extended periods of rainfall (generally greater than 6 hours) in the catchment upstream of Woodend. However, flooding within the urbanised areas of Woodend is largely driven by shorter duration storms which may be only localised over Woodend itself and the immediate surrounding areas.

2.4.1 Historical Events

Woodend has had several flood events within living memory, including in 1993, 1995, 2010, 2011 and 2022. A brief description of these events and their impacts with the exception of the 2022 event are summarised in the sections below.

2.4.1.1 1993 Flood Event

During the 1993 flood event, Woodend witnessed widespread flooding along all major waterways around the township, with flood levels overtopping the Calder Highway at Five Mile Creek. Figure 2-3 shows this event at the Woodend Park Reserve and Bowling Club. Based on photographs of this event, other areas where significant flooding overtopped the road also included:

- Wallan-Woodend Road (Romsey Road)
- Coach Road
- Boundary Road
- Russels Road

It is also noted that the Football Ground was significantly inundated during the flood.



Figure 2-3 1993 Event - Woodend Park Reserve and Bowling Club (Source: North Central Catchment Management Authority)

2.4.1.2 1995 Flood Event

There are not a lot of documented records of the impacts of the 1995 flood event, beyond those along Five Mile Creek itself. Recorded flood levels indicate that the peak flood level was approximately 0.56m lower than the 1993 flood event. Apart from along Five Mile Creek, other areas which witnessed significant flooding included:

- Woodend-Wallan Road (Romsey Road)
- Mt Macedon Road



Figure 2-4 1995 Event – Five Mile Creek at Calder Highway (Source: Geoff Crapper)

2.4.1.3 2010 and 2011 Flood Events

The 2010 and 2011 flood events occurred within 2 months of each other, with the 2011 event being the larger of the 2 events. Limited information was captured for the 2010 event to be able to assess the extent of flooding. For the 2011 event, Council obtained surveyed flood levels which indicate a significant level of flooding along Five Mile Creek.



Figure 2-5 2011 Event – Adjacent to Primary School (Source North Central Catchment Management Authority)

2.4.2 Design Events

Flooding within Woodend is predominately limited to along the existing major drainage lines including Five Mile Creek and its associated tributaries.

In the 0.2EY event, significant flooding occurs along the major waterways including Five Mile Creek, but it is mostly contained to within the drainage reserves, however where break out flows do occur, some flooding of the road network is present.

In the 10% AEP event, most overland flow paths throughout Woodend exceed the underground drainage capacity, with a continuous overland flow path discharging into Five Mile Creek.

In the 5% AEP event, the carpark from the shopping centre located directly to the south of Five Mile Creek is inundated by overland flows.

In the 2% AEP and 1% AEP events, there is not a significant difference in the extent of flooding, apart from the overland flow paths extending further up the catchment. However, there is a significant increase in the depth of flooding along all major overland flow paths.

3 Available Information

3.1 Introduction

This section summarises the key information that has been used in the hydrologic and hydraulic analyses. A full data review can be found in the data review report (dated 28/02/2020) which includes a description of all information provided at project inception.

3.2 Historical Flood Data

At the inception of this project, Council in conjunction with the North Central Catchment Management Authority (NCCMA), provided information on the 1993, 1995 and 2011 flood events. This information mainly consisted of photographs of flooding during these events as well as recorded flood levels along Five Mile Creek generally between Wallan-Woodend Road and the Calder Highway.

The September 1993 event occurred over the period between 15th to the 16th of September 1993, during which a total of 103.1mm of rainfall was recorded at the Woodend Rainfall Station (88061). Based on previous calibrated modelling of the catchment, this resulted in a peak flow rate at the Calder Highway Bridge of 26.3 m^3/s.

The November 1995 event occurred from the 3rd to the 4th of November 1995, with rainfall ranging from 105mm in the upper reaches of Five Mile Creek to 70-80mm in the lower parts of the catchment, with an estimated peak flow rate just upstream of the Calder Highway along Five Mile Creek of 15 m^3/s. Figure 3-1 below shows flooding during the 1995 event upstream of Woodend-Wallan Road (Romsey Road) at approximately 16:30 on the 6th of November (the peak is estimated to have occurred half an hour earlier at 16:00).

The November 2010 event occurred over the period between 26th to the 28th of November 2010, with a total of 83.3mm of rainfall recorded and a peak flow of 23.8 m^3/s just upstream of the Calder Highway along Five Mile Creek.

The January 2011 event occurred from the 12th to the 14th of January 2011, with a total of 229.6mm of rainfall falling and a peak flow of 41.8 m^3/s being recorded at a stream gauge just upstream of the Calder Highway along Five Mile Creek.

Council have provided to Cardno (now Stantec) with flood hotspot data from reported flooding and drainage issues throughout the catchment. Some of this data is from the 1993 event and therefore it is likely that changes in the catchment including the Calder Highway bypass and other mitigation works may limit the reliability of some of this data.



Figure 3-1 The 1995 Event Upstream of Woodend-Wallan Road (Romsey Road) (Source: Geoff Crapper)

3.3 Data Collection

3.3.1 Information from Site Visit

A site visit was undertaken by representatives from Cardno (now Stantec) and Council on Tuesday the 4th of February 2020. The weather was 25 degrees with 0.2 mm of rainfall recorded in the in the previous 24 hours at the Woodend rainfall gauge. In the preceding week, a total of 21.6 mm of rainfall had occurred, with 20.2 mm of rainfall falling 2 days before the site visit.

The site visit was used to visit key features within the catchment, such as the flood levees, the Calder Highway Bridge along with other points of interest. The site visit was also used to help fill in the dimensions of bridges and culverts where they were found to be incomplete in the provided dataset as well as to gather a detailed understanding of both flood mechanisms within the catchment and areas where there are known flood issues.

All photographs captured during the site visit are included in Appendix 0.

3.3.2 Floor Level Survey

In order to be able to complete the damage assessment, Cardno (now Stantec) undertook a floor level survey of 80 buildings as shown in Figure 3-2. All buildings which intersected the 1% AEP flood extent were identified for survey, but due to both council budgetary and time constraints, a high-level assessment of the flood risk (based on depth of flooding intersecting the building) for each identified building was instead undertaken.

For building where a floor level survey was not undertaken, a consistent methodology to assign floor levels was adopted as described in section 9.2.1.3. This was then relied on for the damages assessment undertaken.

Appendix 0 contains the results of the Floor Level Survey.

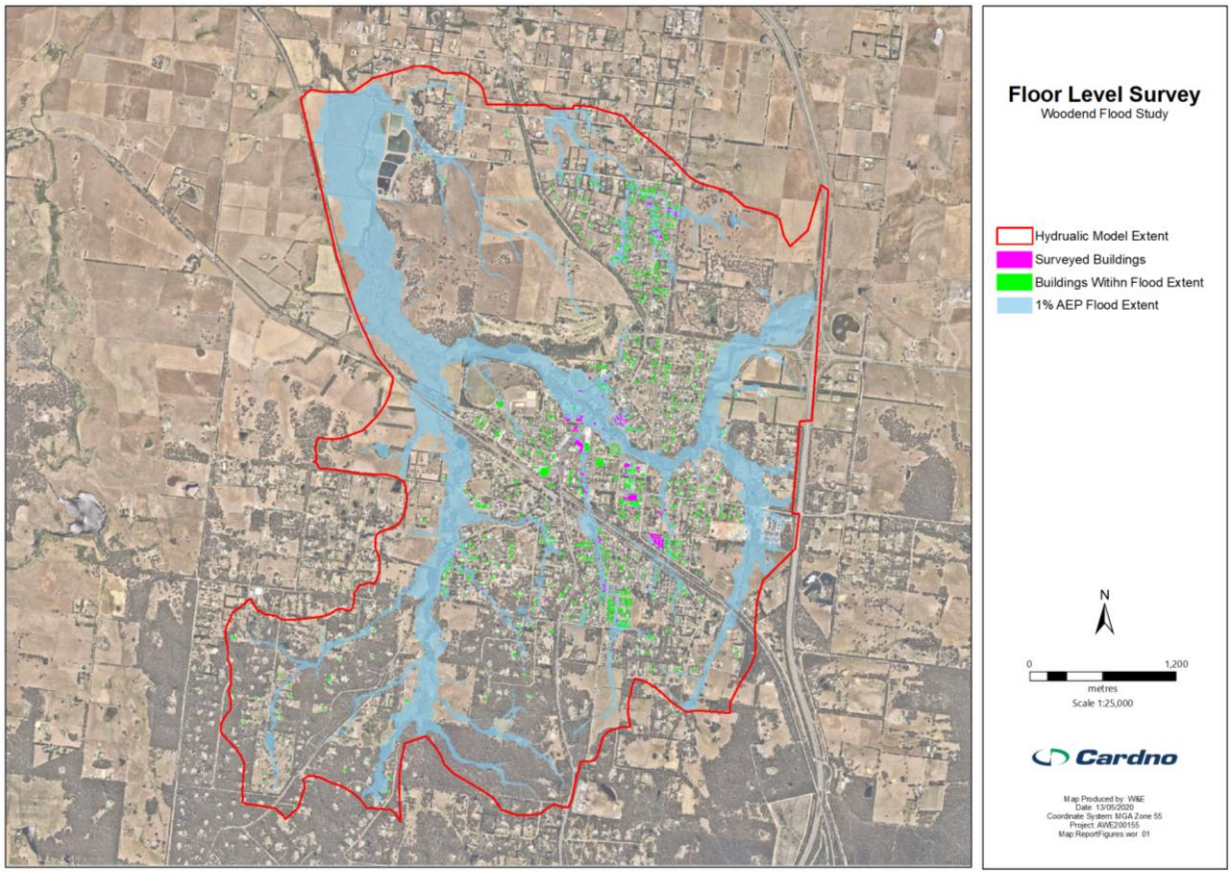


Figure 3-2 Floor Level Survey

3.3.3 Topographic and Aerial Survey and Imagery

Nearmap Aerial Photography was accessed at the commencement of the study in January 2019. This dataset was used to confirm fraction impervious values for the modelling and as base map contextual information.

3.3.4 DEM Development

A comprehensive Digital Terrain Model (DTM) was compiled from the LiDAR data (captured in 2017). The digital elevation model (DEM) was then constructed as a rectangular grid of elevations sampled from this DTM.

The DEM defines the topography of the catchment and has been used in the hydrological analysis to delineate the catchment / sub-catchments. The DEM was also used in the hydraulic modelling stages to define the 2D model topography and report the subsequent results.

It should be noted that the supplied 1m LiDAR did not cover the entire catchment. A section to the east of the Calder Freeway has been defined using ELVIS 1 second LiDAR. However, it should be noted that this area was not part of the hydraulic model bounds and was only used to designate the hydrologic model sub-catchments in this area.

3.3.5 Parcel and Land Use Data

Parcel and land use data was downloaded from Vic Data Online (www.data.vic.gov.au). This data was used:

- as contextual base map information; and
- in the derivation of fraction impervious based on the land use type of the parcel.

3.3.6 Pipe and Pit Data

The data review document (dated 28/02/2020) details the pipe and pit data supplied. The location of pipes was used to help define catchments and sub-catchments. In topographically flat areas, this data also assisted in determining the direction of flow of the catchments. The pits and pipes were also input into the hydraulic model as 1D elements.



Figure 3-3 1993 Event – South of High Street Bridge (Source North Central Catchment Management Authority)

3.3.7 Rating Table for Gauge 406269A

As part of this study, Cardno (now Stantec) assessed the rating table for gauge 406269A. As neither council nor the gauge operator (Ventia) were able provide the gauge zero, Cardno (now Stantec) obtained survey of the gauge board located directly upstream of the Calder Highway Bridge, which determined a gauge zero of 548.81 mAHD based on the zero mark on the gauge board.

During the course of the study Ventia provided information to the independent reviewer of the 9 rating tables that have been adopted during the life of the gauge. The dates of when the various rating tables applied are shown in Table 3-1, along with the maximum flow and stage provided by each rating table.

Table 3-1 Rating tables provided by Ventia

Start date	End date	Rating table number	Max flow (ML/d)	Max flow (m^3/s)	Max stage (m)
19/07/2000	02/11/2000	3	2400	27.8	2
02/11/2000	21/03/2001	1	2400	27.8	2
21/03/2001	11/04/2003	2	2400	27.8	2
11/04/2003	26/01/2005	Not available	NA	NA	NA
26/01/2005	13/02/2007	6	2400	27.8	2
13/02/2007	13/01/2011	5	4000	46.3	2.4
13/01/2011	23/05/2011	7	4000	46.3	2.4
23/05/2011	07/07/2011	4	4000	46.3	2.4
07/07/2011	13/03/2014	8	4000	46.3	2.4
13/03/2014	Present	9	4000	46.3	2.4

The 9 different rating tables are plotted in Figure 3-4. On this log scale, the variation in the relationship between gauge reading and flow is emphasised for low flows (less than 10ML/D). It is noted that rating curve during the January 2011 event (refer to rating table 7 within Figure 3-4), is one of three low flow outliers when compared to the other adopted rating curves. Cardno (now Stantec) did receive advice from Venita that the gauge reference point may have been shifted 100mm at some point in its service period. However, this was not able to be confirmed during the course of the study.

Despite the uncertainties noted above, the recorded flow data has been used in the development of the hydrological RORB model.

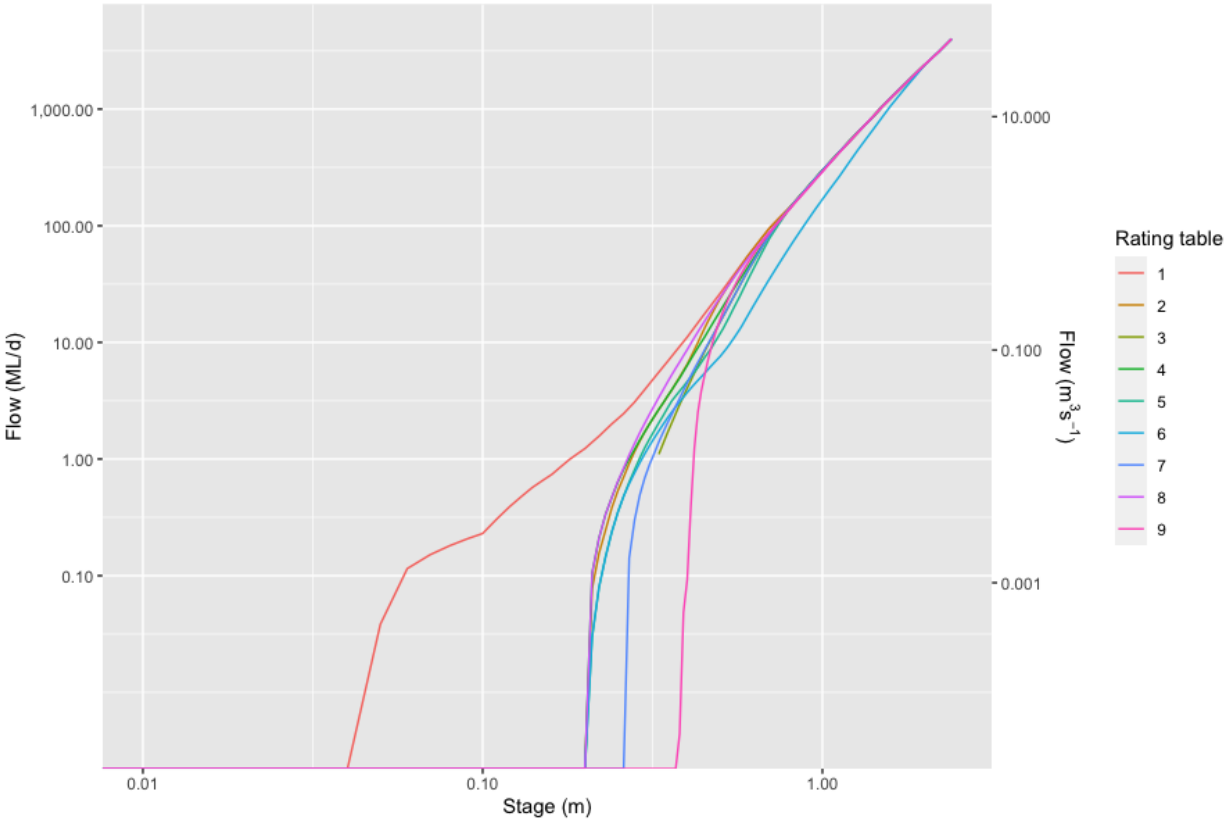


Figure 3-4 Plot of the 9 rating tables

4 Community Consultation

4.1 First Round of Community Consultation

Cardno (now Stantec) worked with Council in February 2020 on a proposed methodology to undertake the first round of community consultation for this project. This included:

- Developing content for an online survey to be disseminated on the '*Have Your Say*' section of the MRSC website
- Developing a media release to be disseminated
- Developing a draft letter to send to flood affected residents

Targeted community consultation was also undertaken to obtain flood intelligence from community groups and community representatives. This included obtaining information from the Woodend Historical Society on recent flood events as one particular example.

4.2 Second Round of Community Consultation

During the second round of community consultation, it is intended that Council will release the results of the flood study to the community in order to seek public comments on the study's findings.



Figure 4-1 1993 Event – Near Calder Highway (Source: North Central Catchment Management Authority)

5 Hydrological Analysis

5.1 Model Selection

The hydrological modelling software RORB (version 6.45) was used in this flood mapping project. RORB calculates flood hydrographs from storm rainfall hyetographs and can be used for modelling natural, part urban and fully urban catchments. RORB is an industry standard hydrological model that has been used widely in previous studies undertaken in Victoria and throughout Australia.

The base hydrological model was created in GIS, utilising the MapInfo plug-in, MiRORB. The methodology implemented in MiRORB is outlined in Section 5.2. Furthermore, the RORB modelling methodology has been outlined in Sections 5.3, 5.4 and 5.5.

5.2 Hydrological Model Setup

5.2.1 Catchment / Sub-Catchment Delineation

The overall catchment and internal sub-catchments were delineated primarily based on topography and drainage assets.

Topography and drainage asset data was used to ensure all areas that can contribute flow in the 1% AEP storm event were included in the catchment, regardless of the flow mechanism (pipe or overland). The entire upstream catchment contributing flow to the study area was included in the hydrologic model.

Occasionally, topographical flow paths contradict pipe flow directions. In these cases, topographic flow paths were relied on to delineate catchments.

The catchment and subarea boundaries are illustrated in Figure 5-1.

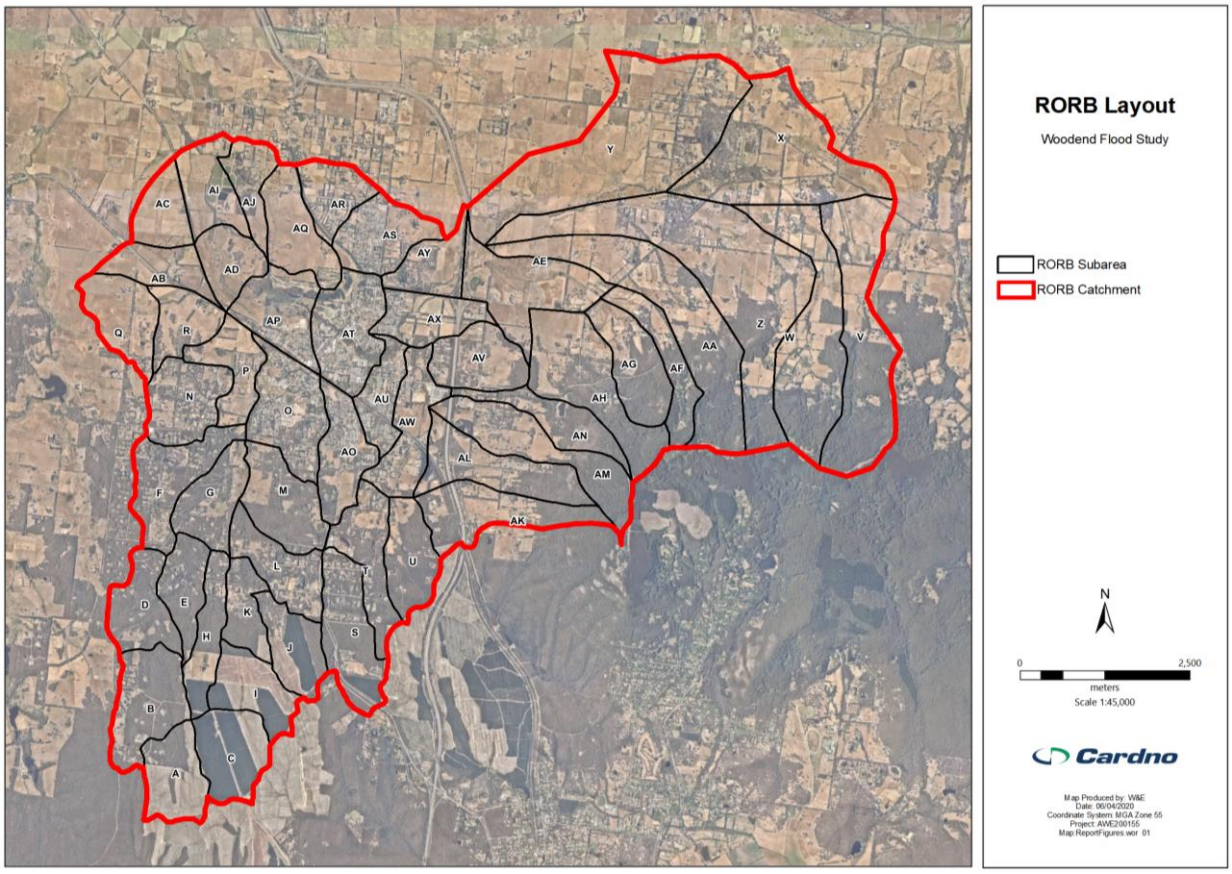


Figure 5-1 RORB Layout

5.2.2 Nodes and Reaches

Nodes were located as required at centroids of subareas, at the downstream end of each subarea and at any confluence. The nodes were placed so that they made some allowance for the time taken for subarea flows to reach the main channel. Flows routing from the various sub-catchments use control codes appropriate to the flow routing required.

Reach types were selected to represent the likely routing properties of the subareas. Reach Type 1 (natural) was used to represent both the formed natural waterways and the virgin catchments with reach type 2 (excavated but unlined) selected to represent all other sub catchments (farmland and developed catchments). Due to the Woodend township comprising two separate catchments, in order to create a single hydrological model, Reach Type 5 (dummy) has been used to link the two catchments together.

5.2.3 Storages

Storages were included in the hydrologic model at any significantly topographically distinct formal and informal storages identified from aerial imagery and the DEM. Six storages were included in the RORB model, with the aim of accurately representing the detention of flows within the hydraulic model. This allows for a better estimate of critical durations within RORB.

Storage parameters for RORB were sourced from existing models, retarding basin design plans, LiDAR and pipe data. Where existing models were not available, stage-storage relationships and outlet information were derived from retarding basin design plans, as well as council pipe data. If neither were available, parameters were estimated from LiDAR and pipe data.

Table 5-1 outlines the initial water level for each of the retarding basins included with the hydrological RORB model, which corresponds to the natural top water level (NTWL) of each basin. While Figure 5-2 illustrates the sub-catchments, nodes, reaches and storage locations.

Table 5-1 Retarding Basin Initial Water Levels within RORB Model

Storage	Modelled Initial Water Level (mAHD)
Calder Freeway – Five Mile Creek	561.30
Romsey Road	558.10
Calder Freeway – North of Mount Macedon Road	561.60
Calder Freeway – South of Sullivans Road	563.00
Calder Freeway – North of Kinsellas Lane	563.40
Quarry Road Retarding Basin	558.00
Railway Line – West of Woodend Township	542.30

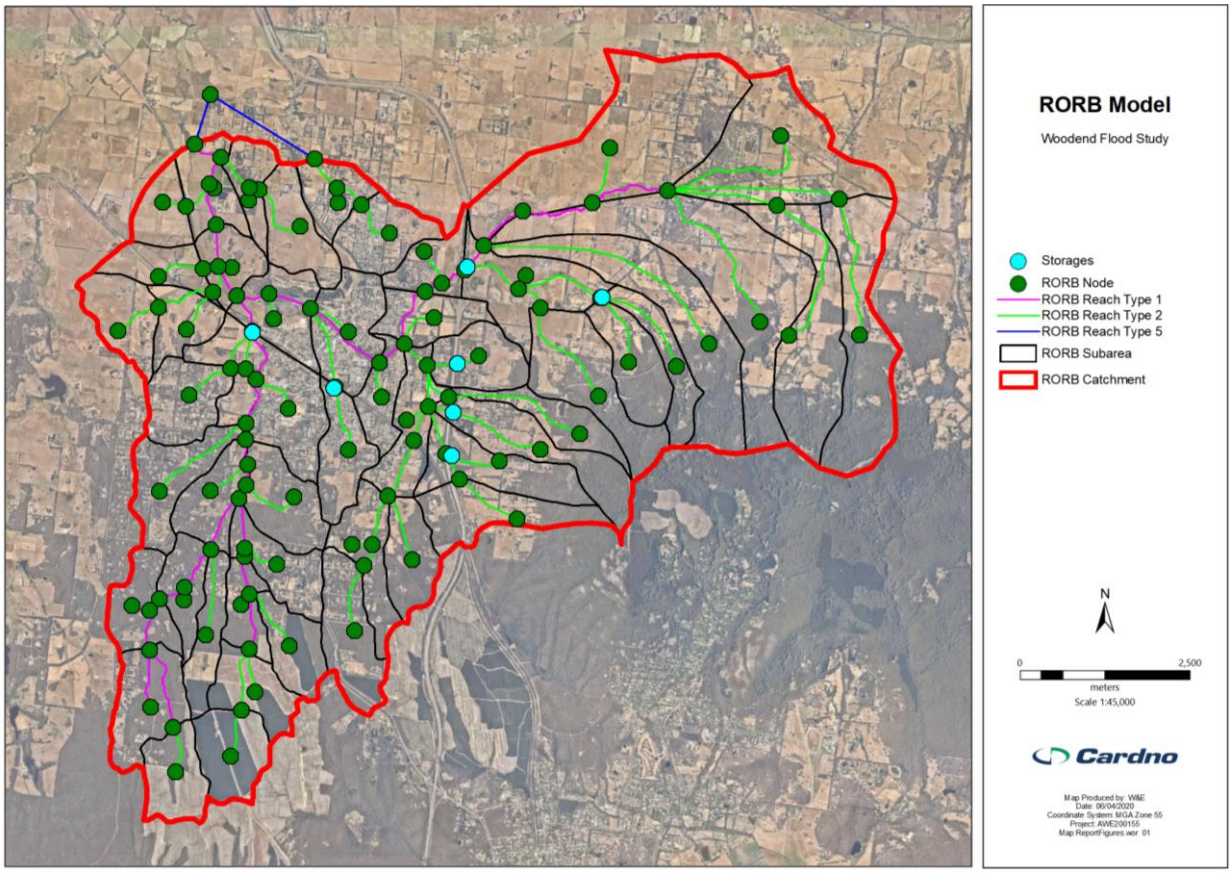


Figure 5-2 RORB Model

5.2.4 Fraction Impervious Methodology

ARR 2019 advises the loss model is made of three impervious types.

- Effective Impervious Areas (EIA) – where rainfall is directly transformed to runoff, after an initial storage loss;
- Indirectly Connected Impervious Areas (ICIA) – where rainfall runs from an impervious surface across another surface where some continuing losses occur; and
- Pervious Areas (PA) – where rainfall falls on pervious areas (only to be used for natural undeveloped/forested areas in urban/semi-rural areas).

ARR 2019 discusses that using GIS techniques to identify directly connected impervious areas (identifying road, roof and driveway areas) show that the EIA is typically between 70% and 80% of the measured impervious area. However, this may trend to 100% as the catchment imperviousness increases to 100%. When measured at a catchment scale, without considering connectedness, the EIA is approximately 55-65% of the Total Impervious Area (Phillips et al, 2014).

For this assessment, we have assumed Fraction Impervious (FI) values are the measured impervious areas (from GIS) for each land use type. These FI values were estimated to be in line with relevant guidance including Melbourne Water's Technical Specification (Melbourne Water 2019). An EIA factor was then calculated for each area based on land use type and visual inspection of aerial images.

The EIA for a land use type in the sub-catchment was then calculated using the following formula:

EIA = (total land use area) * TechSpecFI* EIAFactor

The sub-catchment EIA was then calculated as the sum of the EIAs for each land use type within the given sub-area. Table 5-2 shows fraction impervious values and EIA factors for each land use type. The individual land use zone EIA values were assessed against Table M1 of the Melbourne Water Technical Specification (Melbourne Water 2019) and found to be within a reasonable margin of variation.

Table 5-2 Fraction Impervious Factors Adopted

Zone	Zone Code	Fraction Impervious	EIA Factor	EIA reasoning
Commercial Zone	C1Z	0.9	0.9	ARR predicts a high level of connectivity for highly impervious commercial areas. Commercial zones in less developed areas have higher proportions of pervious areas and lower EIA factors due to the trend mentioned above.
Farming Zone	FZ	0.1	0.1	It is estimated that there will be a very low level of impervious and a very low level of directly connected areas due to a lack of formalised drainage.
Industrial Zone	IN3Z	0.8	0.8	It is estimated that the majority of runoff from impervious areas will enter directly into the pipe system through roof and carpark drainage.
Low Density Residential Zone	LDRZ	0.15	0.4	Generally, the impervious areas in low density residential zones will be connected to the local drainage network which results in
Neighborhood Residential Zone	NRZ2/NRZ3 NRZ4/NRZ5/ NRZ6	Varying (0.2-0.6)	Varying (0.4-0.6)	Generally consistent with the residential area discussed above, but with greater variation in the level of development.
Public Conservation and Resource Zone	PCRZ	0.1	0.1	With the majority of the area being pervious and with little to no council pipes, it is expected that the majority the areas are indirectly connected.
Public Park and Recreation Zone	PPRZ	0.05	0.1	The areas are highly pervious, with little to no council pipes present, therefore it is expected that the majority of these areas are indirectly connected.
Public Use – Service and Utility	PUZ1	Varying (0.1-0.4)	Varying (0.1-0.2)	Several easements. Both contain a mix of pervious and impervious areas.
Public Use - Education	PUZ2	0.4	0.5	Schools with medium levels of impervious areas and connectedness.
Public Use – Transport	PUZ4	0.2	0.2	Some impervious areas, of which a limited number are expected to be directly connected.
Public Use – Cemetery/Crematorium	PUZ5	Varying (0.1-0.5)	Varying (0.1-0.5)	Generally pervious, but large impervious areas are present. Impervious areas are expected to be connected to formalised drainage.
Public Use – Local Government	PUZ6	Varying (0.2-0.4)	Varying (0.1-0.6)	Local government facilities, with some open space. Assumed that carpark and roof drainage will be directly connected.
Public Use – Other Public Use	PUZ7	Varying (0.1-0.4)	Varying (0.1-0.6)	Predominately open space with some commercial areas that have higher FI and EIA values.
Rural Conservation Zone	RCZ1/RCZ2	Varying (0.1-0.2)	0.1	Mostly consist of open pervious areas with low directly connected factors.
Road Zone	RDZ1/RDZ2	Varying (0.1-0.6)	Varying (0.1-0.9)	Roads range from undeveloped easements to dirt roads and from sealed roads up to freeways all with varying degrees of impervious and directly connected values.

Zone	Zone Code	Fraction Impervious	EIA Factor	EIA reasoning
Rural Living Zone	RLZ	0.1	0.1	Mostly consist of open pervious areas with limited rural residential developments, which are estimated to have a low directly connected factors.
Special Use Zone	SUZ1/SUZ3	Varying (0.1-0.2)	0.1	Predominately open space with limited development.
Other – Open Space	N/A	0.1	0.1	Contains large pervious areas within individual planning zones. These areas are highly pervious and in turn have a low directly connected factor.

Figure 5-3 illustrates the Effective Impervious Fraction across the catchment. Furthermore, Appendix B summarises the sub-catchment characteristics, including ID, Area and Effective Impervious Fraction.

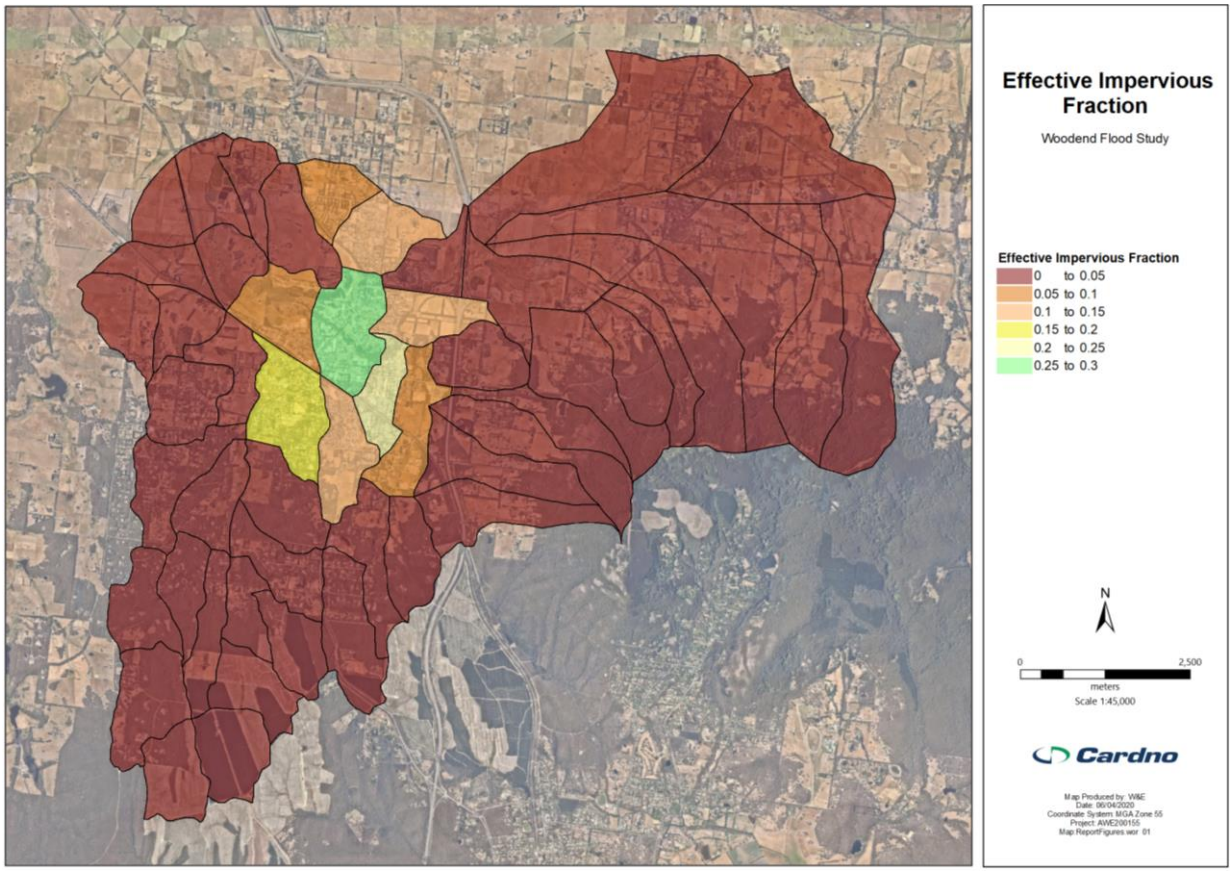


Figure 5-3 Effective Impervious Fraction

5.2.5 Fully Developed Permissible Land Use

In order to model the fully developed permissible land use scenario, the following factors were updated to the maximum allowable values according to the relevant planning scheme descriptions:

- Fraction impervious values; and
- EIA factor

Table 5-3 outlines the fraction impervious values and EIA factor values for this scenario, with Figure 5-4 showing the fully developed permissible land use effective impervious fractions. Furthermore, Appendix B summarises the sub-catchment characteristics, including ID, Area and Effective Impervious Fraction.

As the Fully Developed Permissible Land Use has been based on the planning scheme, increases to the fraction imperious and EIA factor (and the resultant Effective Fraction Impervious value) results in a maximum uniform value for each planning scheme zone.

Table 5-3 Fully Developed Permissible Land Use Fraction Impervious Factors Adopted

Zone	Zone Code	Fraction Impervious	EIA Factor
Commercial Zone	C1Z	0.9	0.9
Farming Zone	FZ	0.1	0.1
Industrial Zone	IN3Z	0.9	0.9
Low Density Residential Zone	LDRZ	0.2	0.4
Neighborhood Residential Zone	NRZ2/NRZ3 NRZ4/NRZ5/NRZ6	Varying (0.4-0.9)	Varying (0.6-0.9)
Public Conservation and Resource Zone	PCRZ	0.2	0.5
Public Park and Recreation Zone	PPRZ	0.2	0.5
Public Use – Service and Utility	PUZ1	0.5	0.5
Public Use - Education	PUZ2	0.9	0.9
Public Use – Transport	PUZ4	0.2	0.3
Public Use – Cemetery/Crematorium	PUZ5	0.9	0.9
Public Use – Local Government	PUZ6	0.9	0.9
Public Use – Other Public Use	PUZ7	Varying (0.2-0.6)	Varying (0.5-0.6)
Rural Conservation Zone	RCZ1/RCZ2	0.2	Varying (0.1-0.5)
Road Zone	RDZ1/RDZ2	Varying (0.5-0.9)	Varying (0.2-0.9)
Rural Living Zone	RLZ	0.2	0.5
Special Use Zone	SUZ1/SUZ3	0.2	0.5

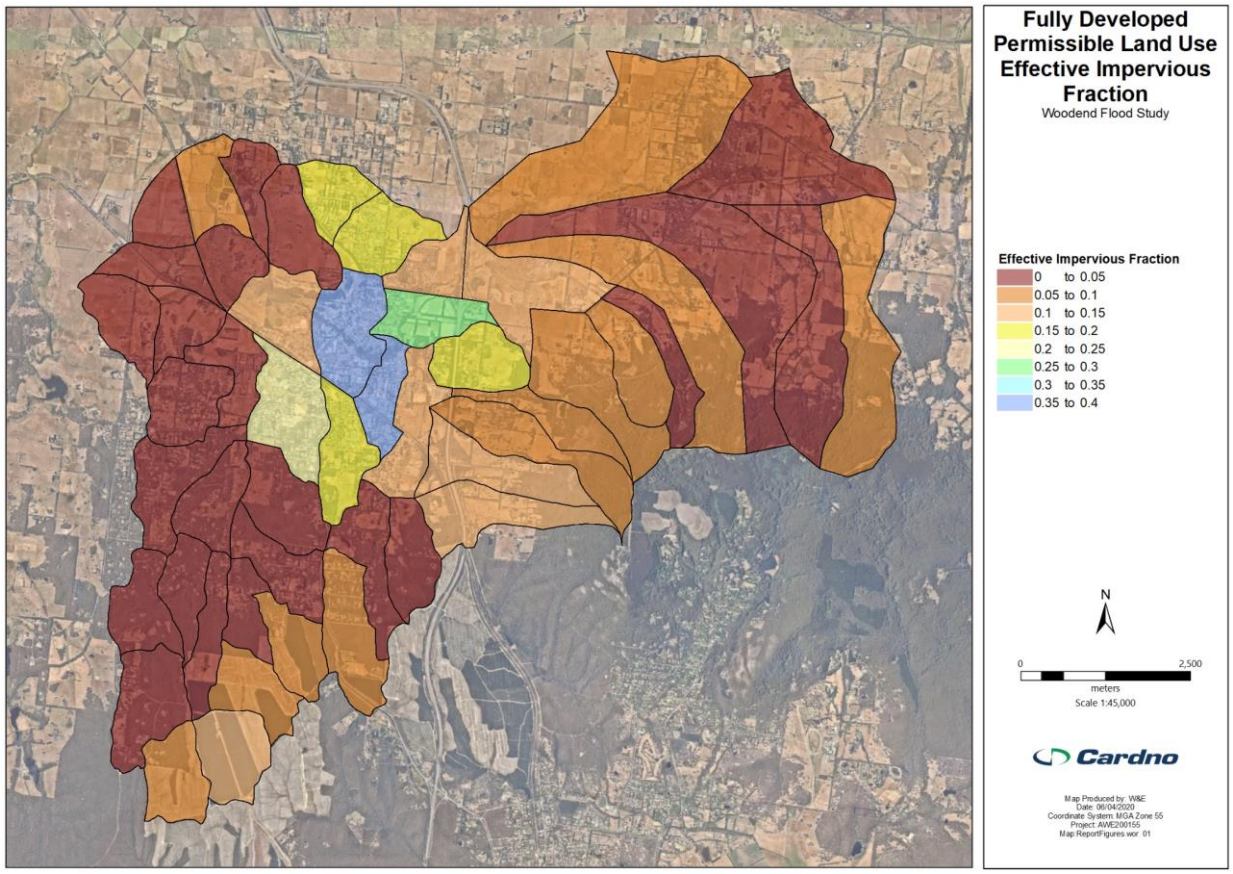


Figure 5-4 Fully Developed Permissible Land Use Effective Impervious Fraction

5.3 Hydrological Model Parameters Selection

5.3.1 Intensity Frequency Duration (IFD) Relationships

5.3.1.1 Current Climate

ARR 2019 'Intensity Frequency Duration' (IFD) values were adopted for this study. Standard and non-standard durations were used, ranging from 10 minutes to 168 hours.

Data was downloaded from the Bureau of Meteorology (BoM) website for frequent, infrequent and rare storms. A summary of this information downloaded from the ARR Data Hub can be found in Appendix 0.

5.3.1.2 Future Climate

As per ARR2019, there are two different methods to calculate percentage increase in rainfall expected by 2100 due to climate change, namely:

- Increase in rainfall intensity; and
- Increase in temperature.

Table 5-4 outlines the assumed increase in rainfall intensity and temperature based on future climate change scenarios adopted. For this study, the temperature increase method was used as it results in a slightly higher increase in rainfall.

Table 5-4 Assessment of Calculation Method for Future Climate Scenarios

Method	Increase
Increase in Rainfall Intensity	23%
Increase in Temperature	23.3%

5.3.2 Rainfall Spatial Patterns

As the total catchment size is greater than 20 km^2, an analysis of the spatial variation of rainfall was undertaken. This was done by comparing the IFD rainfall depths at four dispersed locations throughout the catchment (as shown in Figure 5-5). This assessment showed that the Coefficient of Variation between the relevant rainfall depths did not exceed 5% in any event for durations less than 30 hours, apart from in the 1% AEP for events less than 45 minutes. Due to the small magnitude of the Coefficient of Variation, it was determined that the use of the spatially varying rainfall patterns was not required for this assessment.

Table 5-5 Coefficient of Variation between Rainfall Depths at Three Locations in Woodend Catchment

Duration	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 in 1000
10 min	2.22%	3.60%	4.94%	6.84%	7.77%	6.04%
15 min	1.26%	2.41%	3.79%	4.33%	5.40%	3.83%
20 min	1.84%	2.71%	3.28%	4.05%	5.12%	3.72%
25 min	1.48%	2.82%	3.55%	4.35%	5.03%	3.74%
30 min	1.26%	2.25%	3.46%	4.30%	5.09%	3.44%
45 min	0.99%	1.76%	2.20%	3.20%	3.66%	2.56%
1 hour	0.68%	1.45%	2.20%	2.79%	3.30%	2.27%
1.5 hour	0.89%	1.48%	2.17%	2.93%	3.61%	2.51%
2 hour	0.82%	1.61%	2.32%	2.98%	3.57%	2.57%
3 hour	0.81%	1.51%	2.38%	3.11%	3.84%	2.59%
4.5 hour	0.71%	1.33%	2.10%	2.86%	3.38%	2.28%
6 hour	0.55%	1.07%	1.52%	2.27%	2.79%	1.71%
9 hour	0.54%	0.54%	0.83%	1.48%	1.91%	1.11%
12 hour	1.19%	0.90%	0.95%	1.16%	1.35%	1.76%
18 hour	2.41%	2.28%	2.30%	2.29%	2.09%	3.54%
24 hour	3.35%	3.39%	3.33%	3.35%	3.24%	4.99%
30 hour	5.08%	5.25%	5.41%	5.58%	5.83%	7.26%
36 hour	5.79%	6.06%	6.35%	6.66%	7.04%	7.94%
48 hour	6.32%	6.50%	6.60%	7.12%	7.38%	9.27%

5.3.3 Hydrological Loss Model and Parameters

The Initial Loss/Continuing Loss model has been adopted as per ARR2019. Regional rural loss estimates were downloaded from the ARR Data Hub for the four dispersed locations assessed for variance as shown in Figure 5-5. These were estimated as ranging from 27 mm to 28 mm for the Initial Loss and ranging from 3.1 mm/hr to 4 mm/hr for the Continuing Loss.

In reference to loss estimates for ICIA, Section 3.5.3.2 of ARR 2019 Book 5 recommends that 60-80% of the rural estimate be used for the initial loss for urban areas. As the Five Mile Creek catchment is considered to be predominately rural, Cardno (now Stantec) have adopted an initial loss of 25mm, which is below the 27mm obtained from the ARR2019 Datahub but does not represent a significant deviation. It is also acknowledged that from other studies, loss values within the ARR Data Hub have been assessed as being over-estimated,

hence adopting slightly lower loss values is considered a reasonable approach. It should be noted that adopting a lower initial loss, will result in higher peak flows in the design events.

ARR also states that values between 1-4 mm/h would be an appropriate estimate for Continuous Loss in Australia, with 2.5mm/h for most urban areas. Based on the results of the RORB model calibration (see section 5.4) a continuing loss of 1.5 mm/hr has been adopted, which aligns with both the 2010 and 2011 calibration results which adopted a continuing loss of 1.4mm/hr and 1.5mm/hr respectively.

5.3.4 Pre-burst rainfalls

Pre-burst rainfalls have been applied as per the process outlined in ARR19 using the in-built functionality of RORB. The method adopted is also consistent with Melbourne Water's Technical Specifications. Median pre-burst data downloaded from the ARR2019 Data Hub was read into RORB and applied in a single increment prior to the design burst. The time increments were manually set to be compatible with the imported temporal pattern increments from the ARR2019 Data Hub.

Given that pre-burst depths for durations of less than one hour are not available from the ARR2019 Data Hub, depths for the one-hour duration were adopted for all durations of less than one hour. Furthermore, as the pre-burst information obtained from ARR2019 Data Hub does not contain information for events greater than the 1% AEP event, these were linearly extrapolated from the provided pre-burst data.

5.3.5 Areal Reduction Factor (ARF)

The total size of the Woodend catchment model is 74 km^2. However, the average sub-catchment discharging into the main flow path within the hydraulic model area is generally around 1 km^2. As water will be applied to the hydraulic model on a sub-catchment basis, using an ARF of the entire catchment would under-represent the actual volume of water being generated.

As such, the RORB model was run with six different ARF values as shown in Figure 5-5:

- An ARF of 1 km^2 was used to generate the inflows for each sub-catchment within hydraulic model boundary. The implication of selecting this value is that for flows along the main drainage trunk lines and areas where the catchment is greater than 1km^2, results will be slightly conservative. An ARF of 1 km^2 has also been adopted for several routed inflows into the hydraulic model, where the routed inflow catchment is approximately 1 km^2.
- For all other routed inflow locations, ARF values have been adopted based on the catchment upstream of the inflow location. These ARF's are 2, 3, 4, 5 & 28 km^2.

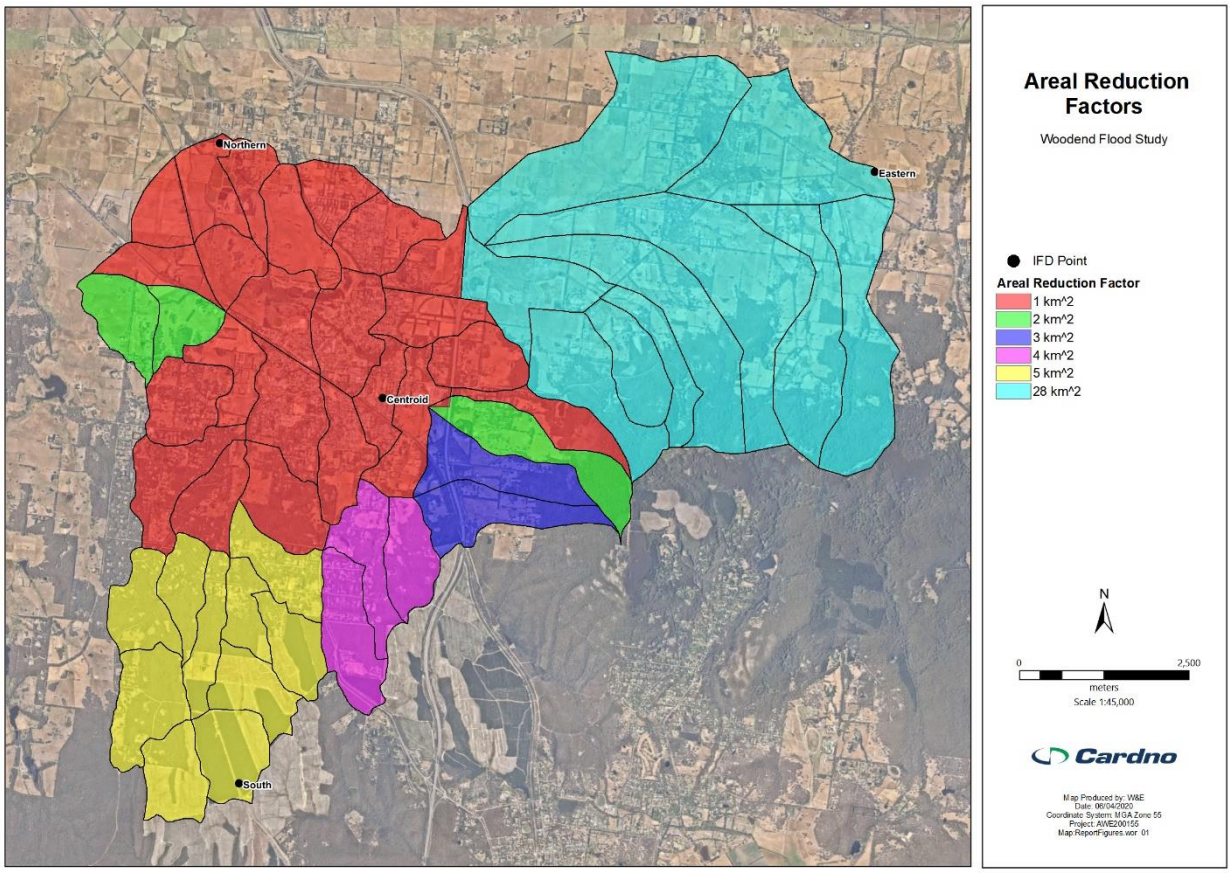


Figure 5-5 Areal Reduction Factors

5.3.6 Rainfall Temporal Patterns

Given that neither the study area or the upstream catchment exceeds 75 km^2, areal temporal patterns were not required. Critical temporal patterns were determined by Monte Carlo Assessment in Section 5.5.3. Point temporal patterns were downloaded from the ARR data hub and applied in RORB and are detailed in Appendix 0.

5.3.7 Routing parameters

The *m* routing parameter has been set to 0.8. This is consistent with standard industry practice. The K_c routing parameter has been estimated using a comparison methodology as discussed in Section 5.4.4

5.4 Hydrological Model Calibration

Three distinct large historical flood events have been selected in order to attempt to calibrate the hydrological model to the Calder Highway Bridge, these events are:

- September 1993
- November 2010
- January 2011

5.4.1 Pluviograph Station

The pluviograph station used to extract data for the 2010 and 2011 events is Station Number 406266, located at the Woodend Water Treatment Plant (approximately 2.5km northwest of the Calder Highway Bridge). Data for this station was obtained from the Department of Environment, Land, Water & Planning (DELWP). This pluviograph station is a 0.2mm tipping bucket gauge, which has been active since 1998. As rainfall is recorded in 0.2 mm increments and not equal time intervals, all recorded data has been resampled to 1-hour intervals.

As this pluviograph station was not operational at the time of the 1993 event, it was not able to be used to calibrate the RORB model, therefore other sources of pluviograph data were investigated for this event, including the approach used for the Coomes 1997 study. It was found that Coomes used the temporal pattern from the Macedon pluviograph station. As the Macedon station is located on the southern side of the Macedon Ranges (with Woodend located on the northern side), the recorded rainfall was significantly different to that recorded by the Woodend gauge. As such, this data was deemed to not be suitable for use.

Upon further investigation, Cardno (now Stantec) assessed that the most appropriate pluviograph data to use for the RORB calibration was the data used by Crapper (1995). This was because the data was captured within Five Mile Creek catchment, which removed the potential of any rain shadow affect caused by the Macedon Ranges located between Macedon and Woodend and subsequently increased the reliability of the rainfall data.

It is acknowledged that Cardno (now Stantec) have not been able to source the raw pluviograph referenced by Crapper or the pluviograph rainfall from the private gauges to verify this data's accuracy. However, given its use in previously Council approved studies, it is considered that this provides sufficient verification status for Cardno (now Stantec) to be comfortable in its use.

5.4.2 Steam Flow Gauge

The Stream Flow Gauge 406269A (privately owned by Ventia) has been used to extract data for the 2010 and 2011 events. While the gauge is privately owned, it is relied upon by Council to assist in both flood warning and emergency management planning.

The gauge is located upstream of the heritage listed Calder Highway Bridge across Five Mile Creek in the centre of the Woodend Township.

This stream flow gauge has been operational since 1996, with the largest recorded gauging occurring during the January 2011 event.

As this gauge was not operational in 1993, an alternative source of determining the design flow was required for this event. As no other suitable stream flow gauge could be determined, the RORB model was calibrated using results from Five Mile Creek 1993 calibrated RORB model (Crapper, 1995) for this event.

5.4.3 Historical Events

5.4.3.1 September 1993 Event

As outlined in section 3.2, the September 1993 event occurred over the period between 15th to the 16th of September, during which a total of 103.1mm of rainfall was recorded at the Woodend Rainfall Station (88061). Based on previous calibrated modelling of the catchment, this result in a peak flow rate at the Calder Highway Bridge of 26.3 m^3/s.

When the Woodend IFD data is compared to the peak intensities (for different durations) captured within the pluviograph data used for the 1993 calibration event, a total recorded rainfall of 103.1 mm over 33 hours would

indicate a 20% to 10% AEP event for durations longer than the 1080-minute event (18 hour), while as shown in Table 5-6 for a 1 hour event this would only correspond to an >12EY event.

Table 5-6 Comparison of Peak Rainfall Intensities from the 1993 Event to Design Rainfall Intensities

Duration (hours / minutes)	AEP
1 hour (60 minutes)	>12 EY
2 hours (120 minutes)	6 to 4 EY
3 hours (180 minutes)	6 to 4 EY
6 hours (360 minutes)	1 to 1 EY
9 hours (540 minutes)	63.2% to 50% AEP

Duration (hours / minutes)	AEP
12 hours (720 minutes)	50% to 20% AEP
18 hours (1080 minutes)	20% to 10% AEP
24 hours (1440 minutes)	20% to 10% AEP
36 hours (2160 minutes)	20% to 10% AEP

As outlined in the sections above, no suitable pluviograph rainfall or streamflow data independent to that complied by and used by Crapper (1995) for the 1993 event was identified. Therefore, the RORB model for the 1993 event was calibrated to the results of the previously calibrated RORB model for the 1993 event (Crapper, 1995).

Using the Cardno (now Stantec) developed hydrological model, it was found that this 1993 flood event was best represented by a K_c value of 25, an initial loss of 10 mm and a continuing loss of 1.8 mm/hr. Table 5-7 outlines the differences between the Cardno (now Stantec) calibration of the 1993 event and Crappers calibration.

Table 5-7 Comparison between Crapper and Cardno (now Stantec's) 1993 Event RORB Calibration

RORB parameter	Crapper	Cardno (now Stantec)
K_c	23	25
Initial Loss	10 mm	10 mm
Continuing Loss	1.5 mm/hr	1.8 mm/hr
Peak Flowrate	26.3 m^3/s	26.5 m^3/s



Figure 5-6 1993 Event – Coach Road (From Northern End) (Source: North Central Catchment Management Authority)

5.4.3.2 November 2010 Event

The comparison of the November 2010 and January 2011 event to design rainfall is based on pluviograph data with the maximum intensity determined for each duration and represented in Table 5-8 and Table 5-9.

As outlined in section 3.2, the November 2010 flood event occurred over the period between 26th to the 28th of November 2010, during which a total of 83.3mm of rainfall was recorded at the pluviograph station 406266, with a peak stream flow reading of 23.8 m^3/s at gauge 406269A.

Based on the design rainfall intensities for Woodend a total recorded a total of 83.3mm of rainfall recorded over 39 hours would indicate a 50% to 20% AEP event for durations longer than the 1080-minute event (18 hour) as shown in Table 5-8.

Table 5-8 Comparison of Peak Rainfall Intensities from the 2010 Event to Design Rainfall Intensities

Duration (hours / minutes)	AEP	Duration (hours / minutes)	AEP
1 hour (60 minutes)	12 to 6 EY	12 hours (720 minutes)	63.2% AEP
2 hours (120 minutes)	3 to 2 EY	18 hours (1080 minutes)	50% to 20% AEP
3 hours (180 minutes)	4 to 3 EY	24 hours (1440 minutes)	50% to 20% AEP
6 hours (360 minutes)	3 to 2 EY	36 hours (2160 minutes)	50% to 20% AEP
9 hours (540 minutes)	2 to 1 EY	48 hours (2880 minutes)	50% to 20% AEP

Using the Cardno (now Stantec) developed hydrological model, this event was best represented by a K_c value of 25, an initial loss of 10 mm and a continuing loss of 1.4 mm/hr. Figure 5-7 shows the RORB calibration for this event.

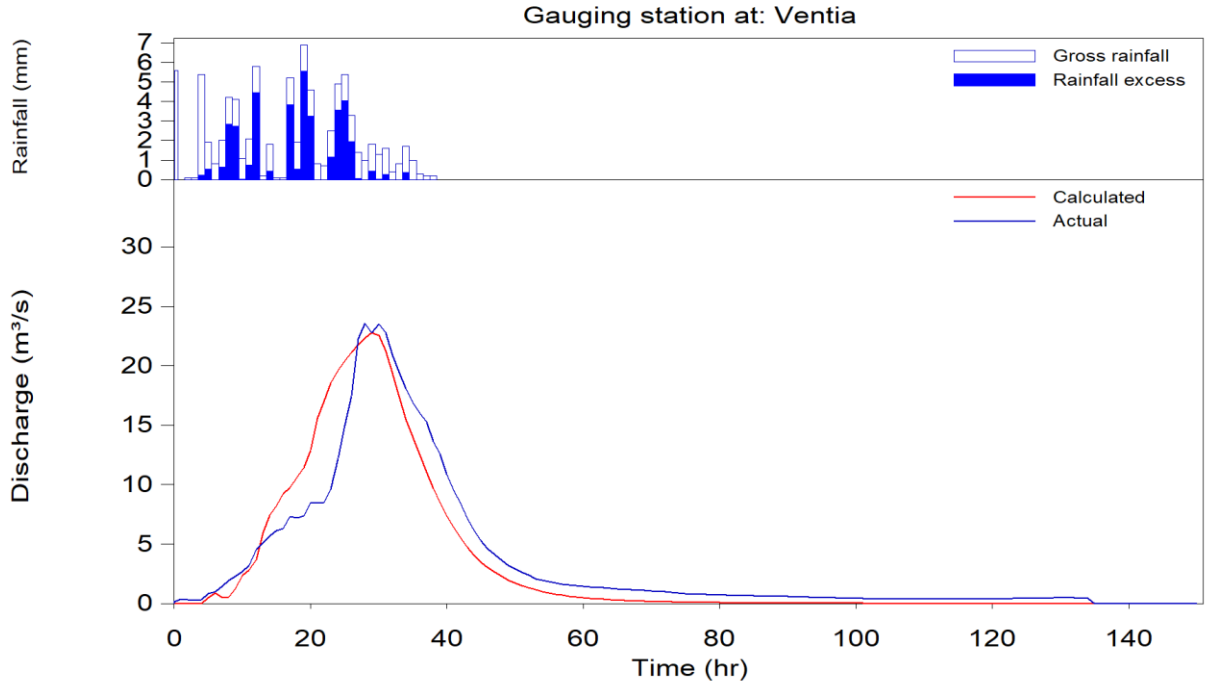


Figure 5-7 2010 Event RORB Calibration

5.4.3.3 January 2011 Event

As outlined in section 3.2, the January 2011 flood event occurred from the 12th to the 14th of January 2011 during which a total of 229.6mm of rainfall was recorded by the pluviograph station 406266, with a peak stream flow reading of 41.8 m^3/s at the 406269A gauge.

Based on the design rainfall intensities for Woodend a total recorded a total of 229.6mm of rain falling over 100 hours indicates a 1% to 0.5% AEP event for durations longer than the 4,320-minute event (72 hour) as shown in Table 5-9.

Table 5-9 Comparison of Peak Rainfall Intensities from the 2011 Event to Design Rainfall Intensities

Duration (hours / minutes)	AEP
1 hour (60 minutes)	5% to 2% AEP
2 hours (120 minutes)	5% to 2% AEP
3 hours (180 minutes)	2% to 1% AEP
6 hours (360 minutes)	5% to 2% AEP
9 hours (540 minutes)	10% to 5% AEP
12 hours (720 minutes)	5% to 2% AEP
18 hours (1080 minutes)	5% to 2% AEP

Duration (hours / minutes)	AEP
24 hours (1440 minutes)	5% to 2% AEP
36 hours (2160 minutes)	5% to 2% AEP
48 hours (2880 minutes)	2% to 1% AEP
72 hours (4320 minutes)	1% to 0.5% AEP
96 hours (5760 minutes)	1% to 0.5% AEP
120 hours (7200 minutes)	1% to 0.5% AEP

Using the Cardno (now Stantec) developed hydrological model, it was found that this event was best represented by a K_c value of 25, an initial loss of 119mm and a continuing loss of 1.5 mm/hr. Figure 5-8 shows the RORB calibration for this event.

It is acknowledged that the initial loss of 119mm appears high, however our experience and knowledge of models calibrated for other nearby locations for the January 2011 flood event would indicate that this approach is consistent with other similar studies. The Heathcote Flood Study (BMT WBM, 2016) adopted an initial loss of 101mm and the Rochester Flood Management Plan (Water Technology, 2013) had an initial loss of up to 90 mm for the hydrological models calibrated for 2011 event.

They key reason as to this high initial loss value can be clearly seen in Figure 5-8. This shows that the rainfall recorded by the pluviograph rainfall station for approximately the first 60 hours of the event does not result in a measurable response to the streamflow gauge within Five Mile Creek at the Calder Highway. However, it is important data to incorporate for this event as it provides an indication of the rainfall leading up to rising limb represented in the hydrograph in Figure 5-8. If the event was identified as starting later, the initial loss would be reduced by the corresponding difference in rainfall.

It is also important to note that within this first 60 hours there is also an intense 30mm burst of rainfall recorded within a single hour which makes up a large proportion of the initial loss. If this intense burst of rainfall was an erroneous pluviograph recording and did not actually occur, it would have no effect on the calibration results apart from a reduction in the adopted initial loss for the 2011 event.

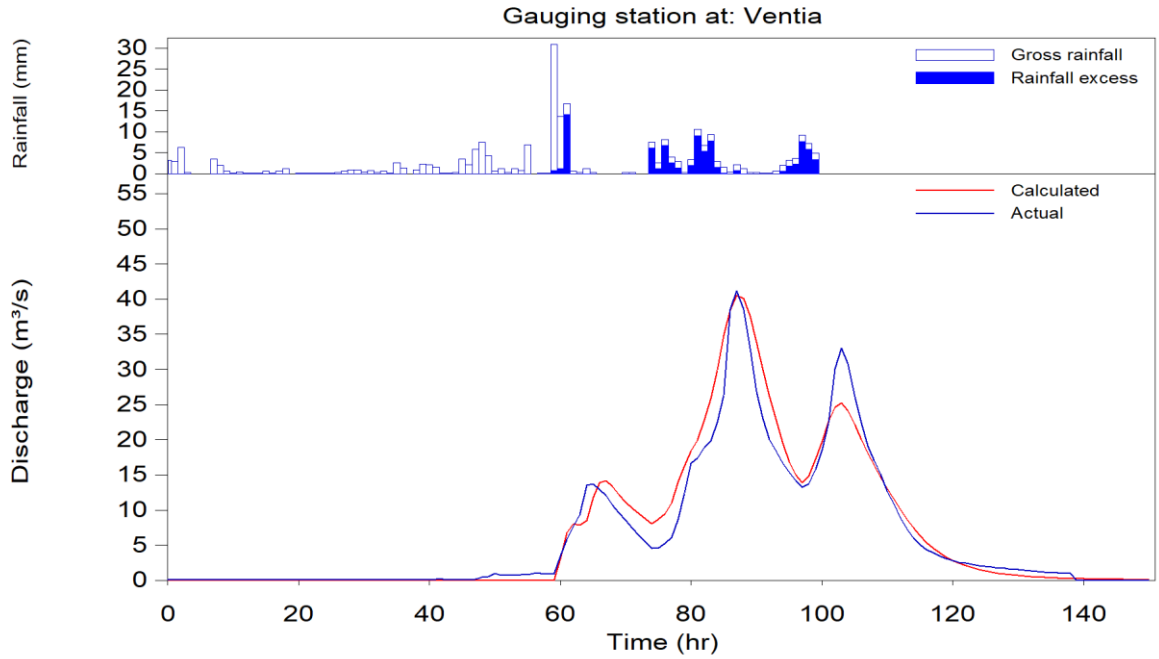


Figure 5-8 2011 Event RORB Calibration

5.4.4 Calibration Results

Table 5-10 shows that by adopting a K_c value of 25, the RORB model is able to be well calibrated to the three historical events in 1993, 2010 and 2011.

Table 5-10 RORB Calibration Results

Comparison	1993 Event	2010 Event	2011 Event
K_c Value	25	25	25
Initial Loss	10 mm	10 mm	119 mm
Continuing Loss	1.8 mm/hr	1.4 mm/hr	1.5 mm/hr
Difference in Peak Flow Rate Between Calculated and Actual Event	+0.7%	-3.2%	-1.7%
Difference in Peak Time to Peak Between Calculated and Actual Event	NA	+3.6%	0%
Difference in Peak Volume Between Calculated and Actual Event	NA	-8.8%	+6.8%

5.5 Hydrological Model Results

5.5.1 Determination of Design Flow Events

A probabilistic (Monte Carlo) assessment was completed in order to determine the design flow events. This methodology includes:

- Undertaking multiple runs, using parameters, while sampling from the defined temporal patterns;
- Undertaking 2,000 runs for each duration storm;
- Extracting the average or median design event for each duration and locations, using statistics to derive the appropriate flood frequency curve; and
- Specifying the critical duration at strategically chosen locations within the RORB model and outlining the rainfall temporal pattern that can reproduce the flood event.

This methodology is a more efficient, more defensible and robust approach for deriving the appropriate flood frequency curve (and hence appropriate design events) for the catchment. It is also reproducible, as the sampling size is suitably large to reduce the uncertainty in the derived flood frequency curve.

The process described above was undertaken for 20 strategically chosen locations throughout the catchment, as shown in Figure 5-9. These locations were chosen throughout the catchment, in order to capture sub-area variances. It was especially important to select a wide range of locations, representing upper areas (likely to have shorter critical durations) and main branch flow areas, as well as areas of differing fraction imperviousness.

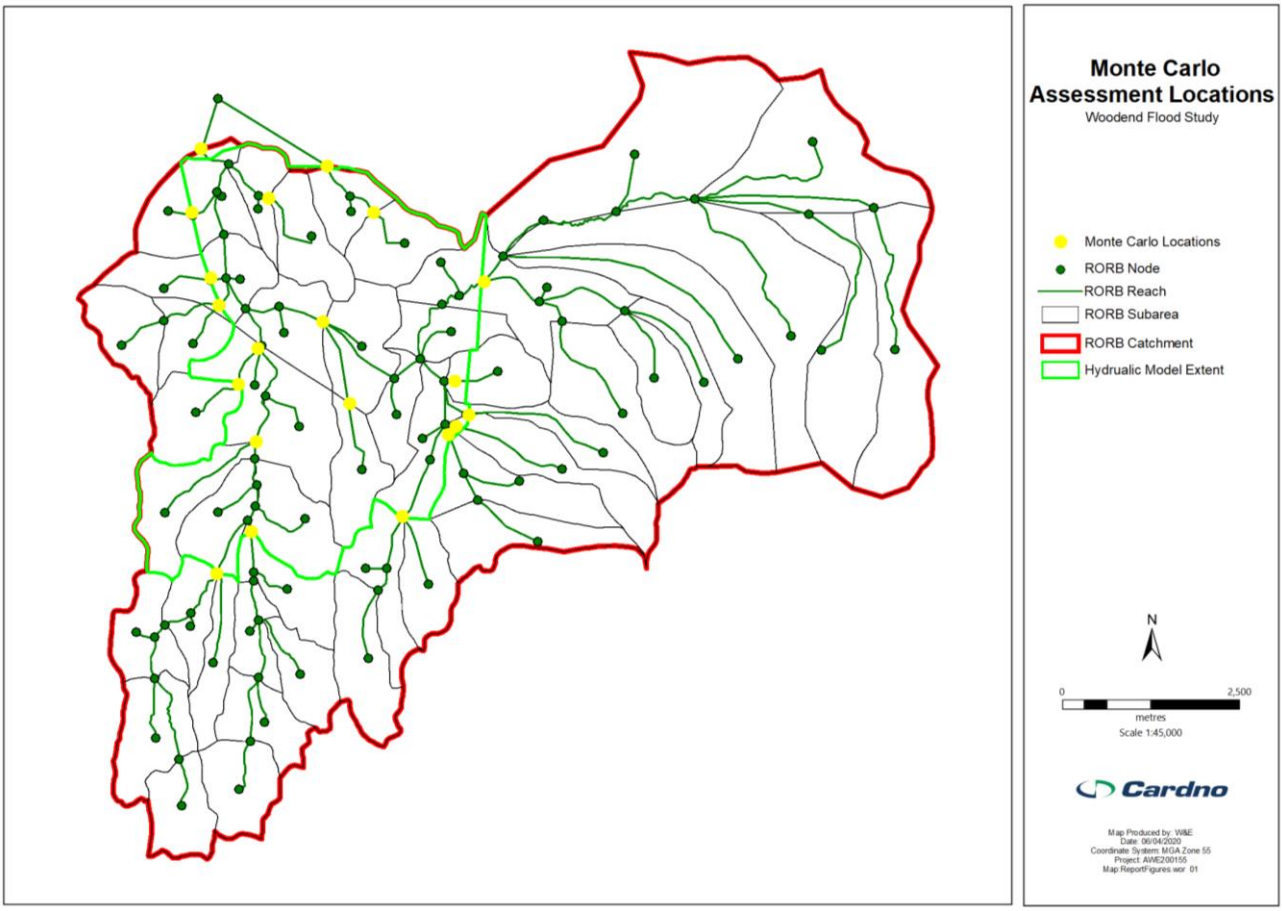


Figure 5-9 Monte Carlo Assessment Locations

5.5.2 Monte Carlo Assessment Methodology

The Monte Carlo approach was undertaken using the flowing steps:

- ARR parameters were downloaded from the Data Hub including, temporal patterns, aerial reduction factors and rainfall pre-burst information
- BoM IFD parameters (2019 version) were also downloaded
- A Monte Carlo analysis was run using K_c , m and fixed losses as derived using the methodology in 5.3.3, 5.3.7 and 5.4.4.

The Monte Carlo assessment was run using the MC analysis module in RORB. The module divides the rainfall distribution into 50 discretised intervals and runs 40 samples from each interval. This results in a total of 2,000 runs per storm duration. The flood frequency curve is then derived using exceedance probability calculations based on the total probability theorem.

An example of the outputs from the runs undertaken for a set of rainfall is shown in Figure 5-10. This shows a wide range of flood hydrographs at a specific location depending on the parameters adopted including rainfall temporal pattern selected and/or loss rates. From this sample, a distribution of likely hydrograph peaks can be assessed and an expected peak flow rate assigned to the flood probability. This is shown as the red distribution in Figure 5-11.

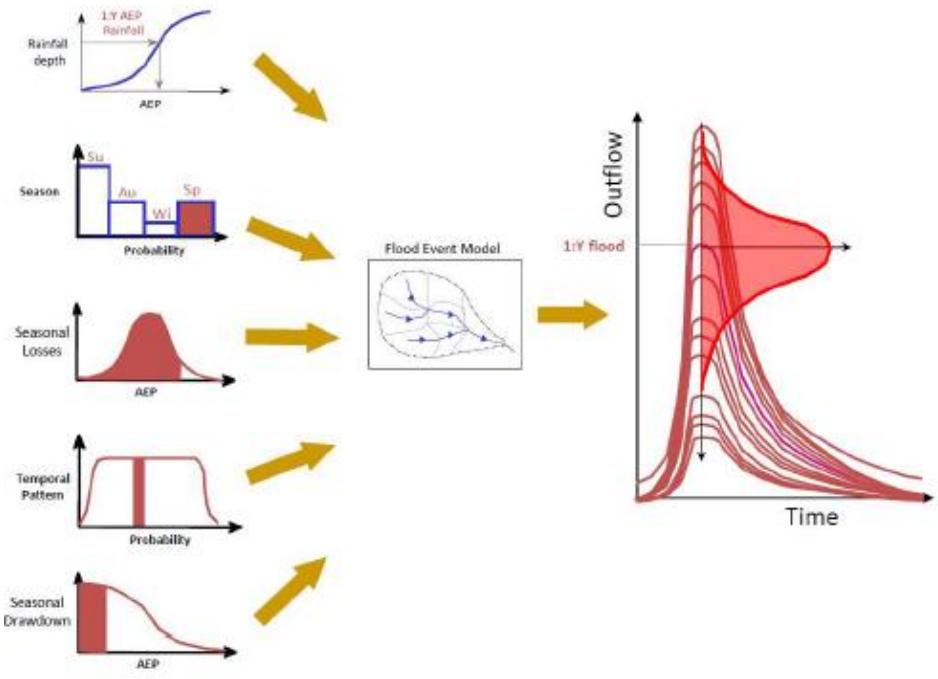


Figure 5-10 Example Monte Carlo Input Sampling (HARC, 2016)

The example above shows the assessment for a given location and expected rainfall probability. This approach can be extended across the full range of the rainfall frequency curve by breaking the curve down into intervals (in this case 50 intervals) and sampling a number of times from each interval. This result is an estimate of the distribution of the peak flow for each rainfall interval. Taking the expected peak flow for each interval yields the flood frequency curve. This curve can then be used to derive the appropriate selection of design flood events to represent the expected behaviour of the system. Figure 5-11 shows the flood frequency derivation process.

Both initial and continuing losses have been fixed during the Monte Carlo analysis. This was undertaken to ensure that the mean event as determined in the Monte Carlo analysis, will be within the range of the 10 storms determined by the ensemble, where the losses are fixed.

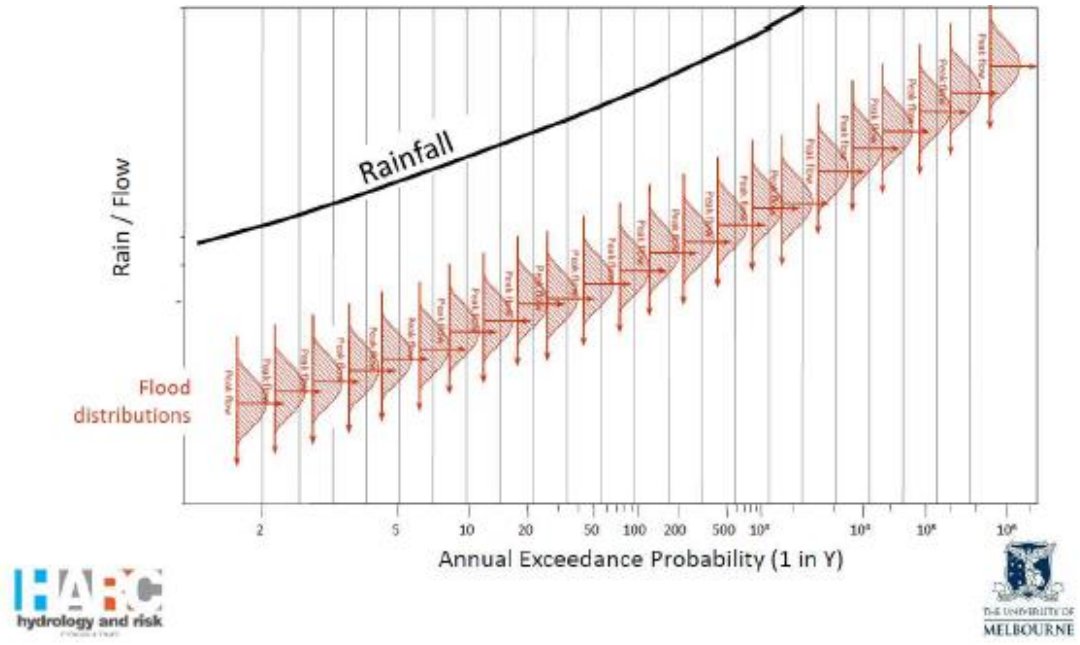


Figure 5-11 Deriving the Flood Frequency Curve (HARC, 2016)

5.5.3 Monte Carlo Assessment Outcomes

Based on the outcome of the RORB calibration to the 1993, 2010 and 2011 flood events (Section 5.4), a K_c value of 25 has been adopted for the design events. Furthermore, also based on the outcome of the calibrations an initial loss of 25mm has been adopted along with a continuing loss of 1.5mm/hr. This results in the Monte Carlo analysis predicting a peak 1% AEP flow rate of 79 m^3/s at the Calder Highway Bridge as summarised below in Figure 5-12 and Table 5-11. The Scenarios presented in Table 5-11 are consistent with the first four (4) scenarios presented within Table 1-1.

Table 5-12 shows that while the peak 1% AEP flow rate occurs in the 12-hour event, other events including the 9, 18 and 36 hour events all produce a peak flow rate within 10% of that produced by the 12 hour event. This trend where several different durations produce peak flow rates which are very similar to each other is observed across all assessed AEPs, with this trend most evident in the 10% AEP event. In this event the 12, 18 and 24 hour events all produce an identical peak flow rate of 34 m^3/s (when rounded to the nearest whole number), with the 9, 30, 36 and 48 hour events also all producing a peak flow rate above 30 m^3/s.

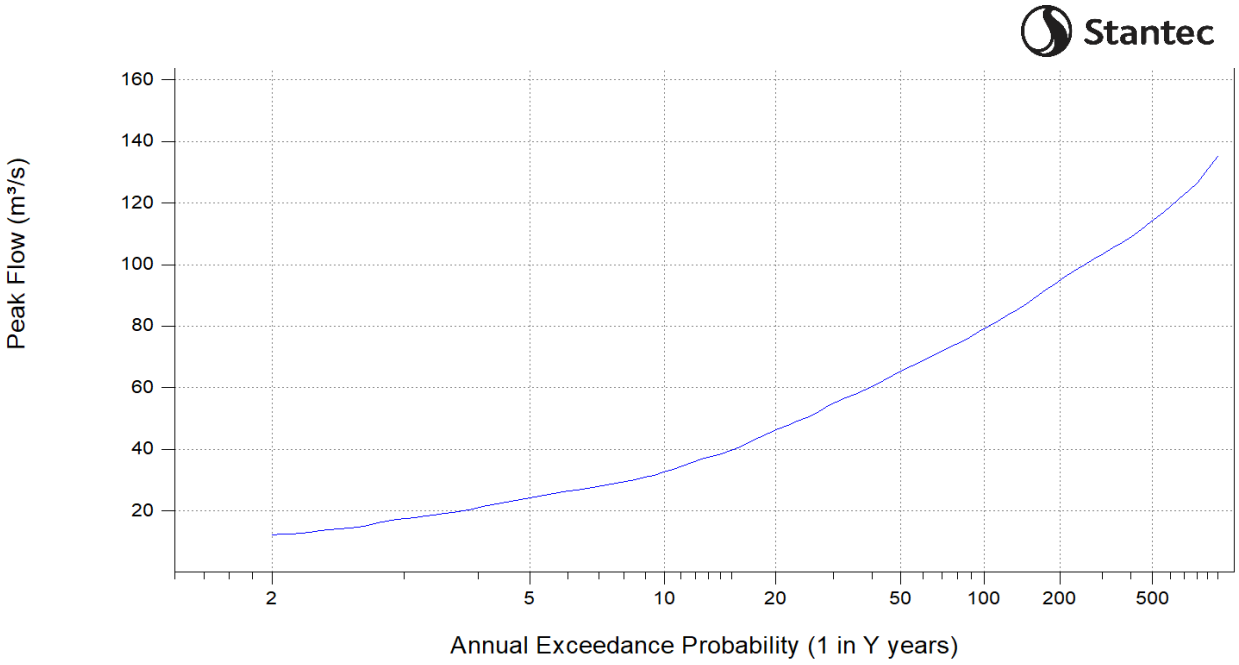


Figure 5-12 Peak Design Flow Rate at Calder Highway Bridge Plot (Monte Carlo Analysis)

Table 5-11 Peak Design Flow Rate at Calder Highway Bridge (Monte Carlo Analysis)

AEP	Base Case (Scenario 2B) m^3/s	Fully Developed for Permissible Land Uses (Scenario 3) m^3/s	Sensitivities to Climate Change (Scenario 4D) m^3/s
0.2EY	27	-	-
10%	34	-	-
5%	47	48	62
2%	64	-	-
1%	79	81	97
0.1%	132	136	162

Table 5-12 Peak Design Flow Rate for Various Storm Lengths – Base Case

AEP	3 Hour (m^3/s)	6 Hour (m^3/s)	9 Hour (m^3/s)	12 Hour (m^3/s)	18 Hour (m^3/s)	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)
0.2EY	6	13	8	24	26	27	26	24	27
10%	10	19	30	34	34	34	33	31	30
5%	16	28	42	47	45	44	42	39	37
2%	26	45	58	64	63	60	58	62	49
1%	35	58	73	79	77	69	69	73	61
0.1%	65	110	125	132	125	111	110	120	106

5.6 Hydrological Model Validation

To determine if the peak design flow rates are appropriate, four separate methods have been used to help validate the hydrological model, to the Calder Highway Bridge as outlined below.

5.6.1 Validation Method 1 – Gauge Analysis

Within the Woodend township area, there are three streamflow gauges which are summarised in Table 5-13 below.

Table 5-13 Summary of Gauges within Woodend Township

Gauge	Operating Period	Maximum Flow Rating (m^3/s)	Comments About Gauge Recordings
406266	1992 - Present	4.6	Gauge has 28 years of records. Large flood events which are known to have occurred since 1992 do not appear to be correctly recorded by the gauge.
406268	1998 - 2002	1.6	Gauge only has 4 years of records.
406269A – Ventia*	1996 – Present	12.3	Gauge has 24 years of records. Large flood events which are known to have occurred since 1996 are clearly visible in the gauge results.

*Located Upstream of the Calder Highway Bridge

Based on the findings outlined in Table 5-13, a Flood Frequency Analysis (FFA) was undertaken for Gauge 406269A, the results of which are presented in Table 5-14. The RORB estimates are within the bounds of the FFA results. Half of Gauge's 406269A's recordings occurred during the Millennium drought, which may understate the flow rate for the smaller AEP events. Additionally, as the gauge has only 24 years of recorded data, it should not be relied upon to accurately predict the expected flow rates for larger AEP events. As such, there are very large 90% Quantile Limits for the larger events especially for the 1% AEP event which is 749 m^3/s and representative of an upper confidence limit.

Table 5-14 Flood Frequency Analysis Results for Gauge 406269A

AEP	Expected Parameter Quantile (m^3/s)	Lower 90% Monte Carlo Quantile Limits (m^3/s)	Upper 90% Monte Carlo Quantile Limits (m^3/s)
20%	11.1	6.2	22.1
10%	21.2	10.8	51.9
5%	36.5	16.7	118.6
2%	68.2	26.0	339.1
1%	104.2	34.1	749.3

5.6.2 Validation Method 2 – Regional Flood Frequency Estimate

A Regional Flood Frequency Estimate (RFFE) was undertaken at the Calder Highway Bridge. As shown in Table 5-15, the RFFE indicates an expected 1% AEP flow rate of 41.6 m^3/s. Approximately half of the gauges sampled by the RFFE are located on the southern slopes of the Macedon Ranges, which drain towards Melbourne and Port Phillip Bay, whereas Woodend is located on the northern slopes of the Macedon Ranges drain towards Echuca and the Murray River. This is likely to add significant uncertainty to the values obtained using this methodology.

Table 5-15 Regional Flood Frequency Estimate

ARI 1 in Y	Expected Parameter Quantile (m^3/s)	Lower 5% Confidence Limits (m^3/s)	Upper 5% Confidence Limits (m^3/s)
20%	14.0	5.1	28.7
10%	19.2	6.8	54.0
5%	25.1	8.7	72.3
2%	33.9	11.3	103
1%	41.6	13.3	131

5.6.3 Validation Method 3 – Previous Hydrological Models

Several studies of flooding along Five Mile Creek have been undertaken within the last 30 years. All of these previous studies have been undertaken in line with ARR1987. This guidance document is now obsolete and has been replaced with ARR2019 which has been used for this study. ARR2019 marked a significant revamping of the guidance and so it should not be expected that the results of this modelling will directly align with those from the previous studies undertaken.

As the majority of the hydrology for these past studies has been based on the calibrated RORB model for the 1993 event developed by Crapper (Crapper, 1995), they generally result in very similar peak 1% AEP flow rates. Table 5-16 outlines the adopted 1% AEP flow rate from the previous studies which have been based on the calibrated RORB model created by Crapper (Crapper, 1995).

Table 5-16 Peak Flow Rate at Calder Highway Bridge from Previous Studies

Study	Adopted Peak 1% AEP Flow Rate at Calder Highway Bridge (m^3/s)
Woodend Township Drainage Study (Coomes, 1997)	109
Woodend Detention Basin Investigations (Lawson Treloar, 1998)	99
Expert opinion – Flooding and Storm water Issues 2-4 Davy Street Woodend (Water Technology 2016)	108.5

5.6.4 Validation Method 4 – High Level Comparative Estimations

Two separate high level estimations were applied to assess the peak 1% AEP flow rate at the Calder Highway Bridge, which has an upstream catchment of $45km^2$. These estimation methodologies are based on observed results from a range of catchments, but as every catchment is different, they should only be used as a general guide to check whether the results are within a reasonable/expected bound. The two methodologies used were:

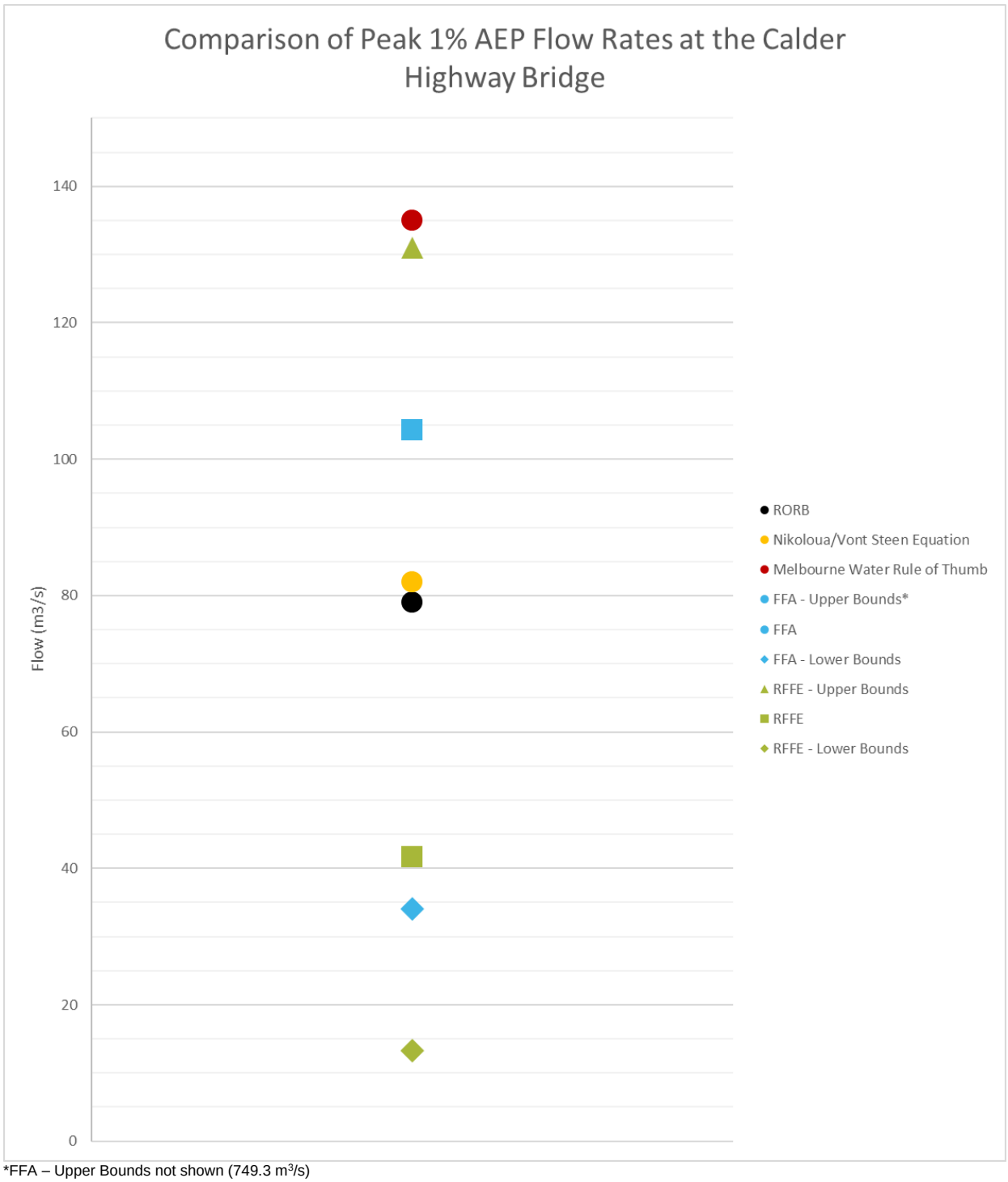
- Nikolaou/Von't Steen Equation (Greyson, 2006)
  - $Q_{100} = 4.67A^{0.766}$
  - At the Calder Highway Bridge this results in a 1% AEP peak flow rate of 82 m^3/s
- Melbourne Water's rule of thumb for rural catchment of 3 m^3/s per 100 ha.
  - At the Calder Highway Bridge this results in a 1% AEP peak flow rate of 135 m^3/s.

It is noted that the adopted flow rate of 79 m^3/s for the 1% AEP peak flow compares closely to the result when applying Nikolaou/Von't Steen Equation (Greyson, 2006).

5.6.5 Summary of the Results of the Validation Analysis

All approaches to validate the RORB have limitations as discussed in the sections above. However, the adoption of a peak flow rate based on the RORB modelling undertaken as part of this assessment of 79 m^3/s (section 5.5.3) represents a reasonable fit considering the detailed investigation undertaken to inform and underpin this study as well as the adoption of the updated ARR2019 guidelines.

Figure 5-13 below shows each of the above peak 1% AEP flows resulting from the above validation methodologies against that resulting from the RORB modelling undertaken for this study. As can be seen, this flowrate fits well within the expected range of between 41.6 m^3/s from the RFFE and 135m^3/s from Melbourne Water's rule of thumb. As such, the modelling has been deemed appropriate for use in this study. The upper confidence limit for the FFA is well above the highest graphed value.



*FFA – Upper Bounds not shown (749.3 m^3/s)

Figure 5-13 Comparison of Peak 1% AEP Flow Rates at the Calder Highway Bridge

5.7 Discussion of The Results

5.7.1 Analysis of Peak Flow Results from the Monte Carlo Analysis

It is considered that the adopted peak flow rates as determined by the Monte Carlo analysis are within the bounds (which are admittedly large) predicted by the FFA (as outlined in Section 5.6.1). The discrepancy between the results is predominantly driven by the short operational life of the gauge. As this gauge has only been operational since 1996, half of the gauging's operating period occurred during the millennium drought. This results in a peak annual median gauging of only 3.8 m^3/s, compared to peak annual average gauging of 7.5 m^3/s, which is larger than the peak median gauging due to a maximum gauging of 41.7 m^3/s, which occurred during the January 2011 flood event. This skews the results of the FFA to under-predict the lower events and over-predict the higher flow events.

For the Monte Carlo to match the 1% AEP flow rates predicted by the FFA, an initial loss of 0 mm and continuing loss of 0 mm/hr would need to be adopted. Adopting a loss rate of 0 mm whether either for an initial loss or continuing loss is highly inappropriate for the Five Mile Creek catchment.

The Monte Carlo analysis was used to estimate the 1% AEP peak flow rate of $79m^3/s$. It is acknowledged that this is lower than the 1% AEP peak flow rate adopted in the previous studies undertaken for this catchment, which were all undertaken in accordance with the outdated ARR1987 guidance documents. Additionally it is lower than the adopted 1% AEP peak flow rate of $95m^3/s$ as determined by the TUFLOW hydraulic modelling. Differences between the RORB and TUFLOW design events and flood estimates is discussed in more detail in section 6.5.2.2.

5.7.2 Adoption of the 1% AEP Peak Flow Rate

The peak flow as determined in this study is underpinned by:

- A rigorous model calibration process undertaken as part of this study including the adoption of suitable design parameters that are consistent with ARR2019;
- The RORB model was calibrated against the 1993, 2010 and 2011 flood events with an identical K_c value of 25 across all calibration events;
- The calibrated RORB model provides good representation and consistency with the result of Crapper (1995);
- The model results were validated against four other comparative methods and was found to be within the expected range of the results of these assessments;
- An additional period of data and flood history including the 2010 and 2011 events is now available and has been incorporated into this study since Crapper's calibrated RORB model was developed in 1995;
- Validation of the hydraulic model to Council hotspots as detailed in 6.4.4; and
- The TUFLOW model has been rigorously calibrated to the 1993 and 2011 flood events.

It should be noted that it is not unreasonable to expect that results will differ with the aid of additional historic data including the 1993, 2010 and 2011 events and significantly updated guidance documentation (ARR2019) on which this assessment has been based.

Refer to section 6.5.2 and Table 6-5 for more details of the design flow rates adopted for the study.

5.7.3 Storm Losses Adopted and Implication on Results

As outlined in Section 5.3.3, the losses adopted for the design events are based on the outcomes of both the hydrological model calibration (Section 5.4) and guidance from ARR2019, rather than results from the FFA of the gauge data. A reconciliation of results from the FFA (Section 5.6.1) and the Monte Carlo Analysis indicates the following:

- In more frequent events, the adopted loss parameters result in predicting a higher flow rate than those predicted by the FFA; and
- In less frequent events, the adopted loss parameters result in predicting a lower peak flow rate than predicted by the FFA.

This is consistent with the expectations with regards to the data which underpins the FFA as discussed in Section 5.7.1. This is particularly in regards to the impact of the millennium drought and the limited operational period of the gauge.

5.7.4 Design Flow Rate for Planning Purposes

In order to provide consistency with the flood levels reported in this study, all flow rates used for design purposes should be obtained from the TUFLOW model which are outlined in Table 6-5.

5.7.5 Comparison Between the Design Flow Rate and The Ultimate Design Flow Rate

As outlined in Section 5.2.5, in order to assess the impacts of development within Woodend and its surrounds, the effective fraction impervious was increased based on the planning scheme zones. As can been seen in Table 5-11 it is not expected that an increase in development will lead to a significant increase in the peak flow rates along Five Mile Creek. This is due to several factors including but not limited to peak flow rates along Five Mile Creek being primarily driven by the catchment upstream of the Calder Freeway and not from the urban areas within Woodend itself. The existing culverts located below the freeway act to limit the flow along Five Mile Creek from the upstream catchment areas.

It should be noted that whilst an increase in development may not lead to an increase in peak flow rates, uncontrolled development has the potential to lead to Woodend becoming more exposed and susceptible to flood risk. Therefore land use and development controls and other mitigation measures are important in ensuring no increased risk and help manage and reduce existing flood risks.

5.8 Critical Storm Events and Associated Temporal Patterns

Using the above methodology, critical storm events (and associated temporal patterns) were identified for the catchment are shown in 0. These were extracted using the Monte Carlo module of RORB which derives the expected flood frequency curve for each identified location and provides a corresponding peak flow rate.

In order to assess the impact of the Fully Developed for Permissible Land Uses (scenario 3), the design events determined to be critical in base case (scenario 2B) were adopted for both scenarios.

Table 5-17 Critical Storm Durations and Temporal Patterns

Event AEP (%)	Critical Durations (hours / minutes)	Temporal Patterns
0.2 EY	3 hours (180 minutes)	2
	9 hours (540 minutes)	7
	12 hours (720 minutes)	7
	24 hours (1440 minutes)	10
10%	12 hours (720 minutes)	17
	18 hours (1080 minutes)	16
	30 hours (1800 minutes)	16
5%*	6 hours (360 minutes)	17
	9 hours (540 minutes)	12
	12 hours (720 minutes)	17
2%	1.5 hours (90 minutes)	24
	6 hours (360 minutes)	24
	12 hours (720 minutes)	21
	18 hours 1080 minutes)	21, 29
1%*	2 hours (120 minutes)	22, 27
	4.5 hours (270 minutes)	21, 28

Event AEP (%)	Critical Durations (hours / minutes)	Temporal Patterns
	6 hours (360 minutes)	24
	12 hours (720 minutes)	30
	18 hours (1080 minutes)	21, 29
0.1%*	2 hours (120 minutes)	25, 27
	4.5 hours (270 minutes)	24, 28
	6 hours (360 minutes)	24
	12 hours (720 minutes)	27, 29
	18 hours (1080 minutes)	21
5% Climate Change	2 hours (120 minutes)	12,13,18
	18 hours (1080 minutes)	16
	30 hours (1800 minutes)	17
1% Climate Change	2 hours (120 minutes)	26
	4.5 hours (270 minutes)	25
	12 hours (720 minutes)	21
	18 hours (1080 minutes)	26
0.1% Climate Change	0.5 hours (30 minutes)	26
	1 hour (60 minutes)	26
	2 hours (120 minutes)	28

Event AEP (%)	Critical Durations (hours / minutes)	Temporal Patterns
	4.5 hours (270 minutes)	25

*Critical Durations and Temporal Patterns for Fully Developed for Permissible Land Uses (scenario 3)

6 Hydraulic Analysis

This section of the report details the key hydraulic structures and controls, the hydraulic model developed for the study, the calibration and validation of the model undertaken, the difference between RORB and TUFLOW flood results and the overall hydraulic model results.

6.1 Hydraulic Controls

Within the floodplain near the Woodend Township, there are several different hydraulic control structures that significantly impact the flood behaviour. These include the Calder Highway Bridge, various flood levees and the railway. These features are described in detail in the following sections.

6.1.1 Calder Highway Bridge

The Calder Highway Bridge across Five Mile Creek was constructed in 1862 and is now heritage listed. Based on available records, it appears that not much has changed with the bridge structure over time. However, changes to the land form around the bridge have occurred including the construction of a formalised path along the banks of Five Mile Creek below the bridge. Figure 6-1 shows the difference in land form around the bridge between 1934 and 2020.



Figure 6-1 Calder Highway Bridge Circa 1934 (Source: State Library of Victoria) and Eastern side of Calder Highway Bridge from the Site Visit.

6.1.2 Railway Line

Bisecting Woodend and running east to west is the Bendigo Main Railway Line. The Bendigo Main Line is raised to be above the floodplain on both the eastern and western sides of Woodend. Figure 6-2 shows the railway underpass located at the end of Templeton Street. The Woodend Railway Station accessible from Urquhart Street and situated to the west of High Street opened in 1861.



Figure 6-2 Railway Underpass Located at the end of Templeton Street

6.1.3 Flood Levees

Several flood levees were constructed along Five Mile Creek in the early 2000's, including both the Pyke Street and the Campaspe Drive levees. During flood events, both the Pyke Street and Campaspe Drive levees require Council to manually close the penstock and turn on the pumps in order to drain the land protected by the levees. Figure 6-3 shows the Pyke Street levee captured during the site visit.



Figure 6-3 Pyke Street Levee

6.1.4 Retarding Basins

There are several Council owned retarding basins located throughout Woodend. The largest is located at 21 Quarry Road. This basin is approximately 2m deep, 150m long and 150m wide as shown in Figure 6-4.



Figure 6-4 21 Quarry Road Retarding Basin

6.2 Model Selection

A 1D/2D hydraulic model was developed for the Woodend catchment. This type of model allows for dynamic links between the overland flow and pipe components based on the capacity of the drainage system. As such, once the drainage system is exceeded, the resultant overland flow patterns are determined by the two-dimensional hydraulic model. The combined TUFLOW HPC 2D and ESTRY 1D hydraulic model (version 2020-01-AB-iDP-w64) was adopted for this study.

6.3 Hydraulic Model Setup

A 1D/2D hydraulic model requires several different inputs, which represent the different characteristics of the catchment are summarised below.

6.3.1 Model Topography

The hydraulic model topography has been defined using LiDAR which was captured in 2017. The LiDAR was resampled to a 3m grid for use within the hydraulic model, as shown in Figure 6-5.

Woodend is currently experiencing significant development growth and this is likely to continue into the foreseeable future. This results in limitations with regards to having updated model topography data (i.e. LiDAR) that comprehensively represents existing surface conditions. However, we don't anticipate this to have a significant impact on the hydraulic modelling results.

Key topographic features including the top of levees, the bottom of channels and major flows paths have been explicitly included within the hydraulic model as gully/ridge lines, as shown in Figure 6-5.

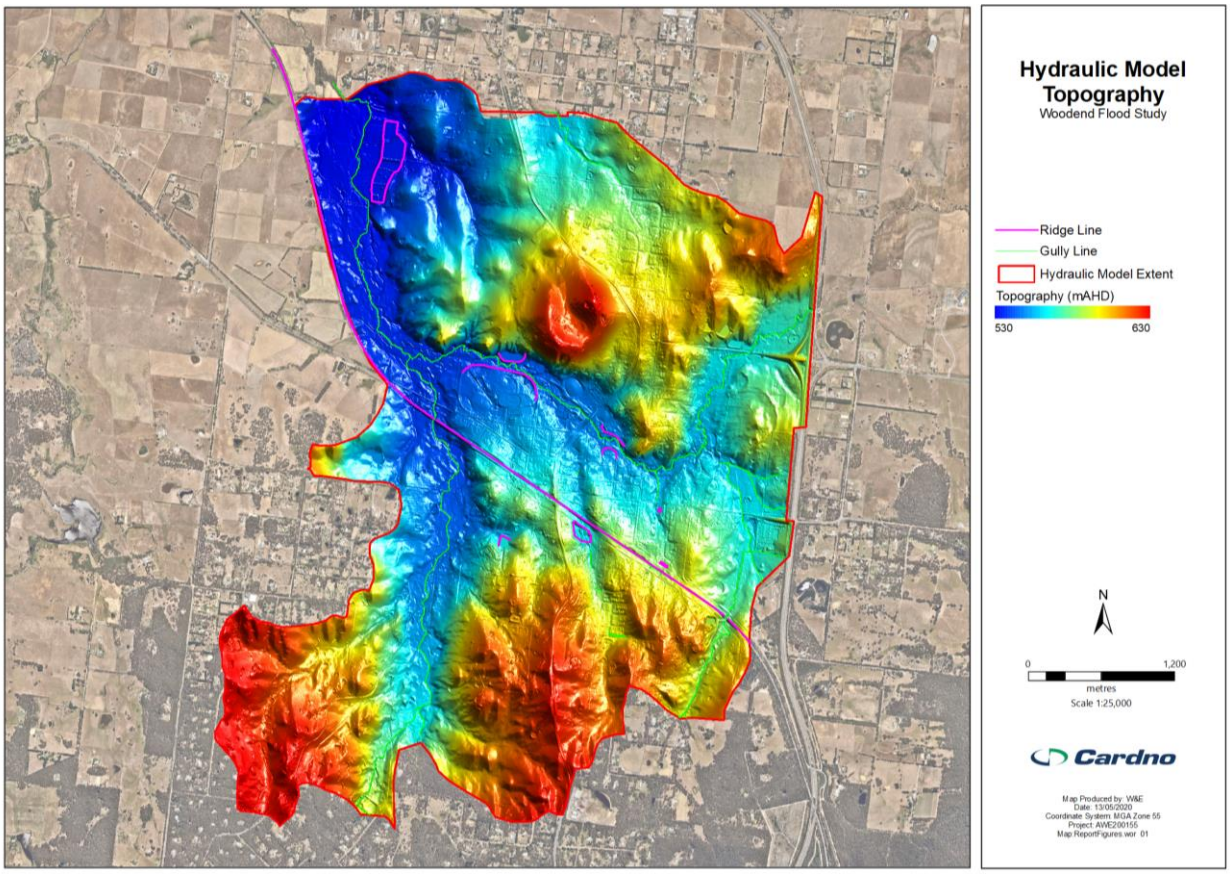


Figure 6-5 Hydraulic Model Topography

6.3.2 Hydraulic Model Roughness

Hydraulic model roughness has been defined using Manning's 'n' values. Hydraulic roughness has been defined based on land use as identified using aerial imagery. The adopted values are shown in Figure 6-6.

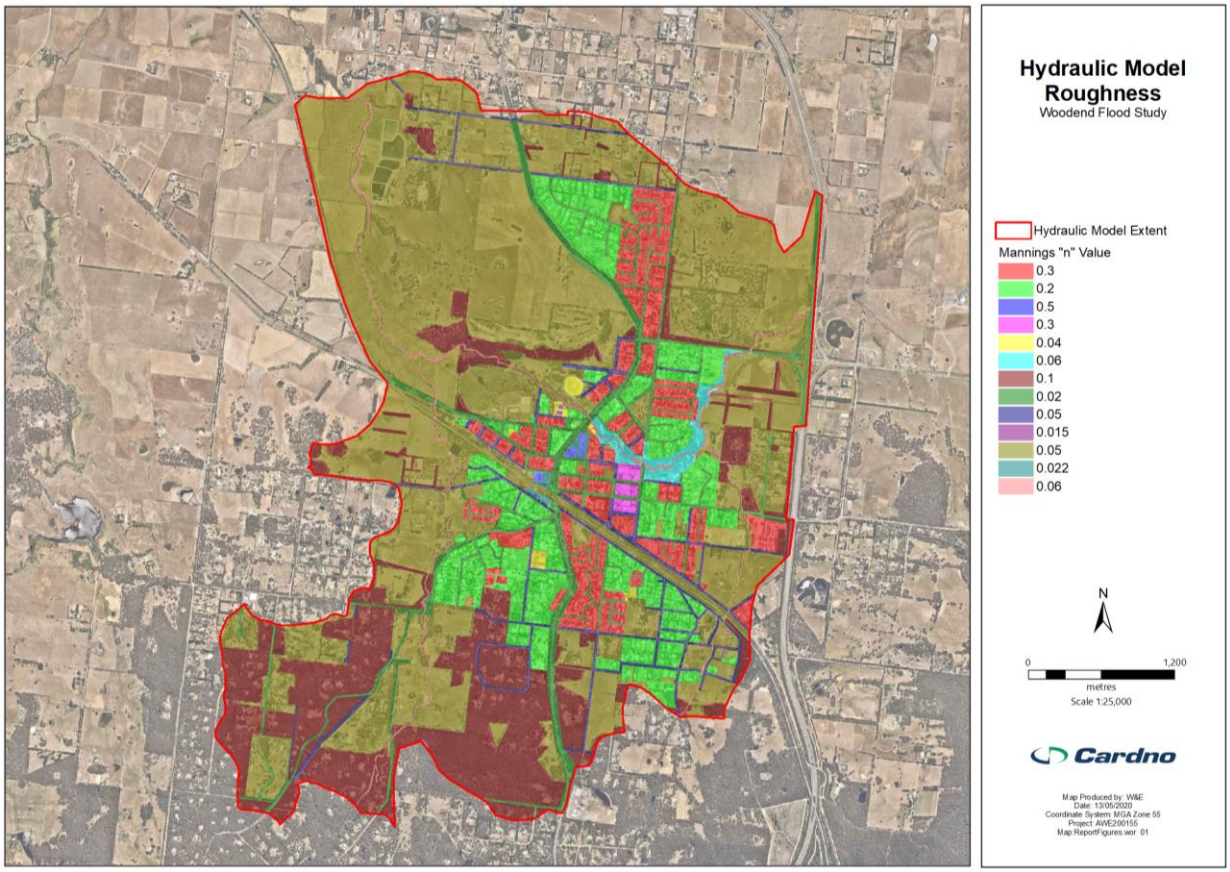


Figure 6-6 Hydraulic Model Roughness

6.3.3 Stormwater Network

Stormwater network data for Woodend as supplied by Council (16/01/2020) has been included within the hydraulic model through the ESTRY 1D component of TUFLOW. This is shown in Figure 6-7.

6.3.3.1 Stormwater Pipes

For inclusion within the hydraulic model, all pipes must have an assigned dimension (pipe size), and upstream and downstream invert levels. Where either a dimension or invert level was identified as missing, the process outlined below was adopted to infill the missing data:

Step 1: Infilling was based on the dimension of the adjacent downstream pipe.

Step 2: Where this was not possible, the pipe was then infilled based on the dimension of the adjacent upstream pipe.

Step 3: If the pipe did not have an adjacent downstream or upstream pipe with a known size, engineering judgement was used based on the location of the drainage network to infill the missing dimension.

Where an invert level (either upstream or downstream) was identified as missing, a 3-step hierarchy was developed in order to infill the missing invert as outlined below:

Step 1: The missing invert level was based on the supplied invert of the adjacent pit.

Step 2: The missing invert was based on the supplied invert of the lowest pipe at the same pit as where the pipe was missing the invert.

Step 3: The invert is then determined based on the assumption that the pipe has 600mm of cover.

Once all missing pipe data had been infilled, checks were undertaken to ensure that all pipes both flowed downhill and no pipe was located above the ground surface.

6.3.3.2 Stormwater Pits

Stormwater pits provided by Council were also explicitly included in the hydraulic model. In areas where a pit was found to be missing from the provided dataset, such as where two pipes intersect, an additional pit was included within the hydraulic modelled pit and pipe network. This occurred predominantly where there was a junction between different branches within a pipe network.

Where pit sizes were not supplied, they were assumed to be rectangular (R), with height and width equal to 1 metre.

A review of the pit types listed within the supplied dataset was undertaken to identify which pits were sealed within the drainage system (i.e. junction pits, etc.). All pits have been modelled as 2D SX connections apart from pit types JP, JHP and Ghost, which have been modelled as being sealed.

6.3.3.3 Initial Water Level in Basins and Storages

As all basins/storages have been designed as retarding basins with historical imagery/LiDAR indicating that they are generally dry, they have been modelled as initially being dry. This allows for their full mitigation affect to be captured by the hydraulic model. Table 6-1 outlines invert for each basin (based on LiDAR).

Table 6-1 Invert (based on LiDAR) for formalised Basins and Storages Within the Hydraulic Model

Basin/Storage	Invert of Basin (From LiDAR) (mAHD)
26 Edna Walling Boulevard Woodend Drainage Basin	563.50
Arthur Court Reserve Basin	558.03
Jones Court Reserve	569.73
Lilley Court Basin	567.07
Quarry Road Detention Basin	558.38
Reidwell Drive Reserve Basin	568.45
Roxanne Court Reserve (Behind) Basin	564.93
Shirley Park Basin	555.34
Sproule Place Reserve	546.54
Washington Lane	566.95

6.3.3.4 Bridges

There are several bridges present within the hydraulic model extent as shown in Figure 6-7. These bridges have been included within the hydraulic model as Layered Flow Constriction Shapes (LFCSH). In order to use LFCSH shapes, various blockage and flow constriction factors are required for each layer (i.e. below the soffit, the bridge deck itself and railings above the bridge deck). These values were all estimated using the following data (depending on availability):

- Design drawings
- Measurements from the site visit
- Site visit photos
- Aerial photos
- Google street view photos.

Furthermore, all flow constriction factor values were calculated using the methodologies outlined in Hydraulics of Bridge Waterways (1978) as recommended by the TUFLOW manual.

All attributes used in the estimation of blockage and flow constriction factors can be found in Appendix 0.

6.3.3.5 Pumps

As part of the current flood response actions within Woodend, there are two sets of pump stations. One set is associated with the Pyke Street levee and the other with the Campaspe Drive Levee. As a part of the project, Council suppled the operating procedure for these pumps which are enacted during a flood event (Five Mile Creek Woodend – Flood Mitigation Infrastructure Operating Procedures July 2012).

The operating procedure for both pump stations states that during a flood event, the penstocks need to be manually closed and the pump manually started. This modelling has been undertaken on the assumption that both of these tasks are successfully completed.

6.3.3.5.1 Pyke Street Pump

The Pyke Street pump has been included within the hydraulic model as having a maximum pumping rate of 390 litres per minute and starts pumping once the flood level reaches 551.2 mAHD as per the operating procedure discussed above.

6.3.3.5.2 Campaspe Drive Pump

The Campaspe Drive pump station comprises two pumps, one which starts pumping once the flood level reaches 551.1 mAHD, with the second which starts to operate once the flood level reaches 551.4 mAHD.

As the pumping rate for the Campaspe Drive pumps were not listed within the operating manual, it has been assumed that they comprise of 2 x 300 litres per minute pumps based on advice provided by Council.

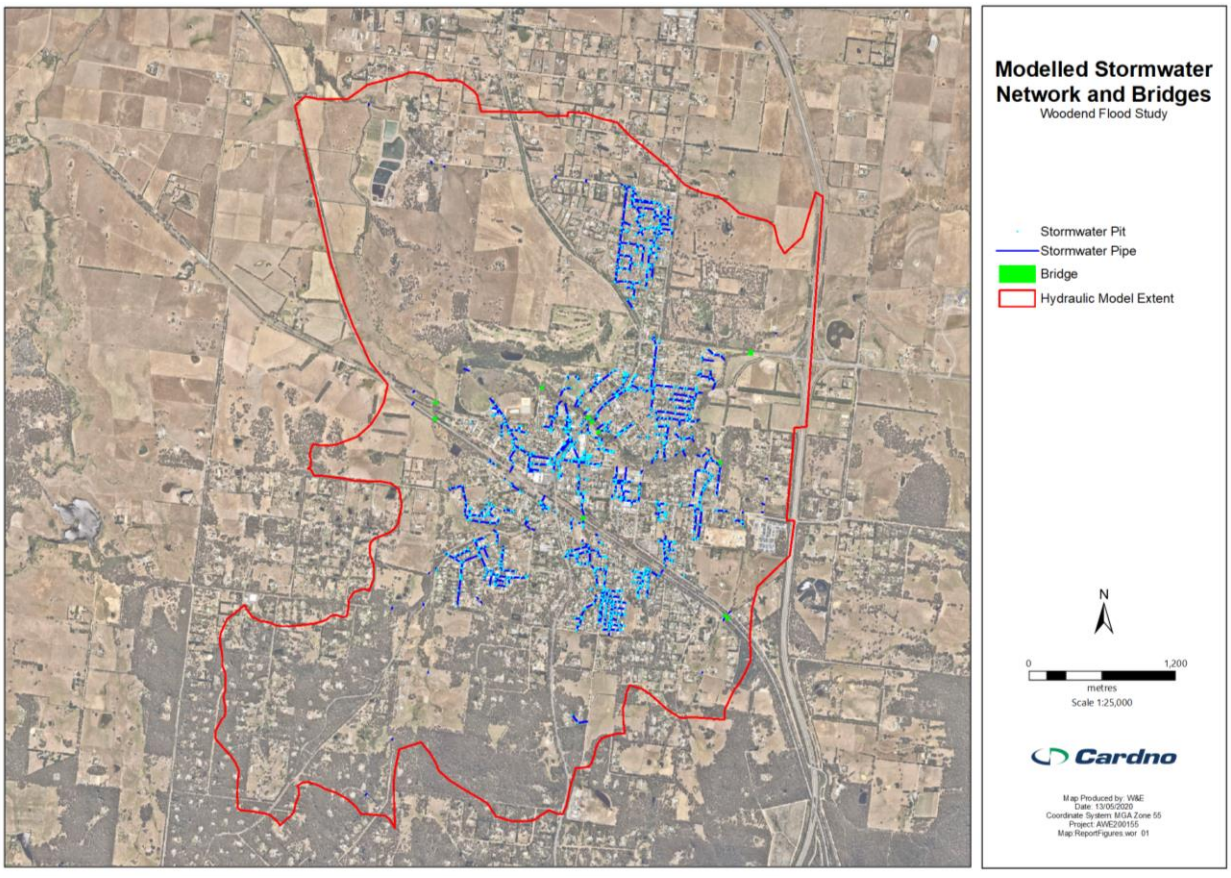


Figure 6-7 Modelled Stormwater Network and Bridges

6.3.4 Application of Rainfall

As the hydraulic model extent does not cover the entire upstream catchment, two different types of rainfall applications area applied to the model, namely:

1. Excess rainfall; and
2. Routed rainfall

The application of both is shown in Figure 6-8 and are discussed in following sections.

6.3.4.1 Routed Rainfall

Routed rainfall is rainfall which has been routed within the hydrological model in order to provide a peak flow rate at a set location. Routed rainfall has been used for all catchments upstream of the hydraulic model extent and applied to the model as a point inflow via 2d SA polygons located just inside the model boundary.

6.3.4.2 Excess Rainfall

Excess rainfall is rainfall which has not been routed within a hydrological model and instead relies on the hydraulic model to undertake the routing process. Excess rainfall has been applied to all catchments located within the hydraulic model extent, and is applied via a 2d SA ALL polygon to simulate rainfall falling across the sub-catchment.

6.3.5 Downstream Boundary Conditions

Due to the use of TUFLOW HPC, the downstream boundaries have been modelled as steady Height Time (HT) relationships as shown in Figure 6-8. The heights chosen were selected to be just above the channel obverts and were located outside of the township and far enough downstream of the area of interest so that results within the township were not affected.

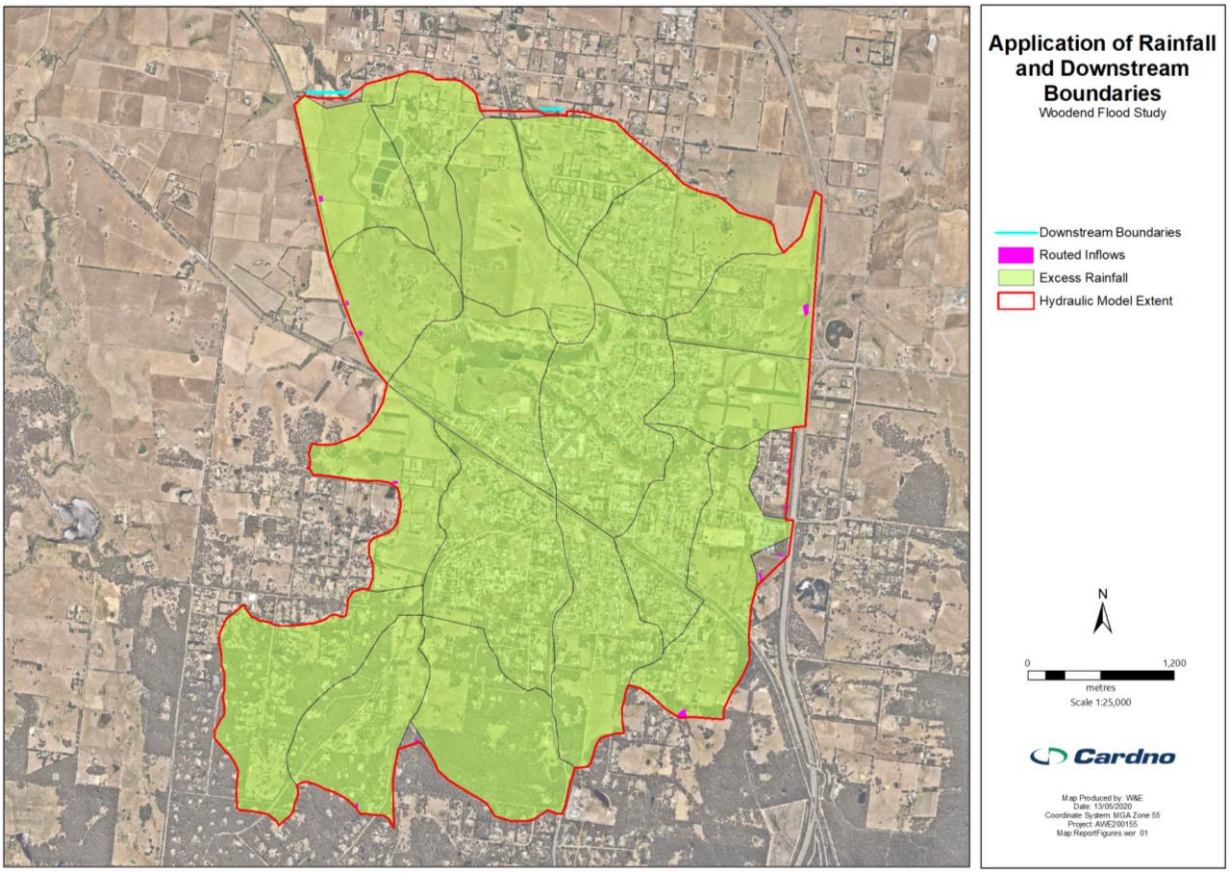


Figure 6-8 Application of Rainfall and Downstream Boundaries

6.4 Hydraulic Model Calibration and Validation

To test the accuracy of the RORB calibration, two historic flood events were selected to calibrate the TUFLOW model. These events were the 1993 event and the 2011 event. Due to lack of gauge data for the 1993 event and limitations with the high flow gauge data, surveyed flood levels for both the 1993 and 2011 events have been used for the hydraulic model calibration. It should be noted that some of the provided flood levels for the 1993 event were captured during a survey undertaken in 1995 based on photographs and recollections of residents and so may not be entirely accurate.

6.4.1 September 1993 Flood Event

Figure 6-9 shows the results of the calibrated TUFLOW model for the 1993 flood event. The calibration points are shown in a colour ramp with a deviation between the hydraulic model levels and those captured after the flood event. Comparing the calibration points against the surveyed flood levels, it is shown that the hydraulic model is closely replicating the recorded flood levels along Five Mile Creek as outlined in Table 6-3. This model used a Manning's roughness along Five Mile Creek of 0.06.

While the flood levels from the hydraulic model for the 1993 event closely match those captured along Five Mile Creek as shown in Figure 6-9, they did not represent the recorded level through the properties along the north side of Campaspe Drive such as that shown in Figure 6-10.

It should be noted that as both the Pyke Street and Campaspe Drive Levees were constructed after 1993 event, they were removed from the topography used within the hydraulic model to more accurate represent the on ground conditions in 1993. However, a review of historical aerial imagery suggests that a significant amount of additional works have occurred within the area protected by the Campaspe Drive levee since the 1993. These included sealing and raising of the roads and construction of kerbs. It is suspected that these works are the reason for the discrepancies in results in this area as discussed above.

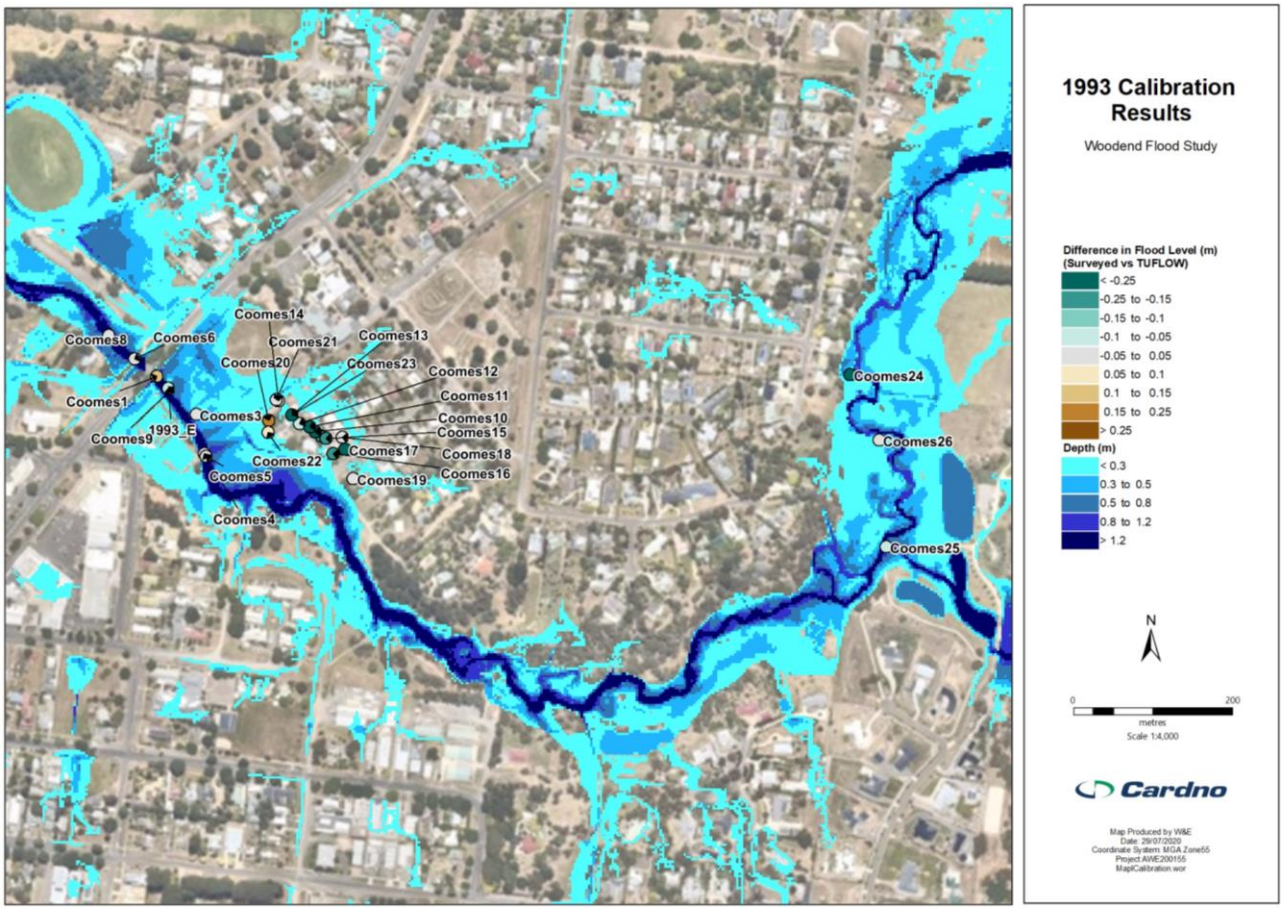


Figure 6-9 1993 TUFLOW Calibration Results



Figure 6-10 Flooding from the 1993 Event believed to be at 1 Heron Street (Source: North Central Catchment Management Authority)

6.4.2 January 2011 Flood Event

Figure 6-11 shows the results of the calibrated TUFLOW model for the 2011 flood event with calibration points identified within the figure with the difference between the modelled and recorded values labelled. Comparing the calibration points against the surveyed flood levels, the hydraulic model closely replicates the recorded flood levels along Five Mile Creek as outlined in Table 6-4. This model used a Manning's roughness of 0.06 along Five Mile Creek. Figure 6-12 shows flooding from this event adjacent to the Woodend Primary School which is represented within the hydraulic model.

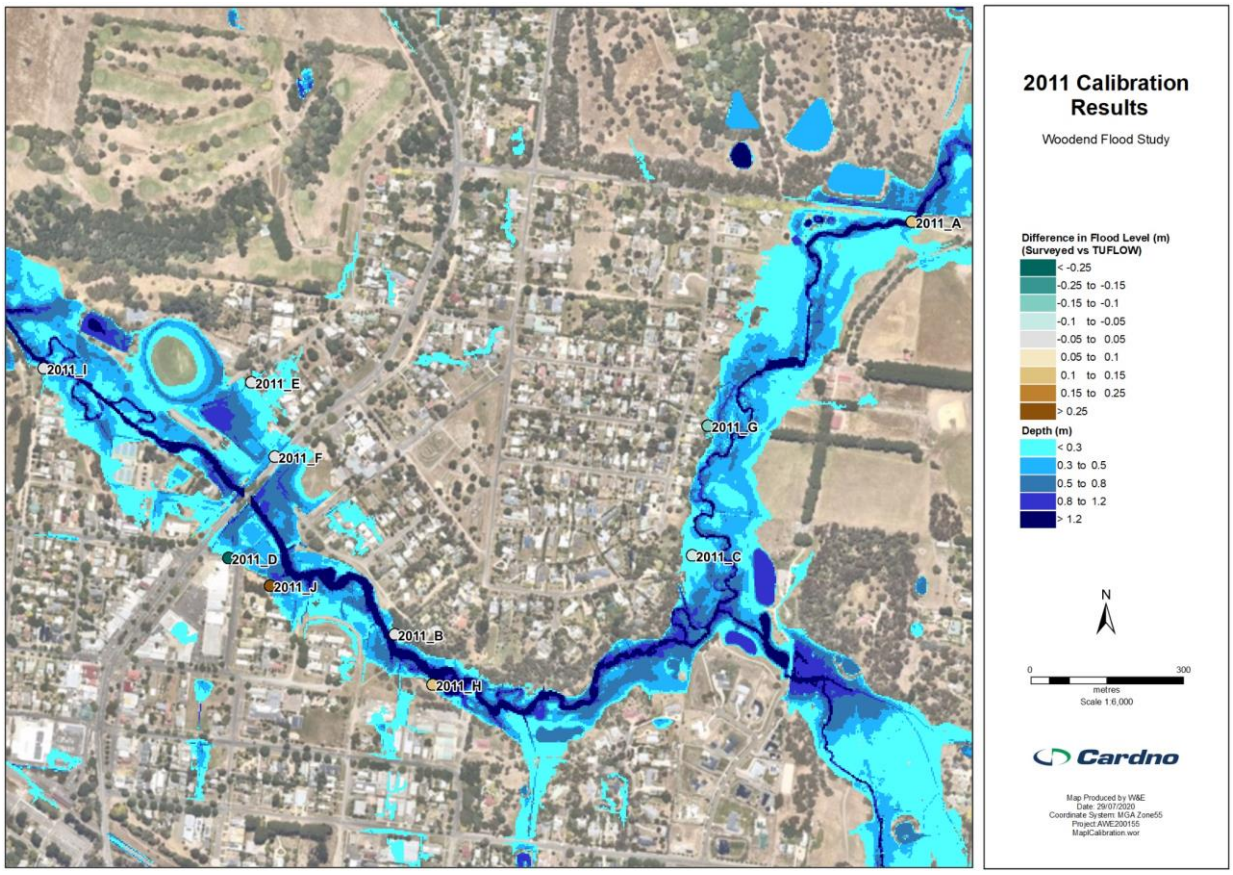


Figure 6-11 2011 TUFLOW Calibration Results



Figure 6-12 Flooding from the 2011 Event Adjacent to Woodend Primary School (Source: North Central Catchment Management Authority)

6.4.3 Hydraulic Calibration Model Sensitivity

In order to assess the sensitivity of the hydraulic model, both of the calibrated events (1993 and 2011) have been run with a roughness of 0.17 within the channel as adopted by Geoff Crapper within his calibrated HecRas model for the 1993 event. According to Chow (1973), the characteristics of a waterway with a hydraulic roughness of 0.17 are “Dense Willows, summer, straight”. In comparison, Chow lists the Cardno (now Stantec) calibrated roughness of 0.06 as “sluggish reaches, weedy, deep pools”.

Table 6-2 outlines the findings of the sensitivity analysis along Five Mile Creek just upstream of the Calder Highway Bridge.

Table 6-2 Findings of the Sensitivity Analysis at Calder Highway Bridge

Event	0.06 Manning’s - Flood level (mAHD)	0.17 Manning’s - Flood level (mAHD)	Difference (m)
1993 Event	551.06	551.23	+0.17
2011 Event	551.33	551.42	+0.09

Table 6-3 shows the results of the sensitivity analysis using the 26 surveyed flood levels from the 1993 event (as plotted in Figure 6-9). The locations of all recorded flood levels for the 1993 event were interpolated based on text-based descriptions within the Coomes report.

As outlined above, flood levels within Five Mile Creek were found to closely match within Five Mile Creek, but Cardno (now Stantec) were not able to replicate flooding along the rear of the houses located on Campaspe Drive for the 1993 event due to significant changes to land form occurring between Campaspe Drive and Five Mile Creek since the 1993 event. This is considered to be the likely cause of some of the are outliers in the results presented, while other are unexplained for example *Coombes 13 & Coombes 23* are located very close

to each other but the difference between surveyed flood level is 0.72m, however as discussed above the overall trend indicates a close match to the 1993 event.

When a hydraulic model roughness of 0.06 is adopted for along Five Mile Creek, the average difference in flood level from those surveyed is 0.14 m, while when a hydraulic roughness of 0.17 is selected the average difference is 0.18 m. As such, it can be seen that adopting a roughness of 0.06 gives a slightly better overall representation of the flood levels. However, it can also be seen that the Creek is not overly sensitive to the roughness adopted.

Table 6-3 Findings of the Sensitivity Analysis at all Survey Points for the 1993 Flood Event

ID	Recorded Flood Level (mAHD)	0.06 Manning's - Flood level (mAHD)	Difference (m)	0.17 Manning's - Flood level (mAHD)	Difference (m)
Coomes1	550.91	551.06	0.15	551.22	+0.31
Coomes2	551.19	551.11	-0.08	551.28	+0.09
Coomes3	551.24	551.20	-0.04	551.35	+0.11
Coomes4	551.32	551.31	-0.01	551.44	+0.12
Coomes5	551.34	551.32	-0.02	551.45	+0.11
Coomes6	550.87	550.91	0.04	551.10	+0.23
Coomes8	550.85	550.86	0.01	551.00	+0.15
Coomes9	551.78	551.63	-0.15	551.63	-0.15
Coomes10	551.79	551.53	-0.26	551.53	-0.26
Coomes11	551.78	551.43	-0.35	551.43	-0.35
Coomes12	551.44	551.38	-0.06	551.41	-0.03
Coomes13	551.41	551.34	-0.07	551.40	0.00
Coomes14	551.19	551.26	0.07	551.40	+0.21
Coomes15	551.88	551.64	-0.24	551.64	-0.24
Coomes16	551.87	551.70	-0.17	551.70	-0.17
Coomes17	552.09	551.80	-0.29	551.80	-0.29
Coomes18	552.02	552.07	0.05	552.07	+0.05
Coomes19	552.14	552.10	-0.05	552.10	-0.05
Coomes20	551.27	551.46	0.19	551.46	+0.19
Coomes21	551.24	551.26	0.02	551.40	+0.16
Coomes22	551.35	551.42	0.07	551.50	+0.14
Coomes23	552.13	551.34	-0.79	551.41	-0.72
Coomes24	557.20	556.85	-0.35	556.87	-0.33
Coomes25	555.85	555.79	-0.06	555.90	0.05
Coomes26	556.36	556.35	-0.01	556.39	+0.03

Table 6-4 below shows the results of the sensitivity analysis using the 10 surveyed flood levels from the 2011 event (as plotted in Figure 6-11). The surveyed flood levels are based on debris marks after the flood event, therefore it is reasonable to expect an error band associated with these recorded flood levels.

When a hydraulic model roughness of 0.06 is adopted for along Five Mile Creek, the average difference in flood level from those surveyed is 0.14 m whereas when a hydraulic roughness of 0.17 is selected, the average difference is 0.22 m. This further indicates that adopting a hydraulic model roughness along Five Mile Creek of 0.06 is more appropriate then adopting 0.17 as per Geoff Crapper (1995).

Table 6-4 Findings of the Sensitivity Analysis at All Survey Points For 2011 Flood Event

ID	Recorded Flood Level (mAHD)	0.06 Manning's - Flood level (mAHD)	Difference (m)	0.17 Manning's - Flood level (mAHD)	Difference (m)
2011_A	559.95	560.07	+0.12	560.26	+0.31
2011_B	552.8	552.79	-0.01	553.01	+0.21
2011_C	556.37	556.3	-0.07	556.36	-0.01
2011_D	551.82	551.47	-0.35	551.56	-0.26
2011_E	551.02	550.98	-0.04	550.98	-0.04
2011_F	551.00	550.99	-0.01	551.1	+0.1
2011_G	557.87	557.73	-0.14	557.78	-0.09
2011_H	553.13	553.25	+0.12	553.62	+0.49
2011_I	548.71	548.75	+0.04	548.83	+0.12
2011_J	551.55	551.9	+0.35	552.09	+0.54

6.4.4 TUFLOW Validation to Council Flood Hotspots

Results from the hydraulic model have been validated against all supplied (71) Council hotspots including all locations mentioned in the Coomes 1997 study. Figure 6-13 shows each modelled flood extent for the assessed AEPs compared to all known Council hotspots.

There is a reasonable match between the modelled flood extents and the associated defined flow paths with known Council hotspots. However, there are some outliers represented in the dataset with some hotspots represented in locations outside of any modelled flood extents and defined flow paths. It is likely that this is a factor of the supplied hotspots dating back over 25 years. Previous works undertaken may have rectified known flood issues since the hotspots were logged. Furthermore, some of the hotspots may have been identified as localised drainage hotspots caused from a blocked pipe or drain that we wouldn't expect to be identified within the hydraulic model.

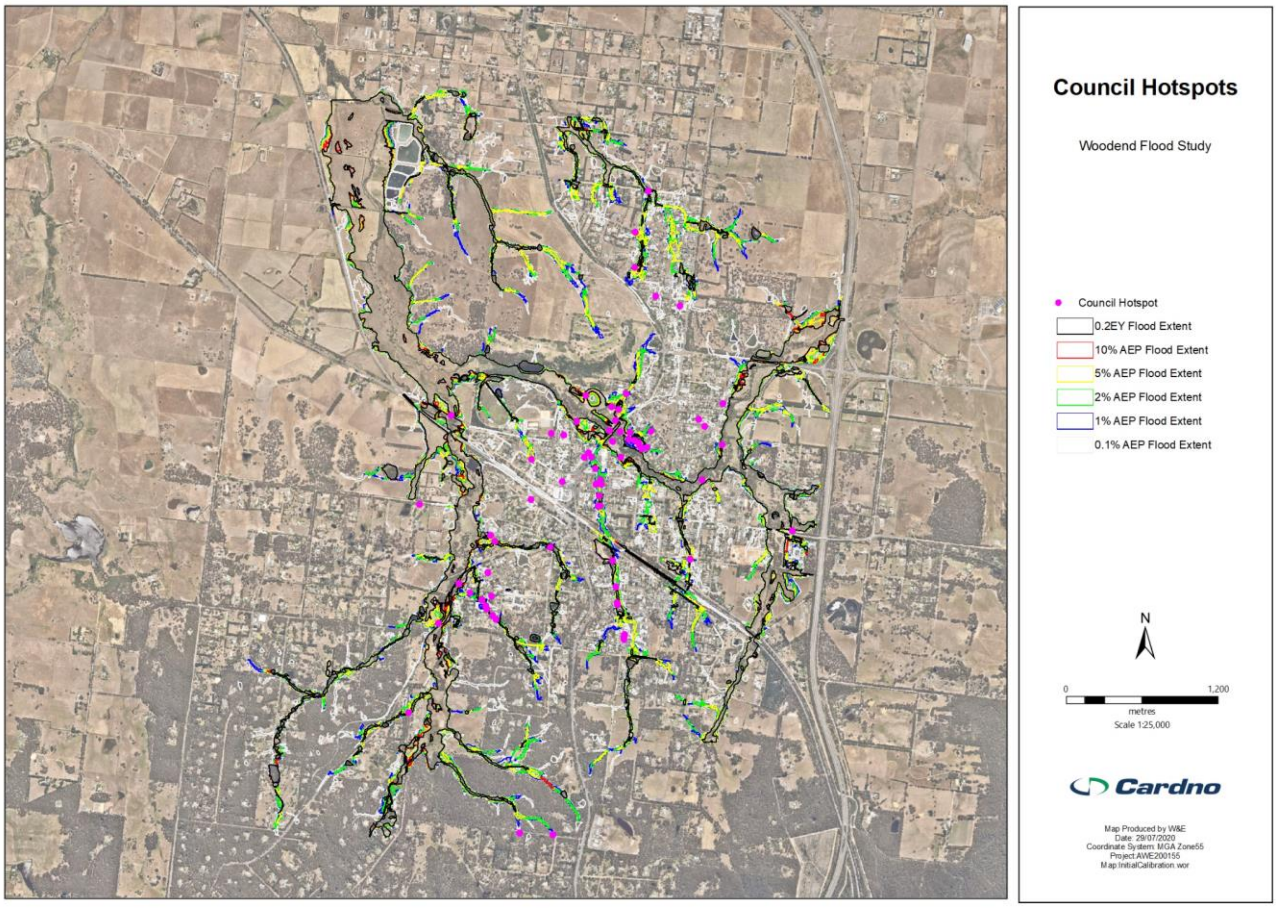


Figure 6-13 Council Hotspots

6.4.5 Routing within the Hydraulic Model

Due to differences in the way the hydrological and hydraulic models route flows, checks have been undertaken to ensure that the hydraulic model is behaving as would be expected.

6.4.5.1.1 Upstream Catchment K_c Sensitivity

While both the hydrological and hydraulic models were calibrated to known historical events, the hydrological model was only been calibrated to the gauge at the Calder Highway, with routed inflows being applied to the hydraulic model significantly upstream of the gauge. In order to assess the sensitivity of the adopted K_c on the routed inflows upstream of the gauge, a K_c/D_{av} ratio check was undertaken, where the calibrated K_c/D_{av} ratio is used to determine the K_c value at the most significant upstream inflow, which is on Five Mile Creek at the Calder Freeway. In order to ensure that outcome of this assessment is not affected by storages within the RORB model, it has been undertaken directly upstream of any storage affects offered by the Calder Freeway Bridge at Five Mile Creek.

The K_c/D_{av} ratio from the calibrated RORB model is 25/8.7=2.87

The D_{av} for Five Mile Creek at the Calder Freeway is 5.19, which results in a K_c value of 14.89 at the Calder Freeway to maintain a K_c/D_{av} ratio of 2.87, which has been applied via an interstation area.

In the January 2011 event of the calibrated RORB model, the peak flow at Five Mile Creek at the Calder Freeway is 30.59 m^3/s.

With the use of an interstation area on Five Mile Creek at the Calder Highway with a K_c value of 14.89 results in a peak flow rate of 30.61 m^3/s, demonstrating that the upstream catchments are not overly sensitive to the adopted K_c value.

6.4.5.1.2 Routing within the Hydraulic Model

With a RORB model, sufficient routing is required for realistic hydrographs to be produced. Ideally this is achieved by having several catchments upstream of each routed inflow, with RORB also requiring all sub-catchments to generally be approximately the same magnitude in size. However, if there are too many sub-catchments within a model, RORB will generally over attenuate flows. In order to check whether sufficient routing is occurring within the RORB model prior to the inflows being applied to the TUFLOW model, routed inflow hydrographs have been checked to see if they appear realistic. This check has been undertaken by plotting the routed inflows against a reporting line (PO) within the TUFLOW model before the routed inflow joins the main waterway. Figure 6-14 shows the results of this assessment for inflow “Calculated Hydrograph: BT”, which is the node located at the downstream end of subarea AB to the north-west of the Woodend Township. As shown, the hydrograph is not overly peaky and is of a reasonable shape. which demonstrates that there is likely to be sufficient routing occurring within the RORB model before routed the flow is applied to the TUFLOW model with further routing occurring in the TUFLOW model as demonstrated by the reduction in peak flow at the PO line just prior to the flow path connecting with the downstream watercourse.

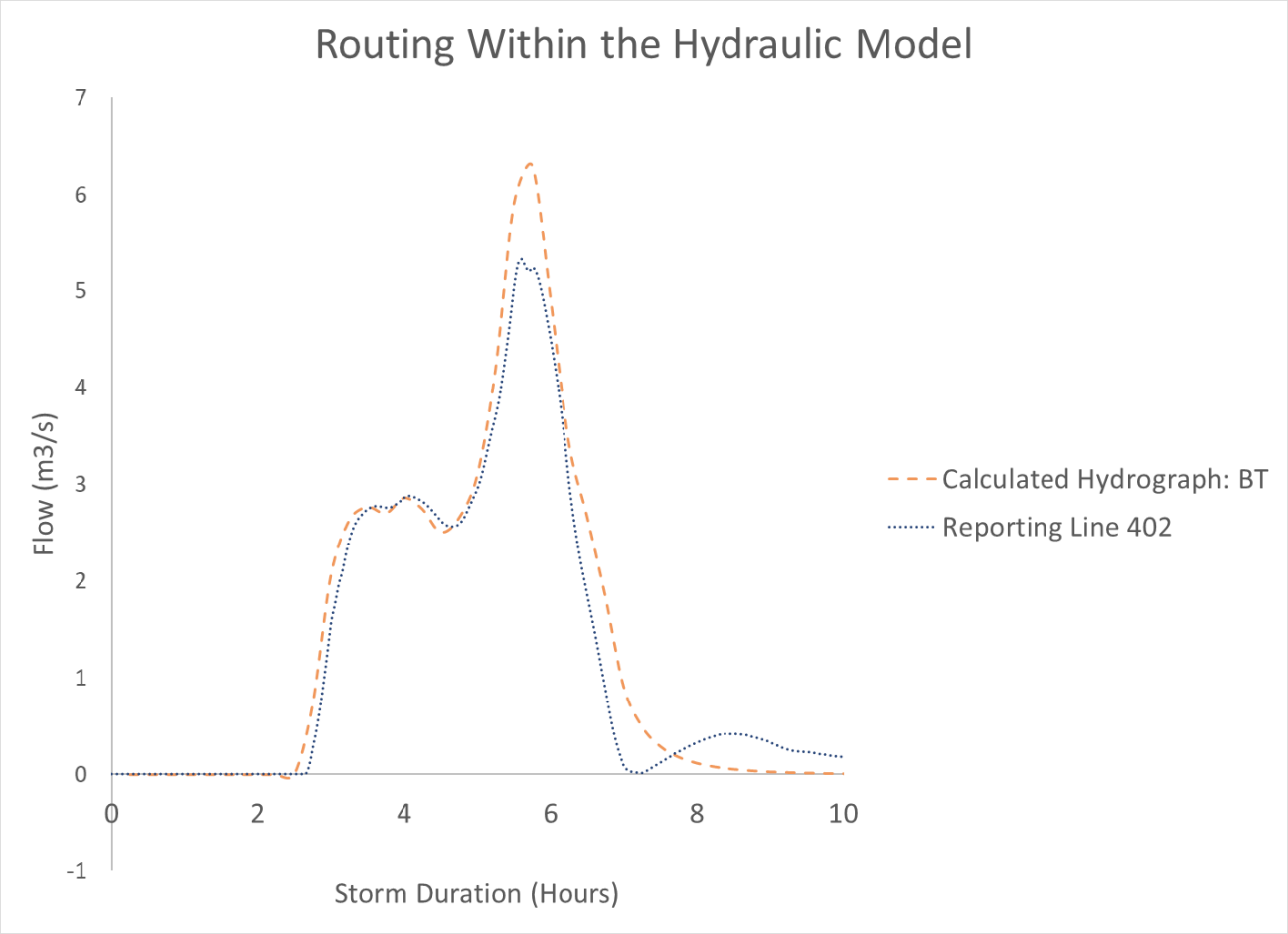


Figure 6-14 Routing within the Hydraulic Model

6.5 Overall Model Results

The results from the hydraulic model were processed in-line with the methodology outlined by Swan et al 2018, where the results from each run of the hydraulic model (runs vary by duration and temporal pattern) are combined based on AEP. Where the peak value (depth, levels, velocities etc.) from all the combined runs forming the final output.

Flooding in Woodend is generally limited to along the waterways and depressions throughout the township. In the greater Woodend area, several major roads are expected to be overtopped by flooding in the 1% AEP event, with some expected to be overtopped in events as frequent as the 0.2EY event including:

- The Calder Highway at Five Mile Creek;
- Wallan-Woodend Road (Romsey Road);
- Tylden Road;
- Walkers Road and Bawden Road intersection;
- Mt Macedon Road; and
- Ashbourne Road.

Figure 6-15 shows flood water overtopping Wallan-Woodend Road (Romsey Road) during the 1993 event.



Figure 6-15 Wallan-Woodend Road (Romsey Road) in the 1993 event (Source: North Central catchment Management Authority)

6.5.2 Design Flow Rates at the Calder Highway Bridge

In order to provide design flow rates that produce flood levels which are consistent with those outlined in this report, peak rates as determined within the hydraulic model should be adopted as the design event flow rates. These values are outlined in outlined in Table 6-5.

Table 6-5 Hydraulic Model Design Flow Rates

AEP	Hydraulic Model Peak Flow Rate (m^3/s)
0.2EY	36 m^3/s
10% AEP	40 m^3/s
5% AEP	55 m^3/s
2% AEP	77 m^3/s
1% AEP	95 m^3/s
0.1% AEP	159 m^3/s

6.5.2.2 Difference Between RORB and TUFLOW Design Events

It is acknowledged that there are differences in peak flows at the Calder Highway Bridge between the outputs from the RORB and TUFLOW design event models. However, it should be noted that the hydraulic model has been calibrated based on historical surveyed flood levels for both the 1993 and 2011 events (refer to section 6.4), with a conservative approach being adopted for this study.

Further explanations and clarifications of the differences between the RORB and TUFLOW design event outputs are summarised below:

> When the RORB peak flow rate was determined during the Monte Carlo assessment (Section 5.5) at the Calder Highway Bridge, an ARF of 45 km^2 was adopted, which is the catchment area upstream of the bridge. Whereas, within the hydraulic model, a varying ARF has been adopted based on the upstream catchment size of each sub-catchment as discussed in Section 5.3.5.

> During the RORB Monte Carlo assessment, the statistically most likely peak flow rate at each of the assessed locations was determined independently of the other locations being assessed. This can result in the critical duration and temporal pattern at certain locations slightly overestimating those critical flow at other locations.

> For the RORB model, a K_c value of 25 was adopted. This only applies to routed inflows applied to the hydraulic model, as excess rainfall inflows are routed within the hydraulic model based on a number of factors including topography, hydraulic roughness and the drainage network.

In addition to the above, the results produced from RORB and TUFLOW are underpinned by detailed work to calibrate the models along Five Mile Creek at the Calder Highway Bridge (refer section 5.4 and section 6.4) and validate the model to flood hotspots (refer section 5.6 and 6.4). All of this work has been undertaken in alignment with best practice guidelines including ARR2019 and Melbourne Water Specifications and has been checked via an independent peer review process.

7 Consequences of Flooding on the Community

The township of Woodend is flood prone due to its proximity to both Five Mile Creek and the Macedon Ranges, with a series of well-known flooding issues. Areas known to experience flooding include:

- Ashbourne Road at the Tributary of Five Mile Creek;
- Barbara Street;
- Between Washington Lane and High Street;
- Calder Highway at Five Mile Creek;
- Campaspe Drive
- Davy Street;
- Football Oval;
- Mahoneys Road;
- Plants Lane Underpass;
- Roxanne Court;
- Some of the shops along the western side of High Street, south of Forrest Street;
- Timber Lane;
- Tree Change Way; and
- Woodend-Wallan Road (Romsey Road) at Five Mile Creek.

7.1 Flood Impacts

7.1.1 Flood Levels at Roads

Several major roads within Woodend experience overtopping in floods as frequent as the 0.2EY event. The flood levels of each of the six major road crossings is outlined below in Table 7-1.

Table 7-1 Flood Levels and Depths Over Major Roads

AEP	Woodend-Wallan Road (Romsey Road)	Bawden Road at Walkers Road	Mt Macedon Road	Calder Highway Bridge	Ashbourne Road	Tylden Road
0.2EY	560.35 mAHD (not overtopped)	564.10 mAHD (0.16 m)	559.49 mAHD (0.14 m)	551.18 mAHD (0.13 m)	552.74 mAHD (0.06 m)	553.98 mAHD (0.06 m)
10% AEP	560.41 mAHD (0.01 m)	564.10 mAHD (0.16 m)	559.49 mAHD (0.14 m)	551.22 mAHD (0.15 m)	552.80 mAHD (0.12 m)	554.05 mAHD (0.08 m)
5% AEP	560.55 mAHD (0.15 m)	564.17 mAHD (0.23 m)	559.57 mAHD (0.22 m)	551.31 mAHD (0.24 m)	552.90 mAHD (0.22 m)	554.17 mAHD (0.11 m)
2% AEP	560.70 mAHD (0.30 m)	564.22 mAHD (0.28 m)	559.63 mAHD (0.28 m)	551.39 mAHD (0.32 m)	552.99 mAHD (0.31 m)	554.28 mAHD (0.14 m)
1% AEP	560.77 mAHD (0.37 m)	564.26 mAHD (0.32 m)	559.67 mAHD (0.32 m)	551.45 mAHD (0.38 m)	553.04 mAHD (0.36 m)	554.33 mAHD (0.16 m)
0.1% AEP	560.99 mAHD (0.59 m)	564.41 mAHD (0.47 m)	559.77 mAHD (0.42 m)	551.66 mAHD (0.59m)	553.17 mAHD (0.49 m)	554.47 mAHD (0.24 m)

7.1.2 1% AEP Levee Freeboard

In the 1% AEP event the Campaspe Drive levee is expected to have 0.4m of freeboard.

In the 1% AEP event the Pyke Street Levee is expected to have 0.05m of freeboard.

7.1.3 Levees Failure and Overtopping

The impacts of levee failure and overtopping has been assessed for both the Campaspe Drive and Pyke Levees. The two sets of constructed levees are expected to provide flood protection in the 1% AEP event along Five Mile Creek. This assessment has assumed a total catastrophic failure of both levee systems prior to the flood event which results in neither levee offering any form of protection to the community during elevated flood levels along Five Mile Creek.

Due to the levee failure, it is expected that flood levels in areas which are currently protected by the levee will be identical to those within Five Mile Creek at the associated locations.

Flood Maps for levee failure have been included in Appendix 0.

7.1.4 Impacts of Climate Change

Due to the effects of climate change, Woodend is expected to become more susceptible to flooding. This will be in respect to both the extent and depth of flooding experienced.

Climate change has been incorporated into this study as per ARR2019 by adopting methods to an apply increase in rainfall intensity and increase in temperature for future climate change scenarios. Refer to section 5.3.1.2 and Table 5-4 for the Future Climate Scenarios adopted for this study.

Flood maps for the 10% AEP, 1% AEP and 0.1% AEP climate change events are included within Appendix 0. Along the major flow paths, it is expected that flood levels will generally increase by up to 0.4m in the 10% AEP event, and generally up to 0.2m in both the 1% AEP and 0.1% AEP events with little increase in flood extents. Along the minor flow paths, flood level increases are similar to those experienced along the major flow paths but typically experience a larger increase in the extent of flooding.

7.1.5 Impacts of Fully Developed for Permissible Land Uses

Without appropriate land use and development controls in place, future development has the potential to exacerbate flooding risk, particularly with respect to the depth of flooding experienced.

Flood maps for the 5% AEP, 1% AEP and 0.1% AEP Fully Developed for Permissible Land Uses events are included within Appendix 0. Across Woodend flood levels are generally expected to increase by 0.1m as a result of this development. However, it is expected that this would lead to only a minor increase in the extent of flooding.

While the development within Woodend is only expected to lead to a small increase in the depth of flooding it should not absolve developers from being required to continue to retard runoff from any development back to existing levels.

7.2 Performance of Hydraulic Control Structures Upstream of the Hydraulic Model Extent

The hydraulic performance of four critical drainage assets located upstream of the hydraulic model extent have been analysed using TUFLOW for the 5% AEP, 1% AEP and 0.1% AEP events. Three of these structures are located below the Calder Freeway including the File Mile Creek Bridge, with an additional structure located below the Bendigo Train Line to the west of the township as shown in Figure 7-1. The hydraulic TUFLOW model has been modified/extended in order to include these crossings, with critical durations determined from the hydrological RORB model.

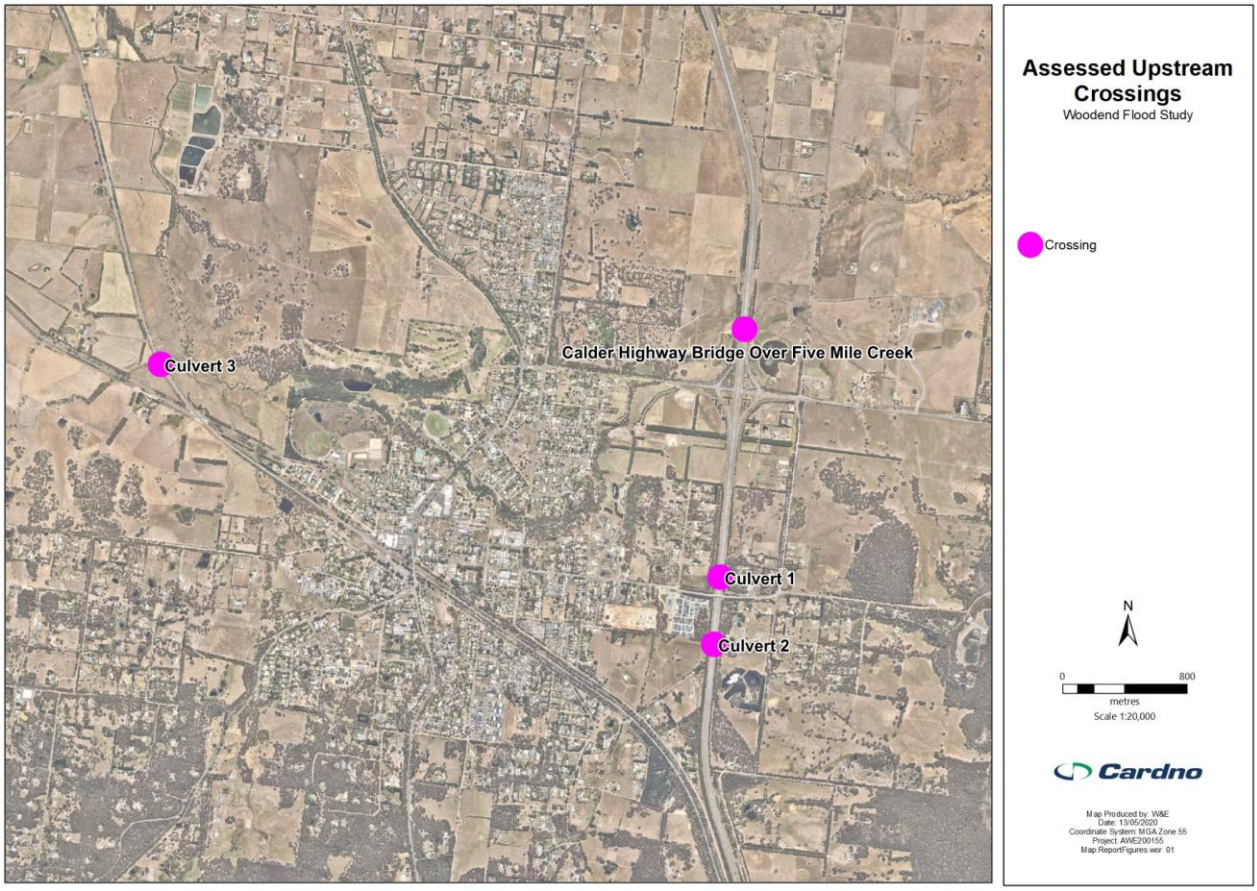


Figure 7-1 Assessed Upstream Crossings

7.2.1 Calder Freeway Bridge Over Five Mile Creek

The Calder Freeway Bridge over Five Mile Creek is located north of Romsey Road. Table 7-3 summarises the key bridge parameters as well as the resulting flood levels, which shows that the Calder Freeway at Five Mile Creek is located above the 0.1% AEP flood level.

Table 7-2 Summary of Results - Calder Highway Bridge over Five Mile Creek

Criteria	Value
Channel Invert (From LiDAR)	561.50 mAHD
Deck Obvert	565.50 mAHD
Road/Railway Crest Level (from LiDAR)	566.80 mAHD
5% AEP Flood Level	563.73 mAHD
1% AEP Flood Level	564.23 mAHD
0.1% AEP Flood Level	564.81 mAHD

7.2.2 Culvert 1

Culvert 1 is located below the Calder Freeway north of Mount Macedon Road. Table 7-3 summarises the key culvert parameters as well as the resulting flood levels, which shows that due to the bund directly upstream of the Freeway it is not overtopped in the 0.1% AEP event.

Table 7-3 Summary of Results for Culvert 1

Criteria	Value
Culvert Size	1.05 m dia.
Upstream Culvert Invert	562.07 mAHD
Downstream Culvert Invert	560.46 mAHD
Road Crest Level (from LiDAR)	564.14 mAHD
Upstream Bund Crest Level (from LiDAR)	567.01 mAHD
5% AEP Flood Level	563.16 mAHD
1% AEP Flood Level	563.71 mAHD
0.1% AEP Flood Level	564.66 mAHD

7.2.3 Culvert 2

Culvert 2 is located below the Calder Freeway at the end of Sullivan's Road. Table 7-4 summarises the key culvert parameters as well as the resulting flood levels, which shows that due to the bund directly upstream of the Freeway it is not overtopped in the 0.1% AEP event.

Table 7-4 Summary of Results for Culvert 2

Criteria	Value
Culvert Size	0.75 m dia.
Upstream Culvert Invert	563.93 mAHD
Downstream Culvert Invert	562.575 mAHD
Road Crest Level (from LiDAR)	565.38 mAHD
Upstream Bund Crest Level (from LiDAR)	568.32 mAHD
5% AEP Flood Level	565.5 mAHD
1% AEP Flood Level	566.09 mAHD
0.1% AEP Flood Level	567.33 mAHD

7.2.4 Culvert 3

Culvert 3 is a bluestone culvert located below the Bendigo mainline to the west Gregory Street. Table 7-5 summarises the key culvert parameters as well as the resulting flood levels, which shows the railway line is overtopped in the 1% AEP event. As shown in Figure 7-2 it can clearly be seen that the culvert is not free draining with water pooling on both the upstream and downstream side of the culvert under dry conditions.

Table 7-5 Summary of Results for Culvert 3

Criteria	Value
Culvert Size	1.5m x 1.1m Arch
Upstream Culvert Invert	540.60 mAHD
Downstream Culvert Invert	540.59 mAHD
Railway Crest Level (from LiDAR)	543.55 mAHD
5% AEP Flood Level	543.37 mAHD
1% AEP Flood Level	543.67 mAHD
0.1% AEP Flood Level	543.80 mAHD



Figure 7-2 Aerial Imagery of Culvert 3 (Captured 03/04/2021)

7.3 Hydraulic Model Sensitivity

Three separate sensitivity scenarios were assessed in order to determine how sensitive the hydraulic model was to a change in parameters. The assessed scenarios include blockage, hydraulic manning's roughness and a change in the downstream boundary levels and has been undertaken for the 5% AEP, 1% AEP and 0.1% AEP flood events. The assessment has been undertaken on the event which produces the highest flow rate at the Calder Highway Bridge along Five Mile Creek. The events assessed were:

- 5% AEP 540 Minute Temporal Pattern 12
- 1% AEP 720 Minute Temporal Pattern 30
- 0.1% AEP 720 Minute Temporal Pattern 29

Due to the difference in the adopted 1% AEP flow rate between this study and that adopted by Coomes 1997, a further sensitivity analysis was undertaken with a peak flow rate of 113m^3/s at the Calder Highway Bridge in order to assess the impact of a high flow scenario.

7.3.1 Blockage

A blockage assessment was undertaken as per the guidance outlined in ARR2019. All blockages have been assessed independently. Any impacts have been shown to be limited to the immediate vicinity of the assessed bridge. This assessment identified five key bridges for which this assessment has been undertaken. For ease of reporting all assessed bridges have been represented within a single figure as shown in Figure 7-3. The outcomes of the blockage assessment are summarised in Table 7-6.

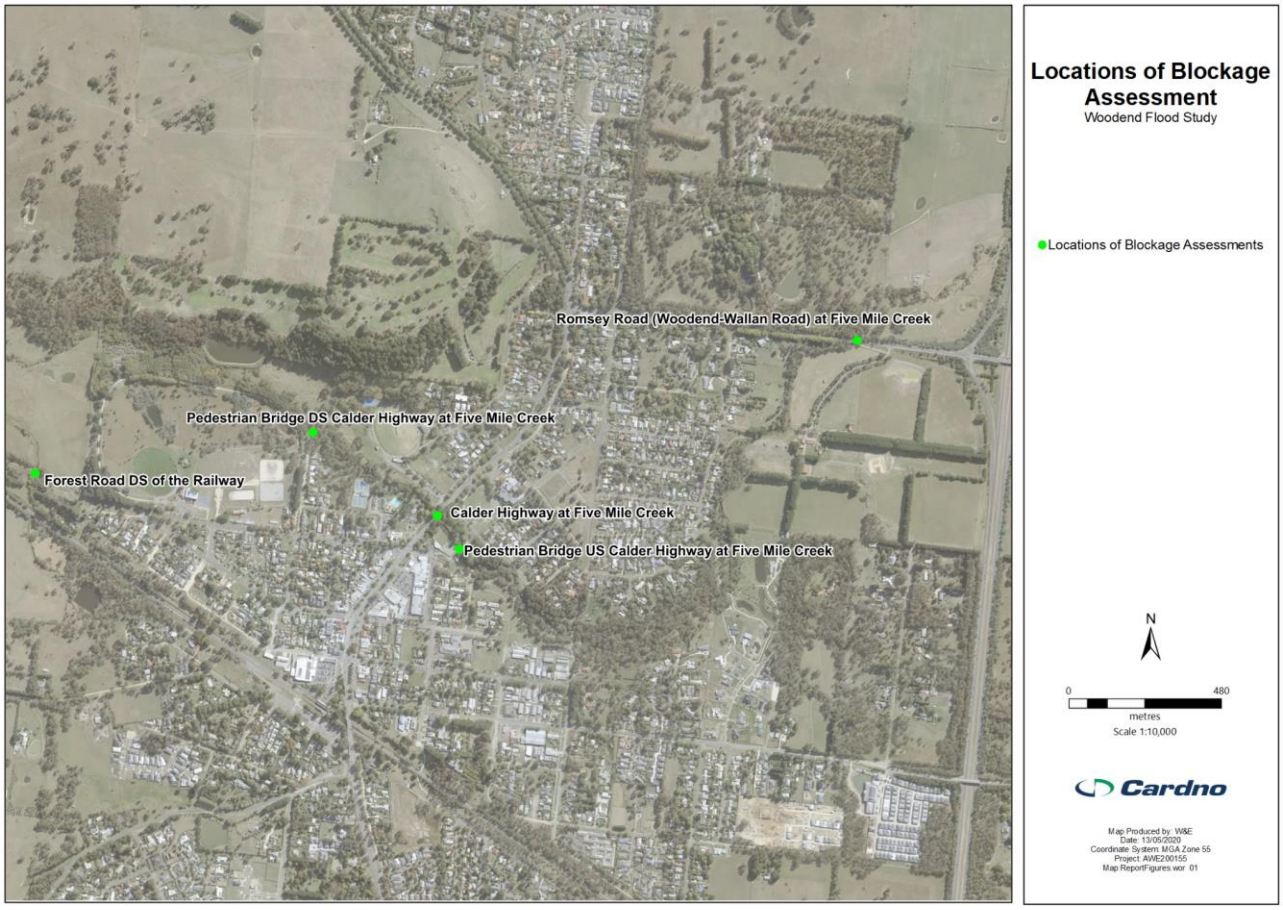


Figure 7-3 Locations of Blockage Assessment

Table 7-6 Outcome of the Blockage Assessment

Bridge	Blockage Factor
Forest Road DS of the Railway	10%
Pedestrian Bridge DS Calder Highway at Five Mile Creek	20%
Calder Highway at Five Mile Creek	10%
Pedestrian Bridge US Calder Highway at Five Mile Creek	10%
Romsey Road (Woodend-Wallan Road) at Five Mile Creek	20%

For the Calder Highway Bridge at Five Mile Creek the area most likely to block is in the area below the top of the pedestrian railings. Therefore, for this bridge a 20% blockage was applied, which is the equivalent of a 10% blockage to the total cross-sectional area of the bridge.

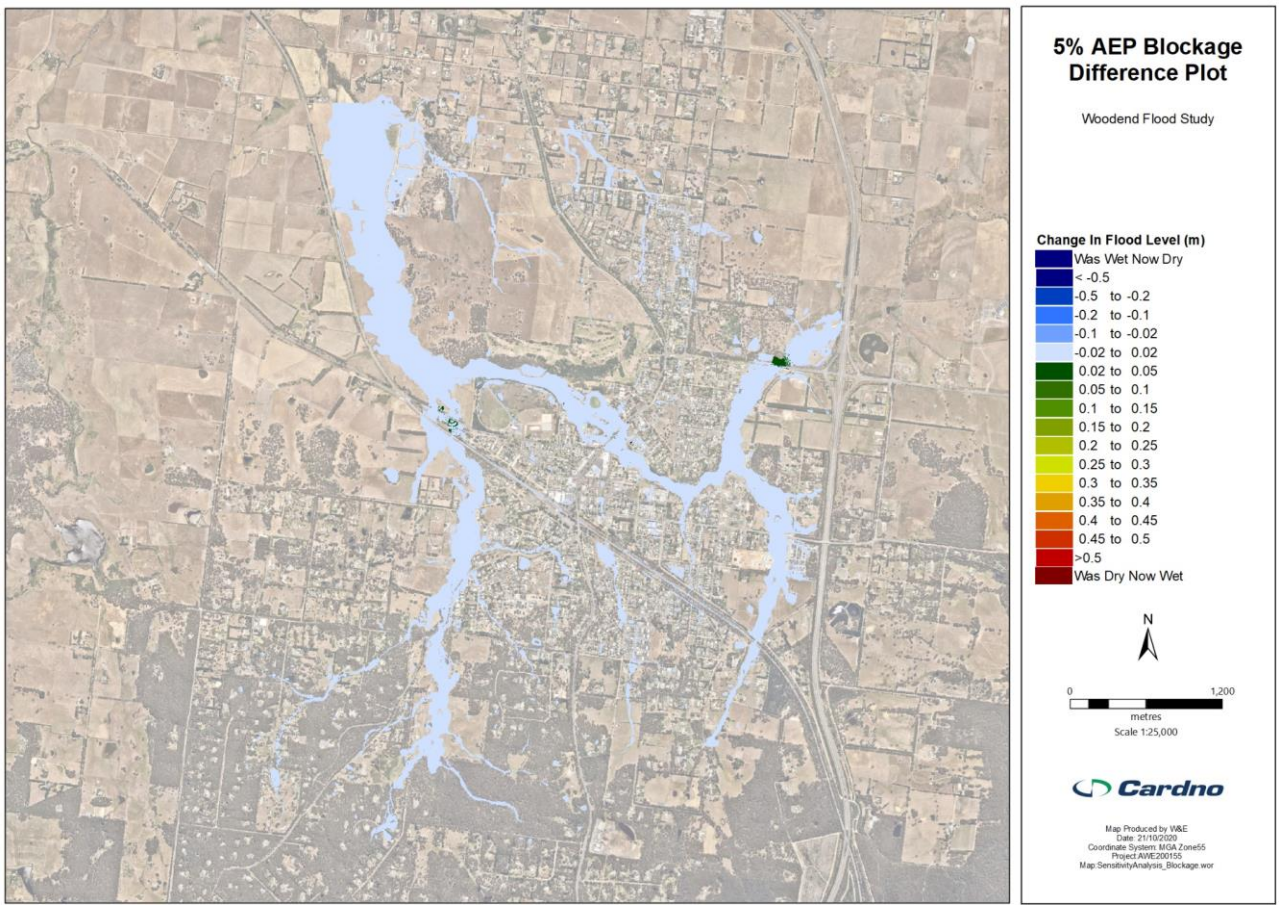


Figure 7-4 5% AEP Blockage Difference Plot

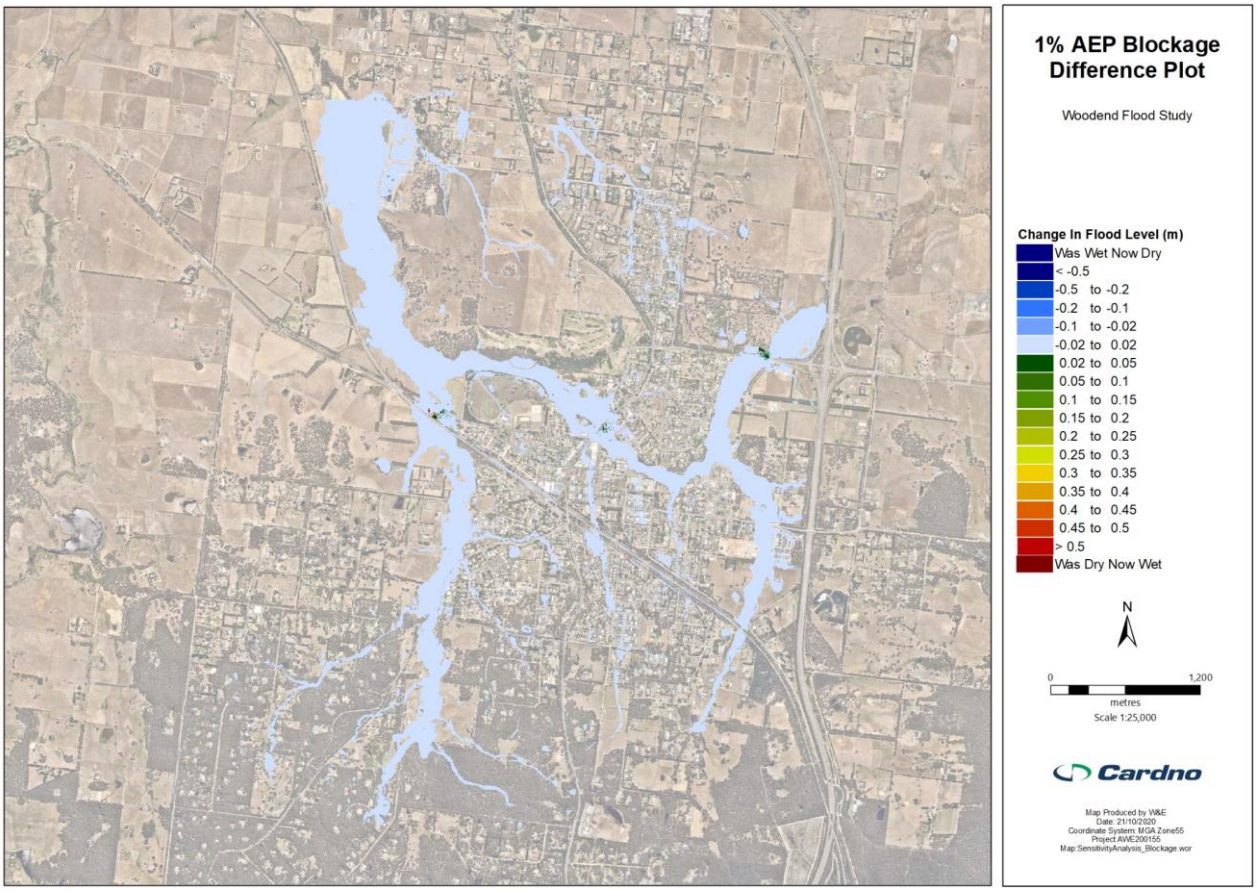


Figure 7-5 1% AEP Blockage Difference Plot

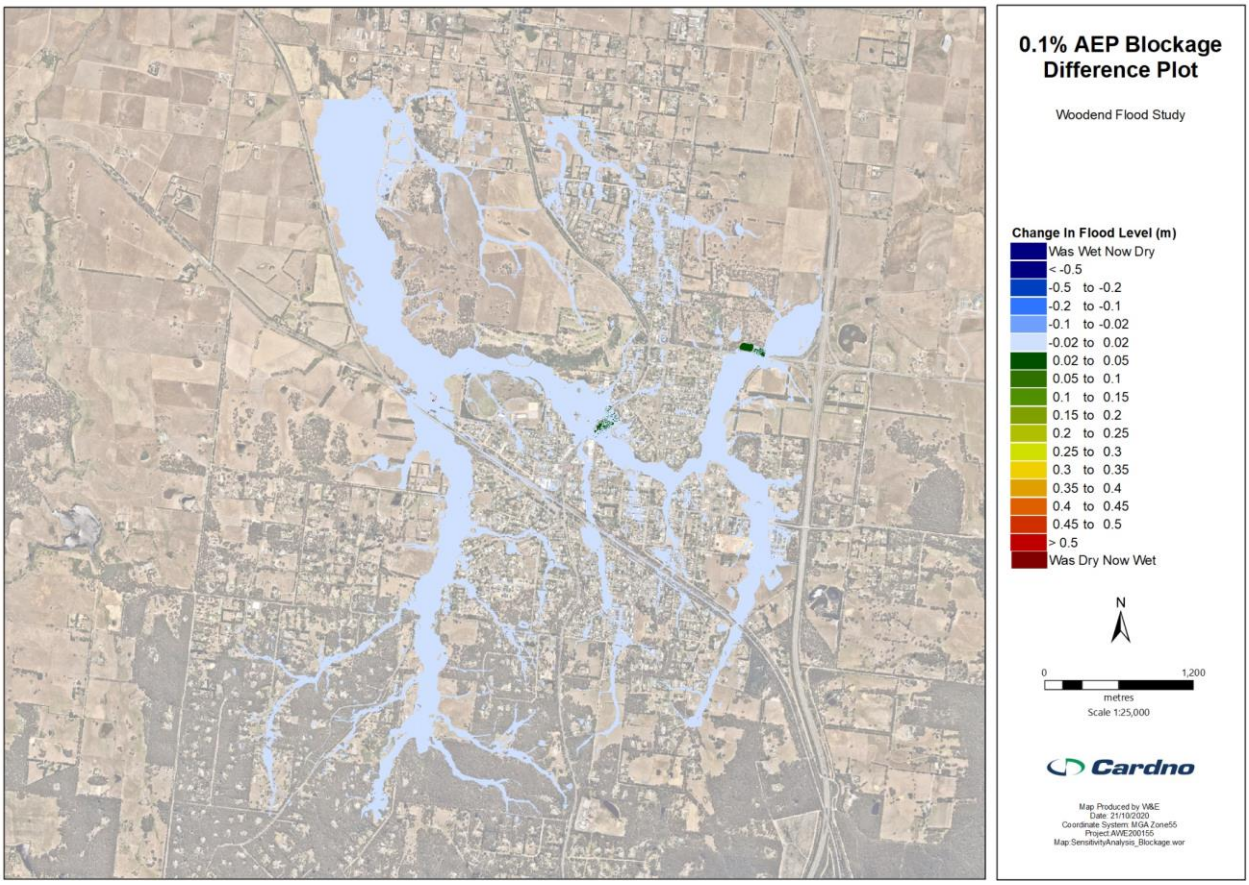


Figure 7-6 0.1% AEP Blockage Difference Plot

As can be seen in Figure 7-4 to Figure 7-6, flood levels along Five Mile Creek are not sensitive to blockages at the key structures. Upstream of the assessed structures, any increases to the flood levels are limited to being in the immediate vicinity of the assess bridges generally being contained to within 100m of the structure and are no greater than 50mm in magnitude, with any downstream impacts quickly dissipating.

7.3.2 Roughness

Two separate roughness sensitivity analyses were undertaken. The first analysis was undertaken with the hydraulic roughness set to the lowest acceptable value for each defined factor, with the second analysis undertaken with the hydraulic roughness set to the highest acceptable value.

Flood levels along Five Mile Creek are highly sensitive to changes in hydraulic roughness as shown in Figure 7-7 to Figure 7-12 (although it should be noted that these are extreme roughness changes that are being modelled). In the high roughness analysis, flood levels generally increase by 0.25m in all modelled events, but there is very little increase in the extent of the flooding unless it tips over a hydraulic control such as the Pyke Street Levee in the 1% AEP event. Behind the railway on the western side of Woodend, there is a significant increase in flood levels due to the adopted high manning's roughness of 0.17 within Five Mile Creek. We expect that this significantly reduces the capacity through the Calder Highway bridge at Five Mile Creek. In the low roughness analysis, flood levels generally decrease by up to 0.2m along Five Mile Creek, again with little change in the extent of flooding.

The roughness sensitivity analyses undertaken provided a good indication of the sensitivity of the model to significant roughness differences. The analysis provided a level of confidence regarding the roughness parameters adopted for the study, identified some sensitivity to change in flood levels from significantly different roughness parameters adopted, but minimal sensitivity to changes to flood extents.

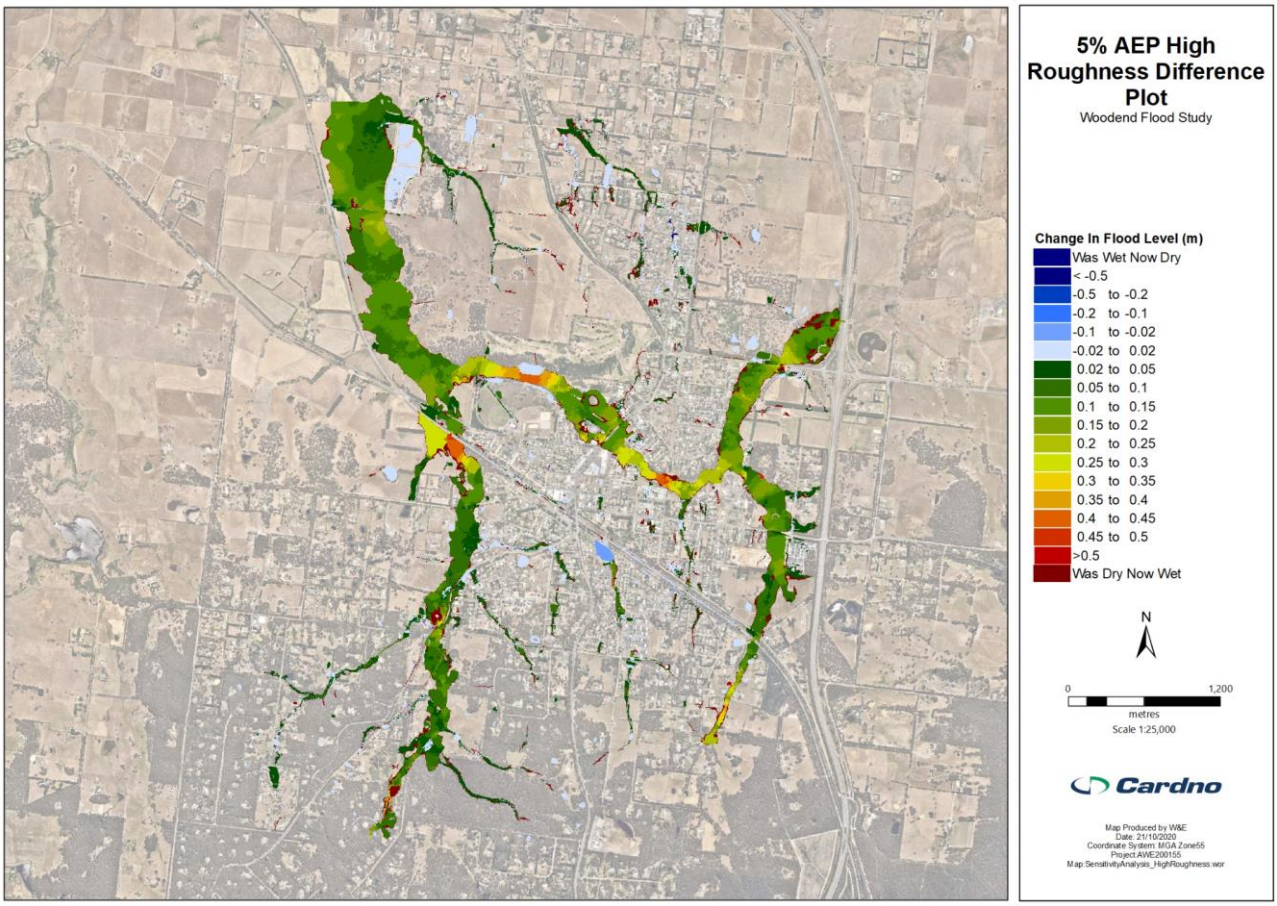


Figure 7-7 5% AEP High Hydraulic Roughness Difference Plot

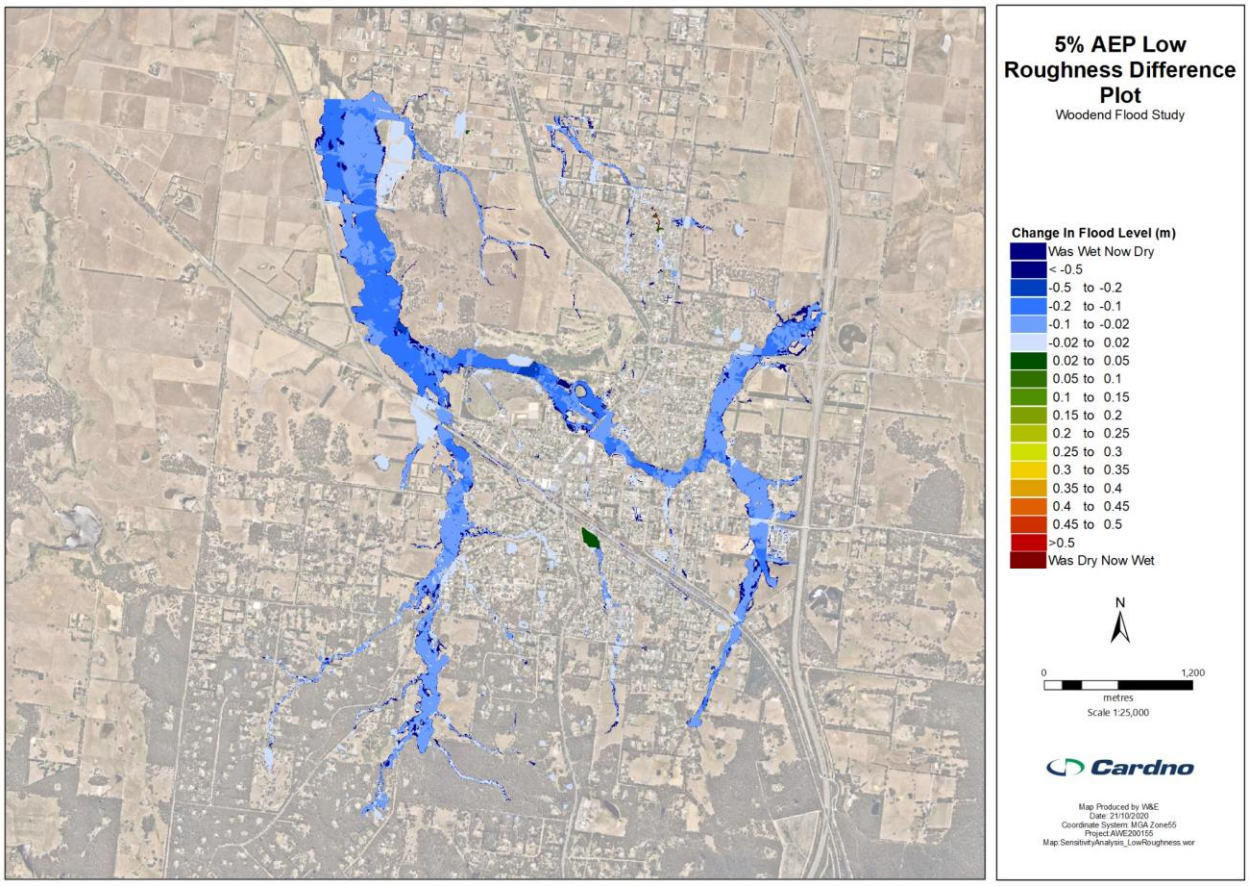


Figure 7-8 5% AEP Low Hydraulic Roughness Difference Plot

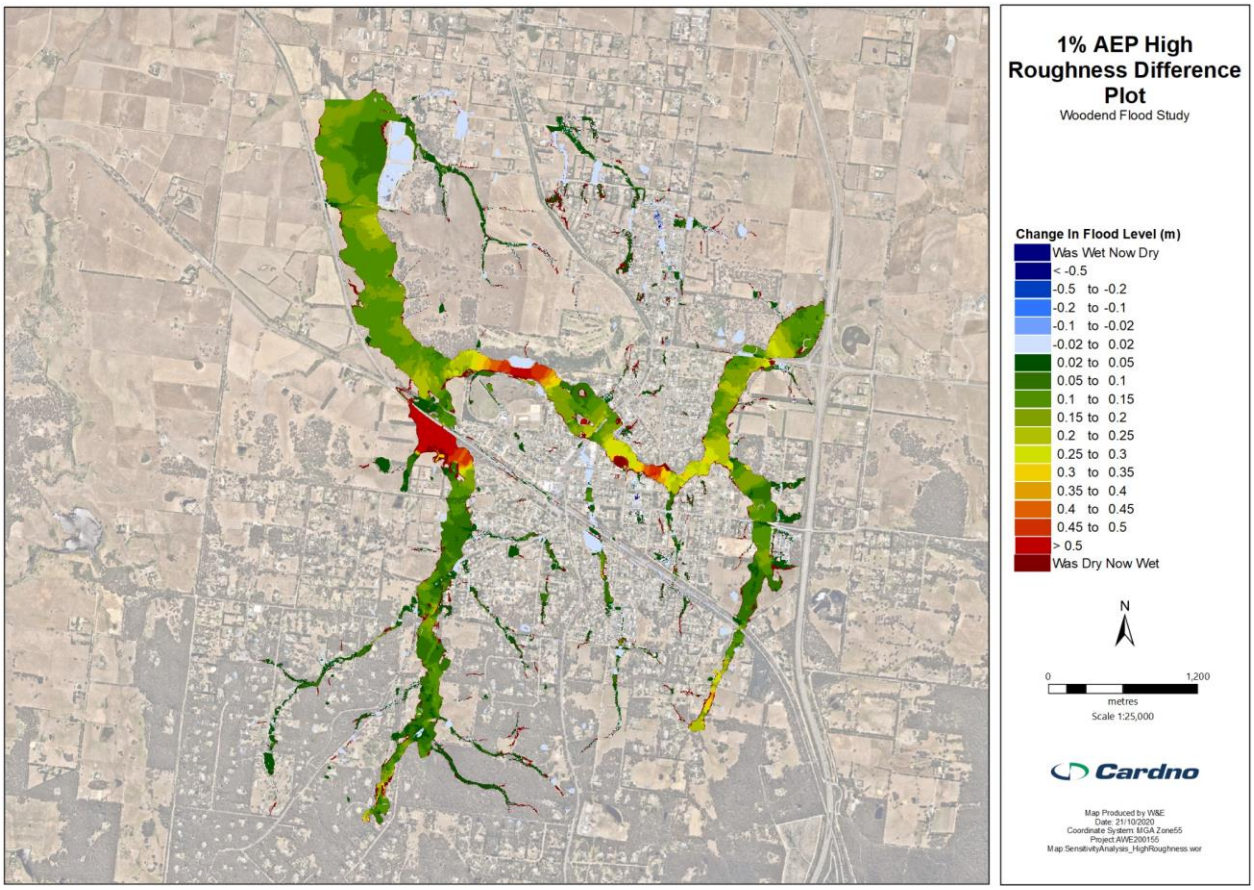


Figure 7-9 1% AEP High Hydraulic Roughness Difference Plot

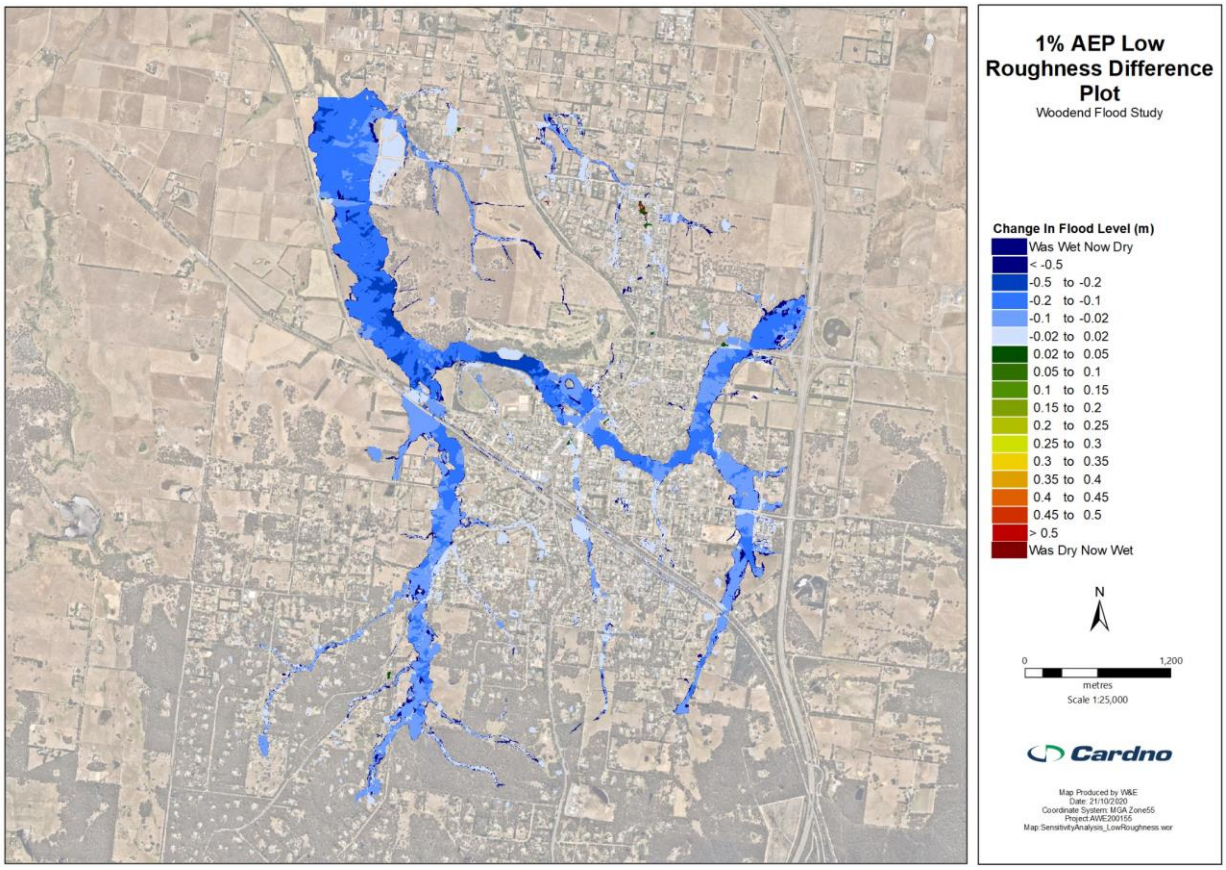


Figure 7-10 1% AEP Low Hydraulic Roughness Difference Plot

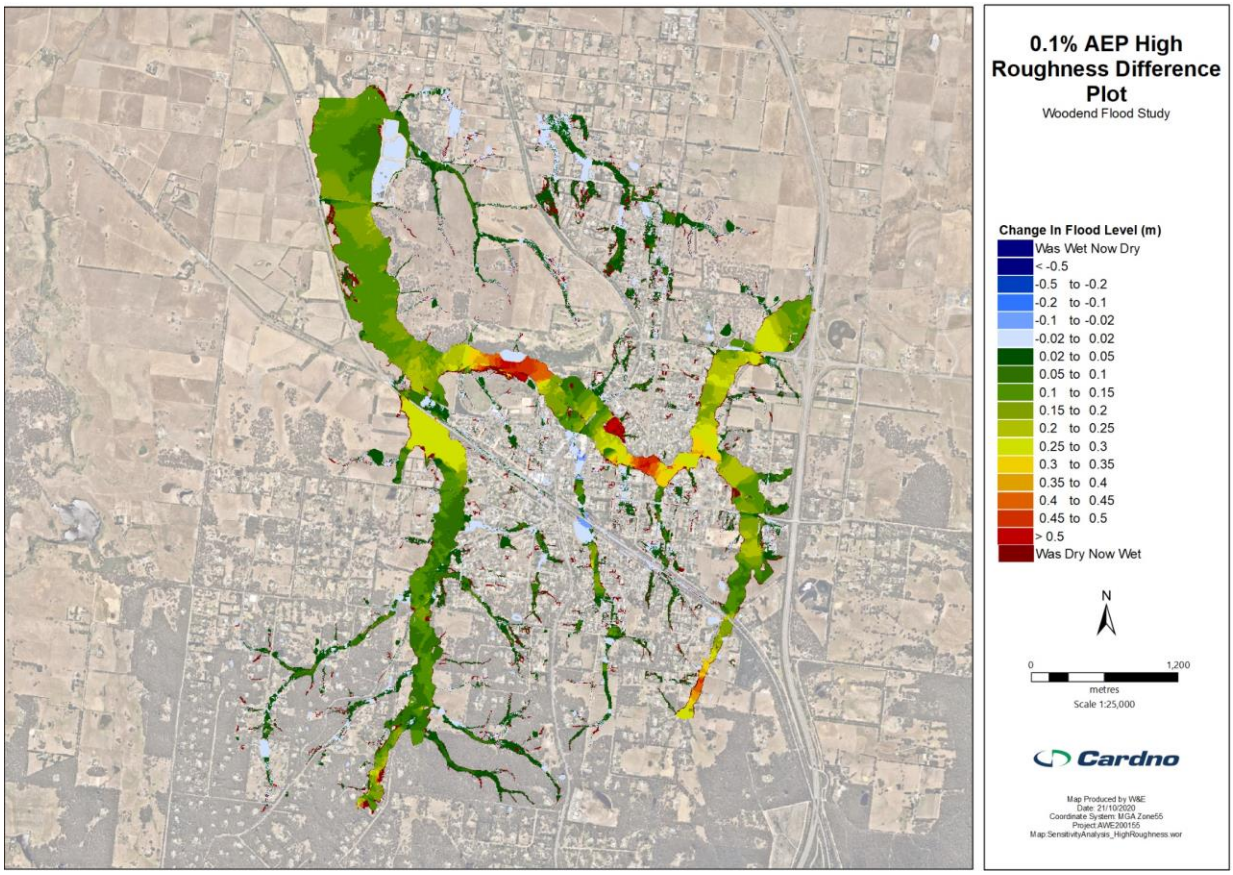


Figure 7-11 0.1% AEP High Hydraulic Roughness Difference Plot

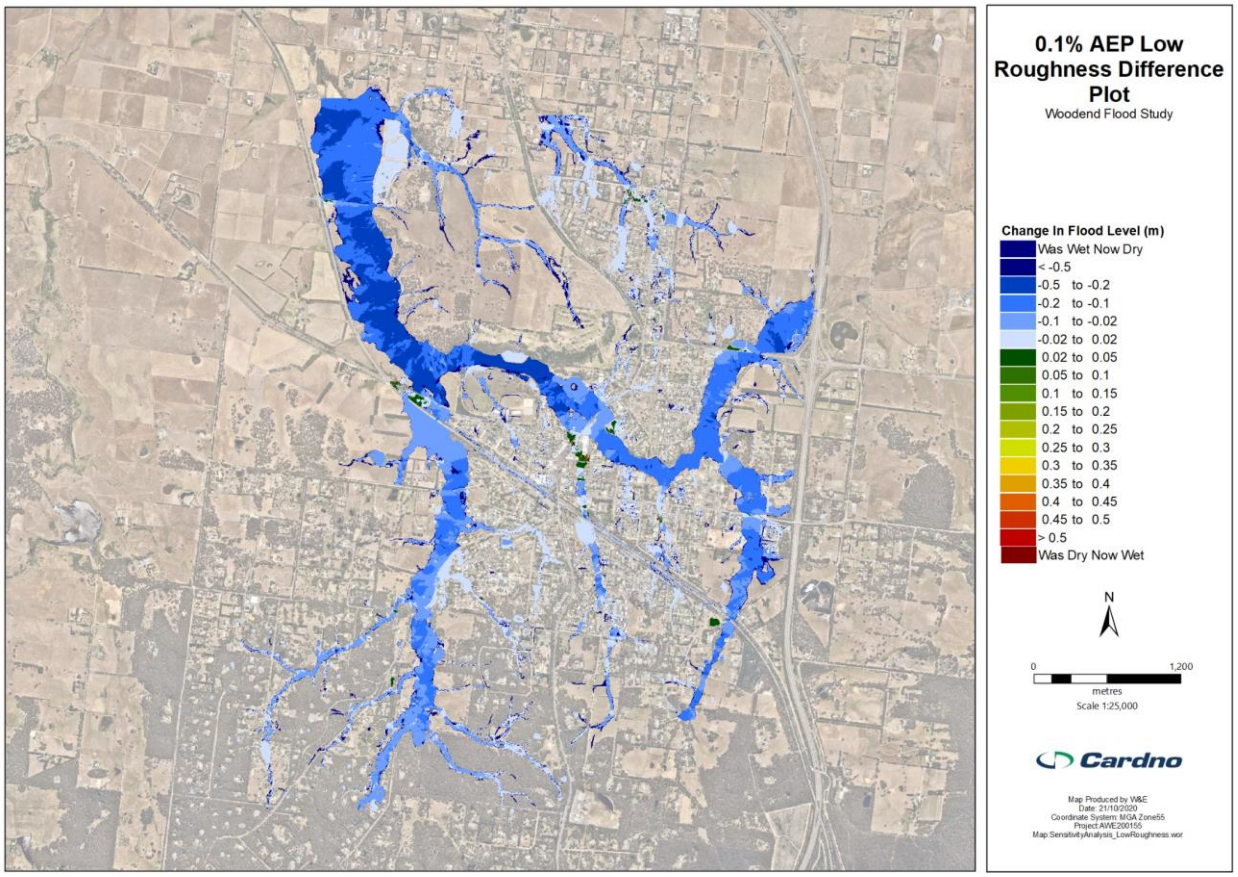


Figure 7-12 0.1% AEP Low Hydraulic Roughness Difference Plot

7.3.3 Downstream Boundary

The downstream boundary assessment involved changing the boundary type from a HT (Head-Time) boundary to a HQ (Head-Flow) boundary. The HQ boundary was set to the natural slope of the creek at the relevant location. As shown in Figure 1-1 to Figure 1-1, this only affects a small section at the downstream end of the model and does not extend into the area of interest for this study.

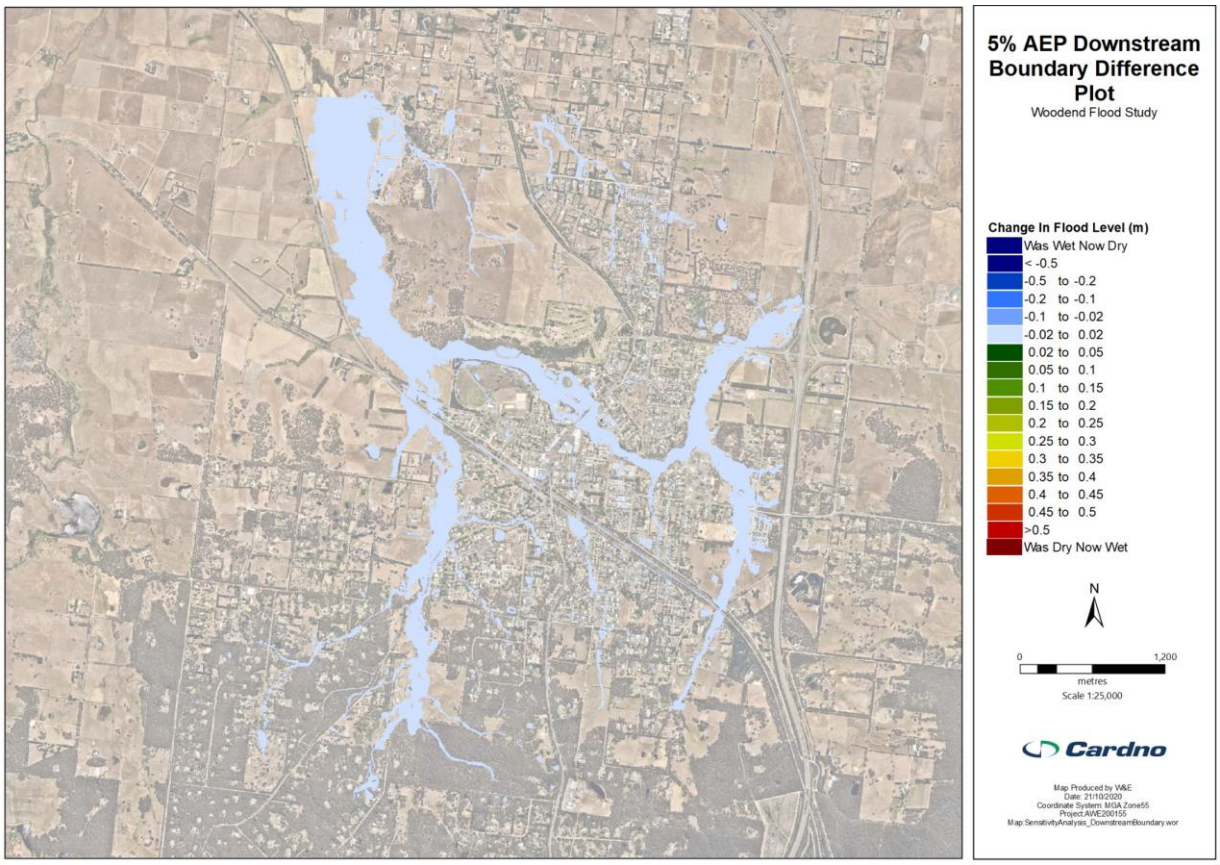


Figure 7-13 5% AEP Downstream Boundary Difference Plot

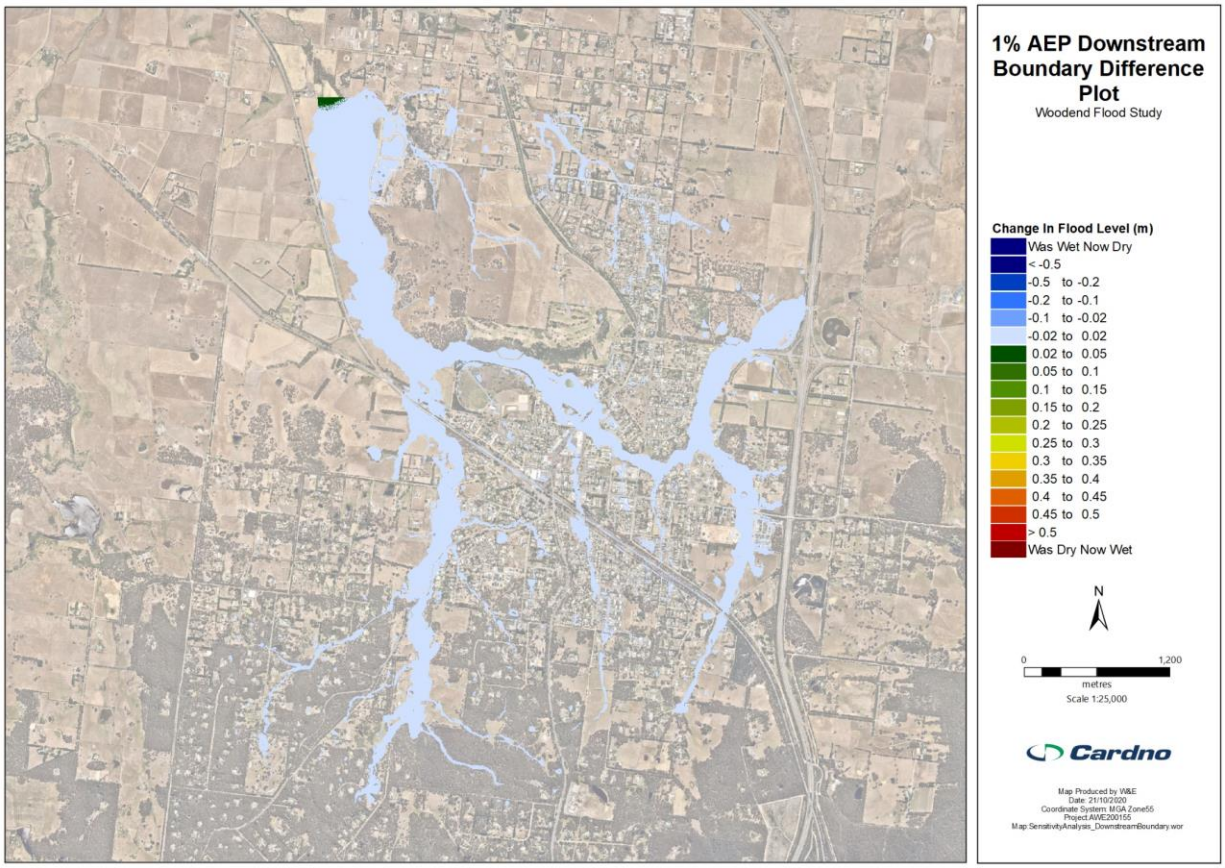


Figure 7-14 1% AEP Downstream Boundary Difference Plot

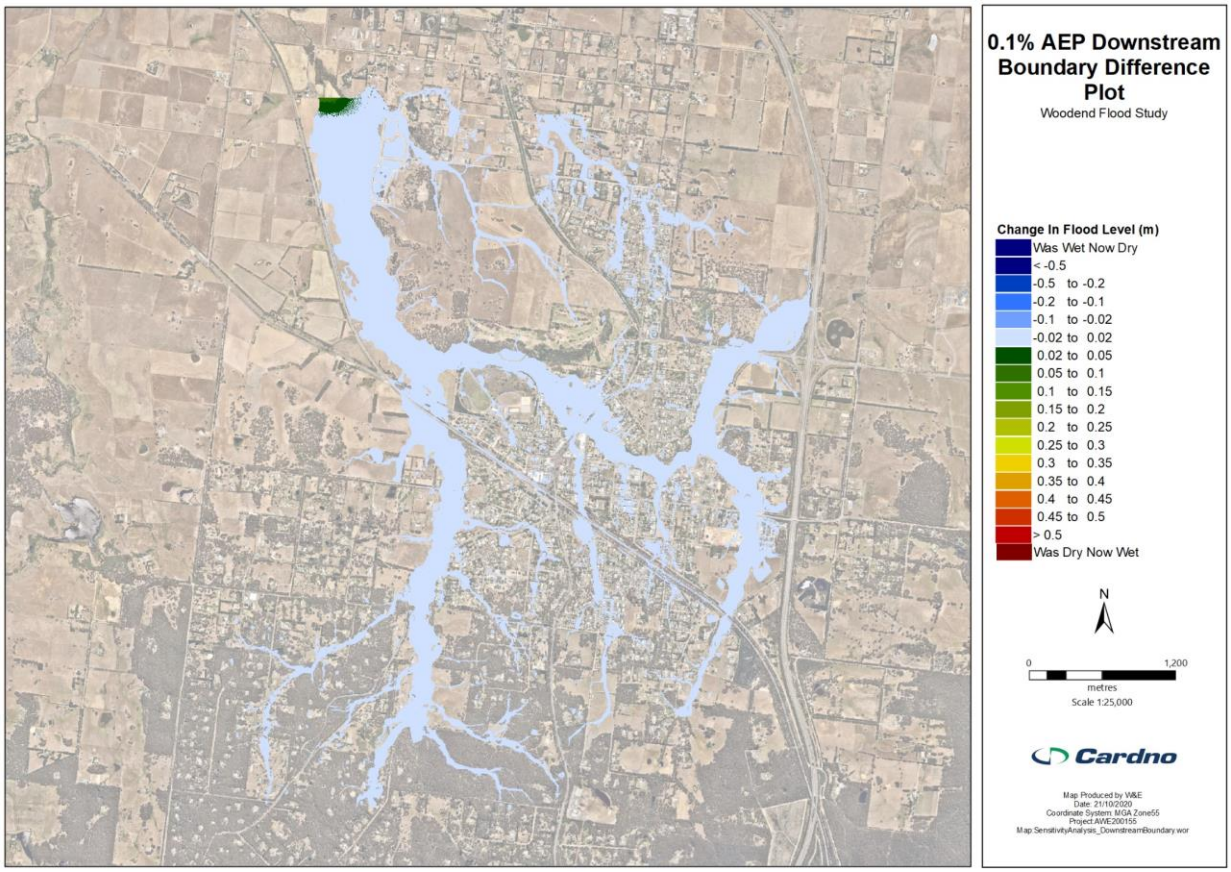


Figure 7-15 0.1% AEP Downstream Boundary Difference Plot

7.3.4 High Flow

Due to difference in the 1% AEP peak flow rate adopted by this study compared to Coomes (1997), a sensitivity analysis was undertaken where the 1% AEP 360-minute temporal pattern 27 event was included within the 1% AEP design event runs (as determined during the hydrological modelling stage of the project). This event produces a peak flow rate at the Calder Highway Bridge at Five Mile Creek of 113m^3/s which is slightly above that adopted by Coomes and so should be comparable to this assessment. As shown in Figure 7-16, flood levels along Five Mile Creek increase by generally up to 0.15m, with the area protected by Pyke Street Levee being inundated as it is no longer protected from flooding at this flood level. Whilst there is an increase in flood levels there is no significant difference in inundation extents between the 2 scenarios except for the area adjacent to the Pyke Street levee which shows some additional flooding in the vicinity of the levee.

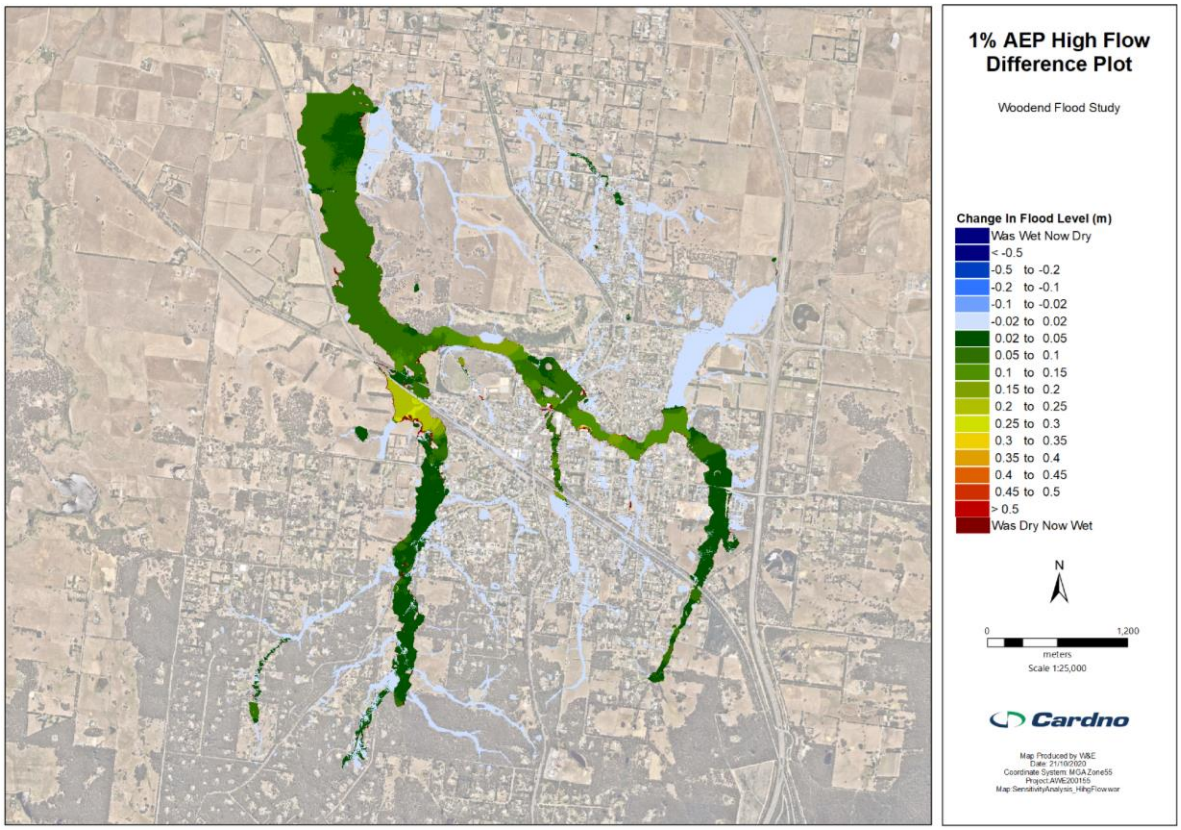


Figure 7-16 1% AEP High Flow Difference Plot

8 Post Processing of Results

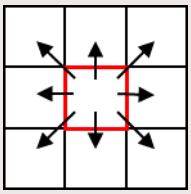
8.1 Post processing methodology

Raw outputs from the 1% AEP event have been processed using the methodology outlined in Table 8-1 including the discussed manual alterations required to ensure that the extent is suitable for planning purposes.

For all scenario 2B (base case) events less than the 1% AEP event, filtering of results has been undertaken as outlined above, apart from the manual alterations. Furthermore, the results were filtered to the 1% AEP flood shape to ensure that no areas which have been manually removed from the 1% AEP extent are included within these results. For the 0.1% AEP event, the results were not been filtered to the 1% AEP flood shape.

For all other scenarios, the results were filtered as outlined above apart from the manual alterations.

Table 8-1 Result Processing Methodology for the 1% AEP Event

Process	Description
Depth filtering	Results were filtered to remove any cells where the depth of flooding (D) is less than 0.05 m.
Area filtering	An area filter was applied to remove isolated 'wet puddles' or 'dry islands' from the flood extent and provide a more cohesive shape. The area threshold was 500m^2, as recommended in the MW technical specifications. In assessing the area of wet puddles or dry islands, it was assumed that diagonal connections constituted a connection. The schematic below shows all cells considered as neighbors and includes diagonal connections. 
Smoothing	To remove the staircase effect from the edge of the flood extent, the shape was smoothed using a process developed by Cardno (now Stantec) and approved by Melbourne Water. This is the final step in the generation of the flood extent.
Suitability for planning purposes	To ensure that the provided 1% AEP flood shape was suitable for planning purposes, the smoothed flood extent was then manually altered to ensure it is suitable for planning purposes including: > Removing areas of wet puddles, which are not located along the major overland flow paths > Connecting sections of the overland flow path to ensure the 1% AEP flood extent produced a coherent flood shape
Provide grid results of the flood extent	The grid cells, which remain within the smoothed flood extent, are extracted to provide a dataset of flood modelling results.

8.2 Flood Maps

Flood Maps for all assessed events outlined in Table 8-2 are included within Appendix 0.

Table 8-2 Assessed events

Scenario	AEP					
	0.2EY	10%	5%	2%	1%	0.1%
2B* - Base Case (Existing Conditions)	√	√	√	√	√	√
3 - Fully Developed for Permissible Land Uses			√		√	√
4D -Sensitivities to Climate Change (Increased Rainfall Intensities)			√		√	√
5 - Design Events for Levee Assessment (Scenarios to also Include the Design Flood and Events above the Design Flood)	√	√	√	√	√	√

*Scenario includes scenarios 8, 9 & 12

9 Information to Inform Decisions on Activities in the Floodplain and Managing Flood Risk

9.1 Emergency Response

Cardno (now Stantec) were provided with a copy of the Macedon Ranges Shire Flood Emergency Plan and the latest Municipal Flood Emergency Plan (MFEP) template from VICSES. This section contains excerpts to inform and update the current Macedon Ranges Shire Flood Emergency Plan with updated flood intelligence from this study.

9.1.1 Appendix A: Flood Threats for Macedon Ranges

As per the existing plan, with section 11 updated to include further locations based on results of hydraulic modelling outlined below.

Woodend

> Rear of the properties between Patricia Way and Washington Lane
> Flooding occurring at Urquhart Street, downstream of the Quarry Road Detention Basin.
> Flooding along Five Mile Creek impacting the Lawn Bowls Club, the Gilbert Gordon Oval and lower parts of the Woodend Primary School Oval.

9.1.2 Appendix C: Woodend Flood Emergency Plan

9.1.2.1 Overview of Flooding Consequences

The township of Woodend, located approximately 65km northwest of Melbourne, sits on the floodplain straddling Five Mile Creek, along with two tributaries of the creek.

Five Mile Creek is part of the Campaspe River Catchment. The area of the Five Mile Creek catchment up to the main crossing (Calder Highway Bridge aka High Street) is approximately 45km^2 comprising of largely rural areas, beyond the Woodend township.

Woodend comprises a variety of land uses ranging from residential with complementary commercial sector that includes a shopping centre through to light industrial. The town's main business precinct lies to the south of the creek. A number of buildings including the Police Station, Ambulance Station, SES Depot and Fire Station are located to the south of the Creek while the drug and alcohol rehabilitation centre is located to the north.

Flooding can result in inundation of properties and building, road closures causing isolation and other flood risks to the community.

9.1.2.2 Flood Behaviour

Woodend has a history of significant flooding including in September 1993, November 1995, November 2010 and January 2011 as discussed below.

9.1.2.2.1 14th – 15th September 1993

The September 1993 flood has been assessed as being somewhere between a 20% to 10% AEP event in Woodend. Many areas of the town, notably the Campaspe Drive area (*flood mitigation works have since been completed in this area*), Duffy Street / Anslow Street "Housing Commission" houses, the High Street supermarket and at least one house in Timber and Booth Lanes and access to Macedon – Woodend Rd was cut. Other areas inundated included: Wallan-Woodend Road (Romsey Road), Coach Road, Boundary Road, Russels Road & The Gilbert Gordon Oval.

9.1.2.2.2 2011 Event

Significant widespread rainfall affected the majority of the State in January 2011. The event was significant enough for the Bureau of Meteorology to publish Special Climate Statement 26 to describe the synoptic conditions associated with the event. In summary, the extreme rainfall recorded was generated by the passing of complex and persistent low-pressure systems. A broad slow moving trough centred over western Victoria and a ridge of high pressure to the south of Tasmania were the main drivers for the rainfall that started to fall on 9th January. The two systems created exceptionally humid conditions and an unstable easterly flow across Victoria. The trough strengthened on the 12th and developed into a low-pressure system over eastern South Australia on the 14th as a high-pressure system moved into the Tasman Sea. The low-pressure system cleared the State on the 14th after adding an additional 50 to 100mm to the deluge already received.

Rising creek levels in Woodend flooded roads and properties including the Woodend Bowls Club, Swimming Pool and Gilbert Gordon Oval.

9.1.2.3 Consequences of Flooding

Table 9-1 Consequences of Flooding

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
0.2EY	**Residential**	10	Over floor flooding expected at BUPA aged Care Woodend. Flooding occurring along the rear of properties between Patricia Way and Washington Lane Flooding occurring at Urquhart Street, downstream of the Quarry Road Detention Basin. Flooding along Five Mile Creek impacting the Lawn Bowls Club, the Gilbert Gordon Oval and lower parts of the Woodend Primary School Oval Five out of 13 buildings with over floor flooding have floor level survey. Major Roads overtopped: ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ BUPA Aged Care	Less than 6 hours	▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway Bridge ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	1				
	Industrial	1				
	Community Use	1				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
10% AEP	**Residential**	10	Flooding starting to occur between High Street and Goldies Lane and between Scotia Drive and Stuart Drive. Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ BUPA Aged Care	Less than 6 hours	▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway Bridge ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	1				
	Industrial	1				
	Community Use	1				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
5% AEP	Residential	37	Flooding occurring from Patricia Way to Five Mile Creek including through the shopping Centre adjacent to Five Mile Creek on High Street. Flooding starting to occur between Gray Street to Honeysuckle Lane. Flooding starting to occur north of South Road east of Washington Lane. Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Washington Laneh	Less than 6 hours	▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway Bridge ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	1				
	Industrial	7				
	Community Use	4				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
2% AEP	**Residential**	73	Flooding starting to occur along Tree Change Way and Barbara Street. Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Goldies Lane ▪ Manifold Road ▪ Peter Godden Drive ▪ South Road ▪ Washington Lane ▪ Winlaton Way	Less than 6 hours	▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway Bridge ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	2				
	Industrial	9				
	Community Use	4				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
1% AEP	**Residential**	117	Flooding generally as per the 2% AEP event, but with wider and deeper overland flow paths. Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Goldies Lane ▪ Manifold Road ▪ Peter Godden Drive ▪ South Road ▪ Timber Lane ▪ Washington Lane ▪ Winlaton Way	Less than 6 hours	▪ Calder Highway at Five Mile Creek ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Woodend-Wallan Road (Romsey Road) ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	2				
	Industrial	13				
	Community Use	5				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
0.1% AEP	**Residential**	318	Flood along Five Mile Creek affecting the Woodend Swimming Pool The Pyke Street Levee is overtopped. Flooding within the Woodend Primary School is limited to within the Oval portion of the site. Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Locations of flooded buildings include (but not limited to): ▪ Anslow Street ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ Brian Road ▪ BUPA Aged Care ▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Doyeswood Drive	Less than 6 hours	▪ Calder Highway at Five Mile Creek ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Woodend-Wallan Road (Romsey Road) ▪ Ashbourne Road ▪ Tylden Road	▪ Woodend FlexiRide Service at Five Mile Creek ▪ Kyneton Woodend at Five Mile Creek
	Commercial	6				
	Industrial	20				
	Community Use	7				

Event	Properties Affected	Buildings with Over Floor Flooding*	Description of risk	Warning Time	Major Road Closure	Bus Route disruption
			▪ Fern Court ▪ Forest Street/Tylden-Woodend Road ▪ Goldies Lane ▪ High Street ▪ Ligar Street ▪ Manifold Road ▪ Mount Macedon Road ▪ Peter Godden Drive ▪ Roxanne Court ▪ Russell Avenue ▪ Scotia Place ▪ South Road ▪ Timber Lane ▪ Tennyson Street ▪ Templeton Street ▪ Washington Lane ▪ Winlaton Way ▪ Wood Street			

*See section 3.3.2

9.1.2.4 Flood Depths Over Major Roads

Table 9-2 Flood Depths Over Major Roads

AEP	Woodend-Wallan Road (Romsey Road)	Bawden Road at Walkers Road	Mt Macedon Road	Calder Highway Bridge	Ashbourne Road	Tylden Road
0.2EY	NA	0.16 m	0.14 m	0.13 m	0.06 m	0.06 m
10% AEP	0.01 m	0.16 m	0.14 m	0.15 m	0.12 m	0.08 m
5% AEP	015 m	0.23 m	0.22 m	0.24 m	0.22 m	0.11 m
2% AEP	0.30 m	0.28 m	0.28 m	0.32 m	0.31 m	0.14 m
1% AEP	0.37 m	0.32 m	0.32 m	0.38 m	0.36 m	0.16 m
0.1% AEP	0.59 m	0.47 m	0.42 m	0.59 m	0.49 m	0.24 m

9.1.2.5 Hazard Class over Major Roads

Table 9-3 Hazard Class over Major Roads

AEP	Woodend-Wallan Road (Romsey Road)	Bawden Road at Walkers Road	Mt Macedon Road	Calder Highway Bridge	Ashbourne Road	Tylden Road
0.2EY	NA	H1	H1	H1	H1	H1
10% AEP	H1	H1	H1	H1	H1	H1
5% AEP	H1	H1	H1	H2	H1	H1
2% AEP	H1	H2	H2	H2	H1	H1
1% AEP	H5	H2	H2	H5	H2	H1
0.1% AEP	H5	H5	H5	H5	H5	H5

9.1.2.6 Flood Mitigation

Existing flood mitigation measures within Woodend comprise Retarding Basins and Levees as discussed in the sections below.

9.1.2.6.1 Levees

Table 9-4 Campaspe Drive Levee

Campaspe Drive Levee	
Owner	Macedon Ranges Shire Council
Crest Height (mAHD) when levee is first overtopped	552.9m AHD
Crest Height Relative to Gauge (m)	552m AHD
Closure Points	Penstock located along Campaspe Drive and Buckland Street
Manual Operation Requirements	Closure of Penstock and activation of pumps
Protection	Houses located along Campaspe Drive, Heron Street and Crisp Street

Table 9-5 Pyke Street Levee

Pyke Street Levee	
Owner	Macedon Ranges Shire Council
Crest Height (mAHD) when levee is first overtopped	553.2 mAHD
Crest Height Relative to Gauge (m)	551.8
Closure Points	Penstock located at end of Pyke Street
Manual Operation Requirements	Closure of Penstock and activation of pumps
Protection	Properties and building located on the eastern side of Pyke Street

9.1.2.6.2 Retarding Basins

Information on storage volumes, crest heights, spillways and design plans of these assets are available from Council.

Table 9-6 Retarding Basins

Asset	**Owner**	**Protecting**
Lilley Court Basin	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, houses located downstream of basin
Jones Court Reserve	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, houses located downstream of basin
Washington Lane	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, houses located downstream of basin
Reidwell Drive Reserve Basin	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, house located downstream of basin
Roxanne Court Reserve (Behind) Basin	Macedon Ranges Shire Council	Flood mitigation, houses located downstream of basin

Asset	Owner	Protecting
Arthur Court Reserve Basin	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, houses located downstream of basin
Campaspe Park Levee	Macedon Ranges Shire Council	Flood mitigation, numerous houses along Campaspe Drive, Heron Street and Crisp Street
Sproule Place Reserve	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, houses located downstream of basin
26 Edna Walling Boulevard, Woodend Drainage Basin	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, limited development downstream of basin
Quarry Road Detention Basin	Macedon Ranges Shire Council	Flood mitigation, houses and main shopping district located downstream of basin
Shirley Park Basin	Macedon Ranges Shire Council	Retarding of runoff from site back to existing levels, limited development downstream of basin,

9.1.2.7 Flood Impacts and Required Actions

9.1.2.7.1 Woodend Rainfall Triggers at the Calder Highway

Due to the relativity short durations for rainfall events likely to cause flooding along Five Mile Creek, the Bureau of Meteorology will not issue specific flood warnings for Woodend. Therefore, the rainfall triggers as determined based on recorded rainfall, at the Woodend Water Treatment Plant (406266), outlined below should be used to help guide the emergency flood response.

The triggers are based on Monte Carlo results from the hydrological RORB model which generate peak flow rates greater than 20m^3/s (the Calder Highway Bridge approach is expected to be overtopped once the flow reaches approximately 25m^3/s).

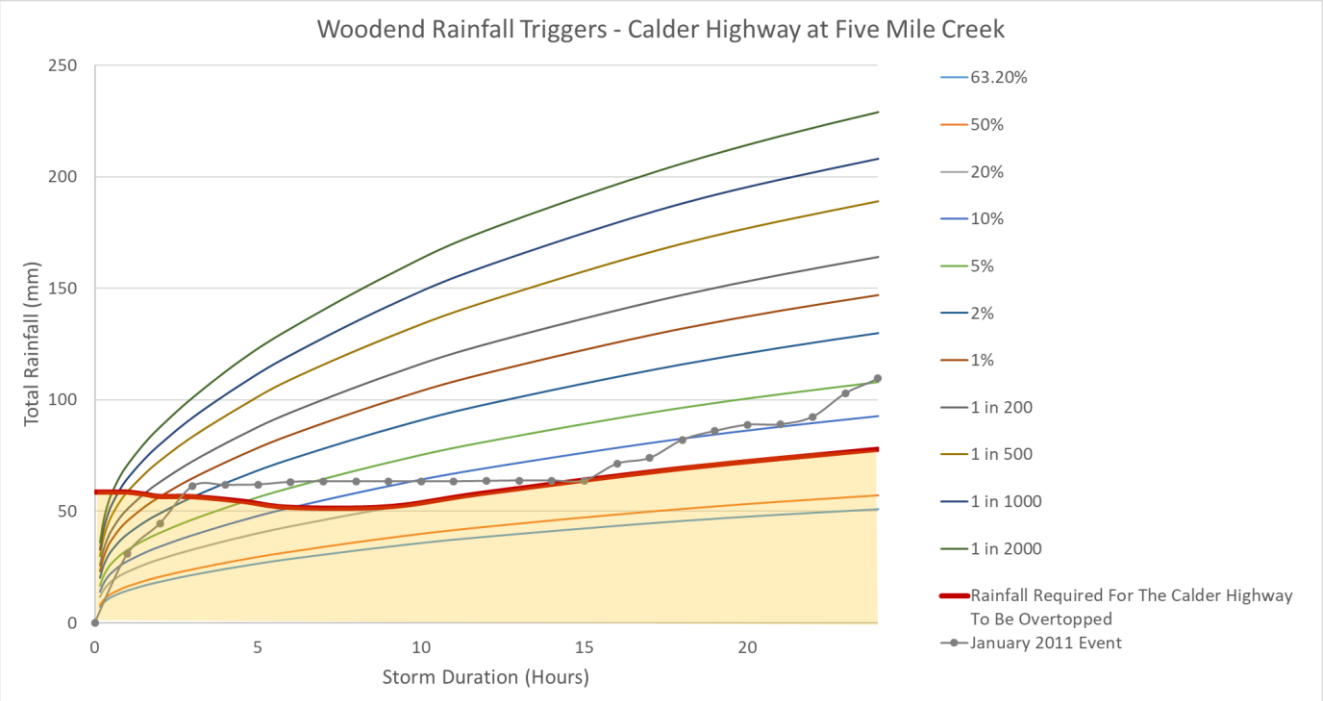


Figure 9-1 Woodend Rainfall Triggers - Calder Highway at Five Mile Creek

9.1.2.8 Flood Intelligence Card

9.1.2.8.1 Gauge Location: Directly Upstream of Calder Highway Bridge over Five Mile Creek

Table 9-7 Flood Intelligence Card for Riverine Flooding

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
Gauge Level: 551.18 mAHD Gauge Board Level: 2.37 m Rainfall: 59.5mm over 12 hours	0.2EY	Major Roads overtopped: ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Flooding along Five Mile Creek impacting the Lawn Bowls Club, the Gilbert Gordon Oval and lower parts of the Woodend Primary School Oval. Number of buildings with over floor flooding: ▪ Residential: 10 ▪ Commercial: 1 ▪ Industrial: 1 ▪ Community Use: 1 Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ BUPA Aged Care	▪ Monitor Roads for potential overtopping and closure ▪ Monitor flood levels within Five Mile Creek at the Calder Highway. Once trigger levels are reached follow procedure outlined in *Five Mile Creek Woodend – Flood Mitigation Infrastructure Operating Procedures July 2012*, (available from Macedon Ranges Shire Council) for manual closure of penstocks and activation of flood mitigation pumps. ▪ Trigger Level 1: 549.15 mAHD – automatic message sent informing of rising flood levels ▪ Trigger Level 2: 550.15 mAHD - automatic message send informing of requirement to manually close penstock and start pumps. (Campaspe Drive 551.1 mAHD, Pyke Street 551.2 mAHD) ▪ Door knock at risk properties ▪ Monitor levees for potential breach, and sandbag as necessary
Gauge Level: 551.23 m AHD Gauge Board Level: 2.41 m	10%	Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road	▪ As above

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
Rainfall: 70mm over 12 hours*		▪ Tylden Road Number of buildings with over floor flooding: ▪ Residential: 10 ▪ Commercial: 1 ▪ Industrial: 1 ▪ Community Use: 1 Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ BUPA Aged Care	
Gauge Level: 551.36 mAHD Gauge Board Level: 2.55 m Rainfall: 75mm over 9 hours 90mm over 12 hours*	5%	Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Assumed Road closures: ▪ Calder Highway at Five Mile Creek Number of buildings with over floor flooding: ▪ Residential: 37 ▪ Commercial: 1 ▪ Industrial: 7 ▪ Community Use: 4 Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road	▪ As above

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
		▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Washington Lane	
Gauge Level: 551.49 mAHD Gauge Board Level: 2.67 m Rainfall: 100mm over 12 hours*	2%	Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Assumed Road closures: ▪ Calder Highway at Five Mile Creek ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road Number of buildings with over floor flooding: ▪ Residential: 73 ▪ Commercial: 2 ▪ Industrial: 9 ▪ Community Use: 4 Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road	▪ As above

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
		▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Goldies Lane ▪ Manifold Road ▪ Peter Godden Drive ▪ South Road ▪ Washington Lane ▪ Winlaton Way	
Gauge Level: 551.58 mAHD Gauge Board Level: 2.76 m Rainfall: 115mm over 12 hours*	1%	Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Assumed Road closures: ▪ Calder Highway at Five Mile Creek ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Woodend-Wallan Road (Romsey Road) ▪ Ashbourne Road	▪ As above

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
		▪ Tylden Road Number of buildings with over floor flooding: ▪ Residential: 117 ▪ Commercial: 2 ▪ Industrial: 13 ▪ Community Use: 5 Locations of flooded buildings include (but not limited to): ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ BUPA Aged Care ▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Fern Court ▪ Goldies Lane ▪ Manifold Road ▪ Peter Godden Drive ▪ South Road ▪ Timber Lane ▪ Washington Lane ▪ Winlaton Way	
Gauge Level: 551.83 mAHD Gauge Board Level: 3.01 m Rainfall:	0.1%	Major Roads overtopped: ▪ Woodend-Wallan Road (Romsey Road) ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road	▪ As above

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
160mm over 12 hours*		▪ Calder Highway South of Five Mile Creek Bridge ▪ Calder Highway North of Five Mile Creek Bridge ▪ Ashbourne Road ▪ Tylden Road Assumed Road closures: ▪ Calder Highway at Five Mile Creek ▪ Bawden Road at Walkers Road ▪ Mt Macedon Road ▪ Woodend-Wallan Road (Romsey Road) ▪ Ashbourne Road ▪ Tylden Road Flood along Five Mile Creek affecting the Woodend Swimming Pool The Pyke Street Levee is overtopped. Flooding within the Woodend Primary School is limited to within the Oval portion of the site. Number of buildings with over floor flooding: ▪ Residential: 318 ▪ Commercial: 6 ▪ Industrial: 20 ▪ Community Use: 7 Locations of flooded buildings include (but not limited to):: ▪ Anslow Street ▪ Ashbourne Road ▪ Banksia Court ▪ Between Tree Change Way and Old Lancefield Road ▪ Brian Road ▪ BUPA Aged Care	

River Height (m) and or River Flow (ML/d)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
		▪ Campaspe Drive ▪ Community Facilities along the Southern side of Five Mile Creek and the Calder Highway ▪ Davy Street ▪ Doyeswood Drive ▪ Fern Court ▪ Forest Street/Tylden-Woodend Road ▪ Goldies Lane ▪ High Street ▪ Ligar Street ▪ Manifold Road ▪ Mount Macedon Road ▪ Peter Godden Drive ▪ Roxanne Court ▪ Russell Avenue ▪ Scotia Place ▪ South Road ▪ Timber Lane ▪ Tennyson Strret ▪ Templeton Street ▪ Washington Lane ▪ Winlaton Way ▪ Wood Street	

*Critical Storm Duration at Gauge

9.2 Average Annual Damages

In order to aid in the understanding of the economic impact of flooding within Woodend now and in the future and the economic viability of mitigation options, an Average Annual Damages (AAD) assessment has been undertaken.

AAD is the expected cost due to flooding within a specified area annualised to a per year cost.

AAD is calculated by a probability approach of flood damages incurred for each design storm event. The total damage is then the summation of all determined damages for each assessed AEP. This has been calculated for the 0.1% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 0.2EY events by plotting the total damage value for each AEP on a probability curve. The AAD is the value of the area under the total damages curve.

The AAD analysis is heavily weighted to the damages incurred in the more frequent storm events. Therefore, it can be expected that any future mitigation options which are targeted to eliminate the more frequent events will perform comparatively better to any mitigation options that are specifically targeted to the less frequent events.

The methodology employed to calculate each category of damage is detailed in the sections below.

9.2.1 Avoided Damages

The economic impact of flooding is defined by what is commonly referred to as 'flood damages.' Flood damages are classified as direct, indirect or intangible costs, as shown in Figure 9-2.

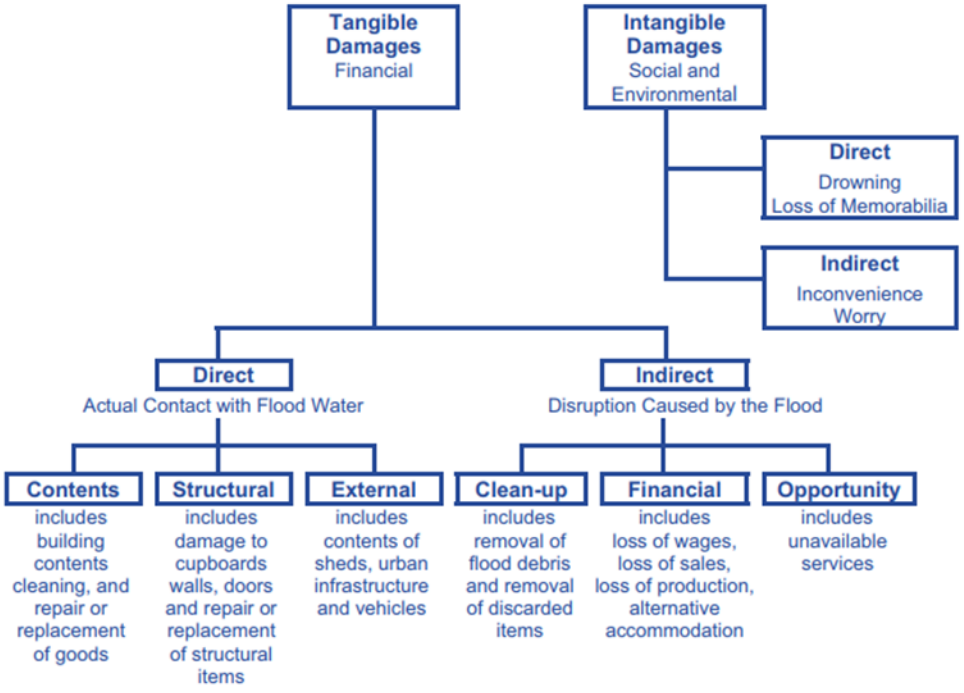


Figure 9-2 Types of flood damage (Floodplain Development Manual, NSW Gov, 2005)

For this AAD assessment, only tangible direct damages have been calculated based on results from the hydraulic model developed for the Woodend Township. Both the indirect and intangible damages have been assumed to be factors of the tangible direct damages. It has been assumed that residents or commercial tenants will have little to no warning time in a flood event and hence, no allowance has been made for protecting or removing valuables. This provides a more conservative estimate of flood damages as the maximum 'potential' damage is assessed in this case.

The assessment has been based the Annual Average damages spreadsheet developed by Melbourne Water which determines flood damages based on:

- Building Damages (residential, commercial and industrial buildings)
- Road Damages (flooding occurring over roads)
- Vehicle Damages (damages associated with building flood depth)
- Indirect Damages (30% of direct tangible damages)
- Intangible Damages (100% of direct tangible damages)

9.2.1.2 Building Damages

Damages for buildings are assigned based on the expected flood level intersecting the building as outlined below.

9.2.1.2.1 Residential

Residential buildings have been assumed to start to accumulate damages once the flood level intersecting the building footprint is 0.5m below the floor level as outlined in Table 9-8. For residential buildings, damages are calculated per building regardless of building size.

Table 9-8 Residential Buildings Damages Curve

Depth of Over Floor Flooding (m)	Damage per Building	Depth of Over Floor Flooding (m)	Damage per Building
-0.5 m	$ 12,261	1.1 m	$ 107,244
-0.1 m	$ 12,261	1.2 m	$ 110,747
-0.05 m	$ 32,358	1.3 m	$ 114,249
0 m	$ 32,737	1.4 m	$ 117,752
0.1 m	$ 72,218	1.5 m	$ 121,255
0.2 m	$ 75,720	1.6 m	$ 124,757
0.3 m	$ 79,223	1.7 m	$ 128,260
0.4 m	$ 82,726	1.8 m	$ 131,763
0.5 m	$ 86,228	1.9 m	$ 135,265
0.6	$ 89,731	2 m	$ 138,768

0.7 m	$ 93,234	2.5 m	$ 142,556
0.8 m	$ 96,736	3 m	$ 146,345
0.9 m	$ 100,239	> 3 m	$ 146,345
1 m	$ 103,741		

9.2.1.2.2 Commercial

Commercial buildings have been assumed to start to accumulate damages once the flood level intersecting the building footprint is 0.5m below the floor level as outlined in Table 9-9. For commercial buildings, damages are calculated per m^2 of flooding.

Table 9-9 Commercial Buildings Damages Curve

Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding	Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding
-0.5 m	$ 6	1 m	$3 51
-0.3m	$ 6	1.1 m	$ 374
-0.101 m	$ 8	1.2 m	$ 396
-0.1 m	$ 10	1.3 m	$ 417
-0.05 m	$ 12	1.4 m	$ 436
0 m	$ 39	1.5 m	$ 456
0.1 m	$ 66	1.6 m	$ 476
0.2 m	$ 120	1.7 m	$ 496
0.3 m	$ 174	1.8 m	$ 516
0.4 m	$ 202	1.9 m	$ 541
0.5 m	$ 229	2 m	$ 568
0.6 m	$ 256	2.5 m	$ 686
0.7 m	$ 280	3 m	$ 766
0.8 m	$ 304	> 3 m	$ 766
0.9 m	$ 328		

9.2.1.2.3 Industrial

Industrial buildings have been assumed to start to accumulate damages once the flood level intersecting the building footprint is 0.05m below the floor level as outlined in Table 9-10. For industrial buildings, damages are calculated per m^2 of flooding.

Table 9-10 Industrial Buildings Damages Curve

Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding	Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding
-0.05 m	$ 0	1.2 m	$ 451
0 m	$ 29	1.3 m	$ 477
0.1 m	$ 58	1.4 m	$ 502
0.2 m	$ 116	1.5 m	$ 527
0.3 m	$ 173	1.6 m	$ 552
0.4 m	$ 210	1.7 m	$ 578
0.5 m	$ 246	1.8 m	$ 604
0.6 m	$ 282	1.9 m	$ 628
0.7 m	$ 310	2 m	$ 651
0.8 m	$ 338	2.5 m	$ 769
0.9 m	$ 365	3 m	$ 824
1 m	$ 393	>3 m	$ 824
1.1 m	$ 422		

9.2.1.2.4 Vehicle Damages

Vehicle damages are based on the depth of flooding at buildings. Vehicles have been assumed to start to accumulate damages when the flood level intersecting the building footprint is at the floor level as outlined in Table 9-11. For vehicles, damage is calculated per building flooded.

Table 9-11 Vehicle Damages Curve

Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding	Depth of Over Floor Flooding (m)	Damage per m^2 of Flooding
-0.05 m	$ 0	0.4 m	$ 15,620
0 m	$ 2,640	0.5 m	$ 24,310
0.1 m	$ 4,125	0.6 m	$ 33,000
0.2 m	$ 5,610	> 0.6 m	$ 33,000
0.3 m	$ 6,930		

9.2.1.2.5 Road Damages

Road damages are based on the total area of road flooded, as outlined in Table 9-12.

Table 9-12 Road Damages

Road Type	Damage Per m^2
Major	$ 4.10
Minor	$ 2.50
Unsealed	$ 1.70

9.2.1.3 Floor Levels

As outlined in Section 3.3.2, floor level survey was not able to be completed for all buildings. In order to be able to complete the damages assessment, the floor levels of the remaining buildings (not including out buildings) were infilled based on the median calculated floor level above ground level obtained from the survey results.

In order to determine the floor levels for each building, the lowest elevation based on LiDAR within the building footprint was identified. This was then compared against the relevant surveyed floor level of the building. This resulted in a first quartile value of 0.365m and a median value of 0.625m. The first quartile value of 0.365m has been adopted as the calculated floor level above ground level for all the buildings which were not included within the building floor level survey. The first quartile value has been adopted as opposed to the median value as it closely aligns with typical freeboard requirements and means a conservative approach is adopted. Figure 9-3 shows the distribution of surveyed floor levels compared to LiDAR.

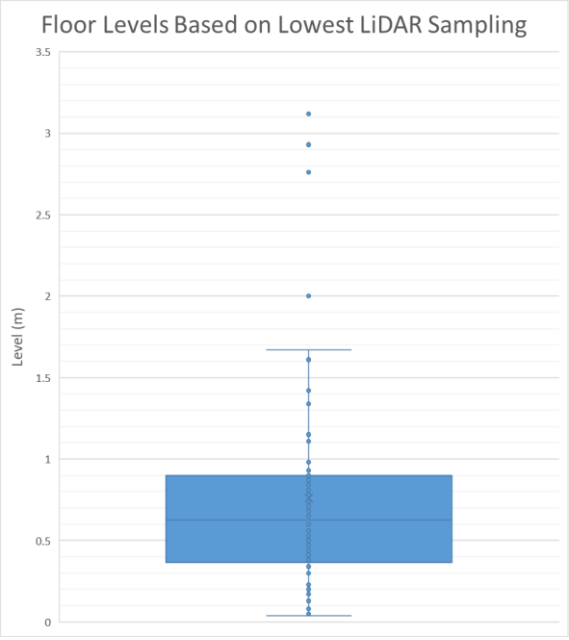


Figure 9-3 Surveyed Floor Levels Compared to LIDAR

9.2.1.4 Average Annual Damages Results

Table 9-13 outlines the expected flood damages associated with each AEP assessed, with a resultant AAD of $2,431,967.

Table 9-13 Expected Damages per AEP

AEP	Damages
0.2EY	$ 3,695,457
10% AEP	$ 3,986,286
5% AEP	$ 11,459,180
2% AEP	$ 19,932,272
1% AEP	$ 26,417,659
0.1% AEP	$ 71,883,487

10 Conclusions

The Woodend Flood Study provides an improved understanding of flood behaviour within and around Woodend. The hydrological model has been successfully calibrated to the September 1993, November 2010 and January 2011 flood events utilising the same K_c value within RORB. The hydraulic model has also been successfully calibrated/validated to both the 1993 and 2011 flood events. Based on flood levels at the Calder Highway Bridge over Five Mile Creek, the 1993 event is estimated to be smaller than a 0.2EY event while the 2011 event was estimated to between a 10% AEP and 5% AEP event. A series of design flood events have been modelled providing important intelligence in regards to the impact of flooding within Woodend ranging from the 0.2EY event up to the 0.1% AEP event.

This study positions Council and its partner stakeholders to explore mitigation options in the future to managing existing and future risks associated with flooding.

11 Recommendations

It is recommended that:

- Council and the NCCMA make available the results of the flood study through an appropriate digital platform to residents of Woodend.
- Land use and/or development controls be implemented via Planning Scheme Overlays to reflect the findings of the study.
- Updates be made to the Municipal Emergency Management Plan reflecting the findings of this study.
- A flood mitigation study be undertaken to investigate options to address the most significant flooding identified in this study.

12 Data Hand Over

At the completion of this project Cardno (now Stantec) will have provided to Council the following:

- This report outlining the methodology, all assumptions and outcomes relating to this study
- The Hydrological RORB model developed as part of this study
- The Hydraulic TULFOW model developed as part of this study
- Results from the Building Floor Level Survey captured as a part of this study
- GIS datasets containing gridded results (including maximum water level, water depth, and velocity) for each assessed flood event and filtered flood extents
- Flood Maps (included within the report) for each assessed event flood event

13 Acknowledgements

Cardno (now Stantec) would like to acknowledge the following organisations and people who have provided invaluable assistance throughout this project

- Leslie Woo from the Macedon Ranges council who has been instrumental directing the project in order to provide council with the results required to inform future decisions within Woodend
- Nathan Treloar from the North Central Catchment Management Authority for providing guidance on historical flood records, past flood studies and past flood mitigation projects within Woodend
- Dr. Tony Ladson from Moroka Pty Ltd for providing expert guidance throughout the project
- The residents of Woodend who have been diligent in capturing and recording information regarding flood events (particularly the 1993 event) within the community and making this information available to both The Shire of Macedon Ranges and to the North Central Catchment Management Authority for use in this study.

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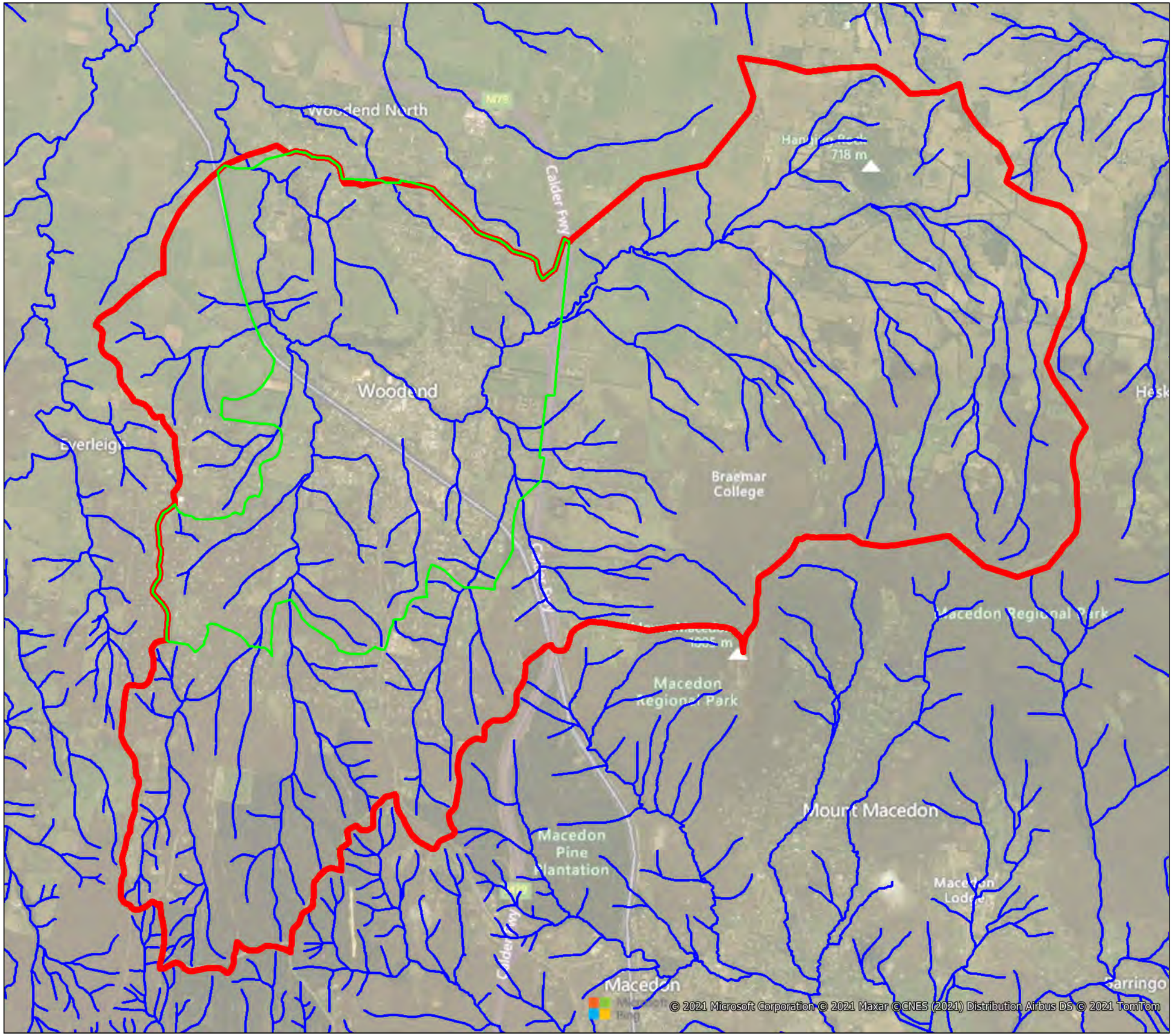
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Appendix A *Figures*



Study Area

Woodend Flood Study

Government Defined Waterway

Hydraulic Model Extent

Hydrological Catchment

N

0 2,500

metres

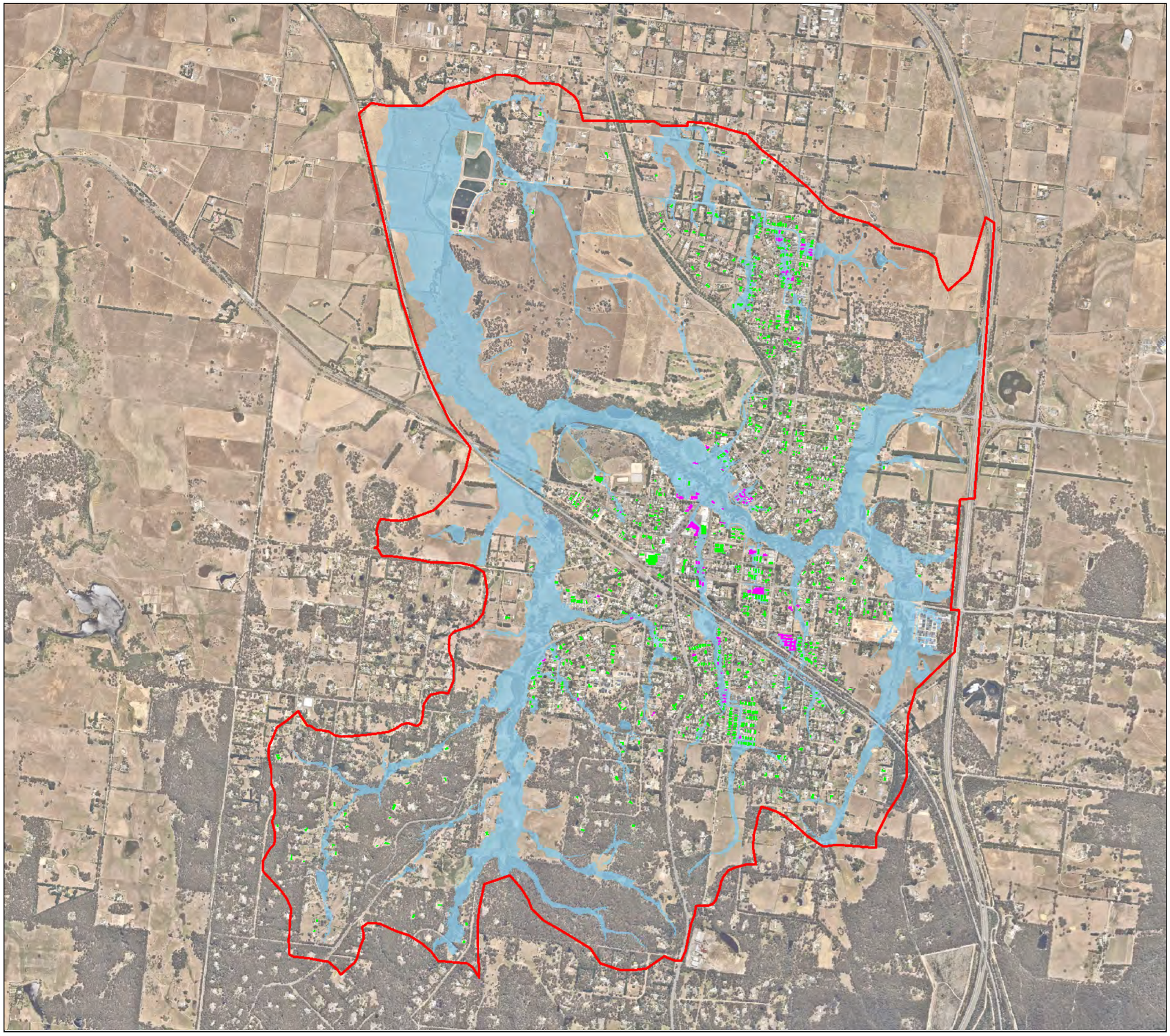
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Cardno

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Date: 06/04/2020
Coordinate System: MGA Zone 55
Project: AWE200155
Map:ReportFigures.wor 01

Floor Level Survey

Woodend Flood Study



Hydrualic Model Extent

Surveyed Buildings

Buildings Witihn Flood Extent

1% AEP Flood Extent

N

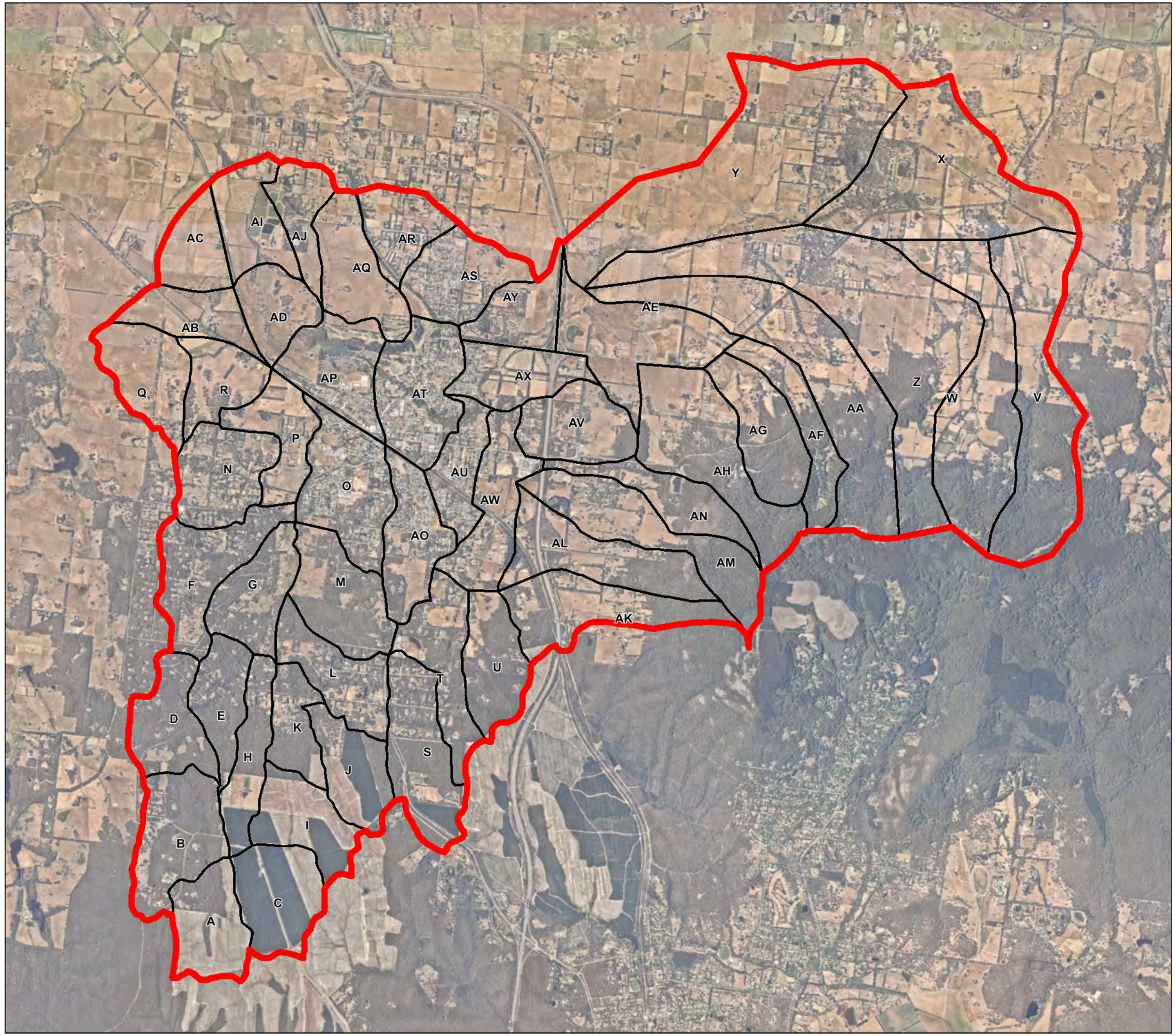
0 1,200

metres

Scale 1:25,000

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RORB Layout

Woodend Flood Study

RORB Subarea

RORB Catchment

N

0 2,500

meters

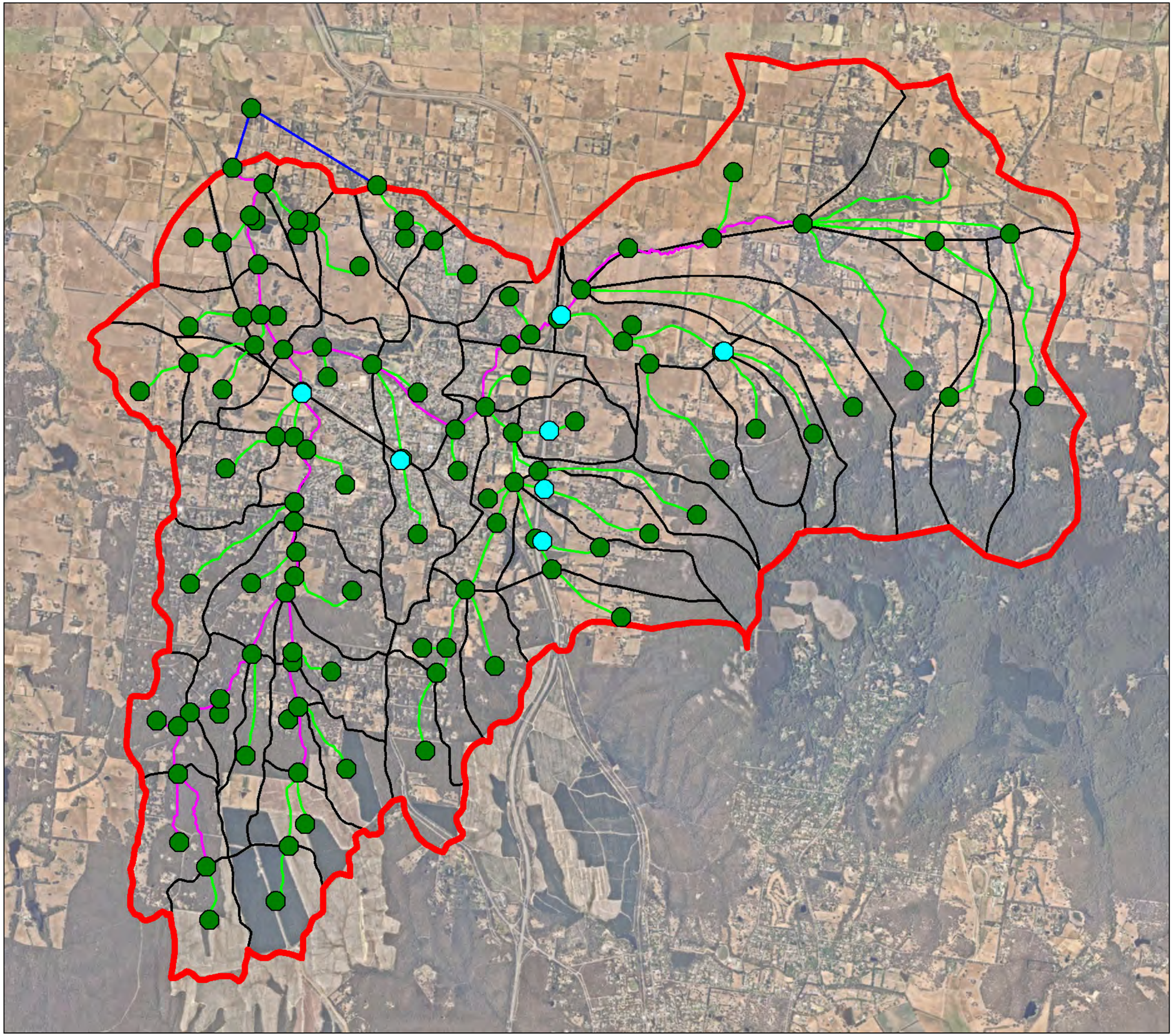
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Map:ReportFigures.wor 01

RORB Model

Woodend Flood Study



Storages
RORB Node
RORB Reach Type 1
RORB Reach Type 2
RORB Reach Type 5
RORB Subarea
RORB Catchment

N

0 2,500
meters

Scale 1:45,000

Cardno

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Effective Impervious Fraction

Woodend Flood Study

Effective Impervious Fraction

0	to 0.05
0.05	to 0.1
0.1	to 0.15
0.15	to 0.2
0.2	to 0.25
0.25	to 0.3

N

0 2,500

meters

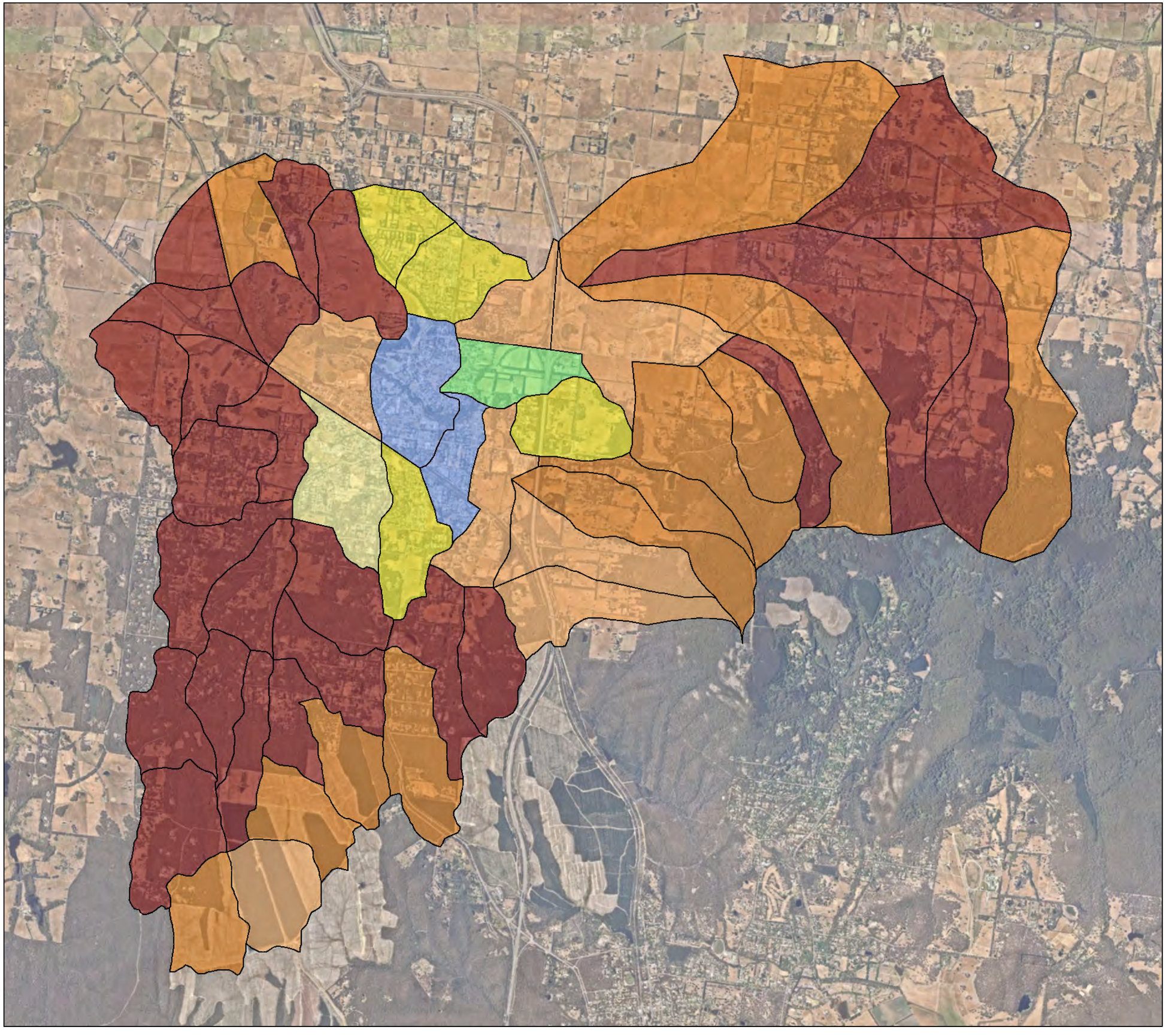
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Coordinate System: MGA Zone 55
Project: AWE200155
Map:ReportFigures.wor 01

Fully Developed Permissible Land Use Effective Impervious Fraction

Woodend Flood Study



Effective Impervious Fraction

0	to 0.05
0.05	to 0.1
0.1	to 0.15
0.15	to 0.2
0.2	to 0.25
0.25	to 0.3
0.3	to 0.35
0.35	to 0.4

N

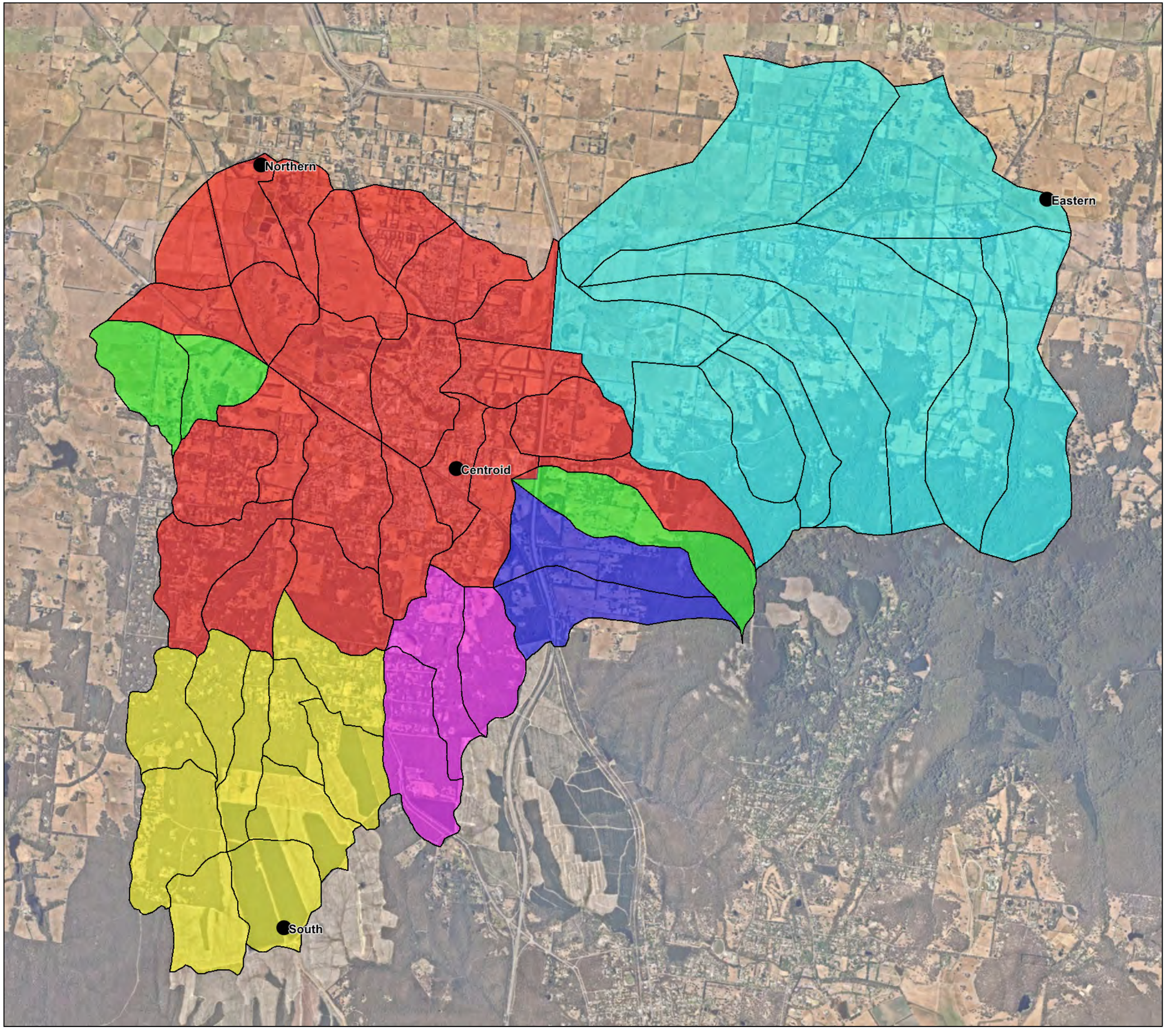
0 2,500

meters

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Coordinate System: MGA Zone 55
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Areal Reduction Factors

Woodend Flood Study

IFD Point

Areal Reduction Factor

- 1 km^2
- 2 km^2
- 3 km^2
- 4 km^2
- 5 km^2
- 28 km^2

N

0 2,500

meters

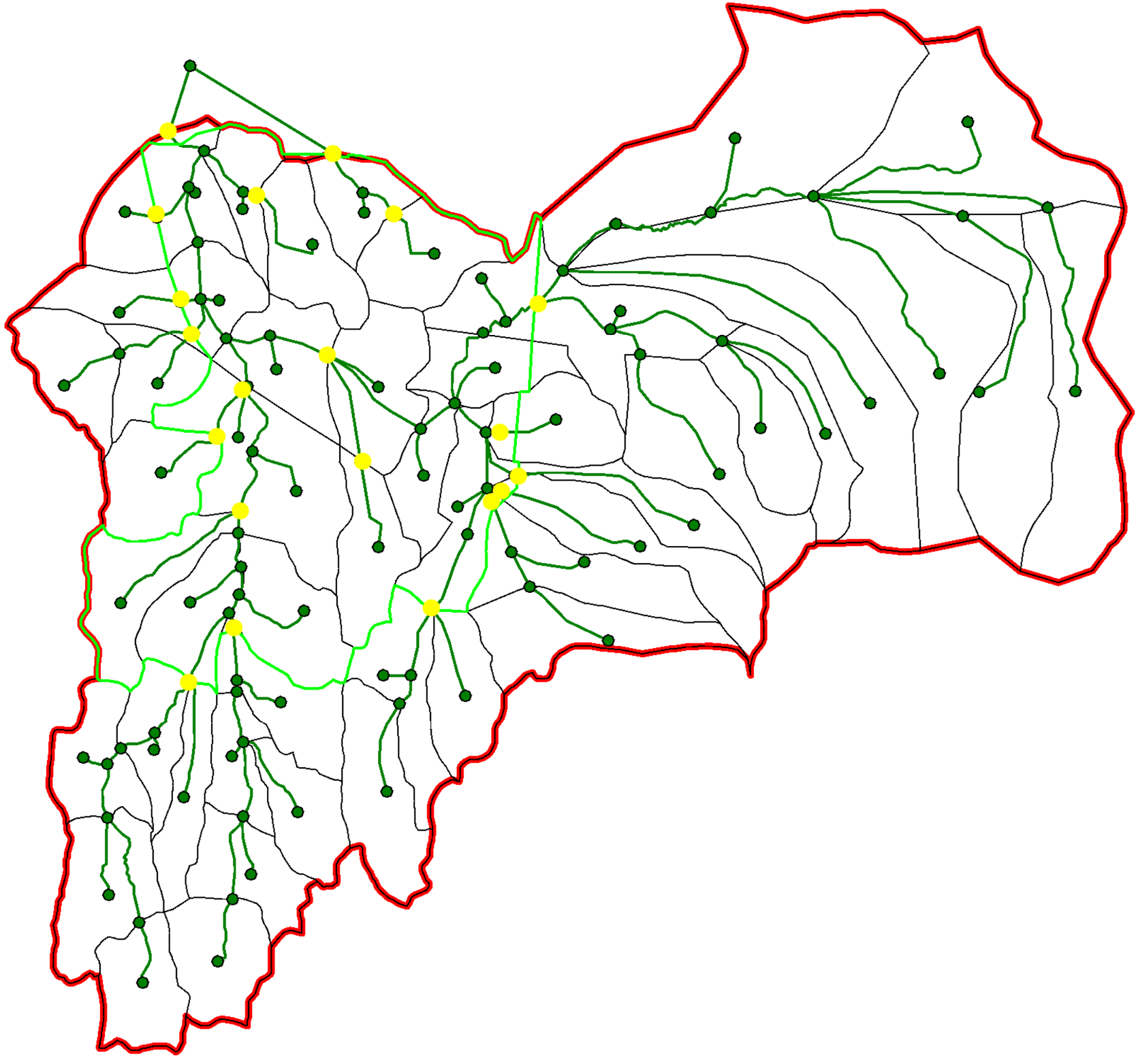
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Project: AWE200155
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Monte Carlo Assessment Locations

Woodend Flood Study



Monte Carlo Locations

RORB Node

RORB Reach

RORB Subarea

RORB Catchment

Hydrualic Model Extent

N

0 2,500

metres

Scale 1:45,000

Cardno

Map Produced by: W&E
Date: 06/04/2020
Coordinate System: MGA Zone 55
Project: AWE200155
Map:ReportFigures.wor 01

Hydraulic Model Topography

Woodend Flood Study

Ridge Line

Gully Line

Hydraulic Model Extent

Topography (mAHD)

530 630

N

0 1,200

metres

Scale 1:25,000

Cardno

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Date: 13/05/2020
Coordinate System: MGA Zone 55
Project: AWE200155
Map:ReportFigures.wor 01

Hydraulic Model Roughness

Woodend Flood Study

Hydraulic Model Extent

Mannings "n" Value

- 0.3
- 0.2
- 0.5
- 0.3
- 0.04
- 0.06
- 0.1
- 0.02
- 0.05
- 0.015
- 0.05
- 0.022
- 0.06

N

0 1,200

metres

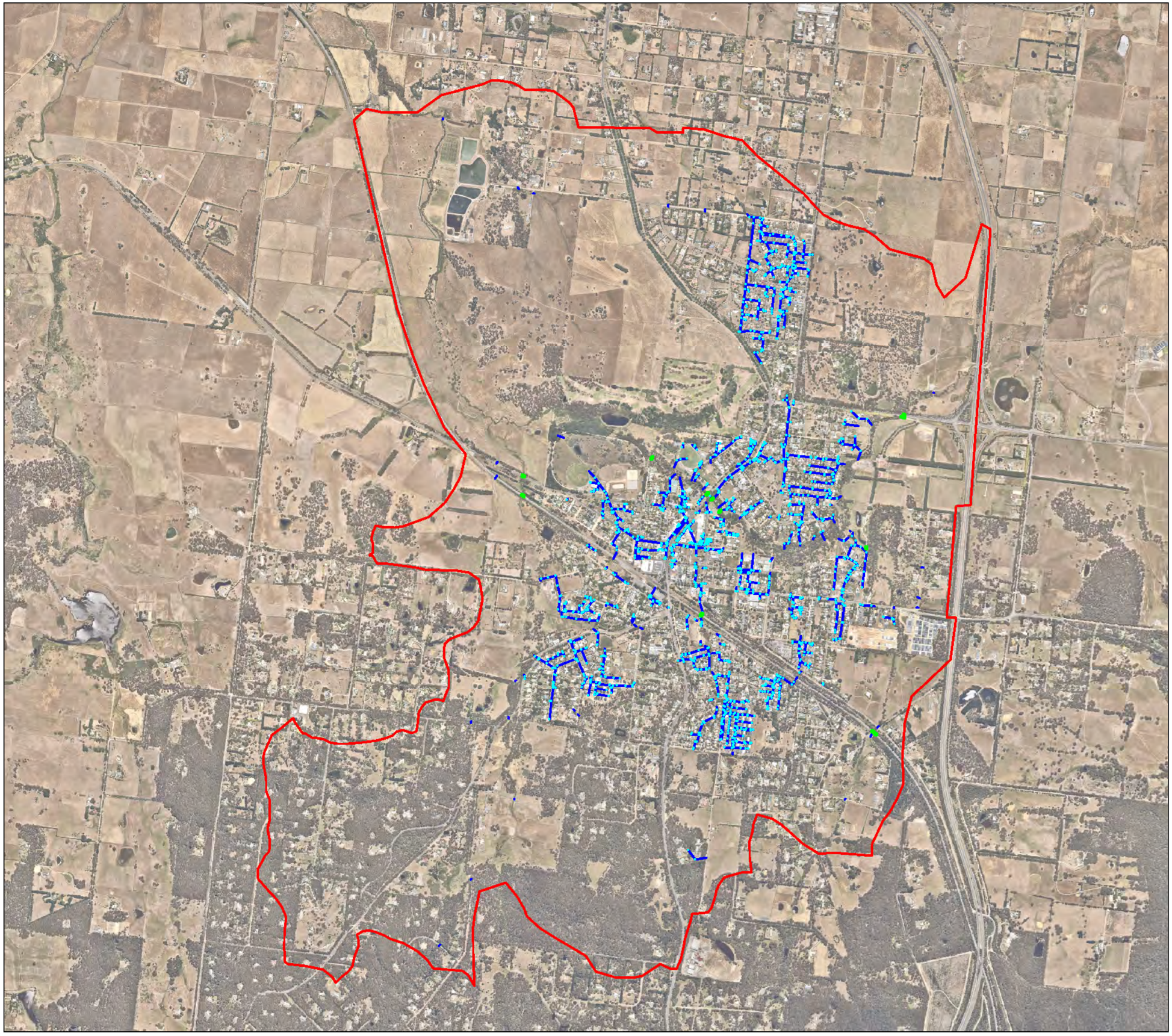
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Modelled Stormwater Network and Bridges

Woodend Flood Study



Stormwater Pit

Stormwater Pipe

Bridge

Hydraulic Model Extent

N

0 1,200

metres

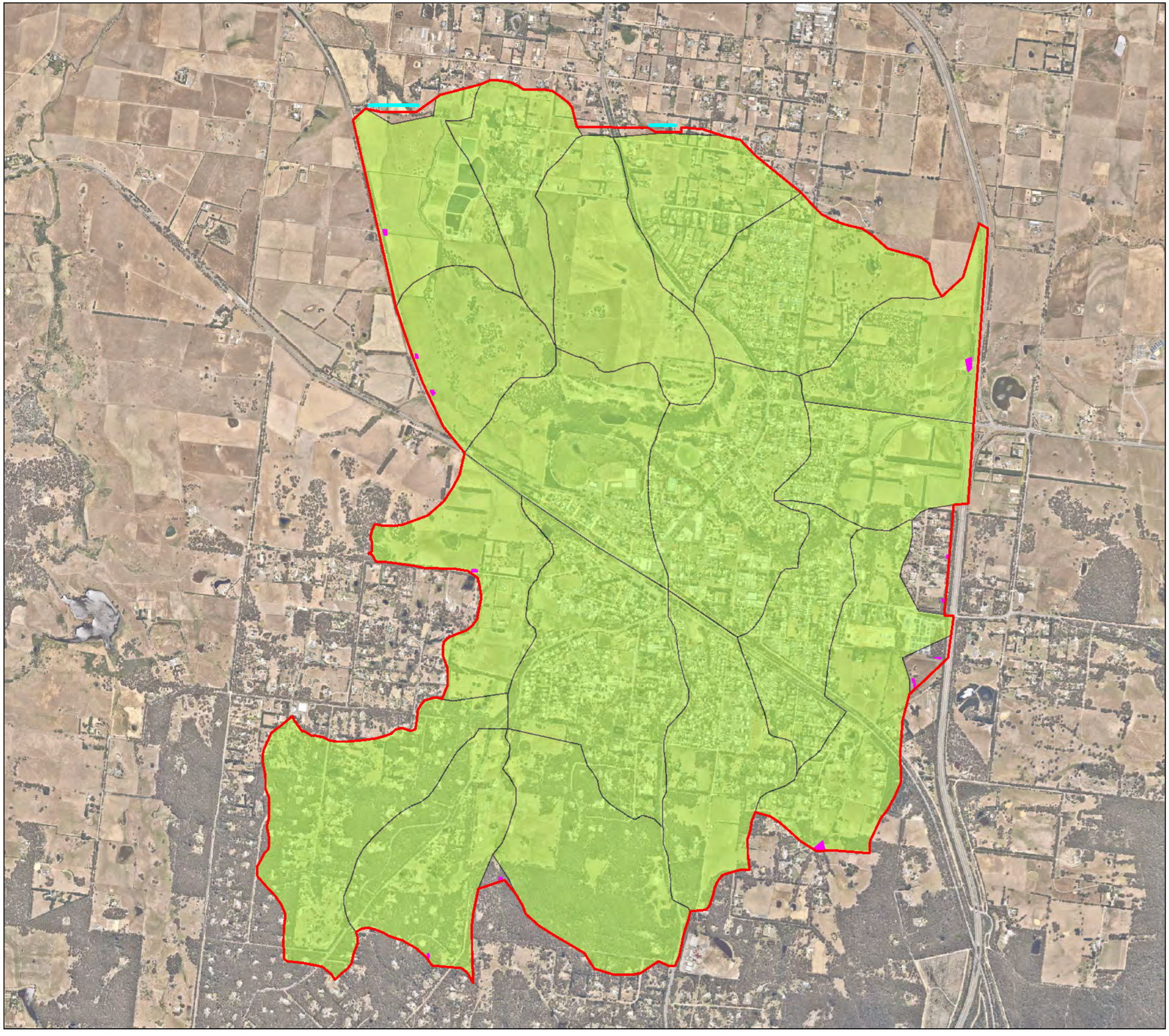
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Date: 13/05/2020
Coordinate System: MGA Zone 55
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Application of Rainfall and Downstream Boundaries

Woodend Flood Study



Downstream Boundaries

Routed Inflows

Excess Rainfall

Hydraulic Model Extent

N

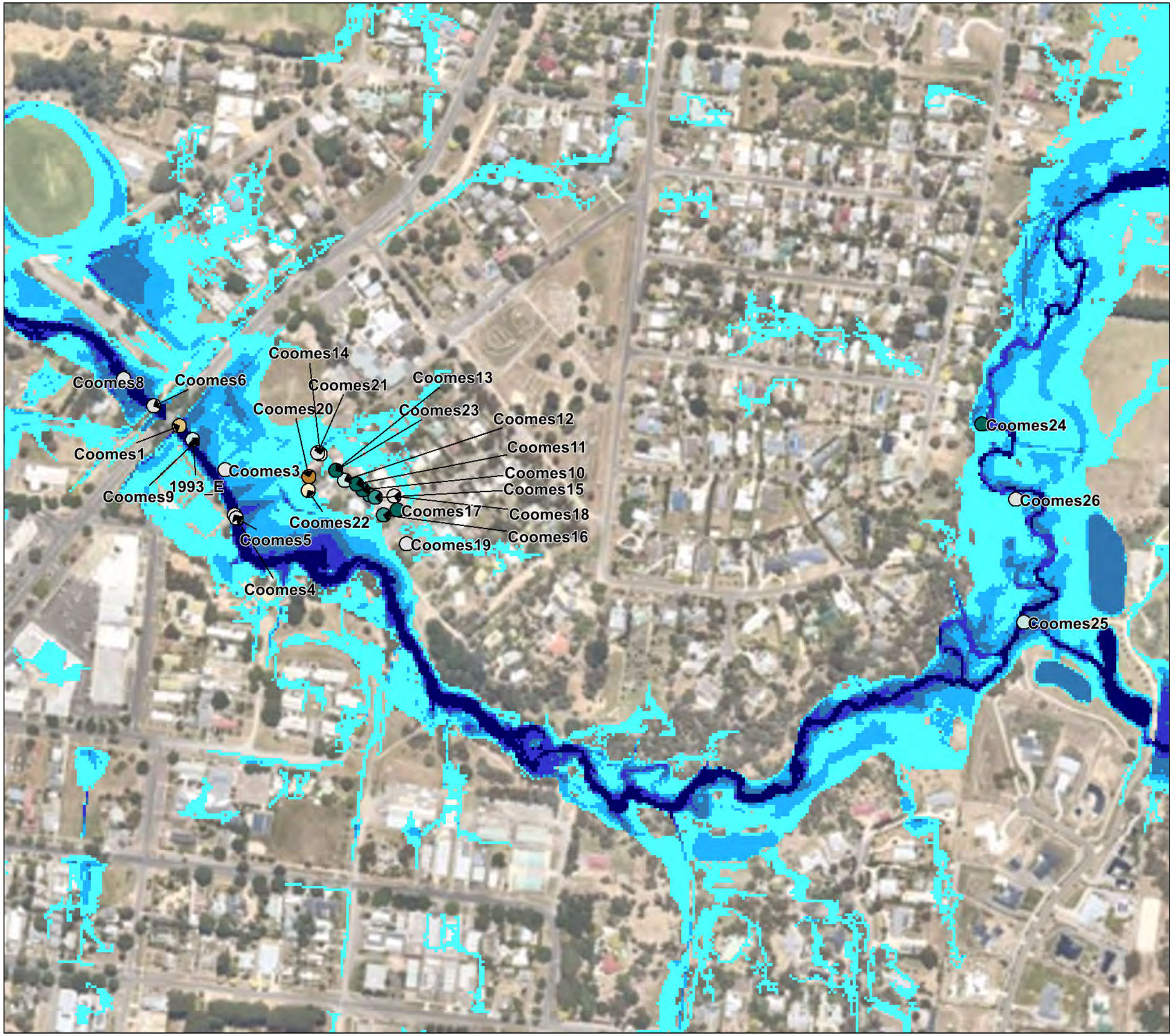
0 1,200

metres

Scale 1:25,000

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Date: 13/05/2020
Coordinate System: MGA Zone 55
Project: AWE200155
Map:ReportFigures.wor 01



1993 Calibration Results

Woodend Flood Study

Difference in Flood Level (m) (Surveyed vs

- < -0.25
- -0.25 to -0.15
- -0.15 to -0.1
- -0.1 to -0.05
- -0.05 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.25
- > 0.25

Depth (m)

- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

N

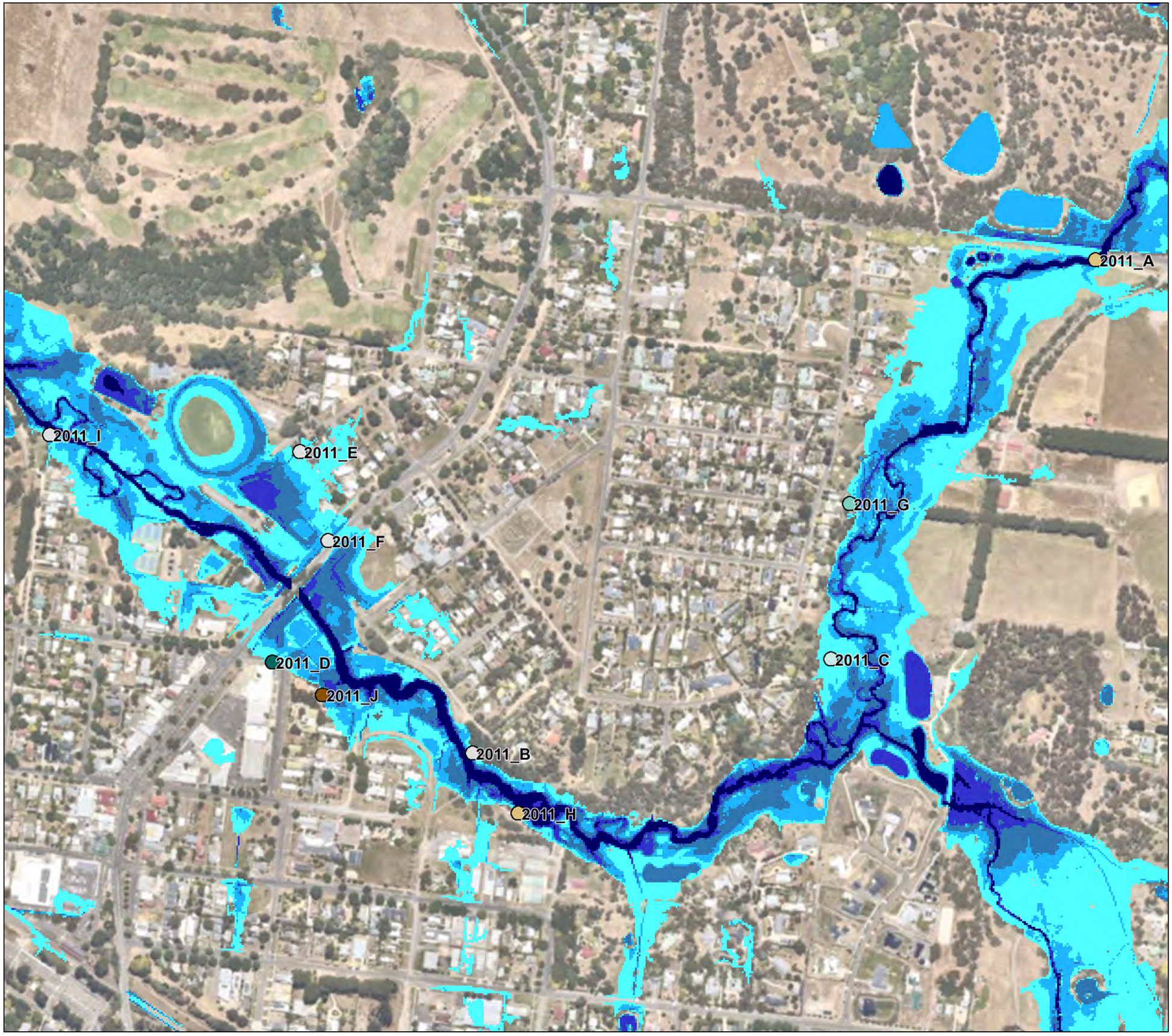
0 200

metres

Scale 1:4,000

Cardno

Map Produced by W&E
Date: 29/07/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:InitialCalibration.wor



2011 Calibration Results

Woodend Flood Study

Difference in Flood Level (m) (Surveyed vs TUFLOW)

- < -0.25
- -0.25 to -0.15
- -0.15 to -0.1
- -0.1 to -0.05
- -0.05 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.25
- > 0.25

Depth (m)

- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

N

0 300

metres

Scale 1:6,000

Cardno

Map Produced by W&E
Date: 29/07/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:InitialCalibration.wor

Council Hotspots

Woodend Flood Study

- Council Hotspot
- 0.2EY Flood Extent
- 10% AEP Flood Extent
- 5% AEP Flood Extent
- 2% AEP Flood Extent
- 1% AEP Flood Extent
- 0.1% AEP Flood Extent

N

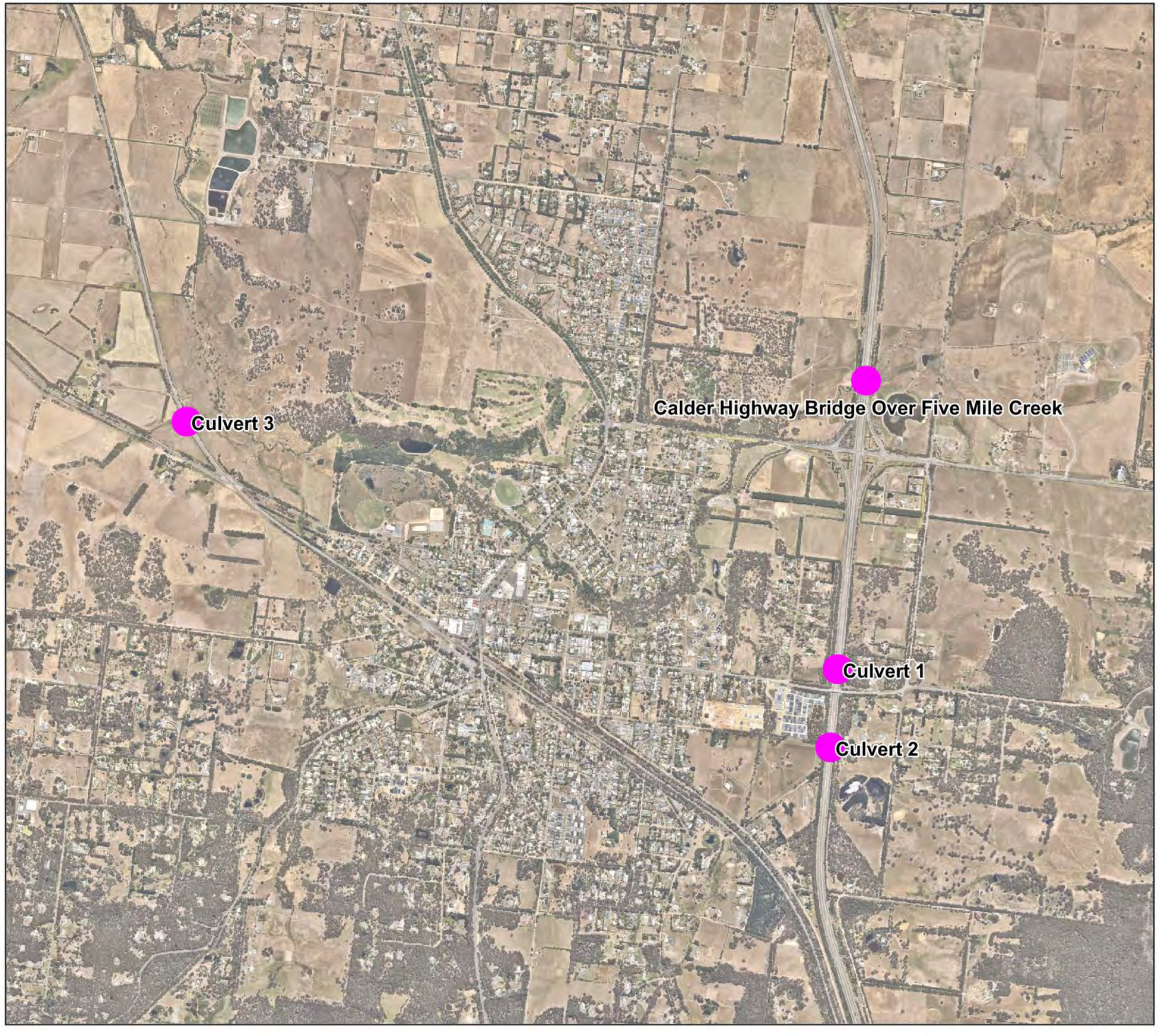
0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
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Coordinate System: MGA Zone55
Project:AWE200155
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Assessed Upstream Crossings

Woodend Flood Study

Crossing

N

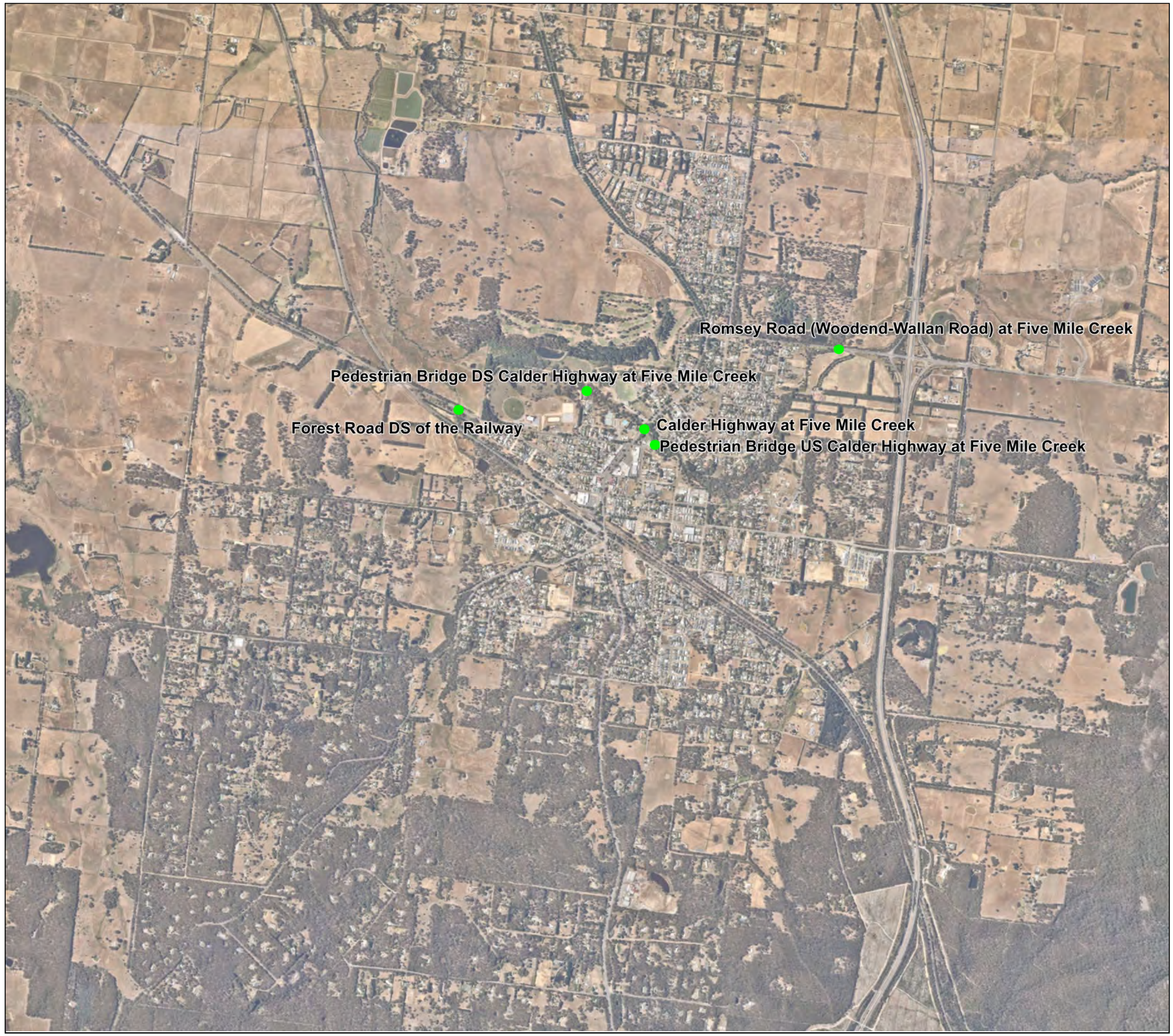
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Date: 13/05/2020
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Locations of Blockage Assessment

Woodend Flood Study

● Locations of Blockage Assessments

N

0 1,200

meters

Scale 1:25,000

Cardno

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Date: 13/05/2020
Coordinate System: MGA Zone 55
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5% AEP Blockage Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- >0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_Blockage.wor



1% AEP Blockage Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

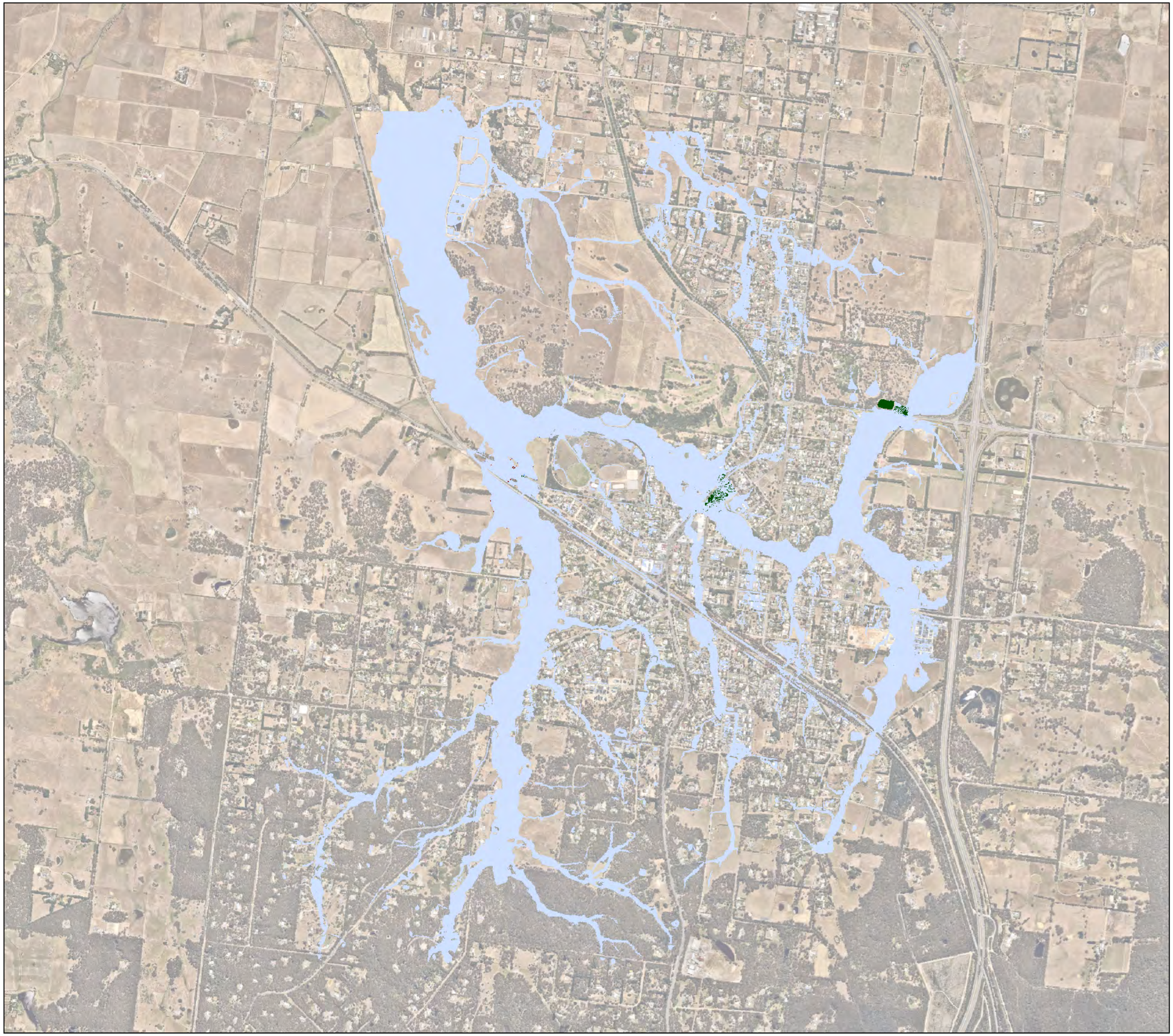
0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_Blockage.wor



0.1% AEP Blockage Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_Blockage.wor

5% AEP High Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- >0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_HighRoughness.wor

5% AEP Low Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- >0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_LowRoughness.wor

1% AEP High Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_HighRoughness.wor

1% AEP Low Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_LowRoughness.wor

0.1% AEP High Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_HighRoughness.wor

0.1% AEP Low Roughness Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_LowRoughness.wor



5% AEP Downstream Boundary Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- >0.5
- Was Dry Now Wet

N

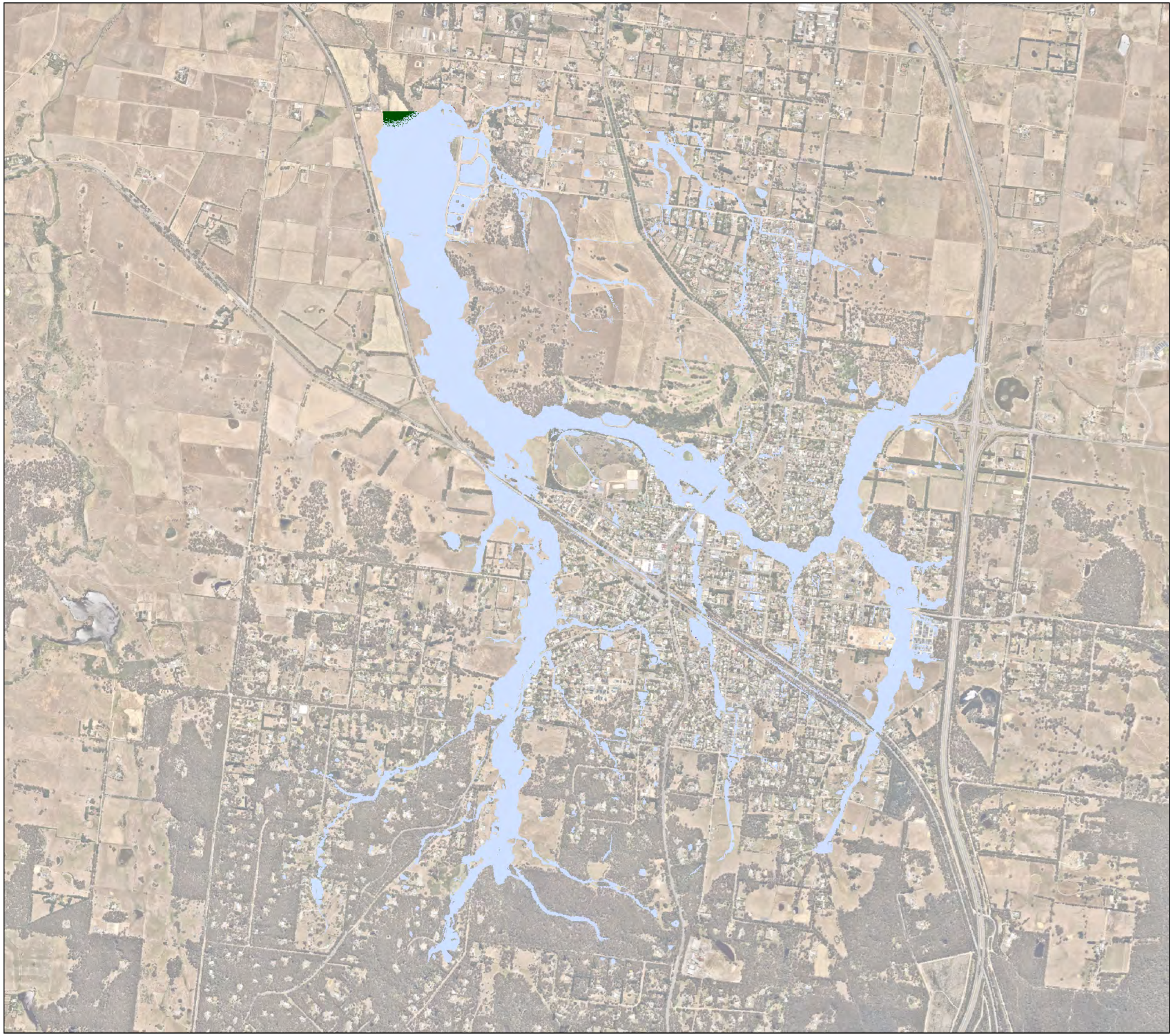
0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_DownstreamBoundary.wor



1% AEP Downstream Boundary Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_DownstreamBoundary.wor

0.1% AEP Downstream Boundary Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_DownstreamBoundary.wor

1% AEP High Flow Difference Plot

Woodend Flood Study

Change In Flood Level (m)

- Was Wet Now Dry
- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.15
- 0.15 to 0.2
- 0.2 to 0.25
- 0.25 to 0.3
- 0.3 to 0.35
- 0.35 to 0.4
- 0.4 to 0.45
- 0.45 to 0.5
- > 0.5
- Was Dry Now Wet

N

0 1,200

metres

Scale 1:25,000

Cardno

Map Produced by W&E
Date: 21/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:SensitivityAnalysis_HihgFlow.wor

Appendix B *Sub Catchment Characteristics*

Sub Area	Area km2	Effective Impervious Fraction	Fully Developed for Permissible Land Uses Effective Impervious Fraction
A	1.093	0.01	0.085
B	1.467	0.01	0.019
C	1.217	0.01	0.104
D	1.088	0.01	0.011
E	0.836	0.01	0.01
F	1.388	0.011	0.023
G	1.057	0.01	0.011
H	0.878	0.01	0.028
I	1.051	0.01	0.095
J	0.966	0.01	0.064
K	0.722	0.01	0.018
L	1.109	0.017	0.031
M	1.342	0.016	0.028
N	1.236	0.012	0.025
O	1.563	0.178	0.233
P	0.921	0.01	0.015
Q	1.139	0.01	0.018
R	0.825	0.011	0.017
S	1.513	0.026	0.087
T	1.202	0.011	0.037
U	1.063	0.01	0.03
V	2.936	0.011	0.052
W	2.808	0.012	0.042
X	3.372	0.011	0.045
Y	5.101	0.011	0.07
Z	4.911	0.011	0.042
AA	3.242	0.012	0.053
AB	0.83	0.014	0.028
AC	0.784	0.011	0.011
AD	0.804	0.011	0.017
AF	0.93	0.012	0.038
AG	1.245	0.012	0.052
AI	1.003	0.011	0.056
AJ	0.709	0.01	0.042
AK	1.47	0.035	0.125
AL	1.521	0.026	0.128
AM	1.707	0.017	0.086
AN	0.945	0.014	0.092

Sub Area	Area km2	Effective Impervious Fraction	Fully Developed for Permissible Land Uses Effective Impervious Fraction
AO	1.129	0.135	0.185
AP	1.245	0.076	0.14
AQ	1.189	0.014	0.031
AR	0.842	0.055	0.164
AS	1.188	0.138	0.181
AT	1.496	0.279	0.377
AU	0.779	0.243	0.361
AV	1.136	0.031	0.155
AW	1.232	0.057	0.137
AX	0.968	0.121	0.257
AY	0.829	0.046	0.112
AH	2.113	0.012	0.074
AE	1.82	0.026	0.128

Appendix C *ARR Data Hub Information*

Results - ARR Data Hub

[STARTTXT]

Input Data Information

[INPUTDATA]

Latitude,-37.359000

Longitude,144.526000

[END_INPUTDATA]

River Region

[RIVREG]

Division, Murray-Darling Basin

River Number,6

River Name,Campaspe River

[RIVREG_META]

Time Accessed,31 March 2020 09:13AM

Version,2016_v1

[END_RIVREG]

ARF Parameters

[LONGARF]

Zone,Southern Temperate

a,0.158

b,0.276

c,0.372

d,0.315

e,0.000141

f,0.41

g,0.15

h,0.01

i,-0.0027

[LONGARF_META]

Time Accessed,31 March 2020 09:13AM

Version,2016_v1

[END_LONGARF]

Storm Losses

[LOSSES]

ID,6329.0

Storm Initial Losses (mm),27.0

Storm Continuing Losses (mm/h),3.1
[LOSSES_META]
Time Accessed,31 March 2020 09:13AM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,MB
Label,Murray Basin
[TP_META]
Time Accessed,31 March 2020 09:13AM
Version,2016_v2
[END_TP]

Areal Temporal Patterns
[ATP]
code,MB
arealabel,Murray Basin
[ATP_META]
Time Accessed,31 March 2020 09:13AM
Version,2016_v2
[END_ATP]

Median Preburst Depths and Ratios
[PREBURST]
min (h)\AEP(%),50,20,10,5,2,1
60 (1.0),2.2 (0.135),2.0 (0.088),1.9 (0.069),1.8 (0.055),1.5 (0.037),1.3 (0.028)
90 (1.5),3.1 (0.164),2.8 (0.108),2.6 (0.084),2.5 (0.066),1.9 (0.042),1.5 (0.029)
120 (2.0),3.0 (0.147),2.6 (0.090),2.3 (0.066),2.0 (0.049),1.9 (0.039),1.9 (0.033)
180 (3.0),3.5 (0.145),3.2 (0.099),3.1 (0.078),2.9 (0.063),5.1 (0.090),6.7 (0.104)
360 (6.0),1.4 (0.043),1.6 (0.037),1.8 (0.034),1.9 (0.032),5.0 (0.068),7.3 (0.087)
720 (12.0),0.3 (0.006),2.8 (0.048),4.4 (0.064),6.0 (0.074),7.5 (0.077),8.7 (0.078)
1080 (18.0),0.3 (0.005),1.4 (0.020),2.1 (0.025),2.8 (0.029),4.6 (0.040),6.0 (0.046)
1440 (24.0),0.0 (0.000),1.1 (0.014),1.8 (0.020),2.6 (0.024),3.1 (0.024),3.4 (0.023)
2160 (36.0),0.0 (0.001),0.1 (0.001),0.1 (0.001),0.2 (0.001),0.4 (0.003),0.6 (0.004)
2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.1 (0.000),0.0 (0.000),0.0 (0.000)
4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)
[PREBURST_META]
Time Accessed,31 March 2020 09:13AM
Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST]

10% Preburst Depths

[PREBURST10]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

[PREBURST10_META]

Time Accessed,31 March 2020 09:13AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST10]

25% Preburst Depths

[PREBURST25]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),0.1 (0.004),0.0 (0.002),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000)

90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

120 (2.0),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

180 (3.0),0.1 (0.004),0.1 (0.002),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000)

360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000)

[PREBURST25_META]

Time Accessed,31 March 2020 09:13AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST25]

75% Preburst Depths

[PREBURST75]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),9.9 (0.605),12.8 (0.560),14.7 (0.532),16.6 (0.508),14.3 (0.360),12.7 (0.277)

90 (1.5),10.8 (0.581),13.2 (0.510),14.8 (0.472),16.3 (0.441),14.8 (0.330),13.8 (0.267)

120 (2.0),12.1 (0.588),14.3 (0.502),15.7 (0.458),17.1 (0.423),16.6 (0.337),16.2 (0.287)

180 (3.0),13.2 (0.551),14.4 (0.439),15.2 (0.385),15.9 (0.343),19.7 (0.349),22.6 (0.348)

360 (6.0),9.5 (0.298),13.7 (0.317),16.5 (0.319),19.1 (0.315),22.4 (0.304),24.8 (0.294)

720 (12.0),6.5 (0.150),11.6 (0.198),14.9 (0.215),18.2 (0.224),24.1 (0.246),28.6 (0.255)

1080 (18.0),5.4 (0.106),10.0 (0.144),13.0 (0.157),15.9 (0.164),19.0 (0.164),21.4 (0.163)

1440 (24.0),3.0 (0.053),6.7 (0.086),9.1 (0.098),11.4 (0.105),14.5 (0.112),16.9 (0.115)

2160 (36.0),5.0 (0.076),6.4 (0.071),7.3 (0.068),8.1 (0.065),8.3 (0.056),8.5 (0.050)

2880 (48.0),0.3 (0.004),1.0 (0.010),1.5 (0.013),2.0 (0.015),3.6 (0.022),4.7 (0.026)

4320 (72.0),0.0 (0.000),0.1 (0.001),0.2 (0.001),0.2 (0.001),0.9 (0.005),1.5 (0.007)

[PREBURST75_META]

Time Accessed,31 March 2020 09:13AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST75]

90% Preburst Depths

[PREBURST90]

min (h)\AEP(%),50,20,10,5,2,1

60 (1.0),22.4 (1.374),27.1 (1.186),30.2 (1.091),33.2 (1.015),27.9 (0.701),24.0 (0.525)

90 (1.5),23.5 (1.259),28.2 (1.090),31.4 (1.003),34.4 (0.932),30.1 (0.670),26.9 (0.521)

120 (2.0),23.9 (1.155),27.8 (0.975),30.4 (0.885),32.8 (0.812),40.3 (0.819),46.0 (0.812)

180 (3.0),23.8 (0.990),27.9 (0.849),30.6 (0.776),33.2 (0.715),41.3 (0.731),47.4 (0.730)

360 (6.0),22.1 (0.691),29.6 (0.684),34.5 (0.668),39.3 (0.648),46.9 (0.639),52.7 (0.625)

720 (12.0),19.0 (0.441),32.1 (0.550),40.7 (0.586),49.0 (0.603),56.1 (0.572),61.4 (0.549)

1080 (18.0),19.8 (0.387),24.0 (0.345),26.7 (0.323),29.4 (0.304),36.3 (0.313),41.6 (0.316)

1440 (24.0),16.2 (0.282),24.6 (0.316),30.2 (0.325),35.5 (0.328),34.9 (0.269),34.4 (0.234)

2160 (36.0),21.1 (0.320),23.8 (0.264),25.6 (0.238),27.4 (0.219),30.2 (0.202),32.3 (0.191)

2880 (48.0),19.1 (0.266),18.4 (0.187),17.9 (0.152),17.4 (0.128),21.8 (0.134),25.0 (0.136)

4320 (72.0),5.2 (0.066),9.4 (0.086),12.2 (0.094),14.8 (0.099),18.6 (0.104),21.5 (0.107)

[PREBURST90_META]

Time Accessed,31 March 2020 09:13AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST90]

Interim Climate Change Factors

[CCF]

,RCP 4.5,RCP6,RCP 8.5

2030,0.816 (4.1%),0.726 (3.6%),0.934 (4.7%)

2040,1.046 (5.2%),1.015 (5.1%),1.305 (6.6%)

2050,1.260 (6.3%),1.277 (6.4%),1.737 (8.8%)

2060,1.450 (7.3%),1.520 (7.7%),2.214 (11.4%)

2070,1.609 (8.2%),1.753 (8.9%),2.722 (14.2%)

2080,1.728 (8.8%),1.985 (10.2%),3.246 (17.2%)

2090,1.798 (9.2%),2.226 (11.5%),3.772 (20.2%)

[CCF_META]

Time Accessed,31 March 2020 09:13AM

Version,2019_v1

Note,ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

[END_CCF]

Baseflow Factors

[BASEFLOW]

Downstream,11070

Area (km2),741.6352

Catchment Number,11088

Volume Factor,0.09606

Peak Factor,0.019987

[BASEFLOW_META]

Time Accessed,31 March 2020 09:13AM

Version,2016_v1

[END_BASEFLOW]

[ENDTXT]

[ENDTXT]

Copyright Commonwealth of Australia 2016 Bureau of Meteorology (ABN 92 637 533 532)

Rare Design Rainfall Depth (mm)

Issued: 31-Mar-20

Location Label:

Requested coordinate: Latitude -37.359 Longitude 144.526

Nearest grid cell: Latitude 37.3625 (S) Longitude 144.5375 (E)

Annual Exceedance Probability (AEP)

Duration	Duration in min	63.20%	50%	20%	0.2EY	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1 min	1	1.46	1.67	2.38	2.43	2.89	3.42	4.16	4.76	5.32	6.12	6.75	7.42
2 min	2	2.39	2.71	3.78	3.85	4.57	5.4	6.58	7.56	8.42	9.62	10.6	11.5
3 min	3	3.26	3.7	5.18	5.28	6.27	7.41	9.03	10.4	11.6	13.2	14.5	15.9
4 min	4	4.02	4.58	6.44	6.57	7.81	9.23	11.2	12.9	14.4	16.5	18.2	19.9
5 min	5	4.69	5.35	7.56	7.71	9.18	10.8	13.2	15.1	16.9	19.4	21.4	23.5
10 min	10	7.06	8.11	11.6	11.8	14.1	16.7	20.3	23.2	25.9	29.8	32.9	36.2
15 min	15	8.58	9.85	14.1	14.4	17.1	20.3	24.7	28.2	31.6	36.3	40.1	44.1
20 min	20	9.68	11.1	15.9	16.2	19.3	22.8	27.8	31.8	35.6	40.9	45.2	49.6
25 min	25	10.6	12.1	17.2	17.6	21	24.8	30.2	34.6	38.6	44.4	49	53.8
30 min	30	11.3	12.9	18.4	18.7	22.3	26.4	32.1	36.8	41.1	47.3	52.2	57.3
45 min	45	13	14.8	20.9	21.3	25.4	30	36.5	41.9	46.8	53.7	59.2	65
1 hour	60	14.3	16.3	22.8	23.3	27.7	32.7	39.8	45.7	51	58.6	64.6	70.8
1.5 hour	90	16.5	18.7	25.9	26.4	31.3	36.9	45	51.7	57.7	66.2	73	80.1
2 hour	120	18.3	20.7	28.5	29	34.3	40.4	49.2	56.6	63.2	72.6	80	87.8
3 hour	180	21.4	24	32.8	33.5	39.4	46.4	56.5	64.9	72.5	83.4	92	101

4.5 hour	270	25.3	28.3	38.4	39.1	46	54	65.6	75.3	84.2	97	107
	118											
6 hour	360	28.6	31.9	43.2	44.1	51.7	60.6	73.5	84.3	94.3	109	120
	132											
9 hour	540	34.1	38.1	51.4	52.4	61.4	71.9	86.9	99.4	111	128	142
	156											
12 hour	720	38.6	43.1	58.3	59.5	69.5	81.3	98.1	112	125	144	160
	176											
18 hour	1080	45.7	51.1	69.3	70.7	82.7	96.5	116	132	147	170	188
	206											
24 hour	1440	51	57.2	77.9	79.4	92.8	108	130	147	164	189	208
	229											
30 hour	1800	55.1	62	84.7	86.3	101	118	141	159	178	205	225
	247											
36 hour	2160	58.5	65.9	90.2	92	107	125	149	169	189	217	238
	261											
48 hour	2880	63.6	71.8	98.5	100	117	137	163	183	205	234	256
	280											
72 hour	4320	70.1	79.2	109	111	130	150	179	201	224	254	279
	303											
96 hour	5760	74.1	83.7	115	117	136	158	188	211	235	268	293
	320											
120 hour	7200	77.2	86.9	118	121	140	162	194	218	243	278	305
	333											
144 hour	8640	79.7	89.5	121	123	143	165	197	223	249	286	315
	346											
168 hour	10080	82.1	91.7	123	125	145	167	200	226	254	293	325
	358											

Appendix D *Site Visit Photographs*



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X: 281393.2 Y: 5862747.46 Heading: 293.693 Time Stamp: 2020:02:04 11:41:25



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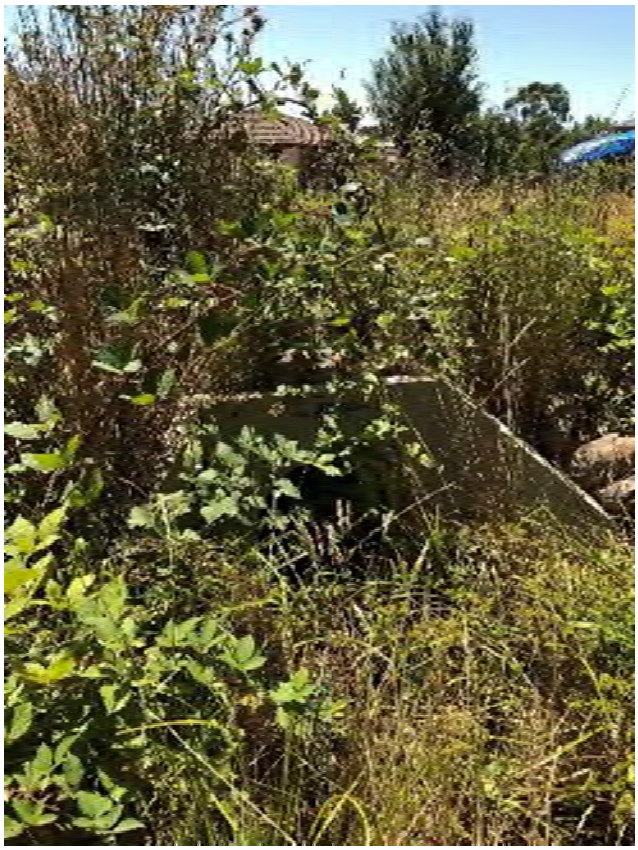
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Appendix E *LFSCH Calculations*

Layered Flow Constriction Shapes (LFCSH) are how TUFLOW model bridges. TUFLOW takes into account the bridge based on several parameters including levels, blockages and form loss coefficients on up to 3 layers i.e area below the deck, the deck and the railings. The Form Loss coefficient (FLC) is used to take into account losses due to pier and railings.

LFCSH PARAMETERS													BRIDGE LOSS CALCULATION DETAILS								
ID	Invert	dz	Shape_Width_or_dMax	Shape_Options	L1_Obvert	L1_pBlockage	L1_LFC	L2_Depth	L2_pBlockage	L2_LFC	L3_Depth	L3_pBlockage	L3_FLC	Bridge Type	Bridge Width	Pier Width	J	Delta K	Bridge Length	L1 FLC	L3 FLC	Bridge Deck Height
WD_1	558.10			MIN NO MERGE	559.45	4.76	0.075	1.15	100.00	0.097	0.75	50.00	0.006	7	10.5	0.5	0.05	0.90	12.0	0.075	0.006	560.60
WD_3	-99999.00			MIN NO MERGE	549.00	0.00	0.000	1.00	100.00	0.126	0.00	0.00	0.000	0	0.0	0.0	0.00	0.00	8.0	0.000	0.000	550.00
WD_4	-99999.00			MIN NO MERGE	554.00	0.00	0.000	0.50	100.00	0.064	0.75	50.00	0.006	0	0.0	0.0	0.00	0.00	8.0	0.000	0.006	554.50
WD_7	-99999.00			MIN NO MERGE	548.00	5.56	0.053	0.30	100.00	0.103	1.00	50.00	0.006	5	18.0	1.0	0.06	0.16	3.0	0.053	0.006	548.30
WD_9	-99999.00			MIN NO MERGE	551.37	0.00	0.000	0.30	100.00	0.103	1.00	50.00	0.006	0	18.0	0.0	0.00	0.00	3.0	0.000	0.006	551.67
WD_10	-99999.00			MIN NO MERGE	556.90	9.09	0.035	0.30	100.00	0.078	1.00	25.00	0.006	7	5.5	0.5	0.09	0.14	4.0	0.035	0.006	557.20
WD_11	-99999.00			MIN NO MERGE	560.30	0.00	0.000	0.30	100.00	0.124	1.00	50.00	0.006	0	25.0	0.0	0.00	0.00	2.5	0.000	0.006	560.60
WD_12	-99999.00			MIN NO MERGE	551.00	0.00	0.000	0.30	100.00	0.124	1.00	50.00	0.006	0	18.0	0.0	0.00	0.00	2.5	0.000	0.006	551.30
WD_13	-99999.00			MIN NO MERGE	568.42	2.56	0.007	1.71	100.00	0.229	0.00	0.00	0.000	7	39.0	1.0	0.03	0.05	7.5	0.007	0.000	570.00
WD_14	-99999.00			MIN NO MERGE	562.50	0.00	0.000	0.61	100.00	0.041	0.00	0.00	0.000	0	4.0	0.0	0.00	0.00	15.3	0.000	0.000	563.11

Appendix F *Flood Maps*

0.2% EY Flood Extent

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_2_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
Freeway
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

0.2% EY Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_2_AEP_FloodMap.wor

0.2% EY Flood Hazard

Woodend Flood Study

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_2_AEP_FloodMap.wor

N

0 800

metres

Scale 1:10,000

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary



10% AEP Flood Extent

Woodend Flood Study

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 10_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

10% AEP Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 10_AEP_FloodMap.wor

10% AEP Flood Hazard

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 10_AEP_FloodMap.wor

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

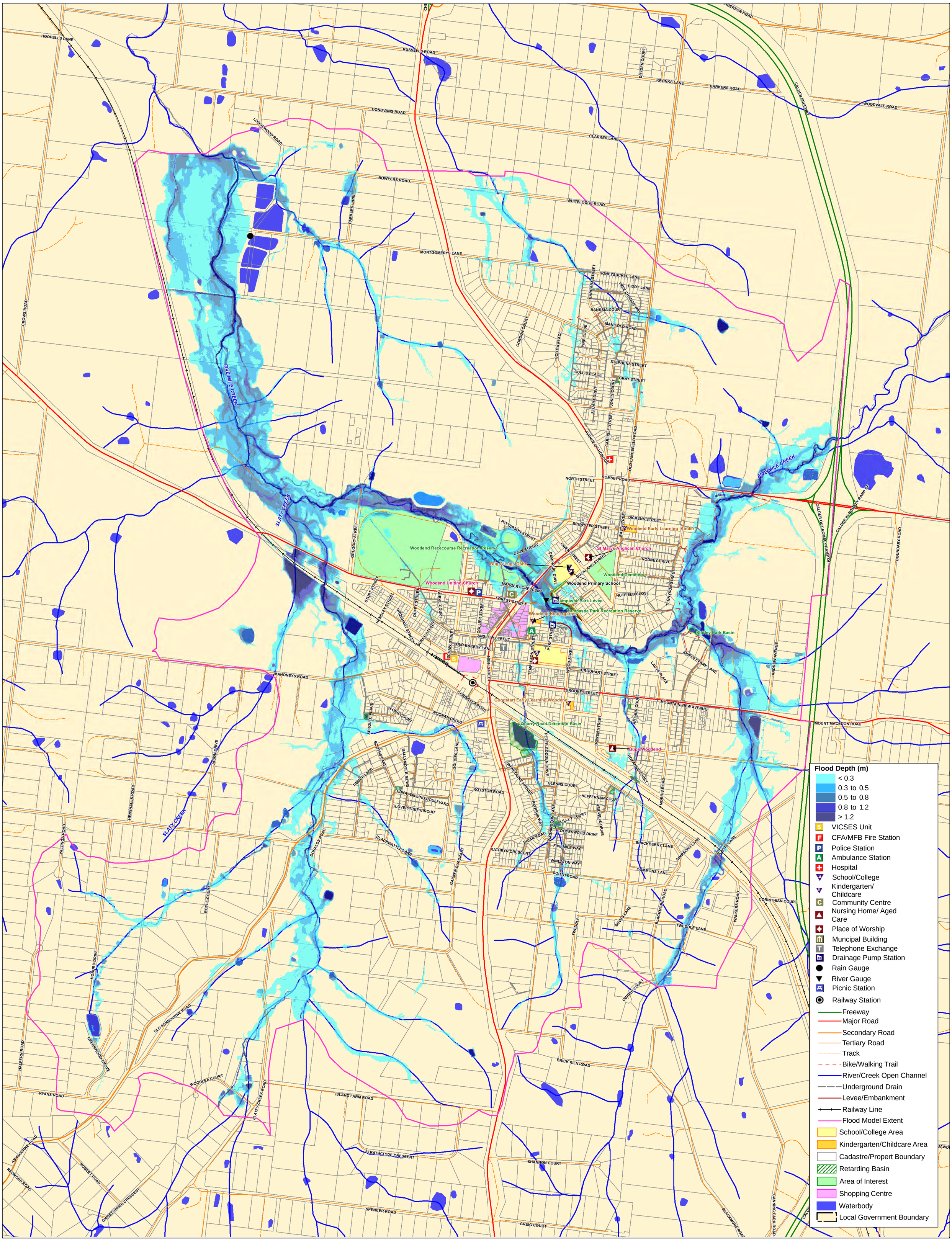
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5% AEP Flood Extent

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

5% AEP Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor

5% AEP Flood Hazard

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor

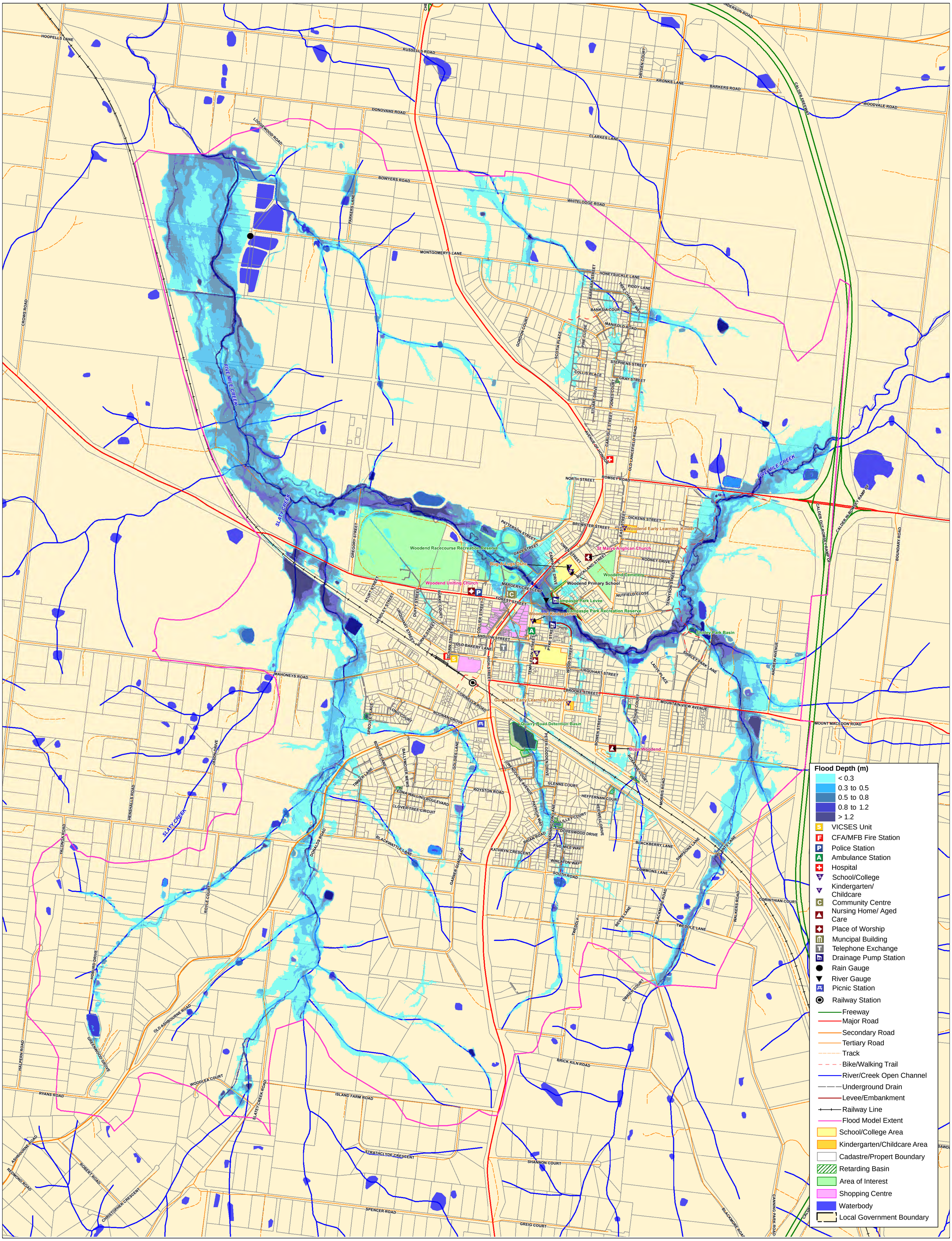
2% AEP Flood Extent

Woodend Flood Study

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
Freeway
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary

N
0
800
metres
Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 2_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

2% AEP Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 2_AEP_FloodMap.wor

2% AEP Flood Hazard

Woodend Flood Study

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 2_AEP_FloodMap.wor

N

0 800

metres

Scale 1:10,000

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
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- Underground Drain
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- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

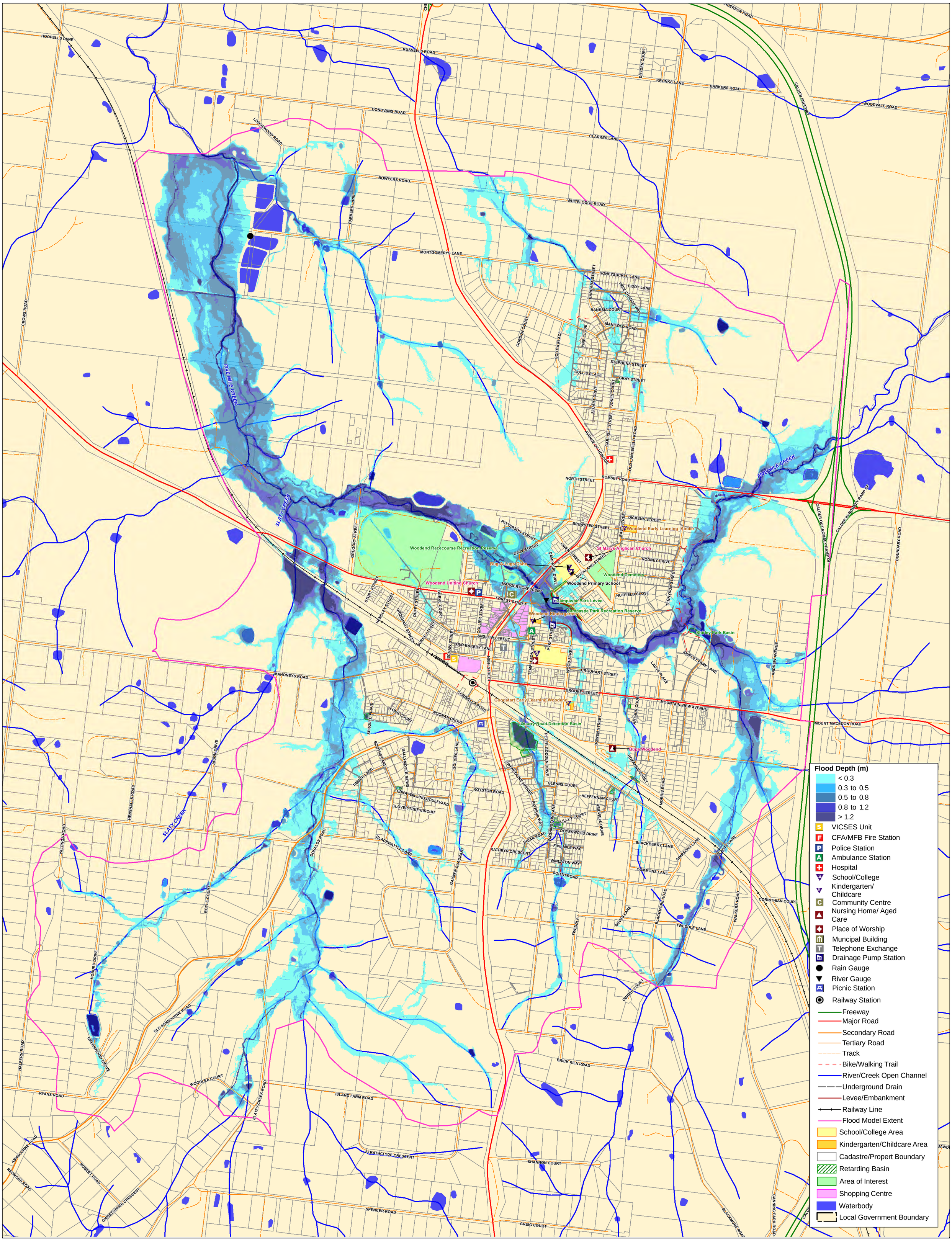
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1% AEP Flood Extent

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

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metres

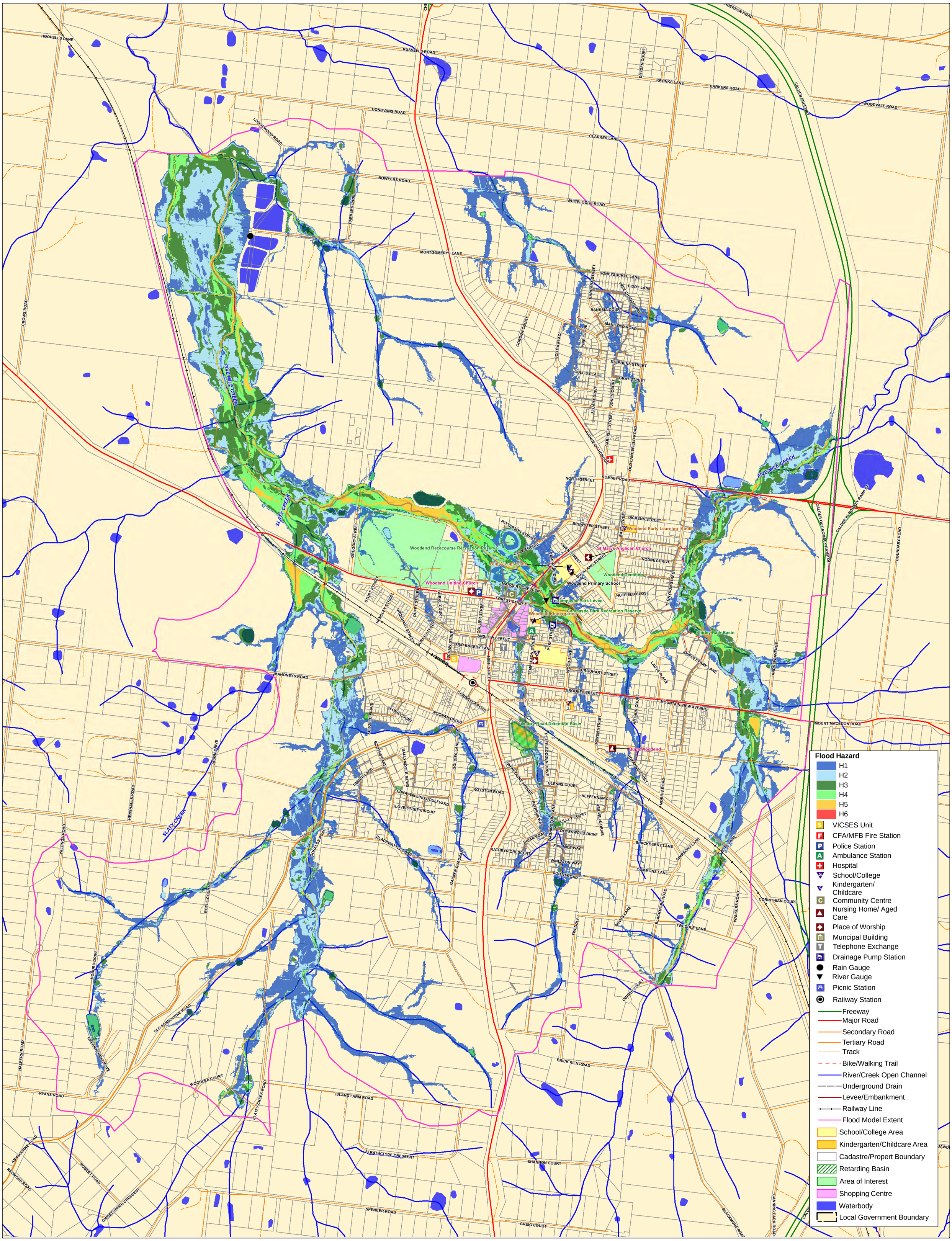
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1% AEP Flood Depth

Woodend Flood Study

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Map Produced by W&E
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Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

1% AEP Flood Hazard

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

0.1% AEP Flood Extent

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

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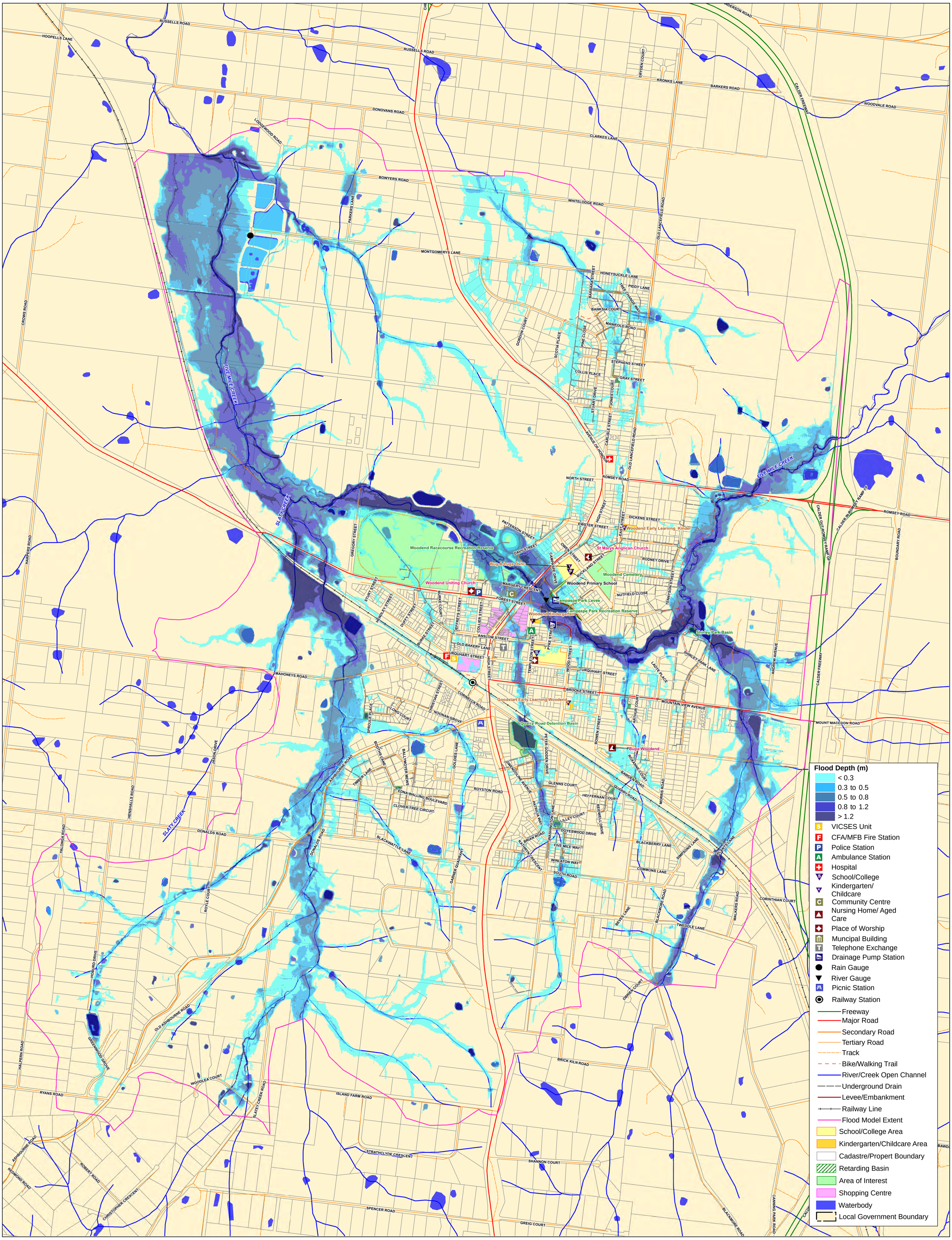
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metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
Freeway
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

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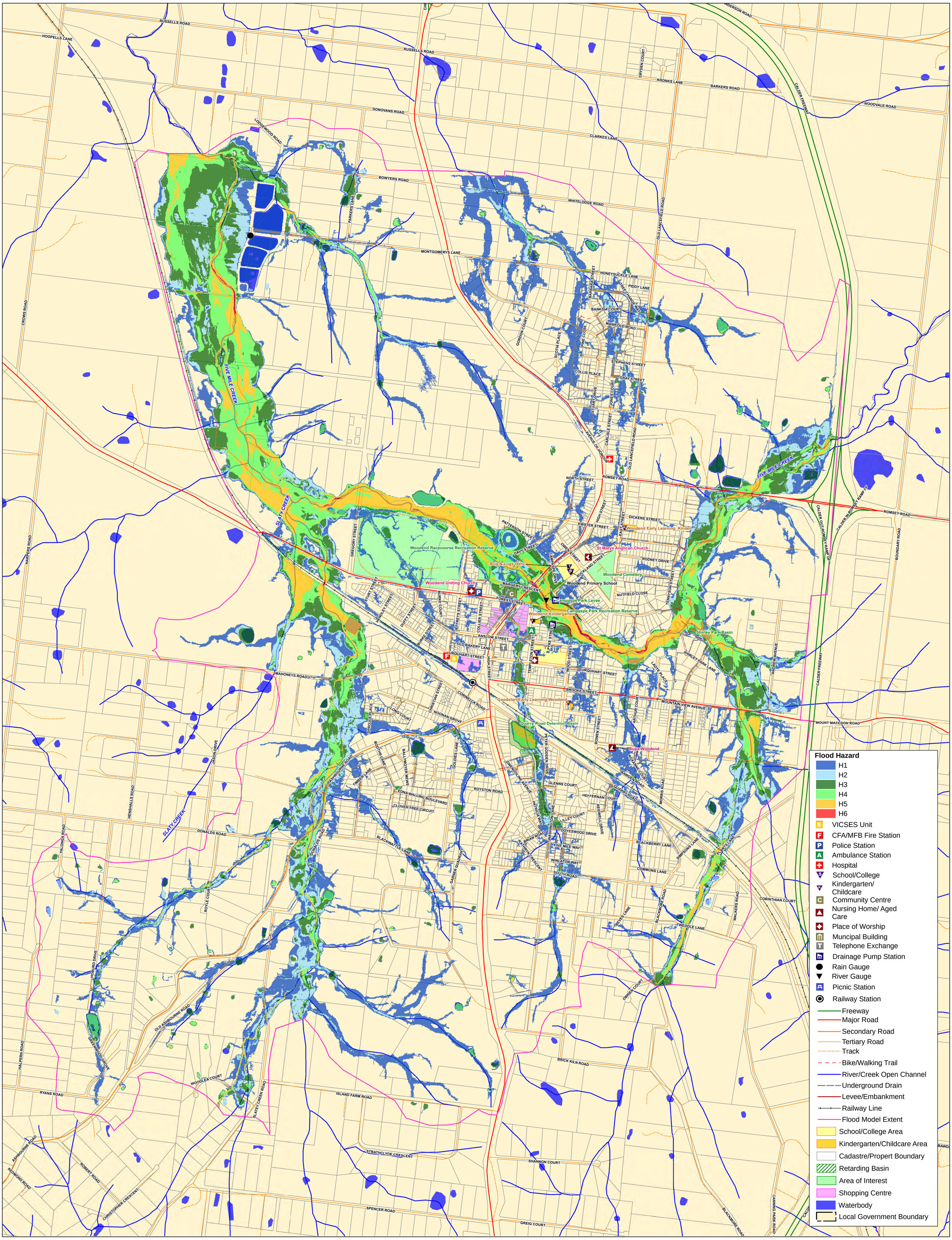
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0.1% AEP Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

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metres

Scale 1:10,000

0.1% AEP Flood Hazard

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

5% AEP Climate Change Flood Extent

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
Freeway
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary

5% AEP Climate Change Flood Depth

Woodend Flood Study

Flood Depth (m)
- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

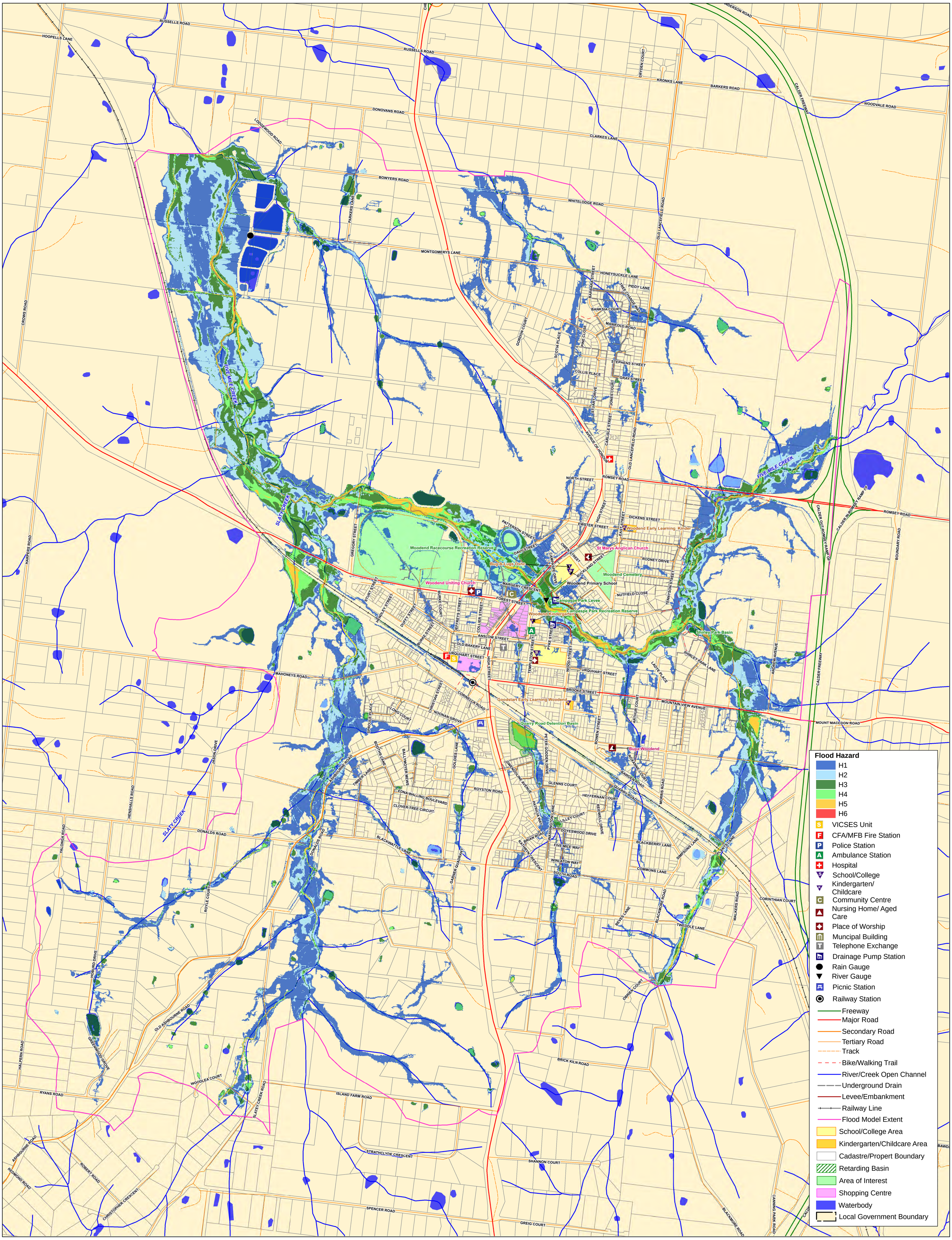
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metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

5% AEP Climate Change Flood Hazard

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

1% AEP Climate Change Flood Extent

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

1% AEP Climate Change Flood Depth

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

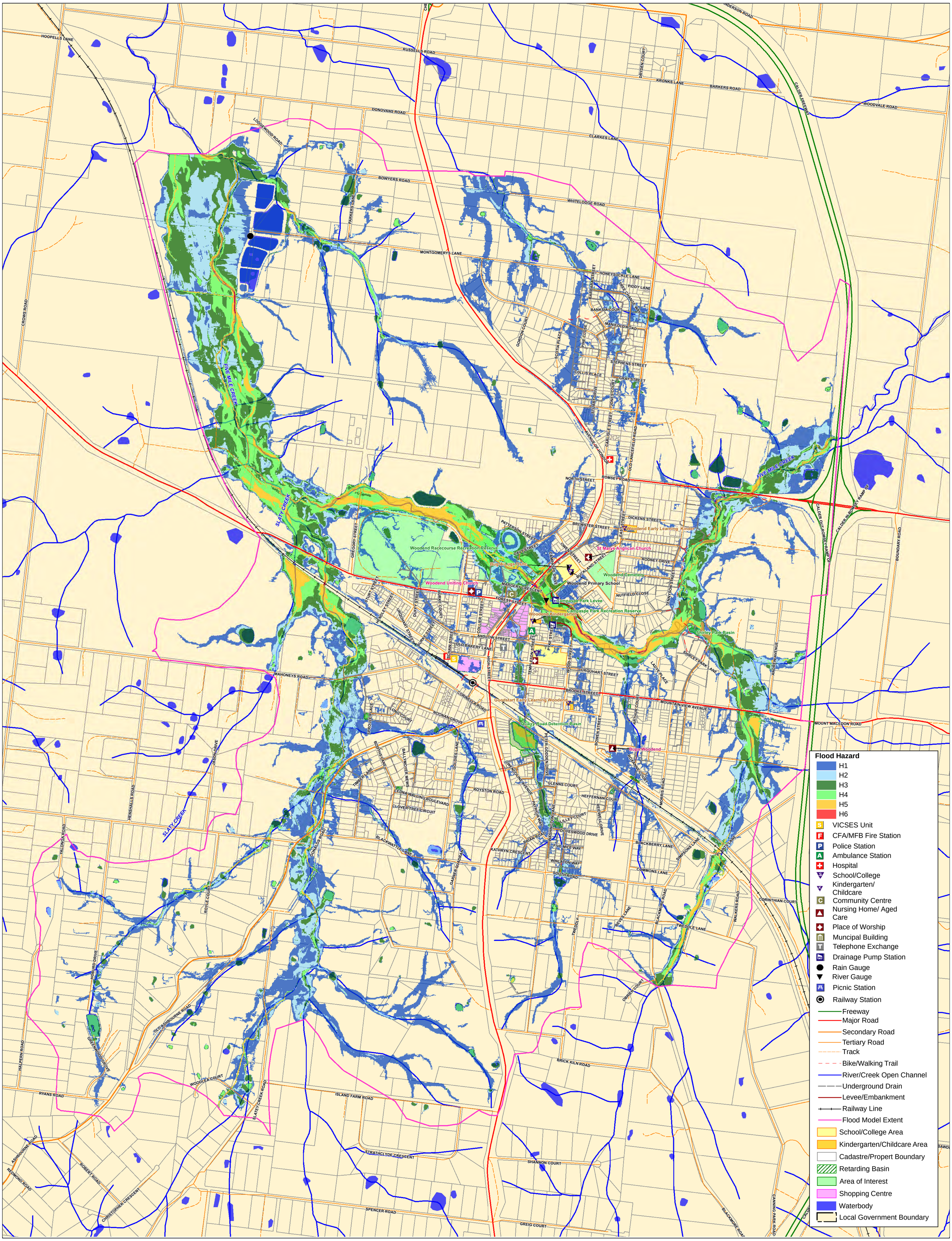
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Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

Flood Depth (m)

- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

1% AEP Climate Change Flood Hazard

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

0.1% AEP Climate Change Flood Extent

Woodend Flood Study

N

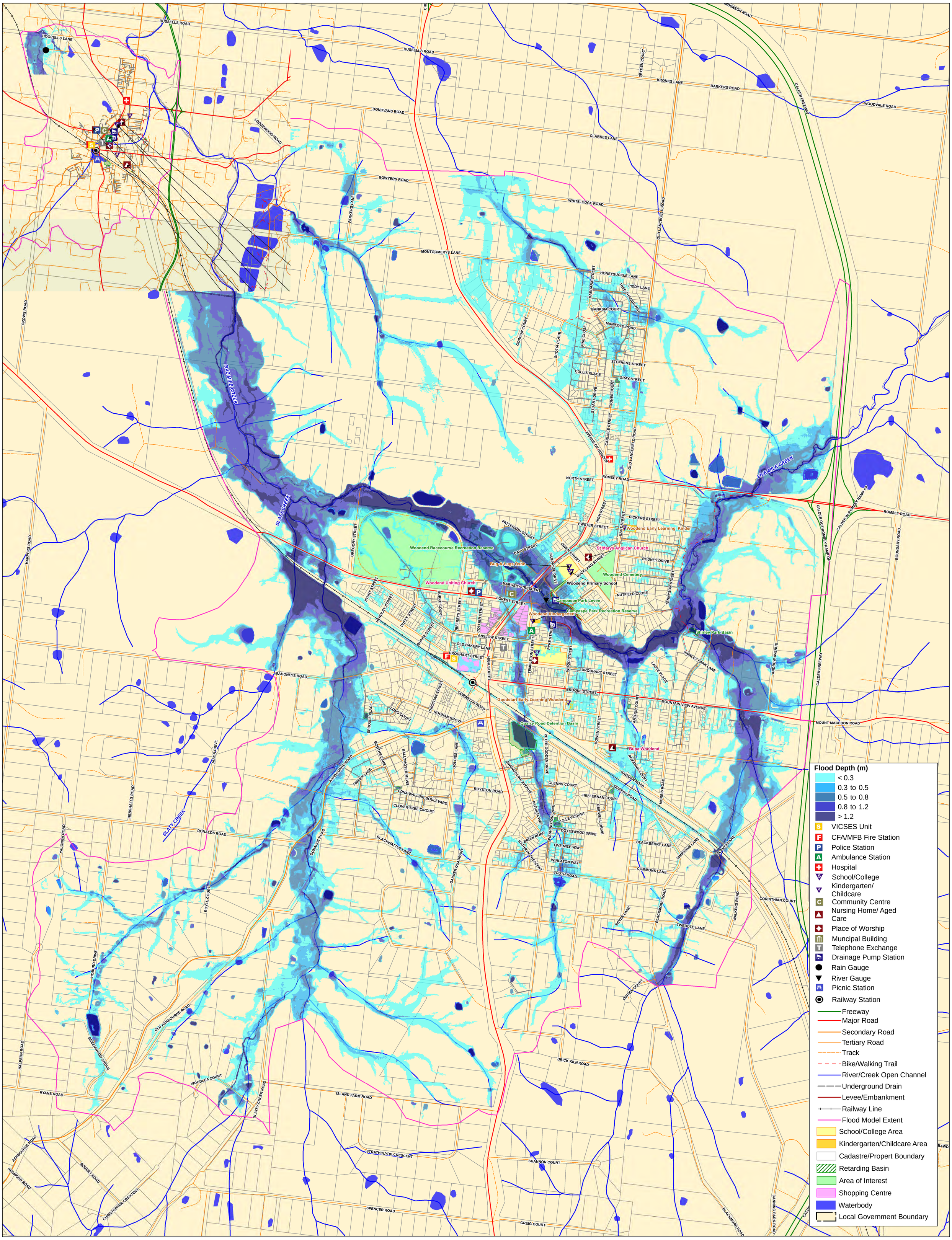
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metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
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Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

0.1% AEP Climate Change Flood Depth

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

0.1% AEP Climate Change Flood Hazard

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary



SES

North Central CMA

Macedon Ranges Shire Council

N

0 800

metres

Scale 1:10,000

5% AEP Fully Developed Flood Extent

Woodend Flood Study

Cardno

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor

5% AEP Fully Developed Flood Depth

Woodend Flood Study

Flood Depth (m)
- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
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- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

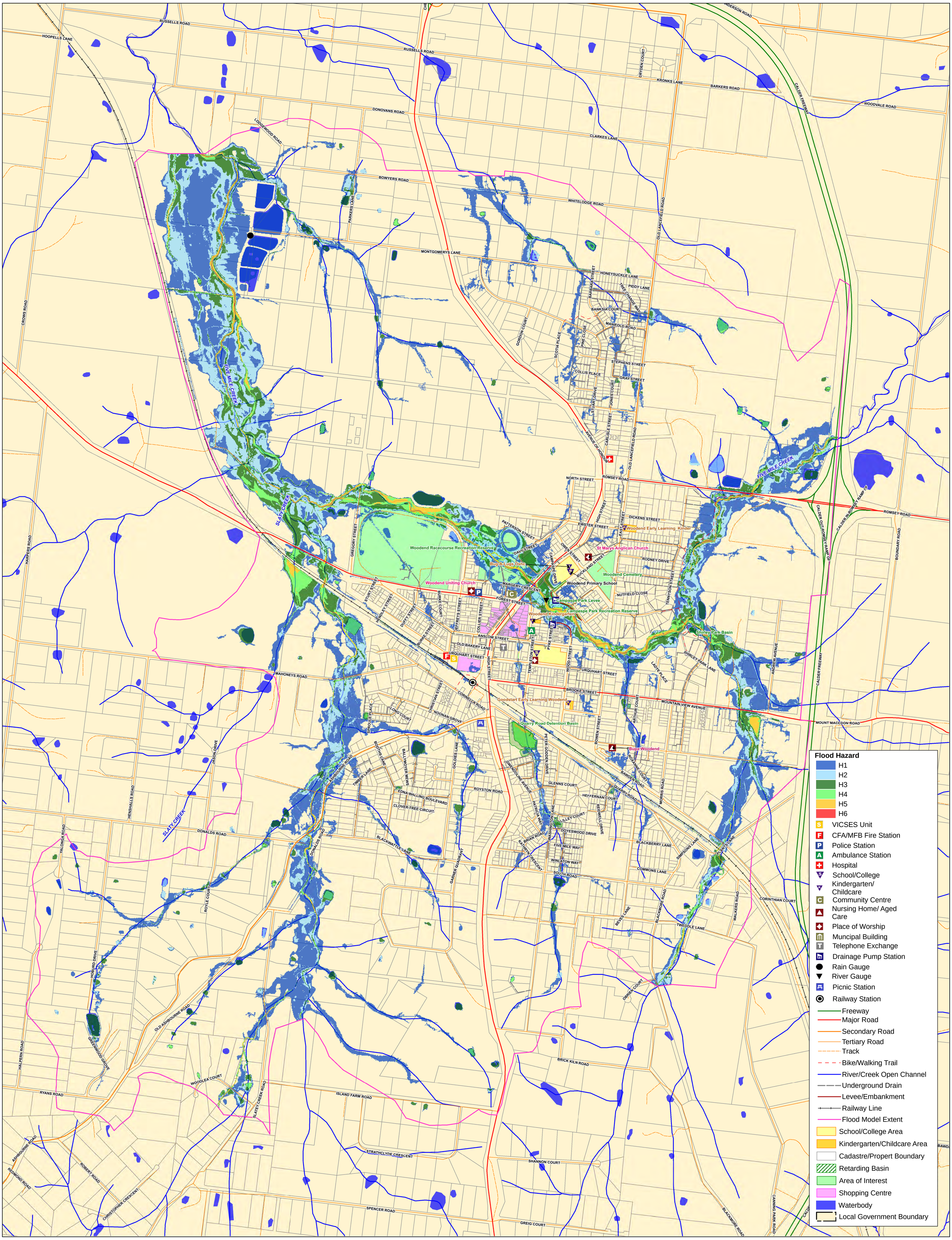
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0 800

metres

Scale 1:10,000

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Project:AWE200155
Map: 5_AEP_FloodMap.wor



5% AEP Fully Developed Flood Hazard

Woodend Flood Study

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 5_AEP_FloodMap.wor

1% AEP Fully Developed Flood Extent

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
Freeway
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary

1% AEP Fully Developed Flood Depth

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

Flood Depth (m)

- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
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- River Gauge
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- Railway Station
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- Secondary Road
- Tertiary Road
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- River/Creek Open Channel
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- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

1% AEP Fully Developed Flood Hazard

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 1_AEP_FloodMap.wor

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

0.1% AEP Fully Developed Flood Extent

Woodend Flood Study

North Central CMA

Macedon Ranges Shire Council

SES

Cardno

N

0 800

metres

Scale 1:10,000

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

Flood Extent
2011 Flood Extent
VICSES Unit
CFA/MFB Fire Station
Police Station
Ambulance Station
Hospital
School/College
Kindergarten/ Childcare
Community Centre
Nursing Home/ Aged Care
Place of Worship
Muncipal Building
Telephone Exchange
Drainage Pump Station
Rain Gauge
River Gauge
Picnic Station
Railway Station
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Underground Drain
Levee/Embankment
Railway Line
Flood Model Extent
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary

0.1% AEP Fully Developed Flood Depth

Woodend Flood Study

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

N

0 800

metres

Scale 1:10,000

Flood Depth (m)

- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
- River Gauge
- Picnic Station
- Railway Station
- Freeway
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

0.1% AEP Fully Developed Flood Hazard

Woodend Flood Study

Map Produced by W&E
Date: 26/04/2021
Coordinate System: MGA Zone55
Project:AWE200155
Map: 0_1_AEP_FloodMap.wor

N

0 800

metres

Scale 1:10,000

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6
- VICSES Unit
- CFA/MFB Fire Station
- Police Station
- Ambulance Station
- Hospital
- School/College
- Kindergarten/ Childcare
- Community Centre
- Nursing Home/ Aged Care
- Place of Worship
- Muncipal Building
- Telephone Exchange
- Drainage Pump Station
- Rain Gauge
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- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- Railway Line
- Flood Model Extent
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

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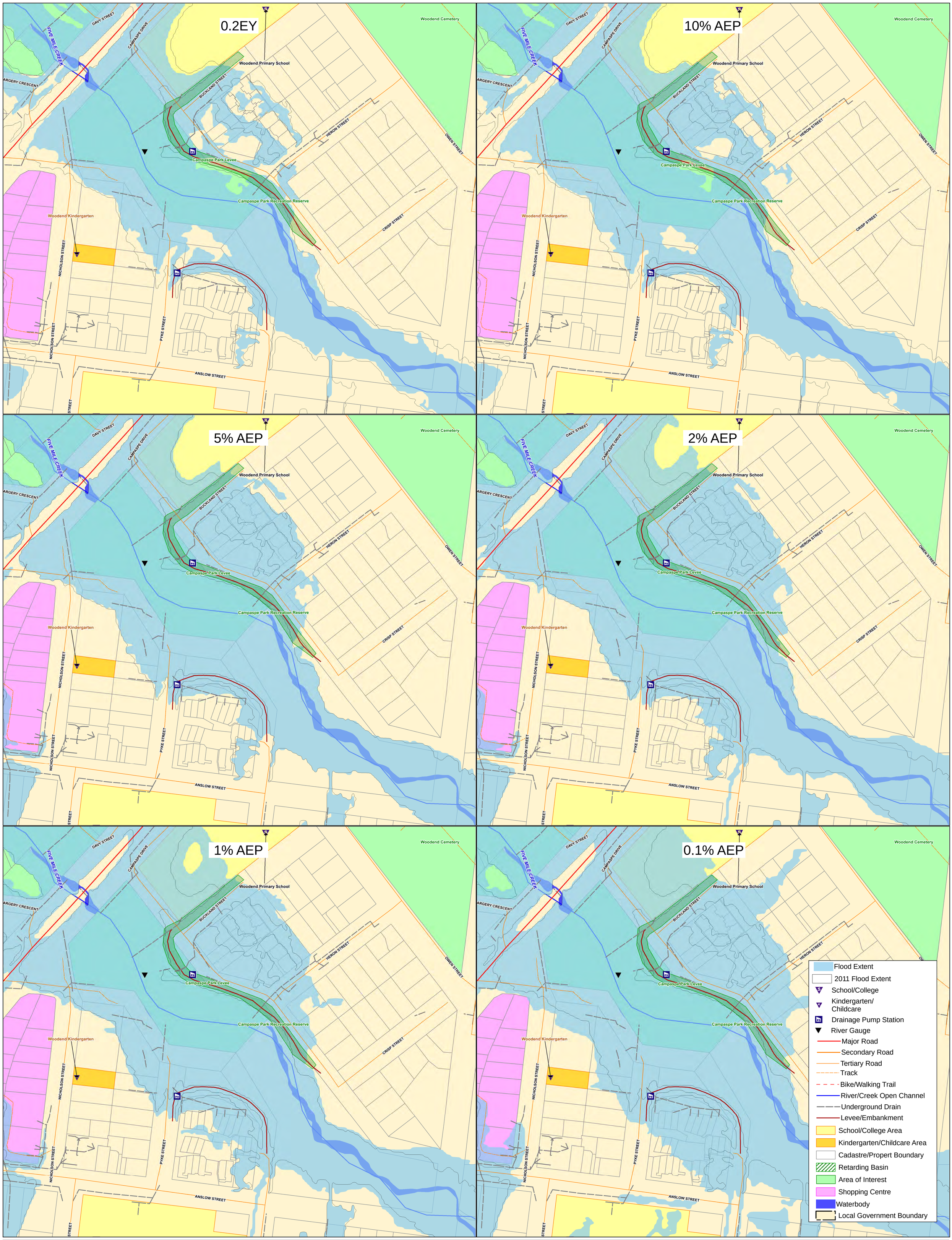
10% AEP

5% AEP

2% AEP

1% AEP

0.1% AEP



N

0 200

meters

Scale 1:2,001

Levee Failure Flood Extent

Woodend Flood Study

Map Produced by W&E
Date: 27/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:10AEP_FloodMap.wor

0.2EY

10% AEP

5% AEP

2% AEP

1% AEP

0.1% AEP

Woodend Cemetery
Woodend Primary School
Woodend Kindergarten
Campaspe Park Levee
Campaspe Park Recreation Reserve
FIVE MILE CREEK
DAVY STREET
CAMPASPE DRIVE
ARGERY CRESCENT
BUCKLAND STREET
HERON STREET
OWEN STREET
CRISP STREET
NICHOLSON STREET
PYKE STREET
ANSLOW STREET

Flood Depth (m)
- < 0.3
- 0.3 to 0.5
- 0.5 to 0.8
- 0.8 to 1.2
- > 1.2

School/College
Kindergarten/ Childcare
Drainage Pump Station
River Gauge
Major Road
Secondary Road
Tertiary Road
Track
Bike/Walking Trail
River/Creek Open Channel
Underground Drain
Levee/Embankment
School/College Area
Kindergarten/Childcare Area
Cadastre/Propert Boundary
Retarding Basin
Area of Interest
Shopping Centre
Waterbody
Local Government Boundary

N

0 200

meters

Scale 1:2,000

Levee Failure Flood Depth

Woodend Flood Study

Map Produced by W&E
Date: 27/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:10AEP_FloodMap.wor

0.2EY

10% AEP

5% AEP

2% AEP

1% AEP

0.1% AEP

Woodend Cemetery
Woodend Primary School
Woodend Kindergarten
Campaspe Park Levee
Campaspe Park Recreation Reserve
FIVE MILE CREEK
DAVY STREET
CAMPASPE DRIVE
ARGERY CRESCENT
BUCKLAND STREET
HERON STREET
OWEN STREET
CRISP STREET
NICHOLSON STREET
PYKE STREET
ANSLOW STREET

Flood Hazard
- H1
- H2
- H3
- H4
- H5
- H6
- School/College
- Kindergarten/ Childcare
- Drainage Pump Station
- River Gauge
- Major Road
- Secondary Road
- Tertiary Road
- Track
- Bike/Walking Trail
- River/Creek Open Channel
- Underground Drain
- Levee/Embankment
- School/College Area
- Kindergarten/Childcare Area
- Cadastre/Propert Boundary
- Retarding Basin
- Area of Interest
- Shopping Centre
- Waterbody
- Local Government Boundary

N

0 200

meters

Scale 1:2,000

Levee Failure Flood Hazard

Woodend Flood Study

Map Produced by W&E
Date: 27/10/2020
Coordinate System: MGA Zone55
Project:AWE200155
Map:10AEP_FloodMap.wor

Appendix G *Floor Level Survey*

MACEDON RANGES SHIRE - WOODEND FLOOD STUDY

Surveyor:	Chris White
Date of Survey (Completed):	17/09/2020
Datum Information:	GDA2020
	Zone 55
AHD Datum:	GNSS Derrived (AUSGeoid2020)
Permanent Mark Connections:	WOODEND PM 66 (387200660) 550.393m AHD
	WOODEND PM 126 (387201260) 557.799m AHD
Notes:	All horizonatal co-ordinates are approximate values only.
	All Reduced Floor Levels have been measured from GNSS observed TBM's. (±0.050m)

No.	Plan_Zone	Address	Eastin	Northin	Floor Level (AHD	Additional Notes
1	Residential	125 HIGH ST, WOODEND VIC 3442	281340	5863115	551.16	
2	Residential	16 DAVY ST, WOODEND VIC 3442	281354	5863256	553.57	
3	Conservation/National Park	1 DAVY ST, WOODEND VIC 3442	281226	5863268	551.88	
4	Conservation/National Park	1 DAVY ST, WOODEND VIC 3442	281147	5863170	550.97	
5	Residential	1 PETER GODDEN DR, WOODEND VIC 3442	281305	5861811	563.87	
6	Residential	13 PETER GODDEN DR, WOODEND VIC 3442	281309	5861939	561.87	
7	Residential	15 PETER GODDEN DR, WOODEND VIC 3442	281321	5861957	561.91	
8	Residential	17 PETER GODDEN DR, WOODEND VIC 3442	281318	5861980	562.03	
9	Residential	28 GOLDIES LANE, WOODEND VIC 3442	280856	5861470	581.40	
10	Residential	8 ARTHUR CT, WOODEND VIC 3442	281852	5862203	561.07	
11	Residential	UNIT 2 1941 MOUNT MACEDON RD, WOODEND VIC 3442	281807	5862146	561.43	UNIT 2
			281807	5862167	561.14	HOUSE REAR
			281803	5862197	561.44	HOUSE FRONT
12	Residential	40 ASHBOURNE RD, WOODEND VIC 3442	280121	5861834	550.70	
13	Residential	2 NOONAN GR, WOODEND VIC 3442	280709	5862111	560.20	ADDRESS WRONG - 9b ASHBOURNE ROAD
14	Residential	28 BOOTHS LANE, WOODEND VIC 3442	280356	5861562	564.49	
15	Residential	2 BANKSIA CT, WOODEND VIC 3442	281701	5864679	564.95	
16	Residential	8 TREE CHANGE WAY, WOODEND VIC 3442	281865	5864625	566.59	
17	Residential	45 OLD LANCEFIELD RD, WOODEND VIC 3442	281939	5864582	567.73	
18	Residential	12 TREE CHANGE WAY, WOODEND VIC 3442	281869	5864651	566.63	
19	Residential	49 OLD LANCEFIELD RD, WOODEND VIC 3442	281942	5864615	567.58	
20	Residential	4 BANKSIA CT, WOODEND VIC 3442	281733	5864678	564.91	
21	Residential	25 TREE CHANGE WAY, WOODEND VIC 3442	281720	5864745	564.72	
22	Residential	3 BANKSIA CT, WOODEND VIC 3442	281718	5864676	564.91	
23	Residential	47 OLD LANCEFIELD RD, WOODEND VIC 3442	281939	5864598	567.43	
24	Residential	40 WASHINGTON LANE, WOODEND VIC 3442	281355	5861547	567.25	
25	Residential	32 WASHINGTON LANE, WOODEND VIC 3442	281361	5861623	566.69	
26	Residential	40 WASHINGTON LANE, WOODEND VIC 3442				NO ACCESS TO REAR OF ADDRESS
27	Residential	2 PATRICIA WAY, WOODEND VIC 3442	281300	5861639	567.15	
28	Residential	16 PATRICIA WAY, WOODEND VIC 3442	281331	5861747	564.68	
29	Residential	36 WASHINGTON LANE, WOODEND VIC 3442	281353	5861586	567.23	
30	Residential	38 WASHINGTON LANE, WOODEND VIC 3442	281351	5861572	567.24	
31	Residential	2 SULLIVANS RD, WOODEND VIC 3442	281750	5861958	564.64	BUPA AGED CARE - FLOOR LEVEL AT FOYER ONLY
32	Residential	UNIT 2 3 HERON ST, WOODEND VIC 3442	281505	5862919	552.00	
33	Residential	5 HERON ST, WOODEND VIC 3442	281538	5862926	552.40	
34	Residential	6 BUCKLAND ST, WOODEND VIC 3442	281481	5862993	552.03	
35	Residential	UNIT 2 2-4 BUCKLAND ST, WOODEND VIC 3442	281478	5862957	552.02	
36	Residential	UNIT 1 2-4 BUCKLAND ST, WOODEND VIC 3442	281468	5862970	552.00	
37	Residential	4 CAMPASPE DR, WOODEND VIC 3442	281437	5862920	552.21	ADRESS WRONG - 3a/3b CAMPASPE DR
38	Residential	1 HERON ST, WOODEND VIC 3442	281503	5862897	552.46	
39	Residential	UNIT 3 3 HERON ST, WOODEND VIC 3442	281495	5862933	551.98	
40	Residential	5 CAMPASPE DR, WOODEND VIC 3442	281473	5862923	551.41	SHED
41	Residential	UNIT 6 2-4 BUCKLAND ST, WOODEND VIC 3442	281465	5862947	552.01	
42	Residential	UNIT 3 3 HERON ST, WOODEND VIC 3442	281522	5862907	552.17	
43	Residential	UNIT 3 2-4 BUCKLAND ST, WOODEND VIC 3442	281483	5862951	552.00	
44	Residential	UNIT 6 2-4 BUCKLAND ST, WOODEND VIC 3442	281455	5862960	552.01	
45	Residential	1 CAMPASPE DR, WOODEND VIC 3442	281421	5862941	552.20	
46	Residential	5 CAMPASPE DR, WOODEND VIC 3442	281471	5862898	552.10	
47	Residential	UNIT 3 2-4 BUCKLAND ST, WOODEND VIC 3442	281470	5862941	552.02	
48	Community Use	47 FOREST ST, WOODEND VIC 3442	281022	5862930	553.38	
49	Community Use	1 MARGERY CR, WOODEND VIC 3442	281162	5862956	550.72	NO BUILDING (NATURAL SURFACE RL)
50	Community Use	49 FOREST ST, WOODEND VIC 3442	281042	5862926	553.07	
51	Community Use	117 HIGH ST, WOODEND VIC 3442	281144	5862928	551.32	
52	Commercial/Business	43 ANSLOW ST, WOODEND VIC 3442	281143	5862760	553.18	
53	Commercial/Business	UNIT 2 48 ANSLOW ST, WOODEND VIC 3442	281148	5862603	555.34	
54	Commercial/Business	44 URQUHART ST, WOODEND VIC 3442	281178	5862491	556.03	
55	Commercial/Business	7 TEMPLETON ST, WOODEND VIC 3442	281209	5862420	556.56	
56	Commercial/Business	11 BROOKE ST, WOODEND VIC 3442	281166	5862424	556.69	
57	Commercial/Business	11 TEMPLETON ST, WOODEND VIC 3442	281211	5862458	557.10	
58	Commercial/Business	42 URQUHART ST, WOODEND VIC 3442	281153	5862512	555.92	
59	Residential	3 FERN CT, WOODEND VIC 3442	281748	5864467	567.69	
60	Residential	5 ADAM CL, WOODEND VIC 3442	281782	5864414	568.57	
61	Residential	6 ADAM CL, WOODEND VIC 3442	281805	5864408	569.57	
62	Residential	2 FERN CT, WOODEND VIC 3442	281767	5864458	567.54	SHED
63	Residential	2 FERN CT, WOODEND VIC 3442	281769	5864474	567.65	
64	Industrial/Utilities	FCTY 2 30 BROOKE ST, WOODEND VIC 3442	281564	5862320	559.54	
65	Industrial/Utilities	30 WOOD ST, WOODEND VIC 3442	281504	5862548	555.12	
66	Industrial/Utilities	37 BOWEN ST, WOODEND VIC 3442	281610	5862548	555.59	
67	Residential	2 WINLATON WAY, WOODEND VIC 3442	281452	5861316	572.10	
68	Residential	BROOKE STREET MEDICAL CENTRE 12-14 BROOKE ST, WOODEND VIC 3442	281202	5862337	557.32	
69	Residential	BROOKE STREET MEDICAL CENTRE 12-14 BROOKE ST, WOODEND VIC 3442	281187	5862365	557.29	
70	Residential	8 BANKSIA CT, WOODEND VIC 3442	281775	5864619	566.01	
			281763	5864624	565.32	SHED AT SAME ADDRESS
71	Residential	21 OLD LANCEFIELD RD, WOODEND VIC 3442	281849	5864009	574.58	
72	Residential	15 SAMUEL CT, WOODEND VIC 3442	281971	5862844	570.80	
73	Residential	UNIT 3 11 PYKE ST, WOODEND VIC 3442	281344	5862766	552.30	
74	Residential	14 NICHOLSON ST, WOODEND VIC 3442	281333	5862854	551.25	BBQ AREA
75	Recreational/Open Space	142 HIGH ST, WOODEND VIC 3442	281263	5862903	551.54	LAWN BOWLS CLUB
76	Commercial/Business	UNIT 2 115 HIGH ST, WOODEND VIC 3442	281122	5862870	552.17	
77	Residential	15 ANSLOW ST, WOODEND VIC 3442	280641	5862833	554.51	
78	Industrial/Utilities	28 BROOKE ST, WOODEND VIC 3442	281523	5862302	559.54	
79	Residential	2 GWENDOLINE AV, WOODEND VIC 3442	281154	5861869	567.29	
80	Residential	20 NOONAN GR, WOODEND VIC 3442	280480	5862269	560.20	
81	Flood Level on Five Mile Creek	142 HIGH ST, WOODEND VIC 3442 (UNDER BRIDGE)	281282	5862974	548.81	**Zero** High Water Level on Gauge