



**Macedon  
Ranges**  
Shire Council

# **ATTACHMENTS**

**Council Meeting  
Under Separate Cover**

**Wednesday, 28 May 2025**





---

## Table of Contents

---

PE.1	Revised Flood Risk Mapping - Request for Ministerial Planning Scheme Amendment	
	Attachment 1 Attachment 1 - Studies for Noting .....	4
PE.3	Consideration of a Planning Panel - Combined Planning Scheme Amendment C147MACR and Planning Permit Application PLN/2022/354 - Benetas Retirement Village	
	Attachment 3 Attachment 3 - Combined Submissions - Redacted.....	513
COR.3	2024 Macedon Ranges Shire Council General Election Report	
	Attachment 1 Macedon Ranges Shire Council - LG24 Election Report .....	550

## Attachment 1 – Flood Studies for Noting

### Updated studies

<ul style="list-style-type: none"><li>Lauriston, Malmsbury and Tylden Rapid Flood Risk Assessment - Climate Change Addendum 2025</li></ul>	Page 2
<ul style="list-style-type: none"><li>Kyneton Flood Study - Climate Change Addendum 2024</li></ul>	Page 11
<h3>Existing studies</h3>	
<ul style="list-style-type: none"><li>Kyneton Flood Study 2019</li></ul>	Page 26
<ul style="list-style-type: none"><li>Rapid Risk Assessment – North Central CMA Region – Malmsbury - 2020</li></ul>	Page 237
<ul style="list-style-type: none"><li>Rapid Risk Assessment – North Central CMA Region – Lauriston – 2020</li></ul>	Page 330
<ul style="list-style-type: none"><li>Rapid Risk Assessment – North Central CMA Region – Tylden - 2020</li></ul>	Page 422

# Lauriston, Malmesbury and Tylden Rapid Flood Risk Assessment

## Climate Change Addendum 2025



North  
Central  
CMA

Connecting rivers, landscapes, people

[www.nccma.vic.gov.au](http://www.nccma.vic.gov.au)



## Acknowledgment of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

Document name: Lauriston, Malmesbury and Tylden Rapid Flood Risk Assessment – Climate Change Addendum 2025  
Front cover photo: Malmesbury Viaduct over the Coliban River during the September 2016 flood.

© North Central Catchment Management Authority, 2025

North Central Catchment Management Authority  
628-634 Midland Highway, Huntly  
PO Box 18, Huntly Victoria 3551  
Telephone 03 5448 7124  
Facsimile 03 5448 7148  
Email [info@nccma.vic.gov.au](mailto:info@nccma.vic.gov.au)

This publication may be of assistance to you, but the North Central Catchment Management Authority and its employees do not guarantee that the publication is without flaw of any kind, or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on information in this publication.

## 1. Introduction

This report details the methodology used to revise the existing flood mapping for Lauriston, Malmsbury and Tylden to incorporate the impacts of climate change in accordance with the recent update to Australian Rainfall and Runoff 2019 Version 4.2 (ARR2019). The climate change scenario adopted for this update is shared socio-economic pathway 5-8.5 (SSP5-8.5) based on a planning horizon of 2100 for the 1% AEP design flood event. The report also recommends updates to the planning scheme overlays in these townships based on the updated climate change flood extents. This report should be read in conjunction with the Lauriston Rapid Flood Risk Assessment 2020 (HARC), Malmsbury Rapid Flood Risk Assessment 2020 (HARC) and Tylden Rapid Flood Risk Assessment 2020 (HARC).

## 2. Background

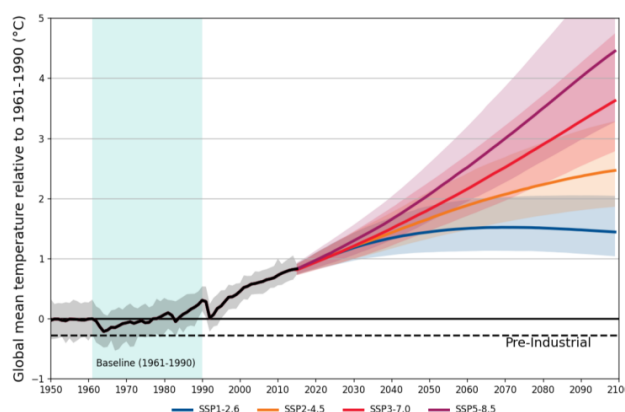
In August 2024, updates were introduced to Book 1, Chapter 6 of ARR2019 to reflect current climate science, which has significantly changed the parameters used to consider the effects of climate change in flood estimation. The general methodology to incorporate consideration of climate change remains the same, with the increase in design rainfall intensity and catchment losses scaled proportionally to global surface temperature. The equation used to calculate the projected design rainfall intensity is shown below.

$$I_p = I \times \left(1 + \frac{\alpha}{100}\right)^{\Delta T}$$

Where,

- $I_p$  is the projected (current or future) design rainfall depth (mm) or intensity (mm/hr).
- $I$  is the historical design rainfall depth (mm) or intensity (mm/hr).
- $\alpha$  is the rate of change relative to global temperature change (%/°C).
- $\Delta T$  is the most up-to-date estimate of global temperature projection for the design period of interest and selected climate scenario relative to a baseline time period.

In determining the projected global temperature increase, ARR2019 presents four potential climate scenarios based on shared socioeconomic pathways (SSP). These pathways range from low emissions scenarios (SSP1-1.9) to very high emissions scenarios (SSP5-8.5) as shown in Figure 1, with SSP5-8.5 resulting in the highest projected temperature increase. The overall temperature increase is dependent on the SSP adopted and the planning horizon. This climate change analysis adopted climate scenario SSP5-8.5 relative to a planning horizon of 2100, resulting in a 4.5°C increase in global temperature. This is relative to a baseline global average temperature recorded between 1961-1990. This baseline period is recommended by ARR2019 as the best estimate of the midpoint of the historical rainfall data period used in estimating the Intensity-Frequency-Duration (IFD) curves developed by the Bureau of Meteorology in 2016 for design flood estimation.



**Figure 1 – Projected global temperature increases associated with each SSP relative to 1961-1990 baseline time period (ARR2019, Book 1 Chapter 6, Figure 1.6.2)**

### 3. Climate Change Analysis

The Rapid Flood Risk Assessments for the townships of Lauriston, Malmsbury and Tylden were completed in 2020, prior to the recent release of the updated ARR2019 climate change guidelines in August 2024. The climate change analysis undertaken for those assessments was based on the advice from the previous version of ARR2019 applicable at the time. This utilised climate scenarios based on representative concentration pathways (RCP) which have now been replaced by SSPs in the latest version of ARR2019. It is important to note that the SSPs yield significantly greater increases in rainfall intensity than the now superseded RCPs as shown in Table 1. In this case, where the critical storm durations for the three townships are 24 hours or longer, the rainfall increase under the updated ARR2019 recommendations are more than double what was previously considered. However, ARR2019 Version 4.2 now also provides recommendations for increasing catchment losses as the warmer temperatures lead to drier catchments, partially offsetting the increase in rainfall intensity.

**Table 1 – Comparison of climate change parameters under the previous (Version 4.1) and updated (Version 4.2) versions of ARR2019**

Climate Scenarios		Rainfall Increase (%)	Initial Loss Increase (%)	Continuing Loss Increase (%)
ARR2019 Version 4.1	RCP8.5, 2090	20.2	0	0
ARR2019 Version 4.2	SSP5-8.5, 2100, 24 hour storm duration	41.0	15	34

The following analysis adopted the RORB models developed for Lauriston, Malmsbury and Tylden during the Rapid Flood Risk Assessment 2020 study. Subarea delineation, RORB modelling parameters, fraction impervious data, spatial distribution, storm duration and temporal pattern all remained unchanged for this climate change analysis. However, the rainfall intensity and catchment losses were scaled up based on the values in Table 1 in accordance with the recommendations of ARR2019.

The peak flows generated by the RORB model for the SSP5-8.5 2100 climate change scenario were then compared to the design event peak flows determined in the original study to estimate the increase in flood level and associate flood extent. This was undertaken using an indicative rating curves presented in Section 8 of each of the Rapid Flood Risk Assessments to correlate peak flow with flood level. The results for each township are shown in Table 2.

**Table 2 – Comparison of peak flows and corresponding flood level increases of various design events for each township**

		Design Events		
		1% AEP	0.5% AEP	1% AEP Climate Change Scenario (SSP5-8.5, 2100)
Lauriston	Peak Flow (m3/s)	216.4	261.0	353.2
	Increase in flood level compared to 2020 Study 1% AEP level (m)	-	0.3	0.9
Malmsbury	Peak Flow (m3/s)	228.4	275.9	288.9
	Increase in flood level compared to 2020 Study 1% AEP level (m)	-	0.25	0.3
Tylden	Peak Flow (m3/s)	55.0	64.2	78.8
	Increase in flood level compared to 2020 Study 1% AEP level (m)	-	0.1	0.2

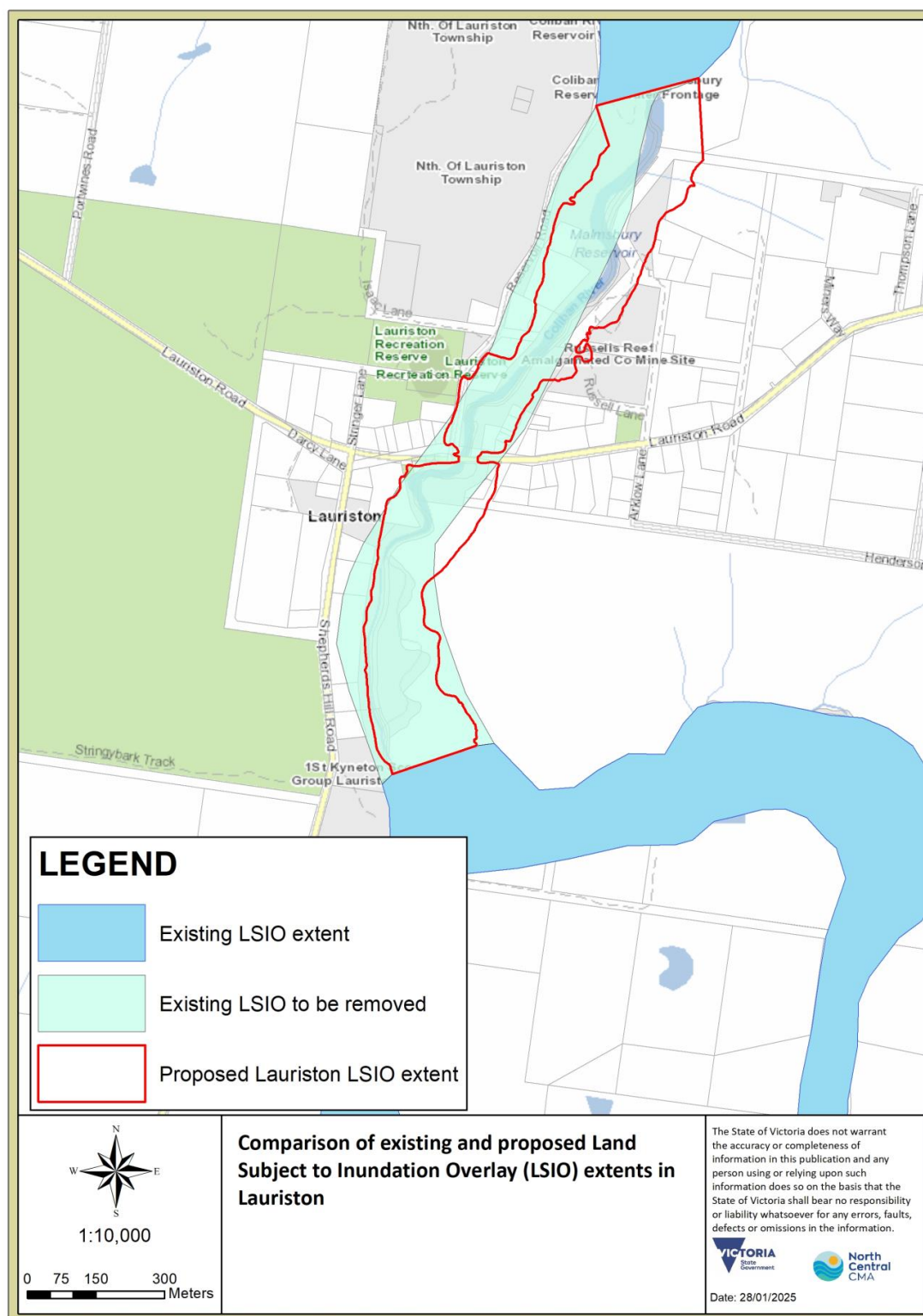
It can be seen from Table 2 that the 1% AEP climate change (SSP5-8.5, 2100) levels for both Malmsbury and Tylden are within approximately 0.1 metres of the 0.5% AEP flood levels. Additionally, due to the steep nature of the topography in the upper catchment, the floodplains for Malmsbury and Tylden are generally confined and well-defined. Consequently, the 1% AEP climate change scenario flood extent for these two towns does not differ significantly from the 0.5% AEP extent, and thus the 0.5% AEP extent has been adopted as a sufficient approximation of the climate change flood extent in these cases. However, in Lauriston the 1% AEP climate change scenario peak flows are considerably greater than the 0.5% AEP flood levels, yielding flood levels that are approximately 0.6 metres higher. Therefore, the applicable climate change flood extent has been produced based on flood levels that are 0.6 metres above the 0.5% AEP flood levels.

## 4. Planning Overlay Recommendations

The results of the modelling and climate change analysis detailed previously have been used to inform proposed updates to the existing flood planning overlays for the townships of Lauriston, Malmsbury and Tylden. The final proposed overlay extents were based on the hydraulic modelling undertaken in the original Rapid Flood Risk Assessment 2020 and refined by smoothing the extents based on a tolerance of 20 metres and isolated areas less than 1000 square metres were removed. Figures 2 to 4 compare the existing and proposed Land Subject to Inundation Overlay extents.

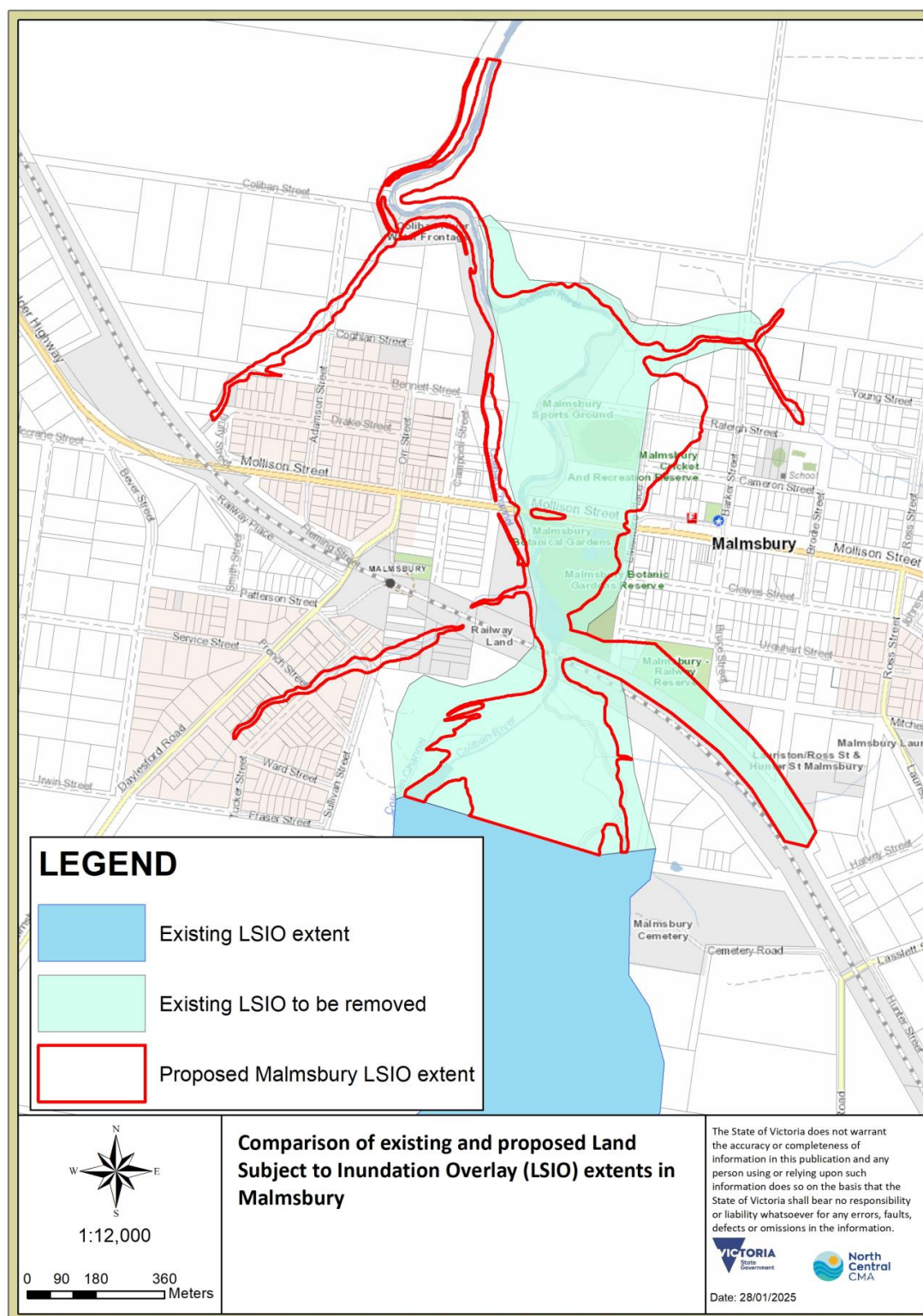
Given the original mapping was developed using a rapid modelling approach, and the subsequent climate change analysis is comparative rather than explicitly modelled, it is recommended that only the Land Subject to Inundation Overlay be applied rather than delineating a more restrictive Floodway Overlay based on areas of higher flood hazard. It is considered that this approach recognises the associated uncertainty while still providing an effective planning tool for ensuring future development is appropriate and resilient in regard to the inherent flood risk. It is also noted that the proposed overlay extent is based on the best available information and is more accurate than the existing Land Subject to Inundation Overlay extents that applies to each of the three townships.



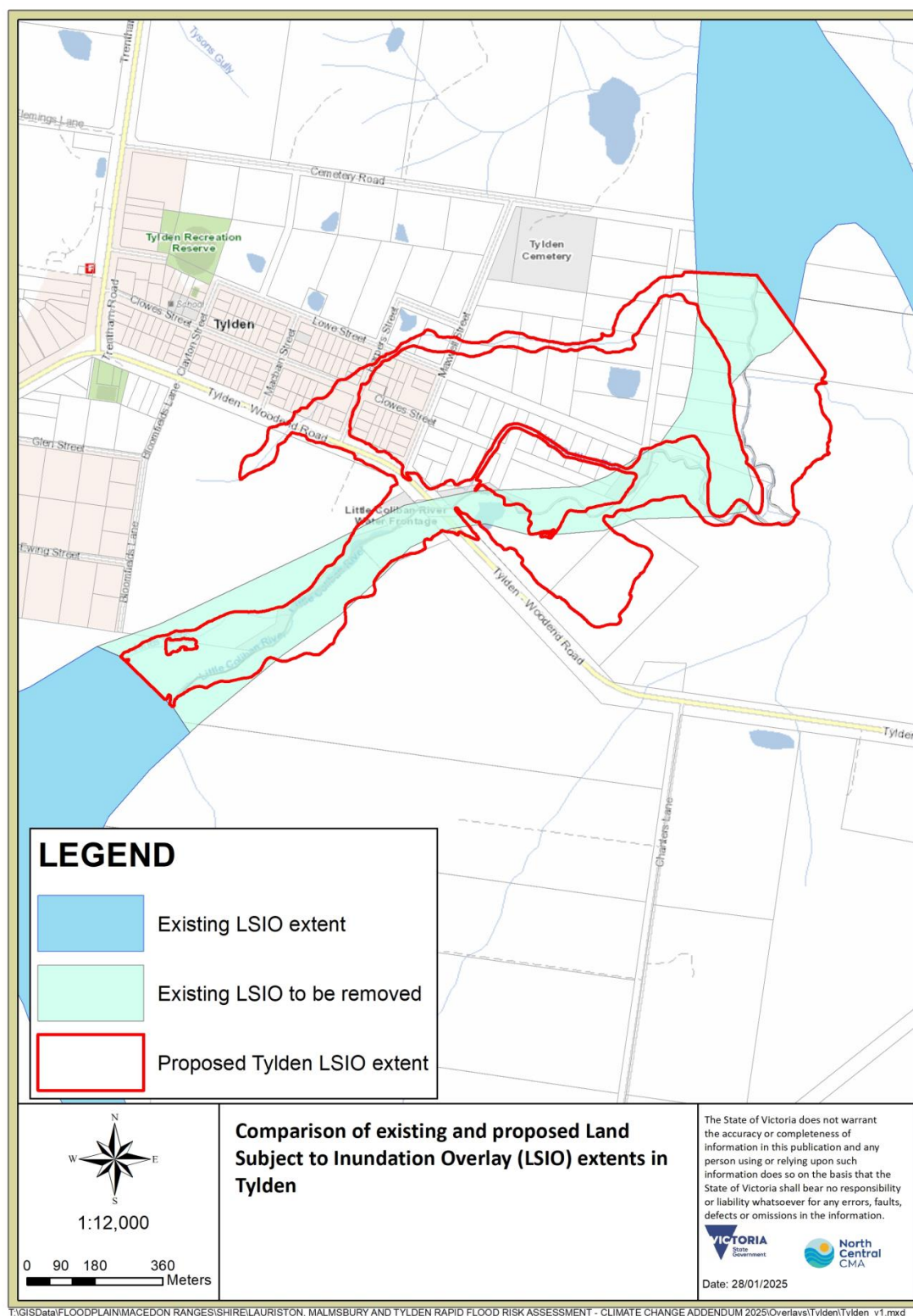


**Figure 2 – Comparison of the existing and proposed Land Subject to Inundation Overlay (LSIO) extents in Lauriston**





**Figure 3 – Comparison of the existing and proposed Land Subject to Inundation Overlay (LSIO) extents in Malsbury**



**Figure 4 – Comparison of the existing and proposed Land Subject to Inundation Overlay (LSIO) extents in Tylden**

## 5. Conclusion

This addendum has documented the methodology used to update the 1% AEP design flood determined by the Lauriston, Malmsbury and Tylden Rapid Flood Risk Assessments (2020) to reflect the recently revised climate change recommendations in ARR2019. It is recommended that these climate change scenario flood extents be used to amend the existing flood planning overlays in Lauriston, Malmsbury and Tylden to ensure future development responds appropriately to flood risk and maintains or improves the flood resilience of existing development.



# Kyneton Flood Study

## Climate Change Addendum 2024



North  
Central  
CMA

Connecting rivers, landscapes, people

[www.nccma.vic.gov.au](http://www.nccma.vic.gov.au)



## Acknowledgment of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

Document name: Kyneton Flood Study – Climate Change Addendum 2024  
Front cover photo: Campaspe River at the Greenway Lane Weir during the September 2016 flood.

© North Central Catchment Management Authority, 2024

North Central Catchment Management Authority  
628-634 Midland Highway, Huntly  
PO Box 18, Huntly Victoria 3551  
Telephone 03 5448 7124  
Facsimile 03 5448 7148  
Email [info@nccma.vic.gov.au](mailto:info@nccma.vic.gov.au)

This publication may be of assistance to you, but the North Central Catchment Management Authority and its employees do not guarantee that the publication is without flaw of any kind, or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on information in this publication.

## 1. Introduction

This report outlines the methodology and results of the modelling update for the Kyneton Flood Study 2019 to incorporate recent climate change recommendations in accordance with Australian Rainfall and Runoff 2019 Version 4.2 (ARR2019). The climate change scenario adopted for this update is shared socio-economic pathway 5-8.5 (SSP5-8.5) based on a planning horizon of 2100 for the 1% AEP design flood event. The report also recommends updates to the planning scheme overlays along the Campaspe River and Post Office Creek based on this updated climate change modelling. Additionally, it is recommended that mapping from a recently completed flood risk assessment for Kyneton Commercial Estate be used to extend the available flood information and controls along Post Office Creek. This report should be read in conjunction with the Kyneton Flood Study 2019 (North Central CMA) and Kyneton Commercial Estate Flood Risk Assessment 2020 (Water Modelling Solutions).

## 2. Background

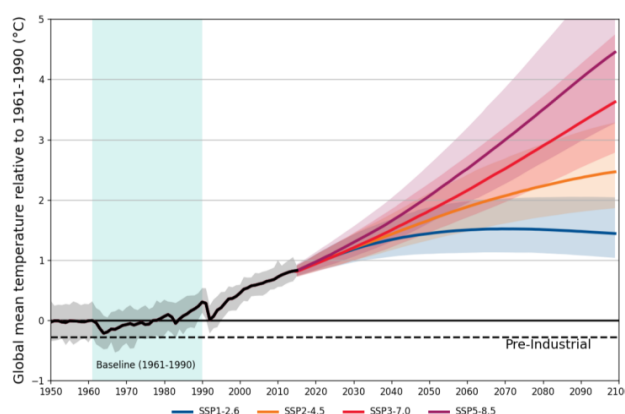
In August 2024, updates were introduced to Book 1, Chapter 6 of ARR2019 to reflect current climate science, which has significantly changed the parameters used to consider the effects of climate change in flood estimation. The general methodology to incorporate consideration of climate change remains the same, with the increase in design rainfall intensity and catchment losses scaled proportionally to global surface temperature. The equation used to calculate the projected design rainfall intensity is shown below.

$$I_p = I \times \left(1 + \frac{\alpha}{100}\right)^{\Delta T}$$

Where,

- $I_p$  is the projected (current or future) design rainfall depth (mm) or intensity (mm/hr).
- $I$  is the historical design rainfall depth (mm) or intensity (mm/hr).
- $\alpha$  is the rate of change relative to global temperature change (%/°C).
- $\Delta T$  is the most up-to-date estimate of global temperature projection for the design period of interest and selected climate scenario relative to a baseline time period.

In determining the projected global temperature increase, ARR2019 presents four potential climate scenarios based on shared socioeconomic pathways (SSP). These pathways range from low emissions scenarios (SSP1-1.9) to very high emissions scenarios (SSP5-8.5) as shown in Figure 1, with SSP5-8.5 resulting in the highest projected temperature increase. The overall temperature increase is dependent on the SSP adopted and the planning horizon. This climate change analysis adopted climate scenario SSP5-8.5 relative to a planning horizon of 2100, resulting in a 4.5°C increase in global temperature. This is relative to a baseline global average temperature recorded between 1961-1990. This baseline period is recommended by ARR2019 as the best estimate of the midpoint of the historical rainfall data period used in estimating the Intensity-Frequency-Duration (IFD) curves developed by the Bureau of Meteorology in 2016 for design flood estimation.



**Figure 1 – Projected global temperature increases associated with each SSP relative to 1961-1990 baseline time period (ARR2019, Book 1 Chapter 6, Figure 1.6.2)**

### 3. Hydrologic Model Update

This study adopted the calibrated RORB models for the Campaspe River and Post Office Creek which were developed by the original Kyneton Flood Study 2019. Subarea delineation, RORB modelling parameters, fraction impervious data, spatial distribution, storm duration and temporal pattern all remained unchanged for this climate change analysis. The rainfall intensity and catchment losses were updated in accordance with the recommendations of ARR2019 as detailed below.

#### 3.1. Rainfall

The most recent ARR2019 climate change recommendations were applied to generate the long-term (2100) rainfall intensities for the SPP5-8.5 climate scenario. Table 1 below illustrates the increase in 1% AEP rainfall intensity relative to the IFD obtained from the Bureau of Meteorology and used in the original 2019 Kyneton Flood Study for both the Campaspe River and Post Office Creek models. It should be noted that the increase in rainfall intensity is dependent on the critical storm duration, with shorter duration predicted to experience greater increases. The critical storm durations for the Campaspe River and Post Office Creek catchments were determined to be 24 hours and 12 hours respectively.

**Table 1 – 1% AEP design rainfall comparison**

	Kyneton Flood Study 2019 - 1% AEP Rainfall (mm)	Climate Change Scenario (SSP5-8.5, 2100) – 1% AEP Rainfall (mm)	Difference (%)
Campaspe River Model	132.5	186.8	41%
Post Office Creek Model	99.5	146.3	47%

#### 3.2. Losses

As temperatures increase with climate change, catchments will dry out. This is reflected in the RORB models by increasing both initial and continuing loss parameters based on the projected global temperature increase. Table 2 shows the design loss increases relative to climate scenario SSP5-8.5 at 2100 as recommended in ARR2019.

**Table 2 – 1% AEP design losses comparison**

		Kyneton Flood Study 2019	Climate Change Scenario (SSP5-8.5, 2100)	Difference (%)
Campaspe River Model	Initial Loss (mm)	31.5	36.2	15%
	Continuing Loss (mm/hr)	1.0	1.33	33%
Post Office Creek Model	Initial Loss (mm)	26.9	30.9	15%
	Continuing Loss (mm/hr)	1.0	1.33	33%

### 3.3. Design Flows

Based on the updated climate change parameters, the 1% AEP peak design flows have increased by 63% and 66% for the Campaspe River and Post Office Creek respectively. It is also noted that the 1% AEP climate change peak flows significantly exceed even the 1 in 200 AEP peak flows determined in the Kyneton Flood Study 2019 which were based on the 2016 Bureau of Meteorology IFD. A comparison of these flows is provided in Table 3.

Table 3 – 1% AEP design flow comparison

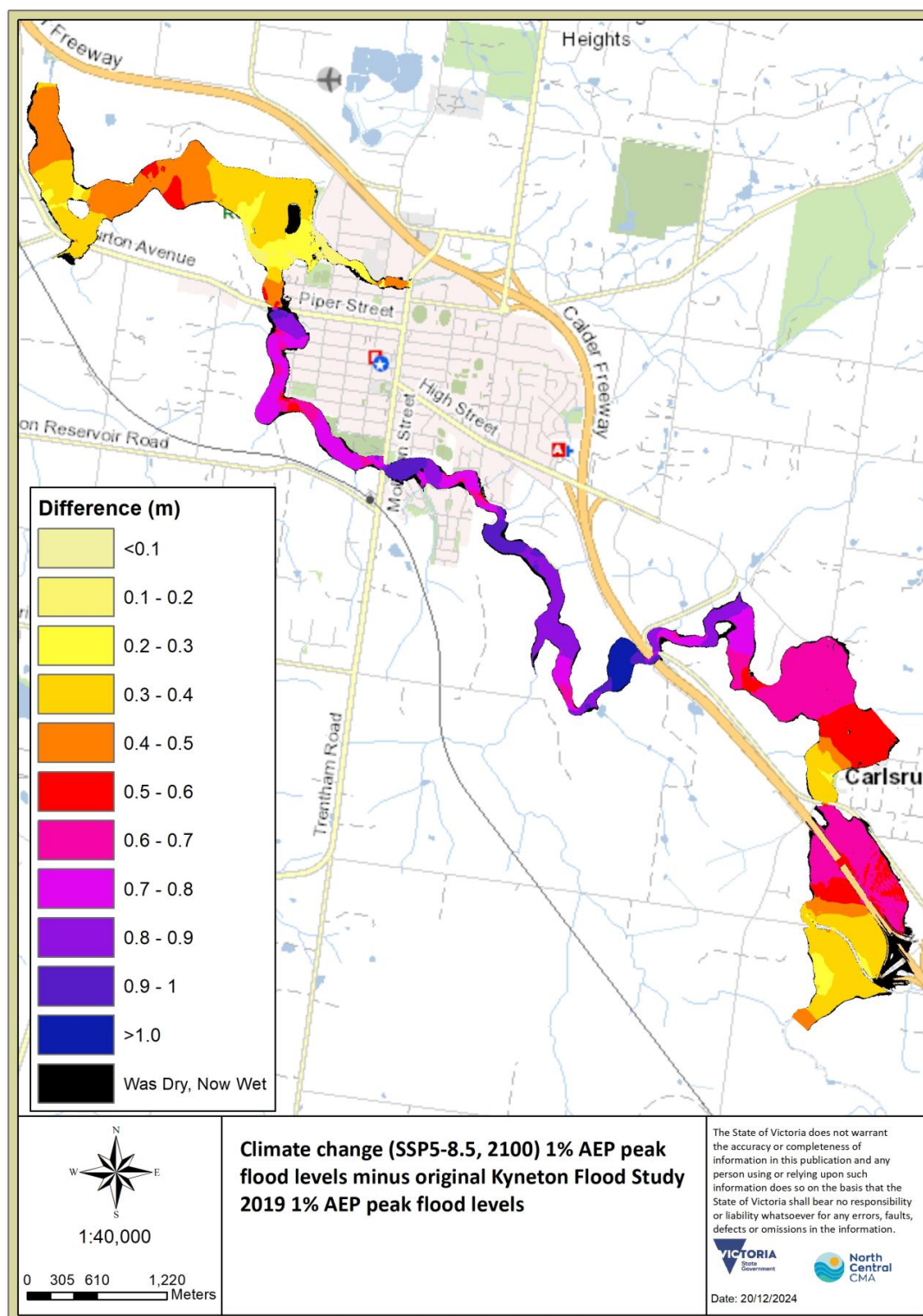
	Kyneton Flood Study 2019 - 1% AEP Peak Flow (m³/s)	Kyneton Flood Study 2019 – 0.5% AEP Peak Flow (m³/s)	Climate Change Scenario (SSP5-8.5, 2100) – 1% AEP Peak Flow (m³/s)	Difference (%)
Campaspe River Model	297.0	364.4	468.8	63%
Post Office Creek Model	44.2	52.3	66.8	66%



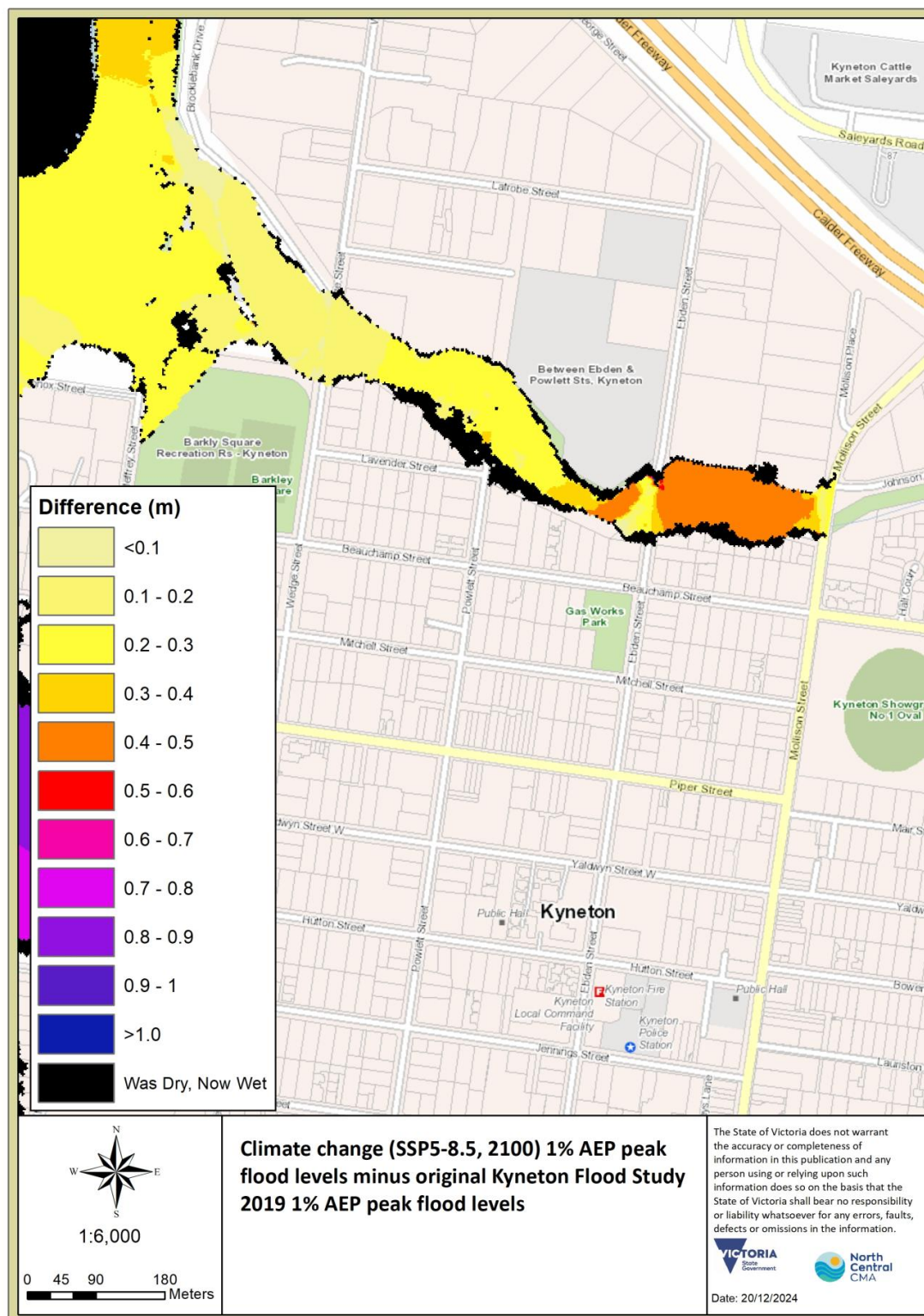
## 5. Hydraulic Model Update

The calibrated TUFLOW model developed by the Kyneton Flood Study 2019 was utilised to produce the climate change scenario modelling. This model covers both the Campaspe River and Post Office Creek study areas. The model parameters such as roughness and outlet boundary conditions remained the same as the original study. However, the model inflows were replaced with the 1% AEP climate change design flows determined by the RORB model as detailed in the previous section. The model outputs generated include flood extents, levels, depths and velocities. These results will be used to update the available flood information for the township of Kyneton.

A comparison of the 1% AEP peak flood levels produced by the Kyneton Flood Study 2019 and the climate change scenario are shown in Figures 2 and 3 below. In general, flood levels along Post Office Creek have increased by up to 0.5 metres while the Campaspe River levels have increased by up to 1.0 metre.



**Figure 2 – Comparison between the 1% AEP peak flood levels for the climate change scenario (SSP5-8.5) and the original Kyneton Flood Study 2019**

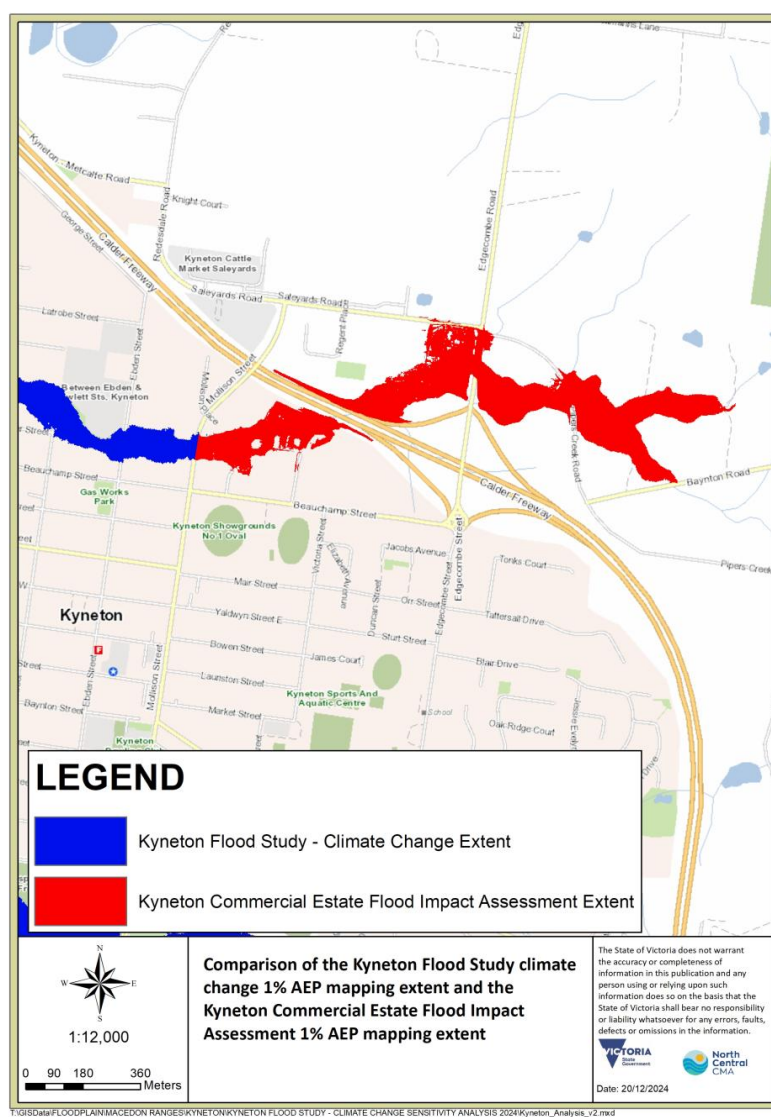


**Figure 3 – Comparison between the 1% AEP peak flood levels for the climate change scenario (SSP5-8.5) and the original Kyneton Flood Study 2019 on Post Office Creek**

## 6. Additional Post Office Creek Flood Mapping

In May 2020, the flood modelling consultants Water Modelling Solutions prepared the Kyneton Commercial Estate Flood Risk Assessment. The report was required to inform a planning permit application for subdivision of land located northeast of Kyneton township which is traversed by Post Office Creek. The mapping provided by the Kyneton Flood Study 2019 did not extend this far upstream due to a lack of LiDAR (Light Detection And Ranging) data required to inform the modelling. Hence, the permit applicant engaged Water Modelling Solutions to undertake flood modelling.

Details of the modelling methodology and results are provided in the Kyneton Commercial Estate Flood Risk Assessment 2020 report. Although the study was completed prior to the recent release of the ARR2019 updated climate change considerations, the 1% AEP peak flow modelled exceeded that of the climate change scenario detailed in Table 3 for Post Office Creek. Therefore, it is considered that the mapping produced by the Kyneton Commercial Estate Flood Risk Assessment 2020 is suitable for extending the available flood information upstream along Post Office Creek. Figure 4 shows the extent of this mapping in comparison to the extent of the updated Kyneton Flood Study climate change mapping.



**Figure 4 – Comparison of the Kyneton Flood Study climate change 1% AEP mapping extent and the Kyneton Commercial Estate Flood Impact Assessment 1% AEP mapping extent**

## 7. Planning Overlay Recommendations

The results of the modelling detailed previously have been used to inform proposed flood planning overlays along the Campaspe River and Post Office Creek. The overlay extents were derived from the TUFLOW 1% AEP event mapping outputs and were assigned based on the following criteria:

- a) Floodway Overlay (FO)
  - i. Depth greater than 0.5 metres; and/or
  - ii. Velocity greater than 2 metres per second; and/or
  - iii. Product of depth and velocity greater than 0.4 square metres per second.
- b) Land Subject to Inundation Overlay (LSIO)
  - i. Land within the applicable flood extent which has a lower flood hazard than that of the Floodway Overlay.

The final overlay extents were also refined by smoothing the extents based on a tolerance of 20 metres and isolated areas less than 1000 square metres were removed. Figures 5 and 6 show the extents of the proposed Land Subject to Inundation Overlay and the Floodway Overlay. Figures 7 and 8 compare the existing LSIO to the proposed LSIO extent.



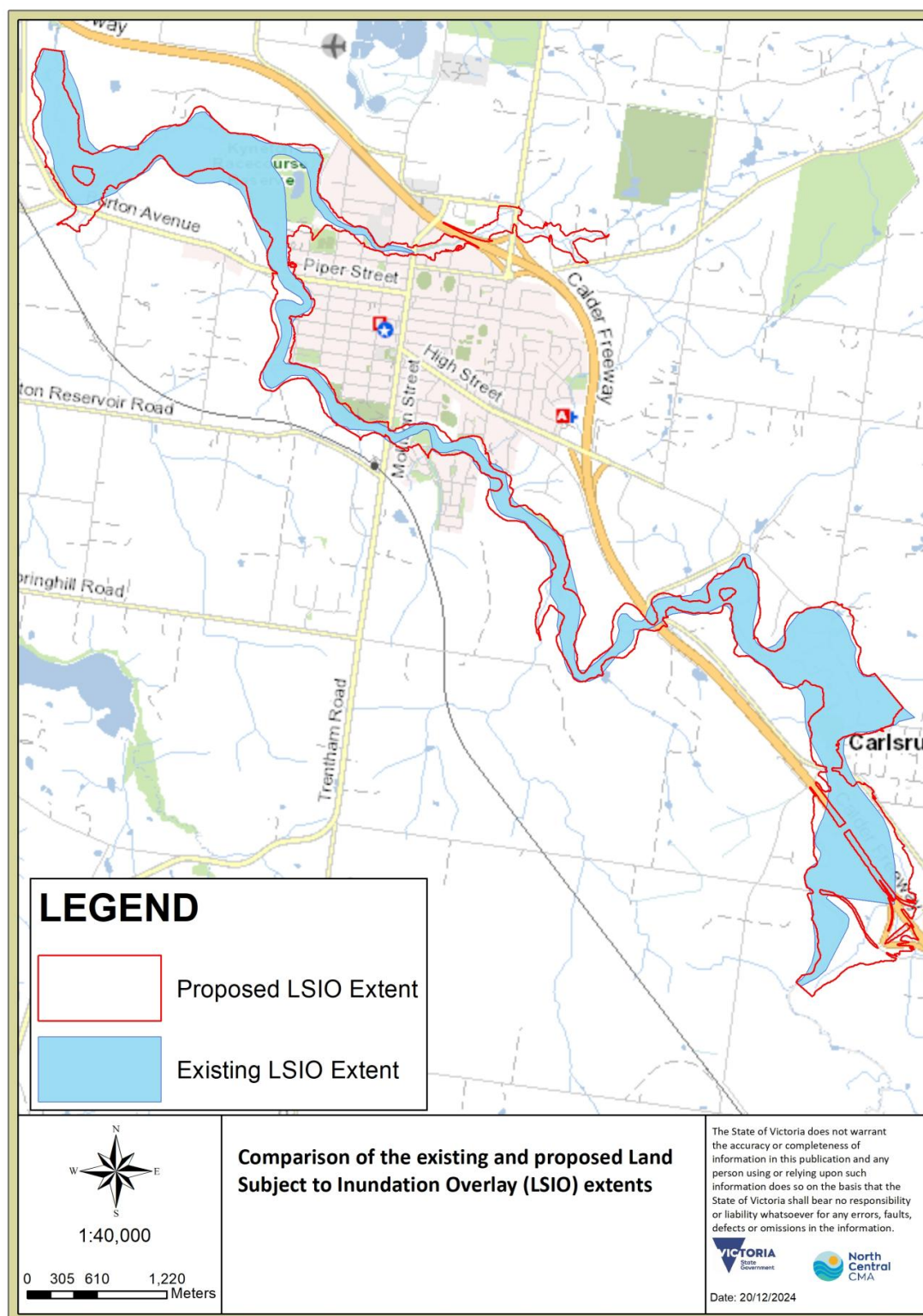


Figure 5 – Comparison of the existing and proposed Land Subject to Inundation Overlay (LSIO) extents



**Figure 6 – Comparison of the existing and proposed Land Subject to Inundation Overlay (LSIO) extents along Post Office Creek**

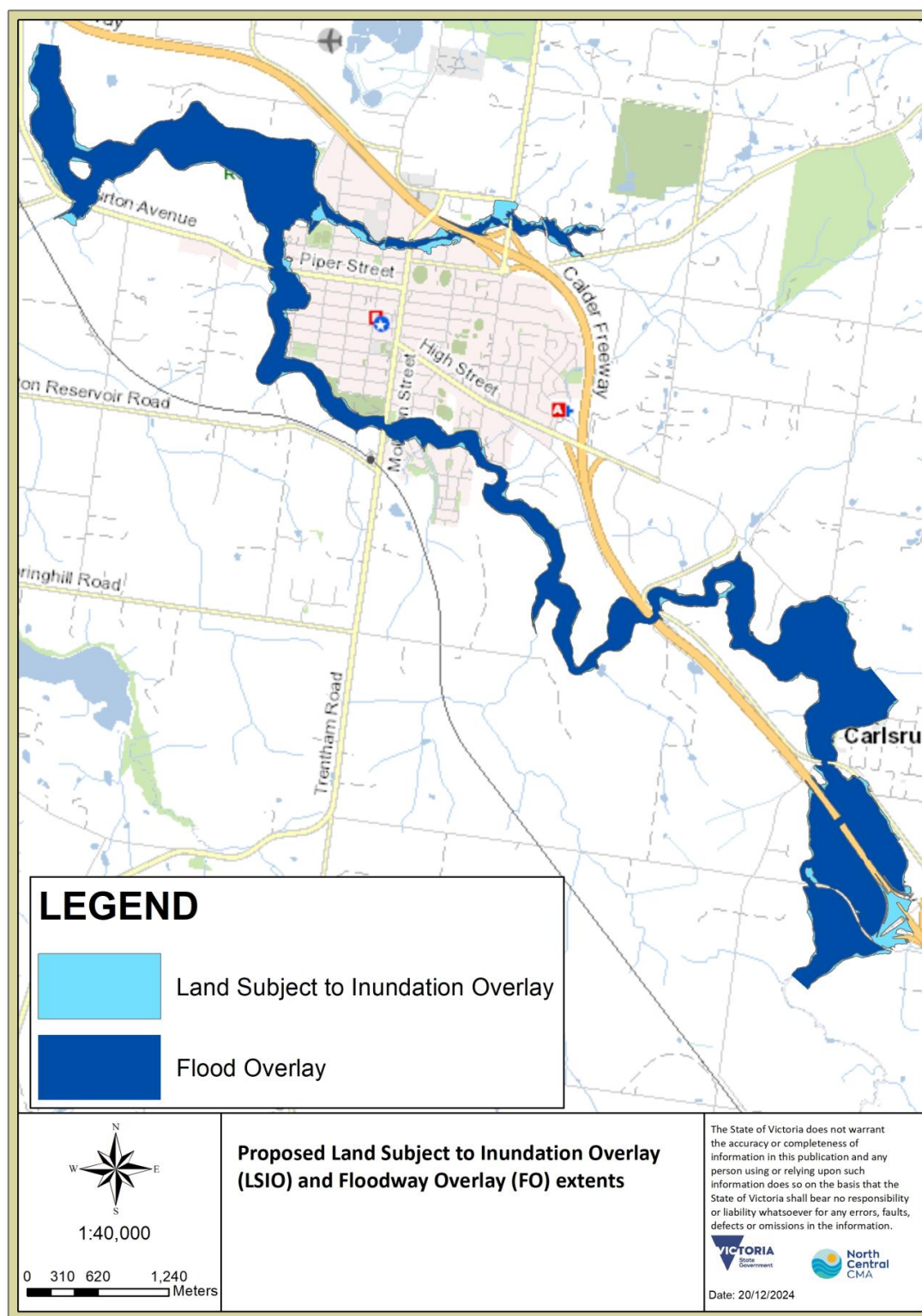
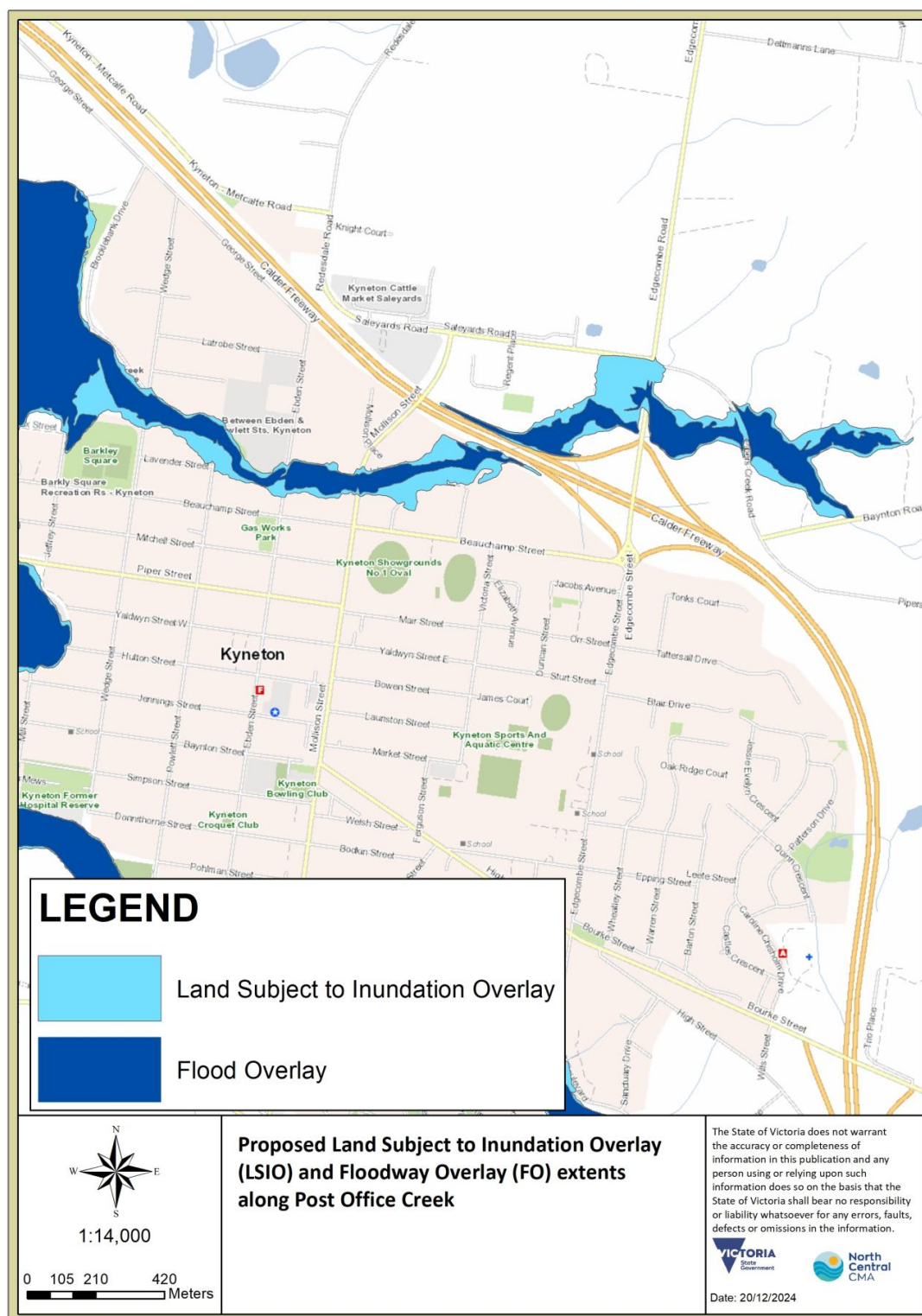


Figure 7 – Proposed Land Subject to Inundation Overlay (LSIO) and Floodway Overlay (FO) extents





**Figure 8 – Proposed Land Subject to Inundation Overlay (LSIO) and Floodway Overlay (FO) extents along Post Office Creek**

## 8. Conclusion

This addendum has documented the methodology used to update the 1% AEP design flood determined by the Kyneton Flood Study 2019 to be in accordance with the recently revised climate change recommendations in ARR2019. This included adjusting the rainfall and catchment loss design parameters and rerunning the calibrated RORB and TUFLOW models. The model results will be used to update the available flood information for the township of Kyneton and enable consideration of the impacts of climate change on flood risk.

It is recommended that the 1% AEP Kyneton Flood Study climate change scenario flood extent and the Kyneton Commercial Estate Flood Impact Assessment 1% AEP extent be used to amend the existing overlays to ensure future development responds appropriately to flood risk and maintains or improves the flood resilience of existing development.

# Kyneton Flood Study

*August 2019*



*North Central CMA has produced this study in*

Regional Floodplain  
Management Strategy  
Everyone has a role to play in preparing for floods



**NORTH CENTRAL**  
Catchment Management Authority  
*Connecting Rivers, Landscapes, People*

## KYNETON FLOOD STUDY

**Acknowledgement of Country**

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

North Central Catchment Management Authority acknowledges Macedon Ranges Shire Council and VicRoads for providing information regarding the hydraulic structures and previous flood studies for this report.

**Front cover photo:** Campaspe River at the Greenway Lane Weir during the September 2016 flood.

A copy of this report is available on [www.nccma.vic.gov.au](http://www.nccma.vic.gov.au)

© North Central Catchment Management Authority, 2019

This publication is copyright. No part may be reproduced by any process except in accordance with the provisions of the Copyright Act 1968

This publication may be of assistance to you, but the North Central Catchment Management Authority and its employees do not guarantee that the publication is without flaw of any kind, or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on information in this publication.

North Central Catchment Management Authority  
PO Box 18  
Huntly Vic 3551  
T: 03 5440 1800  
F: 03 5448 7148  
E: [info@nccma.vic.gov.au](mailto:info@nccma.vic.gov.au)  
[www.nccma.vic.gov.au](http://www.nccma.vic.gov.au)



## KYNETON FLOOD STUDY

## Glossary of Terms

<b>Annual Exceedance Probability (AEP)</b>	The likelihood of occurrence of a flood of a given size or greater occurring in any one year, usually expressed as a percentage. For example, if a peak flood flow of 500m <sup>3</sup> /s has an AEP of 5%, it means that there is a 5% (one-in-20) chance of a flow of 500m <sup>3</sup> /s or greater occurring in any given year.
<b>Australian Height Datum (AHD)</b>	A common national surface level datum approximately corresponding to mean sea level.
<b>Australian Rainfall and Runoff (ARR)</b>	ARR is a national guideline for the estimation of design flood characteristics in Australia published by Engineers Australia. ARR aims to provide reliable estimates of flood risk to ensure that development does not occur in high risk areas and that infrastructure is appropriately designed. References in this report refer to the 2016 edition unless stated otherwise.
<b>Average Recurrence Interval (ARI)</b>	A statistical estimate of the average number of years between floods of a given size or larger than a selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. See also Annual Exceedance Probability.
<b>Catchment</b>	The area of land draining to a particular site. It is related to a specific location and includes the catchment of the main waterway as well as any tributary streams.
<b>DEM</b>	Digital Elevation Model – a three-dimensional computer representation of terrain.
<b>Design Flood</b>	A hypothetical flood representing a given probability generally based on some form of statistical analysis. An average recurrence interval (ARI) or exceedance probability (AEP) is attributed to the estimate.
<b>Flood</b>	A natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both.
<b>Flood Frequency Analysis (FFA)</b>	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
<b>Flood Hazard</b>	Describes the potential of flooding to cause harm or damage. Flood hazard is computed by multiplying flood depth by flood velocity.
<b>Floodplain</b>	An area of land that is subject to inundation by floods up to, and including, the largest probable flood event.
<b>Flow</b>	The volume of water which passes per unit time. Flow or discharge is measured in volume per unit time, for example, megalitres per day (ML/day) or cubic metres per second (m <sup>3</sup> /sec). Flow is different from the velocity of

## KYNETON FLOOD STUDY

	flow, which is a measure of how fast the water is moving, for example, metres per second (m/s).
<b>Hydraulics</b>	The study of water flow in waterways, channels or pipes; in particular, the evaluation of flow parameters such as water level, extent and velocity.
<b>Hydrograph</b>	A graph that shows how the discharge changes with time at a particular location.
<b>Hydrology</b>	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
<b>Intensity Frequency Duration (IFD)</b>	Statistical analysis of rainfall describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP) and duration (hours). This analysis is used to generate design rainfall estimates.
<b>LiDAR</b>	Light Detection and Ranging – Ground survey taken from an aeroplane typically using a laser. LiDAR is used to generate a DEM.
<b>Land Subject to Inundation Overlay</b>	A Planning Scheme overlay to identify flood affected land. The overlay extent is based on the 1% AEP design flood event.
<b>Manning's n</b>	A measure of the hydraulic roughness, or resistance to flow, due to surface conditions, typically averaged over an area of relative homogeneity. For example, there is greater resistance to flow through an area of heavy brush and trees than over maintained grass.
<b>Peak Flow</b>	The maximum flow occurring during a flood event past a given point in the river system.
<b>Pluviograph</b>	A rain gauge measuring the depth of rainfall over a small period of time, typically much less than a day.
<b>Probable Maximum Flood (PMF)</b>	The largest flood that could conceivably occur at a particular location.
<b>Rating Curve</b>	The relationship defining discharge for a given water level at a particular recording location.
<b>RORB</b>	The hydrological modelling program used in this study to calculate the runoff generated from historic and design rainfall events.
<b>Runoff</b>	The amount of rainfall that becomes stream flow; also known as rainfall excess.
<b>TUFLOW</b>	The hydraulic modelling program used in this study to simulate the flow of floodwater through the floodplain. The model uses numerical equations to describe the movement of water.

## KYNETON FLOOD STUDY

## Executive Summary

The Flood Management Plan for Macedon Ranges Shire, Melbourne Water and North Central CMA (2013) was developed collaboratively by the three named agencies. The plan outlines roles and responsibilities and documents actions to jointly advance the understanding of drainage challenges and improve flood management and coordination. A key issue identified in the plan relates to limited and outdated flood modelling and mapping. In particular, the need for flood modelling of both the Campaspe River and Post Office Creek in Kyneton was identified as a priority. A comprehensive flood study for Kyneton has never been undertaken. Current flood extents are based on geological mapping and is considered to have a very low or uncertain reliability (EGIS Consulting, 2000). In order to address this issue, one of the specific actions identified in the plan is to undertake flood modelling of Kyneton Township to update the accuracy and availability of flood information.

The purpose of this study was to update flood information available for the township of Kyneton. The information produced by this study may be used to:

- **Assess the flood risk to existing and proposed development.** Kyneton is expanding particularly along the banks of the Campaspe River and hence there is a need to improve the limited flood information currently available for Kyneton in order to facilitate appropriate future development.
- **Define flood related controls in the Macedon Ranges Shire planning scheme.** Although Kyneton currently does have a Land Subject to Inundation Overlay (LSIO) applied along the Campaspe River and a section of Post Office Creek, this study will enable the LSIO mapping through Kyneton to be further refined.
- **Develop flood intelligence products and inform emergency response planning.** The flood data will assist in identifying the flood risk to existing buildings and infrastructure. This data will also facilitate a damage assessment to be undertaken for the township if complemented with a floor level survey of potentially impacted properties.
- **Assist in the preparation of community flood awareness and education products.**
- **Support the assessment of flood risk for insurance purposes.**

It should be noted that the scope of this study excludes the assessment of any mitigation options.

This report details the methodology and assumptions used to develop the design flood information. This included the creation of a hydrologic rainfall-runoff model using RORB which was calibrated to the September 2010, November 2010, and January 2011 historical floods. This model was then used to derive design flood hydrographs for 20%-0.5% annual exceedance probability (AEP) flood events. Hydrographs were also estimated for the probable maximum flood (PMF). The design flows were compared to other peak flow estimation techniques for verification and then used as inputs into a hydraulic model using TUFLOW.

Once calibrated, the TUFLOW model was used to generate flood mapping of the 20%-0.5% AEP design flood events as well as the PMF. The outputs included gridded data of the water surface elevation, depth, velocity and hazard for the range of design events modelled. Flood intelligence was then produced from this mapping by assessing the flood impacts on buildings, properties and roads.

## KYNETON FLOOD STUDY

## Table of Contents

Glossary of Terms.....	3
Executive Summary.....	5
List of Figures .....	11
List of Tables .....	15
1 Introduction .....	17
1.1 Study Area.....	17
1.2 Historical Flood Investigations.....	19
1.3 Historical Flood Records .....	20
1.4 Site Visit.....	21
2 Data Review and Assessment .....	22
2.1 Topographic and Physical Data.....	22
2.1.1 LiDAR Data.....	22
2.1.2 Structure Survey.....	25
2.1.3 Kyneton Drainage Network.....	32
2.2 Streamflow Data .....	32
2.3 Rainfall Data .....	34
2.4 Storage Data.....	36
3 Hydrologic Analysis .....	37
3.1 Overview .....	37
3.2 Flood Frequency Analysis.....	38
3.2.1 Data Analysis.....	38
3.2.2 FLIKE .....	39
3.3 RORB Model Construction .....	41
3.3.1 Subarea Delineation, Reach Type and Loss Model .....	41
3.3.2 Fraction Impervious Data.....	45
3.4 Campaspe River RORB Model Calibration .....	48
3.4.1 Overview .....	48
3.4.2 RORB Model Calibration Event Data.....	49
3.4.2.1 Observed Streamflow Data.....	49
3.4.2.2 Baseflow Separation .....	51
3.4.2.3 Observed Rainfall Data.....	53



## KYNETON FLOOD STUDY

3.4.2.4	Losses .....	55
3.4.3	September 2010 Flood Event Calibration .....	55
3.4.4	November 2010 Flood Event Calibration .....	58
3.4.5	January 2011 Flood Event Calibration .....	60
3.4.6	Discussion.....	61
3.4.6.1	Routing Parameter .....	61
3.4.6.2	Losses .....	63
3.5	Campaspe River Design Event Modelling .....	64
3.5.1	Calibrate Design Losses .....	64
3.5.1.1	IFD .....	64
3.5.1.2	Areal Reduction Factor .....	65
3.5.1.3	Design Temporal Pattern .....	65
3.5.1.4	Design Spatial Pattern.....	66
3.5.1.5	Simulation Parameters.....	68
3.5.1.6	Design Losses .....	68
3.5.2	Design Model Parameters.....	72
3.5.2.1	IFD .....	72
3.5.2.2	Areal Reduction Factor .....	73
3.5.2.3	Design Temporal Pattern .....	74
3.5.2.4	Design Spatial Pattern.....	75
3.5.2.5	Simulation Parameters.....	75
3.5.2.6	Design Losses .....	75
3.5.2.7	Baseflow .....	76
3.5.3	Design Flow Results.....	77
3.5.3.1	Monte Carlo Analysis .....	77
3.5.3.2	Ensemble Analysis.....	79
3.5.4	Summary .....	81
3.6	Post Office Creek RORB Model Calibration.....	85
3.6.1	Overview .....	85
3.6.2	Routing Parameter .....	85
3.6.3	Fraction Impervious .....	87
3.6.4	Observed Rainfall Data.....	87
3.6.5	Loss Model .....	88

## KYNETON FLOOD STUDY

3.6.6	Hydrographs for Calibration.....	88
3.7	Post Office Creek Design Event Modelling.....	89
3.7.1	Design Model Parameters.....	89
3.7.1.1	Fraction Impervious .....	89
3.7.1.2	IFD .....	89
3.7.1.3	Areal Reduction Factor .....	90
3.7.1.4	Design Temporal Pattern .....	90
3.7.1.5	Design Spatial Pattern.....	91
3.7.1.6	Simulation Parameters.....	91
3.7.1.7	Design Losses .....	91
3.7.1.8	Baseflow .....	92
3.7.2	Design Flow Results.....	92
3.7.2.1	Monte Carlo Analysis .....	92
3.7.3	Discussion.....	94
3.8	Design Flow Verification .....	96
3.8.1	Regional Flood Frequency Estimation.....	96
3.8.2	Probabilistic Rational Method .....	96
3.8.3	Deterministic Rational Method.....	97
3.8.4	DCNR Regional Method .....	97
3.8.5	Previous Flood Studies.....	97
3.8.5.1	Calder Highway Karlsruhe to Kyneton – Hydrologic and Hydraulic Investigations (CMPS&F, 1995) .....	97
3.8.5.2	River Walk Flood Study (Earth Tech, 2005).....	98
3.8.5.3	Kyneton Township Stormwater Drainage Study (Aurecon, 2011).....	98
3.8.6	Summary .....	99
3.9	Sensitivity Analysis .....	104
3.9.1	Campaspe River.....	104
3.9.2	Post Office Creek.....	106
3.10	Probable Maximum Flood.....	107
3.11	Summary .....	108
4	Hydraulic Modelling.....	111
4.1	Overview .....	111
4.2	Hydraulic Model Construction and Parameters .....	111

## KYNETON FLOOD STUDY

4.2.1	Model Overview.....	111
4.2.2	Modelling Parameters.....	111
4.2.2.1	Projection.....	111
4.2.2.2	Extent.....	111
4.2.2.3	Topography.....	113
4.2.2.4	Timestep.....	113
4.2.2.5	Runtime.....	114
4.2.2.6	Hydraulic Roughness.....	114
4.2.3	Boundary Conditions.....	118
4.2.4	Structures.....	118
4.3	Hydraulic Model Calibration and Validation.....	119
4.3.1	Overview.....	119
4.3.2	January 2011 Calibration.....	121
4.3.3	September 2010 Validation.....	131
4.3.4	September 2016 Validation.....	137
4.3.5	Summary.....	143
4.4	Sensitivity Analysis.....	145
4.4.1	Roughness Sensitivity.....	145
4.4.2	Outflow Boundary Condition Sensitivity.....	148
4.4.3	Model Inflow Sensitivity.....	151
4.4.4	Hydrograph Volume Sensitivity.....	154
4.5	Design Flood Modelling.....	157
4.5.1	Coincidence of Campaspe River and Post Office Creek flows.....	157
4.5.2	Blockage of Structures.....	157
4.5.2.1	Blockage determination for Campaspe River structures.....	157
4.5.2.2	Blockage determination for Post Office Creek structures.....	159
4.5.2.3	Impact of blockages.....	160
4.5.3	Model Quality Assurance.....	160
4.5.4	Design Results.....	161
4.6	Design Flood Behaviour.....	164
5	Conclusion.....	167
6	Reference.....	169
7	Appendix.....	170

**KYNETON FLOOD STUDY**

7.1	Design Flood Depth Maps (20% AEP to PMF) .....	170
7.2	Longitudinal Profiles (20% to 0.5% AEP Flood Events) .....	185
7.3	Data Hub .....	188
7.3.1	Redesdale Data Hub Information.....	188
7.3.2	Kyneton Data Hub Information.....	198
7.3.3	Post Office Creek Data Hub Information .....	203

## KYNETON FLOOD STUDY

## List of Figures

Figure 1-1	Campaspe River catchment at Kyneton and Redesdale (Statewide 25m LIDAR DEM)	18
Figure 1-2	Land Subject to Inundation Overlay (DELWP Planning Scheme Online, 2017)	19
Figure 2-1	1m resolution LiDAR coverage of the study area	23
Figure 2-2	Survey and LiDAR elevations along Clarke Crescent	24
Figure 2-3	Survey and LiDAR elevations along Campaspe Place	24
Figure 2-4	Difference between survey and LiDAR elevations along Edgcombe Street (difference between levels shown for clarity)	24
Figure 2-5	Location of key hydraulic structures near Carlsruhe	27
Figure 2-6	Location of key hydraulic structures near Kyneton	28
Figure 2-7	Comparison of current and original ratings curves for Campaspe River at Redesdale gauge	34
Figure 2-8	Locations of rainfall stations and streamflow gauges	35
Figure 3-1	Cross-section at Campaspe River at Redesdale gauge	39
Figure 3-2	Flood frequency analysis of Campaspe River at Redesdale gauge	41
Figure 3-3	Graphical representation of the Campaspe RORB model	43
Figure 3-4	Graphical representation of the Post Office Creek RORB model	44
Figure 3-5	Fraction impervious values for the Campaspe RORB model	46
Figure 3-6	Fraction impervious values for the Post Office Creek RORB model	47
Figure 3-7	Recorded flood hydrograph for the September 2010 event at the 406213 Campaspe River @ Redesdale gauge	50
Figure 3-8	Recorded flood hydrograph for the November 2010 event at the 406213 Campaspe River @ Redesdale gauge	50
Figure 3-9	Recorded flood hydrograph for the January 2011 event at the 406213 Campaspe River @ Redesdale gauge	51
Figure 3-10	Duration Curve (Bureau of Meteorology)	52
Figure 3-11	Pluviograph records for the September 2010 event	53
Figure 3-12	Pluviograph records for the November 2010 event	54
Figure 3-13	Pluviograph records for the January 2011 event	54
Figure 3-14	Total rainfall accumulated over 10 days during September 2010 storm (3 – 13 September)	56
Figure 3-15	Comparison of modelled and observed hydrographs for the September 2010 event on the Campaspe River at Redesdale gauge (406213)	57
Figure 3-16	Comparison of modelled and observed hydrographs for the November 2010 event on the Campaspe River at Redesdale gauge (406213)	59
Figure 3-17	Comparison of modelled and observed hydrographs for the January 2011 event on the Campaspe River at the Redesdale gauge (406213)	60
Figure 3-18	Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Redesdale IFD	65
Figure 3-19	Rainfall temporal pattern 8 for the 36 hour duration, 1% AEP storm	66
Figure 3-20	IFD graph for Kyneton catchment	72



## KYNETON FLOOD STUDY

Figure 3-21	Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Kyneton IFD .....	73
Figure 3-22	Rainfall temporal pattern 5 for the 96-hour duration, 1% AEP storm.....	74
Figure 3-23	Design flood hydrographs at Kyneton Downstream.....	79
Figure 3-24	Duration box plot of temporal patterns for the 1% AEP design event. Note the mean peak flow for each duration is displayed as a blue dot. ....	80
Figure 3-25	Comparison of 1% AEP design hydrographs using ensemble and Monte Carlo analysis 81	
Figure 3-26	Design hydrograph locations for the hydraulic model .....	82
Figure 3-27	Design flood hydrographs at Campaspe at Carlsruhe.....	83
Figure 3-28	Design flood hydrographs at Carlsruhe Tributary.....	83
Figure 3-29	Design flood hydrographs from Subarea F .....	84
Figure 3-30	Pluviograph record (15-minute intervals) for the January 2011 event .....	87
Figure 3-31	Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Post Office Creek IFD.....	90
Figure 3-32	Design flood hydrographs for Post Office Creek.....	94
Figure 3-33	Calder Highway Bridge over Post Office Creek .....	95
Figure 3-34	Comparison of design peak flow estimates for Campaspe River at Redesdale gauge.....	101
Figure 3-35	Comparison of design peak flow estimates for Kyneton Township .....	102
Figure 3-36	Comparison of design peak flow estimates for Post Office Creek.....	103
Figure 3-37	Impacts of climate change on Campaspe River design hydrographs .....	105
Figure 3-38	Impacts of climate change on Post Office Creek design hydrographs.....	106
Figure 3-39	Design flood hydrographs at Campaspe at Carlsruhe.....	108
Figure 3-40	Design flood hydrographs at Carlsruhe Tributary.....	109
Figure 3-41	Design flood hydrographs from Subarea F .....	109
Figure 3-42	Design flood hydrographs for Post Office Creek.....	110
Figure 3-43	Probable Maximum Flood (PMF) hydrographs for all hydraulic model input locations 110	
Figure 4-1	Hydraulic model schematisation.....	112
Figure 4-2	Hydraulic model roughness grid (Manning's roughness) for January 2011 flood event 116	
Figure 4-3	Hydraulic model roughness grid (Manning's roughness) for design flood events .....	117
Figure 4-4	Location of historical flood observations.....	120
Figure 4-5	Inflow hydrographs for the January 2011 flood event .....	121
Figure 4-6	Extent of flooding at the rear of Sacred Heart College looking south-east during the January 2011 flood event.....	122
Figure 4-7	Modelled flood extent of the January 2011 event at the rear of Sacred Heart College. Approximate direction of photo in Figure 4.4 indicated by yellow arrow.....	122
Figure 4-8	Modelled flood extent of the January 2011 event upstream of Mollison Street Bridge 123	
Figure 4-9	Modelled flood extent of the January 2011 event at the Kyneton Botanic Gardens .....	124
Figure 4-10	Modelled flood extent of the January 2011 event along Mill Street.....	125

## KYNETON FLOOD STUDY

Figure 4-11	Modelled flood extent of the January 2011 event along rear of properties north of St Agnes Place	126
Figure 4-12	Modelled flood extent of the January 2011 event along rear of Jennings Street properties	127
Figure 4-13	Modelled flood extent of the January 2011 event upstream of Piper Street Bridge	128
Figure 4-14	Modelled flood extent of the January 2011 event along Campaspe Place	129
Figure 4-15	Modelled flood extent of the January 2011 event on Post Office Creek. Location of surveyed flood mark is shown as a yellow dot	130
Figure 4-16	Inflow hydrographs for the September 2010 flood event	131
Figure 4-17	Modelled flood extent of the September 2010 event at Wedge Street. Approximate direction of the following photos is indicated by yellow arrows.	131
Figure 4-18	September 2010 event looking south-east on Post Office Creek upstream of Wedge Street (refer to Photo 1 in Figure 4-17)	132
Figure 4-19	September 2010 event looking downstream along Post Office Creek towards Wedge Street bridge (refer to Photo 2 in Figure 4-17)	133
Figure 4-20	September 2010 event looking downstream of Wedge Street bridge along the northern bank of Post Office Creek (refer to Photo 3 in Figure 4-17)	134
Figure 4-21	September 2010 event looking downstream of Wedge Street bridge along the southern bank of Post Office Creek (refer to Photo 4 in Figure 4-17)	135
Figure 4-22	Campaspe River flood extent along Burton Avenue during the September 2010 event	136
Figure 4-23	Inflow hydrographs for the September 2016 flood event	137
Figure 4-24	Comparison of modelled flood extent to photo taken during the September 2016 event looking upstream on the Campaspe River from Rennick Drive	138
Figure 4-25	Comparison of modelled flood extent to photo taken during the September 2016 event looking downstream on the Campaspe River from the Kyneton Botanic Gardens	139
Figure 4-26	Comparison of modelled flood extent to photo taken during the September 2016 event of the Campaspe River at the Greenway Lane Weir	140
Figure 4-27	Modelled flood extent of the September 2016 event at Wedge Street. Approximate direction of the following photos is indicated by yellow arrows.	141
Figure 4-28	September 2016 event looking south-east on Post Office Creek upstream of Wedge Street (refer to Photo 4 in Figure 4-27)	141
Figure 4-29	September 2016 event looking toward northern bank of Post Office Creek immediately upstream of Wedge Street (refer to Photo 5 in Figure 4-27)	142
Figure 4-30	September 2016 event looking downstream of Wedge Street bridge along the southern bank of Post Office Creek (refer to Photo 6 in Figure 4-27)	143
Figure 4-31	1% AEP afflux map comparing base case scenario to sensitivity scenario with Manning's roughness increased by 20% (Sensitivity Scenario – Base Case Scenario)	146
Figure 4-32	1% AEP afflux map comparing base case scenario to sensitivity scenario with Manning's roughness decreased by 20% (Sensitivity Scenario – Base Case Scenario). The red insert shows the area of maximum difference.	147
Figure 4-33	1% AEP afflux map comparing base case scenario to sensitivity scenario with the outflow boundary slope reduced to 0.002 (Sensitivity Scenario – Base Case Scenario)	149

## KYNETON FLOOD STUDY

Figure 4-34	1% AEP afflux map comparing base case scenario to sensitivity scenario with the outflow boundary slope increased to 0.02 (Sensitivity Scenario – Base Case Scenario).....	150
Figure 4-35	1% AEP afflux map comparing base case scenario to sensitivity scenario with inflows increased by 10% (Sensitivity Scenario – Base Case Scenario).....	152
Figure 4-36	1% AEP afflux map comparing base case scenario to sensitivity scenario with inflows decreased by 10% (Sensitivity Scenario – Base Case Scenario).....	153
Figure 4-37	Campaspe @ Carlsruhe 1% AEP design inflow hydrograph volume increased by 25% 154	
Figure 4-38	1% AEP afflux map comparing base case scenario to sensitivity scenario with inflow hydrographs increased by 25% (Sensitivity Scenario – Base Case Scenario).....	156
Figure 4-39	Debris during the September 2010 flood event (Kyneton Historical Society, 2010) ..	158
Figure 4-40	Blockage at the Ebdon Street culverts .....	159
Figure 4-41	Design flood extents for study area.....	162
Figure 4-42	Design flood extents for Kyneton Township .....	163
Figure 5-1	Comparison of existing LSIO to the 1% AEP design flood extent.....	168
Figure 7-1	20% AEP design flood depth for study extent .....	171
Figure 7-2	20% AEP design flood depth for Kyneton Township.....	172
Figure 7-3	10% AEP design flood depth for study extent .....	173
Figure 7-4	10% AEP design flood depth for Kyneton Township.....	174
Figure 7-5	5% AEP design flood depth for study extent .....	175
Figure 7-6	5% AEP design flood depth for Kyneton Township.....	176
Figure 7-7	2% AEP design flood depth for study extent .....	177
Figure 7-8	2% AEP design flood depth for Kyneton Township.....	178
Figure 7-9	1% AEP design flood depth for study extent .....	179
Figure 7-10	1% AEP design flood depth for Kyneton Township.....	180
Figure 7-11	0.5% AEP design flood depth for study extent .....	181
Figure 7-12	0.5% AEP design flood depth for Kyneton Township.....	182
Figure 7-13	PMF design flood depth for study extent .....	183
Figure 7-14	PMF design flood depth for Kyneton Township .....	184

## KYNETON FLOOD STUDY

## List of Tables

Table 1-1	Historical flood events measured at the Campaspe River at Redesdale gauge .....	20
Table 2-1	Details of key hydraulic structures within the study area .....	25
Table 2-2	Images of key hydraulic structures within the study area .....	29
Table 2-3	Streamflow gauge details.....	32
Table 2-4	Gaugings taken at the Campaspe River at Redesdale gauge during the September 2016 flood event 33	
Table 2-5	Pluviograph station details.....	36
Table 2-6	Daily rainfall station details.....	36
Table 3-1	Campaspe River at Redesdale FFA results .....	40
Table 3-2	Land use and fraction impervious values.....	45
Table 3-3	RORB model calibration events .....	49
Table 3-4	RORB calibration parameters and results for September 2010 event .....	57
Table 3-5	RORB calibration parameters and results for the November 2010 event.....	59
Table 3-6	RORB calibration parameters and results for the January 2011 event .....	61
Table 3-7	Comparison to additional routing parameter estimates .....	62
Table 3-8	Adopted RORB model parameters.....	62
Table 3-9	RORB calibration loss parameters – September 2010.....	63
Table 3-10	RORB calibration loss parameters – November 2010.....	63
Table 3-11	RORB calibration loss parameters – January 2011 .....	63
Table 3-12	Rochester Flood Management Plan (2013) calibration losses.....	63
Table 3-13	Design spatial pattern for Campaspe River catchment to Redesdale .....	67
Table 3-14	Initial loss distribution.....	68
Table 3-15	Median preburst depths (mm) for various flood AEPs and durations.....	69
Table 3-16	Comparison of flows at Campaspe River at Redesdale gauge for various design loss combinations 70	
Table 3-17	Comparison of Campaspe River at Redesdale gauge flood frequency curve to Monte Carlo analysis of design initial and continuing losses .....	71
Table 3-18	Adopted design initial and continuing losses.....	71
Table 3-19	Design spatial pattern for Campaspe River catchment to Kyneton.....	75
Table 3-20	Initial loss distribution.....	76
Table 3-21	Continuing loss AEP factors.....	76
Table 3-22	Individual design runs from the Monte Carlo analysis .....	78
Table 3-23	Comparison of routing parameter estimates .....	86
Table 3-24	Adopted RORB model parameters.....	86
Table 3-25	Adopted losses for Post Office Creek RORB model – September 2010.....	88
Table 3-26	Adopted losses for Post Office Creek RORB model – January 2011 .....	88
Table 3-27	Adopted losses for Post Office Creek RORB model – September 2016.....	88
Table 3-28	Adopted design initial and continuing losses.....	91
Table 3-29	Initial loss distribution.....	92
Table 3-30	Individual design runs from Monte Carlo analysis.....	93
Table 3-31	Study design peak flows at Carlsruhe Bridge .....	98

**KYNETON FLOOD STUDY**

Table 3-32	Comparison of various estimates of the 1% AEP peak flow .....	100
Table 3-33	Interim climate change factors for Kyneton .....	104
Table 3-34	Comparison of climate change scenario peak flows for Campaspe River .....	105
Table 3-35	Comparison of climate change scenario peak flows for Post Office Creek .....	107
Table 3-36	PMF peak flow estimates .....	108
Table 4-1	Roughness values.....	115
Table 4-2	Head loss across bridges .....	118
Table 4-3	Summary details for the historical events selected for calibration and validation .....	119



## KYNETON FLOOD STUDY

### 1 Introduction

This study has been undertaken to update the flood information available for the township of Kyneton. The outputs from this study may be used to:

- Assess the flood risk to existing and proposed development
- Define flood related controls in the Macedon Ranges Shire planning scheme
- Develop flood intelligence products and inform emergency response planning
- Assist in the preparation of community flood awareness and education products
- Support the assessment of flood risk for insurance purposes

The study involved detailed hydrological and hydraulic modelling of the Campaspe River and Post Office Creek through Kyneton. This report details the methodology and assumptions used to develop the design flood information. The study included the creation of a hydrologic rainfall-runoff model using RORB which was calibrated to the September 2010, November 2010, and January 2011 historical floods. This model was then used to derive design flood hydrographs for 20%-0.5% annual exceedance probability (AEP) flood events. The design flows produced from this model were compared to other peak flow estimation techniques for verification, including the probabilistic rational method.

The design hydrographs generated from RORB were then input into a hydraulic model using TUFLOW to generate the required flood data, including flood heights and depths for a range of design events.

#### 1.1 Study Area

Kyneton is a township of 6,951 residents (2016 Census), located approximately 80km north-west of Melbourne, within the municipality of Macedon Ranges Shire. The town is primarily located on the north-eastern bank of the Campaspe River, with new residential development currently expanding on the south-western side of the river. The Campaspe River catchment for Kyneton is approximately 233km<sup>2</sup> and extends to the south of Woodend with headwaters in the Great Dividing Range, as shown in Figure 1-1. It consists predominately of forested land, including Wombat State Forest, and undulating open farmland. There are no significant storages within the Kyneton catchment.

As Kyneton is situated high up in the Campaspe catchment, this reach of the Campaspe River is steep with a well-defined waterway cross-section. Hence, the floodwaters are contained within the Campaspe valley and impacts on the township are relatively minor. In a 1% AEP flood event, floodwaters are generally confined to the waterway except immediately downstream of the township where water breaks out onto the floodplain, impacting the Kyneton Racecourse.

A significant tributary of the Campaspe River, Post Office Creek, is situated at the northern extent of the township and the confluence of the two waterways is located north of the Kyneton Township. Although Post Office Creek has a much smaller catchment (12km<sup>2</sup>) than the Campaspe River, it is surrounded by existing residential and industrial development which may be impacted by flooding.

## KYNETON FLOOD STUDY

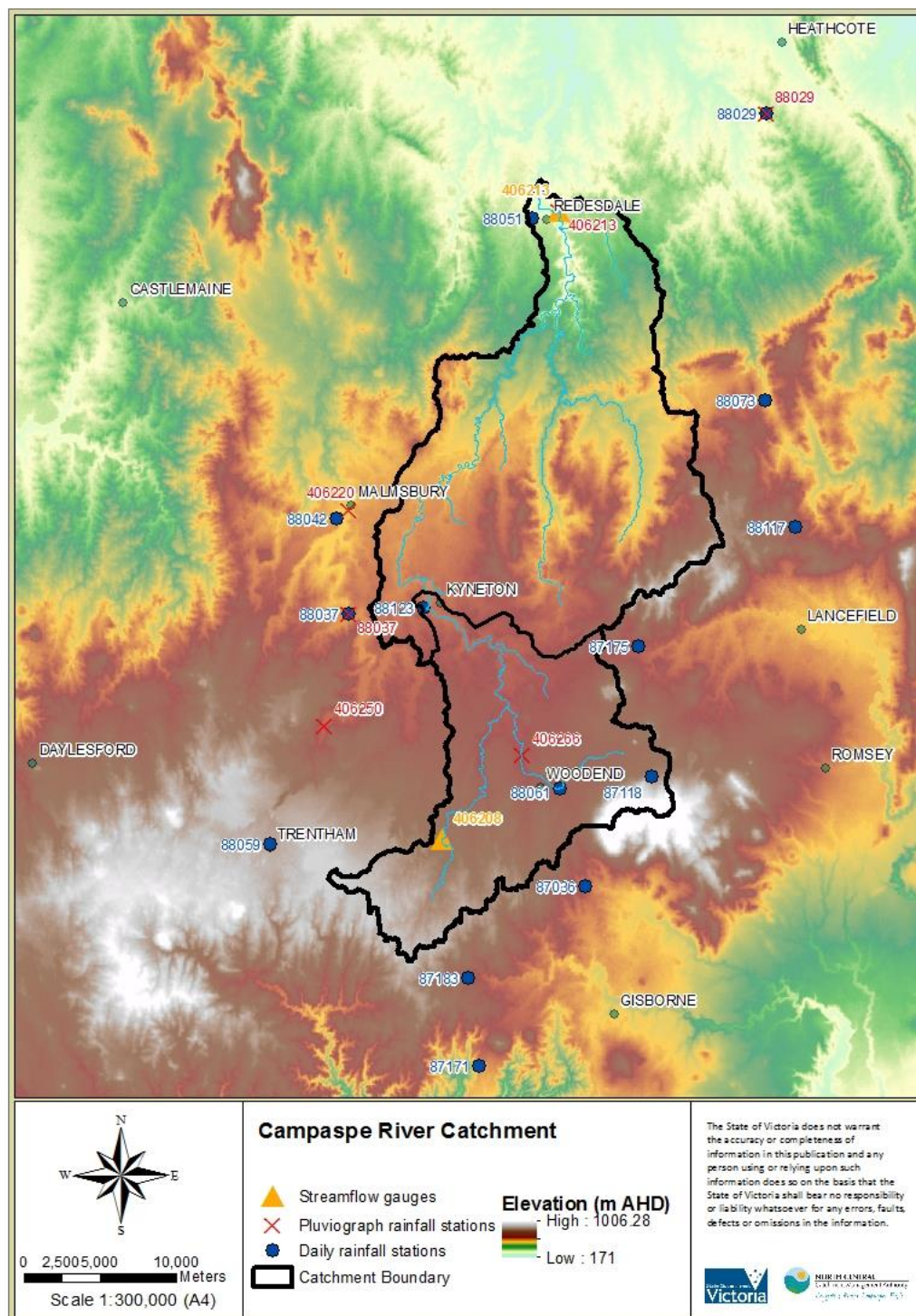
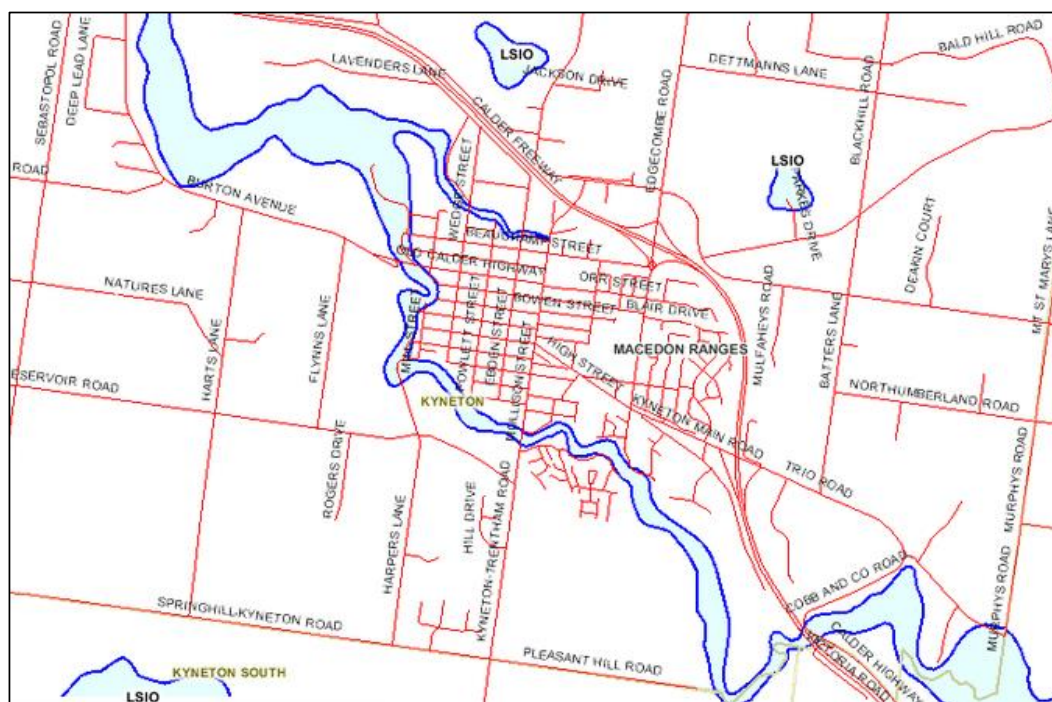


Figure 1-1 Campaspe River catchment at Kyneton and Redesdale (Statewide 25m LIDAR DEM)

## KYNETON FLOOD STUDY

### 1.2 Historical Flood Investigations

The existing Land Subject to Inundation Overlay (LSIO) through Kyneton currently describes the 1% AEP flood extent for area. As shown in Figure 1-2, the LSIO closely follows the Campaspe River and also includes Post Office Creek downstream of Mollison Street.



**Figure 1-2 Land Subject to Inundation Overlay (DELWP Planning Scheme Online, 2017)**

Flood studies previously undertaken for Kyneton include:

- **Calder Highway Carlsruhe to Kyneton – Hydrologic and Hydraulic Investigations (CMPS&F, 1995)** – VicRoads commissioned a hydrological and hydraulic investigation for the Calder Freeway crossing of the Campaspe River between Carlsruhe and Kyneton. This report is available on FloodZoom.
- **River Walk Flood Study (Earth Tech, 2005)** – In April 2005, a flood study was conducted by Earth Tech for a reach of the Campaspe River south of Kyneton Township to determine the 1% Annual Exceedance Probability (AEP). A one-dimensional HECRAS model was utilised for the study. A copy of this report is held by North Central CMA.
- **Kyneton Township Stormwater Drainage Study (Aurecon, 2011)** – Macedon Ranges Shire Council commissioned a stormwater drainage study for the township of Kyneton to identify the existing infrastructure limitations and determine the future requirements. As part of this assessment, estimated 1% AEP design flows were modelled on the Campaspe River and Post Office Creek. The Council is the custodian of this information.

## KYNETON FLOOD STUDY

### 1.3 Historical Flood Records

Table 1-1 displays the ten largest floods that have been recorded at the Campaspe River at Redesdale streamflow gauge which has a continuous instantaneous flow records dating back to 1966. The information provided at this gauge provides an indication of when significant Campaspe River floods occurred in Kyneton.

**Table 1-1 Historical flood events measured at the Campaspe River at Redesdale gauge**

Rank	Date	Peak Flow Rate (m <sup>3</sup> /s)	Peak Level (m)
1	September 1975	422	6.697
2	May 1974	353	Level not available
3	September 2016*	348*	4.540
4	January 2011	322	6.295
5	September 2010	260	5.138
6	June 1968	231	Level not available
7	July 1990	228	4.584
8	November 2010	216	4.388
9	September 1983	189	3.362
10	June 1973	182	Level not available

\*Note that there is uncertainty regarding the reliability of the peak flow rate record during the September 2016. Refer to Section 2.2 for further detail.

*The Remarkable Flood Rains over South-Eastern Australia* report (Bureau of Meteorology, 1909) describes the flood events during the winter of 1909. A description is given of flooding on the Campaspe River through Kyneton. In particular, the report mentions that 'flood marks have been cut on the north abutment of the Mollison Street Bridge'. A site inspection was undertaken however the flood marks referred to in the report could not be located. However, plans of the Mollison Street Bridge dated 10 March 1995 contain the following notation: 'existing northern masonry abutment and wingwalls to be dismantled, re-founded on basalt and reconstructed to the same appearance'. Hence, it is likely that the flood marks referred to in the report have been removed as a result of these works.

## KYNETON FLOOD STUDY

### 1.4 Site Visit

A site visit was undertaken on 13 December 2017 and 2 October 2018 with local community members. A number of locations along the Campaspe River and Post Office Creek were investigated to better understand the flood behaviour. This provided an opportunity to collect data on recent flood events, including extents and relative flood heights. Photos and measurements of key hydraulic structures were also recorded.

Additional photos, videos and anecdotal information were also obtained from the Kyneton Historical Society and several other local community members.



## KYNETON FLOOD STUDY

## 2 Data Review and Assessment

### 2.1 Topographic and Physical Data

The hydrological and hydraulic models require the input of both topographic and physical data. As described below, this study has utilised Light Detection and Ranging (LiDAR) data and information derived from survey of hydraulic structures.

#### 2.1.1 LiDAR Data

Two sources of LiDAR data were available for this study:

- **Statewide\_DEM** – covers Victoria at a grid resolution of 25 metres. Due to the low resolution, this LiDAR data was only used to define the subcatchment areas for the hydrological model where other LiDAR was not available.
- **MD\_Rivers\_ISC\_2010** – produced by the Department of Environment and Primary Industries in 2010 for the Index of Stream Condition (ISC) analysis. The LiDAR has a quoted horizontal accuracy of  $\pm 30\text{cm}$  and a vertical accuracy of  $\pm 10\text{cm}$ . As this dataset has a grid resolution of 1 metre and covers the Campaspe River and the associated floodplain it was deemed suitable for the hydraulic model. Figure 2-1 shows the extent of the LiDAR and elevations around the Kyneton Township relative to the Australian Height Datum (AHD).

It should be noted that the method used to collect LiDAR data does not penetrate the surface of water and therefore the data generated does not represent the natural surface level of the bed of the waterway. No bathymetric survey has been undertaken for this reach of the Campaspe River and Post Office Creek, and funding was not available for this study to obtain this information. However, the MD\_Rivers\_ISC\_2010 LiDAR data was collected during an extensive period of drought in the north central region. Consequently, the water level was low at the time the data was gathered and therefore it provides a reasonable approximation of the topography of the waterway.

Field surveys from several sources were used to validate the accuracy of the MD\_Rivers\_ISC\_2010 LiDAR. The available survey was from three locations around the township and consisted of spot heights captured along road centre lines. A comparison between the survey information and the LiDAR data was undertaken and the results shown in Figure 2-2 to Difference between survey and LiDAR elevations along Edgecombe Street (difference between levels shown for clarity)Figure 2-4. Overall, the LiDAR was found to correspond well to the survey data, with a mean difference of 80mm and no skew evident. Consequently, only minor modifications to the LiDAR were undertaken in order to more accurately represent the low flow channels in the hydraulic model.

## KYNETON FLOOD STUDY

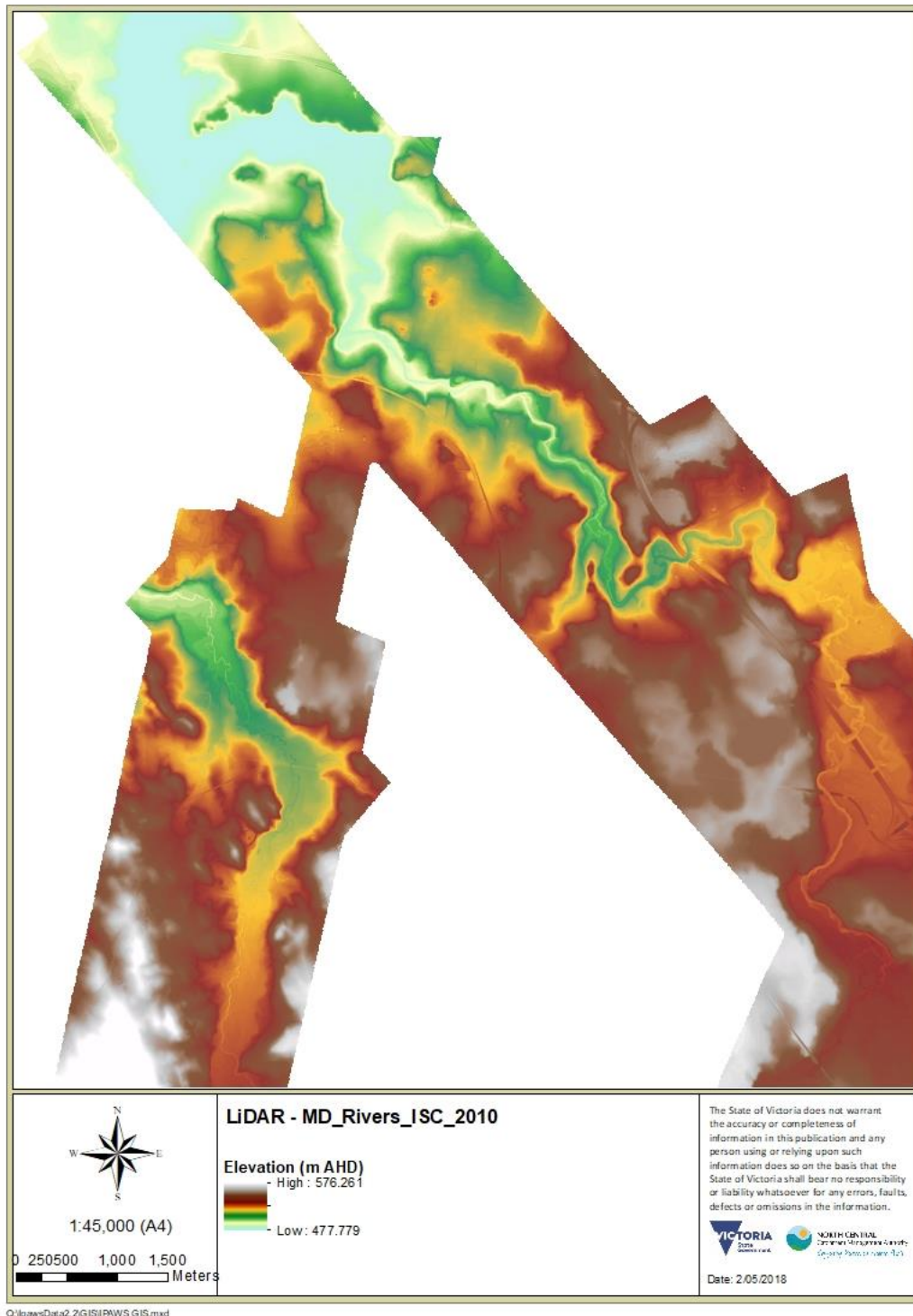
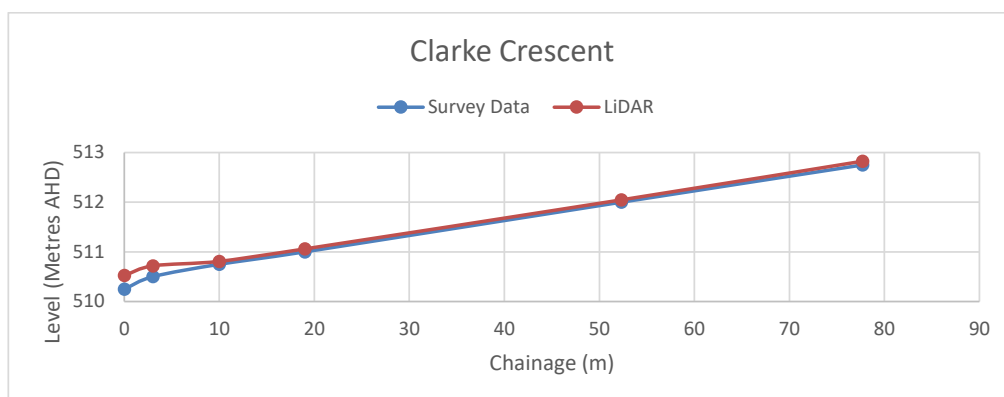
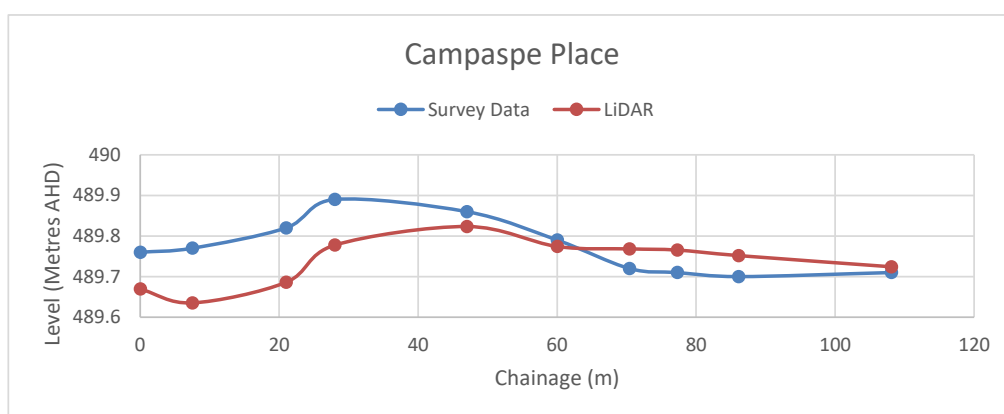


Figure 2-1 1m resolution LiDAR coverage of the study area

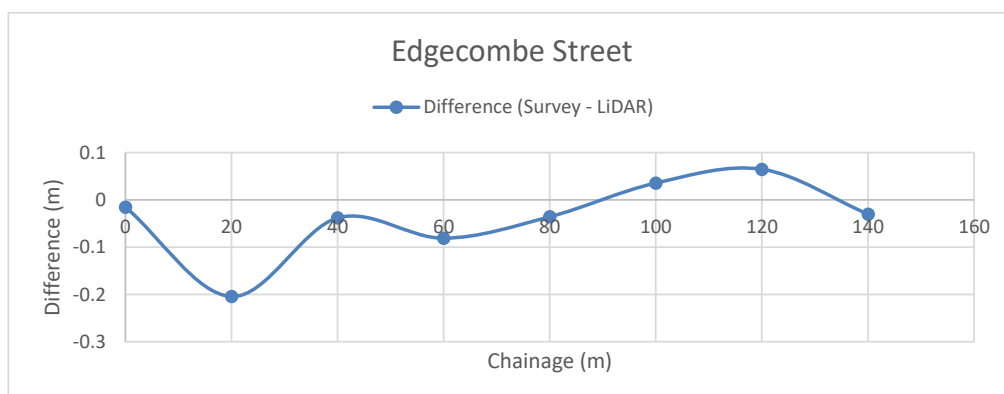
## KYNETON FLOOD STUDY



**Figure 2-2** Survey and LiDAR elevations along Clarke Crescent



**Figure 2-3** Survey and LiDAR elevations along Campaspe Place



**Figure 2-4** Difference between survey and LiDAR elevations along Edgecombe Street (difference between levels shown for clarity)

## KYNETON FLOOD STUDY

**2.1.2 Structure Survey**

The hydraulic model requires the input of key hydraulic structures that impact on flood behaviour. There are numerous bridges and weirs on both the Campaspe River and Post Office Creek as detailed in Table 2-1, Figure 2-5 and Figure 2-6. Table 2-2 shows photos of these structures. Plans of the bridges were supplied by VicRoads and the Macedon Ranges Shire Council. However, no details of the weirs were available from the Local Council or the applicable water authorities. The weirs are all of a historical nature and it is likely that they were originally constructed by local landowners. The crest levels of the weirs are picked up reasonably well in the available LiDAR used for the hydraulic model. These levels were also checked during the site visit to ensure they were reasonable. Therefore, no additional structure survey was required for the model construction.

**Table 2-1 Details of key hydraulic structures within the study area**

Waterway	Structure Name	Managing Authority	Structure Details	Reference Number
Campaspe River	S1 – Carlsruhe Central Road Bridge	Local Council	5-span bridge Width = 75.7m	Asset ID 220
	S2 - Carlsruhe Central Road North Culverts	Local Council	15 3.1x1.5m box culverts	Asset ID 219
	S3 - Carlsruhe Central Road South Culverts	Local Council	15 3.1x1.35m box culverts	Asset ID 218
	S4 - Calder Highway South Bridges	VicRoads	Two parallel bridges 4-span bridge Width = 69m	SN9680 & SN9681
	S5 - Calder Highway Culverts	VicRoads	Two parallel sets of culverts 11 3.1x1.8m box culverts	SN9678 & SN9679
	S6 - Cobb and Co Road South Bridge	Local Council	6-span bridge Width = 55m	Asset ID 221
	S7 - Cobb and Co Road North Bridge	Local Council	6-span bridge Width = 66.5m	Asset ID 223
	S8 - Calder Highway North Bridges	VicRoads	Two parallel bridges 2-span bridge Width = 56m	SN9682 & SN9683
	S9 – Mollison Street Bridge	VicRoads	3-spans bridge Width = 52.6m	SN4415
	S10 - Mollison Street Weir	N/A		
	S11 - Greenway Lane Weir	N/A		

## KYNETON FLOOD STUDY

	S12 - Hutton Street Weir	N/A		
	S13 - Piper Street Bridge	VicRoads	4-span bridge Width = 53.6m	SN0164
	S14 - Campaspe Place Weir	N/A		
Post Office Creek	S15 - Mollison Street Culverts	VicRoads	Four 1.8m diameter culverts	SN1255
	S16 - Ebden Street Culverts	Local Council	Four 1.8m diameter culverts	Asset ID 32
	S17 - Wedge Street Bridge	Local Council	Single span bridge Width = 5.1m	Asset ID 119



## KYNETON FLOOD STUDY

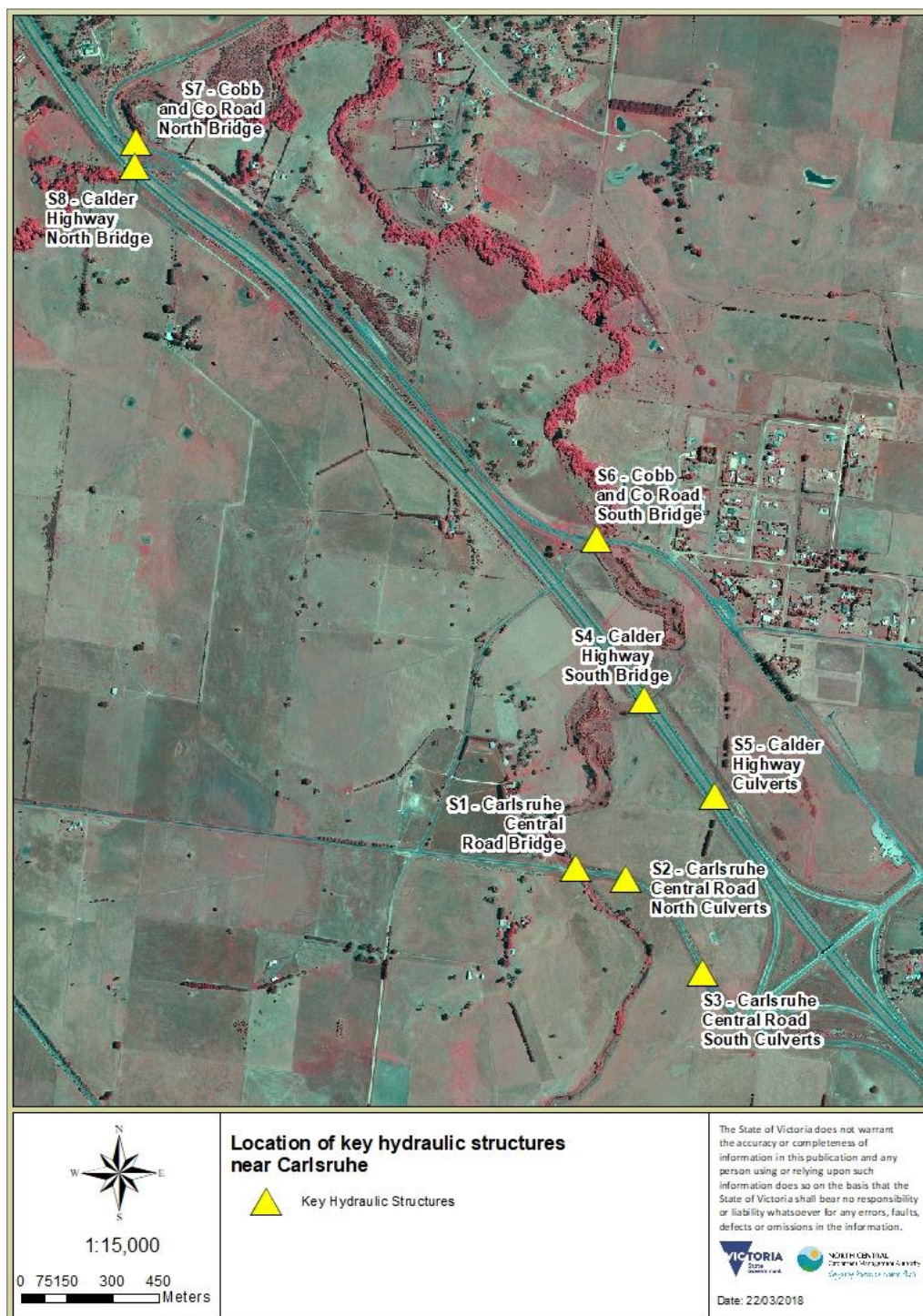


Figure 2-5 Location of key hydraulic structures near Carlsruhe



## KYNETON FLOOD STUDY

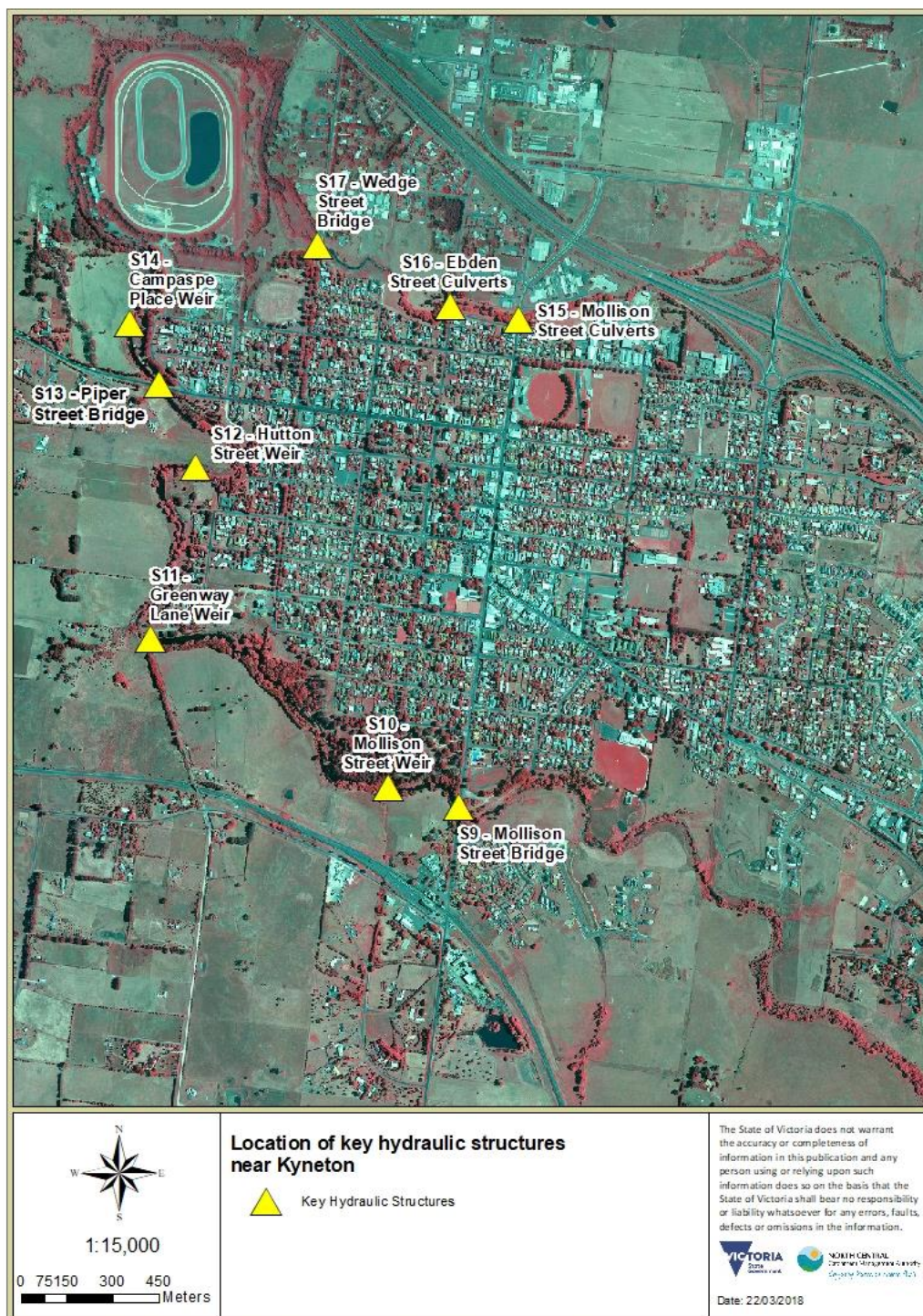



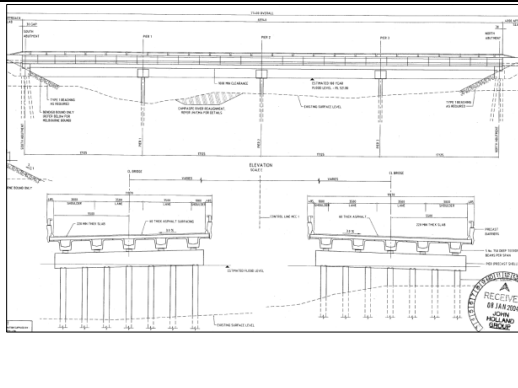




Figure 2-6 Location of key hydraulic structures near Kyneton



## KYNETON FLOOD STUDY

Table 2-2 Images of key hydraulic structures within the study area

	
<b>S1 – Carlsruhe Central Road Bridge</b>	<b>S2 - Carlsruhe Central Road North Culverts</b>
	
<b>S3 - Carlsruhe Central Road South Culverts</b>	<b>S4 - Calder Highway South Bridges</b>
	
<b>S5 - Calder Highway Culverts</b>	<b>S6 - Cobb and Co Road South Bridge</b>

## KYNETON FLOOD STUDY

**S7 - Cobb and Co Road North Bridge****S8 - Calder Highway North Bridges****S9 - Mollison Street Bridge****S10 - Mollison Street Weir****S11 - Greenway Lane Weir****S12 - Hutton Street Weir**



## KYNETON FLOOD STUDY

**S13 - Piper Street Bridge****S14 - Campaspe Place Weir****S15 - Mollison Street Culverts****S16 - Ebden Street Culverts****S17 - Wedge Street Bridge**



## KYNETON FLOOD STUDY

### 2.1.3 Kyneton Drainage Network

The underground drainage network was not included in this hydraulic model. The purpose of this study is to investigate how large flood events are conveyed through Kyneton Township by the Campaspe River and Post Office Creek. Hence, this study does not consider the stormwater system which would have a negligible impact on the riverine flood behaviour.

## 2.2 Streamflow Data

Streamflow data was required for the calibration of the hydrological model. The two active streamflow gauges in the catchment are the Campaspe River at Ashbourne gauge and the Campaspe River at Redesdale gauge (see Table 2-3). However, as the Campaspe River at Ashbourne gauge is located at the top of the catchment it was not suitable for the hydrological model calibration. Instantaneous streamflow data was sourced from the Department of Environment, Land, Water and Planning (DELWP) Water Measurement Information System and the *Victorian Surface Water Information to 1987 – Volume 4* (Rural Water Commission of Victoria, 1990).

**Table 2-3 Streamflow gauge details**

Station Name	Station No.	Status	Data Type	Period of record
Campaspe River @ Redesdale	406213	Active	Instantaneous Flow, Mean Daily Flow, Water Level	November 1953 – Present
Campaspe River @ Ashbourne	406208	Active	Instantaneous Flow, Water Level	April 1933 – Present

A review of the Campaspe River at Redesdale streamflow data quality revealed a discrepancy in the flow records for the September 2016 flood event. In addition to the quality of this peak flow data being described as a rating extrapolation, there are also several reasons to doubt the validity of this measurement:

- **Comparison of rainfall AEP to flood AEP**

Rain gauge 87175 was used as an indicative measure of the rainfall over the Redesdale catchment. During the September 2016 event 125mm rain fell over 7 days. Based on the IFD for the Redesdale catchment the 7 day rainfall had the rarest intensity equivalent to between a 20% and 10% AEP rainfall event. However, the peak flow at the Campaspe River at Redesdale gauge was estimated to be around a 3% AEP event (Table 1-1), indicating that there may be some discrepancy in the peak flow measurement.

- **Model Calibration**

A hydrologic model analysis of the September 2016 rainfall using RORB required unrealistic values for the losses in order to reproduce the recorded hydrograph. A very low value of the  $k_c$  parameter was also required which was not consistent with the results determined for the

## KYNETON FLOOD STUDY

three historical events selected for calibration, namely September 2010, November 2010 and January 2011 (Section 3.4).

- **Comparison to historical events**

It is evident when comparing the peak gauge levels and corresponding flows from previous historical events that the September 2016 event does not correlate. For example, the total rainfall during January 2011 was much higher than the September 2016 event and occurred within a shorter time. Moreover, the peak gauge height was almost two metres higher during the January 2011 flood compared to the September 2016 flood. However, the flow during the September 2016 event is stated as being higher than the January 2011 event (Table 1-1). Furthermore, the September 2010 peak gauge level was 600mm higher than the September 2016 event yet, contradictorily, the 2016 peak flow rate was recorded as almost 90m<sup>3</sup>/s greater.

- **Anecdotal Evidence**

Anecdotal evidence from the local community also confirmed that flooding in Kyneton was relatively minor during September 2016 and that the January 2011 flood was significantly larger. Photos taken during both events also establish this.

The anomaly with the September 2016 event appears to be due to the updated ratings table for the Campaspe River at Redesdale gauge. The significant change in the ratings table is presumably based on three gaugings that were taken during this flood event on the 14<sup>th</sup> and 15<sup>th</sup> of September 2016. These gaugings were obtained from the Bureau of Meteorology website and are listed in Table 2-4 below.

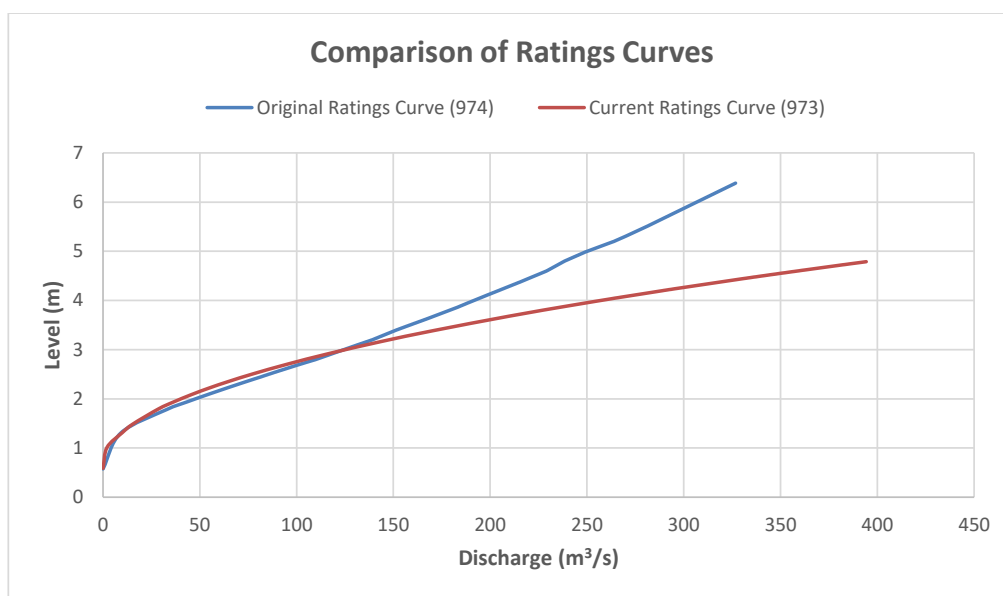
**Table 2-4 Gaugings taken at the Campaspe River at Redesdale gauge during the September 2016 flood event**

Time	Watercourse Level (m)	Watercourse Discharge (m <sup>3</sup> /s)
15/09/2016 12:10	2.934	114.568
14/09/2016 13:22	3.819	234.016
14/09/2016 12:19	4.051	157.158

When compared to the original ratings curve (blue curve in Figure 2-7), which has been in operation since 2005, the flows measured at gauge levels 2.934m and 4.051m coincide reasonably well. However, the flow measured at gauge level 3.819m is substantially greater than the flow indicated on the original ratings curve. Furthermore, it can be seen that this gauging is inconsistent with the gauging taken at a gauge level of 4.051m. Although the former gauging is 0.2 metres lower, the corresponding

## KYNETON FLOOD STUDY

measured flow was almost  $80\text{m}^3/\text{s}$  greater. As a result, this single gauging appears to have significantly influenced the current ratings curve at the upper end, which is displayed as the red curve in Figure 2-7. However, the lower end of the ratings curve, below a level of approximately 3m, remains essentially unchanged.



**Figure 2-7 Comparison of current and original ratings curves for Campaspe River at Redesdale gauge**

If the original ratings curve is applied, the September 2016 peak gauge height would correspond to a peak flow of approximately  $226\text{m}^3/\text{s}$ , rather than  $348\text{m}^3/\text{s}$ . This peak flow correlates more reasonably with the other historical flows when considering the depth and duration of rainfall and the peak gauge height recorded during each event. Furthermore, it also allows good calibration to be achieved using similar hydrologic parameters to those derived from the other historical events modelled. Hence, due to the inconsistency and the low data reliability, the September 2016 event was not included in the flood frequency analysis (Section 3.2) nor selected to calibrate the hydrologic model (Section 3.4).

### 2.3 Rainfall Data

Calibration of the hydrologic model requires both pluviograph and daily rainfall data which was sourced from the Bureau of Meteorology and DELWP Water Measurement Information System. Pluviograph rainfall data is used to understand the temporal distribution of a historical rainfall event while daily rainfall data provides the spatial variation in rainfall depths. This data is essential to calibrate the hydrological model.

Figure 2-8 shows the locations of daily rainfall and pluviograph stations in the region. As detailed in Table 2-5, there are seven pluviograph stations within, or in the vicinity of, the catchment. Daily rainfall records were obtained from 14 applicable daily rainfall stations which are shown in Table 2-6.

## KYNETON FLOOD STUDY

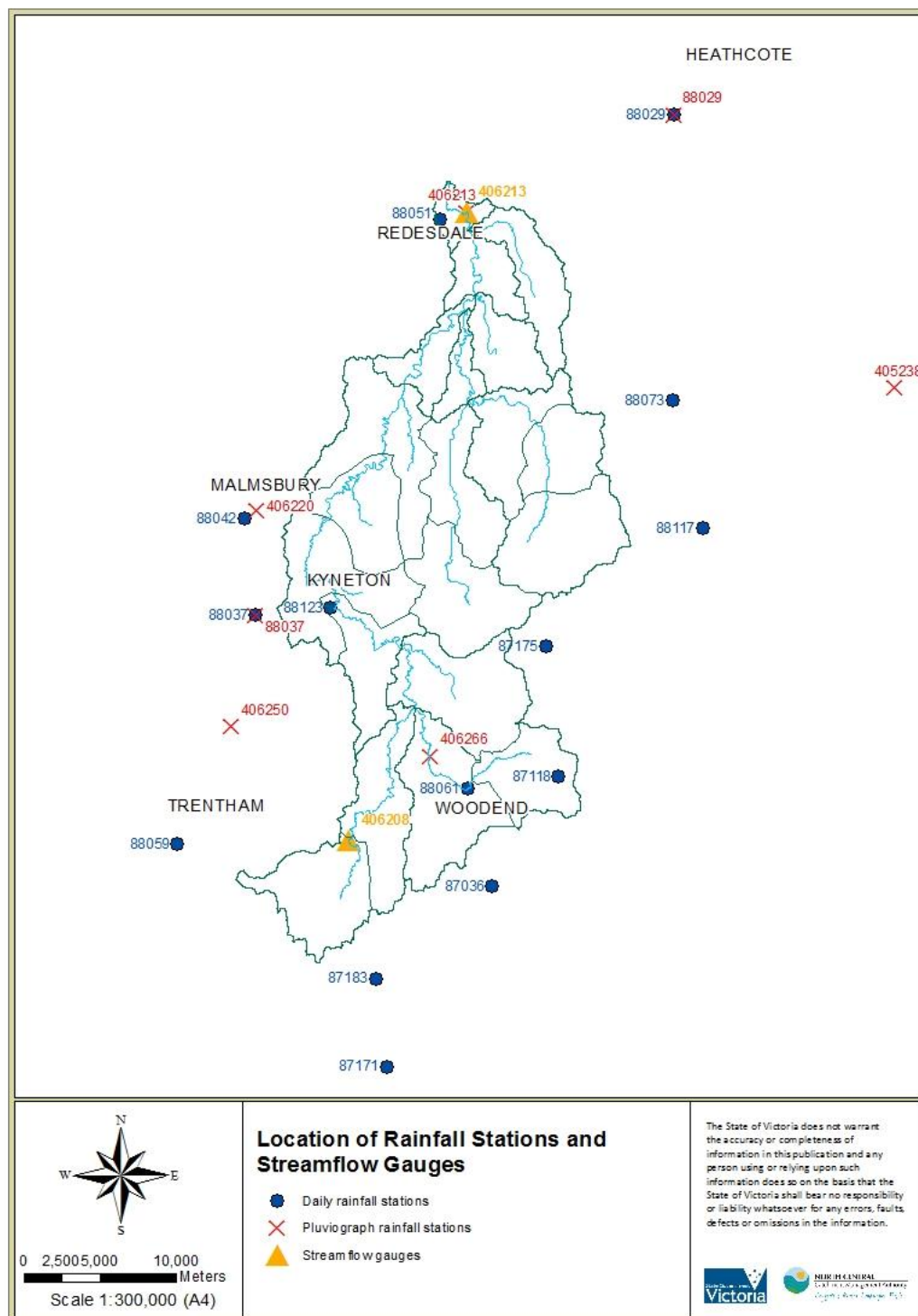


Figure 2-8 Locations of rainfall stations and streamflow gauges

## KYNETON FLOOD STUDY

Table 2-5 Pluviograph station details

Station Name	Station Number	Period of Record
Heathcote	88029	Jan 1882 – Present
Lauriston Reservoir	88037	Jul 1948 - Present
Mollison Creek @ Pyalong	405238	May 1966 – Present
Campaspe River @ Redesdale	406213	Feb 1989 – Present
Coliban River @ Malmsbury Reservoir (Head Gauge)	406220	April 2014 – Present
Coliban River @ Springhill-Tylden Road	406250	Oct 2010 – Present
Five Mile Creek @ Woodend Treatment Plant	406266	Oct 1998 – Present

Table 2-6 Daily rainfall station details

Station Name	Station Number	Period of Record
Baynton	88073	Mar 1953 – Present
Benloch	88117	Jan 1969 – Jun 2015
Bullengarook (North West)	87183	Oct 2010 – Jan 2012
Heathcote	88029	Jan 1882 – Present
Hesket (Straws Lane)	87118	Dec 1968 – Present
Kyneton	88123	Aug 1969 – Present
Lauriston Reservoir	88037	Jul 1948 – Present
Macedon Forestry	87036	Dec 1873 - Present
Malmsbury Reservoir	88042	Aug 1872 – Present
Newham (Cobaw)	87175	Jan 1995 – Present
Redesdale	88051	Jan 2003 - Present
Trentham (Post Office)	88059	Jan 1878 – Present
Woodend (Carlisle Street)	88061	Aug 1889 – Present
Bullengarook South	87171	Mar 1992 - Present

## 2.4 Storage Data

There are no significant water storages located within the study area.

## KYNETON FLOOD STUDY

### 3 Hydrologic Analysis

#### 3.1 Overview

A hydrologic model of the catchment was developed using the rainfall-runoff program RORB (version 6.32). The hydrologic model was calibrated to the Campaspe River at Redesdale gauge using three historical flood events. Design event hydrographs were then derived from RORB to be input as boundary conditions in the TUFLOW hydraulic model.

RORB is a non-linear runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. The catchment is delineated into subareas which are connected by reach storages. Specific losses are subtracted from the rainfall on each subarea to produce rainfall-excess. The rainfall-excess is then routed through the catchment storage to generate hydrographs at any location.

The following methodology was applied for the hydrologic modelling of the Campaspe River catchment up to the Campaspe River at Redesdale gauge:

- A flood frequency analysis was undertaken for the Campaspe River at Redesdale gauge to produce a flood frequency curve;
- A RORB model was prepared. Catchment subareas were initially obtained from a previous RORB model which was created for the Rochester Flood Management Plan (2013). However, the extent of the RORB model was reduced for the Kyneton Flood Study, terminating at the Campaspe River at Rochester gauge site;
- The catchment subareas were further delineated based on the topography to provide an adequate number of subareas upstream of Kyneton Township. Additional hydrograph print locations were also added to the existing RORB model to obtain the required inputs for the hydraulic model;
- The inputs adopted from the Rochester Flood Management Plan (2013) were inspected and revised reaches, slopes and subarea fraction impervious values were input where necessary;
- Storm files for the November 2010 and January 2011 events were adopted from the Rochester Flood Management Plan (2013) with minor changes, including updated pluviographs. A storm file for the September 2010 event was also created to calibrate the RORB model. All storm files were assembled using the available pluviograph and daily rainfall data for each event;
- The RORB model parameter  $k_c$  was calibrated to the observed Campaspe River at Redesdale gauge flood hydrographs for the September 2010, November 2010 and January 2011 events;
- A Monte Carlo analysis was undertaken on the RORB model to determine appropriate design losses by fitting it to the Campaspe River at Redesdale gauge flood frequency curve;
- Using the design losses and the calibrated parameter,  $k_c$ , a second RORB Monte Carlo analysis was run using the applicable design inputs for the Kyneton catchment to determine the flood frequency curve for the critical storm duration at the township.
- Individual runs from the Monte Carlo analysis, which produced peak flows approximately equal to the required design flood AEPs, were then selected.



## KYNETON FLOOD STUDY

- The inputs of the selected runs (including rainfall depth, loss factors and temporal patterns) were then used to produce complete hydrographs for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP design events. These design hydrographs were then used as inflow boundary conditions for the hydraulic model.

A separate, smaller RORB model was prepared for Post Office Creek, which flows into the Campaspe River just downstream of Kyneton. No streamflow gauge exists for this waterway and therefore the RORB model could not be calibrated to historical flood events. Instead, the routing parameter ( $k_c$ ) for this model was scaled from the calibrated Campaspe River RORB model. The design losses were also adopted from this model. Using these design parameters, a Monte Carlo analysis was undertaken to determine the flood frequency curve for the critical storm duration of the catchment. Individual sets of model parameters were then chosen to produce the design event hydrographs. The peak flow rates of these hydrographs were then compared to other peak flow estimates to ensure they were reasonable.

### 3.2 Flood Frequency Analysis

#### 3.2.1 Data Analysis

A flood frequency analysis was conducted on the Campaspe River at Redesdale gauge to assist with the RORB model calibration and generation of design hydrographs. Flood frequency analysis (FFA) involves the fitting of a probability model to an annual series of maximum recorded flows to relate the magnitude of extreme events to their frequency of occurrence. This statistical analysis allows the estimation of design flood flows.

The annual maximum flood series for the Campaspe River at Redesdale gauge was extracted from the available 52 years of instantaneous streamflow data, from 1966 to 2017. This data was evaluated to ensure that the annual maximum flows were independent and homogenous. During the gauge streamflow record no significant storages have been constructed upstream of the gauge and there has not been a significant increase in urbanisation of the gauge catchment. Hence, the annual maximum series derived from the gauge satisfies the criterion of homogeneity. Additionally, all annual maximum flows were produced from separate storm events; therefore, the independence criterion is also achieved. However, as discussed in Section 2.2, there is some uncertainty as to the accuracy of the 2016 measurement and therefore this flow was censored from the analysis.

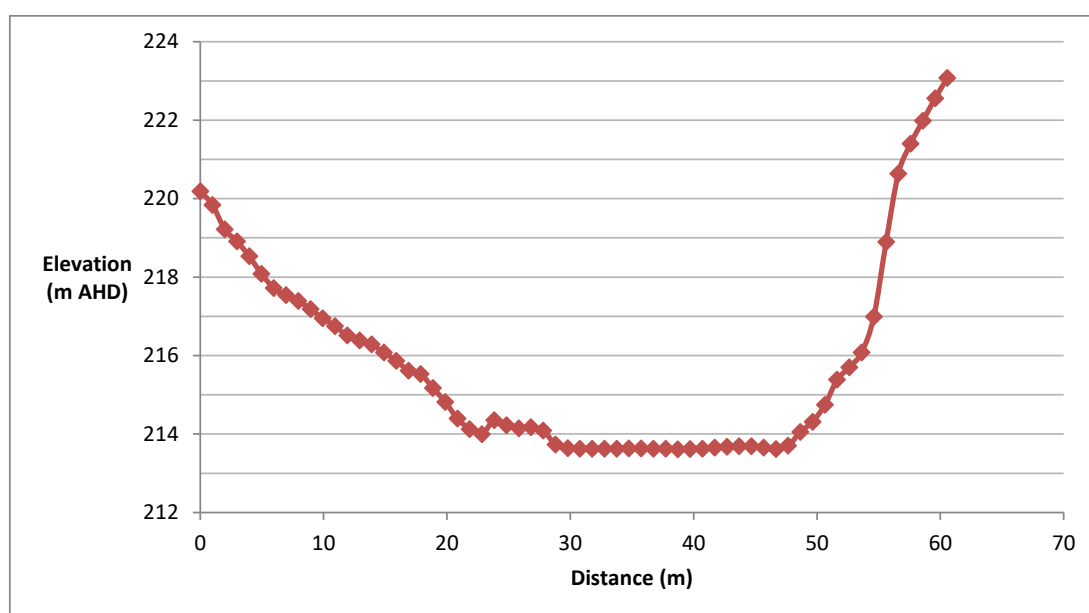
Most of the gauge discharge data is classified as good quality. However, the quality of the larger annual maximum flows is described by DELWP's Water Measurement Information System as 'Rating extrapolated due to insufficient gaugings'. Hence, it is necessary to analyse the waterway cross-section at the gauge site to determine whether the extrapolation is a valid assumption.

The Campaspe River is reasonably confined at the location of the Campaspe River at Redesdale gauge. The cross-section shown below in Figure 3-1 was generated from the MD\_Rivers\_ISC\_2010 LiDAR. It should be noted that as the LiDAR cannot penetrate the water surface this cross-section does not

## KYNETON FLOOD STUDY

display the natural surface levels of the river bed. However, according to the Water Measurement Information System the zero-gauge datum is 213.053 metres AHD.

The gauge rating curve has been produced by measuring the flow rate corresponding to a particular gauge level of a historical event. The maximum water level used to calibrate the rating curve was 5.714 metres corresponding to a flow of 389m<sup>3</sup>/s. However, the maximum water level recorded at this gauge was 6.697 metres. Hence, the rating curve was extrapolated in order to estimate the corresponding flow rate. To determine whether the rating curve extrapolation is reasonable, the maximum water level is compared to the cross-section of the topography at the gauge site (Figure 3-1). The gauge level of 6.697 metres corresponds to an elevation of 219.750 metres AHD. As shown in the cross-section below, this level is still within the confined area of the waterway. As there is no significant change in the gauge cross-section up to the maximum water level recorded at the gauge the extrapolated flows can be considered reasonable.



**Figure 3-1** Cross-section at Campaspe River at Redesdale gauge

### 3.2.2 FLIKE

The program FLIKE was used to undertake a flood frequency analysis of the annual maximum series of flows at the Campaspe River at Redesdale gauge. A Log Pearson Type III distribution was fitted to the annual maximum flood series using the Bayesian Inference method consistent with the recommendations of ARR, Book 3, Chapter 2.

## KYNETON FLOOD STUDY

No prior information from the Regional Flood Frequency Estimation method was incorporated into the analysis. An initial analysis was undertaken using the regional parameters and it was determined that they were not consistent with the gauge data. This is in accordance with ARR, Book 3, Section 2.3.10 and 2.6.3.5, which states that regional prior information should be used unless there is evidence that it is not applicable to the catchment of interest.

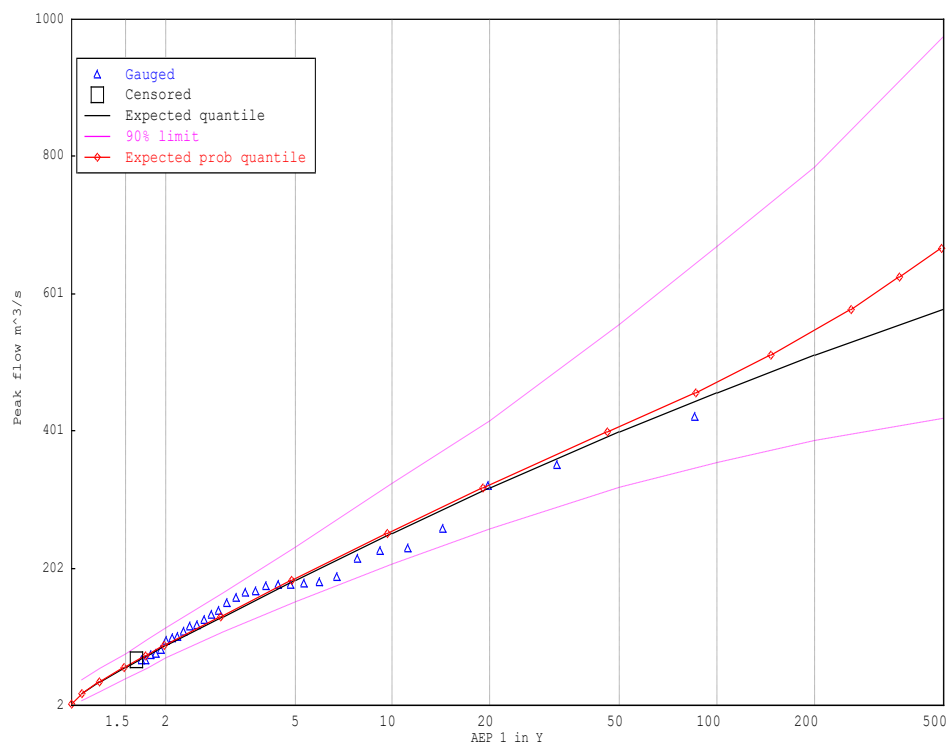
As recommended in ARR, Book 3, Section 2.8.6, the multiple Grubbs-Beck test was used to identify potentially influential low flows. These low flows are not representative of the population of floods and it is important that they are censored so that they do not unduly influence the distribution fit. The multiple Grubbs-Beck test identified 20 low flows which were censored to achieve an improved distribution fit.

Table 3-1 and Figure 3-2 present the AEP quantile estimates and their 90% confidence limits. The results of the FLIKE flood frequency analysis indicate that the September 2010 (259.6m<sup>3</sup>/s), November 2010 (216m<sup>3</sup>/s) and January 2011 (322m<sup>3</sup>/s) flood events were approximately 7%, 13% and 5% AEP flood events respectively.

**Table 3-1      Campaspe River at Redesdale FFA results**

AEP (%)	5% Confidence Limit (m <sup>3</sup> /s)	Quantile Estimate (m <sup>3</sup> /s)	95% Confidence Limit (m <sup>3</sup> /s)
50	70	89	114
20	151	183	231
10	207	252	323
5	258	318	415
2	318	399	556
1	355	457	668

## KYNETON FLOOD STUDY



**Figure 3-2 Flood frequency analysis of Campaspe River at Redesdale gauge**

### 3.3 RORB Model Construction

#### 3.3.1 Subarea Delineation, Reach Type and Loss Model

The catchment area for the Campaspe River RORB model is approximately 642.6km<sup>2</sup>. The catchment has been divided into 20 subareas for the Campaspe River RORB model. Figure 3-3 shows the subarea delineation for the study area. The RORB model outlet is located at the Campaspe River at Redesdale gauge.

A RORB model was also prepared for the Post Office Creek catchment with the downstream outlet at the Mollison Street bridge crossing. The Post Office Creek catchment area, approximately 12.1km<sup>2</sup>, was delineated into six subareas as shown in Figure 3-4. The location of the downstream outlet adopted for the RORB model was largely determined by the extent of LiDAR data available for the hydraulic model.

For both models, nodes were placed at areas of interest (including streamflow gauges and inflow locations to the hydraulic model) and the junction of any two reaches. Reaches were then used to connect the nodes, representing the length and type. As all reaches were classified as natural based on aerial photography, the reach slope was not required to be input into RORB. Additionally, as there

## KYNETON FLOOD STUDY

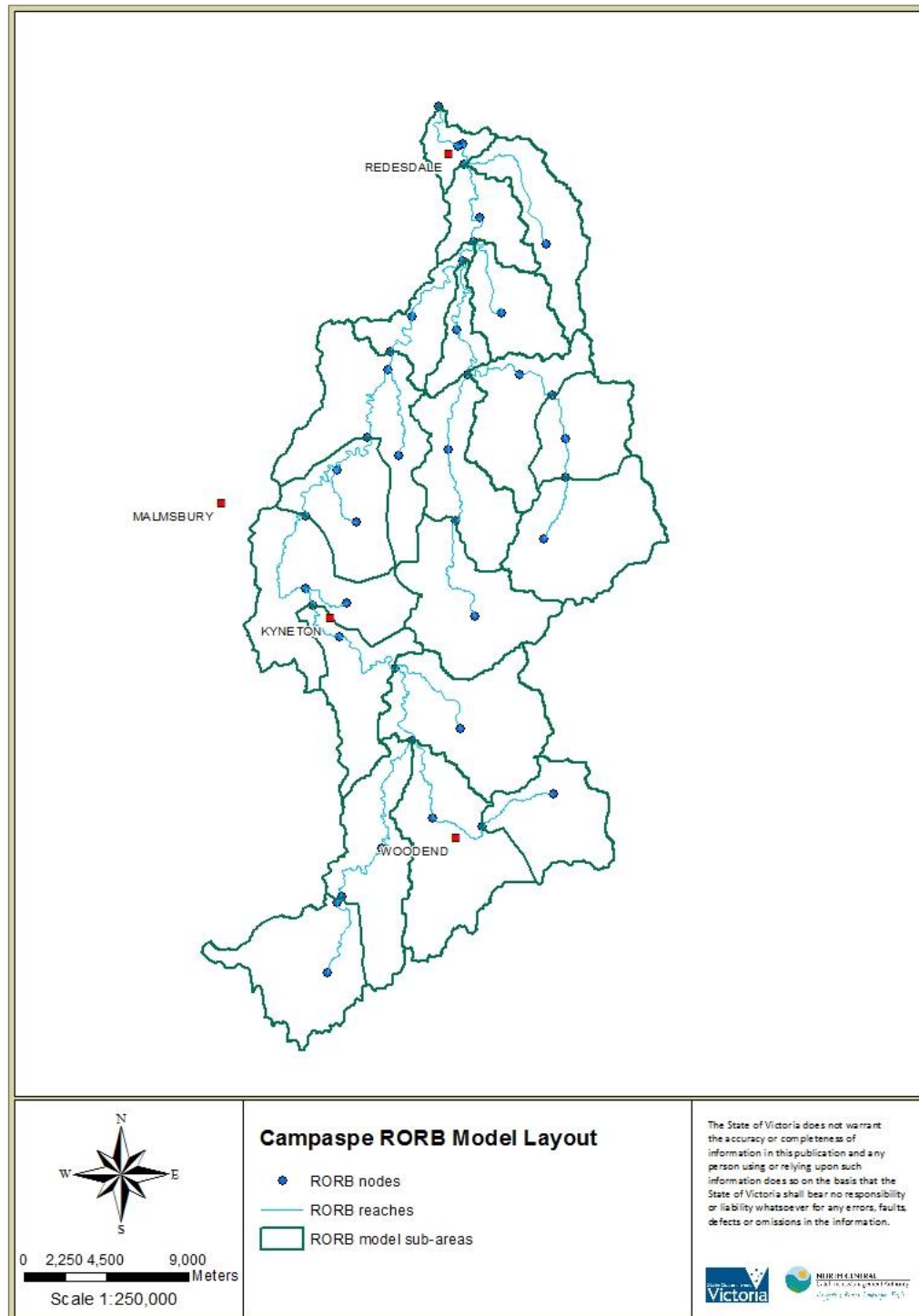
are no significant storages on either the Campaspe River or Post Office Creek in the study area, drowned reaches were not required.

In order to determine the corresponding runoff generated by a particular rainfall event, RORB provides two alternative models of the loss processes:

- Initial loss and runoff coefficient (constant proportional rate of loss)
- Initial loss and continuing (constant) loss

The RORB manual recommends the use of the runoff coefficient method for urban or partly urban catchments but notes that either model is suitable for rural catchments. However, Australian Rainfall and Runoff 2016 (ARR) states that the continuing loss model is the most suitable for design flood estimation for both rural and urban catchments (ARR, Book 4, Section 2.6.2). For the Campaspe River RORB model, the continuing loss method was adopted as the majority of the catchment is rural. This also allowed a comparison with the Rochester Flood Management Plan RORB model which also utilised this loss model. Similarly, the continuing loss method was also adopted for the Post Office Creek RORB model to be consistent with the Campaspe River RORB model. It was critical that the model parameters and design losses could be applied from the Campaspe River RORB model to the Post Office Creek model due to the lack of historical flood data available for calibration.

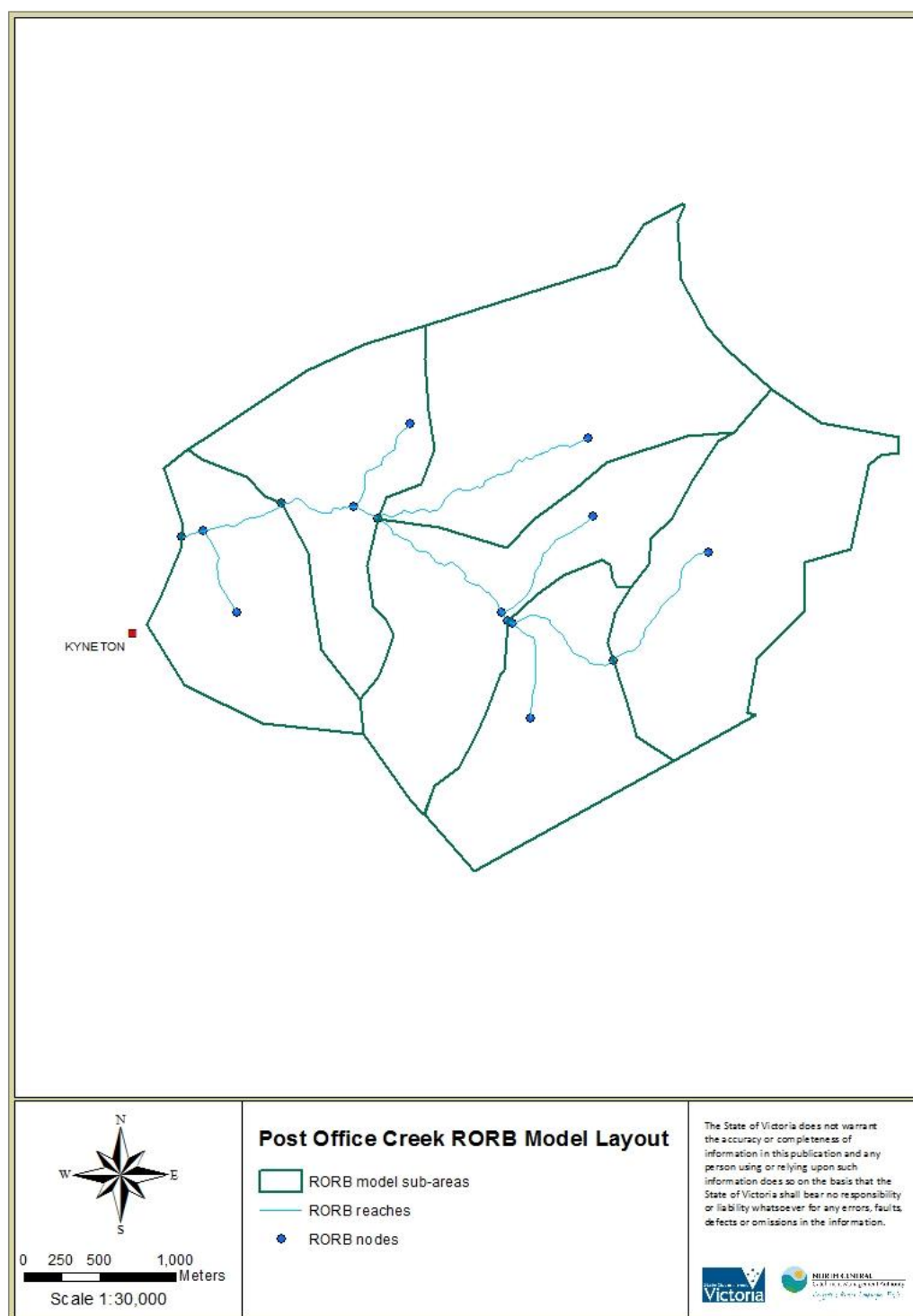
## KYNETON FLOOD STUDY



**Figure 3-3** Graphical representation of the Campaspe RORB model



## KYNETON FLOOD STUDY



**Figure 3-4** Graphical representation of the Post Office Creek RORB model

## KYNETON FLOOD STUDY

**3.3.2 Fraction Impervious Data**

The RORB model for both the Campaspe River and Post Office Creek require the input of fraction impervious values for the subareas. Values were assigned based on the various planning zones, as shown below in Table 3-2. The fraction impervious values adopted were derived from the Rochester Flood Management Plan (2013).

**Table 3-2 Land use and fraction impervious values**

Land Use Zone	Description	Fraction Impervious
Commercial Zone (B1Z & B3Z)	Commercial centres with retail, office, business and community uses	0.80
Farm Zone (FZ)	Rural areas	0.001
Industrial Zone (IN1Z, IN2Z)	Manufacturing and storage facilities	0.80
Low Density Residential (LDRZ)	0.4 Ha minimum lot size	0.20
Public Conservation and Resource Zone (PCRZ)	Natural environment with associated facilities	0
Public Park and Recreation Zone (PPRZ)	Public recreation and open space	0.01
Public Use Zone (PUZ1-7)	Public utility and community services and facilities	0.60
Residential Zone (R1Z, TZ)	Normal range of densities	0.45
Rural Conservation Zone (RCZ, RCZ1, RCZ2)	Natural environment and agricultural use	0
Road Zone (RDZ1, RDZ2)	Secondary and local roads	0.60
Rural Living Zone (RLZ1, RLZ2, RLZ5)	Rural residential and agricultural use	0
Special Use Zone (SUZ1)	Private educational uses	0.60
Special Use Zone (SUZ2)	Racecourses and associated uses	0.01
Special Use Zone (SUZ3)	Golf Courses and associated uses	0.01
Special Use Zone (SUZ4)	Private hospitals	0.60

The spatial distribution of the fraction impervious data is shown in Figure 3-5 and Figure 3-6 for the Campaspe River and Post Office Creek catchments respectively. The average fraction impervious for both catchments is 0.022 and 0.156 respectively.

## KYNETON FLOOD STUDY

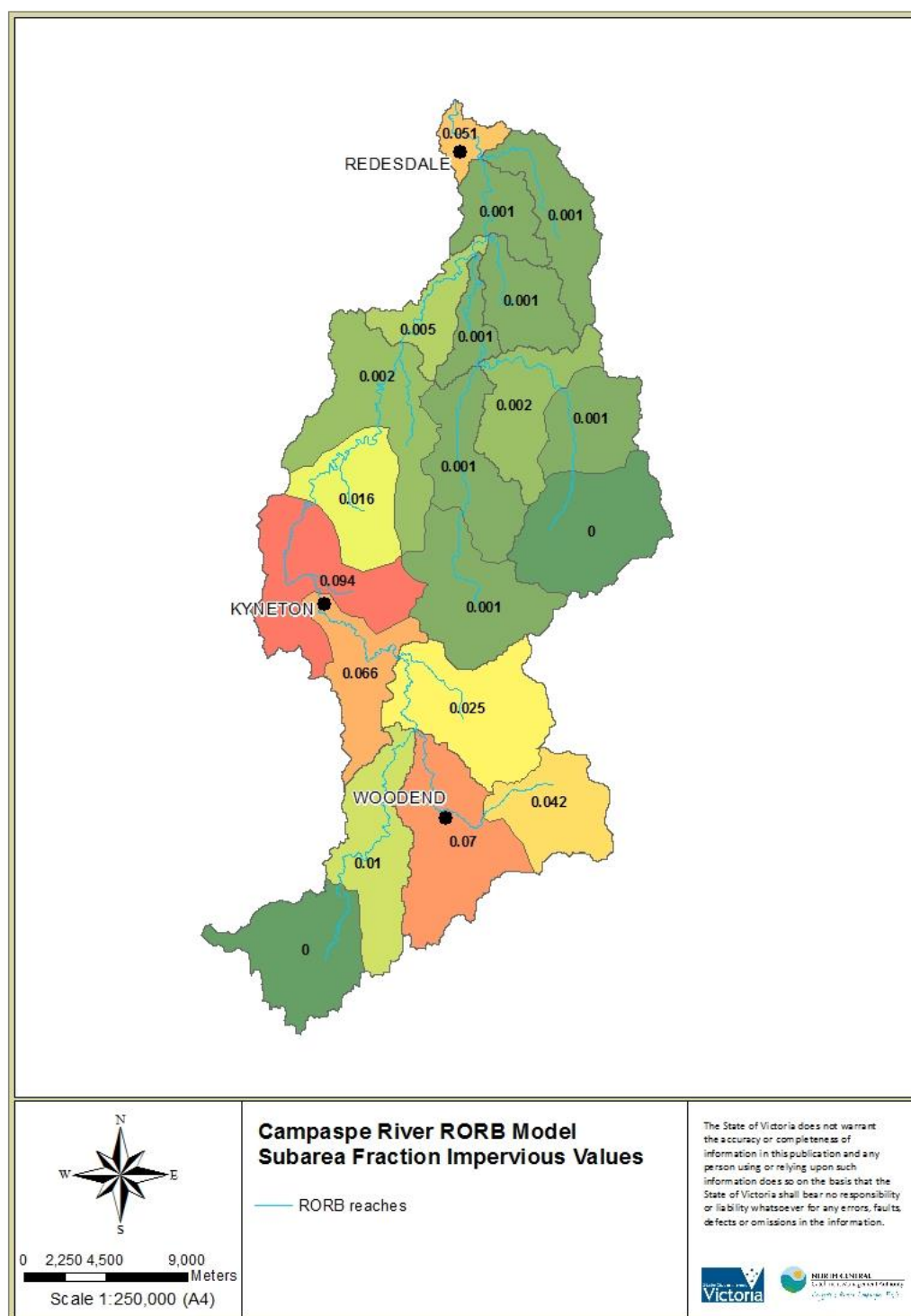


Figure 3-5 Fraction impervious values for the Campaspe RORB model

## KYNETON FLOOD STUDY

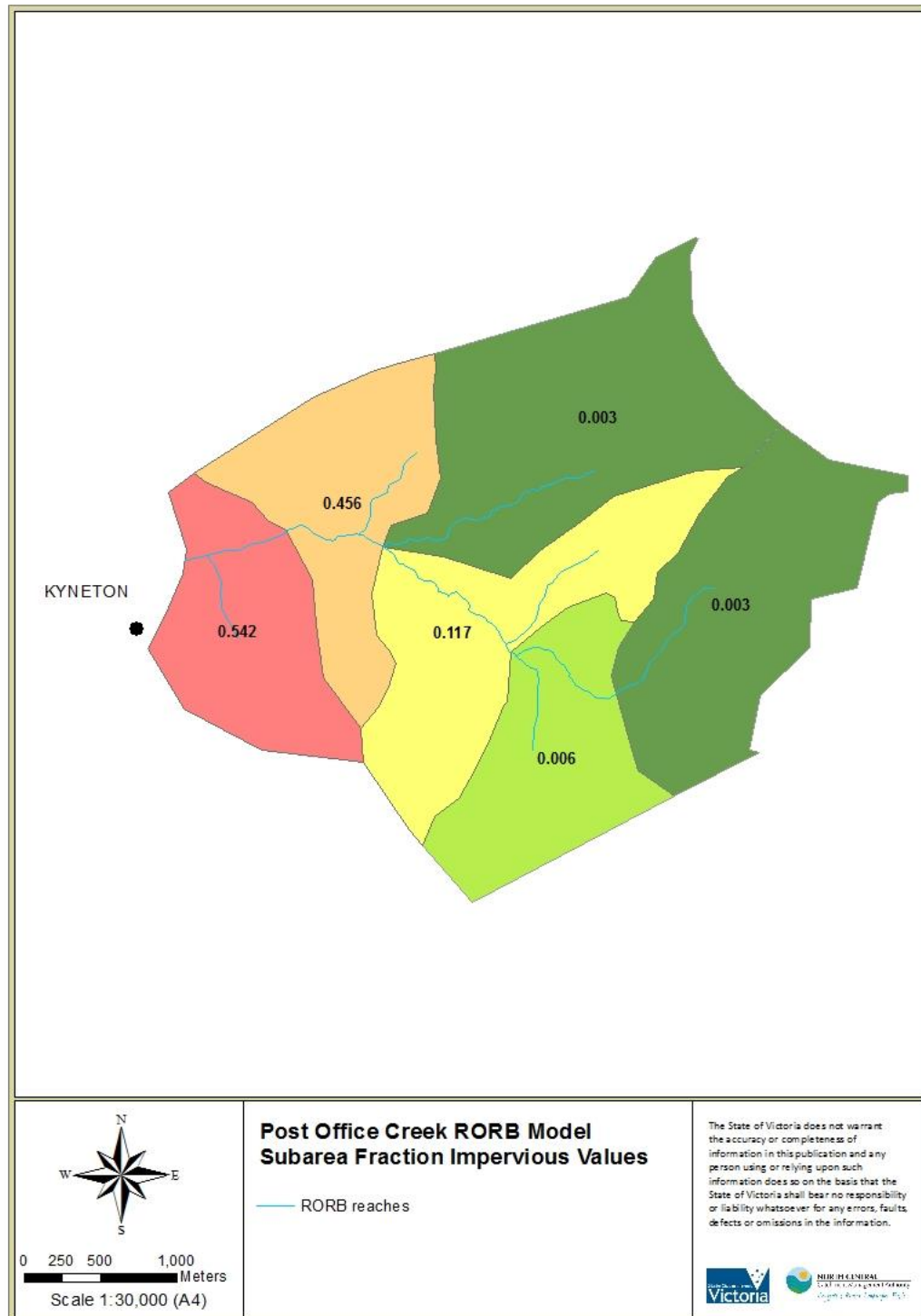


Figure 3-6 Fraction impervious values for the Post Office Creek RORB model

## KYNETON FLOOD STUDY

### 3.4 Campaspe River RORB Model Calibration

#### 3.4.1 Overview

The RORB model was calibrated by fitting it to the observed rainfall and runoff data of recorded flood events to determine the routing parameter  $k_c$ . As recommended in RORB manual, and consistent with the Rochester Flood Management Plan (2013), a value of 0.80 was adopted for the nonlinearity parameter,  $m$ . A trial and error fitting procedure was utilised to reproduce the flood peak, volume and shape of the observed hydrograph. The adopted  $k_c$  value was then compared to regional estimations to assess its reasonableness.

As the catchment does not significantly vary in topography or density of vegetation cover, it is likely to have consistent storage runoff behaviour throughout the catchment. Consequently, it was not considered necessary to vary the parameters by interstation area. Moreover, the Rochester Flood Management Plan (2013) also assessed the results of varying parameters by interstation areas and determined that this does not significantly improve the calibration. Therefore, a single routing parameter has been adopted for the catchment. It should be noted that the  $k_c$  parameter determined in the Rochester Flood Management Plan (2013) could not be directly adopted for this flood study model as the catchment size and shape was not comparable.

The RORB model was calibrated to the Campaspe River at Rochester gauge located further downstream of Kyneton as this was the nearest available gauge. Three recent flood events were considered; September 2010, November 2010 and January 2011. These historical events were selected due to their large size and the fact that they are recent experiences of flooding in Kyneton. It should be noted that although the peak flows recorded in 1974 and 1975 are the highest on record (Table 1-1), pluviograph data was not available to enable these events to be used for calibration. Furthermore, there was uncertainty regarding the reliability of the September 2016 peak flow rate as discussed in Section 2.2 and therefore this event was not selected for calibration. Details of the selected calibration events are provided in Table 3-3 below.

## KYNETON FLOOD STUDY

Table 3-3 RORB model calibration events

Event	September 2010	November 2010	January 2011
Event Start Date	03/09/2010 12:00am	24/11/2010 12:00pm	09/01/2011 12:00am
Event Finish Date	14/09/2010 12:00am	12/12/2010 12:00am	23/01/2011 12:00am
Average Catchment Rainfall (mm)	91.1mm (11 day period)	166.6mm Burst 1: 122.9mm (4 day period) Burst 2: 25.4mm (4 day period) Burst 3: 18.3mm (2 day period)	182.0mm (5 day period)
Recorded Peak Flow at Campaspe River @ Redesdale gauge (m <sup>3</sup> /s)	259.6	216.2	322.1
Recorded Water Level at Campaspe River @ Redesdale gauge (m)	5.138	4.388	6.295
Estimated AEP (based on FFA)	7%	13%	5%

## 3.4.2 RORB Model Calibration Event Data

## 3.4.2.1 Observed Streamflow Data

Instantaneous streamflow data for the Campaspe River at Redesdale gauge was obtained from for the DELWP Water Measurement Information System for the selected calibration events. Gauged streamflow data is shown in Figure 3-7 to Figure 3-9 for the September 2010, November 2010 and January 2011 flood events respectively.

The gauge data quality was reviewed for each of the historical flood events considered for the hydrological model calibration. For both the September 2010 and January 2011 flood peaks the data was estimated by extrapolating the rating curve due to the flow exceeding the maximum rated flow for the gauge. Also, the quality codes indicate that medium editing (more than 30 millimetres) was performed on the majority of the September 2010 event data. The November 2010 event data quality was mostly of good quality. However, data recorded for the second flood peak, from approximately 9:00am 8/12/2010, was classified as raw data which had not been validated.



## KYNETON FLOOD STUDY

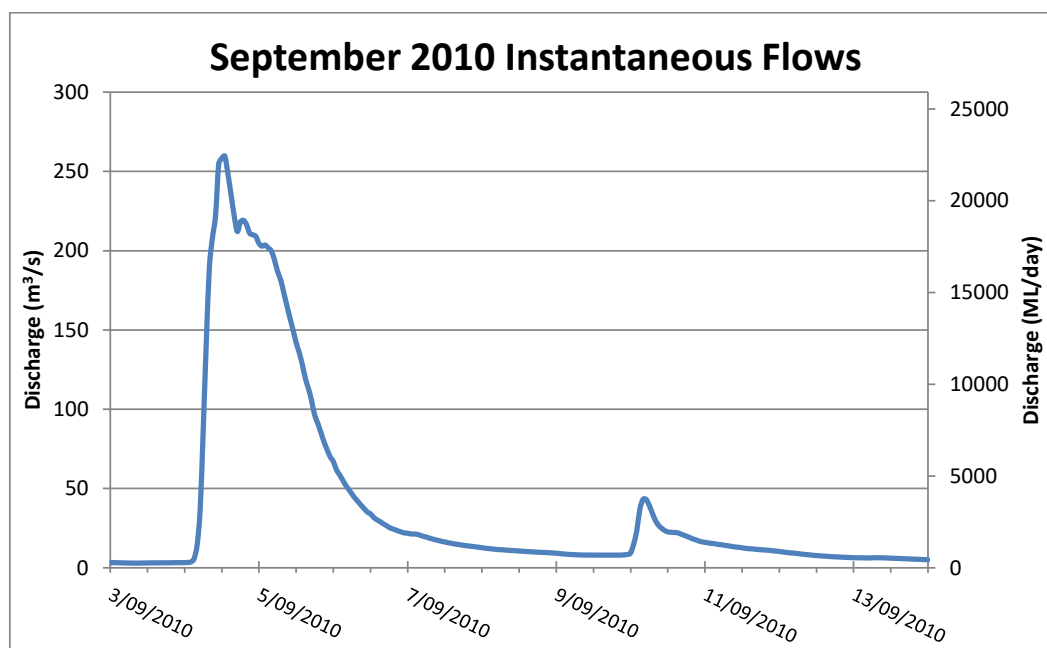


Figure 3-7 Recorded flood hydrograph for the September 2010 event at the 406213 Campaspe River @ Redesdale gauge

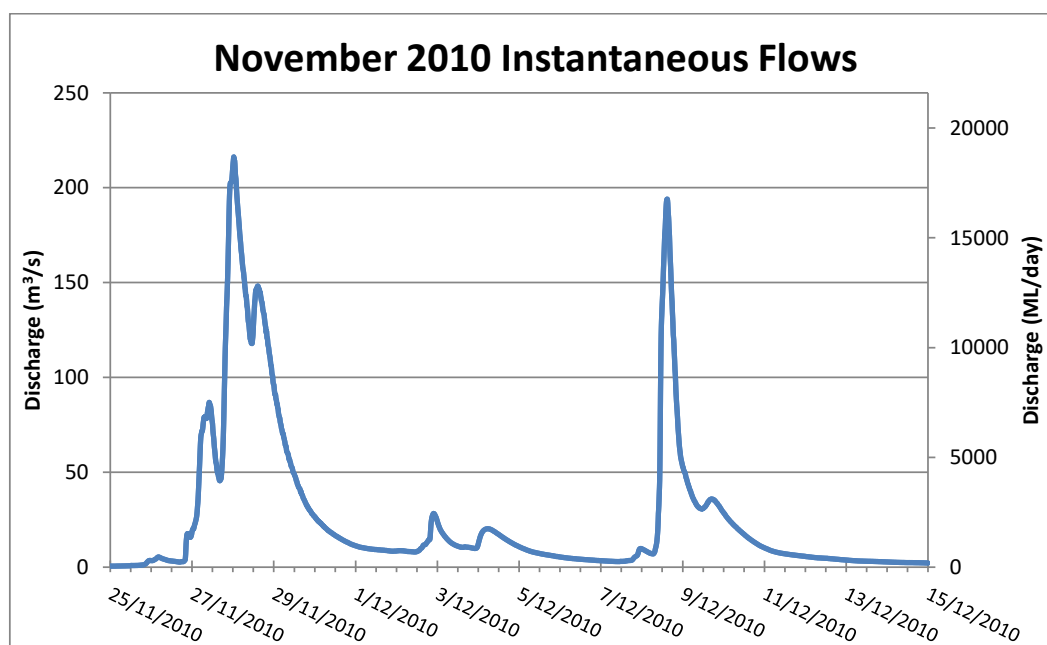
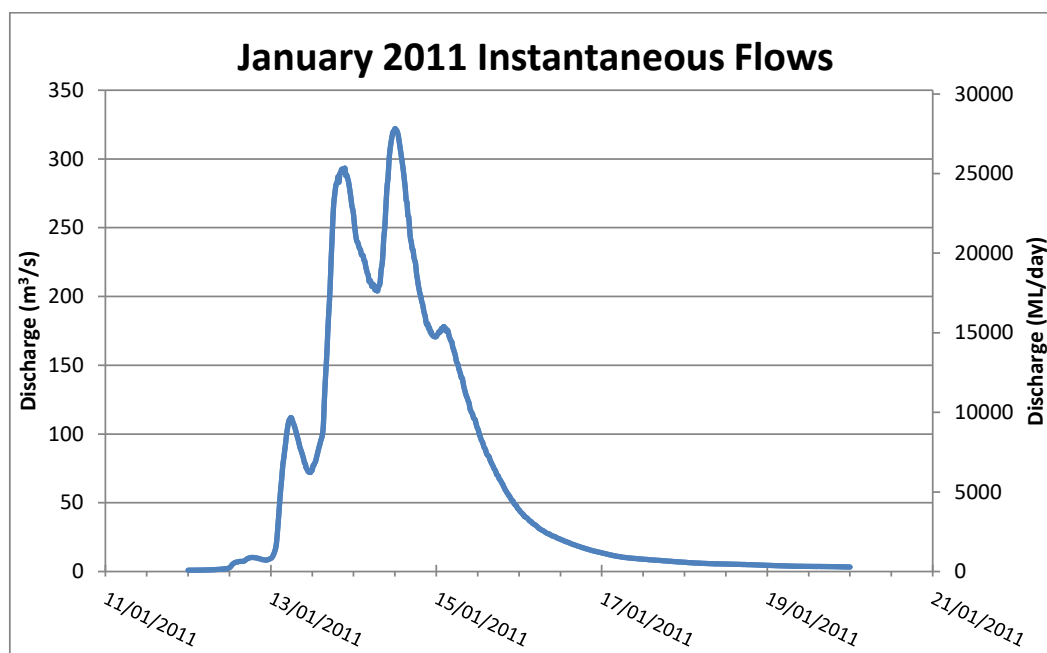


Figure 3-8 Recorded flood hydrograph for the November 2010 event at the 406213 Campaspe River @ Redesdale gauge

## KYNETON FLOOD STUDY



**Figure 3-9** Recorded flood hydrograph for the January 2011 event at the 406213 Campaspe River @ Redesdale gauge

#### 3.4.2.2 Baseflow Separation

Baseflow describes the portion of streamflow resulting primarily from groundwater discharge, as opposed to surface runoff. As RORB only models direct rainfall runoff, it is necessary to understand the different components and, if necessary, separate the total streamflow into surface runoff and baseflow.

The Rochester Flood Management Plan (2013) analysed the baseflow component of the observed flood hydrographs and determined this contribution to be very small. ARR recommends that the following be considered in order to determine whether baseflow is likely to be a significant component of the flood hydrograph:

- **Baseflow Peak Factor**

The Baseflow Peak Factor (BPF) is defined as the relative magnitude of baseflow compared to surface runoff for a 10% AEP event. A map of the BPF is provided in ARR, Book 5, Section 4.4, to allow identification of the appropriate factor for the catchment. According to this map, the Campaspe catchment has a factor of less than 0.05. Furthermore, the AEP scaling factors for the BPF indicate that, for rarer events, the BPF reduces (ARR, Book 5, Section 4.5.2). Hence, for a 1% AEP flood event, the baseflow contribution for the Campaspe catchment is expected to be less than 3% of the surface runoff. Data Hub specifies the BPF for the Redesdale catchment as 0.02 (Section 7.3.1).

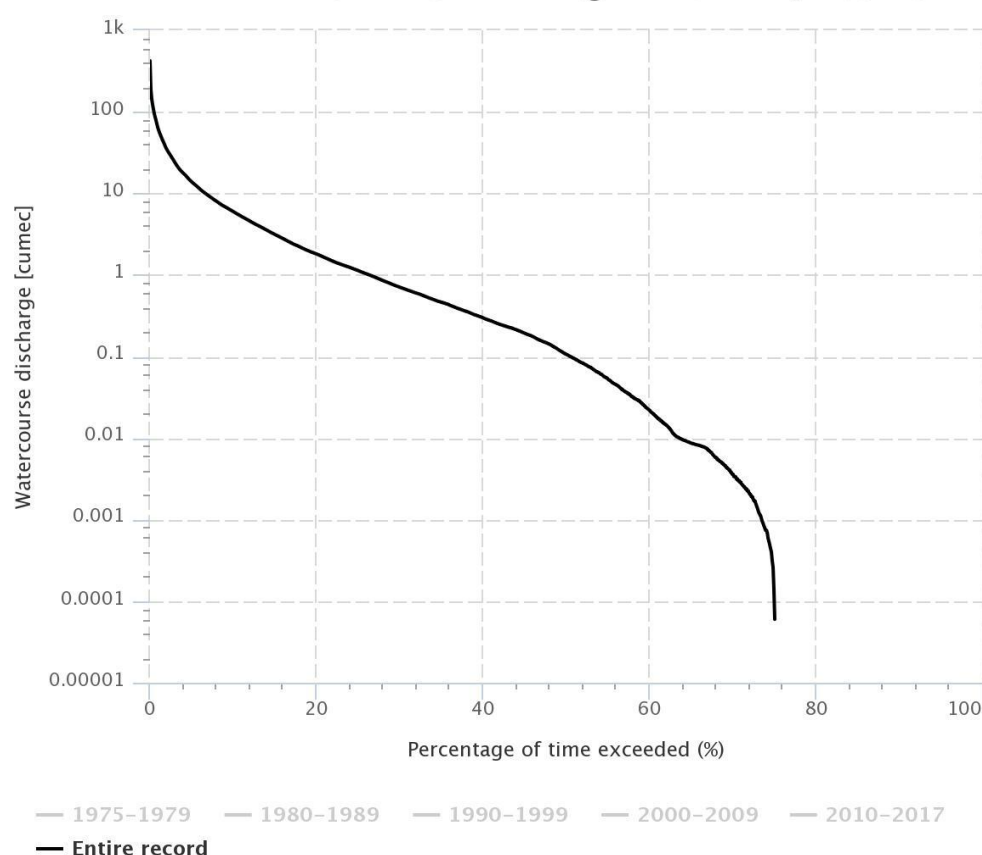
## KYNETON FLOOD STUDY

- Streamflow data review**

A review of the magnitude of flows between flood events relative to the peaks can be used to determine whether baseflow is likely to be an important component of the flood hydrograph. The duration curve shown in Figure 3-10 displays the percentage of time that a particular streamflow is exceeded at the Campaspe River at Redesdale gauge. It can be seen that the majority of flows are very small, with flows only exceeding  $0.1\text{m}^3/\text{s}$  50% of the time over the 41-year gauge record.

Hence, baseflow is considered to have a negligible impact on the flood hydrographs in this catchment and therefore baseflow has not been explicitly removed from the recorded hydrographs.

Duration curve for CAMPASPE RIVER @ REDESDALE / 406213



**Figure 3-10** Duration Curve (Bureau of Meteorology)

## KYNETON FLOOD STUDY

### 3.4.2.3 Observed Rainfall Data

The temporal rainfall distributions for each RORB subarea were sourced from the closest available pluviograph stations for each storm event. The temporal patterns for the available pluviographs during the September 2010, November 2010 and January 2011 flood events are shown in Figure 3-11 to Figure 3-13 respectively.

The total storm rainfall depth is also required at each available daily rainfall gauge for the calibration events. This data is used to produce rainfall isohyets for each event to estimate the rainfall depth for each model subarea for the total storm duration. This process was undertaken for the September 2010 event. However, as this information was already available for the November 2010 and January 2011 events from the Rochester Flood Management Plan (2013), these previously derived rainfall totals were adopted for this study. The pluviographs applied in the calibration modelling of these two events was also reviewed and, for some subareas, more relevant pluviograph data was substituted in.

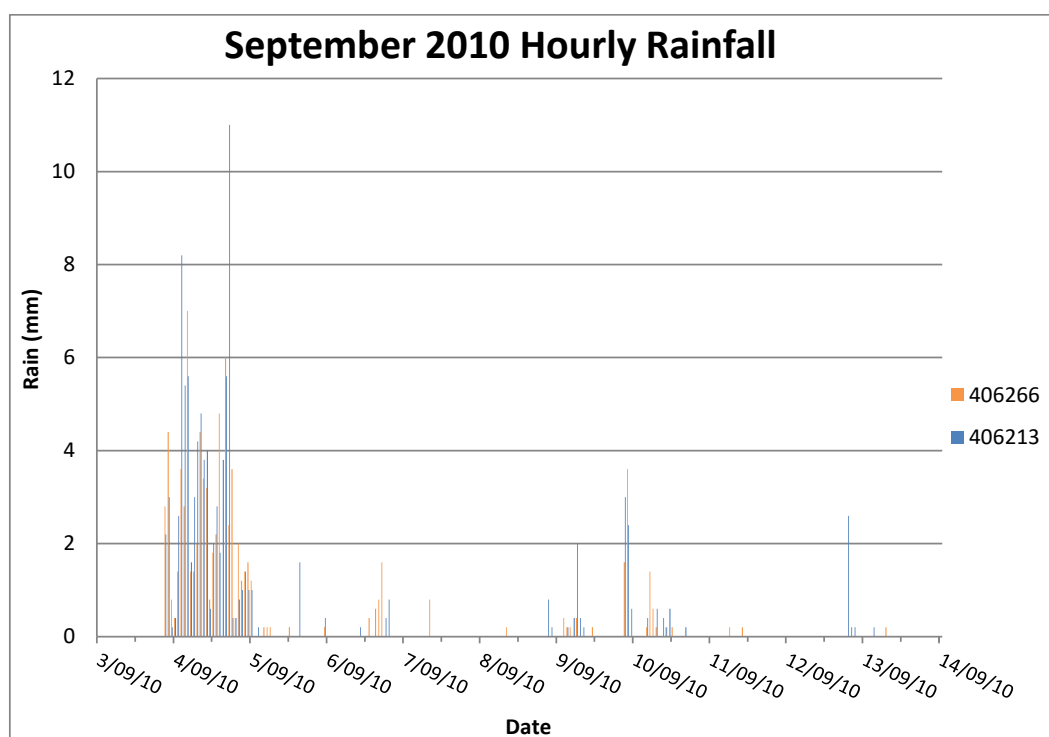


Figure 3-11 Pluviograph records for the September 2010 event

## KYNETON FLOOD STUDY

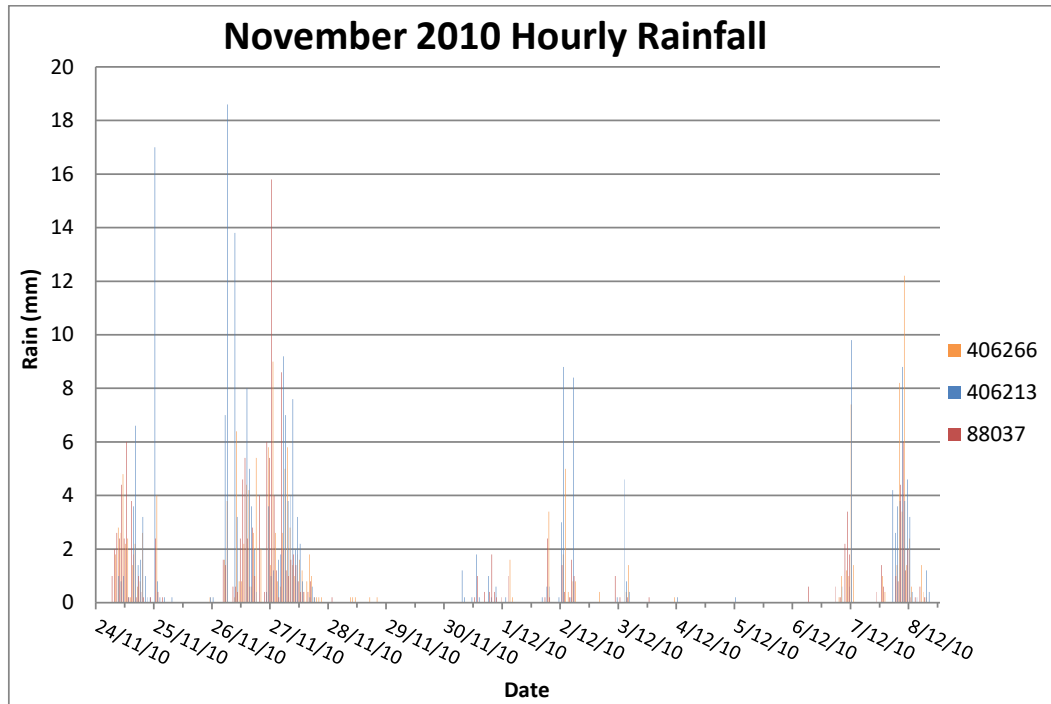


Figure 3-12 Pluviograph records for the November 2010 event

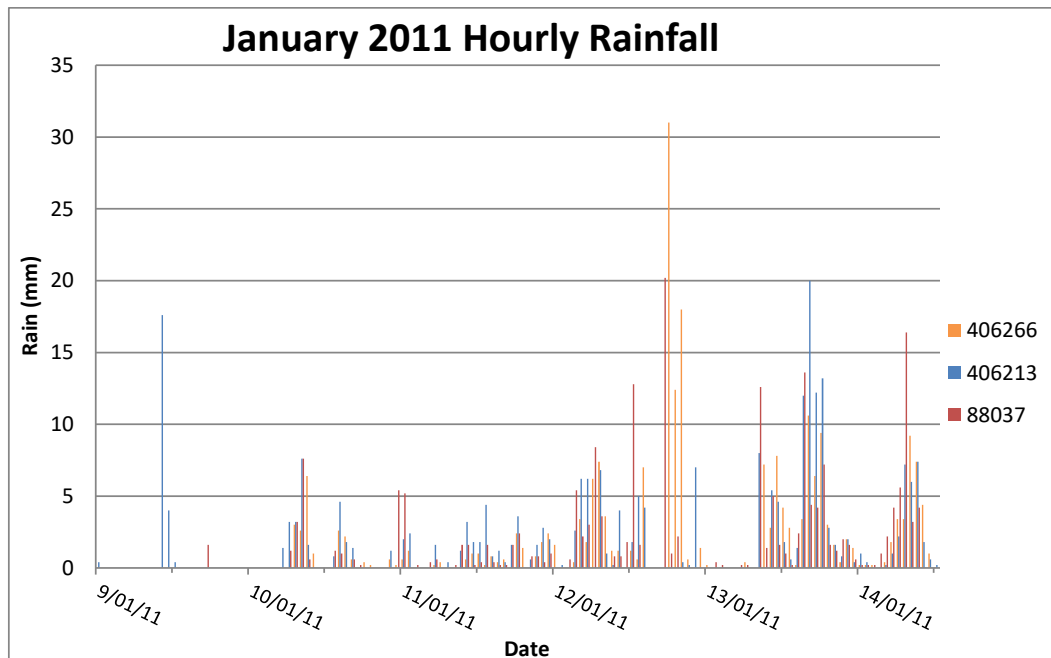


Figure 3-13 Pluviograph records for the January 2011 event



## KYNETON FLOOD STUDY

### 3.4.2.4 Losses

An initial loss/continuing loss model was adopted for the RORB model and calibration was achieved using the FIT option in RORB. The initial loss parameter was determined by trial and error to reasonably reproduce the observed rising limb of the hydrograph. Depending on the initial loss chosen, the FIT option enabled RORB to automatically select the continuing loss value that minimises the error between the calculated and observed hydrograph volume. In addition to ensuring a good model fit, the adopted calibration losses were also reviewed against those adopted in the Rochester Flood Management Plan (2013) as well as whether the values were realistic in general.

### 3.4.3 September 2010 Flood Event Calibration

The September 2010 event was modelled from 12:00am 3<sup>rd</sup> September 2010 to 12:00am 14<sup>th</sup> September 2010. This timing was based on an analysis of the available daily rainfall pluviograph and flow data for this flood event. Based on a flood frequency analysis of the Campaspe River at Redesdale gauge the September 2010 event was approximately a 7% AEP flood event.

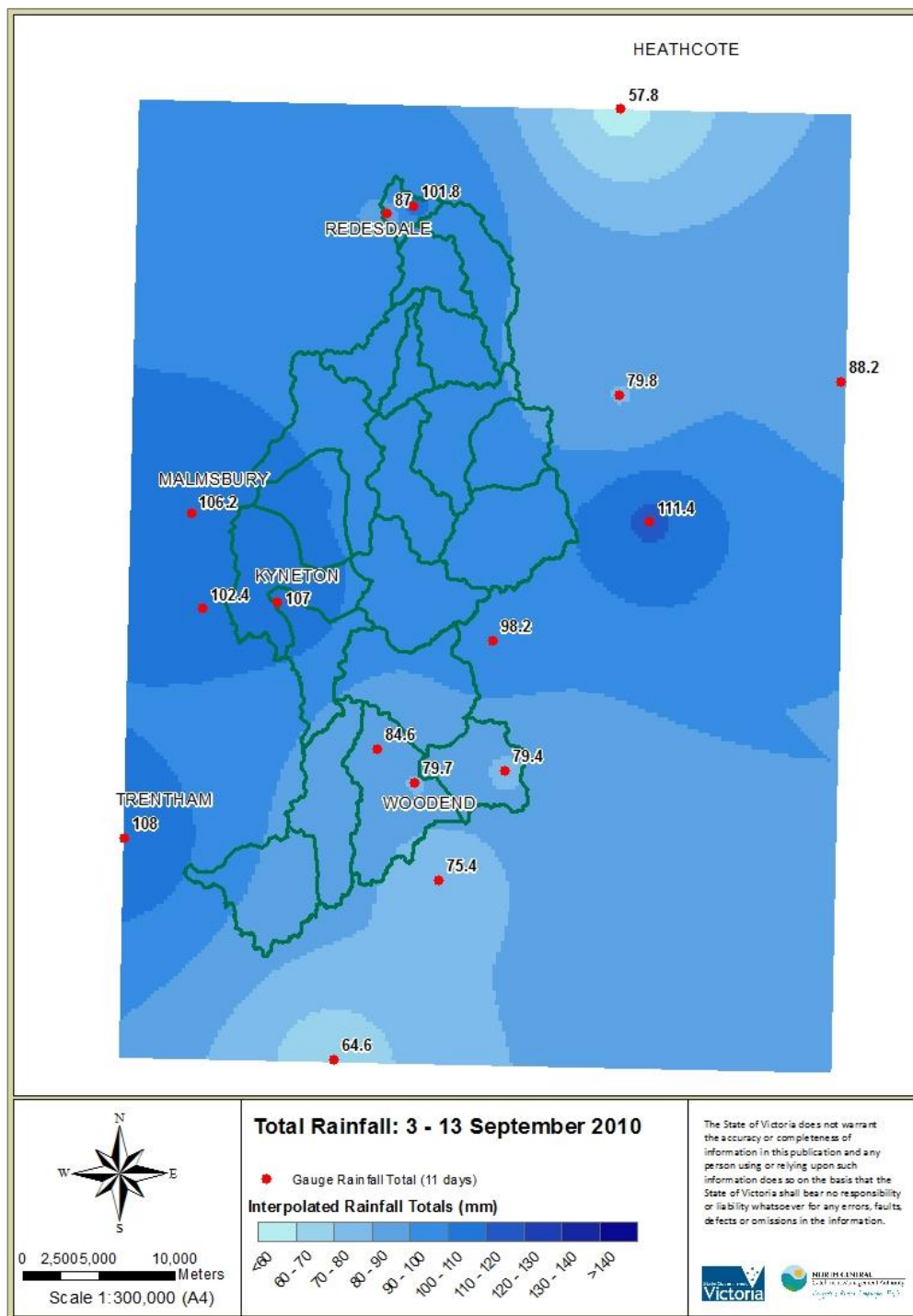
The accumulated rainfall total for the entire storm duration was determined for each rainfall station. These values were then mapped spatially and interpolated to create a raster surface as shown in Figure 3-14. The interpolation was performed using the Inverse Distance Weighted technique based on a minimum of 12 points and cell size of 250 metres. The rainfall totals for each model subarea was then determined from the interpolated rainfall raster surface by averaging the rainfall totals at all grid cells that intersect with the spatial extent of the subarea.

The temporal patterns for each subarea were assigned based on the closest available pluviograph station. As the majority of rainfall fell over 4<sup>th</sup> – 5<sup>th</sup> of September, the rainfall was modelled as a single burst.

Figure 3-15 shows the observed and calculated hydrographs at the Campaspe River at Redesdale gauge. The calculated hydrograph reasonably matches the shape and peak of the observed hydrograph. However, it can be seen that the timing is off by approximately 13 hours. Also, it is evident that the rising limb of the observed hydrograph appears very steep, particularly compared to the other flood hydrographs. It should be noted that the data quality codes for this event indicate that medium editing of more than 30 millimetres was undertaken.

The adopted values of  $k_c$ ,  $m$ , initial loss (IL) and continuing loss (CL) for the calibration are summarised in Table 3-4. As shown, the difference between the observed and modelled peak flow is -1.8% while the difference in flood volume is -0.2%. Overall, the model calibration for the September 2010 flood event is considered good.

## KYNETON FLOOD STUDY



**Figure 3-14** Total rainfall accumulated over 10 days during September 2010 storm (3 – 13 September)

## KYNETON FLOOD STUDY

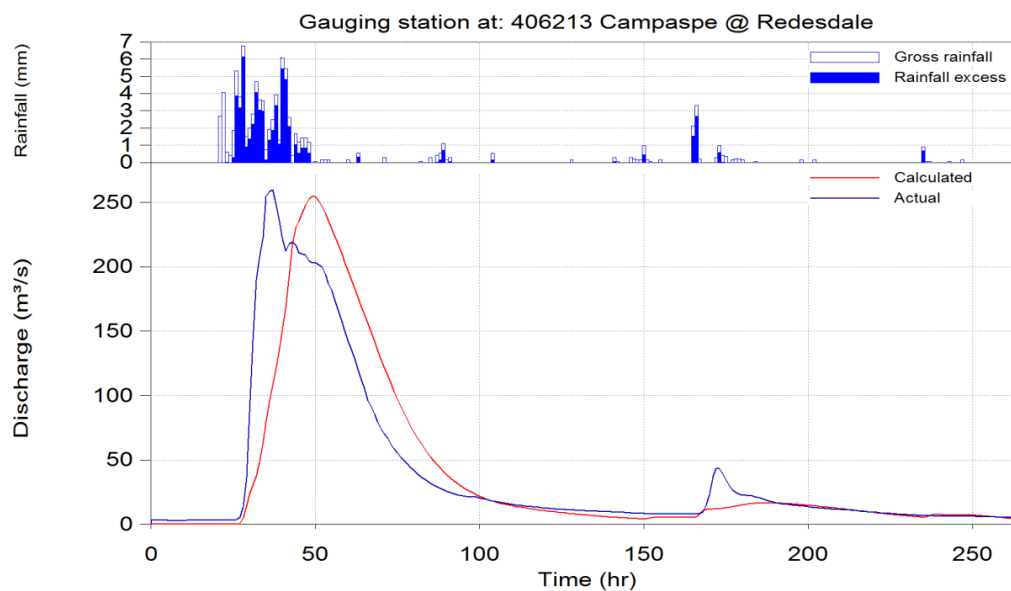


Figure 3-15 Comparison of modelled and observed hydrographs for the September 2010 event on the Campaspe River at Redesdale gauge (406213)

Table 3-4 RORB calibration parameters and results for September 2010 event

Location		Campaspe River @ Redesdale
Model Parameters	$k_c$	62
	$m$	0.8
	IL	10
	CL	0.63
Peak flow ( $m^3/s$ )	Observed	255.0
	Calculated	261.0
	Relative difference (%)	-1.8
Volume (ML)	Observed	$37.6 \times 10^6$
	Calculated	$37.5 \times 10^6$
	Relative difference (%)	-0.2

## KYNETON FLOOD STUDY

**3.4.4 November 2010 Flood Event Calibration**

The November 2010 event was modelled from 12:00am 24<sup>th</sup> November 2010 to 12:00am 11<sup>th</sup> December 2010. This timing was based on an analysis of the available daily rainfall pluviograph and flow data for this flood event. Based on a flood frequency analysis of the Campaspe River at Redesdale gauge the November 2010 event was approximately a 13% AEP flood event.

The accumulated rainfall total for each subarea was adopted from the Rochester Flood Management Plan (2013). The pluviographs applied in the Rochester Flood Management Plan (2013) calibration model was reviewed and the subarea temporal pattern was adjusted where more relevant pluviograph data was available.

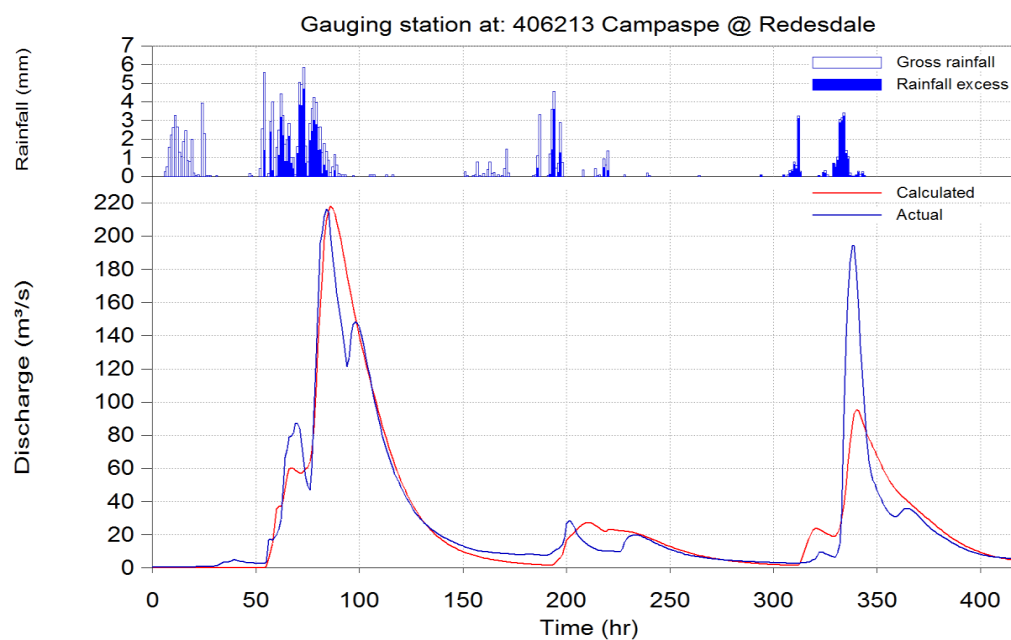
A multiple burst approach was adopted for the November 2010 event to allow the loss parameters to vary across each burst. As discussed in the Rochester Flood Management Plan (2013), this was required since:

- The flooding event resulted from rainfall events that ran over multiple days, resulting in daily variation of rainfall totals (from daily rainfall stations) across subareas;
- The pluviographs (Figure 3-12) show separate rainfall events during the November 2010 flood event. The events were separated by a minimum of 24-hour period of no rainfall; and
- The hydrograph recorded at the gauge also shows multiple peaks (Figure 3-16). Multi-peaked hydrographs can be calibrated better if the event is treated as a multi burst event.

Figure 3-16 shows the observed and calculated hydrographs at the Campaspe River at Redesdale gauge. The calculated hydrograph closely matches the shape and maximum flow of the first and largest observed hydrograph peak. However, the peak at approximately 340 hours is significantly underestimated. Although the quality of the streamflow data was good, the final hydrograph peak was classified as raw data that had not been validated. The model calibration for the Rochester Flood Management Plan (2013) was also not able to achieve a good fit for this peak. It is considered that as the first peak is larger, it is more important to achieve a good fit to this peak.

The adopted values of  $k_c$ ,  $m$ , initial loss (IL) and continuing loss (CL) for the calibration are summarised in Table 3-5. As shown, the difference between the observed and modelled peak flow is 0.8% while the difference in flood volume is 0.0%. Overall, the model calibration for the November 2010 flood event is considered good given the uncertainty of several variables.

## KYNETON FLOOD STUDY



**Figure 3-16** Comparison of modelled and observed hydrographs for the November 2010 event on the Campaspe River at Redesdale gauge (406213)

**Table 3-5** RORB calibration parameters and results for the November 2010 event

Location		Campaspe River @ Redesdale
Model Parameters	$k_c$	62
	$m$	0.8
	IL1	45
	CL1	1.25
	IL2	10
	CL2	1.92
	IL3	0
	CL3	0.17
Peak flow ( $m^3/s$ )	Observed	218.0
	Calculated	216.9
	Relative difference (%)	0.8
Volume (ML)	Observed	$45.2 \times 10^7$
	Calculated	$45.2 \times 10^7$
	Relative difference (%)	0.0

## KYNETON FLOOD STUDY

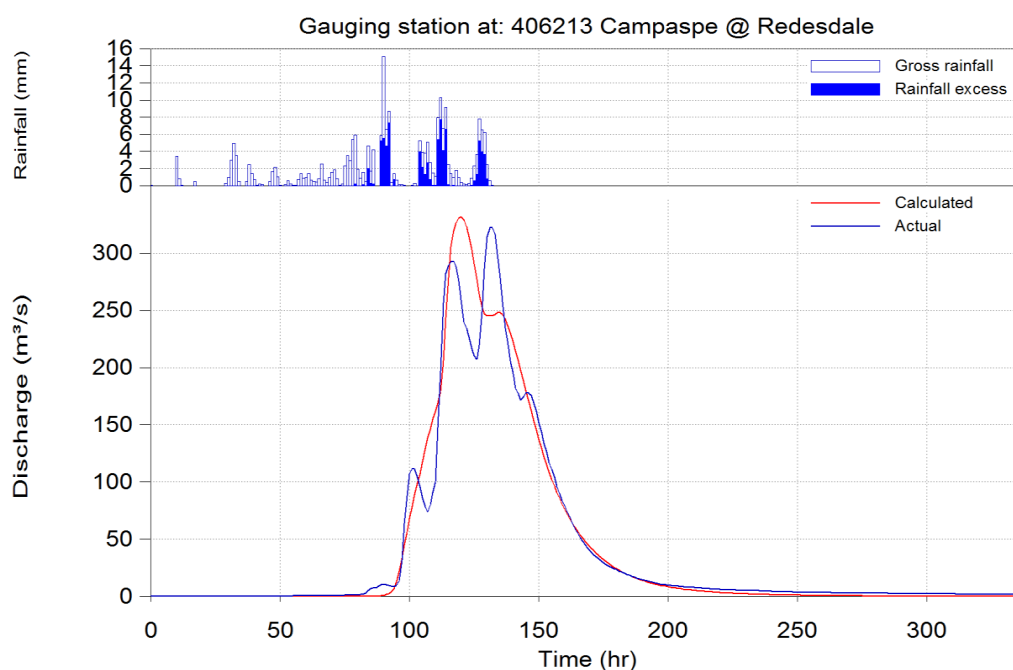
### 3.4.5 January 2011 Flood Event Calibration

The January 2011 event was modelled from 12:00am 9<sup>th</sup> January 2011 to 12:00am 23<sup>rd</sup> January 2011. This timing was based on an analysis of the available daily rainfall pluviograph and flow data for this flood event. Based on a flood frequency analysis of the Campaspe River at Redesdale gauge the January 2011 event was approximately a 5% AEP flood event.

The accumulated rainfall total for each subarea was adopted from the Rochester Flood Management Plan (2013). The pluviographs applied in the Rochester Flood Management Plan (2013) calibration model was reviewed and the subarea temporal pattern was adjusted where more relevant pluviograph data was available. As the rainfall was relatively continuous for the duration of storm and only a single flood peak was observed in the streamflow data, a single burst was adopted for the calibration.

Figure 3-17 shows the observed and calculated hydrographs at the Campaspe River at Redesdale gauge. The calculated hydrograph closely matches the rising and falling limbs in addition to the peak of the observed hydrograph.

The adopted values of  $k_c$ ,  $m$ , initial loss (IL) and continuing loss (CL) for the calibration are summarised in Table 3-6. As shown, the difference between the observed and modelled peak flow is 3.0% while the difference in flood volume is 0.5%. Overall, the model calibration for the January 2011 flood event is considered good.



**Figure 3-17** Comparison of modelled and observed hydrographs for the January 2011 event on the Campaspe River at the Redesdale gauge (406213)



## KYNETON FLOOD STUDY

Table 3-6 RORB calibration parameters and results for the January 2011 event

Location		Campaspe River @ Redesdale
Model Parameters	$k_c$	62
	$m$	0.8
	IL	85
	CL	2.61
Peak flow ( $m^3/s$ )	Observed	322.1
	Calculated	331.6
	Relative difference (%)	3.0
Volume (ML)	Observed	$48.6 \times 10^6$
	Calculated	$48.8 \times 10^6$
	Relative difference (%)	0.5

### 3.4.6 Discussion

#### 3.4.6.1 Routing Parameter

All events were calibrated with a nonlinearity parameter,  $m$ , set to 0.8, which is the value commonly adopted for RORB models. A value of 0.8 was also used for the Rochester Flood Management Plan (2013). There appears to be no reason to vary this value for the Campaspe River catchment and thus 0.8 was used for the calibration and also adopted for the design runs.

The model was calibrated to three large historical events, with estimated magnitudes of 5%, 7% and 13% AEP. This ensured that the derived parameters are suitable for design flood estimation and are AEP neutral. That is, the AEP of the design flow corresponds to the same AEP as the causative rainfall that generates the flow.

Each event was calibrated independently to determine the most appropriate routing parameter,  $k_c$ . The values for each event were very similar and an average value of 62 was adopted which provided the best fit when applied to all three historical events.

Although the routing parameter was calibrated to three separate events, there still remains some uncertainty in the value adopted. In particular, due to the limited available data, the largest event the parameter could be calibrated to has an annual exceedance probability of 5%. Hence, extrapolation of the parameter is required to produce design flood estimates exceeding this value, for example the 1% AEP event. Therefore, the calibrated value of  $k_c$  was compared to a range of recommended prediction equations as shown in Table 3-7. This included the regional equations for Victoria as recommended in ARR. Note that the catchment area ( $A$ ) referred to in the estimation equations is  $642.6 \text{ km}^2$ . Furthermore,  $d_{av}$  provides an indication of the travel distance to the outlet of the RORB

## KYNETON FLOOD STUDY

model, and is given by the weighted average flow distance from all nodes to the catchment outlet. The value of  $d_{av}$  obtained for the Campaspe River RORB model was 48.6km.

**Table 3-7 Comparison to additional routing parameter estimates**

Method	Applicable Region	Equation	Predicted $k_c$
RORB Default Equation (RORB Manual, Equation 2-5)	Australia wide	$k_c = 2.2 * A^{0.5} * (Q_p/2)^{0.8-m}$	55.74
Regional Equation (ARR, Book 5, Equation 3.22)	For areas where annual rainfall <800mm	$k_c = 0.49 * A^{0.65}$	32.76
Regional Equation (ARR, Book 5, Equation 3.21)	For areas where annual rainfall >800mm	$k_c = 2.57 * A^{0.45}$	47.15
Victorian Data (Pearse et al. 2002)	Victoria	$k_c = 1.25 * d_{av}$	60.75
Australian wide Dyer (1994) Data (Pearse et al. 2002)	Australia wide	$k_c = 1.14 * d_{av}$	55.40
Australian wide Yu (1989) Data (Pearse et al. 2002)	Australia wide	$k_c = 0.96 * d_{av}$	46.66
Comparison to Rochester Flood Management Plan (2013) ( $k_c/d_{av} = 1.278$ )	Campaspe catchment	$k_c = 1.278 * d_{av}$	62.11

As shown in Table 3-7, a comparison with the routing parameter adopted for the Rochester Flood Management Plan (2013) was also undertaken by considering the ratio between the routing parameter,  $k_c$ , and the weighted average flow distance from all nodes to the catchment outlet,  $d_{av}$ . The weighted average flow distance for the Rochester RORB model was 126.35km and a value of 161.5 was adopted for  $k_c$ , resulting in a  $k_c/d_{av}$  ratio of 1.278. Applying this same ratio to the weighted average flow distance of the Campaspe River RORB model, 48.6km, gives a  $k_c$  value of 62.11.

A review of the routing parameter estimates determined from alternative methods indicated that the parameters used in calibration were reasonable (Table 3-8). Therefore, the  $k_c$  value determined from the calibration was considered to be suitable for the design runs.

**Table 3-8 Adopted RORB model parameters**

$k_c$	$m$
62	0.8

## KYNETON FLOOD STUDY

### 3.4.6.2 Losses

The losses used in the calibration of each historical event are shown in Table 3-9 to Table 3-11. The initial loss (IL) parameter was determined by trial and error to reasonably reproduce the observed rising limb of the hydrograph. Then, using the FIT option in RORB, a corresponding continuing loss (CL) was automatically determined in RORB to minimise the error between the calculated and observed hydrograph volume. It can be seen that in some cases significant losses were required to achieve a reasonable fit. These values were compared to the losses adopted in the Rochester Flood Management Plan (2013) to assess their reasonableness (shown in

Table 3-12).

It should be noted that the design losses are not derived from the losses used for calibration. This is due to the fact that the losses applied to these historical events depend on the antecedent conditions of the catchment.

**Table 3-9 RORB calibration loss parameters – September 2010**

Location	Burst 1	
	IL (mm)	CL (mm/hr)
Campaspe River @ Redesdale	10	0.63

**Table 3-10 RORB calibration loss parameters – November 2010**

Location	Burst 1		Burst 2		Burst 3	
	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)
Campaspe River @ Redesdale	45	1.25	10	1.97	0	0.17

**Table 3-11 RORB calibration loss parameters – January 2011**

Location	Burst 1	
	IL (mm)	CL (mm/hr)
Campaspe River @ Redesdale	85	2.61

**Table 3-12 Rochester Flood Management Plan (2013) calibration losses**

	November 2010	January 2011
IL1 (mm)	50	82
CL1 (mm/hr)	2.40	2.60
IL2	10	-
CL2	1.00	-

## KYNETON FLOOD STUDY

IL3	0	-
CL3	0	-

### 3.5 Campaspe River Design Event Modelling

This section details the process used to determine appropriate design parameters and flows for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events for the Campaspe River at Kyneton.

#### 3.5.1 Calibrate Design Losses

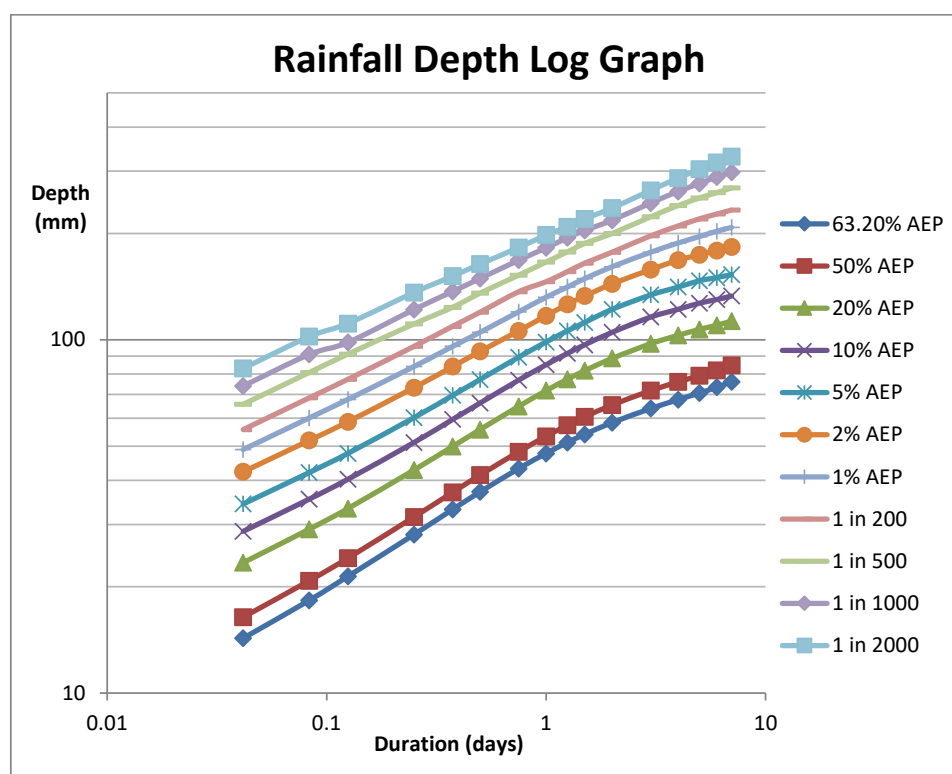
Initially, a Monte Carlo analysis was run for the Campaspe River RORB model to determine the applicable design losses. The critical design parameters for the Campaspe River catchment to Redesdale were used in this model. That is, the Intensity-Frequency-Duration (IFD) design rainfalls, temporal patterns, spatial patterns and Areal Reduction Factors (ARF) relative to the Redesdale catchment centroid were used. These values were used to calibrate the design losses by fitting the Monte Carlo peak flow estimates for the 50-1% AEP events at the Campaspe River at Redesdale gauge to the values determined in the flood frequency analysis for this same gauge. The relevant inputs are described below.

##### 3.5.1.1 IFD

The relevant IFD was obtained from the Bureau of Meteorology website for the entire Redesdale catchment. Rainfall depth units were selected instead of intensity for the RORB input.

Additional durations were added to the IFD table to match the durations for which temporal patterns were available. The table was also expanded by adding the rainfall depths for rare events. At the time of writing, rainfall depths for events from 1 in 200 to 1 in 2000 AEP were not available on the Bureau of Meteorology's website for durations less than 24 hours. Hence, the method recommended in ARR, Book 8, Section 3.6.3 for estimating very rare sub-daily rainfalls was used. Sub-daily rainfall depths are determined by multiplying the relevant 1% AEP design rainfall depth for each duration by specific growth curve factors. ARR notes that due to the method used to derive these growth curve factors there may be the potential for significant discontinuity when compared to the values provided for durations of 24 hours and longer. As a result, it was necessary to smooth the growth factors to ensure the depths varied in a consistent manner across storm durations and exceedance probability. The growth curve factors were applied to the shortest durations and intermediary depths were smoothed between these values and those provided on the Bureau of Meteorology's website for 24-hour storms. A log graph displaying the smoothed results is shown in Figure 3-18.

## KYNETON FLOOD STUDY



**Figure 3-18** Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Redesdale IFD

### 3.5.1.2 Areal Reduction Factor

The Areal Reduction Factor (ARF) is the ratio between the design values of areal average rainfall and point rainfall. It is used to account for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area. The values applied were read into the RORB model from the Data Hub file. The Data Hub parameters are shown in the Appendix (Section 7.3.1).

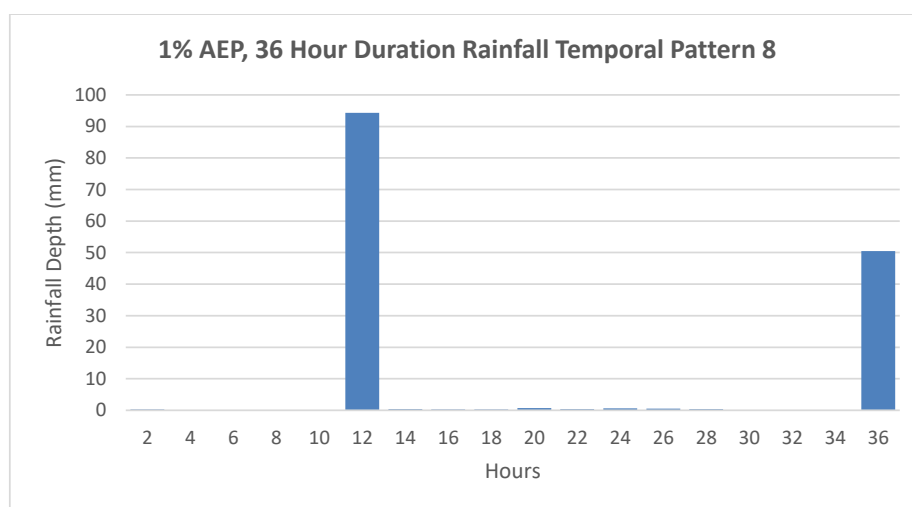
### 3.5.1.3 Design Temporal Pattern

The applicable design temporal patterns were obtained from Data Hub (Section 7.3.1). Areal patterns were applied as the catchment is greater than 75km<sup>2</sup>.

The temporal pattern sample is selected based on the closest area, in this case 500km<sup>2</sup>. Areal temporal patterns were available for following storm durations: 12, 18, 24, 36, 48, 72, 96, 120, 144, and 168 hours. For each duration there are ten different temporal patterns, resulting in a total of 100 patterns available for modelling.

## KYNETON FLOOD STUDY

The temporal patterns have been assessed to determine if any contain embedded bursts which would cause the RORB model to overestimate the peak flows. This was done by comparing the sub-period rainfall totals of a particular temporal pattern against the IFD to determine whether it is rarer than the AEP of the entire burst. The analysis revealed that two temporal patterns contained embedded bursts; pattern 8 from the 36-hour duration storm, and pattern 5 from the 48-hour duration storm. For example, Figure 3-19 shows pattern 8 from the 36-hour duration which contains an embedded rainfall burst rarer than a 1 in 1000 AEP event.



**Figure 3-19** Rainfall temporal pattern 8 for the 36 hour duration, 1% AEP storm

As stated in *Addressing embedded bursts in design storms for flood hydrology* (Scorah et. al., 2016), “Censoring of temporal patterns which contain embedded bursts may be appropriate if the number of afflicted patterns is small.” As the patterns with embedded bursts represent a small proportion of the total number of patterns available these embedded patterns were simply excluded from the modelling.

### 3.5.1.4 Design Spatial Pattern

As the catchment area was greater than 20km<sup>2</sup> and the AEPs modelled were not rarer than the 1% AEP event, the method recommended in ARR, Book 2, Section 6.3 was used to determine the design spatial pattern. The IFDs at each subarea centroid were extracted. Based on a preliminary model run with a uniform spatial pattern, the critical duration for the entire Redesdale catchment was estimated to be 48 hours. Hence, the rainfall depth for each subarea corresponding to the 48-hour duration, 1% AEP storm was collated and used to determine the weighted average rainfall depth. The rainfall depths at each of the subareas were then divided by the weighted average rainfall depth to derive the non-dimensional spatial pattern. The spatial pattern used is shown in

Table 3-13.



## KYNETON FLOOD STUDY

Table 3-13 Design spatial pattern for Campaspe River catchment to Redesdale

Subarea	Area (km <sup>2</sup> )	Rainfall (48hr, 1% AEP) (mm)	Rainfall x Area	Pattern
A	39.2453	200	7849.1	120.81%
B	38.2727	183	7003.9	110.54%
C	29.4384	186	5475.5	112.35%
D	48.5321	182	8832.8	109.94%
E	49.0837	168	8246.1	101.48%
F	28.0527	166	4656.7	100.27%
G	46.0809	157	7234.7	94.84%
H	30.4072	158	4804.3	95.44%
I	47.6609	158	7530.4	95.44%
J	17.965	156	2802.5	94.23%
K	42.308	160	6769.3	96.65%
L	32.7072	156	5102.3	94.23%
M	46.0337	164	7549.5	99.06%
N	26.1505	156	4079.5	94.23%
O	31.0766	155	4816.9	93.63%
P	10.8315	155	1678.9	93.63%
Q	22.8799	153	3500.6	92.42%
R	18.6747	151	2819.9	91.21%
S	28.7242	153	4394.8	92.42%
T	8.48315	146	1238.5	88.19%
		<b>Weighted Average Rainfall</b>	<b>165.6</b>	

## KYNETON FLOOD STUDY

### 3.5.1.5 Simulation Parameters

The default stratified sample was used with 50 rainfall divisions and 20 samples per division. 70 time increments were modelled for each simulation. In accordance with the calibration, the model parameters used were  $k_c = 62$ ,  $m = 0.80$ .

### 3.5.1.6 Design Losses

As recommended in ARR an Initial Loss/Continuing Loss model was applied to the RORB Monte Carlo analysis. To determine appropriate design loss values, a number of values were trialled and compared to the Campaspe River at Redesdale gauge flood frequency curve (see Section 3.2 for the flood frequency analysis for the gauge). The losses that achieved peak flow values close to the gauge flood frequency curve were selected for use in the design flow modelling.

For all trials loss factors were constant and not varied. That is, the initial loss (IL) and continuing loss (CL) were not factored depending on AEP or duration of the event. However, the initial losses were selected stochastically. The default initial loss distribution in RORB is shown in Table 3-14 and shows the initial loss factors exceeded a given proportion of the time (ARR, Book 5, Chapter 3, Table 5.3.13).

**Table 3-14 Initial loss distribution**

Proportion of time value is exceeded	IL Factor
0%	3.190
10%	2.260
20%	1.710
30%	1.400
40%	1.200
50%	1.000
60%	0.850
70%	0.680
80%	0.530
90%	0.390
100%	0.140

The values trialled include the Data Hub recommended regional losses, the design losses applied in the Rochester Flood Management Plan (2013), and losses specifically fitted to the gauge flood frequency curve. The loss values are presented in the following sections and the model results are compared in Table 3-16.

- **Data Hub Loss Values**

The regional loss values obtained from Data Hub (Section 7.3.1) are shown below:

Storm Initial Loss = 28.0mm

Continuing Loss = 4.0mm/hr

## KYNETON FLOOD STUDY

It should be noted that the initial loss is relative to the complete storm and not only the critical design burst that is used in the RORB model. Hence, the storm initial loss must be converted to a burst initial loss as recommended in ARR, Book 2, Section 5.9.9, using the following equation:

$$\text{Burst Initial Loss} = \text{Storm Initial Loss} - \text{Preburst}$$

The median preburst depths for different AEPs and durations were obtained from Data Hub (Section 7.3.1) and are shown in Table 3-15 below.

**Table 3-15 Median preburst depths (mm) for various flood AEPs and durations**

Duration (hrs)	AEP %					
	50	20	10	5	2	1
1	2.2	2.0	1.9	1.8	1.5	1.3
1.5	3.1	2.8	2.6	2.5	1.9	1.5
2	3.0	2.6	2.3	2.0	1.9	1.9
3	3.5	3.2	3.1	2.9	5.1	6.7
6	1.4	1.6	1.8	1.9	5.0	7.3
12	0.3	2.8	4.4	6.0	7.5	8.7
18	0.3	1.4	2.1	2.8	4.6	6.0
24	0.0	1.1	1.8	2.6	3.1	3.4
36	0.0	0.1	0.1	0.2	0.4	0.6
48	0.0	0.0	0.0	0.1	0.0	0.0
72	0.0	0.0	0.0	0.0	0.0	0.0

The expected critical duration of the catchment (both Kyneton and Redesdale) is between 12-48 hours. Hence, a representative preburst depth of 5mm is selected, and the resulting applicable burst initial loss is 23mm.

- **Rochester Flood Management Plan (2013) Loss Values**

For comparison, the losses adopted in the Rochester Flood Management Plan (2013) are 20mm for the initial loss and 0.6mm/hr for the continuing loss.

- **Loss Values Fitted to the Gauge Flood Frequency Curve**

The results in Table 3-16 indicate that the continuing loss from Data Hub is too high. Furthermore, the design losses for the Rochester Flood Management Plan (2013) appear to be too low. Instead the design losses were derived using Monte Carlo analysis by adopting an initial loss of 23mm in accordance with Data Hub (stochastically sampled using the default RORB distribution) and adjusting the continuing loss to match the 50%-1% AEP flows to the flood frequency curve at the Campaspe River at Redesdale gauge.

## KYNETON FLOOD STUDY

Table 3-16 Comparison of flows at Campaspe River at Redesdale gauge for various design loss combinations

AEP (%)	Gauge Flood Frequency Curve (m <sup>3</sup> /s)	Data Hub Losses IL = 23mm CL = 4.0mm/hr	Rochester Flood Management Plan (2013) IL = 20mm CL = 0.6mm/hr	Fitted Design Losses IL = 23mm CL = 0.6mm/hr	Fitted Design Losses IL = 23mm CL = 0.7mm/hr	Fitted Design Losses IL = 23mm CL = 1.0mm/hr	Difference*
50	89 (70-114) <sup>#</sup>	0.05	98.61	84.65	70.47	55.98	-4.9%
20	183 (151-231)	15.30	195.94	186.62	174.52	137.91	2.0%
10	252 (207-323)	39.70	271.14	260.25	251.78	215.98	-0.1%
5	318 (258-415)	74.94	345.95	337.89	324.46	285.71	2.0%
2	399 (318-556)	148.18	448.91	443.72	428.78	391.63	-1.8%
1	457 (355-668)	207.84	535.27	528.65	510.61	468.46	2.5%

<sup>#</sup>90% confidence interval shown in parentheses

\*Note the percentage difference relates to the values highlighted in the table.

## KYNETON FLOOD STUDY

Using the results derived in Table 3-16 above, a final Monte Carlo analysis was run using the fitted continuing loss values which vary with AEP. The results are displayed in Table 3-17 below. The appropriate design losses to be applied for the different AEP events are as shown in Table 3-18.

**Table 3-17 Comparison of Campaspe River at Redesdale gauge flood frequency curve to Monte Carlo analysis of design initial and continuing losses**

AEP (%)	Gauge Flood Frequency Curve (m <sup>3</sup> /s)	Fitted Design Losses IL = 23mm CL = 1.0mm/hr (2%-1%) CL = 0.7mm/hr (10%-5%) CL = 0.6mm/hr (50%-20%)	Difference
50	89 (70-114) <sup>#</sup>	71.91	-19.2%
20	183 (151-231)	181	-1.1%
10	252 (207-323)	247.73	-1.7%
5	318 (258-415)	316.85	-0.4%
2	399 (318-556)	404.28	1.3%
1	457 (355-668)	461.54	1.0%

<sup>#</sup>90% confidence interval shown in parentheses

**Table 3-18 Adopted design initial and continuing losses**

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
50% - 20%	23	0.6
10% - 5%	23	0.7
2% - 1%	23	1.0

## KYNETON FLOOD STUDY

### 3.5.2 Design Model Parameters

The RORB model has been calibrated to the downstream Campaspe River at Redesdale gauge using the September 2010, November 2010 and January 2011 historical events to determine the model parameters  $k_c$  and  $m$ . The design losses were calibrated by fitting the RORB Monte Carlo analysis results to the flood frequency curve at the same gauge. Using these values, a RORB Monte Carlo analysis was rerun with parameters specific to the Kyneton catchment including the applicable IFD rainfall data, spatial patterns and temporal patterns. The adopted design parameters are detailed below.

#### 3.5.2.1 IFD

The IFD was obtained from the Bureau of Meteorology website for the Kyneton catchment centroid as opposed to the entire Redesdale catchment. Additional durations were added to the table to match the durations for which temporal patterns were available. A chart of the data downloaded from the Bureau of Meteorology displaying the IFD for events ranging from 63.2% AEP to 1% AEP is shown in Figure 3-20.

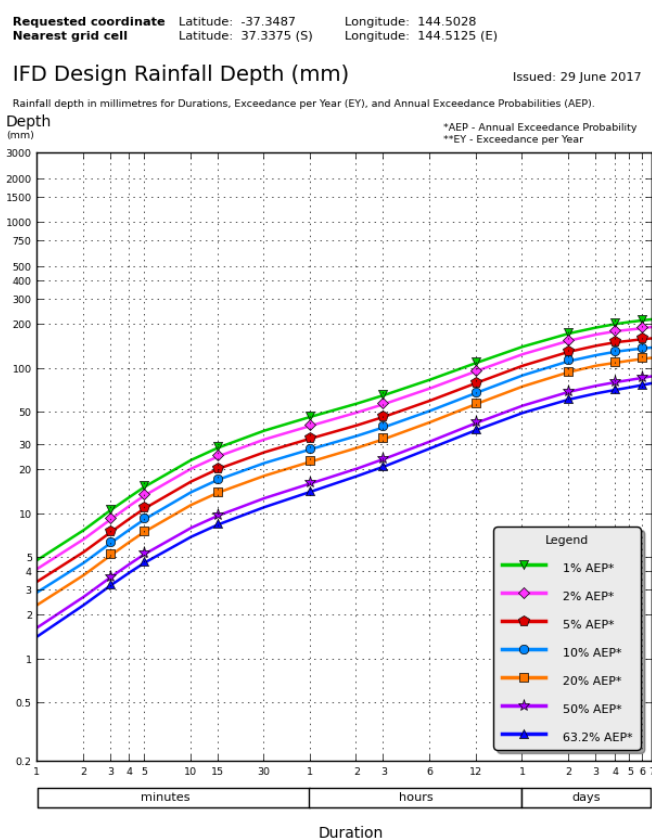
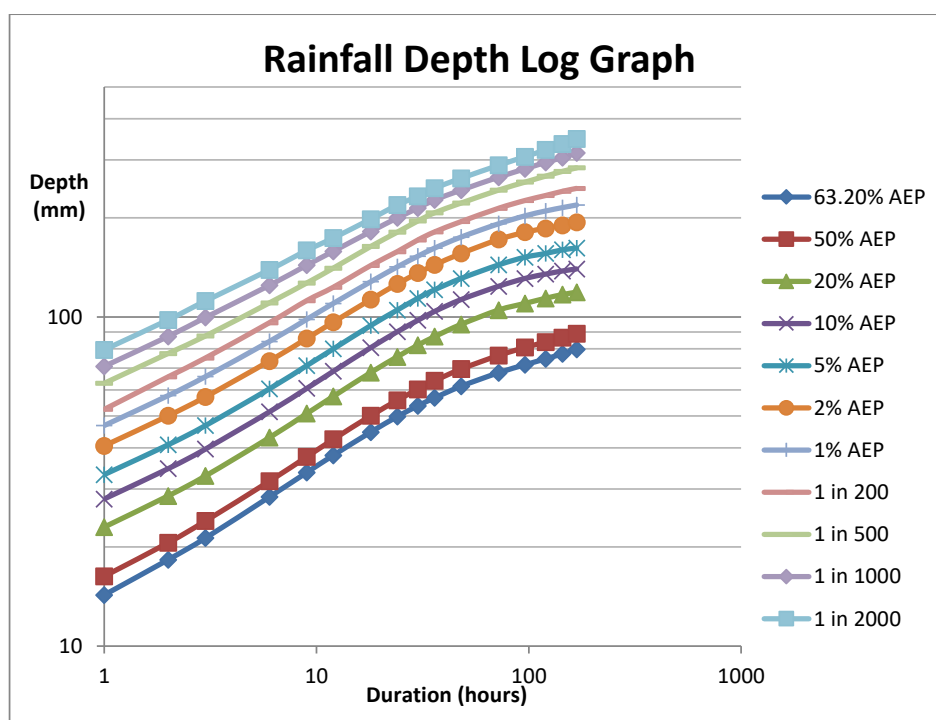


Figure 3-20 IFD graph for Kyneton catchment



## KYNETON FLOOD STUDY

Similar to the Redesdale IFD, the table was expanded by adding the depths of rare events. At the time of writing, rainfall depths for events from 1 in 200 to 1 in 2000 AEP were not available on the Bureau of Meteorology's website for durations less than 24 hours. Hence, the method recommended in ARR, Book 8, Section 3.6.3 for estimating very rare sub-daily rainfalls was used. Rainfall depths are determined by multiplying the relevant 1% AEP design rainfall depth by specific growth curve factors. ARR notes that due to the method used to derive these growth curve factors there may be the potential for significant discontinuity when compared to the values provided for durations of 24 hours and longer. As a result, it was necessary to smooth the growth factors to ensure the depths varied in a consistent manner across storm durations and exceedance probability. The growth curve factors were applied to the shortest durations and intermediary depths were smoothed between these values and those provided on the Bureau of Meteorology's website for 24-hour storms. A log graph displaying the smoothed results is shown in Figure 3-21.



**Figure 3-21** Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Kyneton IFD

### 3.5.2.2 Areal Reduction Factor

The applicable ARF values were read into RORB directly from the Data Hub file. However, as the Kyneton catchment is smaller than the Rochester catchment the replacement option in RORB was used so that the ARF values were based on the Kyneton catchment (232.78km<sup>2</sup>) rather than the Redesdale catchment. The Data Hub parameters are shown in Section 7.3.2.

## KYNETON FLOOD STUDY

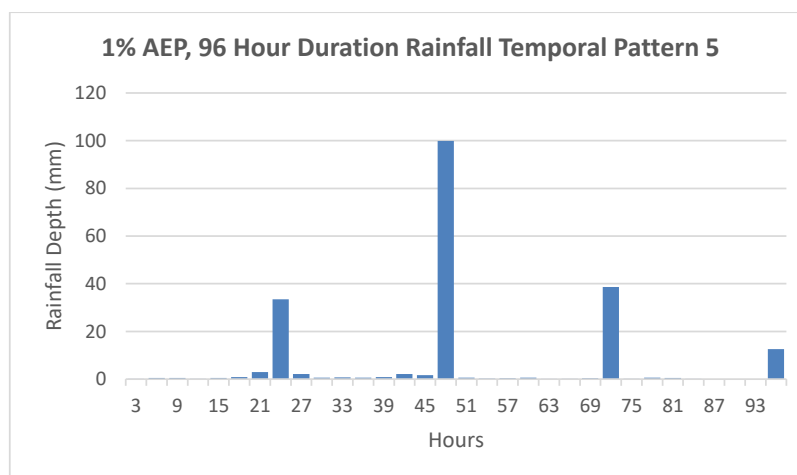
### 3.5.2.3 Design Temporal Pattern

The applicable design temporal patterns were obtained from Data Hub (Section 7.3.2). Areal patterns were applied as the catchment is greater than 75km<sup>2</sup>.

The temporal pattern sample is selected based on the closest area. It should be noted that the temporal patterns applied will be different to those used in the model of the entire Redesdale catchment due to the difference in catchment size. The applicable catchment area selected for Kyneton was 200km<sup>2</sup>.

Areal temporal patterns were available for following storm durations: 12, 18, 24, 36, 48, 72, 96, 120, 144, and 168. For each duration there are ten different temporal patterns, resulting in a total of 100 patterns available for modelling.

The temporal patterns have been assessed to determine if any contain embedded bursts which would cause the RORB model to overestimate the peak flows. This was done by comparing the sub-period rainfall totals of a particular temporal pattern against the IFD to determine whether it is rarer than the AEP of the entire burst. The analysis revealed that four temporal patterns contained embedded bursts; pattern 4 from the 72-hour duration storm, pattern 2 and 5 from the 96-hour duration storm, and pattern 3 from the 120-hour storm. For example, Figure 3-22 shows pattern 5 from the 96-hour duration which contains an embedded rainfall burst rarer than a 1 in 1000 AEP event.



**Figure 3-22** Rainfall temporal pattern 5 for the 96-hour duration, 1% AEP storm

As stated in *Addressing embedded bursts in design storms for flood hydrology* (Scorah et. al., 2016), "Censoring of temporal patterns which contain embedded bursts may be appropriate if the number of afflicted patterns is small." As the patterns with embedded bursts represent a small proportion of the total number of patterns available these embedded patterns were simply excluded from the modelling.

## KYNETON FLOOD STUDY

### 3.5.2.4 Design Spatial Pattern

The design spatial pattern for the Kyneton catchment was derived in a similar method to that used for the Redesdale catchment in Section 3.5.1.4. The catchment area was greater than 20km<sup>2</sup> and the AEPs modelled were not rarer than the 1% AEP event, hence the method recommended in ARR, Book 2, Section 6.3 was applicable. The IFDs at each subarea centroid in the Kyneton catchment were extracted. Based on a preliminary model run with a uniform spatial pattern, the critical duration for the Kyneton catchment was estimated to be 18 hours. Hence, the rainfall depth for each subarea corresponding to the 18-hour duration, 1% AEP storm was collated and used to determine the weighted average rainfall depth. The rainfall depths at each of the subareas were then divided by the weighted average rainfall depth to derive the non-dimensional spatial pattern. The spatial pattern used is shown in Table 3-19.

**Table 3-19 Design spatial pattern for Campaspe River catchment to Kyneton**

Subarea	Area (km <sup>2</sup> )	Rainfall (18hr, 1%AEP) (mm)	Rainfall x Area	Pattern
A	39.2453	138	5415.9	106.16%
B	38.2727	131	5013.7	100.78%
C	29.4384	132	3885.9	101.55%
D	48.5321	131	6357.7	100.78%
E	49.0837	124	6086.4	95.39%
F	28.0527	124	3478.5	95.39%
		<b>Weighted Average Rainfall</b>	<b>130.0</b>	

### 3.5.2.5 Simulation Parameters

The default stratified sample was used with 50 rainfall divisions and 20 samples per division. 70 time increments were modelled for each simulation.

In accordance with the calibration, the parameters used were  $k_c = 62$ ,  $m = 0.80$ .

### 3.5.2.6 Design Losses

The design losses used were as determined in the analysis in Section 3.5.1. Hence, an initial loss of 23mm was selected. The Monte Carlo analysis included stochastic selection of the initial loss, with a mean value of 23mm, using the default RORB distribution shown in Table 3-20.

## KYNETON FLOOD STUDY

**Table 3-20 Initial loss distribution**

Proportion of time value is exceeded	IL Factor
0%	3.190
10%	2.260
20%	1.710
30%	1.400
40%	1.200
50%	1.000
60%	0.850
70%	0.680
80%	0.530
90%	0.390
100%	0.140

The design continuing loss varied with AEP. The continuing loss was set as 1.0 mm/hr and varied with AEP in accordance with the factors shown in Table 3-21.

**Table 3-21 Continuing loss AEP factors**

AEP	Continuing Loss Factor
63.2%	0.6
50%	0.6
20%	0.6
10%	0.7
5%	0.7
2%	1.0
1%	1.0
1 in 200	1.0
1 in 500	1.0
1 in 1000	1.0
1 in 2000	1.0

### 3.5.2.7 Baseflow

As discussed in Section 3.4.2.2, baseflow in this catchment is insignificant. Hence, no allowance for baseflow has been added to the design hydrographs due to there being a negligible impact on the design flood hydrograph.

## KYNETON FLOOD STUDY

### 3.5.3 Design Flow Results

#### 3.5.3.1 Monte Carlo Analysis

The design parameters detailed above were used to undertake a Monte Carlo simulation for the Kyneton catchment. The critical storm duration for the Kyneton catchment was determined to be 24 hours. The results of the Monte Carlo flood frequency analysis (FFA) are shown in column 2 of

Table **3-22**. These flows were generated just downstream of Piper Street, Kyneton, and labelled 'Kyneton Downstream'. The individual design runs used for the Monte Carlo analysis were then assessed to determine which provided the most similar peak flow to the Monte Carlo FFA while still utilising reasonable parameters. The design parameters adopted for these particular runs are displayed in columns 3 to 9 of

Table **3-22**.

These run parameters were used to generate the complete hydrographs for the design floods ranging from the 50% - 0.5% AEP events. The design hydrographs are shown in Figure 3-23 below. It should be noted that the areal reduction factor (ARF) was not input into the individual design hydrograph runs as this factor is already incorporate into the rainfall depth parameter for each simulation run in the Monte Carlo analysis.

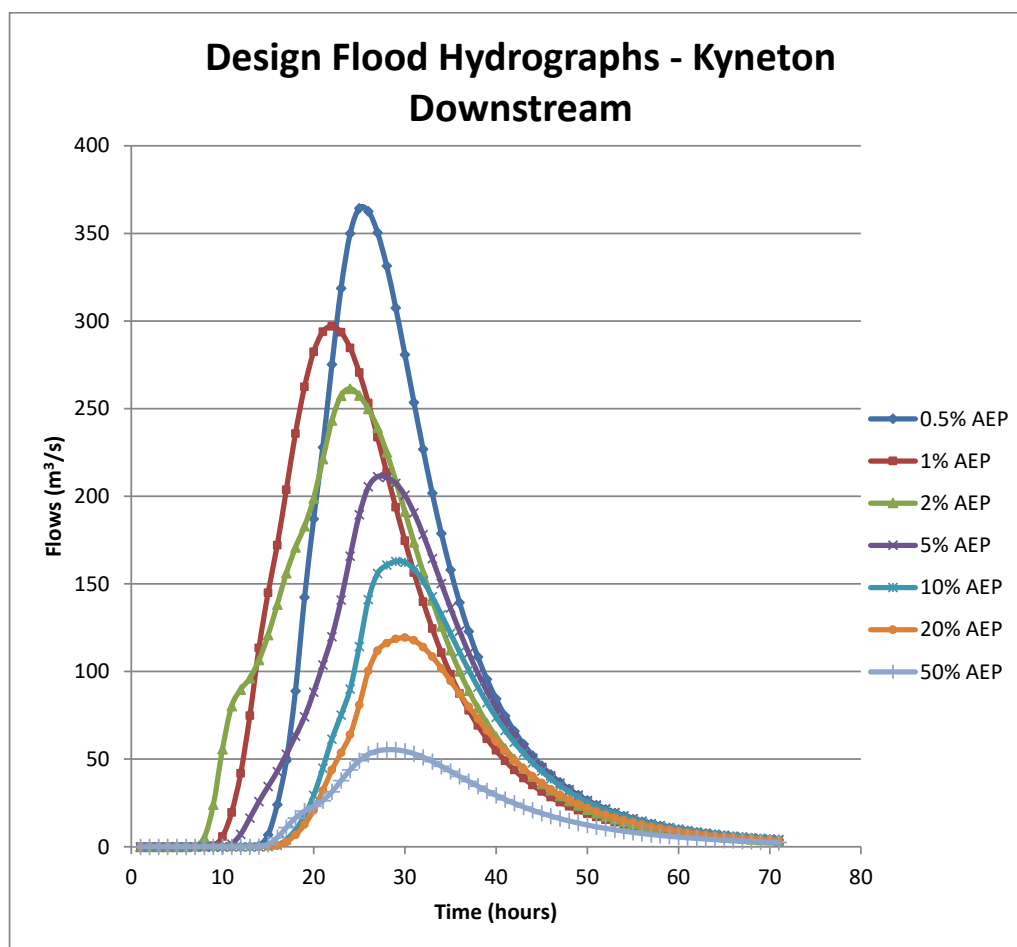
## KYNETON FLOOD STUDY

Table 3-22 Individual design runs from the Monte Carlo analysis

AEP	Peak Flow from MC FFA at Kyneton Downstream (m <sup>3</sup> /s)	Run	Rainfall ARI	Rainfall Depth (mm)	Temporal Pattern	IL Stochastic Factor	CL AEP Factor	Run Peak Flow (m <sup>3</sup> /s)
50%	55.52	24hr, Div 4, Run 8	1.9	51	5	1.06	0.6	55.65
20%	119.23	24hr, Div 14, Run 5	3.8	65.8	2	0.99	0.6	119.29
10%	162.45	24hr, Div 23, Run 17	9.6	84.3	2	1.29	0.69	162.72
5%	211.37	24hr, Div 29, Run 2	23.3	102	8	1.15	0.73	211.17
2%	261.16	24hr, Div 32, Run 8	37.7	112.2	6	0.56	0.88	261.50
1%	299.00	24hr, Div 37, Run 5	97.6	132.5	7	1.37	1	296.31
0.5%	363.64	24hr, Div 41, Run 6	216.6	149.5	10	2	1	364.05



## KYNETON FLOOD STUDY

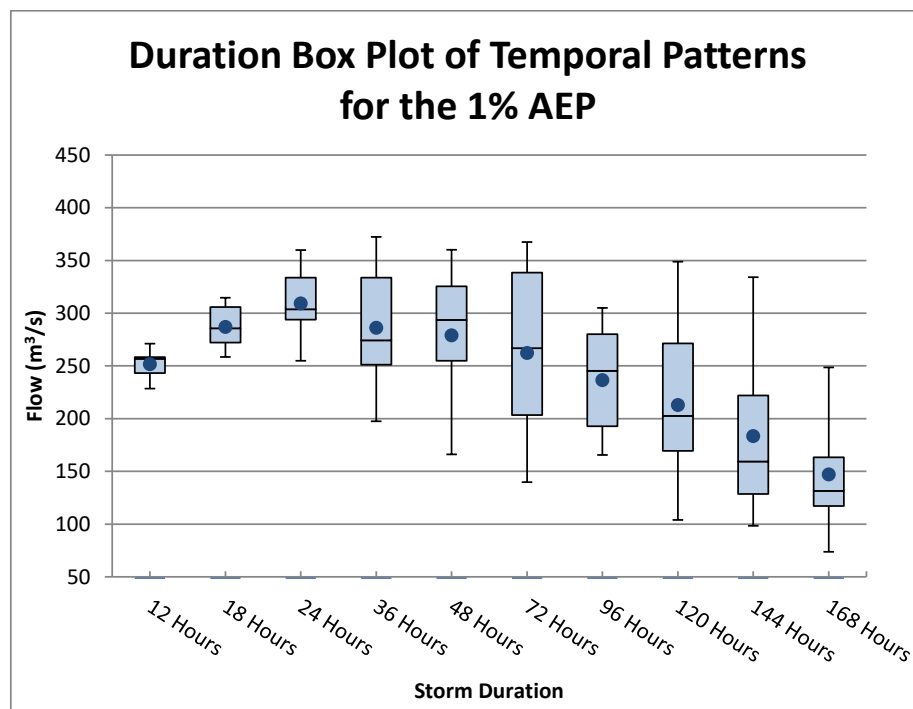


**Figure 3-23** Design flood hydrographs at Kyneton Downstream

### 3.5.3.2 Ensemble Analysis

An ensemble assessment of the temporal patterns for the 1% AEP event was also undertaken for comparison with the Monte Carlo analysis. Ensemble analysis is generally used to determine the applicable temporal pattern to be applied to generate the design hydrographs. Ten areal temporal patterns for each storm duration were assessed. The results are presented in the box plot shown in Figure 3-24. The box plot shows that the 24-hour duration is critical as it has the highest mean flow. The temporal pattern that yielded the peak flow closest to the mean 24-hour storm peak flow of 309.2m³/s was adopted as the design temporal pattern and is used to generate the design hydrograph for the ensemble analysis. The applicable temporal pattern was '6' which produced a peak flow of 305.4m³/s.

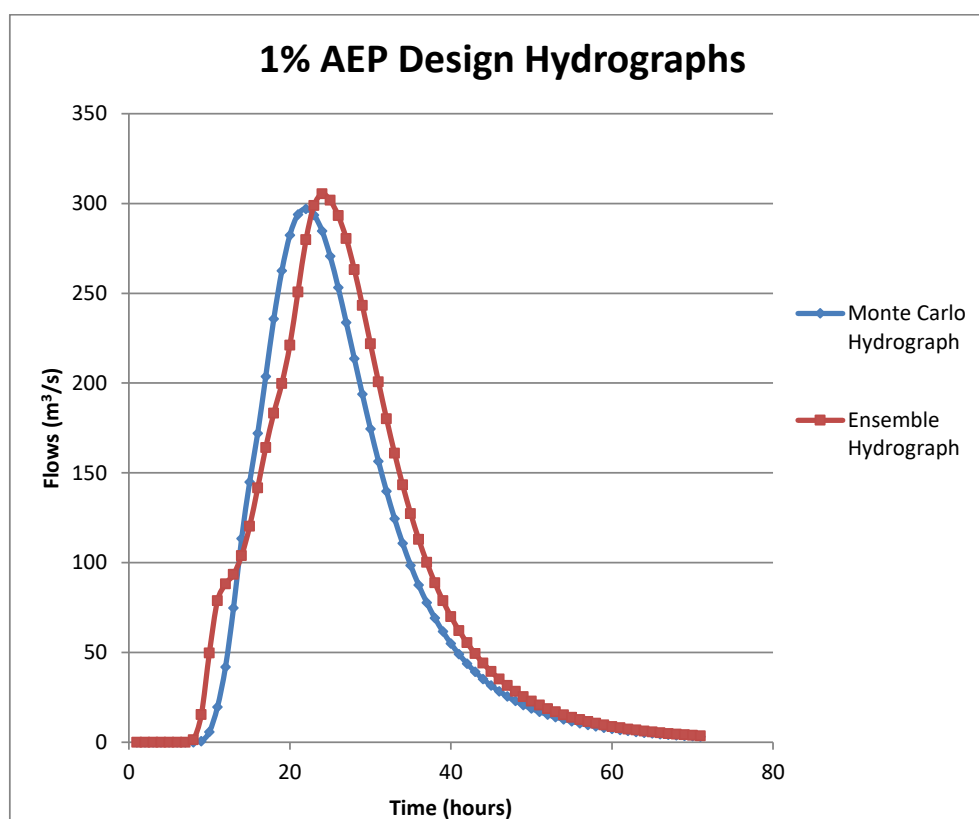
## KYNETON FLOOD STUDY



**Figure 3-24** Duration box plot of temporal patterns for the 1% AEP design event. Note the mean peak flow for each duration is displayed as a blue dot.

Figure 3-25 below compares the 1% AEP design hydrographs produced from the ensemble analysis and the Monte Carlo analysis. The ensemble hydrograph peak flow is 2.8% higher than the Monte Carlo hydrograph peak flow and has a volume 9.5% greater than the Monte Carlo volume. The time to peak of the ensemble hydrograph is 2 hours behind the Monte Carlo hydrograph. Overall, the similarity between the results of the two types of analysis improves the confidence in the Monte Carlo analysis results.

## KYNETON FLOOD STUDY



**Figure 3-25 Comparison of 1% AEP design hydrographs using ensemble and Monte Carlo analysis**

### 3.5.4 Summary

From the Monte Carlo analysis, the critical storm duration was determined to be 24 hours for the Kyneton catchment. The parameters used to generate the individual design hydrographs for the 50% - 0.5% AEP flood events are shown in

Table 3-22 above. The corresponding hydrographs are shown in Figure 3-23 above.

The hydrographs for the hydraulic model were required to be input further upstream of Kyneton Township. Therefore, additional hydrograph print-out locations, labelled Campaspe at Carlsruhe, Carlsruhe Tributary and Subarea F, were added to the RORB model as shown in Figure 3-26 below. The design parameters used to produce these hydrographs were the same as those adopted to generate the design hydrographs at Kyneton as this produces critical flows through township. The design hydrographs for these three locations are shown in Figure 3-27 to Figure 3-29 below.

## KYNETON FLOOD STUDY

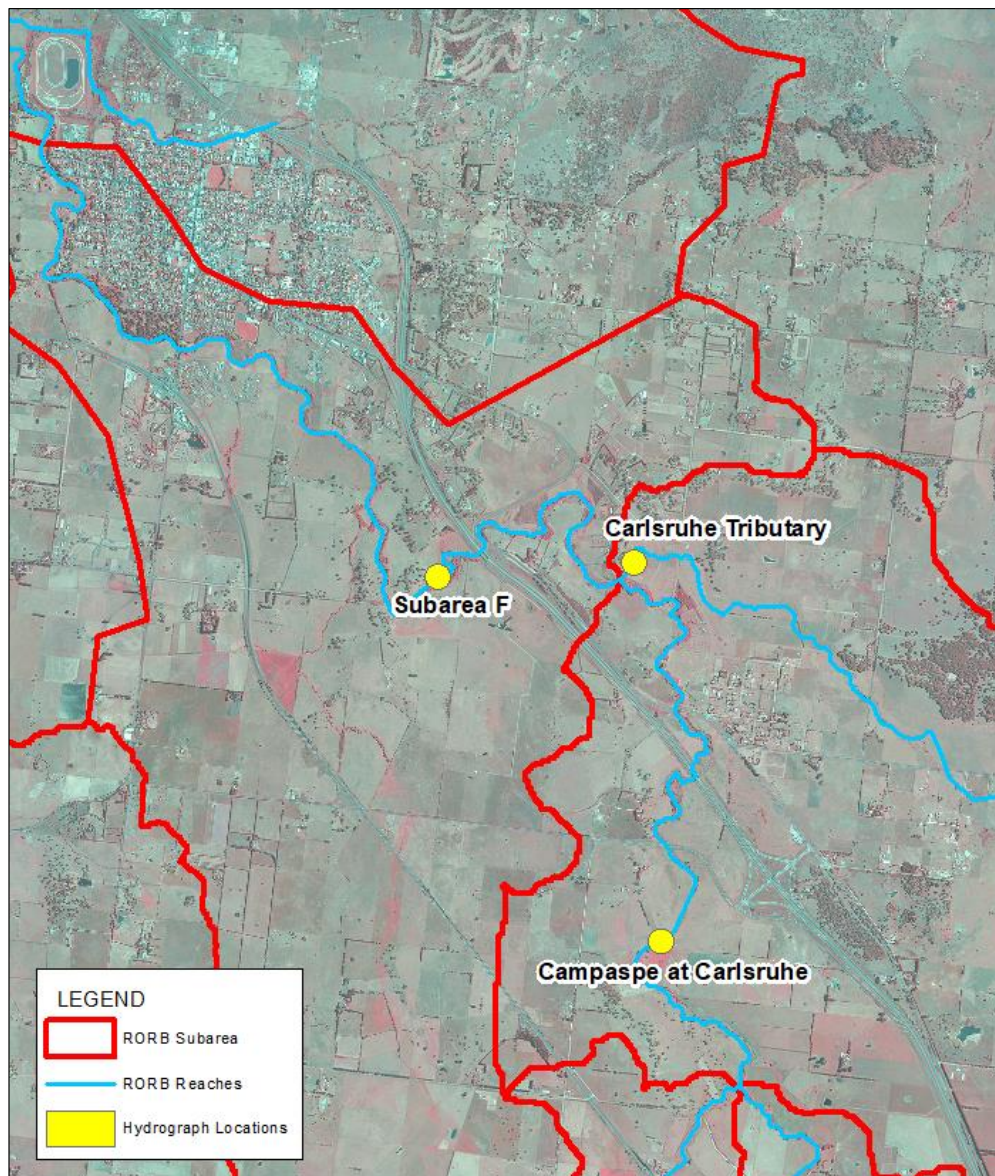


Figure 3-26 Design hydrograph locations for the hydraulic model

## KYNETON FLOOD STUDY

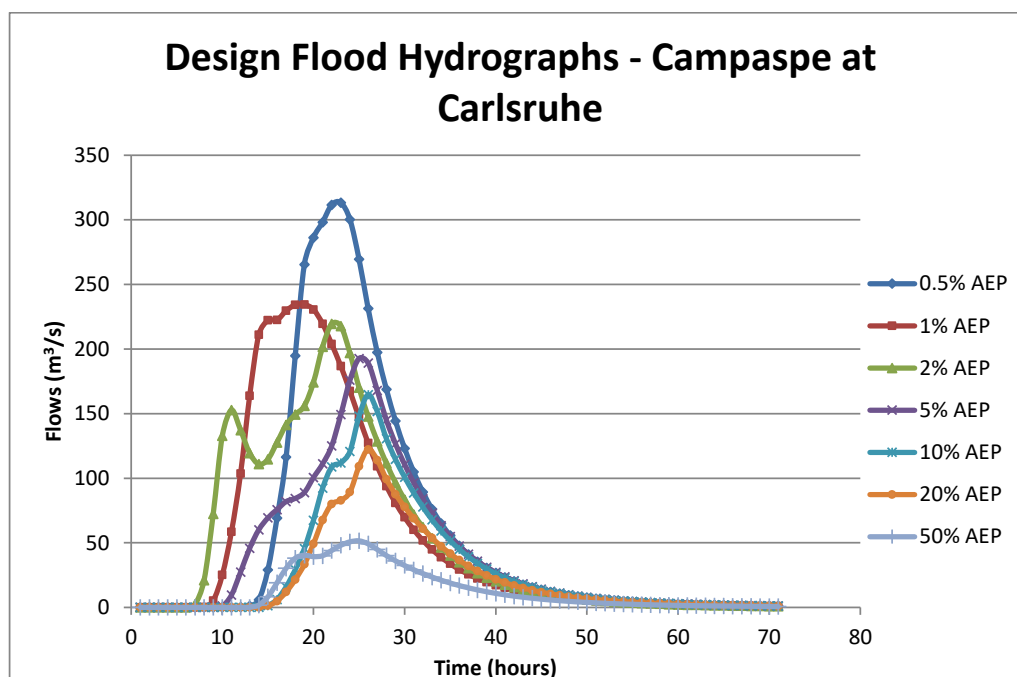


Figure 3-27 Design flood hydrographs at Campaspe at Carlsruhe

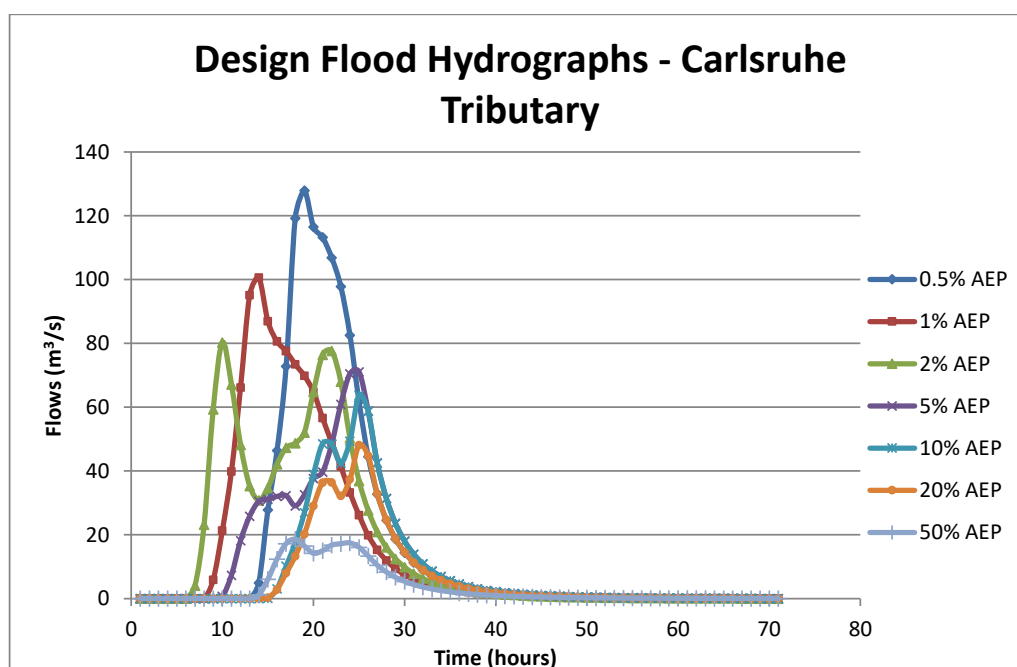


Figure 3-28 Design flood hydrographs at Carlsruhe Tributary

## KYNETON FLOOD STUDY

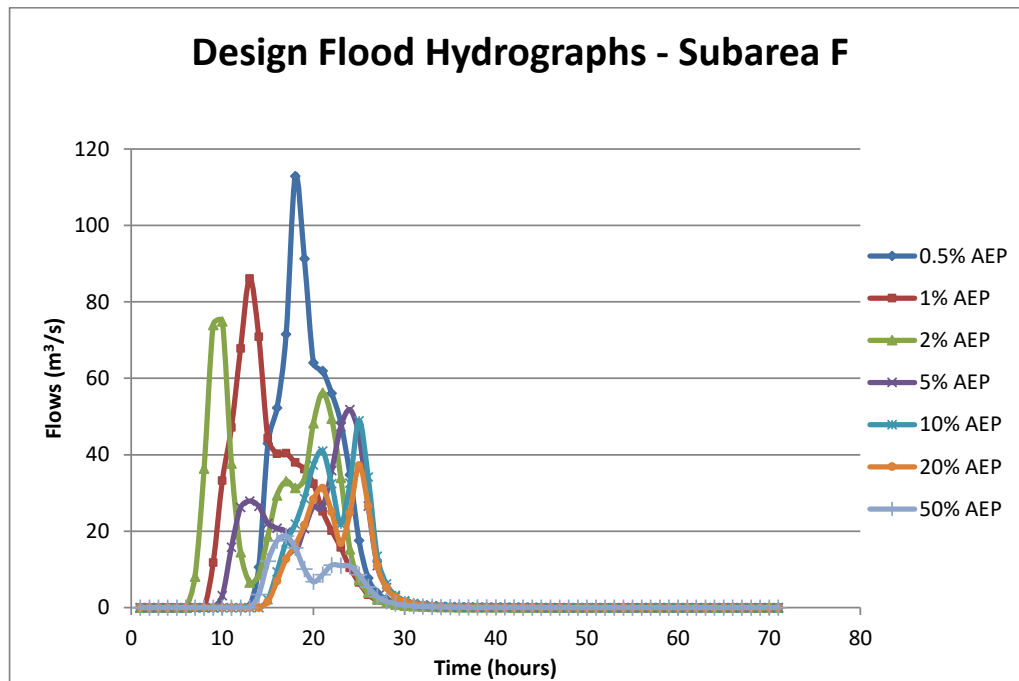


Figure 3-29 Design flood hydrographs from Subarea F



## KYNETON FLOOD STUDY

### 3.6 Post Office Creek RORB Model Calibration

#### 3.6.1 Overview

Due to the limited data available, the RORB model for Post Office Creek was unable to be calibrated to observed streamflow data. However, although there is no gauge to calibrate the model to, a flood level was recorded on Post Office Creek during the January 2011 flood event. Furthermore, there were numerous photographs and videos taken during recent floods in September 2010, January 2011 and September 2016. Hence, the RORB model was utilised to produce hydrographs based on the historical rainfall. The hydrographs were then input into the TUFLOW model and the results were compared to the recorded flood mark and available photographs to calibrate the hydraulic model. This section describes the hydrological parameters selected for the RORB calibration model in order to generate hydrographs on Post Office Creek for the following historical events: September 2010, January 2011 and September 2016. Section 4.3 describes the hydraulic calibration using these historical hydrographs.

#### 3.6.2 Routing Parameter

The nonlinearity parameter,  $m$ , was set to 0.8 in accordance with the Campaspe River RORB model. The routing parameter,  $k_c$ , was estimated for the ungauged Post Office Creek catchment by comparison with regional relationships and relating it to previous models undertaken within the area.

Similar to the Campaspe River RORB model, the parameters were not varied by interstation areas, and therefore a single routing parameter was adopted for the catchment. It should be noted that the  $k_c$  parameter determined in the Campaspe River RORB model and the Rochester Flood Management Plan (2013) RORB models could not be directly adopted for this flood study model as the catchment size and shape was not comparable. However, the parameter was scaled in order to make this comparison.

The various  $k_c$  estimation techniques are detailed in Table 3-23. This included the regional equations for Victoria as recommended in ARR. Note that the catchment area ( $A$ ) referred to in the estimation equations is  $12.07\text{km}^2$ . Furthermore,  $d_{av}$  provides an indication of the travel distance to the outlet of the RORB model, and is given by the weighted average flow distance from all nodes to the catchment outlet. The value of  $d_{av}$  obtained from the RORB model was  $3.02\text{km}$ .

## KYNETON FLOOD STUDY

**Table 3-23 Comparison of routing parameter estimates**

Method	Applicable Region	Equation	Predicted $k_c$
RORB Default Equation (RORB Manual, Equation 2-5)	Australia wide	$k_c = 2.2 * A^{0.5} * (Q_p/2)^{0.8-m}$	7.64
Regional Equation (ARR, Book 5, Equation 3.22)	For areas where annual rainfall <800mm	$k_c = 0.49 * A^{0.65}$	2.47
Regional Equation (ARR, Book 5, Equation 3.21)	For areas where annual rainfall >800mm	$k_c = 2.57 * A^{0.45}$	7.88
Victorian Data (Pearse et al. 2002)	Victoria	$k_c = 1.25 * d_{av}$	3.78
Australian wide Dyer (1994) Data (Pearse et al. 2002)	Australia wide	$k_c = 1.14 * d_{av}$	3.45
Australian wide Yu (1989) Data (Pearse et al. 2002)	Australia wide	$k_c = 0.96 * d_{av}$	2.90
Comparison to Campaspe River @ Redesdale RORB model ( $k_c/d_{av} = 1.276$ )	Campaspe catchment	$k_c = 1.276 * d_{av}$	3.86
Comparison to Rochester Flood Management Plan (2013) ( $k_c/d_{av} = 1.278$ )	Campaspe catchment	$k_c = 1.278 * d_{av}$	3.87

As shown in Table 3-23, a comparison with the routing parameters adopted for the Campaspe River and Rochester Flood Management Plan (2013) RORB models was also undertaken by considering the ratio between the routing parameter,  $k_c$ , and the weighted average flow distance from all nodes to the catchment outlet,  $d_{av}$ . For example, the weighted average flow distance for the Campaspe River RORB model was 48.6km and a value of 62.0 was adopted for  $k_c$ , resulting in a  $k_c/d_{av}$  ratio of 1.276. Applying this same ratio to the weighted average flow distance of the Kyneton RORB model, 3.02km, indicates a  $k_c$  value of 3.86.

Based on a review of the routing parameter estimates, the RORB model parameters shown in Table 3-24 were adopted.

**Table 3-24 Adopted RORB model parameters**

$k_c$	$m$
3.9	0.8

## KYNETON FLOOD STUDY

### 3.6.3 Fraction Impervious

The fraction impervious values for the RORB subareas were based on the planning zones as described in Section 3.3.2. For the calibration, these values were further refined based on the aerial photography of the area taken in 2010.

### 3.6.4 Observed Rainfall Data

Due to the small catchment size a sub-hourly pluviograph was required. The temporal rainfall distribution for the September 2010 and September 2016 events were sourced from the closest pluviograph station, 406266, which provided data in 15-minute intervals. This station was also used to derive hourly rainfall data for the calibration of the Campaspe River RORB model as described in Section 3.4.2.3.

Data from pluviograph station 406266 was also initially used for the January 2011 event. However, a concentrated high intensity rainfall in the sub-hourly temporal pattern produced an unrealistic peak flow, significantly larger than the estimated 1 in 200 AEP design event (Section 3.7.2), which was not experienced based on the available anecdotal, photographic and recorded flood level information. Hence, the historical temporal pattern from the next closest pluviograph station, 406250, was applied. This station was located a similar distance from the Post Office Creek catchment and produced flows that were more aligned with the evidence available from this event. A comparison of the two pluviograph records is shown in Figure 3-30.

The accumulated rainfall totals for each event were adopted from the data used for subarea G of the Kyneton RORB model as the Post Office Creek catchment covers a significant portion of this subarea.

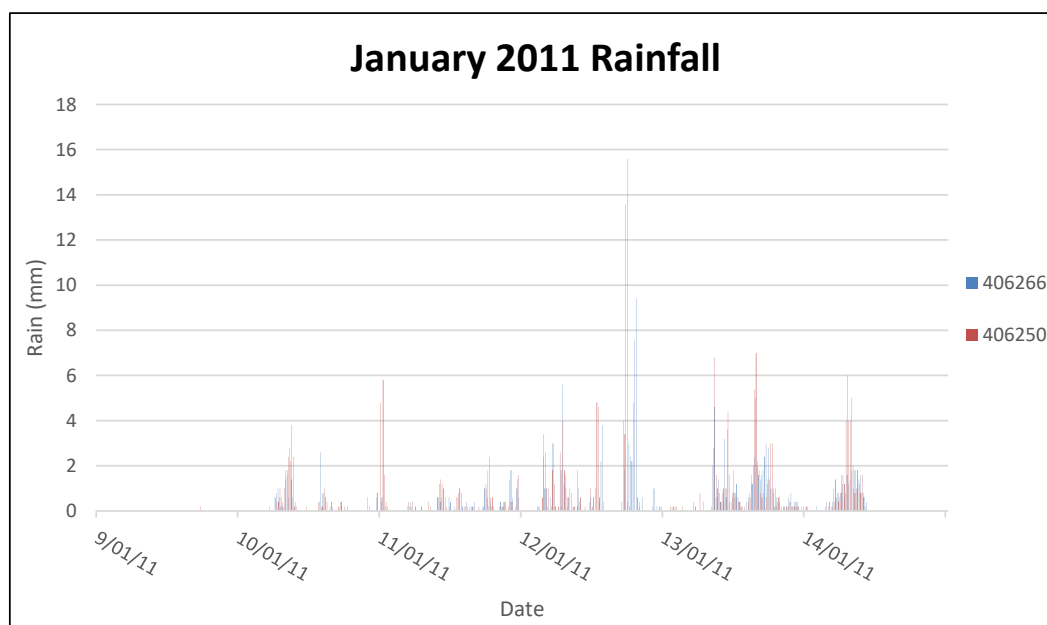


Figure 3-30 Pluviograph record (15-minute intervals) for the January 2011 event

## KYNETON FLOOD STUDY

### 3.6.5 Loss Model

An initial loss/continuing loss model was adopted for the Post Office Creek RORB model. The initial loss and continuing loss values were adopted based on the Campaspe River RORB calibration for the historical events as described in Section 3.4.6.2. As the September 2016 event could not be calibrated to the Campaspe River at Redesdale gauge the losses were selected based on the design losses determined in Section 3.5.1.6. An initial loss of 23mm and a continuing loss of 0.6mm/hour was adopted as the September 2016 event was estimated to be close to a 20% AEP event in Kyneton (Section 3.7.2.1). It should be noted that the peak flow for this event is not sensitive to the initial loss adopted due to the significant volume of rain occurring prior to the peak. The losses adopted for each historical event are shown in Table 3-25 to Table 3-27.

**Table 3-25 Adopted losses for Post Office Creek RORB model – September 2010**

IL (mm)	CL (mm/hr)
10	0.63

**Table 3-26 Adopted losses for Post Office Creek RORB model – January 2011**

IL (mm)	CL (mm/hr)
85	2.61

**Table 3-27 Adopted losses for Post Office Creek RORB model – September 2016**

IL (mm)	CL (mm/hr)
23	0.60

### 3.6.6 Hydrographs for Calibration

Using the parameters described in the preceding sections, hydrographs were generated for the following historical events: September 2010, January 2011 and September 2016. These Post Office Creek hydrographs are shown in Section 4.3 along with the Campaspe River historical hydrographs generated at the inflow locations to the hydraulic model. The hydrographs were then input into the TUFLOW model to replicate these four historical flood events and the model results were compared to the available historical data as described in Section 4.3.

## KYNETON FLOOD STUDY

### 3.7 Post Office Creek Design Event Modelling

The section details the process used to determine appropriate design parameters and flows for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events for Post Office Creek at Kyneton.

#### 3.7.1 Design Model Parameters

In order to produce appropriate design hydrographs a Monte Carlo analysis was run with model parameters specific to the Post Office Creek catchment including temporal patterns, IFD and ARF values. The parameters adopted are detailed below.

##### 3.7.1.1 Fraction Impervious

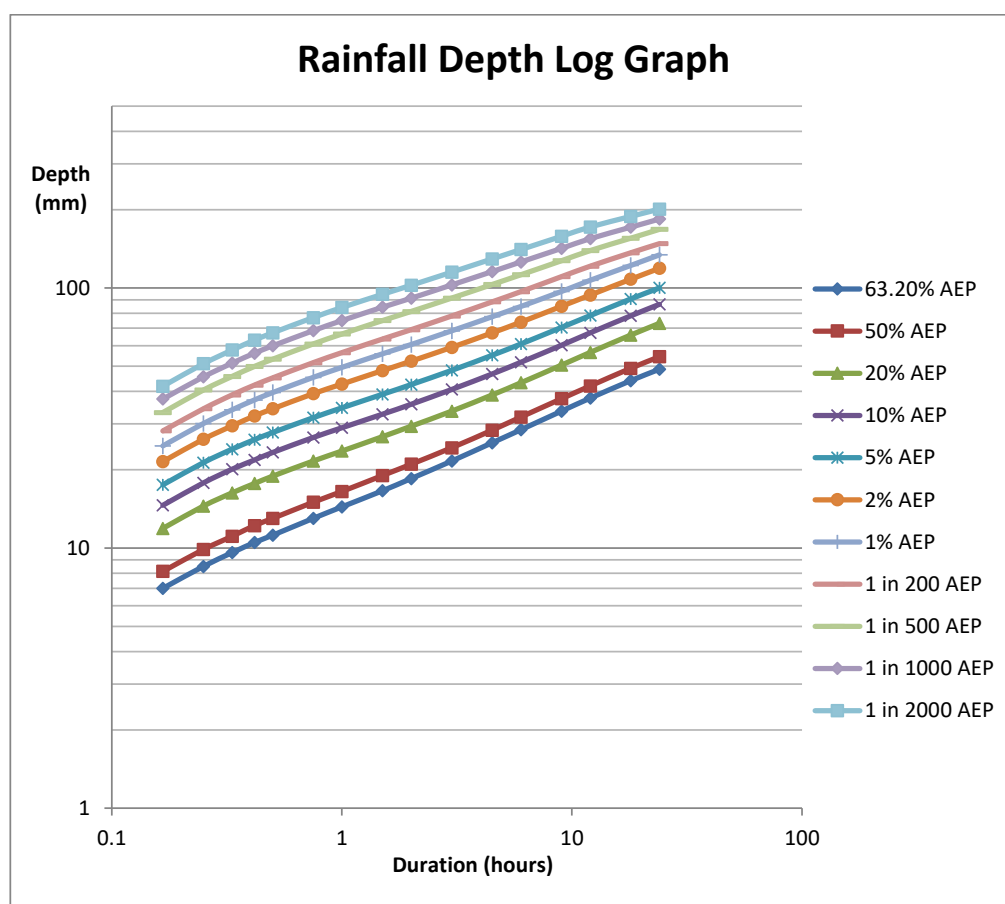
The fraction impervious values for the RORB subareas were based on the planning zones as described in Section 3.3.2. Unlike the calibration, these values were not refined using aerial photography as it represents the runoff potential based on future development in accordance with the planning scheme.

##### 3.7.1.2 IFD

The IFD was obtained from the Bureau of Meteorology website for the Post Office Creek catchment. Additional durations were added to the table to match the durations for which temporal patterns were available.

The IFD table was expanded by adding the depths of rare events. At the time of writing, rainfall depths for events from 1 in 200 to 1 in 2000 AEP were not available on the Bureau of Meteorology's website for durations less than 24 hours. Hence, the method recommended in ARR, Book 8, Section 3.6.3 for estimating very rare sub-daily rainfalls was used. Rainfall depths were determined by multiplying the relevant 1% AEP design rainfall depth by specific growth curve factors. ARR notes that due to the method used to derive these growth curve factors there may be the potential for significant discontinuity when compared to the values provided for durations of 24 hours and longer. As a result, it was necessary to smooth the growth factors to ensure the depths varied in a consistent manner across storm durations and exceedance probability. The growth curve factors were applied to the shortest durations and intermediary depths were smoothed between these values and those provided on the Bureau of Meteorology's website for 24-hour storms. A log graph displaying the smoothed results is shown in Figure 3-31.

## KYNETON FLOOD STUDY



**Figure 3-31** Log graph showing smoothing of depth-duration relationship for very rare rainfall events (1 in 200 to 1 in 2000) for Post Office Creek IFD

### 3.7.1.3 Areal Reduction Factor

The applicable ARF values were read into RORB from the Data Hub file for Post Office Creek. The Data Hub parameters are shown in Section 7.3.3.

### 3.7.1.4 Design Temporal Pattern

The design temporal patterns were obtained from Data Hub (Section 7.3.3). As the catchment is less than 75km<sup>2</sup> in size (12.07km<sup>2</sup>), point temporal patterns were applied, as recommended in ARR, Book 2, Section 5.9.1. Point temporal patterns are available for the following storm durations: 10, 15, 20, 25, 30, 45, 60 mins, 1.5, 2, 3, 4.5, 6, 9, 12, 18, 24, 30, 36, 48, 72, 96, 120, 144, 168 hours. For each duration there are 30 different temporal patterns: 10 each for frequent, intermediate and rare events. Hence, in total there are 720 patterns available for modelling.

## KYNETON FLOOD STUDY

The temporal patterns have been assessed to determine if any contain embedded burst which would cause the RORB model to overestimate the peak flows. This was done by comparing the sub-period rainfall totals of a particular temporal pattern against the IFD to determine whether it is rarer than the AEP of the entire burst. The analysis revealed that two temporal patterns contained embedded bursts;

- pattern 5 from the rare, 24-hour duration storms.
- pattern 7 from the intermediate, 24-hour duration storms.

For example, pattern 5 from the rare, 24-hour duration temporal patterns for the 1% AEP event contained an embedded rainfall burst which was between a 1 in 200 AEP and 1 in 500 event.

As stated in *Addressing embedded bursts in design storms for flood hydrology* (Scorah et. al., 2016), "Censoring of temporal patterns which contain embedded bursts may be appropriate if the number of afflicted patterns is small." As the patterns with embedded bursts represent a small proportion of the total number of patterns available these embedded patterns were simply excluded from the modelling.

### 3.7.1.5 Design Spatial Pattern

As the catchment area is less than 20km<sup>2</sup> a uniform spatial pattern was applied as recommended in ARR, Book 2, Section 6.3.1.

### 3.7.1.6 Simulation Parameters

The default stratified sample was used with 50 rainfall divisions and 20 samples per division. 70 time increments were modelled for each simulation.

In accordance with the calibration, the parameters used were  $k_c=3.9$ ,  $m=0.80$ .

### 3.7.1.7 Design Losses

An initial loss/continuing loss model was used for the Monte Carlo analysis. The design initial and continuing losses determined for the Campaspe River RORB model were also adopted for Post Office Creek. The values are shown in Table 3-28 below. Additionally, the initial loss was stochastically selected from the default RORB distribution shown in Table 3-29.

**Table 3-28 Adopted design initial and continuing losses**

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
50% - 20%	23	0.6
10% - 5%	23	0.7
2% - 1%	23	1.0



## KYNETON FLOOD STUDY

Table 3-29 Initial loss distribution

Proportion of time value is exceeded	IL Factor
0%	3.190
10%	2.260
20%	1.710
30%	1.400
40%	1.200
50%	1.000
60%	0.850
70%	0.680
80%	0.530
90%	0.390
100%	0.140

## 3.7.1.8 Baseflow

As discussed in Section 3.4.2.2, baseflow in this catchment is insignificant. Hence, no allowance for baseflow has been added to the design hydrographs due to there being a negligible impact on the design flood hydrograph.

## 3.7.2 Design Flow Results

## 3.7.2.1 Monte Carlo Analysis

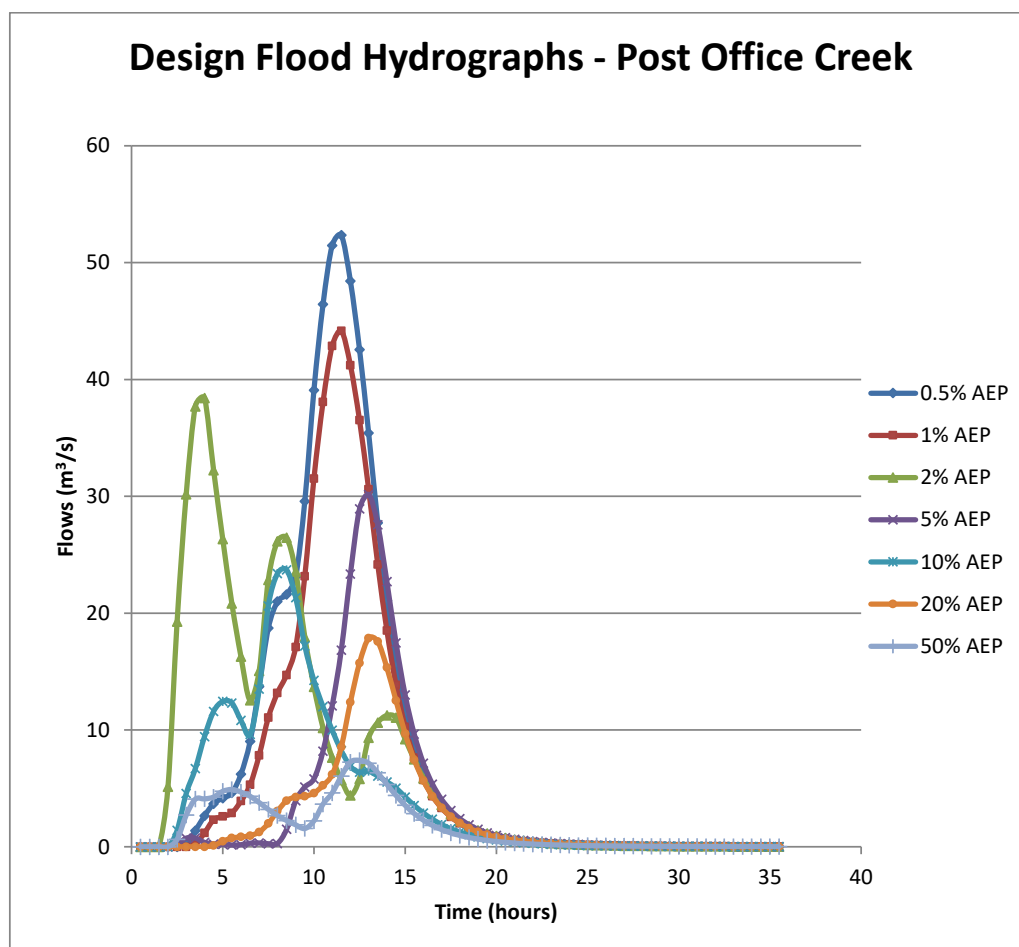
The design parameters detailed above were used to undertake a Monte Carlo simulation for the Post Office Creek catchment. The critical storm duration for the Post Office Creek catchment was determined to be 12 hours. The results of the Monte Carlo flood frequency analysis (FFA) are shown in column 2 of Table 3-30. The individual design runs used for the Monte Carlo analysis were then assessed to determine which provided the most similar peak flow to the Monte Carlo FFA while still utilising reasonable parameters. The design parameters adopted for these particular runs are shown in columns 3 to 9 of Table 3-30. These run parameters were used to generate the complete hydrographs for the design floods ranging from 50% - 0.5% AEP events. The design hydrographs are shown in Figure 3-32 below.

## KYNETON FLOOD STUDY

Table 3-30 Individual design runs from Monte Carlo analysis

AEP	Peak Flow from MC FFA (m <sup>3</sup> /s)	Run	Rainfall ARI	Rainfall Depth (mm)	Temporal Pattern	IL Stochastic Factor	CL AEP Factor	Run Peak Flow (m <sup>3</sup> /s)
50%	7.43	12hr, Div 1, Run 16	1.6	36.8	2	0.76	0.6	7.41
20%	17.84	12hr, Div 16, Run 6	4.6	54.1	10	1.25	0.6	17.84
10%	23.49	12hr, Div 23, Run 16	8.2	62.7	12	0.64	0.66	23.70
5%	29.72	12hr, Div 27, Run 4	18.4	74.9	19	1.7	0.70	30.16
2%	38.41	12hr, Div 33, Run 18	48.0	90.4	29	0.47	0.98	38.47
1%	44.07	12hr, Div 36, Run 12	80.1	99.5	26	1.17	1.0	44.14
0.5%	52.03	12hr, Div 40, Run 20	185.7	115.4	26	1.03	1.0	52.35

## KYNETON FLOOD STUDY



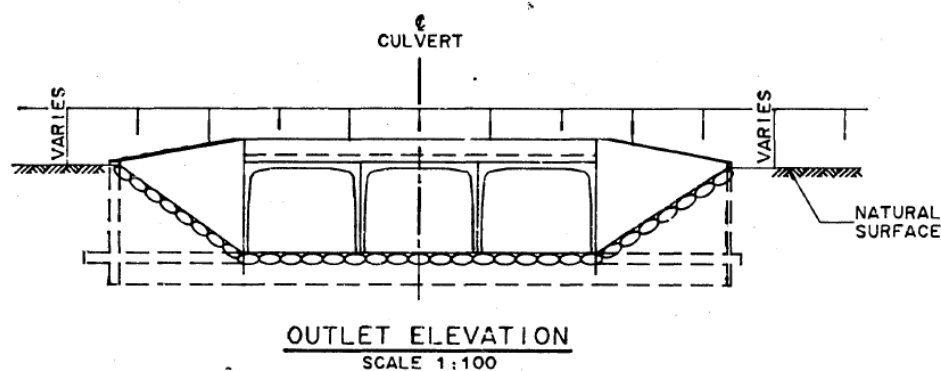
**Figure 3-32** Design flood hydrographs for Post Office Creek

### 3.7.3 Discussion

The Calder Highway crosses Post Office Creek approximately 450 metres upstream of the location of the RORB model outlet where the flow is determined. The RORB model outlet location was selected based on the extent of LiDAR available for the TUFLOW model. It is therefore necessary to check the capacity of the Calder Highway Bridge to ensure it is sufficient to convey the calculated flows from Post Office Creek.

The Calder Highway Bridge consists of three 2.4 x 3.0 metre box culverts as shown in Figure 3-33 below which was received from VicRoads.

## KYNETON FLOOD STUDY



**Figure 3-33 Calder Highway Bridge over Post Office Creek**

The capacity of the bridge was determined using the design charts in the CPAA Design Manual – Hydraulics of Precast Concrete Conduits. Both inlet and outlet analyses were undertaken to establish what flow regime the culverts operate under. The culverts are 78 metres long with wingwall flares within  $30^{\circ}$  to  $75^{\circ}$ . A Manning's  $n$  value of 0.013 was adopted for the concrete pipes and the headwater depth was assumed to be the same as the culvert height of 2.4 metres. The total flow capacity of the culverts under inlet control was calculated to be  $57\text{m}^3/\text{s}$ . Under outlet control, the culvert capacity was estimated at  $120\text{m}^3/\text{s}$ . Therefore, the culverts operate under inlet control with sufficient capacity to convey the 0.5% AEP flow, hence the design flows determined in the RORB model will not be restricted by the Calder Highway Bridge.

## KYNETON FLOOD STUDY

### 3.8 Design Flow Verification

The design flows are largely dependent on the adopted RORB model design parameters. Therefore, these flows were compared to several other peak flow estimates for verification. The methods used to verify the design flows generated from RORB included:

- Regional Flood Frequency Estimation
- Probabilistic Rational Method
- Deterministic Rational Method
- DCNR Regional Method
- Comparison to previous studies

These methods are discussed in the following sections. A summary of the results is shown in Table 3-32 and Figure 3-34 to Figure 3-36.

#### 3.8.1 Regional Flood Frequency Estimation

ARR recommends the use of the Regional Flood Frequency Estimation (RFFE) tool for estimating peak design flows. The RFFE tool was developed as part of the revision of ARR and is available on the ARR website. The tool requires the following inputs: catchment area, outlet location and catchment centroid location. Essentially, the RFFE approach transfers flood frequency characteristics from a group of gauged catchments to the location of interest. This estimation technique is limited to catchments that meet the following criteria:

- Catchment area is greater than 100km<sup>2</sup>;
- Urban areas account for less than 10% of total catchment area;
- Catchment does not contain large storages. Small farm dams do not significantly impact on the estimate; and,
- Land use has not changed significantly.

The RFFE tool was used to estimate peak flows at the Campaspe River at Redesdale gauge, Kyneton Township and on Post Office Creek at Mollison Street and the results are summarised in Table 3-32 and Figure 3-34 to Figure 3-36.

#### 3.8.2 Probabilistic Rational Method

Although no longer recommended by ARR, the Probabilistic Rational Method was used to estimate 1% AEP peak flows for comparison. The calculations were undertaken in accordance with the technique described in ARR 1987, using the 1987 IFD values that apply to this method.

Additionally, the VicRoads Probabilistic Rational Method was also calculated. This method is identical to the Probabilistic Rational Method except that it applies an additional factor to account for catchment area. For large catchments, such as that of Kyneton, the VicRoads method yields the same

## KYNETON FLOOD STUDY

flow estimate as the Probabilistic Rational Method. However, for the smaller Post Office Creek catchment, the estimated VicRoads method flow is 57% greater.

The results of both methods are shown in Table 3-32 and Figure 3-34 to Figure 3-36.

### 3.8.3 Deterministic Rational Method

The Deterministic Rational Method is also no longer recommended by ARR as it has been replaced by the Regional Flood Frequency Estimation tool. However, this method was used to provide a rapid estimate of the 1% AEP peak flow on Post Office Creek for comparison. The Deterministic Rational Method involves assigning a runoff coefficient to all land within the catchment to specify the rainfall runoff. Standard runoff coefficients were applied to land based on the current zoning. Similar to the Probabilistic Rational Method, the rainfall intensity applied for this method was derived from the 1987 IFD as this is the dataset from which the method was created. The results of this methods are shown in Table 3-32 and Figure 3-36.

### 3.8.4 DCNR Regional Method

The *Hydrological Recipes – Estimation Techniques in Australian Hydrology* (Grayson et al., 1996) recommends the use of the regional method developed by the Department of Conservation and Natural Resources. This technique is based solely on the correlation between peak flow rate and catchment area. Two regional equations are provided for use depending on whether the catchment is mostly rural or urban. These equations are only applicable to small to medium sized catchments in the region of the Great Dividing Range. Furthermore, these equations do not apply to catchments affected by artificial or natural storages such as floodplains, reservoirs or breakaway channels. Hence, the use of this estimation method is appropriate in this case. The results of these equations are shown in Table 3-32 and Figure 3-34 to Figure 3-36, with the urban regional method shown simply for comparison.

### 3.8.5 Previous Flood Studies

#### 3.8.5.1 Calder Highway Karlsruhe to Kyneton – Hydrologic and Hydraulic Investigations (CMPS&F, 1995)

VicRoads commissioned a hydrologic and hydraulic investigation for the Calder Highway crossings of the Campaspe River between Karlsruhe and Kyneton. In determining appropriate design peak flows two methods were considered:

1. A flood frequency analysis was undertaken for both the Campaspe River at Redesdale gauge and the Campaspe River at Ashbourne based on 26 years and 22 years of records respectively. The design flows at Karlsruhe were estimated using the results of this analysis on the basis of a linear relationship between catchment area and flow per unit area.

## KYNETON FLOOD STUDY

2. A rainfall-runoff model was created and calibrated to the September 1993 event and the peak 5 year ARI flow at the Ashbourne gauge. The design flows generated by this model were considered more reliable since the flood frequency analysis was based on a relatively short record. Hence, the rainfall-runoff model results were adopted for the study's hydraulic model. The results are shown in Table 3-31 below. It should be noted that the flows are determined at Carlsruhe Bridge, located approximately 9km upstream of Kyneton Township.

**Table 3-31 Study design peak flows at Carlsruhe Bridge**

ARI	Flood Frequency Analysis Peak Flows (m <sup>3</sup> /s)	Rainfall-Runoff Modelling Peak Flows (m <sup>3</sup> /s)
5 year	134	85
20 year	188	175
100 year	222	315

A comparison of the flows are provided below in Table 3-32 and Figure 3-34 and Figure 3-35.

### 3.8.5.2 River Walk Flood Study (Earth Tech, 2005)

In April 2005, a flood study was conducted by Earth Tech for a reach of the Campaspe River south of Kyneton Township to determine the 1% AEP flood levels for a residential development. The study utilised information determined from a 2002 report, prepared by Egis Consulting Australia, which had determined a 1% AEP flow of 275m<sup>3</sup>/s at the Calder Freeway bridge in Carlsruhe. This flow was then linearly scaled in accordance with the additional catchment area of the downstream site to derive a flow at Sanctuary Drive, Kyneton. Hence, the peak flow adopted for this study was 297m<sup>3</sup>/s. This is shown in Table 3-32 and Figure 3-35.

### 3.8.5.3 Kyneton Township Stormwater Drainage Study (Aurecon, 2011)

Macedon Ranges Shire Council commissioned this stormwater drainage study for the township of Kyneton to identify the existing infrastructure limitations and determine the future requirements. As part of this assessment, a one-dimensional hydraulic model was prepared for Post Office Creek. The study report does not describe how the 1% AEP design flow applied in the hydraulic model was determined. However, based on other calculations detailed in the report, the flows appear to have been estimated using the Deterministic Rational Method. This flow is displayed in Table 3-32 and Figure 3-36 for comparison with the other methods.



## KYNETON FLOOD STUDY

**3.8.6 Summary**

Table 3-32 below shows the 1% AEP peak flow estimations for the three locations of interest: the Campaspe River at Redesdale gauge, Campaspe River at Kyneton Township, and Post Office Creek. The estimated design peak flows are graphed for each of these locations in Figure 3-34 to Figure 3-36 respectively.

It can be seen that the RORB model results for the Redesdale catchment correlates well to the gauge flood frequency curve as it was calibrated to this. The RORB model results are significantly less than that estimated by the RFFE; however, the 1% AEP peak flow is similar to the Probabilistic Rational Method estimate.

For the Campaspe River peak flow estimates at Kyneton, the RORB model results correlated well with the two previous flood studies undertaken for the catchment. It is significantly higher than flows estimated by the RFFE and Probabilistic Rational Method.

The Post Office Creek RORB model yields a similar 1% AEP flow to that utilised in the Kyneton Township Stormwater Drainage Study and also estimated by the Deterministic Rational Method. It exceeds the RFFE and Probabilistic Rational Method due to the substantial proportion of urban development within the catchment. Hence, these estimation techniques are not directly applicable to this catchment. As expected the RORB model 1% AEP peak flow lies between the Regional Method estimates for fully rural and urban catchments.

## KYNETON FLOOD STUDY

Table 3-32 Comparison of various estimates of the 1% AEP peak flow

	Campaspe River @ Redesdale Gauge (m <sup>3</sup> /s)	Campaspe River at Kyneton Township (m <sup>3</sup> /s)	Post Office Creek (at Mollison Street Bridge) (m <sup>3</sup> /s)
Probabilistic Rational Method	452	188	20.5
VicRoads Probabilistic Rational Method	452	188	32.2
Deterministic Rational Method	-	-	42.4
Regional Method (Rural)	645	299	31.2
Regional Method (Urban)	1009	493	60.3
Flood Frequency Analysis	457 (355 – 668) <sup>#</sup>	-	-
Flood Frequency Analysis (Bureau of Meteorology)	430	-	-
Regional Flood Frequency Estimation (AR&R)	861 (266 – 2800)	236 (74.5 – 754)	20.9 (6.6 – 66.7)
Kyneton Township Stormwater Drainage Study (Aurecon, 2011)	-	-	46.7
River Walk Flood Study Report (Earth Tech, 2005)	-	297	-
Calder Highway Karlsruhe to Kyneton – Hydrological and Hydraulic Investigations (CMPS&F, 1995)	355 (108 – 1164)	315	-
RORB Model	462	299	44.1

<sup>#</sup> 90% confidence interval shown in parentheses

## KYNETON FLOOD STUDY

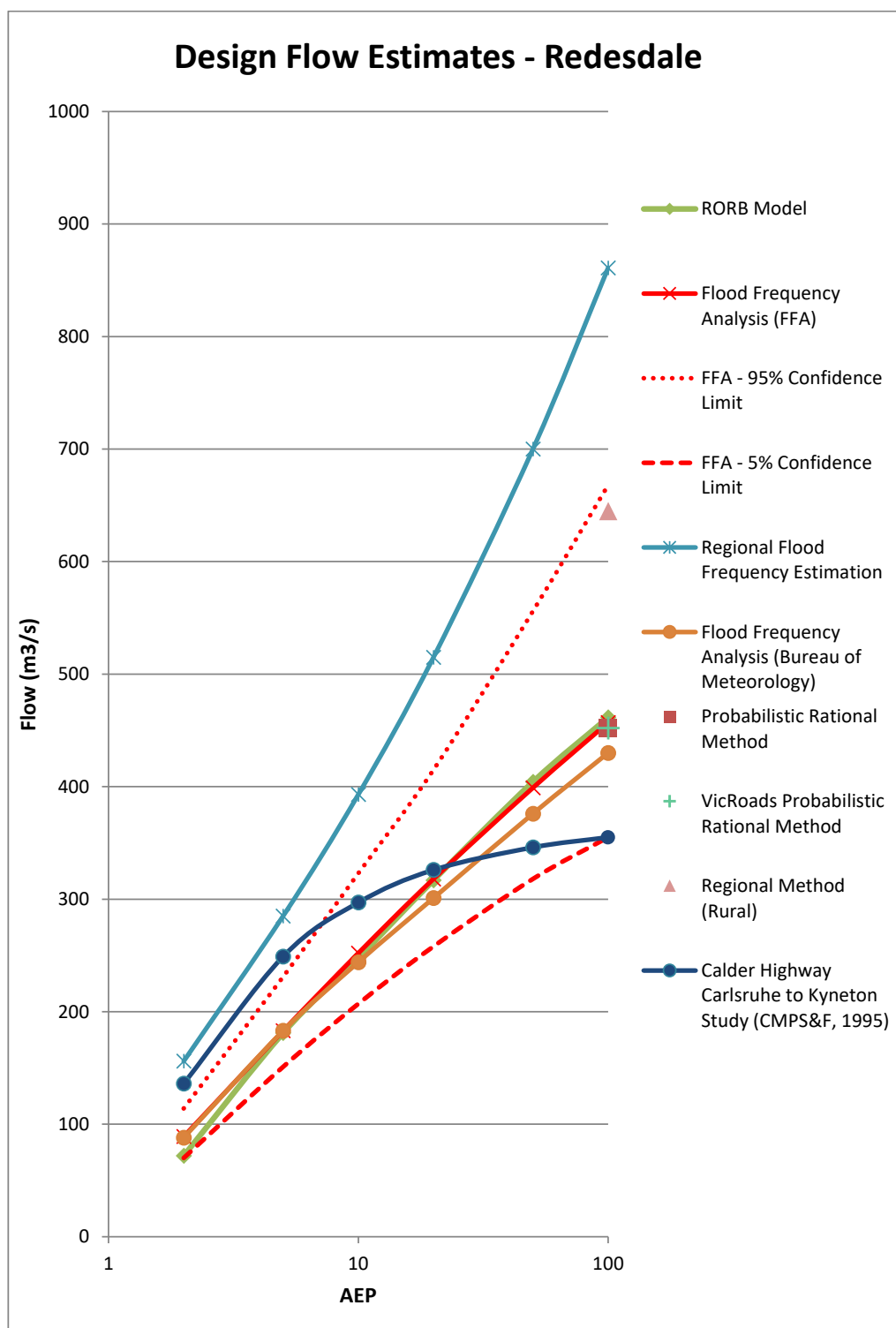


Figure 3-34 Comparison of design peak flow estimates for Campaspe River at Redesdale gauge

## KYNETON FLOOD STUDY

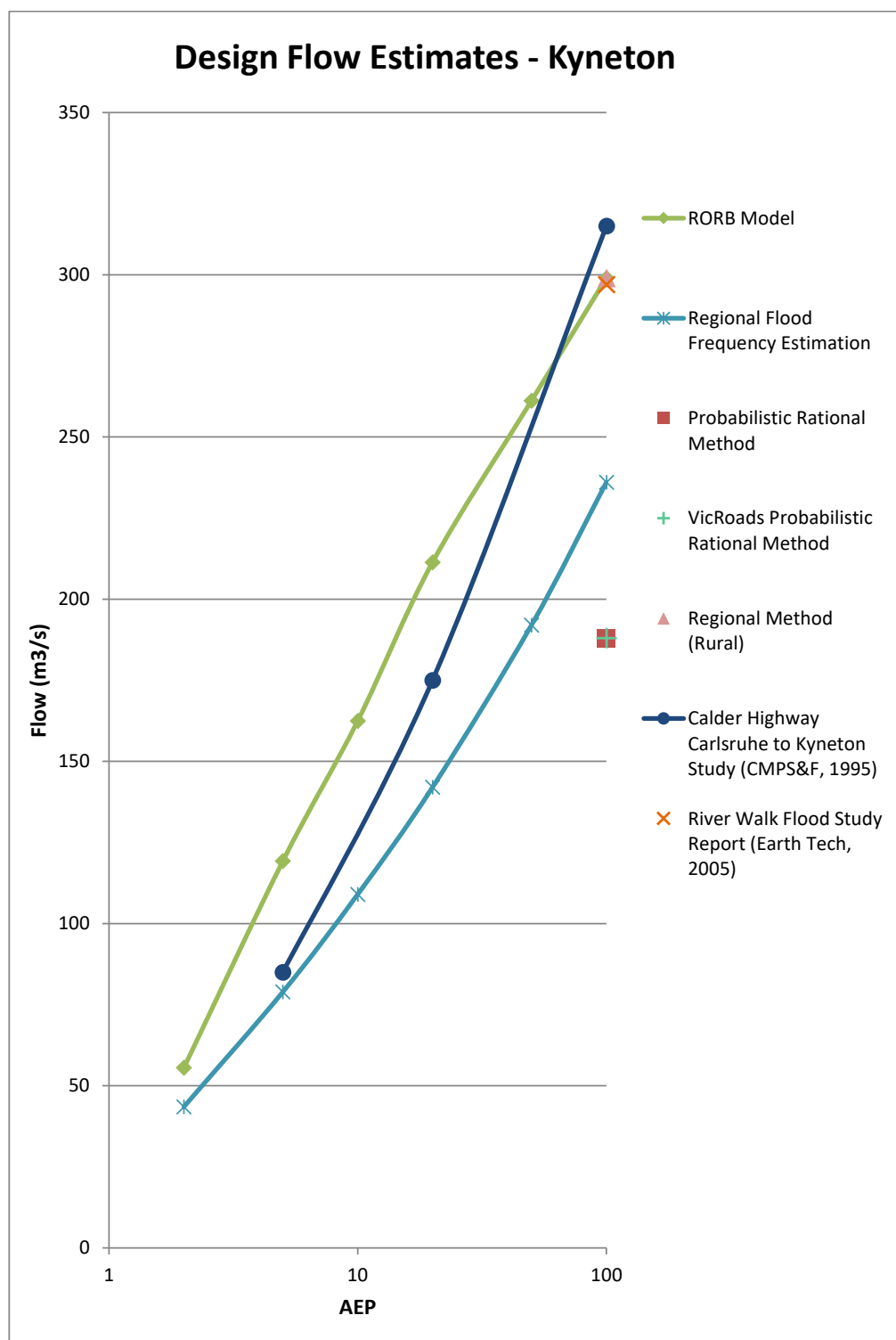


Figure 3-35 Comparison of design peak flow estimates for Kyneton Township

## KYNETON FLOOD STUDY

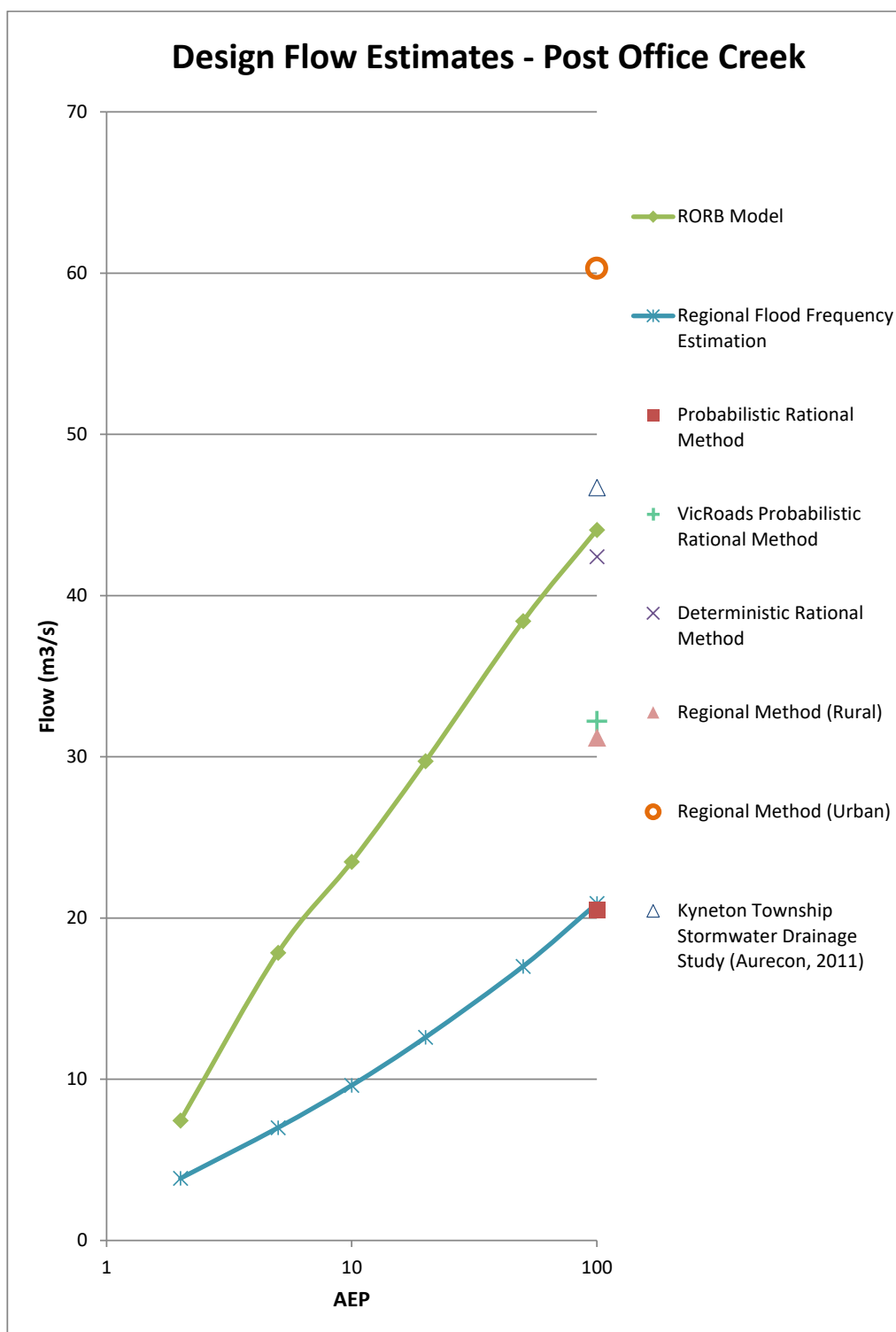


Figure 3-36 Comparison of design peak flow estimates for Post Office Creek

## KYNETON FLOOD STUDY

### 3.9 Sensitivity Analysis

The RORB Monte Carlo analysis used to determine the design flows inherently accounts for variation in the temporal pattern, losses and rainfall depth by stochastic sampling. Hence, further sensitivity analysis on these parameters is not required.

However, ARR recommends that the potential impacts of various climate change projections be considered. This involves adjusting the IFD rainfall data to future climates by using the method recommended in ARR, Book 1, Section 6.3.5. This method is based on temperature scaling using temperature projections from the CSIRO and is preferred as climate models produce temperature estimates more reliably than individual storm events.

The Data Hub file (Section 7.3.2) includes the interim climate change factors to apply based on the different climate scenarios modelled and the planning horizon (shown in Table 3-33). The climate scenarios are based on Representative Concentration Pathways (RCPs) which describe the different concentrations of greenhouse gases and aerosols. These factors are applicable to both the Campaspe River and Post Office Creek catchments at Kyneton.

**Table 3-33 Interim climate change factors for Kyneton**

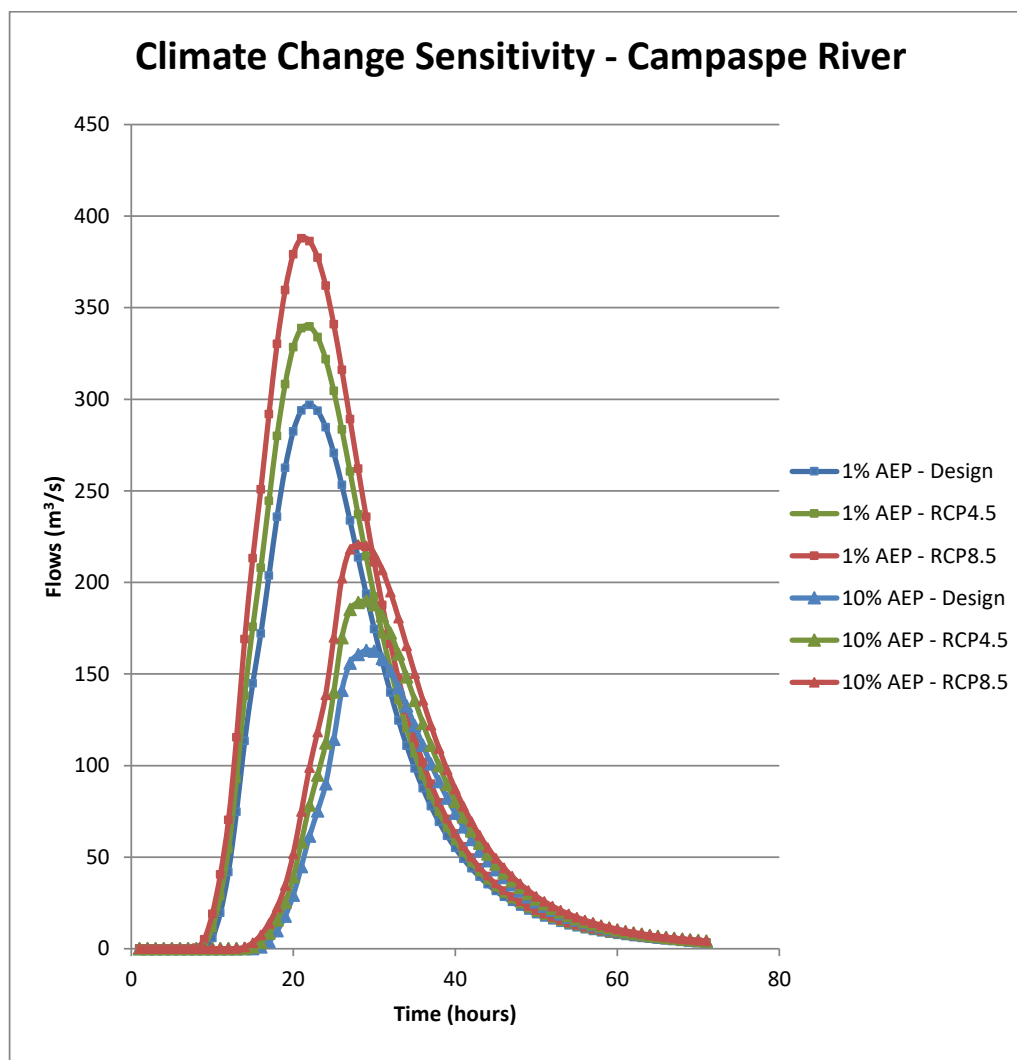
Planning Horizon	RCP4.5		RCP6		RCP8.5	
	Temp. Increase (°C)	Increase in Rainfall	Temp. Increase (°C)	Increase in Rainfall	Temp. Increase (°C)	Increase in Rainfall
2030	0.85	4.3%	0.845	4.2%	0.974	4.9%
2040	1.086	5.4%	1.05	5.3%	1.341	6.7%
2050	1.303	6.5%	1.283	6.4%	1.734	8.7%
2060	1.478	7.4%	1.539	7.7%	2.212	11.1%
2070	1.629	8.1%	1.775	8.9%	2.753	13.8%
2080	1.741	8.7%	2.036	10.2%	3.26	16.3%
2090	1.793	9.0%	2.316	11.6%	3.748	18.7%

For the sensitivity analysis, the planning horizon of 2090 was adopted. ARR, Book 1, Section 6.2 recommends the use of both RCP 4.5 and 8.5 to consider the impacts of low and high concentrations. Hence, based on these assumptions, the table above indicates 9.0% and 18.7% increase in rainfall for scenarios RCP 4.5 and 8.5 respectively.

#### 3.9.1 Campaspe River

Figure 3-37 below compares the resulting design flood hydrographs for the different climate change scenarios to the standard design hydrograph for the 10% and 1% AEP events on the Campaspe River. Table 3-34 displays the increase in peak flow for each of the climate change scenarios, which are greater than the corresponding increases in rainfall depths. For example, under scenario RCP 8.5 the rainfall is increased by 18.7% however the 1% AEP peak flow has increased by 30.6% and exceeds the 0.5% AEP peak flow under current climate conditions. Similarly, the 10% AEP peak flow is increased to the equivalent of the 5% AEP peak flow under climate scenario RCP 8.5.

## KYNETON FLOOD STUDY



**Figure 3-37** Impacts of climate change on Campaspe River design hydrographs

**Table 3-34** Comparison of climate change scenario peak flows for Campaspe River

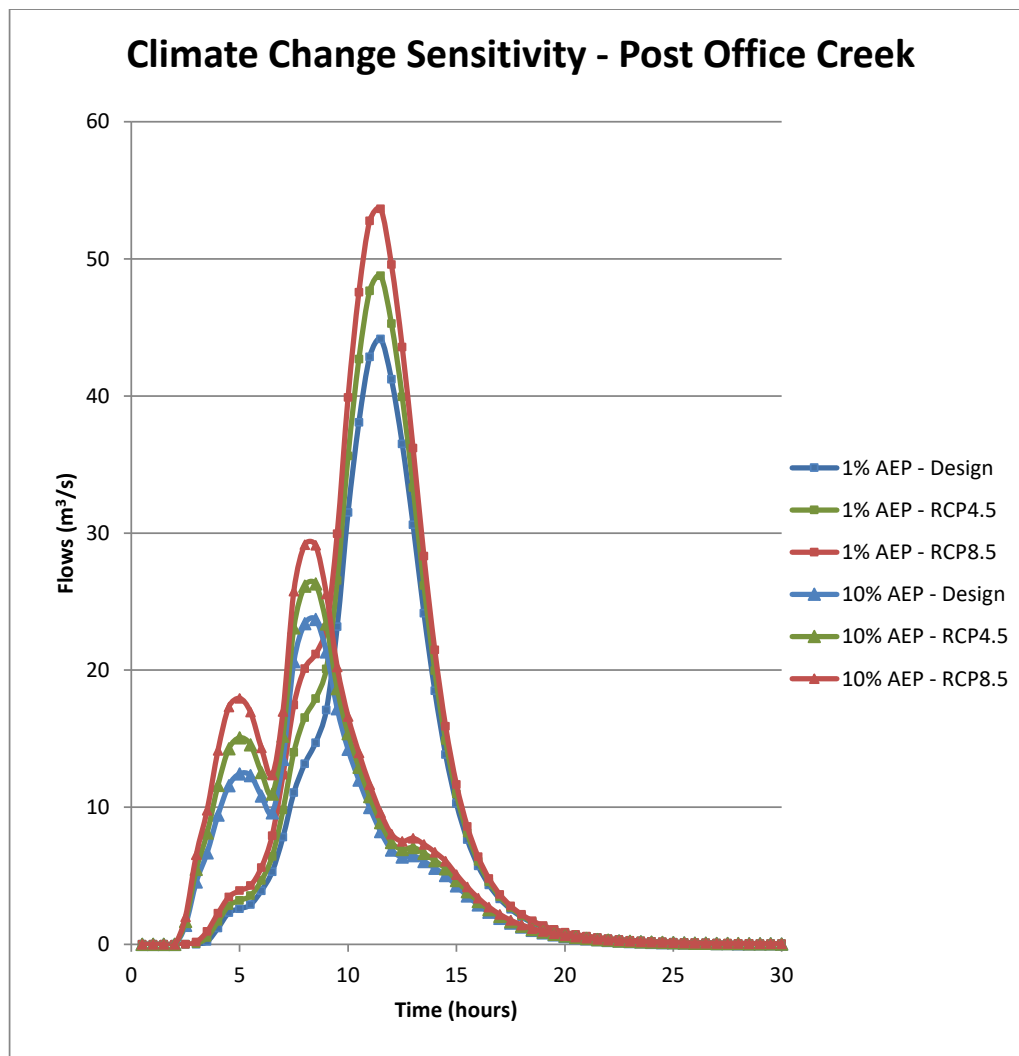
	Design Peak Flow (m <sup>3</sup> /s)	RCP4.5 Peak Flow (m <sup>3</sup> /s)	Difference	RCP8.5 Peak Flow (m <sup>3</sup> /s)	Difference
1% AEP Event	297.0	339.7	14.4%	387.8	30.6%
10% AEP Event	162.8	190.0	16.7%	220.6	35.5%



## KYNETON FLOOD STUDY

**3.9.2 Post Office Creek**

Figure 3-38 below compares the resulting design flood hydrographs for the different climate change scenarios to the standard design hydrograph for the 10% and 1% AEP events on Post Office Creek. Table 3-35 displays the increase in peak flow for each of the climate change scenarios. Similar to the Campaspe River analysis, the percentage increase in flows for the climate change scenarios are greater than the corresponding increases in rainfall depths. For example, under scenario RCP 8.5 the rainfall is increased by 18.7% however the 1% AEP peak flow has increased by 21.5% and is equivalent to the 0.5% AEP peak flow under current climate conditions. Similarly, the 10% AEP peak flow is increased to almost the current 5% AEP peak flow under climate scenario RCP 8.5.



**Figure 3-38** Impacts of climate change on Post Office Creek design hydrographs

## KYNETON FLOOD STUDY

Table 3-35 Comparison of climate change scenario peak flows for Post Office Creek

	Design Peak Flow (m <sup>3</sup> /s)	RCP4.5 Peak Flow (m <sup>3</sup> /s)	Difference	RCP8.5 Peak Flow (m <sup>3</sup> /s)	Difference
1% AEP Event	44.2	48.8	10.4%	53.7	21.5%
10% AEP Event	23.7	26.3	11.0%	29.2	23.2%

### 3.10 Probable Maximum Flood

Estimates of the Probable Maximum Flood (PMF) were determined using the regression equations recommended in *Hydrological Recipes* (Grayson et al., 1996). These equations allow the computation of a triangular PMF hydrograph based on the catchment area. This estimation method was derived from analysis of PMF estimates from 56 catchments in South Eastern Australia ranging in size from 1 - 10,000km<sup>2</sup>. As both the Campaspe River and Post Office Creek catchments investigated in this study have catchment areas within this range and do not have any significant storages, this method is directly applicable. For the South East Australia method, the PMF peak flow rates were calculated using the following equation where  $Q$  is the peak flow rate in m<sup>3</sup>/s and  $A$  is the catchment area in km<sup>2</sup>:

$$Q = 500A^{0.43}$$

The peak flows estimated by this method were also compared to regression equations based on empirical analysis of global flood observations as recommended in ARR, Book 1, Section 3.4.4. The following relationships are proposed by Herschy (2003) based on a data set of worldwide flood maxima:

$$Q = 500A^{0.43} \quad \text{for values of } A \text{ greater than } 90\text{km}^2$$

$$Q = 100A^{0.8} \quad \text{for values of } A \text{ less than } 90\text{km}^2$$

The PMF peak flow estimates for the two methods at each of the hydraulic model input locations are shown in Table 3-36 below. A comparison of the results shows that the global regression method Herschy (2003) yields significantly higher peak flow estimates than the South East Australia method (Grayson et al., 1996). As the South East Australia method has been derived from local data which is directly applicable to the study catchment, these results have been adopted to represent the PMF flow conditions. The corresponding hydrographs are shown in Figure 3-43. The timing of each hydrograph relative to the other hydrographs was approximated based on the timings determined for the 1% AEP design hydrographs.

## KYNETON FLOOD STUDY

Table 3-36 PMF peak flow estimates

Location	Peak Flow (m <sup>3</sup> /s)	Global Equation (m <sup>3</sup> /s)	Difference (%)
Campaspe at Carlsruhe	2891	4379	51%
Carlsruhe Tributary	1421	2253	59%
Subarea F	1007	1440	43%
Post Office Creek	599	733	22%

## 3.11 Summary

The design hydrographs adopted for the hydraulic model inputs are shown in Figure 3-39 to Figure 3-43 below.

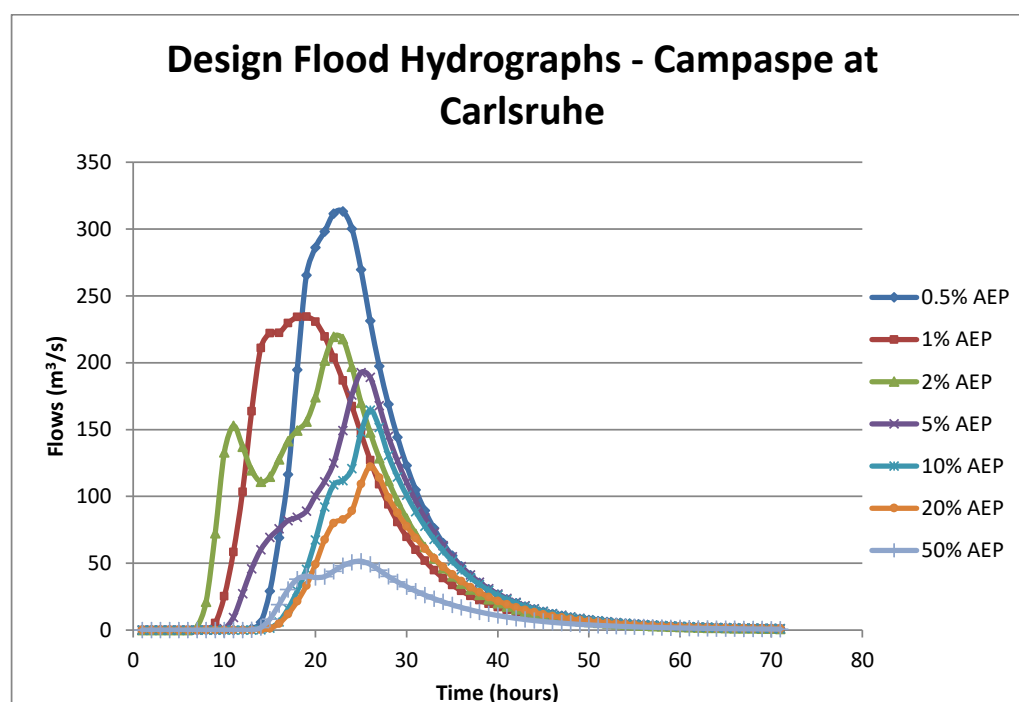


Figure 3-39 Design flood hydrographs at Campaspe at Carlsruhe

## KYNETON FLOOD STUDY

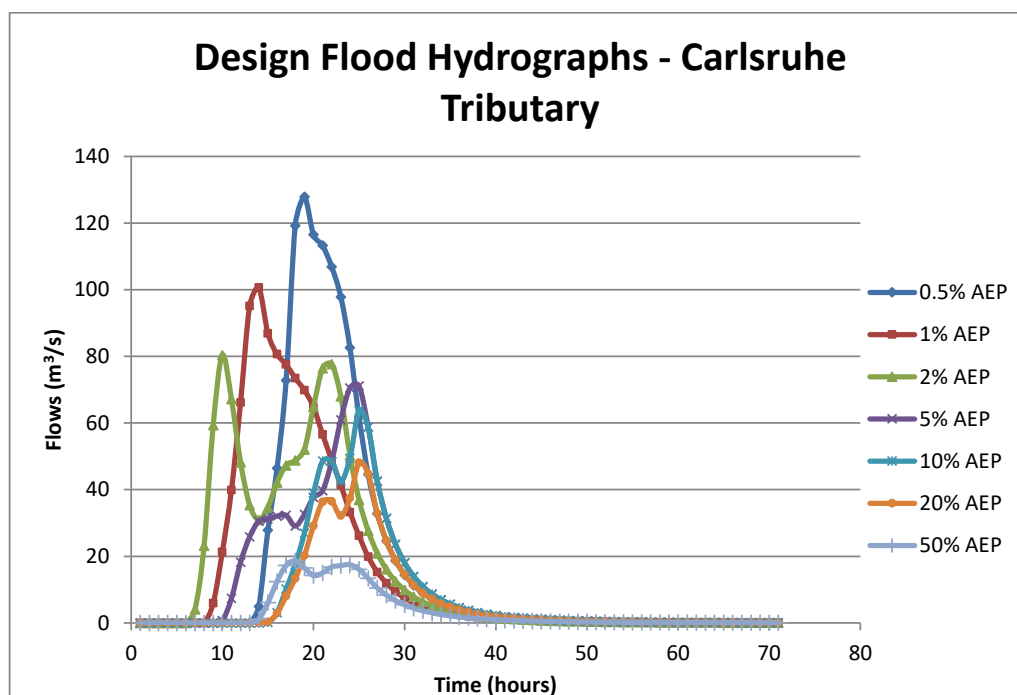


Figure 3-40 Design flood hydrographs at Carlsruhe Tributary

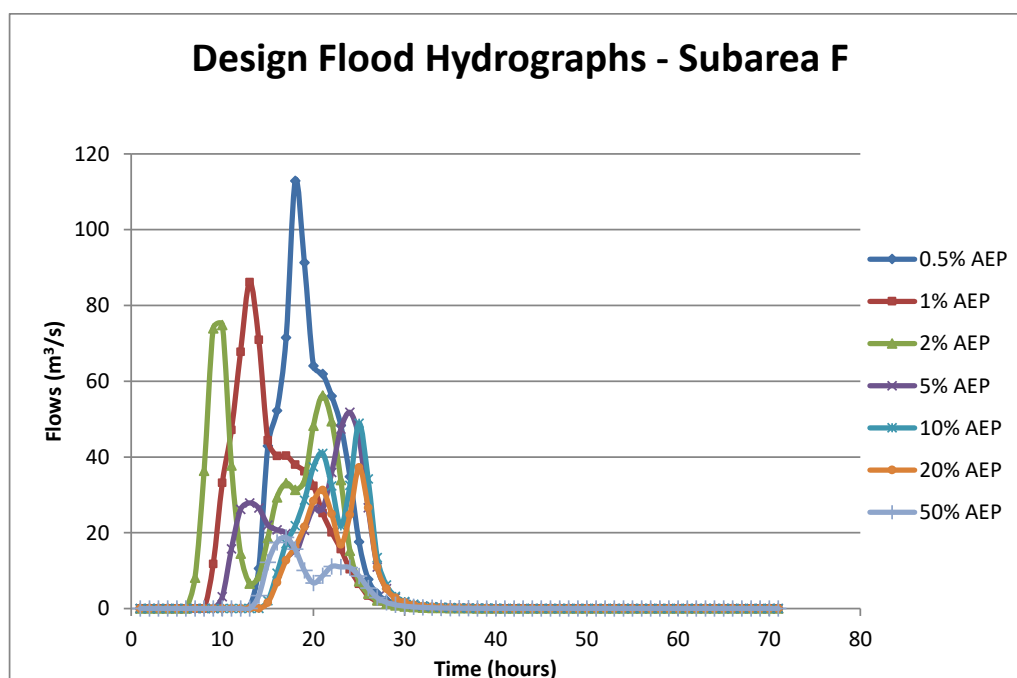


Figure 3-41 Design flood hydrographs from Subarea F

## KYNETON FLOOD STUDY

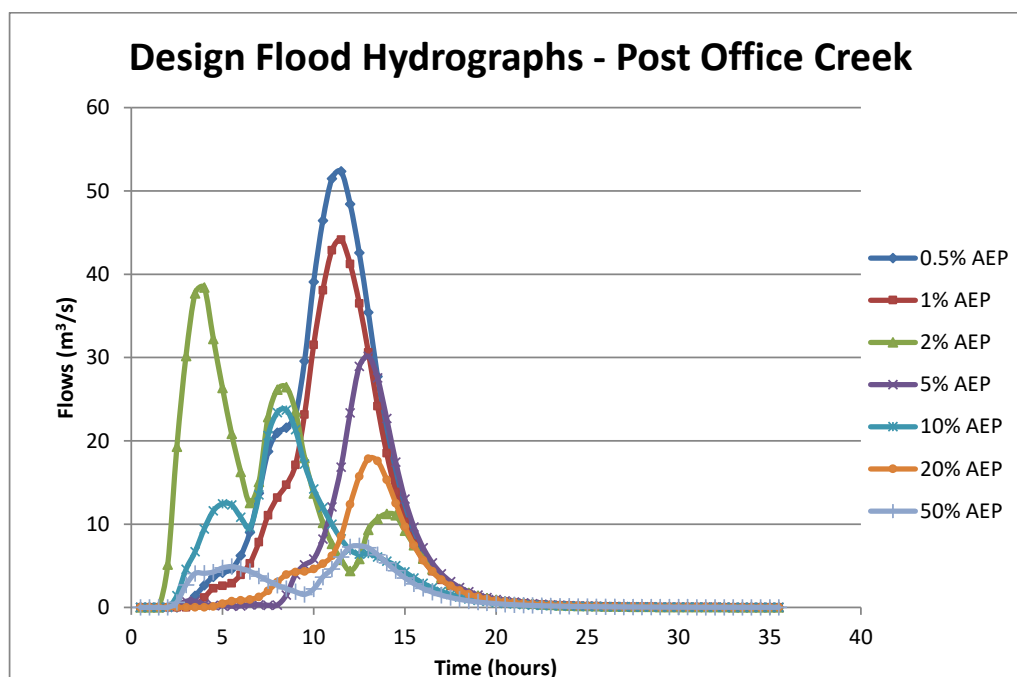


Figure 3-42 Design flood hydrographs for Post Office Creek

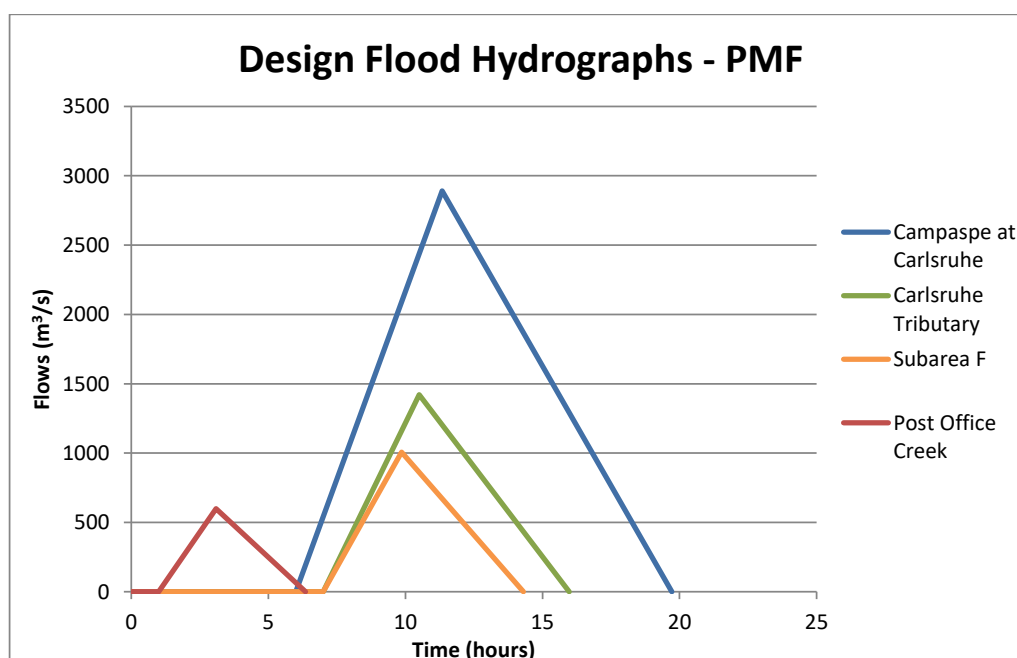


Figure 3-43 Probable Maximum Flood (PMF) hydrographs for all hydraulic model input locations

## KYNETON FLOOD STUDY

## 4 Hydraulic Modelling

### 4.1 Overview

A detailed combined 1D-2D hydraulic model of Kyneton Township was developed to produce flood mapping for the calibration and design flood events. The calibrated hydraulic model simulates flood flow behaviour of both the Campaspe River and Post Office Creek. The following sections detail the hydraulic model setup, calibration and generation of design flood mapping.

### 4.2 Hydraulic Model Construction and Parameters

#### 4.2.1 Model Overview

The hydraulic modelling software TUFLOW was used for this study. The model was run with the most recent TUFLOW build 2017-09-AB-iDP-w64.

TUFLOW is a floodplain modelling tool developed by BMT WBM which can model both 1D and 2D systems. The hydraulic modelling approach consisted of the following components:

- One dimensional (1D) hydraulic model of the culverts;
- Two dimensional (2D) hydraulic model of the waterways, broader floodplain and large multi-span bridges; and
- Links between the 1D and 2D hydraulic models to integrate the 1D hydraulic structures with the broader floodplain flow.

The major waterways, Campaspe River and Post Office Creek, were modelled in the 2D domain rather than as 1D elements due to the following advantages:

- Accounts for form, bend, contraction and expansion losses are explicitly.
- Velocity is calculated for each individual cell rather than averaged horizontally across the channel.

#### 4.2.2 Modelling Parameters

##### 4.2.2.1 Projection

The TUFLOW model was created in GDA94/MGA Zone 55.

##### 4.2.2.2 Extent

The hydraulic model extends along the Campaspe River from upstream of Cheveley Road to immediately upstream of the Calder Freeway bridge north of Kyneton as shown in Figure 4-1. Along Post Office Creek the model was limited by the extent of the available LiDAR for this area and therefore extend to immediately upstream of the Mollison Street. The model encompasses an area of approximately 12km<sup>2</sup>. This extent ensures that the flood behaviour within the study area is reliably represented without undue influence of boundary effects.

## KYNETON FLOOD STUDY

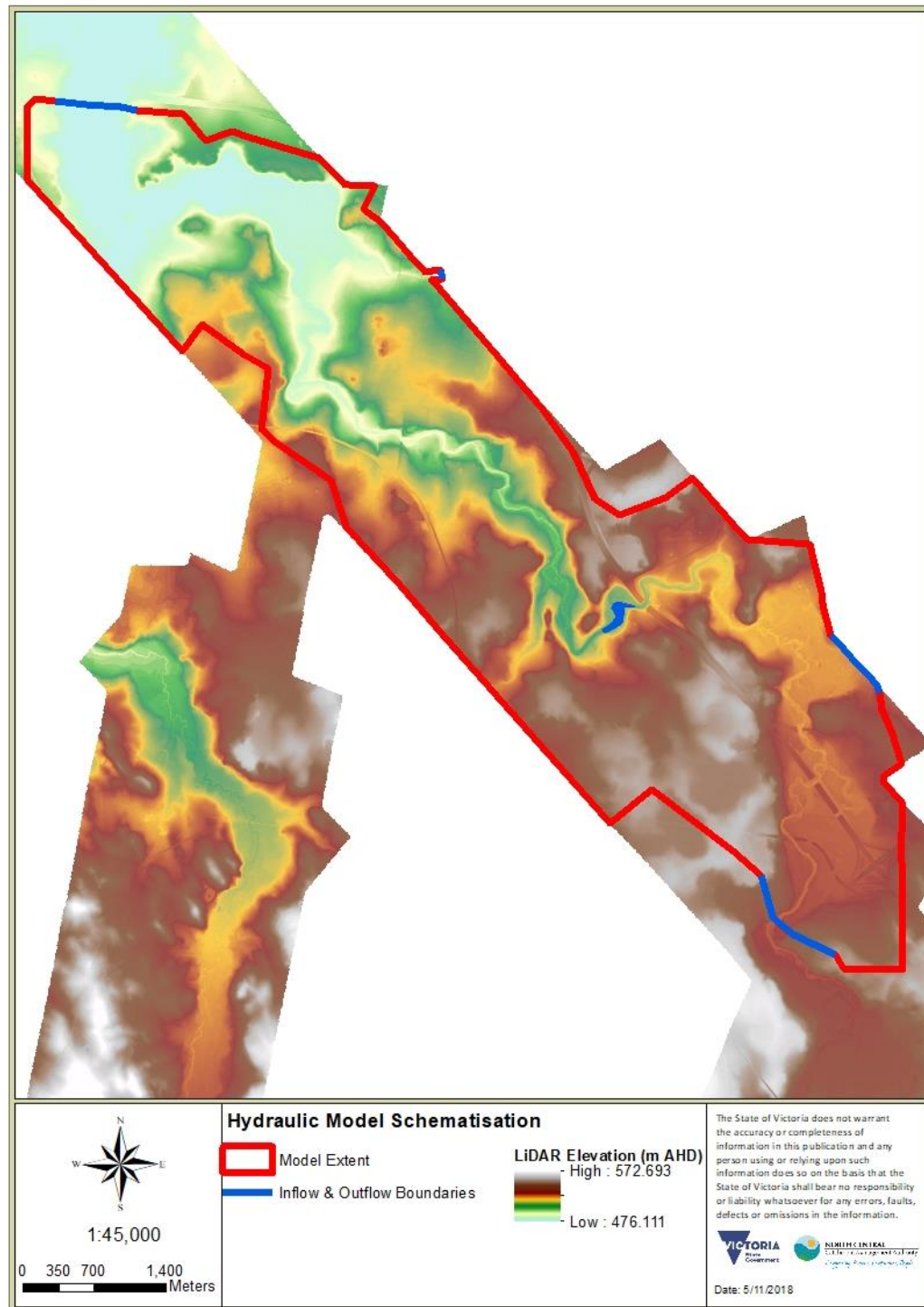


Figure 4-1 Hydraulic model schematisation



## KYNETON FLOOD STUDY

### 4.2.2.3 Topography

The floodplain topography for the model was generated from the MD\_Rivers\_ISC\_2010 LiDAR. This dataset was produced in 2010 and has a resolution of 1m (Figure 4-1). In order to accurately represent the study area while still allowing a reasonable run time, the 2D model domain was based on a 4m grid resolution.

The LiDAR data was collected during an extensive period of drought in the north central region. The method used to collect the data does not penetrate the surface of water and therefore the data generated does not represent the natural surface level of the bed of the waterway. However, the water level was low at the time the data was gathered and hence, provides a reasonable approximation of the topography of the waterway.

Additionally, the water that was in the waterway at the time the LiDAR was created, including the level of weir pools, is an approximate representation of the baseflow prior to a flood event. Consequently, no initial water level (IWL) was set for the model.

Minor modifications were made to the model DEM to ensure that it accurately represented the floodplain topography. This included adjusting areas of the LiDAR that were clearly obscured by vegetation, in addition to enforcing levels of the waterway thalweg, road crests and weirs using breaklines to ensure they were incorporated into the model.

Furthermore, the Mollison Street culverts were located near the boundary of the available LiDAR along Post Office Creek. It was important to model this hydraulic structure since it was likely to influence the downstream flood behaviour. Therefore, due to the limited extent of LiDAR upstream it was necessary to duplicate the LiDAR cross-section in order to extend the model DEM. This achieved a sufficient distance from the model inflow boundary to enable a smooth flow transition between the inflow boundary and the hydraulic structure. However, due to the localised uncertainty of this extended section of the DEM the outputs generated in this area were clipped out of the final datasets.

### 4.2.2.4 Timestep

The timestep selected is critically important for the stability and accuracy of the model. The Courant Number is a measure of the model stability and, for a 2D square grid, is defined as:

$$C_r = \frac{\Delta t \sqrt{2gH}}{\Delta x}$$

where,

- $\Delta t$  = timestep (s)
- $\Delta x$  = cell size (m)
- $g$  = acceleration due to gravity  $m/s^2$
- $H$  = depth of water (m)

For most real-world applications, the Courant Number generally needs to be less than 10 and is typically around 5 for a 2D scheme. In order to achieve this criterion, the computational timestep is typically set to between one half and one quarter of the cell size (TUFLOW Manual 2010, pp. 3-8 – 3-

## KYNETON FLOOD STUDY

9). For this model, a 4-metre cell size was chosen and the 2D timestep used was 1 second. The 1D timestep was set to half the 2D timestep as recommended in the TUFLOW Manual, that is 0.5 seconds.

### 4.2.2.5 Runtime

The model was run long enough for the input hydrograph to peak and for the peak to be conveyed through the model to the outlet. The entire hydrograph was not required to be completely run through the model as the primary cause of flooding for the study area is due to conveyance of the peak flow rather than due to the volume of floodwater conveyed. The typical runtime for the hydraulic model was 20 hours.

### 4.2.2.6 Hydraulic Roughness

Roughness was initially assigned to each cell as a Manning's  $n$  value based on the current zoning of the land. These values were further refined based on aerial photography, site inspections and knowledge of the area. For example, areas zoned for residential have been developed with significant portions of the residential land adjacent to the creek changed to reserve. Hence the reserve area of the residential zone has been altered to reflect the nature of the land use.

For calibration and validation modelling, the roughness values selected were based on the existing conditions at the time. However, for the design events, the roughness values adopted were based on the zoning, regardless of whether the land had been developed already or not. This is to account for the future development of the township. Furthermore, since the January 2011 flood event, significant willow removal was undertaken along the Campaspe River. Consequently, the waterway roughness has changed. A separate roughness layer was therefore prepared for the January 2011 model calibration (Figure 4-2) and the design events (Figure 4-3) to reflect the change in catchment roughness. The Manning's roughness coefficients adopted were based on standard industry values and are shown in Table 4-1 below.

## KYNETON FLOOD STUDY

Table 4-1 Roughness values

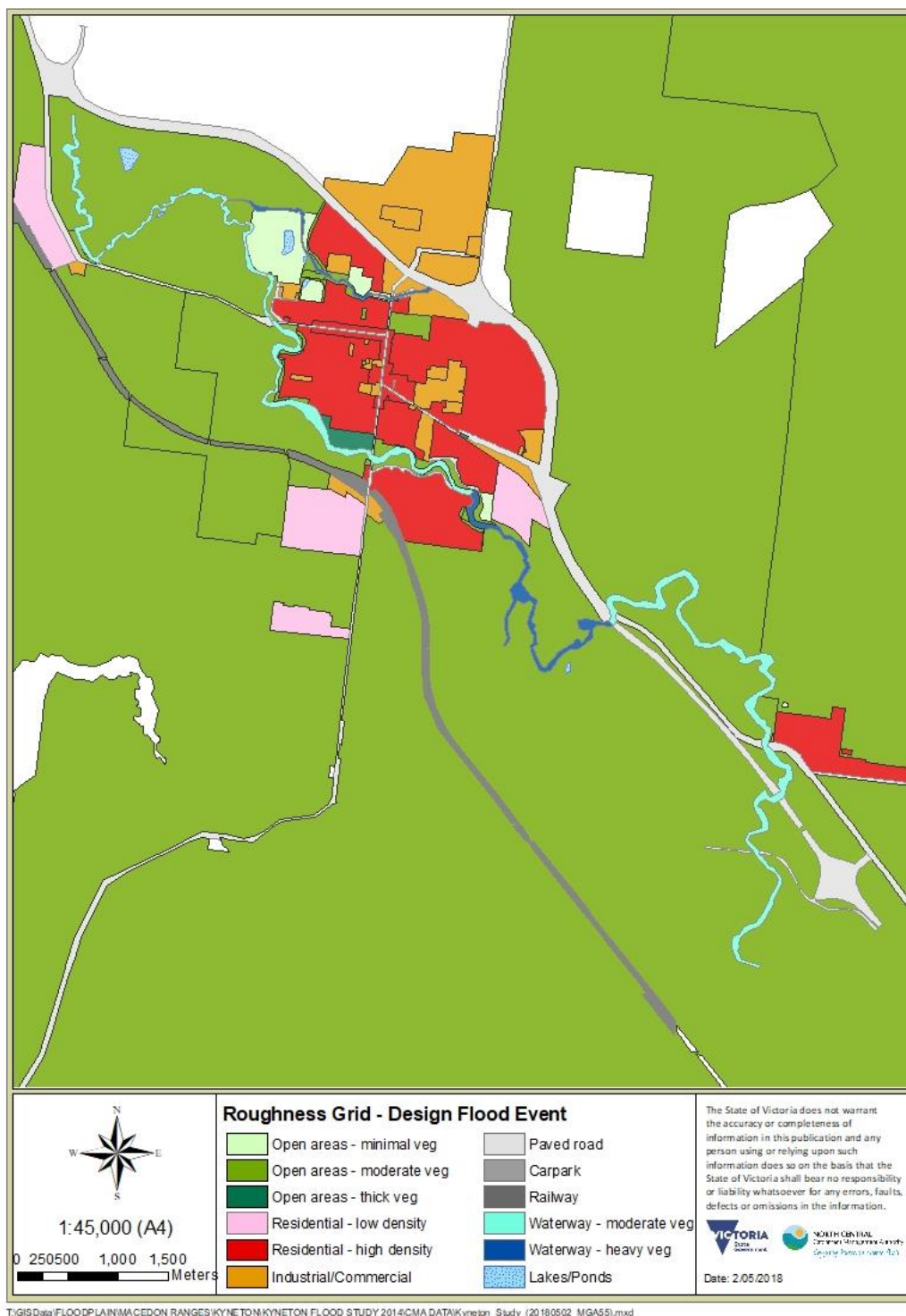
Model Material No.	Land Use	Manning's Roughness
1	Open pervious areas, minimal vegetation (grassed, pasture)	0.05
2	Open pervious areas, moderate vegetation (shrubs)	0.06
3	Open pervious areas, thick vegetation (trees)	0.1
4	Residential – low density	0.1
5	Residential – high density	0.2
6	Industrial/Commercial	0.3
7	Paved road	0.02
8	Unpaved road, tennis court	0.03
9	Carpark	0.025
10	Railway	0.04
11	Concrete lined channels	0.02
12	Waterway with minimal vegetation	0.04
13	Waterway with moderate vegetation	0.08
14	Waterway with heavy vegetation	0.1
15	Waterway with very dense vegetation	0.12
16	Lakes/Ponds (no emergent vegetation)	0.03
17	Wetlands (emergent vegetation)	0.05

**KYNETON FLOOD STUDY**



**Figure 4-2** Hydraulic model roughness grid (Manning's roughness) for January 2011 flood event

## KYNETON FLOOD STUDY



**Figure 4-3** Hydraulic model roughness grid (Manning's roughness) for design flood events

## KYNETON FLOOD STUDY

### 4.2.3 Boundary Conditions

Inflow boundaries were applied to represent flow from the Campaspe River, a tributary in Carlsruhe and Post Office Creek. An internal inflow boundary, termed Subarea F from the RORB model schematisation, was also included to incorporate local runoff from the township catchment. The corresponding historical and design hydrographs derived from the RORB model (see Section 3) were input at these boundaries. An automatically generated stage-discharge relationship, derived from the topography and an estimated water surface slope of 0.01, was applied at the outlet boundary. The outlet boundary was positioned sufficiently downstream of the township so that the estimated flow conditions at this location would have no impact on flood behaviour at the area of interest. The location of these boundaries is shown in Figure 4-1.

### 4.2.4 Structures

The model included a number of hydraulic structures that impact on flood behaviour. The height of weirs was determined from the LiDAR and incorporated into the model topography using breaklines. Culverts were input as 1D elements coupled to the 2D model domain; however, flow over the top of the culverts is simulated in the 2D model domain. Plans of these structures were received from the asset owners and invert levels were estimated based on site inspections and comparisons with the LiDAR data. Large bridges were modelled as 2D layered flow constrictions with the appropriate losses adopted from *Hydraulics of Bridge Waterways (1978)*.

The head loss across each of the bridges modelled in 2D was assessed to ensure the adopted loss factors were reasonable. The head losses for each bridge for both the 10% and 1% AEP design events are shown in Table 4-2 below.

**Table 4-2 Head loss across bridges**

Structure	Head Loss in 10% AEP Event (m)	Head Loss in 1% AEP Event (m)
S1 – Carlsruhe Central Road Bridge	0.20	0.25
S4 - Calder Highway South Bridges	0.25	0.35
S6 - Cobb and Co Road South Bridge	0.20	0.35
S7 - Cobb and Co Road North Bridge	0.30	0.50
S8 - Calder Highway North Bridges	0.20	0.30
S9 – Mollison Street Bridge	0.20	0.40
S13 - Piper Street Bridge	0.40	0.60

## KYNETON FLOOD STUDY

### 4.3 Hydraulic Model Calibration and Validation

#### 4.3.1 Overview

The hydraulic model was calibrated to the January 2011 flood event as this was the largest event which had sufficient evidence with which to calibrate the model. The September 2010 and September 2016 were then modelled to validate the model parameters determined through calibration. This also enabled a range of flows to be simulated to ensure the hydraulic model could reasonably reproduce both frequent and rare flood events. It should be noted that while the September 2016 event could not be used to calibrate the hydrologic model to the Campaspe River at Redesdale gauge due to uncertainties with the recorded gauge flow rates, this does not impact on the applicability of this event for validating the hydraulic model. Additionally, although there were some photos available of the November 2010 event, these were taken well after the flood peak had passed and therefore were of limited value in validating the model. A summary of the historical flood events is displayed in Table 4-3 and the input hydrographs for the September 2010, January 2011 and September 2016 events are shown in Figure 4-5, Figure 4-16 and Figure 4-23 respectively.

**Table 4-3 Summary details for the historical events selected for calibration and validation**

Event	Campaspe River at Redesdale Gauge		Campaspe River at Kyneton		Post Office Creek Inflow	
	Peak Flow (m <sup>3</sup> /s)	AEP (%)	Peak Flow (m <sup>3</sup> /s)	AEP (%)	Peak Flow (m <sup>3</sup> /s)	AEP (%)
September 2010	259.6	7%	123.2	20%	13.3	50%-20%
January 2011	322.1	5%	129.1	20%-10%	25.9	10%-5%
September 2016	347.9*	3%*	89.4	50%-20%	13.2	50%-20%

\*Note that there is uncertainty regarding the reliability of the peak flow rate recorded at the Campaspe River at Redesdale gauge during the September 2016. Refer to Section 2.2 for further detail.

Calibration and validation was based on photographs and anecdotal observations gathered from the community. A site inspection along the Campaspe River through Kyneton was also conducted with a local community member who provided valuable information regarding the flood behaviour during recent flood events. Recorded flood marks within the study area were very limited with only one surveyed flood mark on Post Office Creek available. Figure 4-4 displays the location of the flood observations for each of the events. The following sections describe the hydraulic calibration and validation for each event by comparing the modelled results to the historical observations.



## KYNETON FLOOD STUDY

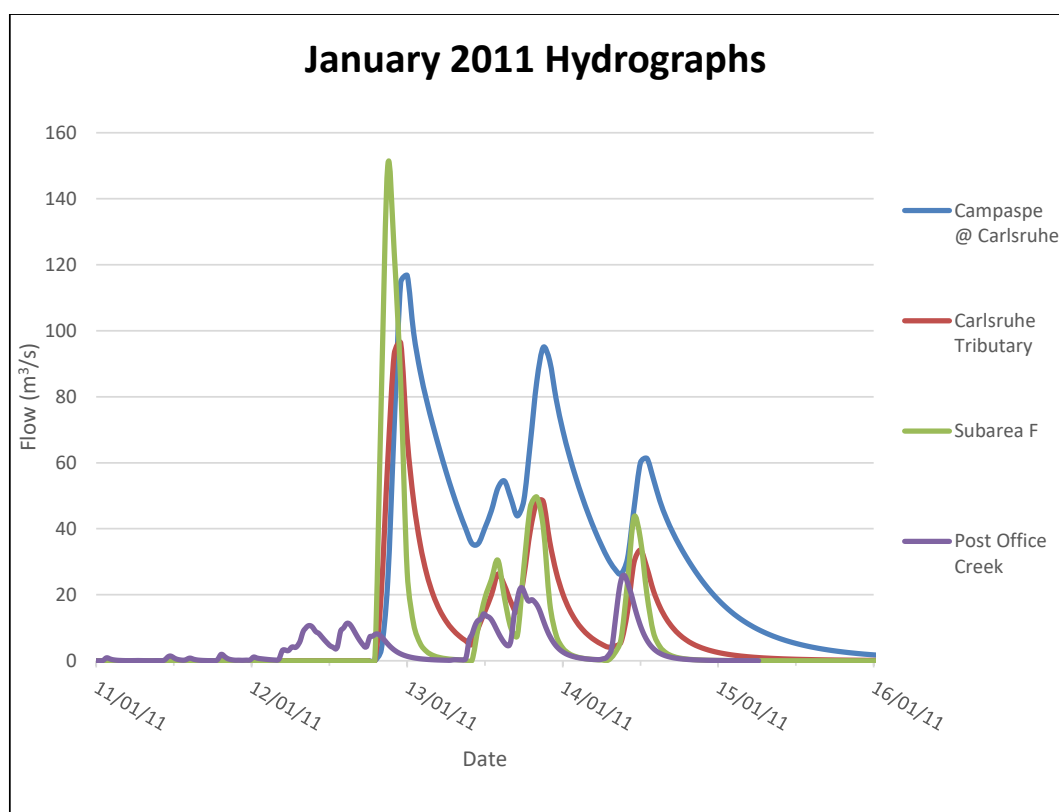


Figure 4-4 Location of historical flood observations

## KYNETON FLOOD STUDY

### 4.3.2 January 2011 Calibration

The RORB hydrologic model was used to generate hydrographs for the January 2011 flood event which are shown in Figure 4-5. The hydrographs were then input into the TUFLOW hydraulic model at the corresponding inflow boundaries. The mapping outputs were compared to the historical observations to calibrate the hydraulic model. The location of the available calibration data is shown in Figure 4-4. The calibration at each of these locations is detailed below.



**Figure 4-5 Inflow hydrographs for the January 2011 flood event**

1. Floodwater was observed up against but not overtopping the dam bank at the rear of Sacred Heart College. The location of the floodwater in relation to this dam is shown in Figure 4-6 below. As seen in Figure 4-7 the hydraulic model of the January 2011 event accurately replicates this.

## KYNETON FLOOD STUDY



**Figure 4-6** Extent of flooding at the rear of Sacred Heart College looking south-east during the January 2011 flood event

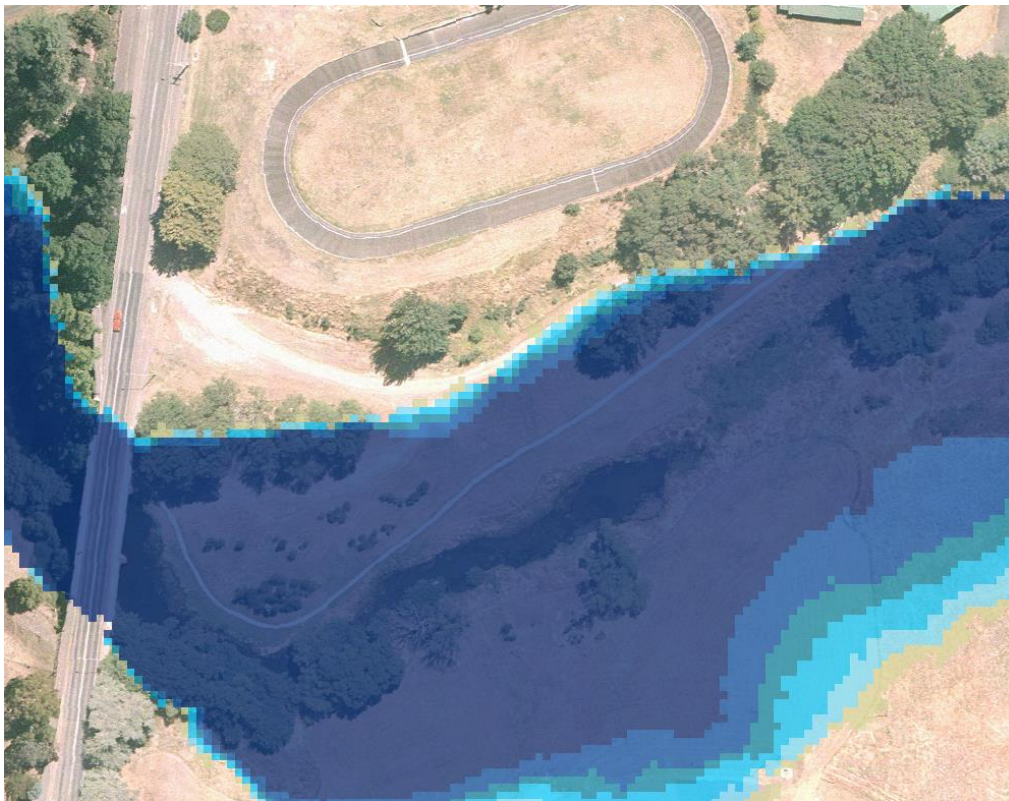


**Figure 4-7** Modelled flood extent of the January 2011 event at the rear of Sacred Heart College. Approximate direction of photo in Figure 4.4 indicated by yellow arrow



## KYNETON FLOOD STUDY

2. Immediately upstream of the Mollison Street Bridge the walking path along the northern bank was completely inundated and the floodwater extended almost to the line of trees adjacent to the gravel road, as shown in Figure 4-8 below.

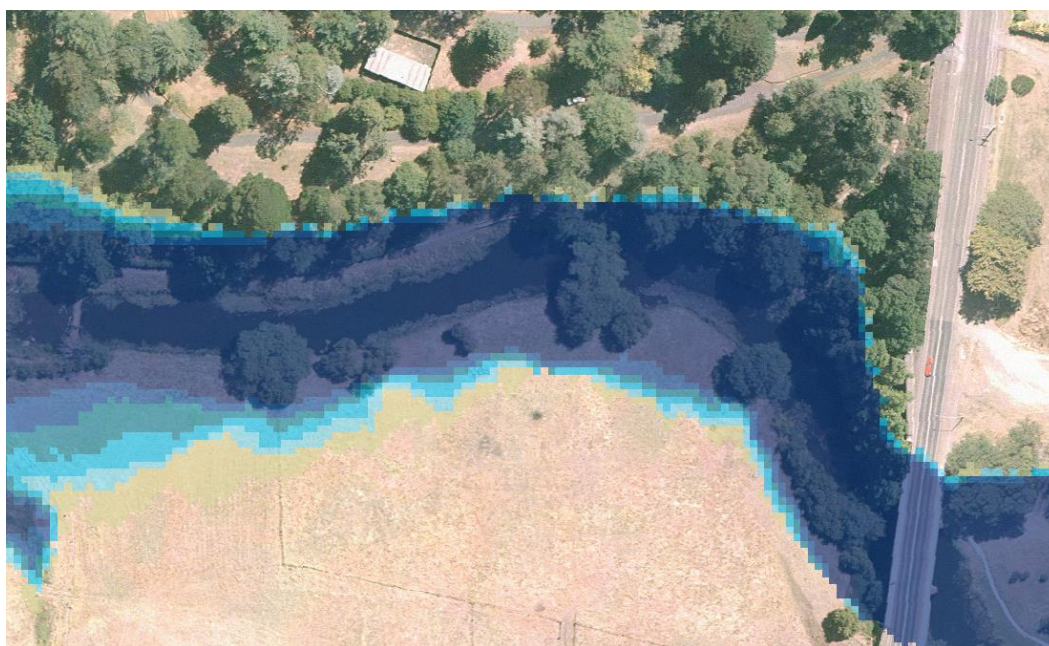


**Figure 4-8**      **Modelled flood extent of the January 2011 event upstream of Mollison Street Bridge**

3. The flood level was observed at a height just below the base of the northern bridge abutment of Mollison Street Bridge, which is reproduced by the model (Figure 4-8). A comparison of the modelled flood level to the LiDAR level adjacent to the bridge abutment indicates that the flood height is approximately 200mm below the abutment.

## KYNETON FLOOD STUDY

4. The original boardwalk along the northern river bank in the Kyneton Botanic Gardens was completely inundated during the 2011 event however the floodwater did not reach the level of the road that runs through the Kyneton Botanic Gardens. As a result, the boardwalk has since been replaced by a gravel walking track located higher up on the river bank. The aerial photography shown in Figure 4-9 was taken prior to the 2011 flood event and therefore shows the original boardwalk that was flooded.



**Figure 4-9**      **Modelled flood extent of the January 2011 event at the Kyneton Botanic Gardens**

## KYNETON FLOOD STUDY

5. Although the low-lying area at the Greenway Lane weir was completely inundated, floodwater reportedly did not overtop Mill Street. Figure 4-10 below shows only minor flooding over Mill Street, generally less than 50mm in depth. An analysis of the flood levels and road surface levels indicated that they are approximately the same height. The slightly deeper areas shown along the road is where water has pooled in the adjacent table drains. Given the depth is only approximately 50mm and covers a small portion of Mill Street, the model is considered to achieve reasonable calibration in this area.



Figure 4-10 Modelled flood extent of the January 2011 event along Mill Street



## KYNETON FLOOD STUDY

6. Properties north of St Agnes Place experienced flooding through the rear of the properties, however there were no reported cases of above floor flooding of the dwellings. Figure 4-11 illustrates that the model reasonably replicates this observed behaviour with only one dwelling potentially having shallow floodwater up against it.

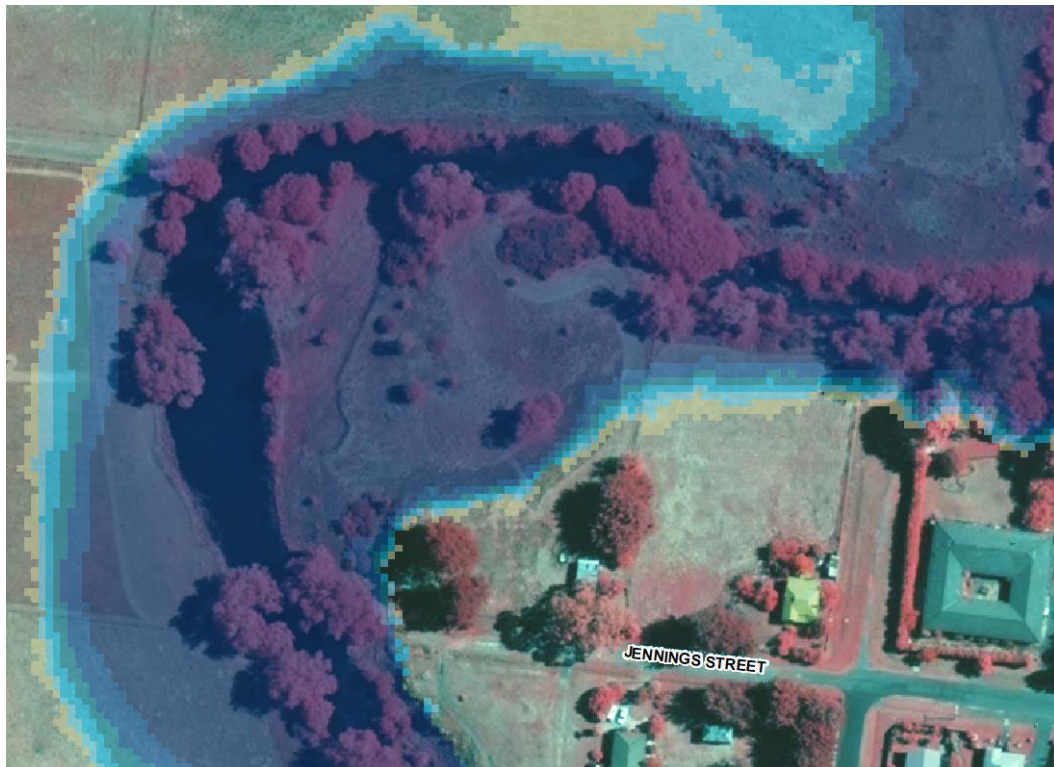


Figure 4-11 Modelled flood extent of the January 2011 event along rear of properties north of St Agnes Place



## KYNETON FLOOD STUDY

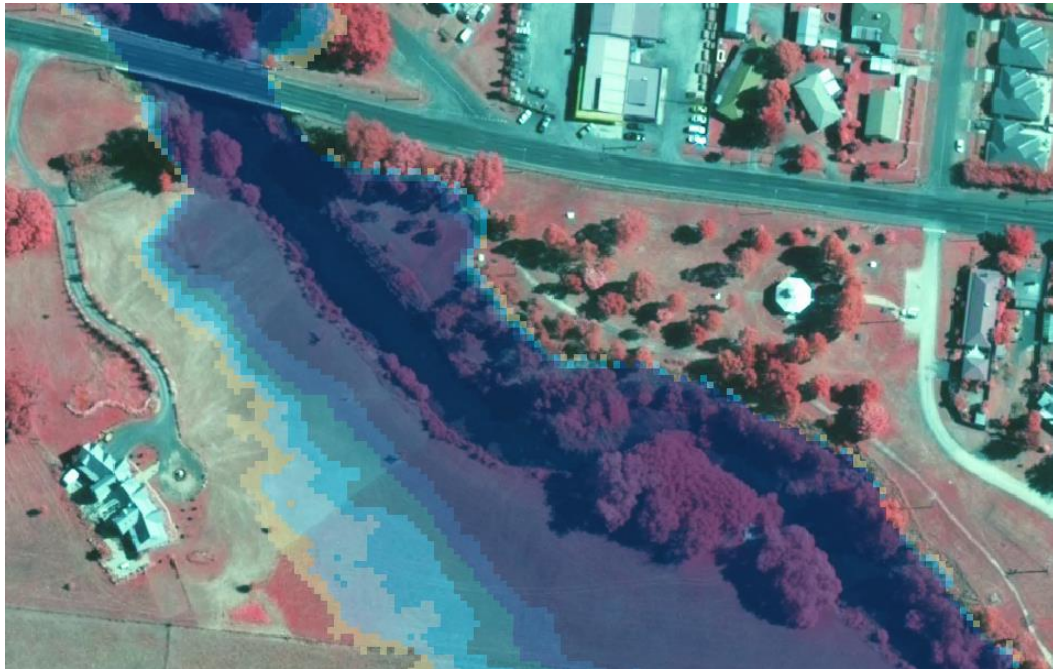
7. Most of the rear of the properties at the end of Jennings Street was inundated to significant depths as reflected in Figure 4-12. The model indicates depths of approximately 2m over these properties.



**Figure 4-12**      Modelled flood extent of the January 2011 event along rear of Jennings Street properties

## KYNETON FLOOD STUDY

8. The Quarry Reserve Park immediately upstream of the Piper Street Bridge, located on the eastern bank, was not flooded. Furthermore, the flood extent did not reach the walking path along the eastern bank. Figure 4-13 shows that the modelled flood extent in this area is in accordance with the observed behaviour.



**Figure 4-13**      **Modelled flood extent of the January 2011 event upstream of Piper Street Bridge**

## KYNETON FLOOD STUDY

9. The horse racing stables along Campaspe Place experienced significant flooding and the horse pool was completely inundated. However, no dwellings were inundated in this area. The model replicates these observations as shown in Figure 4-14. It was also reported that the flood extent almost reached the weigh bridge site at 106-110 Beauchamp Street (located in the north-eastern corner of Figure 4-14). It is unclear how close the floodwater was to the weigh bridge itself and whether this was water backing up from the Campaspe River or stormwater flowing toward the river. Based on the modelled data the flood extent was within approximately 30m of the weigh bridge.

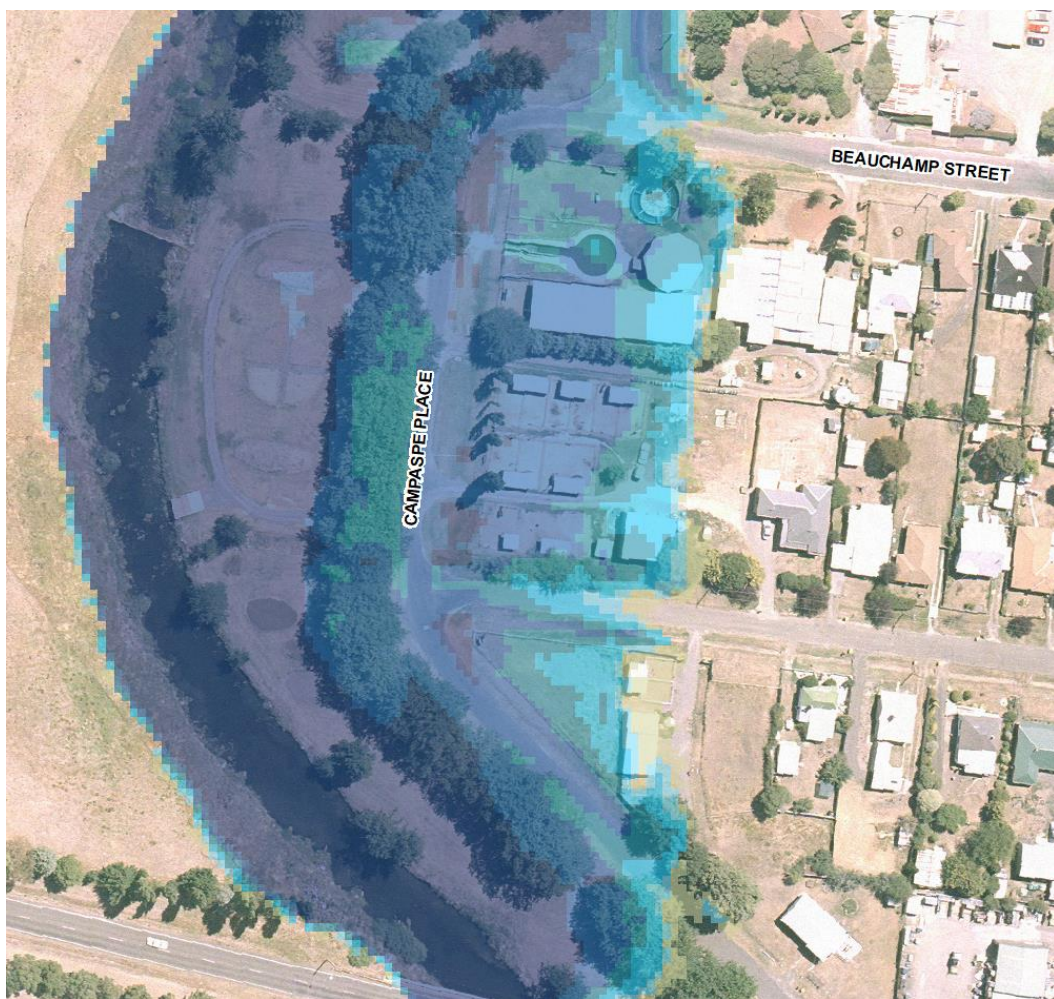


Figure 4-14 Modelled flood extent of the January 2011 event along Campaspe Place



## KYNETON FLOOD STUDY

10. A single flood mark on Post Office Creek was available to calibrate the January 2011 event as shown in Figure 4-15. The flood mark, located immediately upstream of Ebdon Street, was surveyed with an accuracy of 30mm. A comparison to the modelled data shows that the results are approximately 800mm higher than the recorded 2011 flood mark.

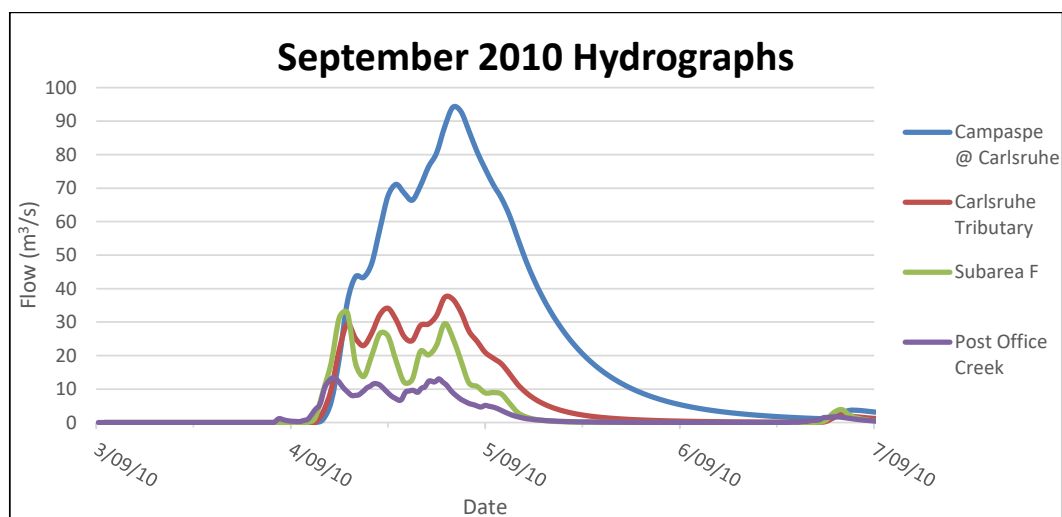


**Figure 4-15** Modelled flood extent of the January 2011 event on Post Office Creek. Location of surveyed flood mark is shown as a yellow dot

## KYNETON FLOOD STUDY

**4.3.3 September 2010 Validation**

The hydrographs input into the hydraulic model for the September 2010 event are shown in Figure 4-16. The mapping outputs were compared to the historical observations to validate the hydraulic model parameters as described below. The location of the available validation data is shown in Figure 4-4.



**Figure 4-16** Inflow hydrographs for the September 2010 flood event



**Figure 4-17** Modelled flood extent of the September 2010 event at Wedge Street. Approximate direction of the following photos is indicated by yellow arrows.

## KYNETON FLOOD STUDY

1. Further upstream of the Wedge Street crossing of Post Office Creek floodwater generally did not overtop the waterway banks during the September 2010 event as shown in Figure 4-18. Figure 4-17 shows that the model reproduced this behaviour, with water contained within the defined creek channel.



**Figure 4-18** September 2010 event looking south-east on Post Office Creek upstream of Wedge Street (refer to Photo 1 in Figure 4-17)

## KYNETON FLOOD STUDY

2. Figure 4-19 was taken immediately upstream of the Wedge Street bridge looking downstream along Post Office Creek. It can be seen that the water level appears to reach the bridge soffit but does not overtop the bridge which is replicated by the hydraulic model. A comparison to Figure 4-17 shows that the modelled flood extends further south than what is shown in Figure 4-19. This difference could be because the photo was not taken at the flood peak or possibly due to an upstream blockage restricting the flow rate downstream.



**Figure 4-19** September 2010 event looking downstream along Post Office Creek towards Wedge Street bridge (refer to Photo 2 in Figure 4-17)



## KYNETON FLOOD STUDY

3. The extent of flooding over the northern bank of Post Office Creek immediately downstream of Wedge Street can be seen in Figure 4-20. The modelled flood extent correlates reasonably well with the floodwater also extending just beyond the tree line (Figure 4-17).



**Figure 4-20** September 2010 event looking downstream of Wedge Street bridge along the northern bank of Post Office Creek (refer to Photo 3 in Figure 4-17)

## KYNETON FLOOD STUDY

4. The hydraulic model reproduces the extensive flooding that occurred over the southern bank of Post Office Creek downstream of Wedge Street as shown through a comparison of Figure 4-17 and Figure 4-21. In particular, the modelled flood just extends to the furthest of the two power poles as shown in Figure 4-21.



**Figure 4-21** September 2010 event looking downstream of Wedge Street bridge along the southern bank of Post Office Creek (refer to Photo 4 in Figure 4-17)

5. The photo in Figure 4-22 was taken from Burton Avenue looking north toward the Campaspe River. It should be noted that this photo would most likely not have captured the peak flood extent which is estimated to have occurred during the night. Consequently, the photo shows some areas that are clearly above the floodwaters whereas the model displays the entire area as completely inundated. Nevertheless, it can be clearly seen in the photo that floodwater did extend up to the road and also that water extended up to the base of a row of four trees (shown on the far right of the photo) which has been reproduced by the model. Hence, given the uncertainty in the observation, this calibration is considered reasonable.

## KYNETON FLOOD STUDY

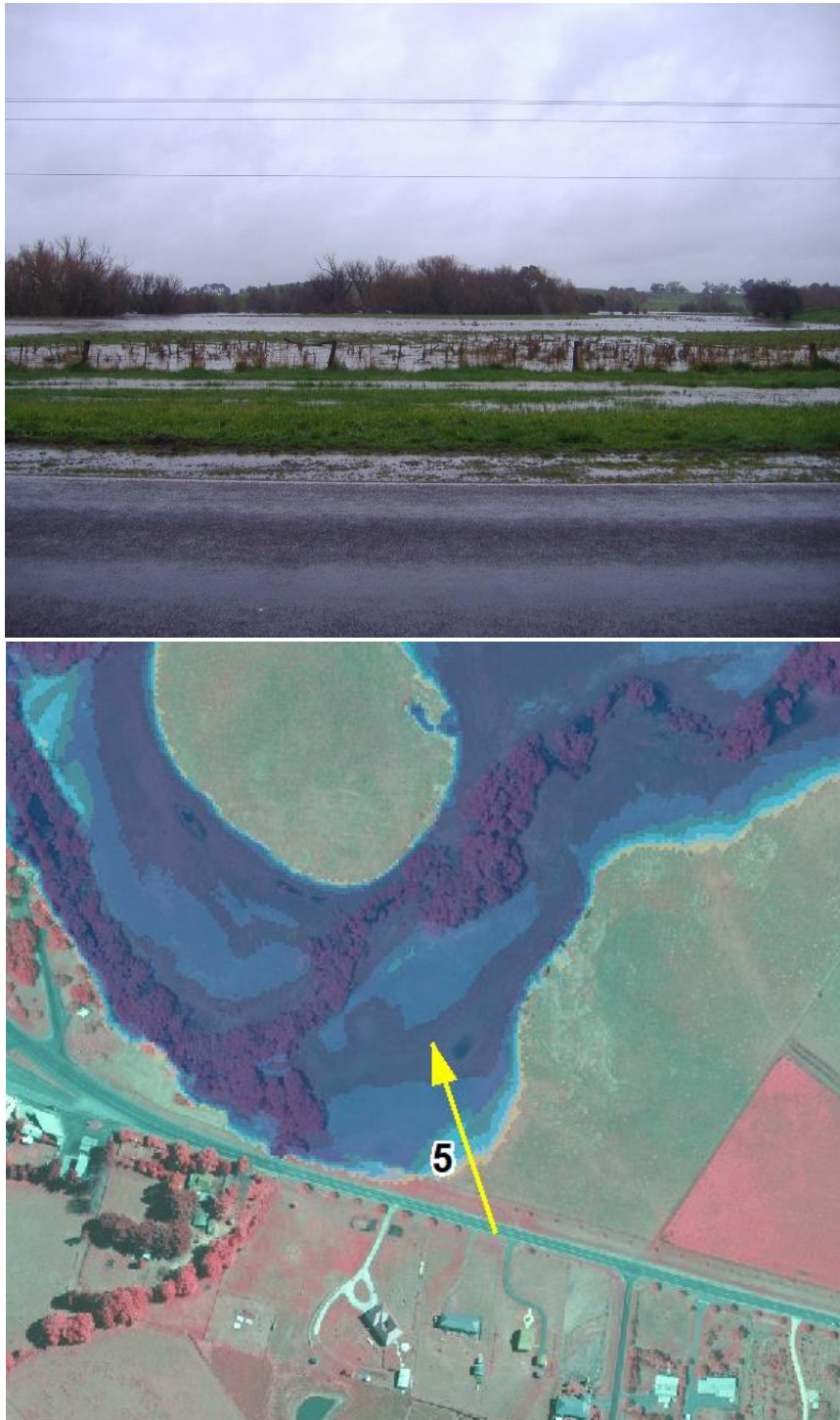


Figure 4-22 Campaspe River flood extent along Burton Avenue during the September 2010 event

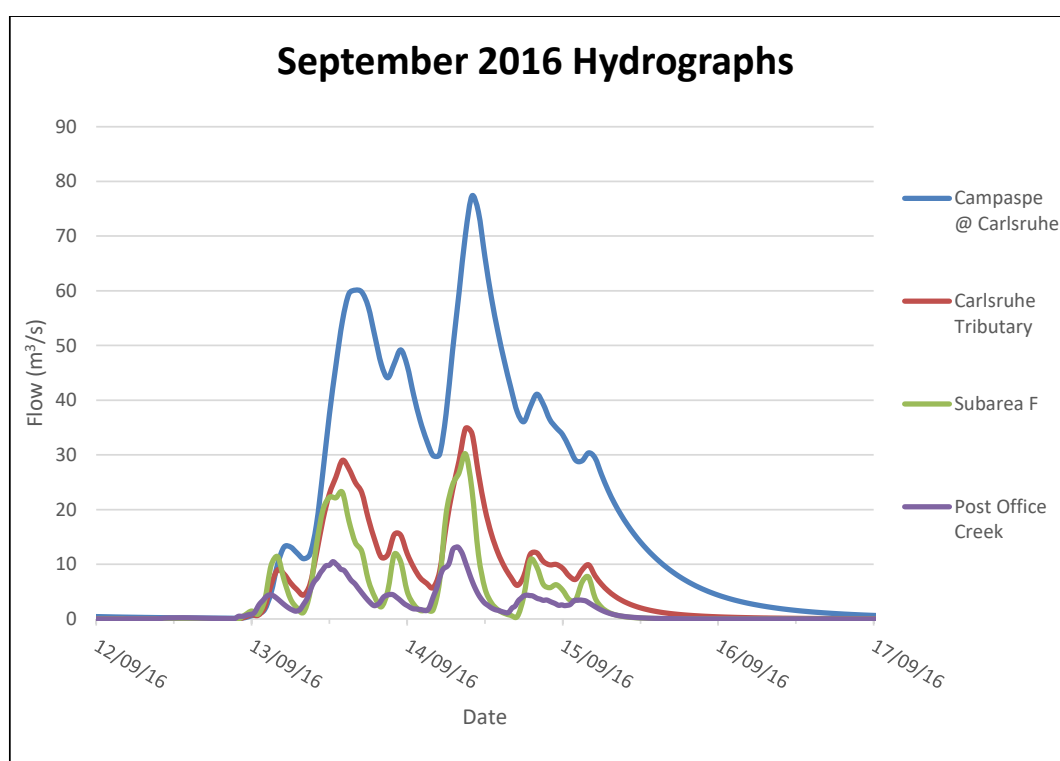


## KYNETON FLOOD STUDY

**4.3.4 September 2016 Validation**

The hydrographs input into the hydraulic model for the September 2016 event are shown in Figure 4-23. The mapping outputs were compared to the historical observations to validate the hydraulic model parameters as described below. The location of the available validation data is shown in Figure 4-4.

It should be noted that the hydraulic model for the September 2016 event incorporates the recent willow removal works along sections of the Campaspe River by reducing the Manning's roughness value. Accordingly, the design hydraulic roughness grid (shown in Figure 4-3) was applicable for this event.



**Figure 4-23 Inflow hydrographs for the September 2016 flood event**

- Figure 4-24 below shows a photo taken during the September 2016 flood event from Rennick Drive looking upstream along the Campaspe River. It should be noted that a subdivision has recently occurred on this site which is not shown on the older aerial photography. The subdivision itself has been developed outside the flood extent however the associated detention basin can be seen in the far right of the photo. Therefore, although minor alterations have since occurred in this area, the modelled flood extent still reasonably reflects the extent shown in the photo.

## KYNETON FLOOD STUDY

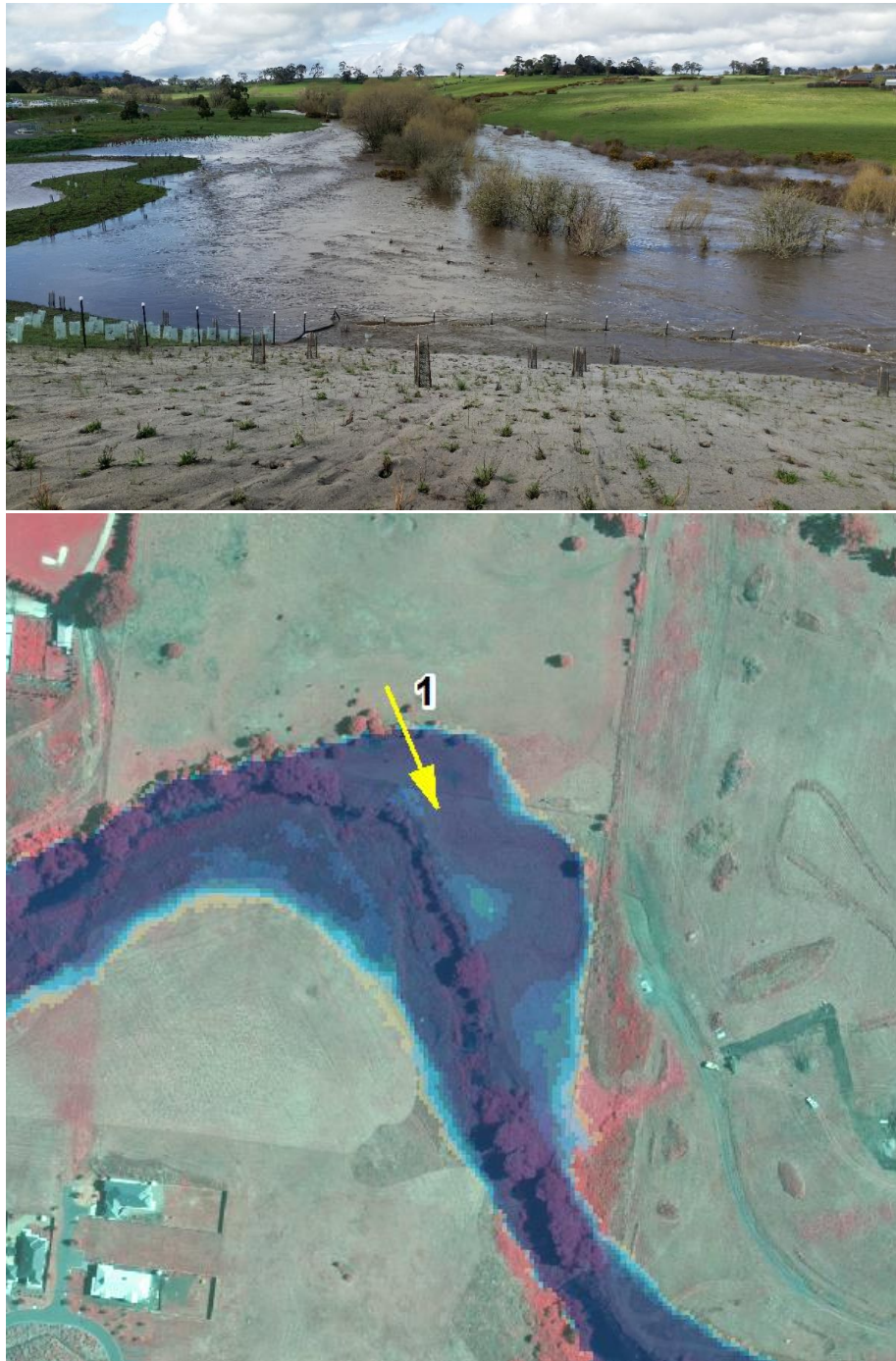


Figure 4-24 Comparison of modelled flood extent to photo taken during the September 2016 event looking upstream on the Campaspe River from Rennick Drive

## KYNETON FLOOD STUDY

2. The photo in Figure 4-25 was taken on the walking path adjacent to the Campaspe River, located near the north western corner of the Kyneton Botanic Gardens. The modelled data shows water abutting and overtopping this path in this area. This is in accordance with the photo which, although not taken at the height of the flood, clearly shows low areas of the path became completely inundated.

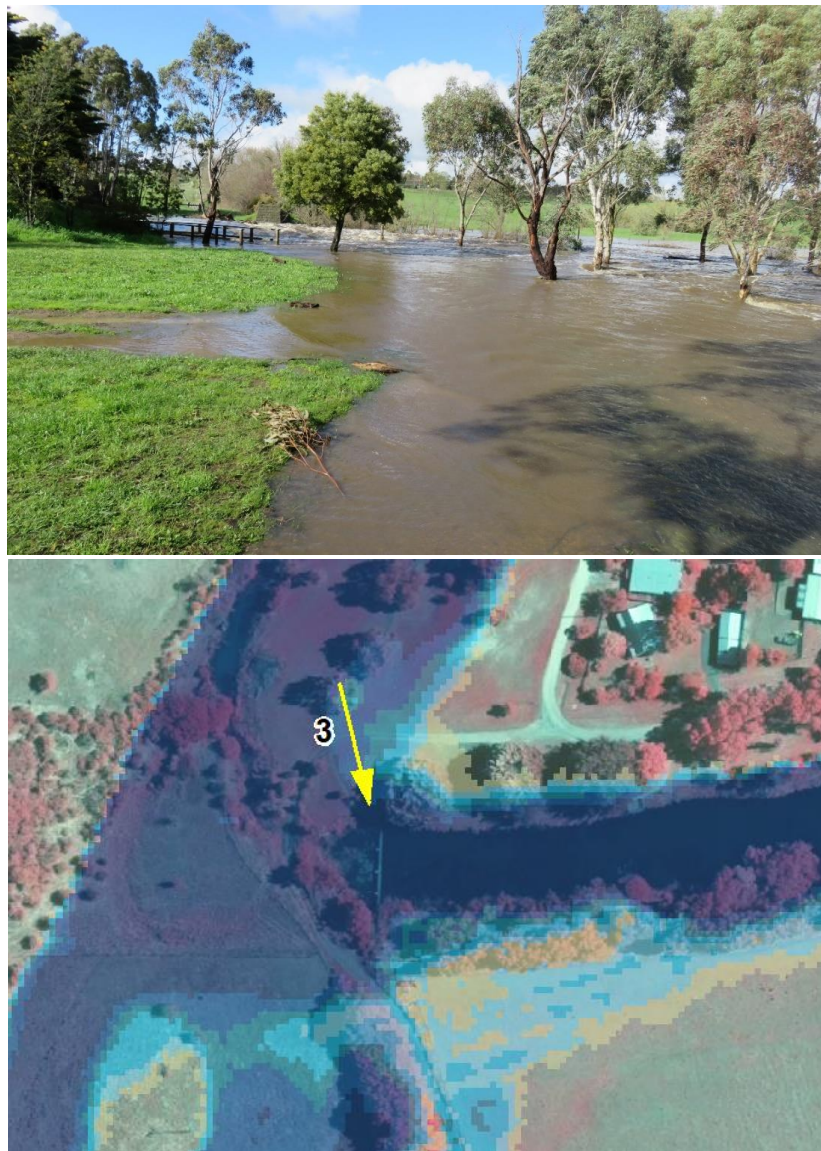


**Figure 4-25** Comparison of modelled flood extent to photo taken during the September 2016 event looking downstream on the Campaspe River from the Kyneton Botanic Gardens



## KYNETON FLOOD STUDY

3. Figure 4-26 compares the modelled data at the Greenway Lane Weir to a photo taken during the September 2016 event. This photo was taken approximately 5 hours prior to the flood peak and hence the peak flood level and extent would have been considerably greater than what is shown in the photo. However, it can be seen that even prior to the peak, floodwater had begun to inundate the adjacent low lying land which is reflected by the modelling. Additionally, observations at this site also indicated that this weir, which is over 1.5 metres high, became completely submerged during this flood resulting in a constant water surface slope across the weir. This flood behaviour was also replicated by the hydraulic model.



**Figure 4-26** Comparison of modelled flood extent to photo taken during the September 2016 event of the Campaspe River at the Greenway Lane Weir



## KYNETON FLOOD STUDY



**Figure 4-27** Modelled flood extent of the September 2016 event at Wedge Street. Approximate direction of the following photos is indicated by yellow arrows.

4. Floodwater was generally contained within the defined Post Office Creek channel upstream of Wedge Street. Figure 4-28 was taken looking upstream along Post Office Creek toward the end of Powlett Street. Figure 4-27 shows the modelled data in relation to the direction of this photo, indicating that the model reflects this flood behaviour.



**Figure 4-28** September 2016 event looking south-east on Post Office Creek upstream of Wedge Street (refer to Photo 4 in Figure 4-27)

## KYNETON FLOOD STUDY

5. Figure 4-29 was taken on Wedge Street looking upstream along Post Office Creek toward the northern bank. The modelled flood extent shown in Figure 4-27 is in accordance with this observation, with floodwater inundating the adjacent garden area but not extending up to the existing dwelling.



**Figure 4-29** September 2016 event looking toward northern bank of Post Office Creek immediately upstream of Wedge Street (refer to Photo 5 in Figure 4-27)



## KYNETON FLOOD STUDY

6. Figure 4-30 shows the extent of flooding over the southern bank of Post Office Creek immediately downstream of Wedge Street. The photo was taken the day before the peak however the flow rate is estimated to be close to the peak flow for this event. A comparison to Figure 4-27 shows that the observed flood extent is only slightly less than the extent modelled for the estimated peak flow as expected.



**Figure 4-30** September 2016 event looking downstream of Wedge Street bridge along the southern bank of Post Office Creek (refer to Photo 6 in Figure 4-27)

#### 4.3.5 Summary

The model results for the calibration (January 2011) and validation (September 2010 and September 2016) flood events replicate the observed flood behaviour along the Campaspe River and Post Office Creek reasonably accurately based on photographs and anecdotal observations. However, the January 2011 model results do not correlate to the surveyed flood mark on Post Office Creek. Reasons for this poor calibration may include:

- The flood mark is located near the Post Office Creek inflow boundary and model results within this proximity are inherently uncertain. Ideally the model inflow boundary would be located a sufficient distance from areas of interest to avoid boundary condition influences. However, due to a lack of available LiDAR data, the hydraulic model cannot be extended upstream any further.
- The available LiDAR is significantly obscured in some areas by the heavy vegetation within Post Office Creek. Although slight modifications have been made to ensure the model represents the topography it is possible that the LiDAR does not accurately represent the channel form in some areas.

## KYNETON FLOOD STUDY

- There is uncertainty regarding potential blockages of structures during the event. The waterway is heavily vegetated and crossed by several hydraulic structures that are susceptible to blockage. Blockages have the potential to significantly impact on upstream and downstream flood levels and flows. It is possible that one of the structures upstream of the flood mark was significantly blocked during the January 2011 flood event, resulting in reduced flows downstream and lower flood levels at the site.
- Only a single flood mark is available for calibration and hence it cannot be validated. Validation of flood marks is important as there may be some uncertainty around the accuracy of the flood mark, particularly if it is based on debris marks. For example, a debris mark may be higher than the actual flood level due to wave action, or underestimate the flood level due to larger debris only being deposited as floodwaters subside. In this case, there are no details available regarding what this flood mark was based on.
- Due to the relatively small catchment size and significant proportion of impervious areas associated with urban land uses, runoff flows for Post Office Creek are correlated closely with rainfall temporal patterns. As the nearest pluviograph stations are approximately 12 kilometres away there exists some uncertainty relating to the applicability of these temporal patterns to the catchment. For example, the temporal pattern from pluviograph station 406266 was initially applied for the January 2011 calibration as it was the closest station. However, due to a short-duration high-intensity rainfall burst, this temporal pattern produced a significant peak flow, exceeding the 0.5% AEP design event, which was not experienced based on the available evidence. Therefore, the temporal pattern was derived instead from pluviograph station 406250 which was located at a similar distance from the catchment. This produced more realistic flows, one third of the size of the previous peak flow. Hence, the RORB model for Post Office Creek appears to be particularly sensitive to rainfall temporal patterns and there is uncertainty as to whether the nearby pluviograph stations provide representative patterns.

Methods to improve the calibration on Post Office Creek are discussed further in Section 0. Overall, the hydraulic model reproduces the observed flood behaviour during the three historical events reasonably well. Therefore, the hydraulic model is considered to be appropriate for use in generating design flood events.

**KYNETON FLOOD STUDY****4.4 Sensitivity Analysis**

The hydraulic model sensitivity was tested by varying the Manning's roughness values, the downstream outflow boundary condition, the model inflows and the hydrograph volumes to determine the influence of these parameters on the model results. The sensitivity analysis was undertaken based on the 1% AEP design results. These various scenarios are detailed in the following sections.

**4.4.1 Roughness Sensitivity**

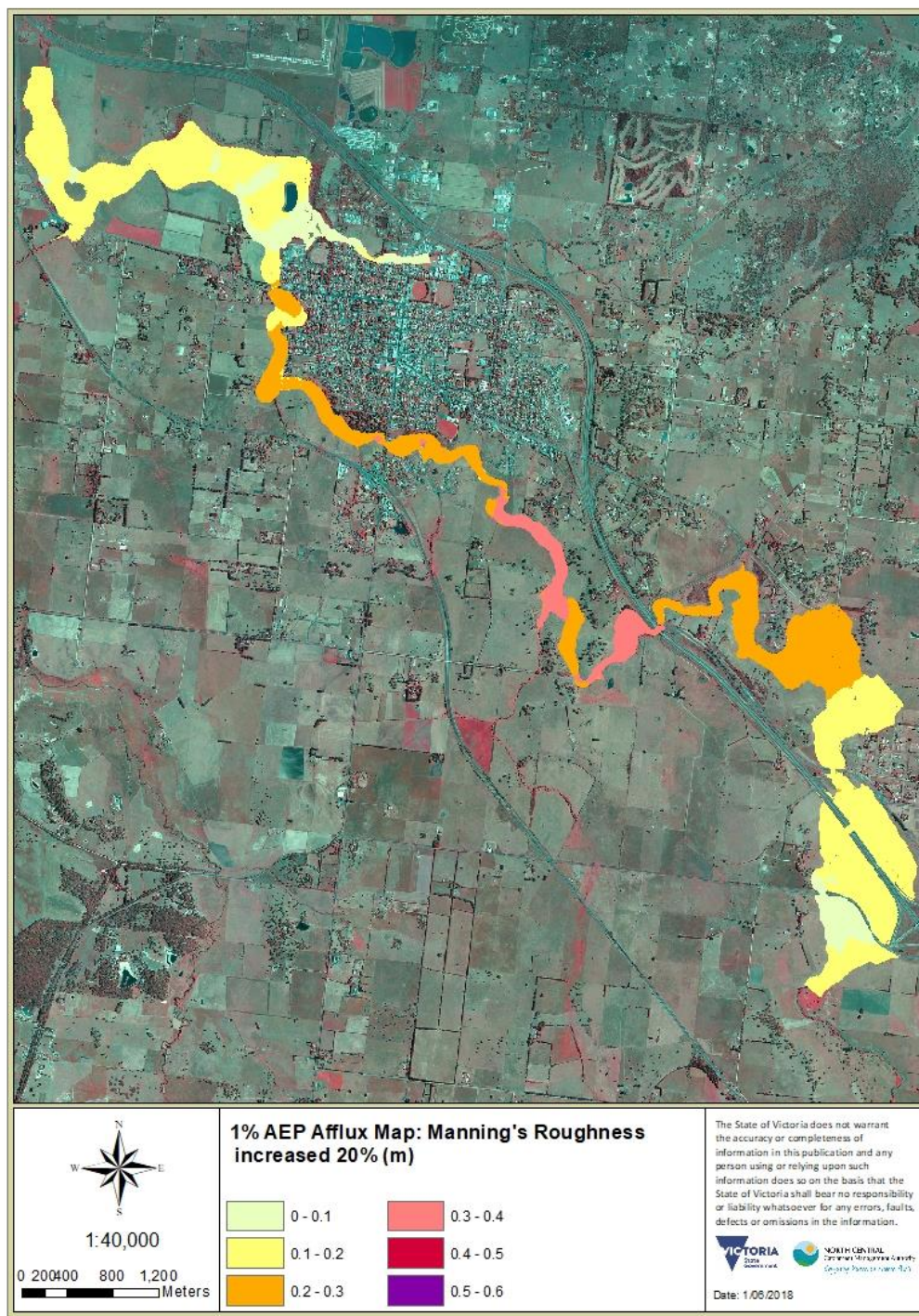
The model sensitivity to the Manning's roughness values was analysed by varying these values by 20% and comparing the results to the base case scenario. The Manning's roughness values adopted for the base case scenario are detailed in Section 4.2.2.6. With the roughness increased by 20% the flood levels were increased by an average of 0.18m. The maximum localised increase in flood height was 0.58m. Due to the steep slopes of the catchment the flood extent for both the Campaspe River and Post Office Creek was only slightly increased. Figure 4-31 below shows the afflux caused by increasing the Manning's roughness by 20%.

Similarly, with the Manning's values reduced by 20%, the flood levels were decreased by an average of 0.19m. Again, the difference in extent was very minor as shown in Figure 4-32. The maximum decrease in flood height was 1.0m, the location of which is shown in the red insert in Figure 4-32. The significant difference at this site is due to the topography of the floodplain. In the sensitivity scenario, the floodwater only briefly overtops a bank to fill this depression but does not maintain this height long enough to equalise the flood level adjacent to the depression.

Overall, a comparison of Figure 4-31 and Figure 4-32 indicate that there is minimal change in flood level based on the roughness selected for Post Office Creek and the wider sections of the Campaspe floodplain. However, the confined reaches of the Campaspe River through Kyneton do appear to be sensitive to the Manning's roughness value applied.



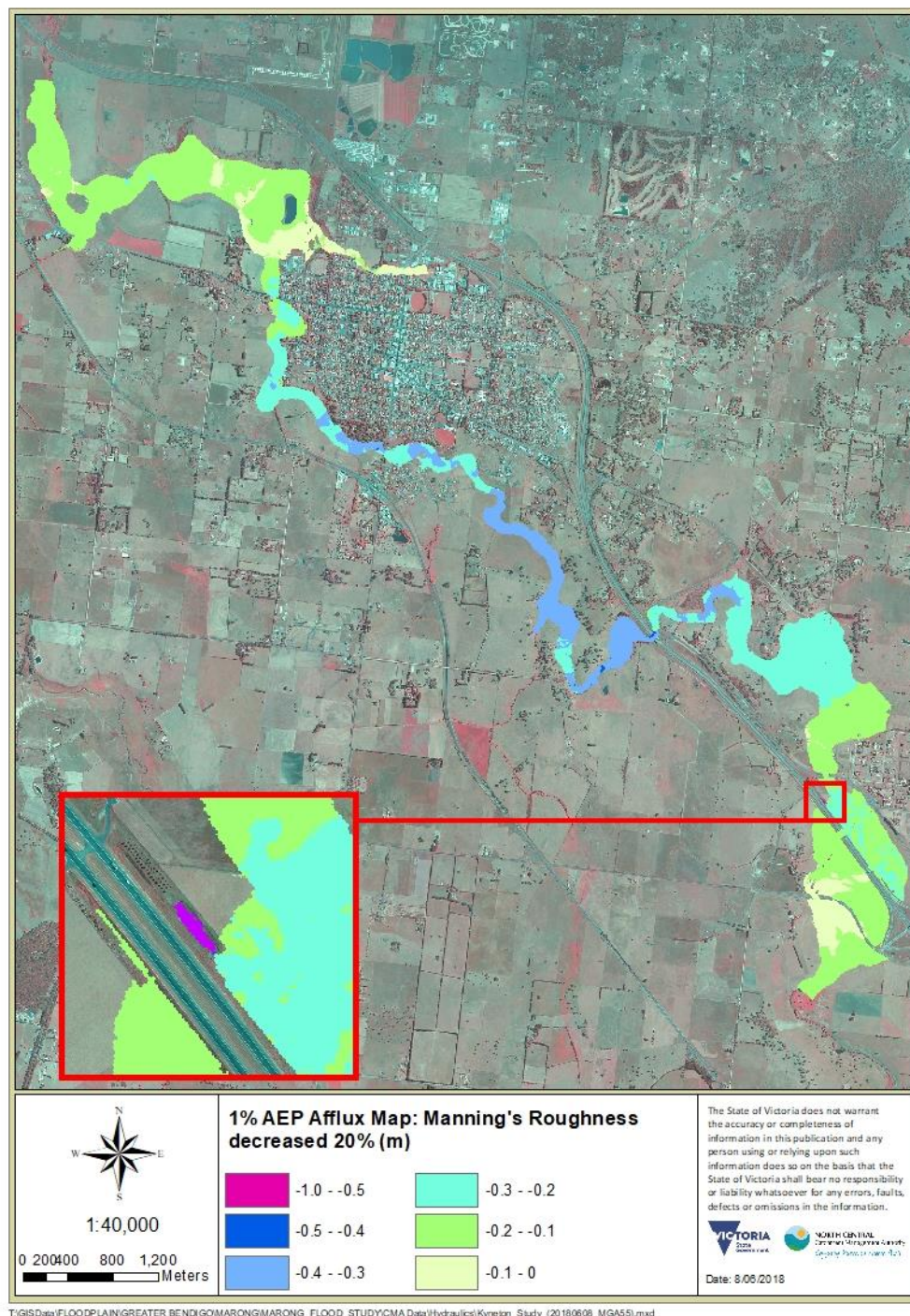
## KYNETON FLOOD STUDY



**Figure 4-31** 1% AEP afflux map comparing base case scenario to sensitivity scenario with Manning's roughness increased by 20% (Sensitivity Scenario – Base Case Scenario)



## KYNETON FLOOD STUDY



**Figure 4-32** 1% AEP afflux map comparing base case scenario to sensitivity scenario with Manning's roughness decreased by 20% (Sensitivity Scenario – Base Case Scenario). The red insert shows the area of maximum difference.

## KYNETON FLOOD STUDY

**4.4.2 Outflow Boundary Condition Sensitivity**

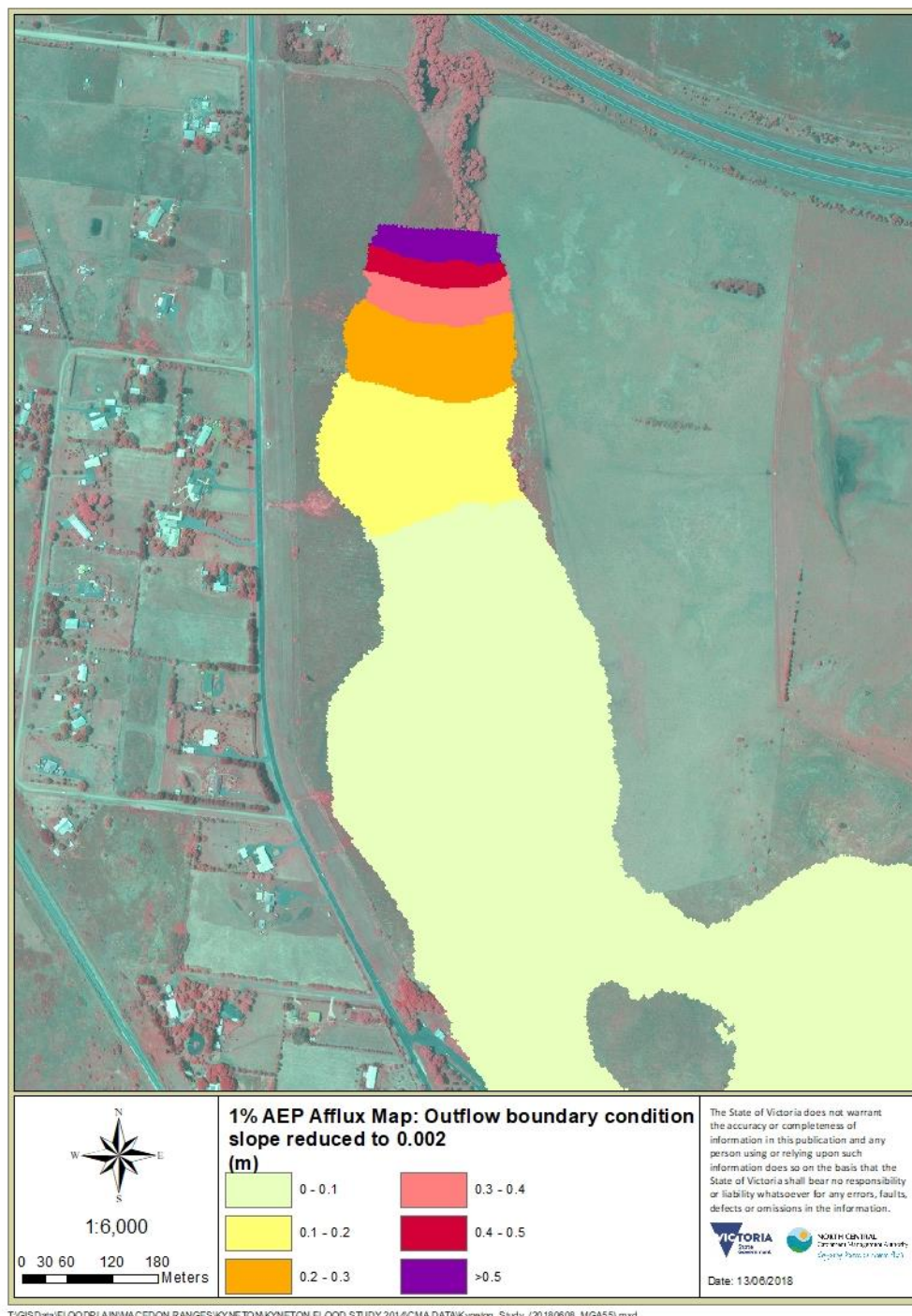
The sensitivity of the hydraulic model to the outflow boundary condition was also analysed. The base case scenario applied a water surface slope of 0.01 at the outflow boundary to determine the flow rate of water leaving the model. This was compared to two sensitivity scenarios, the first of which reduced the water surface slope to 0.002, and the second where it was increased to 0.02.

As expected, the flood levels near the outflow model boundary are increased when the boundary condition slope is reduced to 0.002 as shown in Figure 4-33. The afflux immediately upstream of the model boundary is significant, with flood levels approximately 1.0m higher than the base case scenario. However, the impacts are quickly dissipated further upstream of the boundary to less than a 50mm increase at a distance of 500m from the boundary. Due to the steep river banks this afflux only results in a relatively small increase in flood extent, generally less than 20m. Moreover, the additional area impacted is farm land with no development located within this vicinity.

Figure 4-34 shows the results due to increasing the outflow boundary slope to 0.02. As shown the flood levels are slightly reduced as compared to the base case scenario. The maximum decrease in flood level is approximately 0.25m immediately at the outflow boundary. At a distance of 70m upstream of the outflow boundary the difference in flood level is less than 50mm. Due to the relatively small decrease in flood level there is no significant change in flood extent for this scenario.

Overall, the extent of influence due to the outflow boundary is generally minor and restricted to farm land. Therefore, it is considered that the hydraulic model is not particularly sensitive to the outflow boundary conditions and the areas of interest for the model are not impacted.

## KYNETON FLOOD STUDY



**Figure 4-33** 1% AEP afflux map comparing base case scenario to sensitivity scenario with the outflow boundary slope reduced to 0.002 (Sensitivity Scenario – Base Case Scenario)



## KYNETON FLOOD STUDY



**Figure 4-34** 1% AEP afflux map comparing base case scenario to sensitivity scenario with the outflow boundary slope increased to 0.02 (Sensitivity Scenario – Base Case Scenario)

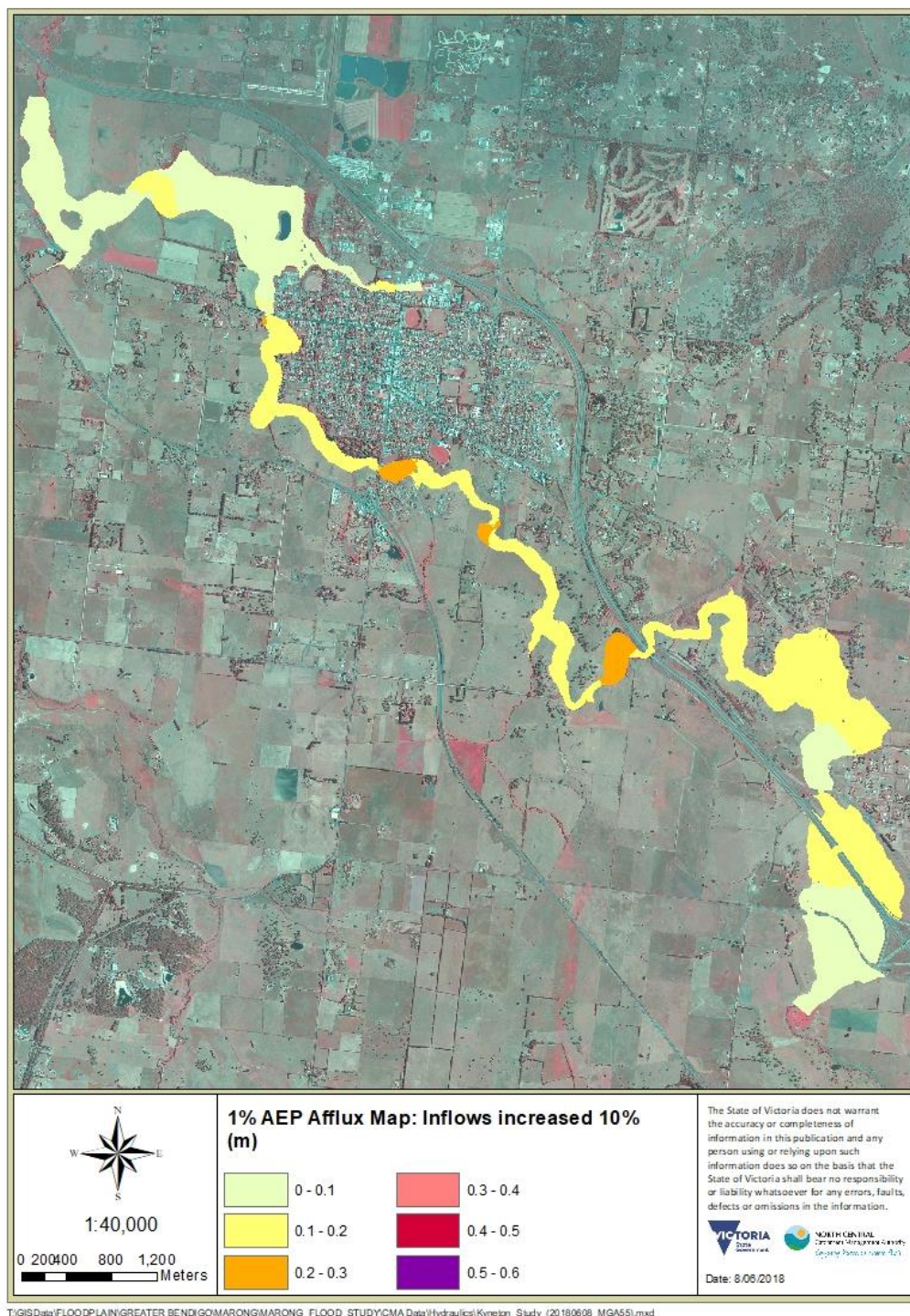
## KYNETON FLOOD STUDY

### 4.4.3 Model Inflow Sensitivity

The sensitivity of the hydraulic model to the inflows was tested by varying all inflow hydrographs by 10%. Figure 4-35 shows the afflux due to the inflow hydrographs being increased by 10%. The flood levels are only increased an average of 0.1m compared to the base case scenario, with localised increases on over 0.2m. Moreover, there is no material increase in flood extent.

The afflux results for a 10% reduction of the inflow hydrographs is shown in Figure 4-36. There is an average decrease of 0.1m in flood level and an overall minor decrease in flood extent. The areas impacted by variations in the model inflow appear to be reasonably consistent as shown by comparing Figure 4-35 and Figure 4-36. The Campaspe River reach through Kyneton appears to be the most sensitive to changes in flow, with levels varying by approximately 0.2m along this section due to a 10% increase or decrease in the inflow hydrographs.

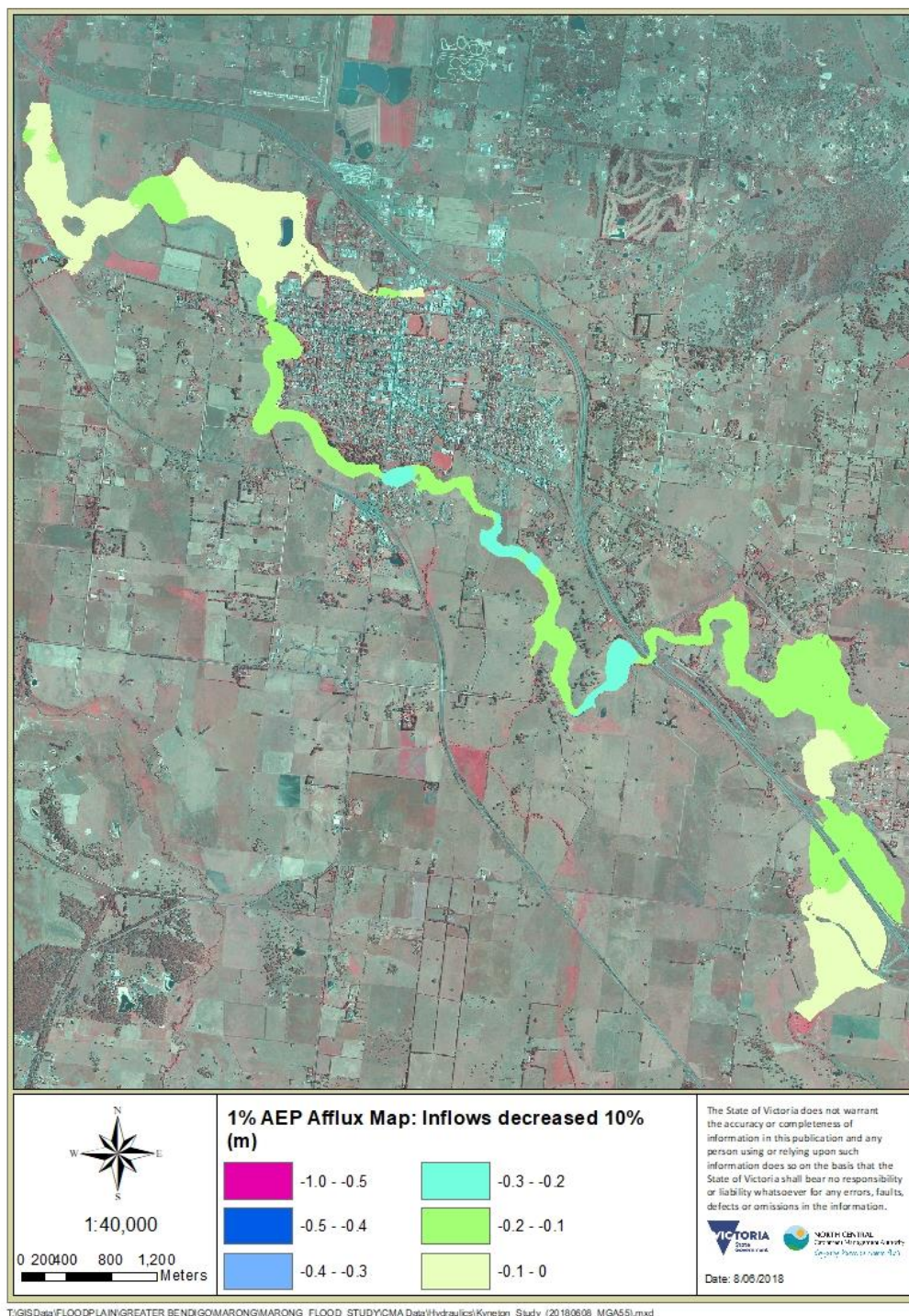
## KYNETON FLOOD STUDY



**Figure 4-35** 1% AEP afflux map comparing base case scenario to sensitivity scenario with inflows increased by 10% (Sensitivity Scenario – Base Case Scenario)



## KYNETON FLOOD STUDY



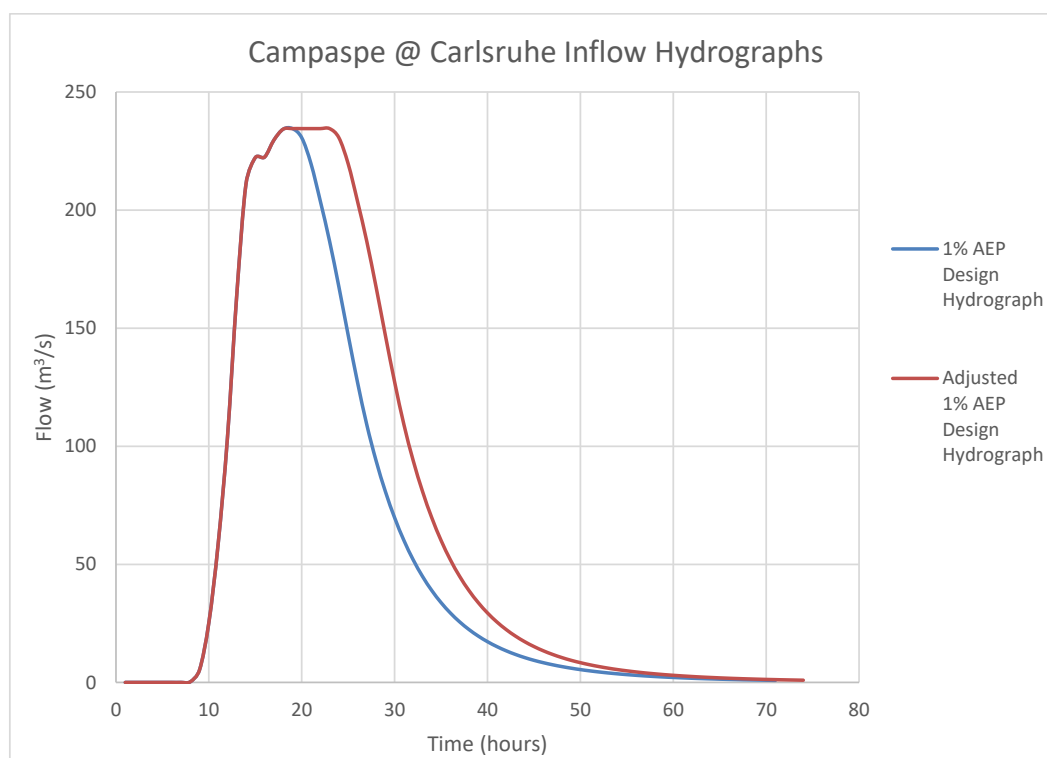
**Figure 4-36** 1% AEP afflux map comparing base case scenario to sensitivity scenario with inflows decreased by 10% (Sensitivity Scenario – Base Case Scenario)

## KYNETON FLOOD STUDY

#### 4.4.4 Hydrograph Volume Sensitivity

It is important to note that the preceding hydrologic analysis detailed in Section 3 is dependent on the implicit assumption that the peak flood levels on the floodplain occur coincidentally with the peak catchment flow rate. However, this is not necessarily the case. For some floodplains, peak flood conditions are controlled by the total hydrograph volume with peak water levels occurring significantly after the peak flow has passed. Hence, it is essential that sensitivity testing be undertaken to justify this assumption.

The sensitivity of the hydraulic model to hydrograph volume was tested by increasing the volume of the 1% AEP inflow hydrographs by 25%. The duration of the peak flow rate for each hydrograph was extended to achieve the 25% increase in volume. A comparison of the hydrographs at the Campaspe @ Karlsruhe model inflow location is shown in Figure 4-37 below to illustrate this method. It should be noted that this is a conservative approach to the volume analysis as the peak flow rate would typically be lower for a hydrograph with greater volume.



**Figure 4-37** Campaspe @ Karlsruhe 1% AEP design inflow hydrograph volume increased by 25%

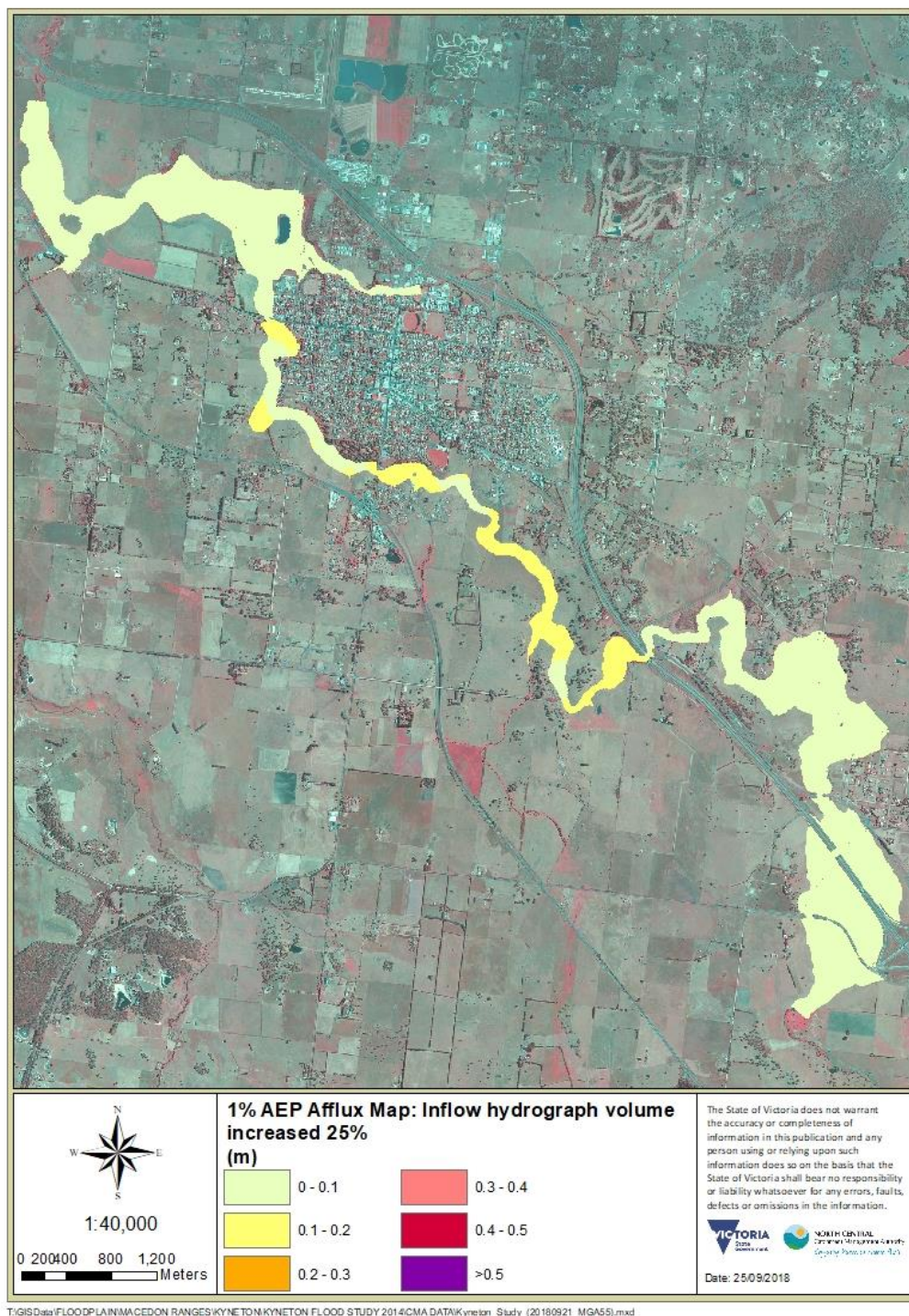
Figure 4-38 shows the difference in flood height due to the inflow hydrograph volumes being increased by 25%. There is an average increase of 50mm in flood height across the entire model domain, with the maximum afflux limited to less than 140mm, resulting in a negligible increase in flood extent.

**KYNETON FLOOD STUDY**

Although there is a slight increase in flood levels the afflux is relatively minor particularly considering that this is a conservative estimation. In comparison, Section 4.4.3 discusses the impacts of increasing flows by 10%, which effectively increases the hydrograph volume by approximately only 10%. In that analysis, the average increase in flood levels was 100mm, twice the afflux caused by increasing the volume by 25%. Consequently, this indicates that peak flow rate has a greater influence than total hydrograph volume on flood behaviour. This is also consistent with the topography of this waterway reach, characterised by steep slopes with confined floodplains, which is typically associated with flood behaviour that is controlled by peak flow rate. Hence, this analysis demonstrates that the increase in flood level due to the increased hydrograph volume is negligible, thus validating the assumption that peak flood conditions for this floodplain are dependent on peak flow rate as opposed to hydrograph volume.



## KYNETON FLOOD STUDY



**Figure 4-38** 1% AEP afflux map comparing base case scenario to sensitivity scenario with inflow hydrographs increased by 25% (Sensitivity Scenario – Base Case Scenario)

## KYNETON FLOOD STUDY

## 4.5 Design Flood Modelling

### 4.5.1 Coincidence of Campaspe River and Post Office Creek flows

There is a significant difference in catchment size between Post Office Creek and the Campaspe River (12km<sup>2</sup> and 233km<sup>2</sup> respectively). Hence, for a given storm event, the peak flow from Post Office Creek will pass through Kyneton hours before the Campaspe River peaks within the Township. Consequently, flood interactions between the two waterways are limited. Furthermore, due to the steep gradient of both waterways and the fact that the location of the confluence is located approximately one kilometre north of the township, any localised impacts from backwater would be limited. Therefore, the design hydrographs for both the Campaspe River and Post Office Creek have simply been modelled together.

### 4.5.2 Blockage of Structures

Blockage of bridges and culverts were assessed in accordance with ARR, Book 6, Chapter 6. Blockage assessments were undertaken for three structures on the Campaspe River and three on Post Office Creek, as described in the following sections. These structures were selected based on the potential of the blockages to impact on urban areas. Details of these structures are provided in Section 2.1.2.

The blockage scenarios were modelled simultaneously on the Campaspe River and Post Office Creek since any impacts from the blocked structures are localised on both waterways and therefore the flood behaviour effects are independent. Regarding the blockage combinations that were simulated, it was considered that if multiple structures on the same waterway were blocked the restricted flows from the upstream blockages would lessen the impacts of downstream blockages. Hence, a single bridge on each waterway was modelled as blocked while the other structures remained clear for each scenario as this appears to result in the most adverse flood behaviour.

The 'all clear' base scenario was then augmented with the various blockage scenarios and an envelope of the maximum results was created for the 1% AEP flood event. This ensures that the impacts of individual blocked structures are properly simulated in the enveloped solution in addition to the 'all clear' flood impacts. However, it must therefore be noted when considering the results that in any single historic event, the recorded flood surface will likely only reach the envelope levels at some locations due to the variability in actual blockages (ARR, Book 6, Section 6.4.4.10).

#### 4.5.2.1 Blockage determination for Campaspe River structures

A blockage assessment of the following three Campaspe River bridges was undertaken:

- S7 – Cobb and Co Road North Bridge
- S10 – Mollison Street Bridge
- S13 – Piper Street Bridge

These structures were specifically selected based on their proximity and potential impact on urban areas. Figure 2-5 and Figure 2-6 display the locations of these bridges. It should be noted that the Cobb and Co Road North Bridge (S7 in Figure 2-5) was selected to be block rather than the Calder Highway



## KYNETON FLOOD STUDY

North Bridge (S8) as it is located immediately upstream of the later bridge and has a shorter span. Therefore, any blockage is more likely to occur at this bridge and also hence reduce the potential for blockage at the downstream bridge.

The blockage assessment for the structures is detailed below:

- 1) Debris Types and Dimensions – estimated  $L_{10} = 3\text{m}$ , where  $L_{10}$  is defined as the average length of the longest 10% of the debris reaching the structure. An example of debris located upstream of Piper Street bridge is shown in Figure 4-39.
- 2) Debris Availability = Medium
- 3) Debris Mobility = High
- 4) Debris Transportability = High
- 5) 1% AEP Debris Potential = High (HHM from above assessment)
- 6) AEP Adjusted Debris Potential = High (for 5% - 0.5% AEP)
- 7) Most Likely Inlet Blockage,  $B_{DES\%} = 10\%$  (Clear width of inlet (bridge spans) is greater than 13m, hence  $W > 3 * L_{10}$ )

Hence, a separate simulation was modelled with each bridge having the determined blockage factor of 10% applied.



Figure 4-39 Debris during the September 2010 flood event (Kyneton Historical Society, 2010)



## KYNETON FLOOD STUDY

**4.5.2.2 Blockage determination for Post Office Creek structures**

Similarly, the blockage assessment of the four 1.8m diameter culvert structures on Mollison Street and Ebdon Street (structures S15 and S16 respectively in Figure 2-6) is described below:

- 1) Debris Types and Dimensions – estimated  $L_{10} = 2\text{m}$ , where  $L_{10}$  is defined as the average length of the longest 10% of the debris reaching the structure
- 2) Debris Availability = High
- 3) Debris Mobility = Medium
- 4) Debris Transportability = Medium
- 5) 1% AEP Debris Potential = Medium (HMM from above assessment)
- 6) AEP Adjusted Debris Potential = Medium (for 5% - 0.5% AEP)
- 7) Most Likely Inlet Blockage,  $B_{DES\%} = 50\%$  (Clear width of inlet (i.e. culvert diameter) is 1.8m, hence  $W < L_{10}$ )

Figure 4-40 below shows an example of a blockage that has occurred at the Ebdon Street culverts, indicating that the estimated culvert blockage of 50% is reasonable.



**Figure 4-40 Blockage at the Ebdon Street culverts**

Additionally, for the single span bridge on Wedge Street (S17), the blockage assessment was as follows:

- 1) Debris Types and Dimensions – estimated  $L_{10} = 2\text{m}$  where  $L_{10}$  is defined as the average length of the longest 10% of the debris reaching the structure
- 2) Debris Availability = High
- 3) Debris Mobility = Medium

## KYNETON FLOOD STUDY

- 4) Debris Transportability = Medium
- 5) 1% AEP Debris Potential = Medium (HMM from above assessment)
- 6) AEP Adjusted Debris Potential = Medium (for 5% - 0.5% AEP)
- 7) Most Likely Inlet Blockage,  $B_{DES\%} = 10\%$  (Clear width of inlet (i.e. bridge span) is 5.1m, hence  $L_{10} \leq W \leq 3 * L_{10}$ )

It should be noted that willow removal works have been undertaken along a segment of the waterway immediately upstream of the Wedge Street bridge. Anecdotal evidence provided by a local landowner suggests that minimal debris is transported along this section of waterway and that no significant blockage at this bridge has previously occurred. This is most likely due to the restriction caused by the upstream culvert structures at Ebdon Street and Mollison Street which limit the debris that arrives at the Wedge Street bridge. Therefore, applying a 10% blockage factor is considered appropriate.

Hence, scenarios of each culvert structure on Post Office Creek with a 50% blockage were modelled separately, in addition to a scenario with the Wedge Street bridge blocked by a factor of 10%.

### 4.5.2.3 Impact of blockages

A comparison of the blockage scenarios to the base case scenario for the 1% AEP design event shows that the impacts of typical blockages on the Campaspe River bridges are minor with localised increases of less than 100mm upstream of the structures. However, the impacts of structure blockages on Post Office Creek are more significant due to the likelihood of a large blockage occurring. In particular, the afflux at Ebdon Street due to a 50% blockage of the culverts increases upstream flood levels by up to 450mm.

### 4.5.3 Model Quality Assurance

To ensure the modelling was fit for purpose, the TUFLOW model results were assessed. Checks were made to ensure that input data such as topography, surface roughness, and hydraulic structures were appropriately represented by the hydraulic model. Model inflow and outflow boundaries were located a sufficient distance from areas of interest to ensure that the boundary conditions did not influence model results. The absence of any negative depth warnings or significant volume fluctuations for the modelled events also indicated the stability of the hydraulic model. Furthermore, the peak cumulative mass error for the various model scenarios were less than 0.25% and therefore within acceptable limits.

A review of the individual scenario outputs was undertaken to identify any discontinuities in flow behaviour as well as any other erroneous results that might indicate underlying issues with model inputs such as steep topography or unrealistic roughness values. The water surface elevations for each design event were also compared to events both rarer and more frequent events to ensure that the results were consistent. For instance, the 10% AEP flood levels were compared to the 20% AEP level to ensure that they were indeed higher at every point in the model. This analysis revealed that the 1% AEP flood levels were actually higher than the 0.5% AEP flood level on a section of Post Office Creek between Ebdon Street and Mollison Street. This was due to the fact that blockages were only considered for the 1% AEP flood event. Therefore, since this was a localised area, the original 0.5%

## KYNETON FLOOD STUDY

AEP outputs were combined with the 1% AEP outputs and the highest critical values were selected for each grid to generate updated data for the 0.5% AEP event. This process ensured consistency between the datasets.

### 4.5.4 Design Results

The hydraulic model was used to generate water surface elevations (flood levels), depths, velocities and hazard (depth multiplied by velocity) rasters for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP flood events as well as the PMF. These outputs were then post-processed to generate flood extents, flood contours velocity vectors and longitudinal profiles for all design events. The extents produced from the raster data were smoothed using the Polynomial Approximation with Exponential Kernel (PAEK) algorithm and applying a tolerance of 20 metres. This provided a more realistic extent of flooding while still sufficiently preserving the definition of the raster data. Additionally, any small islands occurring within the flood extent with an area less than 400m<sup>2</sup> were removed for clarity.

Figure 4-41 and Figure 4-42 shows all design flood extents overlayed on a single map for comparison. It can be seen that due to the confined floodplain along this reach of the Campaspe River there is not a substantial difference between the 20% AEP flood extent and the 0.5% AEP flood extent, although the average difference in flood level is 1 metre. The flood depth maps for each design event are shown in the Appendix (Section 7.1). A comparison of the longitudinal profiles for each design event is shown in Section 7.2.



## KYNETON FLOOD STUDY

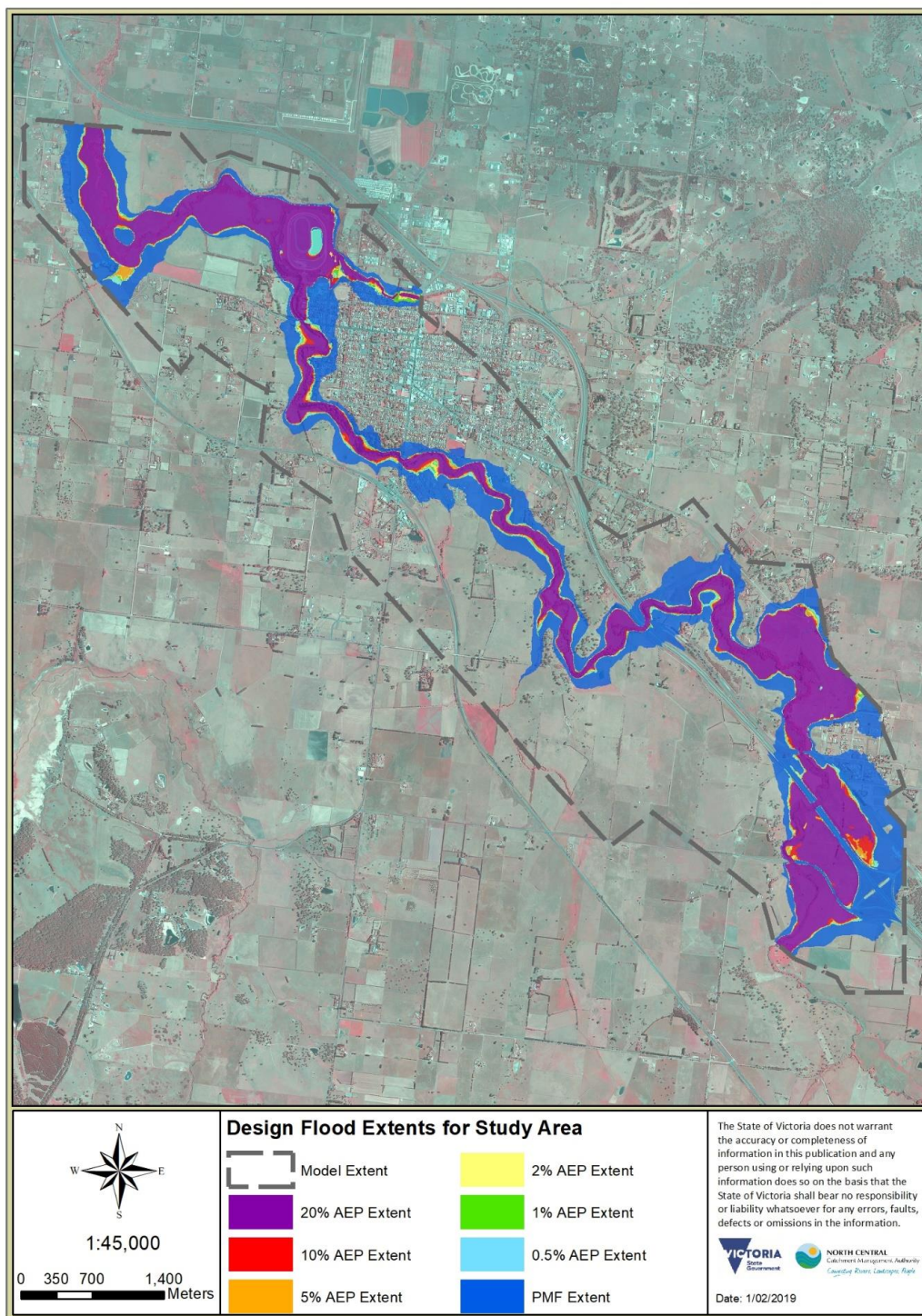
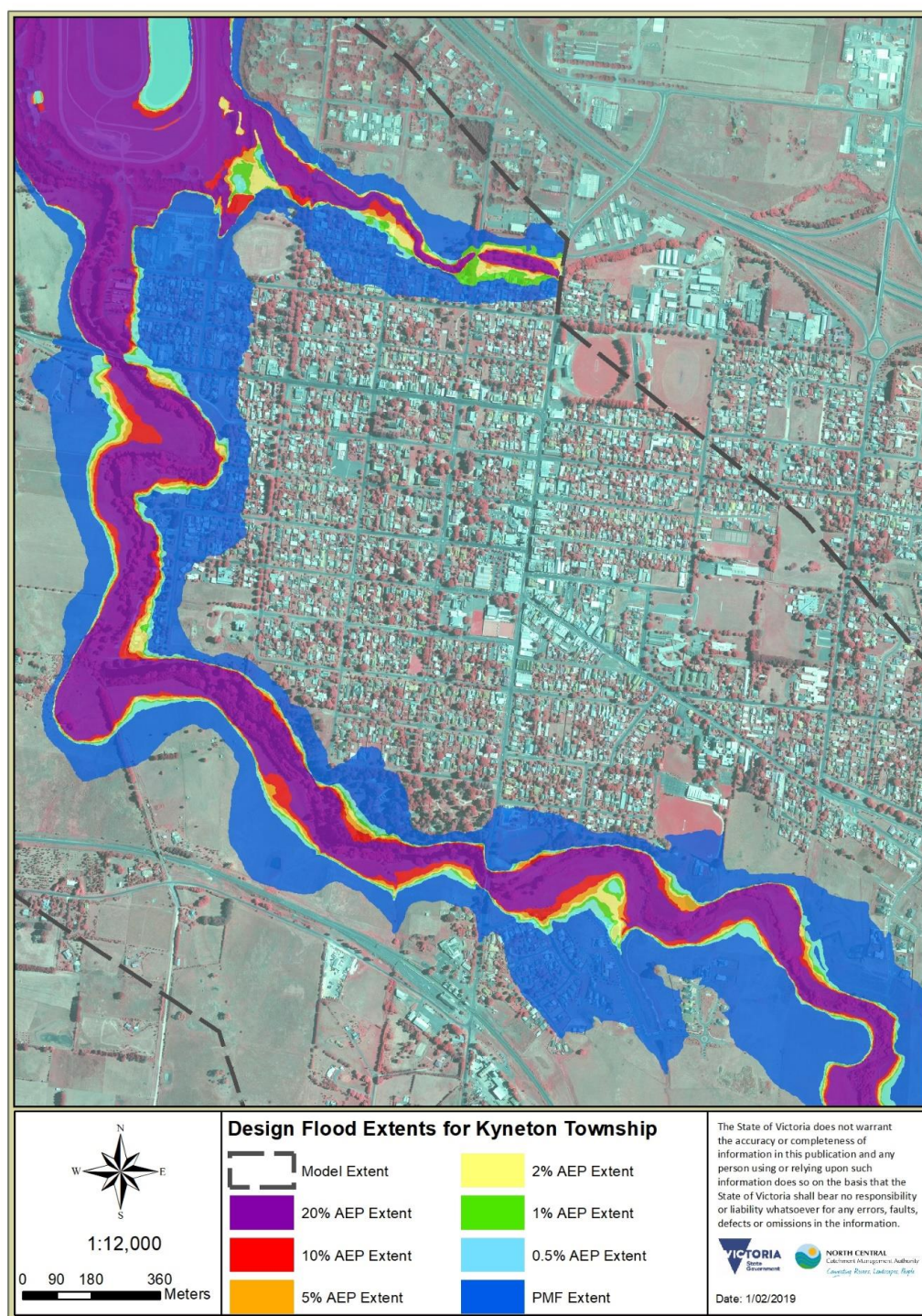


Figure 4-41 Design flood extents for study area



## KYNETON FLOOD STUDY



**Figure 4-42** Design flood extents for Kyneton Township

## KYNETON FLOOD STUDY

#### 4.6 Design Flood Behaviour

Based on the design flood mapping for events ranging from the 20% AEP to the 0.5% AEP event (Figure 4-41 and Figure 4-42), it can be seen that flooding is generally confined through Kyneton Township by the steep banks of the Campaspe River. However, floodwaters do break out over the rural land surrounding Carlsruhe and also inundate the Racecourse north of Kyneton Township. Due to the defined nature of the floodplain, the increase in flood levels for rarer events typically do not result in a significant increase in flood extent and impacts. Flood depth maps for each event is shown in Section 7.1. The following comments summarise the key flood impacts for each design event.

##### 20% AEP Flood Event

- Campaspe River
  - Some properties along Ebdon Street and Pultney Street in Carlsruhe flooded. No buildings appear to be inundated.
  - Significant flooding on rural properties north of Carlsruhe.
  - Intersection of Trio Road and Murphys Road inundated to a depth of over 0.5 metres.
  - The rear of properties on Degraes Court flooded. Some outbuildings may be impacted.
  - Shallow inundation of St Agnes Place.
  - The rear of some properties along Mill Street flooded.
  - Some properties along Jennings Street inundated.
  - Properties along Campaspe Place and Lennox Street flooded.
  - Kyneton Racecourse entirely inundated.
  - Farm land downstream of Kyneton Township inundated. No buildings appear to be impacted
- Post Office Creek
  - Floodwater generally contained within creek.
  - Possible impacts to Hall Court properties fronting Post Office Creek.
  - Shallow flooding over Wedge Street bridge.
  - Properties immediately upstream of Wedge Street bridge may be impacted.

##### 10% AEP Flood Event

The 10% AEP flood levels are on average 0.25 metres higher than the 20% AEP flood levels.

- Campaspe River
  - Impacts similar to 20% AEP flood event.
  - Campaspe Drive inundated to a depth of approximately 0.5 metres.
  - Franklin Place inundated.
  - St Agnes Place becomes inundated to a depth over 0.8 metres.
  - The rear of properties along Mill Street and St Agnes Place flooded. Dwellings may be impacted.



**KYNETON FLOOD STUDY**

- Post Office Creek
  - Impacts similar to 20% AEP flood event.

**5% AEP Flood Event**

The 5% AEP flood levels are on average 0.2 metres higher than the 10% AEP flood levels.

- Campaspe River
  - Impacts similar to 10% AEP flood event.
  - Campaspe Drive inundated to a depth of over 1 metre.
  - Some properties near the Campaspe Drive and Windridge Way intersection flooded. Dwellings may be impacted.
  - St Agnes Place becomes inundated to a depth over 1 metre.
  - Property at the end of Argyle Lane (immediately upstream of Piper Street bridge) significantly impacted.
  - 171 and 185 Burton Avenue partially inundated. Dwellings potentially impacted.
  - Shallow inundation of Burton Avenue.
- Post Office Creek
  - Wedge Street bridge overtopped by approximately 0.2 metres.

**2% AEP Flood Event**

The 2% AEP flood levels are on average 0.15 metres higher than the 5% AEP flood levels.

- Campaspe River
  - Impacts similar to 5% AEP flood event.
  - Property at the end of Argyle Lane (immediately upstream of Piper Street bridge) significantly impacted. Dwelling potentially impacted.
  - Burton Avenue overtopped to a depth of approximately 0.3 metres.
- Post Office Creek
  - Shallow inundation on Johnson Court.
  - Mollison Street bridge overtopped by approximately 0.4 metres.
  - Flooding over Ward Street up to 0.5 metres.
  - Some properties along Ward Street inundated. Dwellings potentially impacted.
  - Properties at the end of Powlett Street may be impacted. Some dwellings potentially impacted.
  - Wedge Street bridge overtopped by approximately 0.4 metres.

**1% AEP Flood Event**

The 1% AEP flood levels are on average 0.1 metres higher than the 2% AEP flood levels.

**KYNETON FLOOD STUDY**

- Campaspe River
  - Impacts similar to 2% AEP flood event.
  - Victoria Road inundated.
  - Greater flooding on Mill Street and St Agnes Place properties.
- Post Office Creek
  - Property immediately upstream of Mollison Street bridge significantly impacted. Dwelling potentially impacted.
  - Mollison Street bridge overtopped by approximately 0.6 metres.
  - Flooding on Ward Street over 1 metre.
  - Most properties along Ward Street inundated. Dwellings potentially impacted.
  - Ebden Street bridge overtopped by approximately 0.5 metres.
  - Property immediately downstream of Ebden Street bridge flooded. Dwelling potentially impacted.
  - Wedge Street bridge overtopped by approximately 0.5 metres.

**0.5% AEP Flood Event**

The 0.5% AEP flood levels are on average 0.35 metres higher than the 2% AEP flood levels.

- Campaspe River
  - Impacts similar to 1% AEP flood event.
  - Cobb and Co Road may overtop by 200mm between Nicholson Street and Three Chain Road.
  - Shallow flooding on Piper Street adjacent to Piper Street bridge.
  - Burton Avenue overtopped to a depth of over 0.5 metres.
- Post Office Creek
  - Mollison Street bridge overtopped by approximately 0.7 metres.
  - Ebden Street bridge overtopped by approximately 0.5 metres.
  - Property immediately downstream of Ebden Street bridge flooded. Dwelling potentially impacted.
  - Wedge Street bridge overtopped by approximately 0.5 metres.

## KYNETON FLOOD STUDY

## 5 Conclusion

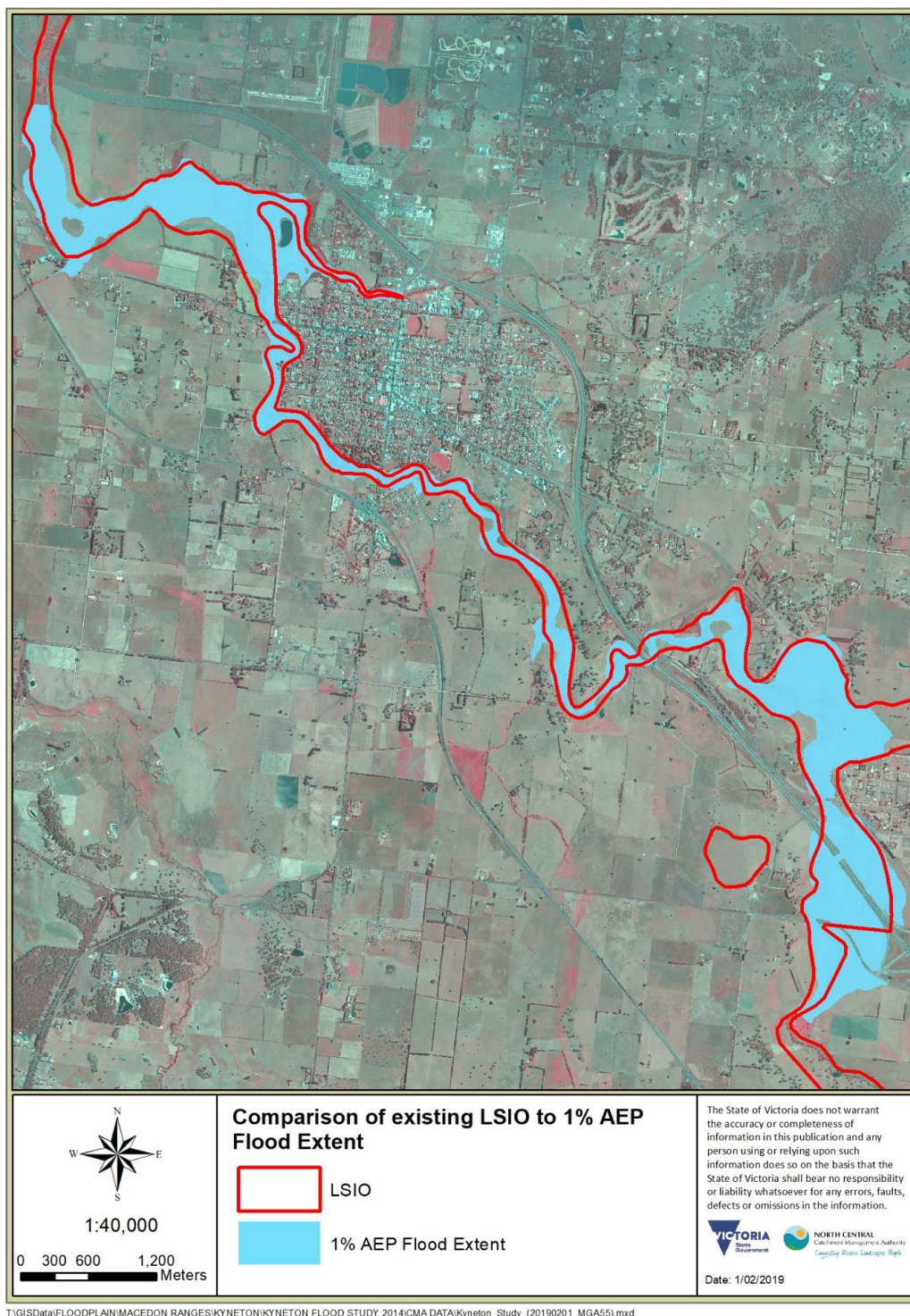
This report has documented the methodology and results of the Kyneton Flood Study. Through the development and calibration of hydrologic and hydraulic models, the flood behaviour has been determined for various design flood events ranging from the 20% AEP to the PMF. The model outputs generated for these design events include flood extents, levels, depths and velocities. These results will be used to update the available flood information for the township of Kyneton.

It should be noted that, although the model provides a reasonable indication of flooding for Post Office Creek, there were limits to the calibration of the hydrologic and hydraulic models due to a lack of data and historical information. Recommendations for a future study to improve the flood data along Post Office Creek include:

- Obtain additional LiDAR and survey of the creek area to:
  - Extend the hydraulic model. Preferably, the model should extend upstream of Baynton Road so that several upstream hydraulic structures, including the Calder Freeway culverts, can be considered in the hydraulic model. By incorporating the impact of these structure in restricting downstream flows a better calibration to historical events is likely to be achieved.
  - Improve quality of data. The existing LiDAR is obscured by vegetation and does not appear to accurately reflect the topography of the waterway in several places.
- With extended and improved terrain data, a refined hydraulic model for Post Office Creek could be undertaken. In addition to incorporating the additional upstream structures, a finer grid resolution for the 2D model would allow the creek channel to be more accurately defined.

It is recommended that the current Land Subject to Inundation Overlay (LSIO) be amended to reflect the 1% AEP design results determined by this study. This is in accordance with Policy 13a of the Victorian Floodplain Management Strategy (2016) which states that the 1% AEP flood will remain the design flood extent for the land use planning and building systems in Victoria. Although the existing LSIO covers the majority of the determined flood extent due to the confined nature of the floodplain, Figure 5-1 below shows that the extent should be refined by increasing the overlay in some areas and decreasing it in other areas.

## KYNETON FLOOD STUDY



**Figure 5-1 Comparison of existing LSIO to the 1% AEP design flood extent**

## KYNETON FLOOD STUDY

## 6 Reference

- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M & Testoni I (2016), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia
- BMT WBM (2018), *TUFLOW User Manual Build 2017-09-AC*,  
<https://www.tuflow.com/Download/TUFLOW/Releases/2017-09/TUFLOW%20Manual.2017-09.docx>
- CMPS&F Environmental (1995), *Calder Highway Karlsruhe to Kyneton – Hydrologic and Hydraulic Investigations: Final Report*
- Concrete Pipe Association of Australasia (2012), *CPAA Design Value – Hydraulics of Precast Concrete Conduits*,  
[http://www.cpaas.asn.au/images/publications/engineering\\_guidelines/cpaas\\_design\\_manual\\_hydraulics\\_jan13.pdf](http://www.cpaas.asn.au/images/publications/engineering_guidelines/cpaas_design_manual_hydraulics_jan13.pdf)
- Department of Environment, Land, Water and Planning (2016), *Victorian Floodplain Management Strategy*, Victorian Government, Melbourne
- Earth Tech (2005), *River Walk Flood Study*
- EGIS Consulting (2000), *Flood Data Transfer Project – Flood Mapping Report Shire of Macedon Ranges*, Department of Natural Resources and Environment, Victoria
- Herschy, R (2003), *World Catalogue of Maximum Observed Floods*, International Association of Hydrological Sciences, UK,  
<http://hydrologie.org/redbooks/a284/RB284.pdf>
- Institution of Engineers Australia (1987), *Australian Rainfall and Runoff*, Vol. 1&2. (Ed: Pilgrim, D.H.)
- Joseph Bradley (1978), *Hydraulics of Bridge Waterways*, Federal Highway Administration, USA,  
[http://www.ciccp.es/ImgWeb/Castilla%20y%20Leon/Documentaci%C3%B3n%20T%C3%A9cnica/Hydraulics%20of%20Bridge%20Waterways%20\(1978\).pdf](http://www.ciccp.es/ImgWeb/Castilla%20y%20Leon/Documentaci%C3%B3n%20T%C3%A9cnica/Hydraulics%20of%20Bridge%20Waterways%20(1978).pdf)
- Macedon Ranges Shire Council, Melbourne & North Central Catchment Management Authority (2013), *Flood Management Plan for Macedon Ranges Shire, Melbourne Water and North Central CMA*
- Rural Water Commission of Victoria (1990), *Victorian Surface Water Information to 1987 – Volume 4*,  
<http://data.water.vic.gov.au/WebDocs/SW/VSWI-Volume4.pdf>
- Scorah, M., P. Hill, S. Lang and R. Nathan (2016), *Addressing embedded bursts in design storms for flood hydrology*, 37th Hydrology & Water Resources Symposium Tasmania, Engineers Australia.
- Water Technology (2013), *Rochester Flood Management Plan*

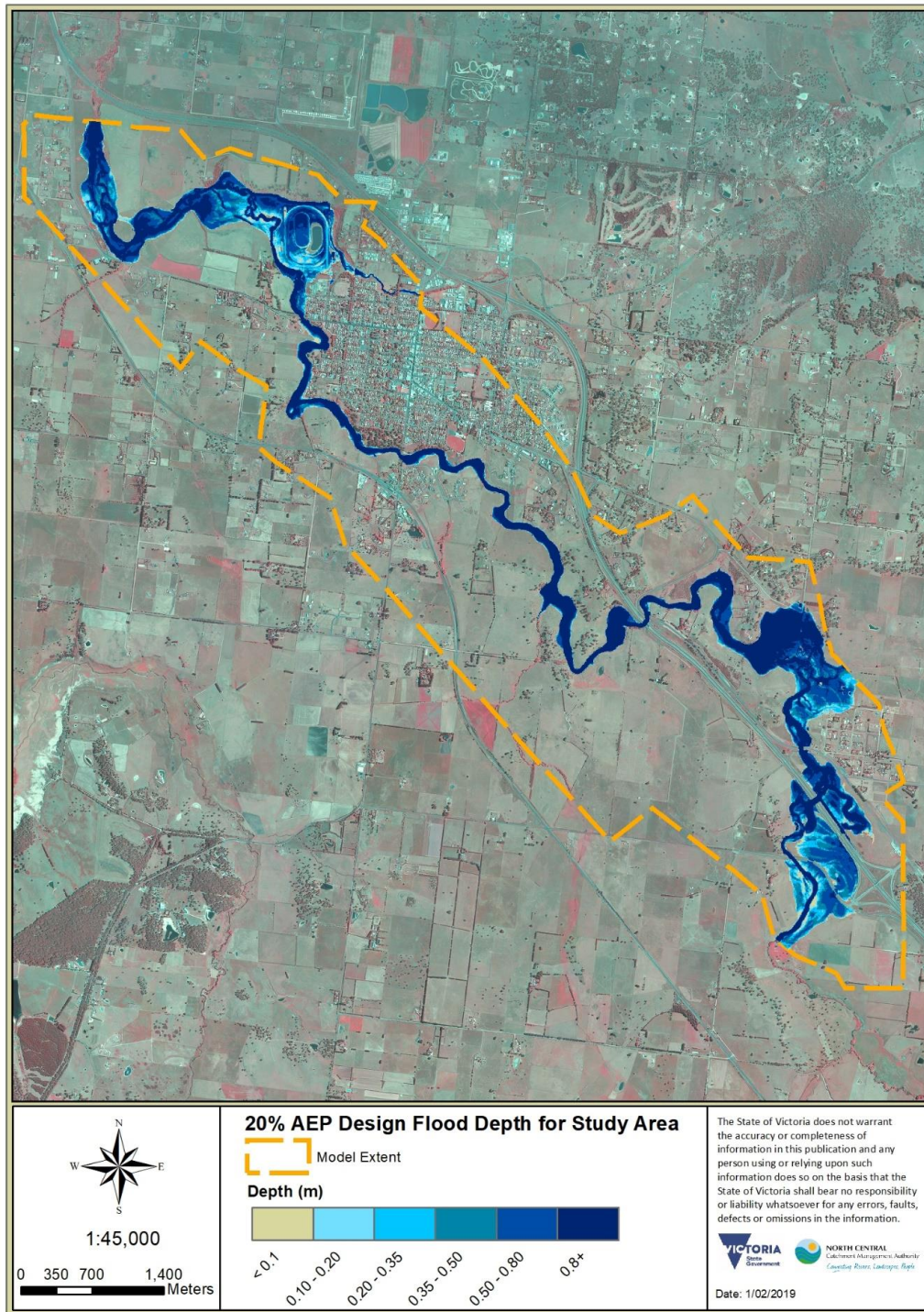


## KYNETON FLOOD STUDY

## 7 Appendix

### 7.1 Design Flood Depth Maps (20% AEP to PMF)

## KYNETON FLOOD STUDY



**Figure 7-1** 20% AEP design flood depth for study extent



## KYNETON FLOOD STUDY

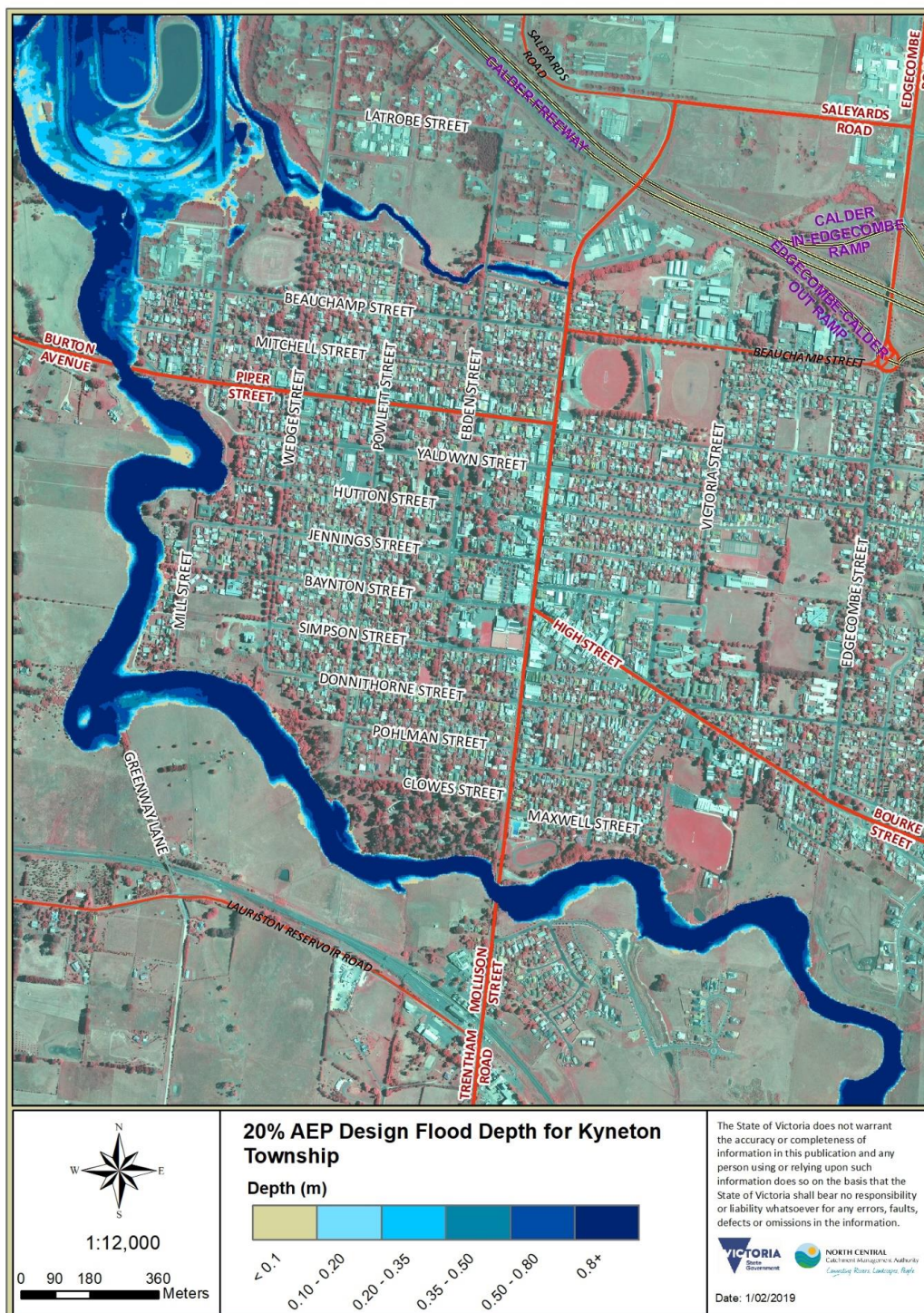
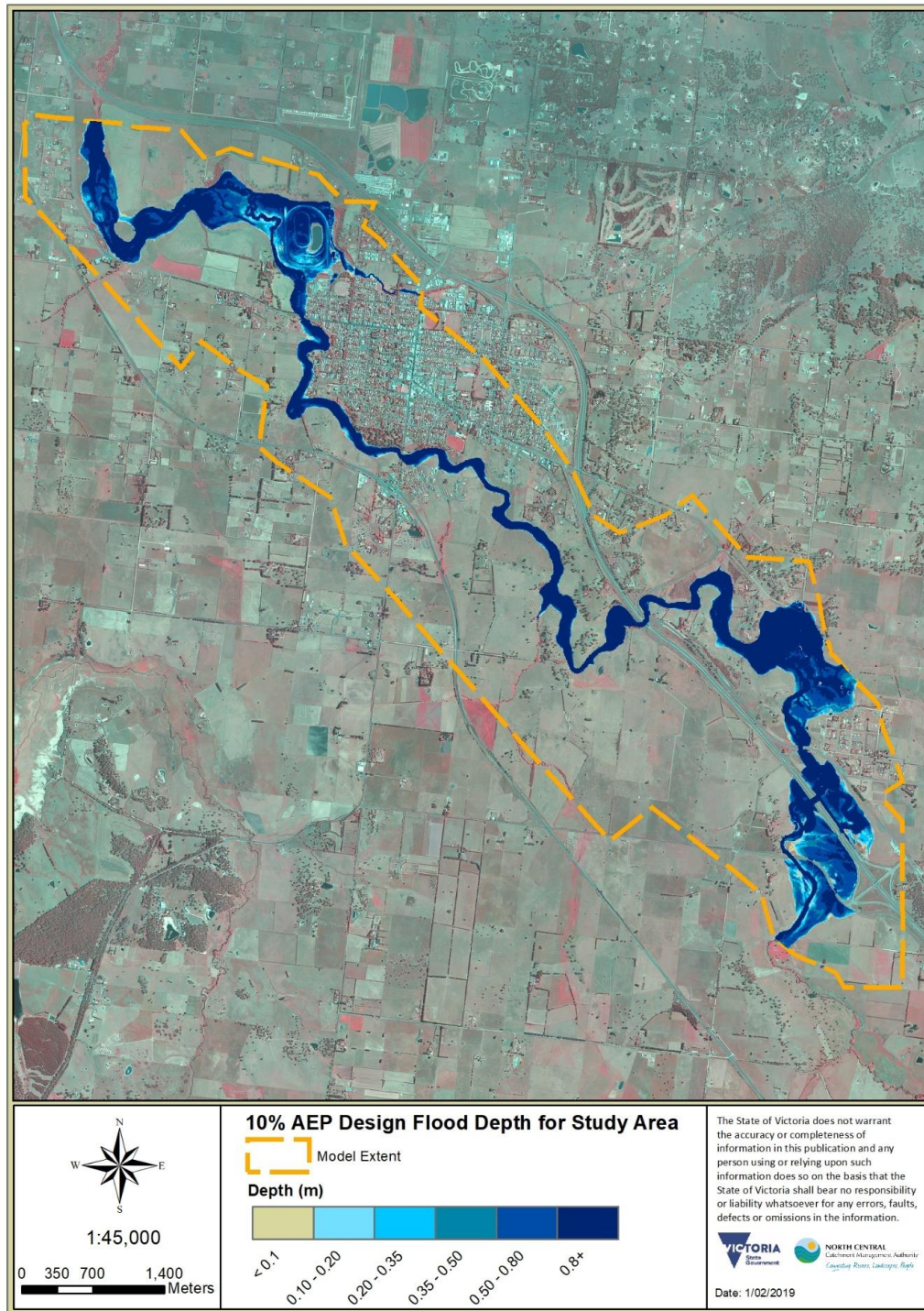


Figure 7-2 20% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-3** 10% AEP design flood depth for study extent



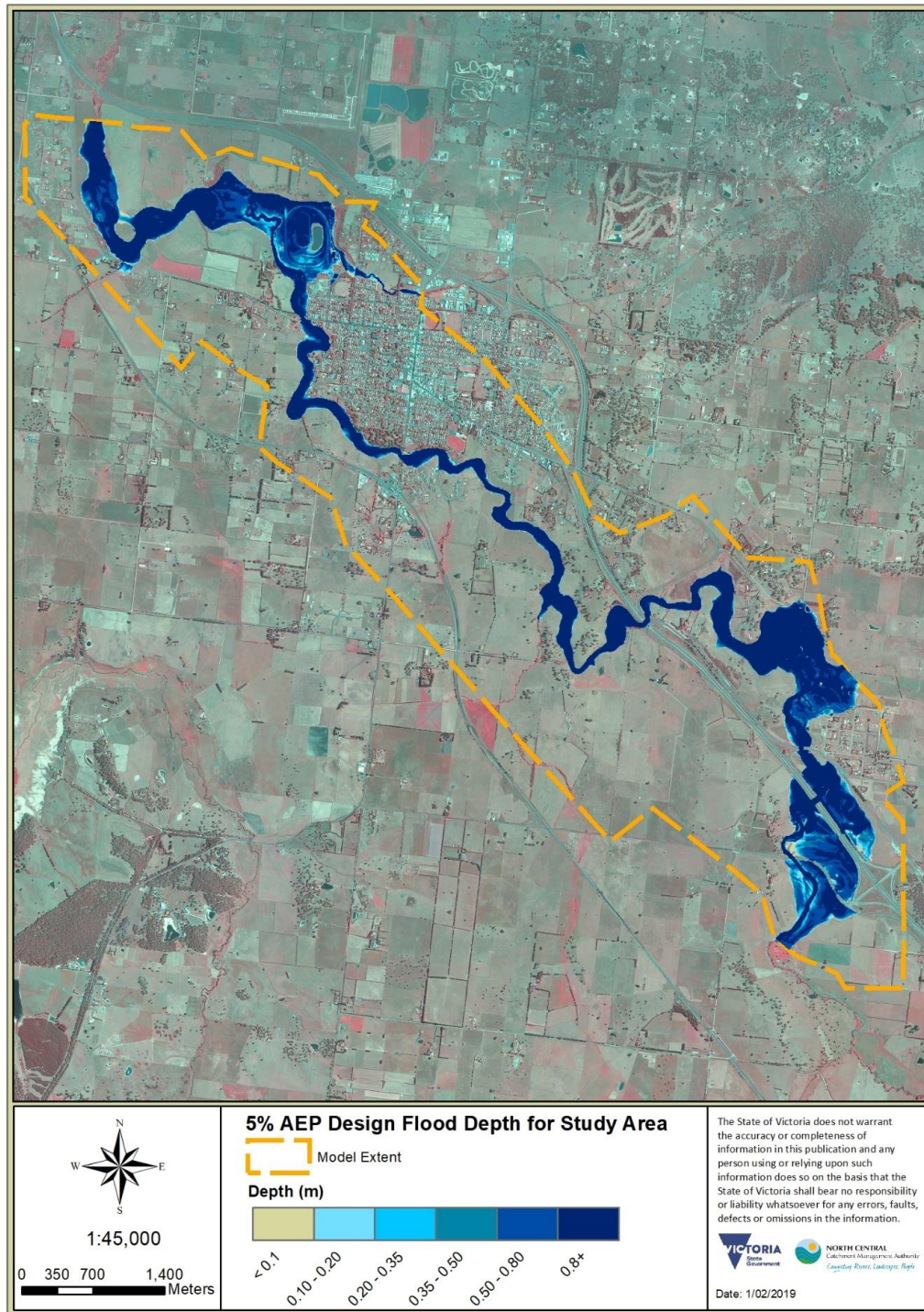
## KYNETON FLOOD STUDY



Figure 7-4 10% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-5** 5% AEP design flood depth for study extent



## KYNETON FLOOD STUDY

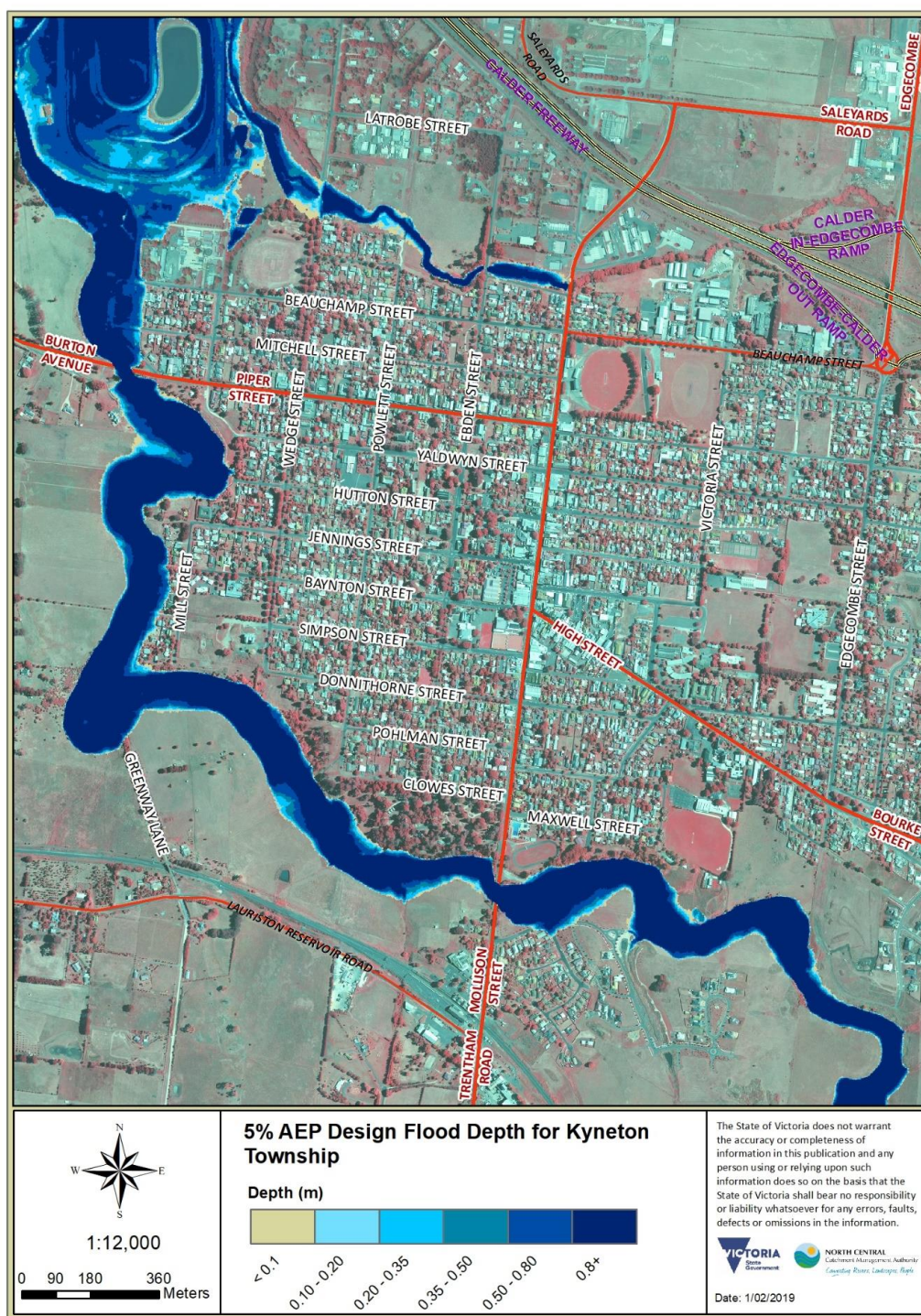
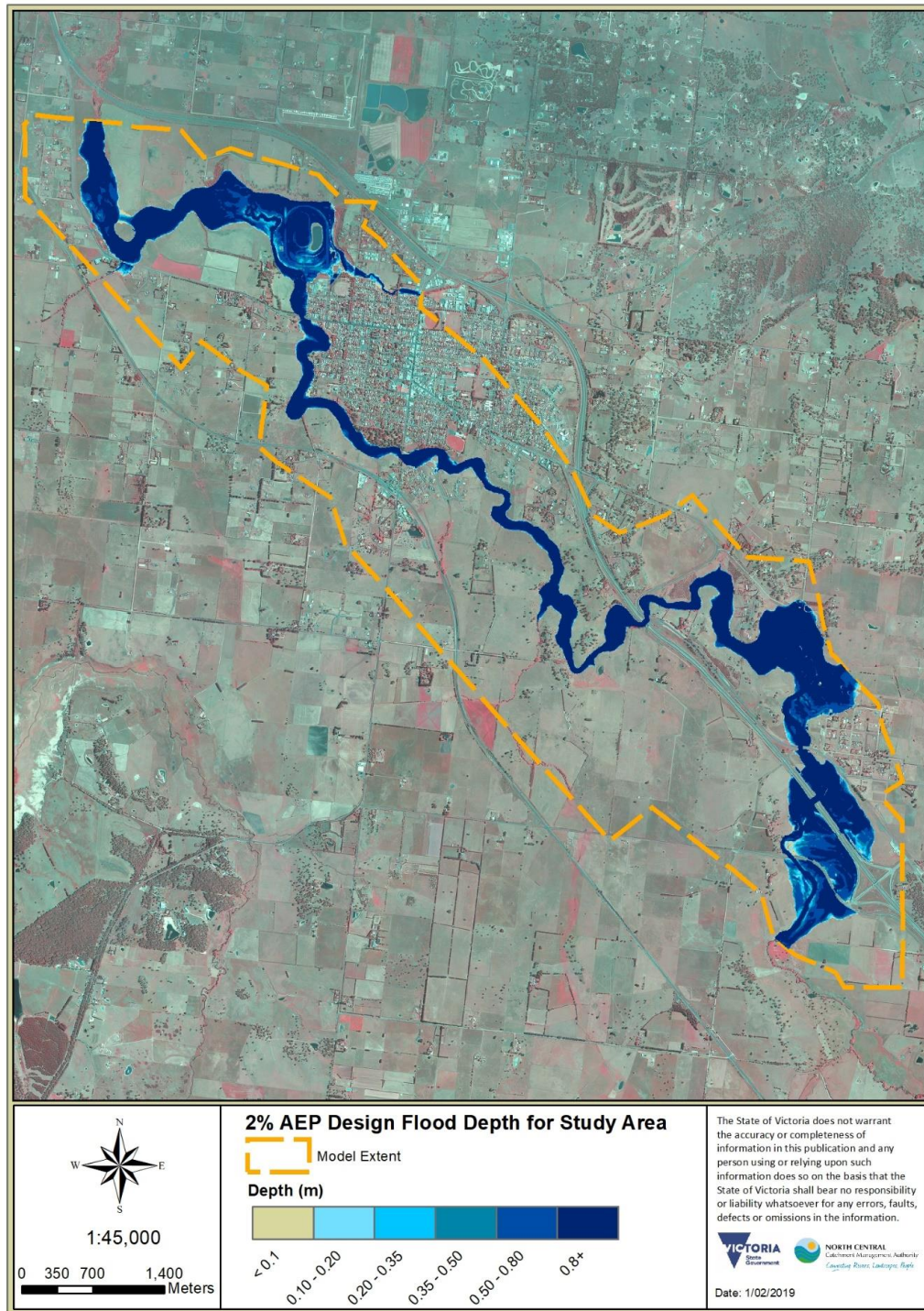


Figure 7-6 5% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-7** 2% AEP design flood depth for study extent



## KYNETON FLOOD STUDY

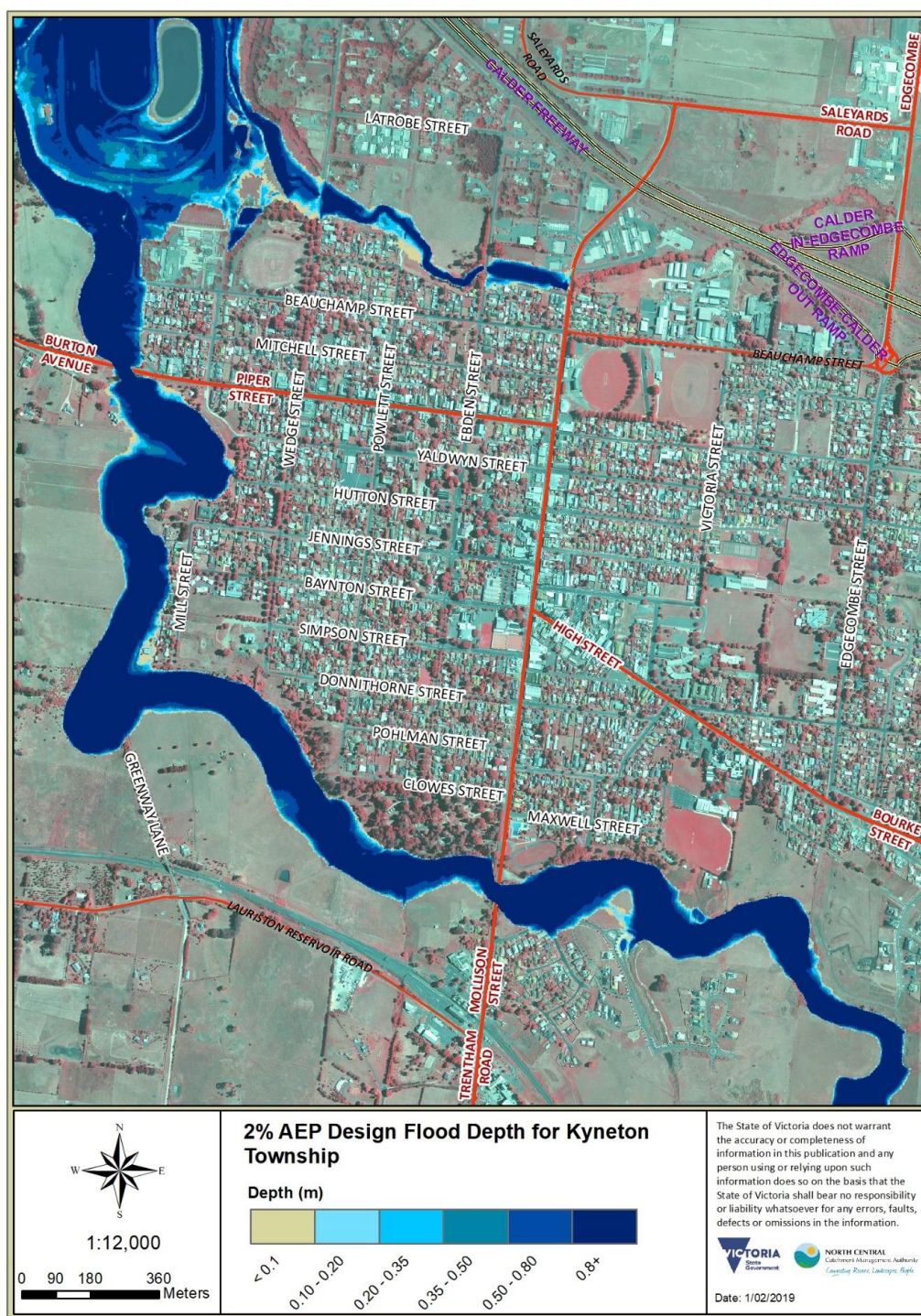
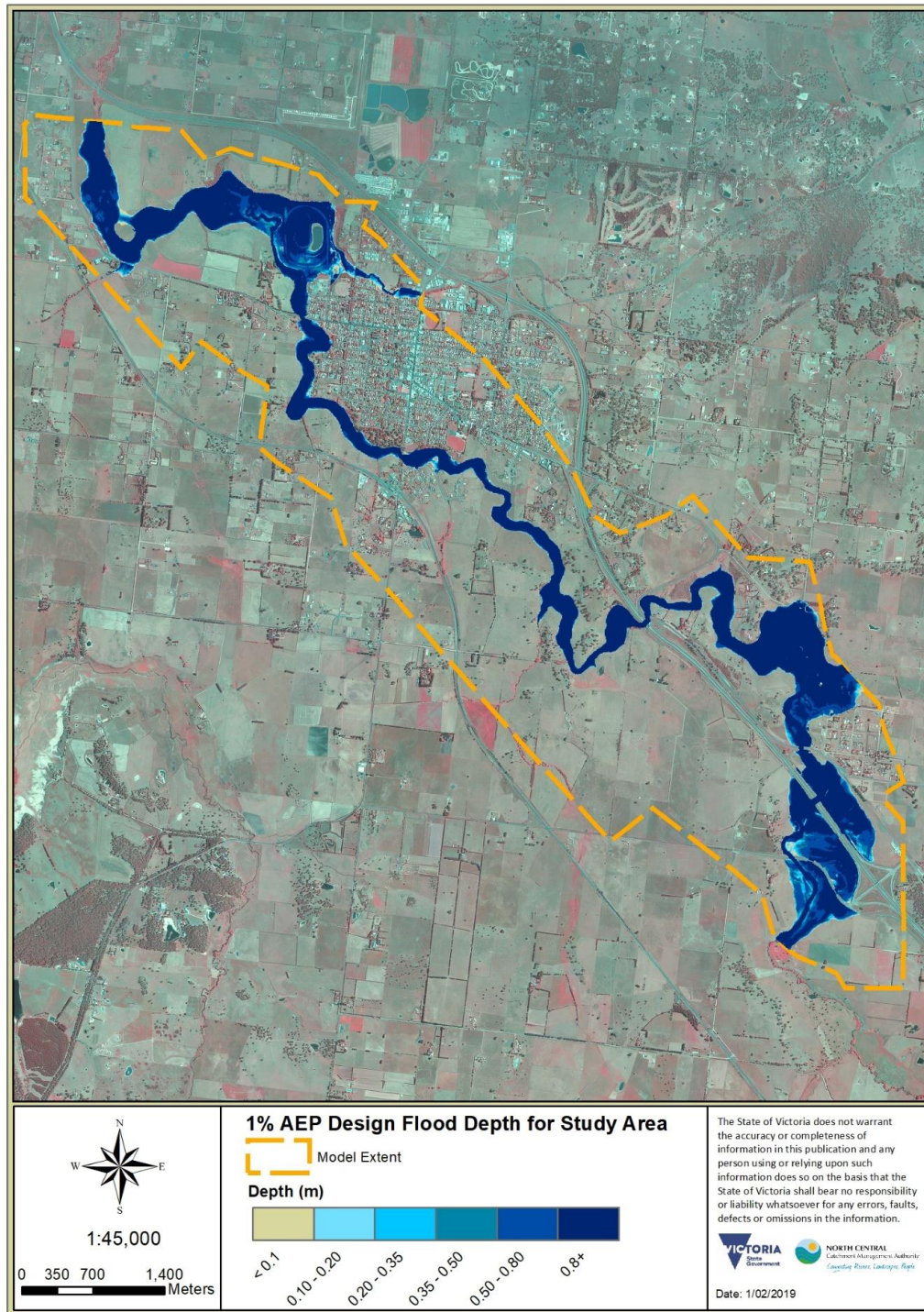


Figure 7-8 2% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-9** 1% AEP design flood depth for study extent



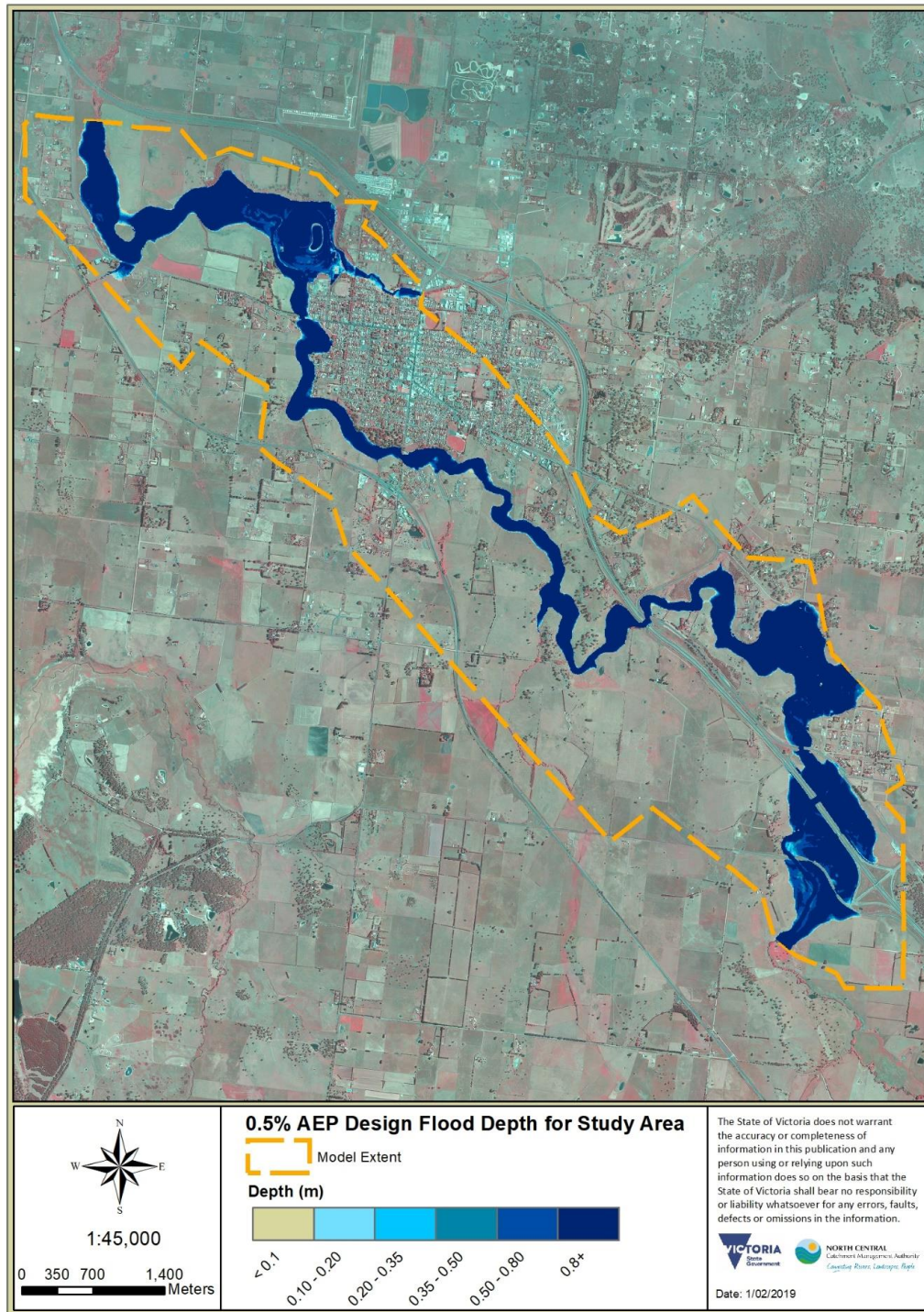
## KYNETON FLOOD STUDY



Figure 7-10 1% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-11 0.5% AEP design flood depth for study extent**



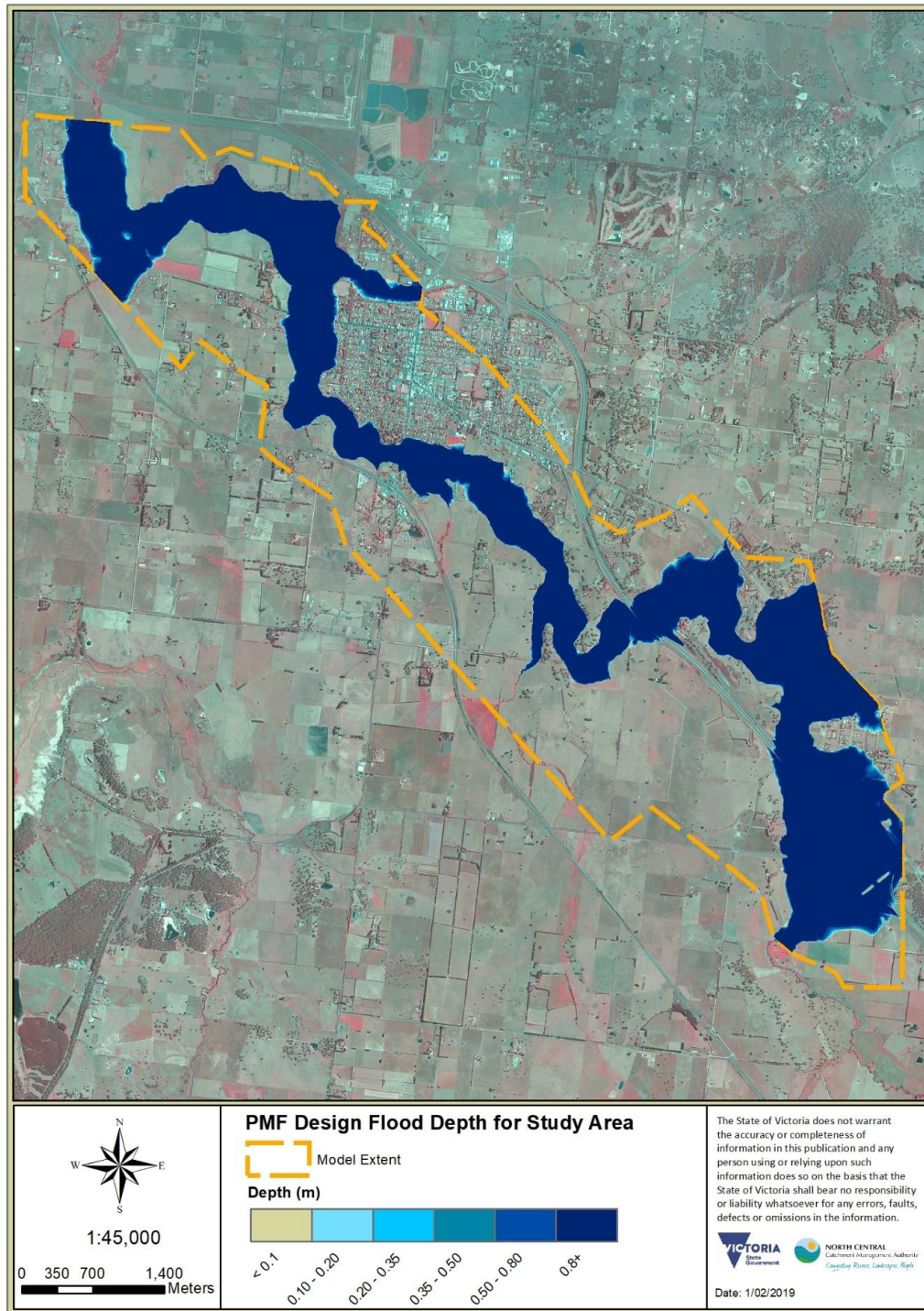
## KYNETON FLOOD STUDY



Figure 7-12 0.5% AEP design flood depth for Kyneton Township



## KYNETON FLOOD STUDY



**Figure 7-13** PMF design flood depth for study extent



## KYNETON FLOOD STUDY

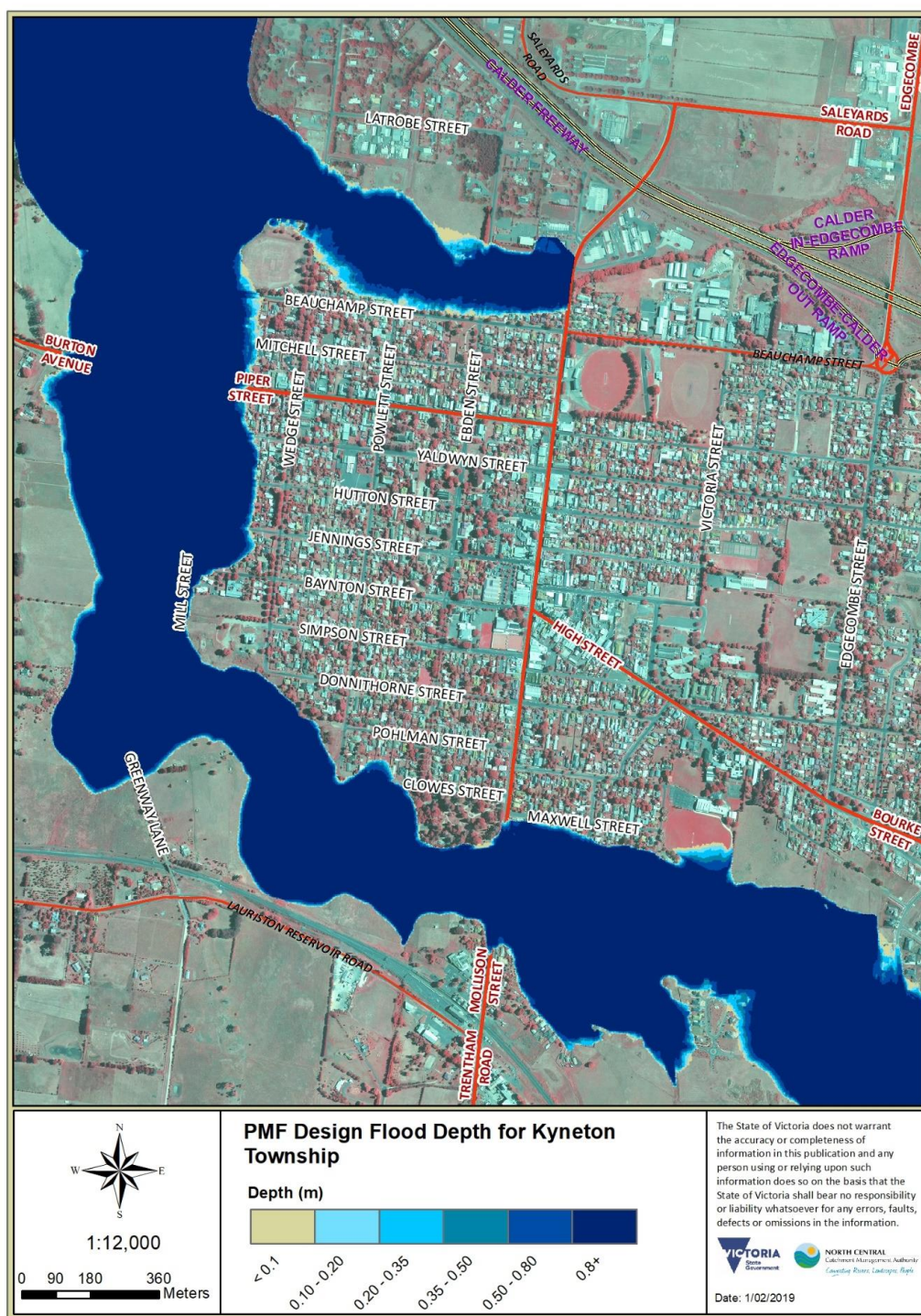


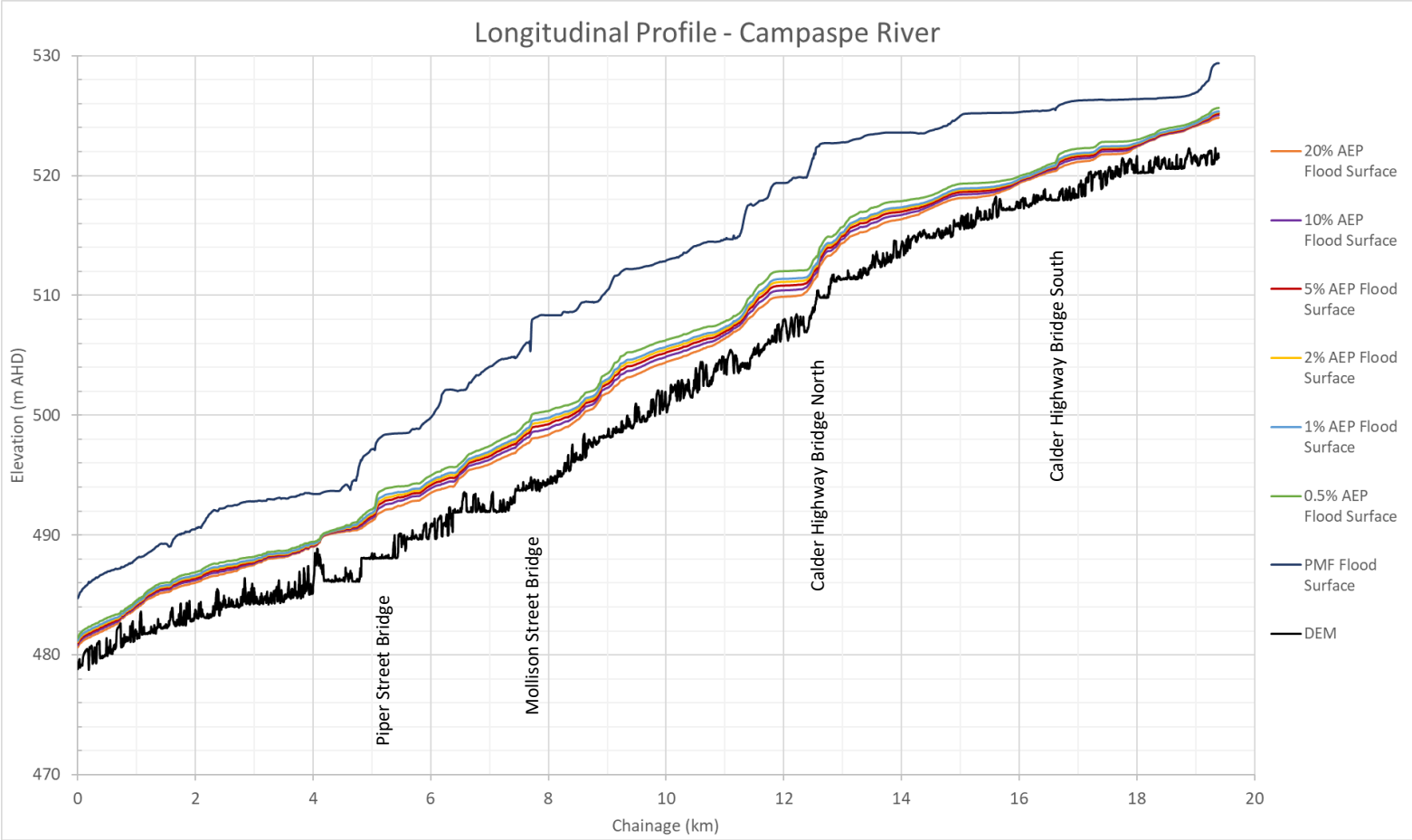
Figure 7-14 PMF design flood depth for Kyneton Township



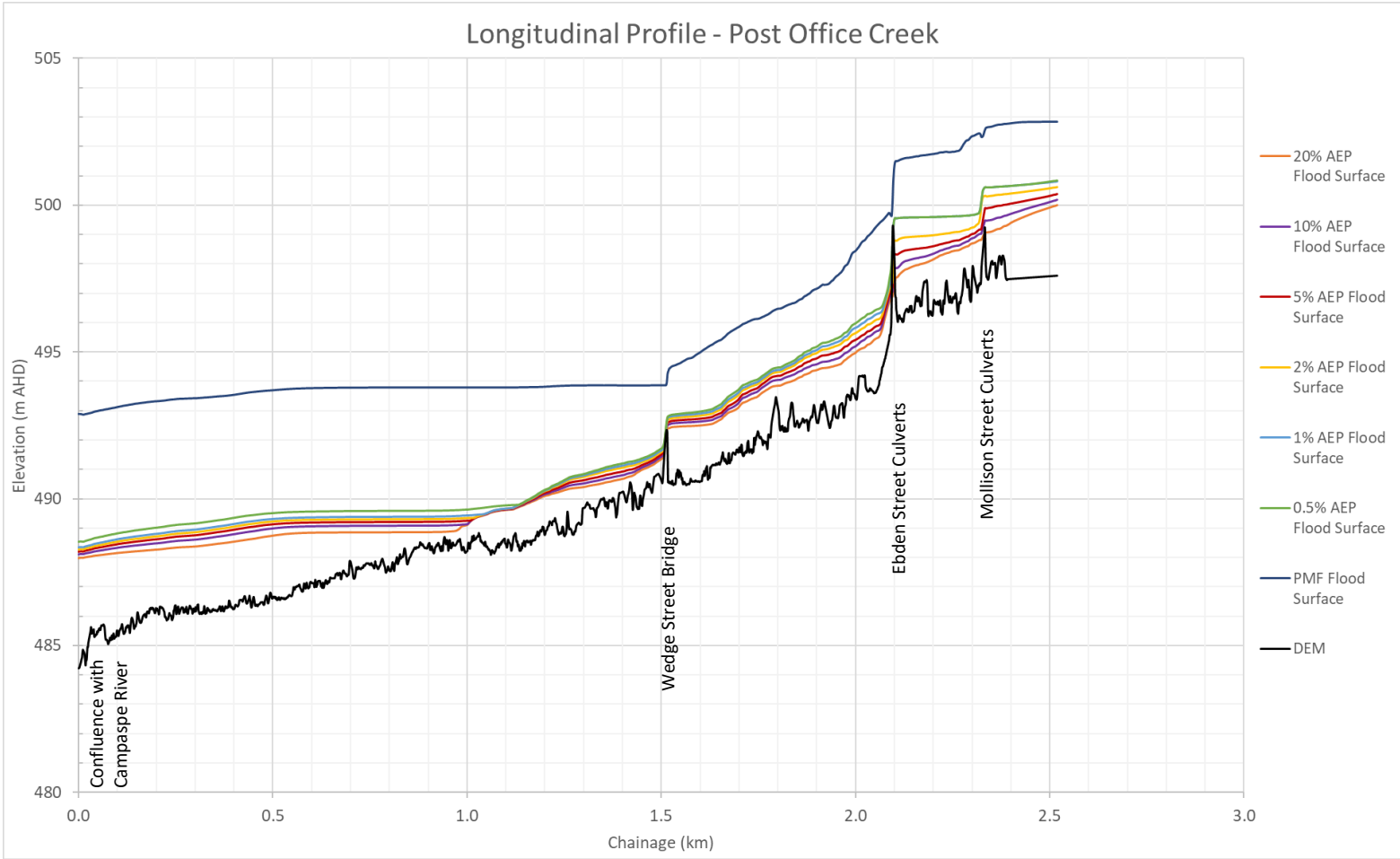
## KYNETON FLOOD STUDY

**7.2 Longitudinal Profiles (20% to 0.5% AEP Flood Events)**

KYNETON FLOOD STUDY



KYNETON FLOOD STUDY



KYNETON FLOOD STUDY

7.3 Data Hub

7.3.1 Redesdale Data Hub Information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	144.522
Latitude	-37.23
Selected Regions (clear)	
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
Interim Climate Change Factors	show
Baseflow Factors	show

Region Information

Data Category	Region
River Region	Campaspe River
ARF Parameters	Southern Temperate

## KYNETON FLOOD STUDY

## Data

## ARF Parameters

## Long Duration ARF

$$\text{Areal reduction factor} = \text{Min} \left\{ 1, \left[ 1 - a \left( \text{Area}^b - c \log_{10} \text{Duration} \right) \text{Duration}^{-d} \right. \right. \\ \left. \left. + e \text{Area}^f \text{Duration}^g \left( 0.3 + \log_{10} \text{AEP} \right) \right. \right. \\ \left. \left. + h 10^{i \text{Area} \frac{\text{Duration}}{1440}} \left( 0.3 + \log_{10} \text{AEP} \right) \right] \right\}$$

Zone	Southern Temperate
a	1.58E-01
b	2.76E-01
c	3.72E-01
d	3.15E-01
e	1.41E-04
f	4.10E-01
g	1.50E-01
h	1.00E-02
i	-2.70E-03

## Short Duration ARF

$$\text{ARF} = \text{Min} \left[ 1, 1 - 0.287 \left( \text{Area}^{0.265} - 0.439 \log_{10}(\text{Duration}) \right) \cdot \text{Duration}^{-0.36} \right. \\ \left. + 2.26 \times 10^{-3} \times \text{Area}^{0.226} \cdot \text{Duration}^{0.125} \left( 0.3 + \log_{10}(\text{AEP}) \right) \right. \\ \left. + 0.0141 \times \text{Area}^{0.213} \times 10^{-0.021 \frac{(\text{Duration} - 180)^2}{1440}} \left( 0.3 + \log_{10}(\text{AEP}) \right) \right]$$

## Layer Info

Time Accessed	08 June 2017 03:20PM
---------------	----------------------



## KYNETON FLOOD STUDY

Version	2016_v1
---------	---------

## Storm Losses

Storm Initial Losses (mm)	28.0
Storm Continuing Losses (mm/h)	4.0

## Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

## Temporal Patterns | Download (.zip)

CODE	MB
LABEL	Murray Basin

## Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

## Areal Temporal Patterns | Download (.zip)

CODE	MB
LABEL	Murray Basin

## KYNETON FLOOD STUDY

## Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

## Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP (%)	50	20	10	5	2	1
60 (1.0)	3.2 (0.198)	3.0 (0.127)	2.8 (0.098)	2.6 (0.077)	1.8 (0.043)	1.2 (0.024)
90 (1.5)	2.4 (0.125)	2.3 (0.085)	2.2 (0.068)	2.1 (0.055)	1.4 (0.03)	0.9 (0.017)
120 (2.0)	3.6 (0.175)	3.4 (0.118)	3.3 (0.093)	3.2 (0.075)	1.9 (0.038)	1.0 (0.017)
180 (3.0)	3.3 (0.136)	3.4 (0.101)	3.4 (0.085)	3.5 (0.072)	5.6 (0.095)	7.1 (0.105)
360 (6.0)	1.6 (0.052)	2.0 (0.046)	2.2 (0.043)	2.4 (0.041)	4.4 (0.06)	5.9 (0.07)
720 (12.0)	0.4 (0.009)	1.3 (0.024)	1.9 (0.029)	2.6 (0.033)	4.4 (0.048)	5.8 (0.055)
1080 (18.0)	0.0 (0.001)	0.6 (0.009)	0.9 (0.012)	1.2 (0.014)	2.2 (0.021)	3.0 (0.025)
1440 (24.0)	0.0 (0.0)	0.2 (0.002)	0.3 (0.003)	0.4 (0.004)	0.6 (0.005)	0.7 (0.006)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

## KYNETON FLOOD STUDY

### Layer Info

Time Accessed	08 June 2017 03:20PM
---------------	----------------------

### 10% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
360 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

### Layer Info

Time Accessed	08 June 2017 03:20PM
---------------	----------------------

Version	2016_v1
---------	---------

## KYNETON FLOOD STUDY

## 25% Preburst Depths

min (h)\AEP (%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.001)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.001)	0.1 (0.001)
360 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

## Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

## KYNETON FLOOD STUDY

### 75% Preburst Depths

min (h) AEP(%)	50	20	10	5	2	1
60 (1.0)	12.8 (0.78)	14.9 (0.635)	16.3 (0.567)	17.6 (0.514)	14.9 (0.353)	12.9 (0.264)
90 (1.5)	10.9 (0.582)	13.2 (0.495)	14.6 (0.451)	16.0 (0.415)	14.8 (0.311)	13.9 (0.252)
120 (2.0)	12.9 (0.619)	15.4 (0.528)	17.0 (0.481)	18.6 (0.443)	17.1 (0.331)	16.0 (0.267)
180 (3.0)	13.6 (0.567)	14.5 (0.436)	15.1 (0.374)	15.6 (0.328)	20.7 (0.353)	24.5 (0.362)
360 (6.0)	8.7 (0.278)	13.1 (0.307)	16.1 (0.313)	18.9 (0.313)	21.7 (0.296)	23.8 (0.283)
720 (12.0)	6.4 (0.154)	10.0 (0.18)	12.4 (0.188)	14.8 (0.191)	18.9 (0.204)	22.1 (0.21)
1080 (18.0)	5.0 (0.103)	7.7 (0.119)	9.5 (0.124)	11.3 (0.126)	15.1 (0.142)	18.0 (0.15)
1440 (24.0)	2.9 (0.054)	4.0 (0.056)	4.8 (0.057)	5.5 (0.056)	9.0 (0.077)	11.6 (0.088)
2160 (36.0)	0.2 (0.003)	1.3 (0.016)	2.0 (0.021)	2.7 (0.024)	5.7 (0.043)	7.9 (0.053)
2880 (48.0)	0.0 (0.0)	0.4 (0.005)	0.7 (0.006)	0.9 (0.008)	2.3 (0.016)	3.4 (0.021)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.002)	0.6 (0.003)

### Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1



## KYNETON FLOOD STUDY

## 90% Preburst Depths

min (h) VAEP(%)	50	20	10	5	2	1
60 (1.0)	22.9 (1.397)	27.0 (1.152)	29.8 (1.036)	32.4 (0.945)	30.3 (0.716)	28.7 (0.586)
90 (1.5)	21.9 (1.164)	25.7 (0.967)	28.2 (0.87)	30.7 (0.793)	29.0 (0.609)	27.8 (0.504)
120 (2.0)	24.8 (1.194)	29.2 (1.004)	32.2 (0.908)	35.0 (0.831)	41.1 (0.793)	45.7 (0.761)
180 (3.0)	24.6 (1.024)	28.3 (0.85)	30.8 (0.764)	33.1 (0.694)	43.4 (0.74)	51.1 (0.754)
360 (6.0)	22.3 (0.709)	28.0 (0.654)	31.7 (0.619)	35.3 (0.587)	43.0 (0.587)	48.7 (0.58)
720 (12.0)	27.1 (0.655)	29.8 (0.534)	31.5 (0.476)	33.2 (0.43)	38.6 (0.417)	42.7 (0.405)
1080 (18.0)	17.3 (0.358)	20.0 (0.308)	21.8 (0.283)	23.5 (0.263)	28.9 (0.272)	33.0 (0.275)
1440 (24.0)	16.2 (0.304)	18.8 (0.262)	20.5 (0.241)	22.2 (0.225)	26.9 (0.23)	30.4 (0.231)
2160 (36.0)	5.3 (0.087)	9.9 (0.121)	12.9 (0.133)	15.8 (0.141)	24.9 (0.188)	31.7 (0.214)
2880 (48.0)	4.0 (0.061)	6.6 (0.075)	8.4 (0.08)	10.0 (0.083)	18.4 (0.128)	24.7 (0.154)
4320 (72.0)	1.4 (0.019)	3.0 (0.031)	4.1 (0.035)	5.1 (0.038)	12.5 (0.079)	18.0 (0.101)

## Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

## KYNETON FLOOD STUDY

### Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	RCP 8.5
2030	0.85 (4.3%)	0.845 (4.2%)	0.974 (4.9%)
2040	1.086 (5.4%)	1.05 (5.3%)	1.341 (6.7%)
2050	1.303 (6.5%)	1.283 (6.4%)	1.734 (8.7%)
2060	1.478 (7.4%)	1.539 (7.7%)	2.212 (11.1%)
2070	1.629 (8.1%)	1.775 (8.9%)	2.753 (13.8%)
2080	1.741 (8.7%)	2.036 (10.2%)	3.26 (16.3%)
2090	1.793 (9.0%)	2.316 (11.6%)	3.748 (18.7%)

### Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

### Baseflow Factors

DOWNSTREAM	11070.0
AREA_SQKM	741.635
CATCH_NO	11088.0
R3RUNOFF	0.096
R1RUNOFF	0.02

KYNETON FLOOD STUDY

Layer Info

Time Accessed	08 June 2017 03:20PM
Version	2016_v1

Download TXT

Download PDF

KYNETON FLOOD STUDY

7.3.2 Kyneton Data Hub Information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	144.503
Latitude	-37.349
Selected Regions	
ARF Parameters	
Temporal Patterns	
Areal Temporal Patterns	
Interim Climate Change Factors	
Baseflow Factors	

Region Information

Data Category	Region
River Region	Campaspe River
ARF Parameters	Southern Temperate
Temporal Patterns	Murray Basin

## KYNETON FLOOD STUDY

### Data

#### ARF Parameters

##### Long Duration ARF

$$\text{Areal reduction factor} = \text{Min} \left\{ 1, \left[ 1 - a \left( \text{Area}^b - \log_{10} \text{Duration} \right) \text{Duration}^{-d} \right. \right. \\ \left. \left. + e \text{Area}^f \text{Duration}^g \left( 0.3 + \log_{10} \text{AEP} \right) \right. \right. \\ \left. \left. + h 10^{i \text{Area} \frac{\text{Duration}}{1440}} \left( 0.3 + \log_{10} \text{AEP} \right) \right] \right\}$$

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

##### Short Duration ARF

$$\text{ARF} = \text{Min} \left[ 1, 1 - 0.287 \left( \text{Area}^{0.265} - 0.439 \log_{10}(\text{Duration}) \right) \cdot \text{Duration}^{-0.36} \right. \\ \left. + 2.26 \times 10^{-3} \times \text{Area}^{0.226} \cdot \text{Duration}^{0.125} \left( 0.3 + \log_{10}(\text{AEP}) \right) \right. \\ \left. + 0.0141 \times \text{Area}^{0.213} \times 10^{-0.021 \frac{(\text{Duration}-180)^2}{1440}} \left( 0.3 + \log_{10}(\text{AEP}) \right) \right]$$

#### Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v1



## KYNETON FLOOD STUDY

## Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are NOT FOR USE in urban areas

Storm Initial Losses (mm)	28.0
Storm Continuing Losses (mm/h)	4.0

## Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v1

## Temporal Patterns

code	MB
Label	Murray Basin

## Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v2

## Areal Temporal Patterns

code	MB
arealabel	Murray Basin

## Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v2

## KYNETON FLOOD STUDY

## Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.2 (0.135)	2.0 (0.088)	1.9 (0.068)	1.8 (0.054)	1.5 (0.037)	1.3 (0.027)
90 (1.5)	3.1 (0.164)	2.8 (0.107)	2.6 (0.083)	2.5 (0.065)	1.9 (0.041)	1.5 (0.028)
120 (2.0)	3.0 (0.147)	2.6 (0.09)	2.3 (0.066)	2.0 (0.048)	1.9 (0.039)	1.9 (0.033)
180 (3.0)	3.5 (0.145)	3.2 (0.098)	3.1 (0.078)	2.9 (0.063)	5.1 (0.089)	6.7 (0.102)
360 (6.0)	1.4 (0.044)	1.6 (0.038)	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 (0.065)	6.0 (0.075)	7.5 (0.078)	8.7 (0.079)
1080 (18.0)	0.3 (0.005)	1.4 (0.02)	2.1 (0.026)	2.8 (0.03)	4.6 (0.041)	6.0 (0.047)
1440 (24.0)	0.0 (0.0)	1.1 (0.015)	1.8 (0.02)	2.6 (0.024)	3.1 (0.024)	3.4 (0.024)
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 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

## Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v2

## KYNETON FLOOD STUDY

### Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% Increase in rainfall)

	RCP 4.5	RCP6	RCP 8.5
2030	0.85 (4.3%)	0.845 (4.2%)	0.974 (4.9%)
2040	1.086 (5.4%)	1.05 (5.3%)	1.341 (6.7%)
2050	1.303 (6.5%)	1.283 (6.4%)	1.734 (8.7%)
2060	1.478 (7.4%)	1.539 (7.7%)	2.212 (11.1%)
2070	1.629 (8.1%)	1.775 (8.9%)	2.753 (13.8%)
2080	1.741 (8.7%)	2.036 (10.2%)	3.26 (16.3%)
2090	1.793 (9.0%)	2.316 (11.6%)	3.748 (18.7%)

### Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

### Baseflow Factors

downstream	11070
area_sqkm	741.6352
catch_no	11088
Volume Factor	0.09606
Peak Factor	0.019987

### Layer Info

Time Accessed	29 June 2017 01:08PM
Version	2016_v1

## KYNETON FLOOD STUDY

## 7.3.3 Post Office Creek Data Hub Information

**Australian Rainfall & Runoff Data Hub - Results****Input Data**

Longitude	144.479
Latitude	-37.243

**Selected Regions**

River Region
ARF Parameters
Temporal Patterns
Areal Temporal Patterns
Interim Climate Change Factors
Baseflow Factors

**Region Information**

Data Category	Region
River Region	Campaspe River
ARF Parameters	Southern Temperate
Temporal Patterns	Murray Basin

**Data****River Region**

division	Murray-Darling Basin
rivregnum	6
River Region	Campaspe River

**Layer Info**

Time Accessed	06 July 2017 09:44AM
Version	2016_v1

## KYNETON FLOOD STUDY

## ARF Parameters

## Long Duration ARF

$$\text{Areal reduction factor} = \text{Min} \left\{ 1, \left[ 1 - a \left( \text{Area}^b - \log_{10} \text{Duration} \right) \text{Duration}^{-d} \right. \right. \\ \left. \left. + e \text{Area}^f \text{Duration}^g \left( 0.3 + \log_{10} \text{AEP} \right) \right. \right. \\ \left. \left. + h 10^{i \text{Area} \frac{\text{Duration}}{1440}} \left( 0.3 + \log_{10} \text{AEP} \right) \right] \right\}$$

Zone	Southern Temperate
<b>a</b>	0.158
<b>b</b>	0.276
<b>c</b>	0.372
<b>d</b>	0.315
<b>e</b>	0.000141
<b>f</b>	0.41
<b>g</b>	0.15
<b>h</b>	0.01
<b>i</b>	-0.0027

## Short Duration ARF

$$\text{ARF} = \text{Min} \left[ 1, 1 - 0.287 \left( \text{Area}^{0.265} - 0.439 \log_{10} (\text{Duration}) \right) \cdot \text{Duration}^{-0.36} \right. \\ \left. + 2.26 \times 10^{-3} \times \text{Area}^{0.226} \cdot \text{Duration}^{0.125} \left( 0.3 + \log_{10} (\text{AEP}) \right) \right. \\ \left. + 0.0141 \times \text{Area}^{0.213} \times 10^{-0.021 \frac{(\text{Duration}-186)^2}{1440}} \left( 0.3 + \log_{10} (\text{AEP}) \right) \right]$$

## Layer Info

<b>Time Accessed</b>	06 July 2017 09:44AM
<b>Version</b>	2016_v1



## KYNETON FLOOD STUDY

## Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are NOT FOR USE in urban areas

Storm Initial Losses (mm)	28.0
Storm Continuing Losses (mm/h)	4.0

## Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v1

## Temporal Patterns

code	MB
Label	Murray Basin

## Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

## Areal Temporal Patterns

code	MB
arealabel	Murray Basin

## Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

## KYNETON FLOOD STUDY

### BOM IFD Depths

[Click here](#) to obtain the IFD depths for catchment centroid from the BoM website

### Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

### Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	3.1 (0.185)	2.7 (0.113)	2.4 (0.084)	2.2 (0.064)	1.6 (0.038)	1.2 (0.024)
90 (1.5)	2.4 (0.125)	2.5 (0.092)	2.5 (0.077)	2.6 (0.066)	1.8 (0.038)	1.3 (0.023)
120 (2.0)	3.5 (0.165)	3.1 (0.104)	2.8 (0.078)	2.5 (0.06)	1.9 (0.036)	1.4 (0.023)
180 (3.0)	3.2 (0.133)	3.2 (0.096)	3.2 (0.079)	3.2 (0.066)	5.6 (0.094)	7.4 (0.108)
360 (6.0)	1.4 (0.043)	1.6 (0.038)	1.8 (0.035)	2.0 (0.033)	4.8 (0.065)	6.9 (0.082)
720 (12.0)	0.3 (0.007)	2.0 (0.035)	3.1 (0.046)	4.1 (0.053)	5.9 (0.063)	7.2 (0.067)
1080 (18.0)	0.1 (0.003)	0.9 (0.014)	1.5 (0.019)	2.0 (0.022)	3.1 (0.029)	4.0 (0.033)
1440 (24.0)	0.0 (0.0)	0.5 (0.007)	0.9 (0.01)	1.2 (0.012)	1.6 (0.013)	1.8 (0.014)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.001)	0.3 (0.002)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

### Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

## KYNETON FLOOD STUDY

## 10% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
360 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

## Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

## KYNETON FLOOD STUDY

### 25% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.001)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.001)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.002)	0.0 (0.001)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.001)
360 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

### Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v2

## KYNETON FLOOD STUDY

## 75% Preburst Depths

min (h)\AEP (%)	50	20	10	5	2	1
60 (1.0)	11.7 (0.708)	14.0 (0.594)	15.6 (0.539)	17.1 (0.495)	14.7 (0.344)	12.9 (0.261)
90 (1.5)	10.7 (0.567)	13.1 (0.491)	14.7 (0.451)	16.3 (0.417)	14.9 (0.31)	13.9 (0.249)
120 (2.0)	12.9 (0.614)	14.9 (0.508)	16.3 (0.456)	17.6 (0.415)	16.7 (0.32)	16.1 (0.266)
180 (3.0)	13.4 (0.55)	14.4 (0.43)	15.2 (0.373)	15.8 (0.329)	20.5 (0.346)	23.9 (0.35)
360 (6.0)	9.1 (0.285)	13.2 (0.305)	15.9 (0.307)	18.5 (0.304)	21.9 (0.296)	24.4 (0.287)
720 (12.0)	6.2 (0.147)	10.5 (0.186)	13.4 (0.2)	16.2 (0.206)	21.4 (0.228)	25.4 (0.238)
1080 (18.0)	4.3 (0.087)	8.1 (0.122)	10.6 (0.136)	13.0 (0.143)	16.8 (0.155)	19.6 (0.161)
1440 (24.0)	2.8 (0.052)	4.8 (0.066)	6.1 (0.07)	7.3 (0.073)	10.8 (0.091)	13.4 (0.1)
2160 (36.0)	1.8 (0.029)	2.8 (0.034)	3.5 (0.035)	4.2 (0.036)	7.3 (0.054)	9.7 (0.064)
2880 (48.0)	0.1 (0.001)	0.6 (0.006)	0.9 (0.008)	1.2 (0.009)	2.8 (0.019)	4.0 (0.025)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.6 (0.004)	1.0 (0.005)

## Layer Info

Time Accessed 06 July 2017 09:44AM

Version 2016\_v2



## KYNETON FLOOD STUDY

## 90% Preburst Depths

min (h)\AEP (%)	50	20	10	5	2	1
60 (1.0)	22.4 (1.359)	27.3 (1.154)	30.5 (1.052)	33.6 (0.97)	29.3 (0.686)	26.1 (0.528)
90 (1.5)	23.0 (1.215)	26.7 (0.994)	29.1 (0.888)	31.4 (0.804)	28.9 (0.6)	27.0 (0.484)
120 (2.0)	24.4 (1.164)	28.0 (0.954)	30.4 (0.851)	32.7 (0.77)	41.8 (0.8)	48.7 (0.803)
180 (3.0)	23.5 (0.968)	27.8 (0.827)	30.6 (0.754)	33.4 (0.693)	42.9 (0.726)	50.0 (0.732)
360 (6.0)	23.6 (0.74)	29.4 (0.68)	33.3 (0.643)	37.0 (0.608)	45.5 (0.615)	51.9 (0.611)
720 (12.0)	21.9 (0.522)	29.5 (0.523)	34.6 (0.514)	39.4 (0.503)	44.5 (0.474)	48.4 (0.454)
1080 (18.0)	16.3 (0.331)	20.3 (0.307)	22.9 (0.293)	25.4 (0.28)	31.3 (0.29)	35.7 (0.293)
1440 (24.0)	14.7 (0.271)	19.3 (0.264)	22.3 (0.258)	25.2 (0.252)	28.9 (0.243)	31.7 (0.237)
2160 (36.0)	11.7 (0.189)	14.9 (0.178)	17.0 (0.172)	19.0 (0.166)	26.1 (0.194)	31.5 (0.208)
2880 (48.0)	9.4 (0.14)	10.5 (0.116)	11.2 (0.104)	11.9 (0.096)	20.2 (0.138)	26.4 (0.161)
4320 (72.0)	1.9 (0.026)	5.8 (0.058)	8.3 (0.07)	10.7 (0.079)	17.0 (0.105)	21.7 (0.12)

## Layer Info

Time Accessed 06 July 2017 09:44AM

Version 2016\_v2

## KYNETON FLOOD STUDY

### Interim Climate Change Factors

Values are of the format temperature Increase in degrees Celcius (% Increase in rainfall)

	RCP 4.5	RCP6	RCP 8.5
2030	0.85 (4.3%)	0.845 (4.2%)	0.974 (4.9%)
2040	1.086 (5.4%)	1.05 (5.3%)	1.341 (6.7%)
2050	1.303 (6.5%)	1.283 (6.4%)	1.734 (8.7%)
2060	1.478 (7.4%)	1.539 (7.7%)	2.212 (11.1%)
2070	1.629 (8.1%)	1.775 (8.9%)	2.753 (13.8%)
2080	1.741 (8.7%)	2.036 (10.2%)	3.26 (16.3%)
2090	1.793 (9.0%)	2.316 (11.6%)	3.748 (18.7%)

### Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

### Baseflow Factors

downstream	11070
area_sqkm	741.6352
catch_no	11088
Volume Factor	0.09606
Peak Factor	0.019987

### Layer Info

Time Accessed	06 July 2017 09:44AM
Version	2016_v1



## Rapid Flood Risk Assessment - North Central CMA Region

Malmsbury

Version 2

22/04/2020

Rapid Flood Risk Assessment - North  
Central CMA Region  
Malmsbury



## Contents

<b>1.</b>	<b>Introduction</b>	<b>4</b>
<b>2.</b>	<b>Available Data</b>	<b>8</b>
2.1	Information Used in Hydrological Analysis	8
2.1.1	Previous Hydrological models	8
2.2	Information Used in Hydraulic Analysis	8
2.2.1	Hydraulic Structures	8
2.2.2	Topographic Data	9
2.3	Previous Flood Studies	9
<b>3.</b>	<b>Hydrologic model development</b>	<b>10</b>
3.1	Malmsbury RORB model	11
<b>4.</b>	<b>Design hydrology approach and inputs</b>	<b>15</b>
4.1	Overview of adopted design flood approach	15
4.2	Overview of design flood hydrology inputs	18
4.2.1	Rainfall depths	19
4.2.2	Areal reduction factors	19
4.2.3	Spatial patterns	20
4.2.4	Temporal patterns	20
4.2.5	Losses	21
4.2.6	Pre-burst rainfall depths and temporal patterns	22
4.2.7	Baseflow	23
4.2.8	Drawdown	23
<b>5.</b>	<b>Hydrologic model verification</b>	<b>27</b>
5.1	Adopted parameters	27
5.2	Verification	27
5.3	Comparison to regional parameters	28
<b>6.</b>	<b>Design flood hydrology</b>	<b>30</b>
6.1	Design flows for the 20% to 0.5% AEP events	30
6.2	PMF estimate	30
6.3	Climate change and sensitivity analysis	32
<b>7.</b>	<b>Hydraulic Model</b>	<b>35</b>
7.1	Topography	35
7.2	Cell size	35
7.3	Roughness values	35
7.4	Hydraulic structures	38
7.5	Inflows	38

Rapid Flood Risk Assessment - North  
Central CMA Region  
Malmsbury



7.6	Downstream boundary	38
8.	Flood Risk Assessment	40
8.1	Flood Mapping	40
8.2	Flood behaviour and impact of flooding	41
8.3	Climate change	45
8.4	Flood Intelligence Information	46
8.5	Developing Indicative Quick Look Flood / No-Flood Tools	46
8.5.1	Guidance on the use of the Quick Look Flood / No flood Tool	47
8.5.1.1	In the lead up to a flood	47
8.5.1.2	During a flood - using the quick look tool	47
8.5.1.3	After a flood – updating the tool	48
8.5.1.4	Example use of the quick look tool	48
9.	Summary of rating of key areas	51
10.	Limitations	53
11.	Conclusion	54
12.	References	55
Appendix A	Maps	57



Rapid Flood Risk Assessment - North  
Central CMA Region  
Malmbsbury



### Document status

Client	North Central Catchment Management Authority
Project	Rapid Flood Risk Assessment - North Central CMA Region
Document	NCC00002_RFRA_NCC_15_Malmbsbury_Version2.docx
This version	Version 2
Authors	Tim Craig, Andrew Northfield
Project manager	Andrew Northfield
File name	S:\3_Projects\NCC00002\6_Deliverables\
Project number	NCC00002

### Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	06/01/2020	D. Stephens	D. Stephens	N. Treloar	For discussion
Version 1	12/03/2020	D. Stephens	D. Stephens	N. Treloar	
Version 2	22/04/2020	D. Stephens	D. Stephens	N. Treloar	Minor updates

### Copyright and Limitation

The report has been prepared based on the information and specifications provided to HARC by North Central Catchment Management Authority. HARC does not warrant this document as being complete, current or free from error and disclaims all liability for any loss, damage, costs or expenses (including consequential losses) relating from this report. It should only be used for its intended purpose by North Central Catchment Management Authority and should not be relied upon by third parties.



The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments.

This work is licensed under a Creative Commons Attribution 4.0 International licence. You are free to re-use the work under that licence, on the condition that you credit Hydrology and Risk Consulting Pty Ltd as author. The licence does not apply to any images, photographs or branding. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>

#### Acknowledgment of Country

We acknowledge Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

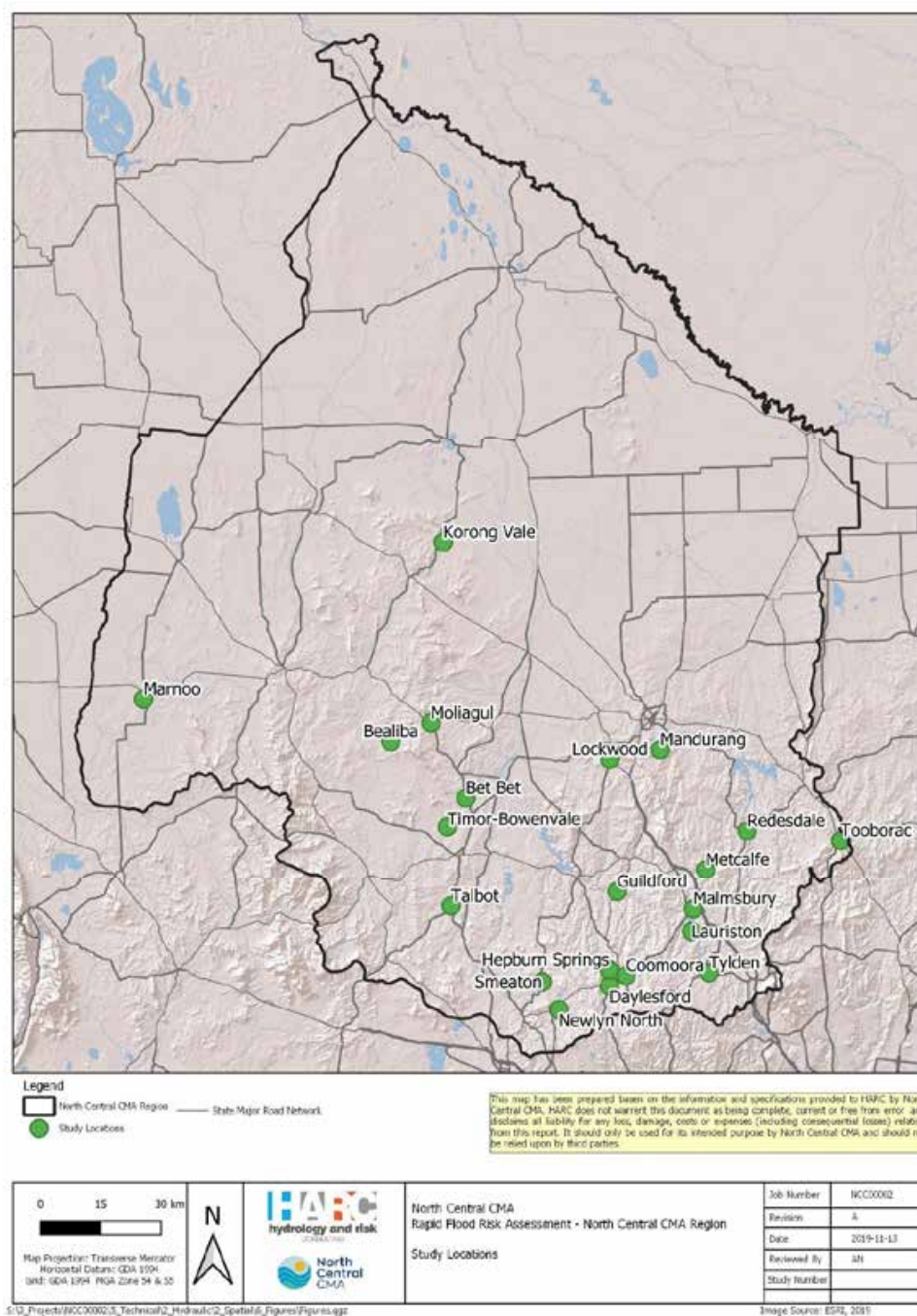
Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 1. Introduction

The North Central Catchment Management Authority (CMA) commissioned HARC to undertake a rapid flood risk assessment for 21 townships in the North Central CMA region. The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments. The study focused on providing mapped flood extents for a range of AEPs using a range of existing and new hydrologic and hydraulic models. The rapid nature of the assessment precluded detailed, site specific studies, extensive model calibration or community engagement. The outcomes of the study were used to provide preliminary estimates of flood risk at the 21 locations, and to help identify and prioritise areas where more detailed, site specific flood studies were recommended. The study locations are shown in Figure 1-1 and the list of townships is shown in Table 1-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



■ Figure 1-1 Rapid Flood Risk Assessment Project Study Locations

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



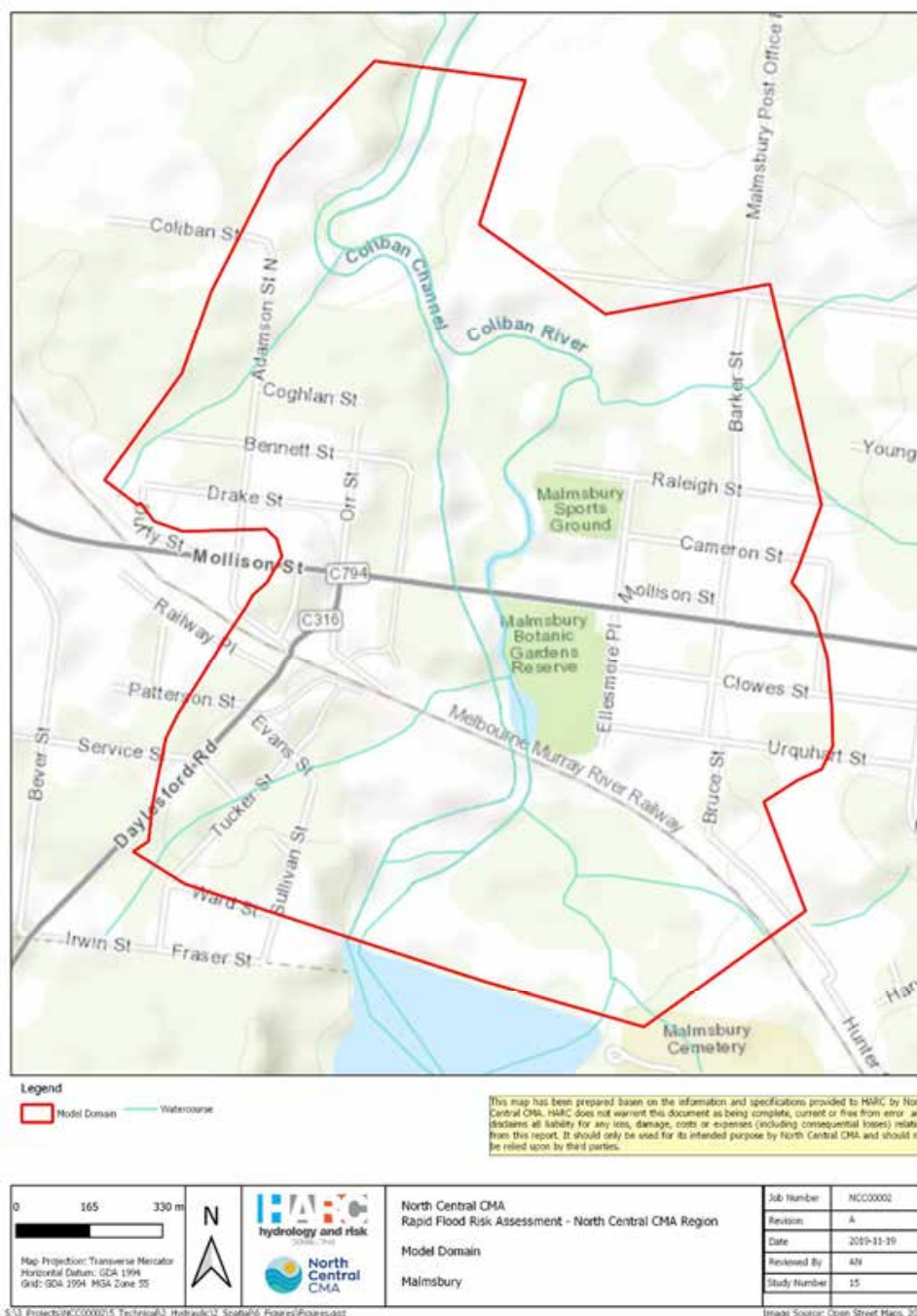
- **Table 1-1 List of Study Locations (Study Location in bold denotes the township covered in this report)**

No.	Name	No.	Name
1	Lockwood	12	Daylesford
2	Mandurang	13	Hepburn Springs
3	Redesdale	14	Korong Vale
4	Moliagul	<b>15</b>	<b>Malmsbury</b>
5	Bet Bet	16	Lauriston
6	Talbot	17	Tylden
7	Bealiba	18	Tooborac
8	Timor-Bowenvale	19	Guildford
9	Coomoora	20	Metcalfe
10	Newlyn North	21	Marnoo
11	Smeaton		

This report documents the investigation undertaken for the study location of Malmsbury.

Malmsbury has a population of approximately 831 and is located immediately downstream of Malmsbury Reservoir, approximately 54 km south-east of Bendigo. The Coliban River runs through the centre of the town, which has an upstream catchment area of 289 km<sup>2</sup>. The river channel is well defined within the study area. The Coliban River flow is significantly regulated by several large storages (Upper Coliban, Lauriston and Malmsbury Reservoir) upstream of the town. A map of the study area is shown in Figure 1-2.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



■ Figure 1-2 Malmbsbury study area



Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 2. Available Data

This section describes the key information used in the hydrological and hydraulic investigation.

### 2.1 Information Used in Hydrological Analysis

#### 2.1.1 Previous Hydrological models

There was a RORB model set up as part of the Upper Coliban Storages Hydrology update (SKM, 2010) which included Malmsbury. Table 2-1 summarises the key RORB parameters from the previous study.

■ **Table 2-1 Previous RORB model summary of key parameters**

No.	Study Area	Previous Study	$k_c$	$d_{av}$	$C_{0.8}$ ( $k_c/d_{av}$ )	IL (mm)	CL (mm/h)	Shire
15	Malmsbury	Upper Coliban Storages: Malmsbury Hydrology	60	23.8	2.5	45	3	Macedon Ranges

### 2.2 Information Used in Hydraulic Analysis

#### 2.2.1 Hydraulic Structures

There are several hydraulic structures located within the study area. The main structures are listed in Table 2-2 and the location of these structures is shown in Figure 7-2. There may be other minor crossings within the study area but they have been assessed as likely to have little/no impact on the flood extents. The North Central CMA approached three organisations to provide information on their bridges and culverts. The three organisations were:

- VicRoads;
- VicTrack; and
- Council

■ **Table 2-2 Summary of hydraulic structures for consideration**

No.	Township Name	Source	Structure Type	Description
15	Malmsbury	VicRoads	Bridge	Calder Hwy (SN0166)
		VicTrack	Bridge	Railway Crossing 1
		Estimated*	Bridge	Malmsbury Post Office Rd
		Estimated*	Culvert	Evans St
		Estimated*	Culvert	Railway Crossing 2
		Estimated*	Culvert	Calder Hwy

\* The structures without details were generally estimated based on the aerial image and street view from Google in conjunction with the existing information of the structures in the area.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



### 2.2.2 Topographic Data

To undertake detailed hydraulic modelling requires high quality ground surface information. For this study, aerial captured ground survey, LIDAR, was supplied by North Central CMA. The LIDAR was used to generate a Digital Elevation Model (DEM) of the study area. This LIDAR covered the whole model extent. Further information on the LiDAR dataset used for this study is provided in Section 7.1.

### 2.3 Previous Flood Studies

The North Central CMA provided a number of reports to provide background information for this project. The main reports relevant to this study area are listed in Table 2-3.

■ **Table 2-3 Summary of flood studies**

No.	Township Name	Previous Studies
15	Malmsbury	Rochester Flood Management Plan (2013), Water Technology

Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



### 3. Hydrologic model development

A rainfall runoff model (RORB) was established for the catchment, terminating at the study area downstream boundary (refer to Figure 1-2). RORB (Laurenson, Mein and Nathan, 2010) is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non-linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal spatial distribution of rainfall as well as losses, and can model flows at any number of points throughout a catchment (including upstream and downstream of reservoirs). RORB also has the capacity to use a Monte-Carlo approach to produce design flood estimates that incorporate the joint probability of several factors that influence flood characteristics.

In general terms, development of a RORB model entails sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storage locations.

Four different types of reaches can be defined in RORB, each having different properties and different relative delay times. The reach types are identified as natural, excavated but unlined, lined channel or pipe and drowned reaches. Drowned reaches were used within reservoir water bodies; natural reaches were used for all other reaches. Excavated and lined channel reaches are normally only applied in urbanised areas and hence were not used in this study.

Impervious fractions are required for each sub-area. For rural areas the impervious fraction was assumed to be zero. For any areas within a dam or reservoir water body, an impervious fraction was calculated based on the percentage of the sub-area that would be inundated. The RORB model also includes some urban areas. The total impervious area (TIA) was estimated for the urban areas using aerial photography and land use information. The Victorian Land Use Information System (VLUIS) dataset was used to define the land use. Because not all impervious areas are well connected to the drainage network (i.e. they flow onto pervious parts of the catchment), the effective impervious area (EIA) is less than the TIA. ARR2019 (Book 5, Chapter 5, Hill and Thomson, 2015) and Phillips et al. (2014) have consolidated the recommended industry practice for estimating EIA and loss parameters for the pervious portion of urban catchments. Phillips et al. (2014) analysed eight catchments and concluded that EIA is typically 55 to 65% of the TIA. ARR2019 recommends an EIA/TIA ratio of 60%. For the RORB model the TIA fraction was multiplied by 0.6 to estimate EIA. The EIA assigned to each land use is shown in Table 3-1.

■ Table 3-1 EIA assigned for each land use

Land Use Type	EIA
Residential areas – high density	0.45
Residential areas – low density	0.12
Industrial/commercial – low density	0.54

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



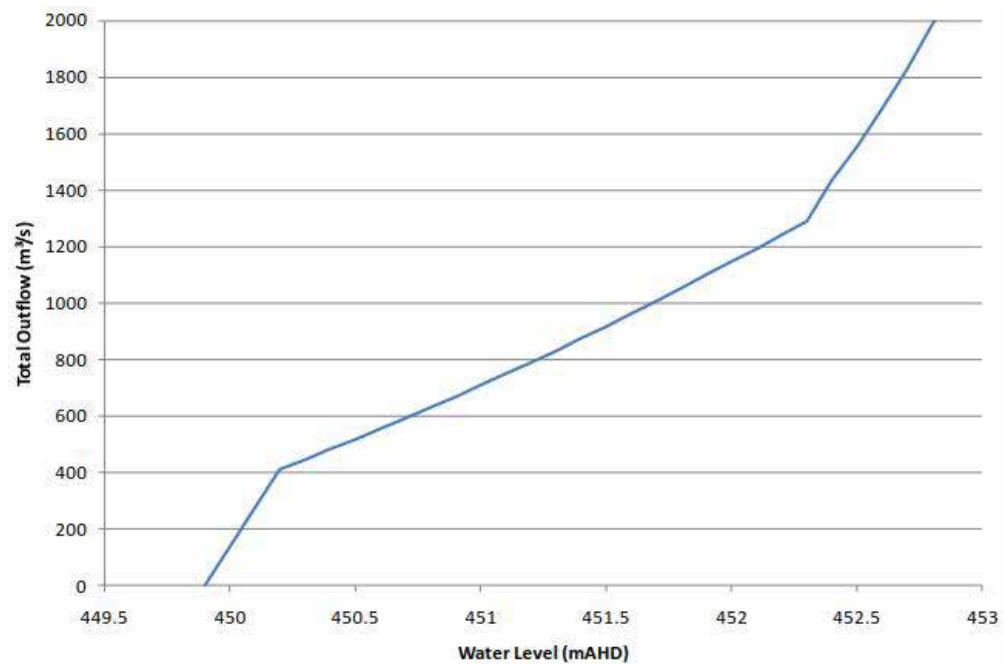
Land Use Type	EIA
Open space or waterway – minimal vegetation	0.0
Open space or waterway – moderate vegetation	0.0
Open space or waterway – heavy vegetation	0.0
Paved roads/car park/driveways	0.6
Railway line	0.6
Grass reserves/floodway (regularly mowed)	0.0
Rural floodplains in clear paddocks	0.0
Forested (heavy stand of timber)	0.0
Dam/Reservoir body of water	1.0

### 3.1 Malmsbury RORB model

The Malmsbury RORB model was based on the RORB model established by SKM for updating the hydrology for the Upper Coliban Storages Flood Hydrology (SKM, 2010). The subarea layout and reach types were adopted from this study. Some minor adjustments were made to the subareas within the study area to better represent the local catchment. The RORB model layout is shown in Figure 3-4.

Malmsbury, Lauriston and Upper Coliban storages were modelled as storages in RORB, with the elevation discharge relationships taken from SKM (2010). These relationships are shown in Figure 3-1, Figure 3-2 and Figure 3-3 respectively. The outflow from Lauriston and Malmsbury Dams is a function of gate operation. No information was provided on how the gates at Lauriston or Malmsbury are operated so for this investigation the same approach as SKM, 2010 was adopted. For Lauriston it is assumed that all gates are fully open when the reservoir has exceeded FSL (i.e. 479.5 m AHD) by more than 300mm. This is reflected by the straight line in the rating curve between an elevation of 479.5 and 479.8 m AHD. Similarly for Malmsbury it is assumed that the reservoir will rise 300 mm above FSL (i.e. 449.9 m AHD) before the gates are fully opened. In order to comment on the impact that this assumption has on flows out of the dams then details on the gate operations would need to be coded into the RORB model, which could be done as part of future, detailed flood studies.

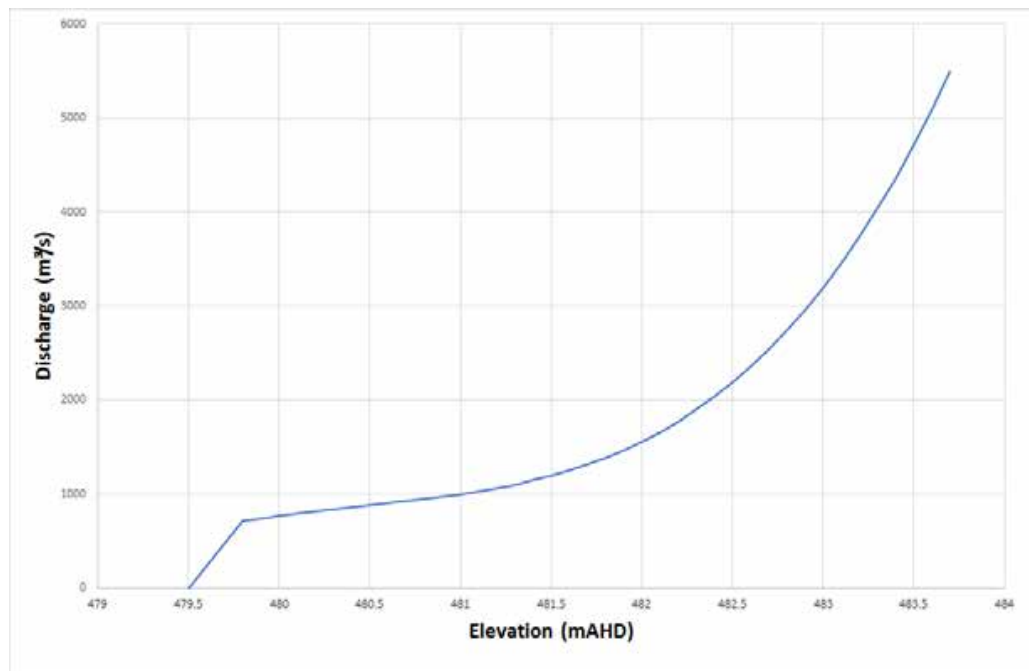
Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



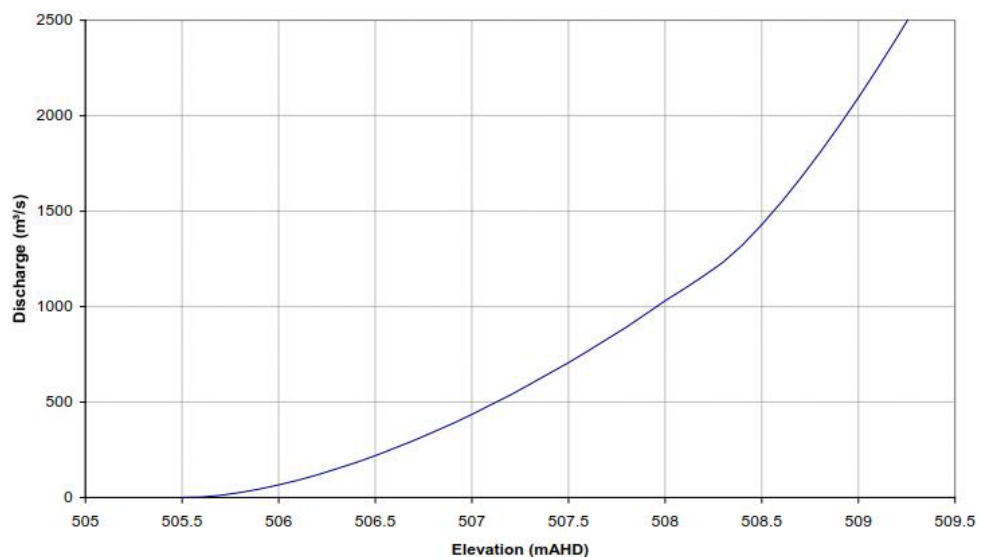
■ Figure 3-1 Elevation discharge relationship for Malmsbury Dam (SKM 2010)



Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury

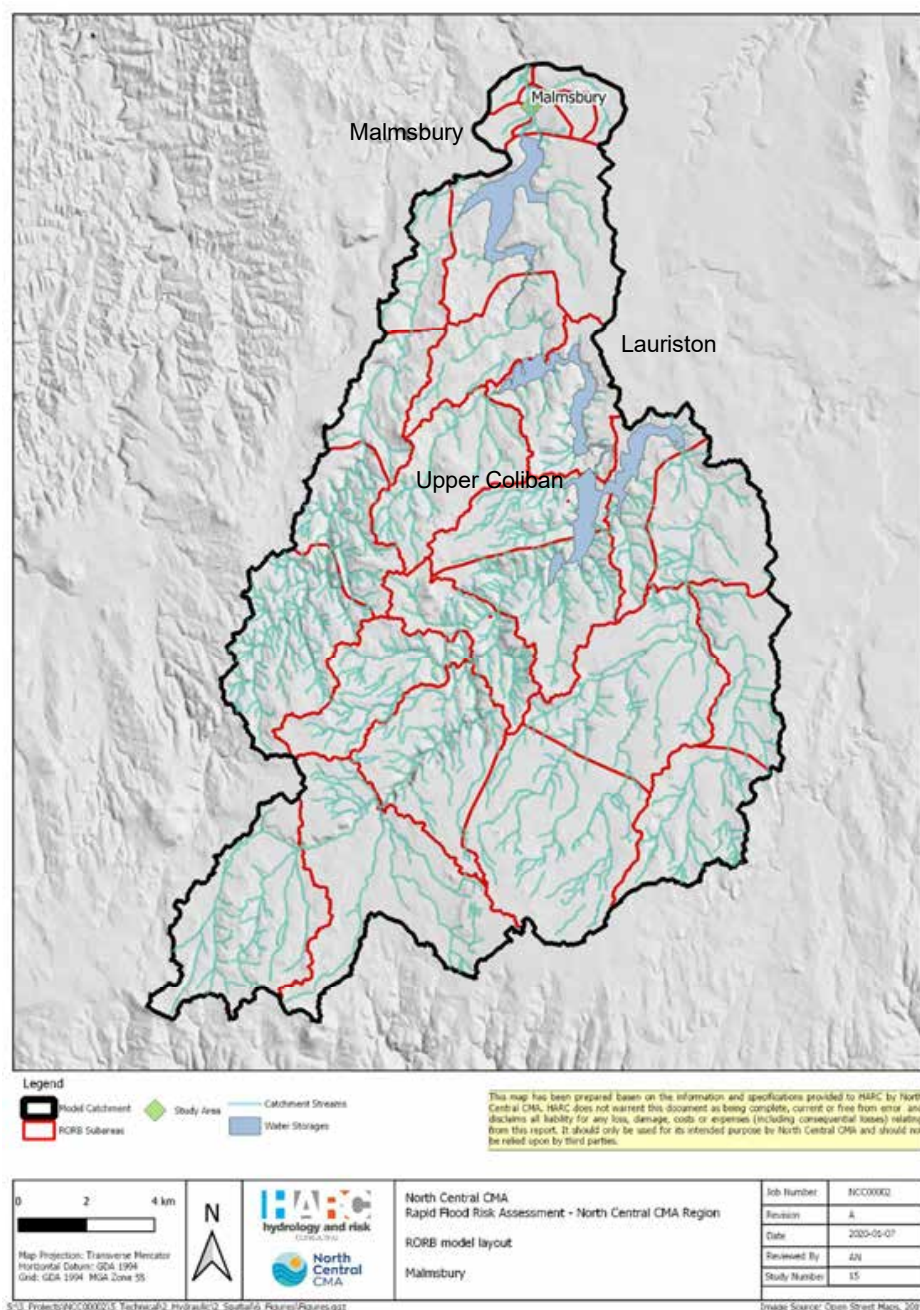


■ Figure 3-2 - Elevation discharge relationship for Lauriston Dam (SKM 2010)



■ Figure 3-3 - Elevation discharge relationship for Upper Coliban Dam (SKM 2010)

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ Figure 3-4 RORB model layout

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



## 4. Design hydrology approach and inputs

### 4.1 Overview of adopted design flood approach

The estimation of design floods has traditionally been based on the 'design event' approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 4-1 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are 'AEP-neutral', that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

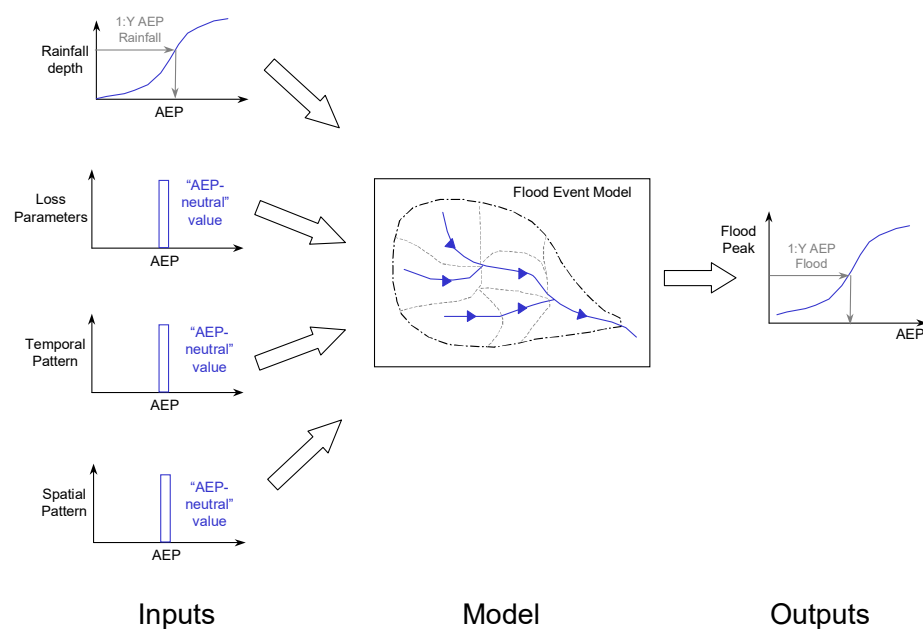
This approach suffers from the limitations that:

- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such as the variability in rainfall spatial and temporal pattern) becomes rapidly more complex and less easy to defend.

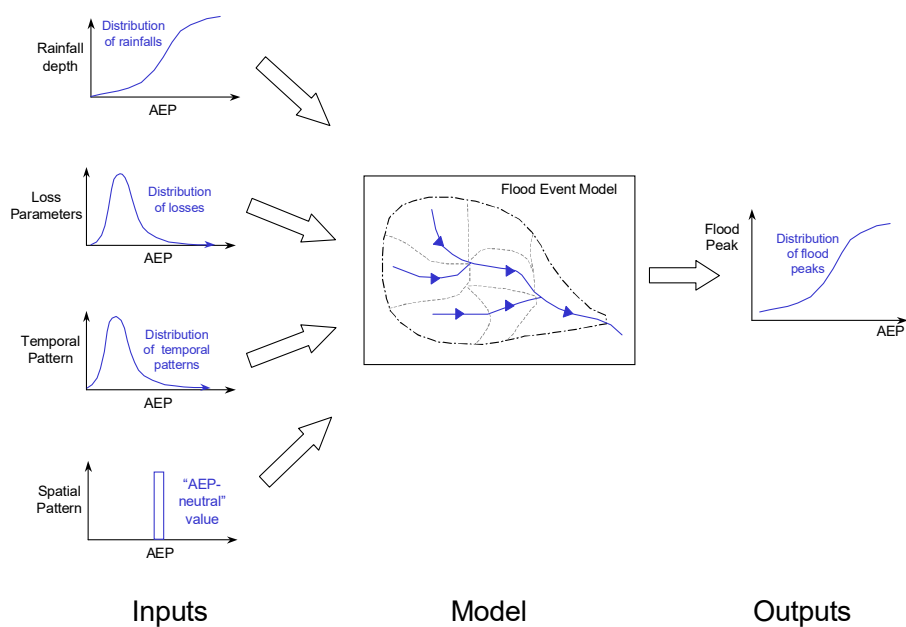
Joint probability techniques offer an improvement to the traditional design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated catchment, or a large storm on a dry catchment. In probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic 'mother nature' in that the influence of the key probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The application of joint probability approaches to flood estimation is widely acknowledged to be a more thorough and defensible approach to design flood estimation than the design event approach in Australian practice, and has been incorporated in the 2019 version of Australian Rainfall and Runoff (Ball et al., 2019).

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ **Figure 4-1 Schematic illustration of the design event approach**

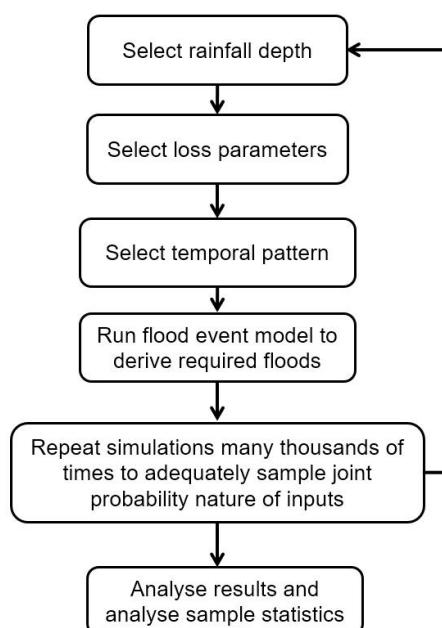


■ **Figure 4-2 Schematic illustration of the joint probability approach**

## Rapid Flood Risk Assessment - North Central CMA Region Malmesbury



The joint probability framework adopted for the study was developed by Nathan et al (2002, 2003) and is summarised in Figure 4-3. In essence the approach involves undertaking numerous model simulations, where the model inputs are sampled from non-parametric distributions that are based either on readily available design information or on the results of recent research. For those study areas where reservoir starting water level is applicable, the level in the storage is also sampled.



■ **Figure 4-3 Overview of adopted joint probability framework**

In developing the joint probability framework particular attention was given to ensuring that the model inputs and the manner in which they were incorporated was consistent with ARR (Ball et al., 2019). The following briefly describes the main inputs, and how they will relate to establishing design information.

*Select rainfall depth.* Rainfall depths were stochastically sampled from the cumulative distribution of rainfall depths.

*Select storm losses.* Storm initial losses were stochastically sampled from a nonparametric distribution that was determined from the analysis of a large number of catchments across Australia (Hill et al., 2014). The limited number of investigations that have explored the correlation between initial and continuing loss values have concluded that there is little systematic dependence between the two. There is little information regarding the correlation between initial and continuing loss rates, and since antecedent conditions have most influence on initial loss rates, in this study the continuing loss rates will be held constant. Current practice is for initial losses to



## Rapid Flood Risk Assessment - North Central CMA Region Maldenbury



be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

*Select temporal pattern.* Temporal patterns were randomly selected from a sample of temporal patterns relevant to the catchment area and duration of the storm. The temporal patterns in the data hub were derived from large historic storms that have been observed in the region.

*Monte-Carlo simulation.* Simulations were undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 100 probability of exceedance, a reduced number of simulations were undertaken over a specified number of probability intervals. In this study, the rainfall frequency curve was divided into 100 intervals uniformly spaced over the standardised normal probability domain, and 250 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered. This approach accounts for the natural variability inherent in floods. Monte Carlo techniques are grounded in, and consistent with, the principle that “no two floods are ever the same”.

The key advantage of the Monte Carlo approach is that it reduces uncertainty by accounting for variability. The results of a Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, however it must be remembered that the natural variability of the key inputs is built into these median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Using the technique described above hydrographs were produced for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

In the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994).

### 4.2 Overview of design flood hydrology inputs

Design inputs were produced in accordance with ARR2019. Inputs include:

- Rainfall depths (IFD - BOM),
- Areal reduction factors (Data hub),
- Spatial patterns (Rainfall depths over the catchment – based on IFD)
- Temporal patterns (Rainfall depths over time – Data hub)
- Losses (ARR guidance)
- Pre-burst (Data hub)
- Baseflow (ARR guidance)

## Rapid Flood Risk Assessment - North Central CMA Region Malmbsbury



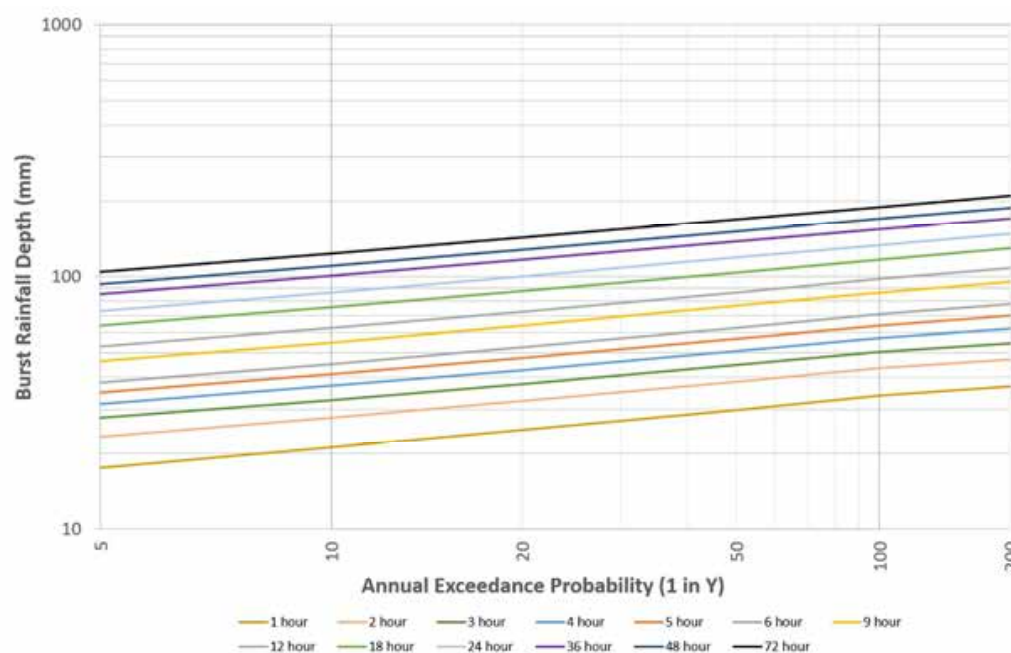
### 4.2.1 Rainfall depths

Catchment average point design rainfall depths for burst durations between 1 and 72 hours, and AEPs from 1 in 5 to 1 in 200, were taken from the Bureau of Meteorology (2016) (<http://www.bom.gov.au/water/designRainfalls/revise-ifd/>).

### 4.2.2 Areal reduction factors

The point rainfall estimates were converted to areal values using the ARR2019 areal reduction factors (Jordan et al, 2016) extracted from the ARR Data Hub. Conceptually, these factors account for the fact that larger catchments are less likely to experience high intensity storms over the whole catchment.

A summary of the complete, catchment average areally reduced design rainfall depths adopted are shown in Figure 4-4 and Table 4-1.



■ Figure 4-4 Adopted design rainfall depths

■ Table 4-1 Adopted design rainfall depths

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
5	17	23	28	31	35	38	46	53	64	73	85	94	105
10	21	28	33	37	41	45	55	63	76	87	101	111	124

Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
20	25	32	38	43	48	53	64	73	88	100	117	128	143
50	30	38	45	51	57	63	77	87	104	119	138	152	170
100	34	44	50	57	64	71	87	98	117	134	155	170	190
200	37	47	55	62	70	78	96	108	130	148	171	188	211

#### 4.2.3 Spatial patterns

The spatial pattern for the catchment has been based on the rainfall depths from the Bureau of Meteorology, i.e. the IFD, which is recommended in ARR2019.

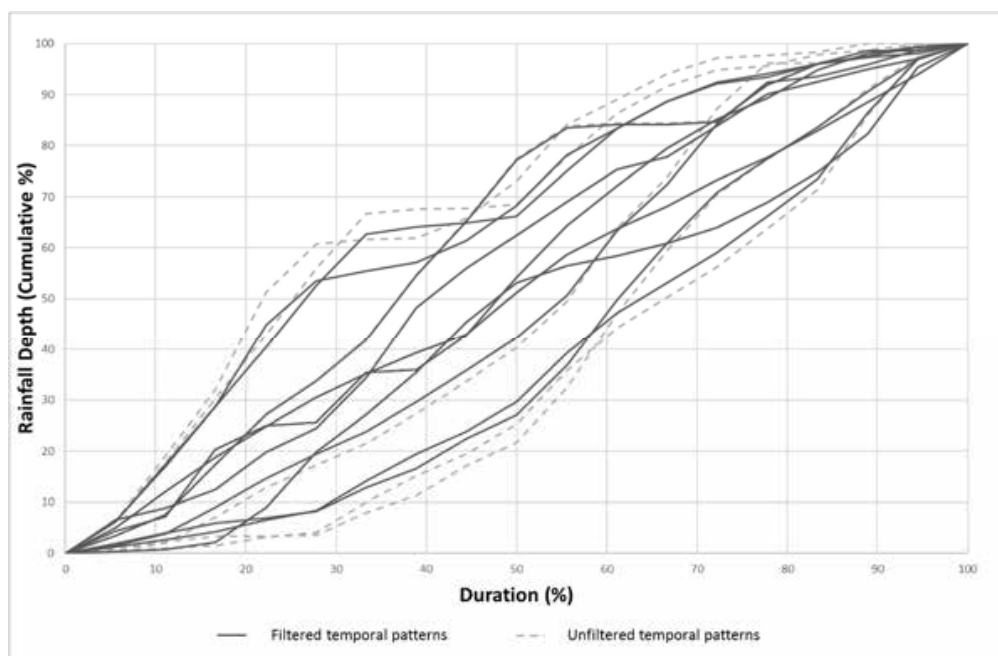
#### 4.2.4 Temporal patterns

For catchment areas greater than 75km<sup>2</sup> ARR recommends the use of the sample of areal temporal patterns available from the ARR data hub (Geoscience Australia, 2019) for long durations (greater than 24 hours). The derivation of these patterns is discussed in ARR 2019 (Ball et al., 2019). For the shorter duration storms, the sample of temporal patterns derived by Jordan et al (2005) was used. For catchment areas less than 75km<sup>2</sup> ARR recommends the use of ARR data hub (Geoscience Australia, 2019) point patterns.

Before the temporal patterns were used, they required some filtering to remove embedded bursts. An embedded burst is a sub-period of rainfall within a given temporal pattern that has a rarer AEP than the actual burst itself. The method described by Scoria et al. (2016) was used to smooth out the embedded bursts. As an example, Figure 4-5 shows the 24 hour design temporal patterns, before and after embedded bursts are removed.

All temporal patterns in the sets used for sampling were given equal probability of selection in the Monte Carlo simulation.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ **Figure 4-5 24-hour design temporal patterns before filtering and after filtering to remove embedded bursts**

#### 4.2.5 Losses

There are two key types of loss models that are typically adopted when modelling design floods:

- Initial loss/continuing loss
- Initial loss/proportional loss

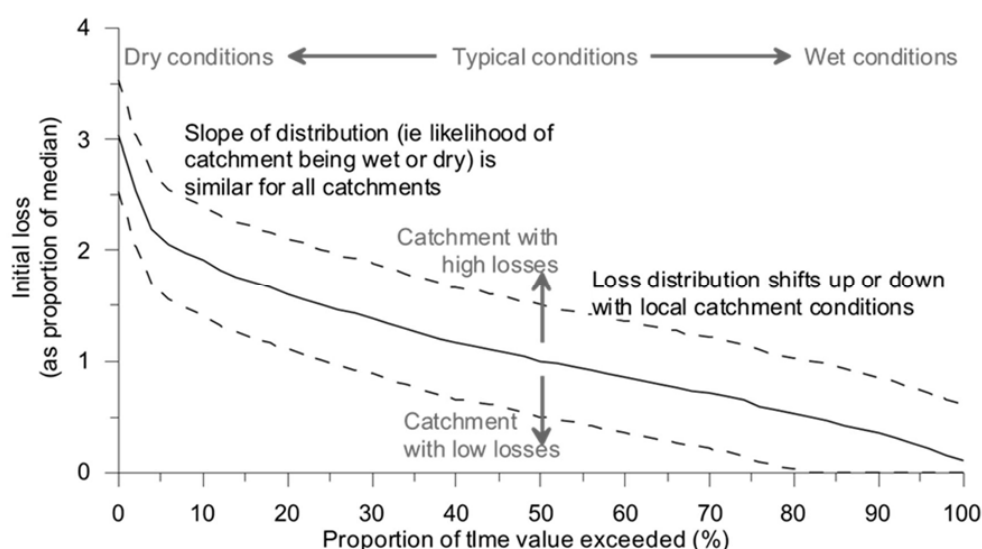
Investigations by Hill et al. (2014) as part of the ARR 2019 revision were inconclusive as to which loss model works best. Even for catchments where one of the loss models performed better for a majority of events, there were still some events for which the other approach was better. Similarly, there was no obvious relationship between the relative performance of the loss models and hydro-climatic or catchment characteristics.

The advice in ARR is that the initial loss/continuing loss model is most suitable for design flood modelling, because it can be used to estimate flood peaks and volumes for all AEPs. In contrast, it is often difficult to derive unbiased estimates of flood quantiles using the initial loss/proportional loss model over the same range of AEPs. The initial loss/proportional loss model underestimates peak flows for extreme floods if the proportional loss is not varied appropriately with AEP; and to date there is little evidence about how proportional loss varies with AEP. Therefore, for this study an initial loss/continuing loss model was adopted.

## Rapid Flood Risk Assessment - North Central CMA Region Malmbsbury



The shape of the initial loss distribution used in the design flood modelling was derived by Hill et al. (2014) from flood modelling results for a large number of catchments across Australia. Hill et al. (2014) developed a non-dimensional distribution of initial loss values for each catchment, by representing initial losses as a proportion of the median loss. This allowed the distributions of initial losses across different catchments to be directly compared. The standardised distributions exhibited a high degree of consistency, and suggested that while the magnitude of initial losses may vary between different catchments, the shape of the distribution does not. That is, while it may be expected that typical loss rates vary from one catchment to another, the likelihood of a catchment being in a relatively dry or wet state is similar for all catchments. The adopted distribution of initial loss is shown in Figure 4-6.



■ **Figure 4-6 Cumulative probability distribution of initial loss**

The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for this study.

### 4.2.6 Pre-burst rainfall depths and temporal patterns

Estimates of the percentage of burst depth of rainfall antecedent to the main burst were taken from the ARR data hub (Geoscience Australia, 2019). The data hub provides a distribution of pre-burst depths by duration and AEP. The median pre-burst depths for each duration was compared across AEPs, and for the purpose of design flood modelling, it was decided that adopting an average of the median for each duration was appropriate (Figure 4-7).

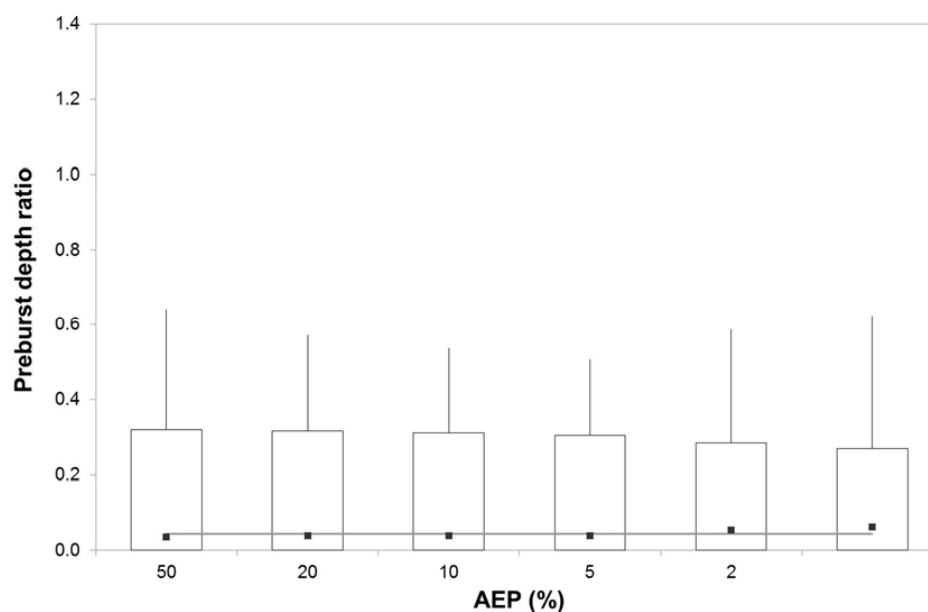
Although the ARR data hub provides pre-burst depths, it does not contain information regarding the temporal patterns. Therefore, temporal patterns of rainfall antecedent to the main burst were taken



## Rapid Flood Risk Assessment - North Central CMA Region Malmesbury



from Minty and Meighen (1999) and applied to burst durations of 12 hours and longer (Minty and Meighen, 1999). For the shorter durations, the pre-burst patterns from Jordan et al (2005) were applied.



- Figure 4-7 Pre-burst rainfall depths – 6 hour burst – shown as a ratio of burst depth, using a box plot of the 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> percentiles. The grey line shows the adopted value for the design flood modelling; this is the average of the median values across the available AEPs.

### 4.2.7 Baseflow

As RORB only estimates the surface runoff, baseflow needs to be added. For baseflow, regional estimates were used. From the ARR data hub the peak factor was extracted. The baseflow peak factor is applied to the estimated surface runoff peak flow to give the value of peak baseflow for a 10% AEP event. ARR 2019 provides a scaling factor to be applied to the 10% AEP baseflow peak factor to determine the baseflow peak factor for events of various AEPs.

A frequency distribution of baseflow with AEP was estimated by using the Regional Flood Frequency Estimation (RFFE - refer to Section 5) distribution. This provided the frequency distribution for baseflow under the peak of the annual maxima flood events.

### 4.2.8 Drawdown

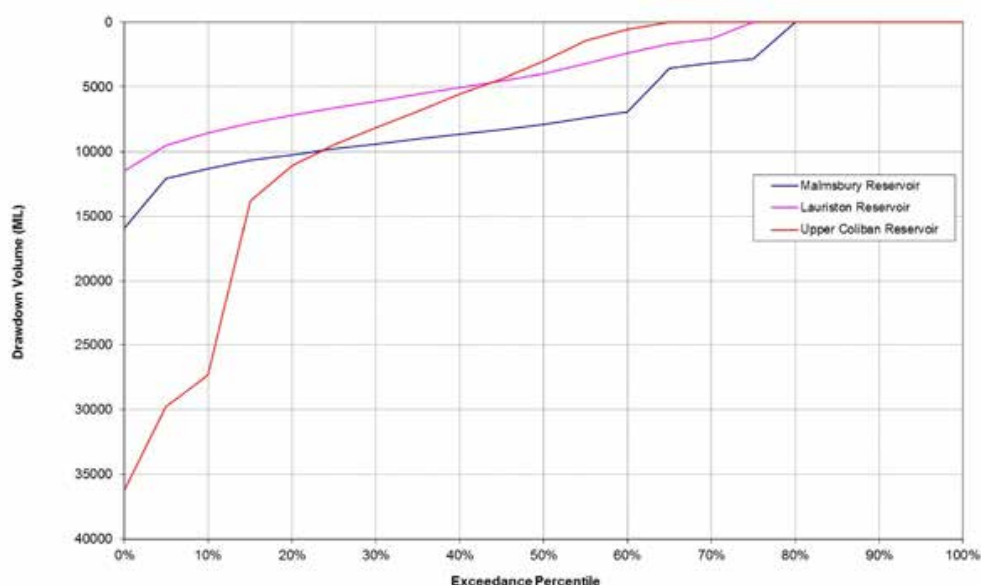
Due to the proximity of the major storages regulating the flow on the Coliban River just upstream of the study area, it is important to consider the potential impact reservoir starting level (drawdown) has on the design events.

## Rapid Flood Risk Assessment - North Central CMA Region Malmsbury



There are three storages upstream of Malmsbury, namely Upper Coliban, Lauriston and Malmsbury Reservoirs, which are in series with each other. For this investigation the same approach as adopted by SKM 2010 was followed and is summarised below.

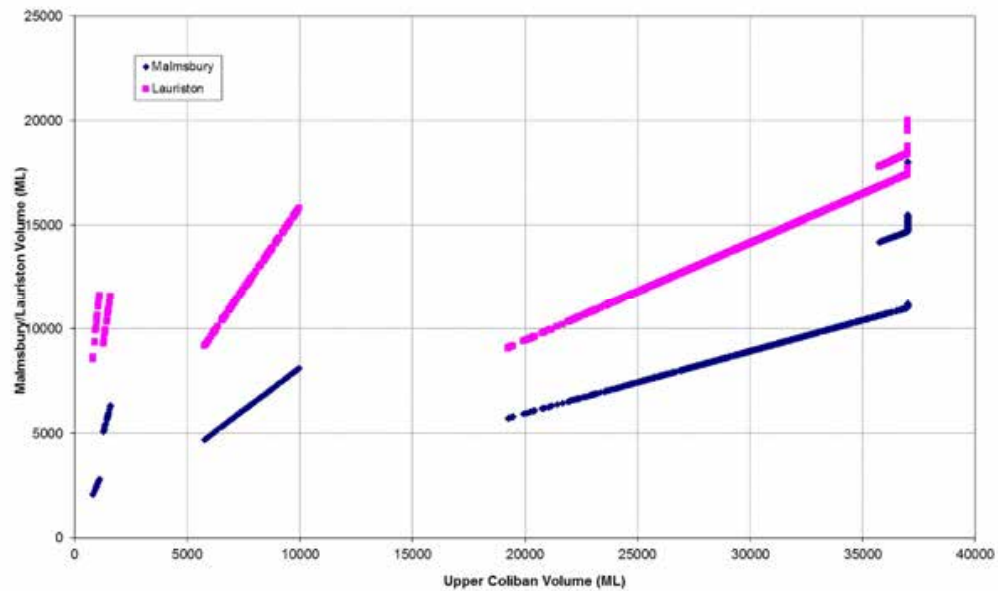
Figure 4-8 shows the drawdown distributions for the Upper Coliban storages which was generated using the Goulburn Simulation Model (GSM) with 115 years of rainfall and current demands.



■ **Figure 4-8 - Modelled drawdown distribution for Upper Coliban storages (SKM, 2010)**

Due to the interconnected nature of the three storages, both Lauriston and Malmsbury storages are dependant on the storage level in Upper Coliban reservoir. Figure 4-9 shows the correlated storage volumes in Malmsbury and Lauriston storage when compared to Upper Coliban reservoir.

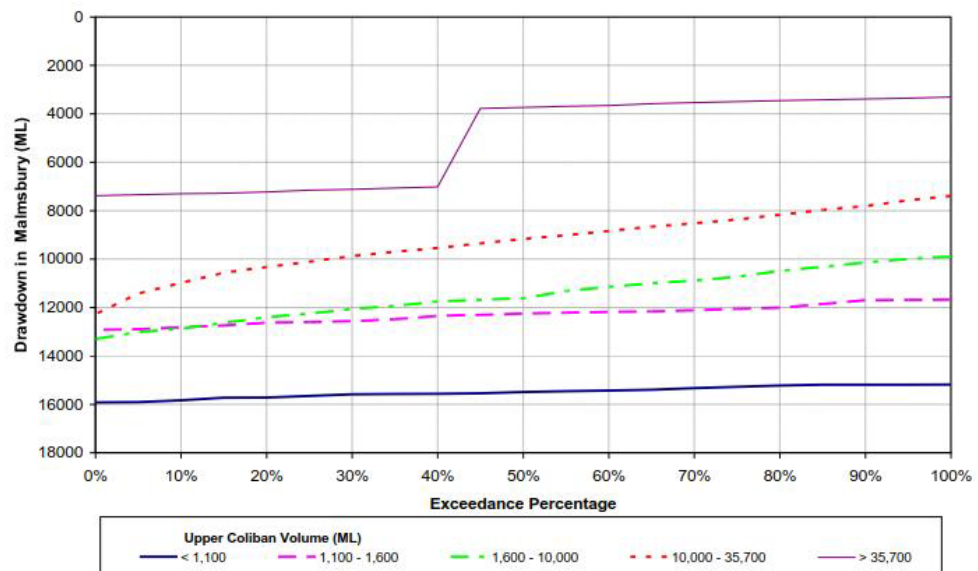
Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ **Figure 4-9 - Correlated storage volumes in Malmsbury and Lauriston when compared to the volume in Upper Coliban (SKM, 2010)**

Since the volume in Lauriston is quite constant, the volume in Malmsbury was correlated with that in Upper Coliban and the volume in Lauriston was set to the median volume (10,100 ML or 7,900 ML drawdown). Figure 4-10 show the correlated drawdown curves for Malmsbury reservoir that have been modelled in conjunction with the drawdown distribution at Upper Coliban Reservoir.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ Figure 4-10 Correlated drawdown between Malmsbury and Upper Coliban storages (SKM, 2010)

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 5. Hydrologic model verification

### 5.1 Adopted parameters

For the RORB model the routing parameters ( $m$  and  $k_c$ ) were taken from the Upper Coliban Storages Hydrology update (SKM, 2010). For the routing parameter,  $k_c$ , the ratio of  $k_c/d_{av}$  was used to ensure that the same routing was applied to the RORB model established for the study area as per the previous model. McMahon and Muller (1983) showed that  $k_c$  is directly proportional to  $d_{av}$ , where  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model). Therefore, a way to measure the similarity of two different RORB models is to compare  $k_c/d_{av}$ .

The RORB model established for the Upper Coliban Storages Hydrology update (SKM, 2010) was calibrated to three events only i.e. October 1985, September 1993 and October 2000. The RORB model was also verified to a flood frequency curve (FFC) at Coliban River @ Springhill-Tylden Road (406250).

Initially, the losses were taken from the Upper Coliban Storages Hydrology update (SKM, 2010) (refer to Table 2-1). However, with the updates in the design inputs from ARR2019 the RORB model was re-verified (refer to Section 5.2).

As the RORB model established for the Upper Coliban Storages Hydrology update (SKM, 2010) was calibrated and verified to a local gauged at-site flood frequency, this gives some confidence that the parameters adopted for this investigation are representative of the catchment characteristics. Table 5-1 summarises the RORB parameters adopted for Malmsbury.

■ **Table 5-1 Summary of key parameters adopted for the RORB model**

Parameter	Value
$k_c$	65.9
$d_{av}$	26.1
$C_{0.8} (k_c/d_{av})$	2.53
$m$	0.8
IL (mm)	10.0
CL (mm/hr)	1.0

### 5.2 Verification

For Malmsbury there is a streamflow gauge located within the study area (Coliban River @ Malmsbury Rail Bridge (406200)). To gain additional confidence in the losses, the loss values were adjusted and the RORB model results were compared to a flood frequency curve at the Coliban River @ Malmsbury Rail Bridge. Streamflow is available at Coliban River @ Malmsbury Rail Bridge from November 1973 through to present. To develop a complete flood frequency curve a combination of a peaks over threshold (POT) and a generalized extreme value distribution (GEV) was used. Notionally a POT is used for AEP's up to and including the 1 in 10 AEP. This blended

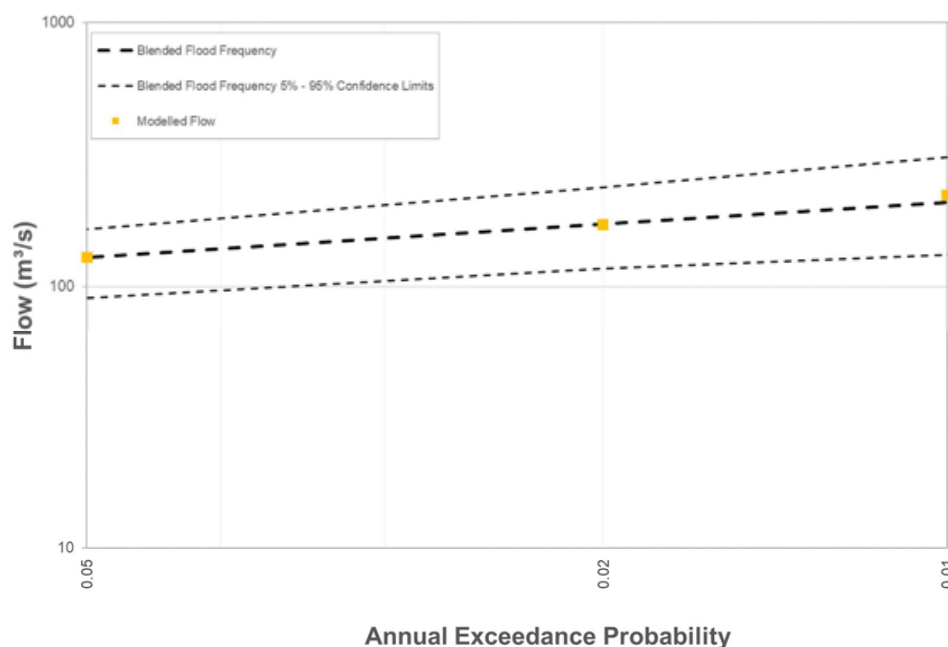


## Rapid Flood Risk Assessment - North Central CMA Region Malmsbury



curve was required due to the zero-flow years which occur in the flow record for the dry years where the storages are significantly drawn down through the year but this artificially reduces the more frequent (1 in 5 and 1 in 10 AEP) flow estimates. For the verification process only the 1 in 20, 50 and 100 AEP events were considered. The 1 in 5 and 1 in 10 AEP events were taken from the Monte Carlo suite of runs to match the blended flood frequency curve.

Figure 5-1 shows the flood frequency curve at the Coliban River @ Malmsbury Rail Bridge (blended) using the parameters shown in Table 5-1. Figure 5-1 shows that the RORB model matches the flood frequency curve at the Coliban River @ Malmsbury Rail Bridge gauge very well.



### ■ Figure 5-1 Verification results

#### 5.3 Comparison to regional parameters

As mentioned in Section 5.1 the choice of  $k_c$  for the Malmsbury catchment was based on the calibration result from the Upper Coliban Storages Hydrology update (SKM, 2010) however, the results from the calibration were compared to a number of regional estimates.

For Victorian regions with a mean annual rainfall of less than 800 mm  $k_c$  is estimated using equation 1 from ARR 2016 (Hansen et al, 1986).

$$k_c = 0.49 A^{0.65} \quad (1)$$

Where A is the area in km<sup>2</sup>.

## Rapid Flood Risk Assessment - North Central CMA Region Malmsbury



The  $k_c$  value from calibration was also compared to another regional estimate by Pearse et. al. (2002). Pearse et. al. (2002) analysed a large database of routing parameters collated by the CRC for Catchment Hydrology and derived a prediction equation applicable to Victoria. The  $d_{av}$  for the catchment was used to predict the  $k_c$  value where  $k_c$  is directly proportional to  $d_{av}$  giving equation 2

$$k_c = C d_{av} \quad (2)$$

Where  $C$  is a characteristic of the catchment independent of the scale or size of the catchment and  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model).

Pearse et al. (2002) also gave an expected value and one standard deviation (High and Low).

Table 5-2 provides a summary of the regional estimates along with the adopted value. Table 5-2 shows the  $k_c$  based on the calibration event undertaken in the Upper Coliban Storages Hydrology update (SKM, 2010) is different to the regional estimates highlighting the need to calibrate the model, where possible.

### ■ Table 5-2 $k_c$ values – regional estimates

Location	Area (km <sup>2</sup> )	$k_c$ (equation 1)	$k_c$ (equation 2)			$k_c$ (adopted)
			Expected	High	Low	
Malmsbury	281	19.5	32.6	54.0	19.6	65.9

The ARR2019 data hub provides some regional estimates of losses. The regional losses are to only be used as a guide as ARR2019 clearly states it is always desirable to reconcile design values with independent flood frequency estimates where possible. Table 5-3 shows the regional estimates along with the adopted values. Table 5-3 shows that the adopted values are different to the regional estimates highlighting the need to verify the model, where possible.

### ■ Table 5-3 Loss values – regional estimates

Location	Regional		Adopted	
	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Malmsbury	27.0	4.1	10.0	1.0

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 6. Design flood hydrology

### 6.1 Design flows for the 20% to 0.5% AEP events

The RORB model was run in the joint probability framework, with the design inputs and the adopted routing parameters, initial and continuing losses to generate design flood frequency curves and inflow hydrographs.

In order to generate hydrographs the RORB model was run in the joint probability framework described in Section 4.1, with the design inputs summarised in Section 4.2 and the adopted parameters summarised in Section 5.

The joint probability framework provides a peak flow, whereas the hydraulic model requires a set of hydrographs. The results of the Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Hydrographs were chosen from the set of Monte Carlo results that best matched the median peak flows and were an unbiased transformation from input rainfall AEP to flood AEP.

For the hydraulic model hydrographs were extracted at key locations within the study area. Table 6-1 shows the peak flows at downstream end of the study area from the event centred over the entire catchment.

■ **Table 6-1 Summary of modelled peak flow estimates for Malmsbury**

AEP (1 in Y)	Peak Flow (m <sup>3</sup> /s)	Critical Duration (hours)
5	98.9	72.0
10	109.2	72.0
20	128.2	48.0
50	179.2	48.0
100	213.9	48.0
200	281.5	36.0

### 6.2 PMF estimate

As mentioned earlier in the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994). Nathan et al. (1994) looked at 56 sites across South-Eastern Australia and developed a series of equations to estimate the peak, volume and time to peak of a PMF.

Nathan et al. (1994) estimates of the PMF magnitude are based on the catchment area using the following equations.

$$Q_p = 129.1 * A^{0.616} \quad (1)$$

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



$$V = 497.7 * A^{0.984} \quad (2)$$

$$T_p = 1.066 * 10^{-4} * A^{-1.057} * V^{1.446} \quad (3)$$

And from a mass balance taking Equations (1) and (2).

$$T_r = \frac{V}{1.8 * Q_p} \quad (4)$$

Where:  $Q_p$  is peak flow ( $m^3/s$ );

$A$  is catchment area ( $km^2$ )

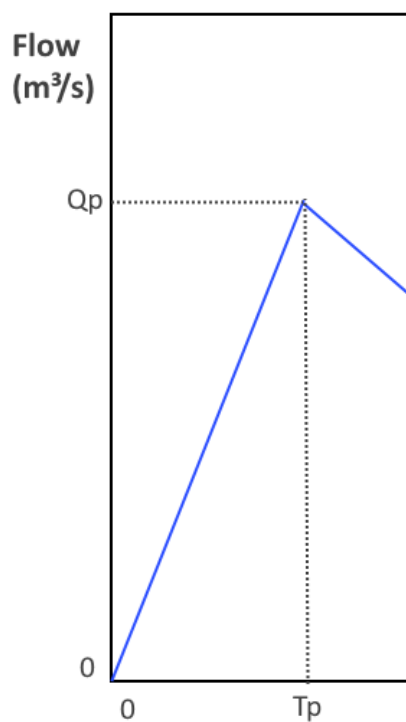
$V$  is the Volume of the hydrograph (ML)

$T_p$  is the time to peak flow (hours)

$T_r$  is the total time of the hydrograph (hours)

Each of these characteristics has been used to determine a 'triangular' PMF hydrograph. Figure 6-1 illustrates the characteristics of the 'triangular' PMF hydrograph.

Rapid Flood Risk Assessment - North Malmsbury



■ Figure 6-1 - Characteristics of 'tr

The peak PMF flow was estimated to be

### 6.3 Climate change and sens

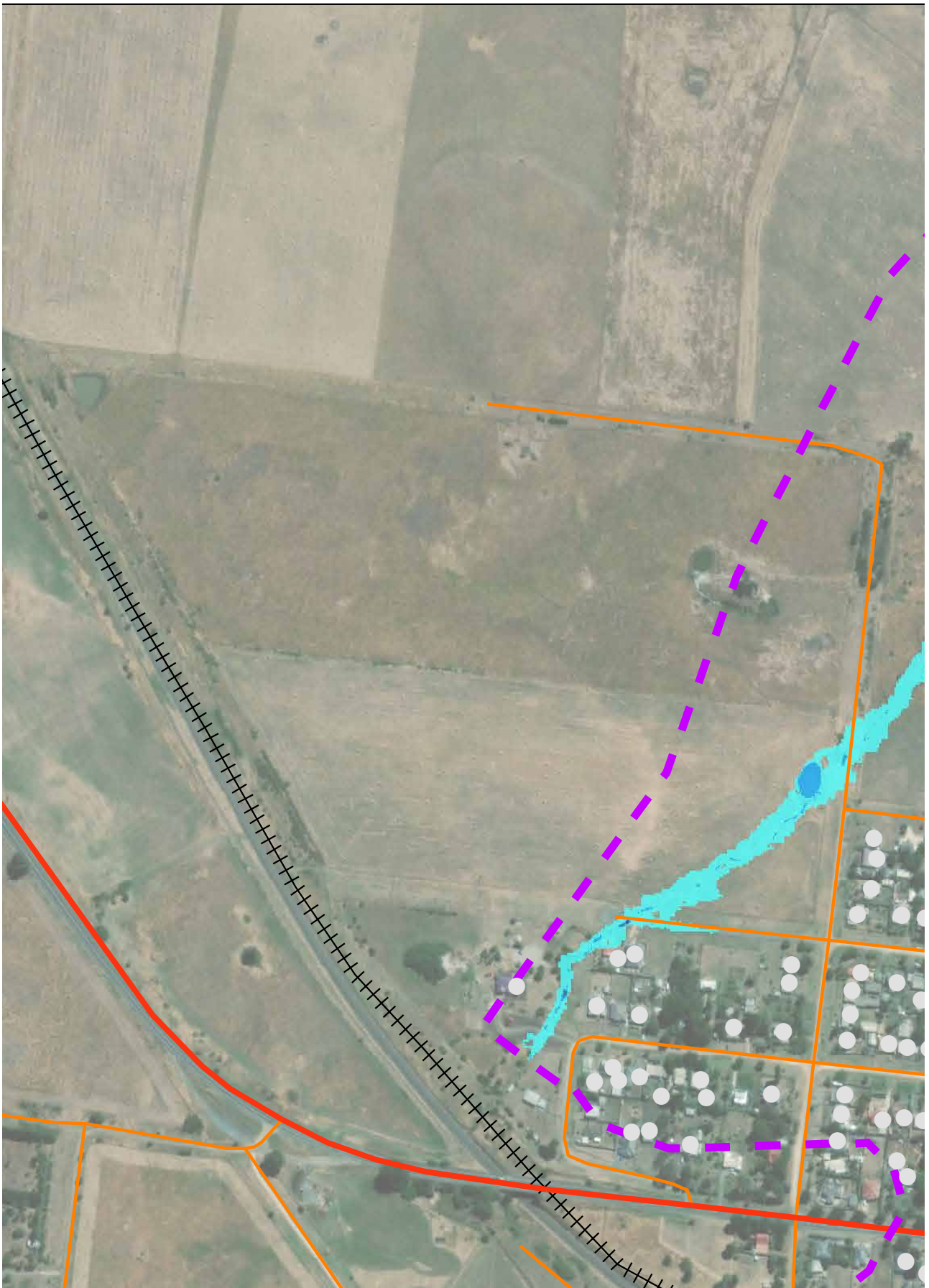
An important aspect of any hydrological testing. Sensitivity testing helps to understand the influence of different parameters on the result. The Monte Carlo analysis already takes into account the influence of different parameters (i.e. temporal patterns and spatial patterns) on the result. This way the Monte Carlo analysis already takes into account the influence of different parameters on the result. However, an important aspect of any hydrological testing is the design flow estimates.

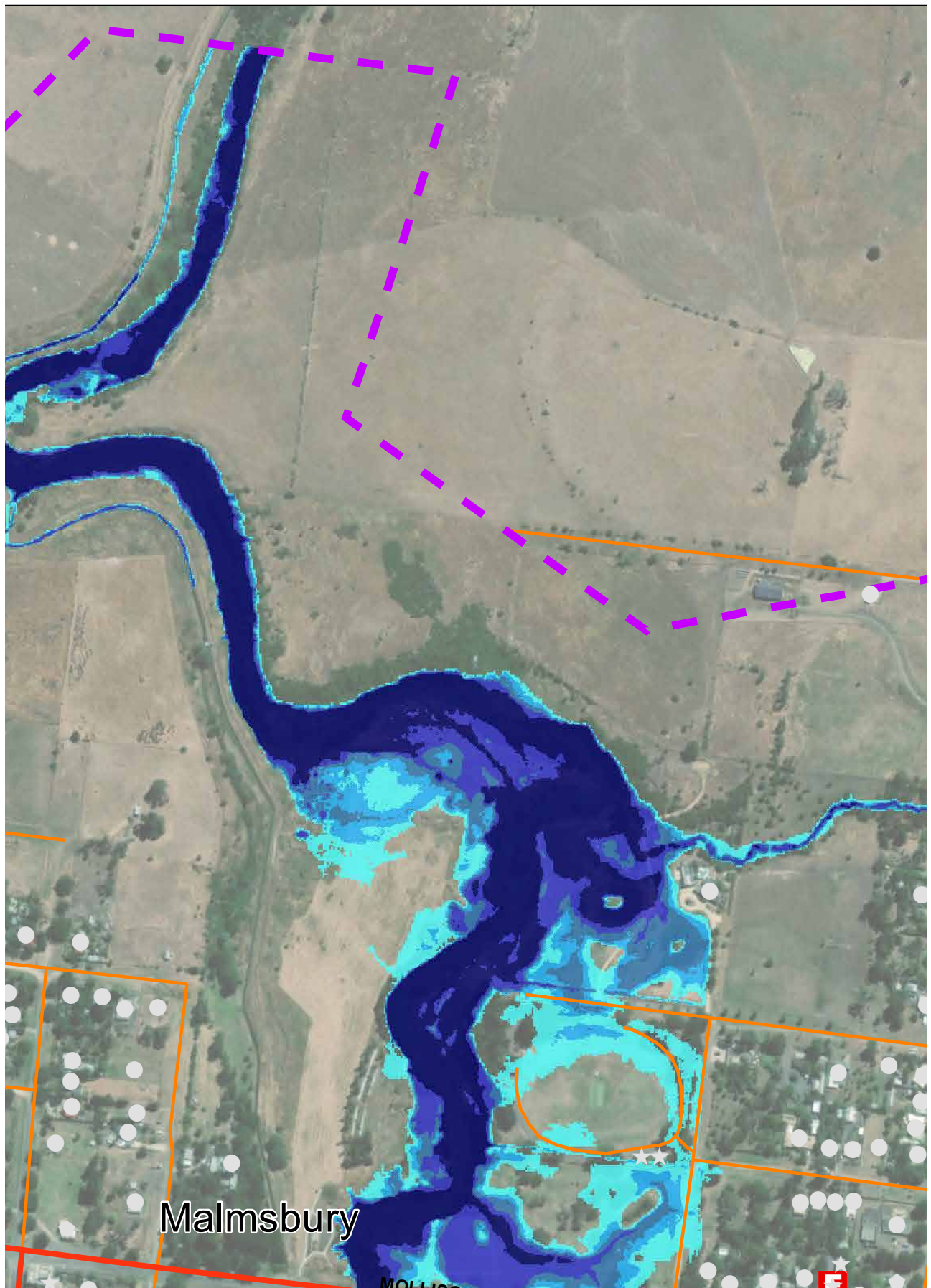
ARR2019 offers interim advice on estimating design flow estimates with a range of climate change scenarios from the Climate Futures web tool developed by the Department of Natural Resource Management. Climate Models (GCMs) can be explored to provide a range of climate change scenarios.

NCC00002\_RFRA\_NCC\_15\_Malmsbury\_Version2

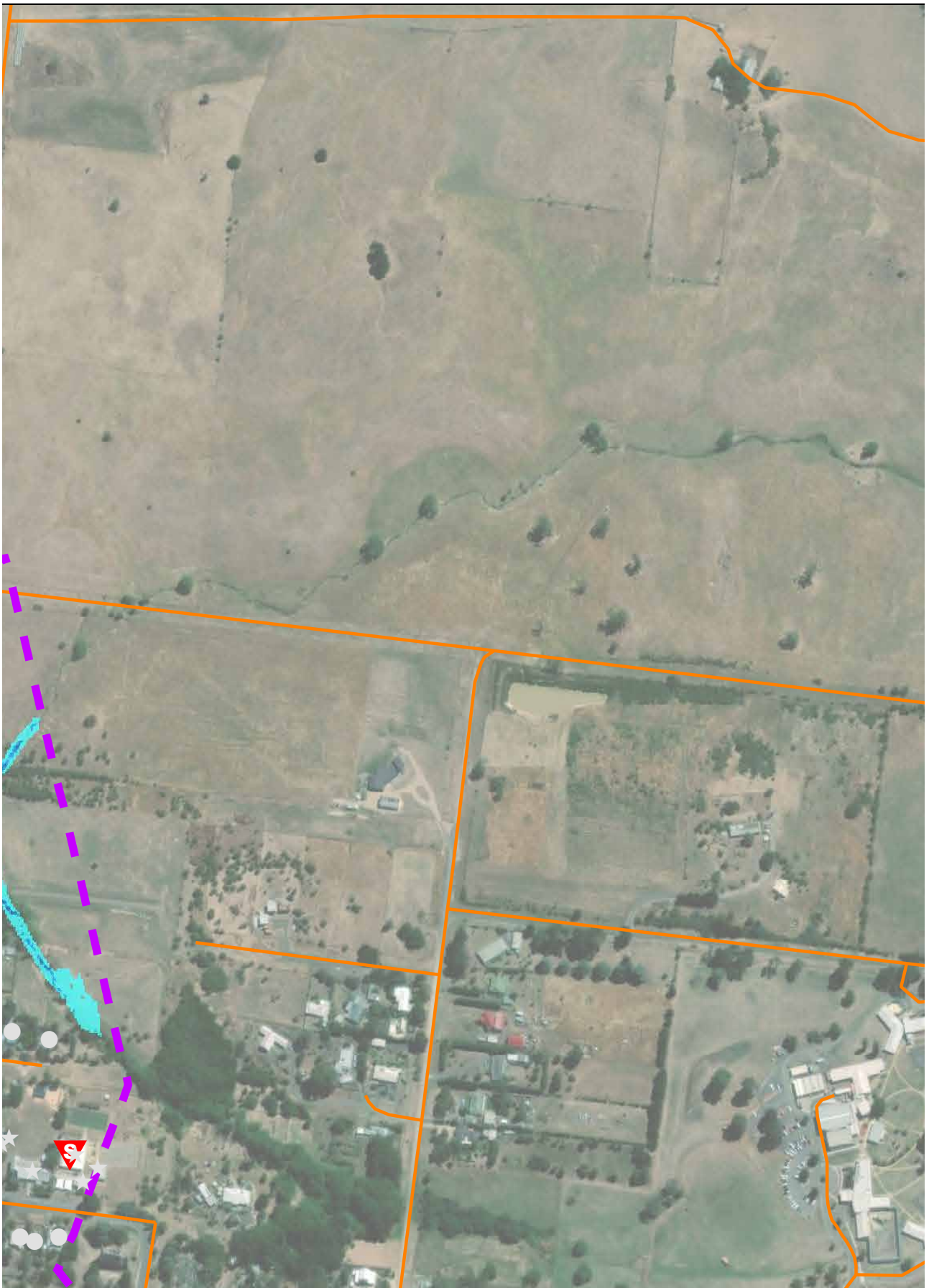














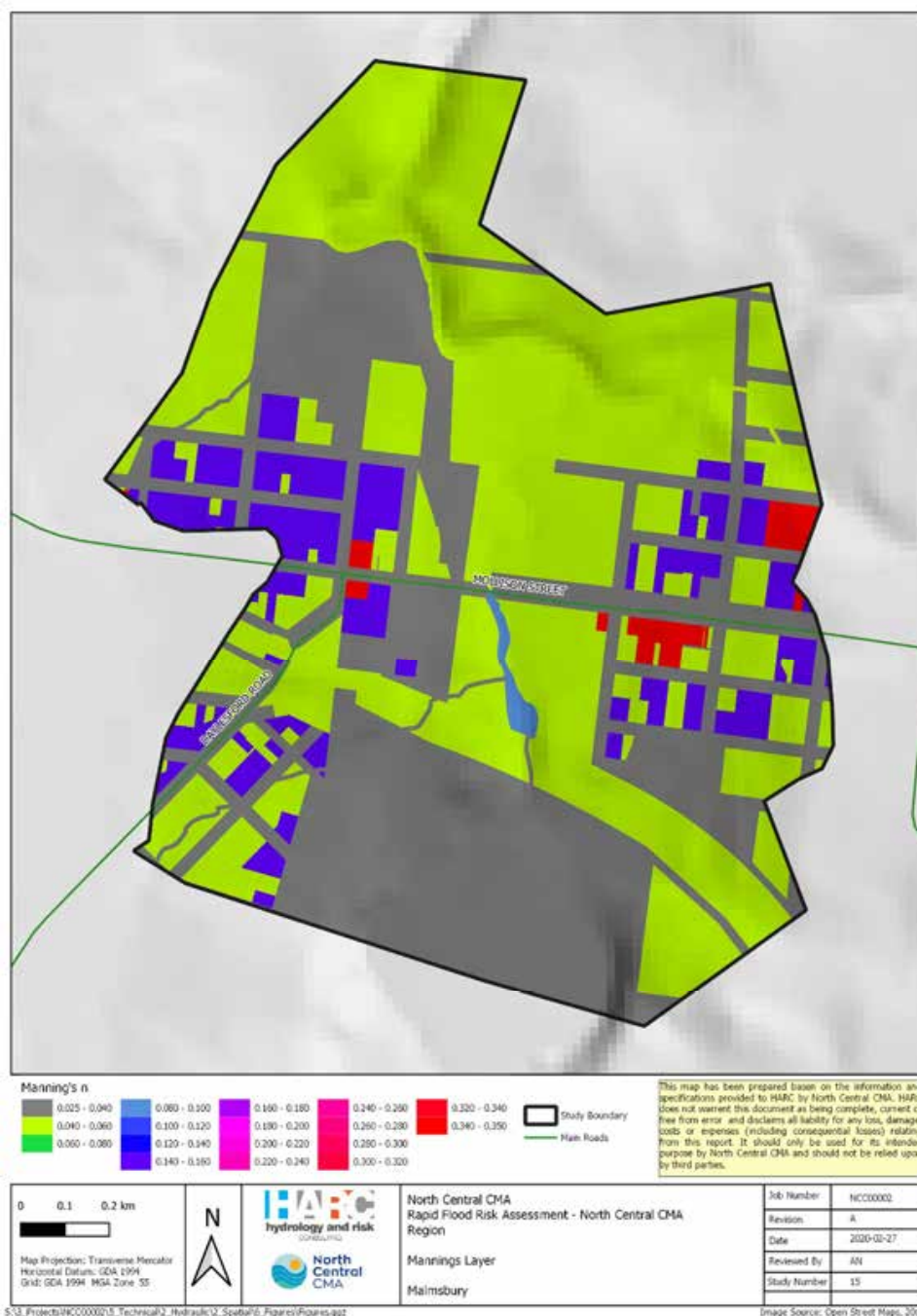
## Flood Risk Assessment - North Central CMA Region Malmsbury

Categories were selected to be in line with the values provided by ARR2019. No calibration of the hydraulic models was undertaken for this project.

**Table 7-1 Manning's n values for different land use types**

Land Use Type	Manning's n adopted
Residential areas – urban high density (dwelling and parcel combined)	0.35
Residential areas – rural high density (dwelling and parcel combined)	0.15
Industrial/commercial or large buildings	0.30
Residential areas – rural low density (dwelling only or large blocks with house)	0.05
Open space or waterway – minimal vegetation	0.04
Open space or waterway – moderate vegetation	0.06
Open space or waterway – heavy vegetation	0.095
Paved roads/car park/driveways	0.025
Grassway line	0.05
Grass reserves/floodway (regularly mowed)	0.035
Grass floodplains in clear paddocks	0.05
Forested (heavy stand of timber)	0.12
Canal/Reservoir body of water	0.035

Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



■ Figure 7-1 Surface roughness distribution



Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



#### 7.4 Hydraulic structures

Table 2-2 lists the culverts/bridges that were entered into the model. Bridges were represented using a layered flow constriction and culverts in 1D.

Bridge structures were modelled with the appropriate losses derived from Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways (Austroads, 1994). The layered flow constrictions used to model these bridges allows for typical bridge characteristics such as deck height and thickness, pier shape and width and blockages associated with guard or hand rails to be directly incorporated into the 2D domain. The details of these were extracted from supplied plans. Where plans were not available the losses and dimensions were estimated based on typical bridge configurations and loss parameters.

The 1D elements were dynamically linked to the 2D domain. Details of the culverts were extracted from supplied plans, details provided by Council or the North Central CMA.

#### 7.5 Inflows

The inflows to the hydraulic model were taken from the RORB model, as discussed in Section 6 and modelled in TUFLOW as two-dimensional source area polygons distributing the inflow over the polygon. The polygons were located along the waterways within the study area.

The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. The hydrographs entered into the hydraulic model were chosen from the suite of runs from the Monte Carlo analysis such that the single hydrographs matched the peak flows.

#### 7.6 Downstream boundary

The downstream boundary condition was entered as a normal depth relationship with a slope of 3% based on the LIDAR data.

A schematisation of the hydraulic model is found in Figure 7-2.

All the hydraulic models were run for the 1 in 5, 10, 20, 50, 100 and 200 AEP and PMF events, for the critical durations identified in Table 6-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



■ Figure 7-2 Hydraulic model schematisation

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 8. Flood Risk Assessment

### 8.1 Flood Mapping

Flood maps showing flood level, depth, velocity and hazard (depth x velocity) have been produced for the 1 in 5, 10, 20, 50, 100 and 200 AEP event along with the PMF. The flood maps are shown in Appendix A.

Table 8-1 shows the flood map reference numbers that correspond to the maps in Appendix A.

■ **Table 8-1 Flood maps reference table**

Map Number	Map Name	Map Number	Map Name
15-5-1	1 in 5 year Depth Map	15-5-4	1 in 5 year Hazard Map
15-10-1	1 in 10 year Depth Map	15-10-4	1 in 10 year Hazard Map
15-20-1	1 in 20 year Depth Map	15-20-4	1 in 20 year Hazard Map
15-50-1	1 in 50 year Depth Map	15-50-4	1 in 50 year Hazard Map
15-100-1	1 in 100 year Depth Map	15-100-4	1 in 100 year Hazard Map
15-200-1	1 in 200 year Depth Map	15-200-4	1 in 200 year Hazard Map
15-PMF-1	PMF Depth Map	15-PMF-4	PMF Hazard Map
15-5-2	1 in 5 year Depth x Velocity Map	15-5-5	1 in 5 year Velocity Map
15-10-2	1 in 10 year Depth x Velocity Map	15-10-5	1 in 10 year Velocity Map
15-20-2	1 in 20 year Depth x Velocity Map	15-20-5	1 in 20 year Velocity Map
15-50-2	1 in 50 year Depth x Velocity Map	15-50-5	1 in 50 year Velocity Map
15-100-2	1 in 100 year Depth x Velocity Map	15-100-5	1 in 100 year Velocity Map
15-200-2	1 in 200 year Depth x Velocity Map	15-200-5	1 in 200 year Velocity Map
15-PMF-2	PMF Depth x Velocity Map	15-PMF-5	PMF Velocity Map
15-5-3	1 in 5 year Elevation Map		
15-10-3	1 in 10 year Elevation Map		
15-20-3	1 in 20 year Elevation Map		
15-50-3	1 in 50 year Elevation Map		
15-100-3	1 in 100 year Elevation Map		
15-200-3	1 in 200 year Elevation Map		
15-PMF-3	PMF Elevation Map		

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 8.2 Flood behaviour and impact of flooding

The following section summarises the impact of flooding. Table 8-2 provides a summary of the water level at the location shown in Figure 8-1 along with the main impacts for each AEP. Table 8-3 is a summary of the number of properties that are inundated for each AEP event. Table 8-4 is a summary of the number of properties that are inundated above floor for each AEP event. Table 8-5 is a summary of the main roads that are overtopped.

■ **Table 8-2 Summary of impacts of flooding**

AEP (1 in Y)	Water level downstream of railway line (mAHD)	Impact
5	435.3	No properties are inundated
10	435.4	Two properties are inundated at Malmsbury Sports Ground
20	435.5	Mollison Street (Calder Hwy) overtopped. Two properties are inundated as above
50	435.8	Mollison Street (Calder Hwy) overtopped. Two properties are inundated as above
100	435.9	Mollison Street (Calder Hwy) overtopped. Two properties are inundated as above
200	436.2	Four additional properties are inundated. One is upstream of Mollison Street and three are near Raleigh Street

There is a limited amount of data available on a historical event on the catchment which occurred in October 2000. The 2000 event is nominally a 1 in 10 to 1 in 20 AEP event. It was reported that the Calder Highway overtopped during this event. The flood modelling and flood mapping (Appendix A) results are consistent with the historical anecdotal evidence.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury

■ Table 8-3 Summary of property inundation

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	2	0	0	0	0	0	0	0
20	0	0	0	2	0	0	0	0	0	0	0
50	0	0	0	2	0	0	0	0	0	0	0
100	0	0	0	2	0	0	0	0	0	0	0
200	3	0	0	3	0	0	0	0	0	0	0

■ Table 8-4 Summary of over floor flooding\*

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	2	0	0	0	0	0	0	0
20	0	0	0	2	0	0	0	0	0	0	0
50	0	0	0	2	0	0	0	0	0	0	0
100	0	0	0	2	0	0	0	0	0	0	0
200	1	0	0	2	0	0	0	0	0	0	0

\* Note the floor levels have assumed to be 300 mm above the natural surface level for those buildings without surveyed floor levels



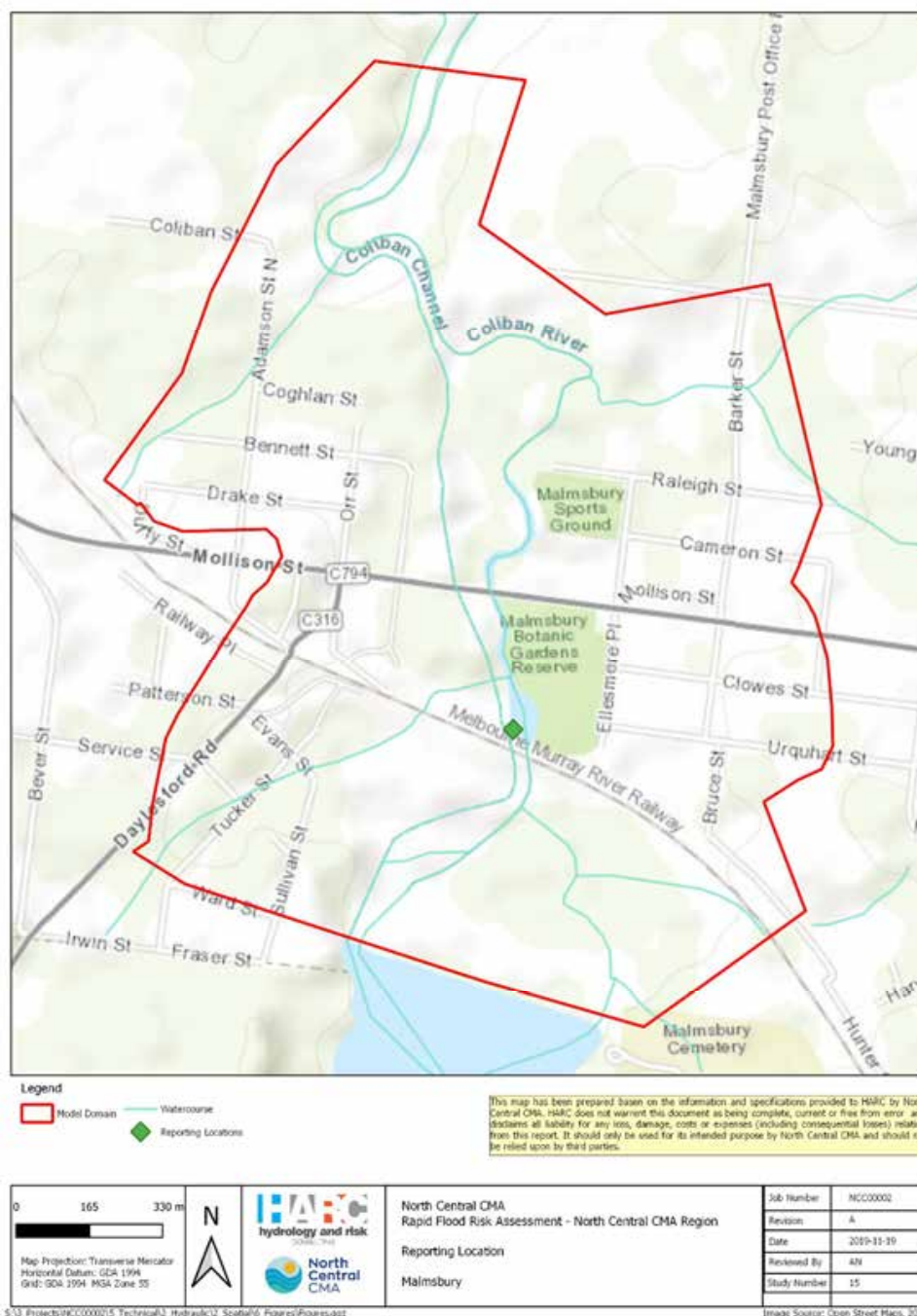
Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



■ Table 8-5 Summary of road Inundation

AEP (1 in Y)	Roads impacted by flooding	Maximum depth over road (m)	Duration of inundation (hours)
5	Mollison Street	0	0
10	Mollison Street	0	0
20	Mollison Street	0.1	4
50	Mollison Street	0.2	14
100	Mollison Street	0.2	15
200	Mollison Street	0.4	21

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



■ Figure 8-1 Reporting location

## Rapid Flood Risk Assessment - North Central CMA Region Malmsbury

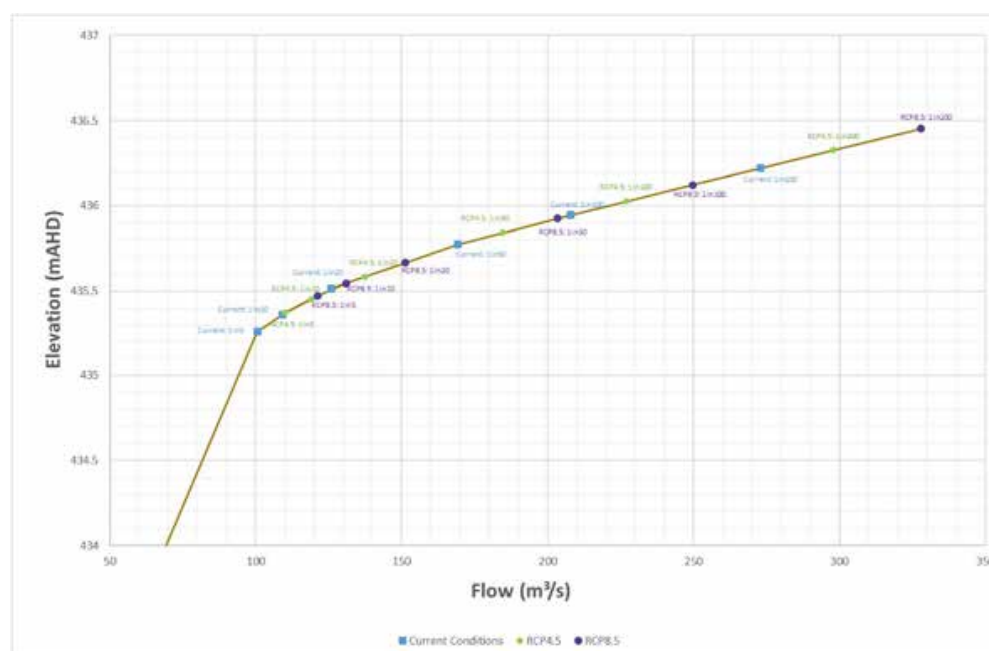


### 8.3 Climate change

The increase in flows due to climate change was discussed in Section 6.3. To present the sensitivity of flood levels to changes resulting from climate change a rating curve of flow and water level at a key location within the study area is shown in Figure 8-2. Figure 8-1 shows the location of the rating curve and Table 8-6 the flows. The flow for the current conditions shown in Table 8-6 was taken from the TUFLOW model. The climate change flows were derived by multiplying the current climate peak flows by the percentages as discussed in Section 6.3. The rating curve shows the water level that corresponds to a peak flow under existing climate conditions as well as the corresponding water level under climate change conditions (RCP 4.5 and 8.5).

#### ■ Table 8-6 Climate change peak flow estimates

AEP (1 in Y)	Current Climate – Peak Flow (m <sup>3</sup> /s)	Climate Change – Peak Flow (m <sup>3</sup> /s)	
		RCP 4.5	RCP 8.5
5	100.8	110.0	121.1
10	109.0	119.1	131.1
20	125.9	137.4	151.3
50	169.2	184.8	203.4
100	207.8	226.9	249.8
200	272.9	298.0	328.0



#### ■ Figure 8-2 Estimated changes in peak water level associated with climate change

## Rapid Flood Risk Assessment - North Central CMA Region Malmesbury



Table 8-7 shows which AEP map to consider adopting under various climate change scenarios. Note that the results have been based on the flows shown in Table 8-6 and rounded to the nearest AEP.

### ■ Table 8-7 Map to consider adopting under various climate change scenarios

Current AEP	Event Map to consider adopting under various climate change scenarios	
	RCP4.5	RCP8.5
1 in 5	1 in 10	1 in 20
1 in 10	1 in 20	1 in 20
1 in 20	1 in 20	1 in 50
1 in 50	1 in 50	1 in 100
1 in 100	1 in 100	1 in 200

## 8.4 Flood Intelligence Information

Results from this investigation have been used to update the MFEPs with key information. This has included:

- Interpreting relevant flood related intelligence and consequence information from the mapping and modelling including typical flood travel times, rates of rise, etc;
- Identifying properties, roads and other community assets (e.g. essential infrastructure and services, high risk facilities, emergency service properties, low points in roads, etc.) affected by flooding;
- Identifying likely isolations and shrinking islands;
- Identifying areas of probable high flood risk / high hazard;
- Building flood intelligence tables; and
- Extracting catchment descriptions and flooding chronology from project deliverables.

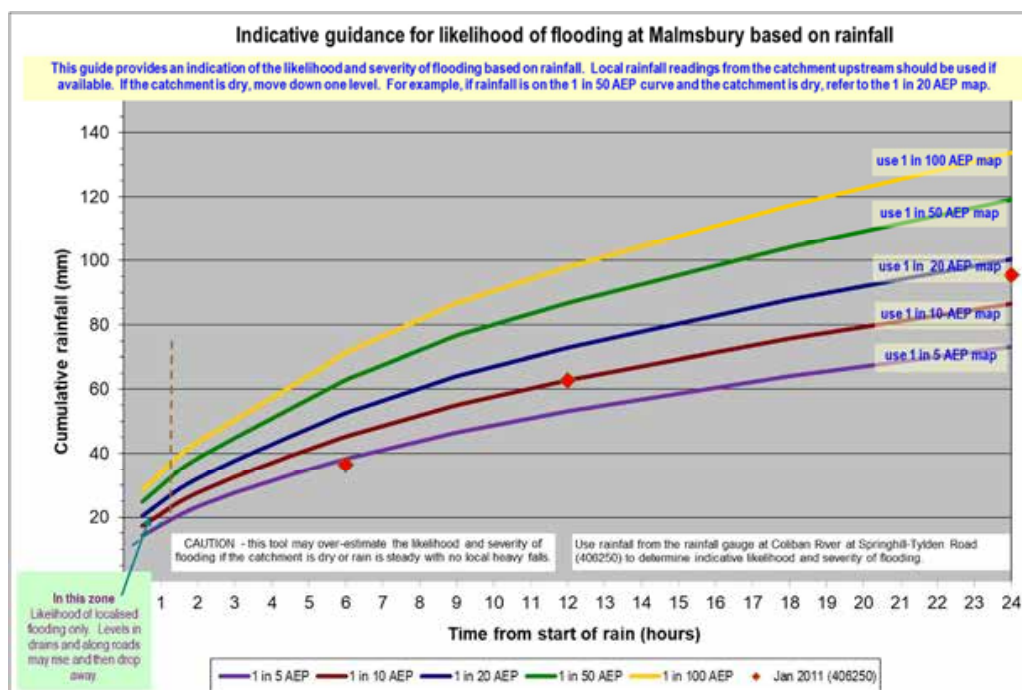
## 8.5 Developing Indicative Quick Look Flood / No-Flood Tools

Using the results of the hydrologic and hydraulic modelling work, an indicative quick look flood / no-flood assessment tool has been developed for the study area.

The tool is aimed at providing a rapid indication of whether flooding is likely with some lead time. It is intended to be indicative only and will not provide a forecast of expected flood depth. The tool is designed to be linked to the mapping and intelligence produced by this project and in that way provides an indication of likely consequences.

The tool is driven by rainfall recorded at Coliban River at Springhill-Tylden Road (406250). IFD data from this location has been compared to the study area specific IFD data. Adjusted rainfall depths were then plotted against time to produce the tool as shown in Figure 8-3.

## Rapid Flood Risk Assessment - North Central CMA Region Malmbsbury



■ Figure 8-3 Quick look tool

### 8.5.1 Guidance on the use of the Quick Look Flood / No flood Tool

#### 8.5.1.1 In the lead up to a flood

The quick look indicative flood / no-flood tool provided in Figure 8-3 gives guidance on the likelihood and severity of expected flooding at Lockwood.

Rainfall recorded at Coliban River at Springhill-Tylden Road (406250) was used to develop the quick look tool. The tool may not perform to expectations in severe thunderstorm situations and / or when there is locally heavy rainfall embedded in more general rain.

Unless there are unusual circumstances, actions as per the Flood Intelligence Card in the MFEP should be initiated as soon as the tool suggests flooding is likely. Response can be escalated if the tool indicates an increase in the expected severity of flooding.

#### 8.5.1.2 During a flood - using the quick look tool

Plot cumulative rainfall depth against elapsed time on a copy of the tool. Do not start using the tool until rainfall exceeds approximately 2 mm an hour (i.e. ignore early drizzle or very light rain).

At each time step, after plotting the cumulative rainfall, assess the likelihood and expected severity of flooding from the curves. Some degree of judgement is required to determine if the quick look



## Rapid Flood Risk Assessment - North Central CMA Region Malmsbury



tool is providing an answer that is in line with expected outcomes. When plotted rainfall data crosses a curve on Figure 8-3 this indicates that flooding of around that severity is possible.

If the catchment is dry, it would generally be appropriate to step down one level. For example, if the rainfall plot is on the 1 in 50 AEP curve and the catchment is dry, refer to the 1 in 20 AEP map and associated consequences listed in the flood intelligence card available in the MFEP. The exception to this would be if there was very heavy rain on a dry catchment. In that circumstance, adopt a cautious approach and do not step down a level.

If the catchment is dry and / or rain extends over more than 12 hours, the quick look tool will tend to over-estimate the likelihood of flooding.

The tool is based on the reservoirs upstream being at FSL or very close to it (i.e. spilling during the event). If the storage is below FSL and unlikely to spill during the event, it would be appropriate to step down a level.

### 8.5.1.3 After a flood – updating the tool

After a flood event, plot the event rainfall depth (with date) on the quick look tool. At the same time, include an overview of the event, along with commentary on antecedent conditions and other relevant information, in the relevant Appendix of the MFEP.

### 8.5.1.4 Example use of the quick look tool

The section below is a fictitious example of how to use the quick look tool. Table 8-7 shows the rainfall depths recorded at the rain gauge and the action to take on the basis of the recorded rainfall. Figure 8-4 shows the fictitious example plotted up on the quick look tool.

Note that in cases where the tool has not been used from the start of rain (i.e. from early in the event), data should be either picked up from the start of the event or the first data plotted should include an estimate of how much rain has fallen and the time over which it has fallen. If this is not done, the tool will likely under-estimate likely flood severity.

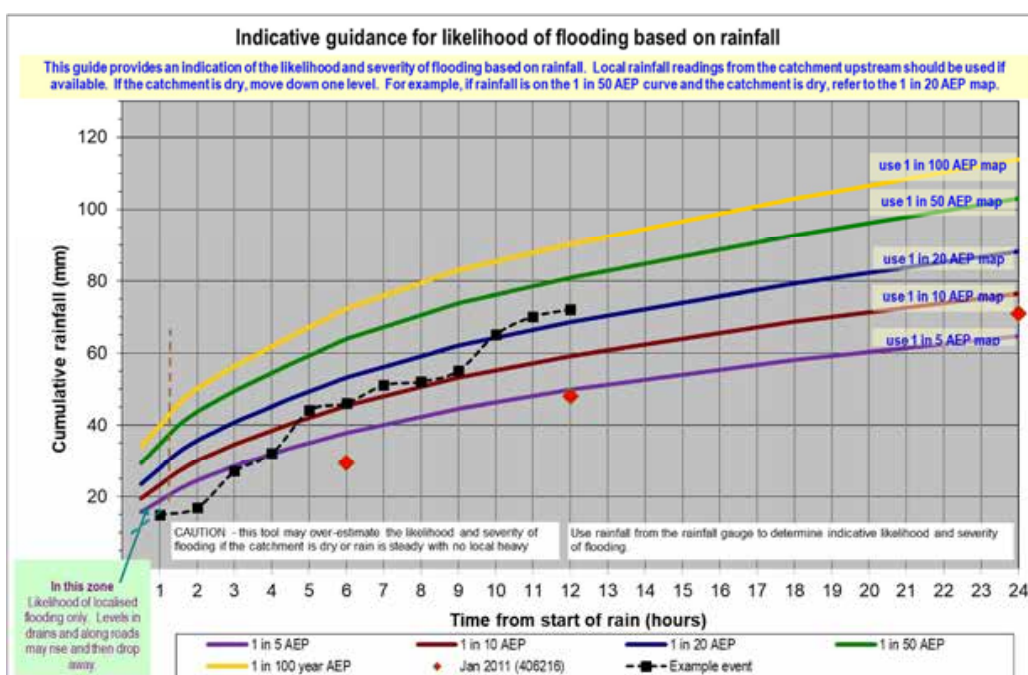
#### ■ Table 8-8 Rainfall depths for example use of tool

Time (hours)	Rainfall Depth (mm)	Action
0	1	Ignore
1	2	Ignore
3	2	Ignore
4	1	Ignore
5	15	Plot as 15 mm at 1 hour
6	2	Plot as 17 mm at 2 hours
7	10	Plot as 27 mm at 3 hours
8	5	Plot as 32 mm at 4 hours Indicates it may be a 5-year (20% AEP) event

Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



Time (hours)	Rainfall Depth (mm)	Action
9	12	Plot as 44 mm at 5 hours Indicates it may be a 10-year (10% AEP) event Start planning for a 10% AEP event
10	2	Plot as 46 mm at 6 hours More confident that a 10% AEP event is likely
11	5	Plot as 51 mm at 7 hours
12	1	Plot as 52 mm at 8 hours
13	3	Plot as 55 mm at 9 hours
14	10	Plot as 65 mm at 10 hours Indicates it may be a 20-year (5% AEP) event.
15	5	Plot as 70 mm at 11 hours More confident that a 5% AEP event is likely
16	2	Plot as 72 mm at 12 hours



■ Figure 8-4 Quick look tool example

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



### 8.6 Flood classification – Bureau of Meteorology

Electronic maps have been produced for the minor<sup>1</sup>, moderate<sup>2</sup> and major<sup>3</sup> flood (as defined by the BoM). The minor, moderate and major flood has been based on the flood impacts. For Malmsbury the 1 in 5, 10 and 20 AEP has been adopted for the minor, moderate and major flood respectively.

---

<sup>1</sup> Minor Flooding - Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

<sup>2</sup> Moderate Flooding - In addition to minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required

<sup>3</sup> Major Flooding – In addition to moderate flooding, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 9. Summary of rating of key areas

The following section provides a summary rating of each of the key areas of the project. The rating is subjective but has been rated against current standards and industry best practice for undertaking detailed flood studies.

The intention is that this will enable the North Central CMA to easily identify the areas where additional caution may need to be applied when using the information from this investigation for making decisions on flooding issues. In addition it will identify the areas of additional investigation, should a more detailed study be undertaken in the future.

Table 9-1 shows a summary of the rating for Malmsbury where green is considered to be good, orange is OK and red is poor. Below is a summary of the main considerations given to each aspect of the study:

- *RORB model set up.* Adequacy of sub-area division, reach types, impervious fractions
- *RORB model parameters.* Has the RORB model been calibrated and/or verified to streamflow gauge information
- *Currency of hydrology.* Rated based on whether the hydrology used in the study is consistent with current practice and data sets.
- *Topographic data.* Typically will be rated orange or red if LiDAR data is not available and if the state wide DEM is required for use.
- *Manning's n.* Has land use been represented with appropriate values
- *Modelling of key structures.* Reflects whether the model was attempted to incorporate key hydraulic structures within the inundation zone and to what degree.
- *TUFLOW model set up.* Considers such aspects as does the cell size capture key features and the boundary conditions.
- *TUFLOW parameters.* Has the TUFLOW model been calibrated and/or verified to recorded flood levels.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



■ **Table 9-1 Summary of review – Malmsbury**

Category	Comment	Rating
RORB model set up	Adequate sub-area division for larger catchment. However, additional local catchment sub-division recommended if more detailed local flows are required. Note that Lauriston and Malmsbury spillway gate operations are based on a simplified procedure. However, the adopted flows are based on the streamflow gauge Coliban River @ Malmsbury Rail increasing confidence in the flow estimates.	
RORB model parameters	Based on a calibrated and verified model.	
Currency of hydrology	All inputs are based on ARR2019	
Topographic data	LIDAR available for entire study area	
Manning's n	Generally OK but was based on VLUIS	
Modelling of key structures	Bridges and culverts explicitly modelled. Reasonable data was available for each structure. The Coliban Main Channel has not been explicitly modelled but this will only take a small amount of flood flow	
TUFLOW model set up	Cell size adequately represents waterway and boundary conditions modelled appropriately.	
TUFLOW parameters	TUFLOW parameters have not been calibrated or verified to recorded flood levels.	



Rapid Flood Risk Assessment - North Central CMA Region  
Malmbsbury



## 10. Limitations

Any information provided by the Bureau of Meteorology, Geoscience Australia as well as published methodologies (e.g. Australian Rainfall and Runoff) cannot be guaranteed to be free of errors.

The hydrological parameters rely on the previous calibration and verification undertaken for each of the RORB models. Therefore, the accuracy of this will vary depending on the information available to calibrate the models. However, any calibration and verification of the models to streamflow information will most likely be better than just relying on regional parameter estimates.

The proposed methodology for the PMF estimate is preliminary in nature. Other, more detailed techniques are available in which to estimate the PMF. However, for this investigation a preliminary assessment has been considered to be appropriate.

The analysis has relied heavily on the supplied LIDAR terrain data. For this investigation no survey will be undertaken to independently check the terrain data.

For the hydraulic model the intention is that the waterways are represented by 4-5 cells. Where a waterway is less eight metres wide it will be represented by less than the 4-5 cells which could mean that the waterway is not fully represented.

The Manning's roughness adopted for the study areas utilising the VLUIS dataset. As the VLUIS is a state wide dataset there may be some areas that have either been developed since the VLUIS was established or not captured accuracy. Whilst, basic checks have been undertaken to pick up any large errors in assigned land use there may still be some lot scale differences in land use which may not be picked up.

As the hydraulic model was not calibrated to surveyed flood levels the Manning's n values listed in Table 7-1 may not necessarily represent the roughness values accurately.

As mentioned in Section 6.3 the ARR2019 approach to climate change has a number of limitations, including the fact that it does not provide a means to account for potential increases in rainfall losses under a drying climate.

The quick look flood / no flood tools may be replaced where more detailed investigations are undertaken in the future.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## 11. Conclusion

This project forms part of the Rapid Flood Risk Assessment for the North Central CMA region. Outputs from the assessment will assist the North Central CMA to meet a range of business requirements. Outputs can be used to assist in flood related controls, develop flood intelligence products, inform emergency response planning and assist in the preparation of community flood awareness and education products.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



## 12. References

- Agriculture Victoria (2016) Victorian Land Use Information System (VLUIS)
- Austroroads (1994) Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways
- Ball J, Babister M, Nathan R, Week W, Weinmann E, Retallick M, Testoni I, (Editors) (2019) Australian Rainfall and Runoff: A guide to flood estimation, Commonwealth of Australia (Geoscience Australia).
- Babister, M, Trim, A, Testoni, I, Retallick, M. (2016) The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ.
- BMT (2018), TUFLOW Classic/HPC User Manual. Build 2018-03-AD
- Bureau of Meteorology (2016) 2016 Rainfall IFD Data System.  
<http://www.bom.gov.au/water/designRainfalls/revised-ifd/>.
- Hydrology and Risk Consulting (2016) ArcRORB, A tool for creating RORB catchment files in ArcMap, User Manual, version 1.6.
- Hill PI, Graszkiwicz Z, Taylor M and Nathan RJ (2014) Australian Rainfall and Runoff revision project 6: Loss models for catchment simulation. Stage 4: Analysis of rural catchments.
- Hill P and Thomson R (2015) Chapter 3 in Book 5: Losses. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.
- Jordan P, Nathan R, Podger S, Babister M, Stensmyr P and Green J (2016) Chapter 4 in Book 2: Areal reduction factors. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.
- Laurenson EM, Mein RG and Nathan RJ (2010) RORB version 6 runoff routing program - User manual. Monash University Department of Civil Engineering in conjunction with Hydrology and Risk Consulting Pty. Ltd. and the support of Melbourne Water Corporation, Melbourne.
- Minty, L.J and Meighen, J (1999), Development of temporal distributions of rainfall antecedent to large and extreme design bursts over southeast Australia, Hydrology Report Series HRS Report No.6, Hydrometeorological Advisory Service, Bureau of Meteorology.

Rapid Flood Risk Assessment - North Central CMA Region  
Malmesbury



Nathan RJ, Weinmann PE and Hill PI (2002) Use of a Monte Carlo framework to characterise hydrologic risk. Proceedings of the 2002 ANCOLD Conference, Adelaide. Australian National Committee on Large Dams.

Nathan RJ, Weinmann PE and Hill PI (2003) Use of Monte Carlo simulation to estimate the expected probability of large to extreme floods. Proceedings of 28th Hydrology and Water Resources Symposium, Wollongong. Institution of Engineers, Australia.

Nathan RJ, Weinmann PE and Gato SE (1994) A quick method for estimating the probable maximum flood in South Eastern Australia, Water Down Under 94. Hydrology and Water Resources Symposium I.E. Aust. Nat. Conf. Publ. 94/10, pp.229-234

Pearse M, Jordan P and Collins Y (2002) A simple method for estimating RORB model parameters for ungauged rural catchments. Proceedings of 27th Hydrology and Water Resources Symposium, Melbourne. Institution of Engineers, Australia.

Phillips, B, Goyen, A, Thomson, R, Pathiraja, S and Pomeroy, L. (2014), Australian Rainfall and Runoff Revision Project 6: Loss models for catchment simulation - Urban Losses Stage 2 Report, February.

Scorah M, Hill P, Lang S and Nathan R (2016), Addressing embedded bursts in design storms for flood hydrology. Water, Infrastructure and the Environment: Proceedings of the 56th New Zealand Hydrological Society Conference and the 37th Hydrology and Water Resources Symposium, Queenstown, New Zealand. New Zealand Hydrological Society and Engineers Australia.

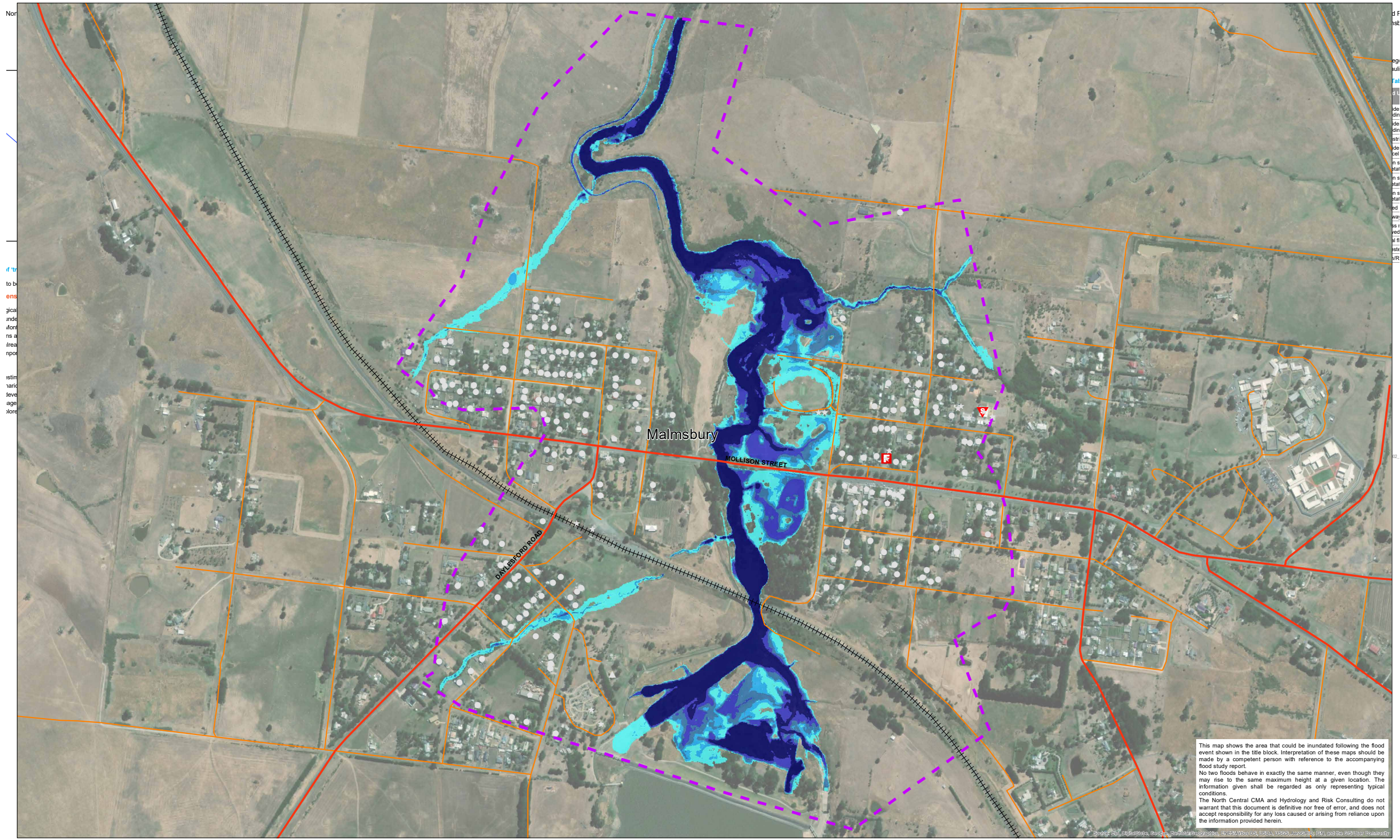
SKM. (2010) Review of the Upper Coliban Storages Flood Hydrology. Final. July 2010

Rapid Flood Risk Assessment - North Central CMA Region  
Malmsbury



## Appendix A Maps





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park

Main Road

Tertiary Road

Railway Line

Flood Model Extent

**Building Classification**

Residential

Commercial

Industrial

Public

**Building Inundation**

not inundated

inundated (without floor level survey)

below floor level (with floor level survey)

above floor level (with floor level survey)

**Max Depth (m)**

< 0.3

0.3 - 0.5

0.5 - 0.8

0.8 - 1.2

> 1.2

Locality Map

Drawn:  
A. SHEN

Checked:  
T. CRAIG

Project Manager:  
A. NORTHFIELD

Project No.:  
NCC00002

North Central CMA  
Project Manager:  
N. TRELOAR

Project Director:  
D. STEPHENS

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT

MAXIMUM DEPTH (m)

Malsbury - 20% AEP Flood Event

0200400

Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:  
1:4,500  
when printed @ A1

Date:  
25/02/2020

Map No.:  
15 - 5 - 1

hydrology and risk  
CONSULTING

North  
Central  
CMA

VICTORIA  
State  
Government

Australian Government

Item PE.1 - Attachment 1

Page 298





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Residential

Commercial

Industrial

Public

not inundated

inundated (without floor level survey)

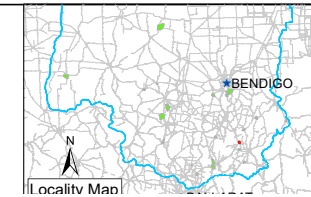
below floor level (with floor level survey)

< 0.4

0.4 - 0.8

0.8 - 1.2

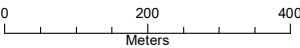
> 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - 20% AEP Flood Event



Scale: 1:4,500 when printed @ A1

Date: 25/02/2020

Map No.: 15 - 5 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carveran Park

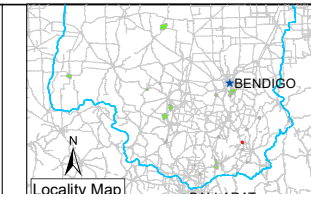
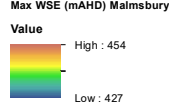
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

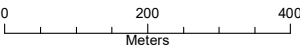
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

Malsbury - 20% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 5 - 3
--------	------------------------------	-------	------------	----------	------------







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road
	Police Station		Tertiary Road
	Hospital		Railway Line
	School/College		Flood Model Extent
	Nursing Home/Aged Care		
	Caravan Park		

**Building Classification**

- Residential
- Commercial
- Industrial
- ★ Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

Drawn: A. SHEN      Project Director: D. STEPHENS

Checked: T. CRAIG

Project Manager: A. NORTHFIELD

Project No.: NCCC00002

North Central CMA  
Project Manager: N. TRELOAR

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM HAZARD**

**Malmsbury - 20% AEP Flood Event**

Scale: 1:4,500  
when printed @ A1

Date: 25/02/2020

Map No.: 15 - 5 - 4

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

hydrology and risk  
collective

North Central CMA

VICTORIA  
State Government

Australian Government





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

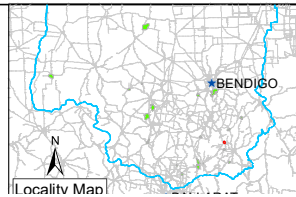
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

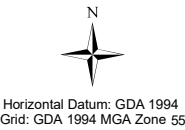
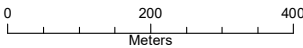
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

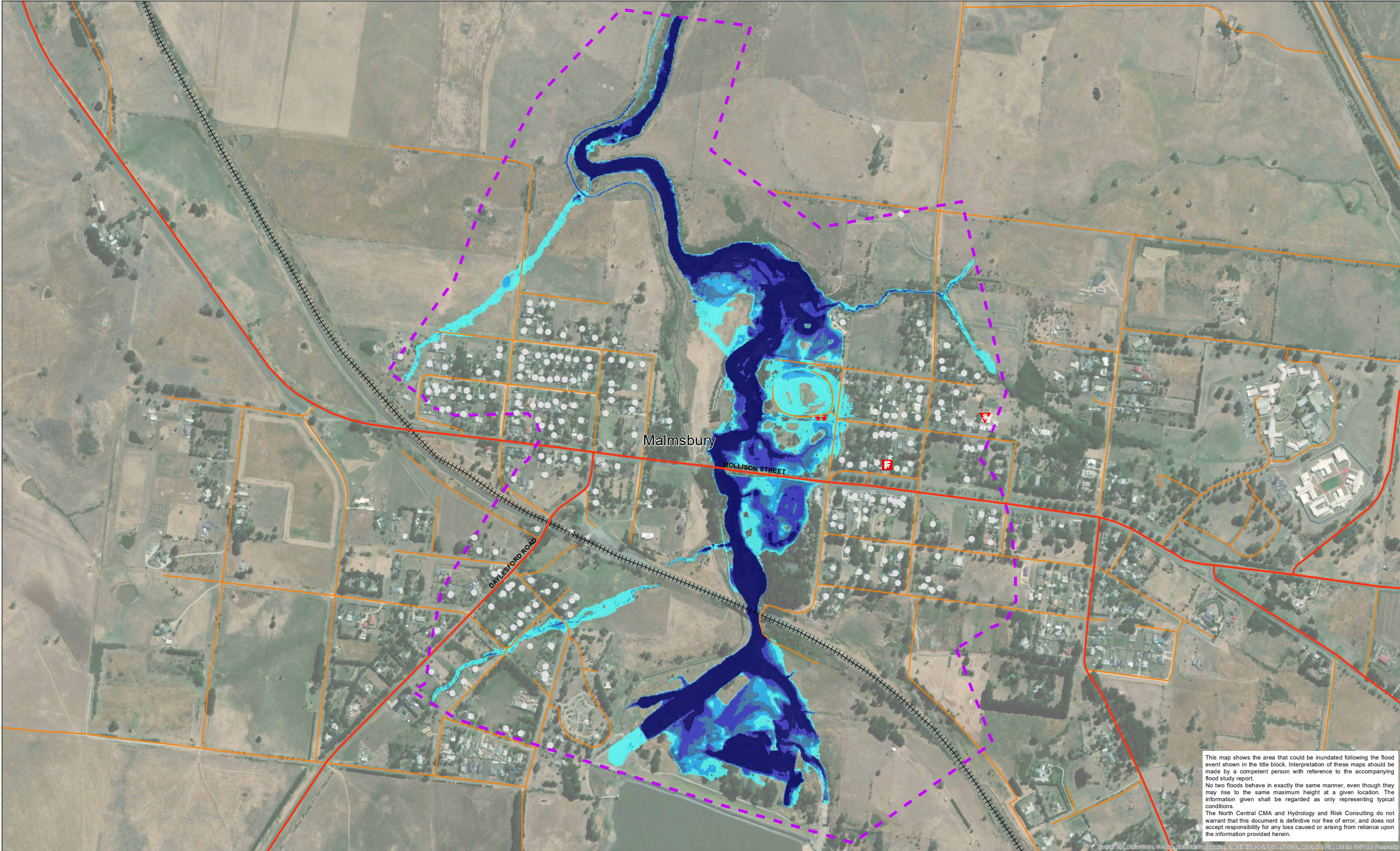
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Malsbury - 20% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 5 - 5





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

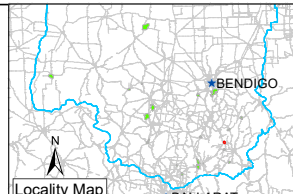
- Main Road
- Tertiary Road
- Railway Line

Building Classification

- Residential
  - Commercial
  - Industrial
  - Public
- Building Inundation**
- not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)
  - above floor level (with floor level survey)

Max Depth (m)

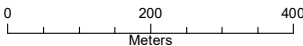
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Malsbury - 10% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 10 - 1





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line

Building Classification

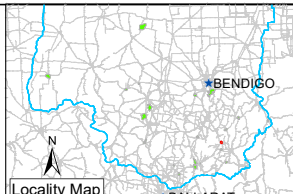
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

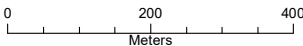
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

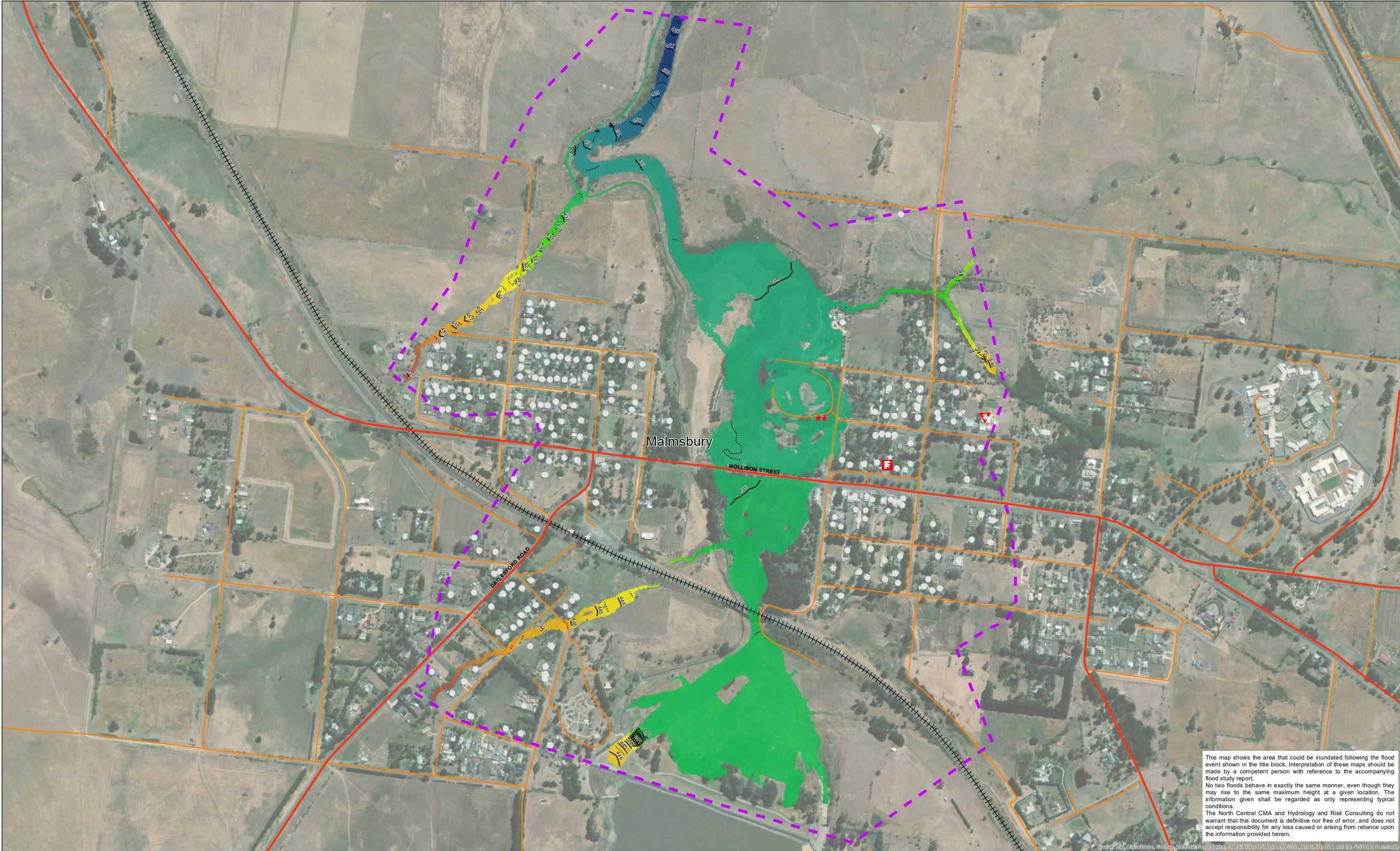
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - 10% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 10 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

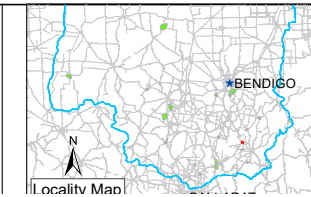
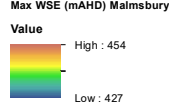
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

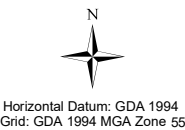
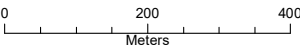
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA			
Project Manager	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Malsbury - 10% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:4,500 when printed @ A1	25/02/2020	15 - 10 - 3







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park

Main Road

Tertiary Road

Railway Line

Flood Model Extent

**Building Classification**

- Residential
- Commercial
- ▲ Industrial
- ★ Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Malsbury - 10% AEP Flood Event**

0 200 400 Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - 10 - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

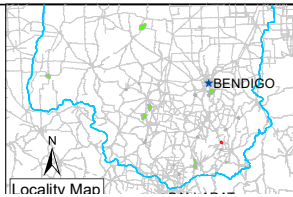
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

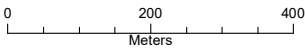
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

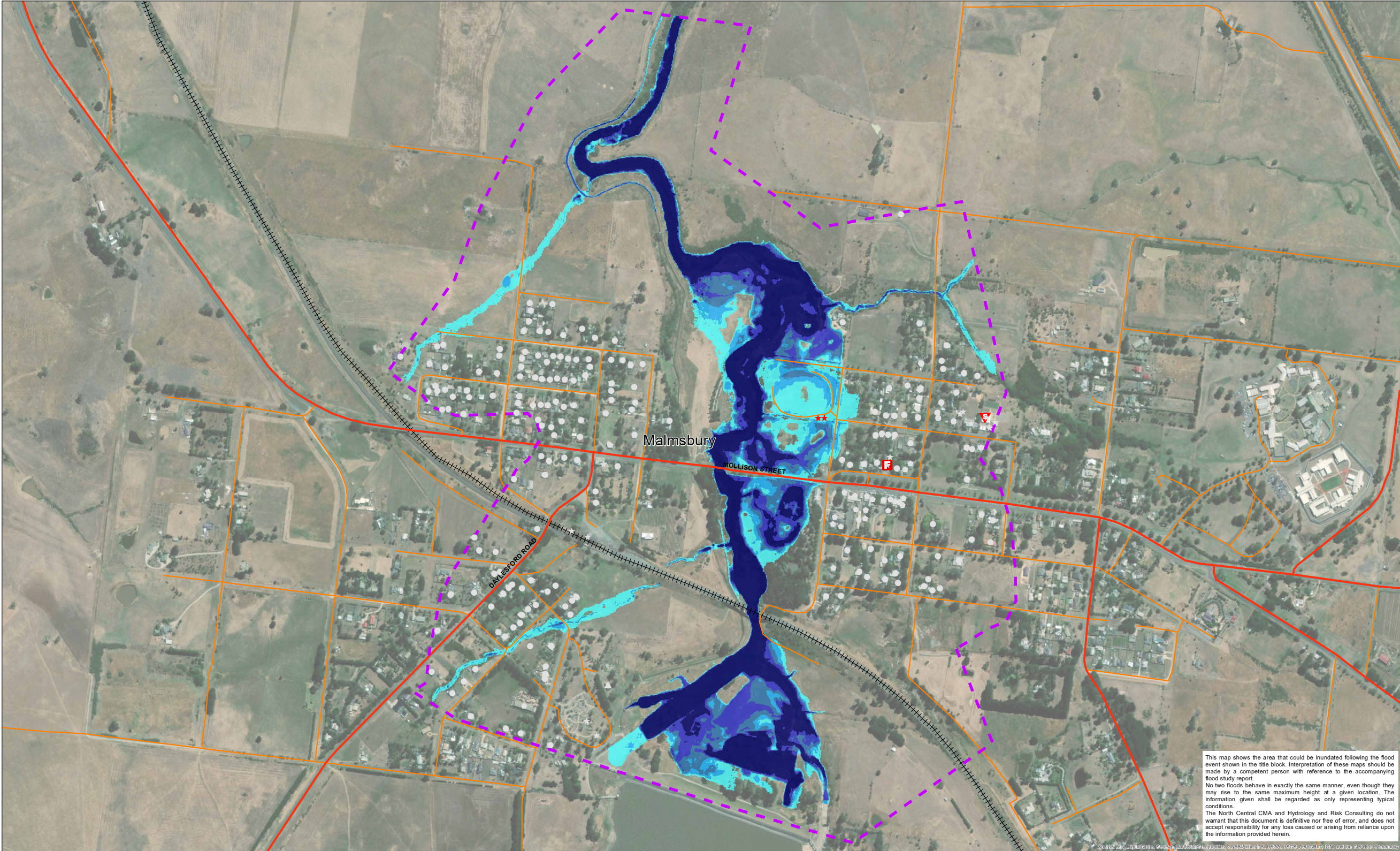
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Malsbury - 10% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 10 - 5





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

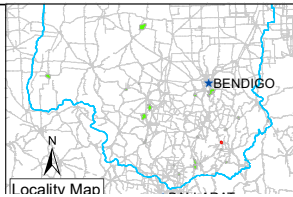
- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
  - Commercial
  - Industrial
  - Public
- Building Inundation**
- not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)
  - above floor level (with floor level survey)

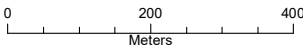
- Max Depth (m)**
- < 0.3
  - 0.3 - 0.5
  - 0.5 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Malsbury - 5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 20 - 1
--------	------------------------------	-------	------------	----------	-------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

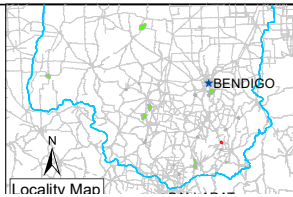
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

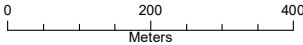
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

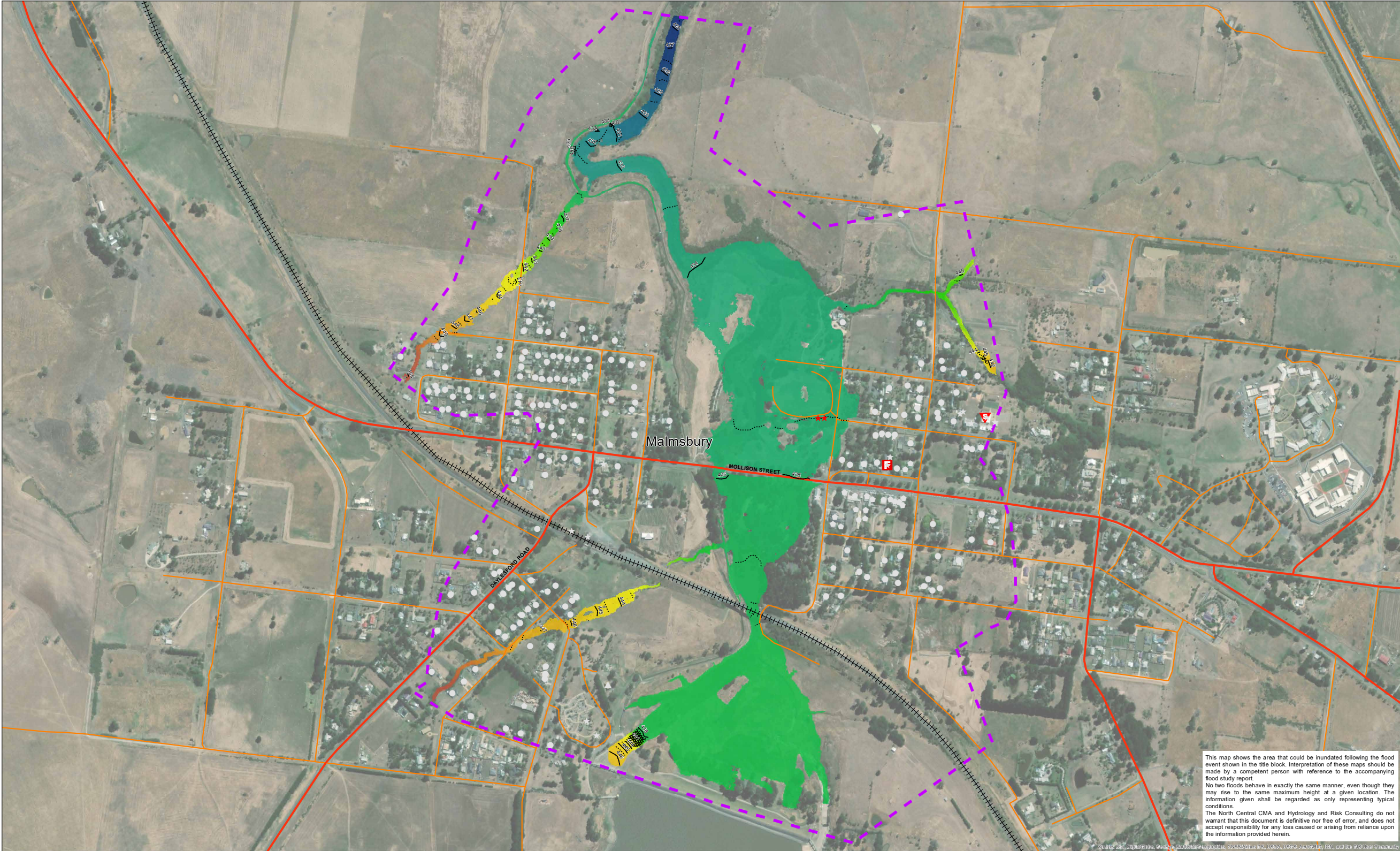
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - 5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 20 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

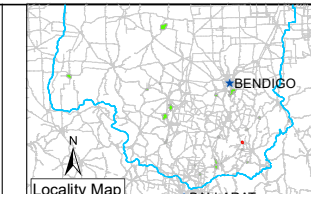
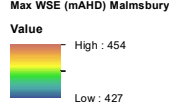
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

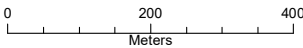
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Malsbury - 5% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:4,500 when printed @ A1	25/02/2020	15 - 20 - 3







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

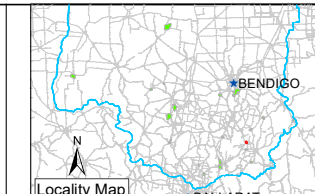
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

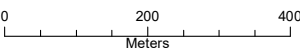
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Malsbury - 5% AEP Flood Event**



Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - 20 - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

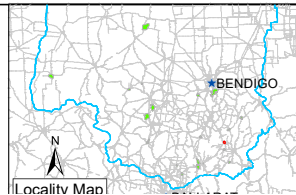
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

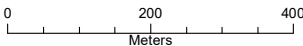
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

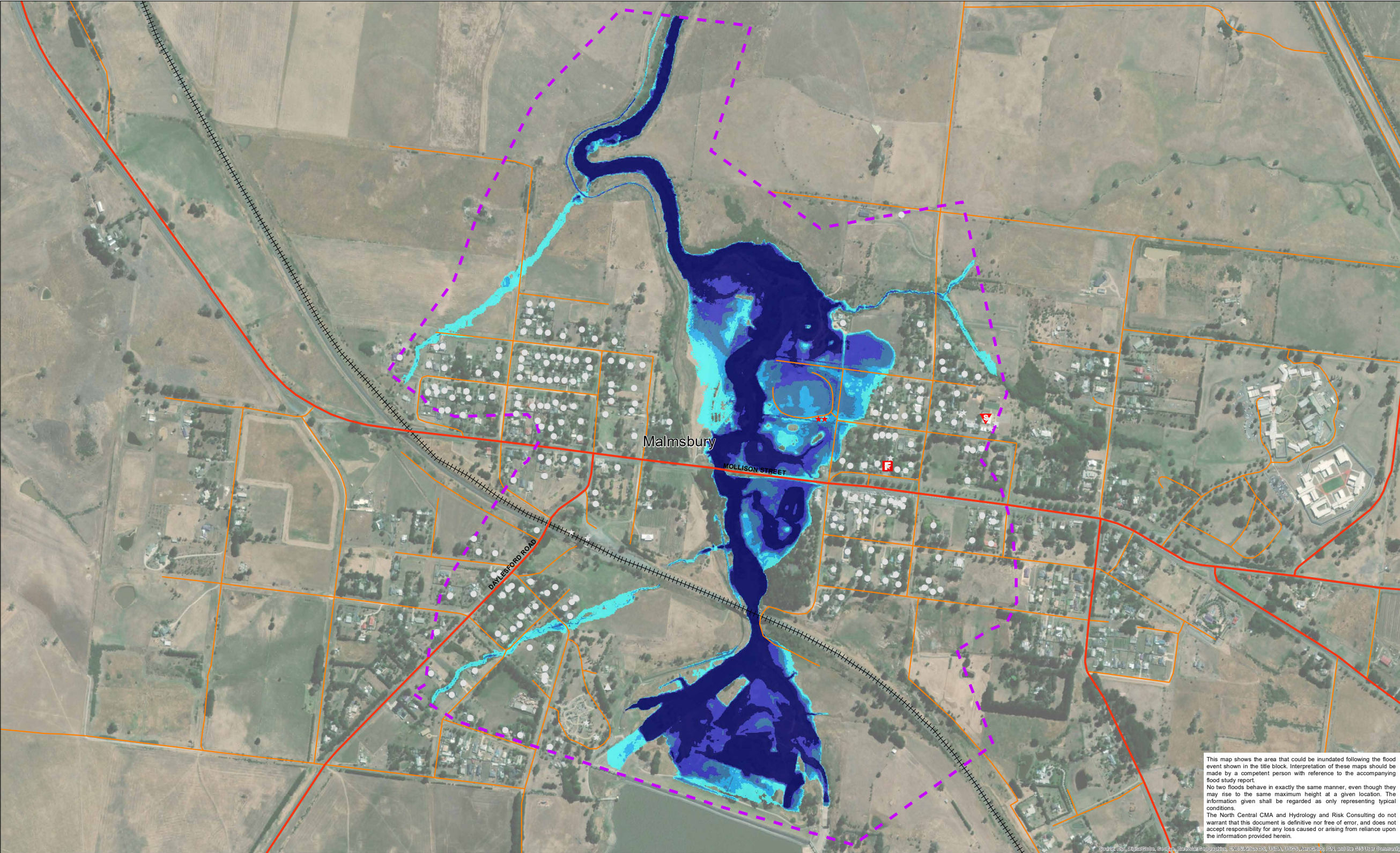
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Malsbury - 5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 20 - 5





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFM/FB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line

Building Classification

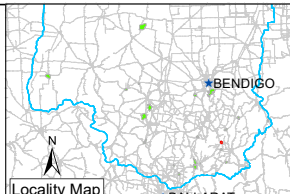
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

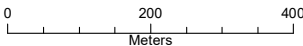
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Malsbury - 2% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 50 - 1





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

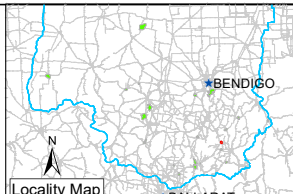
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m²/s)

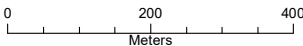
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

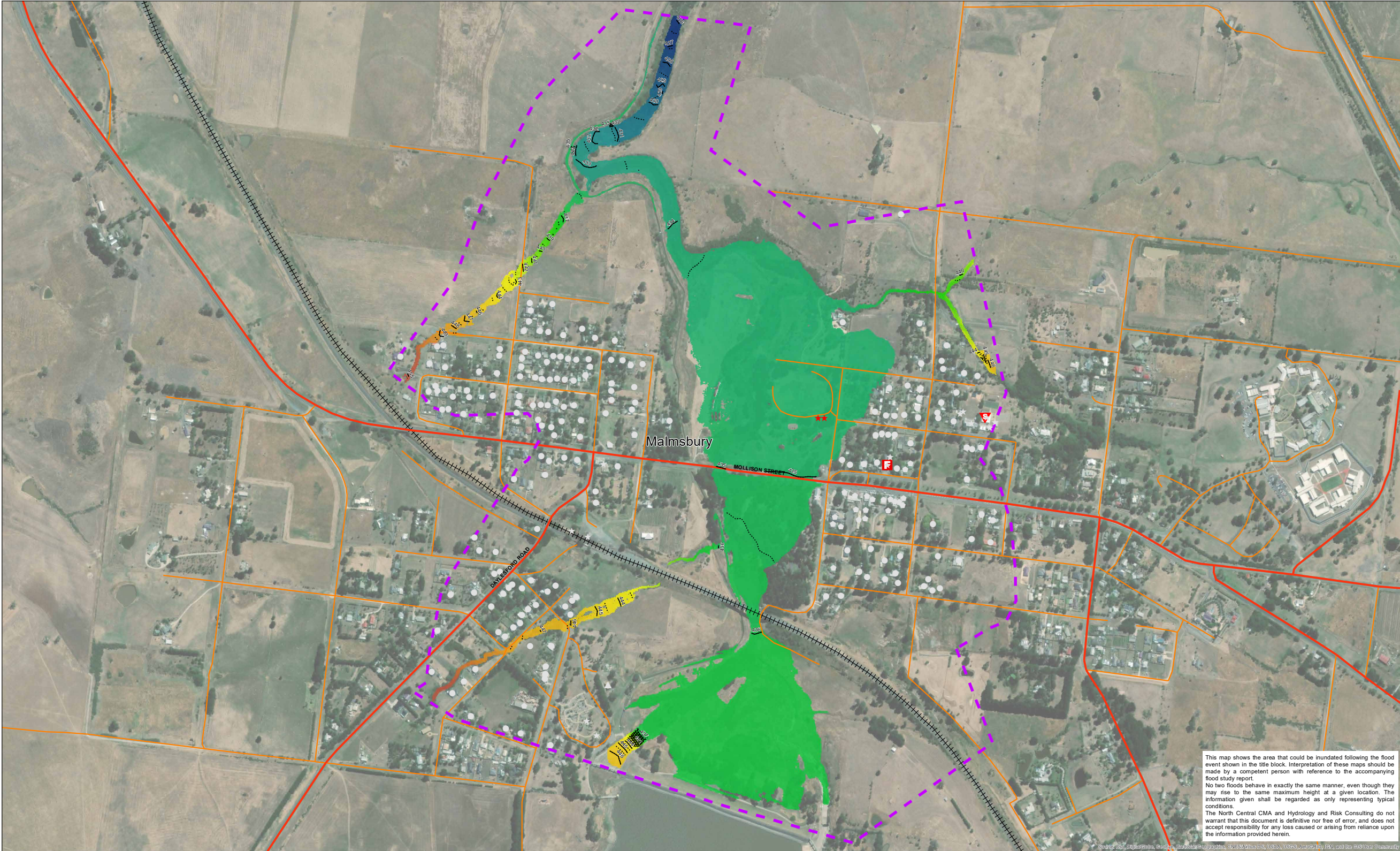
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Malsbury - 2% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 50 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

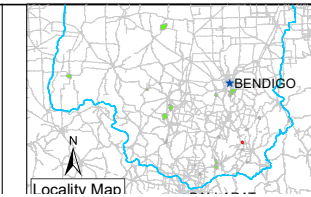
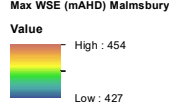
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

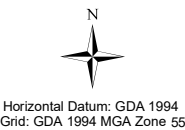
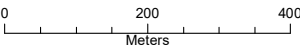
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

Malsbury - 2% AEP Flood Event



Scale: 1:4,500 when printed @ A1

Date: 25/02/2020

Map No.: 15 - 50 - 3





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

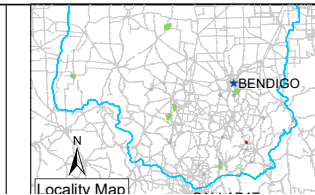
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

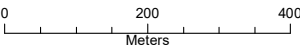
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

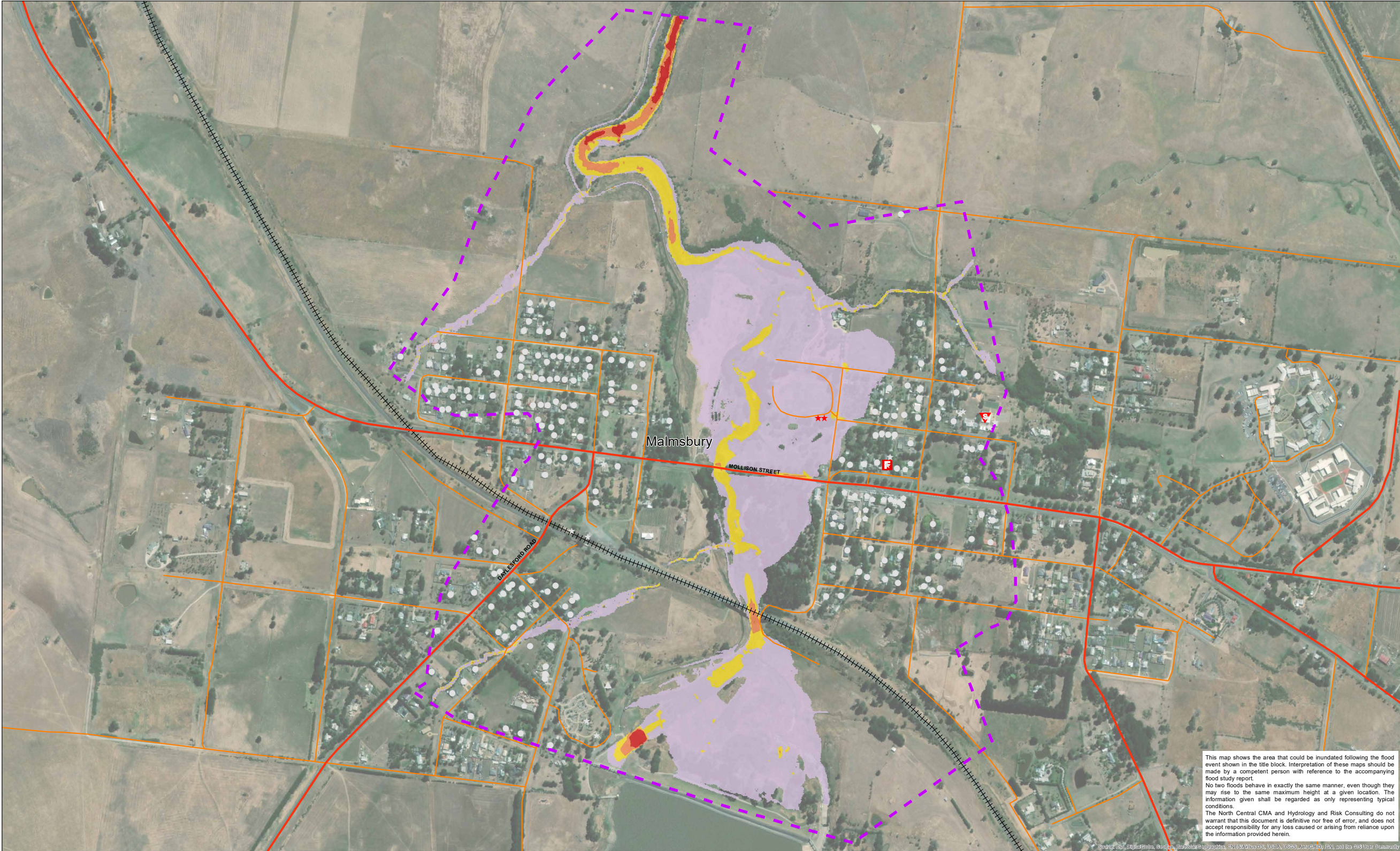
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Malsbury - 2% AEP Flood Event**



Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - 50 - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

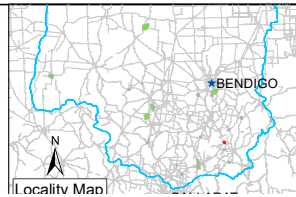
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

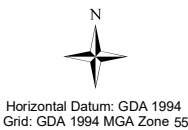
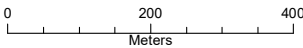
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

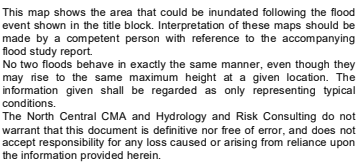
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Malsbury - 2% AEP Flood Event

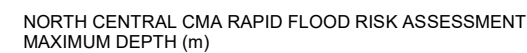


Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 50 - 5

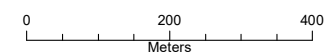




Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,



### Malmsbury - 1% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - 100 - 1
--	---------------------	--------------------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Residential

Commercial

Industrial

Public

not inundated

inundated (without floor level survey)

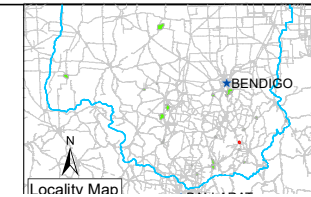
below floor level (with floor level survey)

< 0.4

0.4 - 0.8

0.8 - 1.2

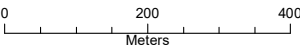
> 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - 1% AEP Flood Event

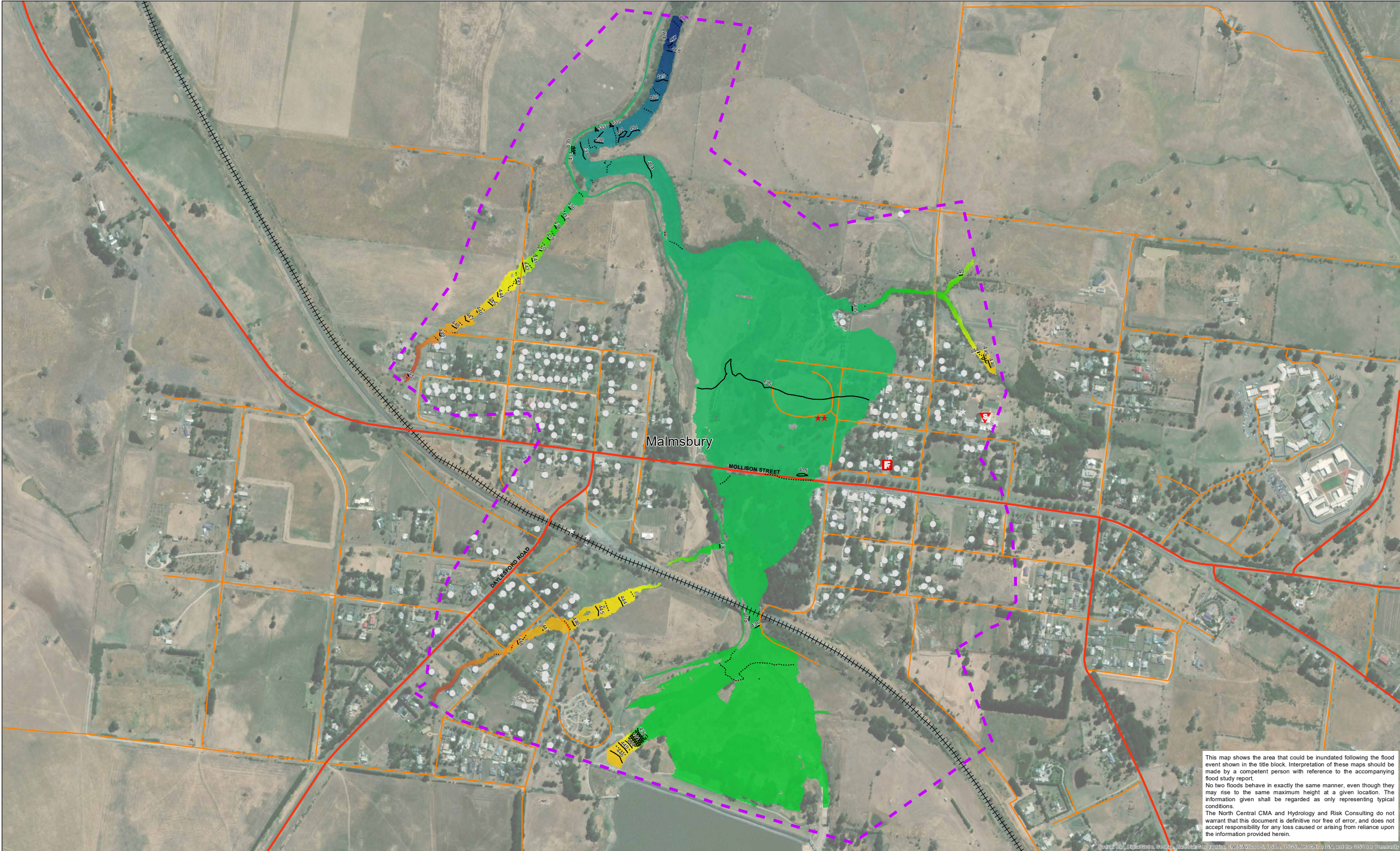


Scale: 1:4,500 when printed @ A1

Date: 25/02/2020

Map No.: 15 - 100 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

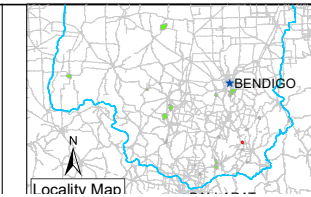
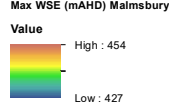
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

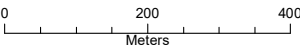
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Malsbury - 1% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:4,500 when printed @ A1	25/02/2020	15 - 100 - 3







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

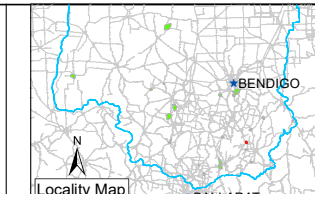
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

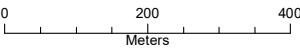
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

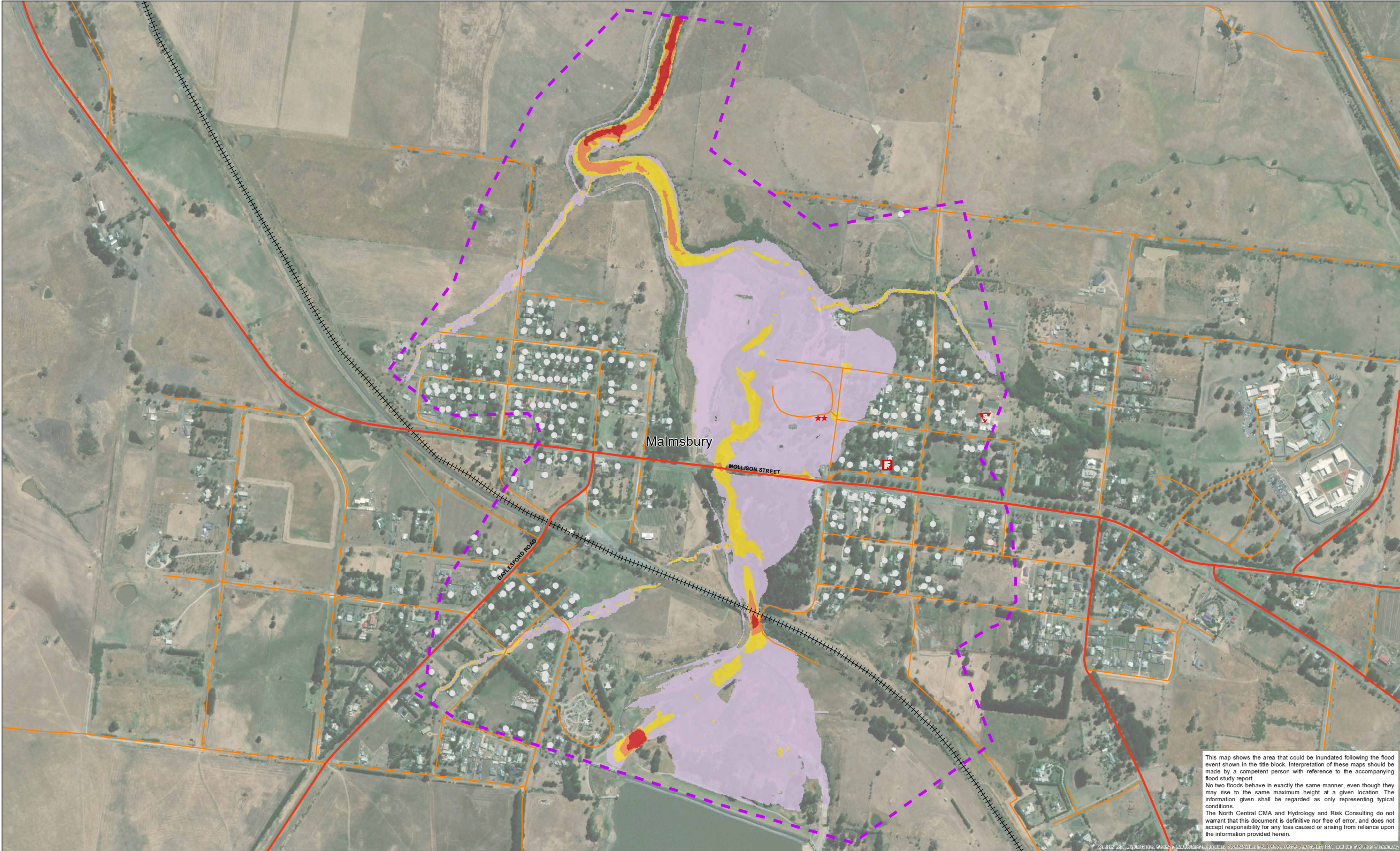
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Malsbury - 1% AEP Flood Event**



Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - 100 - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

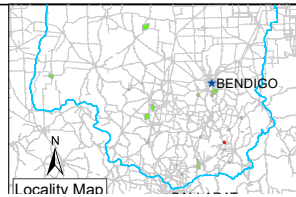
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

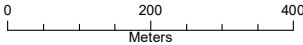
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

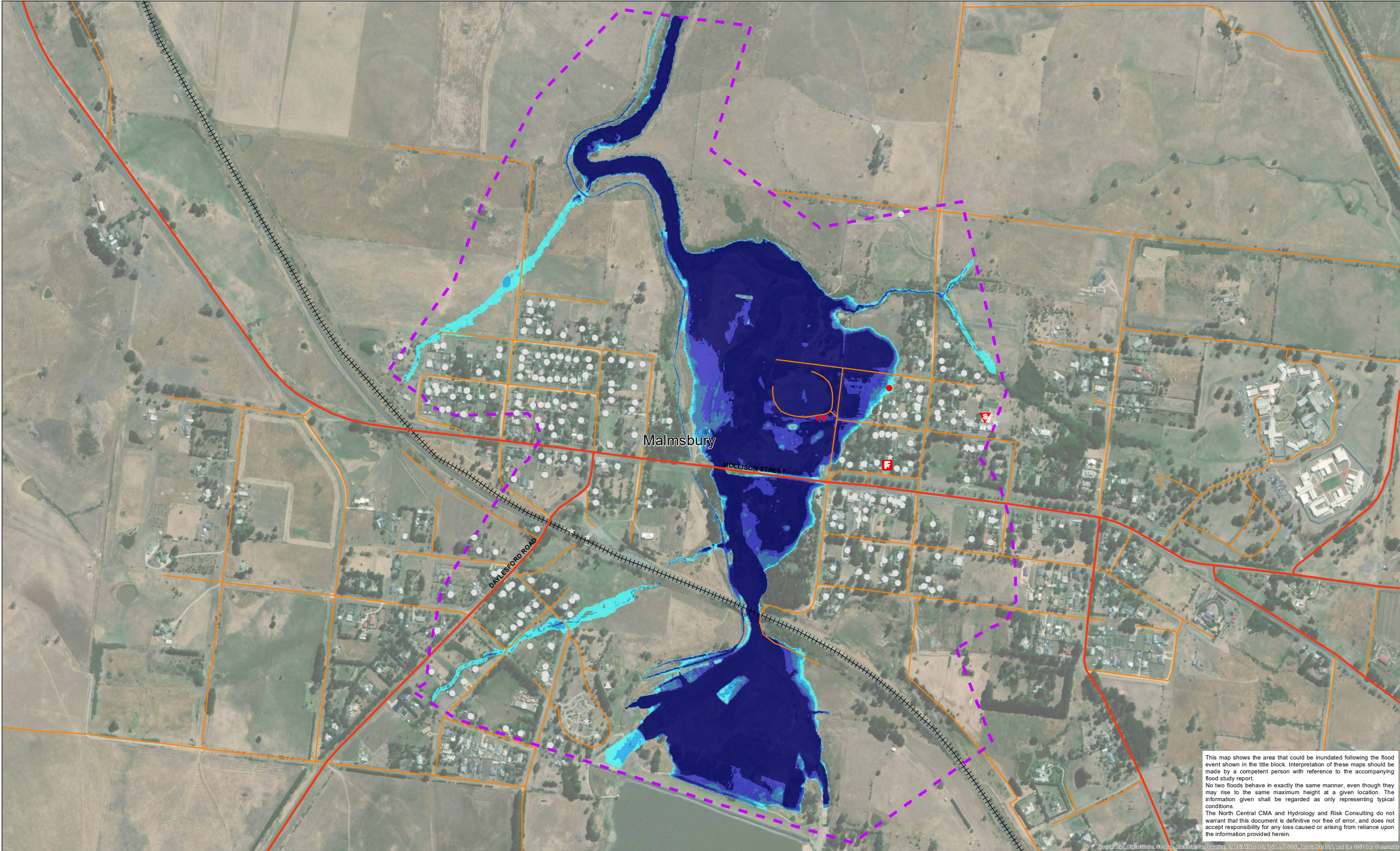
Malsbury - 1% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 100 - 5
--------	---------------------------	-------	------------	----------	--------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line

Building Classification

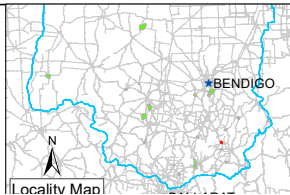
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

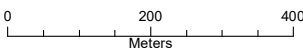
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Malsbury - 0.5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 200 - 1
--------	------------------------------	-------	------------	----------	--------------







This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

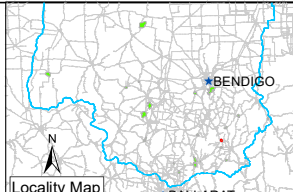
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

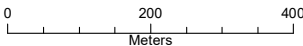
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

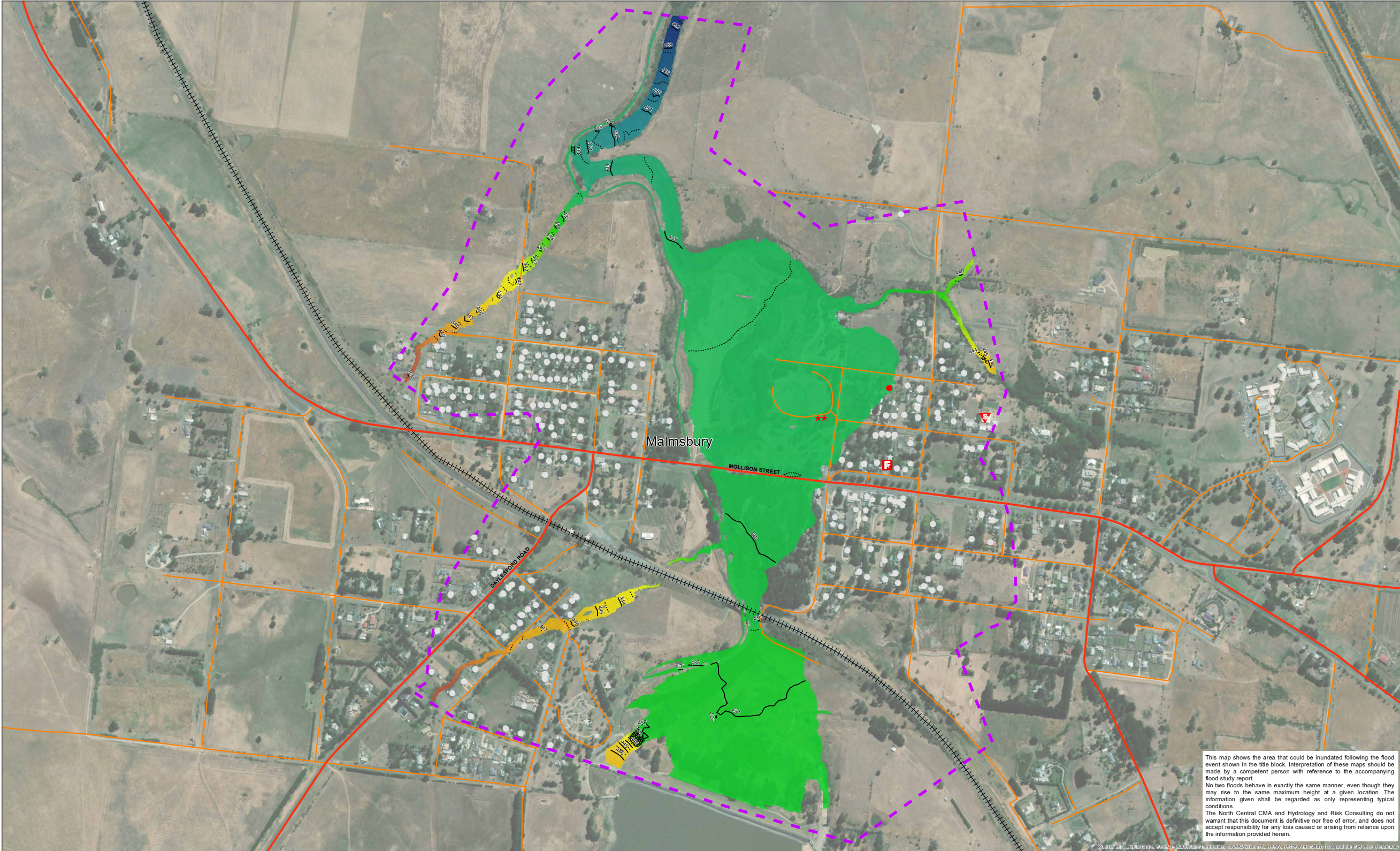
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - 0.5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 200 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

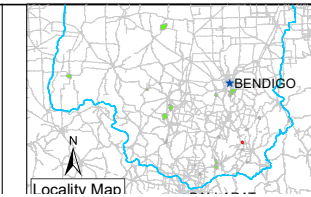
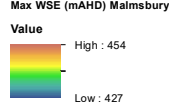
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

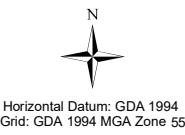
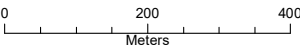
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Malsbury - 0.5% AEP Flood Event



Scale: 1:4,500 when printed @ A1

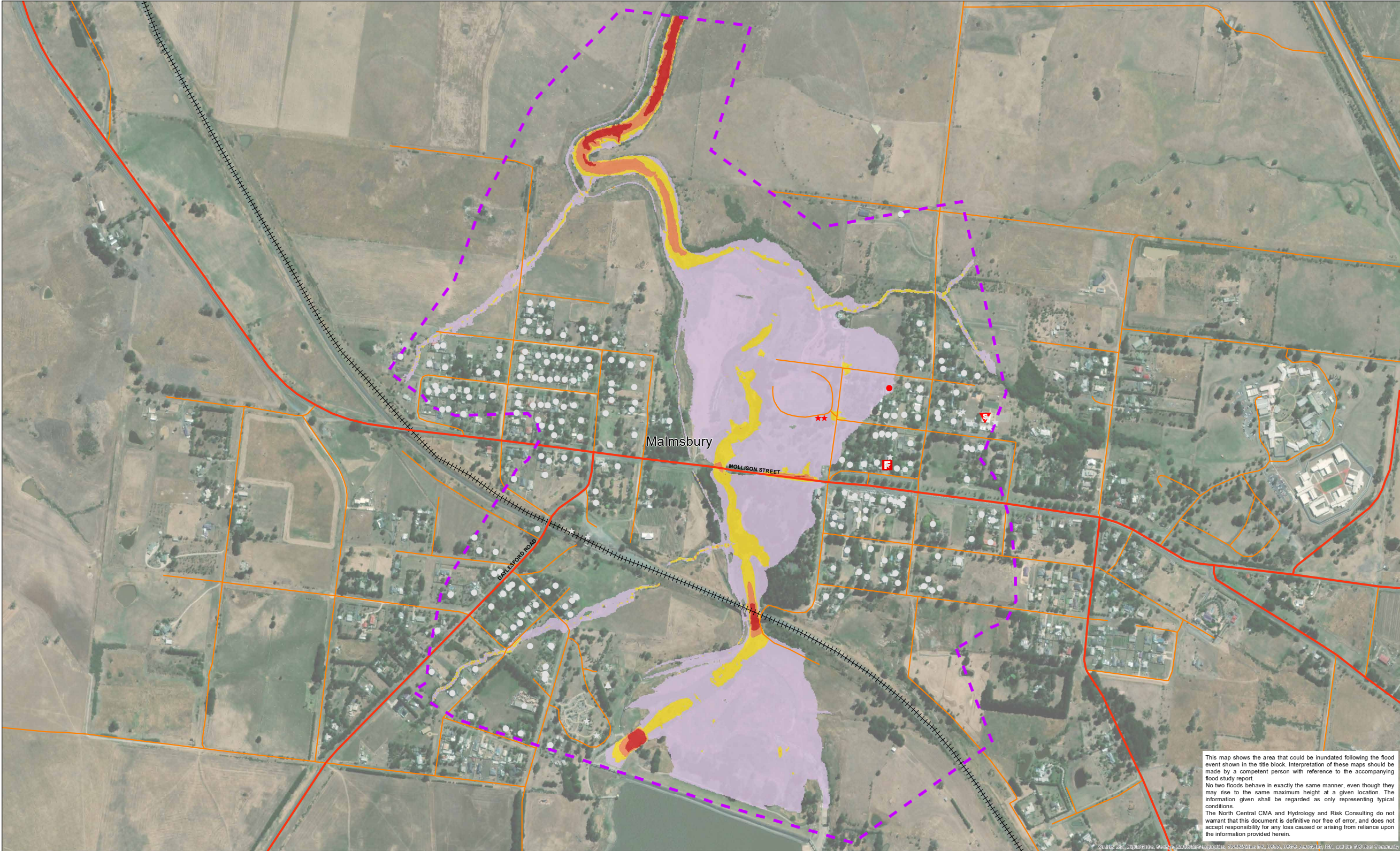
Date: 25/02/2020

Map No.: 15 - 200 - 3









Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

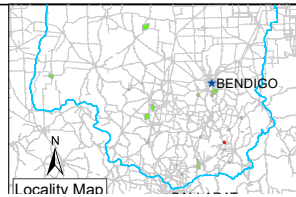
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

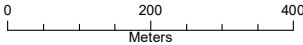
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

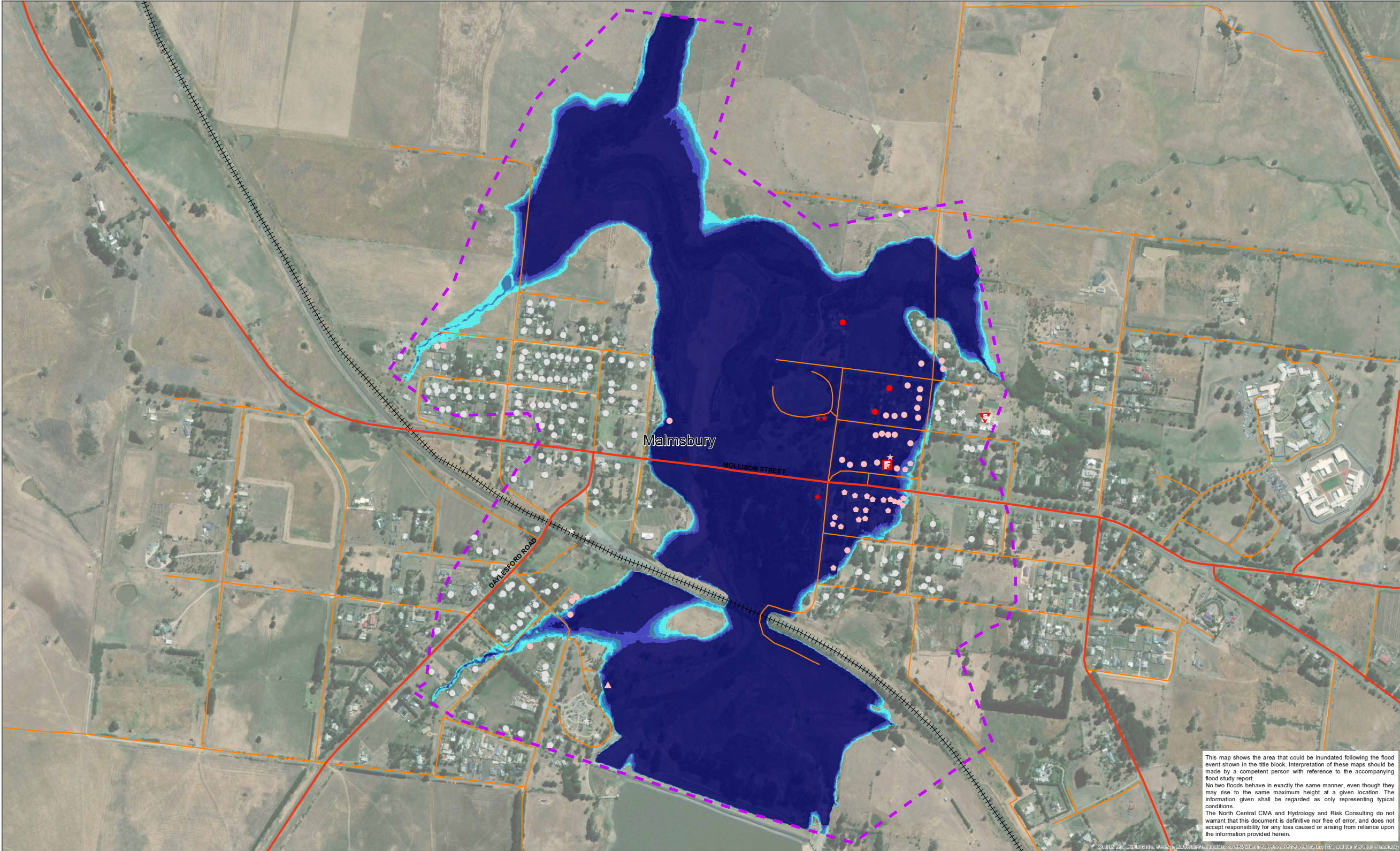
Malsbury - 0.5% AEP Flood Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - 200 - 5
--------	------------------------------	-------	------------	----------	--------------







This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

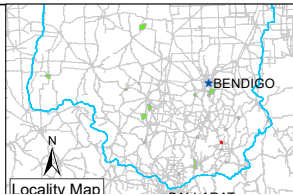
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

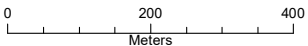
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

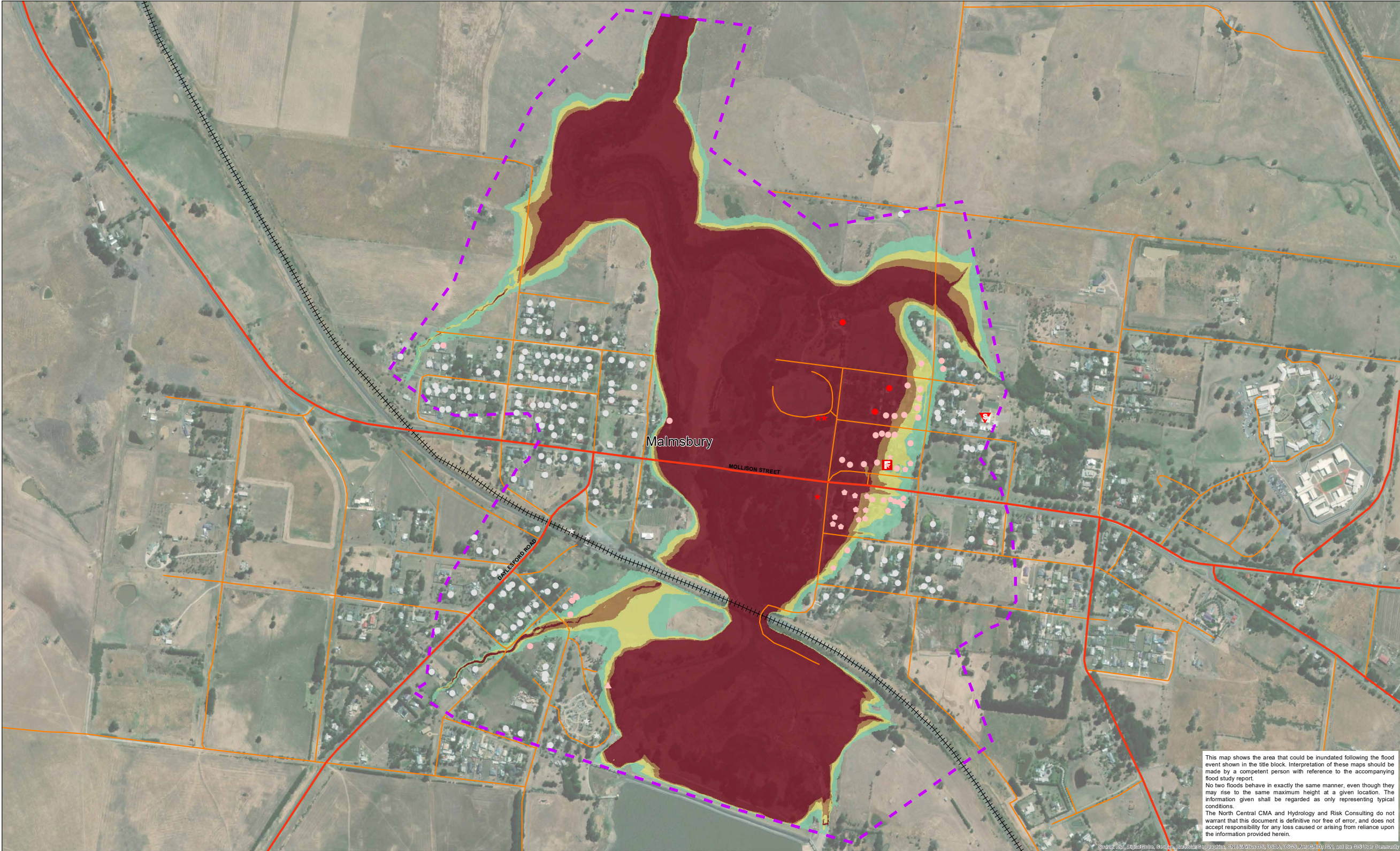
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Malsbury - PMF Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - PMF - 1





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

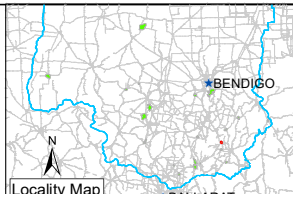
Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC000025\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- |                        |                    |   |
|------------------------|--------------------|---|
| CFA/MFB Fire Station   | Main Road          | Residential                                 |
| Police Station         | Tertiary Road      | Commercial                                  |
| Hospital               | Railway Line       | Industrial                                  |
| School/College         | Flood Model Extent | Public                                      |
| Nursing Home/Aged Care |                    | <b>Building Inundation</b>                  |
| Carveran Park          |                    | not inundated                               |
|                        |                    | inundated (without floor level survey)      |
|                        |                    | below floor level (with floor level survey) |

Max V x D (m<sup>2</sup>/s)

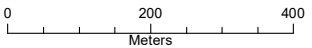
	< 0.4
	0.4 - 0.8
	0.8 - 1.2
	> 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

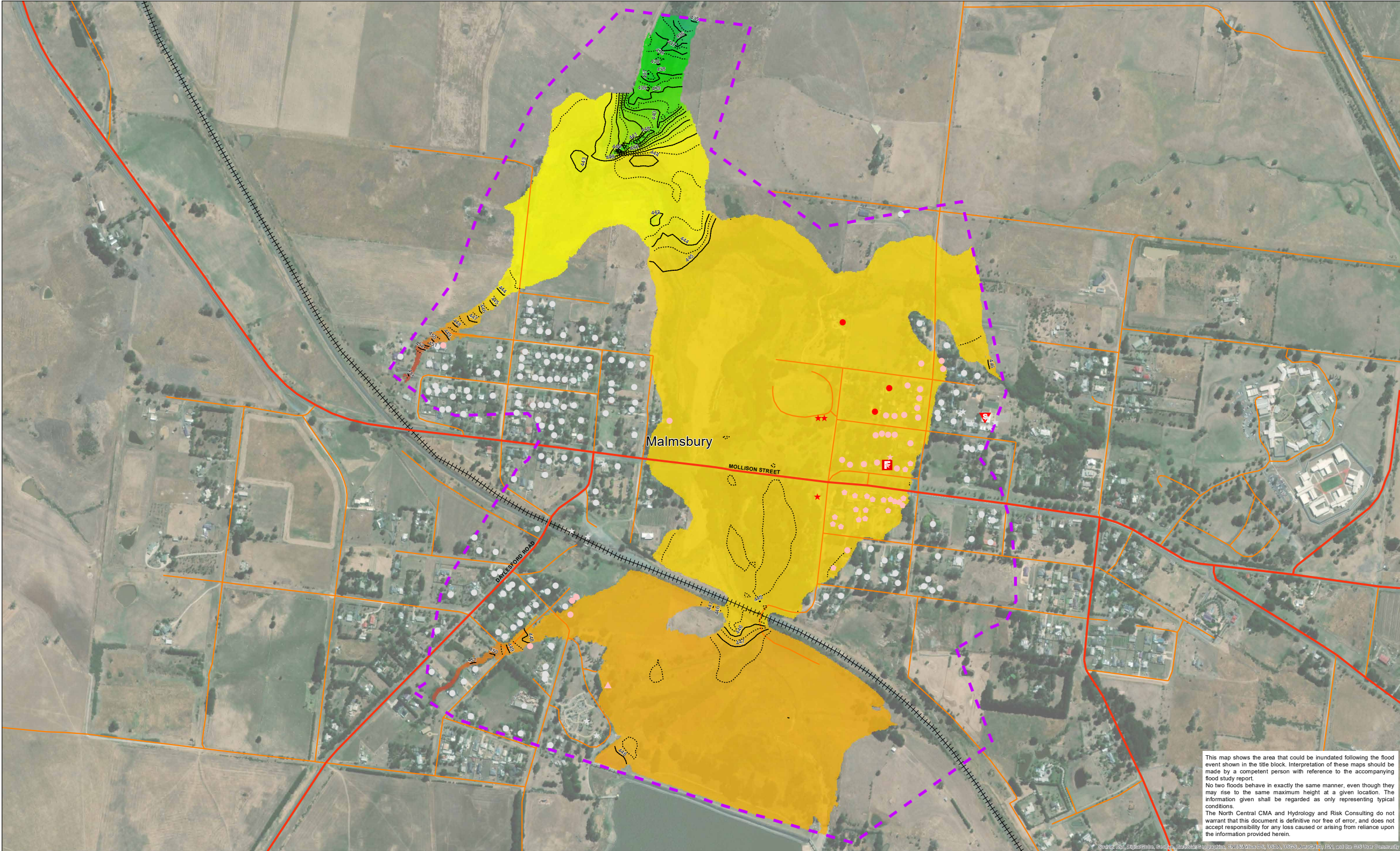
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Malsbury - PMF Event



Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - PMF - 2





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

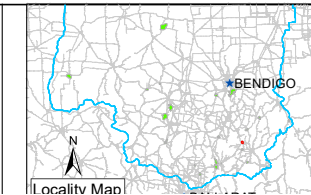
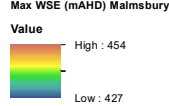
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

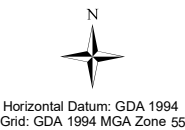
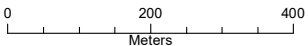
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

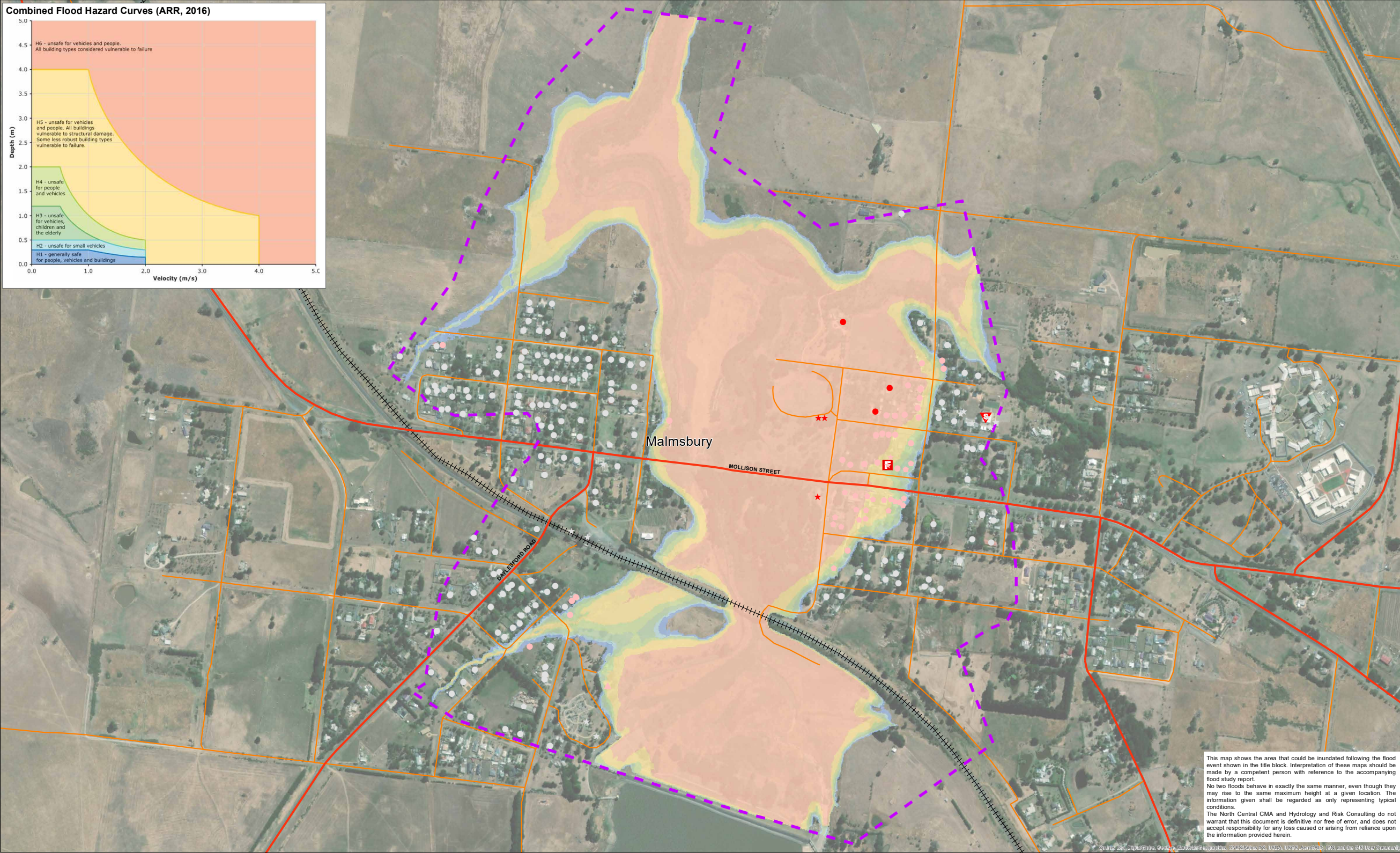
Malsbury - PMF Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	1:4,500 when printed @ A1	Date:	25/02/2020	Map No.:	15 - PMF - 3





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

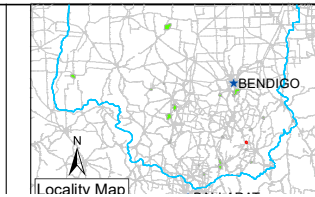
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

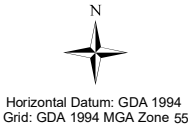
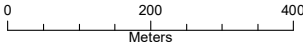
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

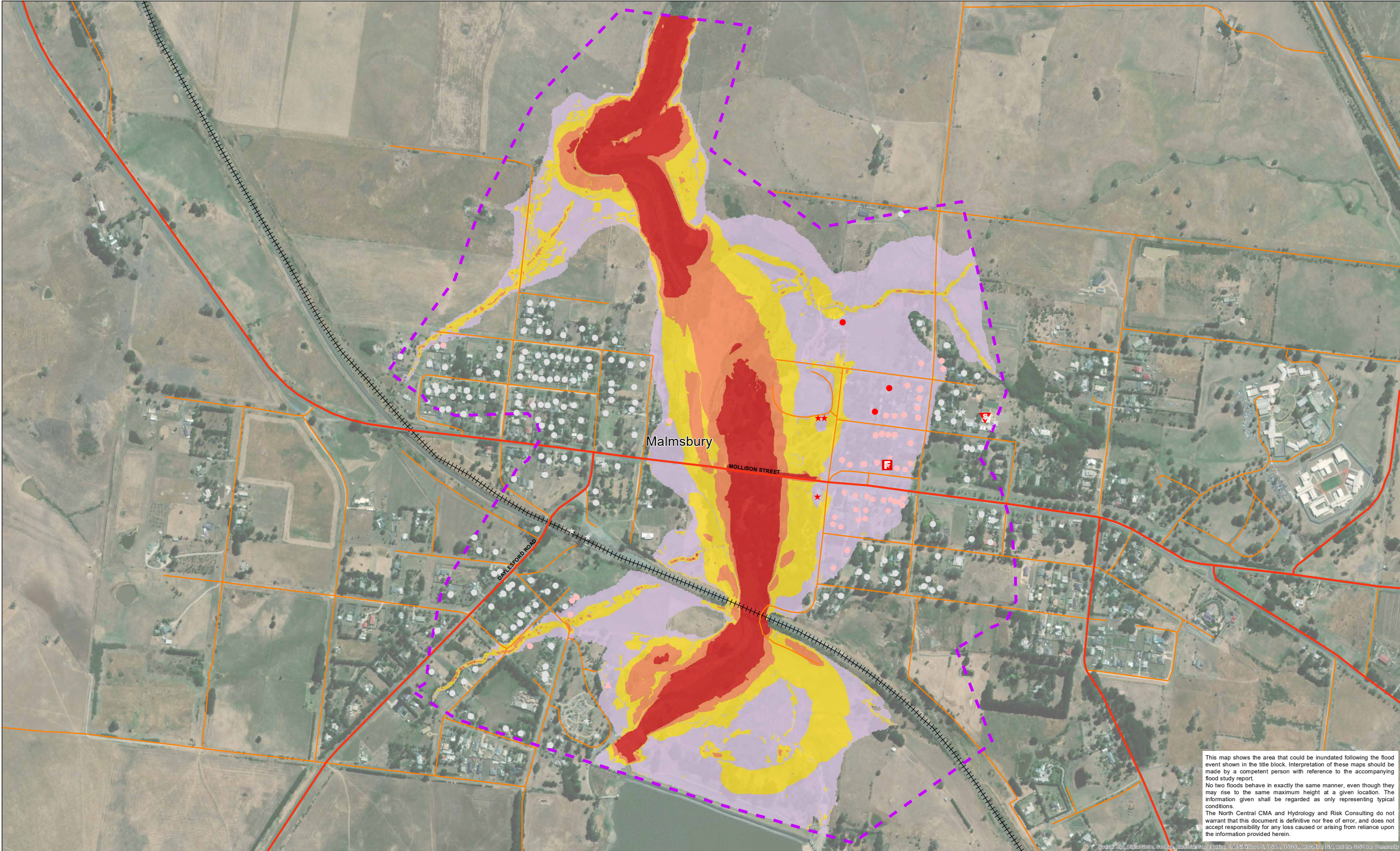
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Malsbury - PMF Event**



Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - PMF - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

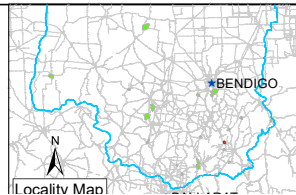
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

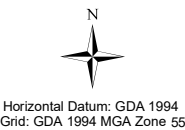
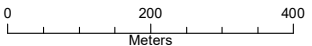
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Malsbury - PMF Event



Scale: 1:4,500 when printed @ A1	Date: 25/02/2020	Map No.: 15 - PMF - 5





## Rapid Flood Risk Assessment - North Central CMA Region

Lauriston

Version 2

22/04/2020

Rapid Flood Risk Assessment - North  
Central CMA Region  
Lauriston



## Contents

<b>1. Introduction</b>	<b>4</b>
<b>2. Available Data</b>	<b>8</b>
<b>2.1 Information Used in Hydrological Analysis</b>	<b>8</b>
2.1.1 Previous Hydrological models	8
<b>2.2 Information Used in Hydraulic Analysis</b>	<b>8</b>
2.2.1 Hydraulic Structures	8
2.2.2 Topographic Data	8
<b>2.3 Previous Flood Studies</b>	<b>9</b>
<b>3. Hydrologic model development</b>	<b>10</b>
<b>3.1 Lauriston RORB model</b>	<b>11</b>
<b>4. Design hydrology approach and inputs</b>	<b>14</b>
<b>4.1 Overview of adopted design flood approach</b>	<b>14</b>
<b>4.2 Overview of design flood hydrology inputs</b>	<b>17</b>
4.2.1 Rainfall depths	18
4.2.2 Areal reduction factors	18
4.2.3 Spatial patterns	19
4.2.4 Temporal patterns	19
4.2.5 Losses	20
4.2.6 Pre-burst rainfall depths and temporal patterns	21
4.2.7 Baseflow	22
4.2.8 Drawdown	22
<b>5. Hydrologic model verification</b>	<b>26</b>
<b>5.1 Adopted parameters</b>	<b>26</b>
<b>5.2 Verification</b>	<b>26</b>
<b>5.3 Comparison to regional parameters</b>	<b>27</b>
<b>6. Design flood hydrology</b>	<b>29</b>
<b>6.1 Design flows for the 20% to 0.5% AEP events</b>	<b>29</b>
<b>6.2 PMF estimate</b>	<b>29</b>
<b>6.3 Climate change and sensitivity analysis</b>	<b>31</b>
<b>7. Hydraulic Model</b>	<b>34</b>
<b>7.1 Topography</b>	<b>34</b>
<b>7.2 Cell size</b>	<b>34</b>
<b>7.3 Roughness values</b>	<b>34</b>
<b>7.4 Hydraulic structures</b>	<b>37</b>
<b>7.5 Inflows</b>	<b>37</b>

Rapid Flood Risk Assessment - North  
Central CMA Region  
Lauriston



7.6	Downstream boundary	37
8.	Flood Risk Assessment	39
8.1	Flood Mapping	39
8.2	Flood behaviour and impact of flooding	39
8.3	Climate change	44
8.4	Flood Intelligence Information	45
8.5	Developing Indicative Quick Look Flood / No-Flood Tools	45
8.5.1	Guidance on the use of the Quick Look Flood / No flood Tool	46
8.5.1.1	In the lead up to a flood	46
8.5.1.2	During a flood - using the quick look tool	46
8.5.1.3	After a flood – updating the tool	47
8.5.1.4	Example use of the quick look tool	47
8.6	Flood classification – Bureau of Meteorology	49
9.	Summary of rating of key areas	50
10.	Limitations	52
11.	Conclusion	53
12.	References	54
Appendix A	Maps	56



Rapid Flood Risk Assessment - North  
Central CMA Region  
Lauriston



### Document status

Client	North Central Catchment Management Authority
Project	Rapid Flood Risk Assessment - North Central CMA Region
Document	NCC00002_RFRA_NCC_16_Lauriston_Version2.docx
This version	Version 2
Authors	Tim Craig, Andrew Northfield
Project manager	Andrew Northfield
File name	S:\3_Projects\NCC00002\6_Deliverables\
Project number	NCC00002

### Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	06/01/2020	D. Stephens	D. Stephens	N. Treloar	For discussion
Version 1	12/03/2020	D. Stephens	D. Stephens	N. Treloar	
Version 2	22/04/2020	D. Stephens	D. Stephens	N. Treloar	Minor updates

### Copyright and Limitation

The report has been prepared based on the information and specifications provided to HARC by North Central Catchment Management Authority. HARC does not warrant this document as being complete, current or free from error and disclaims all liability for any loss, damage, costs or expenses (including consequential losses) relating from this report. It should only be used for its intended purpose by North Central Catchment Management Authority and should not be relied upon by third parties.

The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments.



This work is licensed under a Creative Commons Attribution 4.0 International licence. You are free to re-use the work under that licence, on the condition that you credit Hydrology and Risk Consulting Pty Ltd as author. The licence does not apply to any images, photographs or branding. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>

#### Acknowledgment of Country

We acknowledge Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

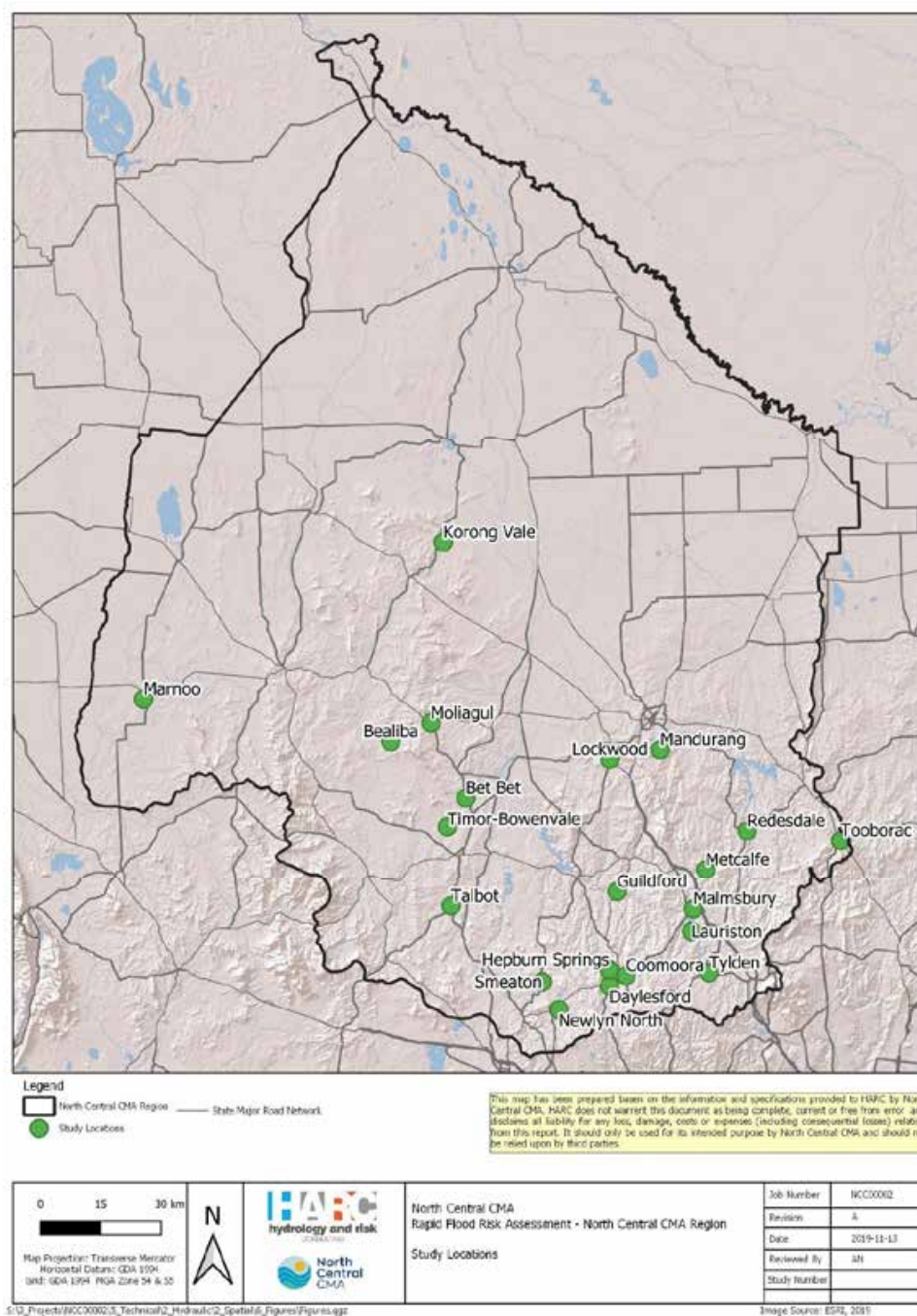
Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 1. Introduction

The North Central Catchment Management Authority (CMA) commissioned HARC to undertake a rapid flood risk assessment for 21 townships in the North Central CMA region. The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments. The study focused on providing mapped flood extents for a range of AEPs using a range of existing and new hydrologic and hydraulic models. The rapid nature of the assessment precluded detailed, site specific studies, extensive model calibration or community engagement. The outcomes of the study were used to provide preliminary estimates of flood risk at the 21 locations, and to help identify and prioritise areas where more detailed, site specific flood studies were recommended. The study locations are shown in Figure 1-1 and the list of townships is shown in Table 1-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 1-1 Rapid Flood Risk Assessment Project Study Locations



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



- **Table 1-1 List of Study Locations (Study Location in bold denotes the township covered in this report)**

No.	Name	No.	Name
1	Lockwood	12	Daylesford
2	Mandurang	13	Hepburn Springs
3	Redesdale	14	Korong Vale
4	Moliagul	15	Malmsbury
5	Bet Bet	<b>16</b>	<b>Lauriston</b>
6	Talbot	17	Tylden
7	Bealiba	18	Tooborac
8	Timor-Bowenvale	19	Guildford
9	Coomoora	20	Metcalfe
10	Newlyn North	21	Marnoo
11	Smeaton		

This report documents the investigation undertaken for the study location of Lauriston.

Lauriston has a population of approximately 236 and is downstream of Lauriston Reservoir, approximately 65 km south-east of Bendigo. The Coliban River runs through the centre of the town, which has an upstream catchment area of 221 km<sup>2</sup>. The river channel is well defined within the study area. The Coliban River flow is significantly regulated by several large storages (Upper Coliban and Lauriston Reservoir) upstream of the town. A map of the study area is shown in Figure 1-2.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 1-2 Lauriston study area

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 2. Available Data

This section describes the key information used in the hydrological and hydraulic investigation.

### 2.1 Information Used in Hydrological Analysis

#### 2.1.1 Previous Hydrological models

There was a RORB model set up as part of the Upper Coliban Storages Flood Hydrology (SKM, 2010) which included Lauriston. Table 2-1 summarises the key RORB parameters from the previous study.

■ **Table 2-1 Previous RORB model summary of key parameters**

No.	Study Area	Previous Study	$k_c$	$d_{av}$	$C_{0.8}$ ( $k_c/d_{av}$ )	IL (mm)	CL (mm/h)	Shire
16	Lauriston	Upper Coliban Storages Flood Hydrology	60	23.8	2.5	45	3	Macedon Ranges

### 2.2 Information Used in Hydraulic Analysis

#### 2.2.1 Hydraulic Structures

There are several hydraulic structures located within the study area. The main structures are listed in Table 2-2 and the location of these structures is shown in Figure 7-2. There may be other minor crossings within the study area but they have been assessed as likely to have little/no impact on the flood extents. The North Central CMA approached three organisations to provide information on their bridges and culverts. The three organisations were:

- VicRoads;
- VicTrack; and
- Council

■ **Table 2-2 Summary of hydraulic structures for consideration**

No.	Township Name	Source	Structure Type	Description
16	Lauriston	Council	Bridge	Lauriston Rd (footbridge)
		Council	Bridge	Lauriston Rd

#### 2.2.2 Topographic Data

To undertake detailed hydraulic modelling requires high quality ground surface information. For this study, aerial captured ground survey, LIDAR, was supplied by North Central CMA. The LIDAR was used to generate a Digital Elevation Model (DEM) of the study area. This LIDAR covered the whole model extent. Further information on the LIDAR dataset used for this study is provided in Section 7.1.



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



### 2.3 Previous Flood Studies

The North Central CMA provided a number of reports to provide background information for this project. The main reports relevant to this study area are listed in Table 2-3.

■ **Table 2-3 Summary of flood studies**

No.	Township Name	Previous Studies
16	Lauriston	Rochester Flood Management Plan (2013), Water Technology

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



### 3. Hydrologic model development

A rainfall runoff model (RORB) was established for the catchment, terminating at the study area downstream boundary (refer to Figure 1-2). RORB (Laurenson, Mein and Nathan, 2010) is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non-linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal spatial distribution of rainfall as well as losses, and can model flows at any number of points throughout a catchment (including upstream and downstream of reservoirs). RORB also has the capacity to use a Monte-Carlo approach to produce design flood estimates that incorporate the joint probability of several factors that influence flood characteristics.

In general terms, development of a RORB model entails sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storage locations.

Four different types of reaches can be defined in RORB, each having different properties and different relative delay times. The reach types are identified as natural, excavated but unlined, lined channel or pipe and drowned reaches. Drowned reaches were used within reservoir water bodies; natural reaches were used for all other reaches. Excavated and lined channel reaches are normally only applied in urbanised areas and hence were not used in this study.

Impervious fractions are required for each sub-area. For rural areas the impervious fraction was assumed to be zero. For any areas within a dam or reservoir water body, an impervious fraction was calculated based on the percentage of the sub-area that would be inundated. The RORB model also includes some urban areas. The total impervious area (TIA) was estimated for the urban areas using aerial photography and land use information. The Victorian Land Use Information System (VLUIS) dataset was used to define the land use. Because not all impervious areas are well connected to the drainage network (i.e. they flow onto pervious parts of the catchment), the effective impervious area (EIA) is less than the TIA. ARR2019 (Book 5, Chapter 5, Hill and Thomson, 2015) and Phillips et al. (2014) have consolidated the recommended industry practice for estimating EIA and loss parameters for the pervious portion of urban catchments. Phillips et al. (2014) analysed eight catchments and concluded that EIA is typically 55 to 65% of the TIA. ARR2019 recommends an EIA/TIA ratio of 60%. For the RORB model the TIA fraction was multiplied by 0.6 to estimate EIA. The EIA assigned to each land use is shown in Table 3-1.

■ Table 3-1 EIA assigned for each land use

Land Use Type	EIA
Residential areas – high density	0.45
Residential areas – low density	0.12
Industrial/commercial – low density	0.54

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



Land Use Type	EIA
Open space or waterway – minimal vegetation	0.0
Open space or waterway – moderate vegetation	0.0
Open space or waterway – heavy vegetation	0.0
Paved roads/car park/driveways	0.6
Railway line	0.6
Grass reserves/floodway (regularly mowed)	0.0
Rural floodplains in clear paddocks	0.0
Forested (heavy stand of timber)	0.0
Dam/Reservoir body of water	1.0

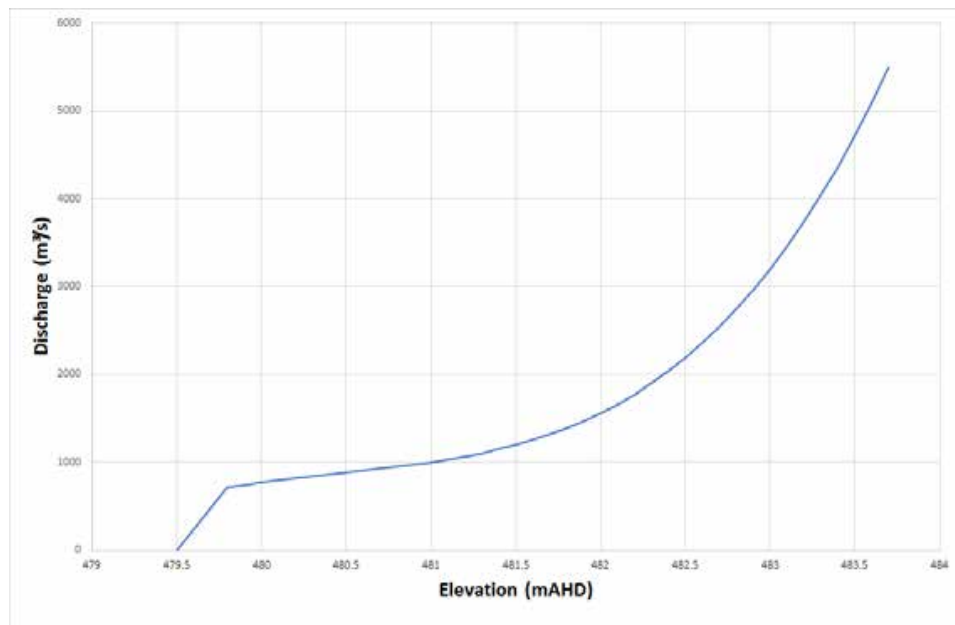
### 3.1 Lauriston RORB model

The Lauriston RORB model was based on the RORB model established by SKM for updating the hydrology for Upper Coliban Storages Hydrology update (SKM, 2010). The subarea layout and reach types were adopted from this study. The RORB model layout is shown in Figure 3-3.

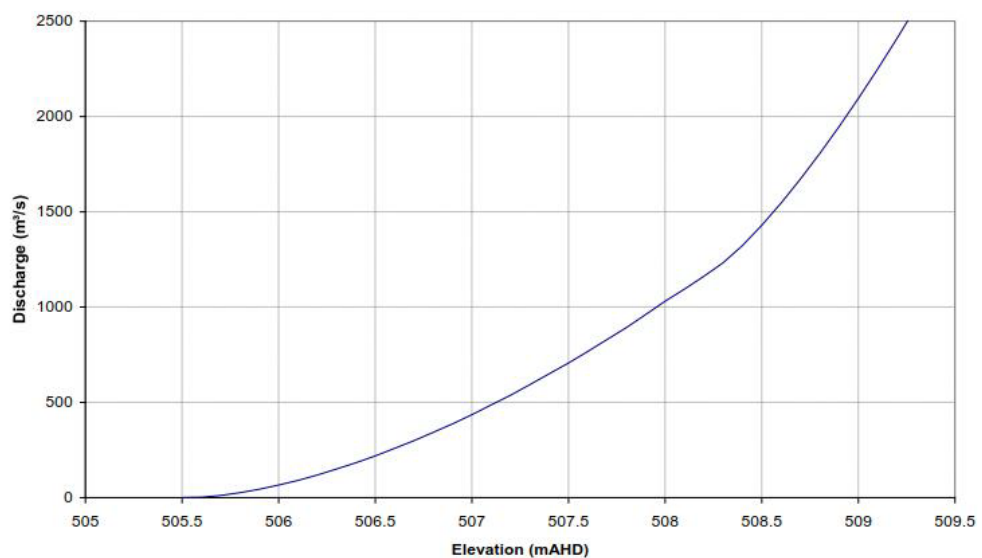
Lauriston and Upper Coliban storages were modelled as storages in RORB, with the elevation discharge relationships taken from SKM (2010). These relationships are shown in Figure 3-1 and Figure 3-2 respectively. The outflow from Lauriston Dam is a function of gate operation. No information was provided on how the gates at Lauriston are operated so for this investigation the same approach as SKM, 2010 was adopted. This assumes that all gates are fully open when the reservoir has exceeded FSL (i.e. 479.5 m AHD) by more than 300mm. This is reflected by the straight line in the rating curve between an elevation of 479.5 and 479.8 m AHD. In order to comment on the impact that this assumption has on flows out of the dam then details on the gate operations would need to be coded into the RORB model, which could be done as part of future, detailed flood studies.



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston

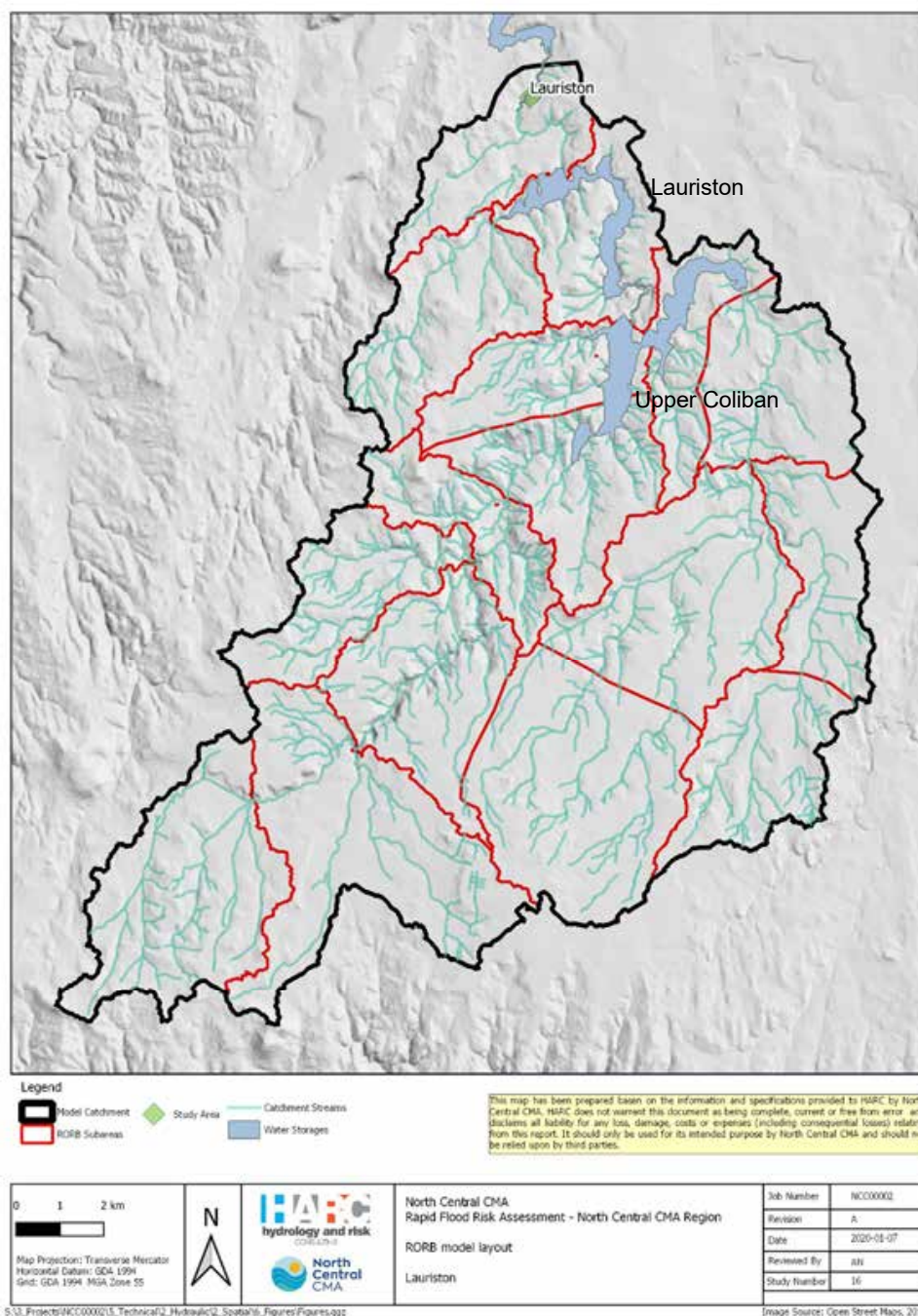


■ Figure 3-1 - Elevation discharge relationship for Lauriston Dam (SKM 2010)



■ Figure 3-2 - Elevation discharge relationship for Upper Coliban Dam (SKM 2010)

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 3-3 RORB model layout

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 4. Design hydrology approach and inputs

### 4.1 Overview of adopted design flood approach

The estimation of design floods has traditionally been based on the 'design event' approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 4-1 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are 'AEP-neutral', that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

This approach suffers from the limitations that:

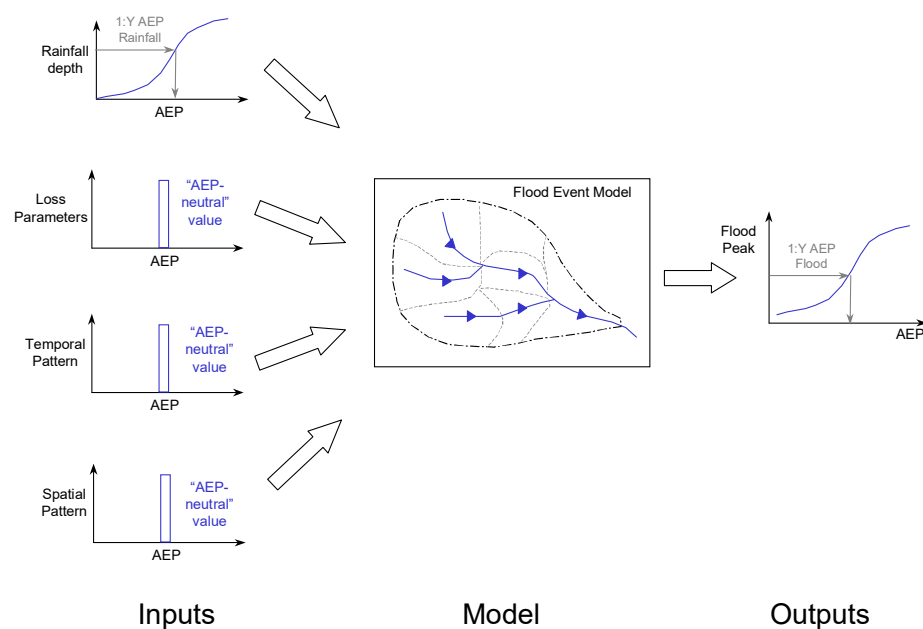
- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such as the variability in rainfall spatial and temporal pattern) becomes rapidly more complex and less easy to defend.

Joint probability techniques offer an improvement to the traditional design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated catchment, or a large storm on a dry catchment. In probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic 'mother nature' in that the influence of the key probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

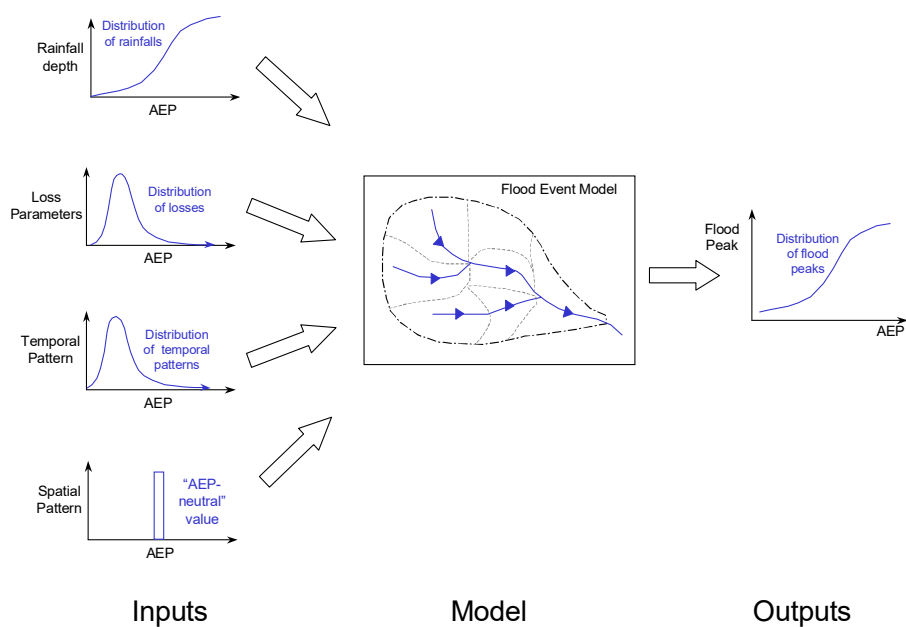
The application of joint probability approaches to flood estimation is widely acknowledged to be a more thorough and defensible approach to design flood estimation than the design event approach in Australian practice, and has been incorporated in the 2019 version of Australian Rainfall and Runoff (Ball et al., 2019).



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ **Figure 4-1 Schematic illustration of the design event approach**

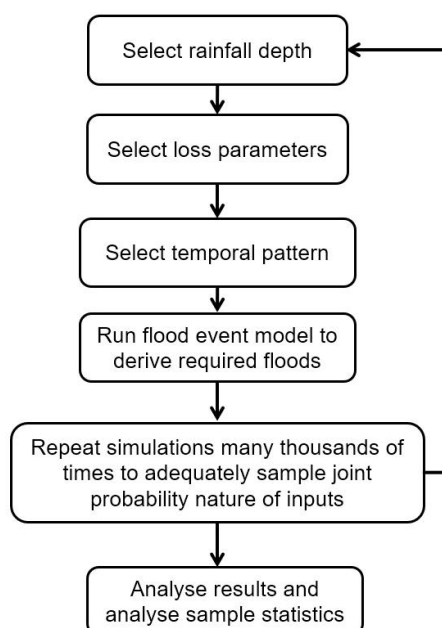


■ **Figure 4-2 Schematic illustration of the joint probability approach**

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



The joint probability framework adopted for the study was developed by Nathan et al (2002, 2003) and is summarised in Figure 4-3. In essence the approach involves undertaking numerous model simulations, where the model inputs are sampled from non-parametric distributions that are based either on readily available design information or on the results of recent research. For those study areas where reservoir starting water level is applicable, the level in the storage is also sampled.



■ **Figure 4-3 Overview of adopted joint probability framework**

In developing the joint probability framework particular attention was given to ensuring that the model inputs and the manner in which they were incorporated was consistent with ARR (Ball et al., 2019). The following briefly describes the main inputs, and how they will relate to establishing design information.

*Select rainfall depth.* Rainfall depths were stochastically sampled from the cumulative distribution of rainfall depths.

*Select storm losses.* Storm initial losses were stochastically sampled from a nonparametric distribution that was determined from the analysis of a large number of catchments across Australia (Hill et al., 2014). The limited number of investigations that have explored the correlation between initial and continuing loss values have concluded that there is little systematic dependence between the two. There is little information regarding the correlation between initial and continuing loss rates, and since antecedent conditions have most influence on initial loss rates, in this study the continuing loss rates will be held constant. Current practice is for initial losses to

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

*Select temporal pattern.* Temporal patterns were randomly selected from a sample of temporal patterns relevant to the catchment area and duration of the storm. The temporal patterns in the data hub were derived from large historic storms that have been observed in the region.

*Monte-Carlo simulation.* Simulations were undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 100 probability of exceedance, a reduced number of simulations were undertaken over a specified number of probability intervals. In this study, the rainfall frequency curve was divided into 100 intervals uniformly spaced over the standardised normal probability domain, and 250 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered. This approach accounts for the natural variability inherent in floods. Monte Carlo techniques are grounded in, and consistent with, the principle that “no two floods are ever the same”.

The key advantage of the Monte Carlo approach is that it reduces uncertainty by accounting for variability. The results of a Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, however it must be remembered that the natural variability of the key inputs is built into these median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Using the technique described above hydrographs were produced for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

In the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994).

### 4.2 Overview of design flood hydrology inputs

Design inputs were produced in accordance with ARR2019. Inputs include:

- Rainfall depths (IFD - BOM),
- Areal reduction factors (Data hub),
- Spatial patterns (Rainfall depths over the catchment – based on IFD)
- Temporal patterns (Rainfall depths over time – Data hub)
- Losses (ARR guidance)
- Pre-burst (Data hub)
- Baseflow (ARR guidance)



## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



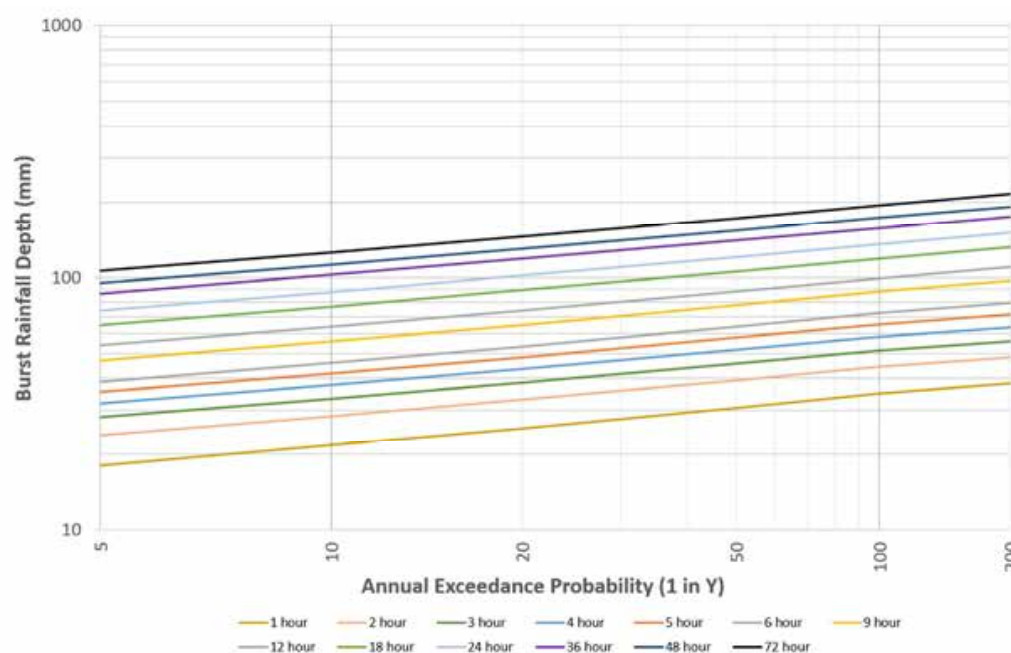
### 4.2.1 Rainfall depths

Catchment average point design rainfall depths for burst durations between 1 and 72 hours, and AEPs from 1 in 5 to 1 in 200, were taken from the Bureau of Meteorology (2016) (<http://www.bom.gov.au/water/designRainfalls/revise-ifd/>).

### 4.2.2 Areal reduction factors

The point rainfall estimates were converted to areal values using the ARR2019 areal reduction factors (Jordan et al, 2016) extracted from the ARR Data Hub. Conceptually, these factors account for the fact that larger catchments are less likely to experience high intensity storms over the whole catchment.

A summary of the complete, catchment average areally reduced design rainfall depths adopted are shown in Figure 4-4 and Table 4-1.



- Figure 4-4 Adopted design rainfall depths
- Table 4-1 Adopted design rainfall depths

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
5	18	24	28	32	35	39	47	54	65	74	87	96	107
10	22	28	33	38	42	46	56	64	77	88	103	113	126

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
20	25	33	38	44	49	53	65	74	89	102	119	131	146
50	31	39	46	52	58	64	78	88	106	121	141	155	173
100	35	45	52	58	65	72	88	100	120	136	158	174	194
200	38	48	56	64	72	80	98	110	132	151	175	192	216

#### 4.2.3 Spatial patterns

The spatial pattern for the catchment has been based on the rainfall depths from the Bureau of Meteorology, i.e. the IFD, which is recommended in ARR2019.

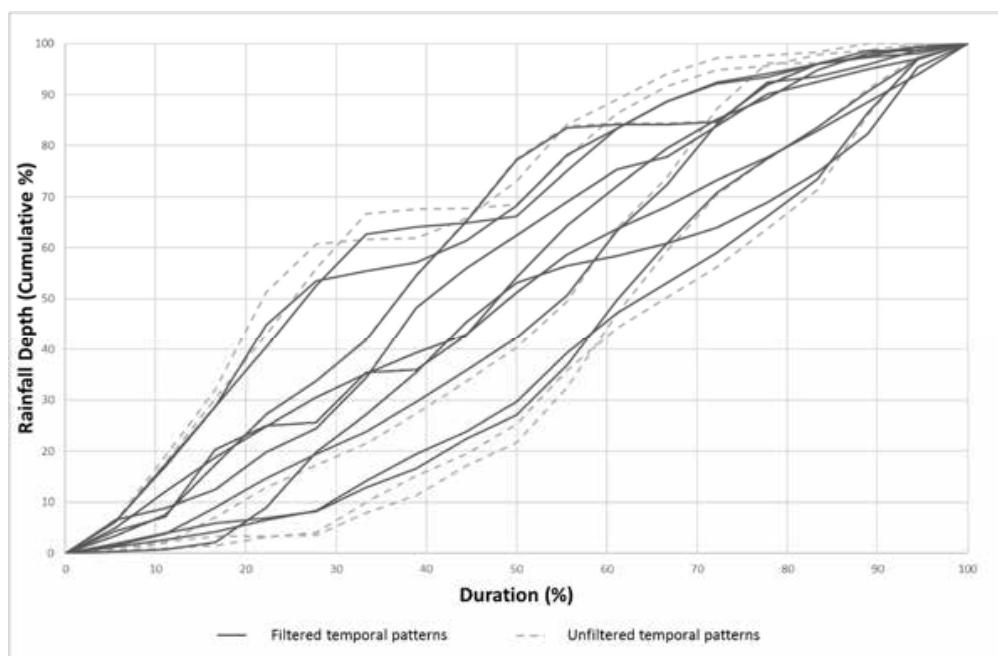
#### 4.2.4 Temporal patterns

For catchment areas greater than 75km<sup>2</sup> ARR recommends the use of the sample of areal temporal patterns available from the ARR data hub (Geoscience Australia, 2019) for long durations (greater than 24 hours). The derivation of these patterns is discussed in ARR 2019 (Ball et al., 2019). For the shorter duration storms, the sample of temporal patterns derived by Jordan et al (2005) was used. For catchment areas less than 75km<sup>2</sup> ARR recommends the use of ARR data hub (Geoscience Australia, 2019) point patterns.

Before the temporal patterns were used, they required some filtering to remove embedded bursts. An embedded burst is a sub-period of rainfall within a given temporal pattern that has a rarer AEP than the actual burst itself. The method described by Scoria et al. (2016) was used to smooth out the embedded bursts. As an example, Figure 4-5 shows the 24 hour design temporal patterns, before and after embedded bursts are removed.

All temporal patterns in the sets used for sampling were given equal probability of selection in the Monte Carlo simulation.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ **Figure 4-5 24-hour design temporal patterns before filtering and after filtering to remove embedded bursts**

#### 4.2.5 Losses

There are two key types of loss models that are typically adopted when modelling design floods:

- Initial loss/continuing loss
- Initial loss/proportional loss

Investigations by Hill et al. (2014) as part of the ARR 2019 revision were inconclusive as to which loss model works best. Even for catchments where one of the loss models performed better for a majority of events, there were still some events for which the other approach was better. Similarly, there was no obvious relationship between the relative performance of the loss models and hydro-climatic or catchment characteristics.

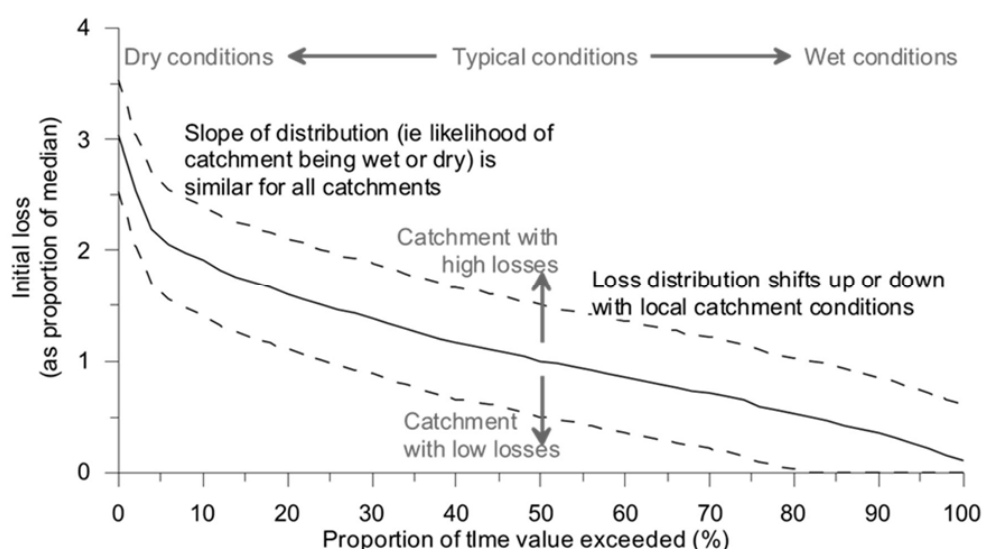
The advice in ARR is that the initial loss/continuing loss model is most suitable for design flood modelling, because it can be used to estimate flood peaks and volumes for all AEPs. In contrast, it is often difficult to derive unbiased estimates of flood quantiles using the initial loss/proportional loss model over the same range of AEPs. The initial loss/proportional loss model underestimates peak flows for extreme floods if the proportional loss is not varied appropriately with AEP; and to date there is little evidence about how proportional loss varies with AEP. Therefore, for this study an initial loss/continuing loss model was adopted.



## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



The shape of the initial loss distribution used in the design flood modelling was derived by Hill et al. (2014) from flood modelling results for a large number of catchments across Australia. Hill et al. (2014) developed a non-dimensional distribution of initial loss values for each catchment, by representing initial losses as a proportion of the median loss. This allowed the distributions of initial losses across different catchments to be directly compared. The standardised distributions exhibited a high degree of consistency, and suggested that while the magnitude of initial losses may vary between different catchments, the shape of the distribution does not. That is, while it may be expected that typical loss rates vary from one catchment to another, the likelihood of a catchment being in a relatively dry or wet state is similar for all catchments. The adopted distribution of initial loss is shown in Figure 4-6.



■ **Figure 4-6 Cumulative probability distribution of initial loss**

The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for this study.

### 4.2.6 Pre-burst rainfall depths and temporal patterns

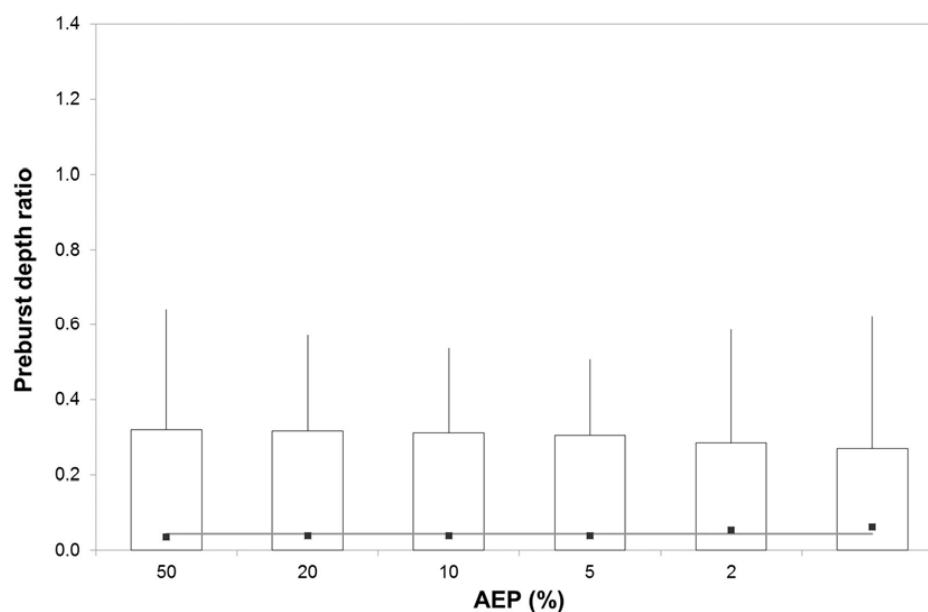
Estimates of the percentage of burst depth of rainfall antecedent to the main burst were taken from the ARR data hub (Geoscience Australia, 2019). The data hub provides a distribution of pre-burst depths by duration and AEP. The median pre-burst depths for each duration was compared across AEPs, and for the purpose of design flood modelling, it was decided that adopting an average of the median for each duration was appropriate (Figure 4-7).

Although the ARR data hub provides pre-burst depths, it does not contain information regarding the temporal patterns. Therefore, temporal patterns of rainfall antecedent to the main burst were taken

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



from Minty and Meighen (1999) and applied to burst durations of 12 hours and longer (Minty and Meighen, 1999). For the shorter durations, the pre-burst patterns from Jordan et al (2005) were applied.



- Figure 4-7 Pre-burst rainfall depths – 6 hour burst – shown as a ratio of burst depth, using a box plot of the 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> percentiles. The grey line shows the adopted value for the design flood modelling; this is the average of the median values across the available AEPs.

### 4.2.7 Baseflow

As RORB only estimates the surface runoff, baseflow needs to be added. For baseflow, regional estimates were used. From the ARR data hub the peak factor was extracted. The baseflow peak factor is applied to the estimated surface runoff peak flow to give the value of peak baseflow for a 10% AEP event. ARR 2019 provides a scaling factor to be applied to the 10% AEP baseflow peak factor to determine the baseflow peak factor for events of various AEPs.

A frequency distribution of baseflow with AEP was estimated by using the Regional Flood Frequency Estimation (RFFE - refer to Section 5) distribution. This provided the frequency distribution for baseflow under the peak of the annual maxima flood events.

### 4.2.8 Drawdown

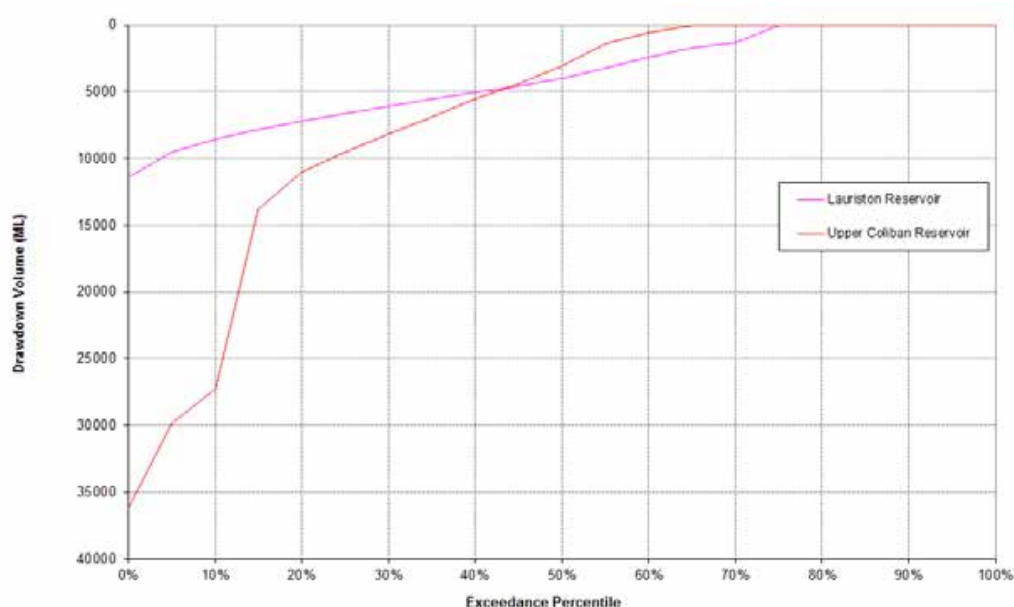
Due to the proximity of the major storages regulating the flow on the Coliban River just upstream of the study area, it is important to consider the potential impact drawdown (i.e. reservoir starting water level) has on the design events.

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



There are two storages upstream of Lauriston, namely Upper Coliban and Lauriston, which are in series with each other. For this investigation the same approach as adopted by SKM 2010 was followed and is summarised below.

Figure 4-8 shows the drawdown distributions for the Upper Coliban storages which was generated using the Goulburn Simulation Model (GSM) with 115 years of rainfall and current demands.

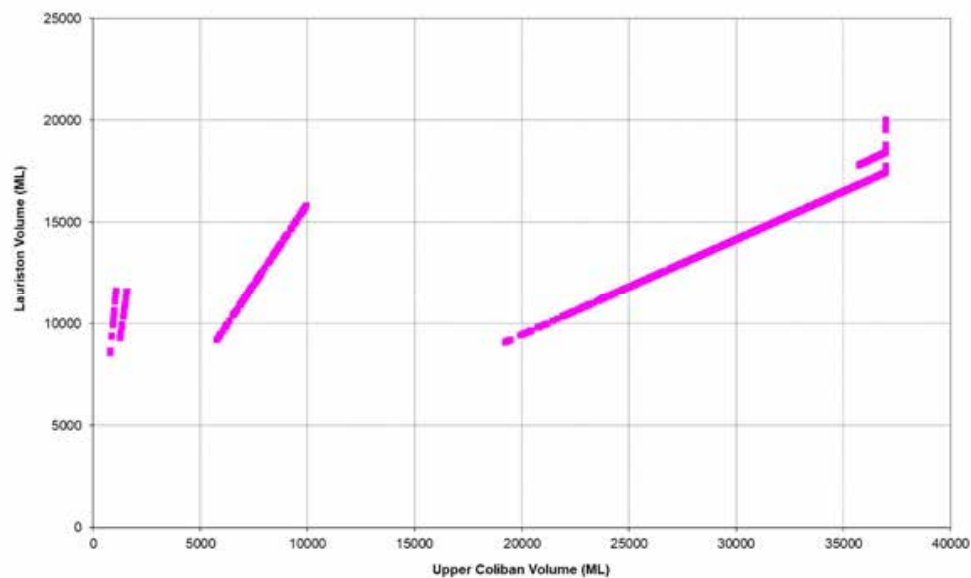


### ■ Figure 4-8 - Modelled Drawdown distribution for Upper Coliban storages (SKM, 2010)

Due to the interconnected nature of the storages, the Lauriston Reservoir water level is dependent on the storage level in Upper Coliban reservoir. Figure 4-9 shows the correlated storage volumes in Lauriston Reservoir when compared to Upper Coliban reservoir.



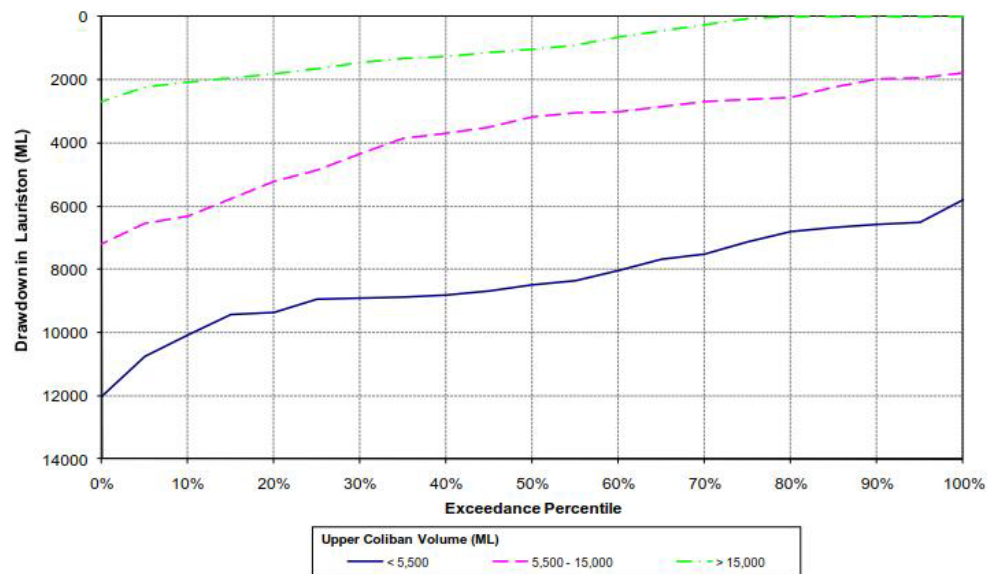
Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ **Figure 4-9 - Correlated storage volumes in Lauriston when compared to the volume in Upper Coliban (SKM, 2010)**

For the purpose of design events for the Lauriston study area, the storage in Lauriston Dam has been modelled in correlation with the storage level in the Upper Coliban Reservoir. Figure 4-10 show the correlated drawdown curves for Lauriston reservoir that have been modelled in conjunction with the drawdown distribution at Upper Coliban Reservoir.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



- Figure 4-10 Correlated drawdown between Lauriston and Upper Coliban storages (SKM, 2010)

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 5. Hydrologic model verification

### 5.1 Adopted parameters

For the RORB model the routing parameters ( $m$  and  $k_c$ ) were taken from the Upper Coliban Storages Hydrology update (SKM, 2010). For the routing parameter,  $k_c$ , the ratio of  $k_c/d_{av}$  was used to ensure that the same routing was applied to the RORB model established for the study area as per the previous model. McMahon and Muller (1983) showed that  $k_c$  is directly proportional to  $d_{av}$ , where  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model). Therefore, a way to measure the similarity of two different RORB models is to compare  $k_c/d_{av}$ .

The RORB model established for the Upper Coliban Storages Hydrology update (SKM, 2010) was calibrated to three events only i.e. October 1985, September 1993 and October 2000. The RORB model was also verified to a flood frequency curve (FFC) at Coliban River @ Springhill-Tylden Road (406250).

The adopted losses for this study were taken from the re-verification undertaken for the Malmsbury rapid flood risk assessment (HARC, 2019) at the streamflow gauge Coliban River @ Malmsbury Rail Bridge (406200).

#### ■ Table 5-1 Summary of key parameters adopted for the RORB model

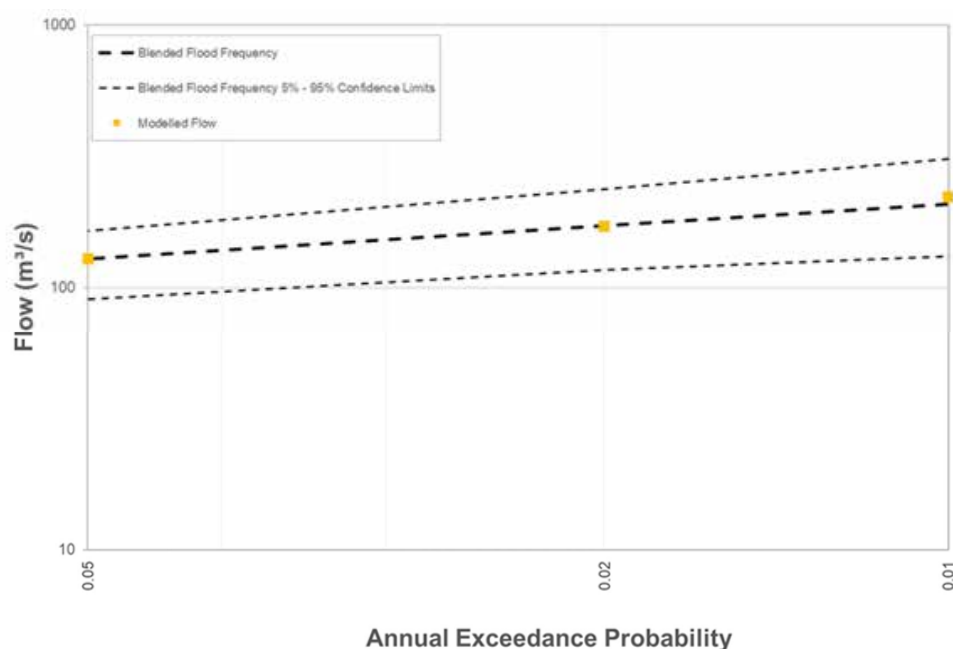
Parameter	Value
$k_c$	48.9
$d_{av}$	19.4
$C_{0.8} (k_c/d_{av})$	2.53
$m$	0.8
IL (mm)	10.0
CL (mm/hr)	1.0

### 5.2 Verification

The parameters adopted for Lauriston were based on the verification at the streamflow gauge Coliban River @ Malmsbury Rail Bridge (406200). Figure 5-1 shows the flood frequency curve and verification results at the Coliban River @ Malmsbury Rail Bridge. Additional details on the verification can be found in the Malmsbury report (HARC, 2020).



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ **Figure 5-1 Verification results**

### 5.3 Comparison to regional parameters

As mentioned in Section 5.1 the choice of  $k_c$  for the Lauriston catchment was based on the calibration result from the Upper Coliban Storages Hydrology update (SKM, 2010) however, the results from the calibration were compared to a number of regional estimates.

For Victorian regions with a mean annual rainfall of less than 800 mm  $k_c$  is estimated using equation 1 from ARR 2016 (Hansen et al, 1986).

$$k_c = 0.49 A^{0.65} \quad (1)$$

Where A is the area in  $\text{km}^2$ .

The  $k_c$  value from calibration was also compared to another regional estimate by Pearse et. al. (2002). Pearse et. al. (2002) analysed a large database of routing parameters collated by the CRC for Catchment Hydrology and derived a prediction equation applicable to Victoria. The  $d_{av}$  for the catchment was used to predict the  $k_c$  value where  $k_c$  is directly proportional to  $d_{av}$  giving equation 2

$$k_c = C d_{av} \quad (2)$$

Where C is a characteristic of the catchment independent of the scale or size of the catchment and  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model).

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



Pearse et al. (2002) also gave an expected value and one standard deviation (High and Low).

Table 5-2 provides a summary of the regional estimates along with the adopted value. Table 5-2 shows the  $k_c$  based on the calibration event undertaken in the Upper Coliban Storages Hydrology update (SKM, 2010) is different to the regional estimates highlighting the need to calibrate the model, where possible.

■ **Table 5-2  $k_c$  values – regional estimates**

Location	Area (km <sup>2</sup> )	$k_c$ (equation 1)	$k_c$ (equation 2)			$k_c$ (adopted)
			Expected	High	Low	
Lauriston	221	16.3	24.2	40.1	14.5	48.9

The ARR2019 data hub provides some regional estimates of losses. The regional losses are to only be used as a guide as ARR2019 clearly states it is always desirable to reconcile design values with independent flood frequency estimates where possible. Table 5-3 shows the regional estimates along with the adopted values. Table 5-3 shows that the adopted values are different to the regional estimates highlighting the need to verify the model, where possible.

■ **Table 5-3 Loss values – regional estimates**

Location	Regional		Adopted	
	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Lauriston	27.0	4.1	10.0	1.0

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 6. Design flood hydrology

### 6.1 Design flows for the 20% to 0.5% AEP events

The RORB model was run in the joint probability framework, with the design inputs and the adopted routing parameters, initial and continuing losses to generate design flood frequency curves and inflow hydrographs.

In order to generate hydrographs the RORB model was run in the joint probability framework described in Section 4.1, with the design inputs summarised in Section 4.2 and the adopted parameters summarised in Section 5.

The joint probability framework provides a peak flow, whereas the hydraulic model requires a set of hydrographs. The results of the Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Hydrographs were chosen from the set of Monte Carlo results that best matched the median peak flows and were an unbiased transformation from input rainfall AEP to flood AEP.

For the hydraulic model hydrographs were extracted at key locations within the study area. Table 6-1 shows the peak flows at downstream end of the study area from the event centred over the entire catchment.

■ Table 6-1 Summary of modelled peak flow estimates for Lauriston

AEP (1 in Y)	Peak Flow (m <sup>3</sup> /s)	Critical Duration (hours)
5	58.5	36.0
10	95.1	36.0
20	131.7	36.0
50	185.8	36.0
100	229.6	24.0
200	266.7	24.0

### 6.2 PMF estimate

As mentioned earlier in the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994). Nathan et al. (1994) looked at 56 sites across South-Eastern Australia and developed a series of equations to estimate the peak, volume and time to peak of a PMF.

Nathan et al. (1994) estimates of the PMF magnitude are based on the catchment area using the following equations.

$$Q_p = 129.1 * A^{0.616} \quad (1)$$



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



$$V = 497.7 * A^{0.984} \quad (2)$$

$$T_p = 1.066 * 10^{-4} * A^{-1.057} * V^{1.446} \quad (3)$$

And from a mass balance taking Equations (1) and (2).

$$T_r = \frac{V}{1.8 * Q_p} \quad (4)$$

Where:  $Q_p$  is peak flow ( $m^3/s$ );

$A$  is catchment area ( $km^2$ )

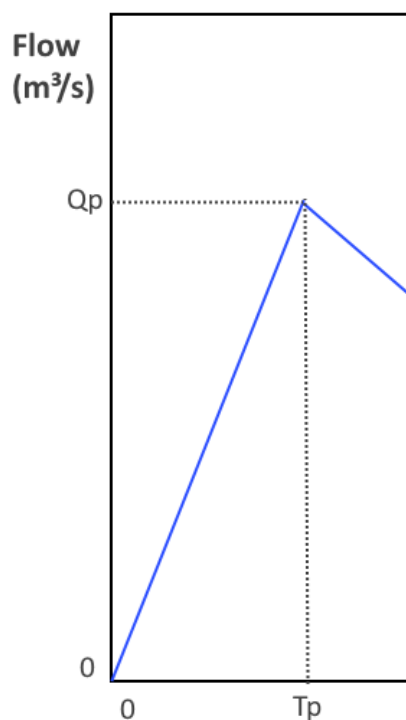
$V$  is the Volume of the hydrograph (ML)

$T_p$  is the time to peak flow (hours)

$T_r$  is the total time of the hydrograph (hours)

Each of these characteristics has been used to determine a 'triangular' PMF hydrograph. Figure 6-1 illustrates the characteristics of the 'triangular' PMF hydrograph.

Rapid Flood Risk Assessment - North  
Lauriston



■ Figure 6-1 - Characteristics of 'tr

The peak PMF flow was estimated to be

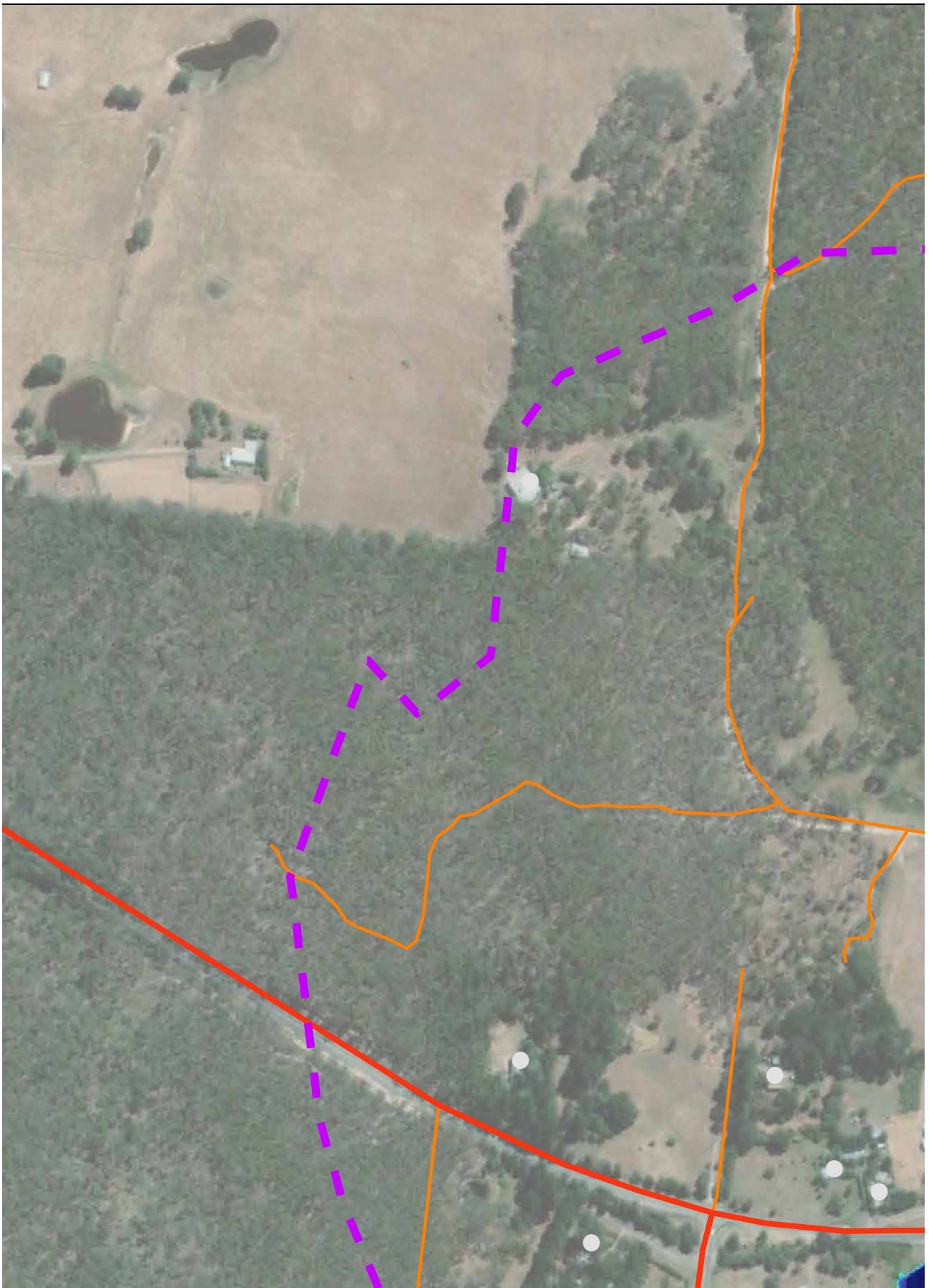
### 6.3 Climate change and sens

An important aspect of any hydrological testing. Sensitivity testing helps to understand the influence of different parameters on the result. The Monte Carlo analysis already takes into account the influence of different parameters (i.e. temporal patterns and spatial patterns) on the result. This way the Monte Carlo analysis already takes into account the influence of different parameters on the result. However, an important aspect of any hydrological testing is the design flow estimates.

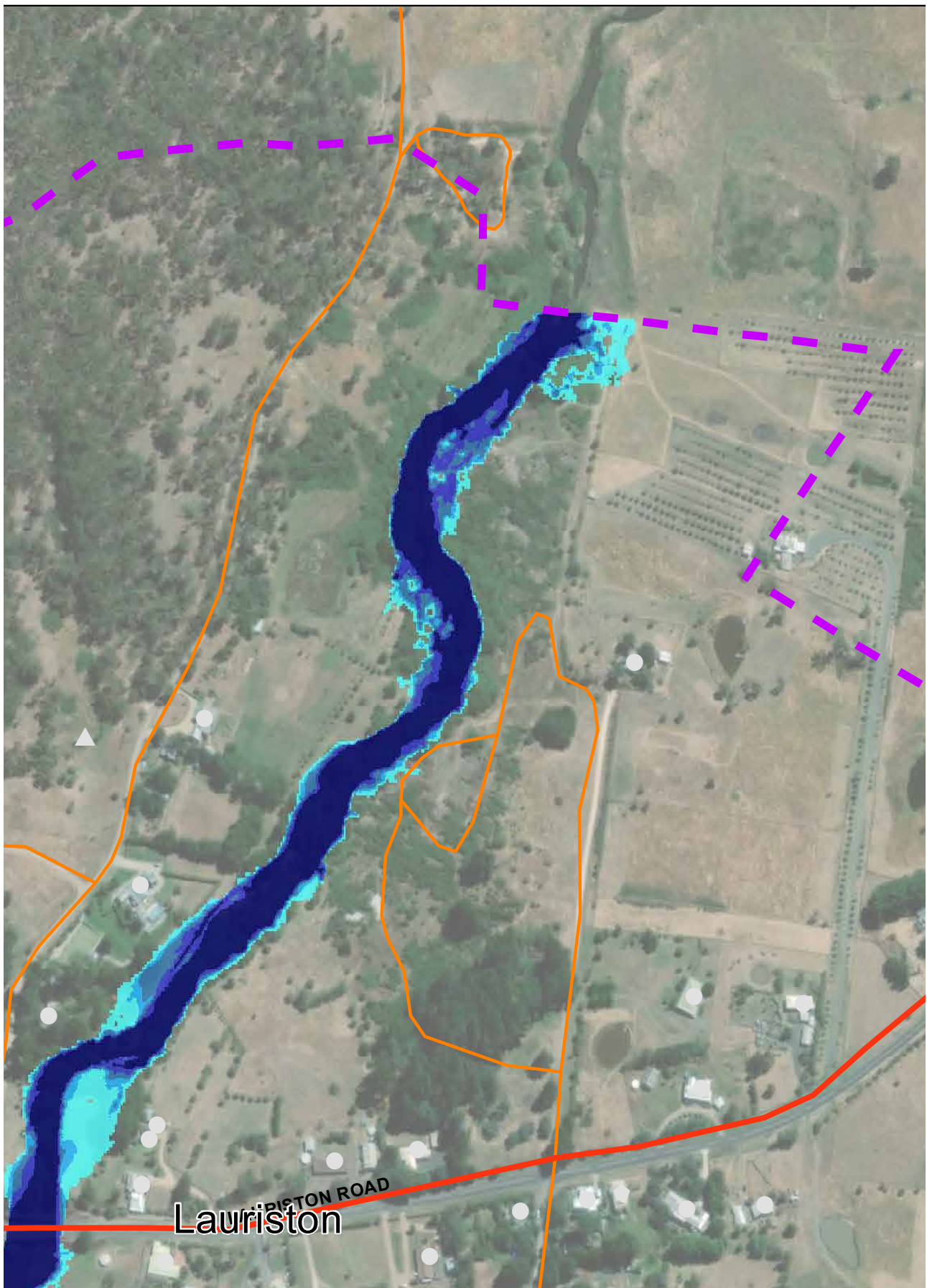
ARR2019 offers interim advice on estimating design flow estimates with a range of climate change scenarios from the Climate Futures web tool developed by the Department of Natural Resource Management. Climate Models (GCMs) can be explored

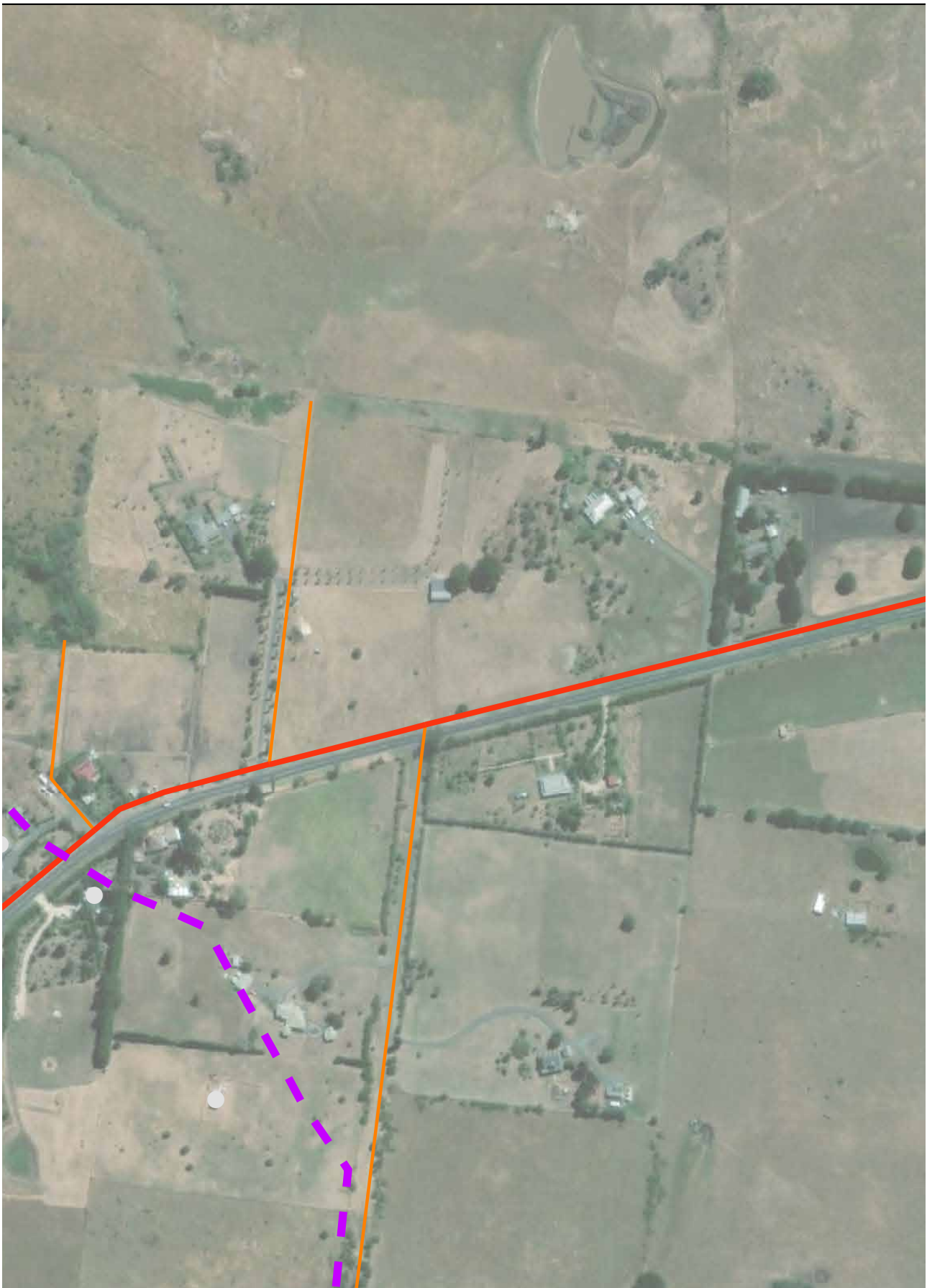
NCC00002\_RFRA\_NCC\_16\_Lauriston\_Version2











## Flood Risk Assessment - North Central CMA Region Lauriston



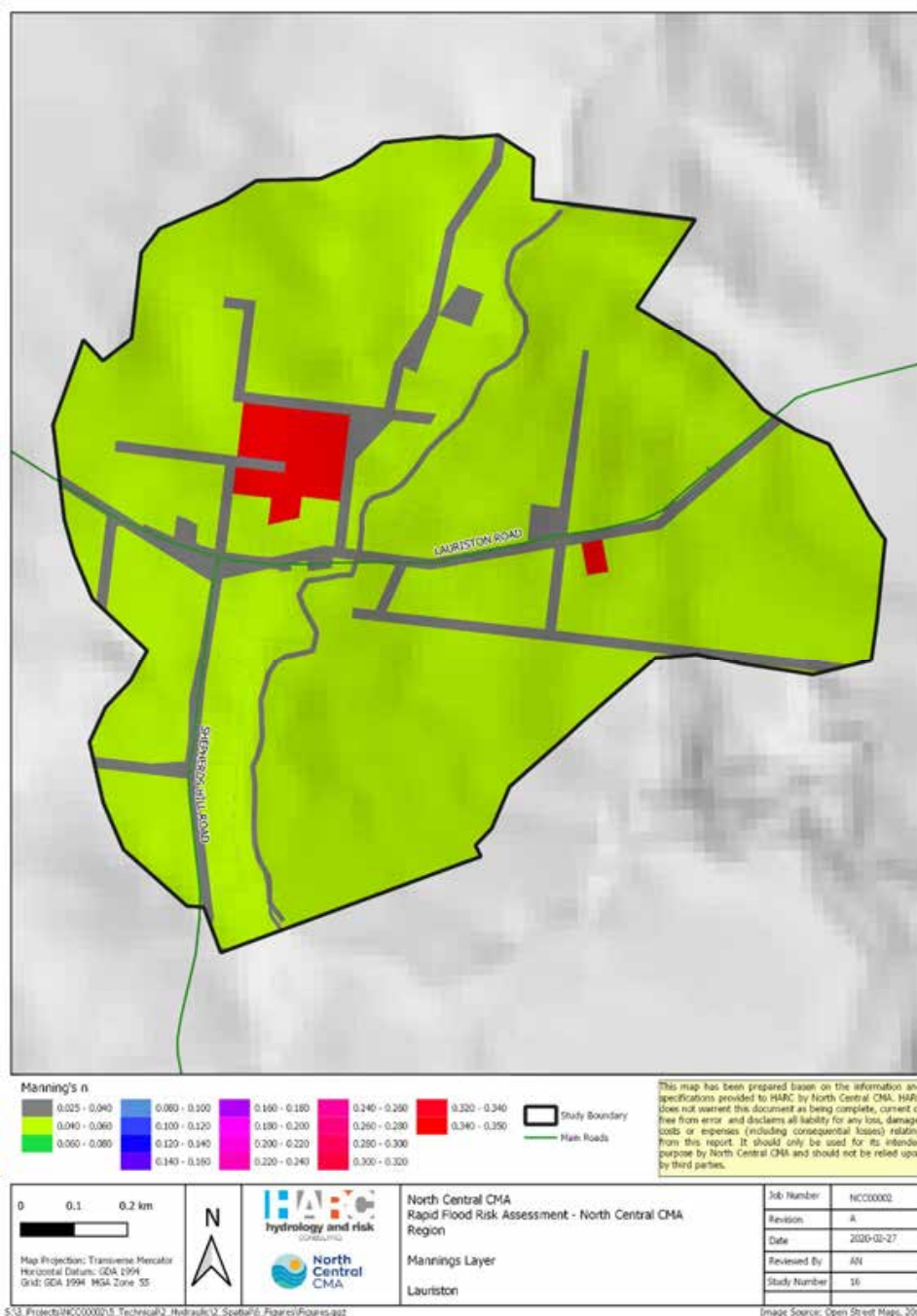
Categories were selected to be in line with the values provided by ARR2019. No calibration of the hydraulic models was undertaken for this project.

**Table 7-1 Manning's n values for different land use types**

Land Use Type	Manning's n adopted
Residential areas – urban high density (dwelling and parcel combined)	0.35
Residential areas – rural high density (dwelling and parcel combined)	0.15
Industrial/commercial or large buildings	0.30
Residential areas – rural low density (dwelling only or large blocks with house)	0.05
Open space or waterway – minimal vegetation	0.04
Open space or waterway – moderate vegetation	0.06
Open space or waterway – heavy vegetation	0.095
Paved roads/car park/driveways	0.025
Grassway line	0.05
Grass reserves/floodway (regularly mowed)	0.035
Grass floodplains in clear paddocks	0.05
Forested (heavy stand of timber)	0.12
Lake/Reservoir body of water	0.035



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 7-1 Surface roughness distribution

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



### 7.4 Hydraulic structures

Table 2-2 lists the culverts/bridges that were entered into the model. Bridges were represented using a layered flow constriction and culverts in 1D.

Bridge structures were modelled with the appropriate losses derived from Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways (Austroads, 1994). The layered flow constrictions used to model these bridges allows for typical bridge characteristics such as deck height and thickness, pier shape and width and blockages associated with guard or hand rails to be directly incorporated into the 2D domain. The details of these were extracted from supplied plans. Where plans were not available the losses and dimensions were estimated based on typical bridge configurations and loss parameters.

The 1D elements were dynamically linked to the 2D domain. Details of the culverts were extracted from supplied plans, details provided by Council or the North Central CMA.

### 7.5 Inflows

The inflows to the hydraulic model were taken from the RORB model, as discussed in Section 6 and modelled in TUFLOW as two-dimensional source area polygons distributing the inflow over the polygon. The polygons were located along the waterways within the study area.

The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. The hydrographs entered into the hydraulic model were chosen from the suite of runs from the Monte Carlo analysis such that the single hydrographs matched the peak flows.

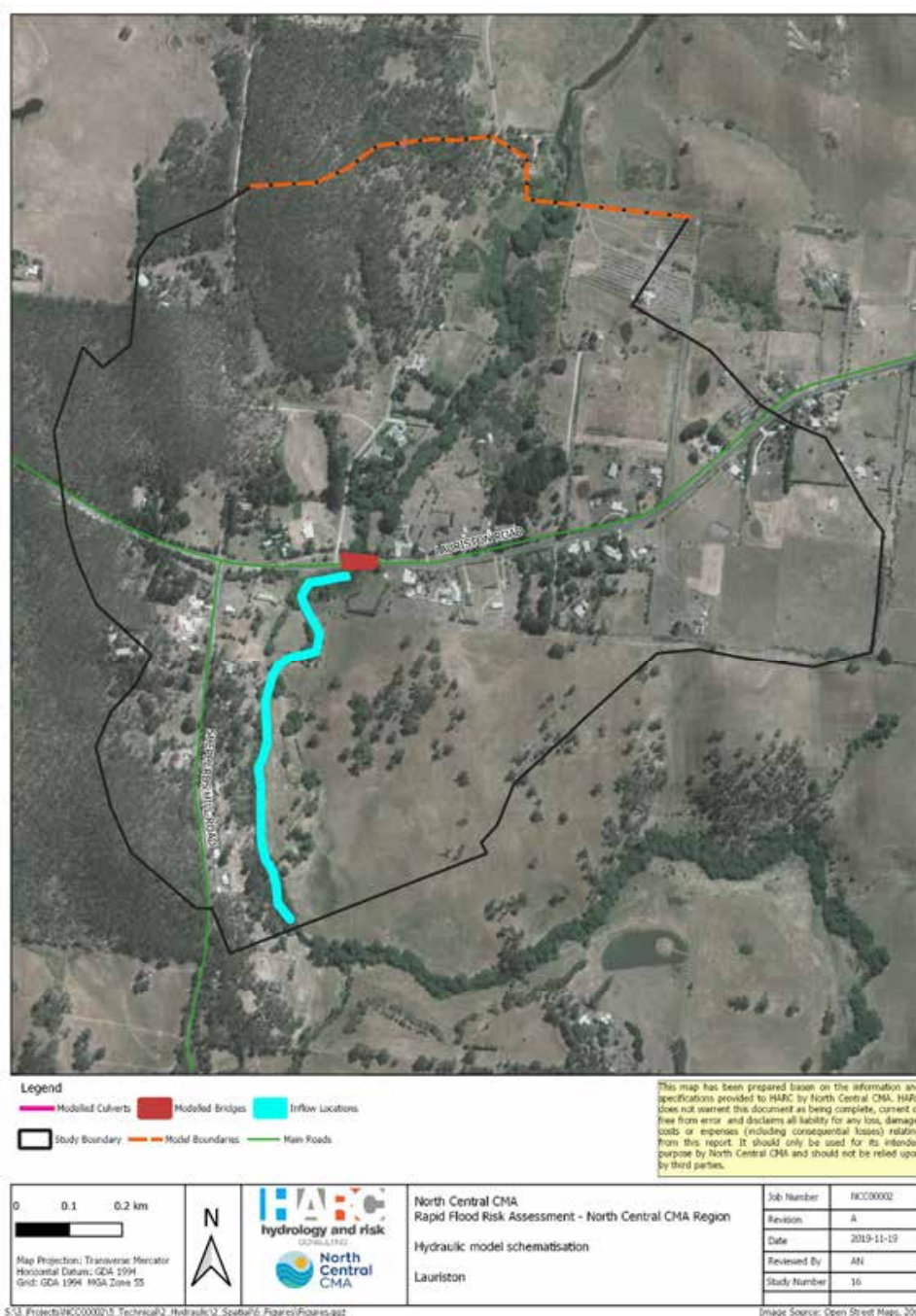
### 7.6 Downstream boundary

The downstream boundary condition was entered as a normal depth relationship with a slope of 0.5% based on the LIDAR data.

A schematisation of the hydraulic model is found in Figure 7-2.

All the hydraulic models were run for the 1 in 5, 10, 20, 50, 100 and 200 AEP and PMF events, for the critical durations identified in Table 6-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 7-2 Hydraulic model schematisation



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 8. Flood Risk Assessment

### 8.1 Flood Mapping

Flood maps showing flood level, depth, velocity and hazard (depth x velocity) have been produced for the 1 in 5, 10, 20, 50, 100 and 200 AEP event along with the PMF. The flood maps are shown in Appendix A.

Table 8-1 shows the flood map reference numbers that correspond to the maps in Appendix A.

■ **Table 8-1 Flood maps reference table**

Map Number	Map Name	Map Number	Map Name
16-5-1	1 in 5 year Depth Map	16-5-4	1 in 5 year Hazard Map
16-10-1	1 in 10 year Depth Map	16-10-4	1 in 10 year Hazard Map
16-20-1	1 in 20 year Depth Map	16-20-4	1 in 20 year Hazard Map
16-50-1	1 in 50 year Depth Map	16-50-4	1 in 50 year Hazard Map
16-100-1	1 in 100 year Depth Map	16-100-4	1 in 100 year Hazard Map
16-200-1	1 in 200 year Depth Map	16-200-4	1 in 200 year Hazard Map
16-PMF-1	PMF Depth Map	16-PMF-4	PMF Hazard Map
16-5-2	1 in 5 year Depth x Velocity Map	16-5-5	1 in 5 year Velocity Map
16-10-2	1 in 10 year Depth x Velocity Map	16-10-5	1 in 10 year Velocity Map
16-20-2	1 in 20 year Depth x Velocity Map	16-20-5	1 in 20 year Velocity Map
16-50-2	1 in 50 year Depth x Velocity Map	16-50-5	1 in 50 year Velocity Map
16-100-2	1 in 100 year Depth x Velocity Map	16-100-5	1 in 100 year Velocity Map
16-200-2	1 in 200 year Depth x Velocity Map	16-200-5	1 in 200 year Velocity Map
16-PMF-2	PMF Depth x Velocity Map	16-PMF-5	PMF Velocity Map
16-5-3	1 in 5 year Elevation Map		
16-10-3	1 in 10 year Elevation Map		
16-20-3	1 in 20 year Elevation Map		
16-50-3	1 in 50 year Elevation Map		
16-100-3	1 in 100 year Elevation Map		
16-200-3	1 in 200 year Elevation Map		
16-PMF-3	PMF Elevation Map		

### 8.2 Flood behaviour and impact of flooding

The following section summarises the impact of flooding. Table 8-2 provides a summary of the water level at the location shown in Figure 8-1 along with the main impacts for each AEP. Table 8-3 is a summary of the number of properties that are inundated for each AEP event. Table 8-4 is

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



a summary of the number of properties that are inundated above floor for each AEP event. Table 8-5 is a summary of the main roads that are overtopped.

■ **Table 8-2 Summary of impacts of flooding**

AEP (1 in Y)	Water level upstream of Lauriston Road (mAHD)	Impact
5	452.4	No properties are inundated
10	452.9	No properties are inundated
20	453.3	No properties are inundated
50	453.7	Four properties are inundated just downstream of Lauriston Road
100	454.0	Four properties are inundated as above
200	454.3	Four properties are inundated as above

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston

■ Table 8-3 Summary of property inundation

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
50	4	0	0	0	0	0	0	0	0	0	0
100	4	0	0	0	0	0	0	0	0	0	0
200	4	0	0	0	0	0	0	0	0	0	0

■ Table 8-4 Summary of over floor flooding\*

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
50	2	0	0	0	0	0	0	0	0	0	0
100	3	0	0	0	0	0	0	0	0	0	0
200	3	0	0	0	0	0	0	0	0	0	0

\* Note the floor levels have assumed to be 300 mm above the natural surface level for those buildings without surveyed floor levels



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Table 8-5 Summary of road Inundation

AEP (1 in Y)	Roads impacted by flooding	Maximum depth over road (m)	Duration of inundation (hours)
5	Lauriston Road	0.0	0
10	Lauriston Road	0.0	0
20	Lauriston Road	0.0	0
50	Lauriston Road	0.0	0
100	Lauriston Road	0.0	0
200	Lauriston Road	0.0	0

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ Figure 8-1 Reporting location

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston

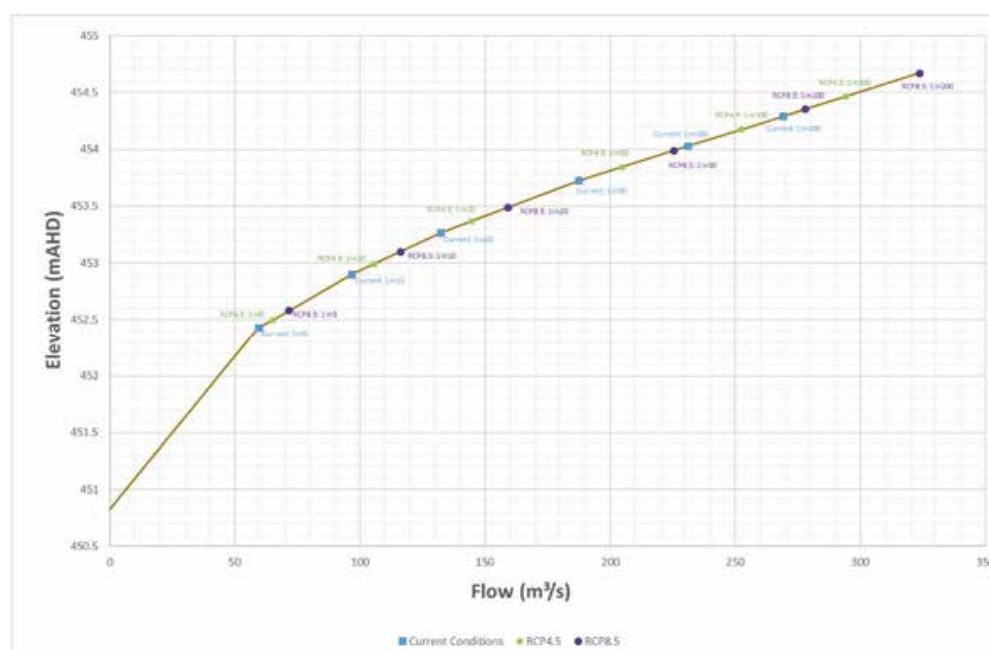


### 8.3 Climate change

The increase in flows due to climate change was discussed in Section 6.3. To present the sensitivity of flood levels to changes resulting from climate change a rating curve of flow and water level at a key location within the study area is shown in Figure 8-2. Figure 8-1 shows the location of the rating curve and Table 8-6 **Error! Not a valid bookmark self-reference.** the flows. The flow for the current conditions shown in Table 8-6 was taken from the TUFLOW model. The climate change flows were derived by multiplying the current climate peak flows by the percentages as discussed in Section 6.3. The rating curve shows the water level that corresponds to a peak flow under existing climate conditions as well as the corresponding water level under climate change conditions (RCP 4.5 and 8.5).

■ Table 8-6 Climate change peak flow estimates

AEP (1 in Y)	Current Climate – Peak Flow (m <sup>3</sup> /s)	Climate Change – Peak Flow (m <sup>3</sup> /s)	
		RCP 4.5	RCP 8.5
5	59.6	65.1	71.7
10	96.8	105.7	116.3
20	132.6	144.7	159.3
50	187.6	204.8	225.5
100	231.2	252.5	277.9
200	269.2	294.0	323.6



■ Figure 8-2 Estimated changes in peak water level associated with climate change



## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



Table 8-7 shows which AEP map to consider adopting under various climate change scenarios. Note that the results have been based on the flows shown in Table 8-6 and rounded to the nearest AEP.

### ■ Table 8-7 Map to consider adopting under various climate change scenarios

Current AEP	Event Map to consider adopting under various climate change scenarios	
	RCP4.5	RCP8.5
1 in 5	1 in 5	1 in 5
1 in 10	1 in 10	1 in 20
1 in 20	1 in 20	1 in 50
1 in 50	1 in 50	1 in 100
1 in 100	1 in 100	1 in 200

## 8.4 Flood Intelligence Information

Results from this investigation have been used to update the MFEPs with key information. This has included:

- Interpreting relevant flood related intelligence and consequence information from the mapping and modelling including typical flood travel times, rates of rise, etc;
- Identifying properties, roads and other community assets (e.g. essential infrastructure and services, high risk facilities, emergency service properties, low points in roads, etc.) affected by flooding;
- Identifying likely isolations and shrinking islands;
- Identifying areas of probable high flood risk / high hazard;
- Building flood intelligence tables; and
- Extracting catchment descriptions and flooding chronology from project deliverables.

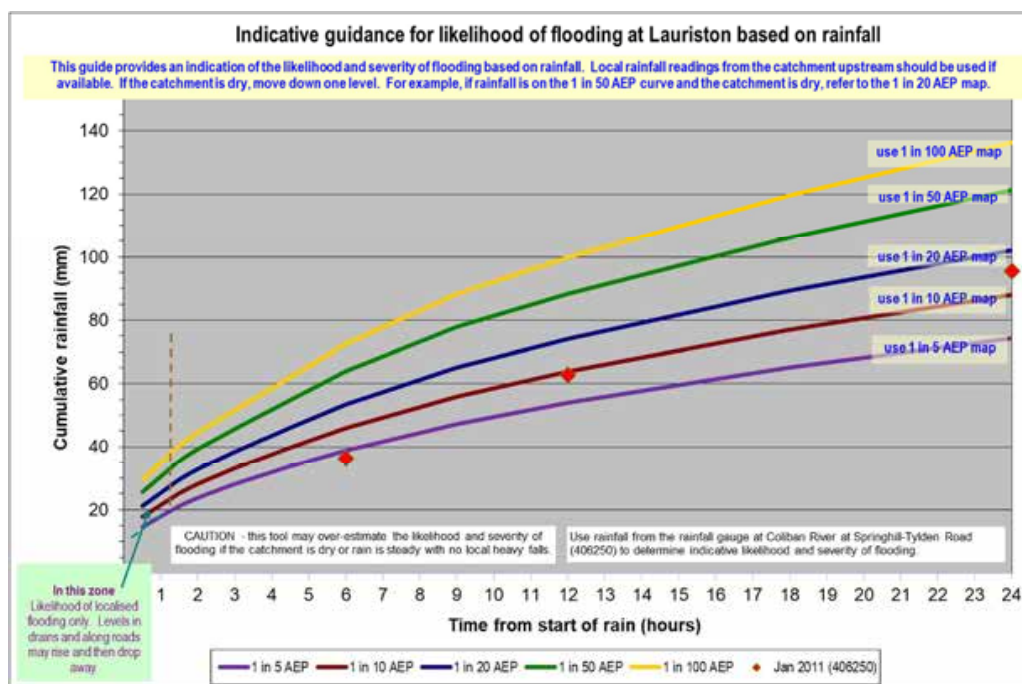
## 8.5 Developing Indicative Quick Look Flood / No-Flood Tools

Using the results of the hydrologic and hydraulic modelling work, an indicative quick look flood / no-flood assessment tool has been developed for the study area.

The tool is aimed at providing a rapid indication of whether flooding is likely with some lead time. It is intended to be indicative only and will not provide a forecast of expected flood depth. The tool is designed to be linked to the mapping and intelligence produced by this project and in that way provides an indication of likely consequences.

The tool is driven by rainfall recorded at Coliban River at Springhill-Tylden Road (406250). IFD data from this location has been compared to the study area specific IFD data. Adjusted rainfall depths were then plotted against time to produce the tool as shown in Figure 8-3.

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



■ **Figure 8-3 Quick look tool**

### 8.5.1 Guidance on the use of the Quick Look Flood / No flood Tool

#### 8.5.1.1 In the lead up to a flood

The quick look indicative flood / no-flood tool provided in Figure 8-3 gives guidance on the likelihood and severity of expected flooding at Lauriston.

Rainfall recorded at Coliban River at Springhill-Tylden Road (406250) was used to develop the quick look tool. The tool may not perform to expectations in severe thunderstorm situations and / or when there is locally heavy rainfall embedded in more general rain.

Unless there are unusual circumstances, actions as per the Flood Intelligence Card in the MFEP should be initiated as soon as the tool suggests flooding is likely. Response can be escalated if the tool indicates an increase in the expected severity of flooding.

#### 8.5.1.2 During a flood - using the quick look tool

Plot cumulative rainfall depth against elapsed time on a copy of the tool. Do not start using the tool until rainfall exceeds approximately 2 mm an hour (i.e. ignore early drizzle or very light rain).

At each time step, after plotting the cumulative rainfall, assess the likelihood and expected severity of flooding from the curves. Some degree of judgement is required to determine if the quick look

## Rapid Flood Risk Assessment - North Central CMA Region Lauriston



tool is providing an answer that is in line with expected outcomes. When plotted rainfall data crosses a curve on Figure 8-3 this indicates that flooding of around that severity is possible.

If the catchment is dry, it would generally be appropriate to step down one level. For example, if the rainfall plot is on the 1 in 50 AEP curve and the catchment is dry, refer to the 1 in 20 AEP map and associated consequences listed in the flood intelligence card available in the MFEP. The exception to this would be if there was very heavy rain on a dry catchment. In that circumstance, adopt a cautious approach and do not step down a level.

If the catchment is dry and / or rain extends over more than 12 hours, the quick look tool will tend to over-estimate the likelihood of flooding.

The tool is based on the reservoirs upstream being at FSL or very close to it (i.e. spilling during the event). If the storage is below FSL and unlikely to spill during the event, it would be appropriate to step down a level.

### 8.5.1.3 After a flood – updating the tool

After a flood event, plot the event rainfall depth (with date) on the quick look tool. At the same time, include an overview of the event, along with commentary on antecedent conditions and other relevant information, in the relevant Appendix of the MFEP.

### 8.5.1.4 Example use of the quick look tool

The section below is a fictitious example of how to use the quick look tool. Table 8-7 shows the rainfall depths recorded at the rain gauge and the action to take on the basis of the recorded rainfall. Figure 8-4 shows the fictitious example plotted up on the quick look tool.

Note that in cases where the tool has not been used from the start of rain (i.e. from early in the event), data should be either picked up from the start of the event or the first data plotted should include an estimate of how much rain has fallen and the time over which it has fallen. If this is not done, the tool will likely under-estimate likely flood severity.

#### ■ Table 8-8 Rainfall depths for example use of tool

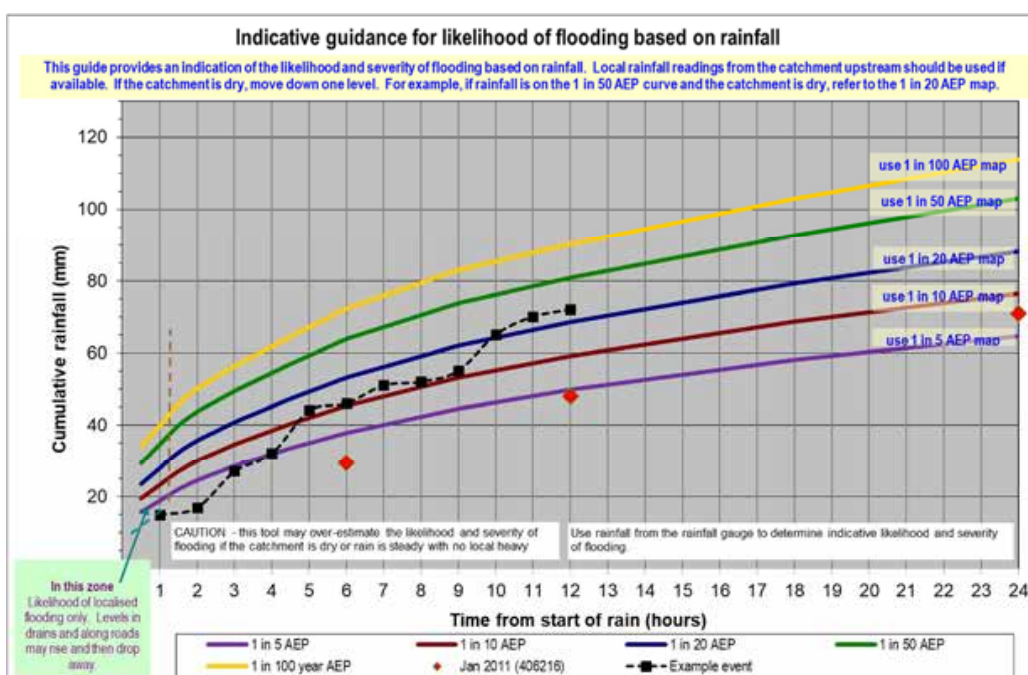
Time (hours)	Rainfall Depth (mm)	Action
0	1	Ignore
1	2	Ignore
3	2	Ignore
4	1	Ignore
5	15	Plot as 15 mm at 1 hour
6	2	Plot as 17 mm at 2 hours
7	10	Plot as 27 mm at 3 hours
8	5	Plot as 32 mm at 4 hours Indicates it may be a 5-year (20% AEP) event



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



Time (hours)	Rainfall Depth (mm)	Action
9	12	Plot as 44 mm at 5 hours Indicates it may be a 10-year (10% AEP) event Start planning for a 10% AEP event
10	2	Plot as 46 mm at 6 hours More confident that a 10% AEP event is likely
11	5	Plot as 51 mm at 7 hours
12	1	Plot as 52 mm at 8 hours
13	3	Plot as 55 mm at 9 hours
14	10	Plot as 65 mm at 10 hours Indicates it may be a 20-year (5% AEP) event.
15	5	Plot as 70 mm at 11 hours More confident that a 5% AEP event is likely
16	2	Plot as 72 mm at 12 hours



■ Figure 8-4 Quick look tool example

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



### 8.6 Flood classification – Bureau of Meteorology

Electronic maps have been produced for the minor<sup>1</sup>, moderate<sup>2</sup> and major<sup>3</sup> flood (as defined by the BoM). The minor, moderate and major flood has been based on the flood impacts. For Lauriston the 1 in 10, 20 and 50 AEP has been adopted for the minor, moderate and major flood respectively.

---

<sup>1</sup> Minor Flooding - Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

<sup>2</sup> Moderate Flooding - In addition to minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required

<sup>3</sup> Major Flooding – In addition to moderate flooding, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 9. Summary of rating of key areas

The following section provides a summary rating of each of the key areas of the project. The rating is subjective but has been rated against current standards and industry best practice for undertaking detailed flood studies.

The intention is that this will enable the North Central CMA to easily identify the areas where additional caution may need to be applied when using the information from this investigation for making decisions on flooding issues. In addition it will identify the areas of additional investigation, should a more detailed study be undertaken in the future.

Table 9-1 shows a summary of the rating for Lauriston where green is considered to be good, orange is OK and red is poor. Below is a summary of the main considerations given to each aspect of the study:

- *RORB model set up.* Adequacy of sub-area division, reach types, impervious fractions
- *RORB model parameters.* Has the RORB model been calibrated and/or verified to streamflow gauge information
- *Currency of hydrology.* Rated based on whether the hydrology used in the study is consistent with current practice and data sets.
- *Topographic data.* Typically will be rated orange or red if LiDAR data is not available and if the state wide DEM is required for use.
- *Manning's n.* Has land use been represented with appropriate values
- *Modelling of key structures.* Reflects whether the model was attempted to incorporate key hydraulic structures within the inundation zone and to what degree.
- *TUFLOW model set up.* Considers such aspects as does the cell size capture key features and the boundary conditions.
- *TUFLOW parameters.* Has the TUFLOW model been calibrated and/or verified to recorded flood levels.



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



■ **Table 9-1 Summary of review – Lauriston**

Category	Comment	Rating
RORB model set up	Adequate sub-area division for larger catchment. However, additional local catchment sub-division recommended if more detailed local flows are required. Note that Lauriston Dam spillway gate operations are based on a simplified procedure.	Yellow
RORB model parameters	Based on a calibrated and verified model.	Green
Currency of hydrology	All inputs are based on ARR2019	Green
Topographic data	LIDAR available for entire study area	Green
Manning's n	Generally OK but was based on VLUIS	Green
Modelling of key structures	Bridge and culvert explicitly modelled. Reasonable data was available for each structure	Green
TUFLOW model set up	Cell size adequately represents waterway and boundary conditions modelled appropriately.	Green
TUFLOW parameters	TUFLOW parameters have not been calibrated or verified to recorded flood levels.	Yellow

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 10. Limitations

Any information provided by the Bureau of Meteorology, Geoscience Australia as well as published methodologies (e.g. Australian Rainfall and Runoff) cannot be guaranteed to be free of errors.

The hydrological parameters rely on the previous calibration and verification undertaken for each of the RORB models. Therefore, the accuracy of this will vary depending on the information available to calibrate the models. However, any calibration and verification of the models to streamflow information will most likely be better than just relying on regional parameter estimates.

The proposed methodology for the PMF estimate is preliminary in nature. Other, more detailed techniques are available in which to estimate the PMF. However, for this investigation a preliminary assessment has been considered to be appropriate.

The analysis has relied heavily on the supplied LIDAR terrain data. For this investigation no survey will be undertaken to independently check the terrain data.

For the hydraulic model the intention is that the waterways are represented by 4-5 cells. Where a waterway is less eight metres wide it will be represented by less than the 4-5 cells which could mean that the waterway is not fully represented.

The Manning's roughness adopted for the study areas utilising the VLUIS dataset. As the VLUIS is a state wide dataset there may be some areas that have either been developed since the VLUIS was established or not captured accuracy. Whilst, basic checks have been undertaken to pick up any large errors in assigned land use there may still be some lot scale differences in land use which may not be picked up.

As the hydraulic model was not calibrated to surveyed flood levels the Manning's n values listed in Table 7-1 may not necessarily represent the roughness values accurately.

As mentioned in Section 6.3 the ARR2019 approach to climate change has a number of limitations, including the fact that it does not provide a means to account for potential increases in rainfall losses under a drying climate.

The quick look flood / no flood tools may be replaced where more detailed investigations are undertaken in the future.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 11. Conclusion

This project forms part of the Rapid Flood Risk Assessment for the North Central CMA region. Outputs from the assessment will assist the North Central CMA to meet a range of business requirements. Outputs can be used to assist in flood related controls, develop flood intelligence products, inform emergency response planning and assist in the preparation of community flood awareness and education products.



Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## 12. References

Agriculture Victoria (2016) Victorian Land Use Information System (VLUIS)

Austroroads (1994) Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways

Ball J, Babister M, Nathan R, Week W, Weinmann E, Retallick M, Testoni I, (Editors) (2019) Australian Rainfall and Runoff: A guide to flood estimation, Commonwealth of Australia (Geoscience Australia).

Babister, M, Trim, A, Testoni, I, Retallick, M. (2016) The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ.

BMT (2018), TUFLOW Classic/HPC User Manual. Build 2018-03-AD

Bureau of Meteorology (2016) 2016 Rainfall IFD Data System.  
<http://www.bom.gov.au/water/designRainfalls/revised-ifd/>.

Hydrology and Risk Consulting (2020) Rapid Flood Risk Assessment – North Central CMA Regional – Malmesbury.

Hydrology and Risk Consulting (2016) ArcRORB, A tool for creating RORB catchment files in ArcMap, User Manual, version 1.6.

Hill PI, Graszkiwicz Z, Taylor M and Nathan RJ (2014) Australian Rainfall and Runoff revision project 6: Loss models for catchment simulation. Stage 4: Analysis of rural catchments.

Hill P and Thomson R (2015) Chapter 3 in Book 5: Losses. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.

Jordan P, Nathan R, Podger S, Babister M, Stensmyr P and Green J (2016) Chapter 4 in Book 2: Areal reduction factors. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.

Laurenson EM, Mein RG and Nathan RJ (2010) RORB version 6 runoff routing program - User manual. Monash University Department of Civil Engineering in conjunction with Hydrology and Risk Consulting Pty. Ltd. and the support of Melbourne Water Corporation, Melbourne.

Minty, L.J and Meighen, J (1999), Development of temporal distributions of rainfall antecedent to large and extreme design bursts over southeast Australia, Hydrology Report Series HRS Report No.6, Hydrometeorological Advisory Service, Bureau of Meteorology.

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



Nathan RJ, Weinmann PE and Hill PI (2002) Use of a Monte Carlo framework to characterise hydrologic risk. Proceedings of the 2002 ANCOLD Conference, Adelaide. Australian National Committee on Large Dams.

Nathan RJ, Weinmann PE and Hill PI (2003) Use of Monte Carlo simulation to estimate the expected probability of large to extreme floods. Proceedings of 28th Hydrology and Water Resources Symposium, Wollongong. Institution of Engineers, Australia.

Nathan RJ, Weinmann PE and Gato SE (1994) A quick method for estimating the probable maximum flood in South Eastern Australia, Water Down Under 94. Hydrology and Water Resources Symposium I.E. Aust. Nat. Conf. Publ. 94/10, pp.229-234

Pearse M, Jordan P and Collins Y (2002) A simple method for estimating RORB model parameters for ungauged rural catchments. Proceedings of 27th Hydrology and Water Resources Symposium, Melbourne. Institution of Engineers, Australia.

Phillips, B, Goyen, A, Thomson, R, Pathiraja, S and Pomeroy, L. (2014), Australian Rainfall and Runoff Revision Project 6: Loss models for catchment simulation - Urban Losses Stage 2 Report, February.

Scorah M, Hill P, Lang S and Nathan R (2016), Addressing embedded bursts in design storms for flood hydrology. Water, Infrastructure and the Environment: Proceedings of the 56th New Zealand Hydrological Society Conference and the 37th Hydrology and Water Resources Symposium, Queenstown, New Zealand. New Zealand Hydrological Society and Engineers Australia.

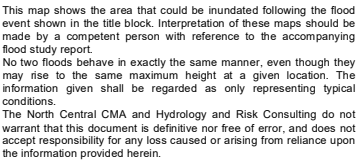
SKM. (2010) Review of the Upper Coliban Storages Flood Hydrology. Final. July 2010

Rapid Flood Risk Assessment - North Central CMA Region  
Lauriston



## Appendix A Maps





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

**Building Classification**

- Residential
- Commercial
- ▲ Industrial
- ★ Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

**Max Depth (m)**

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

**Map Details:**

- Scale: 1:3,500
- Date: 25/02/2020
- Map No.: 16 - 5 - 1
- Horizontal Datum: GDA 1994
- Grid: GDA 1994 MGA Zone 55





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

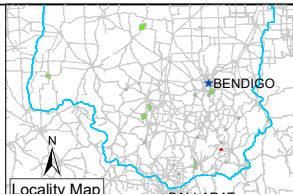
Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

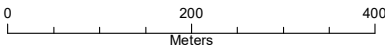
- Max V x D (m<sup>2</sup>/s)
- < 0.4
  - 0.4 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

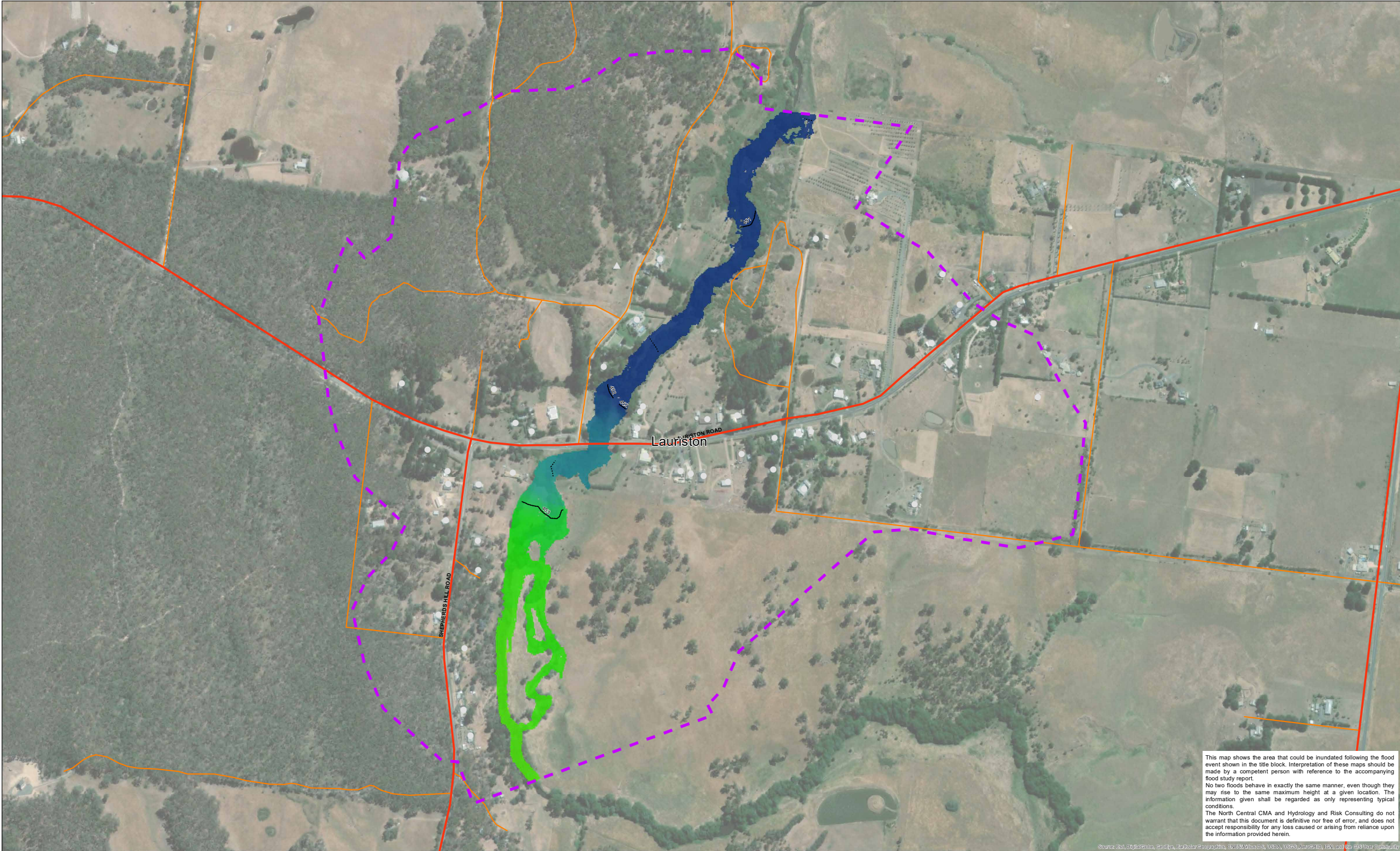
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Lauriston - 20% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 5 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

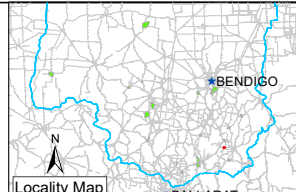
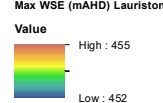
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

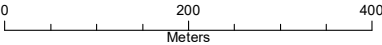
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Lauriston - 20% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 5 - 3
--	---------------------	------------------------







**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Drawn: A. SHEN

Checked: T. CRAIG

Project Manager: A. NORTHFIELD

Project No.: NCC00002

North Central CMA Project Manager: N. TRELOAR

Project Director: D. STEPHENS

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Lauriston - 20% AEP Flood Event**

0 200 400 Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 16 - 5 - 4

hydrology and risk CONSULTING

North Central CMA

VICTORIA State Government

Australian Government





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

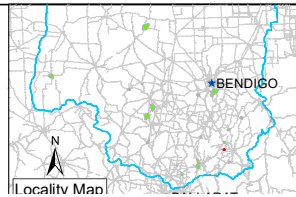
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

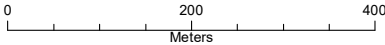
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

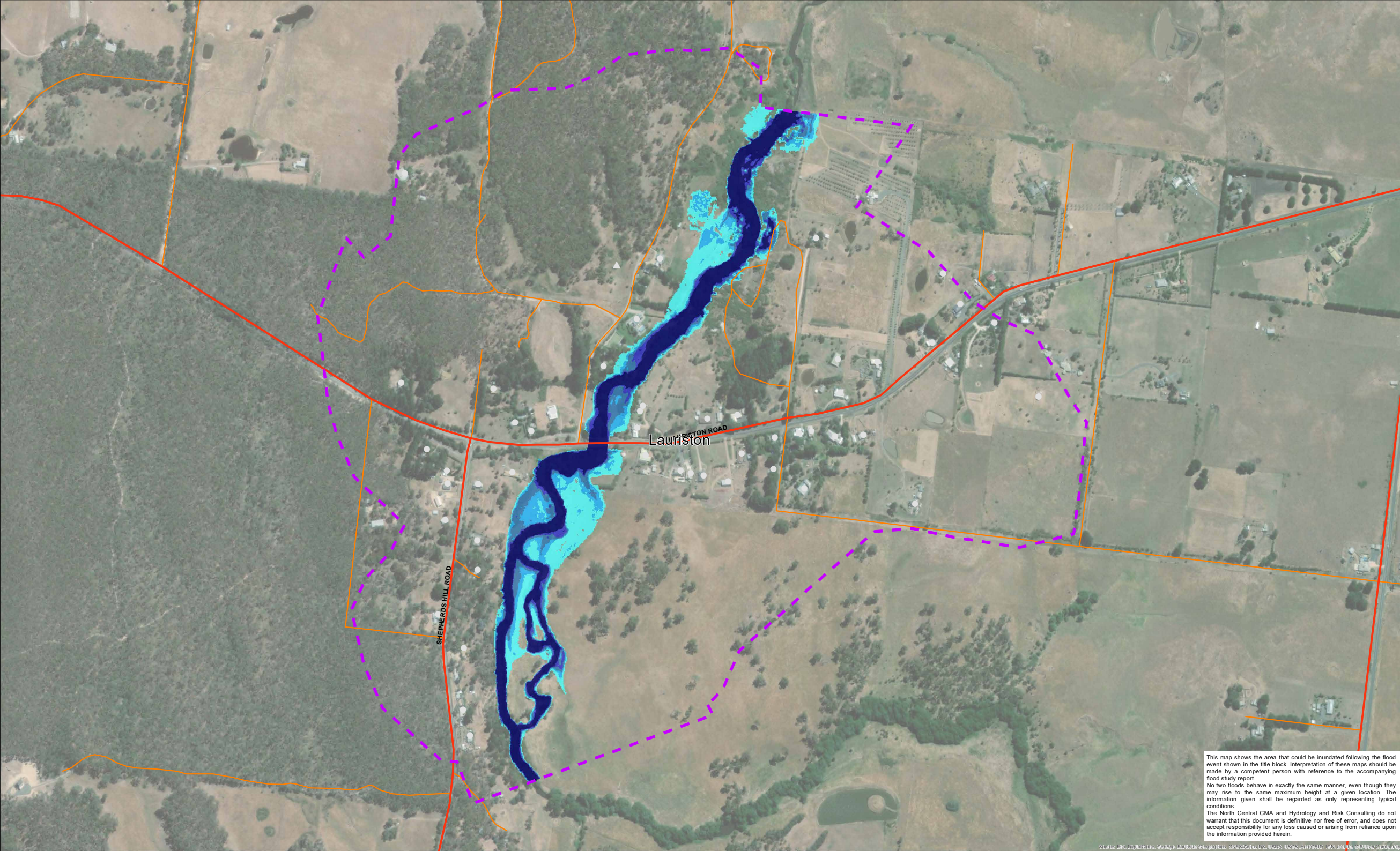
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Lauriston - 20% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 5 - 5





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

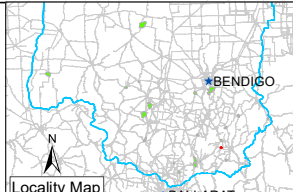
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

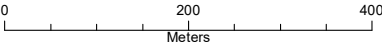
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

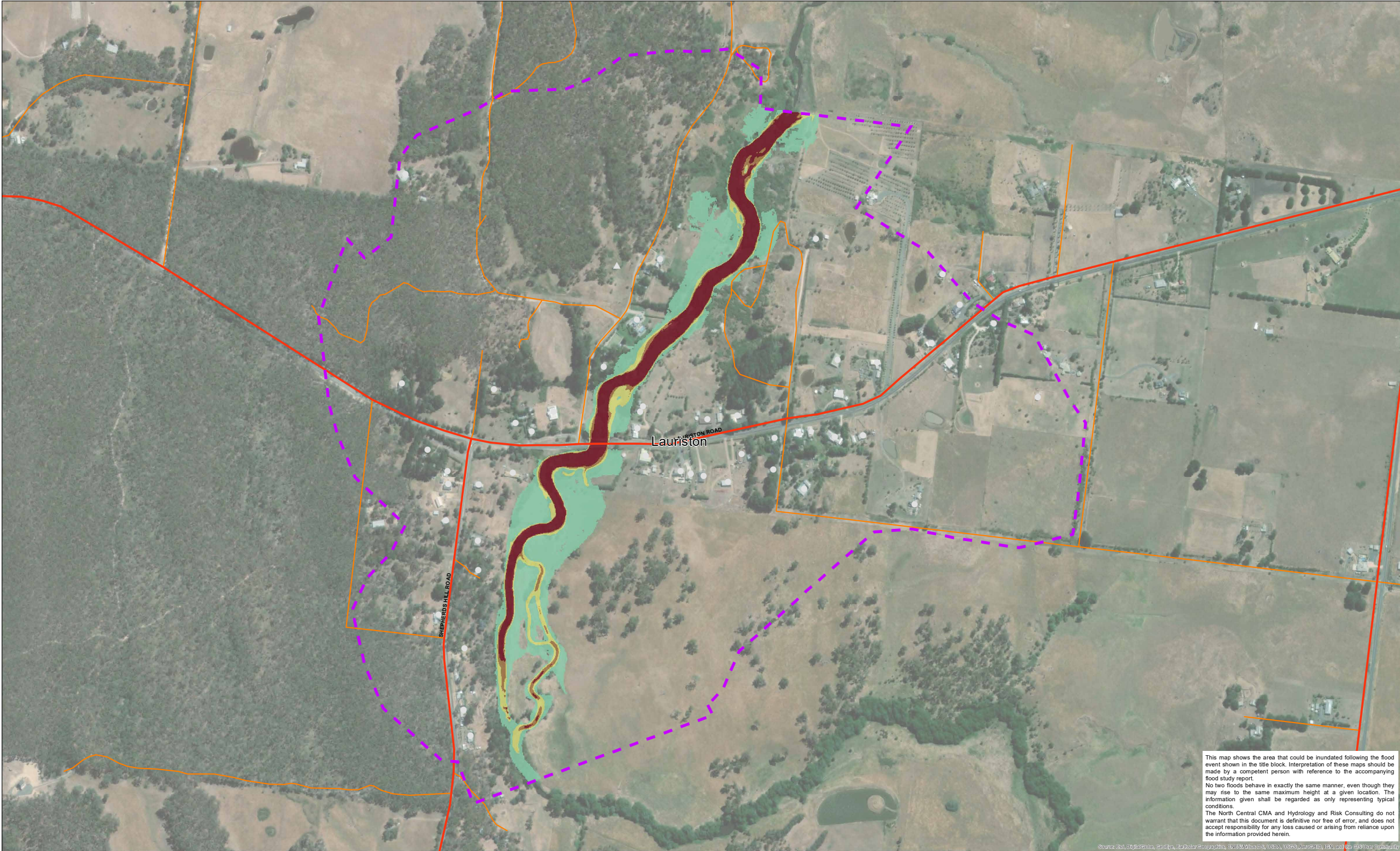
Lauriston - 10% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 10 - 1
--	---------------------	-------------------------







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

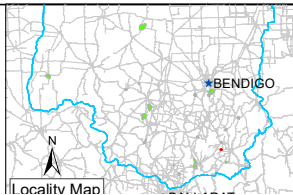
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

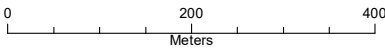
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

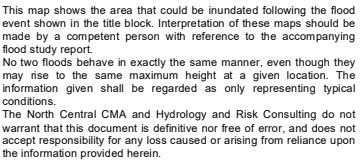
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Lauriston - 10% AEP Flood Event

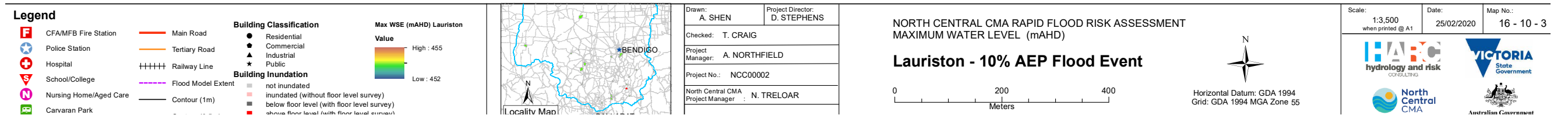


Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 10 - 2





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

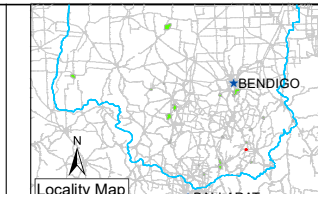
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

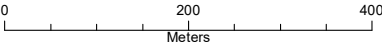
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Lauriston - 10% AEP Flood Event**



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 10 - 4
--------	------------------------------	-------	------------	----------	-------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

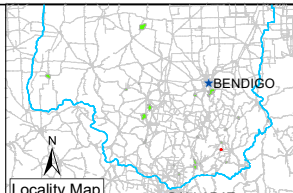
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

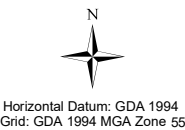
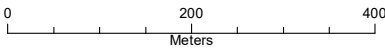
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

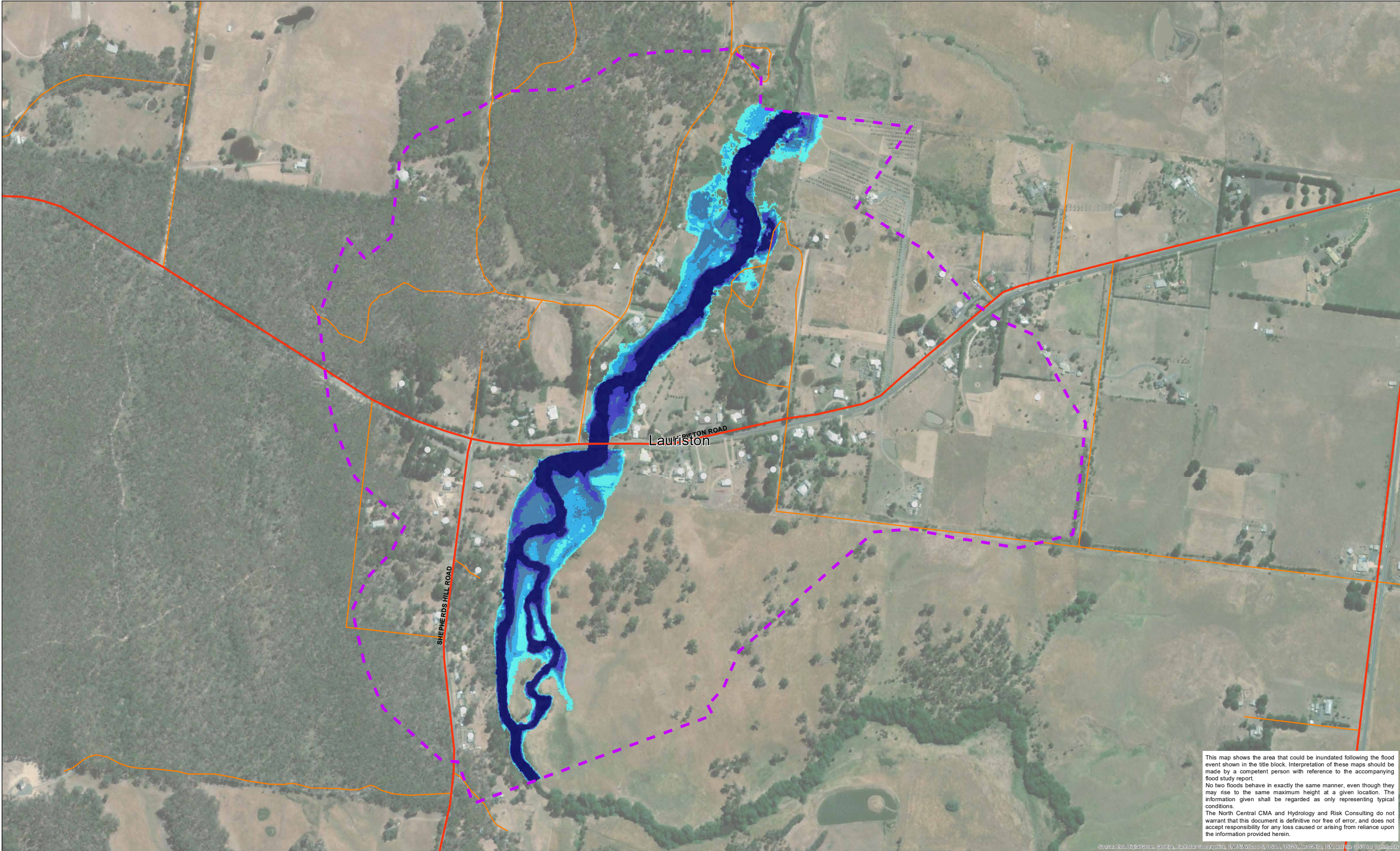
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Lauriston - 10% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 10 - 5





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

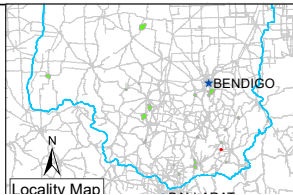
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

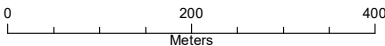
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

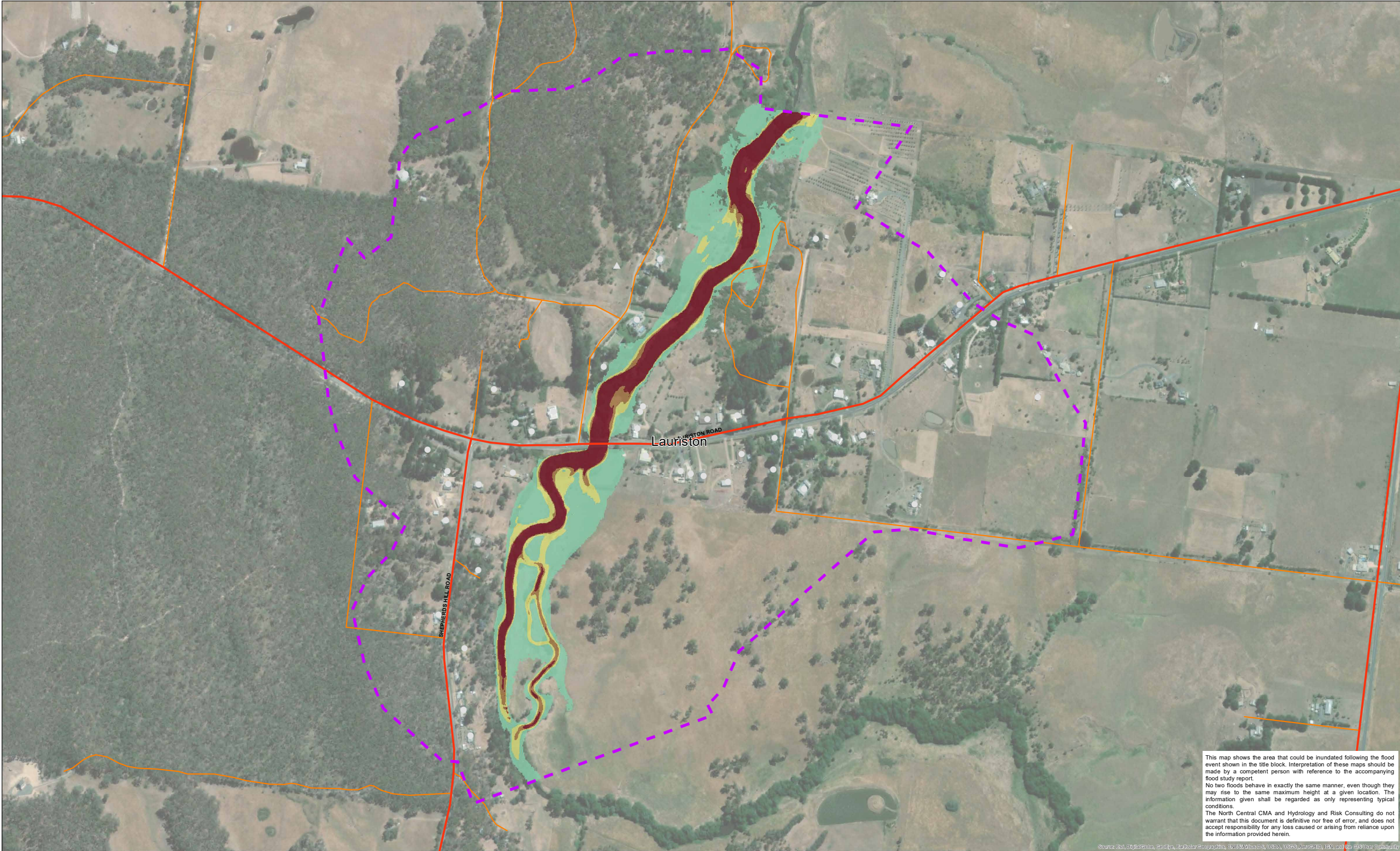
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Lauriston - 5% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 20 - 1





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

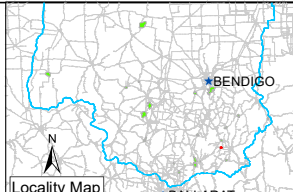
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m²/s)

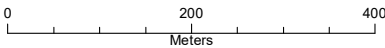
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

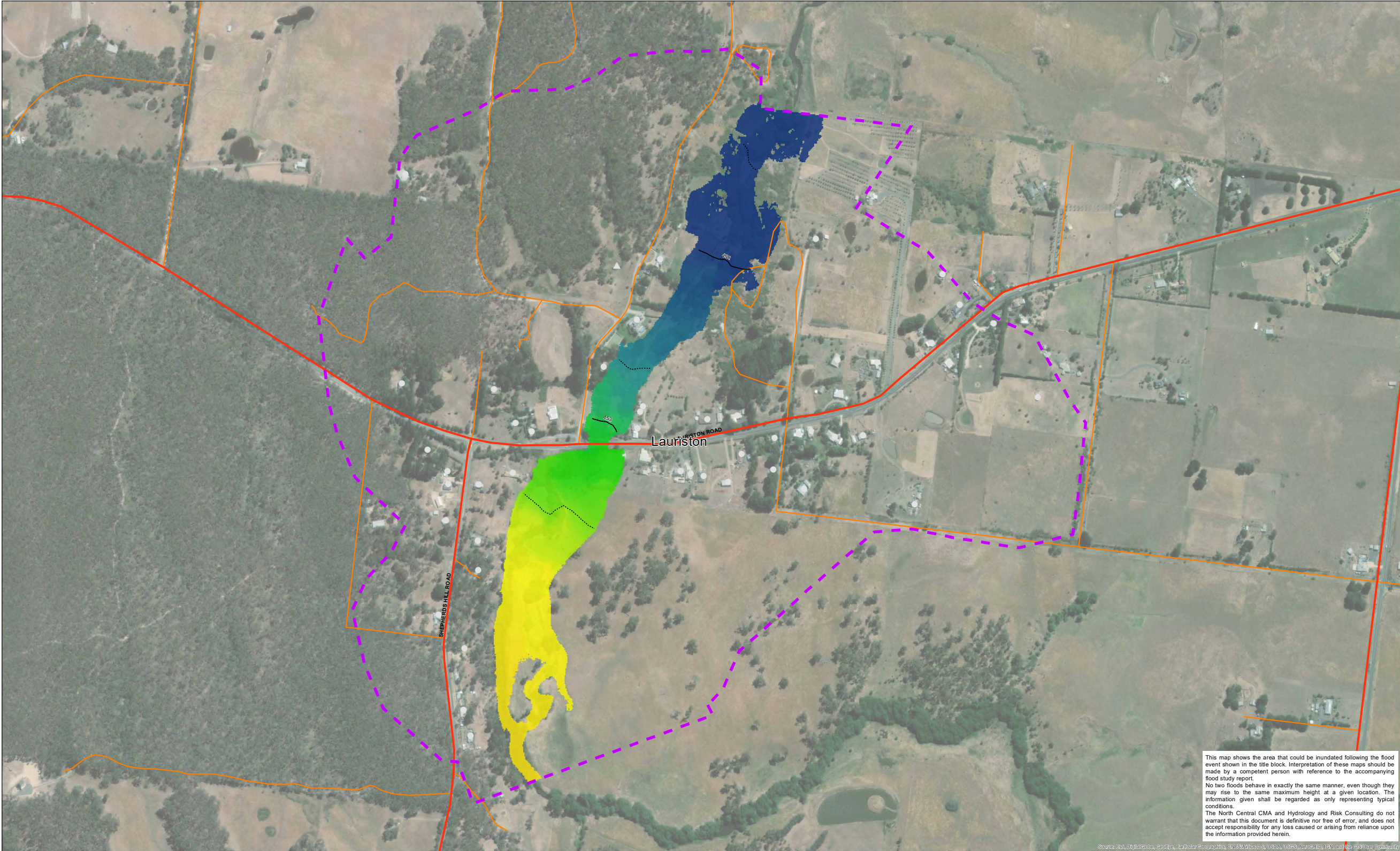
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Lauriston - 5% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 20 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

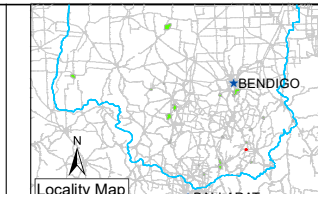
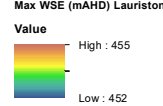
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

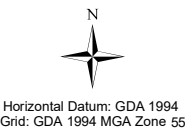
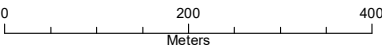
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Lauriston - 5% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 20 - 3
--	---------------------	-------------------------







**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

BENDIGO

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Lauriston - 5% AEP Flood Event**

0 200 400 Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 16 - 20 - 4

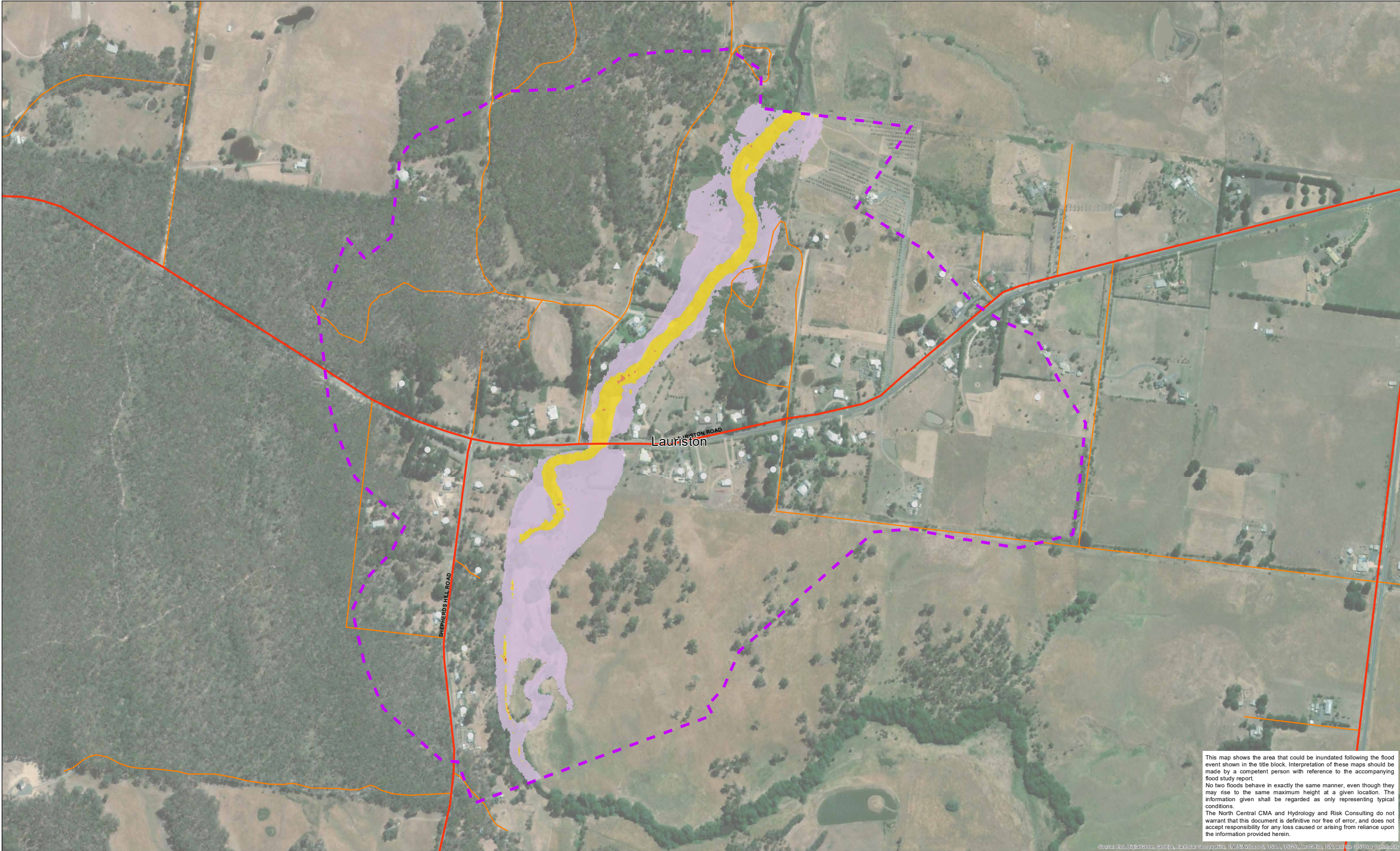
hydrology and risk CONSULTING

North Central CMA

VICTORIA State Government

Australian Government





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

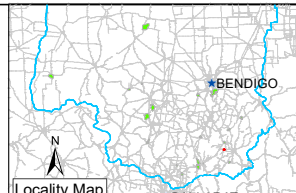
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

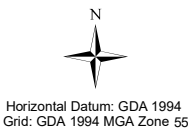
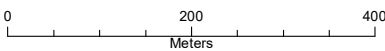
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

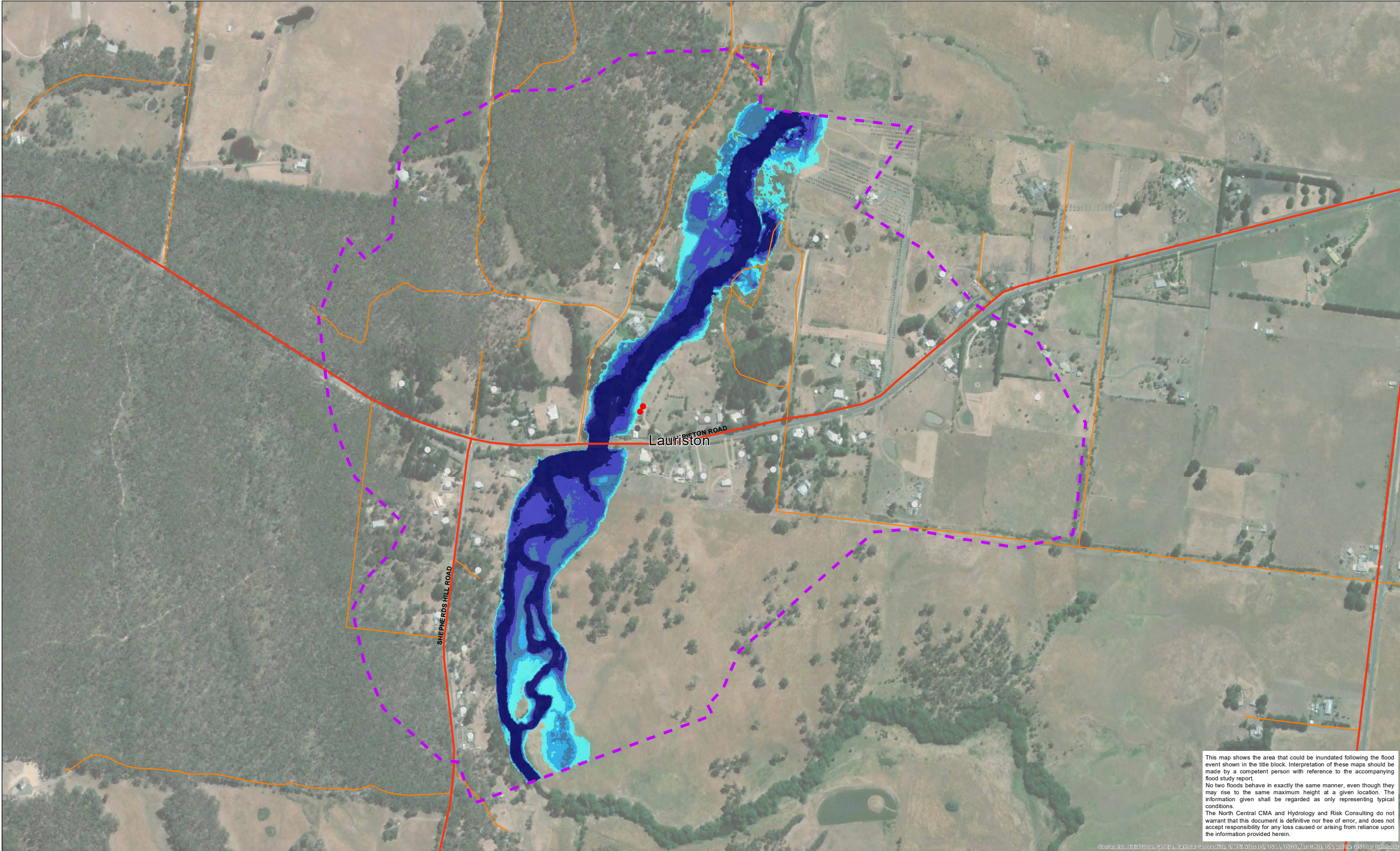
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Lauriston - 5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 20 - 5





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

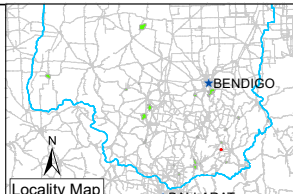
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

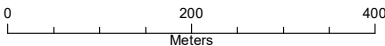
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

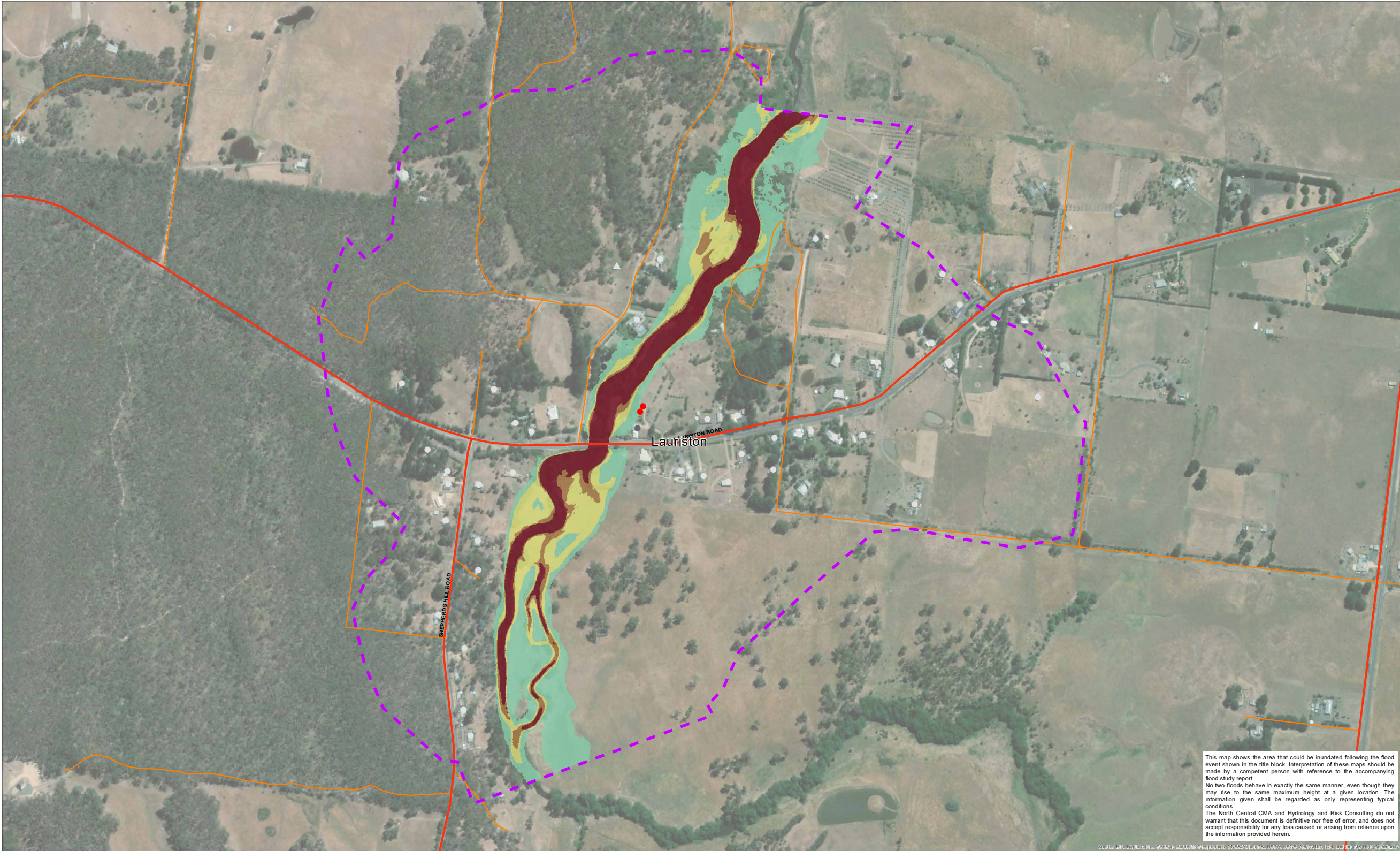
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Lauriston - 2% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 50 - 1





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

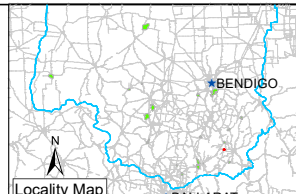
Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

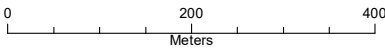
- Max V x D (m<sup>2</sup>/s)
- < 0.4
  - 0.4 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

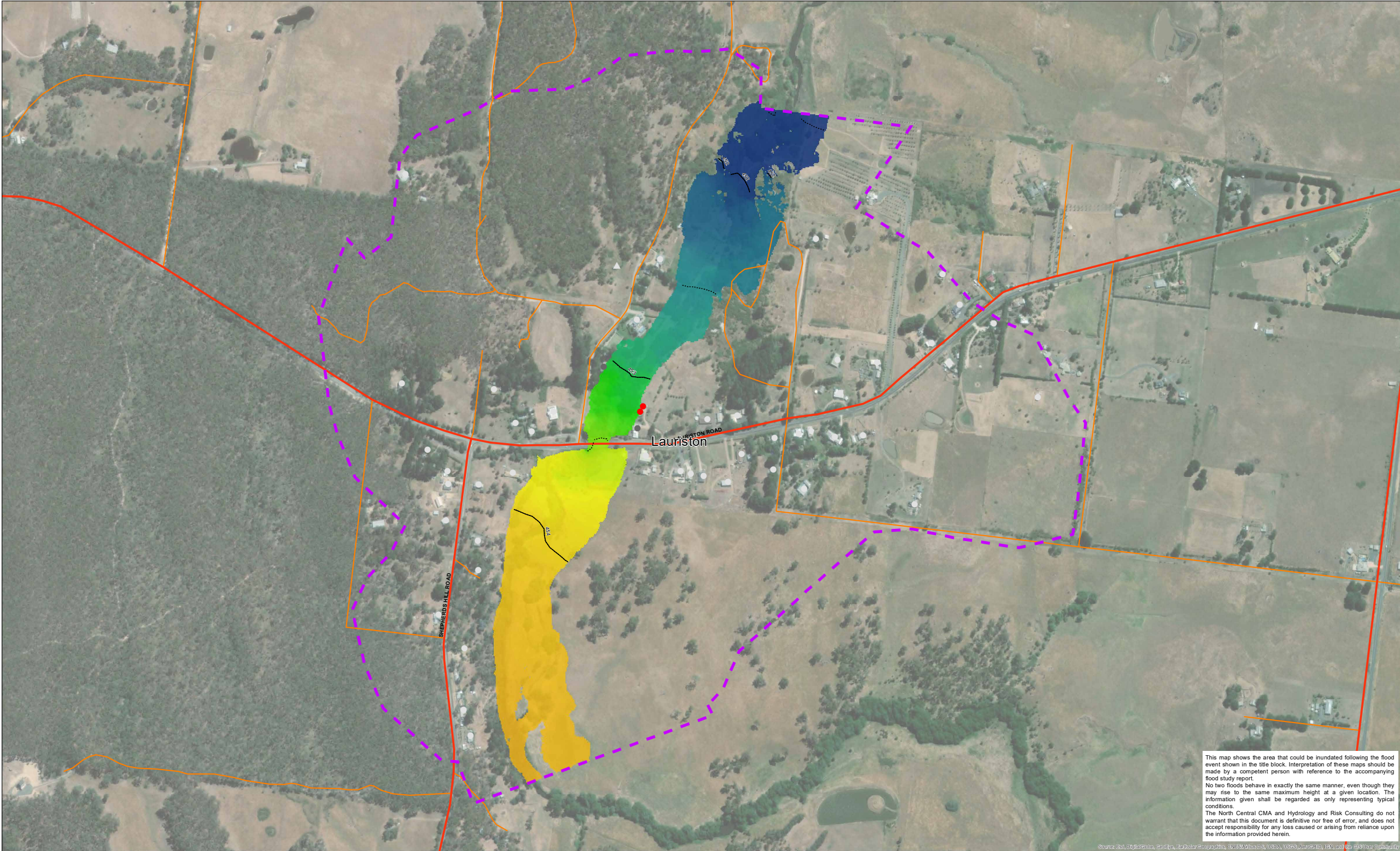
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Lauriston - 2% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 50 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

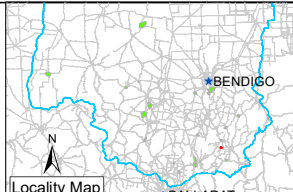
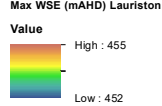
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

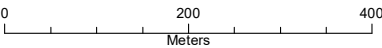
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Lauriston - 2% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 50 - 3
--------	------------------------------	-------	------------	----------	-------------







**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

BENDIGO

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Lauriston - 2% AEP Flood Event**

0 200 400 Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 16 - 50 - 4

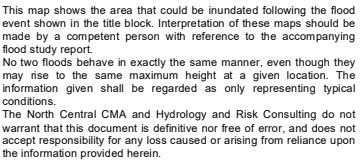
hydrology and risk CONSULTING

North Central CMA

VICTORIA State Government

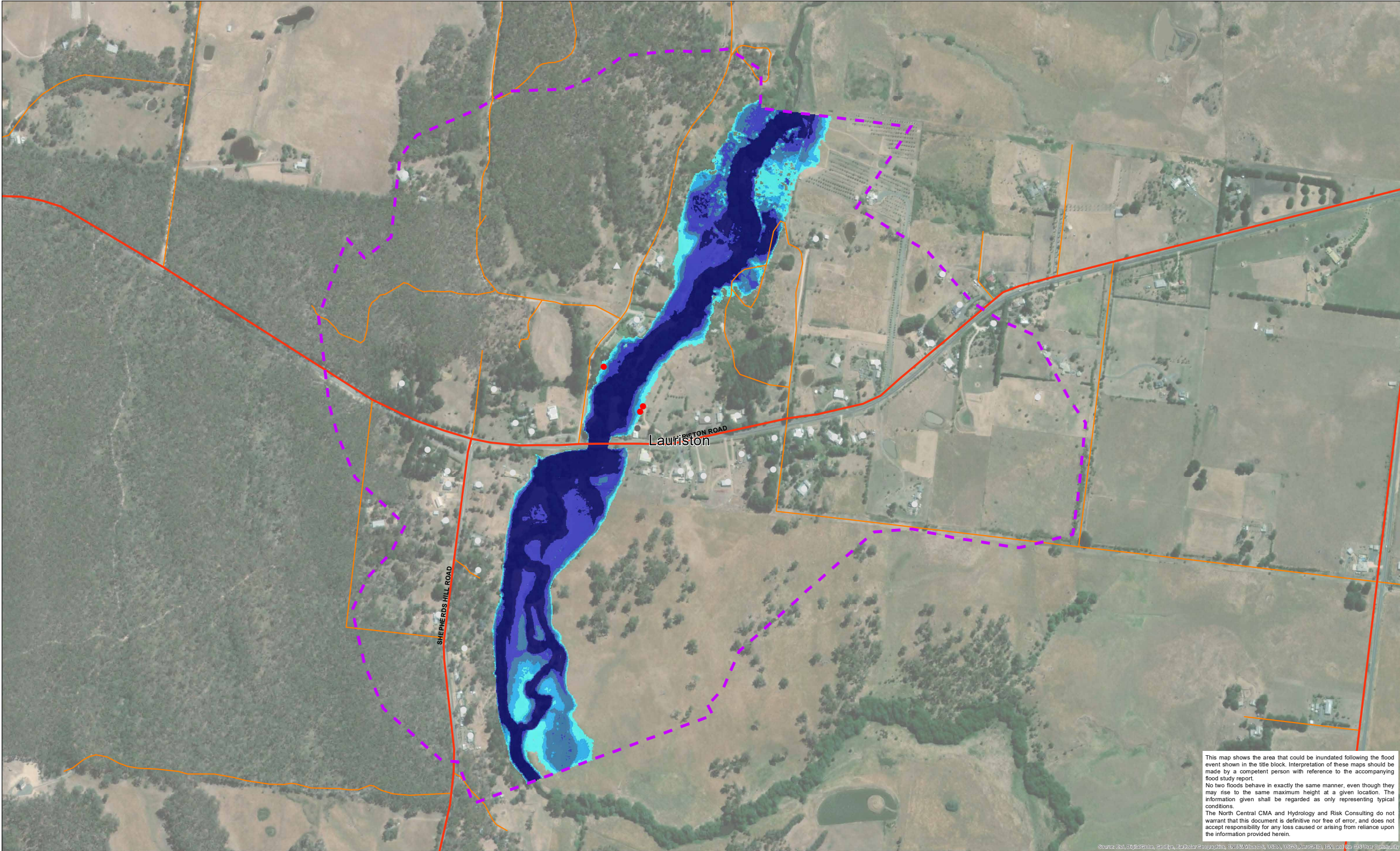
Australian Government





Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 50 - 5





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

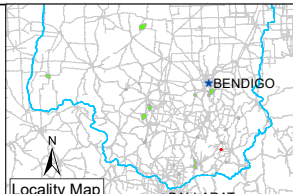
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

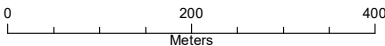
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

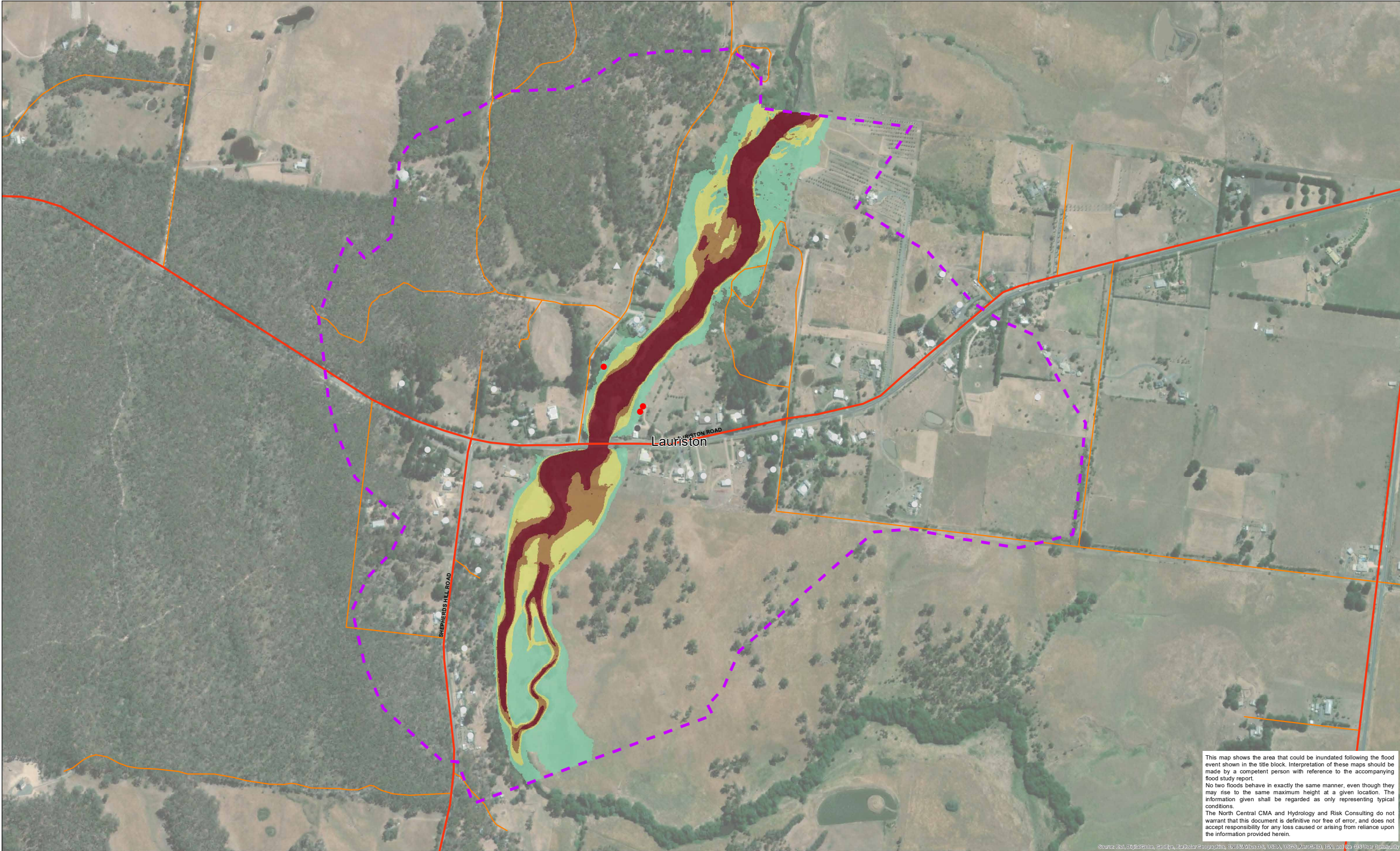
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Lauriston - 1% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 100 - 1





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

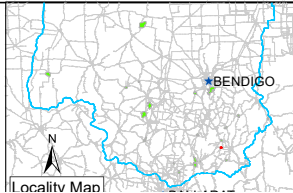
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m²/s)

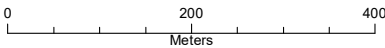
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

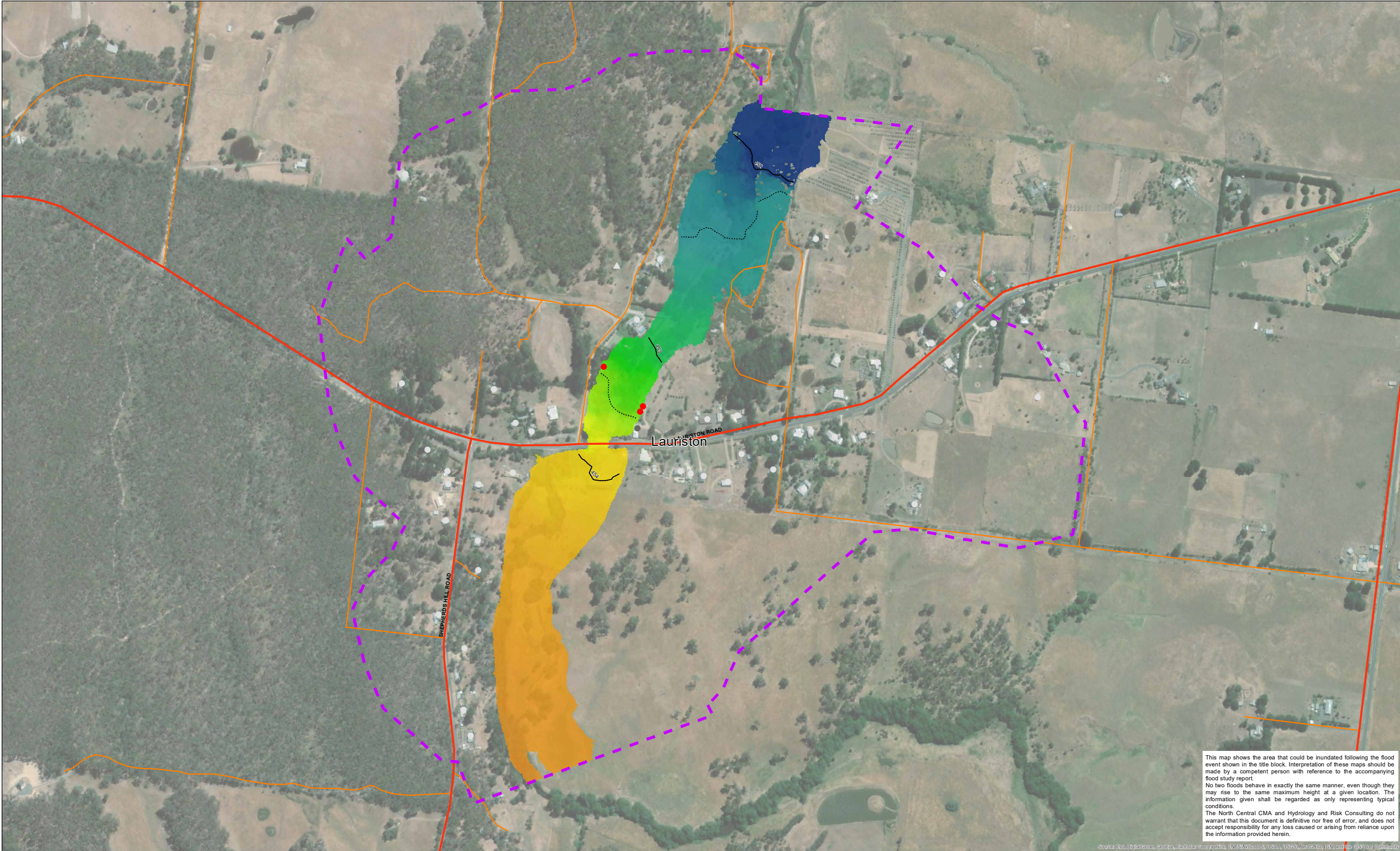
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Lauriston - 1% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 100 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

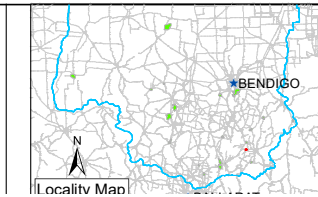
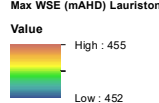
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

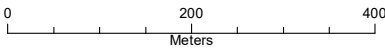
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Lauriston - 1% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 100 - 3
--	---------------------	--------------------------







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

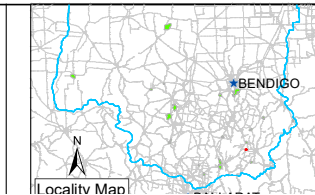
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

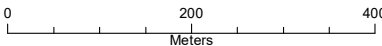
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

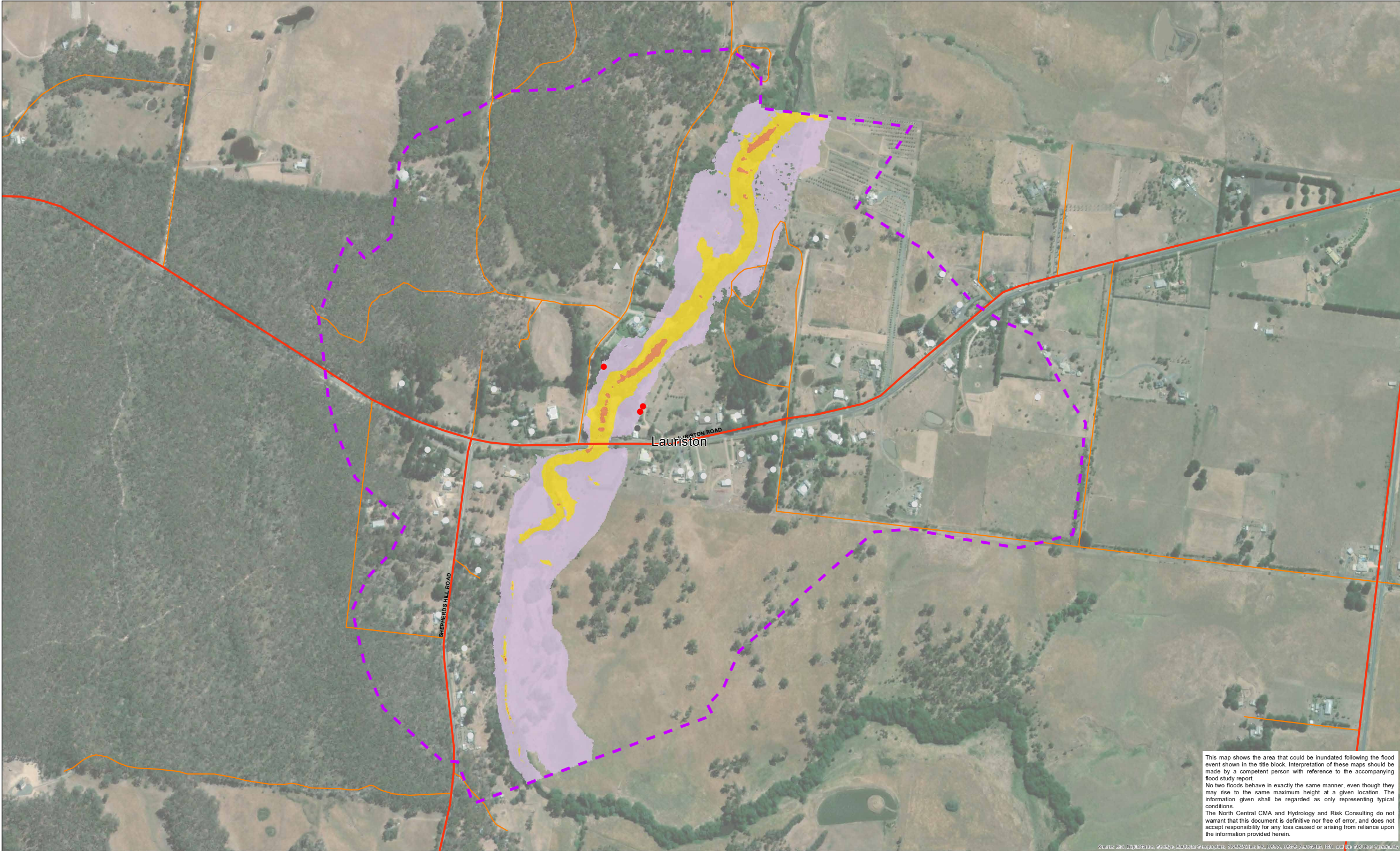
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Lauriston - 1% AEP Flood Event**



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 100 - 4





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

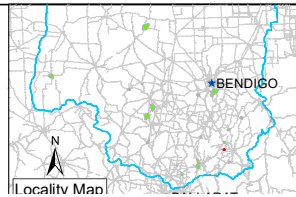
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

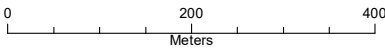
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

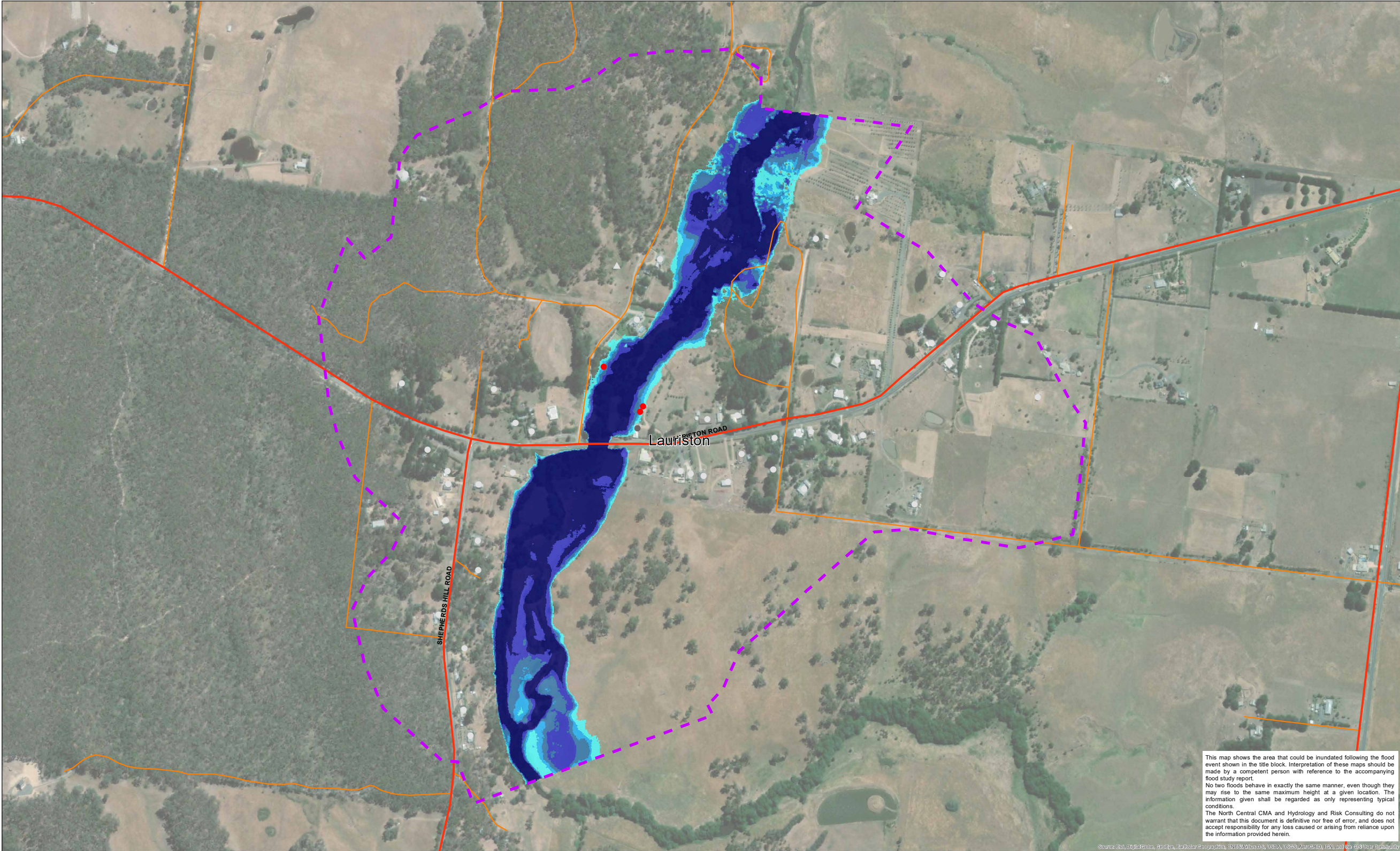
Lauriston - 1% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 100 - 5
----------------------------------	------------------	-----------------------







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

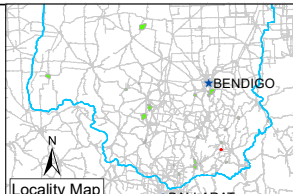
- CFAMFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line

Building Classification

- Residential
  - Commercial
  - Industrial
  - Public
- Building Inundation**
- not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)
  - above floor level (with floor level survey)

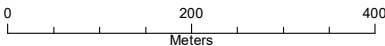
- Max Depth (m)**
- 0.3 - 0.5
  - 0.5 - 0.8
  - 0.8 - 1.2
  - 1.2 - 1.5



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

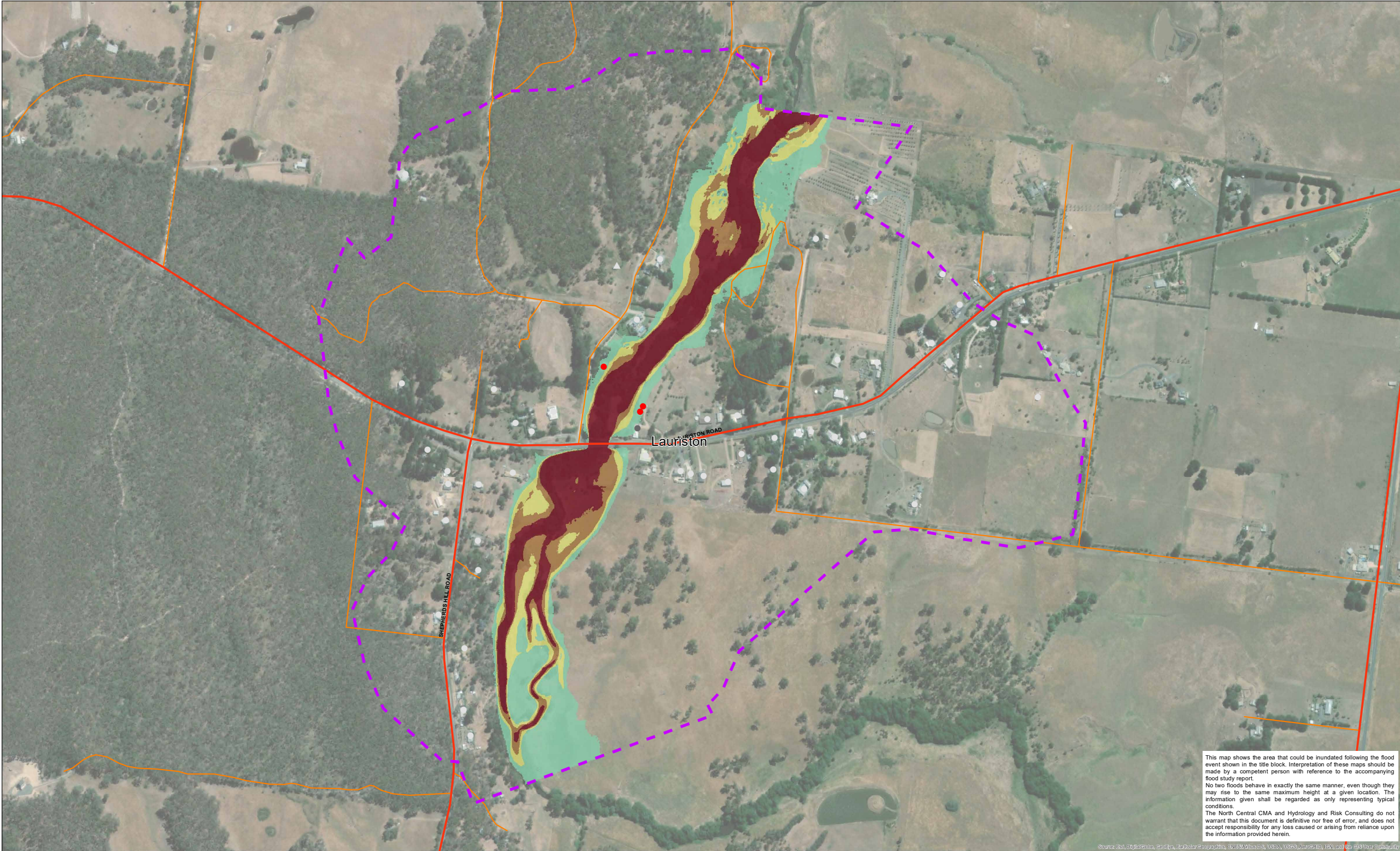
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Lauriston - 0.5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 200 - 1





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park
- Main Road

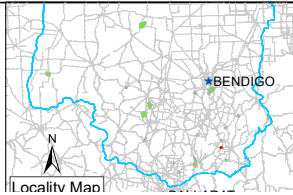
Tertiary Road

Railway Line

Flood Model Extent
- Building Classification**
  - Residential
  - Commercial
  - Industrial
  - Public

**Building Inundation**
  - not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)

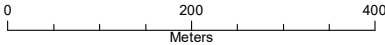
Max V x D (m²/s)
< 0.4
0.4 - 0.8
0.8 - 1.2
> 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Lauriston - 0.5% AEP Flood Event

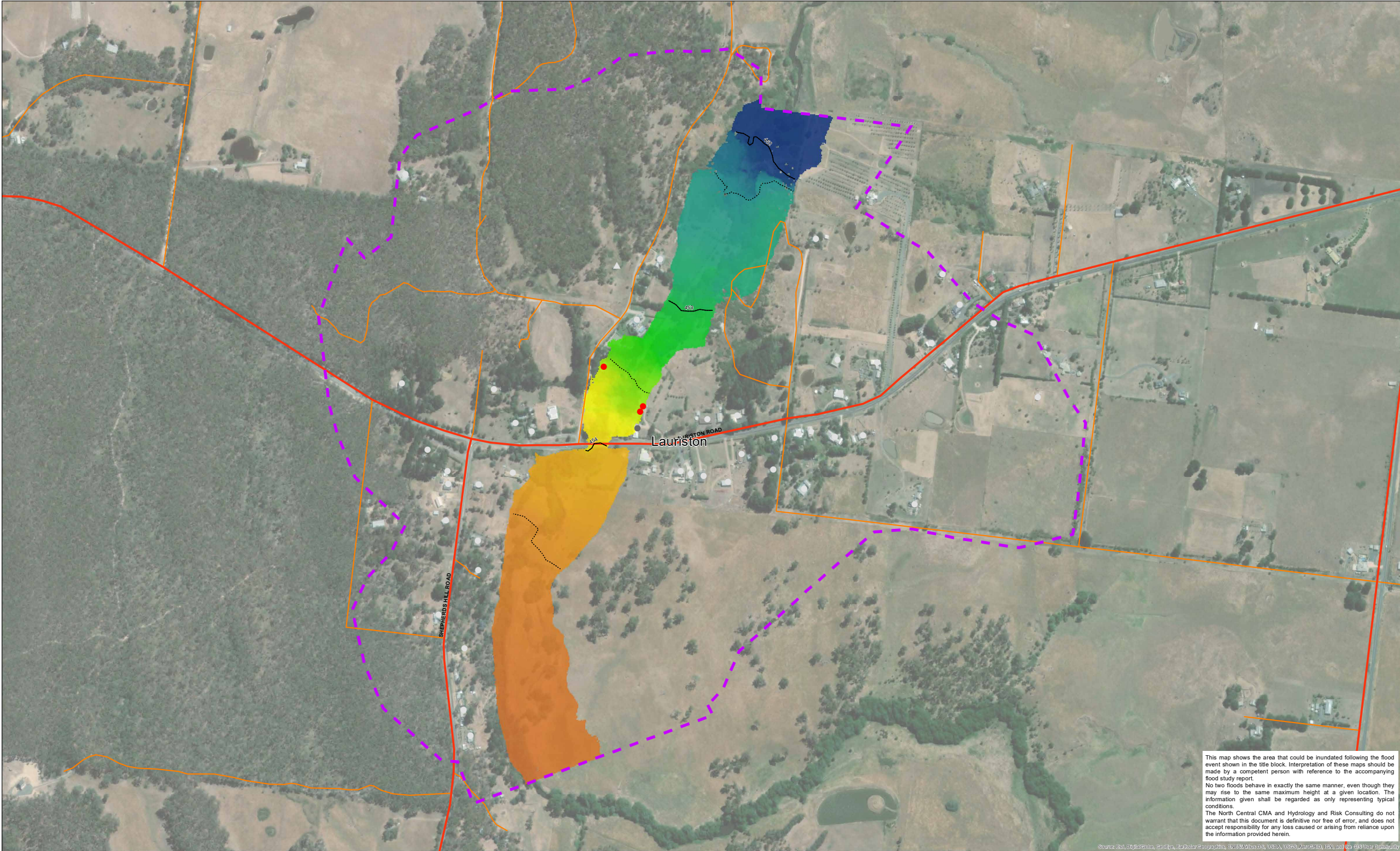


Scale: 1:3,500  
when printed @ A1

Date: 25/02/2020

Map No.: 16 - 200 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

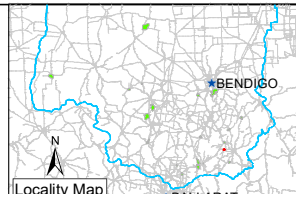
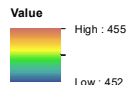
Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

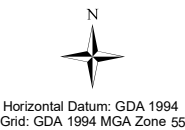
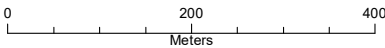
Max WSE (mAHd) Lauriston



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

Lauriston - 0.5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 200 - 3
--------	------------------------------	-------	------------	----------	--------------







This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

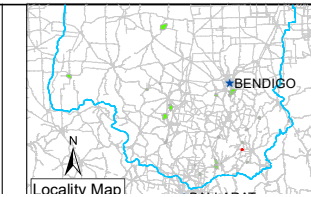
- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

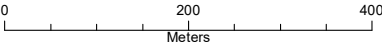
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

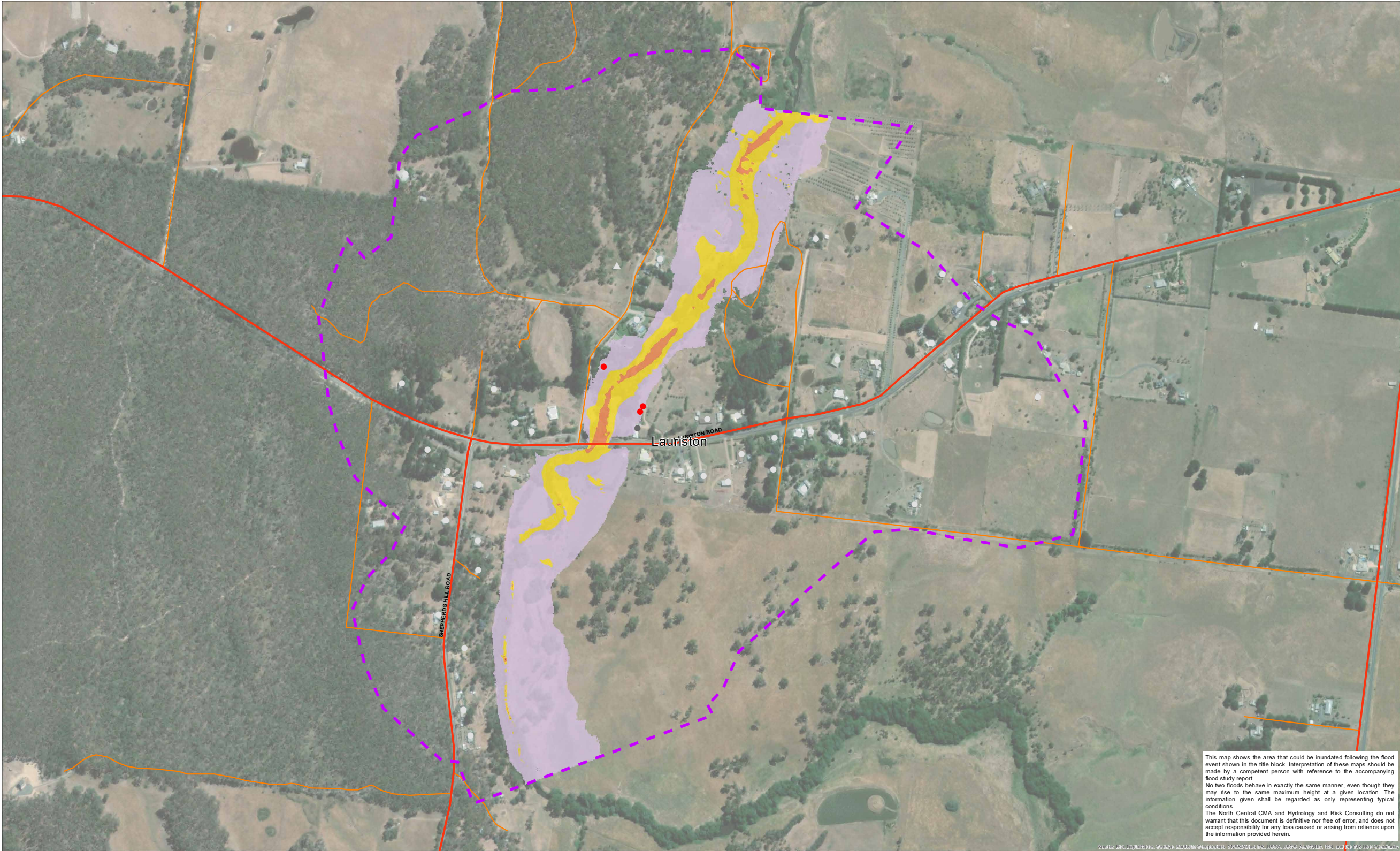
**Lauriston - 0.5% AEP Flood Event**



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - 200 - 4
--------	------------------------------	-------	------------	----------	--------------







This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

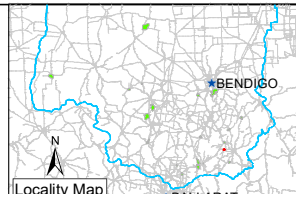
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

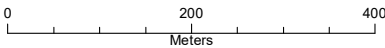
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

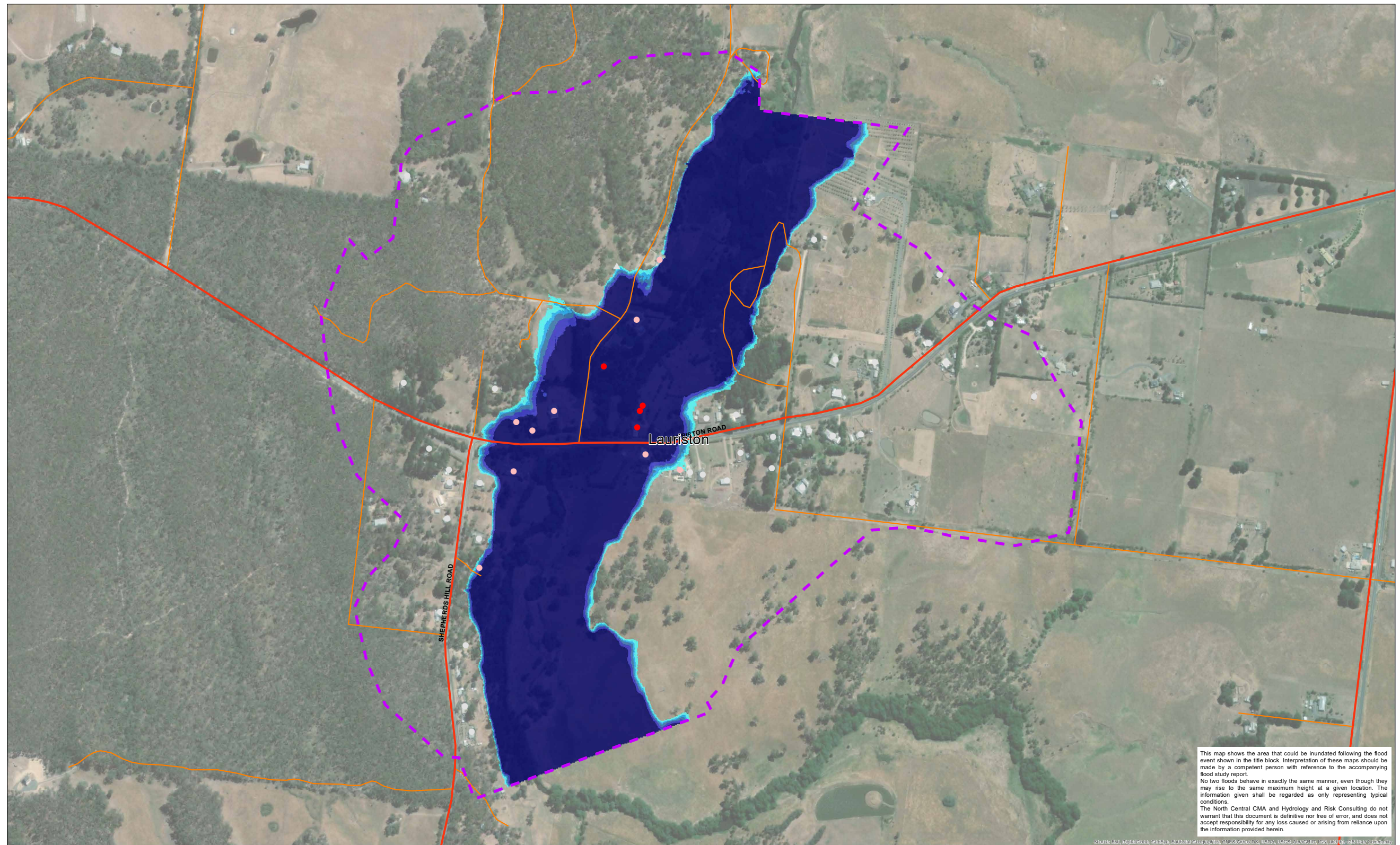
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Lauriston - 0.5% AEP Flood Event

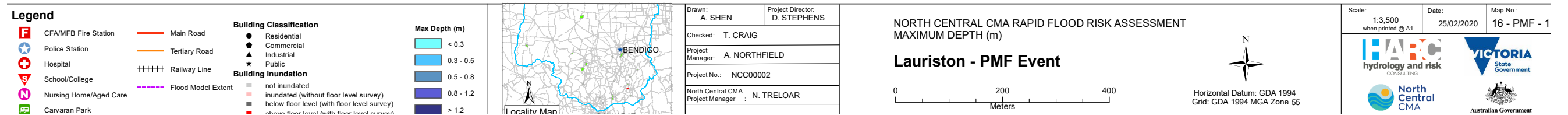


Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - 200 - 5

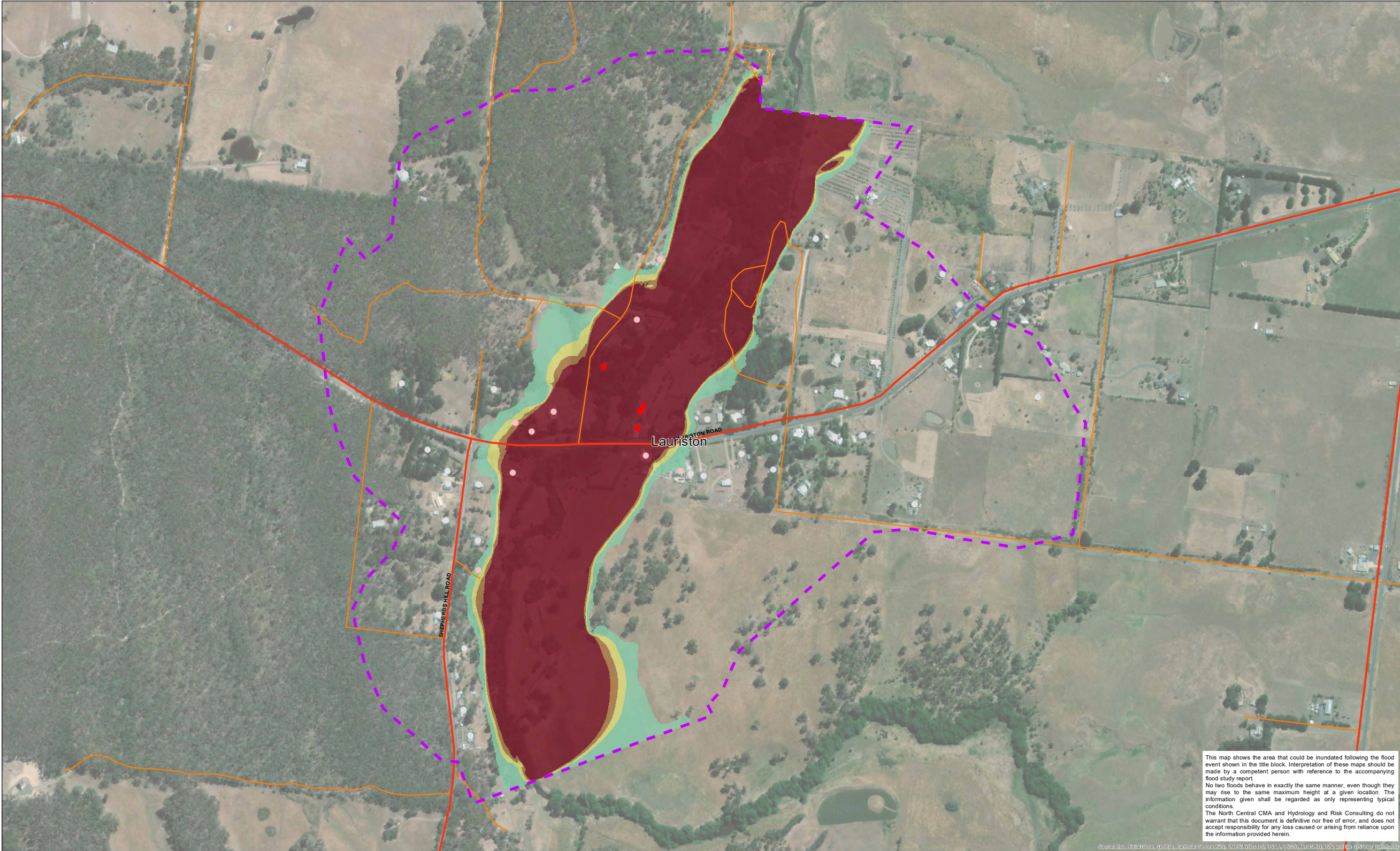




Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

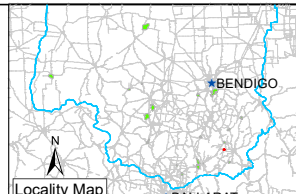
Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

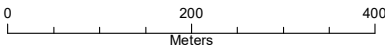
- Max V x D (m<sup>2</sup>/s)
- < 0.4
  - 0.4 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

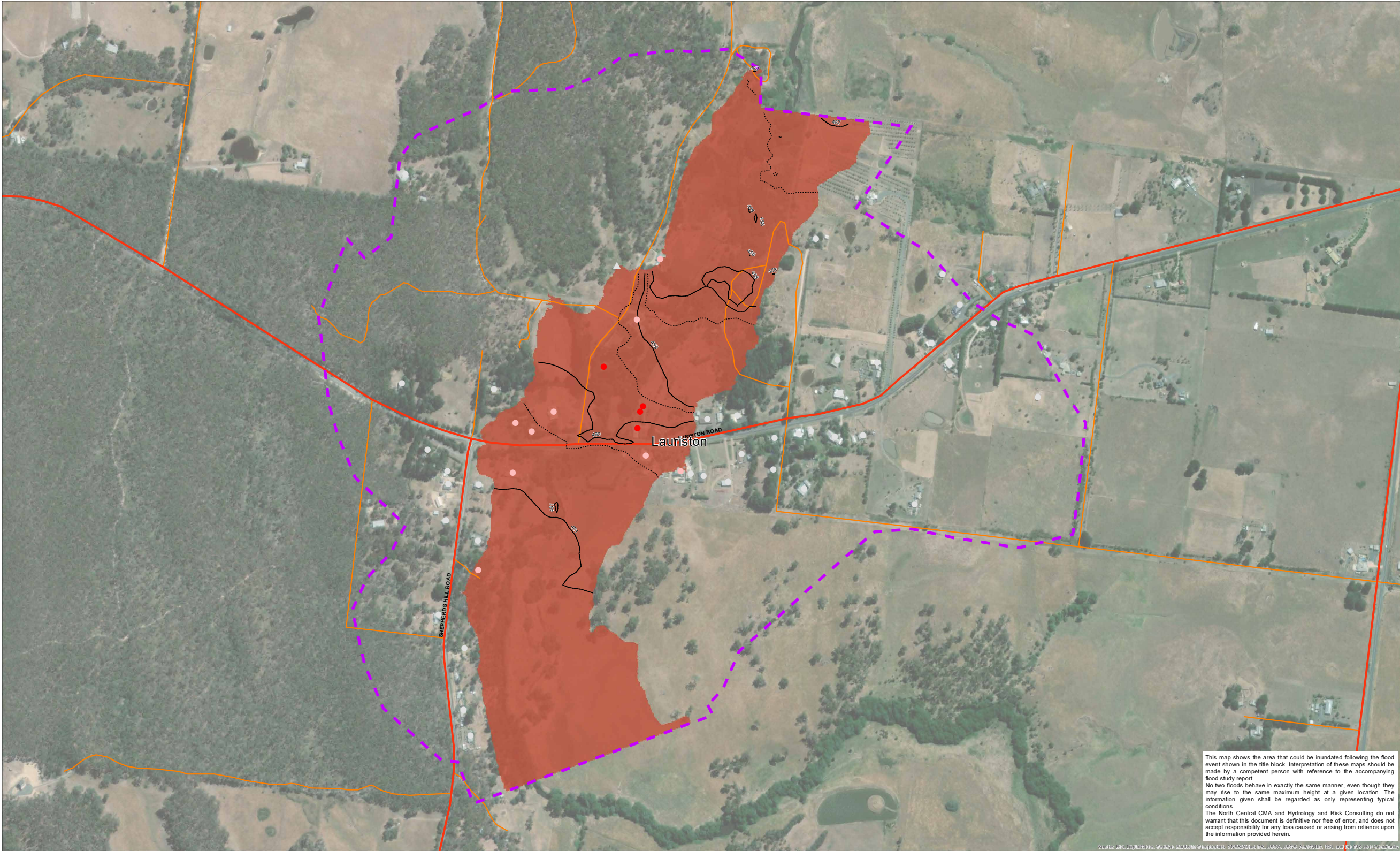
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Lauriston - PMF Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - PMF - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

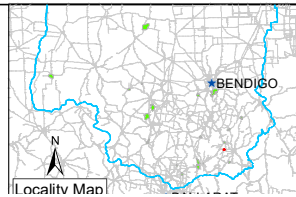
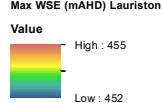
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

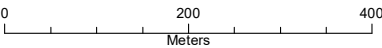
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

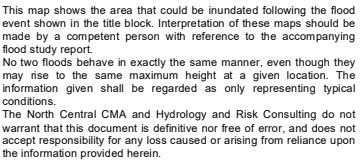
Lauriston - PMF Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - PMF - 3
--------	------------------------------	-------	------------	----------	--------------



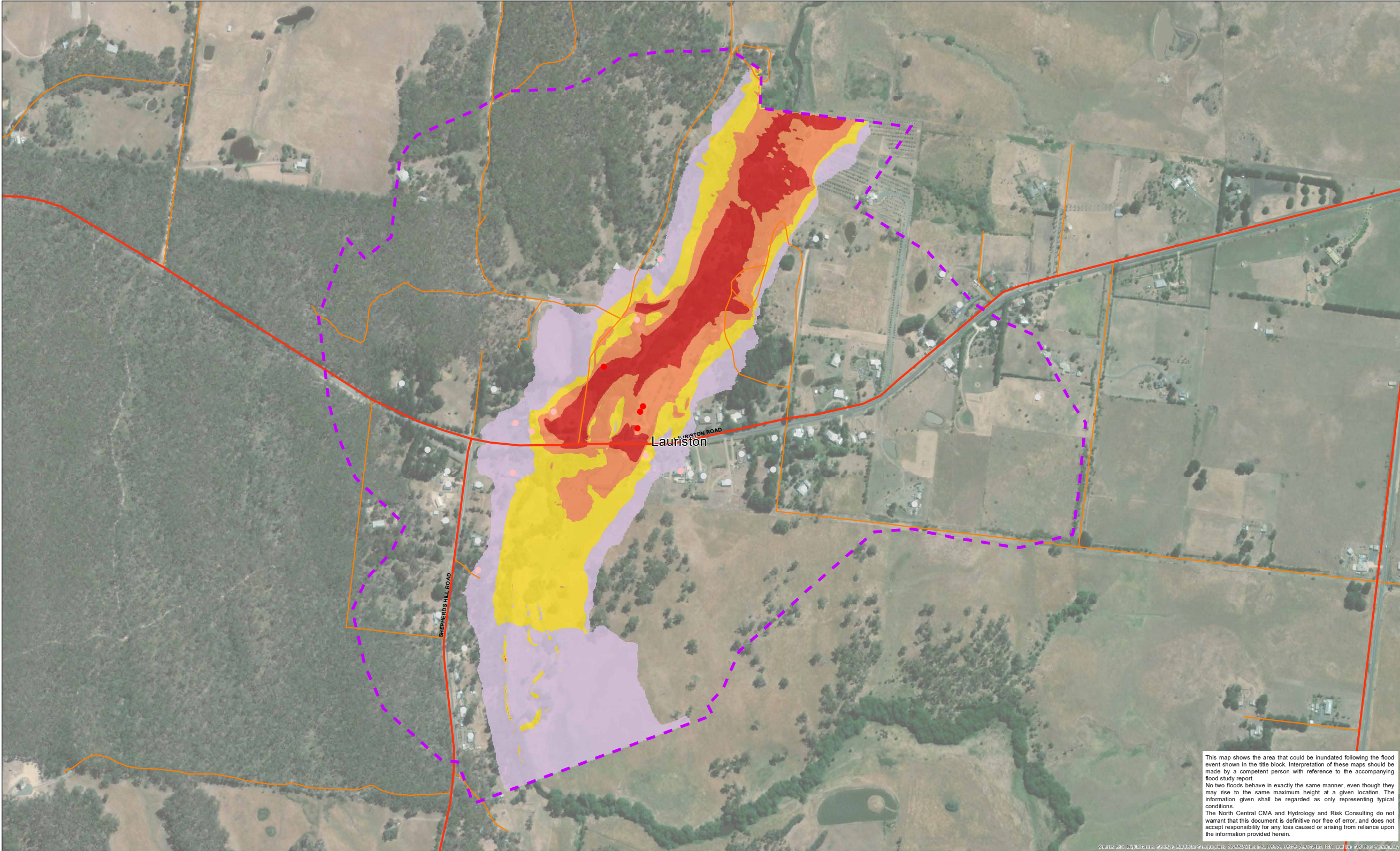




Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend		Building Classification		Building Inundation		Localities		Project Information		Scale and Date		Map No.	
	CFA/MFB Fire Station		Main Road		Residential		not inundated		Drawn: A. SHEN	Project Director: D. STEPHENS	Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 16 - PMF - 4
	Police Station		Tertiary Road		Commercial		inundated (without floor level survey)		Checked: T. CRAIG				
	Hospital		Railway Line		Industrial		below floor level (with floor level survey)		Project Manager: A. NORTHFIELD				
	School/College		Flood Model Extent		Public		above floor level (with floor level survey)		Project No.: NCC00002				
	Nursing Home/Aged Care								North Central CMA Project Manager: N. TRELOAR				
	Caravan Park												





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

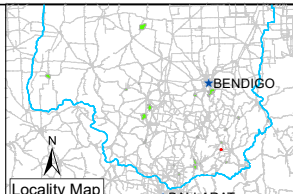
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

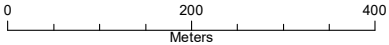
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Lauriston - PMF Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	16 - PMF - 5





## Rapid Flood Risk Assessment - North Central CMA Region

Tylden

Version 2

22/04/2020



Rapid Flood Risk Assessment - North  
Central CMA Region  
Tylden



## Contents

<b>1. Introduction</b>	<b>4</b>
<b>2. Available Data</b>	<b>8</b>
<b>2.1 Information Used in Hydrological Analysis</b>	<b>8</b>
2.1.1 Previous Hydrological models	8
<b>2.2 Information Used in Hydraulic Analysis</b>	<b>8</b>
2.2.1 Hydraulic Structures	8
2.2.2 Topographic Data	8
<b>2.3 Previous Flood Studies</b>	<b>9</b>
<b>3. Hydrologic model development</b>	<b>10</b>
<b>3.1 Tylden RORB model</b>	<b>11</b>
<b>4. Design hydrology approach and inputs</b>	<b>13</b>
<b>4.1 Overview of adopted design flood approach</b>	<b>13</b>
<b>4.2 Overview of design flood hydrology inputs</b>	<b>16</b>
4.2.1 Rainfall depths	17
4.2.2 Areal reduction factors	17
4.2.3 Spatial patterns	18
4.2.4 Temporal patterns	18
4.2.5 Losses	19
4.2.6 Pre-burst rainfall depths and temporal patterns	20
4.2.7 Baseflow	21
<b>5. Hydrologic model verification</b>	<b>22</b>
<b>5.1 Adopted parameters</b>	<b>22</b>
<b>5.2 Verification to the Regional Flood Frequency Estimation Model</b>	<b>22</b>
<b>5.3 Comparison to regional parameters</b>	<b>23</b>
<b>6. Design flood hydrology</b>	<b>25</b>
<b>6.1 Design flows for the 20% to 0.5% AEP events</b>	<b>25</b>
<b>6.2 PMF estimate</b>	<b>25</b>
<b>6.3 Climate change and sensitivity analysis</b>	<b>27</b>
<b>7. Hydraulic Model</b>	<b>30</b>
<b>7.1 Topography</b>	<b>30</b>
<b>7.2 Cell size</b>	<b>30</b>
<b>7.3 Roughness values</b>	<b>30</b>
<b>7.4 Hydraulic structures</b>	<b>33</b>
<b>7.5 Inflows</b>	<b>33</b>
<b>7.6 Downstream boundary</b>	<b>33</b>

Rapid Flood Risk Assessment - North  
Central CMA Region  
Tylden



<b>8. Flood Risk Assessment</b>	<b>35</b>
<b>8.1 Flood Mapping</b>	<b>35</b>
<b>8.2 Flood behaviour and impact of flooding</b>	<b>35</b>
<b>8.3 Climate change</b>	<b>40</b>
<b>8.4 Flood Intelligence Information</b>	<b>41</b>
<b>8.5 Developing Indicative Quick Look Flood / No-Flood Tools</b>	<b>41</b>
8.5.1 Guidance on the use of the Quick Look Flood / No flood Tool	42
8.5.1.1 In the lead up to a flood	42
8.5.1.2 During a flood - using the quick look tool	42
8.5.1.3 After a flood – updating the tool	43
8.5.1.4 Example use of the quick look tool	43
<b>8.6 Flood classification – Bureau of Meteorology</b>	<b>45</b>
<b>9. Summary of rating of key areas</b>	<b>46</b>
<b>10. Limitations</b>	<b>48</b>
<b>11. Conclusion</b>	<b>49</b>
<b>12. References</b>	<b>50</b>
<b>Appendix A Maps</b>	<b>52</b>

Rapid Flood Risk Assessment - North  
Central CMA Region  
Tylden



### Document status

Client	North Central Catchment Management Authority
Project	Rapid Flood Risk Assessment - North Central CMA Region
Document	NCC00002_RFRA_NCC_17_Tylden_Version2.docx
This version	Version 2
Authors	Tim Craig, Andrew Northfield
Project manager	Andrew Northfield
File name	S:\3_Projects\NCC00002\6_Deliverables\
Project number	NCC00002

### Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	06/01/2020	D. Stephens	D. Stephens	N. Treloar	For discussion
Version 1	12/03/2020	D. Stephens	D. Stephens	N. Treloar	
Version 2	22/04/2020	D. Stephens	D. Stephens	N. Treloar	Minor updates

### Copyright and Limitation

The report has been prepared based on the information and specifications provided to HARC by North Central Catchment Management Authority. HARC does not warrant this document as being complete, current or free from error and disclaims all liability for any loss, damage, costs or expenses (including consequential losses) relating from this report. It should only be used for its intended purpose by North Central Catchment Management Authority and should not be relied upon by third parties.

The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments.



This work is licensed under a Creative Commons Attribution 4.0 International licence. You are free to re-use the work under that licence, on the condition that you credit Hydrology and Risk Consulting Pty Ltd as author. The licence does not apply to any images, photographs or branding. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>

#### Acknowledgment of Country

We acknowledge Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.



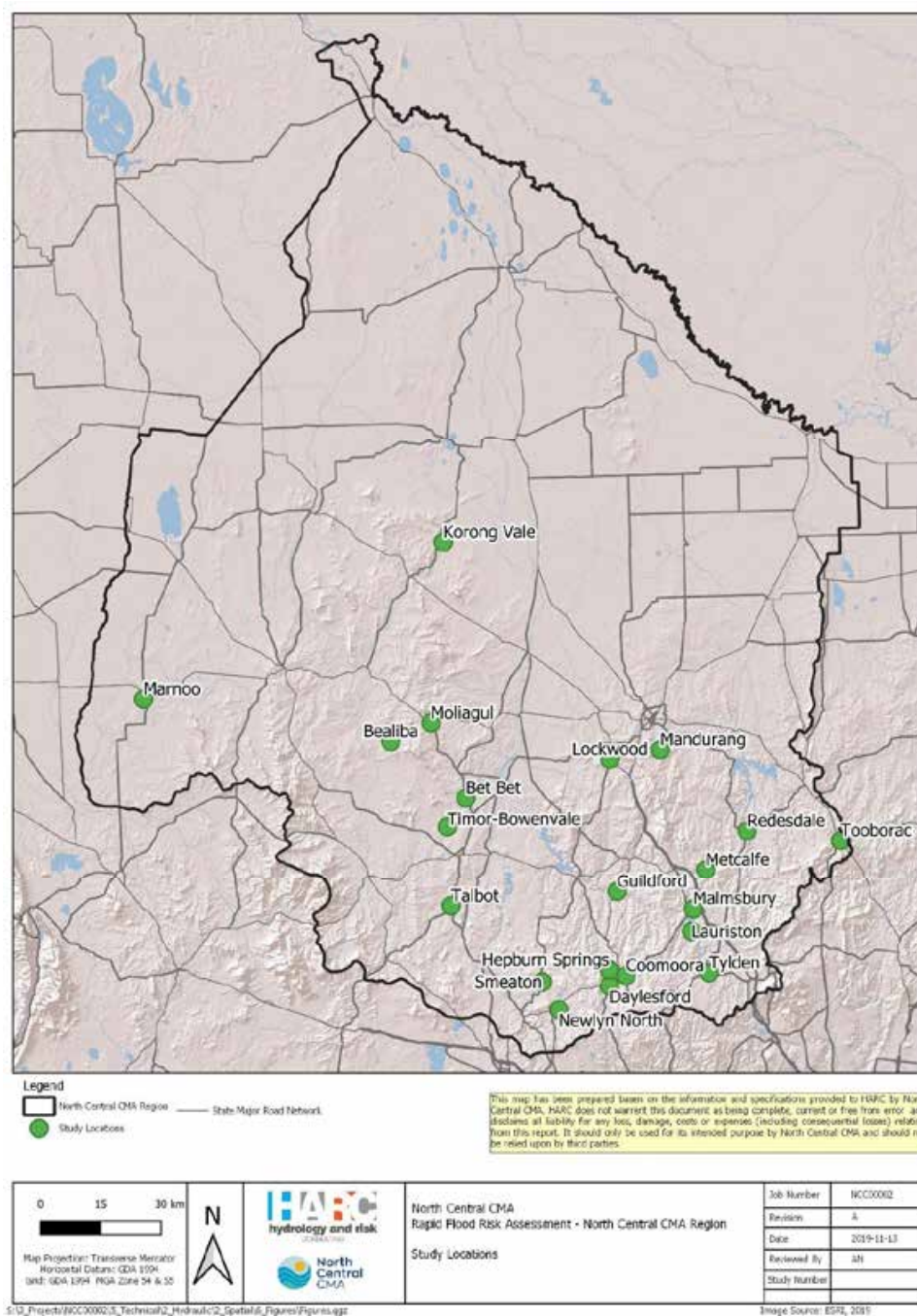
Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 1. Introduction

The North Central Catchment Management Authority (CMA) commissioned HARC to undertake a rapid flood risk assessment for 21 townships in the North Central CMA region. The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments. The study focused on providing mapped flood extents for a range of AEPs using a range of existing and new hydrologic and hydraulic models. The rapid nature of the assessment precluded detailed, site specific studies, extensive model calibration or community engagement. The outcomes of the study were used to provide preliminary estimates of flood risk at the 21 locations, and to help identify and prioritise areas where more detailed, site specific flood studies were recommended. The study locations are shown in Figure 1-1 and the list of townships is shown in Table 1-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 1-1 Rapid Flood Risk Assessment Project Study Locations

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



- **Table 1-1 List of Study Locations (Study Location in bold denotes the township covered in this report)**

No.	Name	No.	Name
1	Lockwood	12	Daylesford
2	Mandurang	13	Hepburn Springs
3	Redesdale	14	Korong Vale
4	Moliagul	15	Malmsbury
5	Bet Bet	16	Lauriston
6	Talbot	<b>17</b>	<b>Tylden</b>
7	Bealiba	18	Tooborac
8	Timor-Bowenvale	19	Guildford
9	Coomoora	20	Metcalfe
10	Newlyn North	21	Marnoo
11	Smeaton		

This report documents the investigation undertaken for the study location of Tylden.

Tylden has a population of approximately 236 and is upstream of the Upper Coliban Reservoir, located approximately 70 km south-east of Bendigo. The Little Coliban River and Jones Creek run to the south of the town, which have an upstream catchment area of 41 km<sup>2</sup>. A small unnamed creek rises immediately to the south west of Tylden-Woodend Road and flows to the north east through the town. Watercourse channels are well defined within the study area. A map of the study area is shown in Figure 1-2.



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 1-2 Tylden study area

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



## 2. Available Data

This section describes the key information used in the hydrological and hydraulic investigation.

### 2.1 Information Used in Hydrological Analysis

#### 2.1.1 Previous Hydrological models

There was a RORB model set up as part of the Upper Coliban Storages Hydrology update (SKM, 2010) which included Tylden. Table 2-1 summarises the key RORB parameters from the previous study.

■ **Table 2-1 Previous RORB model summary of key parameters**

No.	Study Area	Previous Study	$k_c$	$d_{av}$	$C_{0.8}$ ( $k_c/d_{av}$ )	IL (mm)	CL (mm/h)	Shire
17	Tylden	Upper Coliban Dam Hydrology	60	23.8	2.5	45	3	Macedon Ranges

### 2.2 Information Used in Hydraulic Analysis

#### 2.2.1 Hydraulic Structures

There are several hydraulic structures located within the study area. The main structures are listed in Table 2-2 the location of these structures is shown in Figure 7-2. There may be other minor crossings within the study area but they have been assessed as likely to have little/no impact on the flood extents. The North Central CMA approached three organisations to provide information on their bridges and culverts. The three organisations were:

- VicRoads;
- VicTrack; and
- Council

■ **Table 2-2 Summary of hydraulic structures for consideration**

No.	Township Name	Source	Structure Type	Description
17	Tylden	VicRoads	Culvert	Tylden - Woodend Rd (SN4648)
		Estimated*	Bridge	Little Coliban River
		Estimated*	Culvert	Tylden - Woodend Rd 1 (near Macbain St)
		Estimated*	Culvert	Tylden - Woodend Rd 2 (near Macbain St)

\* For structures without details, dimensions were generally estimated based on the aerial image and street view from Google in conjunction with the existing information of the structures in the area.

#### 2.2.2 Topographic Data

To undertake detailed hydraulic modelling requires high quality ground surface information. For this study, aerial captured ground survey, LIDAR, was supplied by North Central CMA. The LIDAR was used to generate a Digital Elevation Model (DEM) of the study area. This LIDAR covered the

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



whole model extent. Further information on the LiDAR dataset used for this study is provided in Section 7.1.

### 2.3 Previous Flood Studies

The North Central CMA provided a number of reports to provide background information for this project. The main reports relevant to this study area are listed in Table 2-3.

#### ■ Table 2-3 Summary of flood studies

No.	Township Name	Previous Studies
17	Tylden	Rochester Flood Management Plan (2013), Water Technology



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



### 3. Hydrologic model development

A rainfall runoff model (RORB) was established for the catchment, terminating at the study area downstream boundary (refer to Figure 1-2). RORB (Laurenson, Mein and Nathan, 2010) is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non-linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal spatial distribution of rainfall as well as losses, and can model flows at any number of points throughout a catchment (including upstream and downstream of reservoirs). RORB also has the capacity to use a Monte-Carlo approach to produce design flood estimates that incorporate the joint probability of several factors that influence flood characteristics.

In general terms, development of a RORB model entails sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storage locations.

Four different types of reaches can be defined in RORB, each having different properties and different relative delay times. The reach types are identified as natural, excavated but unlined, lined channel or pipe and drowned reaches. Drowned reaches were used within reservoir water bodies; natural reaches were used for all other reaches. Excavated and lined channel reaches are normally only applied in urbanised areas and hence were not used in this study.

Impervious fractions are required for each sub-area. For rural areas the impervious fraction was assumed to be zero. For any areas within a dam or reservoir water body, an impervious fraction was calculated based on the percentage of the sub-area that would be inundated. The RORB model also includes some urban areas. The total impervious area (TIA) was estimated for the urban areas using aerial photography and land use information. The Victorian Land Use Information System (VLUIS) dataset was used to define the land use. Because not all impervious areas are well connected to the drainage network (i.e. they flow onto pervious parts of the catchment), the effective impervious area (EIA) is less than the TIA. ARR2019 (Book 5, Chapter 5, Hill and Thomson, 2015) and Phillips et al. (2014) have consolidated the recommended industry practice for estimating EIA and loss parameters for the pervious portion of urban catchments. Phillips et al. (2014) analysed eight catchments and concluded that EIA is typically 55 to 65% of the TIA. ARR2019 recommends an EIA/TIA ratio of 60%. For the RORB model the TIA fraction was multiplied by 0.6 to estimate EIA. The EIA assigned to each land use is shown in Table 3-1.

■ Table 3-1 EIA assigned for each land use

Land Use Type	EIA
Residential areas – high density	0.45
Residential areas – low density	0.12
Industrial/commercial – low density	0.54

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden

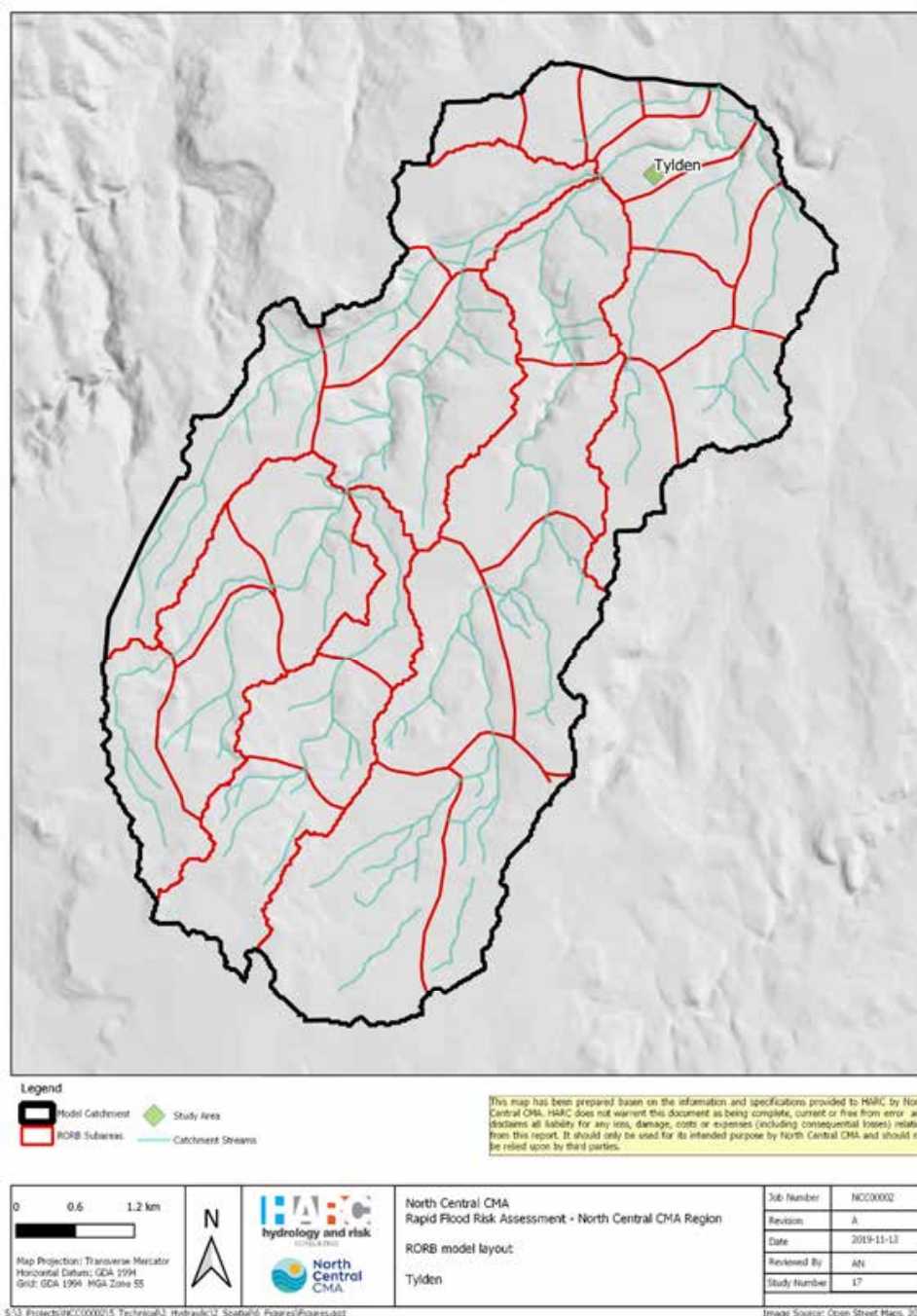


Land Use Type	EIA
Open space or waterway – minimal vegetation	0.0
Open space or waterway – moderate vegetation	0.0
Open space or waterway – heavy vegetation	0.0
Paved roads/car park/driveways	0.6
Railway line	0.6
Grass reserves/floodway (regularly mowed)	0.0
Rural floodplains in clear paddocks	0.0
Forested (heavy stand of timber)	0.0
Dam/Reservoir body of water	1.0

### 3.1 Tylden RORB model

The RORB model established by SKM for updating the hydrology for the Upper Coliban Storages Hydrology update (SKM, 2010) had the Tylden catchment represented by two subareas. This was considered to be too coarse for this study, therefore a new RORB model was developed for this investigation. The RORB model layout is shown in Figure 3-1.

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 3-1 RORB model layout



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 4. Design hydrology approach and inputs

### 4.1 Overview of adopted design flood approach

The estimation of design floods has traditionally been based on the 'design event' approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 4-1 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are 'AEP-neutral', that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

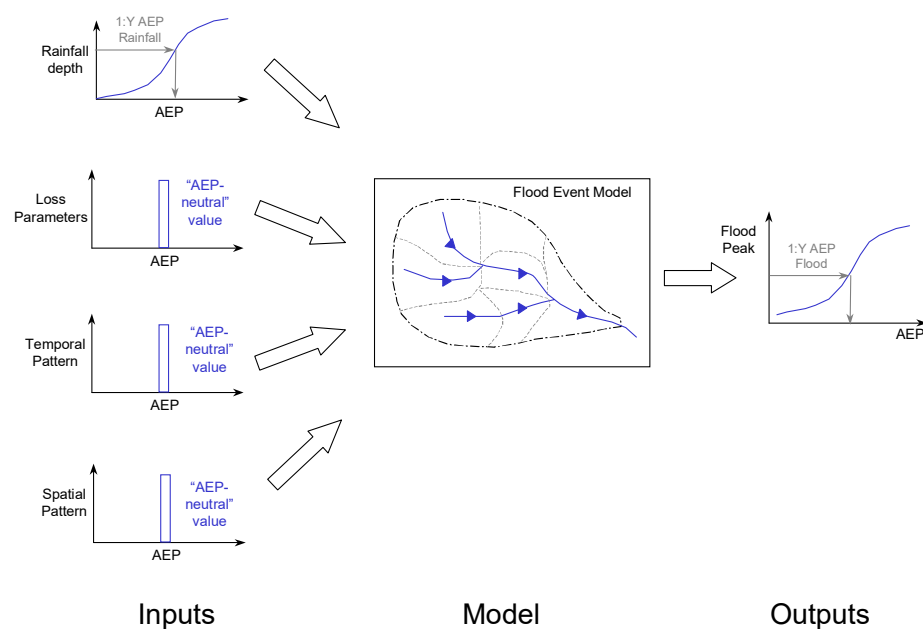
This approach suffers from the limitations that:

- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such as the variability in rainfall spatial and temporal pattern) becomes rapidly more complex and less easy to defend.

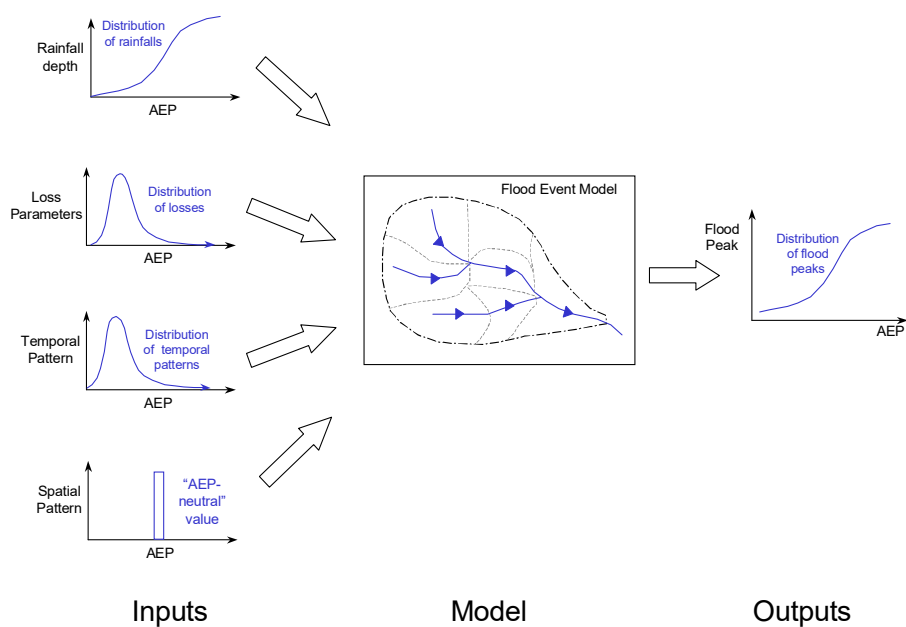
Joint probability techniques offer an improvement to the traditional design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated catchment, or a large storm on a dry catchment. In probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic 'mother nature' in that the influence of the key probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The application of joint probability approaches to flood estimation is widely acknowledged to be a more thorough and defensible approach to design flood estimation than the design event approach in Australian practice, and has been incorporated in the 2019 version of Australian Rainfall and Runoff (Ball et al., 2019).

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 4-1 Schematic illustration of the design event approach

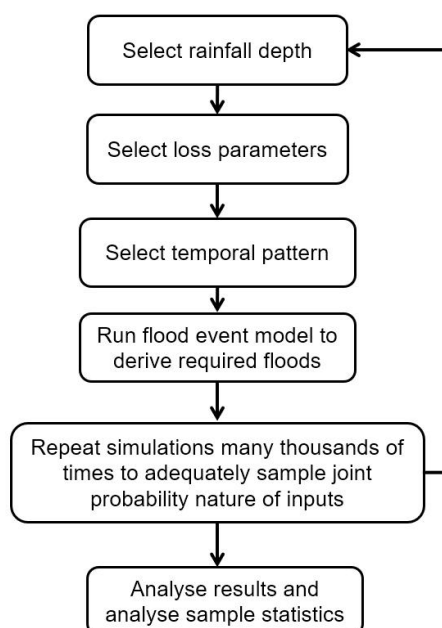


■ Figure 4-2 Schematic illustration of the joint probability approach

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



The joint probability framework adopted for the study was developed by Nathan et al (2002, 2003) and is summarised in Figure 4-3. In essence the approach involves undertaking numerous model simulations, where the model inputs are sampled from non-parametric distributions that are based either on readily available design information or on the results of recent research. For those study areas where reservoir starting water level is applicable, the level in the storage is also sampled.



■ **Figure 4-3 Overview of adopted joint probability framework**

In developing the joint probability framework particular attention was given to ensuring that the model inputs and the manner in which they were incorporated was consistent with ARR (Ball et al., 2019). The following briefly describes the main inputs, and how they will relate to establishing design information.

*Select rainfall depth.* Rainfall depths were stochastically sampled from the cumulative distribution of rainfall depths.

*Select storm losses.* Storm initial losses were stochastically sampled from a nonparametric distribution that was determined from the analysis of a large number of catchments across Australia (Hill et al., 2014). The limited number of investigations that have explored the correlation between initial and continuing loss values have concluded that there is little systematic dependence between the two. There is little information regarding the correlation between initial and continuing loss rates, and since antecedent conditions have most influence on initial loss rates, in this study the continuing loss rates will be held constant. Current practice is for initial losses to



## Rapid Flood Risk Assessment - North Central CMA Region Tylden



be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

*Select temporal pattern.* Temporal patterns were randomly selected from a sample of temporal patterns relevant to the catchment area and duration of the storm. The temporal patterns in the data hub were derived from large historic storms that have been observed in the region.

*Monte-Carlo simulation.* Simulations were undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 100 probability of exceedance, a reduced number of simulations were undertaken over a specified number of probability intervals. In this study, the rainfall frequency curve was divided into 100 intervals uniformly spaced over the standardised normal probability domain, and 250 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered. This approach accounts for the natural variability inherent in floods. Monte Carlo techniques are grounded in, and consistent with, the principle that “no two floods are ever the same”.

The key advantage of the Monte Carlo approach is that it reduces uncertainty by accounting for variability. The results of a Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, however it must be remembered that the natural variability of the key inputs is built into these median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Using the technique described above hydrographs were produced for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

In the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994).

### 4.2 Overview of design flood hydrology inputs

Design inputs were produced in accordance with ARR2019. Inputs include:

- Rainfall depths (IFD - BOM),
- Areal reduction factors (Data hub),
- Spatial patterns (Rainfall depths over the catchment – based on IFD)
- Temporal patterns (Rainfall depths over time – Data hub)
- Losses (ARR guidance)
- Pre-burst (Data hub)
- Baseflow (ARR guidance)

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



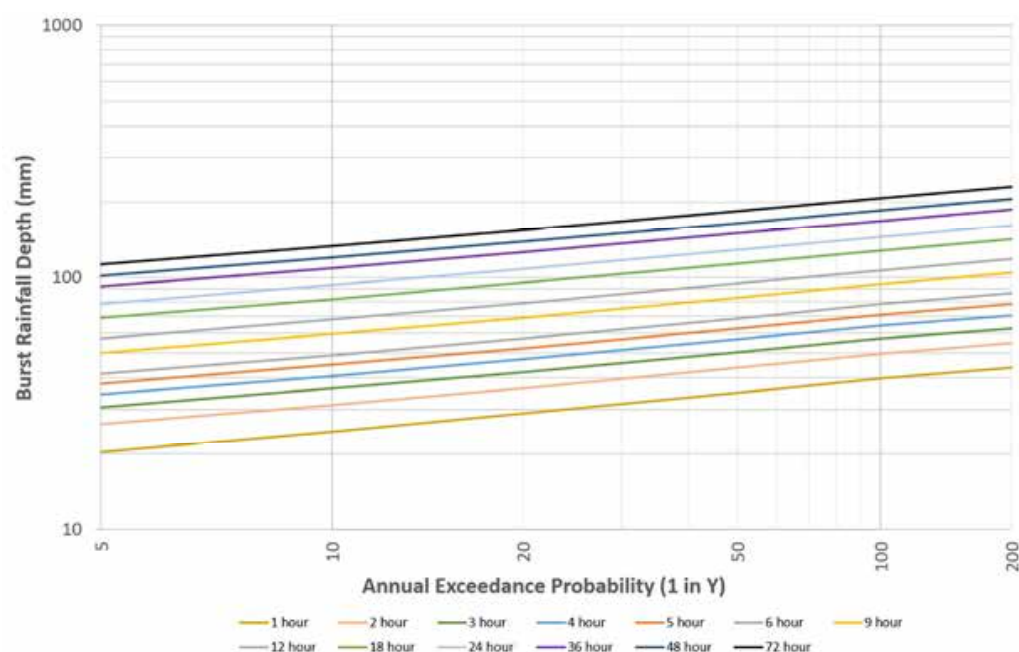
### 4.2.1 Rainfall depths

Catchment average point design rainfall depths for burst durations between 1 and 72 hours, and AEPs from 1 in 5 to 1 in 200, were taken from the Bureau of Meteorology (2016) (<http://www.bom.gov.au/water/designRainfalls/revised-ifd/>).

### 4.2.2 Areal reduction factors

The point rainfall estimates were converted to areal values using the ARR2019 areal reduction factors (Jordan et al, 2016) extracted from the ARR Data Hub. Conceptually, these factors account for the fact that larger catchments are less likely to experience high intensity storms over the whole catchment.

A summary of the complete, catchment average areally reduced design rainfall depths adopted are shown in Figure 4-4 and Table 4-1.



- Figure 4-4 Adopted design rainfall depths
- Table 4-1 Adopted design rainfall depths

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
5	20	26	31	34	38	42	50	57	69	79	92	101	113
10	24	31	36	41	45	49	60	68	82	93	109	120	134

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
20	29	36	42	47	52	57	69	79	95	108	126	139	155
50	35	44	50	57	63	69	83	94	113	129	150	165	184
100	40	50	57	64	71	78	94	107	128	145	169	185	207
200	44	55	63	71	79	87	105	119	142	161	187	206	230

#### 4.2.3 Spatial patterns

The spatial pattern for the catchment has been based on the rainfall depths from the Bureau of Meteorology, i.e. the IFD, which is recommended in ARR2019.

#### 4.2.4 Temporal patterns

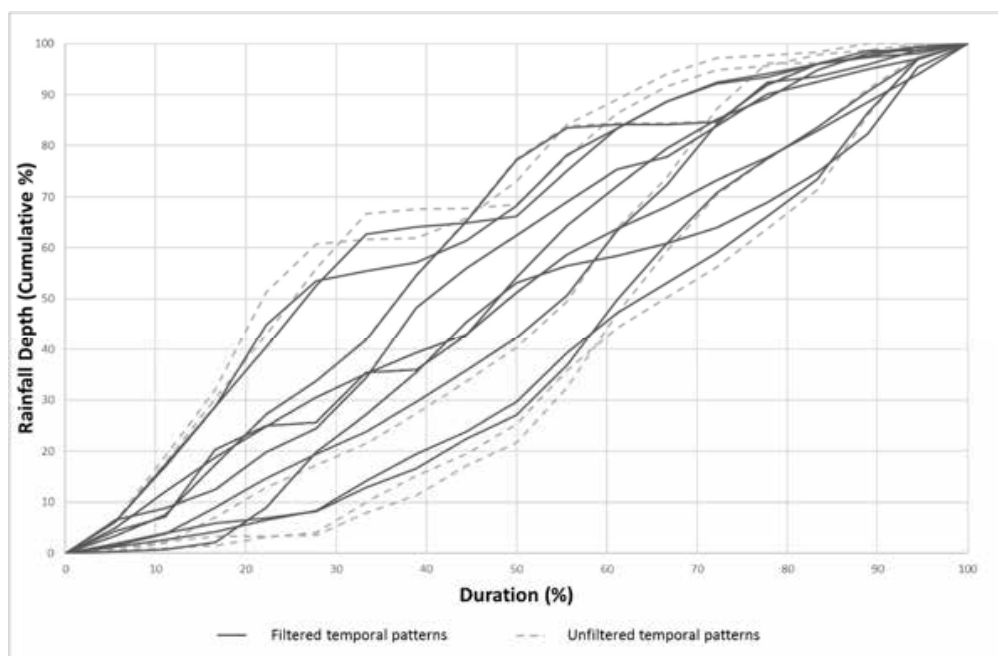
For catchment areas greater than 75km<sup>2</sup> ARR recommends the use of the sample of areal temporal patterns available from the ARR data hub (Geoscience Australia, 2019) for long durations (greater than 24 hours). The derivation of these patterns is discussed in ARR 2019 (Ball et al., 2019). For the shorter duration storms, the sample of temporal patterns derived by Jordan et al (2005) was used. For catchment areas less than 75km<sup>2</sup> ARR recommends the use of ARR data hub (Geoscience Australia, 2019) point patterns.

Before the temporal patterns were used, they required some filtering to remove embedded bursts. An embedded burst is a sub-period of rainfall within a given temporal pattern that has a rarer AEP than the actual burst itself. The method described by Scoria et al. (2016) was used to smooth out the embedded bursts. As an example, Figure 4-5 shows the 24 hour design temporal patterns, before and after embedded bursts are removed.

All temporal patterns in the sets used for sampling were given equal probability of selection in the Monte Carlo simulation.



## Rapid Flood Risk Assessment - North Central CMA Region Tylden



■ **Figure 4-5 24-hour design temporal patterns before filtering and after filtering to remove embedded bursts**

### 4.2.5 Losses

There are two key types of loss models that are typically adopted when modelling design floods:

- Initial loss/continuing loss
- Initial loss/proportional loss

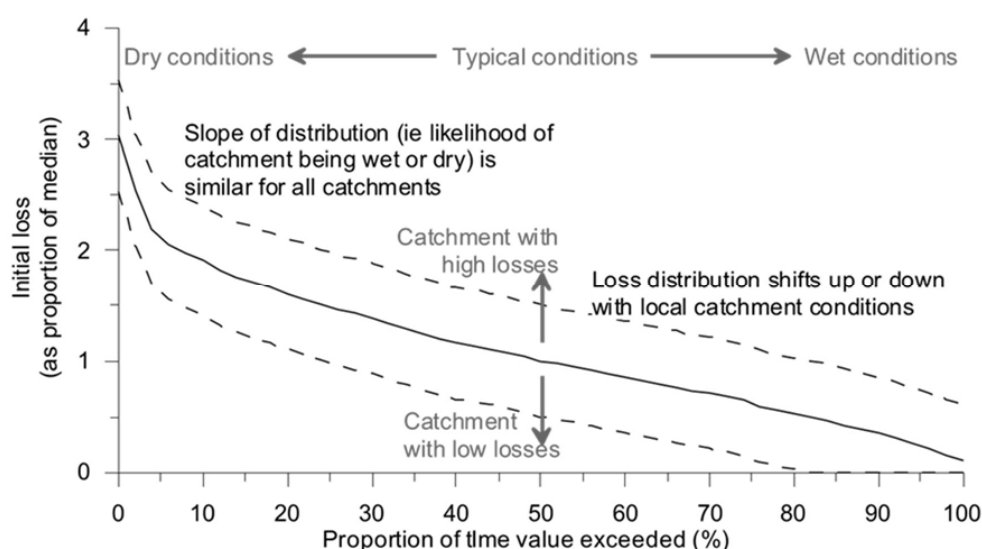
Investigations by Hill et al. (2014) as part of the ARR 2019 revision were inconclusive as to which loss model works best. Even for catchments where one of the loss models performed better for a majority of events, there were still some events for which the other approach was better. Similarly, there was no obvious relationship between the relative performance of the loss models and hydro-climatic or catchment characteristics.

The advice in ARR is that the initial loss/continuing loss model is most suitable for design flood modelling, because it can be used to estimate flood peaks and volumes for all AEPs. In contrast, it is often difficult to derive unbiased estimates of flood quantiles using the initial loss/proportional loss model over the same range of AEPs. The initial loss/proportional loss model underestimates peak flows for extreme floods if the proportional loss is not varied appropriately with AEP; and to date there is little evidence about how proportional loss varies with AEP. Therefore, for this study an initial loss/continuing loss model was adopted.

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



The shape of the initial loss distribution used in the design flood modelling was derived by Hill et al. (2014) from flood modelling results for a large number of catchments across Australia. Hill et al. (2014) developed a non-dimensional distribution of initial loss values for each catchment, by representing initial losses as a proportion of the median loss. This allowed the distributions of initial losses across different catchments to be directly compared. The standardised distributions exhibited a high degree of consistency, and suggested that while the magnitude of initial losses may vary between different catchments, the shape of the distribution does not. That is, while it may be expected that typical loss rates vary from one catchment to another, the likelihood of a catchment being in a relatively dry or wet state is similar for all catchments. The adopted distribution of initial loss is shown in Figure 4-6.



■ **Figure 4-6 Cumulative probability distribution of initial loss**

The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for this study.

### 4.2.6 Pre-burst rainfall depths and temporal patterns

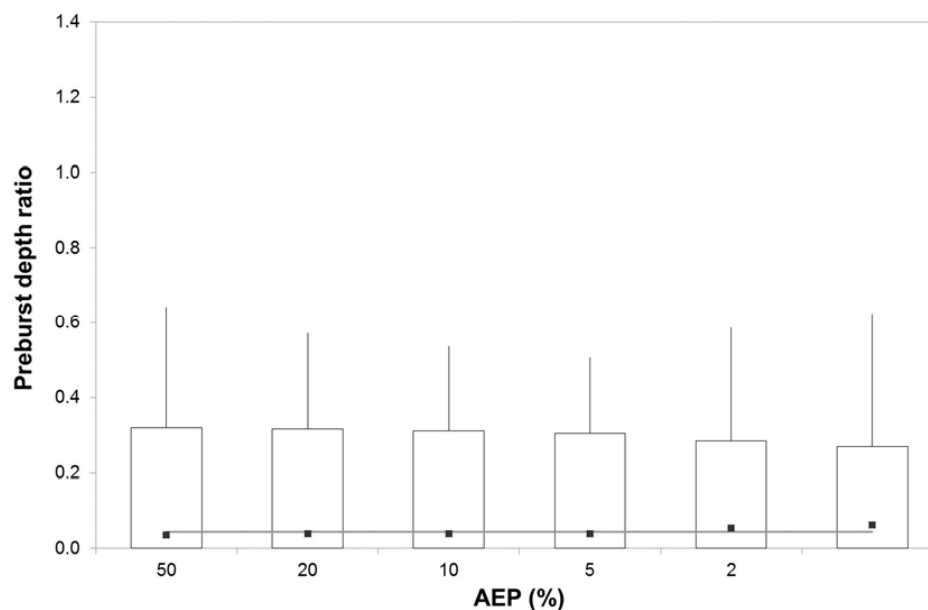
Estimates of the percentage of burst depth of rainfall antecedent to the main burst were taken from the ARR data hub (Geoscience Australia, 2019). The data hub provides a distribution of pre-burst depths by duration and AEP. The median pre-burst depths for each duration was compared across AEPs, and for the purpose of design flood modelling, it was decided that adopting an average of the median for each duration was appropriate (Figure 4-7).

Although the ARR data hub provides pre-burst depths, it does not contain information regarding the temporal patterns. Therefore, temporal patterns of rainfall antecedent to the main burst were taken

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



from Minty and Meighen (1999) and applied to burst durations of 12 hours and longer (Minty and Meighen, 1999). For the shorter durations, the pre-burst patterns from Jordan et al (2005) were applied.



- Figure 4-7 Pre-burst rainfall depths – 6 hour burst – shown as a ratio of burst depth, using a box plot of the 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> percentiles. The grey line shows the adopted value for the design flood modelling; this is the average of the median values across the available AEPs.

### 4.2.7 Baseflow

As RORB only estimates the surface runoff, baseflow needs to be added. For baseflow, regional estimates were used. From the ARR data hub the peak factor was extracted. The baseflow peak factor is applied to the estimated surface runoff peak flow to give the value of peak baseflow for a 10% AEP event. ARR 2019 provides a scaling factor to be applied to the 10% AEP baseflow peak factor to determine the baseflow peak factor for events of various AEPs.

A frequency distribution of baseflow with AEP was estimated by using the Regional Flood Frequency Estimation (RFFE - refer to Section 5) distribution. This provided the frequency distribution for baseflow under the peak of the annual maxima flood events.



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 5. Hydrologic model verification

### 5.1 Adopted parameters

For the RORB model the routing parameters ( $m$  and  $k_c$ ) were taken from the Upper Coliban Storages Hydrology update (SKM, 2010). For the routing parameter,  $k_c$ , the ratio of  $k_c/d_{av}$  was used to ensure that the same routing was applied to the RORB model established for the study area as per the previous model. McMahon and Muller (1983) showed that  $k_c$  is directly proportional to  $d_{av}$ , where  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model). Therefore, a way to measure the similarity of two different RORB models is to compare  $k_c/d_{av}$ .

The RORB model established for the Upper Coliban Storages Hydrology update (SKM, 2010) was calibrated to three events only i.e. October 1985, September 1993 and October 2000. The RORB model was also verified to a flood frequency curve (FFC) at Coliban River @ Springhill-Tylden Road (406250).

The adopted losses for this study were taken from the re-verification undertaken for the Malmsbury rapid flood risk assessment (HARC, 2019) at the streamflow gauge Coliban River @ Malmsbury Rail Bridge (406200).

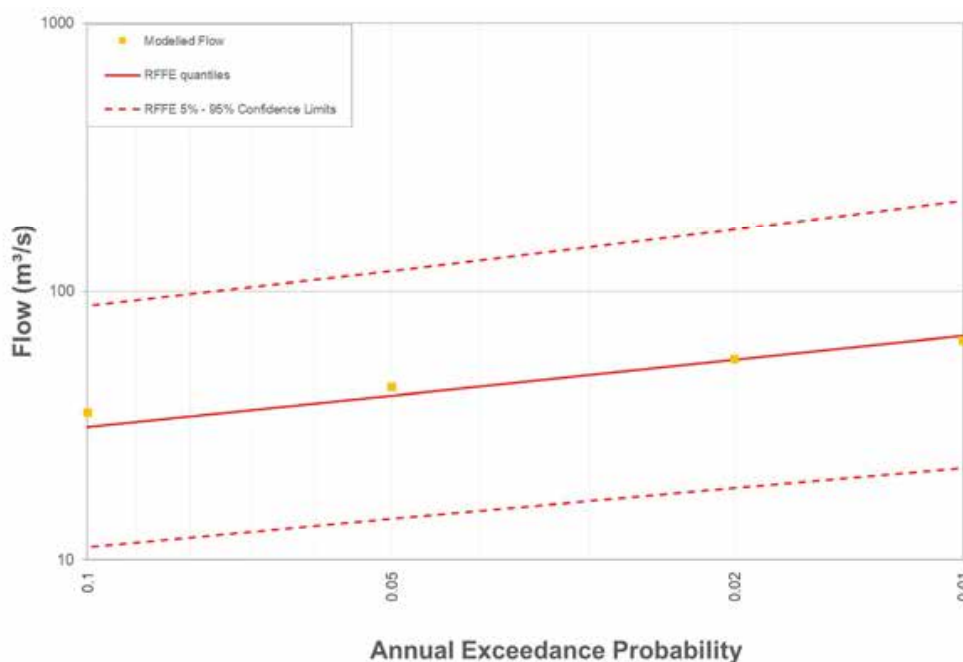
#### ■ Table 5-1 Summary of key parameters adopted for the RORB model

Parameter	Value
$k_c$	19.3
$d_{av}$	7.6
$C_{0.8} (k_c/d_{av})$	2.53
$m$	0.8
IL (mm)	10.0
CL (mm/hr)	1.0

### 5.2 Verification to the Regional Flood Frequency Estimation Model

To gain additional confidence in the parameters adopted, the RORB model results were compared to the Regional Flood Frequency Estimation Model (RFFE) which was developed as part of ARR2019. The RFFE was used as a guide only with more confidence given to the calibration/verification process undertaken for the individual catchment. Figure 5-1 shows the RFFE compared to the RORB model results using the parameters shown in Table 5-1. Figure 5-1 shows that the RORB model matches the RFFE very well.

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



■ Figure 5-1 Verification results compared to RFFE

### 5.3 Comparison to regional parameters

As mentioned in Section 5.1 the choice of  $k_c$  for the Tylden catchment was based on the calibration result from the Upper Coliban Storages Hydrology update (SKM, 2010) however, the results from the calibration were compared to a number of regional estimates.

For Victorian regions with a mean annual rainfall of less than 800 mm  $k_c$  is estimated using equation 1 from ARR 2016 (Hansen et al, 1986).

$$k_c = 0.49 A^{0.65} \quad (1)$$

Where  $A$  is the area in  $\text{km}^2$ .

The  $k_c$  value from calibration was also compared to another regional estimate by Pearse et. al. (2002). Pearse et. al. (2002) analysed a large database of routing parameters collated by the CRC for Catchment Hydrology and derived a prediction equation applicable to Victoria. The  $d_{av}$  for the catchment was used to predict the  $k_c$  value where  $k_c$  is directly proportional to  $d_{av}$  giving equation 2

$$k_c = C d_{av} \quad (2)$$

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



Where  $C$  is a characteristic of the catchment independent of the scale or size of the catchment and  $d_{av}$  is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model).

Pearse et al. (2002) also gave an expected value and one standard deviation (High and Low).

Table 5-2 provides a summary of the regional estimates along with the adopted value. Table 5-2 shows the  $k_c$  based on the calibration event undertaken in the Upper Coliban Storages Hydrology update (SKM, 2010) is different to the regional estimates highlighting the need to calibrate the model, where possible.

### ■ Table 5-2 $k_c$ values – regional estimates

Location	Area (km <sup>2</sup> )	$k_c$ (equation 1)	$k_c$ (equation 2)			$k_c$ (adopted)
			Expected	High	Low	
Tylden	41	5.5	9.5	15.8	5.7	19.3

The ARR2019 data hub provides some regional estimates of losses. The regional losses are to only be used as a guide as ARR2019 clearly states it is always desirable to reconcile design values with independent flood frequency estimates where possible. Table 5-3 shows the regional estimates along with the adopted values. Table 5-3 shows that the adopted values are different to the regional estimates highlighting the need to verify the model, where possible.

### ■ Table 5-3 Loss values – regional estimates

Location	Regional		Adopted	
	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Tylden	29.0	3.7	10.0	1.0



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 6. Design flood hydrology

### 6.1 Design flows for the 20% to 0.5% AEP events

The RORB model was run in the joint probability framework, with the design inputs and the adopted routing parameters, initial and continuing losses to generate design flood frequency curves and inflow hydrographs.

In order to generate hydrographs the RORB model was run in the joint probability framework described in Section 4.1, with the design inputs summarised in Section 4.2 and the adopted parameters summarised in Section 5.

The joint probability framework provides a peak flow, whereas the hydraulic model requires a set of hydrographs. The results of the Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Hydrographs were chosen from the set of Monte Carlo results that best matched the median peak flows and were an unbiased transformation from input rainfall AEP to flood AEP.

For the hydraulic model hydrographs were extracted at key locations within the study area. Table 6-1 shows the peak flows at downstream end of the study area from the event centred over the entire catchment.

■ **Table 6-1 Summary of modelled peak flow estimates for Tylden**

AEP (1 in Y)	Peak Flow (m <sup>3</sup> /s)	Critical Duration (hours)
5	27.2	36.0
10	35.3	36.0
20	45.0	36.0
50	56.3	36.0
100	65.1	36.0
200	75.6	18.0

### 6.2 PMF estimate

As mentioned earlier in the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994). Nathan et al. (1994) looked at 56 sites across South-Eastern Australia and developed a series of equations to estimate the peak, volume and time to peak of a PMF.

Nathan et al. (1994) estimates of the PMF magnitude are based on the catchment area using the following equations.

$$Q_p = 129.1 * A^{0.616} \quad (1)$$

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



$$V = 497.7 * A^{0.984} \quad (2)$$

$$T_p = 1.066 * 10^{-4} * A^{-1.057} * V^{1.446} \quad (3)$$

And from a mass balance taking Equations (1) and (2).

$$T_r = \frac{V}{1.8 * Q_p} \quad (4)$$

Where:  $Q_p$  is peak flow ( $m^3/s$ );

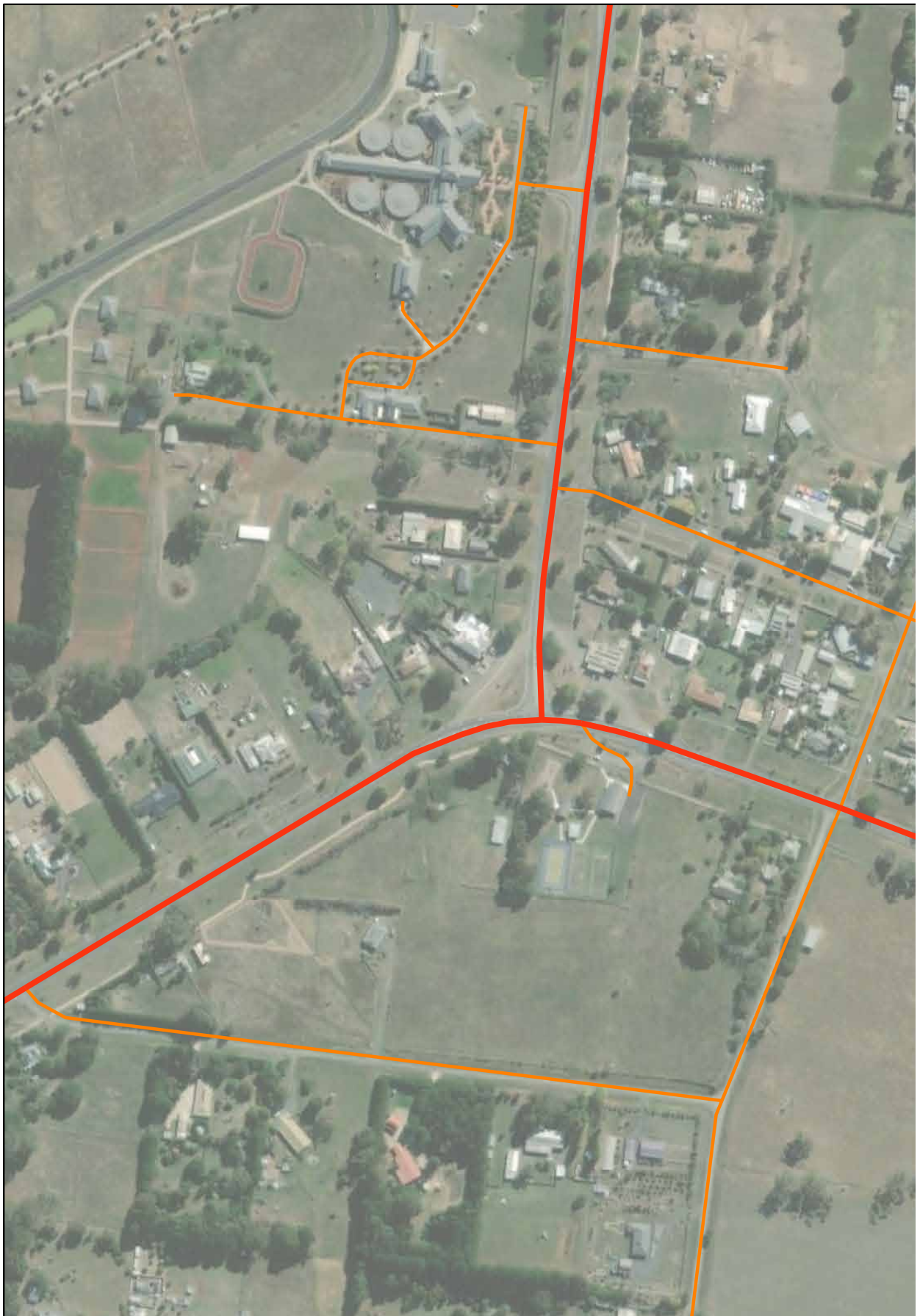
$A$  is catchment area ( $km^2$ )

$V$  is the Volume of the hydrograph (ML)

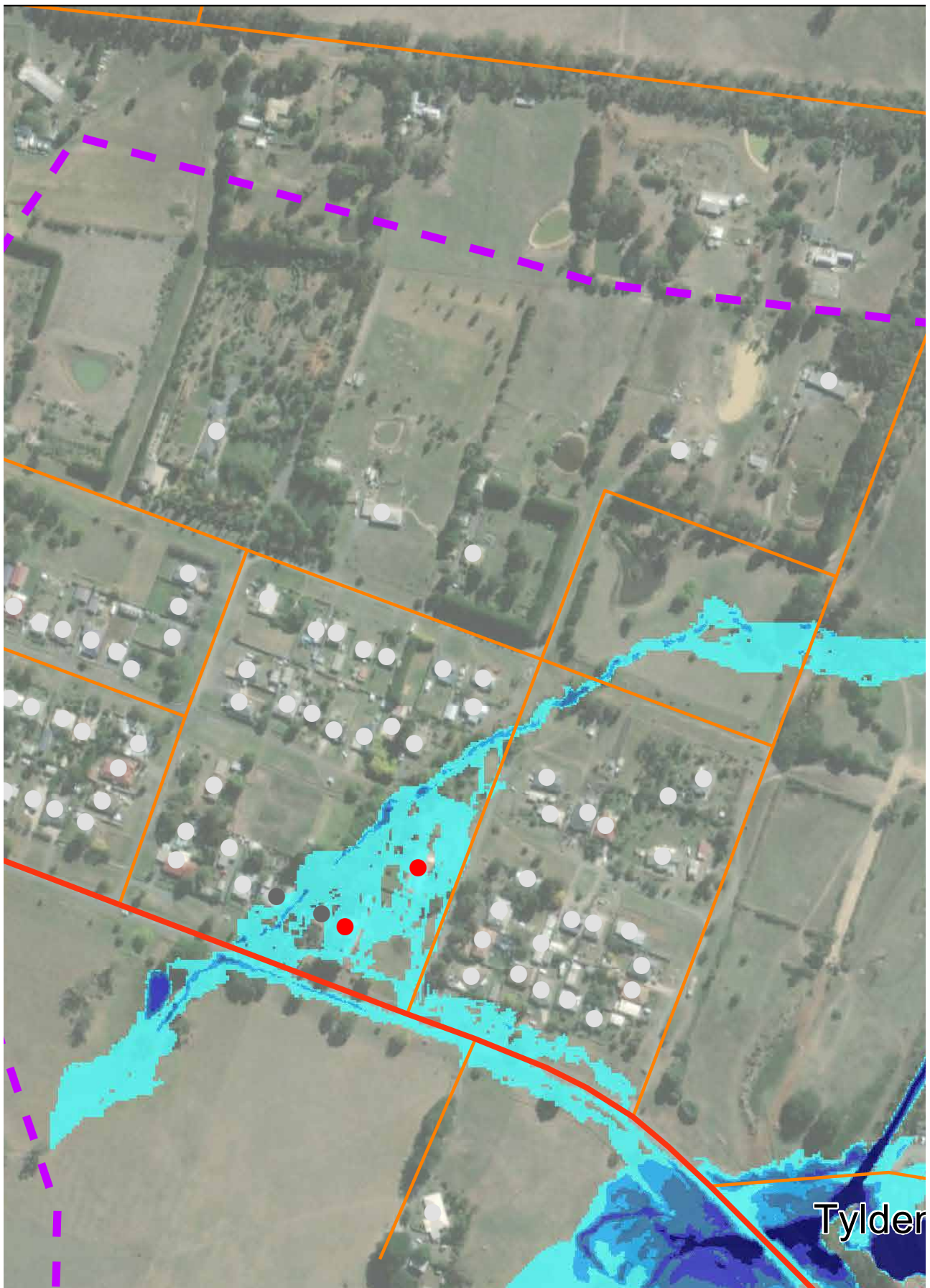
$T_p$  is the time to peak flow (hours)

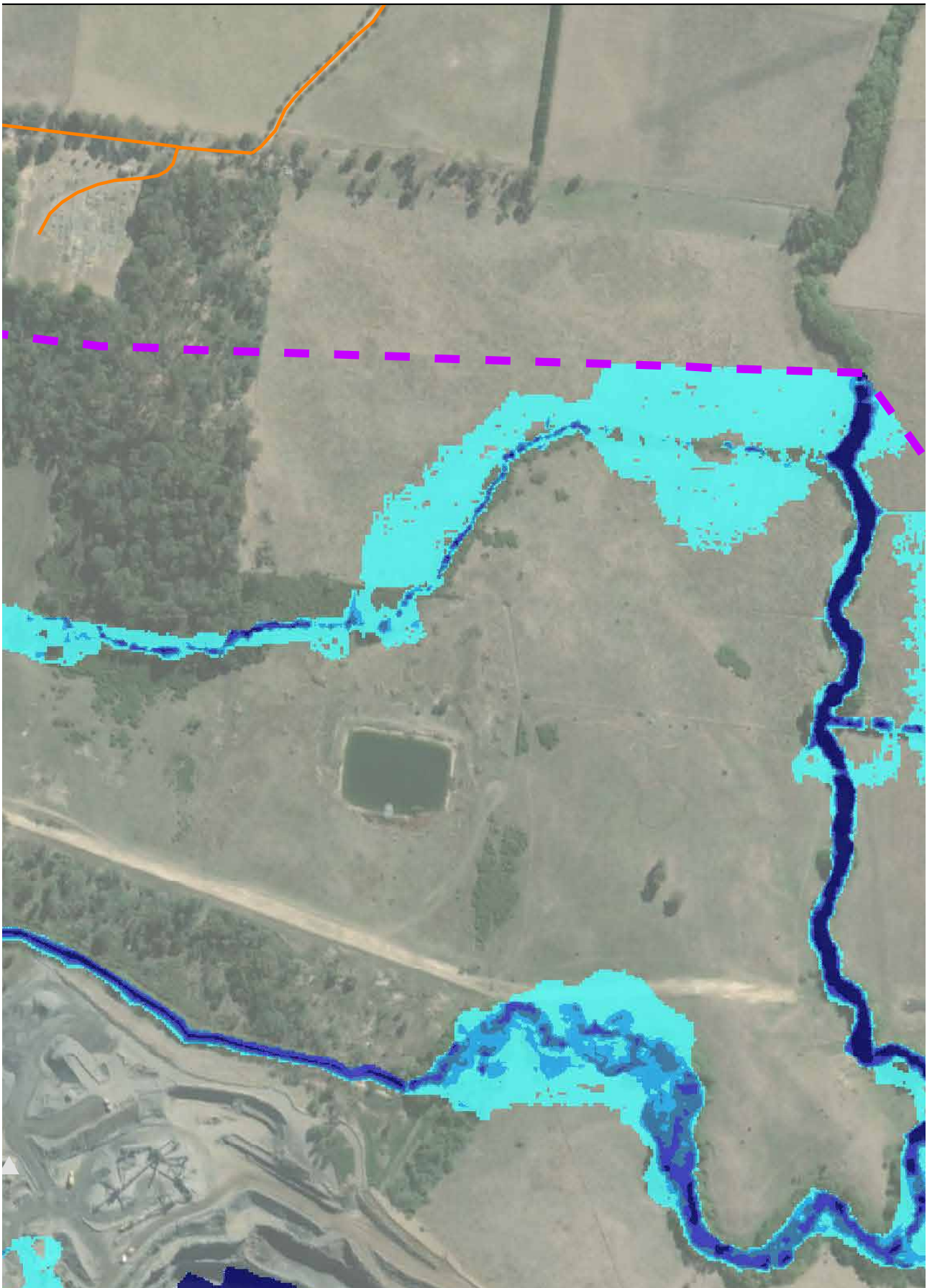
$T_r$  is the total time of the hydrograph (hours)

Each of these characteristics has been used to determine a 'triangular' PMF hydrograph. Figure 6-1 illustrates the characteristics of the 'triangular' PMF hydrograph.













t, flood  
D)  
D code

al CMA.  
a or

the LIDAR  
e the

id element  
on of the  
sulting run  
run times.

s was  
njunction

n (VLUIS)  
ic check  
basic  
scale  
anning's n  
Manning's



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden

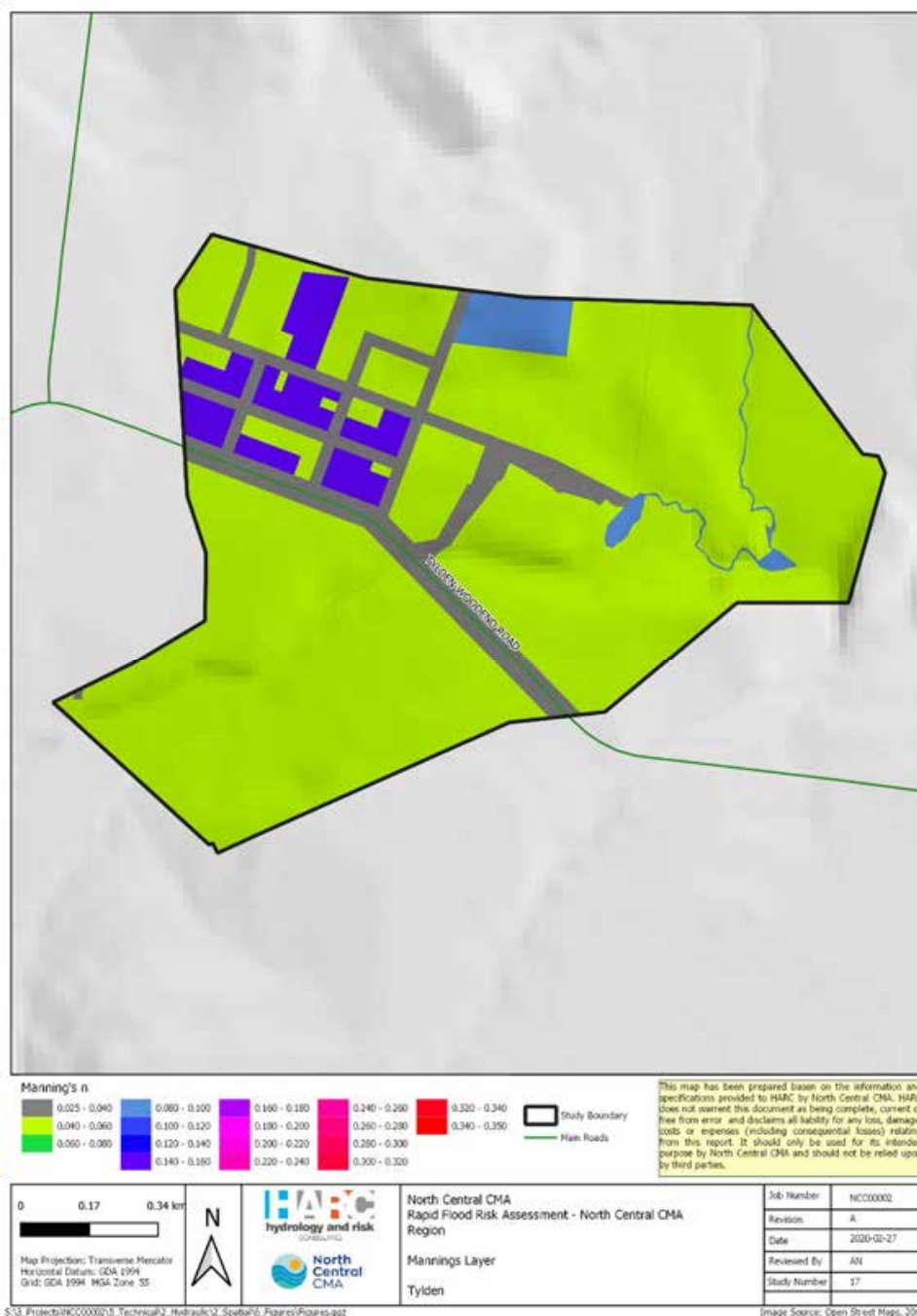


n categories were selected to be in line with the values provided by ARR2019. No calibration of the hydraulic models was undertaken for this project.

■ **Table 7-1 Manning's n values for different land use types**

Land Use Type	Manning's n adopted
Residential areas – urban high density (building and parcel combined)	0.35
Residential areas – rural high density (building and parcel combined)	0.15
Industrial/commercial or large buildings	0.30
Residential areas – rural low density (parcel only or large blocks with house)	0.05
Open space or waterway – minimal vegetation	0.04
Open space or waterway – moderate vegetation	0.06
Open space or waterway – heavy vegetation	0.095
Paved roads/car park/driveways	0.025
Railway line	0.05
Grass reserves/floodway (regularly mowed)	0.035
Rural floodplains in clear paddocks	0.05
Forested (heavy stand of timber)	0.12
Dam/Reservoir body of water	0.035

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 7-1 Surface roughness distribution

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



### 7.4 Hydraulic structures

Table 2-2 lists the culverts/bridges that were entered into the model. Bridges were represented using a layered flow constriction and culverts in 1D.

Bridge structures were modelled with the appropriate losses derived from Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways (Austroads, 1994). The layered flow constrictions used to model these bridges allows for typical bridge characteristics such as deck height and thickness, pier shape and width and blockages associated with guard or hand rails to be directly incorporated into the 2D domain. The details of these were extracted from supplied plans. Where plans were not available the losses and dimensions were estimated based on typical bridge configurations and loss parameters.

The 1D elements were dynamically linked to the 2D domain. Details of the culverts were extracted from supplied plans, details provided by Council or the North Central CMA.

### 7.5 Inflows

The inflows to the hydraulic model were taken from the RORB model, as discussed in Section 6 and modelled in TUFLOW as two-dimensional source area polygons distributing the inflow over the polygon. The polygons were located along the waterways within the study area.

The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. The hydrographs entered into the hydraulic model were chosen from the suite of runs from the Monte Carlo analysis such that the single hydrographs matched the peak flows.

### 7.6 Downstream boundary

The downstream boundary condition was entered as a normal depth relationship with a slope of 0.6% based on the LIDAR data.

A schematisation of the hydraulic model is found in Figure 7-2.

All the hydraulic models were run for the 1 in 5, 10, 20, 50, 100 and 200 AEP and PMF events, for the critical durations identified in Table 6-1.



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 7-2 Hydraulic model schematisation

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 8. Flood Risk Assessment

### 8.1 Flood Mapping

Flood maps showing flood level, depth, velocity and hazard (depth x velocity) have been produced for the 1 in 5, 10, 20, 50, 100 and 200 AEP event along with the PMF. The flood maps are shown in Appendix A.

Table 8-1 shows the flood map reference numbers that correspond to the maps in Appendix A.

■ **Table 8-1 Flood maps reference table**

Map Number	Map Name	Map Number	Map Name
17-5-1	1 in 5 year Depth Map	17-5-4	1 in 5 year Hazard Map
17-10-1	1 in 10 year Depth Map	17-10-4	1 in 10 year Hazard Map
17-20-1	1 in 20 year Depth Map	17-20-4	1 in 20 year Hazard Map
17-50-1	1 in 50 year Depth Map	17-50-4	1 in 50 year Hazard Map
17-100-1	1 in 100 year Depth Map	17-100-4	1 in 100 year Hazard Map
17-200-1	1 in 200 year Depth Map	17-200-4	1 in 200 year Hazard Map
17-PMF-1	PMF Depth Map	17-PMF-4	PMF Hazard Map
17-5-2	1 in 5 year Depth x Velocity Map	17-5-5	1 in 5 year Velocity Map
17-10-2	1 in 10 year Depth x Velocity Map	17-10-5	1 in 10 year Velocity Map
17-20-2	1 in 20 year Depth x Velocity Map	17-20-5	1 in 20 year Velocity Map
17-50-2	1 in 50 year Depth x Velocity Map	17-50-5	1 in 50 year Velocity Map
17-100-2	1 in 100 year Depth x Velocity Map	17-100-5	1 in 100 year Velocity Map
17-200-2	1 in 200 year Depth x Velocity Map	17-200-5	1 in 200 year Velocity Map
17-PMF-2	PMF Depth x Velocity Map	17-PMF-5	PMF Velocity Map
17-5-3	1 in 5 year Elevation Map		
17-10-3	1 in 10 year Elevation Map		
17-20-3	1 in 20 year Elevation Map		
17-50-3	1 in 50 year Elevation Map		
17-100-3	1 in 100 year Elevation Map		
17-200-3	1 in 200 year Elevation Map		
17-PMF-3	PMF Elevation Map		

### 8.2 Flood behaviour and impact of flooding

The following section summarises the impact of flooding. Table 8-2 provides a summary of the water level at the location shown in Figure 8-1 along with the main impacts for each AEP. Table 8-3 is a summary of the number of properties that are inundated for each AEP event. Table 8-4 is

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



a summary of the number of properties that are inundated above floor for each AEP event. Table 8-5 is a summary of the main roads that are overtopped.

■ **Table 8-2 Summary of impacts of flooding**

AEP (1 in Y)	Water level upstream of Tylden-Woodend Road (mAHD)	Impact
5	561.31	Tylden-Woodend Road overtopped. Four properties are inundated within the township. One is inundated upstream of Tylden-Woodend Road near Little Coliban River and one is within the quarry
10	561.39	Six properties are inundated as above
20	561.48	Six properties are inundated as above
50	561.57	Six properties are inundated as above
100	561.63	Six properties are inundated as above
200	561.70	Six properties are inundated as above



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden

■ Table 8-3 Summary of property inundation

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	5	1	0	0	0	0	0	0	0	0	0
10	5	1	0	0	0	0	0	0	0	0	0
20	5	1	0	0	0	0	0	0	0	0	0
50	5	1	0	0	0	0	0	0	0	0	0
100	5	1	0	0	0	0	0	0	0	0	0
200	5	1	0	0	0	0	0	0	0	0	0

■ Table 8-4 Summary of over floor flooding\*

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	2	0	0	0	0	0	0	0	0	0	0
10	2	0	0	0	0	0	0	0	0	0	0
20	2	0	0	0	0	0	0	0	0	0	0
50	2	0	0	0	0	0	0	0	0	0	0
100	2	0	0	0	0	0	0	0	0	0	0
200	2	0	0	0	0	0	0	0	0	0	0

\* Note the floor levels have assumed to be 300 mm above the natural surface level for those buildings without surveyed floor levels

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Table 8-5 Summary of road Inundation

AEP (1 in Y)	Roads impacted by flooding	Maximum depth over road (m)	Duration of inundation (hours)
5	Tylden-Wooden Road	0.2	18
10	Tylden-Wooden Road	0.3	20
20	Tylden-Wooden Road	0.4	22
50	Tylden-Wooden Road	0.5	36
100	Tylden-Wooden Road	0.6	36
200	Tylden-Wooden Road	0.7	25

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Figure 8-1 Reporting location



## Rapid Flood Risk Assessment - North Central CMA Region Tylden

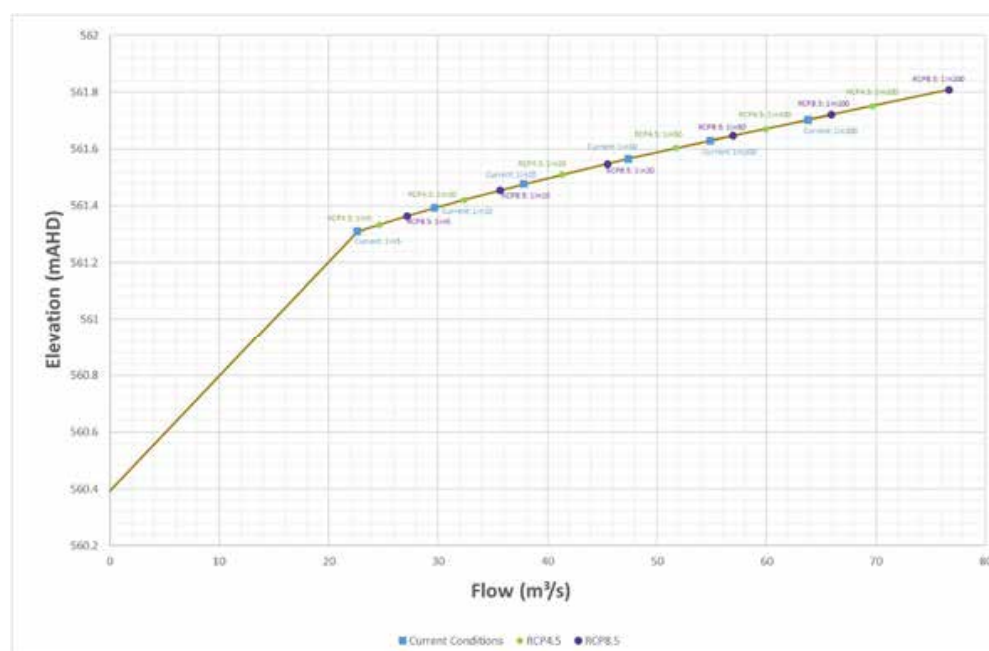


### 8.3 Climate change

The increase in flows due to climate change was discussed in Section 6.3. To present the sensitivity of flood levels to changes resulting from climate change a rating curve of flow and water level at a key location within the study area is shown in Figure 8-2. Figure 8-1 shows the location of the rating curve and Table 8-6 the flows. The flow for the current conditions shown in Table 8-6 was taken from the TUFLOW model. The climate change flows were derived by multiplying the current climate peak flows by the percentages as discussed in Section 6.3. The rating curve shows the water level that corresponds to a peak flow under existing climate conditions as well as the corresponding water level under climate change conditions (RCP 4.5 and 8.5).

#### ■ Table 8-6 Climate change peak flow estimates

AEP (1 in Y)	Current Climate – Peak Flow (m <sup>3</sup> /s)	Climate Change – Peak Flow (m <sup>3</sup> /s)	
		RCP 4.5	RCP 8.5
5	22.6	24.7	27.2
10	29.7	32.4	35.7
20	37.8	41.3	45.5
50	47.4	51.7	56.9
100	54.8	59.9	65.9
200	63.8	69.6	76.7



■ Figure 8-2 Estimated changes in peak water level associated with climate change

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



Table 8-7 shows which AEP map to consider adopting under various climate change scenarios. Note that the results have been based on the flows shown in Table 8-6 and rounded to the nearest AEP.

### ■ Table 8-7 Map to consider adopting under various climate change scenarios

Current AEP	Event Map to consider adopting under various climate change scenarios	
	RCP4.5	RCP8.5
1 in 5	1 in 5	1 in 10
1 in 10	1 in 10	1 in 20
1 in 20	1 in 20	1 in 50
1 in 50	1 in 50	1 in 100
1 in 100	1 in 100	1 in 200

## 8.4 Flood Intelligence Information

Results from this investigation have been used to update the MFEPs with key information. This has included:

- Interpreting relevant flood related intelligence and consequence information from the mapping and modelling including typical flood travel times, rates of rise, etc;
- Identifying properties, roads and other community assets (e.g. essential infrastructure and services, high risk facilities, emergency service properties, low points in roads, etc.) affected by flooding;
- Identifying likely isolations and shrinking islands;
- Identifying areas of probable high flood risk / high hazard;
- Building flood intelligence tables; and
- Extracting catchment descriptions and flooding chronology from project deliverables.

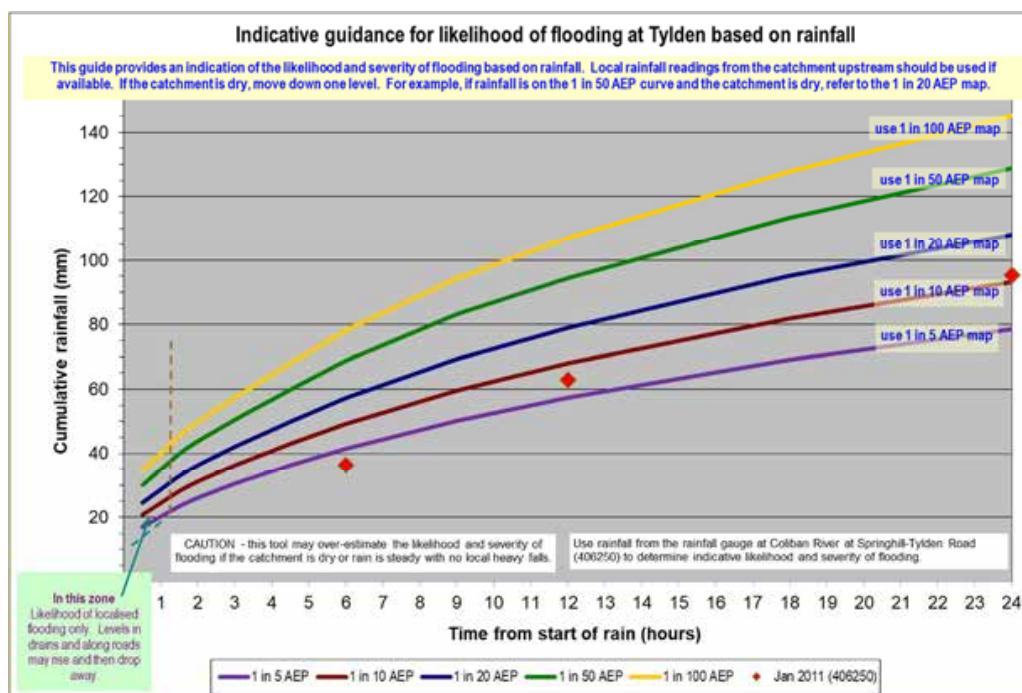
## 8.5 Developing Indicative Quick Look Flood / No-Flood Tools

Using the results of the hydrologic and hydraulic modelling work, an indicative quick look flood / no-flood assessment tool has been developed for the study area.

The tool is aimed at providing a rapid indication of whether flooding is likely with some lead time. It is intended to be indicative only and will not provide a forecast of expected flood depth. The tool is designed to be linked to the mapping and intelligence produced by this project and in that way provides an indication of likely consequences.

The tool is driven by rainfall recorded at Coliban River at Springhill-Tylden Road (406250). IFD data from this location has been compared to the study area specific IFD data. Adjusted rainfall depths were then plotted against time to produce the tool as shown in Figure 8-3.

## Rapid Flood Risk Assessment - North Central CMA Region Tylden



■ **Figure 8-3 Quick look tool**

### 8.5.1 Guidance on the use of the Quick Look Flood / No flood Tool

#### 8.5.1.1 In the lead up to a flood

The quick look indicative flood / no-flood tool provided in Figure 8-3 gives guidance on the likelihood and severity of expected flooding at Tylden.

Rainfall recorded at Coliban River at Springhill-Tylden Road (406250) was used to develop the quick look tool. As the data being used comes from a rain gauge that is outside the Lockwood catchment, the tool may not perform to expectations in severe thunderstorm situations and / or when there is locally heavy rainfall embedded in more general rain. In such situations, rainfalls recorded more locally are likely to drive a more accurate indication of flooding and likely severity.

Unless there are unusual circumstances, actions as per the Flood Intelligence Card in the MFEP should be initiated as soon as the tool suggests flooding is likely. Response can be escalated if the tool indicates an increase in the expected severity of flooding.

#### 8.5.1.2 During a flood - using the quick look tool

Plot cumulative rainfall depth against elapsed time on a copy of the tool. Do not start using the tool until rainfall exceeds approximately 2 mm an hour (i.e. ignore early drizzle or very light rain).



## Rapid Flood Risk Assessment - North Central CMA Region Tylden



At each time step, after plotting the cumulative rainfall, assess the likelihood and expected severity of flooding from the curves. Some degree of judgement is required to determine if the quick look tool is providing an answer that is in line with expected outcomes. When plotted rainfall data crosses a curve on Figure 8-3 this indicates that flooding of around that severity is possible.

If the catchment is dry, it would generally be appropriate to step down one level. For example, if the rainfall plot is on the 1 in 50 AEP curve and the catchment is dry, refer to the 1 in 20 AEP map and associated consequences listed in the flood intelligence card available in the MFEP. The exception to this would be if there was very heavy rain on a dry catchment. In that circumstance, adopt a cautious approach and do not step down a level.

If the catchment is dry and / or rain extends over more than 12 hours, the quick look tool will tend to over-estimate the likelihood of flooding.

### 8.5.1.3 After a flood – updating the tool

After a flood event, plot the event rainfall depth (with date) on the quick look tool. At the same time, include an overview of the event, along with commentary on antecedent conditions and other relevant information, in the relevant Appendix of the MFEP.

### 8.5.1.4 Example use of the quick look tool

The section below is a fictitious example of how to use the quick look tool. Table 8-7 shows the rainfall depths recorded at the rain gauge and the action to take on the basis of the recorded rainfall. Figure 8-4 shows the fictitious example plotted up on the quick look tool.

Note that in cases where the tool has not been used from the start of rain (i.e. from early in the event), data should be either picked up from the start of the event or the first data plotted should include an estimate of how much rain has fallen and the time over which it has fallen. If this is not done, the tool will likely under-estimate likely flood severity.

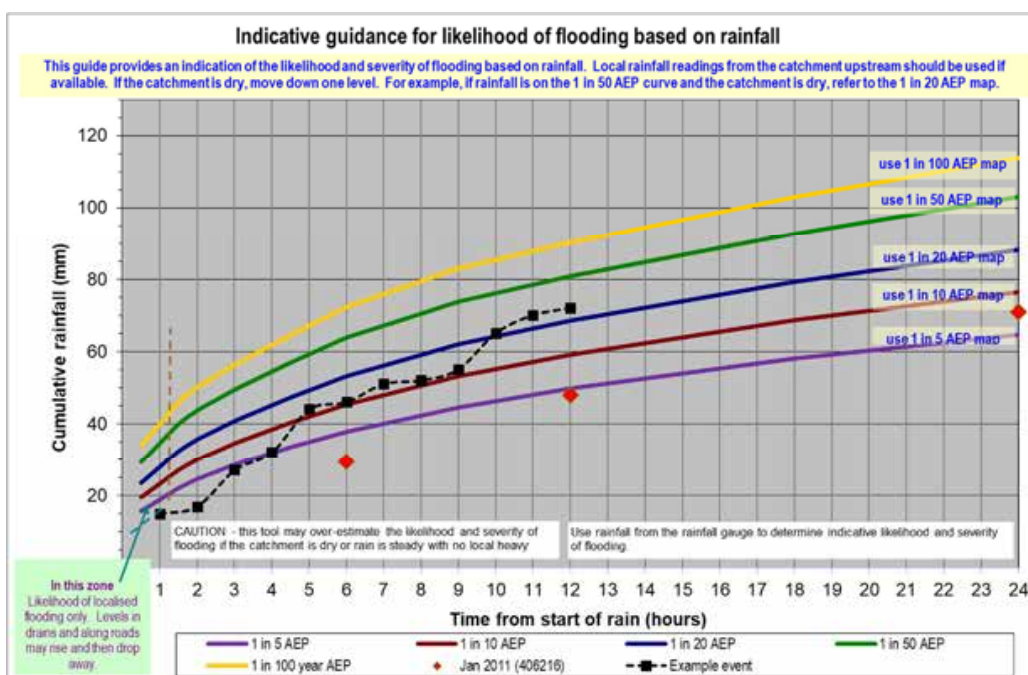
#### ■ Table 8-8 Rainfall depths for example use of tool

Time (hours)	Rainfall Depth (mm)	Action
0	1	Ignore
1	2	Ignore
3	2	Ignore
4	1	Ignore
5	15	Plot as 15 mm at 1 hour
6	2	Plot as 17 mm at 2 hours
7	10	Plot as 27 mm at 3 hours
8	5	Plot as 32 mm at 4 hours Indicates it may be a 5-year (20% AEP) event
9	12	Plot as 44 mm at 5 hours Indicates it may be a 10-year (10% AEP) event Start planning for a 10% AEP event

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



Time (hours)	Rainfall Depth (mm)	Action
10	2	Plot as 46 mm at 6 hours More confident that a 10% AEP event is likely
11	5	Plot as 51 mm at 7 hours
12	1	Plot as 52 mm at 8 hours
13	3	Plot as 55 mm at 9 hours
14	10	Plot as 65 mm at 10 hours Indicates it may be a 20-year (5% AEP) event.
15	5	Plot as 70 mm at 11 hours More confident that a 5% AEP event is likely
16	2	Plot as 72 mm at 12 hours



■ Figure 8-4 Quick look tool example

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



### 8.6 Flood classification – Bureau of Meteorology

Electronic maps have been produced for the minor<sup>1</sup>, moderate<sup>2</sup> and major<sup>3</sup> flood (as defined by the BoM). The minor, moderate and major flood has been based on the flood impacts. For Tylden the 1 in 5, 10 and 20 AEP has been adopted for the minor, moderate and major flood respectively.

---

<sup>1</sup> Minor Flooding - Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

<sup>2</sup> Moderate Flooding - In addition to minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required

<sup>3</sup> Major Flooding – In addition to moderate flooding, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 9. Summary of rating of key areas

The following section provides a summary rating of each of the key areas of the project. The rating is subjective but has been rated against current standards and industry best practice for undertaking detailed flood studies.

The intention is that this will enable the North Central CMA to easily identify the areas where additional caution may need to be applied when using the information from this investigation for making decisions on flooding issues. In addition it will identify the areas of additional investigation, should a more detailed study be undertaken in the future.

Table 9-1 shows a summary of the rating for Tylden where green is considered to be good, orange is OK and red is poor. Below is a summary of the main considerations given to each aspect of the study:

- *RORB model set up.* Adequacy of sub-area division, reach types, impervious fractions
- *RORB model parameters.* Has the RORB model been calibrated and/or verified to streamflow gauge information
- *Currency of hydrology.* Rated based on whether the hydrology used in the study is consistent with current practice and data sets.
- *Topographic data.* Typically will be rated orange or red if LiDAR data is not available and if the state wide DEM is required for use.
- *Manning's n.* Has land use been represented with appropriate values
- *Modelling of key structures.* Reflects whether the model was attempted to incorporate key hydraulic structures within the inundation zone and to what degree.
- *TUFLOW model set up.* Considers such aspects as does the cell size capture key features and the boundary conditions.
- *TUFLOW parameters.* Has the TUFLOW model been calibrated and/or verified to recorded flood levels.

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



■ Table 9-1 Summary of review –Tylden

Category	Comment	Rating
RORB model set up	Adequate sub-area division for larger catchment. However, additional local catchment sub-division recommended if more detailed local flows are required.	Yellow
RORB model parameters	Based on a calibrated and verified model.	Green
Currency of hydrology	All inputs are based on ARR2019	Green
Topographic data	LIDAR available for entire study area	Green
Manning's n	Generally OK but was based on VLUIS	Green
Modelling of key structures	Bridge and culverts explicitly modelled. The data on the culverts was estimated.	Yellow
TUFLOW model set up	Cell size adequately represents waterway and boundary conditions modelled appropriately.	Green
TUFLOW parameters	TUFLOW parameters have not been calibrated or verified to recorded flood levels.	Yellow

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 10. Limitations

Any information provided by the Bureau of Meteorology, Geoscience Australia as well as published methodologies (e.g. Australian Rainfall and Runoff) cannot be guaranteed to be free of errors.

The hydrological parameters rely on the previous calibration and verification undertaken for each of the RORB models. Therefore, the accuracy of this will vary depending on the information available to calibrate the models. However, any calibration and verification of the models to streamflow information will most likely be better than just relying on regional parameter estimates.

The proposed methodology for the PMF estimate is preliminary in nature. Other, more detailed techniques are available in which to estimate the PMF. However, for this investigation a preliminary assessment has been considered to be appropriate.

The analysis has relied heavily on the supplied LIDAR terrain data. For this investigation no survey will be undertaken to independently check the terrain data.

For the hydraulic model the intention is that the waterways are represented by 4-5 cells. Where a waterway is less eight metres wide it will be represented by less than the 4-5 cells which could mean that the waterway is not fully represented.

The Manning's roughness adopted for the study areas utilising the VLUIS dataset. As the VLUIS is a state wide dataset there may be some areas that have either been developed since the VLUIS was established or not captured accuracy. Whilst, basic checks have been undertaken to pick up any large errors in assigned land use there may still be some lot scale differences in land use which may not be picked up.

As the hydraulic model was not calibrated to surveyed flood levels the Manning's n values listed in Table 7-1 may not necessarily represent the roughness values accurately.

As mentioned in Section 6.3 the ARR2019 approach to climate change has a number of limitations, including the fact that it does not provide a means to account for potential increases in rainfall losses under a drying climate.

The quick look flood / no flood tools may be replaced where more detailed investigations are undertaken in the future.



Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 11. Conclusion

This project forms part of the Rapid Flood Risk Assessment for the North Central CMA region. Outputs from the assessment will assist the North Central CMA to meet a range of business requirements. Outputs can be used to assist in flood related controls, develop flood intelligence products, inform emergency response planning and assist in the preparation of community flood awareness and education products.

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## 12. References

Agriculture Victoria (2016) Victorian Land Use Information System (VLUIS)

Austroroads (1994) Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways

Ball J, Babister M, Nathan R, Week W, Weinmann E, Retallick M, Testoni I, (Editors) (2019) Australian Rainfall and Runoff: A guide to flood estimation, Commonwealth of Australia (Geoscience Australia).

Babister, M, Trim, A, Testoni, I, Retallick, M. (2016) The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ.

BMT (2018), TUFLOW Classic/HPC User Manual. Build 2018-03-AD

Bureau of Meteorology (2016) 2016 Rainfall IFD Data System.  
<http://www.bom.gov.au/water/designRainfalls/revised-ifd/>.

Hydrology and Risk Consulting (2016) ArcRORB, A tool for creating RORB catchment files in ArcMap, User Manual, version 1.6.

Hill PI, Graszkiwicz Z, Taylor M and Nathan RJ (2014) Australian Rainfall and Runoff revision project 6: Loss models for catchment simulation. Stage 4: Analysis of rural catchments.

Hill P and Thomson R (2015) Chapter 3 in Book 5: Losses. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.

Jordan P, Nathan R, Podger S, Babister M, Stensmyr P and Green J (2016) Chapter 4 in Book 2: Areal reduction factors. In Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I, (eds) Australian Rainfall and Runoff: A guide to flood estimation. Commonwealth of Australia, Canberra.

Laurenson EM, Mein RG and Nathan RJ (2010) RORB version 6 runoff routing program - User manual. Monash University Department of Civil Engineering in conjunction with Hydrology and Risk Consulting Pty. Ltd. and the support of Melbourne Water Corporation, Melbourne.

Minty, L.J and Meighen, J (1999), Development of temporal distributions of rainfall antecedent to large and extreme design bursts over southeast Australia, Hydrology Report Series HRS Report No.6, Hydrometeorological Advisory Service, Bureau of Meteorology.

Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



Nathan RJ, Weinmann PE and Hill PI (2002) Use of a Monte Carlo framework to characterise hydrologic risk. Proceedings of the 2002 ANCOLD Conference, Adelaide. Australian National Committee on Large Dams.

Nathan RJ, Weinmann PE and Hill PI (2003) Use of Monte Carlo simulation to estimate the expected probability of large to extreme floods. Proceedings of 28th Hydrology and Water Resources Symposium, Wollongong. Institution of Engineers, Australia.

Nathan RJ, Weinmann PE and Gato SE (1994) A quick method for estimating the probable maximum flood in South Eastern Australia, Water Down Under 94. Hydrology and Water Resources Symposium I.E. Aust. Nat. Conf. Publ. 94/10, pp.229-234

Pearse M, Jordan P and Collins Y (2002) A simple method for estimating RORB model parameters for ungauged rural catchments. Proceedings of 27th Hydrology and Water Resources Symposium, Melbourne. Institution of Engineers, Australia.

Phillips, B, Goyen, A, Thomson, R, Pathiraja, S and Pomeroy, L. (2014), Australian Rainfall and Runoff Revision Project 6: Loss models for catchment simulation - Urban Losses Stage 2 Report, February.

Scorah M, Hill P, Lang S and Nathan R (2016), Addressing embedded bursts in design storms for flood hydrology. Water, Infrastructure and the Environment: Proceedings of the 56th New Zealand Hydrological Society Conference and the 37th Hydrology and Water Resources Symposium, Queenstown, New Zealand. New Zealand Hydrological Society and Engineers Australia.

SKM. (2010) Review of the Upper Coliban Storages Flood Hydrology. Final. July 2010

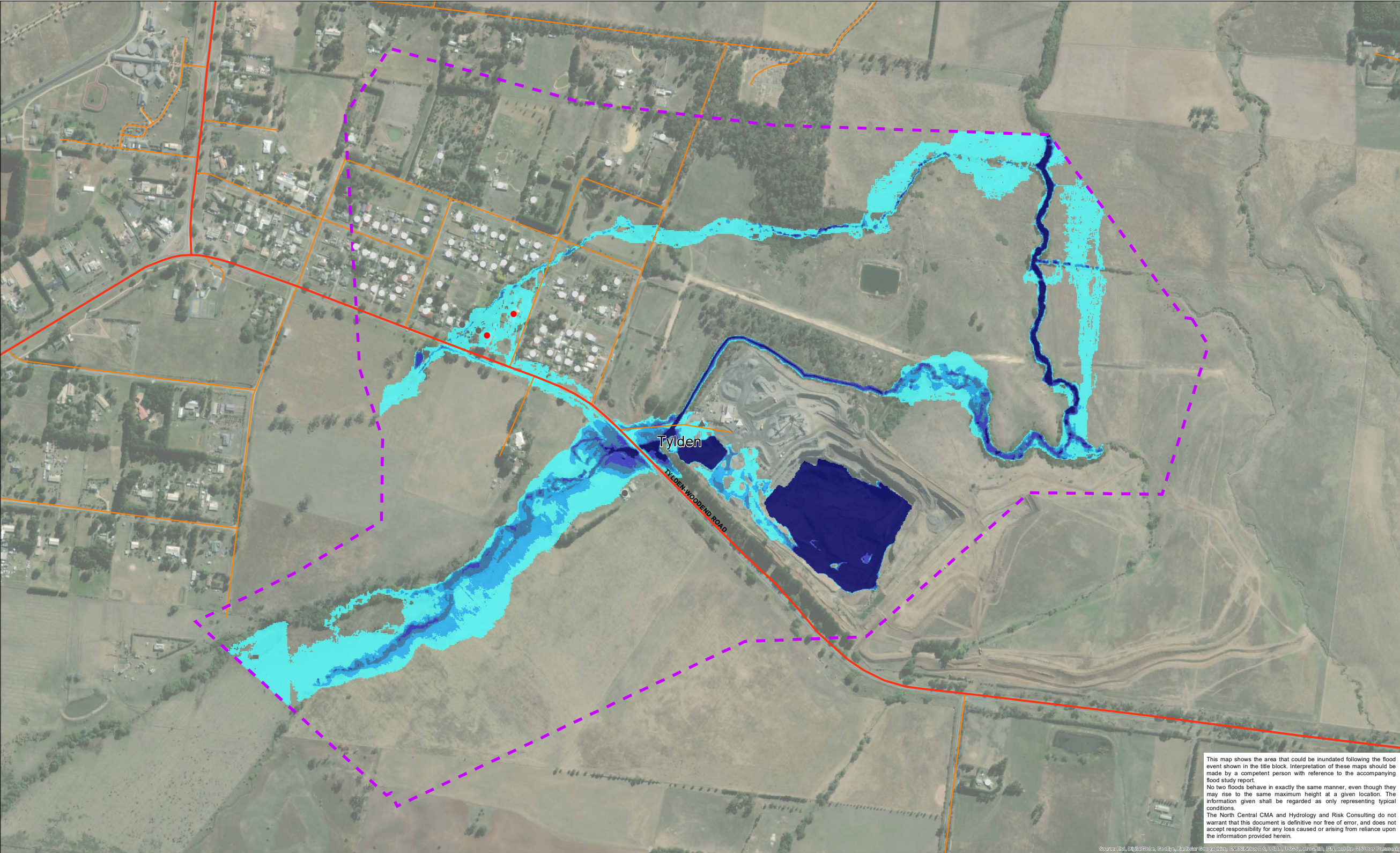


Rapid Flood Risk Assessment - North Central CMA Region  
Tylden



## Appendix A Maps





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFM/FB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

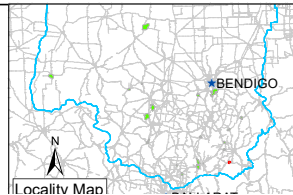
- Main Road
- Tertiary Road
- Railway Line

Building Classification

- Residential
  - Commercial
  - Industrial
  - Public
- Building Inundation**
- not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)
  - above floor level (with floor level survey)

Max Depth (m)

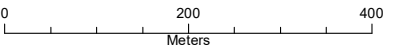
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Tylden - 20% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 5 - 1





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

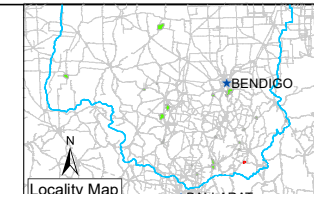
Caravan Park
- Main Road

Tertiary Road

Railway Line

Flood Model Extent
- Building Classification**
  - Residential
  - Commercial
  - Industrial
  - Public

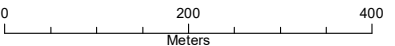
**Building Inundation**
  - not inundated
  - inundated (without floor level survey)
  - below floor level (with floor level survey)
- Max V x D (m<sup>2</sup>/s)**
  - < 0.4
  - 0.4 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Tyden - 20% AEP Flood Event



Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 17 - 5 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

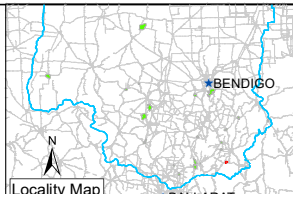
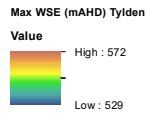
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

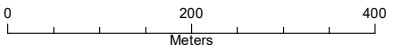
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Tylden - 20% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:3,500 when printed @ A1	25/02/2020	17 - 5 - 3







**Legend**

CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park

Main Road

Tertiary Road

Railway Line

Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Tylden - 20% AEP Flood Event**

0 200 400

Meters

N

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 5 - 4





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

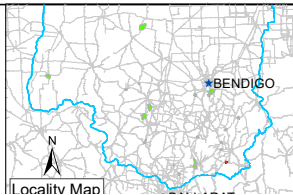
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

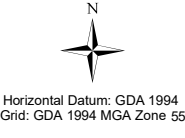
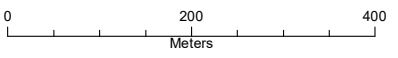
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

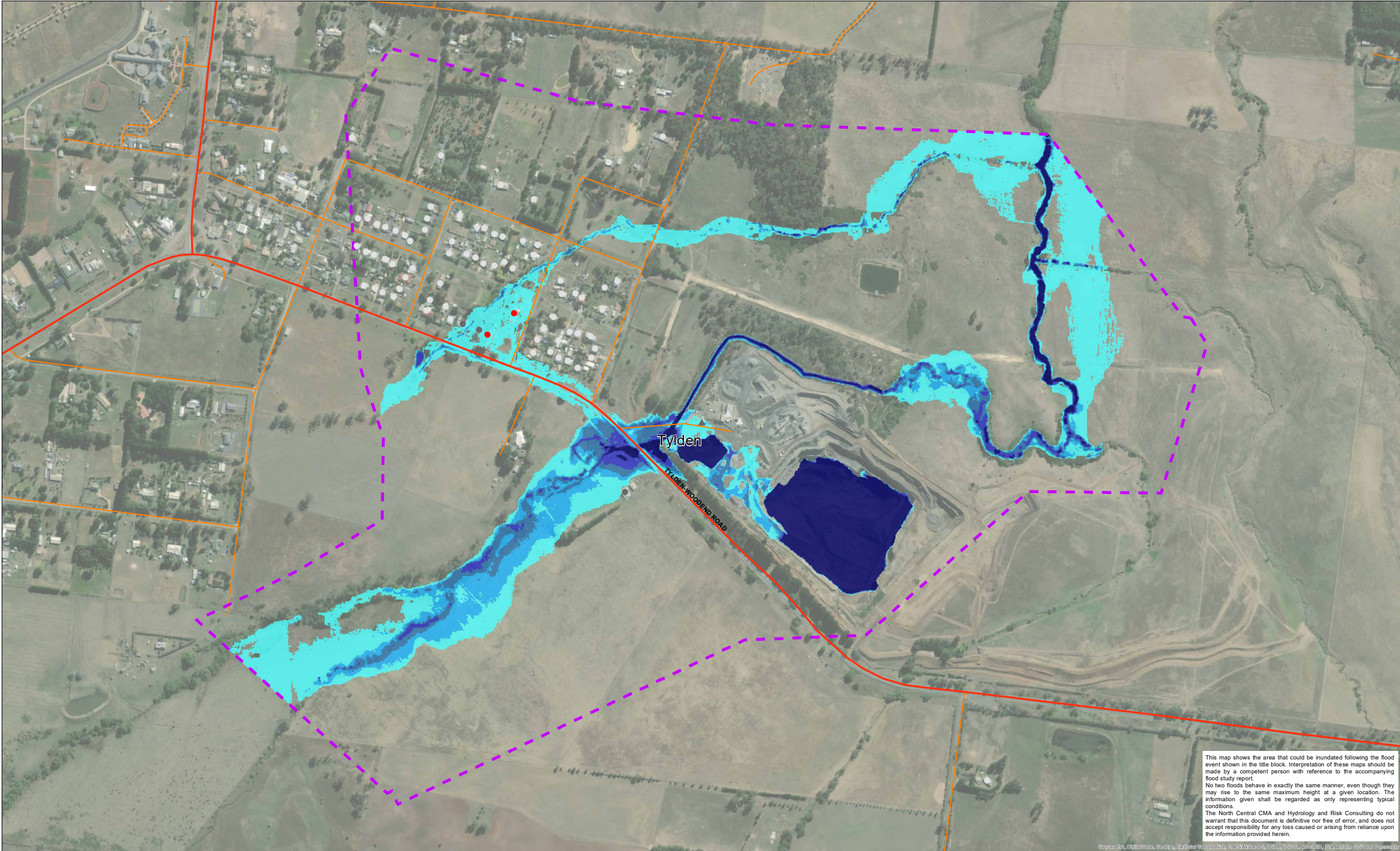
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tylden - 20% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 5 - 5





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFM/FB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

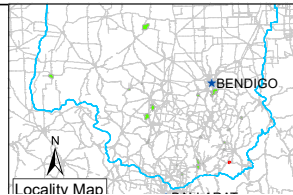
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

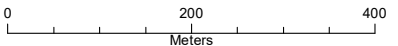
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Tylden - 10% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 10 - 1
----------------------------------	------------------	----------------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

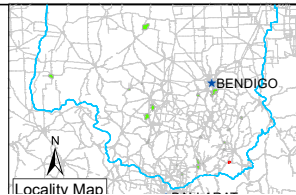
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m²/s)

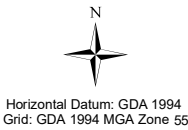
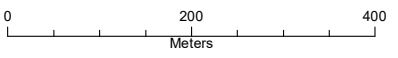
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Tylden - 10% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 10 - 2





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Data\drivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

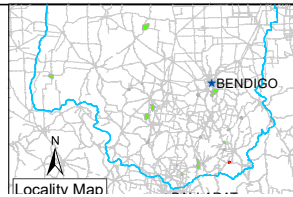
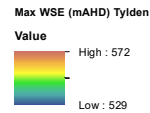
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

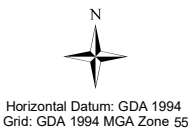
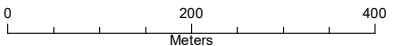
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

Tylden - 10% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 10 - 3
----------------------------------	------------------	----------------------







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

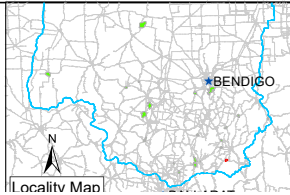
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

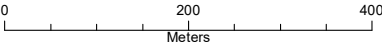
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Tylden - 10% AEP Flood Event**



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 10 - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

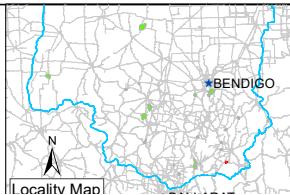
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

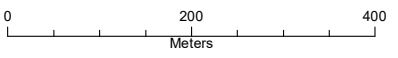
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA			
Project Manager	N. TRELOAR		

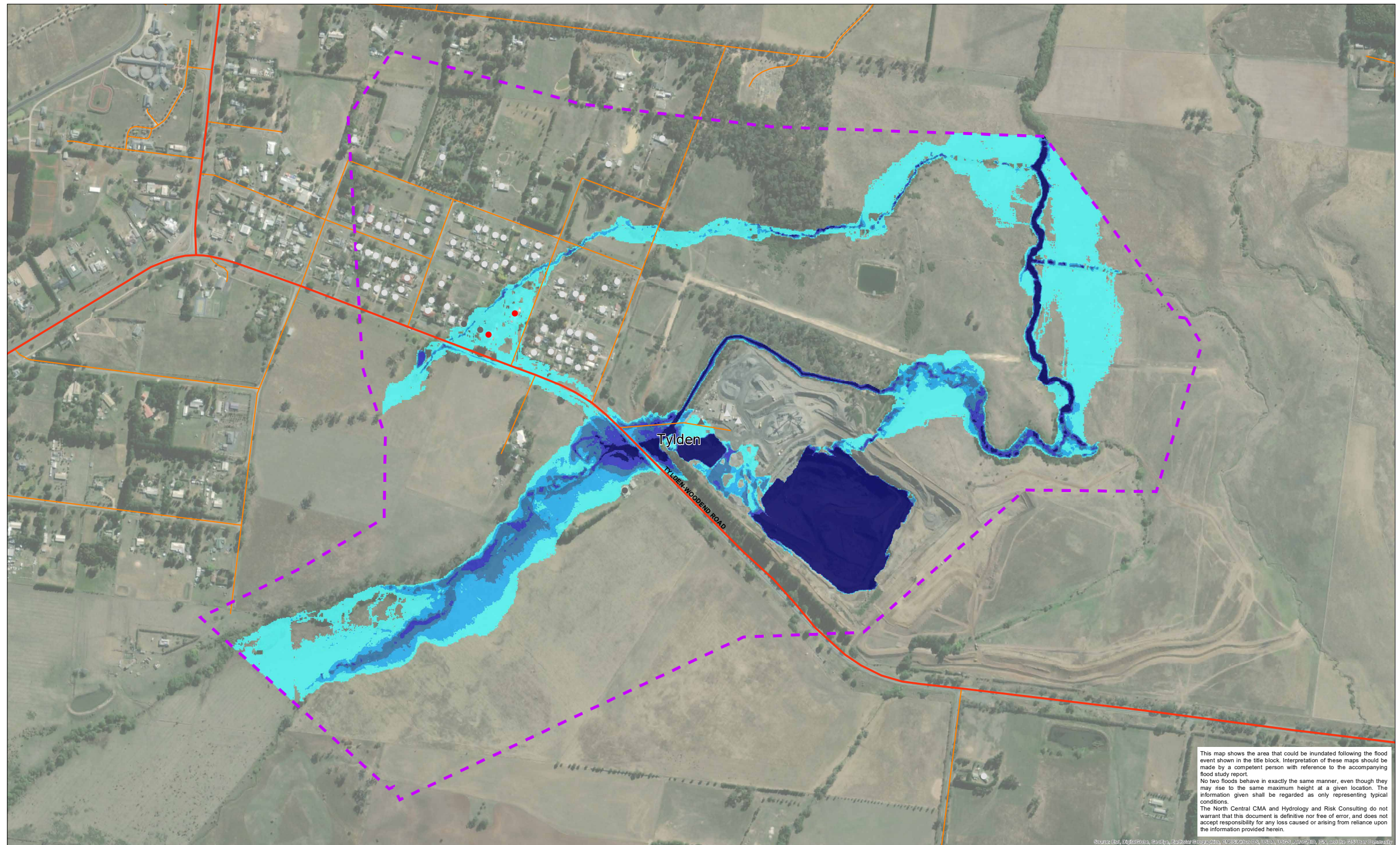
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tylden - 10% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 10 - 5



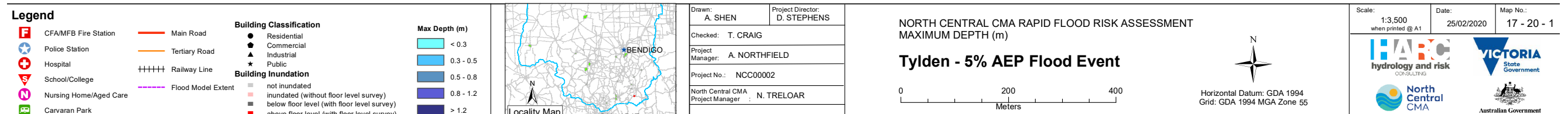


This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

Not all floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

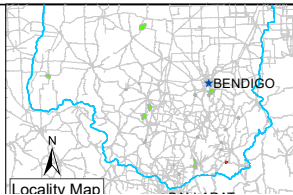
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

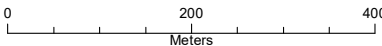
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Tylden - 5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 20 - 2





Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

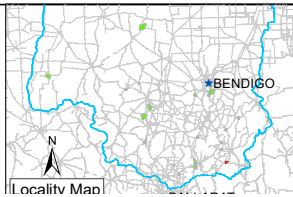
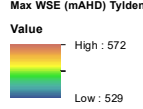
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

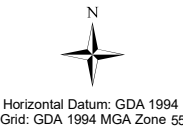
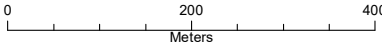
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Tylden - 5% AEP Flood Event

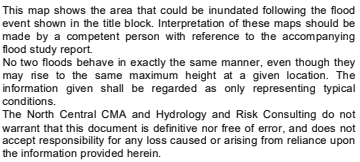


Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

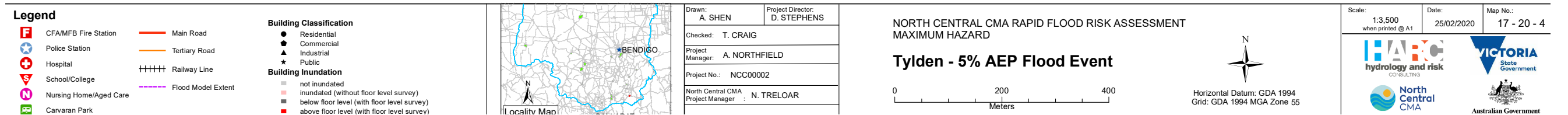
Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 20 - 3
--------	------------------------------	-------	------------	----------	-------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Data\drivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia.







Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

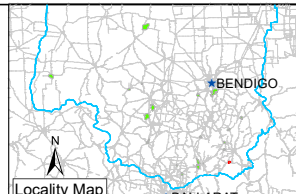
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

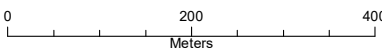
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

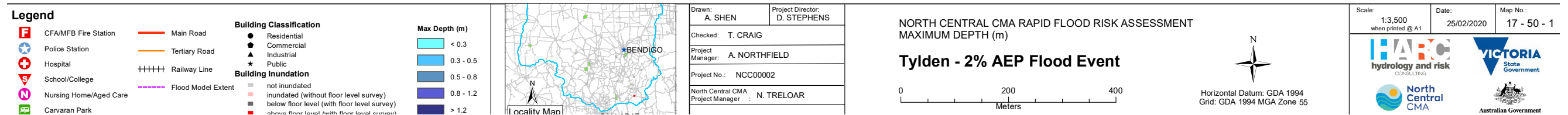
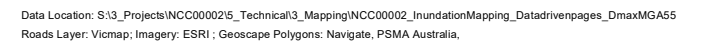
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tylden - 5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 20 - 5









Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

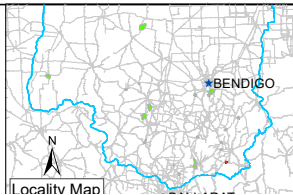
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m²/s)

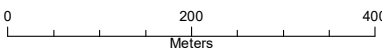
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

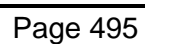
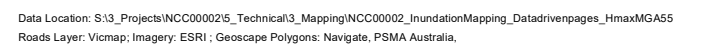
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m²/s)

Tylden - 2% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 50 - 2









Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

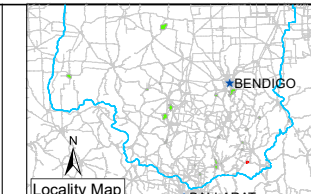
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

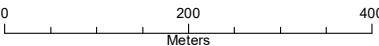
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Tylden - 2% AEP Flood Event**



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 50 - 4



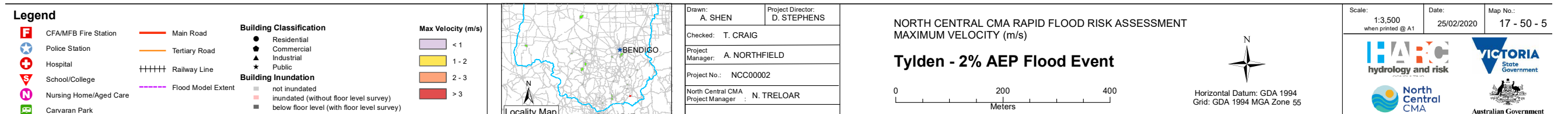


This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

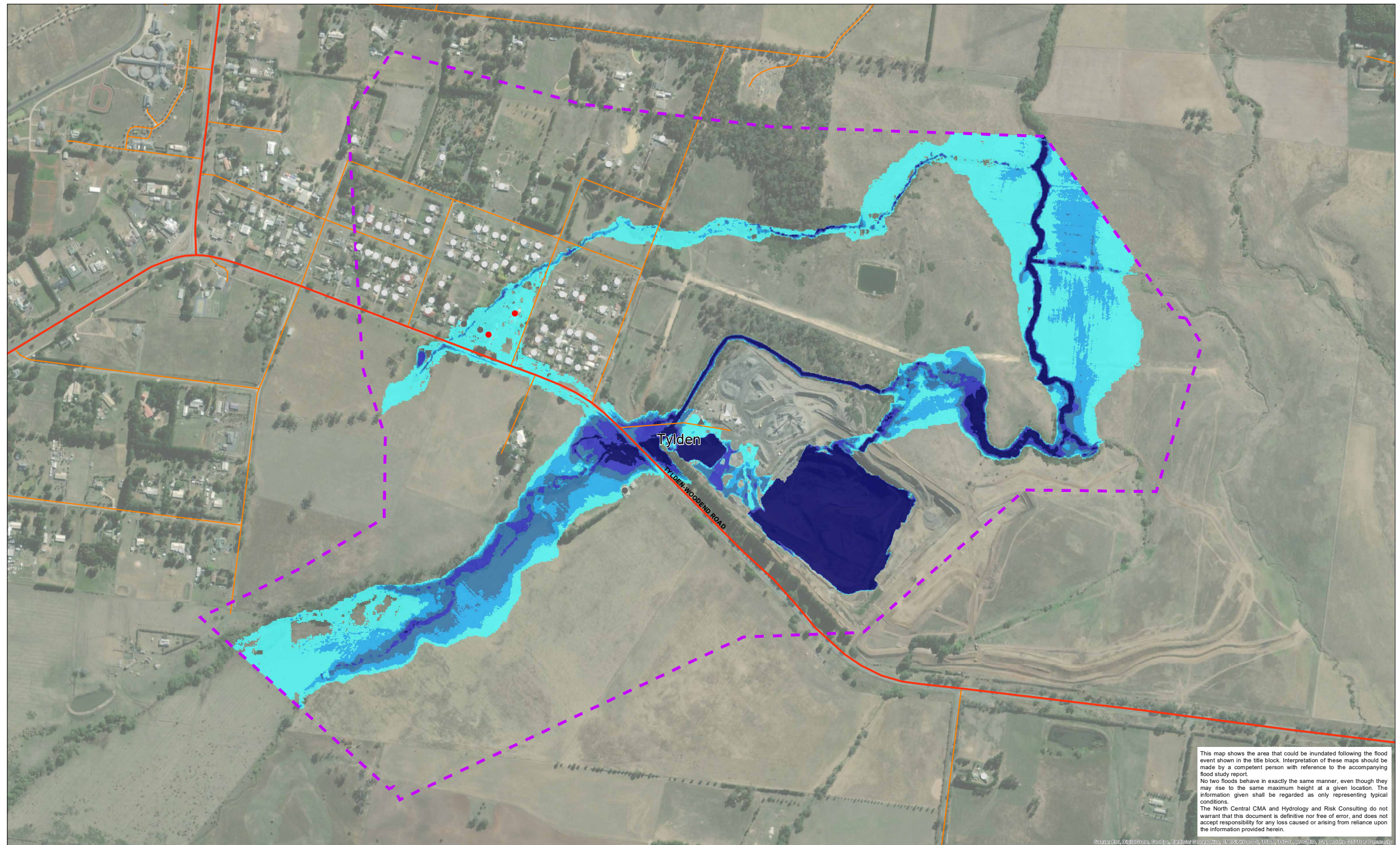
Not all floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,





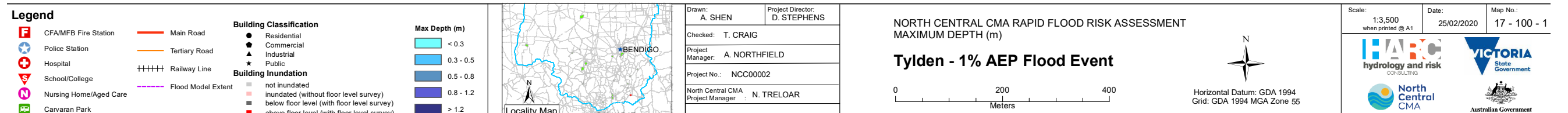


This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

Not all floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC00002\5\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

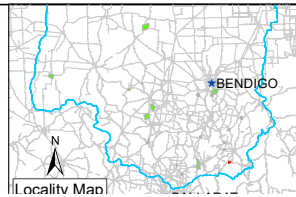
Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

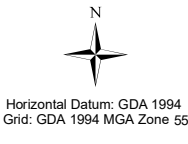
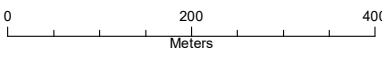
- Max V x D (m<sup>2</sup>/s)
- < 0.4
  - 0.4 - 0.8
  - 0.8 - 1.2
  - > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Tylden - 1% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 100 - 2





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

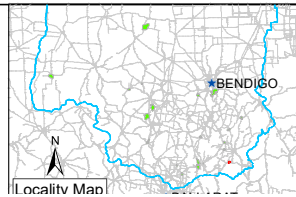
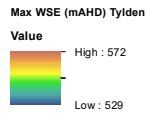
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

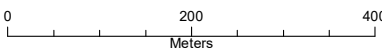
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHd)

Tylden - 1% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 100 - 3
----------------------------------	------------------	-----------------------







**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**

**MAXIMUM HAZARD**

**Tylden - 1% AEP Flood Event**

0 200 400 Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 17 - 100 - 4

hydrology and risk CONSULTING

North Central CMA

VICTORIA State Government

Australian Government





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

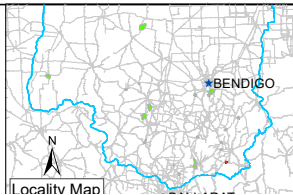
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

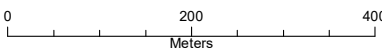
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

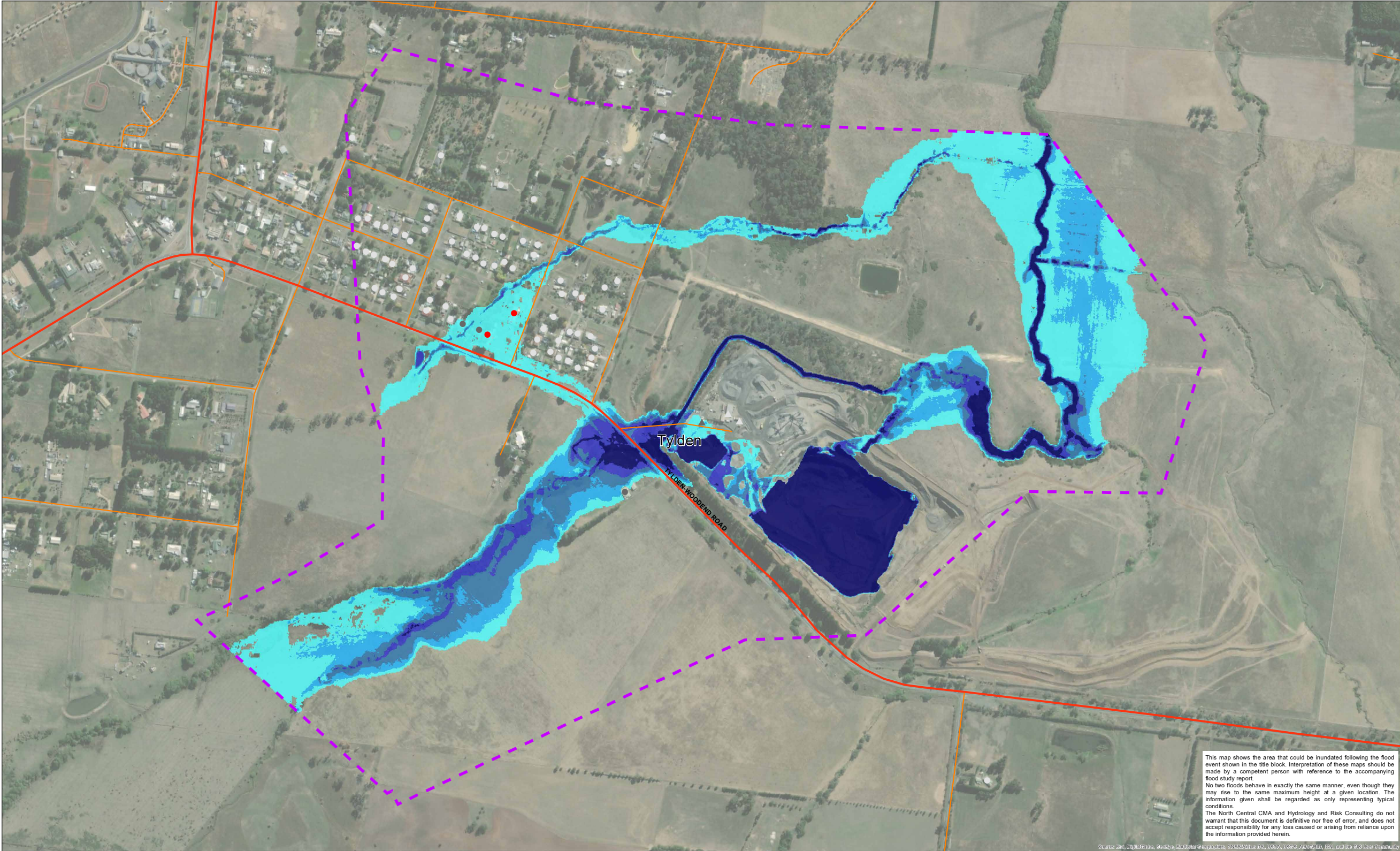
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tylden - 1% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 100 - 5





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFM/FB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

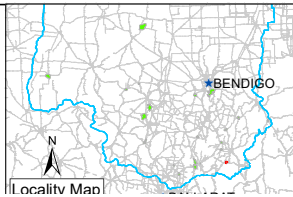
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

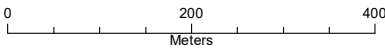
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Tylden - 0.5% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 200 - 1
--	---------------------	--------------------------







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

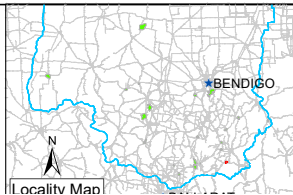
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max V x D (m<sup>2</sup>/s)

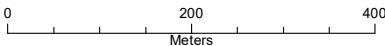
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Tylden - 0.5% AEP Flood Event



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - 200 - 2





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

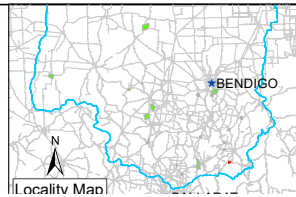
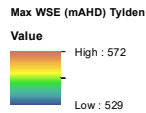
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

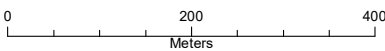
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Tylden - 0.5% AEP Flood Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:3,500 when printed @ A1	25/02/2020	17 - 200 - 3







Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

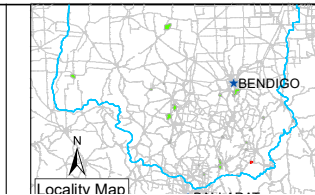
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

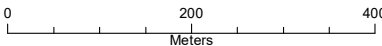
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Tylden - 0.5% AEP Flood Event**



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 200 - 4





This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.  
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.  
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

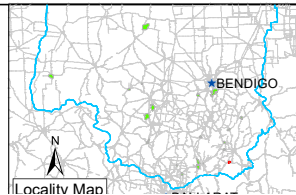
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)

Max Velocity (m/s)

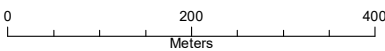
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

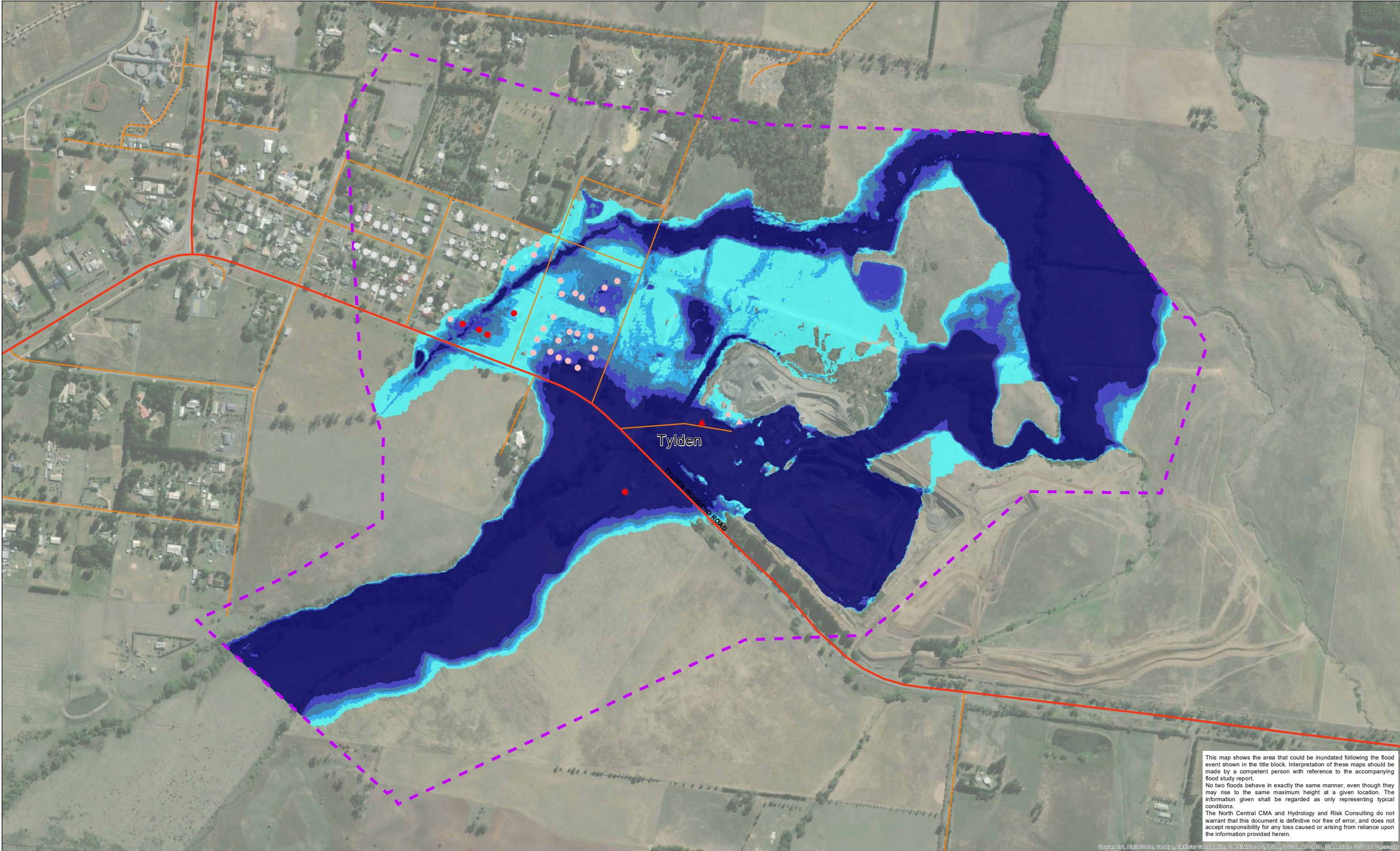
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tylden - 0.5% AEP Flood Event



Scale:	1:3,500 when printed @ A1	Date:	25/02/2020	Map No.:	17 - 200 - 5





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFM/FB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

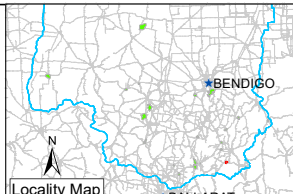
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public
- Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

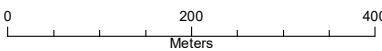
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM DEPTH (m)

Tylden - PMF Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 17 - PMF - 1





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park
- Main Road

Tertiary Road

Railway Line

Flood Model Extent
- Residential

Commercial

Industrial

Public

not inundated

inundated (without floor level survey)

below floor level (with floor level survey)

< 0.4

0.4 - 0.8

0.8 - 1.2

> 1.2

Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM V x D (m<sup>2</sup>/s)

Tyden - PMF Event

Scale: 1:3,500 when printed @ A1

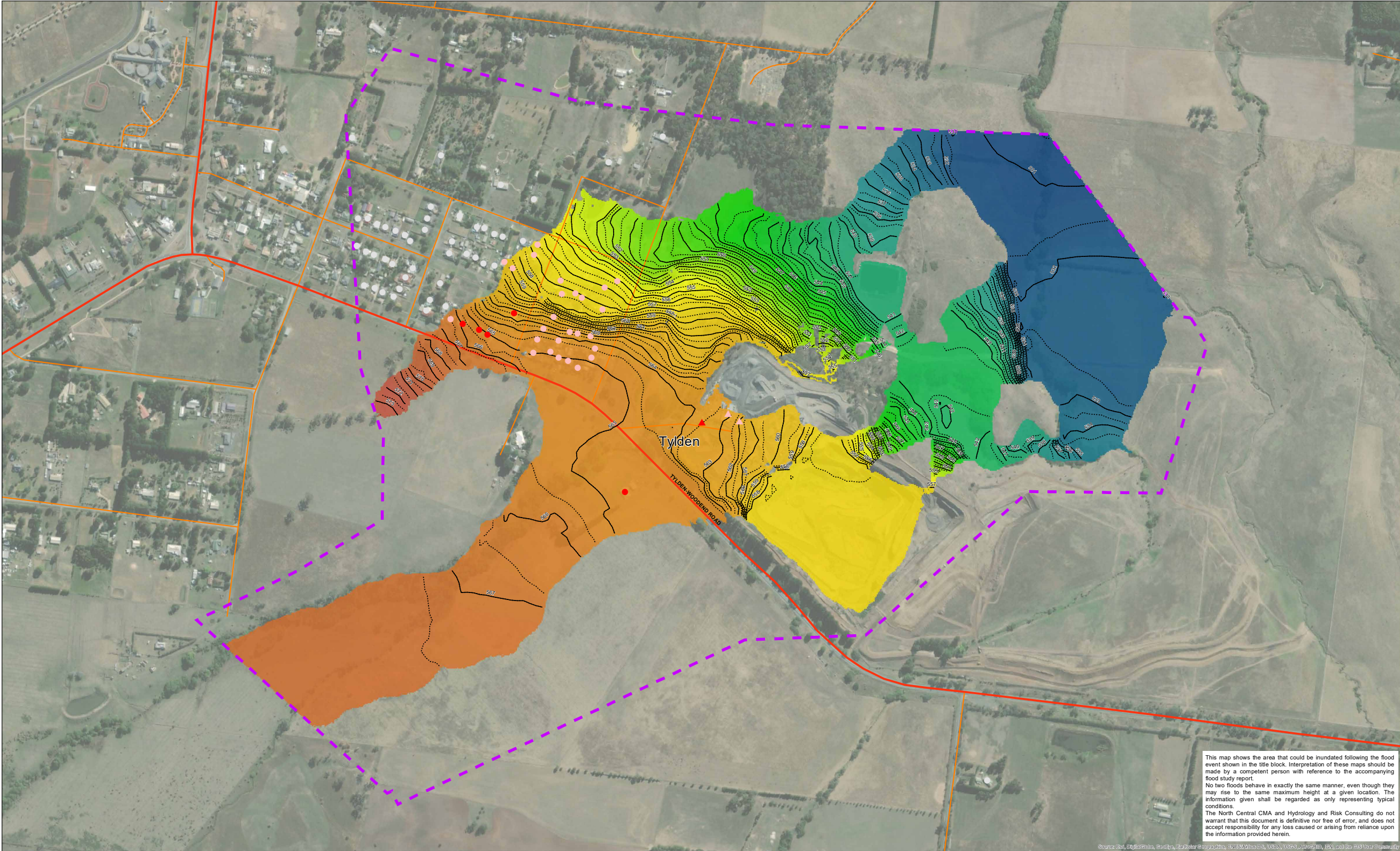
Date: 25/02/2020

Map No.: 17 - PMF - 2

Item PE.1 - Attachment 1

Page 509





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

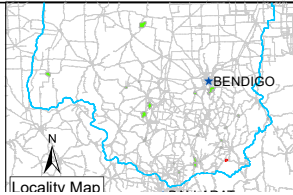
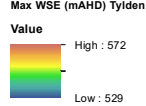
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

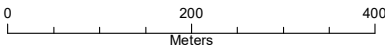
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA			
Project Manager	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM WATER LEVEL (mAHD)

Tyden - PMF Event



Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:3,500 when printed @ A1	25/02/2020	17 - PMF - 3







**Legend**

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Caravan Park

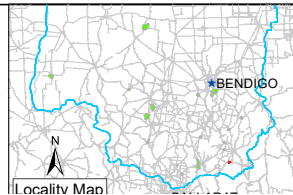
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

**Building Classification**

- Residential
- Commercial
- Industrial
- Public

**Building Inundation**

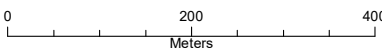
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

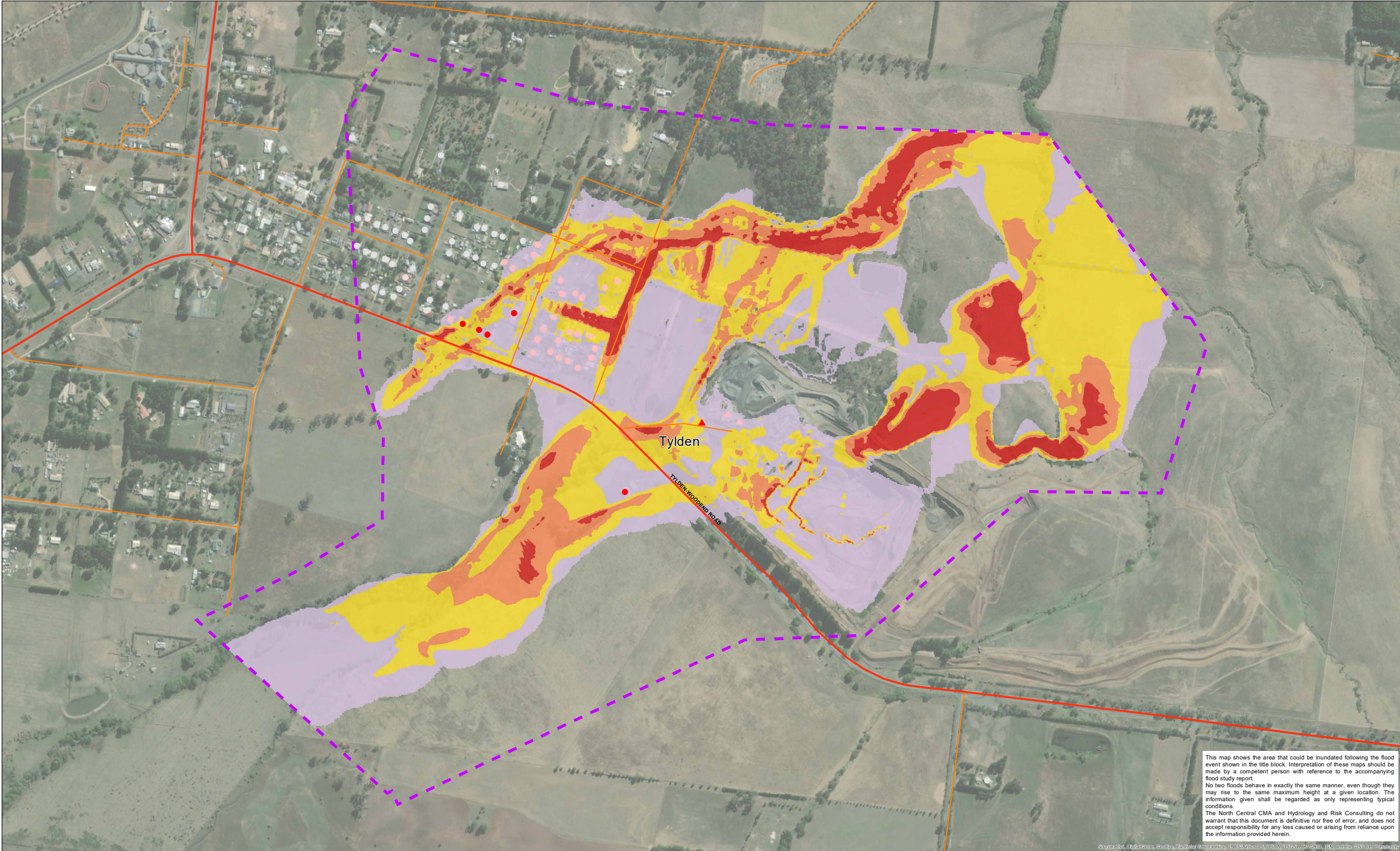
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM HAZARD**

**Tylden - PMF Event**



Scale: 1:3,500 when printed @ A1	Date: 25/02/2020	Map No.: 17 - PMF - 4





Data Location: S:\3\_Projects\NCC000025\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA55  
Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

Legend

CFA/MFB Fire Station

Police Station

Hospital

School/College

Nursing Home/Aged Care

Caravan Park

Main Road

Tertiary Road

Railway Line

Flood Model Extent

**Building Classification**

Residential

Commercial

Industrial

Public

**Building Inundation**

not inundated

inundated (without floor level survey)

below floor level (with floor level survey)

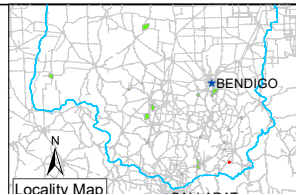
**Max Velocity (m/s)**

< 1

1 - 2

2 - 3

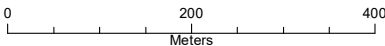
> 3



Drawn:	A. SHEN	Project Director:	D. STEPHENS
Checked:	T. CRAIG		
Project Manager:	A. NORTHFIELD		
Project No.:	NCC00002		
North Central CMA Project Manager:	N. TRELOAR		

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
MAXIMUM VELOCITY (m/s)

Tyden - PMF Event



Scale: 1:3,500 when printed @ A1

Date: 25/02/2020

Map No.: 17 - PMF - 5



# **COMBINED SUBMISSIONS C147MACR - BENETAS**

Redacted

**SUBMISSION 1**

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good Afternoon,

The Cultural Heritage Unit Elders at the Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation have reviewed the proposed amendment to planning scheme C147macr (and associated planning permit application PLN 2022/354).

The Elders note that the amended area is in an area of cultural heritage sensitivity (as defined under the Aboriginal Heritage Act 2006), and as such, a mandatory Cultural Heritage Management Plan (CHMP) will be required for development works within this area. In addition, a large artefact scatter is registered within the property parcel immediately west of the amended area. This artefact scatter contributes to the high cultural heritage sensitivity of this area and contains over 900 artefacts. The CHMP associated with this artefact scatter and the proposed retirement village is currently still in preparation.

Thank you for your consideration of these matters.

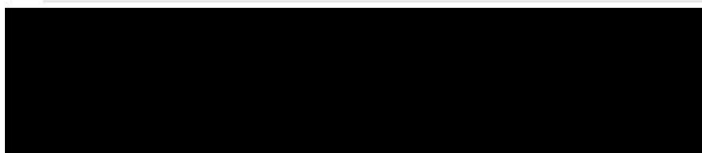
Regards,

**Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation**  
675 Victoria Street | Abbotsford VIC 3067 | [wurundjeri.com.au](http://wurundjeri.com.au)  
Reception: 03 9416 2905



*This email together with any attachments is confidential and may be the subject of legal privilege. Please delete this email immediately if you are not the intended recipient. It is the recipients responsibility to check the email and any attached files for viruses. Thank You.*



**SUBMISSION 2**

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear strategic Planning team,

I write with my OBJECTION of the rezoning of the old Gisborne hospital land.

As the land was donated by the Dixon Family with the condition that it was always used for medical purposes. rezoning it laughs in the face of the Dixon Family's wishes, and also opens up whether other families would do the same and donate important things like land etc when the MRSC don't have the decency to honour there wishes.

"Council agreed to support this rezoning, after discussions around the morality of overriding the Dixon Family's wishes. and On balance the council view was that it was unlikely that a new hospital would be built in Gisborne, therefore the practicality of making the area available for residential use outweighed the act of overriding the family's wishes." (Quote from the Gisborne gazette).

This is just pure rubbish and is pandering to Benetas and them wanting the entire block for there own practicality, development and financial being.

How can Council justify that quote with a straight face and say that the parcel of land

the old hospital is on won't be able to be used as some sort of medical service. ( I already think it bad form that the old community built hospital was even allowed to fall into such disrepair). With the rate that Gisborne is growing thanks to council allowing so many major subdivisions and even on large residential blocks near us, we are going to need more medical services than ever. As it is now, good luck trying to see a doctor in Gisborne, or a psychologist or specialist or allied health, and it's only going to get worse.

That hospital land could very easily be used for some sort of new medical service/s. And SHOULD NOT be meekly handed over to Benetas so that they can have a little Benetas Village of services.

so in answers to the questions that were asked in the Gazette.

1. Is there a demonstrable need In Gisborne for further high/medium density housing.

NO I think that need is being addressed in subdivisions, gee Ross Watt Rd - Rosalia. That will have medium to high density housing according to what I've seen. So NO council is allowing enough subdivisions already to cater for this.

2. Is the need great enough to justify discarding the condition put on the land by the donor family.

Again absolutely NO we already have enough with land subdivisions, without the need to disregard the wish of the donating family.

3. Is it certain that a hospital or other medical service would never require or seek to use the site.

NO it's absolutely NOT CERTAIN. As I have already pointed out that the area NEEDS MORE MEDICAL SERVICES . Even asking that question makes the council look ridiculous.

In closing as the council are our representatives and also representing the donor family's condition on that land, and you are doing neither in this instance, you are not representing us for the best outcome for us or the donor and are purely pandering to Benetas who already have there hands on The Oaks and the old MR community health centre.

I really object to the council rezoning this site for this purpose.

And I cannot believe that at the meeting the discussions lead to that a hospital ( could you not even envisage a different medical service) would unlikely be built in

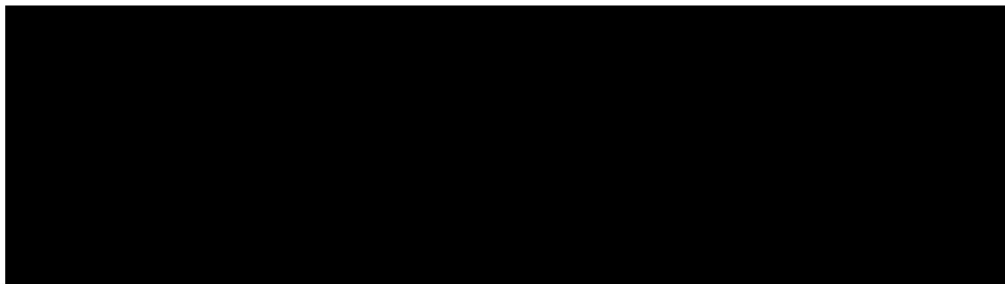


Gisborne and therefore the practicality of making the area residential outweighed the donor family's condition. WE NEED MORE INFRASTRUCTURE AND SERVICES NOT MORE RESIDENTIAL, we have grown too much already.

You are bowing to Benetas, and will benefit with more rates, (as im positive retirement villages pay rates too) and not considering the original donor wishes or the needs of the ever increasing community for further medical facilities.

Another example of how badly we are represented by council.



**SUBMISSION 3****1. High/medium density housing.**

With 12,000 new homes to be built in Gisborne in the near future, does Gisborne require more development in its centre?

Gisborne is now congested, parking and traffic showing the pressure. Pedestrians, in particular children who now walk to school or ride a bike will not be welcome.

**2. Environment**

There are magnificent trees on this site, they will be removed, development over environment again and again.

Is there not another Residential development at the old Macedon house in Gisborne ( heritage trees removed illegally) going ahead? We also have Warrina in New Gisborne, do we need more residential Aged Care Facilities?

3. Benetas removed Allied Health services at MRH ( or do they say reduced). Closed St Mary's clinic at the hospital and left the facility in disrepair. As stated to pursue redevelopment plans.

4. Benetas will greatly benefit from this redevelopment. Does anyone ask what they purchased the Oaks Aged Care Centre, Macedon Ranges Health and the Gisborne Hospital site for?

5. Is the need for another Retirement village more important than the wishes of the Dixon family?

Gisborne has grown extensively in a short expanse of time, we will need a larger medical centre to cope with the explosion in the population. I then ask why have we just built a new state of the art ambulance centre?

How can Macedon Ranges Shire and the Government allow Benetas, who have taken over multiple small nursing homes and have a monopoly of ownership and assets allow the justification of the removal of a bequest from a family such as the Dixon's who were very generous to the people of Gisborne.

Yours sincerely,

A black rectangular box redacting the signature of the submitter.



**SUBMISSION4****Amendment C147macr and Planning Permit Application No. PLN/2022/354**

I write in strong support of this amendment and application.

I am a [REDACTED] involved in the Gisborne volunteer community with a good appreciation of the demographic make-up of our community. My background is in engineering and telecommunications and I have no connection whatsoever to the Health/Aged Care industry nor to MRSC.

**IMPROVING FACILITIES FOR THE AGED**

Gisborne has few suitable facilities for its older people, and many of these are well past their use-by date. This proposal goes some way to improve that situation.

The proposal would provide increased opportunities for Gisborne's older population to have options to continue living here rather than being forced to move away – potentially leaving family and friends behind at a stage of life that is already difficult.

Further, the potential for a co-located Aged Care facility is very exciting, capable of delivering a version of 'ageing-in-place'. We know from family experience how advantageous this arrangement is, which provides further reason to support the proposal.

**AMENITY OF THE LOCAL AREA**

Currently the area West of Neal St. is at best run down and tired. The old hospital appears to be derelict, and the areas to the West of it that are occupied are in poor condition.

From what can be seen in the documentation, this proposal would reverse this situation by providing a public-facing Café, Courtyard etc. This is an excellent improvement and should be supported by MRSC and locals alike.

The end result will be a far more attractive streetscape; I support the removal of native vegetation in order to achieve the desired outcome.

The location of the proposed facility is near-perfect:

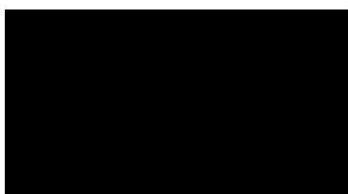
- It is metres away from the Neal St clinic and Macedon Ranges Health, which together provide a wide range of professional medical and health services
- It is close to the centre of Gisborne, with its many shops, cafes and other services
- It is close to the indoor swimming pool and other recreational facilities
- It is not in the middle of a residential area

**INCREASED LAND UTILISATION AND LOCAL EMPLOYMENT**

The area under discussion is currently under-utilised. Successful development of this proposal in full would redress that.

Implementation of the proposal would open up many new employment opportunities in the many and varied roles required to run a complex such as this. The jobs are not just basic entry-level, but provide potential career paths for our young locals.

Yours faithfully



**SUBMISSION 5**

[REDACTED]

[REDACTED]

[REDACTED]

PLANNING APPLICATION NO.: C147MACR, PLN/2022/354  
DEPARTMENT REFERENCE NO: PPR 46261/24  
PROPERTY ADDRESS: ROBERTSON STREET, GISBORNE VIC 3437

**RE: AMENDMENT C147MACR AND PLANNING PERMIT APPLICATION PLN/2022/354**

Thank you for referring documentation for the combined amendment and planning permit application received by the Department of Transport and Planning (Head, Transport for Victoria) on 03 June 2024.

Please quote the reference number in all correspondence and contact with the Head, Transport for Victoria.

The purpose of the proposed amendment is to rezone land (land bound by Robertson Street, Neal Street and Hamilton Street) from the Special Use Zone, Schedule 4 (Private Hospital) to the General Residential Zone, Schedule 1. In addition to the retirement village, the amendment will facilitate the removal of native vegetation (one tree) and alterations to access to a Transport Zone 2 (TRZ2 – Principal Road network) in line with planning application PLN/2022/354.

Although the proposed amendment is likely to be supported by the Head, Transport for Victoria, the following comments are provided to address road safety impacts when assessing any future residential development of the subject land:

**ROAD NETWORK**

As per the Traffic Impact Assessment Report submitted by Cardno ref V181318 dated 24 January 2024:

- There must not be direct vehicle access from the subject land to Robertson Street.
- The impact of the generated traffic movements from the site must not adversely impact the operational efficiency of Neal Street/ Robertson Street roundabout.



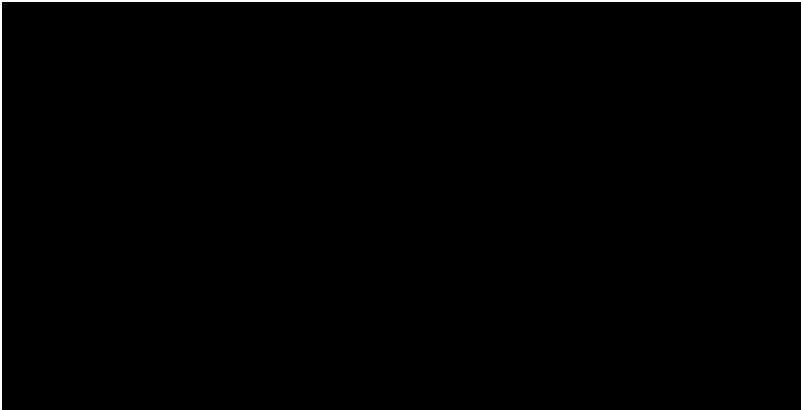
**ACTIVE TRANSPORT**

DTP notes that no pedestrian access or footpath exists along the Neal Street frontage of the subject land and recommends that Council require such provision as part of any planning approval which may issue.

DTP also notes that there is currently no provision for occupants of the subject land to safely access the significant public open space area on the north side of Robertson Street by foot.

Council is therefore strongly encouraged to provide for safe pedestrian crossing opportunities at or near the Roberston Street/Neal Street intersection.

Should you have any enquiries regarding this matter, please contact [REDACTED]  
[REDACTED]



## SUBMISSION 6

Department of Energy, Environment  
and Climate Action

189-229 Lyttleton Terrace Bendigo  
Box 3100, Bendigo DC, VIC 3554  
Telephone: 035430 4444  
[pe.assessment@delwp.vic.gov.au](mailto:pe.assessment@delwp.vic.gov.au)

Ref:00005151  
20240702 CN

**AMENDMENT NO.:** C147MACR  
**PLANNING PERMIT NO.:** PLN/2022/354  
**PROPOSAL:** PLANNING SCHEME AMENDMENT C147MACR AND PLANNING  
PERMIT APPLICATION PLN/2022/354  
**LAND AFFECTED:** ROBERTSON STREET, NEAL STREET AND HAMILTON STREET  
GISBORNE

Thank you for your correspondence dated on 30 June 2024 to the Minister for Environment regarding the above planning scheme amendment.

In accordance with section 96C of the *Planning and Environment Act 1987* (the Act), the Macedon Ranges Shire Council has provided notice of its preparation of an amendment to the planning scheme and notice of an application being considered concurrently with the amendment under this Division, to anyone it believes may be materially affected by the amendment.

The amendment proposes to rezone land from Special Use Zone (SU4) to General Residential Zone and apply the Design and Development Overlay (DDO17) to all of the affected land. Clause 11.01-1L and Clause 52.02 will also be amended. The purpose of the amendment is to facilitate the use of the land for a retirement village.

The permit application PLN/2022/354 is for use and development of a retirement village and removal of native vegetation (one tree) and alterations to a Transport Zone (TRZ2).

Response

The Department of Energy, Environment and Climate Action wishes to advise that it supports the proposed amendment.

If you have any questions regarding this matter, please me at [pe.assessment@delwp.vic.gov.au](mailto:pe.assessment@delwp.vic.gov.au).

Yours sincerely

Any personal information about you or a third party in your correspondence will be protected under the provisions of the *Privacy and Data Protection Act 2014*. It will only be used or disclosed to appropriate Ministerial, Statutory Authority, or departmental staff in regard to the purpose for which it was provided, unless required or authorized by law. Enquiries about access to information about you held by the Department should be directed to [foi.unit@delwp.vic.gov.au](mailto:foi.unit@delwp.vic.gov.au) or FOI Unit, Department of Energy, Environment and Climate Action, PO Box 500, East Melbourne, Victoria 8002.



OFFICIAL



**SUBMISSION 7**

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Macedon Ranges Shire Council  
7<sup>th</sup> July 2024

Please find my objection to the application for the rezoning of the public hospital zoned location (currently zoned SUZ4) to that of a private enterprises application to that of an aged care facility (Zone GRZ1).

The objection relates to the donated land to the bush hospital component only.

The basis of the objection is that the rezoning should have fully disclosed the original donation and the basis of the donation. Not downplaying the current zoning as that of a 'disused' bush hospital.

The founders of this town did not donate land to the council for public use so that the council could through an undisclosed commercial arrangement hope that the residents and rate payers of this town would forget that the reason they received the benefit was for the greater good of the community.

The land for the **Gisborne & District Bush Nursing Hospital** was generously donated by Mr. and Mrs. W. H. (Bill) **Brockwell**.

The land that the private enterprise (namely Anglican Aged care services group t/a benetas) under the applicants [REDACTED] want to rezone was originally donated to the Shire of Gisborne for public use.

The land was developed as a public hospital on that basis and while not in use as a public hospital as the application identifies since 1997, this does not change the underlying purpose of the donation for public use, nor should it give the council the ability at a later point to either sell the land or lease the land to another enterprise without disclosing to the public, that they did not pay for the land or the reasons for the original covenants.

The land should either return to that of a public space/ park,  
or a public tender process should be engaged to ensure the maximum funds are received by the council and if Anglican Aged Care Services Group win the tender, then they should be required to pay to the council / rate payers the increased market value of the land that

rezoning would provide the owners & also purchase public land for public use and donate that land to the council.

This land is prime land in Gisborne and hoping memories are short should not negate the requirements of what the land was donated for.

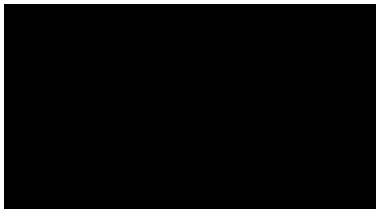
The rezoning of the land should not be carried out in an underhanded way to gain advantage for a registered charitable enterprise, if the ratepayers are not receiving the maximum commercial value.

I am not objecting to the need for aged care facilities in this town, just that this gives a 'charity' an unfair commercial advantage being located next door to that of public land donated.

Further to this the application should be deemed invalid as the proposal, page 1 "The proposal" point I Estimated cost of any development for which the permit is required states "Cost \$35,000,00.00 Is this supposed to be \$3.5M or \$35M or is the hope people will not see the missing 0 meaning it's only \$3.5m

Any amended proposal will carry the same objections, the this should be addressed first.

Regards





## SUBMISSION 8



T: (03) 5422 0333 | [mrsc.vic.gov.au](http://mrsc.vic.gov.au) | ABN 42 686 389 537

### Objection to a Planning Permit Application

Any person who may be affected by the grant of a permit may object. Provided your objection is received prior to the application being decided, your objection will be considered and you will be notified of the decision when it is made. This form has been designed to assist with collecting the required information for an objection, but you are not required to use this form.

For assistance completing this form, call Statutory Planning on (03) 5421 9699.

#### Objector Details

Name/s\*: [REDACTED]

Organisation: [REDACTED]

[REDACTED] [REDACTED] [REDACTED] [REDACTED]

*\* If multiple people are making this objection please list your preferred contact person first as we will only send correspondence regarding the objection to this person.*

#### Planning Permit Application Details

Application Number: PLN/ 2022/354

Property Address: 61 Robertson Street Gisborne Vic 3437

#### PRIVACY COLLECTION NOTICE

Macedon Ranges Shire Council is committed to protecting your privacy. The personal information you provide on this form is being collected for the primary purpose of registering and considering your objection.

Where required, in accordance with the Planning and Environment Act 1987, a copy of your objection will be provided to:

Available to	Information provided
Council staff and external agencies involved in the planning process.	Full copy of objection.
The applicant for the planning permit and their representatives.	Copy showing objector name/s and address with other personal information redacted.
To any persons who wish to inspect your objection prior to a decision being made for the application.	Copy with all personal information redacted available to view/inspect only.
On Council's website if the application goes to a Planning Delegated Committee or Council Meeting.	Copy with all personal information redacted.

If your objection contains personal information of any other parties you must gain their consent to include their personal information in your objection and provide them with a copy of this notice.

Your personal information will not be disclosed to any other external party without your consent, unless required or authorised by law. If you wish to gain access to, or alter, any personal information you have supplied on this form, contact us on (03) 5422 0333.

You can access Council's Privacy Policy at [mrsc.vic.gov.au/privacy](http://mrsc.vic.gov.au/privacy)

**Objection Details**

Ensure that you clearly understand the application prior to objecting. You can view all planning applications at our Gisborne office during business hours. During the 14 day advertising period (where applicable) documents are available to view online at: [mrsc.vic.gov.au/planning-register](https://mrsc.vic.gov.au/planning-register)

**Describe the reason/s for your objection including how you would be affected by the grant of the permit:**



**SUBMISSION 8**

Dear Sir/Madam,

Re: Objection to Planning Permit PLN/2022/354

I am writing to formally object to Planning Permit PLN/2022/354 on the grounds of significant concerns regarding access to my property and the safety and well-being of my family and community members. The proposed development poses critical issues that must be addressed to ensure continuous, unhindered access to the slip lane leading to my residence.

**Access Concerns and Health Requirements**

Our household includes several retirees and a 96-year-old grandmother with significant health concerns. It is imperative that we maintain unobstructed access to our property at all times to accommodate any potential emergencies. The presence of my elderly mother necessitates frequent visits from healthcare providers and, in some cases, emergency services. Any hindrance in access could have severe consequences for her health and well-being.

**Kindergarten Access**

Additionally, the slip lane also serves as an access route to a nearby kindergarten. It is crucial for the safety and convenience of parents, children, and staff that this route remains clear and accessible. Interruptions due to construction activities could disrupt the daily routines of many families and potentially endanger the children attending the kindergarten.

**Emergency Services Accessibility**

Given the health needs of my mother, it is essential that emergency services have unrestricted access to our property at all times. Delays caused by construction activities could have life-threatening implications. Therefore, it is vital to ensure that any development plans include provisions for continuous emergency access.

**Construction and Traffic Management Plans**

The proposed building project appears to be extensive and may take a considerable amount of time to complete. Prior to considering the withdrawal of this objection, I request the submission of both a Construction Management Plan (CMP) and a Traffic Management Plan (TMP). These plans must demonstrate detailed measures to ensure that access to our property and the kindergarten is maintained without disruption throughout the entire construction period. Specifically, these plans should outline the following:

1. Access Routes: Clear designation of alternative routes for residents and emergency services if the slip lane access is temporarily obstructed.
2. Timetable: A detailed construction schedule with specific times and dates when access might be impacted, along with measures to mitigate these disruptions.
3. Communication: Regular updates and direct communication channels between the construction management team and affected residents to address any arising concerns promptly.

In conclusion, while we recognize the importance of development and progress, it must not come at the expense of the safety, health, and convenience of current residents. I urge the planning department to consider these critical points and ensure that appropriate measures are put in place to mitigate the impact on our community before approving Planning Permit PLN/2022/354.

Thank you for your attention to this matter. I look forward to your prompt and favorable response.

[Redacted Signature]

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good afternoon Councillors.

I am forwarding you an email I sent to Strategic planning, Mayor Death and local member and Minister for Health Mary-Anne Thomas.

Please see the below regarding the provision of land (specifically) for the Gisborne Bush Nursing Hospital in 1955 by our family.

Please also see page 45 of <https://www.mrsc.vic.gov.au/files/assets/public/v/1/council/our-council/meeting-attachments/2023/05/10-may-2023-planning-delegated-meeting-attachments.pdf>

Who are the benefitting parties listed, have they been notified last or this year?

I have spoken to my family, the Dixons, direct descendants of Humphrey Dixon, and in no way do they support the zoning changes. They will also be in touch.

The possible rezoning is an affront to the gifting of a significant asset for whole of community benefit. What would the valuation of this land be today? How could that value of that asset be used for community benefit today?

Should the land be rezoned the current value of the land should be paid for by the developer and used for the greater Gisborne community, perhaps in trust for ongoing development of Dixon field?

Rezoning for Benetas' benefit would create a disincentive for future community minded donations of significance. The 1950s is not that long ago.

Please consider.



Good evening.

[REDACTED] resident, [REDACTED] "Uncle" Humphrey Dixon who  
town of Gisborne for a hospital. Where I was born in 1968.

Please find attached a copy of the original document from 1955 detailing the hospital  
proposal and the Dixon donation to enable the hospital to occur.

I would like to discuss with you my family's continuing connection to the town/hospital  
and the appropriateness of future use/s for the site for community health care. While time  
and eras pass the fundamentals of this site, the intention of donation and sentiment  
continue.

(I would also like to discuss the pine plantation next to the Secondary College, another  
parcel of land my family were active in donating to the people of Gisborne.)

Thank you,

[REDACTED]

## SUBMISSION 10



**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Macedon Ranges Shire Council Planning Department,

[REDACTED] am writing to you to object to the proposed Amendment C147macr and Planning Permit PLN/2022/352 on behalf of myself [REDACTED]

The following reasons are why we object to Amendment C147macr and Planning Permit PLN/2022/352:

1. The cover letter of the application incorrectly lists that the amendment will result in "the removal of native vegetation (one tree)". This incorrect statement is throughout the documentation. The Native Vegetation Removal Report also only states that one native tree will be removed. The Amended Arboricultural Assessment and Report contradicts the Native Vegetation Removal Report by listing multiple Australian Native Trees and 4 Indigenous trees that are shown to be removed in the supporting documentation. All Indigenous trees on this land parcel will be removed if this application is approved.
2. Tree No. 35 is one of the 4 indigenous trees that has been marked for removal. Tree No. 35 has a Moderate A, ARB rating. This classification suggests that the tree should be retained and may have cultural significance.
3. In addition to this, the design and development overlay DD017 states in its requirements "To ensure existing significant vegetation is protected". The fact that the highest ARB rated Indigenous tree is being removed is in complete contradiction to this requirement.
4. The plans attached to the application for the proposed retirement village do not show critical details that display the impact on dwellings that border the proposed development. These missing details include:
  - i. Proposed setbacks from the Southern fence line.
  - ii. Proposed roof heights compared to the existing dwellings.
5. The amendment also goes against the wish of the Dixon family who donated the land that is bordered by Hamilton St and Neal St on the provision it remains as land for medical practices. Given the current trend of urban sprawl, and the increasing population of Gisborne and surrounds, it is unreasonable to presume that Gisborne will never require a hospital or additional medical facilities.


I look forward to your feedback on my objection.

My best contact method is via the following email: [REDACTED]








**SUBMISSION 11**  
**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Macedon Ranges Shire Council,

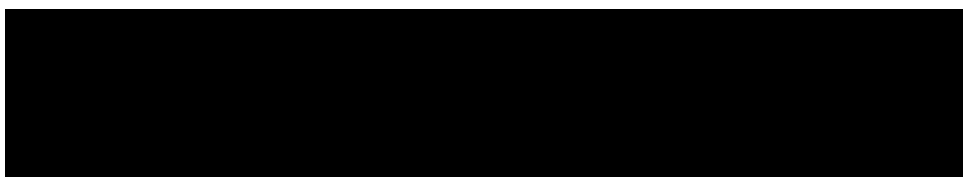
I am writing in oposition to this amendment C147macr to planning application PLN/2022/354, as a local resident and as a health professional. The applicant is seeking removal of the restrictive covenant Lot 1 on LP205979 (known as 61 Robertson Street). This land was gifted to the Gisborne community in the 1950s on the condition it always be used for medical purposes. Removing this restrictive covenant is short sighted and not in the interest of the local community. The Gisborne community is growing rapidly with many multi dwelling developments recently built or currently in development. The Gisborne township area is earmarked for ongoing growth. While there is unlikely to be a hospital at this site after the closure of the previous hospital in 1997, there is an ongoing need for future expansion and development of medical and Allied Health services to support the growing population size of Gisborne.

The restrictive covenant should remain in place to ensure this land can assist in meeting the healthcare needs of the Gisborne community into the future. The removal of this covenant supports the applicant in making a significant profit on donated land, but does not support future planning for health care needs of the local community.





## SUBMISSION 12



[Redacted]  
[Redacted]  
[Redacted]  
[Redacted]  
[Redacted]  
Cc: [Redacted]  
[Redacted]  
[Redacted]  
[Redacted]  
[Redacted]

**Subject:** Opposition to Rezoning of Land on the Corner of Hamilton and Neale Streets from Special Use to General Residential (Amendment C147macr, Planning Permit Application PLN/2022/354)

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Council

**Re: Opposition to Rezoning of Land on the Corner of Hamilton and Neale Streets from Special Use to General Residential (Amendment C147macr, Planning Permit Application PLN/2022/354)**

We are writing to express our strong opposition to the proposed rezoning of land located at the corner of Hamilton and Neale streets from special use to general residential, as outlined in Amendment C147macr and Planning Permit Application PLN/2022/354. This land, generously donated in the 1950's by the Dixon family was intended to be used for medical purposes, and its proposed rezoning undermines the family's wishes and the broader interests of our community.

The history of this land is significant. It was donated by the Dixon family with the explicit condition that it always be used for medical purposes. Up until the closure of the Gisborne Hospital in 1997, this condition was honoured. Following the hospital's closure, the land continued to serve the community's health needs, being repurposed for doctors' surgeries and allied health services until 2020, when Benetas cancelled the tenancies to pursue redevelopment into a retirement "lifestyle village." This planned redevelopment is not in keeping with the spirit of the family's donation and will primarily benefit the landholder, rather than serving the entire community.

Overriding the Dixon family's wishes and stated purpose for this valuable piece

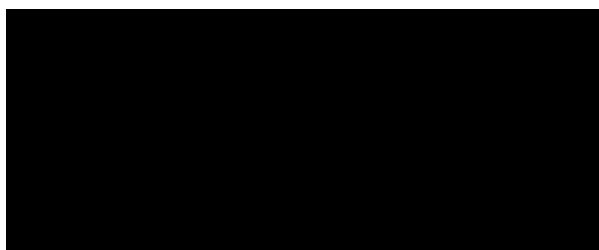
of land, which was donated for the benefit of the whole community is unjustifiable. The argument that a hospital is unlikely to be built in Gisborne does not outweigh the original purpose of the donation, which was to facilitate medical services for the community. Supporting this rezoning is not only short-sighted but also disingenuous and bordering on morally corrupt.

As the Gisborne community continues to develop and its population grows, the need for medical facilities and appropriate land to develop them on will only increase. The rezoning proposal disregards this future necessity. Additionally, there is no demonstrated need for more high or medium-density housing in Gisborne. The proposed retirement village housing type is restrictive, being age-limited to over-50s. Retirement villages are purely residential ventures and do not fulfil the medical use intended for this land. With numerous houses either completed or under construction around Willowbank Road, including two retirement villages, an additional 800 houses approved for New Gisborne, and the Rosalia Ross Watt development of 700 houses and future aged housing development it seems there is no pressing need or justification for this rezoning.

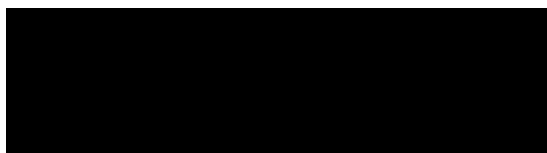
The land in question runs along Neal Street between Hamilton Street and Robertson Street. The council's decision to support the rezoning on the basis that a new hospital is unlikely to be built in Gisborne is not evidence-based and seems to be based on current circumstances without any thought what may occur in the future. When the Sunbury hospital closed, community lobbying led to the establishment of a day hospital in Sunbury. In 2022, designs and consultations were held for expanding this facility as part of a state government-funded program to build community hospitals in growth areas. Gisborne is indeed a growth area, and to claim that a hospital will never be built here is disingenuous at best.

This land is ideally located for a future hospital or, in the meantime, for medical clinics and allied health services. The Dixon family has also donated other land to Gisborne, such as the Dixon Field sports grounds, demonstrating their long-standing commitment to the community. We owe the Dixon family a debt of respect and gratitude for their generosity and community spirit.

We strongly urge the council to refuse the rezoning proposal and honour the Dixon family's wishes. This land should continue to serve its intended purpose of providing medical services to the people of Gisborne, now and in the future.





**SUBMISSION 13**

Strategic Planning <strategicplanning@mrsc.vic.gov.au>

**Subject:** PLN/2022/354

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Submission to the Amendment C147macr. PLN/2022/354

'I object to the above Amendent on the following grounds

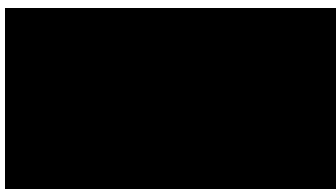
1. The Dixon family were a generous family in donating this land with the proviso that it be retained for medical purposes
2. The Dixon family's wishes were made in good faith that their gift to the town and people of Gisborne would be effective and everlasting
3. To make this Amendment as suggested, to residential or any other zoning, is immoral

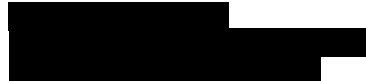
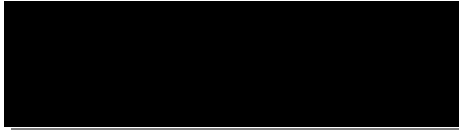
4. To make this Amendment will be detrimental for future philanthropic gestures
- 5 To endorse this Amendment could set in an excuse to change other existing zones which have been generously made over the years
6. The only way forward with this Amendment would be to use the land for purely medical purposes in specific conjunction with the Oaks  
(eg on-site nursing rooms/in-house doctor surgery/a sick-bay to be used for isolation during covid and/or influenza outbreaks)

This would comply with the Dixon family, enhance the virtues of the Oaks, and would not require any high building structure permits

7. The original Bush Hospital on this site was greatly supported by generous financial donations by the people of Gisborne and the current population have the right to 'have their say'

8. I hereby request that attention be brought to the fact that the Ashes of Muriel Joan Daly, widow of Mr Ulick Lord Daly, MBE., are buried on the corner of Hamilton and Neale Streets, beneath a tree especially planted in her memory. There is also a plaque to mark her life membership and is therefore 'sacred ground' Muriel Joan Daly (nee Kimpton) was the governess to Sir Rupert Murdoch, and worthy of much respect'



**SUBMISSION 14**

To: Strategic Planning <strategicplanning@mrsc.vic.gov.au>  
Subject: PLN/2022/354 Benetas etc

CAUTION: This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Councillors

I am amazed and worried that Council is even considering this application of doing away with the current buildings/former Hospital

It's morally wrong that this land bequest from the Dixon family that was made for a specific use is now being considered to be overturned.

Why ?

So if this goes ahead does it bode well for future bequests from Gisborne Citizens to be considered with possibility of future Councils overturning the requested use ?

I don't think so..

In this new world of cyber attacks, natural disasters and supply chain disruption to name a few wouldn't it be appropriate to have some capability like this hospital/building for possible use?

This facility could be renovated/refurbished for many other uses as Speciality Clinic in times of high need.

We just came out of the Covid 19 epidemic by the skin of our teeth as an example.

We hear the talk of needing resilience so much now, yet this proposed action would seem to be the opposite.

Actually this smacks of the similar scenario of the Kennett Government sell off of Victoria of past and the cost of that to Victorians

Again I strongly object to this Proposal going ahead

Yours Sincerely





**SUBMISSION 15**

[REDACTED]  
To: [Macedon Ranges Shire Council](#)  
Subject: Objection: PLN/2022/354  
Date: Thursday, 11 July 2024 8:05:36 PM  
[REDACTED]

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please find attached my Objection to a Planning Permit Form for the application PLN/2022/354.

If you have any questions or queries about this objection please don't hesitate to email me.

Regards





T: (03) 5422 0333 | [mrsc.vic.gov.au](http://mrsc.vic.gov.au) | ABN 42 686 389 537

## Objection to a Planning Permit Application

Any person who may be affected by the grant of a permit may object. Provided your objection is received prior to the application being decided, your objection will be considered and you will be notified of the decision when it is made. This form has been designed to assist with collecting the required information for an objection, but you are not required to use this form.

For assistance completing this form, call Statutory Planning on (03) 5421 9699.

### Objector Details

Name/s\*:

Organisation:

Phone:  Email:

Address:

*\* If multiple people are making this objection please list your preferred contact person first as we will only send correspondence regarding the objection to this person.*

### Planning Permit Application Details

Application Number: PLN/ 2022/354

Property Address: 61 Robertson Street Gisborne Vic 3437

### PRIVACY COLLECTION NOTICE

Macedon Ranges Shire Council is committed to protecting your privacy. The personal information you provide on this form is being collected for the primary purpose of registering and considering your objection.

Where required, in accordance with the Planning and Environment Act 1987, a copy of your objection will be provided to:

Available to	Information provided
Council staff and external agencies involved in the planning process.	Full copy of objection.
The applicant for the planning permit and their representatives.	Copy showing objector name/s and address with other personal information redacted.
To any persons who wish to inspect your objection prior to a decision being made for the application.	Copy with all personal information redacted available to view/inspect only.
On Council's website if the application goes to a Planning Delegated Committee or Council Meeting.	Copy with all personal information redacted.

If your objection contains personal information of any other parties you must gain their consent to include their personal information in your objection and provide them with a copy of this notice.

Your personal information will not be disclosed to any other external party without your consent, unless required or authorised by law. If you wish to gain access to, or alter, any personal information you have supplied on this form, contact us on (03) 5422 0333.

You can access Council's Privacy Policy at [mrsc.vic.gov.au/privacy](http://mrsc.vic.gov.au/privacy)



**Objection Details**

Ensure that you clearly understand the application prior to objecting. You can view all planning applications at our Gisborne office during business hours. During the 14 day advertising period (where applicable) documents are available to view online at: [mrsc.vic.gov.au/planning-register](https://mrsc.vic.gov.au/planning-register)

**Describe the reason/s for your objection including how you would be affected by the grant of the permit:**

Dear Sir/Madam,

Re: Objection to Planning Permit PLN/2022/354

I am writing to formally object to Planning Permit PLN/2022/354 on the grounds of significant concerns regarding access to my property, my in-laws next door and the safety and well-being of my family and community members. The proposed development poses critical issues that must be addressed to ensure continuous, unhindered access to the slip lane of Robertson Street leading to my residence.

#### Access Concerns and Health Requirements

Our household includes young children, as well as next door [REDACTED] our mother [REDACTED] and father [REDACTED] as well as our 96-year-old grandmother all with significant health concerns. It is imperative that we maintain unobstructed access to our property at all times to accommodate any potential emergencies. The presence of my elderly grandmother necessitates frequent visits from healthcare providers and, in some cases, emergency services. Any hindrance in access could have severe consequences for her health and well-being.

#### Kindergarten Access

Additionally, the Robertson Street slip lane also serves as an access route to a nearby kindergarten and maternal health care clinic. It is crucial for the safety and convenience of parents, children, and staff that this route remains clear and accessible. Interruptions due to construction activities could disrupt the daily routines of many families and potentially endanger the children attending the kindergarten.

#### Emergency Services Accessibility

Given the health needs of my parents and grandmother, it is essential that emergency services have unrestricted access to our property at all times. Delays caused by construction activities could have life-threatening implications. Therefore, it is vital to ensure that any development plans include provisions for continuous emergency access.

#### Construction and Traffic Management Plans

The proposed building project appears to be extensive and may take a considerable amount of time to complete. Prior to considering the withdrawal of this objection, I request the submission of both a Construction Management Plan (CMP) and a Traffic Management Plan (TMP). These plans must demonstrate detailed measures to ensure that access to our property and the kindergarten is maintained without disruption throughout the entire construction period. Specifically, these plans should outline the following:

1. Access Routes: Clear designation of alternative routes for residents and emergency services if the slip lane access is temporarily obstructed.
2. Timetable: A detailed construction schedule with specific times and dates when access might be impacted, along with measures to mitigate these disruptions.
3. Communication: Regular updates and direct communication channels between the construction management team and affected residents to address any arising concerns promptly.

In conclusion, while we recognize the importance of development and progress, it must not come at the expense of the safety, health, and convenience of current residents. I urge the planning department to consider these critical points and ensure that appropriate measures are put in place to mitigate the impact on our community before approving Planning Permit PLN/2022/354.

Thank you for your attention to this matter. I look forward to your prompt and favorable response.

Yours sincerely,

27



**SUBMISSION 16**

Dear Council

I refer to the article Crunch time for Gisborne hospital site on page 5 of the Gisborne Gazette July 2024.

I note the council concerns regarding the rezoning of the land that was donated to Gisborne by what appears to be the very generous Dixon family. The donation came with an agreement that the land always be used for medical purposes.

I note councils concerns regarding the morality of rezoning the land and their view that it was unlikely that the new hospital would be built in Gisborne, and therefore the practicality of making the area available for residential use outweighed the act of overriding the family's wishes. I consider this view to be premature in that it could possibly influence the public during a consultative process.

I make the following points:

- Used for medical purposes does not mean a hospital would have to be built on that land.
- Has there been any consultation between Council and the Dixon family (or their descendants) that would support removal of the Special Use zone.

I understand we must progress with our evolving changes and therefore it may be appropriate to make changes of this nature, but you must first deal with the noted morality issue of possibly withdrawing from an agreement that was made as part of a gift to the Gisborne community. At a minimum, consultation and the blessing of the Dixon descendants should be made before there is any suggestion of Council supporting such change.

I would appreciate if you could keep me informed of any progress on this matter.

Regards



**SUBMISSION 17**

---

**Sent:** Friday, July 12, 2024 12:32 PM  
**To:** Strategic Planning <strategicplanning@mrsc.vic.gov.au>  
**Subject:** Submission for permit PLN/2022/354

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Attn: Strategic Planning

Good afternoon MRSC

I write to you in regards to permit number PLN/2022/354.

In the first instance I oppose the application to rezone the land at Robertson Street, Neal Street and Hamilton Road from Special Use Zone to General Residential Zone.

This land was donated by the Daly family for use as a hospital or medical facilities, and this request/instruction should not be disregarded.

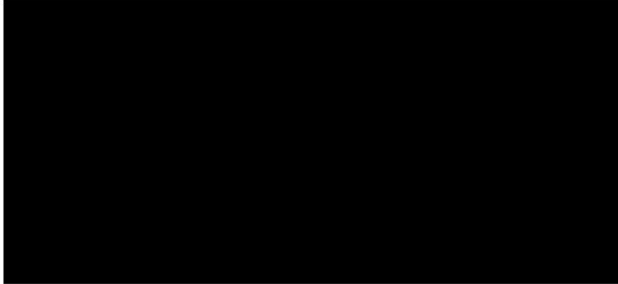
Gisborne is a growing town with a large number of new estates with young families. As someone with a young son, when medical assistance is required after business hours, the nearest hospital that has doctors on duty (Bacchus Marsh Hospital, Kyneton Hospital only has nurses after hours) is over 30 minutes away, on a back country road that is in poor state and dangerous to drive especially in the dark let alone wet weather. Macedon Ranges Shire Council should not approve this application and ensure that this land is kept free for a future hospital or medical clinic to be built.

However, if the permit is approved and the land is rezoned, as a landowner that backs onto the land in question, I oppose the amount of retirement units that has been proposed to be built. If the land is being rezoned to accommodate persons that do not require medical assistance, there needs to be more open/green spaces and less retirement units being built and no two storey units along the fence line that backs onto existing home owners.

The permit application speaks to each unit having car spaces available, as a



landowner in this area, Hamilton Street and Neal Street are already congested at all times without the extra traffic that this retirement village would bring. The infrastructure surrounding the development would need to be expanded for this extra traffic.



**SUBMISSION 18**

**Sent:** Friday, July 12, 2024 4:42 PM

**To:** Strategic Planning <strategicplanning@mrsc.vic.gov.au>

**Subject:** PLN/2022/354

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

RE: Gisborne Hospital Site.

Good Afternoon,

As an owner/occupier on Hamilton St., the following clarifications/considerations are kindly put forward:

- Early Childhood Centre (Manna Gum) has an established block level. The current plan does not consider the existing established level already set by the Child Centre. It is reasonably expected that this level would be consistent from an aesthetic, drainage and privacy perspective for the Child centre. This level of consideration should be for all blocks accessing Road05, Road04 and Road 03. In other words: this should be the level for proposed development.
- Service Lane on Robertson Rd should be wide enough for Public Transport (given this is for the elderly residents who may / may not be mobile, in keeping with accessibility/carbon design considerations.
- Road05, Road04 and Road 03 should be wide enough for Public Transport (given this is for the elderly residents who may / may not be mobile, in keeping with accessibility/carbon design considerations.
- At the junction of Robertson Rd / Hamilton St consideration for a roundabout or speed reduction device to allow for safe enjoyment of the adjoining parks. Further to this, no crossing is mentioned (even in passing). There are many trucks who use Bacchus Marsh / Gisborne Road (C704) and given the demographics of the residents this requires consideration.
- Given the number of existing medium-density housing adjacent to Road05 reduction of the density of RV along south boundary. This is to ensure ample access to light and existing enjoyment of natural surroundings and space. Given these residents did not purchase "affordable housing" with a medium-density footprint



across an entire block (just a small strip was medium density). Whilst greater good is a compelling argument, given the size of the space this nonetheless takes away from the existing feel and initial intent of the design overlay for these residents.

Thank-you

[REDACTED]

[REDACTED]

**SUBMISSION 19**

[REDACTED]

To: Strategic Planning <[strategicplanning@mrsc.vic.gov.au](mailto:strategicplanning@mrsc.vic.gov.au)>

[REDACTED]

**Subject:** re Amendment 147macr. Planning Permit Application PLN/2022/354

Good Afternoon,

We would like to strongly object to the proposal to rezone the Gisborne Bush Nursing Hospital site from Special Use to Residential.

The [REDACTED] family, and its' descendants, have lived in the area for over 180 years. Anne, was amongst the first to be born at the 6 bed hospital in 1959 and was also fortunate to give birth to her son there in 1996 before it closed 1997. Over the years it was a blessing to have the hospital services available and widely used.

The land was donated to the Community by the generous Humphrey Dixon who was able to foresee the growth of the town and need to provide essential health services to support the community. The hospital was built without any Government funding and was a credit to the strong, loyal and resourceful community at the time. I feel that Council are taking advantage of the majority of Gisborne's current population being unaware of the history surrounding this matter. Only the long standing members of the community will know, understand and appreciate the historical significance of the gift bestowed to us. The community have been grateful for Mr Dixon's foresight and incredible generosity and have always been aware of the condition of the bequest that the land was always to be used for medical purposes.

We are at a loss to understand how Council think they can override this clear stipulation of how the land is to be used. You have no right to ignore the clear direction given by the Dixon family regarding the specific use of the site. It is morally and ethically unsound as well as potentially illegal. If the site is not to be used as intended then the land should be given back to the family.

The population of the Gisborne area is predicted to be over 65000 within the next 12 years, far exceeding even the foresight of the Dixon family. Council's inference that there will not be a need for a hospital in the future seems naïve. Given this projected growth, it is clearer than ever that more health and allied health services will be needed to support our expanded community. What better place to locate them but on this site.

With regard to Benetas wanting the site for their Residential Retirement Village, of course they do! Free land in the heart of the town that they will use to prosper from financially!

We hope that the Dixon family's generosity will not be disregarded and that the sight will remain, as intended, for medical facilities and an asset for future generations.

Yours Sincerely

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



**SUBMISSION 20**

**To:** Strategic Planning <strategicplanning@mrsc.vic.gov.au>  
**Subject:** Amendment C147macr. PLN/2022/354 - objection

**CAUTION:** This email originated from outside of Council. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear MRSC,

I am vehemently opposed to the rezoning of this parcel of land.

This land was donated by the Dixon family to the community of Gisborne explicitly for medical reasons.

If it ceases to be used for medical purposes, then the land should be returned to the descendants of the Dixon family.

The bush nursing hospital grounds is the final resting place of Muriel Joan Daly who was a major contributor and supporter of the hospital, a plaque which notes this has been removed by the current owner - a photograph is attached.

Please refuse this application to rezone the land against the purpose of the original donation.



**SUBMISSION 21****Objection to rezoning****Amendment C147macr.****Planning permit application PLN/2022/354**

Address: former hospital site, Hamilton Street and Neal Street, Gisborne.

12 July 2024

**I wish to lodge my objection to this land being rezoned Residential, on two grounds: 1) the land was given to the community on the proviso that it always be used for community health purposes; and 2) there is no demonstrated need for further housing of the type proposed for the site.**

**1. The zoning change sought from Special Use to General Residential overrides the wishes of the family who donated the land. It was donated to the people of Gisborne – and accepted by the council on their behalf – on the specific condition that the land always be used for medical purposes. It goes against basic morality to override the family's wishes, particularly when there is no need to do so.**

- After the hospital closed in 1997, the building was used for over 20 years for doctors' surgeries and allied health. Those doctors moved in 2021 only after the landholder (Benetas) evicted them. Another small building on the site remained in use by a weekly specialist youth clinic until Benetas shut the clinic down in 2024.
- In its deliberations on whether to support rezoning, the council on balance decided it did not believe a new hospital would ever be built in Gisborne. This is not an evidence-based belief. For example (1) when the Sunbury hospital closed a decade or so ago, community lobbying led to the establishment of a day hospital in Sunbury.  
(2) In 2022, a state government funded program to build community hospitals in growth areas was announced. While Gisborne was not included in the 2022 program, it does show that regional community hospitals are at various times exercising the state government mind, and as growth continues in the Gisborne area, there is no basis to claim there will never be a hospital built here.  
As a growing population in the Gisborne area will require more and more medical services, facilities such as long-hour superclinics, a day hospital, potentially a full hospital, could well be prescribed by government. There is already a move to locate emergency medical services in regional areas in the hope of reducing the burden on the major hospitals in Melbourne. There is currently one in Sunbury and one in Melton. The government is looking for more clinics to join this program. There is no reason to believe, given the critical issues that everyone knows exist in the metropolitan hospitals, that this push will not become stronger and more urgent in the years to come.

This land is a well-sited, central spot for a hospital or large emergency clinic, and in the meantime can be used for medical clinics and allied health as it was before the applicant closed them down.

The land was given to the Gisborne community by the Dixon family, who were important figures historically in the township and part of the community for over a century. They had a business in the town since 1861, and over several generations showed their public-spirited nature, serving on the council; contributing to the purchase of 4 acres in 1927 for forestry purposes/bird sanctuary to aid



the secondary school; donating land which is now the sportsground (Dixon Field) in Gisborne; and donating the land which is the subject of this application. Gisborne owes an enormous debt of gratitude to the Dixon family for their generosity and community spirit. This family clearly were concerned that the whole community, into the future, should be the beneficiaries of their gift and it is repugnant in the extreme to consider dishonouring their wishes and the condition on which they gave their land to this community.

**2 There is no demonstrated need for more housing in Gisborne.** There is a great deal of development currently taking place. There are two developments of several hundred houses already in progress in South Gisborne, and another new development of I believe 800 houses is just about to turn the first sod. There are any number of unit developments that are generally between four and eight units occurring in the older parts of town on larger blocks that formerly had only one house on them. There is at least one other retirement village complex under consideration by the council in South Gisborne. The Retirement Village housing type is restrictive in any case, being age-limited to over-50s. The proposed development will do nothing to help the younger demographic that we hear so much about who are struggling to get into the housing market across the entire country, or indeed to cater for the clear need for affordable housing for families across the entire country.

If this rezoning is approved, the community of Gisborne loses something of enormous value to the community at large, and gets something in return which does not assist the community in general, but is targeted to a small, specialised segment of the population.

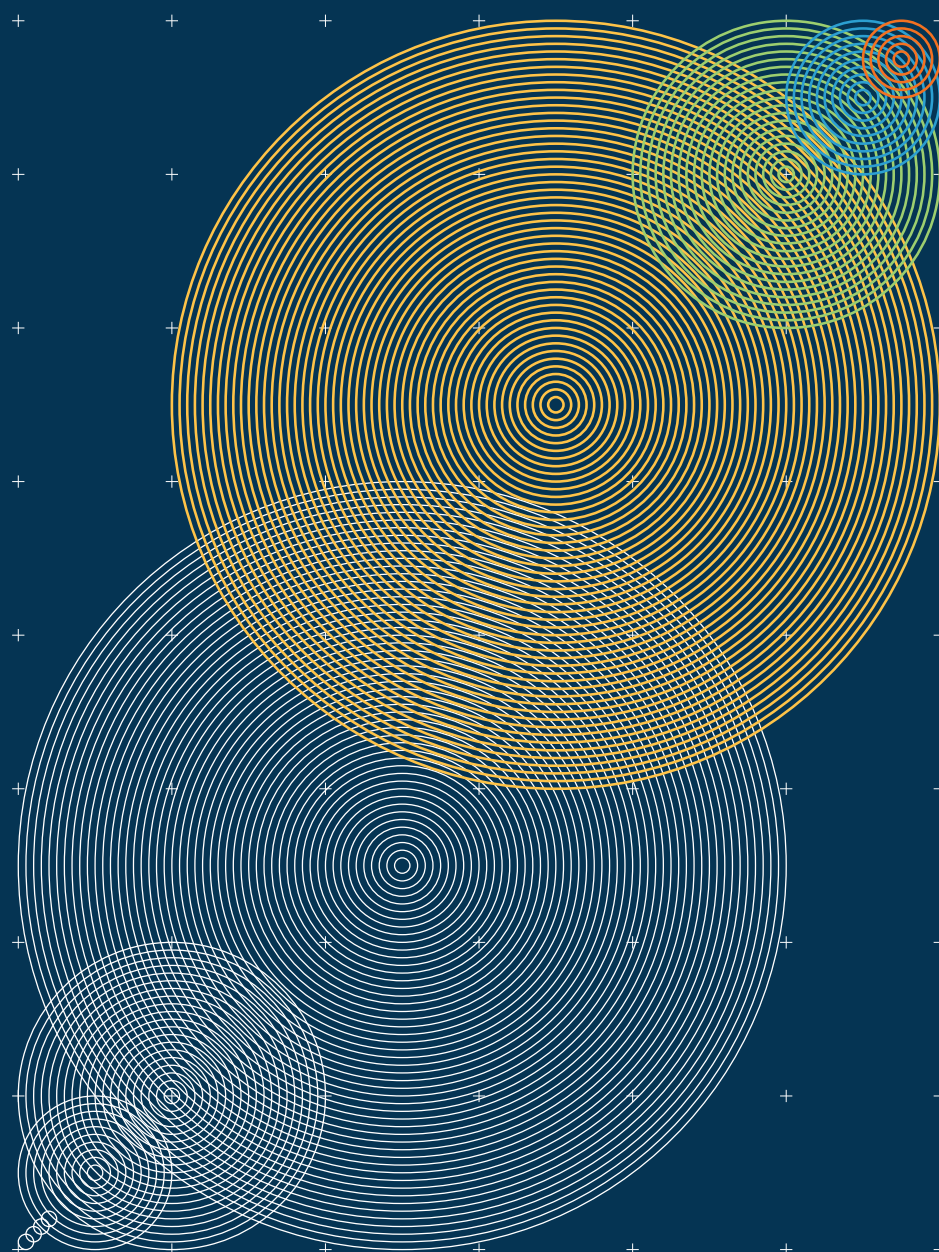
██████████  
██████████████████  
██████████  
██████████

# **Election report**

## **Macedon Ranges Shire Council**

### 2024 Local government elections

April 2025





**Letter of Transmittal**

14 April 2025

Mr Bernie O'Sullivan  
Chief Executive Officer  
Macedon Ranges Shire Council  
PO Box 151  
Kyneton VIC 3444

Dear Mr O'Sullivan

Pursuant to Regulation 83 of the Local Government  
(Electoral) Regulations 2020, I submit this report to the  
Chief Executive Officer of Macedon Ranges Shire Council  
on the general election held in October 2024.

Yours sincerely



**Sven Bluemmel**  
Electoral Commissioner

**Acknowledgement of Country**

The Victorian Electoral Commission (VEC) acknowledges the Aboriginal and Torres Strait Islander people of this nation, as the traditional custodians of the lands on which the VEC works and where we conduct our business. We pay our respects to ancestors and Elders, past, present, and emerging. The VEC is committed to honouring Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to society.

**Election report**  
**Macedon Ranges Shire Council**  
2024 Local government elections



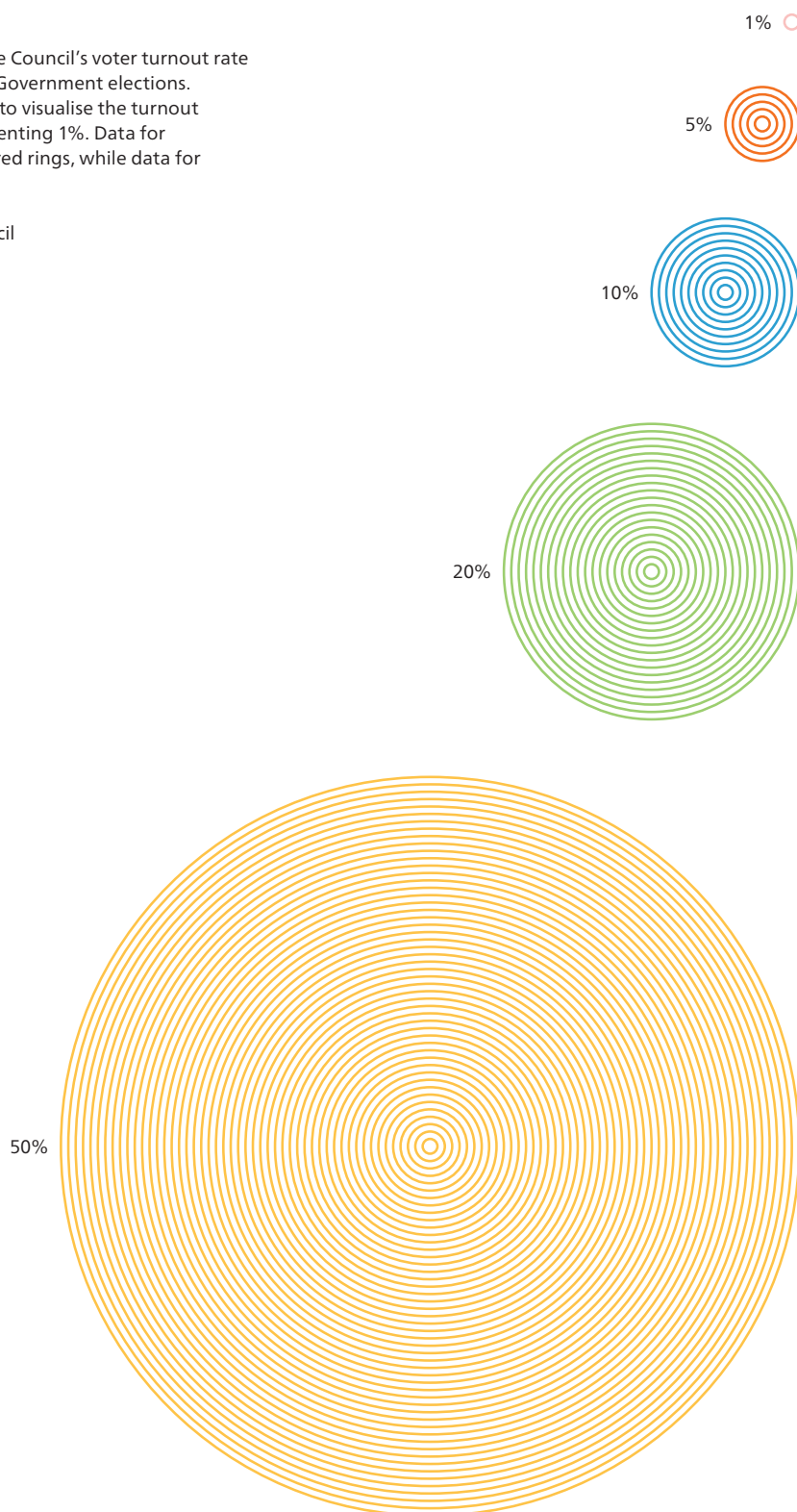
**Voter turnout (front cover)**

Graphic representation of the Council's voter turnout rate for the 2024 and 2020 Local Government elections. Rings are grouped into units to visualise the turnout percentage, each ring representing 1%. Data for 2024 is depicted using coloured rings, while data for 2020 is shown in white.

Macedon Ranges Shire Council

Turnout (2024): 84.82%

Turnout (2020): 84.35%



## Contents

1. Introduction .....	5	Appendix 7:	
2. Key changes.....	6	Daily breakdown of the general mail out.....	44
3. Election dates.....	7	Appendix 8: Result information.....	45
4. About Macedon Ranges Shire Council.....	8	Appendix 9: Election participation statistics.....	47
5. Voters' roll.....	9	Appendix 10: Complaints.....	50
6. Advertising and communication campaign .....	10		
7. Election manager .....	12		
8. Election office .....	13		
9. Candidates.....	14		
10. Voting.....	15		
11. Return of ballot paper envelopes.....	16		
12. Results.....	17		
13. Election statistics .....	18		
14. Complaints.....	19		
15. Post-election activities.....	20		
16. Non-voter follow up.....	21		
17. Evaluating VEC services.....	22		
<b>Appendices.....</b>	<b>23</b>		
Schedule 1:			
Record of ballot papers and declaration envelopes.....	23		
Schedule 2: Certification statement.....	26		
Appendix 1: Breakdown of the voters' roll.....	27		
Appendix 2: Public notices .....	28		
Appendix 3:			
Schedule of media releases and advisories.....	33		
Appendix 4: VoterAlert advisories .....	35		
Appendix 5:			
Voter engagement program and initiatives .....	38		
Appendix 6:			
Final list of candidates in ballot paper order .....	39		





## 1. Introduction

The Victorian local government general elections are held every 4 years as set out in the *Local Government Act 2020* (Vic) (**LG Act**). In 2024, general elections were held for 78 of the 79 Victorian councils with Saturday 26 October marking election day. In accordance with section 263(1) of the LG Act, the Victorian Electoral Commission (**VEC**) is the statutory election service provider for the conduct of local government elections in Victoria.

This report provides information on the 2024 Macedon Ranges Shire Council general election including details of the end-to-end service delivery of electoral activities throughout the election timeline. This report also provides details of post-election activities including compulsory voting enforcement.

### About the Victorian Electoral Commission

The VEC is an independent statutory authority established under the *Electoral Act 2002* (Vic) (**Electoral Act**). The VEC's principal functions are to conduct State elections, local government elections, certain statutory elections and polls, commercial and community elections, and to support electoral representation processes for local councils and the Electoral Boundaries Commission for State electoral boundaries. The VEC is also responsible for maintaining the Victorian register of electors and administering political funding and donation disclosure laws. The VEC has a mandated role to conduct electoral research, provide communication and education services, and inform and engage Victorians in the democratic process.

Sven Bluemmel is the appointed Electoral Commissioner and Dana Fleming is the appointed Deputy Electoral Commissioner. The Electoral Commissioner and Deputy Electoral Commissioner report to the Victorian Parliament in relation to the VEC's operations and activities.

The Electoral Commissioner heads the VEC's Executive Management Group that comprises the Deputy Electoral Commissioner, the Executive Director, Corporate Services and 7 Directors, each leading the main functional areas of the VEC. Each Director acts as subject matter experts and oversees legislative responsibilities under the LG Act and the Electoral Act.

The VEC has a dedicated local government election program framework that incorporates a range of programs, projects and activities that are supported through strategic planning, project management, and process mapping. The program is overseen by the VEC's Delivery Group and has sponsorship from the Executive Management Group.



Key changes

Macedon Ranges Shire Council

## 2. Key changes

### Changes in legislation

The *Local Government Amendment (Governance and Integrity) Act 2024* (Vic) received royal assent on 25 June 2024 and introduced a number of changes to local government electoral legislation.

The VEC implemented the necessary changes to the 2024 local government election program in response to the reforms as they applied to the elections.

---

#### Key changes from *Local Government Amendment (Governance and Integrity) Act 2024*

---

Close of roll	<p>The date for the close of roll was extended from 57 days to 80 days before the election. For all elections after the October 2024 general elections, including by-elections, the date for the close of roll will be 73 days before election day.</p> <p>The previous timelines were no longer viable due to an increase in the scale and complexity of local government elections, including changes to enrolment entitlements, population growth, higher number of wards, likely increase in the number of candidates, and reduction in mail services offered by Australia Post.</p> <p>By moving this date earlier, other key dates including nomination day, the lodgement date for candidate statements and questionnaires, and the period for mailing out of ballot materials have been brought forward through the <i>Local Government (Electoral) Regulations 2020</i> (Vic) (<b>LG Regulations</b>) providing more time to ensure they are sustainable.</p>
Certification of the roll	<p>The timeframe for roll certification was increased to 23 business days (previously 13 business days) to ensure CEOs (or their delegates) and the VEC have adequate time to process enrolment applications and complete related roll certification processes.</p>
Candidate statement word limit	<p>In response to the pandemic, the LG Regulations permitted candidate statements to be increased from 200 to 300 words for the 2020 local government elections, acknowledging that candidates at the 2020 elections would face restrictions in campaigning.</p> <p>As candidates would no longer face pandemic-based barriers to campaigning activities, the word limit was reverted to 200 words. Equivalent amendments were also applied to the <i>City of Melbourne (Electoral) Regulations 2022</i> (Vic).</p> <p>Returning to the original word limit allowed the VEC to produce smaller candidate statement booklets, reducing associated printing costs and administrative burden.</p>
Rejection and amendment of candidate statements	<p>The time allowed for a candidate to amend their statement was reduced by one day to now be the day after the close of nominations (or 38 days before election day). This aligned the periods for rejections and amendments with the earlier deadline for lodging a candidate statement, allowing additional time to print ballot packs.</p>
Close of candidate statements, photos and questionnaires	<p>The deadline for submitting a candidate statement, photograph and questionnaire was amended to close the same day as the close of nominations at 12 noon, facilitating a more efficient process for candidates and allowing the VEC more time to print ballot packs.</p>
Mailout of ballot pack	<p>The timeline for conducting the mailout of ballot materials was extended from occurring over 3 business days to 4 business days, allowing the VEC to manage the risk of mail service level reductions and provide additional safeguards against election fraud.</p>

---

Macedon Ranges Shire Council

Election dates

### 3. Election dates

---

**Key timelines for the 2024 local government elections**

---

Deadline fixed by the VEC for council primary enrolment data	Monday 15 July 2024
Close of roll	4 pm Wednesday 7 August 2024
Opening of the election office to the public	Monday 9 September 2024
Certification of the voters' roll and opening of nominations	Monday 9 September 2024
Close of nominations	12 noon Tuesday 17 September 2024
*Deadline for lodging candidate statements, photographs and questionnaires	12 noon Tuesday 17 September 2024
*Ballot draw	From 10 am Wednesday 18 September 2024
*General mail out of ballot packs to voters	Monday 7 October to Thursday 10 October 2024
*Close of voting	6 pm Friday 25 October 2024
Day prescribed as Election Day	Saturday 26 October 2024
*Close of extended postal vote receipt period	12 noon Friday 1 November 2024
Declaration of election results	No later than Friday 15 November 2024

---

\*Dates with asterisks relate to contested elections only.



About Macedon Ranges Shire Council

Macedon Ranges Shire Council

## 4. About Macedon Ranges Shire Council

Macedon Ranges Shire Council is comprised of 9 councillors elected from a subdivided structure.

The structure was last reviewed in accordance with the *Local Government Act 1989* through an electoral representation review in 2011.

Figure 1: The electoral structure of Macedon Ranges Shire Council at the general election held on 26 October 2024.



Macedon Ranges Shire Council

Voters' roll

## 5. Voters' roll

The VEC prepared the voters' roll for the election under section 8(2)(c) of the Electoral Act and in accordance with section 249 of the LG Act. The close of roll for the election was 4 pm on Wednesday 7 August 2024. Pursuant to section 249(4) of the LG Act, the VEC certified the voters' roll on Monday 9 September 2024.

At certification, the voters' roll for the 2024 Macedon Ranges Shire Council general election included 39,169 enrolled voters.

### Composition of the voters' roll

Section 249 of the LG Act specifies that the voters' roll for a local government election is formed by combining 2 separate lists of voters:

1. The Electoral Commissioner's list (EC list) – list of State electors that are enrolled within that local government area.
2. The Chief Executive Officer's list (CEO list) – list of council-entitled voters.

Refer to **Appendix 1** for a breakdown of the Macedon Ranges Shire Council general election voters' roll.

### Amendments to the voters' roll

In accordance with section 250 of the LG Act, the VEC is able to amend any error or omission in the preparation, printing or copying of the voters' roll, or correct any misnomer or inaccurate description of any person, place or thing on the voters' roll. Amendments to the voters' roll are to be certified by the VEC.

All voters added to the roll were issued with a ballot pack. Where a voter was removed from the roll after the mail-out of ballot material, the VEC had systems in place to ensure that returned ballot papers from the deleted voters could be identified and excluded from the extraction and count. Where roll amendments were required, the total number of voters on the roll was updated.

Following the close of roll, no amendments were required to the council's voters' roll.



## 6. Advertising and communication campaign

### State-wide advertising

The VEC delivered a state-wide advertising campaign to maximise public awareness and participation amongst all eligible voters. Campaign activities and consistent messaging were delivered across 2 phases – enrolment and voting – and through multiple traditional and emerging mediums, including radio, digital and social media, and offline/outdoor advertising.

### Public notices

The VEC published a series of public notices on the VEC website throughout the election as required by the LG Act. The notices included critical information relevant to each milestone of the election timeline.

For the 2024 general election, Macedon Ranges Shire Council nominated the following newspapers for the public notices:

- › Sunbury and Macedon Ranges Star Weekly
- › North Central Review
- › Midland Express

Refer to **Appendix 2** for further information in relation to the public notices.

### VEC website

The VEC provided council specific information regarding the election on its website. The VEC website went live for the local government elections in early July 2024. Whilst some council-specific data remained static during the election, the website was regularly updated with content relevant to the election and at each key milestone such as close of roll, nominations, voting and results.

### Media liaison

An online media briefing was held on Monday 29 July 2024. The briefing was made available to view on the VEC website for media representatives unable to join the live event. The media briefing provided an overview of the planning, timeline, legislative changes and other key information for the 2024 local council elections.

Media outlets were provided with a media handbook that outlined the election timeline and key information, and provided the VEC's head office media contacts. This was made available along with other resources from the VEC's media centre webpage. The VEC's

communication team supported each election manager with managing media interest locally in their council area.

The VEC's media liaison program principally featured scheduled state-wide and tailored council-specific media releases aimed at highlighting key milestones during the election and capitalise on existing general news coverage.

More information on the VEC's media release schedule is available at **Appendix 3**.

The media program also involved a responsive media enquiry service, as well as the translation and distribution of 3 key media releases for multiple non-English news outlets in Victoria.

### Social media campaign

As part of its state-wide advertising campaign, the VEC used paid promotions on social media platforms including Facebook, Instagram, Snapchat, TikTok and WeChat, targeting voters through audience segmentation.

This advertising was supported by a defined timeline of organic social media posts on the VEC's channels, designed to cover each of the key messages of the communication campaign to further extend the reach to the community and promote conversation about the democratic process.

### VoterAlert advisories

State-enrolled voters can sign up to VoterAlert, our free SMS and email service, to receive reminder messages about elections that affect them. They can subscribe to messages via SMS, email, or both.

During the general election, we used VoterAlert to send direct messages on:

**Wednesday 17 to Wednesday 31 July 2024 –**  
22,889 voters were contacted by VoterAlert messages sent by SMS and/or email reminding voters to enrol or update their details by the close of roll.

**Monday 7 October to Monday 14 October 2024 –**  
23,073 voters were contacted by VoterAlert messages sent by SMS and/or email advising that we had commenced posting ballot packs.

**Tuesday 22 October to Wednesday 23 October 2024 –**  
15,130 voters were contacted by VoterAlert messages sent by SMS and/or email reminding voters that it was the last week to post their ballot material back to us.

More information on VoterAlert is available at **Appendix 4**.

Macedon Ranges Shire Council

Advertising and communication campaign

### **Voter engagement**

The VEC delivered an extensive voter engagement program throughout Victoria, specific to local demographics.

A total of 348 telephone calls were recorded for Macedon Ranges Shire Council during the 2024 local government elections. An overall total of 11,758 email queries were received for all councils.

**Appendix 5** contains the full list of initiatives for the 2024 local government elections.

### **Democracy ambassadors**

The VEC delivered education sessions conducted by our Democracy Ambassadors to a range of councils. The sessions focused on enrolment and voting for the election. These sessions were offered to councils in priority areas and delivered at no cost to council. Where resourcing allowed, requests for sessions that were not in the priority area were also fulfilled.

One session was delivered for the Macedon Ranges Shire Council election.

### **Blind and low-vision services**

Braille and large print ballot material was available to blind and low-vision voters who registered for these products by 5 pm on Tuesday 17 September 2024.

The VEC received and processed 3 requests for braille ballot material and 2 requests for large print ballot material for Macedon Ranges Shire Council.

### **Interpreting services**

The VEC engaged the Victorian Interpreting and Language Services' Language Loop to provide a telephone interpreting service for telephone enquiries from voters who had a first language other than English. The VEC advertised direct lines for 20 languages other than English and a general line for all other languages.

### **Public enquiry service**

A centralised contact centre was established to respond to telephone public enquiries. This ensured consistency in messaging, early identification of themes and trends along with the opportunity to enable election offices to focus on election administration. The call centre was also responsible for emails received during the local government elections. Any calls regarding CEO list applications were referred to the relevant councils. Outside the call centre hours of operation, a recorded service was available that provided information on enrolment and voting.

Election offices fielded phone queries from local candidates on issues directly related to their candidacy (as separate to general queries about running as a candidate).



Election manager

Macedon Ranges Shire Council

## 7. Election manager

The VEC maintains a pool of trained senior election officials from across Victoria to fill election management roles for State and local government elections. Election-specific training is provided to senior election officials before they are appointed for each election.

The size of election management teams depends on the size of the council. Under the LG Act, an election manager is appointed to conduct each council's election and is supported by one or more assistant election managers.

In accordance with regulation 21(1) of the LG Regulations, the VEC appointed Kate Daniel as the election manager for the 2024 Macedon Ranges Shire Council general election.

The appointed assistant election manager was Leisa Macartney.

Macedon Ranges Shire Council

Election office

## 8. Election office

The election manager was responsible for establishing and managing the election office at Woodend Community Hub, 49 Forest Street, Woodend. The premises were provided by the Council.



## 9. Candidates

Nominations opened at 9 am on Monday 9 September and closed at 12 noon on Tuesday 17 September 2024. Candidates were required to lodge their nomination forms in person at the election office. The nomination fee was \$250.

### Candidate information

The VEC developed resources to support prospective candidates with the nomination process, including a candidate handbook. From mid-July, candidates could access information about nominating as a candidate for the election. The online Candidate Helper, accessible via the VEC website, went live on Tuesday 20 August 2024. Candidate Helper enabled candidates to complete most of their nomination forms and other forms online before lodging them in person with the election manager.

For the Macedon Ranges Shire Council 2024 elections, the VEC's candidate information session was delivered in person by the election manager. Additionally, a candidate information video was available on the VEC website from Tuesday 20 August 2024.

### Nominations

At the close of nominations, 20 candidates had successfully nominated for the elections, which includes any candidates who retired after the close of nominations. Candidates who withdrew before the close of nominations are not included.

The following is a breakdown of candidate nominations per ward:

- › East Ward - 7 nominations
- › South Ward - 5 nominations
- › West Ward - 8 nominations

Ballot draws to determine the order of the names on the ballot paper were held at the election office following the close of nominations using the VEC's computerised ballot draw application.

See **Appendix 6** for the list of candidates in ballot draw order.

### Candidate statements and photos

In accordance with regulation 39 of the LG Regulations, candidates were able to submit a 200-word statement and a recent photograph for inclusion in the ballot packs sent to voters. The deadline for these items was 12 noon on Tuesday 17 September 2024.

See **Appendix 6.1** for a breakdown of submitted statements and photos and **6.2** for sample ballot material.

### Candidate questionnaires

In accordance with regulation 43 of the LG Regulations, candidates could also submit answers to a set of prescribed questions. The election manager accepted questionnaires from 19 of the 20 candidates at the election.

Voters could read the completed questionnaires on the VEC website or access them by contacting the election office.

### Retirement of a candidate

In accordance with the LG Regulations, at any time after the close of nominations and before election day, a candidate may retire, or be retired by the VEC. A candidate can only retire if it will result in an uncontested election or if they are not qualified to be a Councillor. If the VEC believes a candidate was not entitled to nominate, it must formally query the candidate's qualification and invite written reasons why they are entitled. If the VEC remains satisfied that the candidate is not entitled, it must retire the candidate from the election.

When a candidate is retired from an election, the VEC is required to take all practicable steps to remove the retired candidate's name from ballot papers. If it is not practicable to do so, during the counting of votes the retired candidate's votes are passed on to other candidates according to voters' preferences.

There were no candidate retirements at the Macedon Ranges Shire Council elections.

## 10. Voting

### Ballot pack preparation and redirection

Artwork for ballot papers and candidate statements is generated using the VEC's automation tool. This tool selects from a range of pre-defined artwork templates and populates them with the relevant candidate information directly from the VEC's election management system database.

Following an extensive quality assurance process, print-ready artwork files were securely transmitted directly to the VEC's contracted ballot material printer ready for production. The VEC's contracted mail house directly printed the voters' addresses (mailing and entitlement address) and barcodes on the ballot paper envelopes in preparation for assembly and delivery of ballot packs. The VEC utilised multiple third party providers to assemble the ballot packs prior to the mail house lodging with Australia Post. The mail house allocated a secure area within its operations that was used solely for the printing, insertion, and dispatch of ballot material. This ensured the highest standards of security were met.

Electors could apply to have their ballot material redirected to an address other than their entitlement address. Voters had until the certification day for the voters' roll (also the day that nominations open) to apply for their ballot material to be redirected. The VEC arranged for ballot material to be delivered to any voter applying for redirection to the address specified in their request. For the 2024 local government elections, voters had until Monday 9 September 2024 to submit redirection requests.

The election manager received 17 requests for redirection of ballot packs for the election.

### Early votes

Voters could request an early postal ballot envelope (early vote) before the general mail out of ballot packs. The election manager processed requests and issued early votes where the request was assessed as reasonable. Requests for early votes could be processed from Wednesday 18 September 2024, the day after nominations closed, until the start of the general mail out of ballot packs on Monday 7 October 2024.

Due to the timing of early votes, some early voters may not have had access to the candidate statements, photographs or questionnaires.

The election manager issued a total of 23 early votes for the election.

### Mail-out of ballot packs

The VEC mailed 39,168 ballot packs between Monday 7 and Thursday 10 October 2024.

See **Appendix 7** for a breakdown of the packs sent on each day of the general mail out. The VEC did not mail ballot packs to voters who passed away between the close of roll and generation of the mail-out file.

This included 17 ballot packs which were redirected to alternative addresses for voters who had applied to redirect their ballot pack by Monday 9 September 2024.

In accordance with regulation 49(3) of the LG Regulations, no more than 35% of ballot packs were mailed or delivered to voters on any one day during the mail-out period. All ballot packs were lodged with Australia Post under the priority paid delivery timetable.

The VEC liaised closely with Australia Post during the mail-out period to confirm that ballot packs had been delivered to voters. Australia Post confirmed all ballot packs had been delivered by Tuesday 15 October 2024.

During the voting period, 834 ballot packs were returned to the election office by Australia Post as return-to-sender mail. In most cases, this was likely due to the addressee no longer residing at the address.

### Unenrolled votes

The election manager issued unenrolled votes to people whose names could not be found on the voters' roll but said they were entitled to vote at the election. The unenrolled ballot pack included a declaration for the voter to sign. The election manager assessed the declaration and decided to admit or disallow the vote.

The election manager issued 4 unenrolled votes and following relevant checks, none were admitted to the count.

### Replacement ballot packs

Following the general mail out of ballot packs, a voter who claimed that their ballot pack had not been received, or had been lost, spoiled, or destroyed, could apply for a replacement vote by completing an online application form or contacting the public enquiry service.

A centralised team processed applications and mailed replacement ballot packs to the postal address provided. Voters also had the option to attend the election office in the council for which they hold entitlement, to have a replacement vote issued over the counter.

1,151 replacement ballot packs across all wards during the voting period were issued. Please refer to **Schedule 1** for further information on replacement ballot packs issued.



Return of ballot paper envelopes

Macedon Ranges Shire Council

## 11. Return of ballot paper envelopes

VEC provided voters with a priority reply paid envelope to return their completed ballot paper and ballot paper envelope. The return mail was delivered to the election office from local postal facilities or mail distribution centres. Voters could also put their ballot papers and envelope in a ballot box at the election office.

As ballot paper envelopes were returned, they were progressively checked by the election manager to ensure they had been signed by the voter. Additionally, processes were in place to ensure that only one returned ballot paper from any one voter could proceed to the extraction and count.

The election manager received a total of 28,675 returned ballot paper envelopes across all wards by the close of voting at 6 pm on Friday 25 October 2024.

In accordance with regulation 57(3) of the LG Regulations, the election manager could accept returned ballot paper envelopes until 12 noon on the Friday following the close of voting, if they thought the voter had signed the envelope before voting closed.

The election manager accepted 5,467 ballot paper envelopes across all wards during the extended postal vote receipt period.

The total returned ballot paper envelopes for Macedon Ranges Shire Council was 34,142.

The election manager set aside 770 returned ballot paper envelopes that were not admitted to the extraction and counting process due to the voter not having signed the declaration envelope or, in the case of unenrolled declaration votes, an entitlement was not found for the person, or the declaration envelope was not returned with the vote.

Refer to **Schedule 1** for the total certified record of ballot papers and declaration envelopes across all wards for Macedon Ranges Shire Council.

## 12. Results

### Extraction

The extraction process involved separating the declaration flaps containing voters' details from each admitted ballot paper envelope, and then extracting the ballot papers from the envelopes. This 2-stage process maintains anonymity and ensures the VEC can track the number of envelopes for ongoing reconciliation.

A total of 33,372 ballot paper envelopes were admitted to the extraction process.

Ballot papers were extracted at the election office from Thursday 31 October 2024. The extraction of all admitted ballot paper envelopes was completed on Wednesday 6 November 2024, following the close of the extended postal vote receipt period.

If the VEC found any returned ballot paper envelopes that did not contain a ballot paper, contained more than one ballot paper, or did not contain the correct ballot paper, these were required to be rejected and not counted. There were 148 returned ballot paper envelopes rejected during the extraction activity.

Following the extraction of ballot papers from the ballot paper envelopes, a total of 33,224 ballot papers proceeded to the count.

### Computer count

A computer count information session explaining the process was recorded and available for online streaming from the VEC website from Friday 18 October 2024.

Following the extraction of ballot papers admitted to the count for all wards, preferences on ballot papers were data entered into the VEC's computer counting application at the election office. The application distributes preferences using the proportional representation method once data entry of ballot paper preferences is complete. Results were calculated at the election office on Thursday 7 November 2024.

The VEC published provisional results on its website as they became available. Results were updated as finalised once declarations had taken place.

For a breakdown of first preference results by ward, refer to **Appendix 8**.

### Recounts

At any time before a candidate is declared elected, the election manager or a candidate may initiate a recount. Election managers initiate recounts if margins in

a preference distribution are close or critical. Candidates must ask for a recount in writing, with the reasons for their request. The election manager and head office staff assess candidate recount requests and either accept or deny them.

The election manager received one request for a recount for South Ward. This request did not proceed to the recount process.

### Scrutineers

Scrutineers help deliver fair and transparent elections by observing election activities. They contribute to electoral integrity and help build public trust. Scrutineers can observe all activities involved in ballot paper and envelope processing.

Candidates are not permitted in election venues during extraction and counting activities and instead appoint scrutineers. Each candidate could appoint one scrutineer per election official involved in an activity. To appoint scrutineers, candidates completed a hardcopy 'Appointment and declaration of scrutineer form', which the candidate signed and submitted to the election manager. All scrutineers then had to sign the form's formal declaration in front of an election official. The declaration meant the scrutineers committed to eligibility and legal requirements and the VEC's conditions of entry.

A *Scrutineer handbook* was made available to all candidates and scrutineers with information on the role and responsibility of scrutineers during election activities. It included overviews of the activities so that scrutineers could understand what to expect during election activities they may attend. When scrutineers attended election venues they were briefed on their responsibilities and the processes they would witness. Scrutineers were instructed when and how they could challenge activities when ballot paper formality was being decided and votes were being counted. Scrutineers were allowed to notify election managers if they disagreed with the decision made by an election official on ballot paper formality or whether votes were counted for the selected candidate. Election managers reviewed the challenge and made a final decision on the ballot paper.

### Declaration of results

In the Service Plan, the VEC committed to complete all results declarations by Friday 15 November 2024.

The results of the 2024 Macedon Ranges Shire Council general election were declared at 3 pm on Friday 8 November 2024 at Gisborne Administration Centre, 40 Robertson Street, Gisborne for all wards.

The VEC website was updated following the declaration to reflect the elected candidates.



## 13. Election statistics

### Participation

Participation is measured by the number of voters marked off the roll as a percentage of the total enrolment and can vary from turnout. The overall participation rate in the Macedon Ranges Shire Council election was 86.60%, which is higher than the state average of 83.79% (excluding Melbourne City Council) and lower than the 87.31% rate at the 2020 Macedon Ranges Shire Council general election.

Analysis of voter participation for the different enrolment categories shows that participation is lower for voters who are enrolled on the EC's list (86.56%) compared to voters enrolled on the CEO's list (95.11%).

Refer to **Appendix 9** for further information on participation, including a breakdown by enrolment category.

### Turnout

Voter turnout is measured by the number of formal and informal ballot papers counted in the election as a percentage of voters on the voters' roll for the election.

The overall voter turnout for the 2024 Macedon Ranges Shire Council general election was 84.82%. This is compared to the state average turnout of 81.46% (excluding Melbourne City Council). The voter turnout at the 2020 general election for the council was 84.35%.

### Informality

The overall informal voting rate recorded at the 2024 Macedon Ranges Shire Council general election was 3.64%, compared with the State average of 3.47%. An informality rate of 3.38% was recorded at the Macedon Ranges Shire Council general election held in October 2020.

## 14. Complaints

### Type of complaints

At local government elections, complaints generally fall into 2 broad categories:

#### 1. Election Administration

Complaints about the conduct of the election and services to voters.

#### 2. Election participation and conduct

Complaints about candidates and other participants in the election, at times alleging a breach of the LG Act or local laws.

Most complaints at the 2024 local government elections related to the second category, and often alleged inappropriate or illegal action by a person or group associated with the election.

### Complaints process

The VEC have a streamlined complaints process during elections, developed with local councils and enforcement agencies. Complaints must be lodged in writing, then processed at head office. For the 2024 local government elections, customers could provide feedback and complaints online.

Complaints alleging a breach of the LG Act are forwarded to the Local Government Inspectorate. Complaints relating to local laws are referred to council. Complaints about the VEC's services, or the behaviour or actions of VEC staff and election officials, are the responsibility of the VEC.

The VEC is committed to responding to each complaint within 5 working days.

### Complaints received

The VEC received 8 written complaints relating to the election for Macedon Ranges Shire Council.

Please see **Appendix 10** for a description of complaints received by the VEC.



## 15. Post-election activities

### Storage of election material

The VEC will keep all records from the election safely and secretly in accordance with regulation 79 of the LG Regulations.

### Refund of nomination fees

Nomination fees were refunded to eligible candidates on Tuesday 17 December 2024. Eligible candidates include those elected or who received at least 4% of the first preference vote. Any forfeited nomination fees were remitted to the council on Tuesday 17 December 2024.

### Courts and tribunals

The Victorian Civil and Administrative Tribunal (VCAT) is responsible for hearing disputes on the validity of an election under section 311 of the LG Act.

Applications for a review of the declaration of the results of an election must be lodged within 14 days of the declaration and can be made by a candidate in the election, 10 persons who were entitled to vote at the election, or the VEC.

There were no applications to VCAT disputing the result of the Macedon Ranges Shire Council general election.

Macedon Ranges Shire Council

Non-voter follow up

## 16. Non-voter follow up

In accordance with section 267 of the LG Act, the VEC has commenced its compulsory voting enforcement program. Any person who was required to vote at the election and failed to vote will be issued with an 'Apparent failure to vote' notice in February/March. Apparent non-voters have 28 days to respond.

People who do not respond to the notice, or do not provide a satisfactory response, may be issued with an infringement notice in April/May that will incur a penalty. Further follow-up with a penalty reminder notice in July may also occur – this stage includes the original penalty and a penalty reminder notice fee. Penalties collected on behalf of council will be reimbursed at the end of the infringement and reminder notice stages.

Additionally, during the infringement and penalty reminder notice stages, non-voters may ask for their matter to proceed directly to the Magistrates' Court.

These requests will be actioned at the conclusion of the infringement and penalty reminder notice stages. The VEC will lodge the file of any remaining non-voters with Fines Victoria at the end of the penalty reminder notice stage.

## 17. Evaluating VEC services

The VEC is committed to providing high quality election services to its local government clients. Through a formal feedback and debriefing program, the VEC can gauge its performance and seek advice for future local government election projects.

### Feedback from councils

The VEC invited feedback from councils on its services in December 2024. Additional feedback can be provided to the LG2024 Program Manager by emailing [LGProgram2024@vec.vic.gov.au](mailto:LGProgram2024@vec.vic.gov.au)

### Internal debriefing program

After every electoral event, the VEC conducts an internal debriefing program that includes input from all areas of its workforce. Internal debriefing following the local government elections began in December 2024. The VEC will publish a consolidated report on its performance and key statistics from the elections. This will be tabled in Parliament and available on the VEC website.



Macedon Ranges Shire Council

Schedule 1: Record of ballot papers and declaration envelopes

## Appendices

### Schedule 1: Record of ballot papers and declaration envelopes

<b>East Ward election</b>	
<b>Ballot papers printed</b>	
Victorian Electoral Commission	15,001
Election manager	20
<b>Total</b>	<b>15,021</b>
<b>Ballot papers issued</b>	
General mail out	12,535
Early and replacement votes	368
Unenrolled declaration votes	0
Spoilt	0
Sub total	12,903
Unused	2,118
<b>Total</b>	<b>15,021</b>
<b>Declarations returned</b>	
General mail out admitted to the extraction	10,536
Early and replacement votes admitted to the extraction	229
Unenrolled declaration votes admitted to the extraction	0
Returned declarations unable to be admitted to the extraction	220
Declarations returned to sender	251
Sub total	11,236
Declarations not returned	1,667
<b>Total</b>	<b>12,903</b>

Victorian Electoral Commission

23

Schedule 1: Record of ballot papers and declaration envelopes

Macedon Ranges Shire Council

**South Ward election****Ballot papers printed**

Victorian Electoral Commission	16,001
Election manager	20
<b>Total</b>	<b>16,021</b>

**Ballot papers issued**

General mail out	13,698
Early and replacement votes	407
Unenrolled declaration votes	0
Spoilt	0
Sub total	14,105
Unused	1,916
<b>Total</b>	<b>16,021</b>

**Declarations returned**

General mail out admitted to the extraction	11,414
Early and replacement votes admitted to the extraction	261
Unenrolled declaration votes admitted to the extraction	0
Returned declarations unable to be admitted to the extraction	272
Declarations returned to sender	303
Sub total	12,250
Declarations not returned	1,855
<b>Total</b>	<b>14,105</b>

Macedon Ranges Shire Council

Schedule 1: Record of ballot papers and declaration envelopes

**West Ward election****Ballot papers printed**

Victorian Electoral Commission	16,003
Election manager	20
<b>Total</b>	<b>16,023</b>

**Ballot papers issued**

General mail out	12,935
Early and replacement votes	399
Unenrolled declaration votes	4
Spoilt	1
Sub total	13,339
Unused	2,684
<b>Total</b>	<b>16,023</b>

**Declarations returned**

General mail out admitted to the extraction	10,660
Early and replacement votes admitted to the extraction	272
Unenrolled declaration votes admitted to the extraction	0
Returned declarations unable to be admitted to the extraction	278
Declarations returned to sender	280
Sub total	11,490
Declarations not returned	1,849
<b>Total</b>	<b>13,339</b>

Victorian Electoral Commission

25



Schedule 2: Certification statement

Macedon Ranges Shire Council

## Schedule 2: Certification statement

In accordance with Regulation 77, I certify that Schedule 1 of this report on the conduct of the 2024 Macedon Ranges Shire Council local government election is a true and correct account of the number of ballot papers issued, returned and not used in this election and declarations not returned.



**Sven Bluemmel**  
Electoral Commissioner

Macedon Ranges Shire Council

Appendix 1: Breakdown of the voters' roll

## Appendix 1: Breakdown of the voters' roll

Macedon Ranges Shire Council election	Voters enrolled through an entitlement under section 241 of the LG Act	Voters enrolled through entitlements under sections 242–245 of the LG Act	Total voters enrolled
Macedon Ranges Shire Council	38,985	184	39,169
East Ward	12,468	67	12,535
South Ward	13,659	39	13,698
West Ward	12,858	78	12,936

## Appendix 2: Public notices

### Schedule of public notices

#### Close of roll notice

VEC website/public notices	23 July 2024
Sunbury and Macedon Ranges Star Weekly	23 July 2024
North Central Review	23 July 2024
Midland Express	23 July 2024

#### Notice of election

VEC website/public notices	12 August 2024
Sunbury and Macedon Ranges Star Weekly	13 August 2024
North Central Review	13 August 2024
Midland Express	13 August 2024

#### Voting details notice

VEC website/public notices	20 September 2024
Sunbury and Macedon Ranges Star Weekly	1 October 2024
North Central Review	1 October 2024
Midland Express	1 October 2024

#### Reminder notice

Sunbury and Macedon Ranges Star Weekly	15 October 2024
North Central Review	15 October 2024
Midland Express	15 October 2024



Macedon Ranges Shire Council

Appendix 2: Public notices

---

**Notice of result**

VEC website/public notices	8 November 2024
Sunbury and Macedon Ranges Star Weekly	26 November 2024
North Central Review	26 November 2024
Midland Express	26 November 2024

---

Close of roll

## Notice of election

30

Macedon Ranges Shire Council

Appendix 2: Public notices

## Voting details notice

## Sample Council postal election

*My council, my vote*

An election will be held for Sample Council.

### Check the mail for your ballot pack

Ballot packs containing voting material will be mailed to enrolled voters from **Monday 7 October**.

This is a postal election only.

If you do not receive your ballot pack by **Tuesday 15 October** please visit [vec.vic.gov.au](http://vec.vic.gov.au) to complete the online replacement form, or call **131 832** to arrange a replacement.

### Candidates

Candidates who have nominated for election are listed in the ballot packs and at [vec.vic.gov.au](http://vec.vic.gov.au).

A photo and candidate statement will also be included if provided by candidates. Responses to a candidate questionnaire, if provided, are available at [vec.vic.gov.au](http://vec.vic.gov.au).

### How to vote correctly

You must complete your ballot paper correctly for your vote to count. Put the number 1 in the box next to the candidate you want to see elected, then number all the other boxes in order of your choice. You must number **every box** and only use each number once.

### How to return your ballot pack

Put your completed ballot paper in the ballot paper envelope, complete the declaration, then post it ASAP using the reply-paid envelope provided, or hand deliver it during election office hours to:

Sample election office address

### Voting is compulsory




Voting is compulsory for all voters who were enrolled at 4 pm on Wednesday 7 August. This includes state-enrolled and council-enrolled voters.


If you don't vote and don't have a valid excuse, you may be fined.

Your completed ballot pack must be in the mail or hand delivered by **6 pm Friday 25 October**.

State-enrolled voters can register for free VoterAlert SMS and email reminders at [vec.vic.gov.au](http://vec.vic.gov.au)

@electionavc

 Victorian Electoral Commission

## Reminder notice

## Sample Council postal election

*My council, my vote*

An election is being held for Sample Council.

### Check the mail for your ballot pack

Ballot packs containing voting material were mailed to enrolled voters from **Monday 7 October**.

This is a postal election only.

If you do not receive your ballot pack by **Tuesday 15 October** please visit [vec.vic.gov.au](http://vec.vic.gov.au) to complete the online replacement form, or call **131 832** to arrange a replacement.

### Candidates

Candidates who have nominated for election are listed in the ballot packs and at [vec.vic.gov.au](http://vec.vic.gov.au).

### How to vote correctly

You must complete your ballot paper correctly for your vote to count. Put the number 1 in the box next to the candidate you want to see elected, then number all the other boxes in order of your choice. You must number **every box** and only use each number once.

### How to return your ballot pack

Put your completed ballot paper in the ballot paper envelope, complete the declaration, then post it ASAP using the reply-paid envelope provided, or hand deliver it during election office hours to:

Sample election office address

### Voting is compulsory




Voting is compulsory for all voters who were enrolled at 4 pm on Wednesday 7 August. This includes state-enrolled and council-enrolled voters.


If you don't vote and don't have a valid excuse, you may be fined.

Your completed ballot pack must be in the mail or hand delivered by **6 pm Friday 25 October**.

State-enrolled voters can register for free VoterAlert SMS and email reminders at [vec.vic.gov.au](http://vec.vic.gov.au)

@electionavc

 Victorian Electoral Commission



Appendix 2: Public notices

Macedon Ranges Shire Council

## Declaration of results

<b>Sample Council election</b> Declaration of results	<b>Sample Council logo</b>
--	----------------------------





The following candidates were elected to Sample Council at the general election held in October 2024:


<b>Sample Ward 1</b> Sample elected candidate 1	<b>Sample Ward 5</b> Sample elected candidate 5	<b>Sample Ward 8</b> Sample elected candidate 8
<b>Sample Ward 2</b> Sample elected candidate 2	<b>Sample Ward 6</b> Sample elected candidate 6	<b>Sample Ward 9</b> Sample elected candidate 9
<b>Sample Ward 3</b> Sample elected candidate 3	<b>Sample Ward 7</b> Sample elected candidate 7	
<b>Sample Ward 4</b>		

Further details about the results are available at [vec.vic.gov.au](https://vec.vic.gov.au)

**Sample Election Manager name**  
Election Manager

**Sample declaration date**

[vec.vic.gov.au](https://vec.vic.gov.au) | 131 632 | @electionsvic      
Authorised by S. Blumenthal, Electoral Commissioner, 530 Collins Street, Melbourne, Victoria.

 Victorian Electoral Commission

Macedon Ranges Shire Council

Appendix 3: Schedule of media releases and advisories

## Appendix 3: Schedule of media releases and advisories

### Macedon Ranges Shire Council council-specific media releases and advisories

Enrol now for the Macedon Ranges Shire Council election	Monday 29 July 2024
Call for candidates for Macedon Ranges Shire Council election	Thursday 22 August 2024
Ballot packs mailed for Macedon Ranges Shire Council election	Monday 7 October 2024
Voting closes soon for Macedon Ranges Shire Council election	Tuesday 15 October 2024
New councillors for Macedon Ranges Shire Council	Friday 8 November 2024

### Statewide media releases and advisories

Victorians urged to enrol for upcoming local council elections	Monday 22 July 2024
Media advisory: 2024 local council elections briefing	Monday 22 July 2024
Last chance to enrol for Victorian council elections	Friday 2 August 2024
News alert: Enrolment closes tomorrow for October's council local elections	Tuesday 6 August 2024
Nominations open soon for Victorian local council elections	Monday 26 August 2024
Media advisory: Accessing candidate information for the 2024 Victorian local council elections	Friday 6 September 2024
Nominations for the 2024 Victorian local council elections now open	Monday 9 September 2024
Over 4.6 million enrolled for local council elections	Tuesday 10 September 2024
Time is running out to nominate for this year's local council elections	Monday 16 September 2024
Electoral Commissioner calls for transparency in the use of AI in upcoming local council elections	Tuesday 17 September 2024
Media advisory: Media attendance at local council election ballot draw	Tuesday 17 September 2024
Nominations are in for October local council elections	Wednesday 18 September 2024
Democracy ambassadors help community voices 'Be Heard'	Thursday 19 September 2024
VEC retires 16 local council election candidates	Monday 30 September 2024
Voting starts next week for Victoria's local council elections	Friday 4 October 2024

Victorian Electoral Commission

33

Appendix 3: Schedule of media releases and advisories

Macedon Ranges Shire Council

**Statewide media releases and advisories**

Police investigate break-in at the Ballarat election office	Thursday 10 October 2024
Voters urged to request a replacement ballot pack following van theft	Friday 18 October 2024
Local council elections voting deadline looms	Monday 21 October 2024
Voters urged to request a replacement ballot pack following theft	Thursday 24 October 2024
Final day of voting	Friday 25 October 2024
Media advisory: Results timelines for Victorian local council elections	Friday 25 October 2024
Media advisory: Media attendance at results declarations	Wednesday 6 November 2024
Suspected postal vote tampering in 2 local council elections referred for inquiry	Wednesday 13 November 2024
Didn't vote in the 2024 local council elections?	Monday 17 February 2025
Non-voters asked to explain why they didn't vote in the 2024 local council elections	Friday 7 March 2025
Infringements sent to 2024 local council election non-voters	Scheduled for Monday 14 April 2025
Act on penalty reminder notice or risk enforcement action	Scheduled for Thursday 1 July 2025



Macedon Ranges Shire Council

Appendix 4: VoterAlert advisories

## Appendix 4: VoterAlert advisories

### Appendix 4.1: SMS alerts

**Close of roll – sent from Wednesday 17 July to Wednesday 31 July 2024**

VoterAlert: Vic council elections will be held by post this Oct. Make sure your details are correct before 4pm Wed 7 Aug. More info <https://vec.vic.gov.au/LG24>. If you'd rather not open links in this message, look up the VEC website or call 131 832 to check. Unsubscribe <https://vec.vic.gov.au/voteralert>

**Reminder close of voting – sent from Tuesday 22 October to Wednesday 23 October 2024**

VoterAlert: return your council election ballot pack by 6pm Fri Oct 25. If your ballot pack hasn't arrived, find out how to get a replacement at <https://vec.vic.gov.au/LG24>. Ignore if you've already voted or asked for a replacement. If you'd rather not visit links in this message, look up the VEC website or call 131 832. Unsubscribe: <https://vec.vic.gov.au/voteralert>

**Uncontested election – sent from Wednesday 25 September to Tuesday 1 October 2024**

VoterAlert: the election in your area is uncontested, as only one person nominated per vacancy. You do not need to vote. More info: <https://vec.vic.gov.au/LG24>. If you'd rather not visit links in this message, look up the VEC website or call 131 832. Unsubscribe: <https://vec.vic.gov.au/voteralert>


**Mail-out of ballot packs – sent from Monday 7 October to Monday 14 October 2024**

VoterAlert: ballot packs for the local council elections are on their way, arriving by 15 Oct. Complete and return before 6pm on Fri 25 Oct. For more info visit <https://vec.vic.gov.au/LG24>, look up the VEC website or call 131 832. Unsubscribe: <https://vec.vic.gov.au/voteralert>

## Appendix 4.2: Email alerts

## Close of roll email

Do not reply to this email. Replies go to an unmonitored inbox. [Contact us](#) with any questions.

**VoterAlert** 

Hi

Victorian local council elections are being held by post this October. You must be correctly enrolled by **4 pm on Wednesday 7 August**.

**What you need to do**

Not sure if your enrolment details are up to date? You can check online at [vec.vic.gov.au/enrolment](http://vec.vic.gov.au/enrolment)

If you've changed your address or name since you last voted in an election, you should update your details. Please also check the postal address listed on your enrolment, as this is where we will send your ballot pack.

[CHECK MY DETAILS](#)

If your details **haven't changed** since the last time you voted, get ready to vote. All voting in this election is by post. We will start posting ballot packs out from Monday 7 October.

The full list of candidates will be available on our website from 12 noon on Tuesday 17 September.

[Find out more about your council election](#)

Voting is compulsory – don't risk a fine.

**If you own properties in more than one Victorian council**

Some people are eligible to enrol in more than one council. If you own or pay rates on a property in a Victorian council other than where you normally live, you can apply to enrol with that council. This is known as council enrolment.

Contact the council directly for more information about council enrolment.

[Find out more about council enrolment](#)

You **must** vote for all councils you are enrolled in.

**Electoral structure changes**

Over half of Victoria's local councils have new electoral structures or have changed internal ward boundaries. You may be voting in a new ward this October.

You can check your council's ward boundaries on our [interactive map](#).

**Information in your language**

You can find election information in 20 languages other than English on our website.

[Find in-language information](#)

**Security**

If you would rather not click any links in this email, all this information and more is on our website at [vec.vic.gov.au](http://vec.vic.gov.au). You can also hover over links to confirm they go to a [vic.gov.au](http://vic.gov.au) website before you click them.

Be aware of scams: all emails we send you will have 'Victorian Electoral Commission <[voteralert@info.vec.vic.gov.au](mailto:voteralert@info.vec.vic.gov.au)>' as the sender. We will never ask you to enter credit card details or make payments through a website.

**More information**




Visit [vec.vic.gov.au](http://vec.vic.gov.au) or call us on [131 832](tel:131832) between 8:30 am and 5 pm Monday to Friday.

*Authorised by S. Bluemel, Electoral Commissioner, 530 Collins Street, Melbourne, Victoria.*

**Our mailing address is:**  
Level 11, 530 Collins Street, Melbourne VIC 3000

This message was sent to you by the Victorian Electoral Commission because your contact details are listed on the Victorian electoral roll. Responses are not monitored.


[UNSUBSCRIBE](#)

[VEC website](#) | [Contact us](#) | [Privacy](#) | [Legal](#)

## Uncontested election email

Do not reply to this email. Replies go to an unmonitored inbox. [Contact us](#) with any questions.

**VoterAlert** 

Hi

The Ward election is uncontested as there were the same number of candidates as vacancies at the close of nominations.

You are not required to vote this October.

**If you own properties in any other Victorian councils**

You will still get a ballot pack for any other councils you are enrolled in. Please complete and return all ballot packs you receive before **6 pm on Friday 25 October**.

If you don't vote you may risk a fine.

Check your enrolment online or contact the council directly to check your enrolment details.

[Check my enrolment](#)

**Security**

If you would rather not click any links in this email, all this information and more is on our website at [vec.vic.gov.au](http://vec.vic.gov.au). You can hover your mouse over links to make sure they go to a [vic.gov.au](http://vic.gov.au) website before you click them.

Be aware of scams: all emails we send you will have 'Victorian Electoral Commission <[voteralert@info.vec.vic.gov.au](mailto:voteralert@info.vec.vic.gov.au)>' as the sender. We will never ask you to enter credit card details or make payments through a website.

**More information**




For more information visit [vec.vic.gov.au](http://vec.vic.gov.au) or call us on [131 832](tel:131832) between 8:30 am and 5 pm, Monday to Friday.

*Authorised by S. Bluemel, Electoral Commissioner, 530 Collins Street, Melbourne, Victoria.*

**Our mailing address is:**  
Level 11, 530 Collins Street, Melbourne VIC 3000

This message was sent to you by the Victorian Electoral Commission because your contact details are listed on the Victorian electoral roll. Responses are not monitored.

[UNSUBSCRIBE](#)


[VEC website](#) | [Contact us](#) | [Privacy](#) | [Legal](#)

Macedon Ranges Shire Council

Appendix 4: VoterAlert advisories

## Ballot pack mail-out email

Do not reply to this email. Replies go to an unmonitored inbox. [Contact us](#) with any questions.

**VoterAlert** 

Hi

You are enrolled to vote in the 2024 local council elections.

Your vote matters. Local council elections are your chance to vote on who represents you on the local community issues that you care about.

**How to vote**

Voting in these elections is by **post**.

We have started posting ballot packs to all enrolled voters. They will arrive by **Tuesday 15 October**.

Please follow the instructions in your ballot pack to complete your vote and mail it back to us as soon as possible.

If you're unsure, you can learn [how to fill out a ballot paper](#) on our website.

Voting closes at **6 pm** on **Friday 25 October**, but your local mail collection times may be earlier than this. We recommend you return your completed vote as soon as possible.

You can also drop your vote off at your local election office.

**If you don't get a ballot pack**

Ballot packs are in the mail and will arrive by **Tuesday 15 October**.

If you don't get a ballot pack by then, you can ask us to send you a replacement by calling **131 832** between 8:30 am and 5 pm, Monday to Friday.

**Moved house or away from your address**

If you are away from your mailing address you can request a replacement ballot pack. You can:

- call us on **131 832** between 8:30 am and 5 pm, Monday to Friday
- visit the election office of your **old address** to get a replacement on the spot. If you will be away during the election, you can fill in your vote there and return it straight away.

[Find my election office](#)

**Find candidates**

Information about candidates, including statements and candidate questionnaire responses are on our website.

[Find candidates](#)

**Information in your language**

Our website has information in more than 20 languages. There are also videos explaining how to vote in 10 different languages.

[Find information in your language](#)

**Security**

If you would rather not click any links in this email, all this information and more is on our website: [vec.vic.gov.au](http://vec.vic.gov.au). You can hover your mouse over links to confirm they go to a [vic.gov.au](http://vic.gov.au) website before you click them.

Be aware of scams: all emails we send you will have 'Victorian Electoral Commission <[voteralert@info.vec.vic.gov.au](mailto:voteralert@info.vec.vic.gov.au)>' as the sender. We will never ask you to enter credit card details or make payments through a website.

**More information**




For more information visit [vec.vic.gov.au](http://vec.vic.gov.au) or call us on **131 832** between 8:30 am and 5 pm, Monday to Friday.

*Authorised by S. Bluemmel, Electoral Commissioner, 530 Collins Street, Melbourne, Victoria.*

**Our mailing address is:**  
Level 11, 530 Collins Street, Melbourne VIC 3000

This message was sent to you by the Victorian Electoral Commission because your contact details are listed on the Victorian electoral roll. Responses are not monitored.


[UNSUBSCRIBE](#)

[VEC website](#) | [Contact us](#) | [Privacy](#) | [Legal](#)

## Last week to vote email

Do not reply to this email. Replies go to an unmonitored inbox. [Contact us](#) with any questions.

**VoterAlert** 

**Reminder:** voting for the 2024 local council elections closes at 6 pm this Friday 25 October.

Please ignore this email if you've already voted or asked for a replacement ballot pack.

**How to vote**

Voting in these elections is by **post**.

Please follow the instructions in your ballot pack to complete your vote and mail it back to us as soon as possible. You can find instructions on [how to fill out a ballot paper](#) on our website.

Voting closes at **6 pm** on **Friday 25 October**, but your local mail collection times may be earlier than this. We recommend you return your completed vote as soon as possible.

You can also drop your vote off at your local election office.

[Find my election office](#)

**If you don't get a ballot pack**

If you haven't received your ballot pack in the mail yet, you can ask us to send you a replacement by:

- visiting your election office\* to get a replacement on the spot. You can fill in your vote there and return it straight away.
- calling us on **131 832** between 8:30 am and 6 pm, Monday to Friday
- filling in our [online form](#).

\*This must be the election office for your enrolled address. [Check your enrolment details](#) if you've recently moved.

[Find my election office](#)

**Information in your language**

Our website has information in more than 20 languages. There are also videos explaining how to vote in 10 different languages.

[Find information in your language](#)

**Security**

If you would rather not click any links in this email, all this information and more is on our website: [vec.vic.gov.au](http://vec.vic.gov.au). You can hover your mouse over links to confirm they go to a [vic.gov.au](http://vic.gov.au) website before you click them.

Be aware of scams: all emails we send you will have 'Victorian Electoral Commission <[voteralert@info.vec.vic.gov.au](mailto:voteralert@info.vec.vic.gov.au)>' as the sender. We will never ask you to enter credit card details or make payments through a website.

**More information**




For more information visit [vec.vic.gov.au](http://vec.vic.gov.au) or call us on **131 832** between 8:30 am and 6 pm, Monday to Friday.

*Authorised by S. Bluemmel, Electoral Commissioner, 530 Collins Street, Melbourne, Victoria.*

**Our mailing address is:**  
Level 11, 530 Collins Street, Melbourne VIC 3000

This message was sent to you by the Victorian Electoral Commission because your contact details are listed on the Victorian electoral roll. Responses are not monitored.

[UNSUBSCRIBE](#)

[VEC website](#) | [Contact us](#) | [Privacy](#) | [Legal](#)

Victorian Electoral Commission

37



## Appendix 5: Voter engagement program and initiatives

Program	Program details
Be Heard Democracy Ambassador program	This program provides free peer-led electoral education and information sessions to those under-represented in the electoral process. This includes people with disability and their carers, culturally and linguistically diverse (CALD) communities, people experiencing homelessness and young people. A total of 238 sessions were provided across the state reaching over 10,000 participants.
Specialist mobile enrolment	This program delivered peer-led enrolment sessions in prisons, homeless services, schools and tertiary education settings to reach young people and Aboriginal community settings across Melbourne and regional Victoria.
CALD in-language social media videos	This project produced a series of videos in 11 different languages including Auslan. Languages were chosen to reach language groups most in need of additional support. The videos provided electoral information on how to enrol, how to vote by post, and how to respond to an Apparent Failure to Vote Notice. These were widely distributed and shared through the VEC's social media platforms, community networks, and partner organisations.
Active Citizenship program	Electoral and civics education workshops were delivered to CALD community leaders in 3 locations across regional Victoria.
Aboriginal engagement	This program delivered information and engagement sessions across the greater Melbourne area and regional Victoria. These were designed to raise awareness that voting was compulsory and taking place via post. Culturally appropriate resources were produced to provide information on how to respond to an Apparent Failure to Vote Notice, including a video which was distributed and shared through the VEC's social media platforms and partner organisations.
Easy English guide	This was produced for people with low English proficiency and designed as a co-read product where a person supports the reader. These were distributed by Democracy Ambassadors as a key resource, and also available for download from the VEC's website.

Macedon Ranges Shire Council

Appendix 6: Final list of candidates in ballot paper order

## Appendix 6: Final list of candidates in ballot paper order

The candidates, in ballot paper order, were as follows:

---

**East Ward election**

---

BLEECK, Henry

---

NEIL, Geoffrey Allan

---

SCANLON, Andrew

---

YOUNG, Daniel

---

BORTHWICK, Cassy

---

ALDERTON, Dion

---

McKENZIE, Andy

---

**South Ward election**

---

JOSEPH, Alison

---

LETCHFORD, John

---

BONANNO, Dom

---

WALKER, Christine

---

GUTHRIE, Rob

---

**West Ward election**

---

KEATS, Callum

---

ANDERSON, Jennifer

---

HAINTZ, Andrea

---

KENDALL, Kate

---

HAYMAN, Karan

---

**West Ward election**

---

PEARCE, Janet

---

TEMPLETON, Ryan

---

BAKES, Rob

Victorian Electoral Commission

39

Appendix 6: Final list of candidates in ballot paper order

Macedon Ranges Shire Council

**Appendix 6.1: Candidate statements  
and photographs**

<b>Macedon Ranges Shire Council election</b>	<b>Total number of candidates at close of nominations</b>	<b>Number of candidates that lodged a candidate statement</b>	<b>Number of candidates that lodged a candidate photograph</b>
East Ward	7	7	7
South Ward	5	5	4
West Ward	8	8	8





Macedon Ranges Shire Council




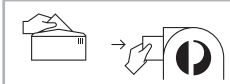

Appendix 6: Final list of candidates in ballot paper order

## Appendix 6.2: Sample ballot material







### Outer envelope

Sample Council	If undeliverable, return to Locked Bag 0000 LOCALITY VIC 0000	POSTAGE PAID AUSTRALIA PRIORITY
STAT-ENVM938 06/24		
Local council elections 2024 Postal ballot pack		
		<b>Voting closes 6 pm Friday 25 October</b>
		 Victorian Electoral Commission

### Reply-paid envelope

Sample Council Sample Ward	Delivery address: Locked Bag 0000 LOCALITY VIC 0000	 PRIORITY	No stamp required if posted in Australia 
Sample Council Sample Ward 	STAT-ENVM937 07/24		
			
Post your completed ballot pack before 6 pm on Friday 25 October  Local post box collection times vary. Check the collection time on your post box to make sure your vote is in the mail on time.		  Election Manager Sample Election Office Sample Ward Reply Paid 00000 LOCALITY VIC 0000	

### Ballot paper envelope

<h2>Ballot paper envelope</h2>	<h3>How to vote</h3> <ol style="list-style-type: none"><li>1. Complete your ballot paper/s.</li><li>2. Put your completed ballot paper/s inside this envelope and seal it.</li><li>3. Sign the declaration on the back of this envelope. We remove it before counting to keep your vote secret.</li></ol> <p>Voters unable to sign: Blind or low vision voters, or voters with low literacy or limited English can ask someone to sign for them. The authorised person must sign and write their name on the back of this envelope.</p> <ol style="list-style-type: none"><li>4. Put this ballot paper envelope into the reply-paid envelope and seal it.</li><li>5. Post it straight away.</li></ol>
    	 Victorian Electoral Commission  STAT-ENV-UG-003 06/24

Appendix 6: Final list of candidates in ballot paper order

Macedon Ranges Shire Council

**Candidate leaflet**

**Voting closes**  
6 pm Friday  
25 October 2024

All voting in this election is by post.  
Post your vote before voting closes.  
We cannot accept late votes.

Local post box collection times vary. Check the collection time on your post box to make sure your vote is in the mail on time.

You can also drop your vote off during business hours to:

Address line 1  
Address line 2  
Address line 3

For more information, visit [vec.vic.gov.au](http://vec.vic.gov.au) or call 131 832 during business hours.

**Voting is compulsory**


You are enrolled to vote in this election.

Voting is your right. By voting, you get to have a say in who represents you on your local council.

Voting is also a responsibility. If you don't vote, you may get a fine.

If your enrolment details have changed, it is your responsibility to update them. Visit [vec.vic.gov.au/update](http://vec.vic.gov.au/update) for more information.

Sample Council  
Sample Ward


**Candidate leaflet**

**Sample Council  
election 2024**  
Sample Ward

Sample Ward**Notice**

The contents of candidate statements are provided by the candidates. Any enquiries about candidate statements should be directed to the relevant candidate.

Candidate statements are not verified or endorsed by the election manager.

Candidate statements are also available at [vec.vic.gov.au](http://vec.vic.gov.au).

Candidates may also provide answers to a questionnaire. Responses are available at [vec.vic.gov.au](http://vec.vic.gov.au).

**How to vote multi-language leaflet***If applicable***How to vote leaflet****Language support**

Visit [vec.vic.gov.au/languages](http://vec.vic.gov.au/languages) for more information in your language.

For interpreter assistance, call us. See the phone numbers on the next page.

STAT-LEAMUL01 07/24**Ballot paper**

**Sample Council  
Sample Ward**

Election of 1 Councillor

Number the boxes 1 to 4 in the order of your choice.  
Number every box to make your vote count.  
You must not use any number more than once.

☐ CANDIDATE, Name

☐ CANDIDATE, Name

☐ CANDIDATE, Name

☐ CANDIDATE, Name

Macedon Ranges Shire Council

Appendix 6: Final list of candidates in ballot paper order

**Appendix 6.3: Sample uncontested ward leaflet**

**Sample Council election 2024**  
Sample Ward

At the close of nominations for the Sample Council, Sample Ward election, one nomination was received for one vacancy. Therefore, Candidate Name will be elected unopposed.

**You are not required to vote.**

**Election Manager Name**  
Election Manager  
For more information call 131 832

 Victorian Electoral Commission



Appendix 7: Daily breakdown of the general mail out

Macedon Ranges Shire Council

## Appendix 7: Daily breakdown of the general mail out

Macedon Ranges Shire Council election	7 October 2024	8 October 2024	9 October 2024	10 October 2024	Total general mail out
Macedon Ranges Shire Council	13,317	13,317	6,268	6,266	39,168
East Ward	4,262	4,262	2,006	2,005	12,535
South Ward	4,657	4,657	2,192	2,192	13,698
West Ward	4,398	4,398	2,070	2,069	12,935

Macedon Ranges Shire Council

Appendix 8: Result information

## Appendix 8: Result information

<b>East Ward count summary</b>		
Enrolment	12,535	
Formal votes	10,288	
Informal votes	431 (4.02% of the total votes)	
Voter turnout	10,719 (85.51% of the total enrolment)	
<b>Candidates (in ballot paper order)</b>	<b>First preference votes</b>	<b>Percentage</b>
BLEECK, Henry	1,154	11.22%
NEIL, Geoffrey Allan	1,137	11.05%
SCANLON, Andrew	1,458	14.17%
YOUNG, Daniel	2,059	20.01%
BORTHWICK, Cassy	2,837	27.58%
ALDERTON, Dion	1,145	11.13%
McKENZIE, Andy	498	4.84%
<b>Successful candidates</b>		
BORTHWICK, Cassy (1st elected)		
YOUNG, Daniel (2nd elected)		
SCANLON, Andrew (3rd elected)		
<b>South Ward count summary</b>		
Enrolment	13,698	
Formal votes	11,278	
Informal votes	342 (2.94% of the total votes)	
Voter turnout	11,620 (84.83% of the total enrolment)	
<b>Candidates (in ballot paper order)</b>	<b>First preference votes</b>	<b>Percentage</b>
JOSEPH, Alison	2,361	20.93%

Victorian Electoral Commission

45

Appendix 8: Result information

Macedon Ranges Shire Council

**South Ward count summary**

LETCHFORD, John	1,218	10.80%
BONANNO, Dom	3,084	27.35%
WALKER, Christine	2,447	21.70%
GUTHRIE, Rob	2,168	19.22%

**Successful candidates**

BONANNO, Dom (1st elected)

WALKER, Christine (2nd elected)

JOSEPH, Alison (3rd elected)

**West Ward count summary**

Enrolment	12,936
Formal votes	10,450
Informal votes	435 (4.00% of the total votes)
Voter turnout	10,885 (84.15% of the total enrolment)

Candidates (in ballot paper order)	First preference votes	Percentage
------------------------------------	------------------------	------------

KEATS, Callum	1,182	11.31%
ANDERSON, Jennifer	2,318	22.18%
HAINTZ, Andrea	407	3.89%
KENDALL, Kate	4,040	38.66%
HAYMAN, Karan	414	3.96%
PEARCE, Janet	1,288	12.33%
TEMPLETON, Ryan	390	3.73%
BAKES, Rob	411	3.93%

**Successful candidates**

KENDALL, Kate (1st elected)

ANDERSON, Jennifer (2nd elected)

PEARCE, Janet (3rd elected)



Macedon Ranges Shire Council

Appendix 9: Election participation statistics

## Appendix 9: Election participation statistics

Participation is measured by the number of marks on the roll as a percentage of total enrolment and can vary from turnout (total ballot papers counted as a percentage of total enrolment).

Macedon Ranges Shire Council election participation	2020	2024	Statewide LG 2024 – excluding Melbourne City Council
18–19	91.60%	88.76%	86.64%
20–24	87.18%	84.81%	80.02%
25–29	80.86%	78.55%	74.09%
30–34	79.37%	76.67%	73.31%
35–39	81.70%	80.28%	76.18%
40–44	83.79%	82.93%	78.99%
45–49	85.64%	83.98%	81.92%
50–54	87.98%	87.93%	84.69%
55–59	91.32%	90.06%	87.46%
60–64	91.73%	90.41%	89.16%
65–69	92.94%	92.17%	90.41%
70+	90.61%	91.05%	88.77%
Voters enrolled through section 241 of the LG Act	88.26%	86.56%	86.27%
Voters enrolled through sections 243–245 of the LG Act	65.78%	95.11%	60.96%
Total voters enrolled	87.31%	86.60%	84.12%

## Appendix 9: Election participation statistics

Macedon Ranges Shire Council

East Ward election participation	2024	Statewide LG 2024 – excluding Melbourne City Council
18–19	90.08%	86.64%
20–24	87.27%	80.02%
25–29	80.11%	74.09%
30–34	76.20%	73.31%
35–39	78.90%	76.18%
40–44	83.61%	78.99%
45–49	84.18%	81.92%
50–54	89.39%	84.69%
55–59	90.88%	87.46%
60–64	92.60%	89.16%
65–69	93.05%	90.41%
70+	92.19%	88.77%
Voters enrolled through section 241 of the LG Act	87.15%	86.27%
Voters enrolled through sections 243–245 of the LG Act	92.54%	60.96%
Total voters enrolled	87.18%	84.12%

South Ward election participation	2024	Statewide LG 2024 – excluding Melbourne City Council
18–19	90.94%	86.64%
20–24	86.09%	80.02%
25–29	79.70%	74.09%
30–34	78.72%	73.31%
35–39	82.48%	76.18%
40–44	82.67%	78.99%
45–49	83.92%	81.92%
50–54	88.21%	84.69%
55–59	90.82%	87.46%
60–64	90.15%	89.16%
65–69	90.97%	90.41%
70+	90.25%	88.77%
Voters enrolled through section 241 of the LG Act	86.59%	86.27%
Voters enrolled through sections 243–245 of the LG Act	97.44%	60.96%
Total voters enrolled	86.63%	84.12%

Macedon Ranges Shire Council

Appendix 9: Election participation statistics

<b>West Ward election participation</b>	<b>2024</b>	<b>Statewide LG 2024 – excluding Melbourne City Council</b>
18–19	85.27%	86.64%
20–24	81.08%	80.02%
25–29	75.84%	74.09%
30–34	75.08%	73.31%
35–39	79.47%	76.18%
40–44	82.50%	78.99%
45–49	83.85%	81.92%
50–54	86.19%	84.69%
55–59	88.49%	87.46%
60–64	88.49%	89.16%
65–69	92.49%	90.41%
70+	90.70%	88.77%
Voters enrolled through section 241 of the LG Act	85.94%	86.27%
Voters enrolled through sections 243–245 of the LG Act	96.15%	60.96%
Total voters enrolled	86.00%	84.12%



## Appendix 10: Complaints

### Written complaints received by the VEC

Where an outcome is a follow-up response, the customer may have replied to the VEC's response and the VEC has therefore replied to that follow-up email.

Where an outcome has no action taken, this could be an anonymous submission that doesn't contain feedback and therefore can't be passed on to another team.

Date	Nature of complaint	Action taken by the VEC
Monday 5 August 2024	VEC Complaint - Checking enrolment	Response provided
Wednesday 9 October 2024	LGI Complaint - Misleading and deceptive material; Conduct of candidate away from election office	Referred to LGI
Thursday 10 October 2024	VEC Complaint - Head office procedures; VEC comms other channels	Response provided
Wednesday 16 October 2024	VEC Complaint - Postal vote receipt delayed	Response provided
Thursday 17 October 2024	LGI Complaint - Postal material from candidates or parties; Breach of laws - other	Referred to LGI
Wednesday 23 October 2024	VEC Complaint - Postal vote receipt delayed	Response provided
Thursday 24 October 2024	VEC Complaint - Overseas and interstate voting; New digital voting options	Response provided
Sunday 3 November 2024	VEC Complaint - Postal vote not received by election; Incorrect enrolment	Response provided







© **State of Victoria**  
(Victorian Electoral Commission)  
April 2025

---

This work, the 2024 Local government elections Macedon Ranges Shire Council Election report, is licensed under a Creative Commons Attribution 4.0 licence [<http://creativecommons.org/licenses/by/4.0/>]. You are free to share this work under that licence, on the condition that you do not change any content and you credit the State of Victoria (Victorian Electoral Commission) as author and comply with the other licence terms. The licence does not apply to any branding, including Government logos.

---



Level 11, 530 Collins Street  
Melbourne Victoria 3000  
T 131 832  
[info@vec.vic.gov.au](mailto:info@vec.vic.gov.au)  
[vec.vic.gov.au](http://vec.vic.gov.au)

---

