Flood Intelligence and Warning Report

Stawell Flood Investigation (C14 2022/23)

Northern Grampians Shire Council

2 December 2024

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Cover Image: Cato Park 2022 Flood Event

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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work. In particular we acknowledge the Jardwadjali and Djab Wurrung Peoples as the Traditional Custodians of the waters and lands on which this this project is based.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

2 December 2024

Steven Cobden
Senior Design Engineer
Northern Grampians Shire Council
PO Box 580 Stawell VIC 3380

Via email: steven.cobden@ngshire.vic.gov.au

Dear Steven

Stawell Flood Investigation (C14 2022/23)

Please see the attached Flood Intelligence and Warning Report for the Stawell Flood Investigation. This report documents the flood intelligence products and warning improvement outputs produced as part of the study.

Flood intelligence information is presented in a format consistent with the Northern Grampians Shire Council Municipal Flood Emergency Plan (MFEP). Information from this report should be used to update the MFEP and be used during the next flood emergency to inform emergency response actions within Stawell.

The report also provides recommendations for improvements to the flood warning system, interpreted from the flood modelling completed during this project.

If you have any questions regarding this report don't hesitate to contact me.

Yours sincerely

Ben Hughes
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WATER TECHNOLOGY PTY LTD

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GLOSSARY

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Northern Grampians Shire Council (NGSC) to undertake the Stawell Flood Investigation. The investigation covered two study areas: the local Stawell township catchment (including Pleasant Creek) and the Stawell Golf Course catchment to the north of Stawell, as shown in Figure 1-1.

No previous flood studies had been undertaken for either of the study areas. The Mt William Creek Flood Investigation (2014) included the Pleasant Creek catchment which covered the southern areas of Stawell. The study utilised RORB hydrologic modelling and TUFLOW two-dimensional hydraulic modelling. Modelling was calibrated to streamflow gauge records, flood frequency analysis and historic flood level data. However, the flood mapping produced only coarsely covered a minor part of southeastern Stawell.

In 2021/2022, Water Technology undertook a hydraulic assessment of flooding in Stawell caused by runoff from Big Hill, located in the eastern portion of the town. The study covered most of central Stawell and utilised a direct rainfall on grid (RoG) modelling approach. The model was not calibrated and limited survey data of hydraulic and topographic features was available.

The Stawell Flood Investigation addresses the uncertainty around flood risk within Stawell and develops an understanding flooding behaviour to inform future land use, prospective mitigation options and emergency management actions. The study has produced reliable flood intelligence for use in emergency management situations, assessed the current flood impact/exposure in terms of annual average damages caused by flooding in Stawell, investigated structural and non-structural mitigation options, and made recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes of the Stawell Flood Investigation. Each reporting stage is shown below:

- R01 - Data Review Report – Draft completed 31 October 2023, final version issued 2 December 2024
  - Detailing the data collated and any gaps in the data required, resulting in further data survey of ground levels and the drainage network.
- R02 – Model Development and Calibration Report – Draft completed 22 December 2023, final version issued 2 December 2024
  - Documenting the development of the hydraulic models and calibration and validation of the Stawell hydraulic model using the 2011 flood events.
- R03 – Design Modelling Report – Draft completed 11 April 2024, final version issued 2 December 2024
  - This report should be read in conjunction with the Model Development and Calibration Report. Detailing the design modelling parameters and outputs.
- **R04 – Flood Intelligence and Warning Report – This report**
  - Describes the flood intelligence products and warning improvement outputs developed as part of the study. The report was written to allow flood emergency personnel to understand the limitations in the intelligence data and make appropriate decisions. This report is closely linked to the Municipality Flood Emergency Planning (MFEP).
- R05 – Flood Damages and Mitigation Report
- R06 – Final Summary Report

1.2 Study area

Stawell is in Victoria's Wimmera region, on the Western Highway, located approximately 110 km northwest of Ballarat and 140 km southwest of Bendigo. There are no major watercourses within the central township, instead flood risk is driven by local stormwater runoff from elevated areas east to the east, including Big Hill. The southwestern parts of town are located within the Pleasant Creek catchment. Pleasant Creek originates approximately 8 km south of Stawell, in the Black Range, flowing northwest along the Western Highway past southwestern Stawell, before eventually running into Lake Lonsdale, 9 km west of Stawell. The Pleasant Creek catchment upstream of Stawell is approximately 28 km^2 and consists of bushland in the upper reaches and cleared pasture in the lower reaches upstream of Stawell, see Figure 1-2.

Stawell can be separated into two distinct types of potential inundation; short duration stormwater flooding and longer duration riverine flooding from Pleasant Creek. While stormwater flooding is the primary driver of damage, Pleasant Creek has still historically caused issues, but affects a smaller portion of the population.

The Stawell Golf Course study area is characterised by the Jerrywell Creek catchment. Jerrywell Creek originates on the eastern slope of Big Hill and flows north crossing the Stawell-Avoca Road. Multiple large overland flow paths from the Deep Lead Nature Conservation Reserve feed into the creek before it joins Concongella Creek, and finally the Wimmera River. The Jerrywell Creek catchment within the study area is largely cleared agricultural land with some vegetated areas in the upper reaches, see Figure 1-2.

Stawell most recently experienced flooding in April 2024 and January and December 2011. While January 2011 was of longer duration and larger magnitude, December 2011 was significantly shorter and more intense causing urban flooding, similar to April 2024.

1.3 Flood intelligence and warning improvement deliverables

The tender document sets out the following flood intelligence and warning products to be delivered as part of the Flood Intelligence and Warning Report:

- Flood/No flood tool – rainfall intensity and flooding indicator.
- Flood peak travel time calculator/warning time available.
- Draft documentation for inclusion in the NGSC MFEP including flood intelligence cards and inundation tables.
- Assessment of existing flood warning arrangements and flood warning service needs.
- Develop the structure and investigate feasibility of a Total Flood Warning System (TFWS).

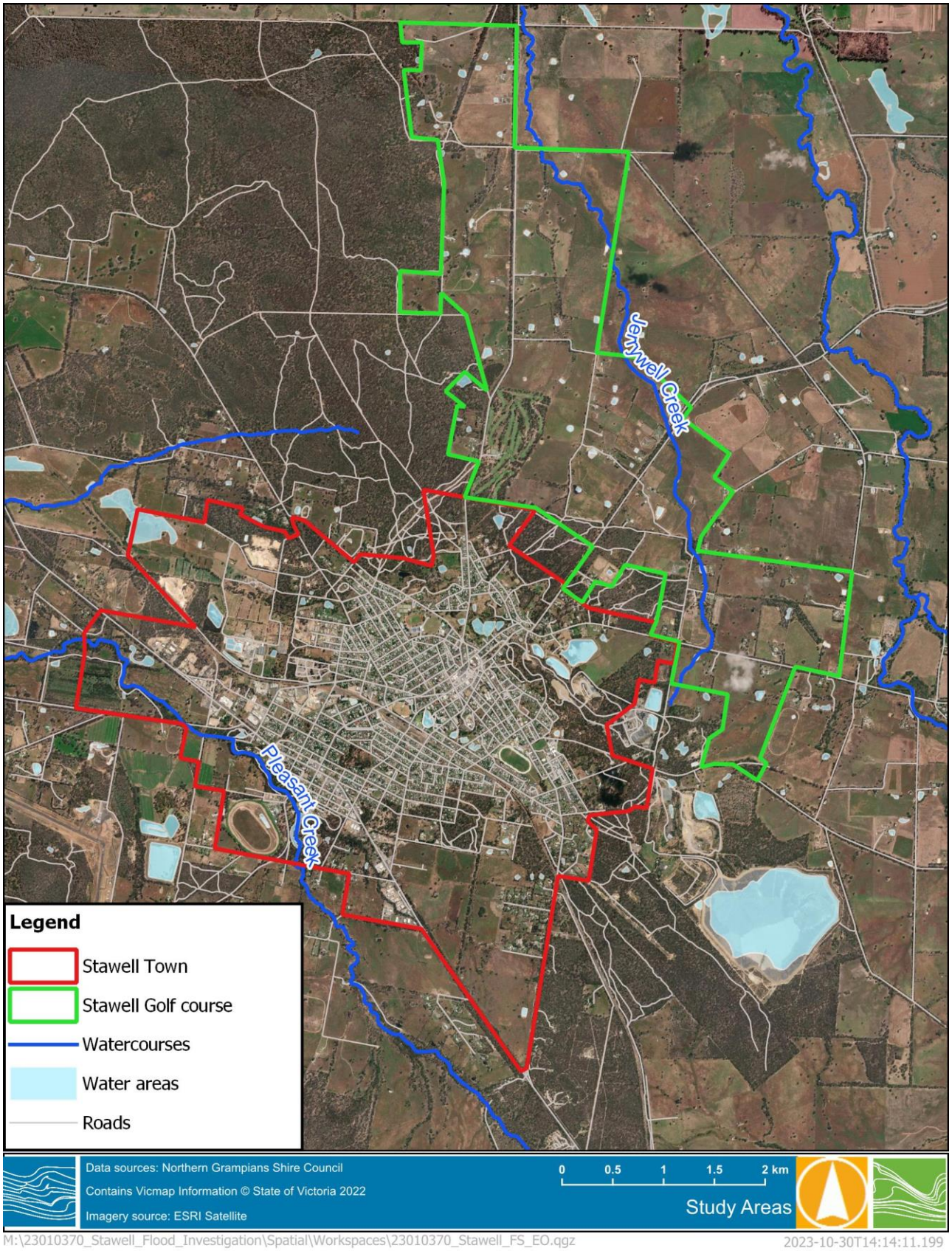

Figure 1-1 Stawell study areas

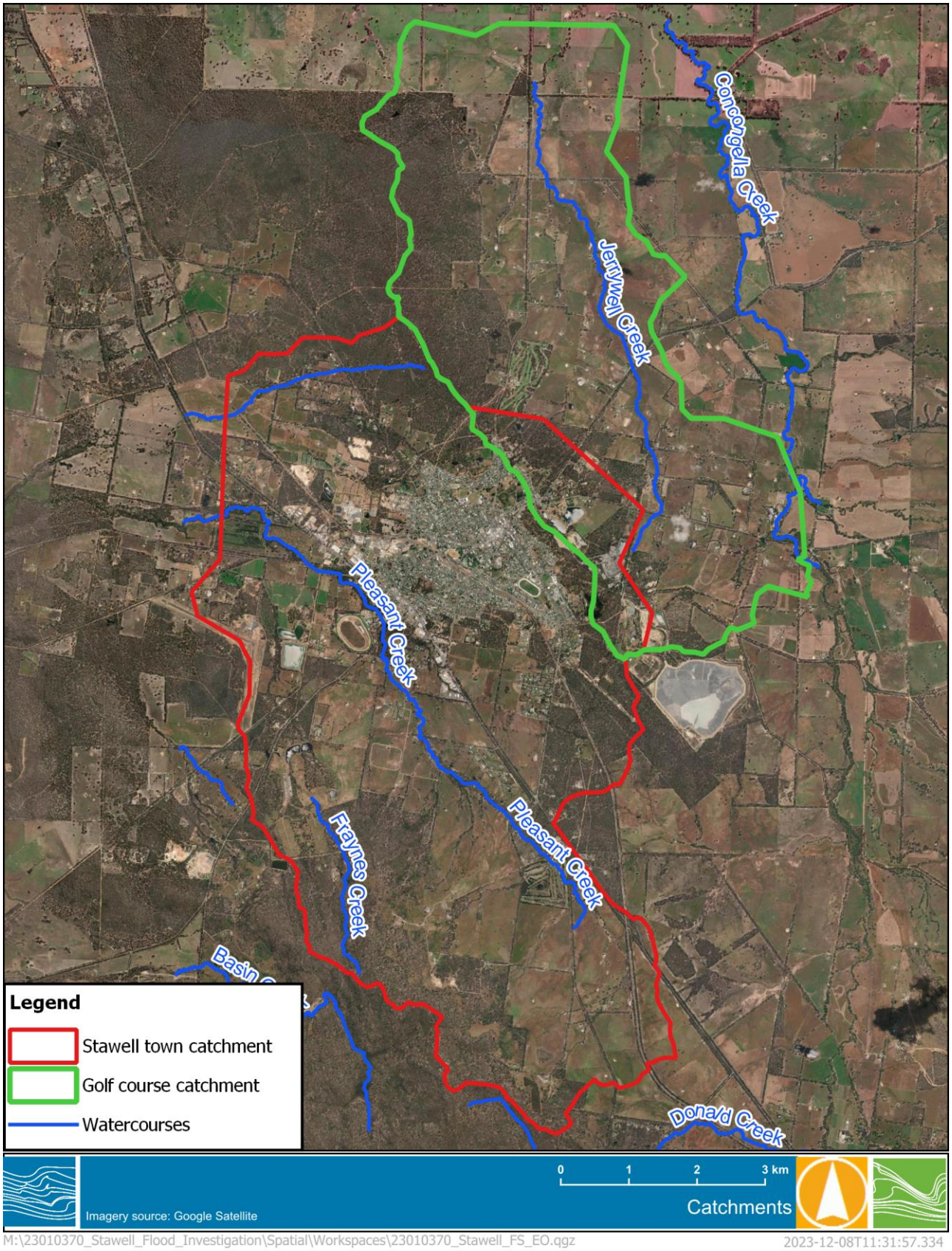

Figure 1-2 Stawell catchments

2 FLOOD BEHAVIOUR AND IMPACTS

2.1 Rainfall and streamflow gauge monitoring network

There were no streamflow gauges available within the study area. In predicting the likely magnitude of flooding on Pleasant Creek near Stawell, real time rainfall forecasts, radar and the rainfall gauge network and are more useful than an upstream streamflow gauge network. The nature of the flooding in Stawell, both from Pleasant Creek and local catchment overland flow inundation, is such that short duration storm events are more likely to cause flooding and are considered to be “flash flooding” type events. Therefore, the warning time is too short for monitoring of streamflow to be of any use as a flood warning tool.

There is one Bureau of Meteorology (BoM) sub-daily rainfall gauge within in the Pleasant Creek catchment at Stawell Aerodrome (079105). Outside of the study catchment, there are several daily and three sub-daily rainfall gauges that are useful for predicting floods in Stawell, see Table 2-1. The rainfall gauge locations are shown in Figure 2-1. Three (3) of the available daily gauges, aside from Stawell Aerodrome, also record sub daily rainfall, typically every 6 minutes. These are Ararat Prison, Wartook Reservoir and Navarre (Avon No.3). These gauges are also highlighted in Figure 2-1.

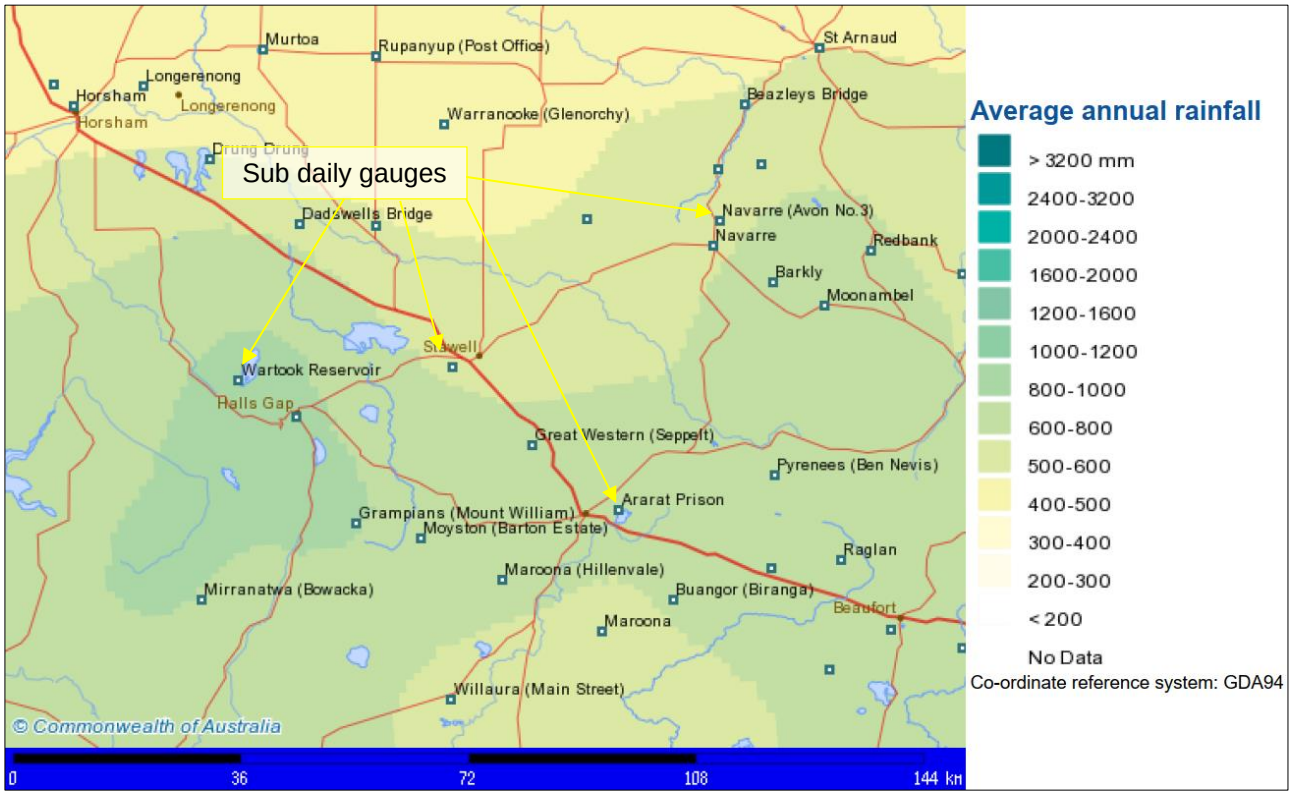

Figure 2-1 Daily Rainfall stations near the study area (BoM)

Table 2-1 Daily rainfall station information

Station Name	Dist. From Stawell	Station No.	Start	End
Stawell Aerodrome	*4 km S*	*079105*	*1996*	*Current*
Great Western (Seppelt)	*16 km SE*	*079019*	*1891*	
Glenorchy	*24 km NW*	*079015*	*1913*	
Halls Gap	*25 km SW*	*079074*	*1958*	

Station Name	Dist. From Stawell	Station No.	Start	End
Morrl Morrl (Valley View)	*26 km NW*	*079032*	*1902*	
Moyston (Barton Estate)	*30 km S*	*079050*	*1906*	
Ararat Prison	*30 km SE*	*089085*	*1969*	
Wartook Reservoir	*30 km W*	*079046*	*1890*	
Grampians (Mount William)	*30 km SW*	*079103*	*2005*	
Dadswells Bridge	*31 km NW*	*079077*	*1968*	
Navarre	*34 km NE*	*079037*	*1897*	
Maroona (Hillenvale)	*36 km S*	*089080*	*1968*	
Warranooke (Glenorchy)	*37 km N*	*079016*	*1878*	
Navarre (Avon No.3)	*37 km NE*	*079086*	*1973*	

The Wunderground database, contains six sub daily rainfall gauges within the study catchment, as shown in Figure 2-2. These may also provide information relevant to flooding in Stawell.

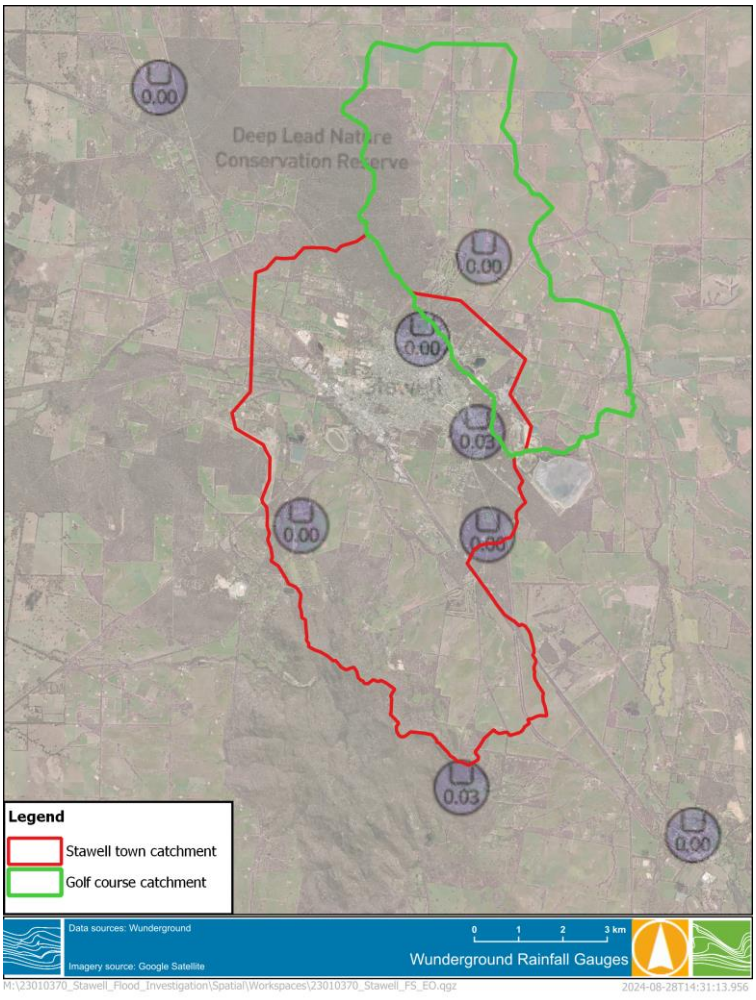

Figure 2-2 Wunderground rainfall gauges near the study area

2.2 Catchment and flood behaviour

2.2.1 Pleasant Creek

Pleasant Creek originates in the Black Range approximately 8 km south of Stawell, flowing northwest along the Western Highway. Directly northeast of the Stawell Racecourse, the creek is joined by a tributary from the east side of the Western Highway, that originates in the bushland southeast of the town. Other tributaries around Stawell include the Main Drain and Fraynes Creek joining Pleasant Creek from the south at Stawell Aerodrome.

When Pleasant Creek floods, the upper reaches of the creek are relatively well contained within a floodplain less than 50 m wide, even in rare events (0.05% AEP). More widespread flooding is observed downstream of Sister Rocks Bushland Reserve where the floodplain is over 100 m wide in a 20% AEP event and over 200 m wide in a 1% AEP event. Breakouts beyond the immediate creek are observed from the Stawell Racecourse and onwards, downstream of the confluence with the Main Drain the creek inundates a wide floodplain across Grampians Road. In the 20% AEP event, the inundated floodplain between Grampians Road and the Western Highway is over 500 m wide and overtops Grampians Road. London Road overtops at Mossman Road and parts of the Stawell Grampians Gate Caravan Park is flooded.

Black Range Road overtops at around a 5% AEP, 100 to 200 m west of the Black Range Road bridge over Pleasant Creek. The Western Highway overtops at Sloane Street in a 2% AEP event. During a 1% AEP event north of Grampians Road, the floodplain is over 700 m wide and the Western Highway is overtopped between Yellow Box Road and Harris Lane by overland flow joining Pleasant Creek. As the flow increases, the overtopping flow paths widen and at a 0.05% AEP event the floodplain covers almost the entire area west of the Western Highway and east of the racecourse and aerodrome, downstream Gilchrist Road. The entire Stawell Grampians Gate Caravan Park and half of the racecourse is flooded.

2.2.2 Stawell township catchment

Flooding in Stawell is driven by local catchment flash flooding, occurring along several main overland flow paths where the underground piped drainage network exceeds capacity. Overland flow originates from elevated areas in the eastern parts of the town, including Big Hill.

In central and eastern Stawell, flow paths form east of Patrick Street at the Secondary College, at Gray Street and at the Community Medical Centre. These flow towards the Maud Street dams located below the hospital, onwards to Cato Park Lake and eventually joining the Main Drain. The Main Drain is an open drainage channel that flows northwest along the railway through central Stawell and curves southwest through the western part of town and under the Western Highway before it joins Pleasant Creek.

In northern Stawell, flow paths form at the Moonlight dams/North Park and in the bushland north of Newington Road. These flow west and join Anderson Creek east of the Western Highway. In southern Stawell, a narrow flow path is formed along open and vegetated areas north of Darcy Street.

In the 20% AEP event, overland flooding is patchy and shallow, concentrated to local depressions, dams and the Main Drain. The Main Drain reaches capacity and spills in areas west of Taylor Street, adjacent to Griffith Street and west of Cooper Street, but does not overtop road crossings. As rainfall intensity increases flow paths become more well defined with increased depth and velocity. In the 2% AEP event, overland flow is occurring along and across several streets, with all previously described flow paths continuous along their respective reaches. Flooding is most widespread in the area along the Main Drain between the railway and the confluence with Pleasant Creek, covering an area up to 400 m wide (albeit with dry patches). In a 2% AEP event and rarer, spilling is observed at the Maude Street dams and Cato Park Lake, and in the 0.05% AEP event a wide flow path stretches from Big Hill in the east to Pleasant Creek in the west.

2.2.3 Jerrywell Creek

Flooding within the Golf Course study area is caused by Jerrywell Creek and its tributaries. The creek originates on the eastern slope of Big Hill and flows north, crossing the Stawell-Avoca Road. The area also includes a few minor tributaries of Concongella Creek near Landsborough Road.

The creek channel is ill-defined in its upper reaches, south of Stawell-Avoca Road and consists of overland flow until the channel begins just prior to the road crossing. Channel breakouts are observed in the 20% AEP event in a small area east of Brook Farm Road. Overtopping is observed at the culvert under Dane Road, and further north, the channel is shallow and discontinuous, causing widespread flooding across Granard Park Road. At this location Jerrywell Creek is joined by several tributaries from the west overtopping Donald-Stawell Road, further contributing to the flooding. In a 20% AEP event, the floodplain is over 600 m wide and overtopping from Jerrywell Creek and tributaries is observed at many roads in the catchment.

In a 5% event, Stawell-Avoca Road is overtopped by a small overland flow path just north of McRae Road, and wider overtopping occurs east of the Jerrywell Creek bridge in a 0.5% AEP event, with the floodplain now 800 m wide and covering a wide segment of Donald-Stawell Road.

3 FLOOD PEAK TRAVEL TIME

3.1 Pleasant Creek catchment

With no active or historic gauges on Pleasant Creek, flood peak travel times were extracted from the modelled hydrographs. Flood timing is influenced by variations in rainfall temporal and spatial patterns, as well as antecedent catchment conditions. Flood peak timing for Pleasant Creek at Stawell was estimated from the start of significant rainfall. The lag time from the beginning of rainfall to the beginning of flooding can be used as an approximate guide in the absence of streamflow gauge data.

The modelled hydrographs in Pleasant Creek downstream of Grampians Road for the 1% AEP and 10% AEP rainfall events are shown in Figure 4-1 and Figure 4-2. The graphs show all modelled AEP events for durations between 30 minutes and 24 hours for three temporal patterns per event; a front loaded, median and a back loaded pattern. A total of 27 hydrographs were produced for each AEP. Also shown on the graphs is the critical duration peak flow at this location, selected in accordance with the recommendations of ARR.

The graphs show a significant range in peak flows and timing produced by rainfall depths of a specified AEP when that rain falls over different durations and temporal patterns within the duration. This illustrates the difficulty in accurately predicting flood peaks and timing from rainfall alone.

The graphs show that flood peaks can manifest around 3 hours from the start of intense rainfall, with the majority of events peaking between 3 hours and 10 hours from the start of the rainfall burst. Some events peak beyond 10 hours from the start of rainfall, however these become rarer and may contain “embedded bursts” where rainfall intensity within an event increases for a short period of time. The graphs also show that the duration of flooding in Pleasant Creek is generally around 10 - 15 hours.

The time it takes rainfall associated with severe weather or thunderstorm activity to develop into runoff and streamflow is highly dependent on catchment antecedent conditions (dryness). The speed a flood hydrograph travels along a waterway is dependent on antecedent conditions and the magnitude of the flood. A flood on a ‘dry’ watercourse will generally travel more slowly than a flood on a ‘wet’ watercourse (e.g. the first flood after a dry period will travel more slowly than the second flood in a series of floods), and big floods tend to travel faster than small floods. In large floods, often the front of the peak may come through reasonably quickly as it travels through the channel, then the peak will come later as the floodplain flow travels a little slower. Hence, the size of the flood, recent flood history, soil moisture and forecast weather conditions all need to be considered when using the following information to direct flood response activities.

3.2 Flash flooding

Note that the travel times discussed above refer to flooding along Pleasant Creek, and do not include travel times for flooding along the overland flow paths within Stawell. Flash flooding within this catchment is characterised by shorter critical rainfall durations, as discussed in the Design Modelling Report (R03), at around 1 hour for the 2% AEP event and rarer, and 6 to 12 hours for more frequent events. Definitive information on the time it takes flash flooding (i.e. resulting from heavy rainfall associated with severe weather or thunderstorm activity) to develop (i.e. to arrive at a location) following the start of heavy rain and the time it takes for the maximum water depth/extent to be reached is very location specific. **However, it is likely to be short in the order of 15 to 30 minutes**.

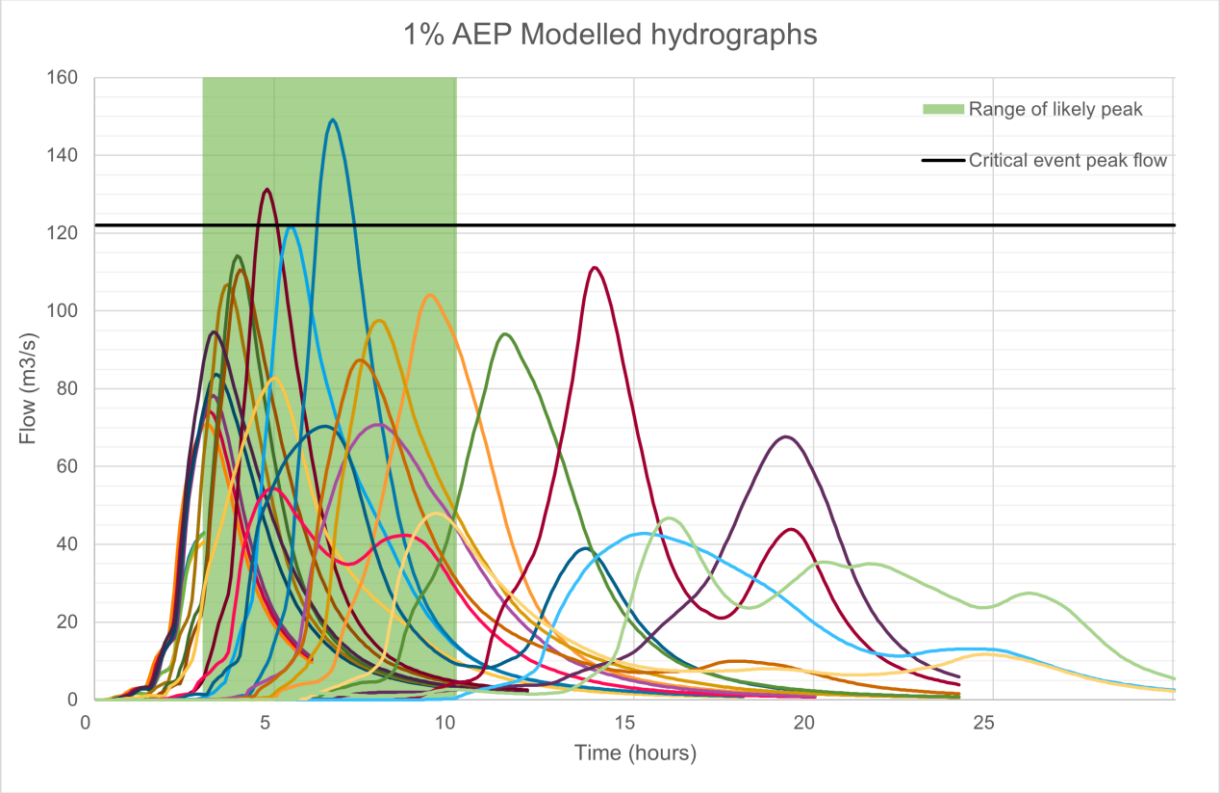

Figure 3-1 1% AEP hydrograph for all modelled rainfall events DS Grampians Road

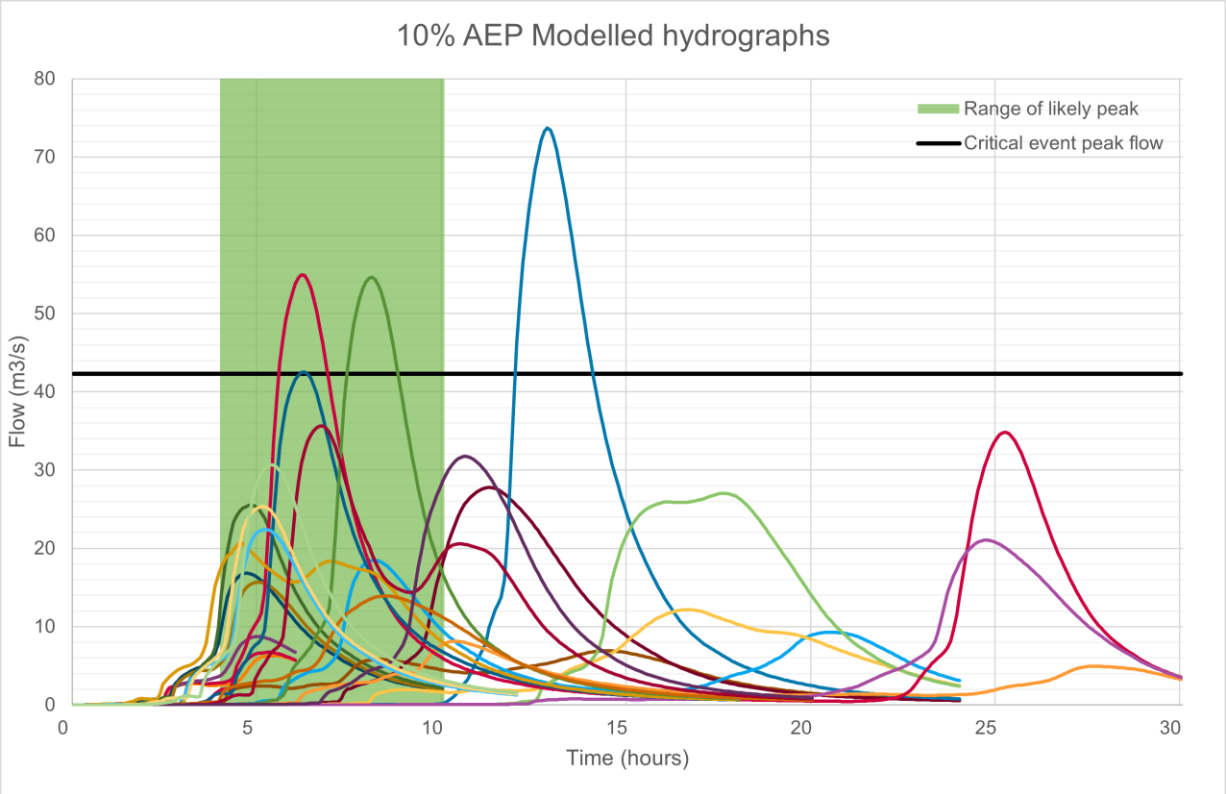

Figure 3-2 10% AEP hydrograph for all modelled rainfall events DS Grampians Road

4 MUNICIPAL FLOOD EMERGENCY PLAN (APPENDIX C)

4.1 Flood/No flood tool

The Flood/No Flood tool in Figure 4-1 provides a graphical representation of the Intensity-Frequency-Duration relationships for various AEP events as presented in the Design Modelling Report (R03).

To use the table, plot the total rainfall depth obtained against elapsed time since the start of the event. Exclude very light rain or drizzle when determining the event start point. Plotting of rainfall data should occur periodically as the event progresses. The likelihood and potential severity of flooding can be estimated by checking the rainfall and adopting the nearest curve AEP event as being likely. The table displays intensity-frequency-duration data developed using statistical analysis of a large number of sub daily rainfall gauges, the closest to Stawell being Stawell Aerodrome (79105), Wartook Reservoir (79046), Ararat Prison (89085) and Navarre (Avon No. 3) (79086). The Flood/No Flood tool can be used in combination with these gauges and/or rainfall observed within the Pleasant Creek and Stawell catchments.

It may be appropriate to step up or down a level depending on catchment antecedent conditions, for example if the rainfall for a 12 hour duration indicates a 5% AEP event will occur, but the catchment is dry with most farm dams empty, it may be appropriate to “step down” to a 10% AEP event or even lower. Similarly a very wet catchment will produce a greater response and may justify a “step up” in estimated AEP for response purposes.

The tool can provide a quick estimate as to whether there will be a flood and how severe that flood may be; however, it must be stressed that the tool cannot provide accurate flood predictions and should not be relied upon entirely. Should life or property be in danger a cautious approach should be taken.

Flooding from Pleasant Creek is characterised by longer critical durations of 6 hours or more as shown in R03 – Design Modelling. Flooding caused by the overland flow path from the east is more likely to occur during shorter, more intense storm events, with durations around 1 hours, causing flash flooding. Given this catchment is located almost entirely within the Stawell urban area, there is essentially no warning time. Due to the lack of sub daily rainfall gauges within this catchment, the Flood/No Flood tool presented in Figure 5-1 is used for both creek flooding and flash flooding.

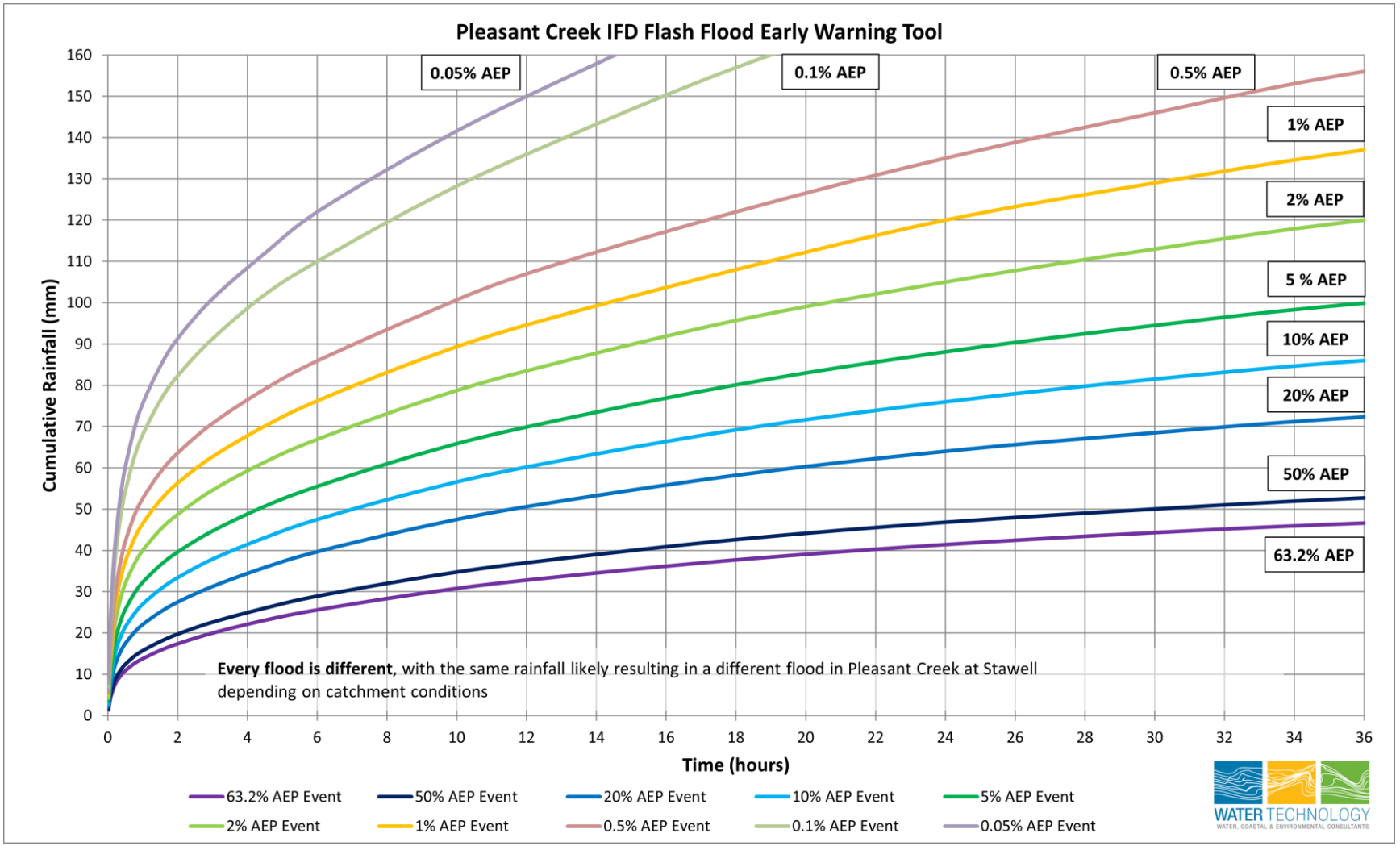

Figure 4-1 Pleasant Creek Flood/No flood too

4.2 Flood warning

The total flood warning system concept includes many elements; flood prediction, interpretation of the flood impact, messaging and communication of the flood risk, generating a timely response from the community and timely reviews of the system.

Given most of Stawell has a small urban upstream catchment, the major flood risk is flash flooding. There are no streamflow gauges in the catchment, so the flood prediction element of the total flood warning system relies on rainfall forecasts and observations.

The Bureau of Meteorology (BoM) will provide Severe Weather Warnings and Flood Watches, forecasting likely conditions. Rainfall gauges available in the Stawell area are shown in Figure 2-1. Rainfall gauges are available in daily or hourly and sub hourly time steps.

A further data source available uniquely from Water Technology through our HydroNET platform, is calibrated radar rainfall data. This is a near real-time high resolution gridded rainfall dataset that provides an enhanced spatial and temporal understanding of storm events (1 km grid every 6 minutes). Storms can be highly localised and may miss the available rainfall gauges, so there is always a risk of a storm event occurring and not adequately being identified by a rainfall gauge network. This occurred recently in November 2018.

The forecast rainfall made available via the BoM and the above mentioned sub-daily rainfall gauges and gridded radar rainfall could be used in combination with an early flood prediction tool to predict possible flash flooding.

Water Technology suggests that NGSC could adopt the following flood prediction procedure:

- Use the BoM Severe Weather Warning and Flood Watch alerts as a trigger to begin monitoring the situation.
- Use a gridded rainfall forecast model such as ACCESS, GFS, ECMWF, ADFD, NOWCAST, etc. to provide a more localised forecast for the region. The ADFD product can be accessed through the BoM MetEye page, but all these products can be made available through the HydroNET platform which Water Technology distributes within Australia. HydroNET can combine forecast rainfall products with observed rainfall products (BoM gauges, Council gauges, water authority gauges and radar rainfall), provides smart visualisation tools, and allows an automated flash flood monitoring and alerting network to be developed for specific catchments. Compare the forecast rainfall depths over various durations and plot on the Flood/No Flood tool provided in Figure 4-1.
- As the storm event begins across Stawell or the Pleasant Creek catchment, monitor the sub-daily rainfall gauges as well as radar rainfall available through HydroNET described above. Compare the observed rainfall depths over various durations and plot on the Flood/No Flood tool provided in Figure 4-1. Alternatively, this Flood/No Flood tool can be built into HydroNET to automate this process.
- By plotting the rainfall depth and storm duration on the Flood/No Flood tool provided Figure 4-1, an indication of the likely AEP of the storm event is provided. Take the maximum AEP for the various rainfall depth/duration observations, and use that flood map and associated consequences in Section 4 to plan and respond to the flash flood event.
- Alert appropriate people regarding the likely flood consequences, including agencies, community members and businesses which may be impacted. HydroNET has alerting capabilities but can also work with other alerting products such as those offered by the Early Warning Network.

If Northern Grampians Shire Council want to establish an automated system to monitor, analyse and alert for flash flood warnings, Water Technology can provide further assistance in this regard.

4.3 Overview of flooding consequences

4.3.1 Warning time

Flooding in Stawell is driven by Pleasant Creek riverine inundation and local catchment flash flooding. The riverine flooding from Pleasant Creek is caused by overbank flows from St Arnaud Creek in the southern and western parts of the township with most events peaking between 3 hours and 10 hours after the onset of rainfall. Due to the nature of the township catchment, the warning time of the flash flooding at Stawell is limited to less than half an hour.

4.3.2 Areas affected

The flood extent map at Stawell (Figure 4-2) and summary of flooding consequences (Table 4-2) provide guidance on where flooding is likely to occur within Stawell.

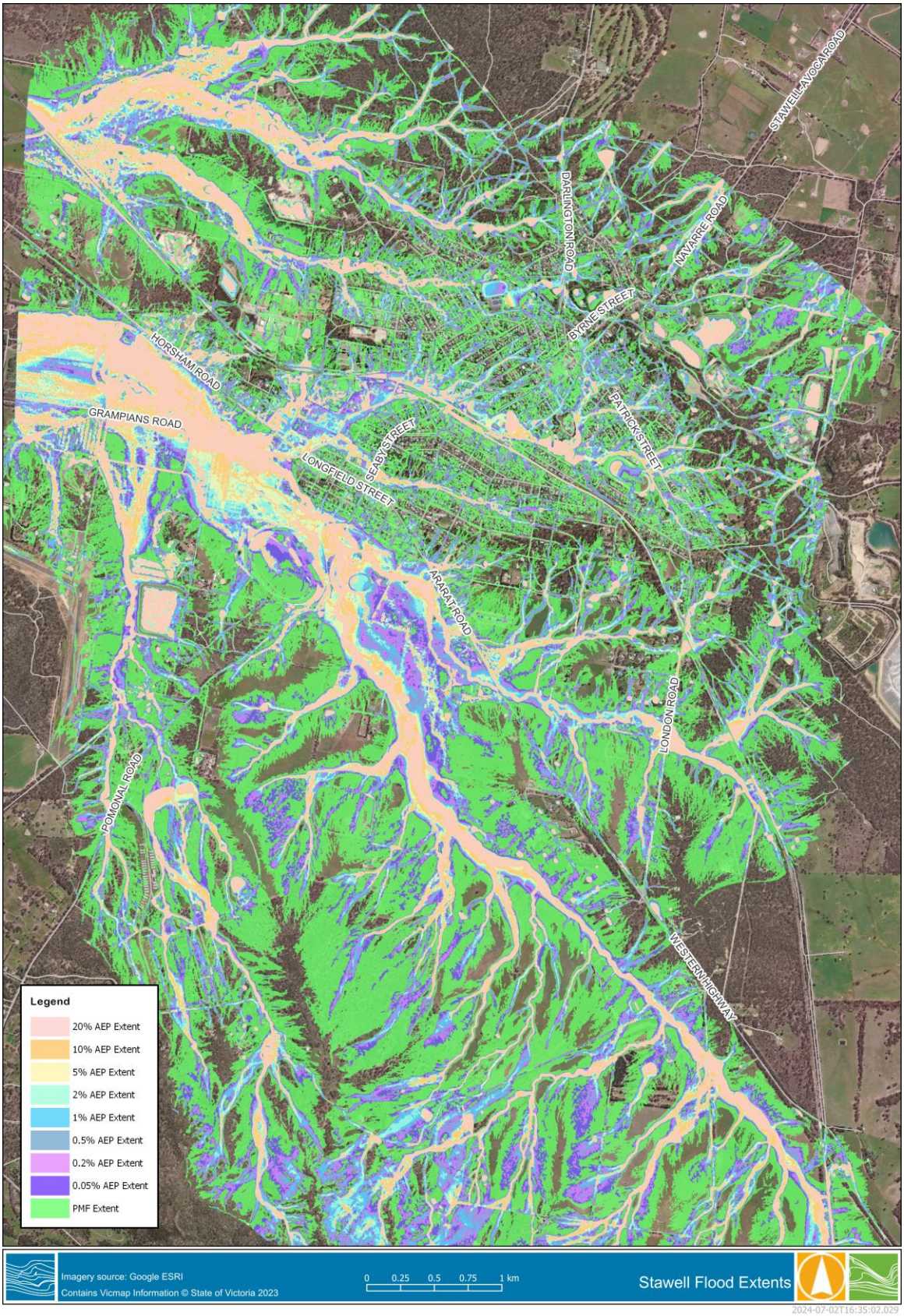

Figure 4-2 Stawell flood extents

4.3.3 Isolation

The main access roads for Stawell include the Western Highway, Stawell-Avoca Road Donald-Stawell Road, Black Range Road/Pomonal Road and Grampians Road. The table provided in Appendix C outlines the roads which are inundated by flooding from 20% up to 0.05% AEP events as well as the PMF, and these roads are shown in maps provided in Appendix B. There is also a table in Appendix C outlining the impassable roads where maximum depths exceed 0.3 m and become unsafe for vehicles.

4.3.4 Property inundation

Flood level survey of 522 buildings was captured within the study area, including 163 commercial and 359 residential buildings. These buildings were selected for survey based on the preliminary flood modelling undertaken during this study. It should be noted that there were minor limitations within the floor level survey data captured, in that only the main residential dwelling or commercial building was captured for each property, outbuildings were not surveyed. It should be noted the number of properties flooded below floor indicates a property with a building on it. This does not include parcels of land which are flooded but do not have an associated building i.e. vacant lots, farm paddocks etc.

To classify the flood risk at a property scale, two categories were used, these were:

- Property flooded below floor.
  - This indicates the flood level is below the surveyed floor level.
- Property flooded above floor.
  - This indicates the flood level is above the surveyed floor level.

The existing conditions 1% AEP flood extent and the properties flooded above floor during the range of modelled design events are shown in Figure 4-3 and Figure 4-4. The table provided Appendix C outlines the properties flooded above and below floor, a summary can be found in Table 4-1. The values in the tables were obtained using flood level minus surveyed floor level for each modelled event. Therefore, a positive value indicates the property is flooded above floor, while a negative value refers to property flooded below floor.

Table 4-1 Summary of property inundation

Design Flood Event AEP	No. of properties flooded above floor - Residential	No. of properties flooded above floor - Commercial
20%	2	4
10%	6	9
5%	18	17
2%	26	24
1%	34	30
0.5%	39	40
0.2%	54	44
0.05%	76	52
PMF	230	82

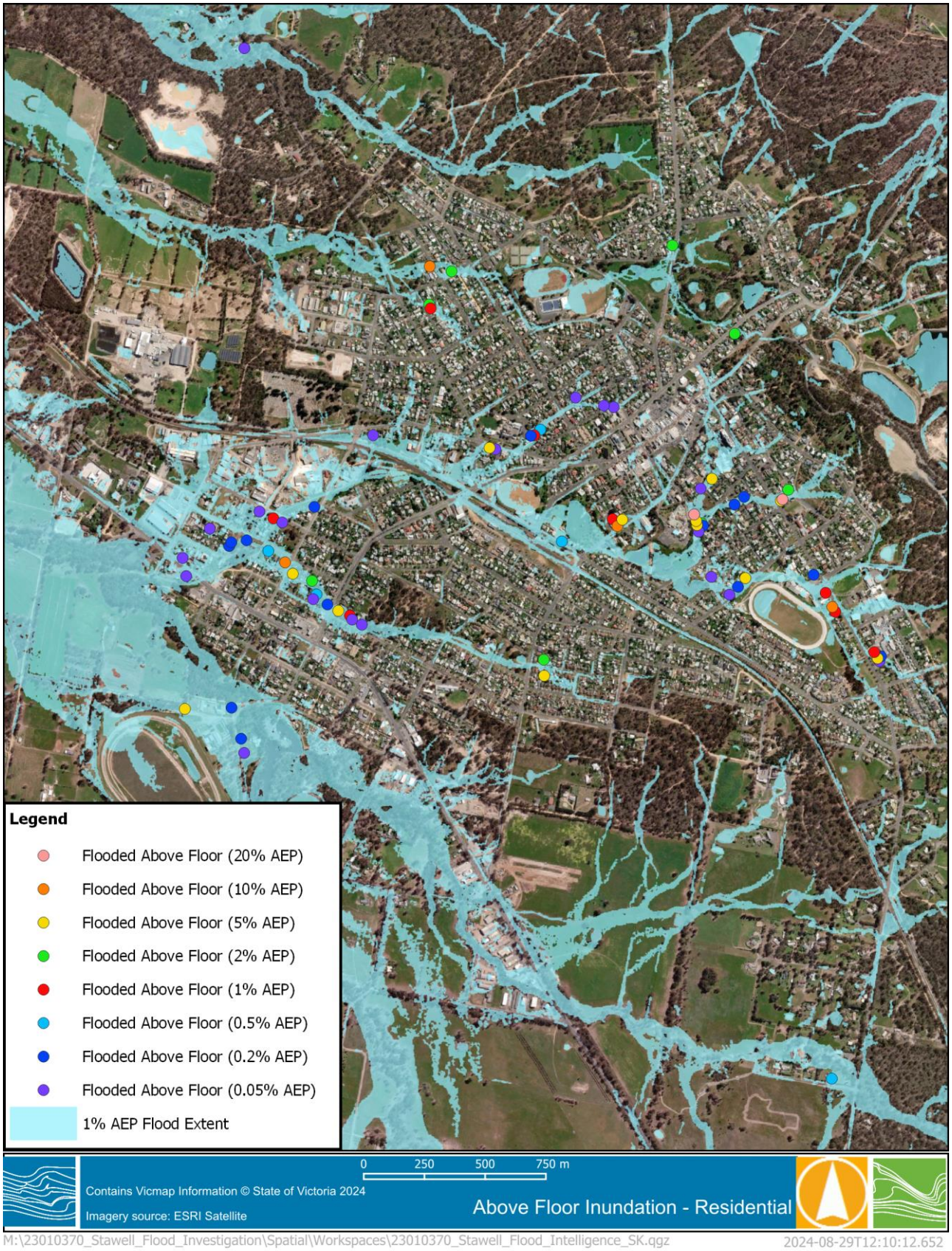

Figure 4-3 Properties flooded above floor – Residential

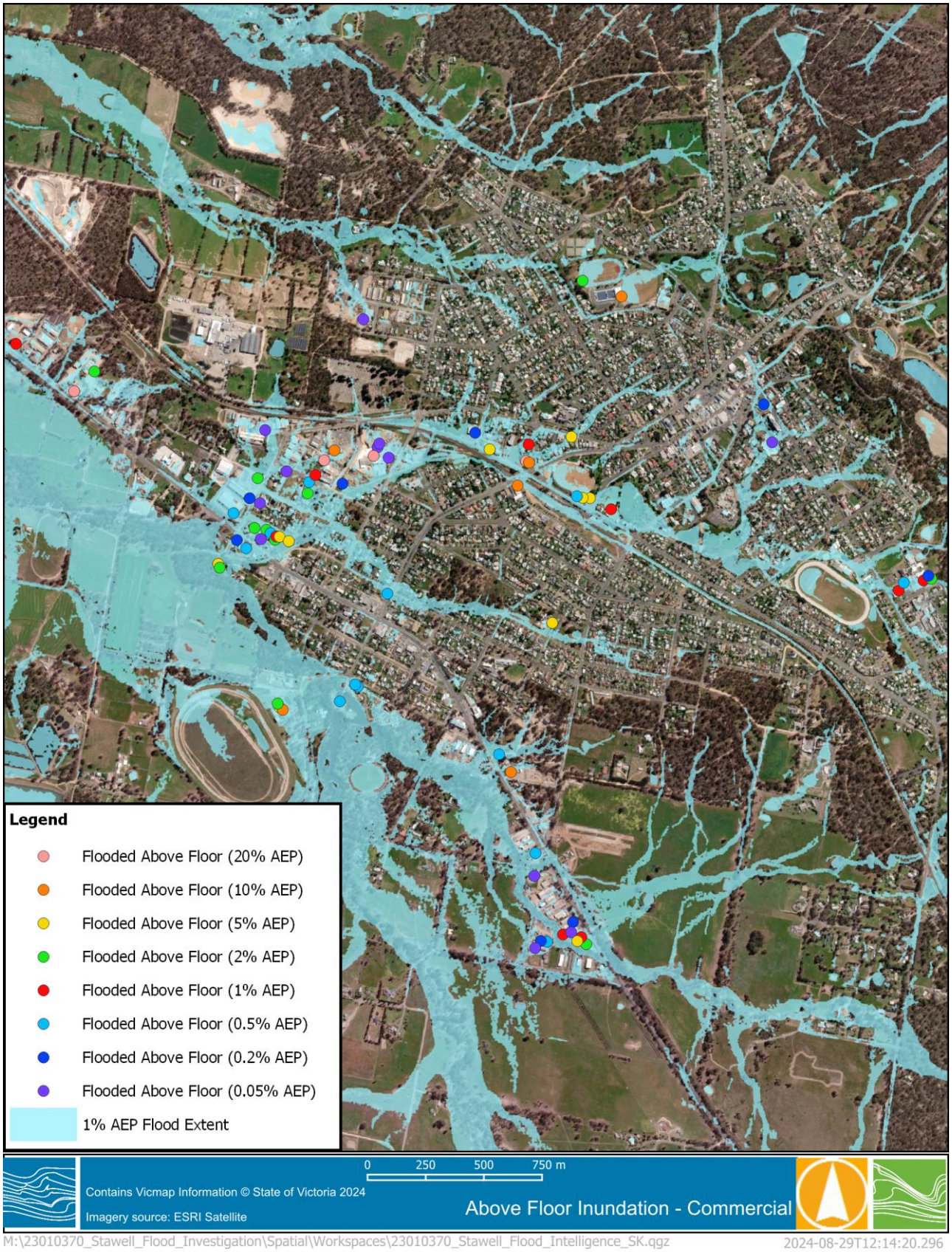

Figure 4-4 Properties flooded above floor – Commercial

4.3.5 Flood intelligence cards

The flood mapping was produced to identify the consequences of flooding for various design flood events. Combined with the flash flood forecasting procedure described in Section 4.1, the flood consequence table allows emergency services and council to quickly understand the likely impacts of flooding and plan accordingly. Table 4-2 describes the key flooding consequences across the study area for each design event.

The table was developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences. For example, if the reader wants to understand the consequences of a 1% AEP event, then the flood characteristics should be read for the 20%, 10%, 5%, 2% and 1% AEP events in succession. It is also recommended that the reader refer to the standard PDF maps provided with this study. There is a separate map for each modelled design event, providing peak flood depths, extents and water surface elevations for each flood event.

While flood intelligence cards provide guidance on the relationship between flood magnitude and flood consequences, flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Further, the hydrologic and hydraulic modelling that underpins much of the intelligence detailed below is informed by several assumptions and approximations that are unlikely to be replicated exactly during a flood event. Actual impacts under similar rainfall conditions are therefore expected to be similar but may not be exactly the same: there are likely to be some differences. More details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series at https://knowledge.aidr.org.au/resources/manual-series/ and in particular in Manual 21 “Flood Warning”.

As a result of the nature of flash flooding in Stawell, residents will have very limited time to respond after the start of rain. It is recommended properties prone to flooding have sandbags prepared to act immediately after the flood warning is issued. Residents will want access to sandbags as soon as possible after it becomes apparent that flooding is likely. Residents using sandbags need to be aware of the correct way to lay sandbags and also be aware that due to the length of inundation some water will pass through the bags. Flood Response Plan should be prepared for properties in approximate to Pleasant Creek to inform the community on appropriate actions before, during and after the flood.

A guidance on sandbagging published by VICSES is available in the SES sandbagging guide here detailed in Appendix A.

Table 4-2 Stawell MFEP intelligence card

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~43 m3/s Jerrywell Creek ~28 m3/s ~22 mm of rainfall in 1 hour ~31 mm of rainfall in 3 hours ~40 mm of rainfall in 6 hours ~51 mm of rainfall in 12 hours	20% AEP (5-year ARI)	**Properties likely Impacted** **13 Properties in Total** • 6 properties are flooded over floor include 2 residential properties (2/50 Wimmera Street, 3/45 Partick Street) and 4 commercial properties. **Community Infrastructure Likely Impacted** • Taylors Gully Playground slightly impacted • Central Park will be slightly impacted. • Ligar Street Playground will be slightly impacted. • Grampians Rail Trail Parking will be slightly impacted. • Federation Park will be flooded. • Cato Park Playground will be slightly impacted. • Norman Castle Reserve starts getting flooded. • Darlington Street Public Park Reserve will be slightly impacted. **Essential Infrastructure Likely Impacted** • Stawell Secondary College schoolyard slightly impacted. • SES unit on St Georges Street – access is impacted by shallow (<0.3m) inundation. • Skeene Street Special School – schoolyard is slightly impacted and east access is impacted by shallow (<0.3m) inundation. **Tourism / Recreation Likely Impacted** • Stawell Harness Racing and Showgrounds; Stawell Racecourse Reserve will be slightly impacted. • The waterways in the Stawell Golf Club and Grange Golf Club start getting filled. • The Grampians Gate Caravan Park will be slightly impacted **Roads Flooded** • Abattoir Road, Aerodrome Road, Albion Road, Ararat Road, Austin Road, Barbara Street, Barnes Street, Brook Farm Road, Burgh Street, Cahill Road, Caroline Road, Clara Street, Clarissa Street, Clifton Avenue, Colquhoun Street, Commercial Road, Crowlands Road, Dane Road, Darcy Street, Darlington Mine Road, Deep Lead Road, Donald-Stawell Road, Durack Street, East West Road, Fieldings Road, Franklin Street, Franklin Street, Gilchrist Road, Golf Course Road, Grampians Road, Granard Park Road, Grant Street, Griffiths Street, Hear Street, Henderson Street, High Street, Holloway Road Cn, Holloway Road E, Holloway Road W, Horsham Road, Horwood Road, Ironbark Road, Jennings Street, Kernot Road, Kingston Avenue, Landsborough Road, Lavett Road, Leviathan Road, Lilian Street, Kindsay Court, Little Burgh Lane, Little Cooper Lane, London Road, Longfield Street, Main Street, Maple Street, Market Lane, Maud Street, Monaghan Road, Mossman Street, Navarre Road, Newington Road, Oliver Road, Oregan Street, Ormston Road, Panrock Reservoir Road, Patrick Lane, Patrick Street, Pickering Road, Pipetrack Road, Playford Street, Pomonal Road, Reefs Road, Rifle Range Road, Rogasch Road, Rose Street, Sanctuary Road, Sargentson Road, Saunders Road, Sloane Street, Smith Street, St George Street, Stawell-Avoca Road, Sumner Street, Sutherland Street, Sylvan Road, Taylor Street, Wakeham Street, Warren Street, Wattle Street, Western Highway, Wilson Lane, Winnifred Street, Wonga Road. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (0.59m depth), Clara Street (0.34m depth), Dane Road (0.59m depth), Gambetta Lane (0.32m depth), Granard Park Road (0.78m depth), Little Burgh Lane (0.59m depth), Panrock Reservoir Road (0.38m depth), St Georges Street (0.30m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated, in particular in the **caravan parks.** • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 10% AEP event and / or sandbagging buildings. • “Water over road” signs should be in place on Grampians Road and Donald -Stawell Road.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~42 m3/s Jerrywell Creek ~35 m3/s ~27 mm of rainfall in 1 hour ~38 mm of rainfall in 3 hours ~48 mm of rainfall in 6 hours ~60 mm of rainfall in 12 hours	10% AEP (10-year ARI)	**Properties likely Impacted** **50 Properties in Total** • 15 properties are flooded over floor including 6 residential properties and 9 commercial properties **Community Infrastructure Likely Impacted** • Taylors Gully Playground start flooding. • Northern part of Central Park starts getting flooded. • Ligar Street Playground starts getting flooded. • Oval of Stawell Pioneers Soccer Club will be slightly impacted. • Grampians Rail Trail Parking start flooding. • Old Lake Oval will be slightly impacted. • Cato Park Playground starts getting flooded. **Essential Infrastructure Likely Impacted** • Macpherson Smith Residential Care – access is partly impacted by shallow (<0.3m) inundation. • Marrang Kindergarten playground will be slightly impacted. • Skeene Street Special School – east access is impacted by impassable (>0.3m) inundation. **Tourism / Recreation Likely Impacted** • Grampians Gate Caravan Park start getting flooded. • Northern part of Stawell Harness Racing and Showgrounds is flooded, the maximum flood depths approximately 1.05m. • Part of Stawell Racecourse reserve start getting flooded. • The water depths in the waterways of Stawell Golf Club and Grange Golf Club will increase. • Stawell Grampians Gate C/park start getting flooded. **Roads Flooded** • Except for the roads included in the events above. Additional roads are flooded include Allen Street, Berry Street, Black Range Road, Bulgana Road, Bullocky Mary Road, Centre Road, Clemes Road, Concongella School Road, Cooper Street, Darlington Road, Doyle Street, Ellen Street, Forest Hill Road, Frayne Street, Freeland Avenue, Gilbert Street, Gray Street, Hawthorn Street, Hill Street, Hines Road, Holt Street, Houston Street, Lake Road, Lamont Street, Ligar Street, Little Bryne Lane, Market Street, McLaughlin Street, Napier Street, Ocallaghan Street, Ord Street, Park Road, Park Street, Phelans Road, Relph Street, Ronchies Road, Rose Lane, Seaby Street, Upper Sloane Street, Victoria Street, White Street, Wimmer Lane, Wimmera Street. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (0.83m depth), Clara Street (0.51m depth), Dane Road (0.74m depth), Fieldings Road (0.31m depth)Gambetta Lane (0.44m depth), Granard Park Road (0.83m depth), Hines Road (0.34m), Holloway Road Cn (0.34m), Little Burgh Lane (0.84m depth), Monaghan Road (0.57m depth), Panrock Reservoir Road (0.64m depth), Patrick Lane (0.37m depth), Rogasch Road (0.32m depth), St Georges Street (0.40m depth), Taylor Road (0.38m depth), Wonga Road (0.36m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 5% AEP event and / or sandbagging buildings. • Plan for the event of the Skeene Street Special School being isolated for a limited time, although not by hazardous inundation. • “Water over road” signs should be in place on Grampians Road, Stawell-Avoca Road, Donald -Stawell Road and Black Range Road/Pomonal Road. • Close Grampians Road.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~65 m3/s Jerrywell Creek ~41 m3/s ~32 mm of rainfall in 1 hour ~45 mm of rainfall in 3 hours ~56 mm of rainfall in 6 hours ~70 mm of rainfall in 12 hours	5% AEP (20-year ARI)	**Properties likely Impacted** **82 Properties in Total** • 35 properties are flooded over floor include 17 residential properties and 18 commercial properties **Community Infrastructure Likely Impacted** • Oval of Stawell Pioneers Soccer Club start getting flooded. • North Park sporting fields and surrounding areas start getting flooded. • Old Lake Oval will be slightly impacted. • Gladstone Park Playground will be slightly impacted. **Essential Infrastructure Likely Impacted** • Skeene Street Special School – east access is impacted by impassable (>0.3m) inundation and remaining access is impacted by shallow (<0.3m) inundation. • Stawell Secondary College - access is impacted by shallow (<0.3m) inundation. **Tourism / Recreation Likely Impacted** • Rifle Range Bushland Reserve starts getting flooded • The water depths in the waterways of Grange Golf Club will increase and start flooding out of the waterways. • Stawell Tennis Club will be slightly impacted. • Stawell Bowling Club starts getting flooded • Stawell Gift Museum and Stawell Tourist Information flooded above floor. **Roads Flooded** • Except for the roads included in the events above. Additional roads are flooded include Evan Street, Harris Lane, Hastings Street, Hodges Street, Hutton Court, Little William Lane, Mareli Street, Miller Lane, Skene Street. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (0.97m depth), Clara Street (0.58m depth), Dane Road (0.89m depth), Deep Lead Road (0.31m depth), Fieldings Road (0.33m depth), Gambetta Lane (0.48m depth), Grampians Road (0.38m depth), Granard Park Road (0.87m depth), Hines Road (0.44m), Holloway Road Cn (0.43m), Little Burgh Lane (0.97m depth), Market Lane (0.32m depth), Monaghan Road (0.73m depth), Panrock Reservoir Road (0.77m depth), Pickering Road (0.31m depth), Patrick Lane (0.42m depth), Rogasch Road (0.38m depth), St Georges Street (0.41m depth), Sutherland Street (0.31m depth),Taylor Road (0.43m depth), Wonga Road (0.36m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 2% AEP event and / or sandbagging buildings. • Plan for the event of the Stawell Regional Health Hospital being isolated for a limited time, although not by hazardous inundation. • “Water over road” signs should be in place on Stawell-Avoca Road, Donald-Stawell Road, Black Range Road/Pomonal Road and the Western Highway. • Grampians Road to remain closed.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~92 m3/s Jerrywell Creek ~60 m3/s ~40 mm of rainfall in 1 hour ~55 mm of rainfall in 3 hours ~67 mm of rainfall in 6 hours ~84 mm of rainfall in 12 hours	2% AEP (50-year ARI)	**Properties likely Impacted** **121 Properties in Total** • 48 properties are flooded over floor include 26 residential properties and 24 commercial properties **Community Infrastructure Likely Impacted** • Old Lake Oval will be flooded • Gladstone Park Playground starts getting flooded. • Oval of Stawell Pioneers Soccer Club and North park sporting fields and surrounding flooded. • Cato Park Neighbourhood Safe Place (bushfire) will be slightly impacted. • Senior Citizens Club - access is impacted by shallow (<0.3m) inundation. **Essential Infrastructure Likely Impacted** • Stawell Regional health hospital - access is impacted by shallow (<0.3m) inundation. • Stawell Primary School schoolyard slightly impacted. **Tourism / Recreation Likely Impacted** • Grampian Pet Resort Stawell will be slightly impacted • The water depths in the waterways of Stawell Golf Club will increase and start flooding out of the waterways. **Roads Flooded** • Except for the roads included in the events above. Additional roads are flooded include Allen Crescent, Bayliss Street, Bennett Street, Brown Street, Byrne Street, Campbell Street, Centenary Court, Childe Street, Church Street, Croft Lane, Croll Street, Crothers Street, Dalton Street, Darlington Lane, Deep Lead Park Road, Fisher Street, Florene Street, Haitts Lane, Kinsella Lane, Layzell Street, Luke Street, Madden Street, Manse Street, McKenzie Street, Moonlight Street, Moore Street, Orrs Road, Rae Street, Robinson Street, Scallan Street, Scenic Street, Scotland Place. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (1.03m depth), Clara Street (0.65m depth), Dane Road (1.01m depth), Deep Lead Road (0.39m depth), Fieldings Road (0.37m depth), Gambetta Lane (0.51m depth), Grampians Road (0.45m depth), Granard Park Road (0.95m depth), Hears Street (0.33m depth), Hines Road (0.51m), Holloway Road Cn (0.49m), Ironbark Road (0.35m depth), Little Burgh Lane (1.04m depth), Market Lane (0.38m depth), Maud Street (0.31m depth), Monaghan Road (0.85m depth), Panrock Reservoir Road (0.85m depth), Pickering Road (0.42m depth), Patrick Lane (0.48m depth), Rogasch Road (0.41m depth), St Georges Street (0.50m depth), Sutherland Street (0.34m depth),Taylor Road (0.51m depth), Wonga Road (0.47m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 1% AEP event and / or sandbagging buildings. • Plan for the event of the Marrang Kindergarten being isolated for a limited time, although not by hazardous inundation. • Plan for the event of the Stawell Health and Community Centre being isolated for a limited time, although not by hazardous inundation. • Plan for the event of the Stawell Police Station being isolated for a limited time, although not by hazardous inundation. • Plan for the event of the Magistrates Court being isolated for a limited time, although not by hazardous inundation. • "Water over road" signs should be in place on Donald-Stawell Road, Stawell-Avoca Road, Black Range Road/Pomonal Road and the Western Highway. • Grampians Road to remain closed.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~122 m3/s Jerrywell Creek ~80 m3/s ~47 mm of rainfall in 1 hour ~63 mm of rainfall in 3 hours ~76 mm of rainfall in 6 hours ~95 mm of rainfall in 12 hours	1% AEP (100-year ARI)	**Properties likely Impacted** **151 Properties in Total** • 64 properties are flooded over floor include 34 residential properties and 30 commercial properties **Community Infrastructure Likely Impacted** • No additional community Infrastructure likely impacted **Essential Infrastructure Likely Impacted** • Marrang Kindergarten - access is impacted by shallow (<0.3m) inundation • Stawell Health and Community Centre - access is impacted by shallow (<0.3m) inundation. • Stawell Police Station - access is impacted by shallow (<0.3m) inundation. • Stawell Magistrates Court- access is impacted by shallow (<0.3m) inundation. **Tourism / Recreation Likely Impacted** • Grampian Pet Resort Stawell starts getting flooded • Stawell Tennis Club starts getting flooded **Roads Flooded** • Except for the roads included in the events above. Additional roads are flooded include Alfred Street, Anne Street, Argyle Street, Chiverton Street, Crerar Street, Curtis Street, Cypress Street, Duke Street, Fleetwood Smith Way, Gertrude Street, Gordon Street, Grieve Street, Hobbs Street, Johnson Street, Jubilee Street, King Street, Little Wakeham Street, Margaret Street, Marjory Brown Close, McLellan Street, Oriental Street, Prince Street, Robson Road, Sharpley Avenue, Shirreff Street, Short Street, Stanton Street. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (1.09m depth), Clara Street (0.73m depth), Cooper Street (0.35m depth), Dane Road (1.13m depth), Deep Lead Road (0.45m depth), Fieldings Road (0.4m depth), Gambetta Lane (0.55m depth), Gilchrist Road (0.36m depth), Grampians Road (0.50m depth), Granard Park Road (0.95m depth), Hears Street (0.35m depth), Hines Road (0.57m), Holloway Road Cn (0.54m), Ironbark Road (0.4m depth), Little Burgh Lane (1.10m depth), Market Lane (0.42m depth), Maud Street (0.35m depth), Monaghan Road (0.99m depth), Panrock Reservoir Road (0.92m depth), Pickering Road (0.51m depth), Patrick Lane (0.52m depth), Rogasch Road (0.42m depth), Sloane Street (0.30m depth), St Georges Street (0.52m depth), Sutherland Street (0.39m depth),Taylor Road (0.59m depth), Wonga Road (0.52m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.5% AEP event and / or sandbagging buildings. • Plan for the event of the Stawell Primary School being isolated for a limited time, although not by hazardous inundation. • Plan for the event of the access to SES Unit on St Georges Street being partially impacted by impassable inundation. • "Water over road" signs should be in place on Donald-Stawell Road, the Western Highway and Stawell-Avoca Road. • Close Black Range Road/Pomonal Road • Grampians Road to remain closed.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~146 m3/s Jerrywell Creek ~101 m3/s ~53 mm of rainfall in 1 hour ~71 mm of rainfall in 3 hours ~86 mm of rainfall in 6 hours ~107 mm of rainfall in 12 hours	0.5% AEP (200-year ARI)	**Properties likely Impacted** **182 Properties in Total** • 79 properties are flooded over floor include 39 residential properties and 40 commercial properties **Community Infrastructure Likely Impacted** • No additional community Infrastructure likely impacted **Essential Infrastructure Likely Impacted** • Stawell Primary School - access is impacted by shallow (<0.3m) inundation. • Stawell Secondary College schoolyard is flooded. • SES unit on St Georges Street – access is partially impacted by impassable (>0.3m) inundation. **Tourism / Recreation Likely Impacted** • No additional Tourism/Recreation likely impacted **Roads Flooded** • Except for the roads included in the events above. Additional roads are flooded include Agnes Street, Cosson Place, Dawson Street, Elizabeth Street, Foster Street, Haughton Street, Leslie Street, Little Foster Lane, Little Griffiths Lane, Little Rickard Street, Magdala Court, Mary Street, Mathers Street, Proctor Street, Robertson Road, Rosemary Street, Smale Street. • Roads are isolated and flood level on the street is above 0.3m: Include Austin Street (1.15m depth), Black Range Road (0.39m depth), Burgh Street (0.32m), Clara Street (0.78m depth), Cooper Street (0.42m depth), Dane Road (1.23m depth), Darcy Street (0.35m depth), Deep Lead Road (0.49m depth), Fieldings Road (0.42m depth), Gambetta Lane (0.59m depth), Gilchrist Road (0.43m depth), Grampians Road (0.56m depth), Granard Park Road (0.99m depth), Hears Street (0.37m depth), Hines Road (0.63m), Holloway Road Cn (0.59m), Ironbark Road (0.44m depth), Kingston Avenue (0.31m depth), Little Burgh Lane (1.16m depth), Market Lane (0.45m depth), Maud Street (0.4m depth), Monaghan Road (1.13m depth), Panrock Reservoir Road (1.01m depth), Pickering Road (0.63m depth), Patrick Lane (0.55m depth), Rogasch Road (0.43m depth), Sloane Street (0.34m depth), St Georges Street (0.51m depth), Sutherland Street (0.47m depth),Taylor Road (0.64m depth), Taylor Street (0.33m depth), Wimmera Street (0.34m depth), Wonga Road (0.56m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.2% AEP event and / or sandbagging buildings. • “Water over road” signs should be in place on Stawell-Avoca Road. • Close Donald-Stawell Road and the Western Highway. • Grampians Road and Black Range Road/Pomonal Road to remain closed.

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			
Pleasant Creek ~198 m3/s Jerrywell Creek ~132 m3/s ~61 mm of rainfall in 1 hour ~82 mm of rainfall in 3 hours ~99 mm of rainfall in 6 hours ~123 mm of rainfall in 12 hours	0.2% AEP (500-year ARI)	**Properties likely Impacted** **225 Properties in Total** • 98 properties are flooded over floor include 54 residential properties and 44 commercial properties **Community Infrastructure Likely Impacted** • No additional community Infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No additional Essential Infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No additional Tourism/Recreation likely impacted **Roads Flooded** • Except for the roads included in the events above, additional roads are flooded include: Charles Street, Conway Street, Crudace Street, Little Leslie Lane, Mahnke Street, Meagher Street, Needham Street, Newton Street, Plantation Drive, Saleyards Road, Sophia Street, Stone Street. • The flood depth of roads flooded over 0.3m mentioned in the events above all slightly increased. Beside those mentioned roads, additional isolated roads include: Allen Street (0.34m depth), Ararat Street (0.34m depth), Donald-Stawell Road (0.35m depth), Gilbert Road (0.37m depth), Griffiths Street (0.40m depth), Little William Lane (0.31m depth), Mcrae Road (0.34m depth), Napier Street (0.31m depth), Saunders Road (0.33m depth).	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.05% AEP event and / or sandbagging buildings. • Sandbagging of Skeene Street School if further inundation is expected • Close Stawell-Avoca Road, • Grampians Road, Black Range Road/Pomonal Road, Donald-Stawell Road and the Western Highway to remain closed.
Pleasant Creek ~309 m3/s Jerrywell Creek ~190 m3/s ~76 mm of rainfall in 1 hour ~101 mm of rainfall in 3 hours ~122 mm of rainfall in 6 hours ~150 mm of rainfall in 12 hours	0.05% AEP (2000-year ARI)	**Properties likely Impacted** **283 Properties in Total** • 128 properties are flooded over floor include 76 residential properties and 52 commercial properties **Community Infrastructure Likely Impacted** • No additional community Infrastructure likely impacted **Essential Infrastructure Likely Impacted** • Skeene Street Special School flooded above floor. **Tourism / Recreation Likely Impacted** • No additional Tourism/Recreation likely impacted **Roads Flooded** • Except for the roads included in the events above, additional roads are flooded include: Brandon Street, Errington Road, Heal Street, Hewett Street, Holmes Court, Jones Street, Mayes Street, Sharps Lane, Simpson Street, Smeaton Street, Wilson Street, Woods Street. • The flood depth of roads flooded over 0.3m mentioned in the events above all slightly increased. Beside those mentioned roads, additional isolated roads include: Brook Farm Road (0.3m depth), Clifton Avenue (0.33m depth), Darlington Mine Road (0.31m depth), Grant Street (0.35m depth), Hodges Street (0.34m depth), Landsborough Road (0.4m depth), London Road (0.36m depth), Miller Lane (0.5m depth), Ocallaghan Street (0.31m depth), Oliver Road (0.34m), Pipetrack Road (0.35m depth), Playford Street (0.39m depth), Smith Street (0.31m depth), Stawell – Avoca Road (0.32m depth), Victoria Street (0.36m depth), Wilson Lane (0.35m)	

Observed Rainfall (see graph)	AEP of flood / year of peak	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
□ It is important that the decision to mobilise to remove furniture etc from buildings is made early and that, in general, sandbagging is reserved for non-weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Obtain rainfall data and use the flood guidance tool to determine the approximate flood severity. Consider the appropriate flood inundation tables and map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES, followed by a call to the MERO at the Northern Grampians Shire Council. Note time available – see below.			

Notes:
• Historical events should be linked to observed rainfall where possible.
• This card to be used with the inundation tables. Any actions necessary that are NOT in the inundation tables will be included here. This may include sandbagging infrastructure (e.g. pump stations), evacuating areas etc.
• There should be an action to notify the downstream municipalities.
• It is intended that this table be easily edited (i.e. it will be generated in word, not excel). Observed data and qualitative road closure information can be included here without depth of flooding.

5 TOTAL FLOOD WARNING SYSTEM

5.1 Overview

A Total Flood Warning System (TFWS) is intended to encompass all of the elements required to produce an appropriate timely response to flooding. The lead guiding document for the development of the TFWS in Australia is Manual 21 – Flood Warning (Attorney-General's Department, 2009). The core elements of the TFWS are shown in Figure 5-1.

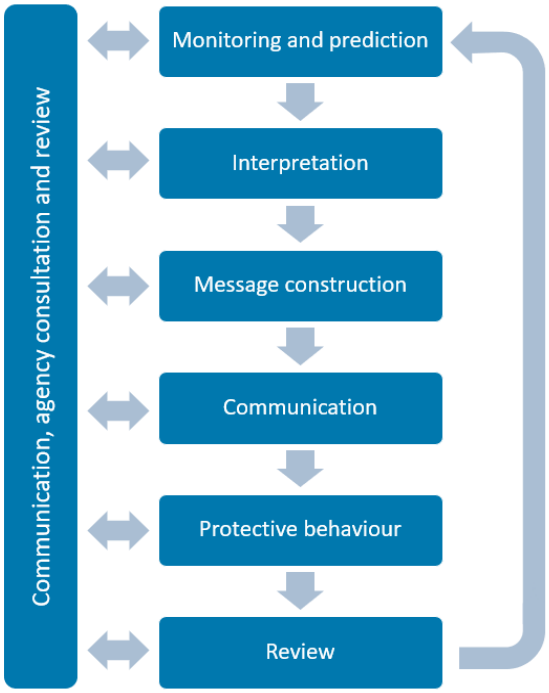

Figure 5-1 Total Flood Warning System elements

The information produced by a flood investigation generally relates to the "monitoring and prediction" and "interpretation" elements. Flood mapping, damages and intelligence produced by the study will be valuable in interpreting incoming data. Some of the elements of the study (for example the "Flood/No Flood" tool produced in the MFEP can aid with prediction.

Flood monitoring generally refers to monitoring rainfall and stream levels but may include other aspects such as storage levels and catchment conditions to name a few. Locations to monitor will depend on the available data sources and the catchment of interest.

Message construction, communication, and protective behaviour are outside the scope of a flood investigation; however, would generally be completed from within an Incident Control Centre (if one has been set up) and the applicable Incident Management Team controlling the incident. Formal flood warning messages in Victoria fall within the remit of the Bureau of Meteorology and fall within two classes: Flood Watches and Flood Warnings.

Flood Watches are general warnings covering a large area and are not specific to particular waterways or townships. They can be delivered well before flooding is expected to arise and are often based on forecast rainfalls. Flood Warnings, on the other hand, are specific to a location and will predict how high the water will peak at that location. Flood Warnings are often related to Flood Class Levels.

Review of the available information should take place after any event, or any other discovery of new flood information as appropriate. Historic events should be added to the available information, particularly the MFEP, as they occur.

Manual 21 stresses that for the TFWS to "work effectively, these components must all be present, and they must be integrated rather than operating in isolation from each other." When designing a TFWS, Manual 21 advises that the following points need to be addressed:

- The system must meet the needs of its clients including identifying:
  - Levels of flooding at which warnings are required.
  - The impacts at the different levels of flooding.
  - Warning time the community requires and what can be provided.
  - Appropriate subject matter content for warning messages.

  - The ways in which warning messages are to be disseminated.
  - The frequency of warning updates.
- The system must be part of the emergency management arrangements established by the relevant State or Territory as defined in disaster or emergency management plans.
- The review of the system must be carried out by all emergency agencies and by the community itself.
- The roles of the emergency agencies must be clearly defined for each component of the system.
- The system must be incorporated into the wider floodplain management.
- The system should be regularly tested and maintained.

A TFWS is the ideal tool to manage flood response, however for locations dominated by flash flooding such as the central parts of Stawell, flood warnings play a limited role due to the limited flood warning time, limited duration of inundation and limited ability to respond in a way which may reduce flood risk and damage.

5.2 Existing flood warning system

5.2.1 Understanding the flood risk

The flood modelling and mapping completed as part of this study has provided a basis for good agency and council understanding of risk in a range of flood events across the study area. It is critical to the success of TFWS formation that those living in the floodplain (and particularly landholders) also understand the flood risk. If people don't know they are at risk of flooding, they will invariably not heed warnings. According to the Victorian Floodplain Management Strategy, "flood study outputs must provide flood-prone communities with concrete information about the real-world consequences of floods of different sizes". (Department of Environment, Land, Water and Planning, 2016).

As a result of this Flood Investigation, there will need to be amendments to NGSC's planning scheme. The extent of flood prone properties identified during the study will be documented in the planning scheme.

Community members will be able to access flood risk property information through Council and hopefully via the VicData website.

5.2.2 Emergency Management Planning

Local councils are required to prepare a MFEP pursuant to Section 20 of the Emergency Management Act 1986 (as amended). The MFEP is a sub plan to the council's MFEP and should be consistent with the EMMV and the Victoria Flood Emergency Plan (Victoria State Emergency Service, 2012). The NGSC MFEP contains flood intelligence information for Stawell based on the Mount William Creek Flood Study (BMT, 2014). This provides limited information on flooding in Stawell caused by Pleasant Creek, and does not take into account the direct rainfall inundation analysed in the current study.

The purpose of this MFEP is to detail arrangements for the planning, preparedness/prevention, response and recovery from flood incidents within the Stawell municipality. As such, the scope of the Plan is to:

- Identify the Flood Risk to the Stawell municipality.
- Support the implementation of measures to minimise the causes and impacts of flood incidents within the Stawell municipality.
- Detail response and recovery arrangements including preparedness, incident management, command and control.

- Identify linkages with local, regional and state emergency and wider planning arrangements with specific emphasis on those relevant to flood.

This report provides details of recommended emergency operation activities to be conducted at different flood levels for the study area. These flood intelligence cards should be incorporated into the NGSC Flood Emergency Plan and replace the existing information for Stawell.

Sensitive infrastructure should all have their own emergency plans that include protective actions related to triggers (e.g. sub-daily rainfall gauge records, BoM warnings). These plans should be updated based on the flood intelligence cards from this report.

5.2.3 Community Flood Education

Community flood education helps people learn how to prepare for and respond to floods (including to flood warnings). The prime outcome is public safety, with a secondary outcome being protection of property.

A Local Flood Guide is used to explain local flood risks for communities at risk. Local flood guides exist for other communities within NGSC and one should be prepared for Stawell based on the information from this study. This includes advice for communities on how to prepare and respond to flood events and who to contact in the event of a flood. It should be produced based on the information in this report. Other future community flood education activities are also recommended and it should be noted that during community consultation undertaken during this project it was apparent the community was generally well aware of their flood risk, generally due to the recent frequency of previous flooding.

5.2.4 Data collation

Section 2.1 of this report details the available flood intelligence data for Stawell. It has been used in the development of the modelling and mapping used to determine the description of catchment and flood behaviour (Section 2), flood peak travel times (Section 3) and the information which will be inserted to the NGSC MFEP (Section 4).

5.2.5 Prediction

The BoM maintains and funds the prediction services for the locations defined in the BoM Service Level Specification for Flood Forecasting and Warning Services. Maintenance includes continually improving prediction techniques.

As part of its prediction services, the BoM issues Flood Watches and Flood Warnings. A Flood Watch provides early advice of potential riverine flooding to emergency services and communities at risk of flooding. Flood Watches are issued when the combination of forecast rainfall and catchment or other hydrological conditions indicate that there is a significant risk of potential flooding. Flood Warnings are issued by the BoM to advise that flooding is occurring or expected to occur in a geographical area based on defined criteria. Flood Warnings may include either qualitative or quantitative predictions or may include a statement about future flooding that is more generalised.

The type of prediction provided depends on the quality of real-time rainfall and river level data, the capability of rainfall and hydrological forecast models and the level of service required. It should be noted that there is no flood class detail provided by the BoM due to the lack of streamflow gauge within the Pleasant Creek catchment.

According to Manual 21 (page 18), ‘warning lead time’ is the time between the issuing of a message containing a prediction and the time when the predicted height is reached. In essence, it is the effective time in which communities can take action if guided by authorities.

Section 3 described the typical travel time along Pleasant Creek with most events peaking between 3 hours and 10 hours after the onset of rainfall. Due to the nature of the critical storm within the township catchment, the warning time of the flash flooding at Stawell is limited to less than half an hour and the BoM only provide Flood Watch information relevant to Stawell. No Flood Warnings will be produced.

5.2.6 Interpretation

Local flood studies produce updated flood mapping that can be used in prediction and the communication of flood warnings to affected communities. DEECA includes updated flood mapping and flood behaviour information in the flood intelligence platform.

According to Manual 21 (page 21), "operational coordination and communication are essential between the prediction agency and the lead response agency involved in the reception and interpretation of predictions. Onsite reports provide valuable feedback to the prediction agency on the impacts of flooding and on the accuracy of the predictions. Information on forecast accuracy can be used to adjust hydrological prediction models so future forecasts can be made more accurate".

For a flood in the study area, the BoM as the prediction agency would liaise with lead response agency (VICSES) at the state, regional and local level. Both agencies would interpret flood data through the appropriate level of Incident Control Centre (ICC). As a flood impacts on the community itself, it is worthwhile for response agencies to develop knowledge of the local conditions and potential reactions, both within the physical and social environments."

The current report and its associated flood intelligence cards through the NGSC Flood Emergency Plan will inform flood predictions in the study area.

It should be noted that DEECA has developed a web-based tool that provides a range of flood information, before, during and after floods. FloodZoom (only available to emergency agencies) brings together flood forecasts, flood mapping, real-time river height gauges and property data to provide flood response agencies with improved knowledge of likely flood impacts. Details of this and other flood warning system improvements are available at

http://www.delwp.vic.gov.au/water/flood-warning-improvements?remap=dewlp.vic.gov.au/floodzoom#sthash.Vt6xiDhb.dpuf

The intelligence provided to the ICC may be enriched by the crowdsourcing of data from an upper catchment information group of landholders organised by Wimmera CMA. This crowdsourcing process involves identifying and training 'flood observers': local landholders that are willing to photograph and/or verbally describe flood heights at certain reference points. This data can be phoned into the ICC to provide real-time intelligence in addition to flood models etc. However, local consultation showed that these crowdsources may have to help protect themselves, others and property and thus are not able to provide data in some floods.

5.2.7 Message construction

Flood Bulletins for Stawell should advise residents of potential road closures and to stay out of floodwaters.

Flood communication (e.g. Flood Bulletins) should be in simple language talking about impacts of potential flooding on the local communities in the study area and required actions including possible evacuation. It should consistently advise people of either stream heights or rainfall depths.

The rapid catchment response and very short time between rainfall and flooding should be acknowledged with at-risk residents and businesses in the Stawell area needing to conduct preparedness activities before the flood even begins. Each property that is prone to flooding should have sandbags prepared to act immediately after the flood warning is issued. Residents will want access to sandbags as soon as possible after it becomes apparent that flooding is likely.

5.2.8 Message Communication

Manual 21 (page 51) identifies two different types of message communication based on target audience:

- General warnings are disseminated ('broadcast') to whole communities or regions.
- Specific warnings are intended for individuals or parts of communities, and reflect the need for 'narrowcasting' to specific audiences who may have specific characteristics or be at different kinds of risk.

General warnings are communicated by VICSES through the appropriate level ICC using Emergency Management Common Operating Picture (EM-COP) which links to the media, emergency service websites, the VICSES Flood and Storm Information Line and social media.

For riverine flooding, specific warnings are communicated by the ICC using Emergency Alert (providing location warning messages to mobile phones and landlines). VICSES (or a delegated authority such as the CFA) also use local and personal communication methods such as doorknocking, community meetings, and community bulletins. Warnings in multiple languages may need to be considered based on community demographics.

5.2.9 Response

Flood response actions are outlined in the NGSC MFEP Intelligence Card (Section 4.3.5). Given the likelihood inundation in Stawell will only be prefaced by Flood Watches or Thunderstorm Warnings from the BoM, the response to flooding will need to be rapid and the MFEP used as a guide only with on ground response actions guided by observed inundation. Council and VICSES will likely lead this response in their respective roles.

5.2.10 Community participation

An important way of attaining shared responsibility is through community participation in disaster management. A VICSES unit is stationed in Stawell and local people can participate in flood emergencies including warning through volunteering.

5.2.11 Review of warning systems

The flood warning system in the study area needs to be reviewed regularly (e.g. through a system monitoring and evaluation process). Local communities should participate in the review of the local flood warnings e.g. through pre-existing committees or community groups.

NGSC Municipal Emergency Management Planning Committee is an appropriate body to review flood warning systems through its governance of the MFEP (which includes a section on flood warning). This plan needs to be reviewed:

- Following any new flood study
- Following changes in non-structural and/or structural flood mitigation measures
- After the occurrence of a significant flood event within Stawell

5.2.12 Existing capability

Currently, there is no formal flood warning system in place for the Pleasant Creek catchment. Additionally, there are no streamflow gauges within the catchment. Due to this, official flood warning capability for the Pleasant Creek and Stawell catchments is limited to the issue of a Flood Watch for the Wimmera River area. Note a Flood Watch is not necessarily guaranteed to be issued prior to flooding.

The Stawell Aerodrome rainfall gauge reports sub-daily rainfalls (30 minute intervals) to the Bureau of Meteorology and is located within the catchment. This gauge is expected to capture rainfall in both Stawell town and the Pleasant Creek catchment quite well.

5.2.13 Potential capability

Given a sub-daily rainfall gauge already exists within the study catchment, additional rainfall gauges would provide limited benefit. In general, flood data monitoring could benefit from the placement of a streamflow gauge within the catchment. However, the rapid Pleasant Creek catchment response of typically 3-10 hours from onset of rainfall to peak flood, and even less time from start of creek rising to peak flood, means that a streamflow gauge may not provide warning time sufficient to enact response actions other than evacuation or shelter in place. The costs associated with installation and maintenance of a gauging station would likely exceed the benefits. Similarly, using rainfall gauge data to predict flash flooding within Stawell may also be of limited use for flood warning.

A streamflow gauge on Pleasant Creek within Stawell would enable monitoring and data gathering, which could improve future flood model development and more detailed catchment analysis. A streamflow gauge upstream of Stawell would, as discussed above not provide sufficient warning time for Stawell given the limited catchment size.

The use of rainfall radar products would provide the most relevant flood warning tool for Stawell, this is discussed further in Section 4.2.

5.3 Improvements

The existing flood warning system lacks stream gauging capabilities and a detailed MFEP for Stawell. This Stawell Flood Intelligence and Warning Report and its associated flood intelligence cards provide improved flood data and interpretation for a local TFWS. However, there are several suggested actions that will improve the existing flood warning system to help develop a TFWS in the study area, these are as follows:

- Enable community members to access the latest flood risk information from NGSC's planning scheme.
- Incorporate flood intelligence cards from this Flood Intelligence and Warning Report into the NGSC MFEP.
- Ensure that any critical infrastructure that is flood prone has its own emergency plan that includes protective actions related to triggers. These plans should be updated based on the flood intelligence cards from this report.
- Produce a local flood guide for Stawell based on this report.
- Conduct other future community flood education activities across the study area based on findings of the report.
- Ensure that flood communication (e.g. Flood Bulletins) are presented in simple language talking about impacts of potential flooding on the local communities in the study area and required actions including possible evacuation. It should consistently advise people of either stream heights or flow volumes.
- Communicate the rapid catchment response to intense rainfall events, meaning that there is limited warning time once a rainfall event commences. Residents need to observe rainfall forecast and take relevant precautions, particularly if evacuation is necessary.
- Ensure that all people in the community (including newcomers and renters) have the opportunity to be included in community flood education and engagement before, during and after flood events.
- Check that the Vulnerable Persons Register is updated and used during a flood emergency.
- Any community flood education should reiterate the message from VicSES regarding the risks of attempting to drive through flood waters. This is the most common cause of flood related fatalities.

- Make tourists in the Grampians National Park aware of flood risks through interpretive programs conducted by the park staff.
- Consider other ways in which the community can participate in the design, implementation and review of the TFWS.
- Amend the MFEP to describe the practical integration of the local flood warning system.
- Investigate the application of rainfall radar for Stawell, enabling a spatial understanding of rainfall depths across the township and associated catchments.

6 SUMMARY

Several flood intelligence products have been developed to improve flood response capability for Stawell and Pleasant Creek, including a flood impact summary table, flood peak timing estimates and the development of a quick “Flood/No Flood” tool designed to estimate the magnitude of flooding based on observed rainfall.

The monitoring capability and infrastructure availability to enable flood warning for Stawell has been discussed, with a streamflow gauge mentioned as a possible but not necessarily beneficial option. A streamflow gauge on Pleasant Creek would improve the monitoring and data gathering capability for creek flooding but may not enable significant flood response and is unlikely to provide a positive cost benefit ratio. A more cost effective and useful solution to improve the spatial understanding of rainfall extent and intensity would be rainfall radar. It is recommended rainfall radar be investigated for Stawell.

Much of the flood intelligence information contained in this report will be included in a draft revision of the NGSC MFEP for SES and Council approval. It is recommended the flood intelligence information is incorporated into council and/or SES community education programs to improve flood awareness.

WATER TECHNOLOGY
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APPENDIX A
VICSES SANDBAGGING GUIDE

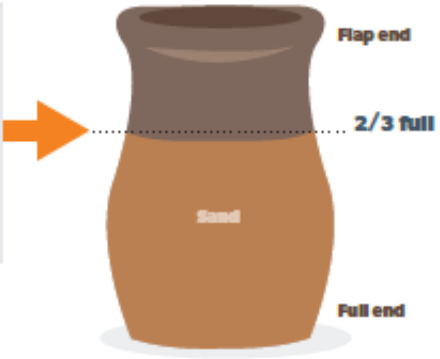
Sandbagging

Protecting your home

Sandbags won't stop the water completely, but can reduce the amount of water entering your home.

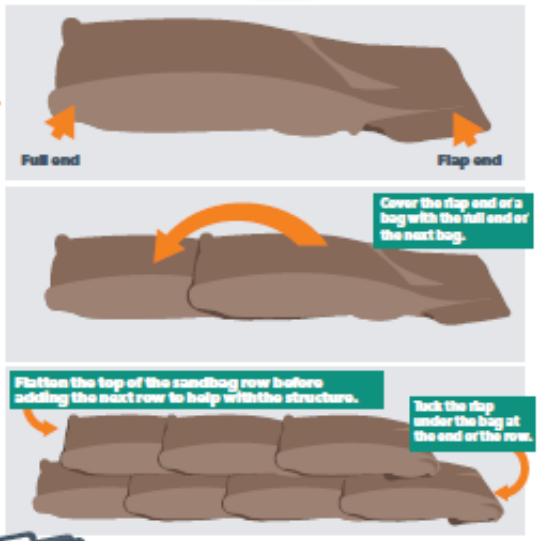
How do I fill a sandbag?

- Only use sand to fill hessian bags. Do not use dirt.
- Only fill sandbag two-thirds full.
- Do not over fill the sandbag as it will be too heavy to carry.
- Do not tie the top of the sandbag.
- Take care when filling and lifting the sandbag, to avoid injury.



How do I lay sandbags?

- Lay sandbags like brickwork. Stagger rows so that the joins do not line up.
- Start at one end and work to the other end.
- Ensure the unfilled part of the bag is covered by the next bag.
- Tuck flap under the bag at the end of the row.
- If the sandbag wall is going to be more than five (5) bags high, you will need to lay two (2) rows wide.



Where do I place the sandbags?

- Place sandbags in plastic bags to cover drainage holes in home (e.g. showers, toilets, sinks) to stop back flow of water.
- Place a small wall across doorways, at least the height of the expected water level. Be careful not to trap yourself inside.
- If available, plastic sheeting may be used under sandbags to reduce the seepage.

What do I do once I have finished with the sandbags?

- Sturdy gloves should be worn when handling wet sandbags as they can contain chemicals, waste and diseases.
- Sandbags that have been in contact with floodwater need to be thrown away.
- Contact your local council to find out how to dispose of your sandbags safely.

Sandbags and sand

Preparing your home

Having sandbag supplies ready can assist you before a flooding emergency occurs.

What supplies do I need to sandbag my home?

- Sandbags
- Sand
- Plastic sheeting
- Gloves and safety goggles
- Shovel or hand scoop

Where can I purchase these supplies?

- Many sandbag supplies can be purchased from hardware stores or garden centers.
- VICSES do not routinely supply sandbags to households.
- During floods, sandbag distribution points may be established in flood-affected areas.

How many sandbags will I need and how much sand?

- Most homes can be protected by less than 25 sandbags.
- The number of sandbags will depend on your local flood risk and availability.
- Sandbags are filled 2/3 full which requires around 15-20kgs of sand per bag.

How do I store my sand and sandbags?

- Filled sandbags only have a short shelf life.
- It is recommended to store sandbags empty.
- Sandbags should be stored in a cool dry area away from UV light.
- Sand should be kept dry and can be stored in water-resistant containers or under a tarp.
- Sand is heavy - ensure it is stored so it can be moved safely.

When should I sandbag my home?

- **You** are best placed to decide if there is a need to sandbag your home, based on local knowledge and past flood events.
- Monitor your local conditions. Stay up-to-date with weather forecasts and warnings by downloading the **BOM Weather** and **VicEmegency** apps, or call the VicEmergency Hotline on 1800 226 226.
- If you think you are at risk, do not wait for an official warning to act.

WATER TECHNOLOGY
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APPENDIX B
ROAD INUNDATION MAPPING

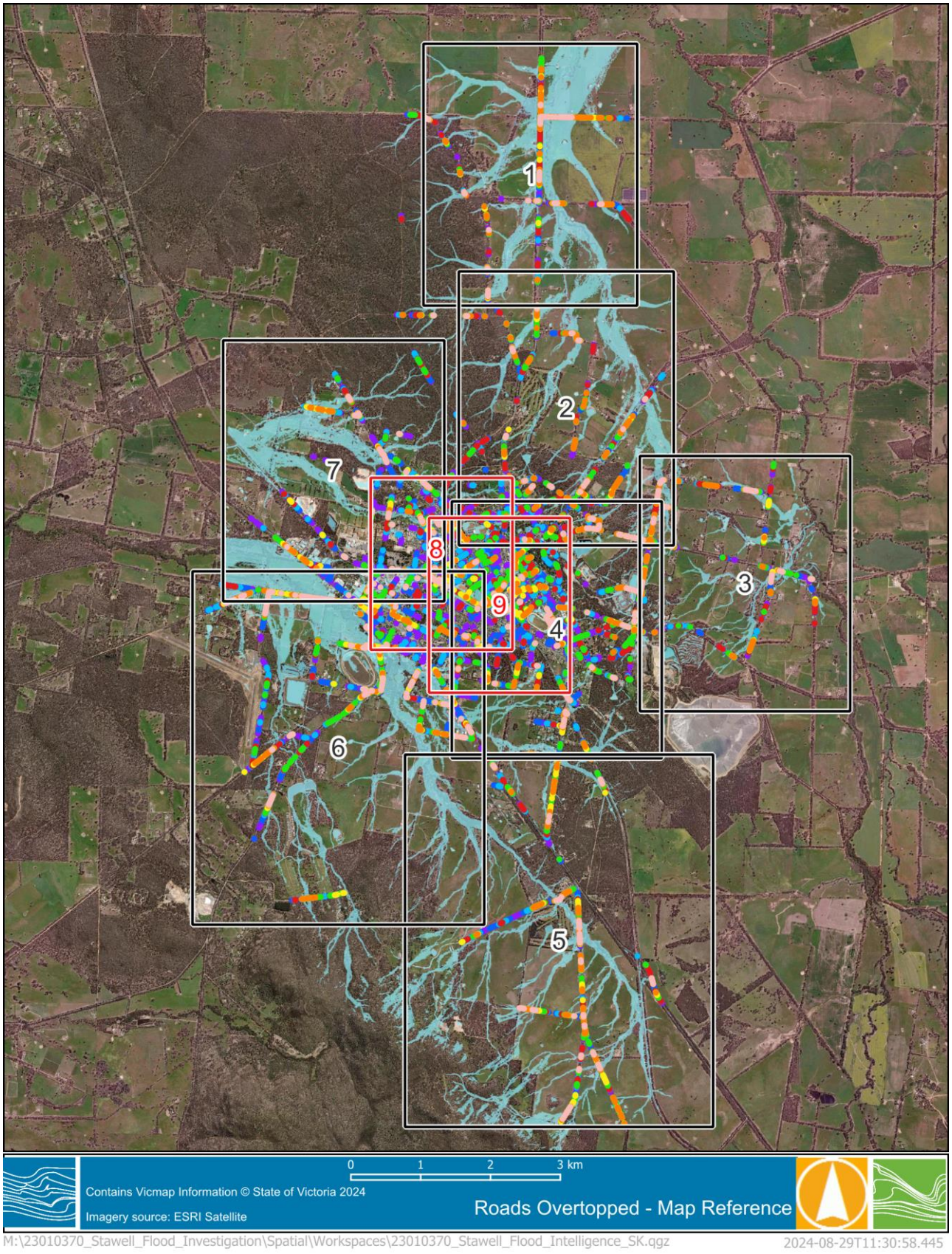

Figure 6-1 Roads overtopped reference map

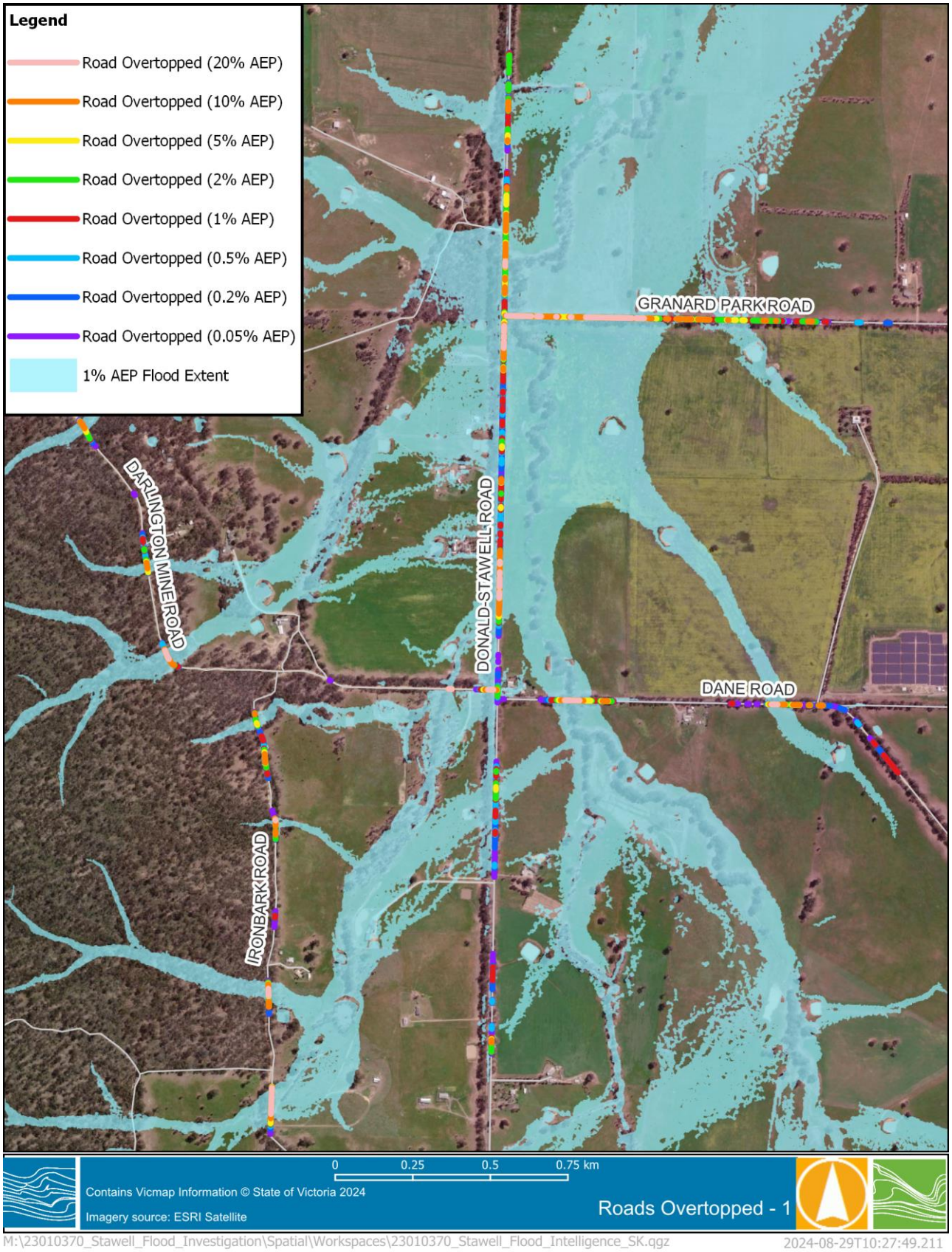

Figure 6-2 Roads overtopped - 1

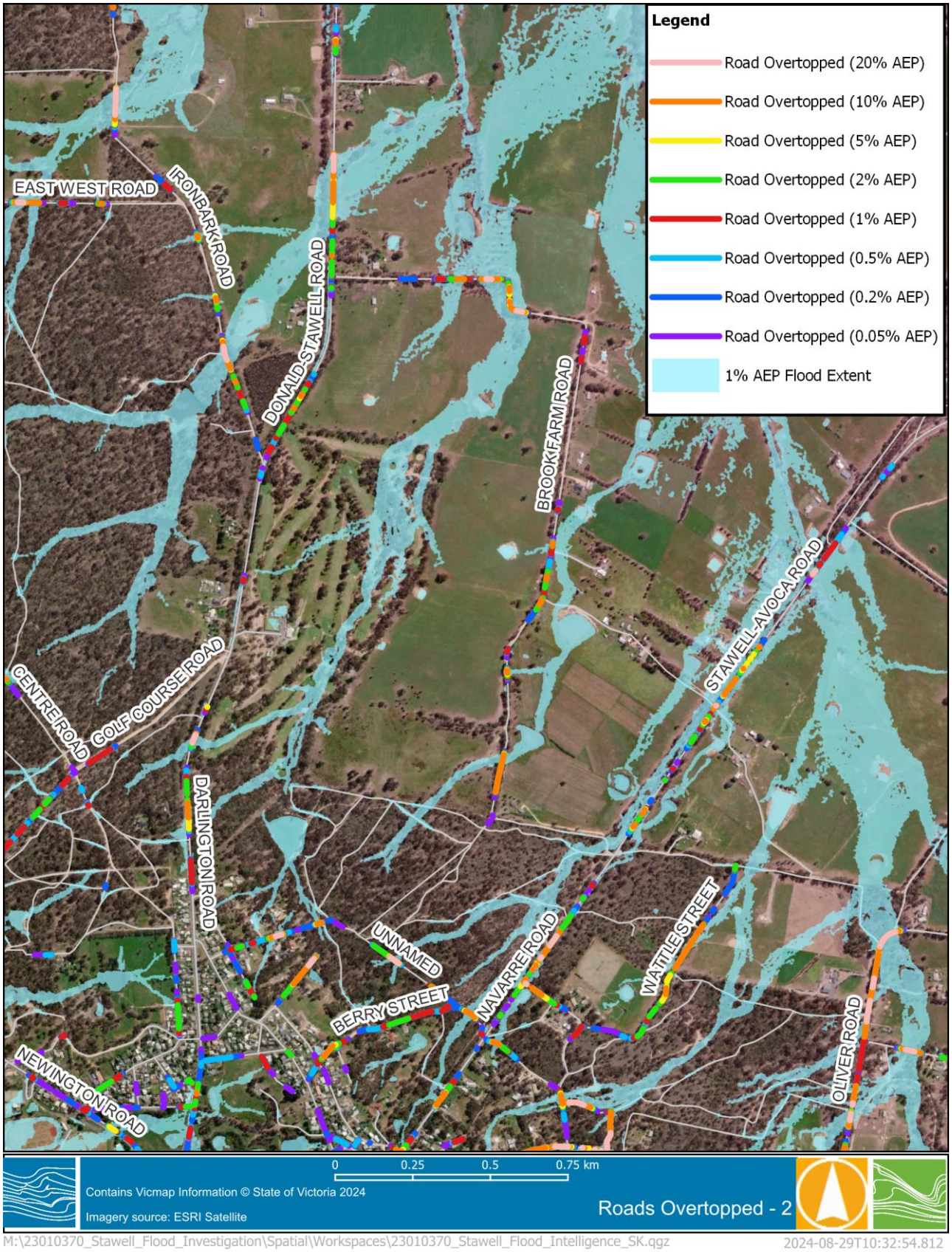

Figure 6-3 Roads overtopped - 2

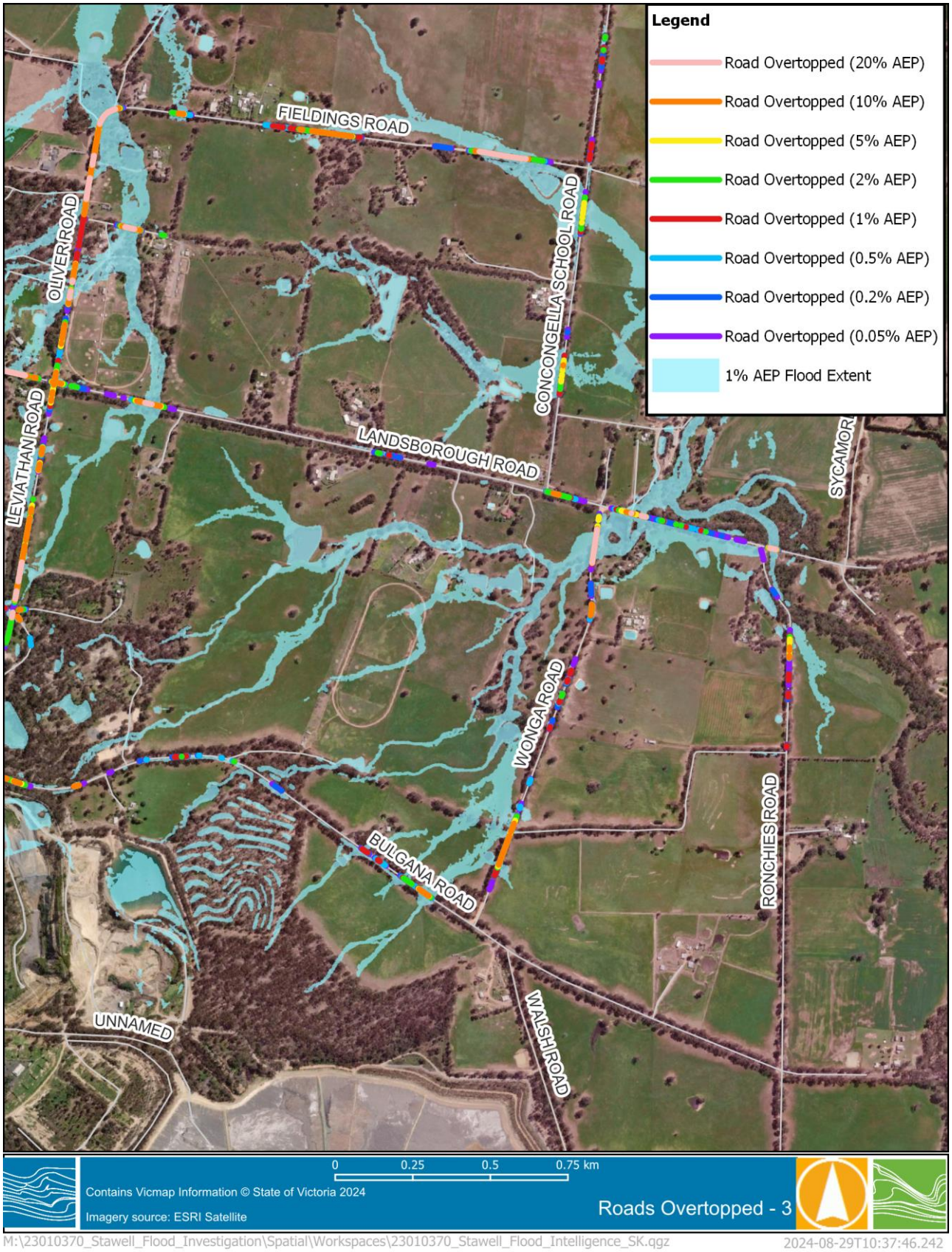

Figure 6-4 Roads overtopped - 3

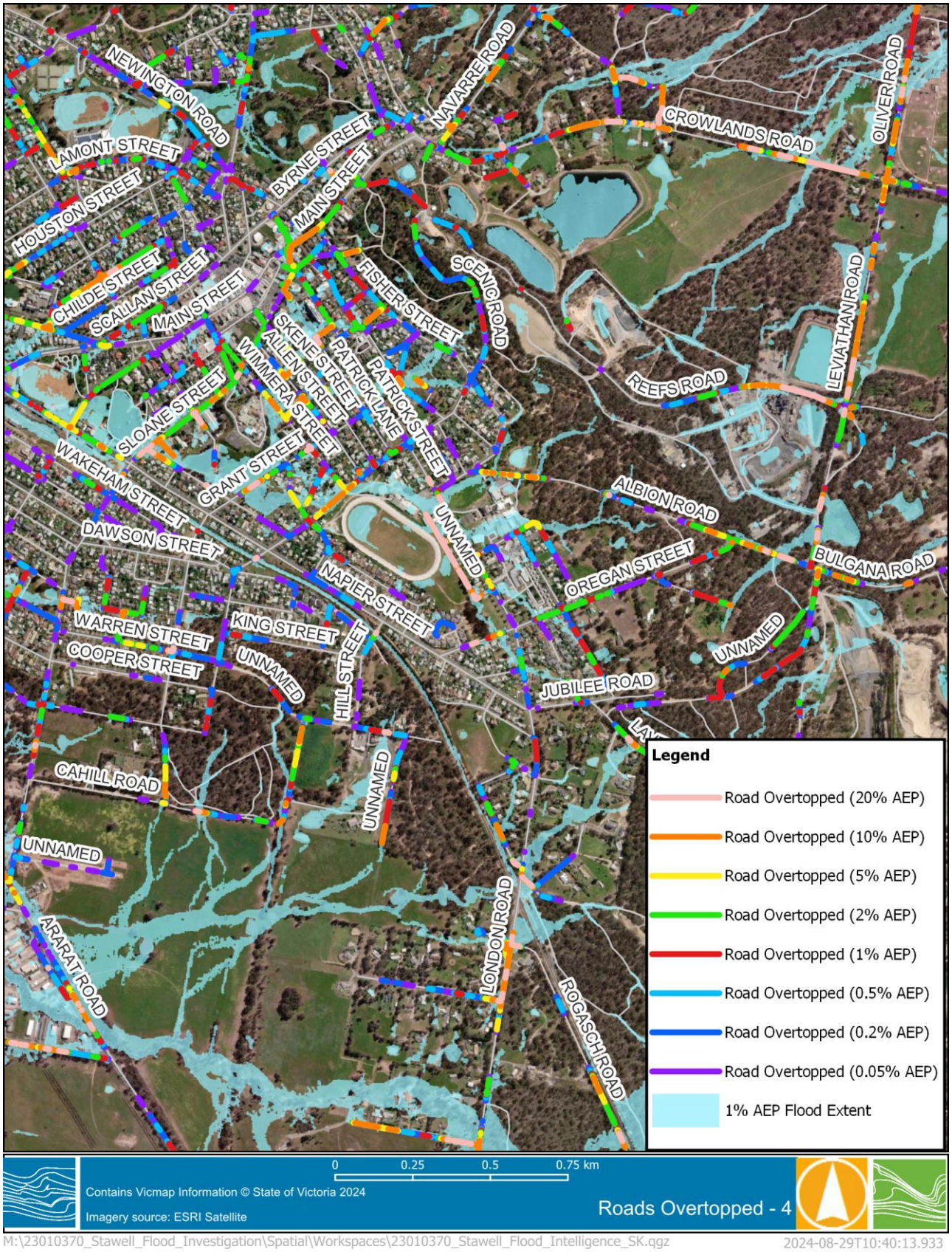

Figure 6-5 Roads overtopped - 4

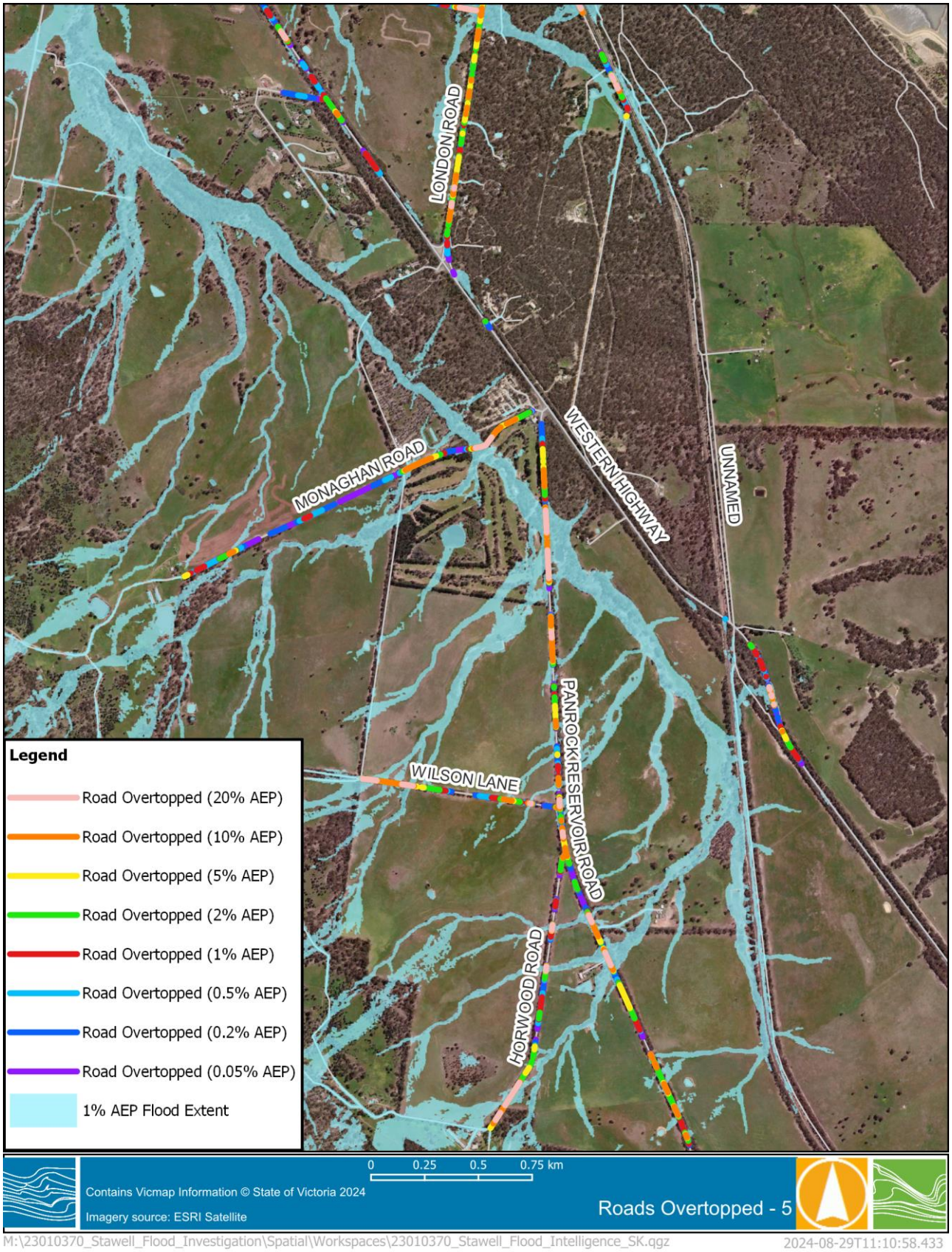

Figure 6-6 Roads overtopped - 5

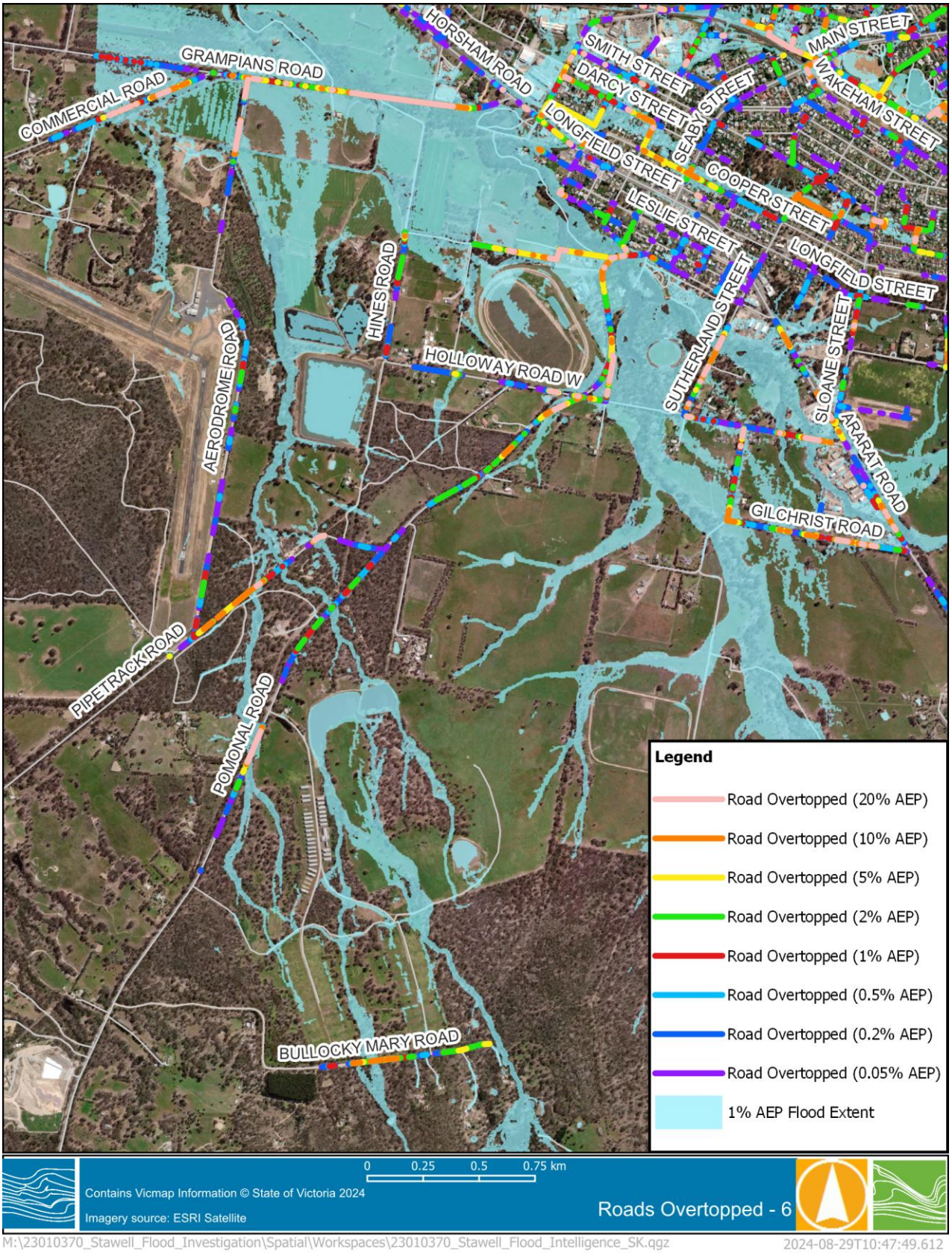

Figure 6-7 Roads overtopped - 6

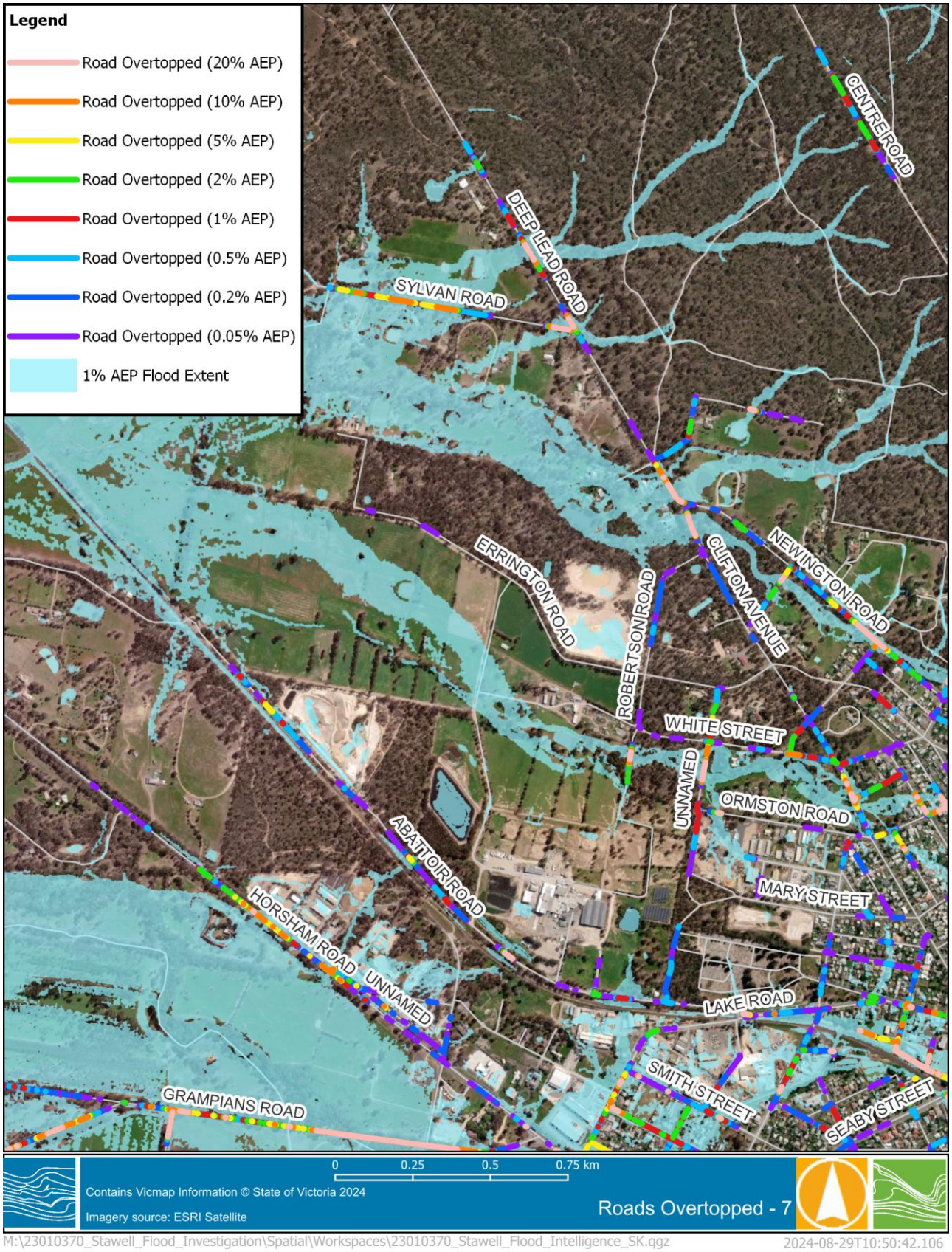

Figure 6-8 Roads overtopped - 7

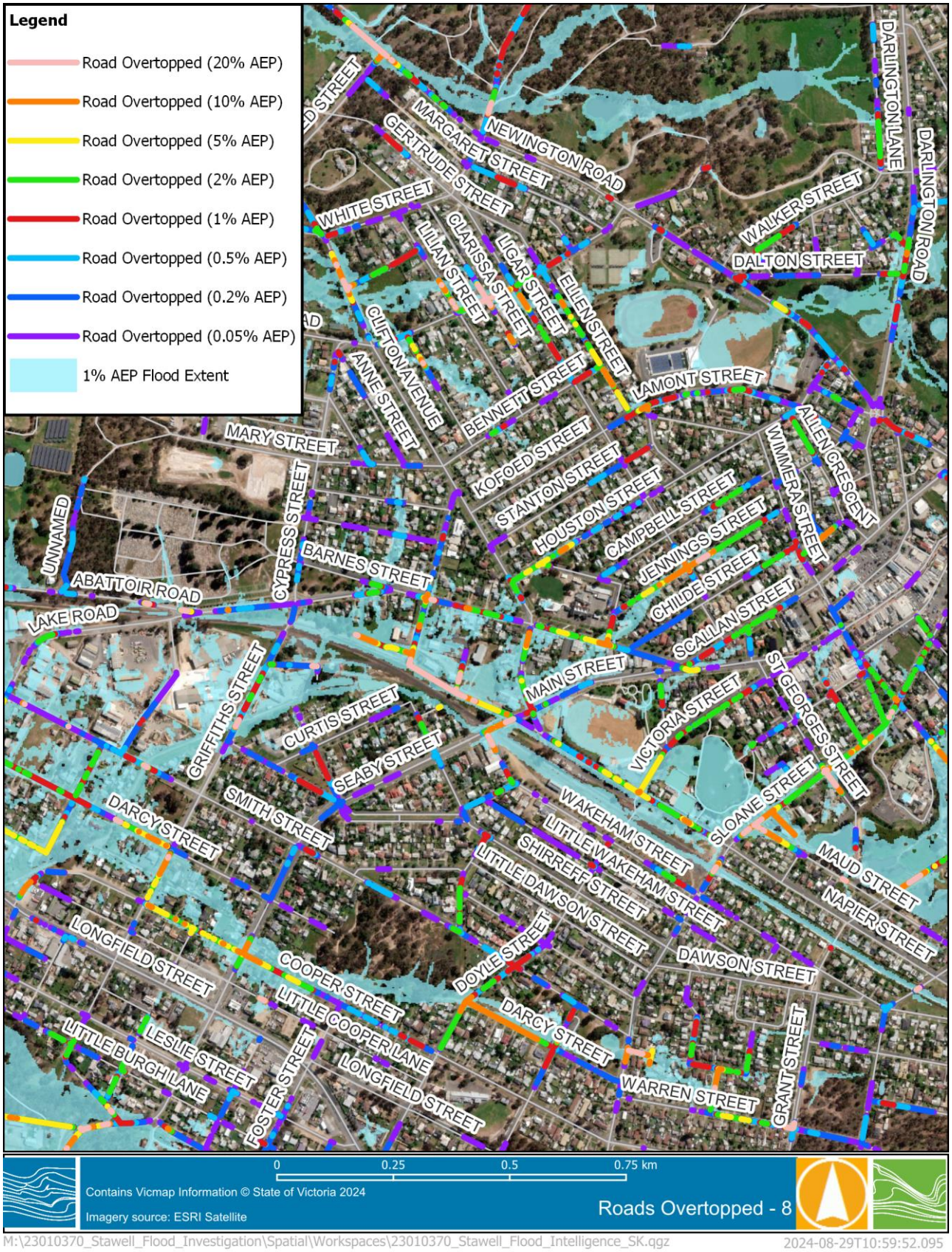

Figure 6-9 Roads overtopped - 8

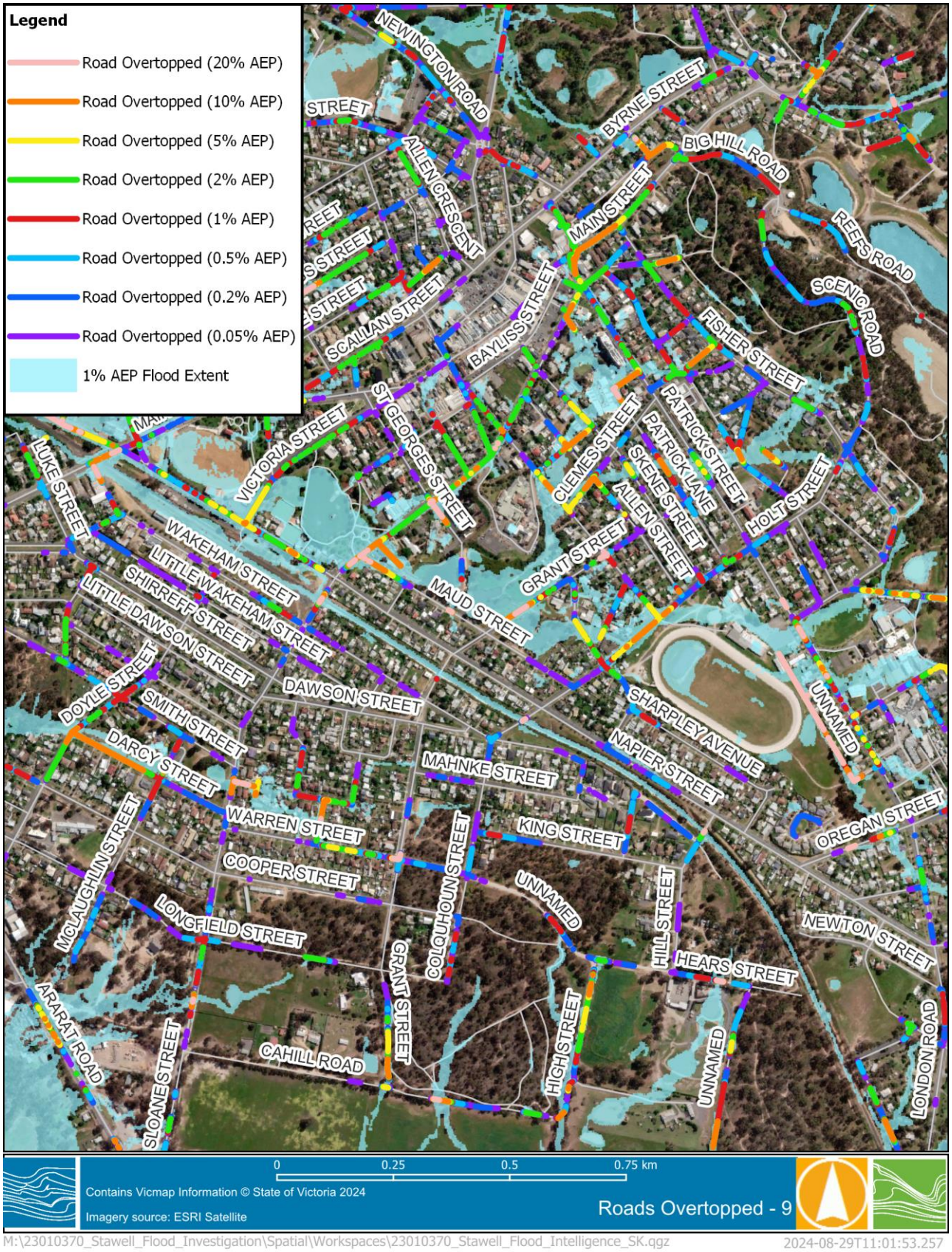

Figure 6-10 Roads overtopped – 9

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX C
ROAD AND PROPERTY INUNDATION TABLES

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Stawell VIC 3380
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