Flood Damages and Mitigation Report

Stawell Flood Investigation (C14 2022/23)

Northern Grampians Shire Council

2 December 2024

Document Status

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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 attached the Flood Damages and Mitigation Report for the Stawell Flood Investigation. This report documents the mitigation assessment by detailing the impact of each modelled option as well as preliminary cost and cost benefit ratio of the most feasible of the modelled options.

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

Yours sincerely

Ben Hughes
Senior Principal Engineer
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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 have been undertaken for either of the study areas. The Mt William Creek Flood Investigation (2014) included the Pleasant Creek catchment which covers 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 study addressed the uncertainty around flood risk within Stawell and developed 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, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Stawell, investigated structural and non-structural mitigation options, and investigated and make 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
  - This report details all 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
  - This report documents 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. Key model parameters are repeated herein; however, the full details of the model builds are contained within the previous report.
- R04 – Flood Intelligence and Warning Report (including Municipal Flood Emergency Plan (MFEP) Documentation) – Draft completed 1 November 2024, final version issued 2 December 2024
  - 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 provided updated appendices to the Municipality Flood Emergency Plan (MFEP).
- **R05 – Flood damages and mitigation report – This report**
  - This report documents the damages associated with flooding in the study area, as well as the assessment of mitigation options, costs and a cost/benefit ratio for the most preferable option.

- 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 or near the town, instead flood risk is driven by local stormwater runoff from elevated areas in the east of the town, 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 has 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.

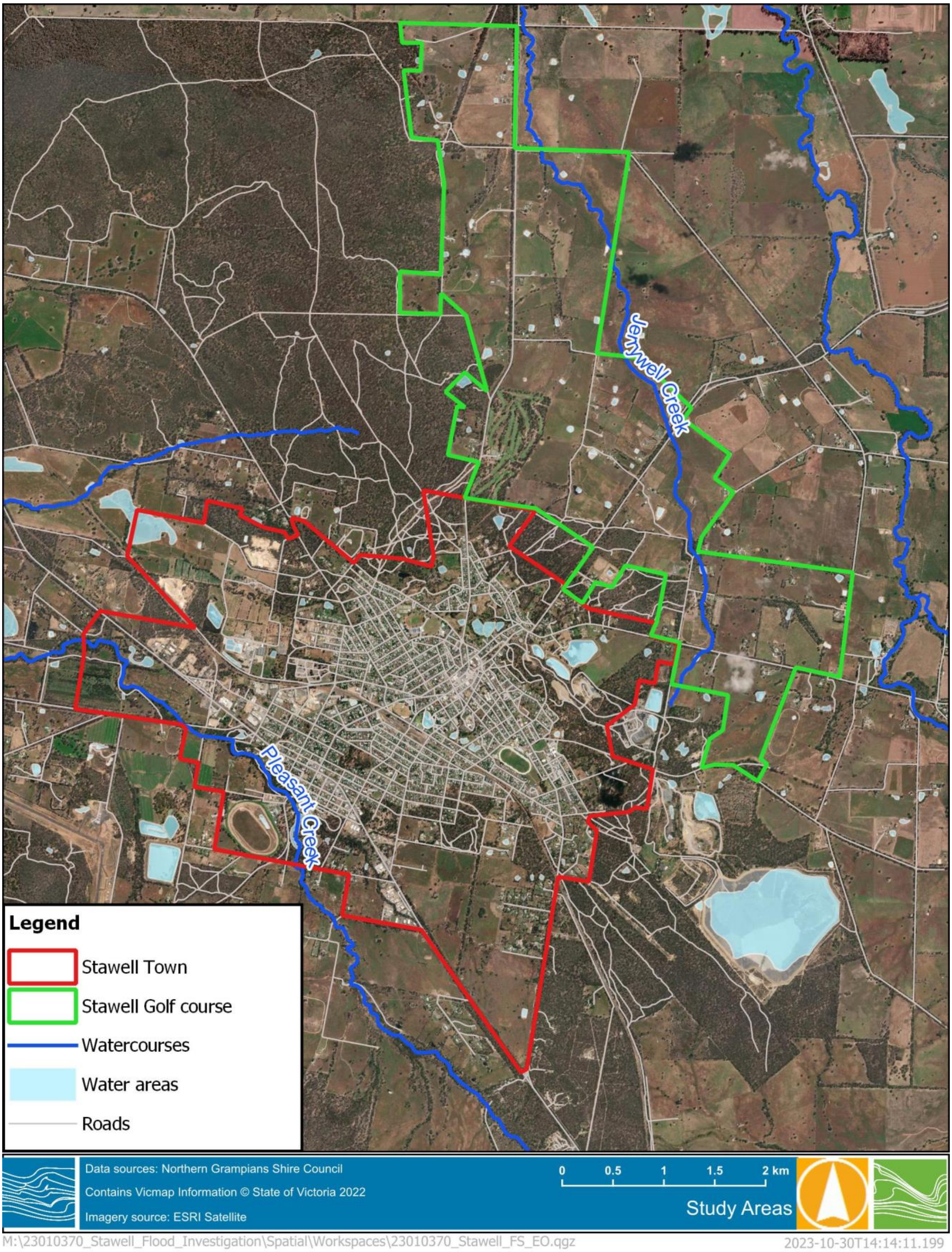

Figure 1-1 Stawell study areas

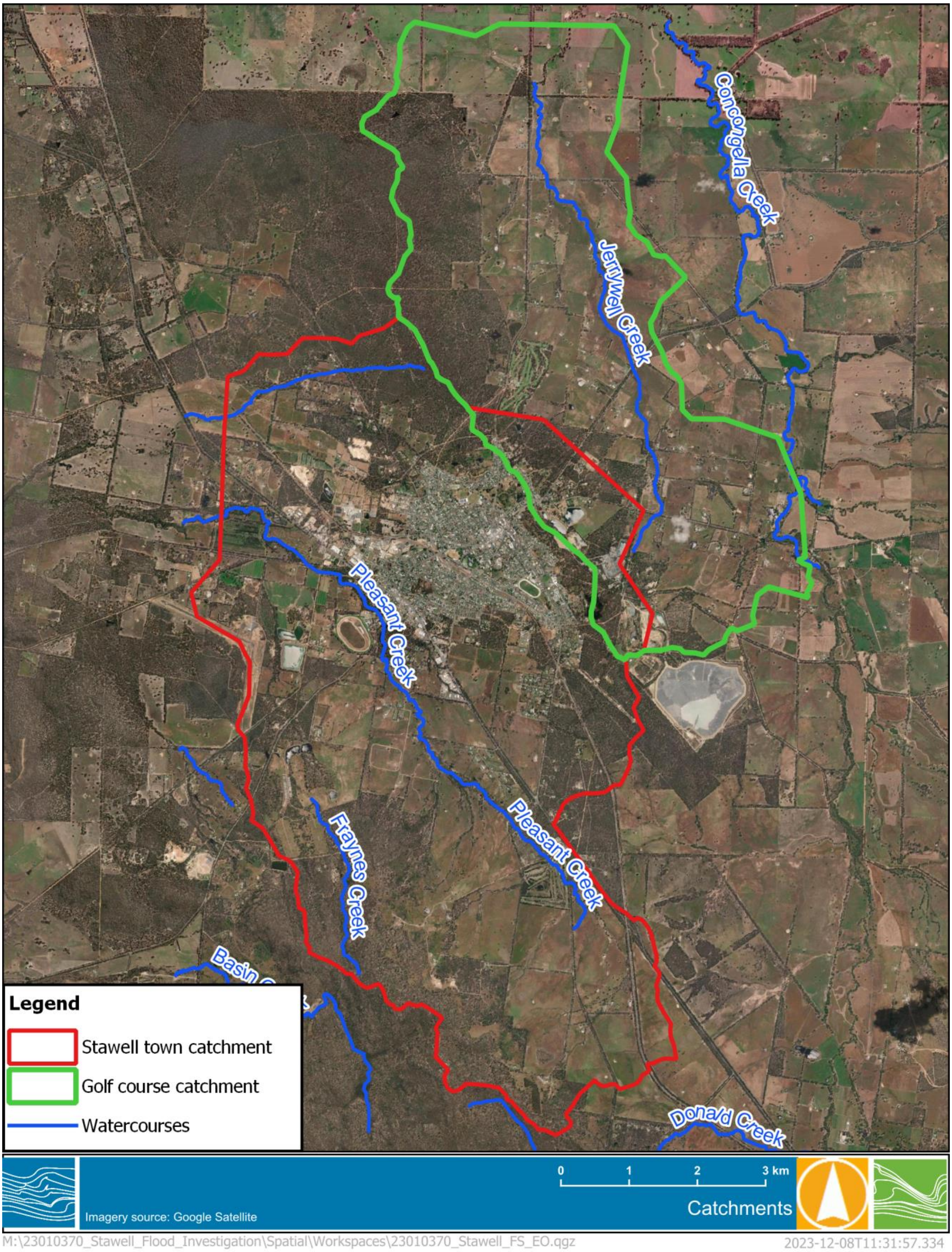

Figure 1-2 Stawell catchments

2 FLOOD BEHAVIOUR

2.1 Overview

2.1.1 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 at 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 area are observed from the Stawell Racecourse onwards, and downstream of the confluence with the Main Drain, the creek inundates a wide floodplain across Grampians Road. In a 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 are flooded.

Black Range Road overtops in a 5% AEP event, around 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. The 1% AEP floodplain north of Grampians Road 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 Grampians Gate Caravan Park and half of the racecourse is flooded.

2.1.2 Stawell township catchment

Flooding in Stawell is driven by local catchment flash flooding and occurs along a few main overland flow paths where the underground piped drainage network exceeds capacity. They originate 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 Stawell 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 joining 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, the 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, the flow paths become more well defined with increased depth and velocity. In the 2% AEP event, overland flow occurs 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 the 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 stretching from Big Hill in the east to Pleasant Creek in the west intersects Stawell.

2.1.3 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 the upper reaches of the Creek south of Stawell-Avoca Road and consists of overland flow only 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. The floodplain is over 600 m wide in a 20% AEP event, overtopping from Jerrywell Creek and tributaries is observed at many roads in the catchment.

Stawell-Avoca Road overtops just east of the Jerrywell Creek bridge in a 0.5% AEP event, with the floodplain 800 m wide and covering a wide segment of Donald-Stawell Road.

2.2 Roads

During major flood events the regional road network often becomes inundated. There is risk associated with travelling through floodwaters of any depth. Flood water can often unknowingly exceed safe vehicle fording depths and velocities. This presents a risk to the community, who may become isolated and seek to evacuate and to operational staff and emergency services, who may inadvertently traverse roads which are unsafe.

Flood mapping shows several roads within the mapped area can become impacted by flood water during relatively frequent flood events (i.e. 20% AEP). Table 2-1 shows a list of major roads impacted by flooding and the lowest magnitude (i.e. most frequent) event at which the road is impacted within the study area. The extent of road inundation for all modelled events is show in Appendix A. Consideration should be given to this information in planning for suitable evacuation routes

Table 2-1 Major roads overtopped in the study area

Design event overtopped (AEP)				
20%	**10%**	**5%**	**2%**	**1%**
Albion Road	Bulgana Road	Black Range Road	Horsham Road	Alfred Street
Ararat Road	Concongella School Road	Longfield Street	Byrne Street	Duke Street
Barnes Street	Darlington Road	Pomonal Road	Church Street	
Clifton Avenue	Seaby Street	Stawell - Avoca Road	Layzell Street	
Crowlands Road			Scallan Street	
Deep Lead Road			Western Highway	
Donald - Stawell Road				
Grampians Road				

Design event overtopped (AEP)				
Landsborough Road				
London Road				
Main Street				
Navarre Road				
Newington Road				
Patrick Street				
Sloane Street				

2.3 Properties

Floor 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 and 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 2-1 and Figure **2-2**.

Table 2-2 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

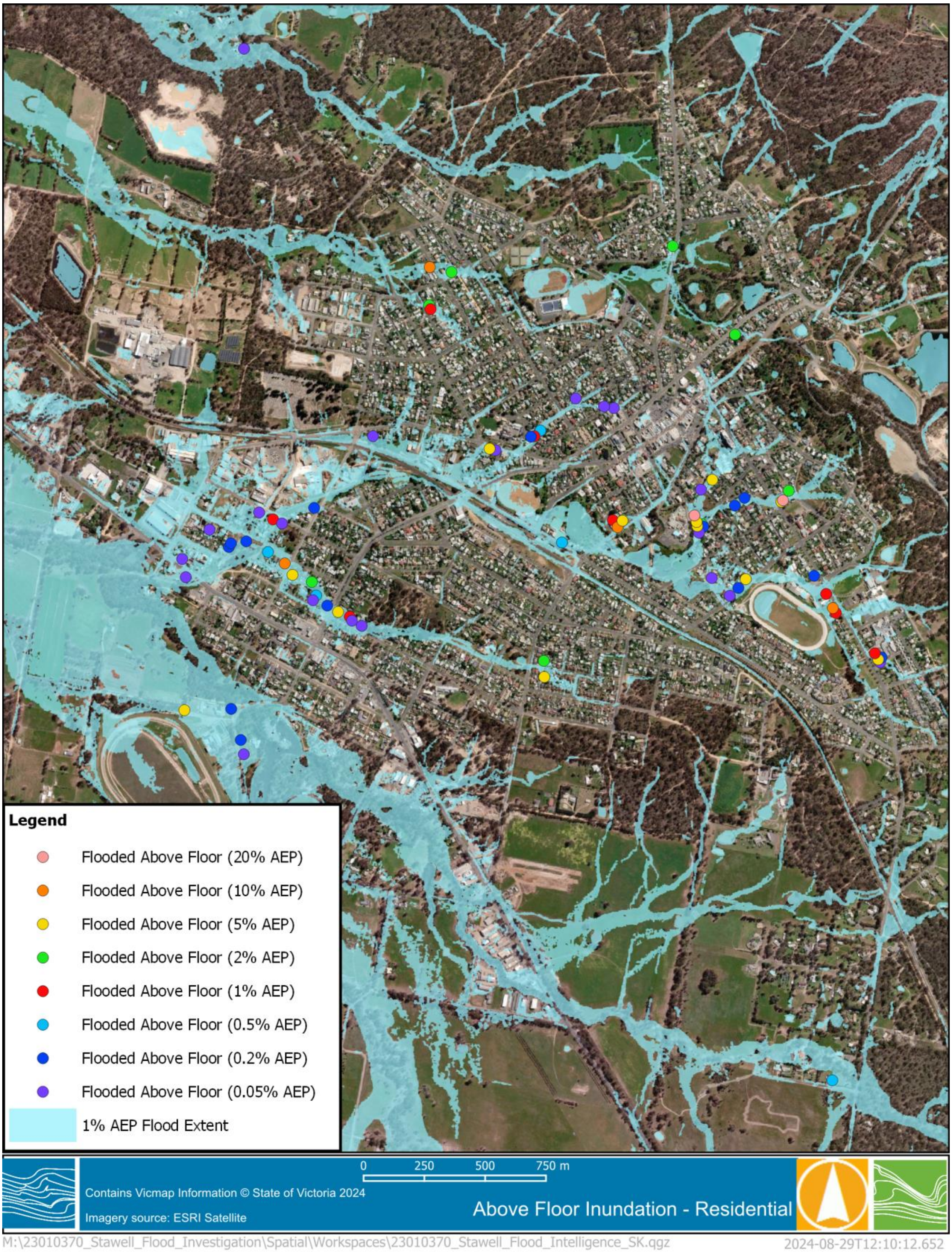

Figure 2-1 Properties flooded above floor – Residential

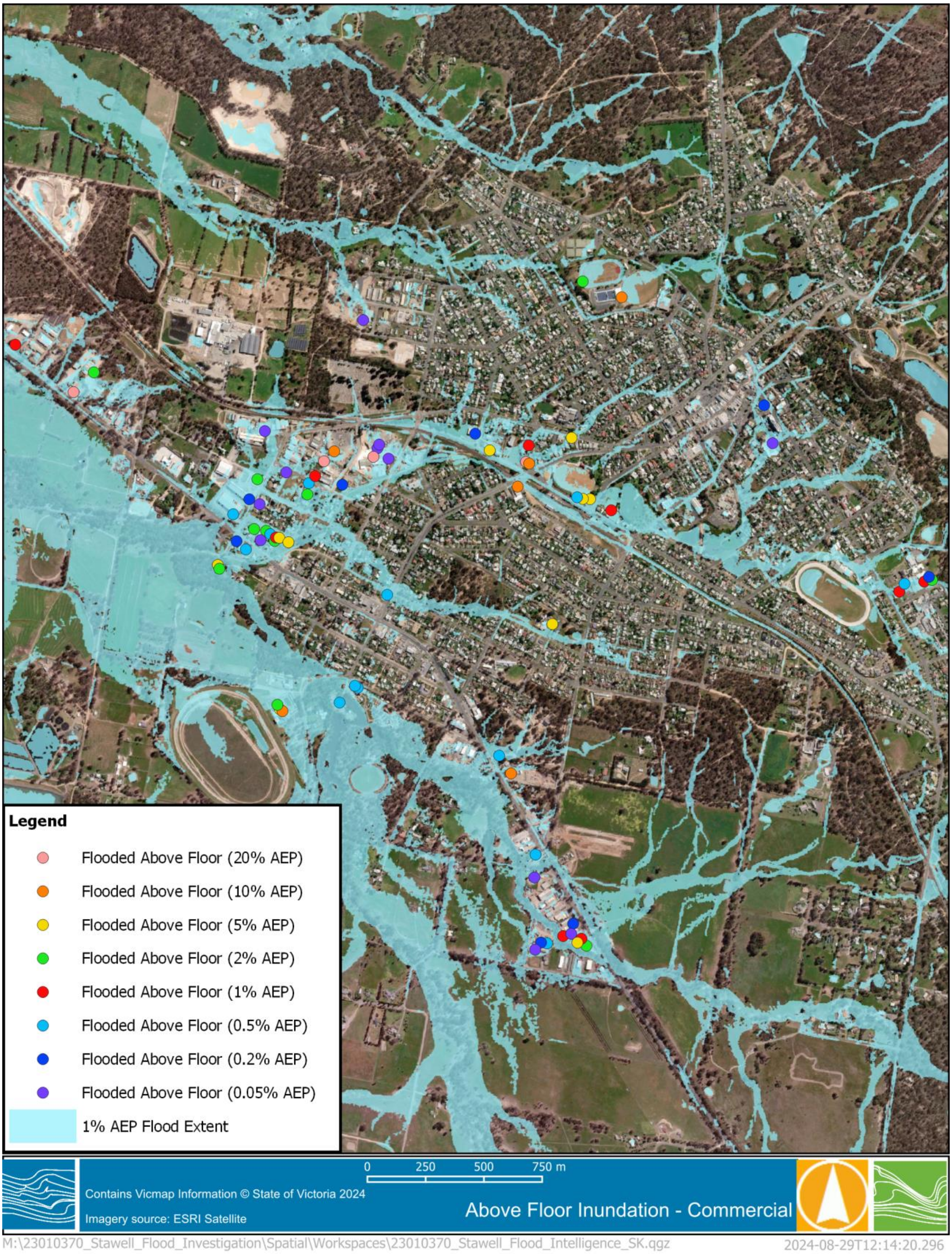

Figure 2-2 **Properties flooded above floor – Commercial**

3 DAMAGES ASSESSMENT

A flood damage assessment was undertaken for the study area under existing conditions. The flood damage assessment determined the monetary flood damage for the range of modelled design events (i.e. 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.05% AEP and PMF floods).

Model results for all mapped flood events were processed to calculate the number and the location of properties and roads affected. These included properties inundated above floor, properties inundated below floor, properties which were not impacted but the grounds of the property were, and the lengths of flood affected roads. It should be noted that only sealed roads were assessed due to the availability of associated costs for flood damages.

Flood damages were calculated and summed for each property and road utilising the damage curves in Table 3-1.

Table 3-1 Damage curves utilised in assessment

Damage category	Damage vs depth curve
Residential	Stage damage curves based on NSW Office of Environment and Heritage 2007 methodology[1] (factored up to 2022 CPI)
Commercial	Stage damage curves based on ANUFLOOD 1992 methodology (increased by 60% as per RAM 2000 methodology[2], and factored up to 2022 CPI)
External Below Floor	Damage curve from NSW DPIE 1992 methodology (factored up to 2022 CPI)

The damage occurring in each of the modelled events was used to calculate an Average Annual Damage (AAD) for the study area, this is the amount of funding required to be set aside each year to repair flood damage. It does not include the emotional or mental health cost of flooding which can be significant but difficult to measure.

A summary of the flood damage assessment is shown in Figure 3-1. It is noted that above floor flooding at residential properties is likely to occur in a 20% AEP flood event, although at a limited number of properties. An AAD cost of $672,954 was determined for the Stawell study area.

[1] NSW Office of Environment and Heritage (2007) Floodplain Risk Management Guidelines: Residential Flood Damages
[2] Rapid appraisal method (RAM) for floodplain management, Victorian Department of Natural Resources and Environment, 2000

EXISTING CONDITIONS									
ARI (years) AEP	PMF 0.000001	2000yr 0.0005	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2
Residential Buildings Flooded Above Floor	229	76	55	40	35	26	18	6	2
Commercial Buildings Flooded Above Floor	120	74	61	53	39	31	20	10	4
Properties Flooded Below Floor	3065	1701	1480	1330	1206	1106	941	833	677
Total Properties Flooded	**3414**	**1851**	**1596**	**1423**	**1280**	**1163**	**979**	**849**	**683**
Direct Potential External Damage Cost	$15,384,349	$6,578,893	$5,233,488	$4,387,096	$3,771,692	$3,097,008	$2,439,456	$1,870,356	$1,109,741
Direct Potential Residential Damage Cost	$18,605,144	$5,251,173	$3,634,449	$2,570,805	$2,219,543	$1,574,916	$967,140	$353,298	$118,283
Direct Potential Commercial Damage Cost	$11,890,755	$2,292,506	$1,348,945	$870,815	$581,386	$344,837	$201,762	$87,543	$43,475
Total Direct Potential Damage Cost	**$45,880,248**	**$14,122,572**	**$10,216,882**	**$7,828,716**	**$6,572,621**	**$5,016,761**	**$3,608,358**	**$2,311,197**	**$1,271,499**
Total Actual Damage Cost *(0.8*Potential)*	**$36,704,198**	**$11,298,058**	**$8,173,506**	**$6,262,973**	**$5,258,097**	**$4,013,409**	**$2,886,686**	**$1,848,958**	**$1,017,199**
Infrastructure Damage Cost	**$7,436,748**	**$4,345,748**	**$3,442,512**	**$2,756,171**	**$2,222,780**	**$1,640,187**	**$1,015,134**	**$733,497**	**$285,929**
Indirect Clean Up Cost									
Indirect Residential Relocation Cost									
Indirect Emergency Response Cost									
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$44,140,946**	**$15,643,806**	**$11,616,017**	**$9,019,143**	**$7,480,876**	**$5,653,596**	**$3,901,820**	**$2,582,455**	**$1,303,129**

Average Annual Damage (AAD)	$672,954

Figure 3-1 Existing conditions Average Annual Damages (AAD)

4 STRUCTURAL MITIGATION OPTIONS

4.1 Overview

Flood risk and flood damages can generally be reduced with structural and non-structural mitigation options. Structural mitigation options are engineering solutions which focus on reducing flood extent, depth and damages. Non-structural mitigation options focus on ensuring that new development does not occur in high flood risk areas, and they aim to raise community awareness of the risk and support improvement to emergency response during a flood event.

Three potential structural mitigation options were tested in the hydraulic model, with initial feasibility screening undertaken for the 1% AEP event. The options focused on reducing damage and hazard associated with the overland flow impacting residential/commercial lots and road crossings. Community feedback regarding mitigation options was sought during community consultation. The modelled mitigation options were discussed with NGSC and were determined as having the potential to reduce flood levels in several locations while not causing adverse impacts in other areas. The three options considered were as follows:

- Increasing the storage capacity and improving capture for seven detention basins within Stawell (Figure 4-1) including:
  - Grant Street dam
  - Taylors Gully Park dam
  - Cooper Street dam
  - Lake Cato
  - Maude Street dams 3 and 4
  - Duke Street dam
- Lowering the Stawell Main Drain 500 mm across the entire width from the Curtis Street dams to the exit into Pleasant Creek (Figure 4-1)
- Doubling the culvert crossing capacity at 11 locations in the Pleasant Creek and Jerrywell Creek catchments (Figure 4-4 and Figure 4-5)

The options were investigated separately, and the modelled 1% AEP water levels produced during each mitigation option were compared to those produced in existing conditions. The change in modelled water levels for each option was thematically mapped to show a graphical representation of the increases and decreases to understand the impact of each respective mitigation option. The water level difference maps for each scenario are presented in Figure 4-2 to Figure 4-7 and are discussed in each of the respective sections.

4.2 Big Hill Flood Investigation recommendations

In 2021/2022, Water Technology undertook a hydraulic assessment of flooding in Stawell caused by runoff from Big Hill, with a focus on assessing cause of inundation at the Skeene Street Specialist School, as well as the units at 48 Wimmera Street, around the reserve between Fisher Street and Gray Street and around Gladstone Park. A hydraulic model was established to identify the localised catchment contributions across Stawell for the 1% and 10% AEP storm events.

The mitigation options tested in the model are listed below, together with a summary of the outcomes.

- Increased pipe dimensions upstream of the Skeene Street School and along Sloane Street.
  - The increase in pipe size didn't reduce the inundation at the Skeene Street School, indicating that the overland flow inundating the school is not addressed by the current drainage infrastructure.

- Inclusion of a retarding basin on the side of Big Hill, upstream of Fisher Street together with open drains from northwest and southeast leading to the dam. Banks were placed along the downhill side of the drains to improve the area draining to the dam.
  - Including a retarding basin on Big Hill reduces the inundation along the overland flow path through Gladstone Park but has no effect on the inundation at the Skeene Street School.
- Inclusion of a levee directly north of the Skeene Street School.
  - Including a levee directly north of the Skeene Street school reduces the local inundation at the school while increasing the inundation upstream of the levee. Also, there is still flow around the eastern end of the levee reaching the school entrance and extending the levee further east would interfere with an existing parking lot and Patrick Lane.
- Inclusion of a second retarding basin in the reserve between Fisher Street and Gray Street.
  - Including a second retarding basin in the reserve between Fisher Street and Gray Street reduces the inundation along the Gladstone Park overland flow path further. However, inundation at 48 Wimmera Street and below the hospital hill remains unchanged. The second retarding basin reduces flood levels at properties along the flow path by 20 to 210 mm, this is 90 mm greater than the one retarding basin on Big Hill.

In general, a lack of piped drainage infrastructure in the area downstream of Big Hill was identified as an issue. A more appropriate mechanism for preventing inundation at the school could be site specific automatic flood gates.

4.3 Increased dam storage capacity

Seven existing detention basins and dams were lowered and/or expanded. In some instances levees and drains diverting water towards the storage were adjusted to improve capture of overland flow. For Lake Cato, only the bed level was lowered to accommodate more volume. The upgraded dam locations are shown in Figure 4-1.

The results show generally reduced flood levels in the flow paths through the upgraded dams. Flood extents are slightly reduced but not enough to reduce the number of roads overtopped in the 1% AEP scenario. Most significant reductions in depth were observed at Sloane Street, downstream of Maude Street Dam 4, and on Victoria Street downstream of Lake Cato. A reduction in and around the Main Drain was also observed, due to the detention of flows from the intercepted flow paths. The change in flood levels is shown in Figure 4-2.

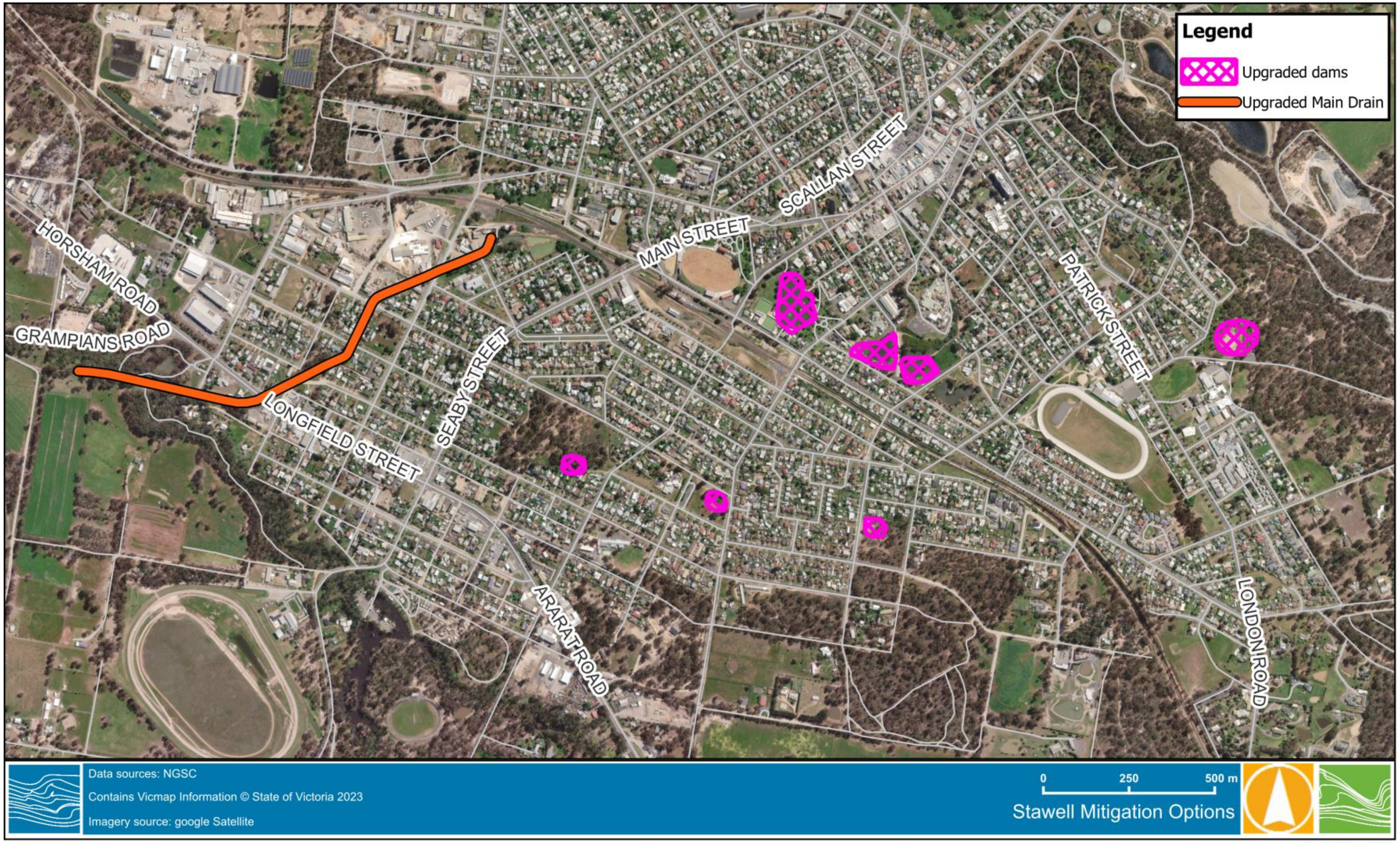

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Figure 4-1 Stawell mitigation options – Upgraded dams and increased Main Drain channel capacity.

Figure 4-2 1% AEP flood level difference – Storage upgrade

4.4 Increased Main Drain channel capacity

The bed level of the Stawell Main Drain was lowered 500 mm across its entire width from the Curtis Street dams to the confluence with Pleasant Creek. The location of channel capacity increase is shown in Figure 4-1.

The results show reduced flood levels in the lowered drain, as well as in the industrial and residential area bound by the Main Drain to the east and Smith Street to the north. The flood level differences are shown in Figure 4-3.

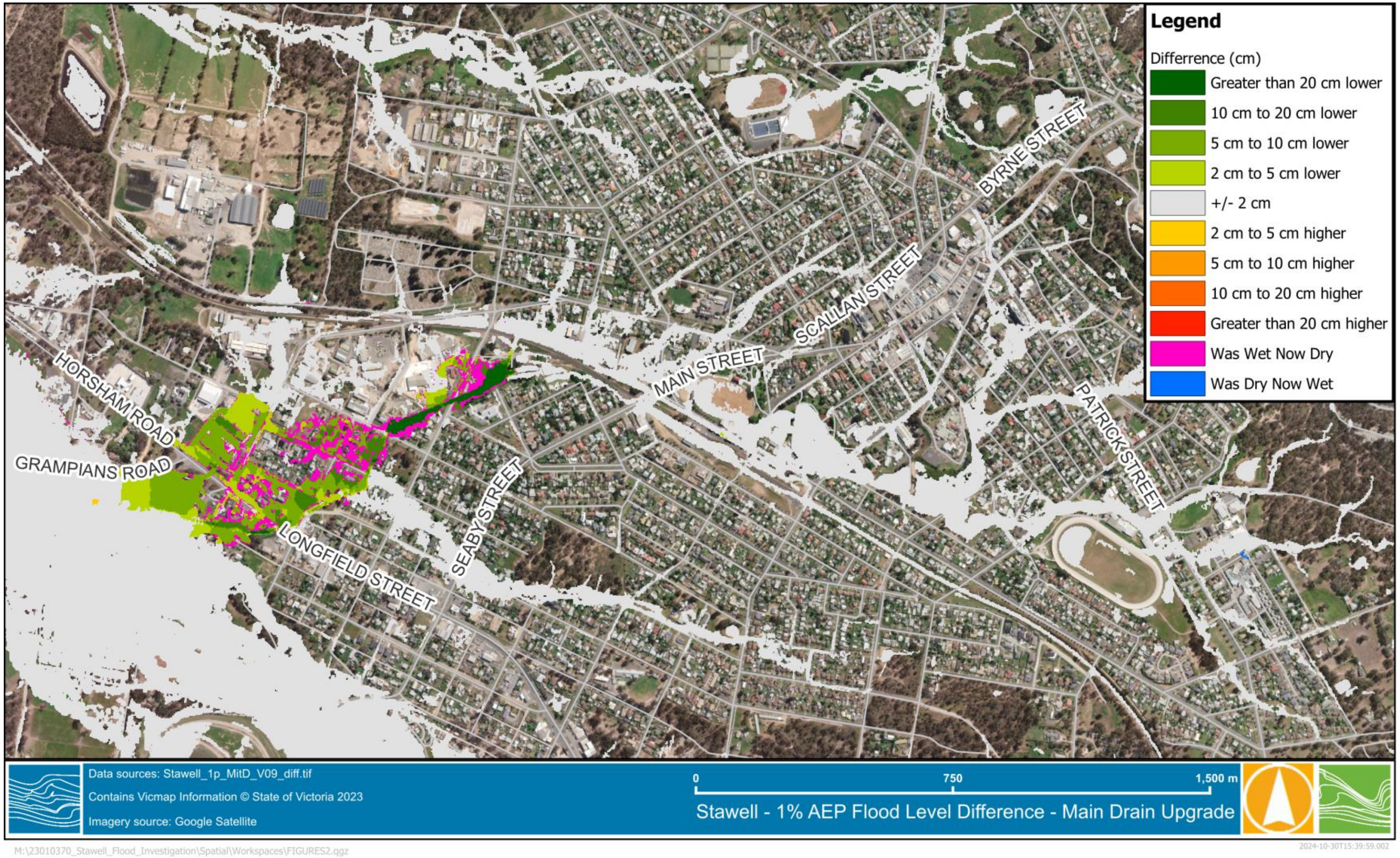

Figure 4-3 1% AEP flood level difference – Main Drain upgrade

4.5 Increased culvert capacity

A number of culverts with insufficient capacity were identified. Culvert capacity was doubled, and in locations where no culvert was present, a culvert was added with dimensions based on similar crossing sizes. The locations included:

- Black Range Road bridges (two) crossing Pleasant Creek
- Holloway Road crosses unnamed waterway - two locations
- Under Ararat Road at 37 Ararat Road
- Wadsworth Road crossing Pleasant Creek
- Monaghan Road crossing Pleasant Creek
- Panrock Reservoir Road crossing Pleasant Creek
- Sutherland Street crossing un-named waterway
- Newington Road crossing overland flow path near Winifred Road
- Clifton Street crossing overland flow just south of Durack Street
- Dane Road crossing Jerrywell Creek
- Darlington Mine Road crossing unnamed waterway
- Fieldings Road crossing Jerrywell creek near Dunns Road

Culvert locations are shown in Figure 4-4 and Figure 4-5 for the Pleasant Creek and Stawell/golf course catchments respectively.

Capacity increases showed very limited positive flood level impacts, with localised increases and decreases in flood levels immediately upstream and downstream the culvert locations. Only one additional road crossing is flood free in the 1% AEP scenario; increasing the culvert capacity under Ararat Road, at 37 Ararat Road, showing the road is no longer overtopping in a 1% AEP event. The change in flood levels is shown in Figure 4-6 and Figure 4-7 for the Pleasant Creek and Stawell/golf course catchments respectively.

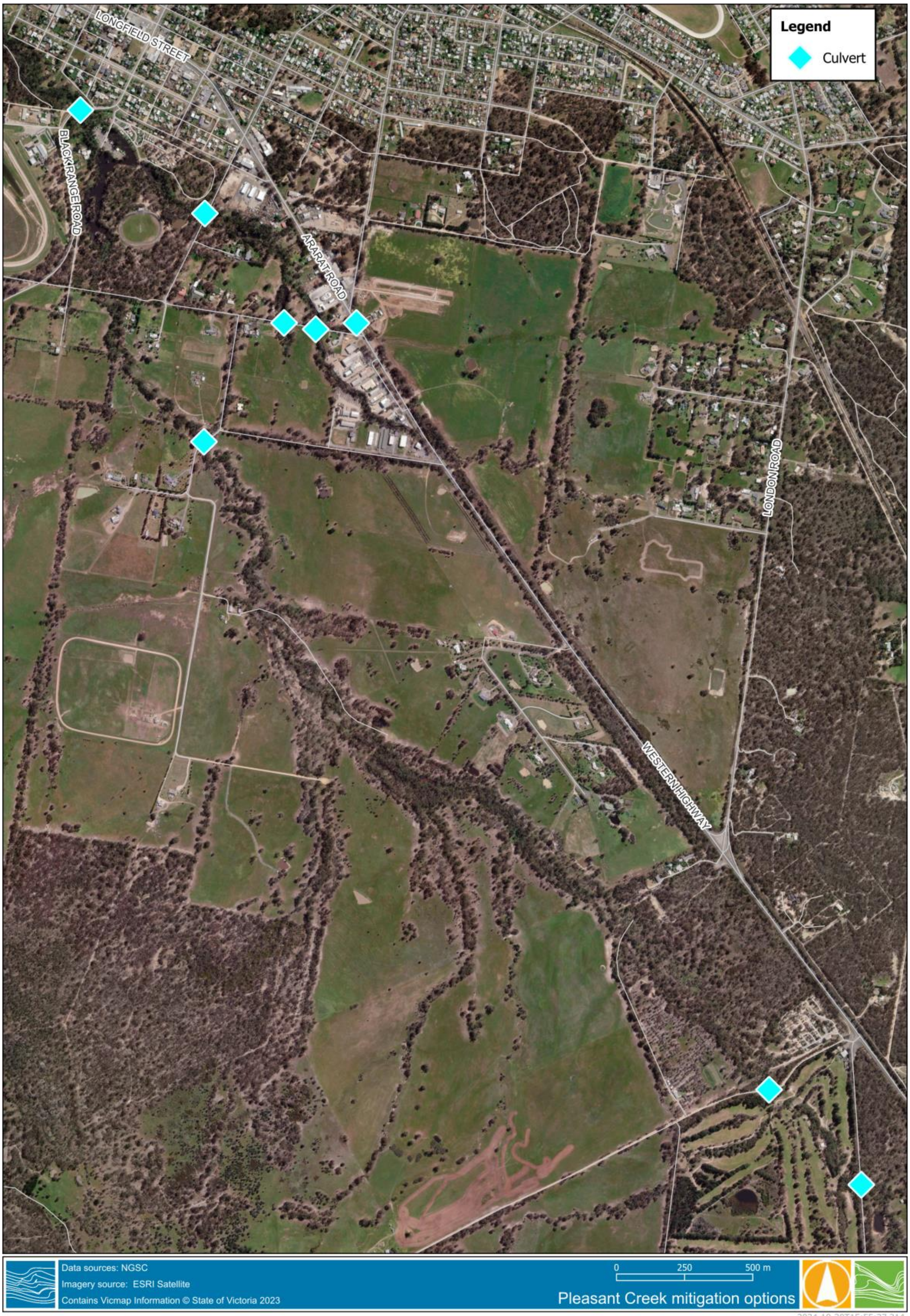

Figure 4-4 Pleasant Creek catchment culvert upgrades

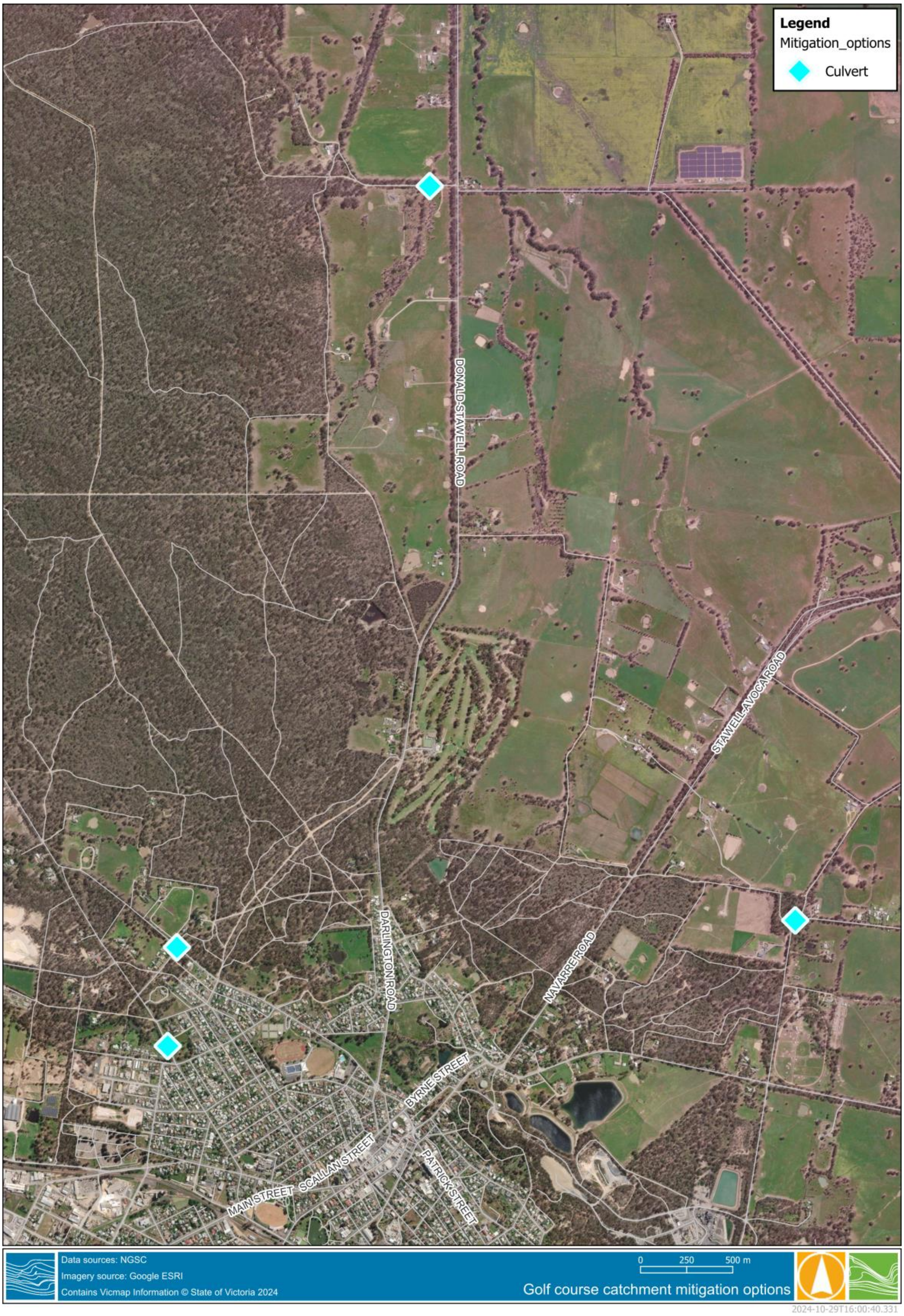

Figure 4-5 Stawell and Stawell Golf Course catchment culvert upgrades

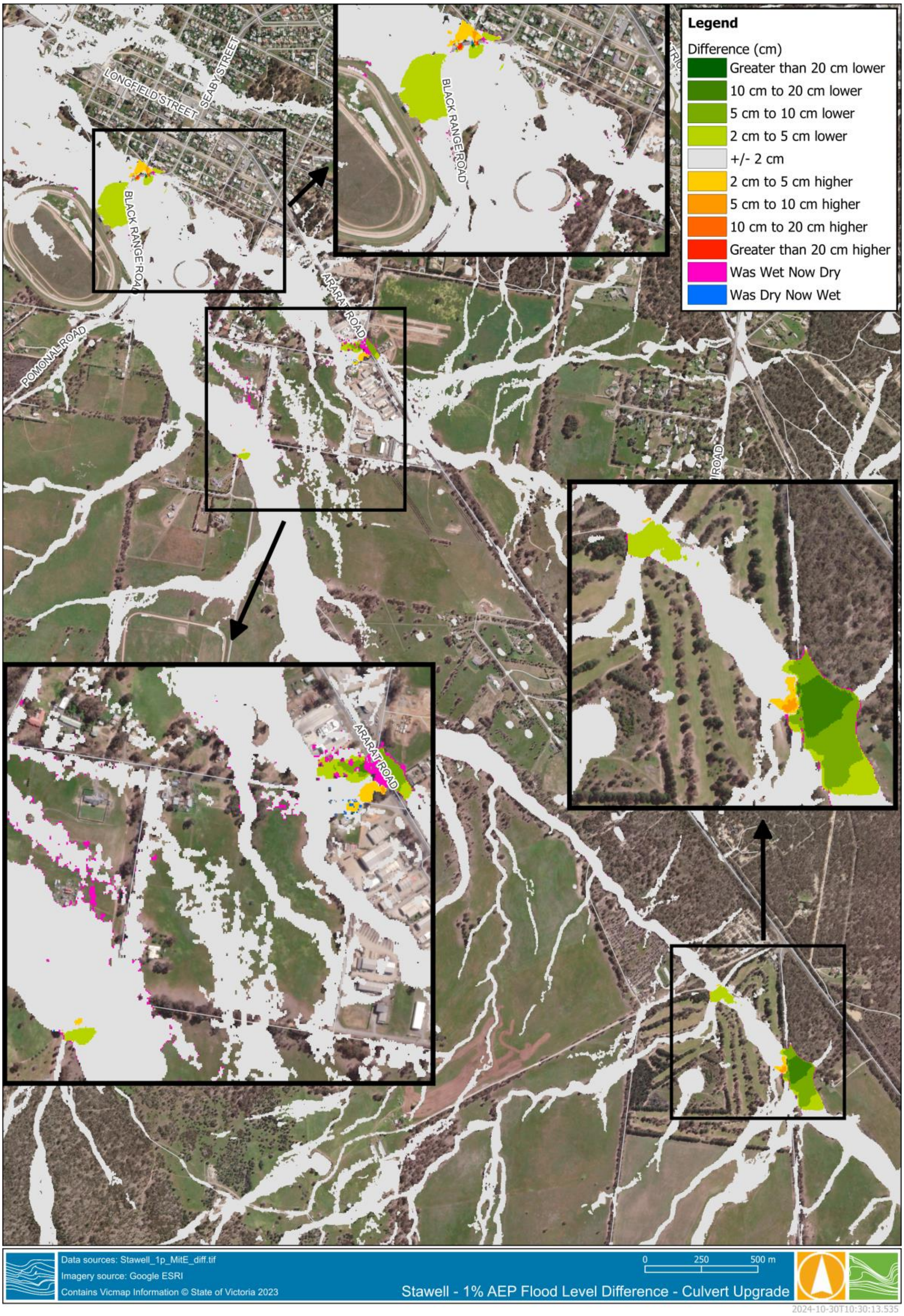

Figure 4-6 1% AEP flood level difference – Culvert upgrade – Pleasant Creek

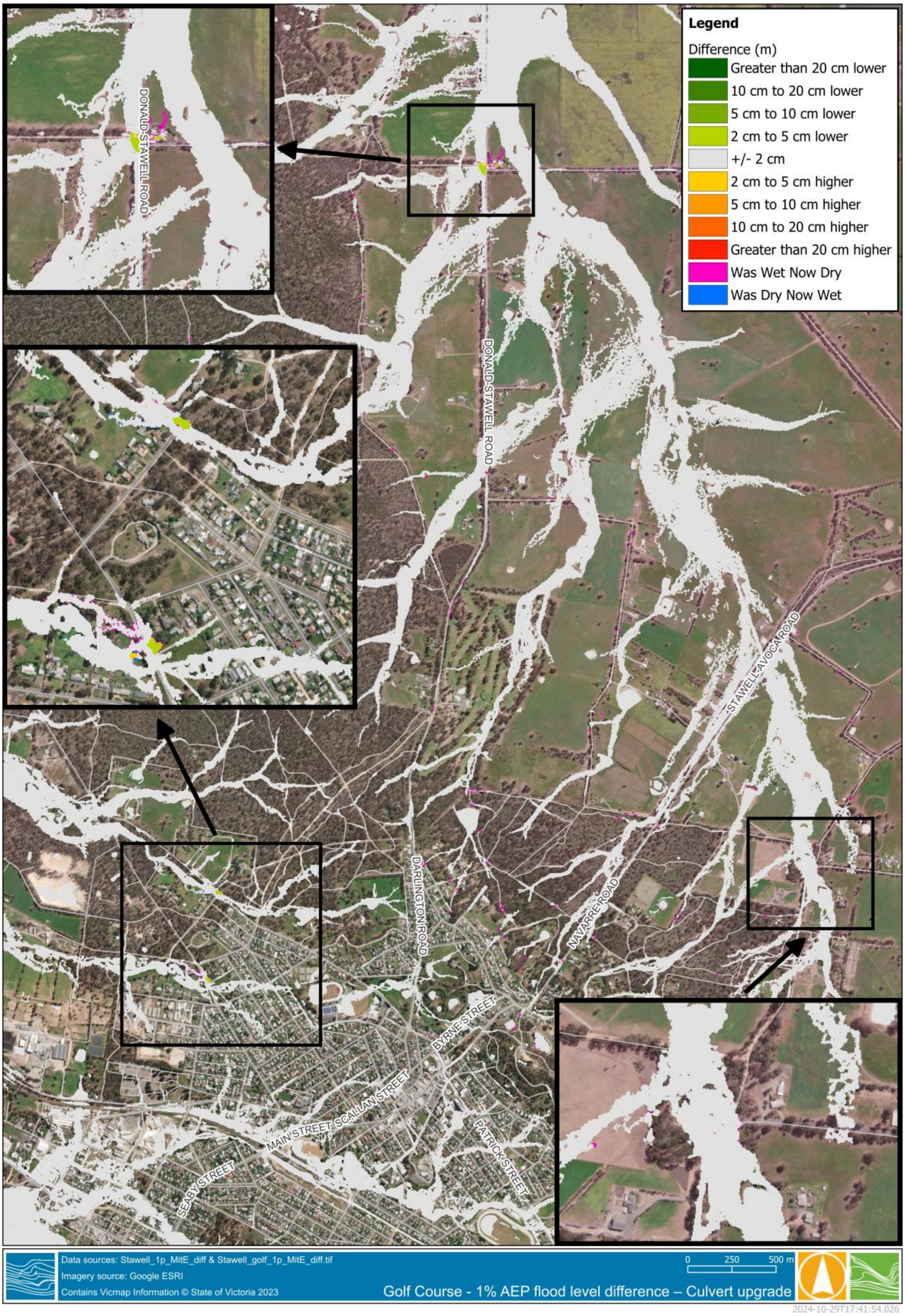

Figure 4-7 1% AEP flood level difference – Culvert upgrade – Stawell and Stawell Golf Course catchment

4.6 Cost-benefit analysis

Based on the initial feasibility screening and discussions with NGSC, it was determined to assess a combination of the increased dam storages and the increased Main Drain capacity for the full range of design events. The 1% AEP water level difference map for this scenario is presented in Figure 4-8. The model results for this mitigation option were then processed to determine the AAD to enable a comparison with existing conditions. Finally, a cost-benefit assessment was undertaken for the mitigation option.

The model results were processed to assess the new AAD for Stawell under the mitigated scenario. The resultant AAD was $569,591 per year, providing an annual reduction of $103,363. The reduction in AAD is a result of fewer properties being inundated above floor in the 10% and rarer AEP events, in total 12 less in the 1% AEP event. There is also a reduction in properties flooded below floor in most of the analysed events, and a significant reduction in costs associated with infrastructure damage for all events.

A high-level cost estimate for the final mitigation option was developed based on Water Technology's experience of works on waterways and developments with supplementation from Rawlinson's Construction Cost Guide 2024. A 30% contingency was included in the total cost estimates for each option to account for administration, project management and unforeseen contingencies, see Table 4-1.

Costs associated with the channel and dam construction are predominantly driven by the cut volume driving the machinery and labour required for construction.

Table 4-1 Mitigation scenario cost estimate

Item	Quantity	Units	$/Unit	Subtotal ($)
Volume of cut to fill (dams to bunds)	3,010	m^3	$22.40	$67,424
Volume of cut to remove offsite (dams)	35,469	m^3	$26.40	$936,382
Transport material offsite (dams)	35,469	m^3	$7	$248,283
Volume of cut to remove offsite (drain)	3,451	m^3	$26.40	$91,106
Transport material offsite (drain)	3,451	m^3	$7	$24,157
Removal of existing brick lining	1,400	m	$200	$280,000
Replacing of existing brick lining	1,400	m	$50	$70,000
Bridge concrete works	4	Per bridge	$40,000	$160,000
Total construction works				$1,877,352
Design and labour	20%			$375,470
Contingency	30% (of total including design and labour)			$675,847
Total				**$2,928,669**

The cost/benefit was assessed in terms of the net present value of the option. A 30-year project timeline was adopted with a discount rate of 6%.

The net present value was assessed according to the below equation:

$$NPV = \sum_{n=1}^{30} \frac{R - M}{(1+i)^n} - C$$

Where:

NPV = Net present value

R = Reduction in AAD ($)

M= Annual Maintenance Cost ($)

i= Discount/Interest Date

C= Capital Cost ($)

n= Year (from 1 to 30)

The resultant net present value for the combined option was -$1,505,594, meaning the project will cost more than it will save, on average, over the 30-year period.

The option has a significant cost associated with it and does not reduce flood damages sufficiently to offset this cost, leaving the project over one and a half a million dollars in deficit after the 30 year period. Further analysis indicates that with the saving of $103,363 in AAD, the total project cost would need to be reduced to $1.4M to achieve an even cost/benefit ratio, i.e. NPV = 0.

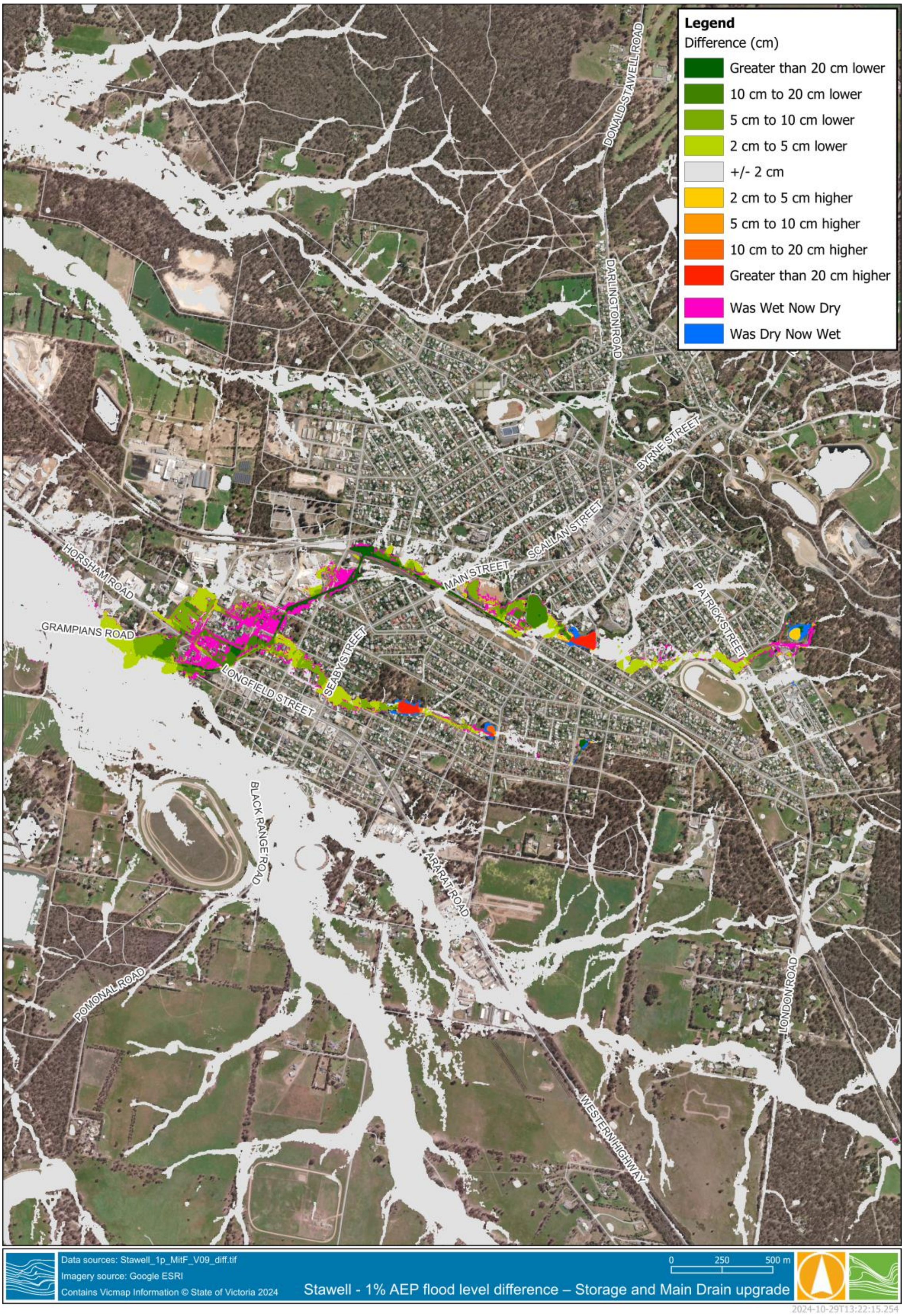

Figure 4-8 1% AEP flood level difference – Storage and Main Drain upgrade

5 NON-STRUCTURAL MITIGATION

5.1 Land use and planning control

The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 6.2(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Environment, Land, Water and Planning's (DELWP) Planning Practice Note 12[3] on Applying the Flood Provisions in Planning Schemes, and The Victorian Floodplain Management Strategy (DELWP, 2016). The objectives of the state planning policy framework[4] for floodplain management is to assist in the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood-carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river health.

Planning Schemes can be viewed online at https://www.planning.vic.gov.au. It is recommended that the planning scheme for this project's study area is amended to reflect the flood risk identified by this project

Currently there is only LSIO and FO developed for Stawell along Pleasant Creek based on the Mt William Creek Flood Investigation (2014) and along Jerrywell Creek based on the Concongella Creek Regional Flood Mapping project (2014). There is no SBO for the study area. Planning overlays will be developed as direct outcomes from this study. Updating the planning scheme mapping allows development applications within the floodplain to be assessed in line with current national, state, regional and local policies. The ultimate effect of this will be to discourage inappropriate development within the floodplain, reducing the number of future buildings and occupants exposed to flood risk.

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[3] DELWP Planning Practice Notes, accessed from https://www.planning.vic.gov.au/resource-library/planning-practice-notes
[4] Victorian Floodplain Management Strategy (2016), accessed from https://www.water.vic.gov.au/__data/assets/pdf_file/0017/53711/Victorian-Floodplain-Management-Strategy-Introduction-Section-1.pdf

6 SUMMARY

Flood damages, in the form of Average Annual Damages (AAD), were assessed for Stawell based on flood modelling undertaken as part of the Stawell Flood Investigation. The average annual cost in Stawell as a result of flooding from Pleasant Creek and direct catchment inundation equates to $672,954 per year. In the 1% AEP flood event, 35 dwellings and 39 commercial properties are inundated above floor and a further 1,206 properties are impacted by floodwaters.

Several mitigation options were tested in the Stawell hydraulic model, focusing on reducing damage and hazard associated with the overland flow impacting residential/commercial lots and road. Impacts of each mitigation option were demonstrated, with increased storage capacity across the catchment combined with increased flow capacity in the Stawell Main Drain deemed as the most feasible option based on initial modelling.

An updated AAD was calculated for this mitigation option. A construction cost estimate was assessed against the option's reduction in AAD from the existing case to inform net present value analysis. The assessed mitigation option was shown to be financially unviable. More detailed investigation could be undertaken to assess components of the mitigation option individually to target flood mitigation works.

The analysis documented in this report has also recommended development and update of planning controls such as the Special Building Overlay (SBO), Land Subject to Inundation Overlay (LSIO) and Flood Overlay (FO) based on criteria relevant to the Northern Grampians Shire Council. These layers would provide a suitable foundation to support development of flood related planning controls.

APPENDIX A
ROAD INUNDATION MAPPING

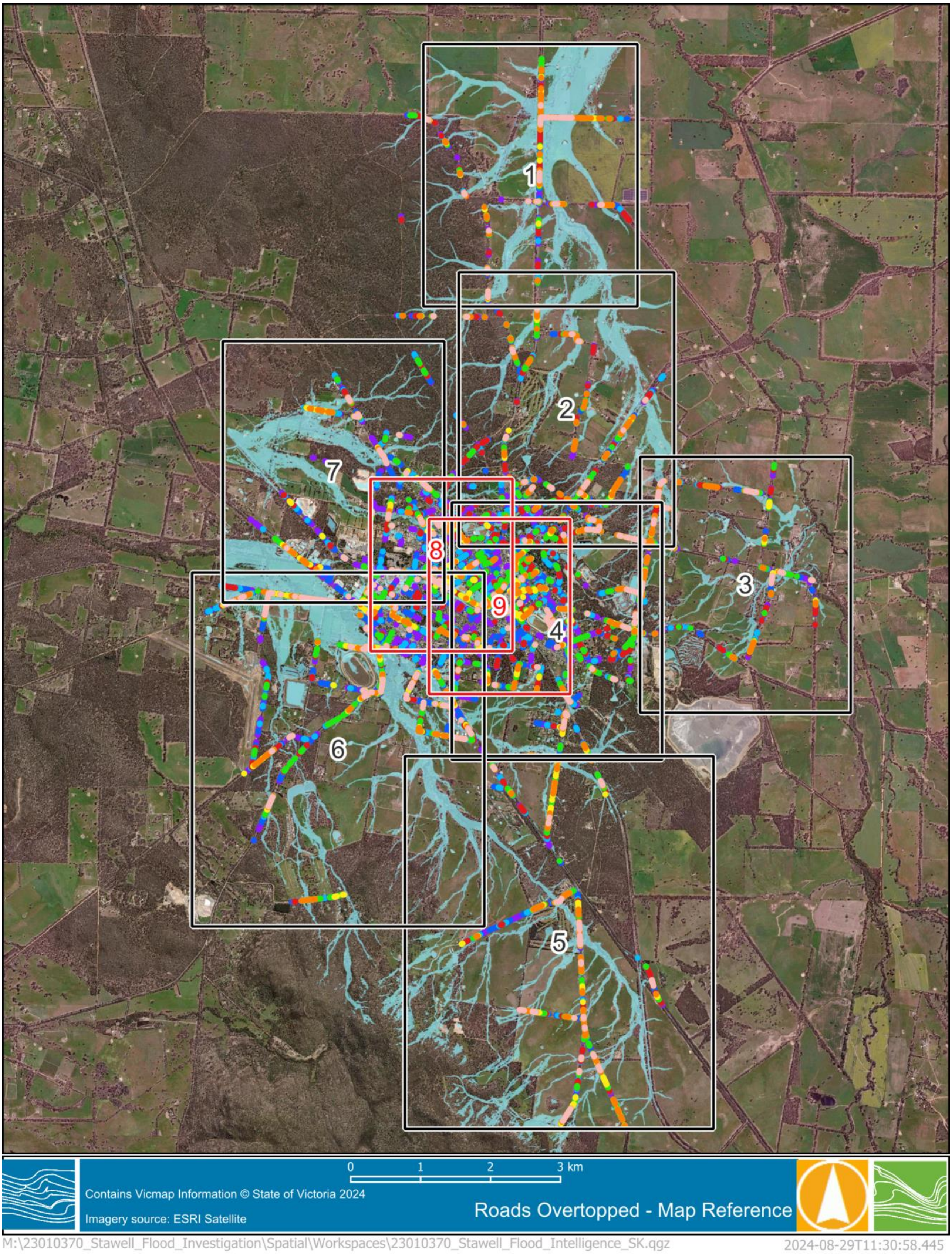

Figure 6-1 Roads overtopped reference map

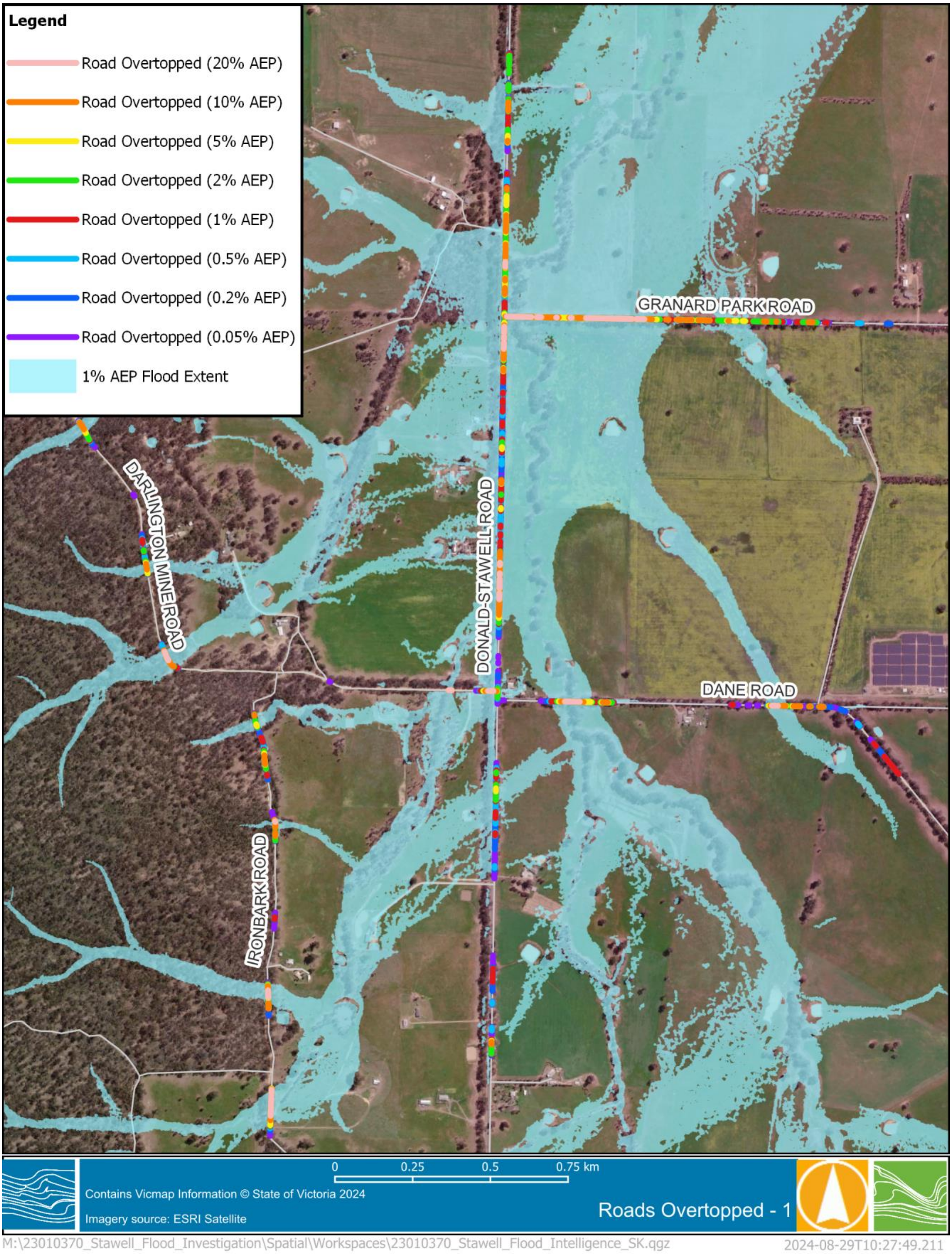

Figure 6-2 Roads overtopped - 1

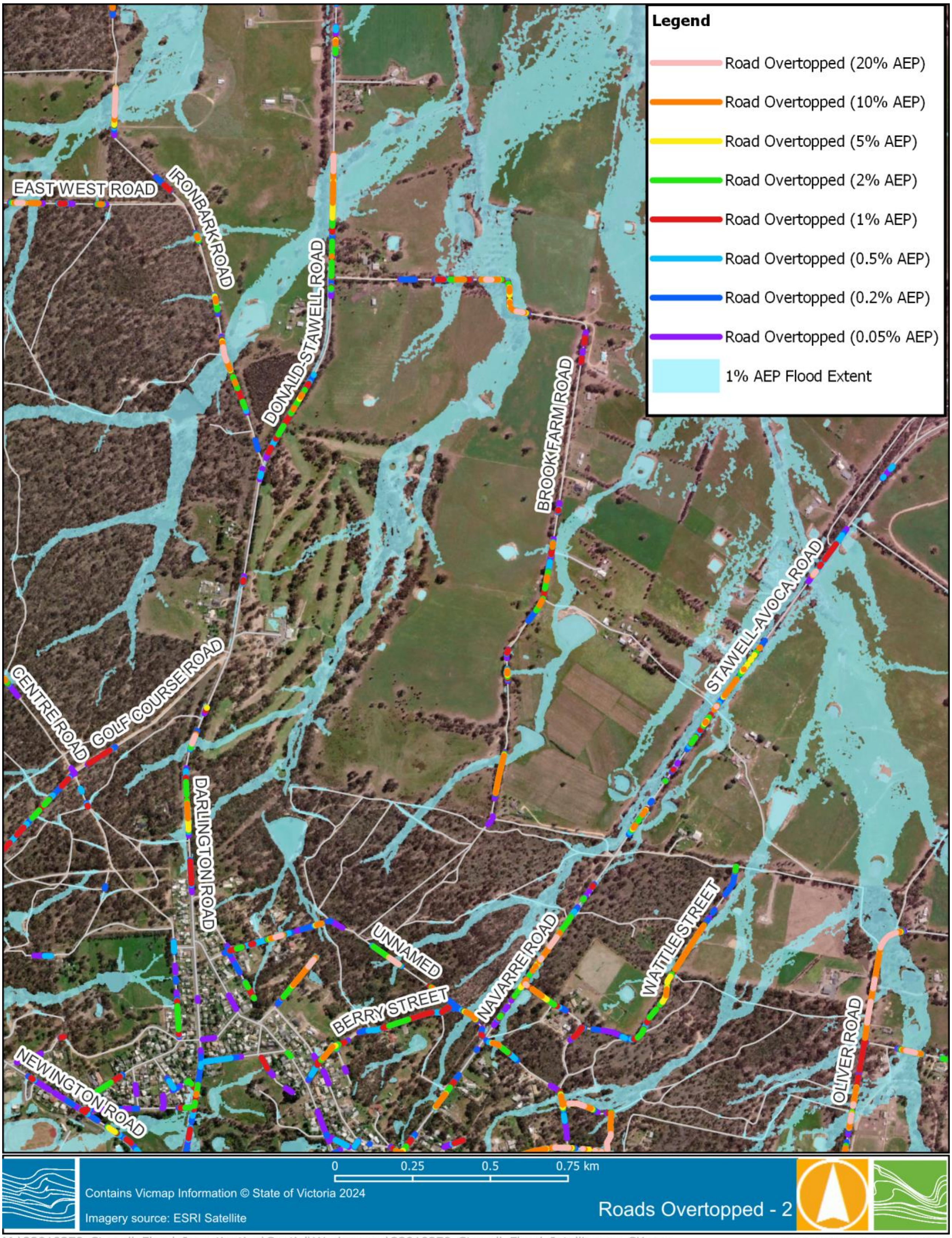

Figure 6-3 Roads overtopped - 2

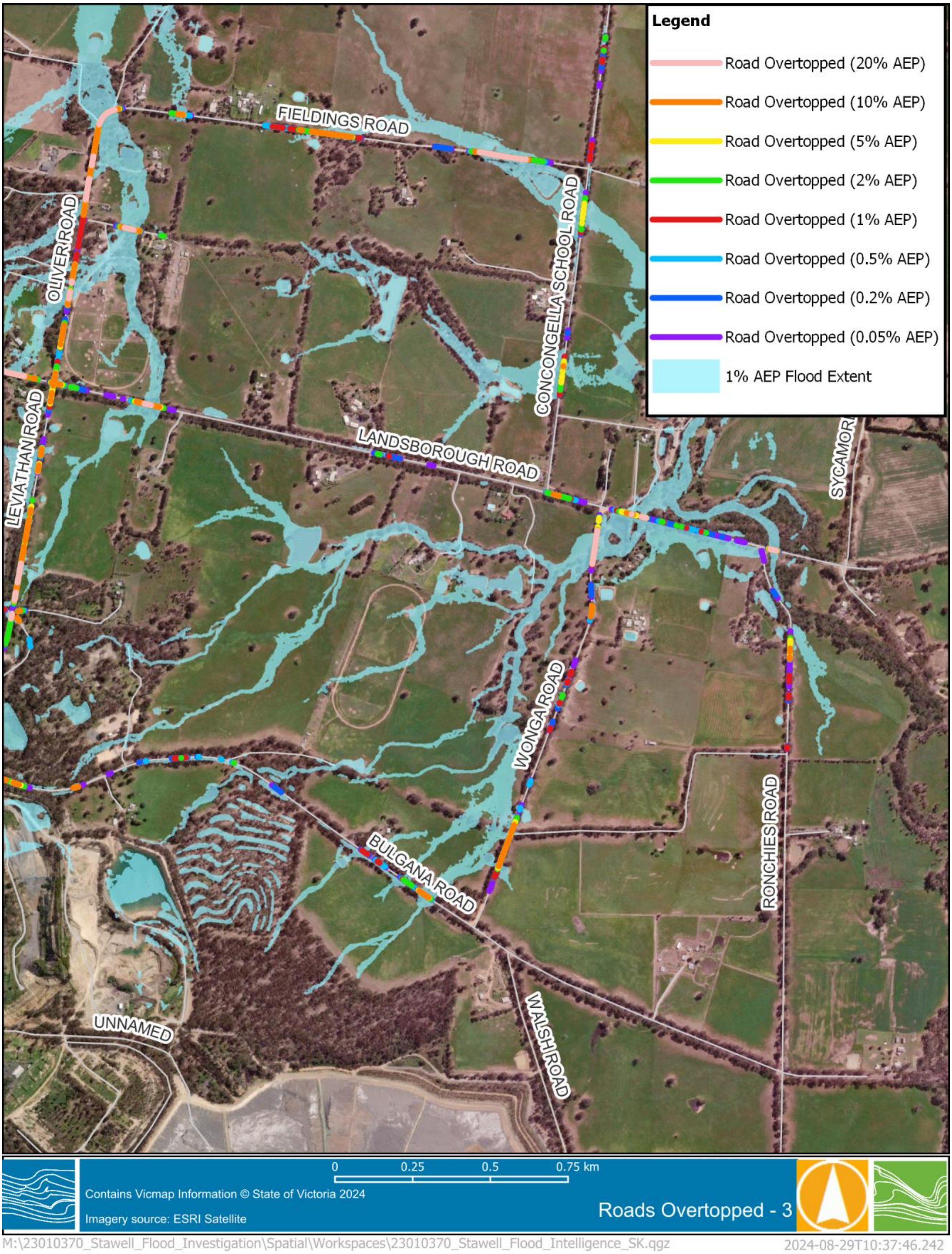

Figure 6-4 Roads overtopped - 3

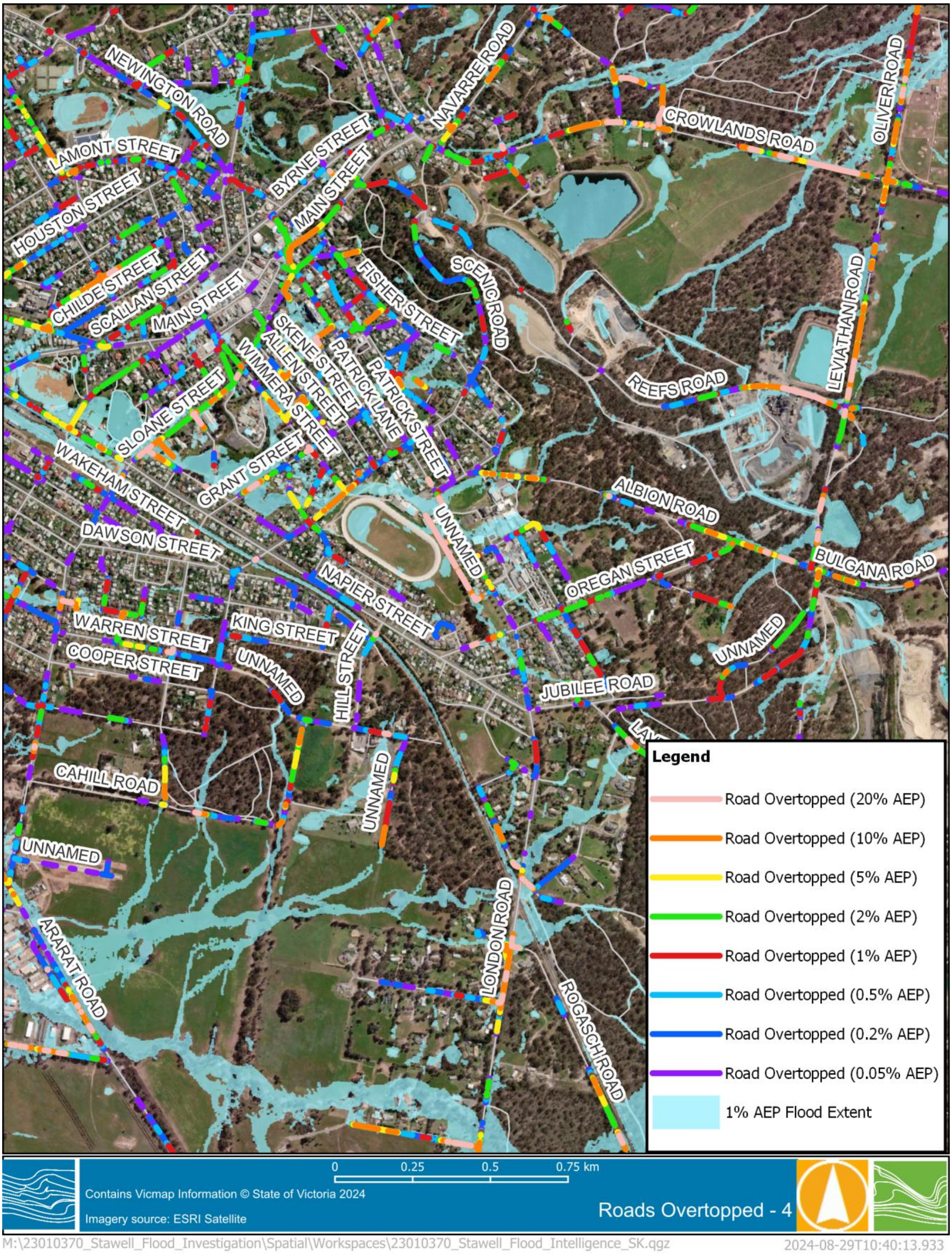

Figure 6-5 Roads overtopped - 4

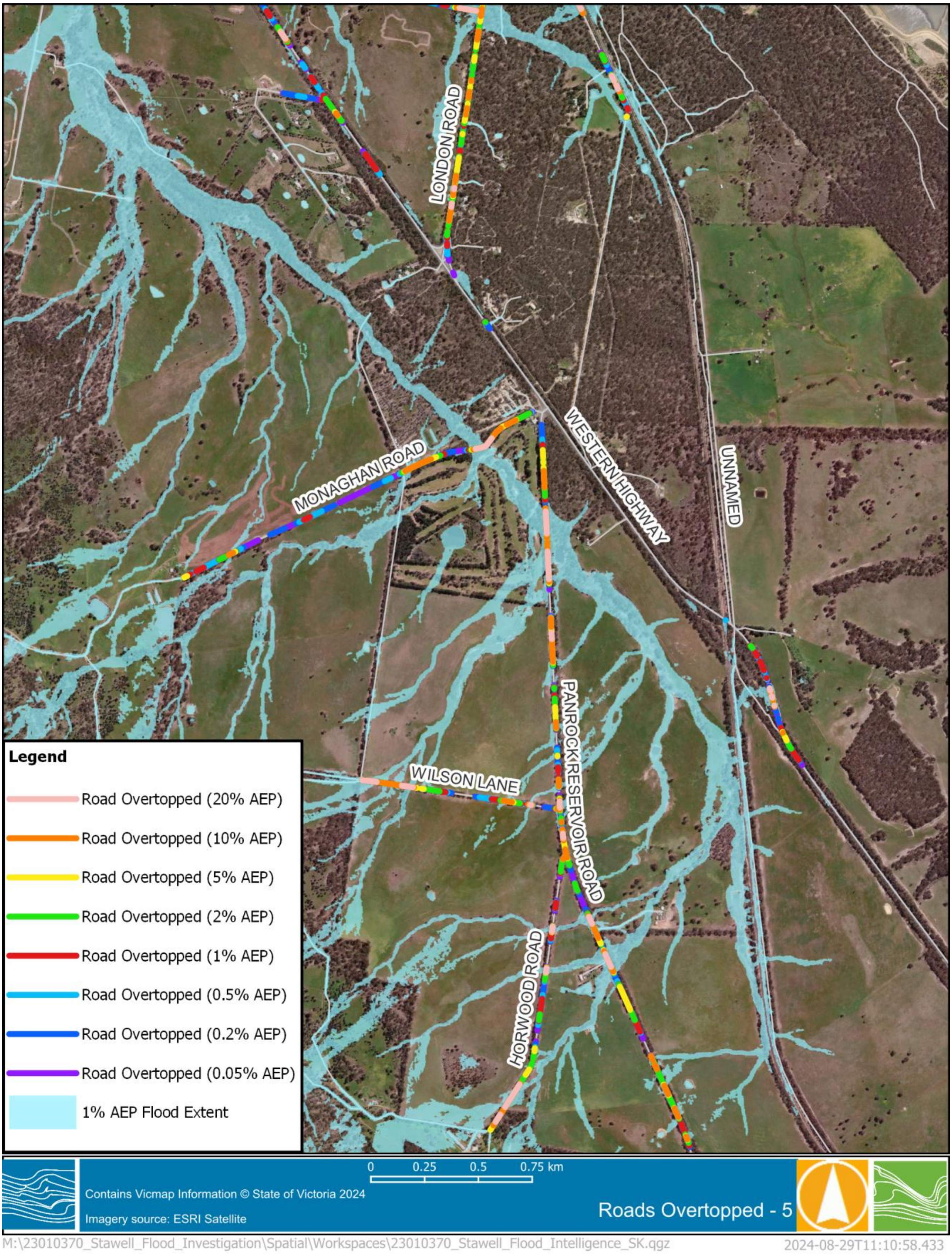

Figure 6-6 Roads overtopped - 5

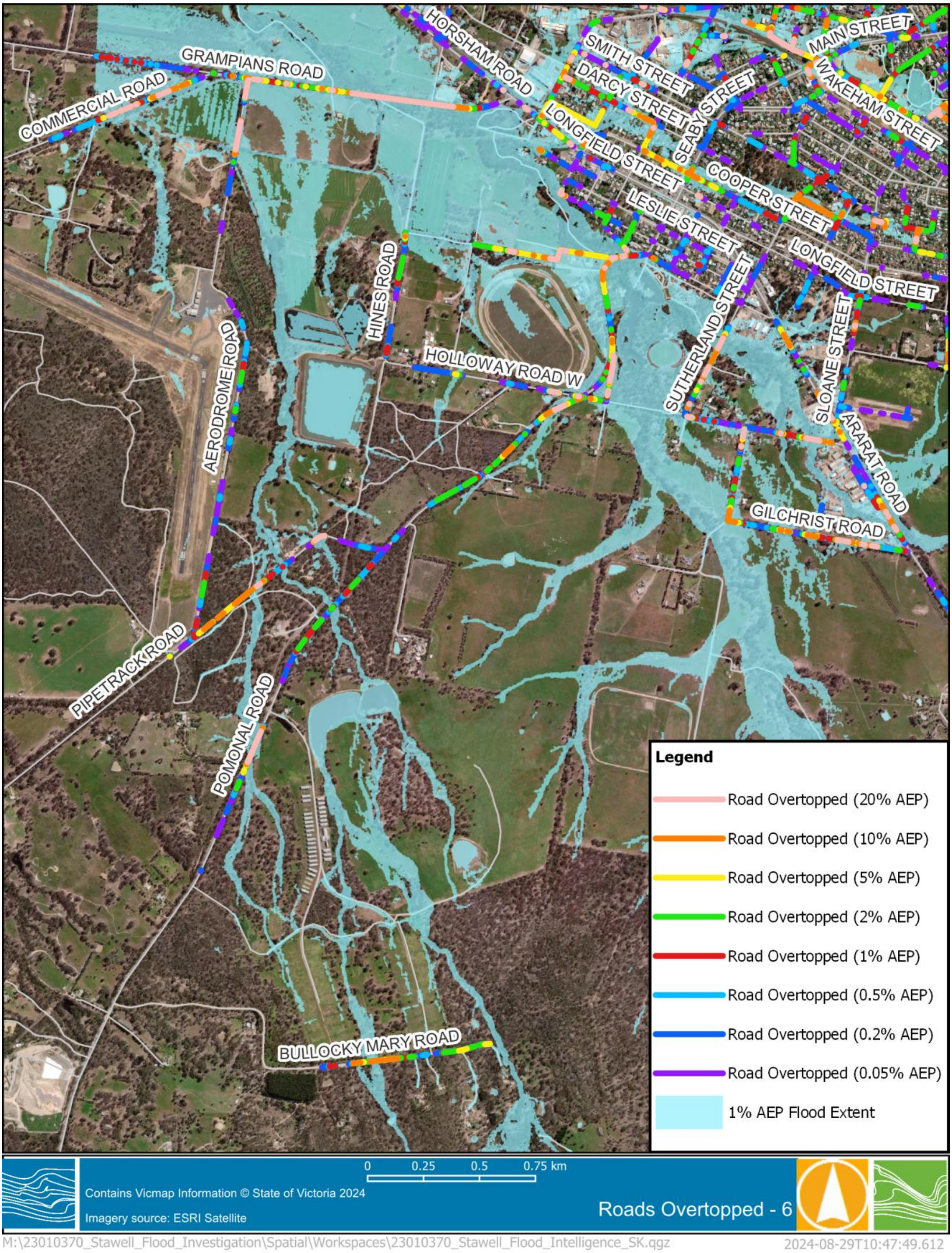

Figure 6-7 Roads overtopped - 6

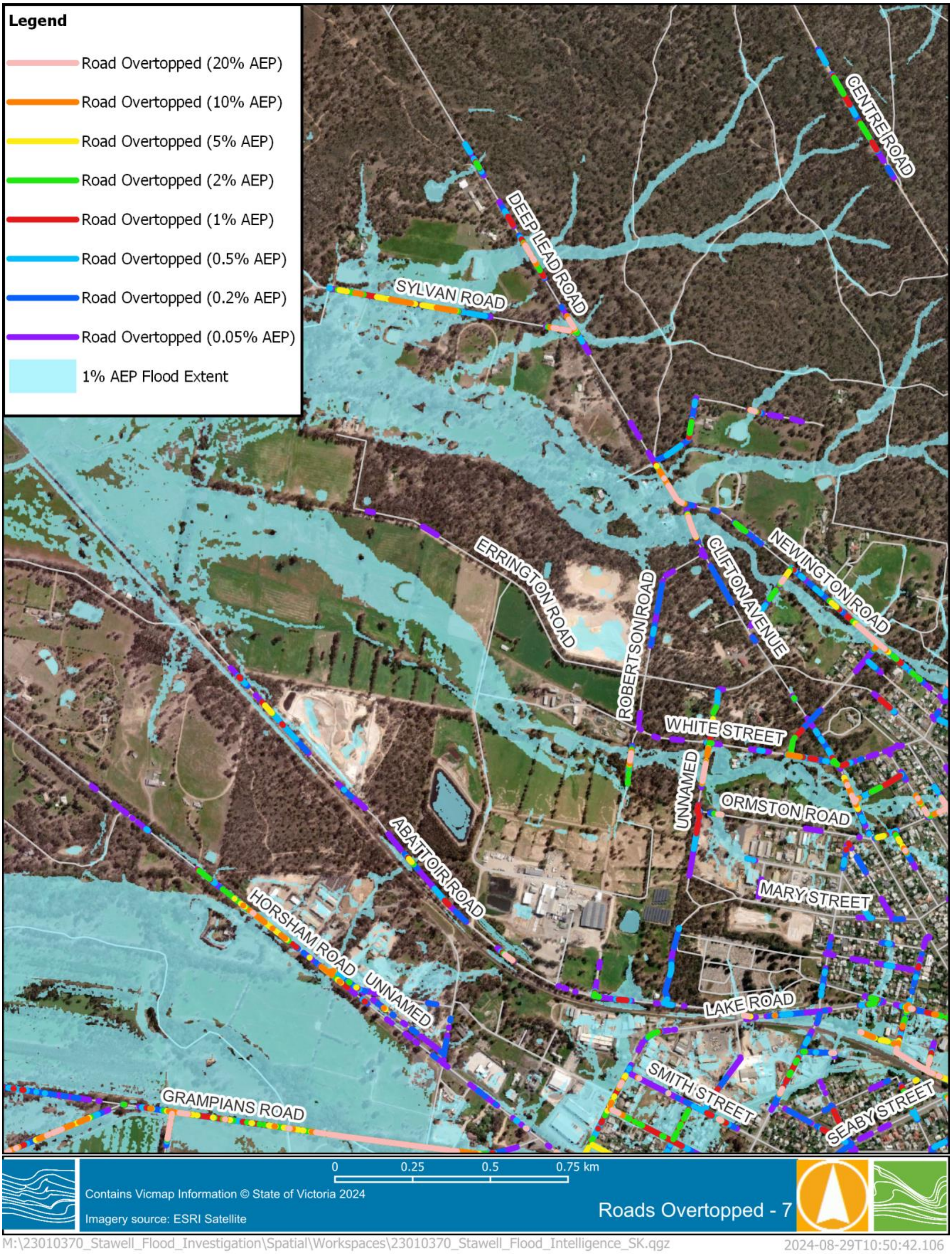

Figure 6-8 Roads overtopped - 7

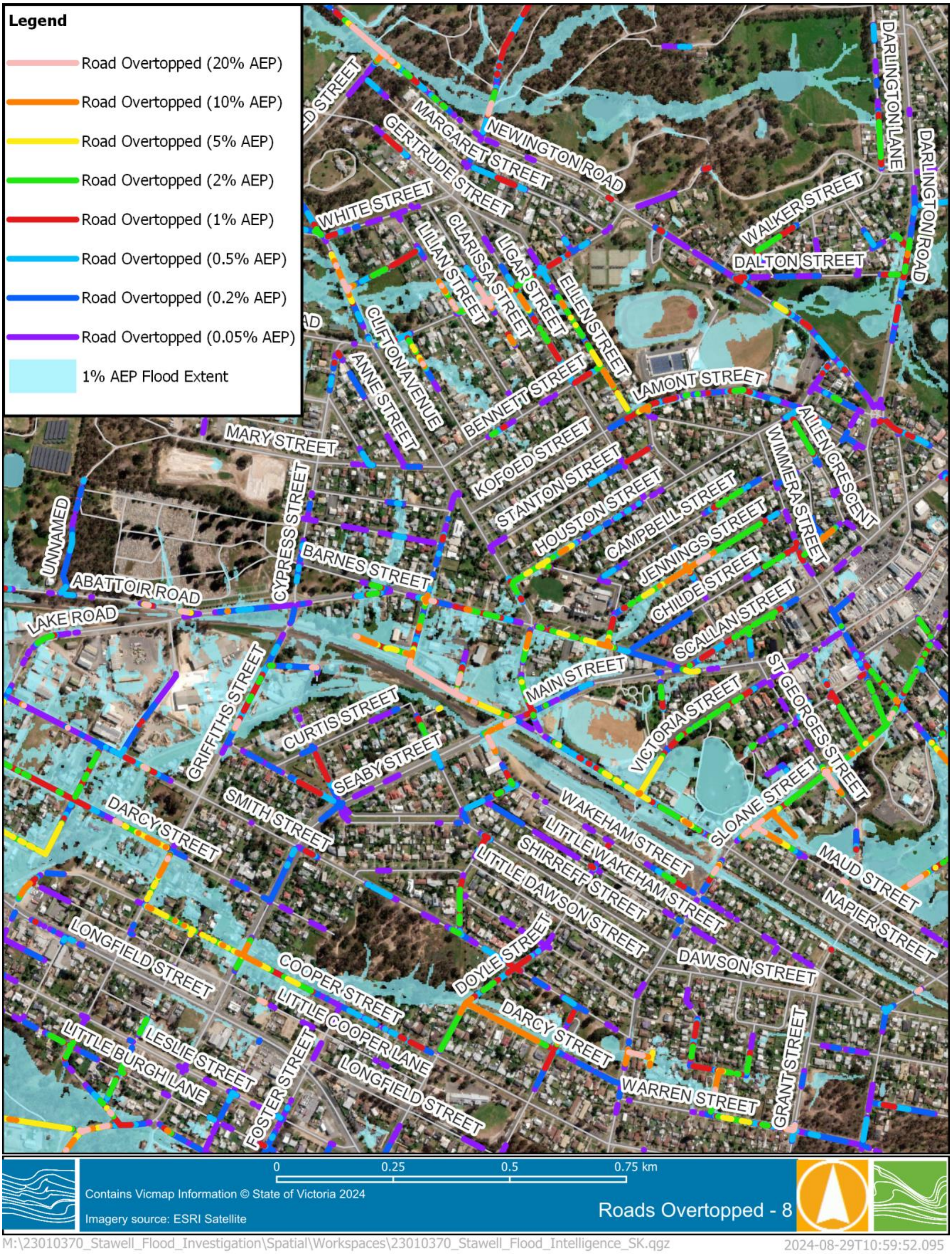

Figure 6-9 Roads overtopped - 8

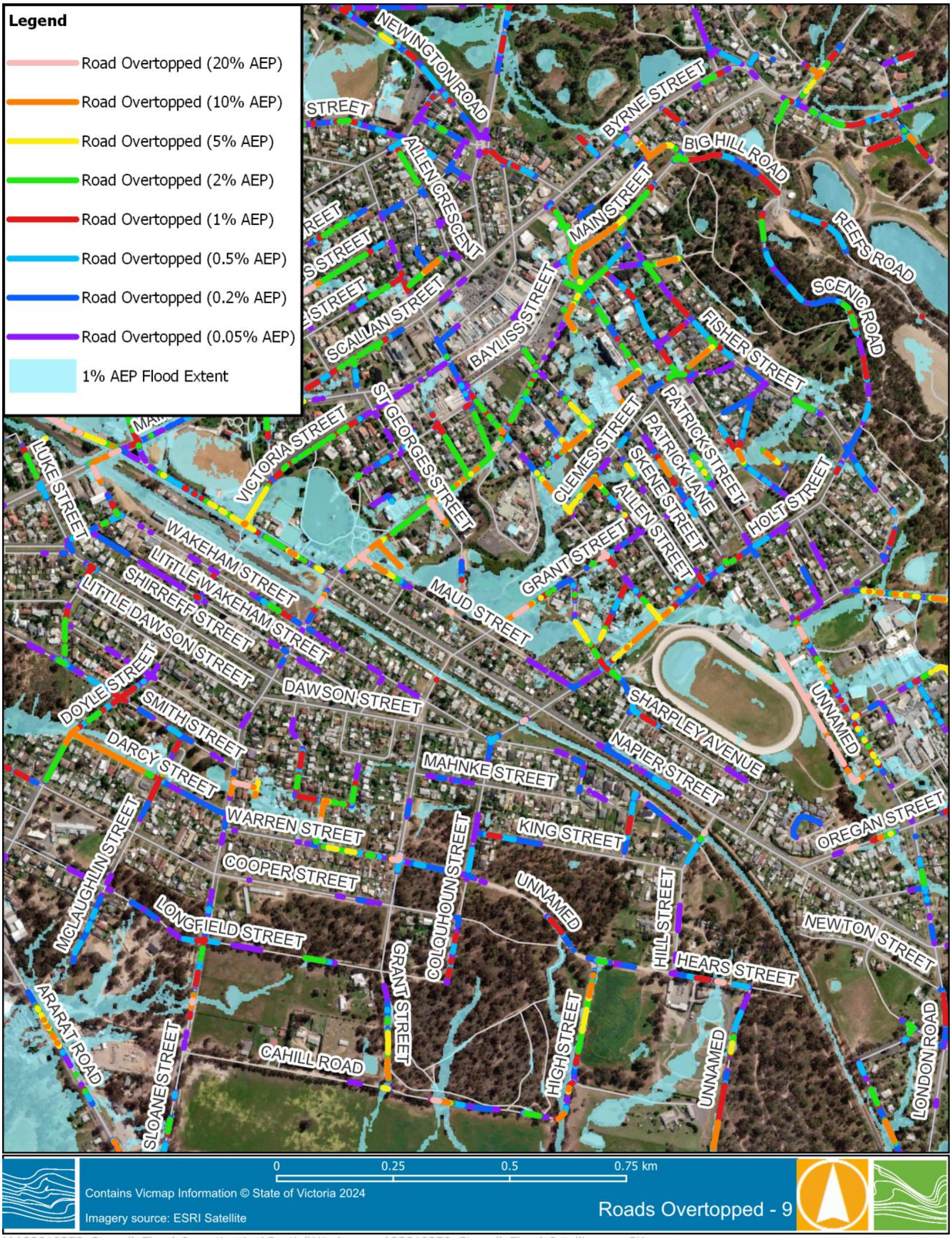

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Figure 6-10 Roads overtopped – 9