Summary Report

Upper Mt. Emu Creek Flood Investigation

Glenelg Hopkins CMA

06 August 2020

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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

06 August 2020

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Dear Tatjana

Upper Mt. Emu Creek Flood Investigation

Please see attached Summary Report. This report summarises the outputs and findings for the Upper Mt. Emu Creek Flood Investigation and covers previous reporting stages.

We would like to thank Glenelg Hopkins CMA for engaging us to complete this project, and Pyrenees Shire Council, Corangamite Shire Council, the Lake Goldsmith Steam Preservation Association, BoM, the Department of Justice VICSES and DELWP for their technical input into the project. Water Technology would specifically like to thank the community members who gave their time to attend meetings, provide their personal observations of flooding, and provide feedback on the flood modelling. Strong contributions from key stakeholders and community members has resulted in improved outcomes from this study, which will assist with flood related land use planning, floodplain risk management, flood emergency response and raising community awareness of individual flood risk.

If you have any questions regarding this report, please do not hesitate to contact me.

Yours sincerely

Ben Hughes
Principal Engineer

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EXECUTIVE SUMMARY

The Upper Mt. Emu Creek Flood Investigation was commissioned by the Glenelg Hopkins Catchment Management Authority (GHCMA). The project aimed to define flood inundation within the Mt. Emu Creek floodplain. The investigation area covered the upper Mt. Emu Creek catchment, extending along Mt. Emu Creek from 4 km upstream of Trawalla to 4 km downstream of Skipton and the entirety of Baillie Creek.

Mt. Emu Creek has a well-known history of flooding, with historic flood events causing substantial damage to both private and public infrastructure. Communities within the study area such as Skipton and the Lake Goldsmith Steam Preservation Association (LGSPA) were severely impacted by these events, resulting in tangible monetary loss and damage to historical artefacts, as well as intangible mental and emotional damage across the broader Mt. Emu Creek floodplain.

The hydrologic analysis completed as part of this project was in accordance with Australian Rainfall and Runoff 2019 Guidelines, determining design flood hydrographs for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% Annual Exceedance Probability (AEP) flood events as well as the probable maximum flood (PMF) throughout the study area with a focus on several key locations. These key locations from upstream to downstream within the catchment include Langi Kal Kal, Trawalla, Mena Park, Lake Goldsmith, Guthries Bridge and Skipton. The adopted design flows at Skipton compared to previous Skipton Flood Investigation (Water technology, 2013) analysis are shown in Table 1 below.

TABLE 1 DESIGN PEAK FLOWS AT SKIPTON

Study	Upper Mt. Emu Creek catchment design peak flow (m^3/s)						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
2019 Upper Mt. Emu Creek Catchment Flood Investigation	81	144	226	364	492	641	871
2013 Skipton Flood Investigation	77	136	220	388	575	830	-

During the review and collection of data, inadequacies in the spatial coverage of available LiDAR datasets were identified. A new LiDAR dataset was flown with additional coverage of a greater area of the Mt. Emu Creek floodplain and the incorporation of a new structure at the Western Freeway. This dataset was verified by comparison to surveyed road transects. The quality and accuracy of the new LiDAR data enabled the hydraulic model to accurately replicate observed flood behaviour within the study area. In mid-2016, flood mitigation works were undertaken in Skipton. These works altered the inundation characteristics within the township and as a result, the flood intelligence elements produced as part of the Skipton Flood Investigation (Water Technology, 2013). These changes were incorporated to the modelling undertaken during this project.

The hydrologic and hydraulic models were jointly calibrated to two historic flood events, January 2011 and September 2016. High quality calibration data enabled an excellent model calibration to be achieved. January 2011 model results showed a strong match to observed flood levels and extents with accurate timing. Modelled timing of the September 2016 flood was slightly late, but matched flood levels and extents well. Mapping for both flood events was also verified by local residents in all key areas within the study area. The outputs of the hydraulic modelling were considered robust for the purpose of this study.

A flood damage assessment was undertaken to determine the monetary flood damage for the range of modelled design events. Model results for all mapped flood events were processed to calculate the number and the locations of properties and roads affected. Above floor flooding occurs during events as low as a 5% AEP (20 year ARI) and the Average Annual Damage (AAD) cost was calculated to be approximately $245,048.

Based on the project brief and discussion within the Project Reference Group, a feasibility assessment was undertaken of five flood mitigation options. Four options targeted an alleviation of flood damages at the LGSPA site, while one option focused on a reduction in flood damage at Skipton. Of the four options assessed for the LGSPA site, construction of a levee around the site appears to be the option most worthy of potential further consideration in terms of viability and cost effectiveness.

To facilitate the implementation of a formal flood warning service at Skipton, the hydraulic model was used to produce theoretical rating curves for use by the Bureau of Meteorology (BoM). The theoretical rating curves focused on relatively high flow events, and are expected to perform much more accurately when flow is dominated by floodplain conveyance. It is recommended that the existing gauge rating curves be modified by joining the current measurement-based rating and the modelled theoretical rating. This will enable an accurate rating at low in channel flows (based on measured data) and high out of bank flows (based on theoretical model results).

Draft Land Subject to Inundation (LSIO) and Floodway Overlay (FO) layers were prepared to reflect the study outcomes. The FO delineates land that is subject to high hazard flooding based on the depth and velocity of flood water, while the LSIO delineated by the 1% AEP inundation extent. The planning overlays produced at Skipton showed a negligible difference to that currently in the planning scheme and no change within the township is recommended. Planning overlays produced outside of Skipton will be beneficial to any future land development within the study area (e.g. Trawalla).

Flood intelligence outputs including flood response maps and property inundation tables were produced. These outputs will be used to update the Pyrenees Shire Council and Corangamite Shire Council Municipal Flood Emergency Plans (MFEP) and assist VICSES and Council to plan for and respond to future flood events.

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1 INTRODUCTION

This report is one of a series, documenting the outcomes of the Upper Mt. Emu Creek Flood Investigation. The study has provided a detailed investigation of the upper Mt. Emu Creek catchment, extending along Mt. Emu Creek from upstream of Trawalla to the township of Skipton, and Baillie Creek from Lake Burrumbeet to its confluence with Mt. Emu Creek. Reporting was broken up into a series of deliverables and each one is standalone technical report as shown below. This report is a summary of key outputs from these reports.

- R01 - Data Review and Validation.
- R02 – Hydrology and Hydraulics Calibration Report.
- R03 – Hydrology and Hydraulics Design Report.
- R04 – Final Modelling and Mapping Report.
- R05 – Flood Warning Improvement Report.
- R06 – Flood Damages and Mitigation Assessment Report.
- R07 – Flood Intelligence Outputs.
- R08 – **Final Summary Report (This report).**

1.1 Overview

Water Technology was commissioned by the Glenelg Hopkins Catchment Management Authority (GHCMA) to undertake the Upper Mt. Emu Creek Flood Investigation. The investigation area covered the upper Mt. Emu Creek catchment, extending along Mt. Emu Creek from Trawalla to Skipton, and Baillie Creek from Lake Burrumbeet too its confluence with the Mt. Emu Creek. Both waterways have a well-known history of flooding and some of the most significant flood events are well recorded. These flood events caused substantial damages to the local infrastructure (e.g. roads and bridges) and agriculture (e.g. fencing) while also impacting on the townships of Skipton, Trawalla and the Lake Goldsmith Steam Preservation Association (LGSPA) facilities and historical artefacts.

A previous flood investigation at Skipton was undertaken by Water Technology in 2013[1]. Since the completion of this study, flood mitigation works have been undertaken in Skipton altering the inundation characteristics and Australian Rainfall and Runoff 2019[2] has been released outlining revised recommendations for hydrologic and hydraulic analysis (updated from Australian Rainfall and Runoff 1987[3]). To incorporate these changes additional updated modelling was required to support the design and establishment of a formal flood warning service for Skipton.

This flood investigation provides a comprehensive flood analysis for several key areas of interest in the upper region of Mt. Emu Creek catchment and up-to-date flood intelligence information for the township of Skipton.

[1] Water Technology (2013), Skipton Flood Investigation.
[2] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia
[3] Institution of Engineers, Australia (1987), Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT

1.2 Project Objectives

The Upper Mt. Emu Creek Flood Investigation has produced outputs which meet several floodplain management objectives, and these were highlighted in the project brief prepared by Glenelg Hopkins CMA as follows:

- Provision of a range of outputs to enable the implementation of a formal flood warning service for Skipton.
- Amended flood class levels for Skipton that account for changed flooding characteristics following completion of mitigation works.
- Heightened understanding of the hydrological drivers of flooding in the project area.
- Increased reliability of flood intelligence information and real time flood monitoring capability via production of (theoretical) stage/discharge ratings for three new gauging sites and improvement of ratings for three existing stations.
- Provision of flood mapping and intelligence products for the entire project area to inform and develop:
  - Emergency response planning.
  - Heightened community resilience to floods.
- Establishment of flood related land use and development controls in the Pyrenees Shire Council planning scheme.
  - The new mapping outputs for Skipton, Trawalla, Langi Kal Kal and the LGSPA of sufficient resolution to enable flood risk management planning at the building envelope scale (i.e. be of suitable resolution and rigour for a planning scheme amendment).
- Provision of reliable flood risk information for insurance purposes.
- Assess options flood mitigation works and activities.

1.3 Study Area

Mt. Emu Creek is located approximately 30 km west of Ballarat at its closest point, flowing from Langi Kal Kal to the Hopkins River west of Cudgee. The Upper Mt. Emu Creek Flood Investigation focuses on the area extending from 4 km upstream of Trawalla to about 4 km downstream of Skipton whilst covering the entirety of Baillie Creek and its associated floodplain. This extends from Lake Burrumbeet to the confluence with Mt. Emu Creek. The total catchment area of the investigation is approximately 1,250 km^2, and spans three municipalities. However, the extent of the required project outputs is only relevant to the Pyrenees and Corangamite Shire areas.

The catchment within and upstream of the study area is largely agricultural, with several key agricultural weirs and other structures in the system. Key areas of interest within this study were identified as follows:

- Trawalla
  - Trawalla is a small township about 4 km south of Langi Kal Kal situated, adjacent to the Western Highway between Beaufort and Ballarat. Due to the reduction in commute time between Beaufort and Ballarat, a potential increase in housing demand, is expected. In the 2011 flood event, 3 houses were impacted by over floor flooding. It is suggested that adoption of planning controls in Trawalla would be a high priority to minimise the potential flood risk for future development.
- Mena Park
  - The Mt. Emu Creek at Mena Park streamflow gauge has instantaneous records from October 1974 to present day. This gauge was a valuable source for both hydrologic and hydraulic model calibration.

- Lake Goldsmith
  - The Lake Goldsmith Steam Preservation Association (LGSPA) facilities are located within the Mt. Emu Creek floodplain. The facilities house one of the most significant collections of historical machinery and artefacts in the southern hemisphere. Historical record shows that the site was severely impacted by the January 2011 flood, resulting in substantial losses of irreplaceable artefacts and significant flood recovery costs.
- Guthries Bridge
  - The Mt. Emu Creek at Skipton will be the flood level prediction gauge for township of Skipton while Guthries Bridge will be a key support location to forecast water level at Skipton.
- Skipton
  - Skipton is the largest town in the investigation area which has a well-known and understood flood risk. The January 2011 flood was the largest event recorded on the Mt. Emu Creek at this location. Although floods in 2010 and 2011 had severe impacts on the town, relatively minor flooding occurred again in September 2016 and its impacts were largely mitigated by the completion of drainage works in Montgomery Street in mid-2016.

The study area of the Upper Mt. Emu Creek Flood investigation is displayed in Figure 1-1.

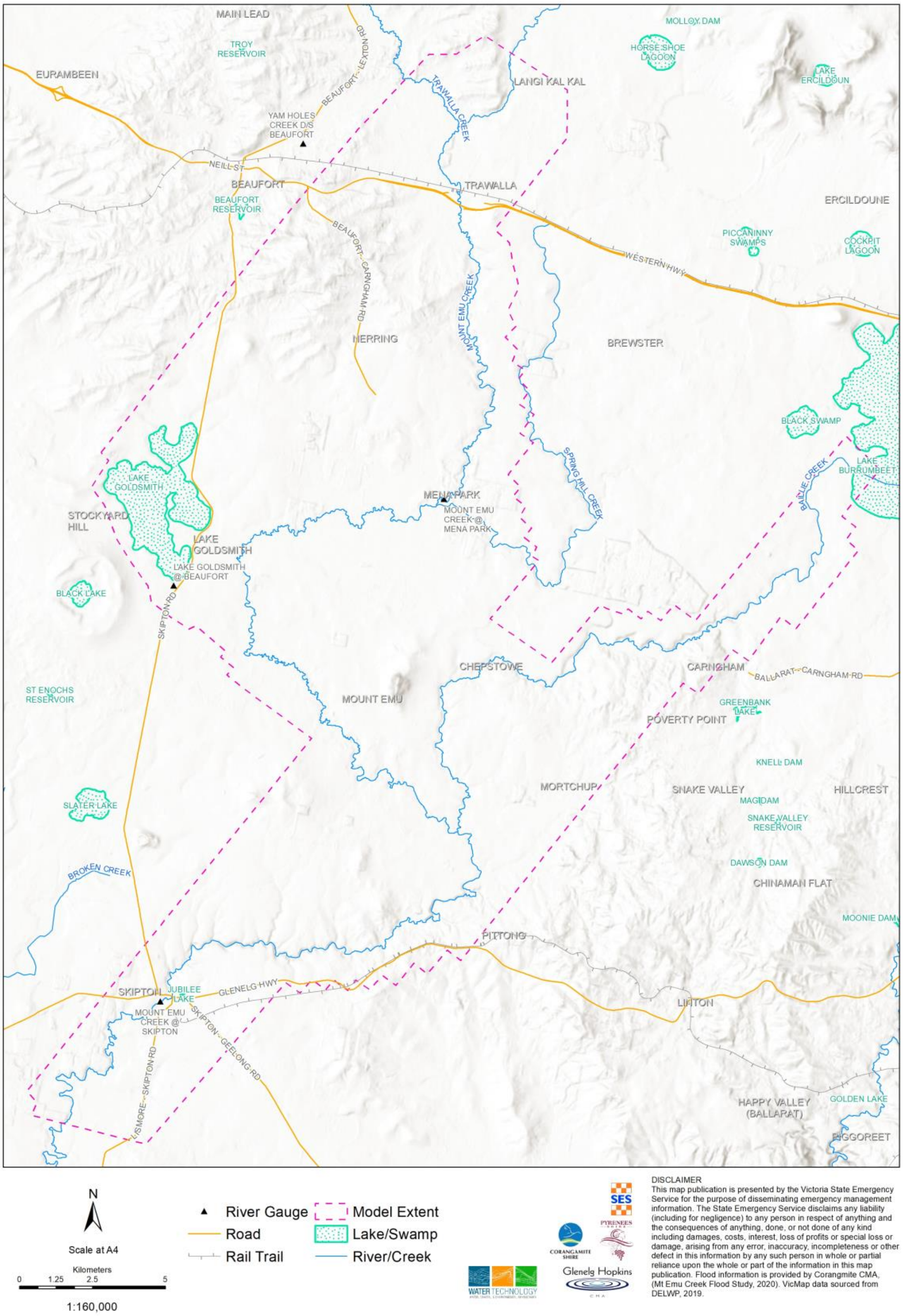

FIGURE 1-1 UPPER MT. EMU CREEK FLOOD INVESTIGATION – STUDY AREA

2 DATA REVIEW AND COLLATION

2.1 Overview

The Data Collation Report (R01) was completed in June 2019 and provided an overview of the available existing data and the proposed modelling methodology used to complete this study. The data review detailed previous studies and historical floods. Rainfall and streamflow data were collected and evaluated. A review of available feature survey of key roads and drainage infrastructures, floor level data and available topography data was completed. As a result of the data review, data gaps were identified in key structures, floor level survey and topography data.

2.2 Methodology

The methodology of the data review for this study was as follows:

- Review of previous related studies.
- Review of historical flood records and available flood information (i.e. flood marks, photos etc.).
- Review and collection of available rainfall and streamflow data.
- Identification of key modelling components (i.e. key hydraulic structures).
- Validation of topography data.
- Review of existing hydrological model.

2.3 Summary and Outcomes

The data review and collation detailed a thorough assessment of the existing data and identified gaps. The major data gaps included feature survey of hydraulic infrastructure, floor level survey and the requirement for additional coverage of topography data (i.e. LiDAR data). To fill these gaps the following was undertaken:

- Feature survey of numerous hydraulic structures was collected within the study area to aid the development of hydraulic model.
- Floor level survey was undertaken, and was used in flood intelligence outputs.
- Additional LiDAR data acquired of the study area, vastly improving the coverage. Additional floodplain areas, Lake Goldsmith and the Western Highway Duplication were all added. The new LiDAR data was verified through comparison to surveyed transects and existing topography data. This LiDAR data was then used as the base data for hydraulic model in this study.

The existing RORB model developed as part of the 2013 Skipton Flood Study[1] was also reviewed. The model was updated and modified to suit the need for the new hydraulic model and to account for recommendations included in AR&R 2019[4] .

3 CALIBRATION

The Calibration Report (R02) was completed in November 2019 and documented the development of hydrological and hydraulic models as well as the calibration process.

3.1 Methodology

The modelling methodology adopted is outlined as follows:

- Modification of the existing hydrological model (RORB).
  - The existing hydrological model produced in the Skipton Flood Investigation (2013) was modified to allow for the transition from a model schematised to produce inflows for the township of Skipton to a regional scale model producing inflows along Mt. Emu Creek and Baillie Creek.
- Hydrological modelling.
  - The January 2011 and September 2016 flood events were simulated in RORB.
  - The daily rainfall data (from several rainfall gauges) was used to generate spatial patterns for each event.
  - The sub-daily rainfall data at the Beaufort gauge was used to generate temporal patterns for each event.
- Hydraulic model development.
  - A 1D/2D hydraulic model – TUFLOW with 5 metre grid resolution was developed and this consisted of:
    - Model inflow/outflow boundaries and domain extent.
    - Model topography.
    - Hydraulic roughness layer.
    - 1D/2D hydraulic structures; including bridges, pipes and culverts, and diversion channel at Lake Goldsmith.
- Model calibration.
  - The model calibration and validation focused on the January 2011 and September 2016 flood events.
  - A joint hydrologic and hydraulic calibration approach was adopted for this study. This enabled the RORB model parameters to be determined through a iterative process comparing the TUFLOW model outputs to observed timing and the flood peaks, while also adjusting the TUFLOW model parameters and setup.

Figure 3-1 shows the hydraulic model extent, flow boundaries and model topography.

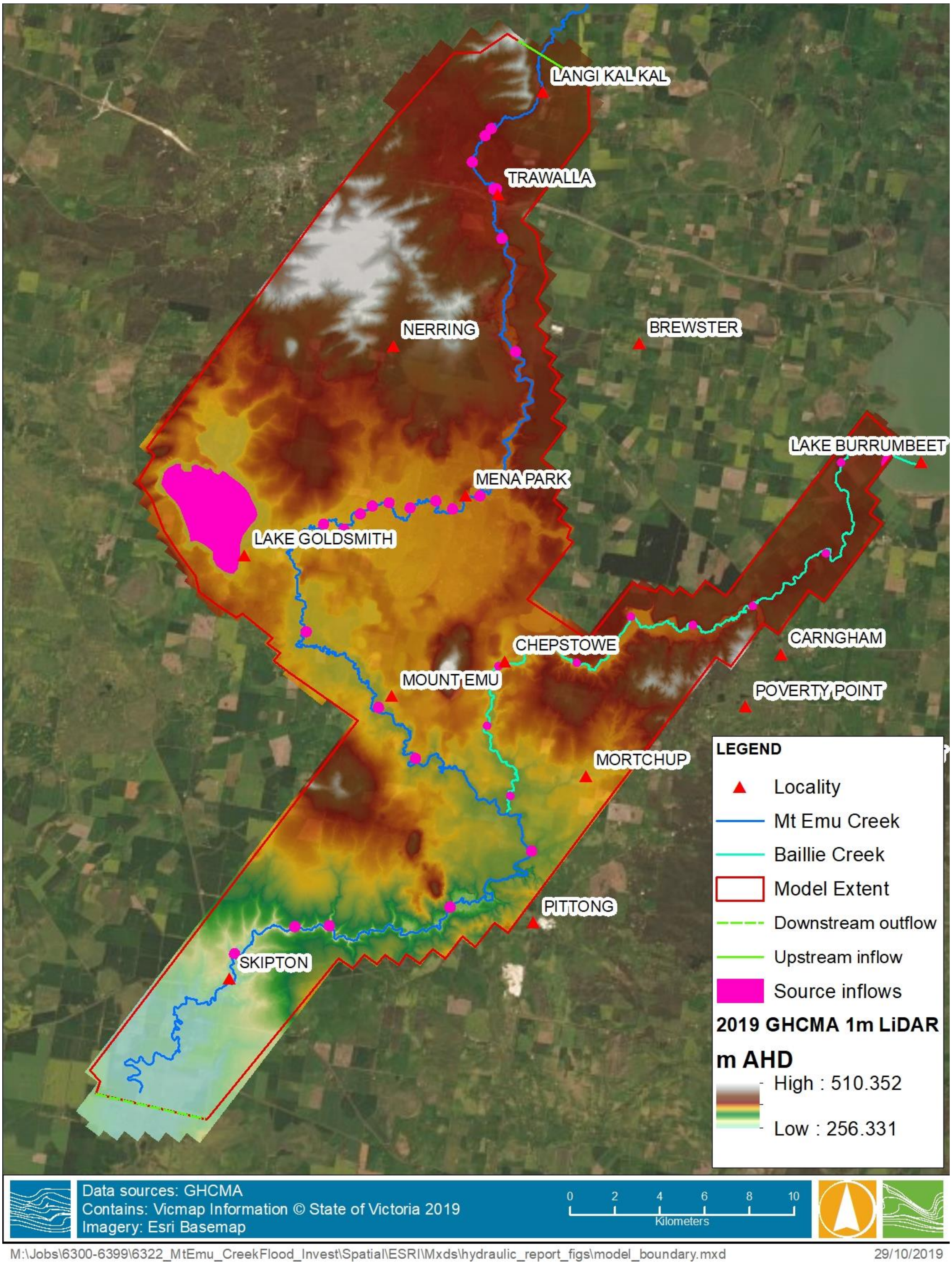

FIGURE 3-1 HYDRAULIC MODEL EXTENT, TOPOGRAPHY AND BOUNDARIES

3.2 Key Assumptions

The modelling assumptions are summarised as follows:

- The hydraulic roughness coefficients were based on aerial imagery and land use types, they were assumed to be static and were verified during modelling of January 2011 and September 2016.
- The Lake Goldsmith diversion channel was modelled as closed during the 2011 flood event and partially open during 2016.
- All bridge structures were modelled with zero blockage as per the AR&R2019[2] blockage assessment.
- Lake Burrumbeet was assumed to be at full capacity at the beginning of both calibration events while Lake Goldsmith was assumed to be empty.

3.3 Summary and Outcomes

The calibration and validation process relied heavily on streamflow gauge flows and heights, surveyed flood marks, aerial flood photos and other anecdotal evidence. Missing gauge records during the events and gauge datums increased the difficulty of model calibration. The September 2016 flood had a relatively limited historic evidence compared to the January 2011 event.

Model calibration for the January 2011 event showed a strong match to the observed flood levels and extents while the timing of the September 2016 flooding was slightly late, but matched flood extents well. The model calibration to both flood events was also verified by local residents in all key areas .

Results of the joint calibration validated the parameters adopted in both the RORB and TUFLOW models and were determined to be of sufficient accuracy to conduct the design modelling.

4 DESIGN MODELLING

The Design Modelling Report (R03) was issued in January 2020, detailing the previous updated Flood Frequency Analysis (FFA) and together with the Final Hydraulic Modelling Report (R04), issued in May 2020, documented all design modelling methods, results and the sensitivity tests on the various assumptions made in the hydrologic and hydraulic modelling.

4.1 Methodology

The FFA completed in the Skipton Flood Investigation (2013) was revised and updated with the additional years of data using the recommended approach in AR&R 2019[3]. This included analysis at the Mt. Emu Creek at Skipton streamflow gauge (236203), Mt. Emu Creek at Mena Park (236213) gauge and Burrumbeet Creek at Lake Burrumbeet gauge (236215). The design flows for a range of design Annual Exceedance Probability (AEP) events were produced for these gauges.

The RORB parameters - k_c of 120 and m of 0.8 determined in the hydrologic and hydraulic model calibration process were adopted whilst the RORB parameters of rainfall losses were adjusted in a reasonable range until the peak flows at Skipton gauge produced in TULFOW model matched to the design estimates from the FFA. Table 4-1 summarises the final adopted RORB model parameters. Figure 4-1 below shows the process of design modelling in RORB and TUFLOW models.

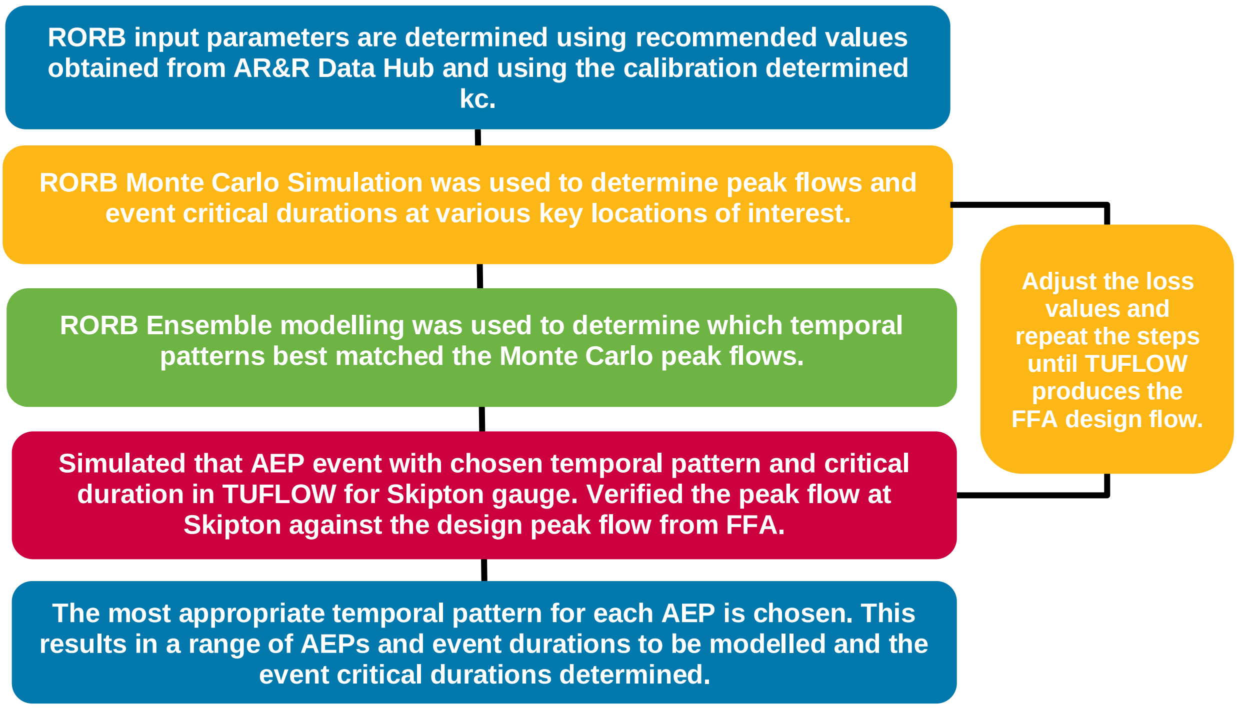

FIGURE 4-1 THE PROCESSES OF HYDROLOGIC AND HYDRAULIC DESIGN MODELLING

TABLE 4-1 ADOPTED RORB MODEL PARAMETERS

Modelled Events	Calibrated K_c value	m	Initial loss (mm)	Continuing loss (mm/hr)
January 2011 event	120	0.8	**22**	**4.5**
September 2016 event			**16**	**2.4**
20% AEP			16	2.1
10% AEP			16	1.6
5% AEP			16	1.4
2% AEP			16	0.8
1% AEP			16	0.5
0.5% AEP			14	0.5
0.2% AEP			12	0.3

Once the design parameters of the RORB model were determined and the temporal patterns and critical durations were identified at key locations, the design inflows were extracted and input into the TUFLOW model.

Design modelling included a range of AEP events, from 20% AEP up to 0.2% AEP and the Probable Maximum Flood (PMF) event, and a range of critical durations identified at key locations, including Langi Kal Kal, Trawalla, Mena park, Lake Goldsmith, Guthries Bridge and Skipton.

4.2 Key Assumptions

The modelling assumptions are summarised as follows:

- The hydraulic roughness coefficients were based on aerial imagery and land use types then verified through hydraulic model calibration. They remained the same across both calibration events and all design events.
- The Lake Goldsmith diversion channel was modelled as closed in all design events.
- All bridge structures were modelled with zero blockage as per the AR&R2019[2] blockage assessment.
- Lake Burrumbeet was assumed to be at full capacity at the beginning of all design events while Lake Goldsmith was assumed to be empty.

4.3 Results

Hydraulic model results for each AEP event were processed to produce the final maximum flood grids (i.e. depth, water level, velocity and hazard). Using the 1% AEP event as an example, there were four durations and five temporal patterns modelled and combined to form a maximum water level grid, calculated using the maximum water levels at each grid cell. Although they are all 1% AEP rainfall events, the water level and flood extents can be dictated by event duration and rainfall temporal pattern. Figure 4-2 to Figure 4-4 show a range of potential flood extents at Trawalla, Lake Goldsmith and Skipton respectively.

Maps for each design event were produced mapping depth, water surface elevation, velocity and flood hazard. These were produced at a catchment wide scale as well as a closer perspective at key locations for easier viewing. An example of the flood depth map (i.e. 1% AEP) is shown in Figure 4-5.

The hydraulic model results were also used to identify flood behaviour. Table 4-2 to Table 4-7 provide a summary of flood behaviour at key locations along Mt Emu Creek, from Langi Kal Kal to Skipton, for the range of modelled design events.

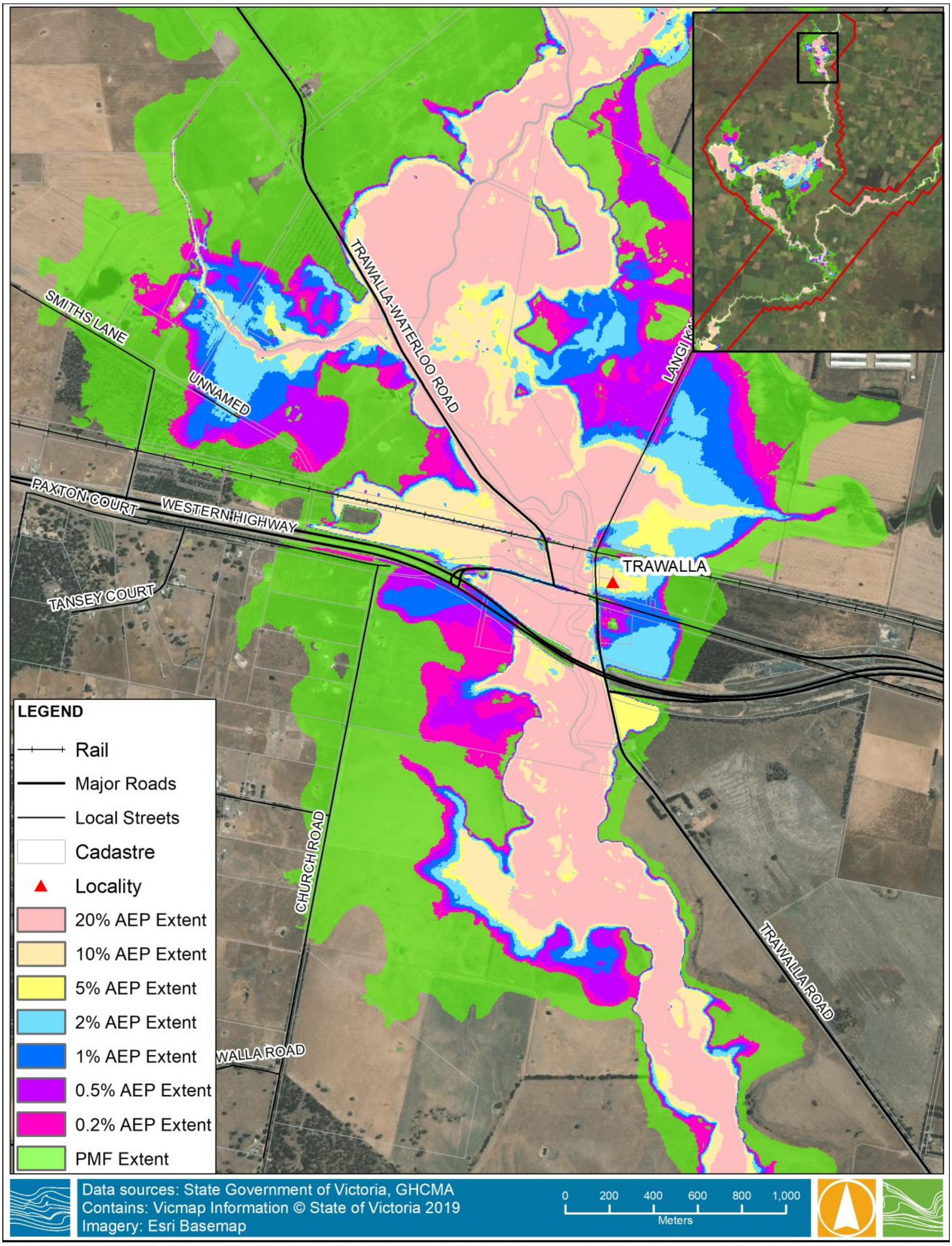

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FIGURE 4-2 DESIGN FLOOD EXTENTS FOR ALL MODELLED AEP IN TRAWALLA

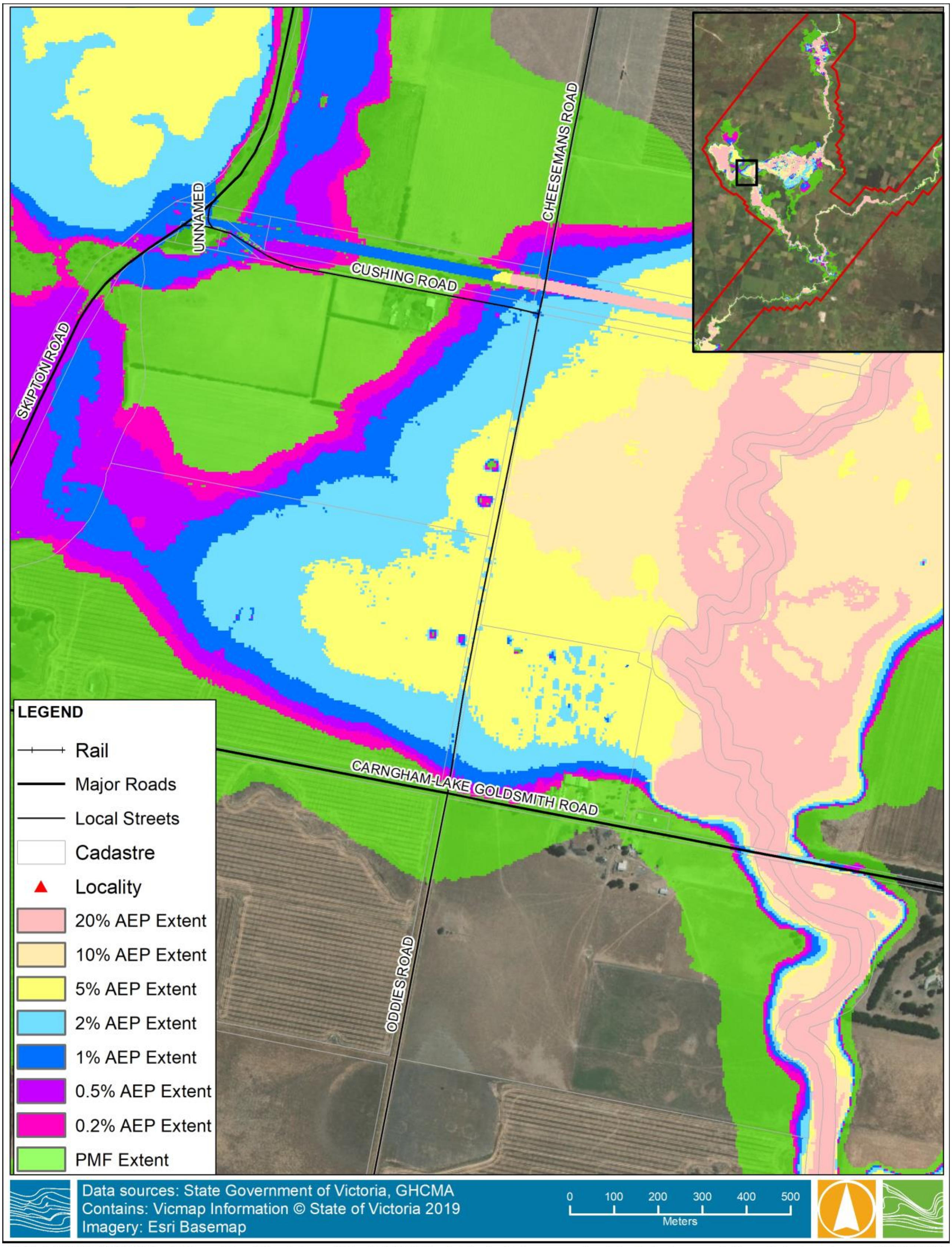

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FIGURE 4-3 DESIGN FLOOD EXTENTS FOR ALL MODELLED AEP IN LGSPA

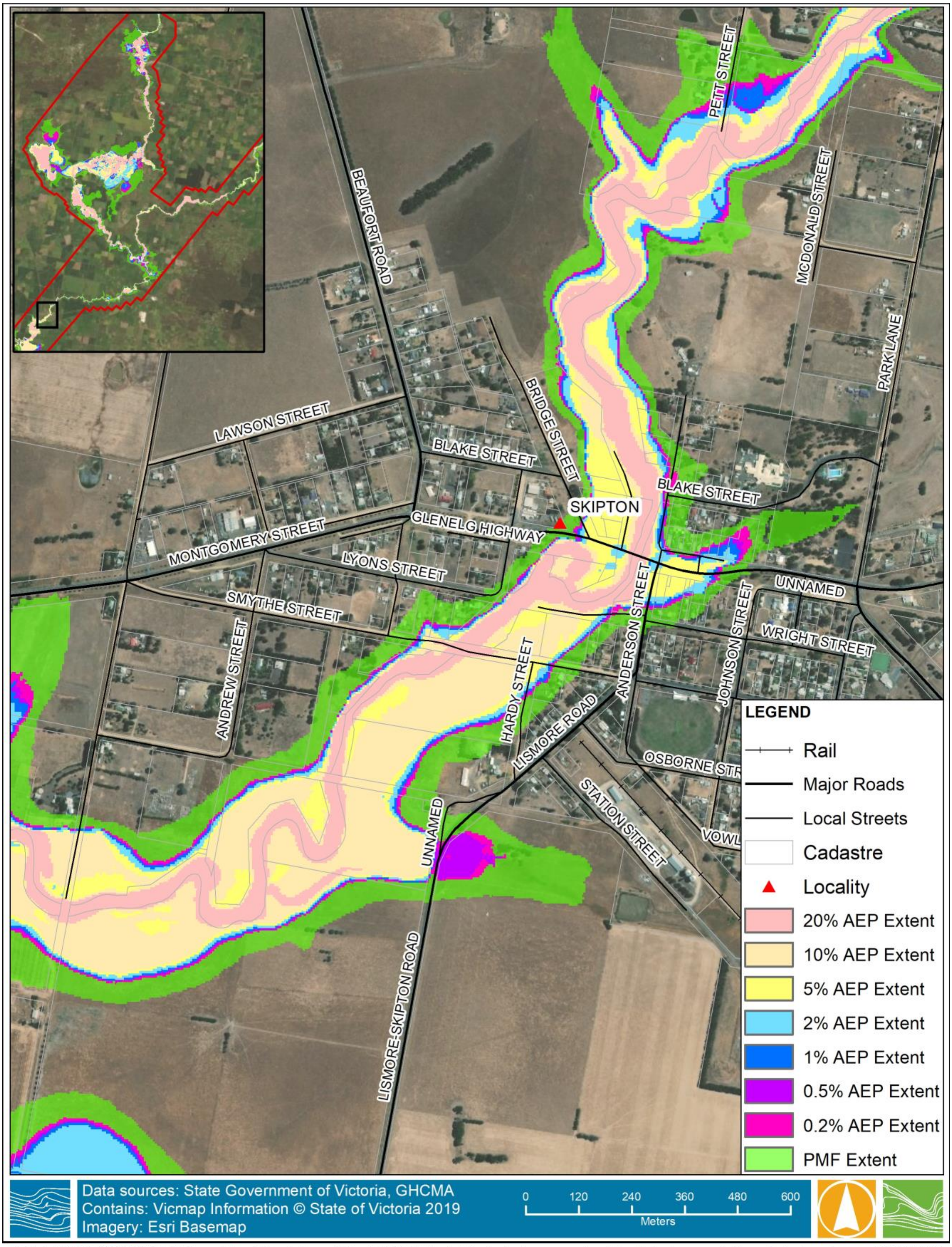

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FIGURE 4-4 DESIGN FLOOD EXTENTS FOR ALL MODELLED AEP IN SKIPTON

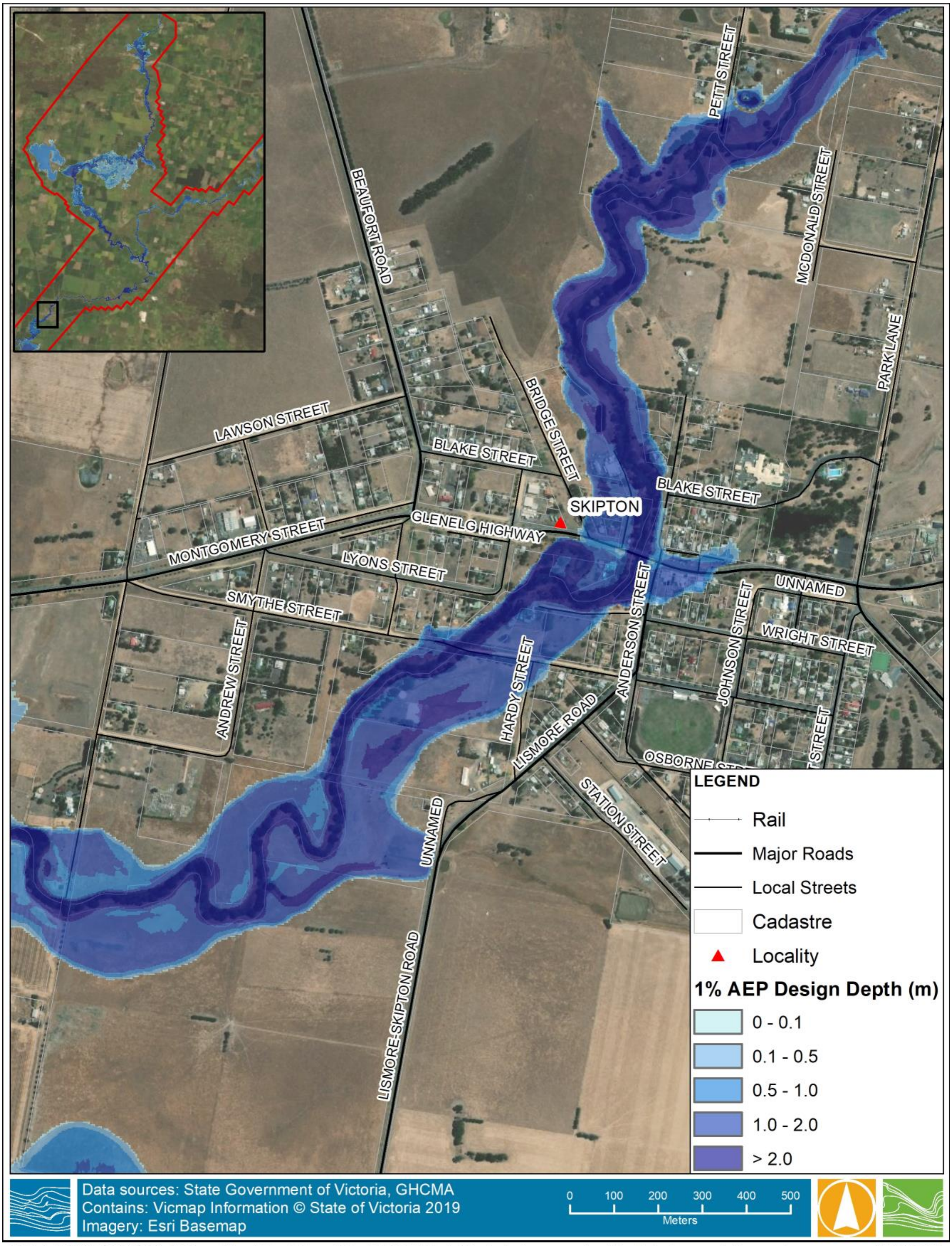

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FIGURE 4-5 1% AEP FLOOD DEPTH MAP IN SKIPTON

4.3.1 Langi Kal Kal

TABLE 4-2 SUMMARY OF FLOOD BEHAVIOUR AT LANGI KAL KAL

Event	Langi Kal Kal
20% AEP	Critical duration – 24hrs ■ Minor overbank flows found upstream and downstream of Racecourse Rd.
10% AEP	Critical duration – 24hrs ■ Shallow water found on Racecourse Rd, breakout from east bank of Mt Emu Creek. ■ Overbank flows into the floodplain along the creek. ■ Overland flows observed west of the prison.
5% AEP	Critical duration – 48hrs ■ Overtopping at Racecourse Rd and an unnamed Rd across Mt Emu Creek, north of the prison. ■ Access roads are overtopped west of the prison causing difficulty to provide access to the building on western bank of the creek.
2% AEP	Critical duration – 24hrs ■ Overtopping at Racecourse Rd and an unnamed Rd across Mt Emu Creek, north of the prison ■ Access roads are overtopped west of the prison causing difficulty to provide access to the building on western bank of the creek..
1% AEP	Critical duration – 24hrs ■ Overtopping at Racecourse Rd and an unnamed Rd across Mt Emu Creek, north of the prison. ■ Access roads are overtopped west of the prison causing difficulty to provide access to the building on western bank of the creek.
0.5% AEP	Critical duration – 36hrs ■ Overtopping at Racecourse Rd and an unnamed Rd across Mt Emu Creek, north of the prison. ■ Access roads are overtopped west of the prison causing difficulty to provide access to the building on western bank of the creek.
0.2% AEP	Critical duration – 36hrs ■ Overtopping at Racecourse Rd and an unnamed Rd across Mt Emu Creek, north of the prison. ■ Access roads are overtopped west of the prison causing difficulty to provide access to the building on western bank of the creek.
PMF	■ Overland flows from the eastern bank of the creek across Langi Kal Kal Rd and flood several buildings within the prison. ■ Backflows in Trawalla Creek overtop Racecourse Rd. ■ Floodplain on both sides of the creek is significantly flooded.

4.3.2 Trawalla

TABLE 4-3 SUMMARY OF FLOOD BEHAVIOUR IN TRAWALLA

Event	Trawalla
20% AEP	Critical duration – 24hrs ■ Overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd north of Western Highway. ■ Overbank flows observed along Mt Emu Creek.
10% AEP	Critical duration – 24hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd. ■ Overland flows found in private properties north of Western Highway. ■ Flooding in marsh areas.
5% AEP	Critical duration – 24hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd. ■ Overland flows are spreading across broader floodplain. ■ Private properties north of Western highway are inundated or isolated by flood water.
2% AEP	Critical duration – 24hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd. ■ Floodplain is flooded on both sides of the creek. ■ Private properties north of Western highway are inundated or isolated by flood water.
1% AEP	Critical duration – 36hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd. ■ Floodplain is significantly flooded on both sides of the creek. ■ Private properties north of Western highway are inundated by flood water. ■ A section of Western Highway is overtopped (west of Skipton Rd).
0.5% AEP	Critical duration – 36hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd. ■ Floodplain is significantly flooded on both sides of the creek. ■ Private properties north of Western highway are inundated by flood water ■ A section of Western Highway is overtopped (west of Skipton Rd)
0.2% AEP	Critical duration – 24hrs to 36hrs ■ Significant overtopping at Trawalla – Waterloo Rd and Langi Kal Kal Rd ■ Floodplain is significantly flooded on both sides of the creek ■ Private properties north of Western highway are inundated by flood water. ■ A section of Western Highway is overtopped (west of Skipton Rd).
PMF	■ The entire floodplain on both sides of the creek is significantly inundated. ■ 500 metres long of Western Highway, west of Skipton Rd is overtopped. ■ Flood water flowing north and overtops Racecourse Rd, east of Trawalla – Waterloo Rd.

4.3.3 Mena Park

TABLE 4-4 SUMMARY OF FLOOD BEHAVIOUR IN MENA PARK

Event	Mena Park Gauge (m)	Mena Park
20% AEP	2.34	Critical duration – 24hrs ■ Overbank flows observed along Mt Emu Creek and Spring Creek. ■ Shallow flood water found in marsh areas and broader floodplain.
10% AEP	2.53	Critical duration – 24hrs ■ Breakout of floodwater from Mt Emu Creek and Spring creek immediate downstream of the gauge. ■ Marsh areas and broader floodplain are flooded.
5% AEP	2.67	Critical duration – 48hrs ■ Spreading of overland flows across broader floodplain results in significant flooding. ■ A section of Beaufort – Carngham Rd is overtopped by shallow flood water. ■ Overbank flows mixed from Mt Emu Ck and Spring Ck in the gauge location and nearby marsh areas are flooded. ■ Moving further downstream of Mena Park, a large area of floodplain south of Mt Emu Creek is flooded.
2% AEP	2.94	Critical duration – 24hrs ■ Spreading of overland flows across broader floodplain results in significant flooding on both sides of the creek. ■ Beaufort – Carngham Rd is overtopped. ■ Moving further downstream of Mena Park, flood water flows down south and inundates a section of Carngham – Lake Goldsmith Rd.
1% AEP	3.11	Critical duration – 36hrs ■ Spreading of overland flows across broader floodplain results in significant flooding on both sides of the creek. ■ Beaufort – Carngham Rd is overtopped ■ Moving further downstream of Mena Park, flood water flows down south and inundates the Carngham – Lake Goldsmith Rd
0.5% AEP	3.25	Critical duration – 24hrs ■ Spreading of overland flows across broader floodplain results in significant flooding on both sides of the creek. ■ Beaufort – Carngham Rd is overtopped. ■ Moving further downstream of Mena Park, flood water flows down south and inundates the Carngham – Lake Goldsmith Rd. ■ A property in Carngham – Lake Goldsmith Rd is flooded below flood

Event	Mena Park Gauge (m)	Mena Park
0.2% AEP	3.42	Critical duration – 24hrs ■ Spreading of overland flows across broader floodplain results in significant flooding on both sides of the creek. ■ Beaufort – Carngham Rd is overtopped. ■ Moving further downstream of Mena Park, flood water flows down south and inundates the Carngham – Lake Goldsmith Rd. ■ A property in Carngham – Lake Goldsmith Rd is flooded.
PMF	-	■ The entire floodplain is significantly flooded, more severe on the southern bank of the creek. ■ Overland flows moving further down south to Carngham – Streatham Rd.

4.3.4 Lake Goldsmith

TABLE 4-5 SUMMARY OF FLOOD BEHAVIOUR IN LAKE GOLDSMITH

Event	Cameron Bridge Gauge (m AHD)	Lake Goldsmith
20% AEP	344.59	Critical duration – 24hrs ■ Flows are mostly confined in Mt Emu Creek upstream of Carngham – Lake Goldsmith Rd. ■ Overbank flows observed further downstream of Carngham – Lake Goldsmith Rd and flooding in marsh areas.
10% AEP	345.22	Critical duration – 24hrs ■ Overland flows observed north of steam rally site, flowing easterly. ■ Marsh areas further downstream of Carngham – Lake Goldsmith Rd are significantly flooded by overbank flows.
5% AEP	345.58	Critical duration – 48hrs ■ The steam rally site is flooded, buildings and sheds are isolated by flood water. ■ Flood water continues flowing easterly. ■ Downstream marsh areas are significantly flooded.
2% AEP	346.17	Critical duration – 36hrs ■ The steam site is flooded, buildings/sheds are inundated with flood water. ■ Carngham- Lake Goldsmith Rd is overtopped. ■ Flood water continues flowing easterly, floodplain areas are inundated. ■ Downstream marsh areas are significantly flooded

Event	Cameron Bridge Gauge (m AHD)	Lake Goldsmith
1% AEP	346.60	Critical duration – 36hrs ■ The steam site is inundated with deep water. ■ Bridge and Carngham- Lake Goldsmith Rd are overtopped. ■ Flood water from Mt Emu Creek enter Lake Goldsmith via overland flows and diversion channel, and there is a breakout from the diversion channel. ■ Downstream marsh areas on both sides of the creek are significantly flooded.
0.5% AEP	346.87	Critical duration – 24hrs ■ The steam site is inundated with deep water. ■ Bridge and Carngham- Lake Goldsmith Rd are overtopped. ■ The lake east of Skipton Rd is filled by overland flows and Skipton Rd is overtopped by shallow water. ■ Downstream marsh areas on both sides of the creek are significantly flooded.
0.2% AEP	347.17	Critical duration – 24hrs ■ The steam site is inundated with deep water. ■ Bridge and Carngham- Lake Goldsmith Rd are overtopped. ■ A large portion of area east of the steam rally site is inundated with deep flood water. ■ Inundation on Skipton Rd. ■ Lake Goldsmith reserve area is filled up with water. ■ Downstream marsh areas on both sides of the creek are significantly flooded.
PMF	-	■ Deep inundation on both sides of the creek. ■ Overland flows from Mt Emu Creek and flood water in Lake Goldsmith join, resulting in the entire region west of the creek becoming significantly flooded.

4.3.5 Guthries Bridge

TABLE 4-6 SUMMARY OF FLOOD BEHAVIOUR IN GUTHRIES BRIDGE

Event	Guthries Bridge Gauge Height (m)	Guthries Bridge
20% AEP	3.08	Critical duration – 48hrs ■ Flows are confined within the Mt Emu Creek.
10% AEP	3.91	Critical duration – 36hrs ■ Flows are confined within the Mt Emu Creek. ■ Back flows to unnamed waterways.

Event	Guthries Bridge Gauge Height (m)	Guthries Bridge
5% AEP	4.84	Critical duration – 36hrs ■ Flows mostly confined within the channel. ■ Shallow flood water found on Guthries Rd. ■ Back flows to unnamed waterways.
2% AEP	6.04	Critical duration – 36hrs ■ Overbank flows occur immediate upstream of the Guthries as a result of the breakout from unnamed waterways. ■ Overtopping at Guthries Bridge.
1% AEP	6.57	Critical duration – 48hrs ■ Overbank flows occur immediate upstream of the Guthries Bridge as a result of the breakout from unnamed waterways. ■ Overtopping at Guthries Bridge. ■ Inundation on Chepstowe – Pittong Rd.
0.5% AEP	6.94	Critical duration – 36hrs ■ Overbank flows occur immediate upstream of the Guthries Bridge as a result of the breakout from unnamed waterways. ■ Overtopping at Guthries Bridge. ■ Inundation on Chepstowe – Pittong Rd. ■ One property is flooded.
0.2% AEP	7.48	Critical duration – 36hrs ■ Overbank flows occur immediate upstream of the Guthries Bridge as a result of the breakout from unnamed waterways. ■ Overtopping at Guthries Bridge and Guthries Rd/Settlement Rd. ■ Inundation on Chepstowe – Pittong Rd. ■ One property is flooded.
PMF		■ Overbank flows occur immediate upstream of the Guthries Bridge as a result of the breakout from unnamed waterways. ■ Overtopping at Guthries Bridge and Guthries Rd/Settlement Rd. ■ Inundation on Chepstowe – Pittong Rd. ■ One property is flooded. ■ Deep inundation on broader floodplain.

4.3.6 Skipton

TABLE 4-7 SUMMARY OF FLOOD BEHAVIOUR IN SKIPTON

Event	Skipton Gauge Height (m)	Skipton
20% AEP	4.18	Critical duration – 48hrs ■ Stewart Park area starts to get filled with water. ■ Flows are confined within Mt Emu Creek.
10% AEP	4.89	Critical duration – 36hrs ■ Flows are confined in channel north of the Skipton. ■ Breakout of flood water from eastern bank overtop Wright St and Smythe St, flood water keeps flowing southward and inundates private property.
5% AEP	5.23	Critical duration – 36hrs ■ Properties in Cleveland St are flooded and overbank flows continue southward towards Glenelg Highway. ■ Glenelg Highway/Montgomery St approaching from each side of the bridge are overtopped. ■ Shops/properties in Anderson St south of the highway and immediate south of the bridge are inundated. ■ Backflow through mitigation culverts appear in Montgomery St.
2% AEP	5.76	Critical duration – 48hrs ■ Significant flooding on the western bank of the creek and floodplain, including properties upstream and downstream of the highway bridge. ■ Significant flooding on the eastern floodplain, including properties mainly through overland flows and backflow from the mitigation culverts. ■ Overtopping at road approaching from each side of the highway bridge. ■ Anderson St (south of Glenelg Highway), Wright St and Smythe St are overtopped.
1% AEP	6.08	Critical duration – 98hrs ■ Significant flooding on the western bank of the creek and floodplain, including properties upstream and downstream of the highway bridge. ■ Significant flooding on the eastern floodplain, including properties mainly through overland flows and backflow from the mitigation culverts. ■ Overtopping at the Glenelg Highway bridge and the road approaches from each side. ■ Anderson St (south of Glenelg Highway), Wright St and Smythe St are overtopped. ■ Inundation of a significant number of properties within the township area.

Event	Skipton Gauge Height (m)	Skipton
0.5% AEP	6.29	Critical duration – 36hrs ■ Significant flooding on the western bank of the creek and floodplain, including properties upstream and downstream of the highway bridge. ■ Significant flooding on the eastern floodplain, including properties mainly through overland flows and backflow from the mitigation culverts. ■ Overtopping at the Glenelg Highway bridge and the road approaches from each side. ■ Anderson St, Wright St, Smythe St, Hardy St and Lismore-Skipton Rd are overtopped. ■ Inundation of a significant number of properties within the township area.
0.2% AEP	6.63	Critical duration – 36hrs ■ Significant flooding on the western bank of the creek and floodplain, including properties upstream and downstream of the highway bridge. ■ Significant flooding on the eastern floodplain, including properties mainly through overland flows and backflow from the mitigation culverts. ■ Overtopping at the Glenelg Highway bridge and the road approaches from each side. ■ Anderson St, Wright St, Smythe St, Hardy St and Lismore-Skipton Rd are overtopped. ■ Inundation of a significant number of properties within the township area.
PMF	-	■ Significant flooding on the western bank of the creek and floodplain, including properties upstream and downstream of the highway bridge. ■ Significant flooding on the eastern floodplain, including properties mainly through overland flows and backflow from the mitigation culverts reaches Jubilee Lake. ■ Deep inundation at the Glenelg Highway bridge and the road approaches from each side. ■ A number of roads and streets are inundated. ■ Deep inundation of a significant number of properties on both sides of the creek.

4.4 Sensitivity Analysis

The hydrologic and hydraulic modelling was based on various assumptions and it is good practice to understand the sensitivity of the model results to these assumptions. The model assumptions tested are listed below along with a summary of the sensitivity analysis undertaken:

- Spatial rainfall variation.
  - **Uniform and spatially varied rainfall depths were tested in RORB using the 1% AEP design.** A uniform spatial pattern uses the average rainfall depth within a catchment based on the catchment centroid, while a spatially varied pattern uses the average rainfall depths in each subarea within the catchment. Model results showed design flows at key locations were consistently greater when applying spatially varied rainfall depth. Increases in design flows were within 5% at key locations and within 3% in Skipton and Lake Goldsmith, which was equivalent to 2 cm and 5 cm increases in water level respectively. ARR 2019 recommends that a non-uniform spatial pattern should be applied for catchment greater than 20 km^2 and this was carried out in these study; however, adopting a uniform pattern showed very little difference to peak flow.
- Temporal Variations of Rainfall
  - **All ten AR&R 2019 recommended temporal patterns were modelled in RORB for the 1% AEP event and design flows were compared across different temporal patterns.** During the design modelling stage, only one temporal pattern was chosen for each key location in the hydraulic model. Figure 4-6 shows the variation of the design flows at each key location using the potential range of possible rainfall temporal patterns. Skipton was the most sensitive followed by Mena Park, whilst Langi Kal Kal and Guthries Bridge were the least sensitive to temporal rainfall variations. The cross markers highlight the selected temporal pattern used in the design flood modelling. Design flows produced at Skipton varied from 340 m^3/s up to 520 m^3/s. This was the equivalent of the adopted design flows ranging from 2% AEP to 0.5% AEP, which corresponds to a 0.5m increase in water level at the Skipton gauge. Overall, design flows at most key locations were relatively sensitive to temporal rainfall variation.

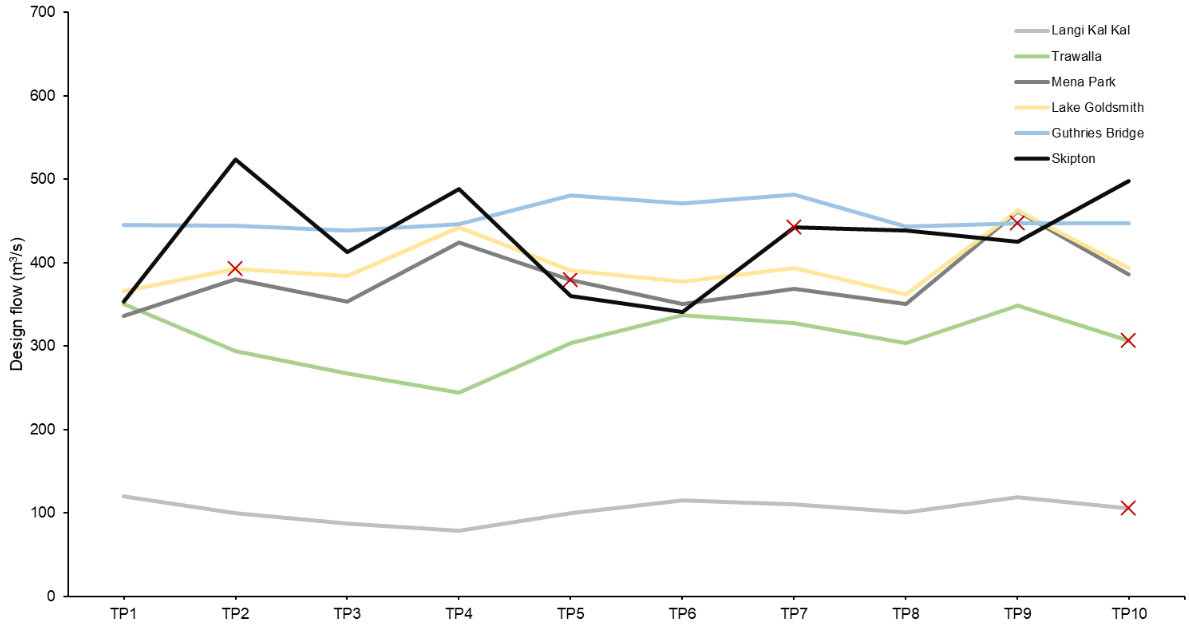

FIGURE 4-6 DESIGN FLOWS VARIATION AT KEY LOCATIONS USING DIFFERENT TEMPORAL PATTERNS

- Design Rainfall Losses.
  - **Initial and continuing losses were independently reduced by 50% and tested in RORB for the 1% AEP event.** The adopted design rainfall losses for each AEP event were applied using a Fraction Impervious for each subarea. The change to the adopted losses showed an increase in design flows and a larger impact by a reduction in continuing loss. Trawalla had the least increase while the Guthries Bridge and Skipton a more significant increase. The 1% AEP peak design flow at Skipton was increased by 11%, which is equivalent to a 12 cm increase in water level at the Skipton gauge. The final adopted loss parameters were calibrated at Skipton but the sensitivity of the losses demonstrates the potential for peak flow to be altered if a catchment is particularly dry or wet.
- Lake Burrumbeet Storage.
  - **The 1% AEP event was modelled in RORB with the Lake Burrumbeet initial storage set as both empty and full.** When Lake Burrumbeet was empty, the outflow from Lake Burrumbeet was found to be negligible when compared to the broader Mt. Emu Creek flow at around 10 m^3/s. The peak also occurred 40 hours after Skipton reached its peak flow. When Lake Burrumbeet was assumed full, much larger flows spilled to Baillie Creek, causing an increase of 30 m^3/s in peak flow at Skipton in a 1% AEP event. This corresponds to a 10 cm increase in flood level. Given these results and the fact that Lake Burrumbeet is known to have spilled in the January 2011 event it was considered an appropriate assumption to represent Lake Burrumbeet as being full during design modelling.
- Lake Goldsmith Storage.
  - **The 1% AEP event was modelled in RORB with the initial storage in Lake Goldsmith set as empty and full.** The sensitivity test revealed there was a negligible impact on the peak flow at Skipton regardless the initial storage was empty or full. When the Lake Goldsmith was empty, it was not filled and did not flow into Mt. Emu Creek. Even if Lake Goldsmith was full before an event, the flow spilling to Mt. Emu Creek was around 0.5 m^3/s.
- Roughness Coefficients.
  - **The modelled hydraulic roughness was increased by 20% and modelled for the 1% AEP event in TUFLOW.** The increase in roughness resulted in an increase of 10 to 20 cm at Trawalla and a slight increase in extent north of the railway. At the Lake Goldsmith steam rally site, there was a slight extension in flood extent, with flood water from Mt. Emu Creek entering Lake Goldsmith. There was a 16 cm increase in flood level at the steam rally site and a 20 cm increase at Camerons Bridge. There was a 20 cm increase in flood level in Skipton.
  - **The modelled hydraulic roughness was decreased by 20% and modelled for the 1% AEP event in TUFLOW.** The decrease in roughness resulted in a 10 to 15 cm reduction in water level at Trawalla and slight reduction in flood extent north of the railway. At the Lake Goldsmith Steam Preservation Association, there was a slight reduction in flood extent and a 17 cm reduction in flood level. A 20 cm reduction in flood level was observed at Camerons Bridge. Within the township of Skipton, there was a 20 cm reduction in water level and a minor reduction in flood extent.
- Bridge Blockage.
  - **A 50% blockage of bridges was modelled for the 1% AEP event in TUFLOW.** The new Western Highway bridge was excluded from this sensitivity test as there is no likelihood that it will be blocked due to the large span and height of the bridge. Results showed a 10 to 20 cm increase in water level and an increase in flood extent immediately upstream of the old Western Highway bridge in Trawalla. There was also an increase in water level upstream of Camerons Bridge which resulted in an increase of less than 10 cm at the Stream Preservation Association. Similarly, 50% blockage of the Glenelg Highway Bridge at Skipton increased water levels by less than 10 cm immediately upstream of the bridge.

- Climate Change.
  - **Modelling of Climate Change Representative Concentration Pathways (RCP) 4.5 and 8.5 for year 2090, was undertaken for the 1% AEP 36-hour and 96-hour events.** Results from the RORB model showed the maximum increase in peak design flows varied from 10% to 25% in the RCP4.5 scenario, and 20% to 50% in the RCP8.5 scenario. Results from the hydraulic model showed that the average increases in flood level ranged from 12 cm in the RCP4.5 scenario and an increase of 25 cm in the RCP8.5 scenario. It should be also noted that although the increase in rainfall intensity was modelled, the initial and continuing loss values were maintained. While predictions suggest rainfall intensity is likely to increase as result of climate change, it is also expected that the average temperature will increase and catchment conditions would be drier which may mean that initial losses are higher, compensating to some degree for the increase in rainfall intensity which may mean that initial losses are higher, compensating to some degree for the increase in rainfall intensity.

5 FLOOD RISK AND DAMAGE

The Flood Damages and Mitigation Assessment Report (R06) documented the level of flood risk and damage within the study area from the hydraulic modelling results. The model results were used to demonstrate which properties and roads would be inundated in each AEP.

5.1 Flood Risk

Flood mapping showed several roads became impacted by flood water during small and large events (i.e. 20% to 0.2% AEP). Table 5-1 summarises the major roads overtopped during the range of modelled design events and Figure 5-1 displays the location of them within the study area.

TABLE 5-1 MAJOR ROADS OVERTOPPED

Location	Road	Design event overtopped
Skipton	Smythe St	20%
Skipton	Wright St	10%
Skipton	Hardy St	5%
Skipton	Montgomery St East	5%
Skipton	Montgomery St West	5%
Skipton	Cleveland St	5%
Skipton	Anderson St South	5%
Skipton	Anderson St North	2%
Skipton	Montgomery St North	5%
Skipton	Montgomery St North2	2%
Skipton	Daly Rd	2%
Skipton	Pett St	1%
Trawalla	Trawalla-Waterloo Rd	20%
Trawalla	Langi Kal Kal Rd (railway north)	20%
Trawalla	Langi Kal Kal Rd (railway south)	10%
Trawalla	Langi Kal Kal Rd (old Western Hwy south)	2%
Trawalla	Langi Kal Kal Rd (further north)	1%
Langi Kal Kal	Racecourse Rd (Mt. Emu Creek)	10%
Mena Park	Beaufort – Carngham Rd (Mena Park gauge)	5%
Lake Goldsmith	Carngham - Lake Goldsmith Rd (Camerons Bridge)	2%
Lake Goldsmith	Cheesemans Rd (west of LGSPA)	5%
Lake Goldsmith	Skipton Rd (Lake Goldsmith)	1%
Lake Goldsmith	Cushing Rd	2%
Lake Goldsmith	Carngham - Streatham Rd (Mt. Emu Ck)	10%
Chepstowe	MortChup – Mt. Emu Rd (Baillie Ck)	20%
Chepstowe	Chepstowe-Pittong Rd (intersection with Guthries Rd)	1%
Chepstowe	Guthreis Rd (Guthries Bridge)	2%

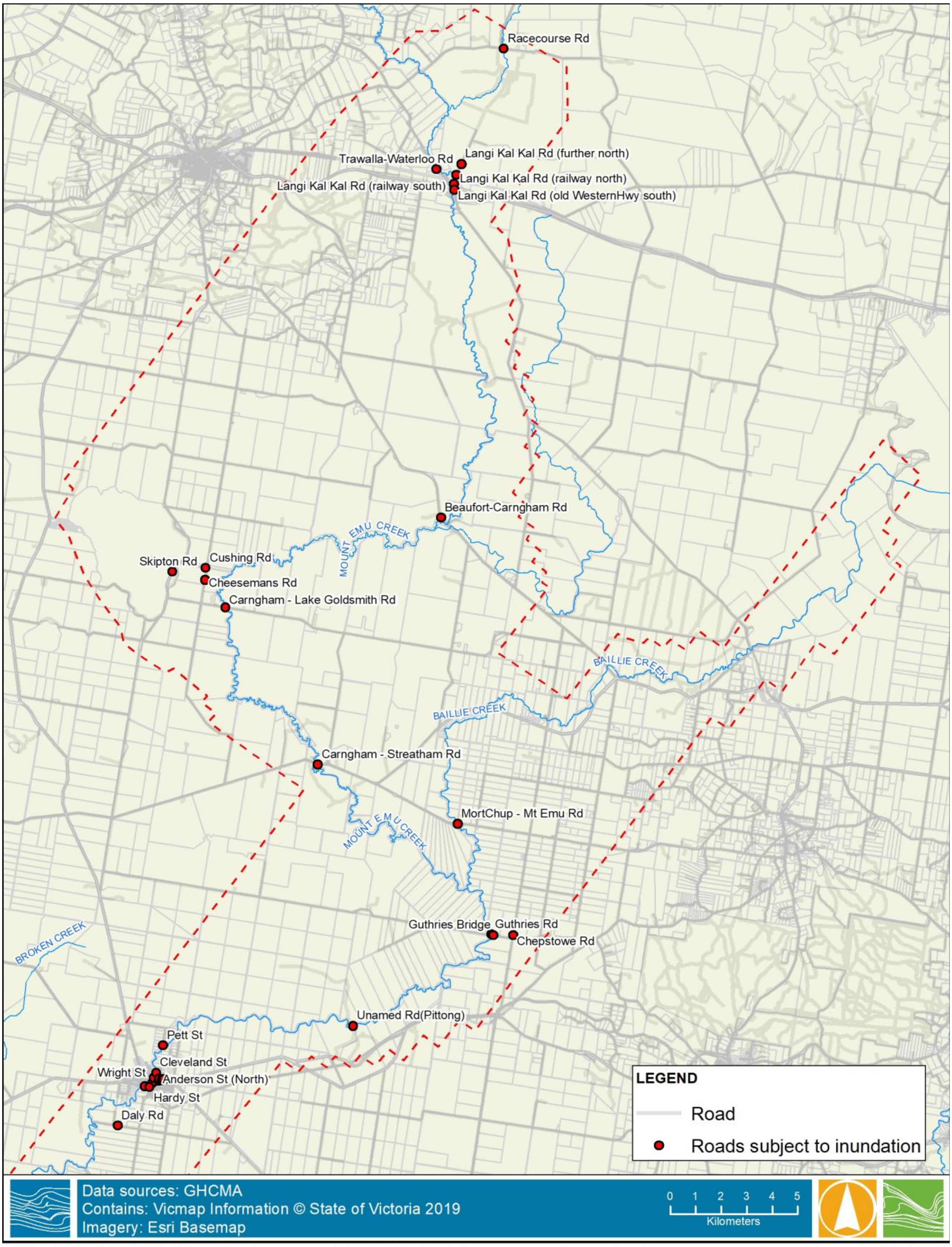

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FIGURE 5-1 KEY ROADWAYS SUBJECT TO INUNDATION

Floor level survey of 151 residential and commercial buildings was captured within the study area, including 78 in the Lake Goldsmith steam rally site. The flood modelling results showed that in a 1% AEP event, there are 32 properties in Skipton (include 11 residential properties), 74 commercial properties at the Lake Goldsmith Steam Preservation Association site and three residential properties in Trawalla identified to have above floor flooding. Figure 5-2 to Figure 5-4 display the properties inundated above floor flooding during the range of modelled AEP events within the study area.

FIGURE 5-2 PROPERTIES FLOODED ABOVE FLOOR DURING A RANGE OF AEP EVENTS (SKIPTON)

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FIGURE 5-3 PROPERTIES FLOODED ABOVE FLOOR DURING A RANGE OF AEP EVENTS (LAKE GOLDSMITH)

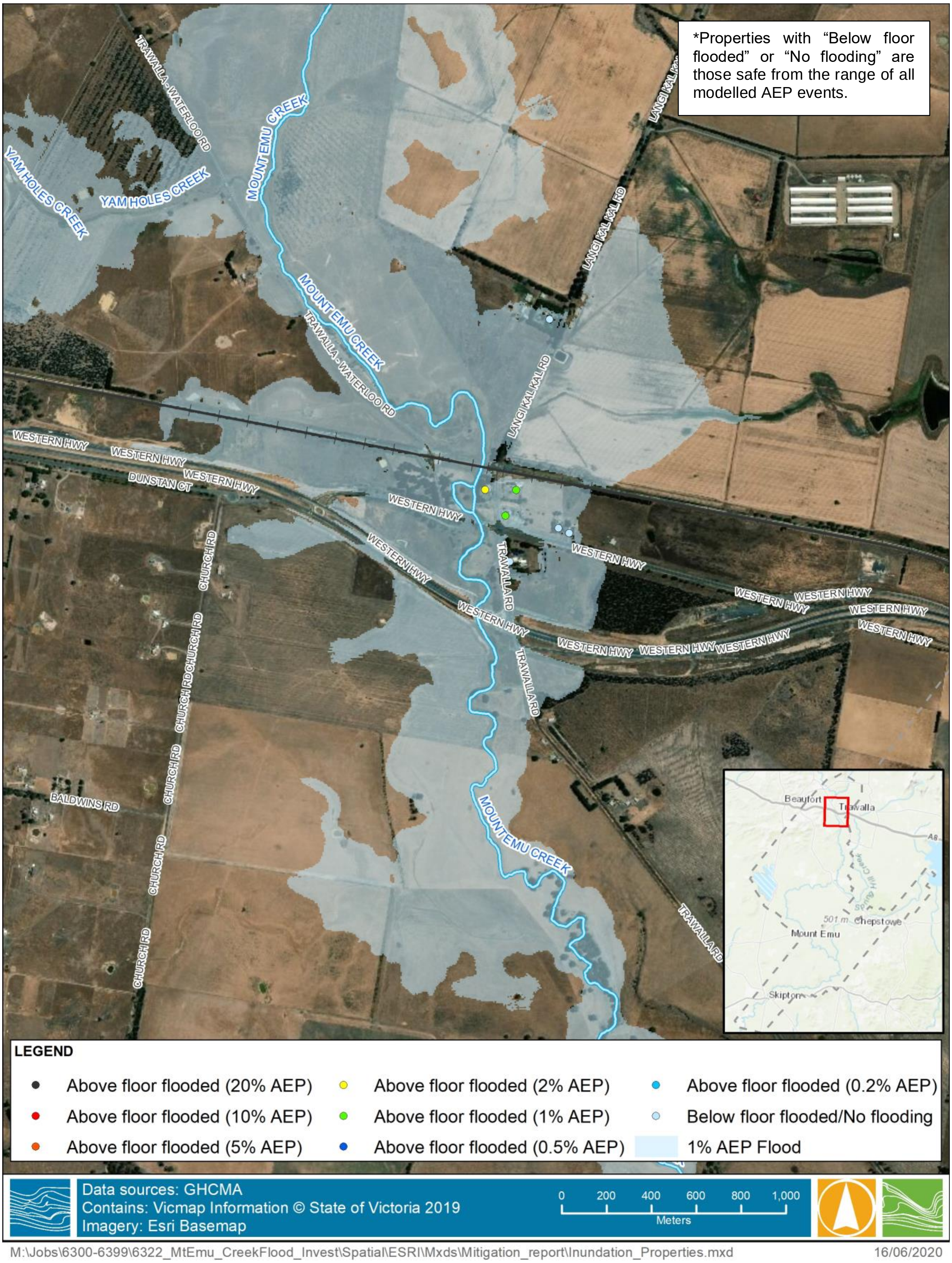

FIGURE 5-4 PROPERTIES FLOODED ABOVE FLOOR DURING A RANGE OF AEP EVENTS (TRAWALLA)

5.2 Damages Assessment

The flood damage assessment determined the monetary flood damage for the range of modelled design events. Model results for all mapped flood events were processed to calculate the number and the locations of properties and roads affected. This included properties inundated above and below floor, that did not have buildings impacted but the surrounding property was, and the length of flood affected roads.

Inundation damage of buildings within the Lake Goldsmith Steam Preservation Association site was assessed classifying each building as "commercial". This applies a commercial use standardised damage curve[6]. During January 2011 the financial cost of damage to the tenants of the Lake Goldsmith Stream Preservation Association was estimated at $300,000[7]; however, this number is considered to be a significant underestimate as it only includes the replacement cost of damaged non fixed assets (e.g. electrical equipment, paperwork, oil, etc.) and does not include the cost of repairs to the stored machinery, labour required to repair damage (a significant cost), earth works to access tracks, irreplaceable machinery lost, machinery which was damaged and failed post inundation etc. The commercial damage curves were considered to give a more realistic representation of the financial cost of inundation at these buildings than using the replacement cost of assets calculated by the LGSPA during January 2011 but are likely to be an overestimate. A detailed site specific damage assessment and development of site specific damage curves would be required to gain a better understanding of the potential economic cost of inundation at the LGSPA.

A summary of flood damage assessment is shown in Table 5-2. Above floor flooding occurs during events as low as a 5% AEP (20 year ARI) event and the number of properties flooded is doubled above 2% AEP (50 year ARI) event. An Average Annual Damage (AAD) cost of $245,000 was determined.

TABLE 5-2 RIVERINE EXISTING CONDITIONS FLOOD DAMAGES

EXISTING CONDITIONS							
ARI (years) AEP	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2
Residential Buildings Flooded Above Floor	15	15	14	11	5	0	0
Commercial Buildings Flooded Above Floor	99	99	97	92	37	0	0
Properties Flooded Below Floor	28	23	23	24	24	20	15
Total Properties Flooded	**142**	**137**	**134**	**127**	**66**	**20**	**15**
Direct Potential External Damage Cost	$170,224	$141,783	$132,296	$120,664	$114,553	$93,198	$37,230
Direct Potential Residential Damage Cost	$1,454,104	$1,325,926	$1,159,236	$870,691	$313,967	$0	$0
Direct Potential Commercial Damage Cost	$8,066,183	$7,251,535	$6,224,529	$4,121,525	$776,425	$0	$0
Total Direct Potential Damage Cost	**$9,690,511**	**$8,719,244**	**$7,516,061**	**$5,112,880**	**$1,204,945**	**$93,198**	**$37,230**
Total Actual Damage Cost *(0.8*Potential)*	**$7,752,409**	**$6,975,395**	**$6,012,849**	**$4,090,304**	**$963,956**	**$74,558**	**$29,784**
Infrastructure Damage Cost	**$594,044**	**$507,721**	**$391,828**	**$286,581**	**$193,488**	**$124,653**	**$85,897**
Indirect Clean Up Cost							
Indirect Residential Relocation Cost							
Indirect Emergency Response Cost							
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$8,346,453**	**$7,483,116**	**$6,404,676**	**$4,376,885**	**$1,157,444**	**$199,211**	**$115,681**
Average Annual Damage (AAD)	$245,048						

[6] NSW Office of Environment and Heritage (2007) Floodplain Risk Management Guidelines, and Neil J. Ericksen, John W. Handmer, David I. Smith (1985), ANUFLOOD : Evaluation of a computerised urban flood-loss assessment policy for New Zealand
[7] Pers. Comm. Lake Goldsmith Steam Preservation Association (Brian Smith).

6 FLOOD MITIGATION

The Flood Damages and Mitigation Assessment Report (R06) documented the flood mitigation measures tested in hydraulic model.

6.1 Overview

The implemented mitigation works in Skipton downstream of Jubilee Lake was reviewed.

Several mitigation options were assessed during this study, focusing on the Lake Goldsmith Steam Preservation Association and Skipton. The modelled mitigation options were either a requirement of the project and detailed in the tender brief or discussed with GHCMA and the project reference group. The mitigation options assessed in this study are summarised as follows:

- LGSPA.
  - Option 1 - A levee around the LGSPA site - 1% AEP flood event.
  - Option 2 - Enlarging the capacity of Cameron Bridge (Pyrenees Shire Bridge 22) - 1% AEP flood event.
  - Option 3 – Enlarging the capacity of Cameron Bridge (Pyrenees Shire Bridge 22) and excavating additional floodplain storage to increase conveyance – 1% AEP flood event.
  - Option 4 - Opening the Lake Goldsmith Diversion Channel at Cheesemans Road - 2016 and all modelled AEP events.
- Skipton.
  - Option 5 - Doubling the size of the Glenelg Highway bridge - 1% AEP flood event.

There are a range of non-structural mitigation options that can be implemented including land use planning, flood warning, flood response and flood awareness.

- The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).
- Flood warning systems provide a means of gathering information about impending floods, communicating information to those at risk and facilitating an effective and timely response. Flood warning systems aim to enable and persuade people and organisation to take action to increase potential safety and reduce the damage caused by flooding.

6.2 Implemented Mitigation Works

An upgrade to culverts in Skipton downstream of Jubilee Lake increasing the conveyance of spills from the lake to Mt. Emu Creek was constructed by Corangamite Shire in mid-2016. The impact of the 2016 flood was considered to have been largely mitigated by these culverts. The culverts direct overflows from Jubilee Park Lake through the Skipton town centre into Mt. Emu Creek. The culverts were upgraded from two Reinforced Concrete Pipes (RCP) to six box culverts. A review of the impact the mitigation culverts has had on flood risk at Skipton was undertaken. The results showed that the mitigation culverts were able to convey outflows from Jubilee Park Lake for up to 2% AEP event. In contrast, the old RCP pipes were unable to convey 20% AEP, as shown in Table 6-1.

It is noted that the Jubilee Park Lake outflow is the dominant flooding mechanism up to the 10% AEP event. For the 5% AEP and above, overbank flooding from the Mt. Emu Creek is the dominant flood mechanism. Overall, the mitigation works completed in mid-2016 can significantly reduce flood risk from Jubilee Park Lake outflows up to 2% AEP event but inundation via Mt. Emu Creek will still occur in events as low as a 5% AEP

TABLE 6-1 MITIGATION CULVERTS CAPACITY UNDER FULL RANGE OF DESIGN FLOWS

AEP	Jubilee Park Lake outflows (m^3/s)	Mitigation culverts flow (m^3/s)	Pipe flow (2x550mm RCP) (m^3/s)
20%	1.65	1.65	1.26
10%	2.10	2.10	1.27
5%	3.11	3.11	1.28
2%	5.22	5.09	1.30
1%	7.00	6.97	1.31
0.5%	7.51	7.46	1.31
0.2%	10.40	8.94	1.33

6.3 Lake Goldsmith Steam Preservation Association

6.3.1 Option 1 - Lake Goldsmith Steam Preservation Association levee

A levee was added around the Lake Goldsmith Steam Preservation Association site to prevent inundation. The levee blocked inundation from Mt. Emu Creek and increased water levels north and west of the site by slightly above 0.5 cm. The impact of the levee also resulted in a slight increase in water level in the diversion channel at Lake Goldsmith by about 2 m. Water levels surrounding the steam rally site were slightly above 347 m AHD (i.e. approximately 1.5 m deep). If a levee were to be constructed it would also most likely require a 0.3-0.6 m freeboard to meet the Victorian Levee Management Guidelines.

Overall, the construction of levee at the Lake Goldsmith Steam Preservation Association site is unlikely to have significant negative impacts on neighbouring properties, there are only minor increases in water level as a result of the levees restriction to floodplain flow.

6.3.2 Option 2 - Cameron Bridge Capacity Increase

Enlarging the Cameron Bridge (Pyrenees Shire Bridge 22) in Carngham – Lake Goldsmith Rd and removing constraints in the waterway channel was proposed to allow additional flow through the bridge and alleviate a backwater through the Lake Goldsmith Steam Preservation Association.

Results showed water levels within the floodplain immediately upstream of the bridge were reduced by more than 0.1 m, including across the Lake Goldsmith Steam Preservation Association site. The flood extent was slightly reduced, with no flood water spilling into the diversion channel. There was also an increase in flood levels downstream of the Carngham – Streatham Rd bridge to Skipton, these increases were shown to be relatively small with no enlargemnt of the flood extent.

This reduction in water level at the Lake Goldsmith Steam Preservation Association site does not effectively alleviate the flood risk. A limited decrease to flood damages is expected.

6.3.3 Option 3 - Cameron Bridge Capacity Increase and Enlargement of the Waterway

An additional mitigation option proposed by the LGSPA was to increase the floodplain conveyance up and downstream of Cameron Bridge (Pyrenees Shire Bridge 22) with a series of excavations as well as increasing the size of Cameron Bridge. This option lowered the floodplain to the same level as the existing creek invert to maximise the potential for mitigation measure to reduce flood levels.

Results showed water levels within the floodplain immediately upstream of the bridge were reduced by more than 60 cm, including across the Lake Goldsmith Steam Preservation Association site. The flood extent was noticeably reduced. However, the site was still inundated by up to 50 cm. There was also an increase in flood levels downstream of the Carngham – Streatham Rd bridge to Skipton. The incresae in water levels at Skipton was between 2 cm to 5 cm with no enlargement of the flood extent.

Overall, the enlargement of waterway cross section to allow more flows can significantly reduce the floodwater levels and flood extent in LGSPA site. However, the economic feasibility of this mitigation option needs to be considered while there is also potential increase in water level at Skipton.

6.3.4 Option 4 - Opening the Lake Goldsmith Diversion Channel at Cheesemans Road

Modelling of the Lake Goldsmith Diversion Channel both open and closed was completed for both the 2016 and all modelled AEP events. This mitigation option aimed to re-assess whether opening the channel could reduce inundation of the Lake Goldsmith Steam Preservation Association and to check the results of the previous analysis[1] using the updated hydrology and hydraulic model. The channel was closed during the 2011 flood event but open during 2016. Modelling demonstrated a minor reduction in water levels could be achieved upstream of the channel. The diversion channel has a limited capacity and it cannot divert enough water to significantly reduce flood levels in Mt. Emu Creek. If this option were to be seriously considered, a large increase in the capacity of the channel would be necessary. However, this would be a costly exercise and be unlikely to significantly change the overall results given the relative comparison between the channel and the Mt. Emu Creek waterway and floodplain. The results of this assessment affirm the conclusions reached in the 2013 study[1].

The parcels that encompass the Lake Goldsmith Diversion Channel are managed by Parks Victoria (Lake Goldsmith Wildlife Reserve), and a grazing licence has been issued to the adjacent landholders. The bluestone structure on Cheesemans Road is within a Government Road managed by Pyrenees Shire Council, with the bridge structure owned and managed by Pyrenees Shire Council. This study (and similar previous investigations) has determined removal of the timber boards associated with the Cheesemans Road structure has no potential to cause a reduction in inundation for the LGSPA or Skipton; however, any flood-related operation of the boards would require approval from an Incident Control Centre or similar emergency response entity. Pyrenees Shire Council’s preference is for any management of flow in this channel to be independent of the Cheesemans Road bridge. The future of the drop board structure is a matter to be resolved via discussion between DELWP, ParksVic, Pyrenees Shire Council and Glenelg Hopkins CMA.

6.3.5 Cost Benefit Analysis

A high level cost versus benefit analysis was completed for the levee option given its apparent feasibility. The assumed characteristics of the assessed levee protecting the LGSPA site was determined and its dimensions were used to calculate a preliminary cost of the levee. The costing was based on standard industry rates used by Melbourne Water for earthworks and construction. The estimated total cost of the LGSPA levee, including engineering, administration and contingency costs was $709,740.

The Average Annual Damage (AAD) of a flood event within the study area was recalculated with the inclusion of the levee protecting the LGSPA site from all events up to a 0.2% AEP event. The revised AAD shows a reduction of around $101,000 from $245,000 to $144,000.

The high level cost versus benefit analysis results are shown in Table 6-2. A net present value model was used by applying a 6% discount rate over a 30 year project life. Assuming the maintenance of the levee of $2,000/year as an indicative sum, this maintenance could be undertaken by the LGSPA and the levee managed as a private asset. The LGSPA levee is a cost effective solution with a benefit cost ratio of 2.0.

TABLE 6-2 BENEFIT COST RATIO FOR THE LGSPA LEVEE

Benefit cost ratio	
Material/ Construction Labour Cost	$ 456,865
Engineering, administration and contingency	$ 252,875
Total Cost	**$ 709,740**
Annual Maintenance	$ 2,000
Existing Conditions AAD	$ 245,000
AAD	$ 144,000
Annual Saving	$ 99,000
NPV 6%	$ 1,392,178.25
Capital Cost	$ 709,740
B-C Ratio	**2.0**

The LGSPA proposed a series of culverts under the Carngham Lake Goldsmith Road to reduce its hydraulic impact, as well as excavating a portion of the floodplain to increase the capacity of a confined section of Mt. Emu Creek. Modelling of this option did not explicitly include the culverts but removed the bridge entirely and increased the available opening to a much greater area than the proposed culverts arrangement could to assess the maximum potential reduction in flood levels upstream of the structure. The cost of the proposed culvert arrangement was indicatively determined using standard industry rates used by Melbourne Water for earthworks and culvert installation. The estimated cost of the culverts, including engineering, administration and contingency costs is $3,760,000. However, increasing the capacity of Cameron Bridge (Pyrenees Shire Bridge 22) is expected to reduce inundation at the LGSPA site by less than 10 cm in a 1% AEP event. The cost of the works far outweighs the benefits and is not considered a viable option.

Modelling of the excavation of the floodplain was also very extensive in order to demonstrate the maximum benefit that could be achieved. The excavation of floodplain storage was estimated to cover around 6.6 Ha and 267,000 m^3. The resulting cost of excavation is around $4,000,000. However, increasing the capacity of Cameron Bridge (Pyrenees Shire Bridge 22) and increasing the capacity of the Mt. Emu Creek channel is expected to reduce inundation at the LGSPA site by 50 – 60 cm at most. With 1% AEP depth still reaching up to 0.5m, the cost of the works far outweighs the benefits and is not considered a viable option.

6.4 Skipton

6.4.1 Option 5 – Increasing the size of the Glenelg Highway bridge at Skipton

Modelling of an increase to the Glenelg Highway bridge capacity (around double) showed flood level decreases of 10-15cm on properties immediately upstream of the bridge while flood risk on other properties within Skipton was not shown to be significantly reduced.

In a 1% AEP event, these properties are inundated to depths exceeding 0.5 m. Increasing the size of the bridge or opening the Lake Goldsmith diversion channel (option 4) do not reduce the level of flood risk or damage likely to be experienced at Skipton according to the results of the modelling assessments. Figure 6-1 below provides a visual representation of this in relation to the likely change in the 1% and 5% AEP flood levels at the Skipton Hotal.

FIGURE 6-1 DEMONSTRATION OF THE REDUCTION IN ABOVE FLOOR INUNDATION AT THE SKIPTON HOTEL

6.5 Land use and planning control

This study has produced the outputs for generation of LSIO and FO layers for inclusion in the Corangamite Shire Council and the Pyrenees Shire Council Planning Schemes. These layers were created in line with the Glenelg Hopkins CMA criteria, as shown below:

- LSIO – area inundated in a 1% AEP flood extent.
- FO – area inundated meeting the following criteria:
  - Land where the 1% AEP flood depth is likely to reach or exceed 0.5 metre, and/or
  - Land where the 1% AEP flood hazard factor (the produce of depth and velocity) is likely to reach or exceed 0.4 m^2/s, and/or

6.5.1 Planning Controls in Upper Mt. Emu Creek Catchment

In assessing how flood controls should be applied within the Upper Mt. Emu Creek Catchment area, consideration must be given to both the extent of 1% AEP flood event as produced by the hydraulic modelling results and the nature of the flood risk. Figure 6-2 and Figure 6-3 show the draft planning overlays produced in this study for Pyrenees Shire Council and Corangamite Shire Council. Other municipalities are covered by the layers produced by this study (Ballarat City Council and Golden Plain Shire Council) which may provide opportunities for amendments to their respective planning schemes.

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent
  - Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known

as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

The LSIO identifies lands in flood fringe areas with shallow or slow moving water.

- **Floodway Overlay (FO)** – defines the high hazard portion of the floodplain
  - Floodway Overlays apply to land that is identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

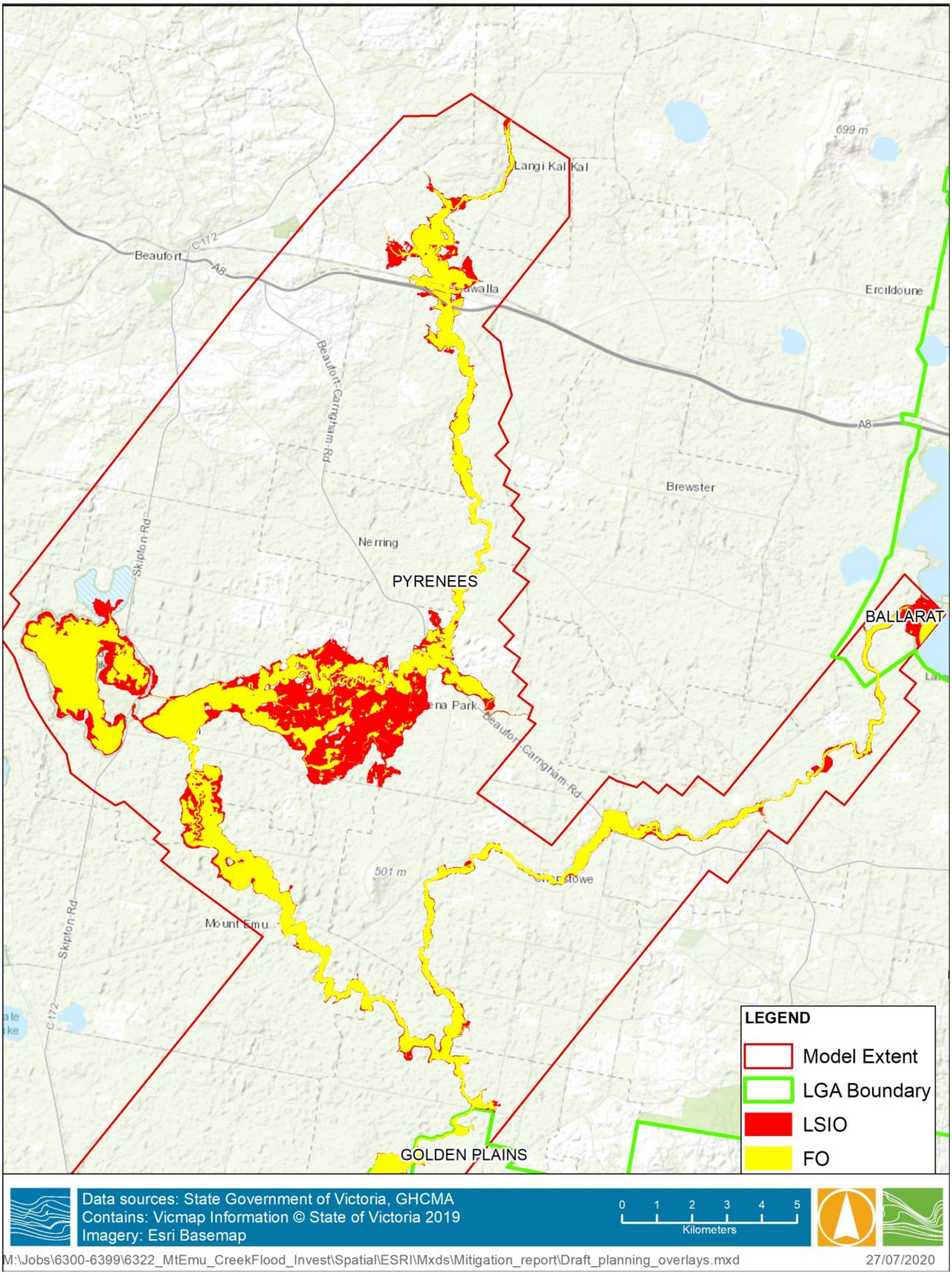

FIGURE 6-2 FLOOD RELATED PLANNING CONTROLS - PYRENEES SHIRE AREA

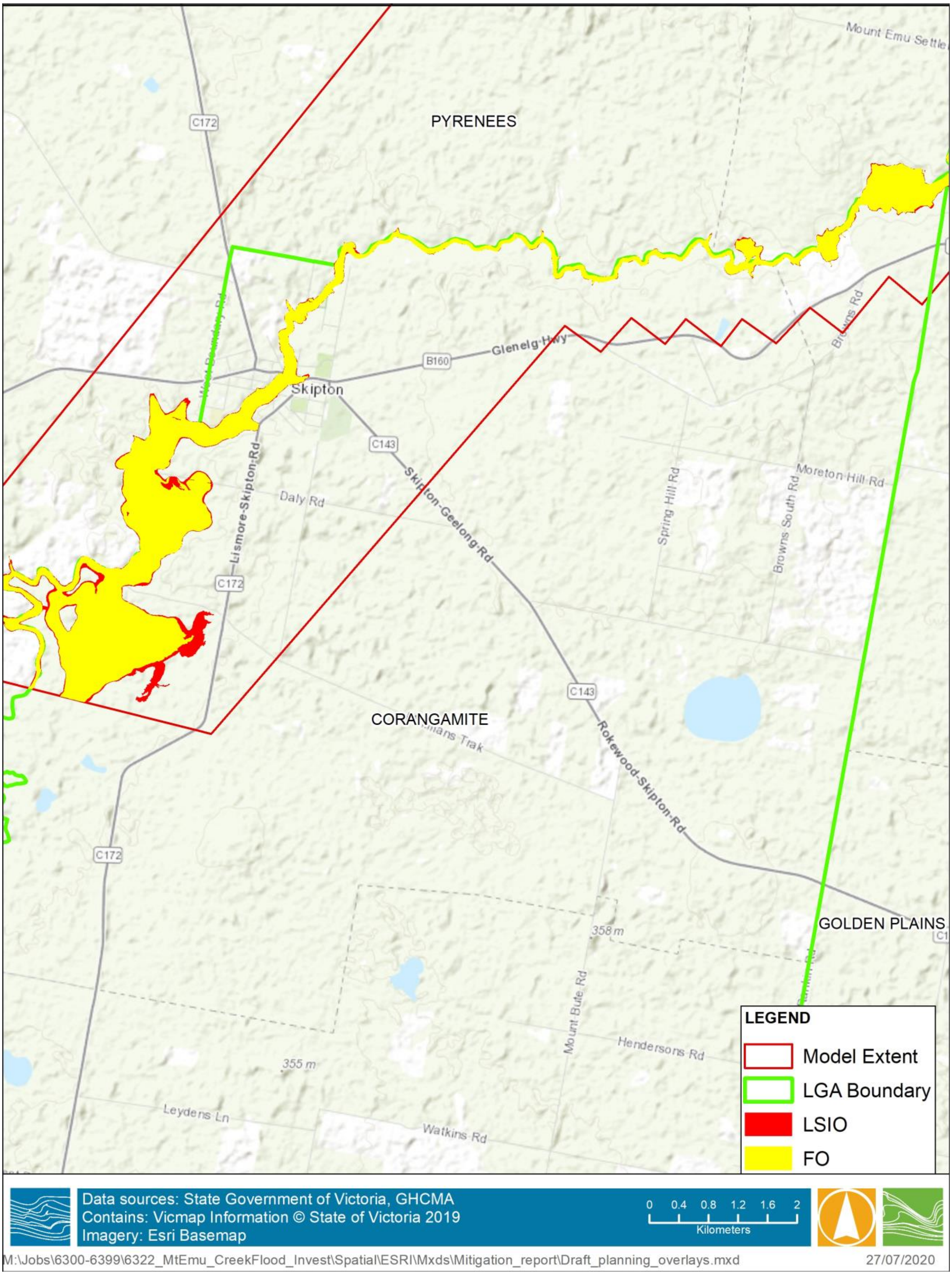

FIGURE 6-3 FLOOD RELATED PLANNING CONTROLS - CORANGAMITE SHIRE AREA

6322_R08V04_MtEmuCk_Summary.docx

7 FLOOD WARNING

The Flood Warning Report (R05) detailed the flood warning deliverables and discussed the uncertainty in rating curve estimates and travel times.

7.1 Overview

The tender document set out several specific flood improvements required to facilitate the implementation of a formal flood warning service for Skipton. The Bureau of Meteorology highlighted the following locations as potentially useful gauging stations for Mt. Emu Creek:

- Mount Emu Creek at Guthrie's Bridge (has been used for PALS deployments).
- Mount Emu Creek at Mena Park (historic gauging station).
- Mount Emu Creek at Camerons Bridge (potential future gauging station (long term) – proposed PALS site (short term)).
- Mount Emu Creek at Skipton (historic gauging station).
- Mount Emu Creek at Trawalla (potential future gauging station).
- Baillie Creek at Carngham – Streatham Road (proposed PALS site).

The hydraulic model was used to produce rating curves at each of the above locations and the flood peak travel time estimates between them. The theoretical rating curves were compared to the available existing curves (where available) and historic observations. Peak travel time estimates are presented in a table showing a range of peak travel times dependent on the magnitude of events.

7.2 Summary and Outcomes

- Gauge Rating Curve Estimates
  - Comparisons between the existing and modelled rating curve was made. Information on low flows was missing in the modelled rating curves given only relatively high flow events were modelled. The modelled rating curves are expected to perform much more accurately in high flow when the total flow is dominated by floodplain flow. The existing gauge rating curves can be revised and updated by combining the gauge rating curve (low flow) with the modelled rating curve. An example combined rating curve comparison at Skipton is shown in Figure 7-1.

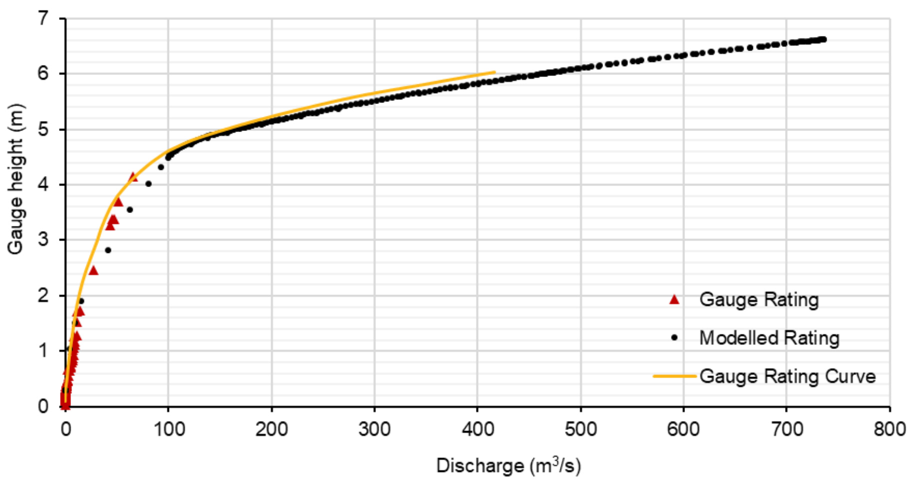

FIGURE 7-1 RATING CURVE COMPARISON AT SKIPTON GAUGE

- Flood Peak Travel Time Estimates
  - The flood peak travel time along the Mt. Emu Creek and Baillie Creek varies between flood events, depending on the storm durations, the magnitude of the event and catchment antecedent conditions. The January 2011 and September 2016 events give an indication of historic timing while the design events give an indication of timing given specific rainfall characteristics. Understanding the timing of historic events is important for future flood warning purposes because of the community and emergency agency perception of these events. It allows for a point of reference for future events as a point of comparison showing similarities or discrepancies. The peak travel time from the Mena Park gauge to Camerons Bridge is generally between 5 to 9 hours. The travel time from upstream gauges along Mt. Emu Creek and Baillie Creek to the Skipton gauge and Guthries Bridge gauge varies depending on which waterway dominates flow. From a flood warning perspective, Guthries Bridge can confirm the expected forecast at Skipton and should be used as a key site supporting flood forecasting. The travel time from Guthries Bridge gauge to Skipton gauge is estimated to be between 2 to 4 hours. An example of travel time for the January 2011 flood is shown below.

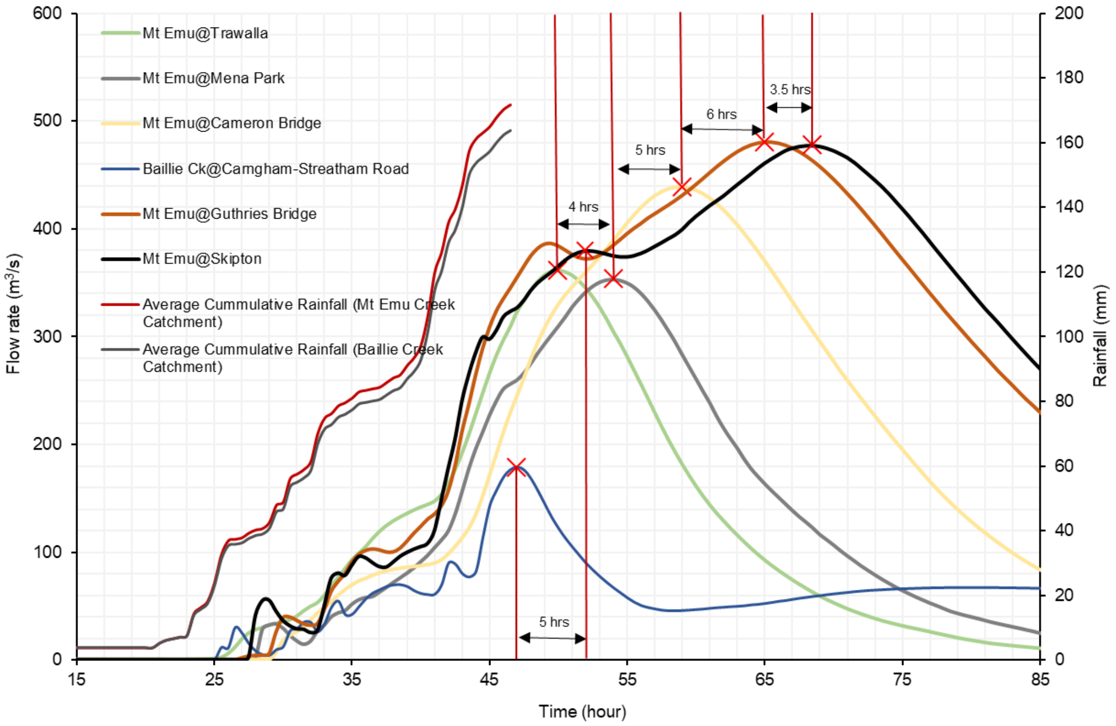

FIGURE 7-2 PEAK TRAVEL TIME ESTIMATES FOR JANUARY 2011 FLOOD

- Flood Classification Levels
  - The flood class levels for Mt. Emu Creek at Skipton Gauge were revised since the existing flood class levels has been invalid after the mitigation works changed the flooding characteristics in Skipton.
  - Minor flood level - 4.18 m
    - The 20% AEP event impacts match well with the minor flood classification definition, and it is suggested a level of 4.18m be adopted as a minor flood class level linking to the 20% AEP event and mapping.
  - Moderate flood level – 4.88 m

  - The 10% AEP event impacts match well with the moderate flood classification definition. It is suggested a level of 4.88m be adopted as a moderate flood class level linking to the 10% AEP event and mapping.
- Major flood level – 5.23 m
  - The 5% AEP event impacts match well with the major flood classification definition. It is suggested a level of 5.23 m be adopted as a major flood class level linking to the 5% AEP event and mapping.

The new flood classification levels are compared and summarised in Figure 7-1below.

TABLE 7-1 COMPARISON AND SUMMARY OF FLOOD CLASS LEVELS AT SKIPTON

Flood class level	2013 Flood study[1]	2019 Flood study
Minor flood level	4.00 m	4.18 m
Moderate flood level	4.70 m	4.88 m
Major flood level	5.10 m	5.23 m

8 FLOOD INTELLIGENCE

The project has produced updated flood intelligence tables for the Corangamite Shire Municipality Flood Emergency Plan (MFEP) and for the first time, flood intelligence tables covering Mt. Emu Creek and Baillie Creek for inclusion in the Pyrenees Shire MFEP. These outputs are provided in the Flood Intelligence Report – R07.

8.1 Flood Intelligence Deliverables

It is important to note that the flood intelligence deliverables produced in this study were tailored to riverine flooding caused by Mt. Emu Creek. At Skipton, flooding can be induced by either Mt. Emu Creek or Jubilee Lake outflow or a combination of both as discussed in Section 6.2.

In addition, timing of flooding in Mt. Emu Creek downstream of the Baillie Creek confluence can be influenced by the concurrence of peak flows in both waterways. This is especially prevalent when a 'double peak' rainfall pattern occurs when two high intensity rainfall bursts occur during the one event. This can result in the timing of the first flow peak in Mt. Emu Creek occurring concurrently with the second peak in Baillie Creek. This double peak temporal pattern can occur within the Mt. Emu Creek catchment and is something emergency response agencies should be aware of during an event.

Table 8-1 and Table 8-2 show the gauge height in reference to design flood events and historical events at existing gauges within the catchment.

TABLE 8-1 MT. EMU CREEK AT SKIPTON GAUGE IN REFERENCE TO FLOOD EVENT

Flood event	Gauge height (m)	Gauge height (m AHD)
20% AEP	4.18	274.66
10% AEP	4.89	275.37
5% AEP	5.23	275.71
2% AEP	5.76	276.24
1% AEP	6.08	276.56
0.5% AEP	6.29	276.77
0.2% AEP	6.63	277.11
2011 flood	6.04	276.52
2016 flood	4.88	275.36

TABLE 8-2 MT. EMU CREEK AT MENA PARK GAUGE IN REFERENCE TO FLOOD EVENT

Flood event	Gauge height (m)	Gauge height (m AHD)
20% AEP	2.34	353.14
10% AEP	2.53	353.33
5% AEP	2.67	353.47
2% AEP	2.94	353.74
1% AEP	3.11	353.91
0.5% AEP	3.25	354.05
0.2% AEP	3.42	354.22
2011 flood	3.43	354.23

Flood event	Gauge height (m)	Gauge height (m AHD)
2016 flood	2.75	353.55

The typical flood peak travel times between key locations along Mt. Emu Creek and Baillie Creek were calculated. Table 8-3 below shows the Typical Flood Peak Travel Times Table for the study area.

TABLE 8-3 TYICAL FLOOD PEAK TRAVEL TIMES

Location From	Location To	Typical Travel Time	Comments
Riverine flooding – Mt Emu Creek			
Start of rainfall	Trawalla	4 to 11 hours	To start of rise, the bigger the flood the closer time will be to 4 hours
Start of rainfall	Mena Park	7 to 14.5 hours	To start of rise, the bigger the flood the closer time will be to 7 hours
Start of rainfall	Cameron's Bridge	8.5 to 20.5 hours	To start of rise, the bigger the flood the closer time will be to 8.5 hours
Start of rainfall	Guthries Bridge	5.5 to 18 hours	To start of rise, the bigger the flood the closer time will be to 5.5 hours
Start of rainfall	Skipton	6.5 to 16 hours	To start of rise, the bigger the flood the closer time will be to 7 hours
End of rainfall	Skipton	22 to 31.5 hours	To peak
Trawalla	Skipton	18.5 to 27 hours	The bigger the flood the closer time will be to 18.5 hours
Mena Park	Skipton	14.5 to 20.5 hours	The bigger the flood the closer time will be to 14.5 hours
Cameron's Bridge	Skipton	9.5 hours to 13.5 hours	The bigger the flood the closer time will be to 9.5 hours
Guthrie's Bridge	Skipton	0.5 to 3.5 hours	The bigger the flood the closer time will be to 0.5 hours
Riverine flooding – Baillie Creek			
Start of rainfall	Carngham – Streatham Road	4.5 to 10.5 hours	To start of rise, the bigger the flood the closer time will be to 4.5 hours
Carngham – Streatham Road	Skipton	20 to 34.5 hours	Peak at Skipton driven by Mt Emu Creek
		3.5 to 5 hours	Peak at Skipton driven by Baillie Creek

Flood intelligence cards were created to inform decision making during a flood event. The describe the water level at each gauge station and the corresponding magnitude of the event (i.e. AEP event), the consequence of inundation and actions required to reduce it. These were outlined in the MFEP outputs for Corangamite Shire Council and Pyrenees Shire Council.

Inundation tables were created to summarise the potential number of properties and roads inundated, their locations and the potential duration of isolation during a flood event. The properties flooded above flood are shown in Table 8-4.

TABLE 8-4 PROPERY INUNDATION TABLE

Location	Depth of over floor flooding at each property for each AEP event							Type of Building
	20%	10%	5%	2%	1%	0.5%	0.2%	
Skipton Gauge Height (m)	**4.18**	**4.89**	**5.23**	**5.76**	**6.08**	**6.29**	**6.63**	-
7 Anderson St (Dwelling and shed, depth over floor refers to dwelling)	0.00	0.00	0.00	0.42	0.80	1.06	1.46	Residential
38 Bridge Rd	0.00	0.00	1.00	1.50	1.81	2.03	2.38	Residential
1 Cleveland St	0.00	0.00	0.29	0.90	1.24	1.48	1.85	Old common school - Bluestone
3 Cleveland St	0.00	0.00	0.28	0.91	1.27	1.51	1.89	Residential
3 Cleveland St	0.00	0.00	0.26	0.87	1.22	1.45	1.83	Residential - Brickhouse
Lot 2 Hardy St	0.00	0.00	0.40	0.92	1.22	1.43	1.76	Commercial - Tin Shed 'Castlebar'
16 Montgomery St	0.00	0.00	0.00	0.00	0.05	0.31	0.71	Residential
18 Montgomery St	0.00	0.00	0.00	0.00	0.00	0.12	0.51	Residential
23 Montgomery St	0.00	0.00	0.41	1.06	1.47	1.73	2.12	Bluestone (Skipton Hotel Bar)
23 Montgomery St	0.00	0.00	0.43	1.09	1.49	1.75	2.15	Render over brick (Hotel Dining Lounge)
23 Montgomery St	0.00	0.00	0.64	1.29	1.69	1.96	2.35	Bluestone Shed (No apparent floor level)
25 Montgomery St	0.00	0.00	0.40	1.04	1.45	1.71	2.11	Weatherboard
27 Montgomery St	0.00	0.00	0.57	0.69	1.10	1.37	1.77	Commercial
31 Montgomery St	0.00	0.00	0.00	0.45	0.84	1.10	1.49	Residential
33 Montgomery St	0.00	0.00	0.00	0.14	0.53	0.80	1.19	Residential
1 Pett St	0.00	0.00	0.48	1.41	1.97	2.36	2.95	Shed on stumps
44 Wright St (Dwelling and shed, depth over floor refers to dwelling)	0.00	0.00	0.00	0.43	0.77	1.01	1.37	Residential
Historical Society Museum	0.00	0.00	0.48	1.00	1.30	1.51	1.86	Commercial

Location	Depth of over floor flooding at each property for each AEP event							Type of Building
	20%	10%	5%	2%	1%	0.5%	0.2%	
Art Gallery (Dwelling and shed, depth over floor refers to dwelling)	0.00	0.00	0.66	1.20	1.51	1.73	2.09	Commercial
Crawford Dowling	0.00	0.00	0.00	0.00	0.00	0.20	0.61	Commercial
Eel Factory	0.00	0.00	0.32	1.03	1.41	1.66	2.06	Commercial
FoodWorks (existing)	0.00	0.00	0.28	0.93	1.34	1.60	1.99	Commercial
FoodWorks (new)	0.00	0.00	0.00	0.13	0.53	0.80	1.19	Commercial
Healthcare Pharmacy	0.00	0.00	0.35	1.01	1.41	1.67	2.07	Commercial
Garage (workshop)	0.00	0.00	0.57	1.21	1.62	1.89	2.28	Commercial
Skipton Pottery	0.00	0.00	0.80	0.72	1.13	1.40	1.80	Commercial
Shed at Cleveland St	0.00	0.00	0.84	1.43	1.77	2.00	2.37	Commercial
Shed at Bridge St	0.00	0.00	0.97	1.53	1.85	2.07	2.43	Commercial
Shed at Stewart Park	0.00	0.00	0.44	1.10	1.48	1.74	2.14	Commercial
Trawalla (no existing relevant gauge location)								-
3862 Western Highway	0.00	0.00	0.00	0.00	0.21	0.35	0.47	Weatherboard dwelling on stumps
11 Langi Kal Kal Road	0.00	0.00	0.00	0.33	0.57	0.71	0.84	Weatherboard dwelling concrete slab
14 Langi Kal Kal Road	0.00	0.00	0.00	0.00	0.11	0.25	0.37	Weatherboard dwelling on stumps

9 STUDY DELIVERABLES

9.1 Overview

This project has enabled development of a comprehensive set of high quality data enabling attainment of the floodplain management objectives listed in the project brief and repeated in Section 1.2. The outputs were supplied on a study hard drive and consist of the background data and outputs listed below:

- Digital copies of study reports in PDF format.
- Study survey data (LiDAR, floor levels, flood levels etc.).
- Model input data including streamflow, rainfall data.
- Property inundation table in GIS format.
- Digital copies of the maps, including MFEP mapping.
- GIS datasets for the model results (MapInfo and Esri format).
- The hydrologic and hydraulic model files.

9.2 GIS Datasets

The following datasets are provided. All GIS files were provided in ESRI and MapInfo format.

- Grids
  - Design events (20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP evets and PMF) – maximum depth, water surface elevation, hazard and velocity
  - Historical events (2011 and 2016 floods).
  - Climate change sensitivity RCP4.5 and 8.5 for year 2090 (1% AEP).
- Shapefiles/Tabfiles
  - Water surface elevation contours.
  - Flood extents.
  - Floor level points.

9.3 Maps

The MFEP flood response maps were produced for the range of all design flood events, including 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events:

- Flood extent with property inundation at key townships (Skipton, Guthries Bridge, Lake Goldsmith, Mena Park, Trawalla)
- Flood depth with. road inundation at key townships (Skipton, Guthries Bridge, Lake Goldsmith, Mena Park, Trawalla).

9.4 Flood Extent Mapping (VFD compliant)

All flood mapping data was prepared to the VFD metadata specifications

9.5 Land Use Planning Maps

A draft FO and LSIO maps were produced and included on the study hard drive.

10 CONCLUSIONS

- Flood risk on access roads and properties
  - Flood mapping shows several major roads within the study area can become impacted by flood water during relatively frequent events (20% AEP). A summary table has been produced to identify the major roads which become overtopped during a range of design events. Consideration should be given based on this table in planning for suitable evacuation routes.
  - Floor level survey of 151 residential and commercial buildings, including 78 in LGSPA site was used to classify the flood risk at a property scale and produce property inundation tables for Corangamite and Pyrenees Shire Councils.
- Flooding characteristics at Skipton
  - Local catchment inflows through Jubilee Lake is the dominant flooding mechanism for more frequent events (up to 10% AEP). For the 5% AEP and above, overbank flooding from the Mt. Emu Creek is the dominant flood mechanism. The mitigation works completed in mid-2016 can significantly reduce flood risk from Jubilee Lake outflows up to 2% AEP event. The flood class levels for Skipton were revised and it is recommended an update to account for changed flooding characteristics following the completion of mitigation works.
- Flood mitigation at LGSPA site
  - The LGSPA site is likely to be impacted by flood water from Mt. Emu Creek during relatively frequent events (i.e. 20% AEP). Several mitigation options were examined using hydraulic model. The most cost-effective solution is to construct a levee around the site.
- Flood warning improvement outputs
  - The establishment of hydraulic model for this study produced theoretical rating curves for existing and potential gauging sites. It is recommended that the existing gauge rating curves to be modified by joining the current measurement-based rating and the modelled theoretical rating. This will enable an accurate rating at low in channel flows (based on measured data) and high out of bank flows (based on theoretical model results).
- Planning Controls
  - Due to the high hazard nature of flood risk at Skipton, the most appropriate planning control for Skipton is the Flood Overlay (FO).
  - The planning overlays produced in this study extend from 4 km upstream of Trawalla to 4 km downstream of Skipton whilst covering associated floodplain along Mt. Emu Creek and the entirety of Baillie Creek.
  - The existing FO in Skipton remains appropriate and no changes is recommended.

11 RECOMMENDATIONS

Recommendations made during the Upper Mt. Emu Flood Investigation have been separated into the agencies responsible for their fulfilment, these are as follows:

- **BoM**
  - Review and consider adoption of the recommended rating curve changes.
  - Utilise the model results to develop flood warning information for Mt. Emu Creek and Baillie Creek.
- **Corangamite and Pyrenees Shire Councils**
  - Review and consider endorsement of the flood study and consider a planning scheme amendment to update the flood related planning overlays – LSIO and FO, noting that no change to the control covering Skipton (FO) is warranted. It is recommended LSIO and FO layers be considered for areas outside of Skipton to reflect flood risk on rural lands.
  - Consider a review of existing roadside water level boards along impacted roads.
  - Review the information provided by this project and consider an update to the MFEP in discussion with VicSES.
  - Actively promote the use of the VicEmergency website and App to the community to improve flood preparedness and awareness.
- **Lake Goldsmith Steam Preservation Association**
  - Consider the potential for a levee around the Lake Goldsmith Steam Preservation Association in discussion with Pyrenees Shire Council.
- **Glenelg Hopkins Catchment Management Authority**
  - Review and consider endorsement of the flood study and use the flood mapping data to inform floodplain risk management decisions.
  - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- **Victoria State Emergency Service** with assistance from Corangamite and Pyrenees Shire Councils:
  - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
  - Update the relevant Local Flood Guides using the flood intelligence outputs from this project.
  - Aid Corangamite and Pyrenees Shire Councils in updating their respective MFEPs if determined appropriate.
  - Review the updated MFEP (when available) and discuss with Council the changes proposed prior to adopting the revised document.

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