Design Modelling 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*

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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 design modelling report for the Stawell Flood Investigation. This report forms documentation of the completed flood modelling for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and 0.05% AEP and PMF design events. Model sensitivity testing and consideration of climate change impacts associated with changed rainfall conditions has also been undertaken. Developed conditions including changes in land use as per the Stawell Structure Plan has been investigated. The results presented in this report form the basis for the flood mitigation, flood warning and flood intelligence outputs. Outputs from the modelling are attached with this report, detailing all modelled design events, parameter adoption and sensitivity testing.

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 covers 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 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 covered a minor part of southeastern Stawell.

In 2021/2022 Water Technology undertook a hydraulic assessment of flooding in Stawell caused by local runoff from Big Hill and its surrounding catchment, 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. This study 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 will produce 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, investigate structural and non-structural mitigation options, and investigate 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 and Validation Report – Draft completed 31 October 2023, final version issued 2 December 2024
  - This report detailed 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 documented the development of the hydraulic models and calibration and validation of the Stawell hydraulic model using the 2011 flood events.
- **R03 – Design Modelling Report – This report**
  - 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
- R05 – Flood Damages and Mitigation Report
- R06 – Final Summary Report

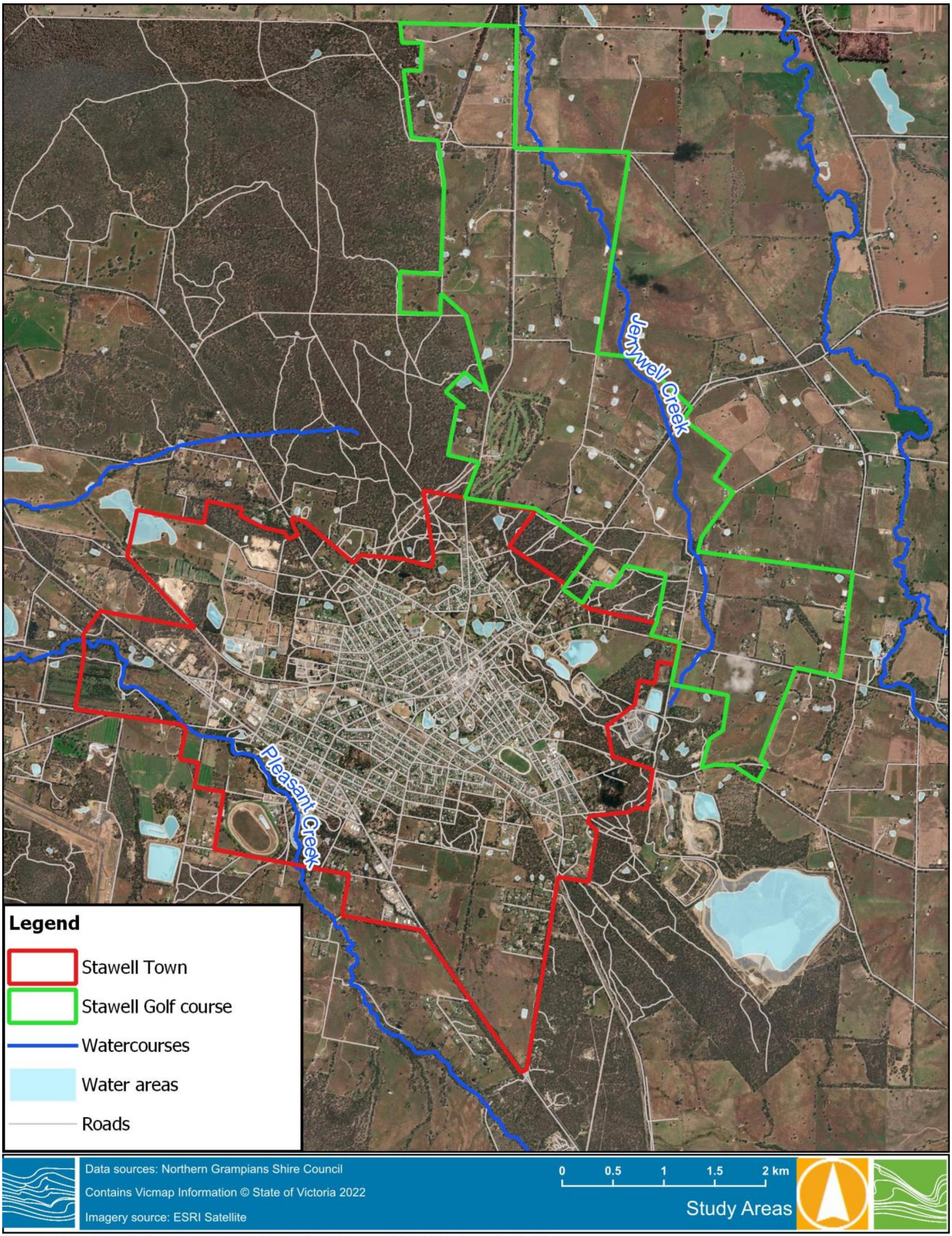
1.2 Study Area

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 or near the town, instead flood risk is driven by local stormwater runoff from elevated areas 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 north, parallel to the Western Highway before passing through the southern part of Stawell and 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.

Inundation risk in Stawell can be separated into two distinct types; short duration stormwater flooding and longer duration riverine flooding from Pleasant Creek, to the southwest of town. 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.



Data sources: Northern Grampians Shire Council
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Imagery source: ESRI Satellite

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Figure 1-1 Stawell study areas

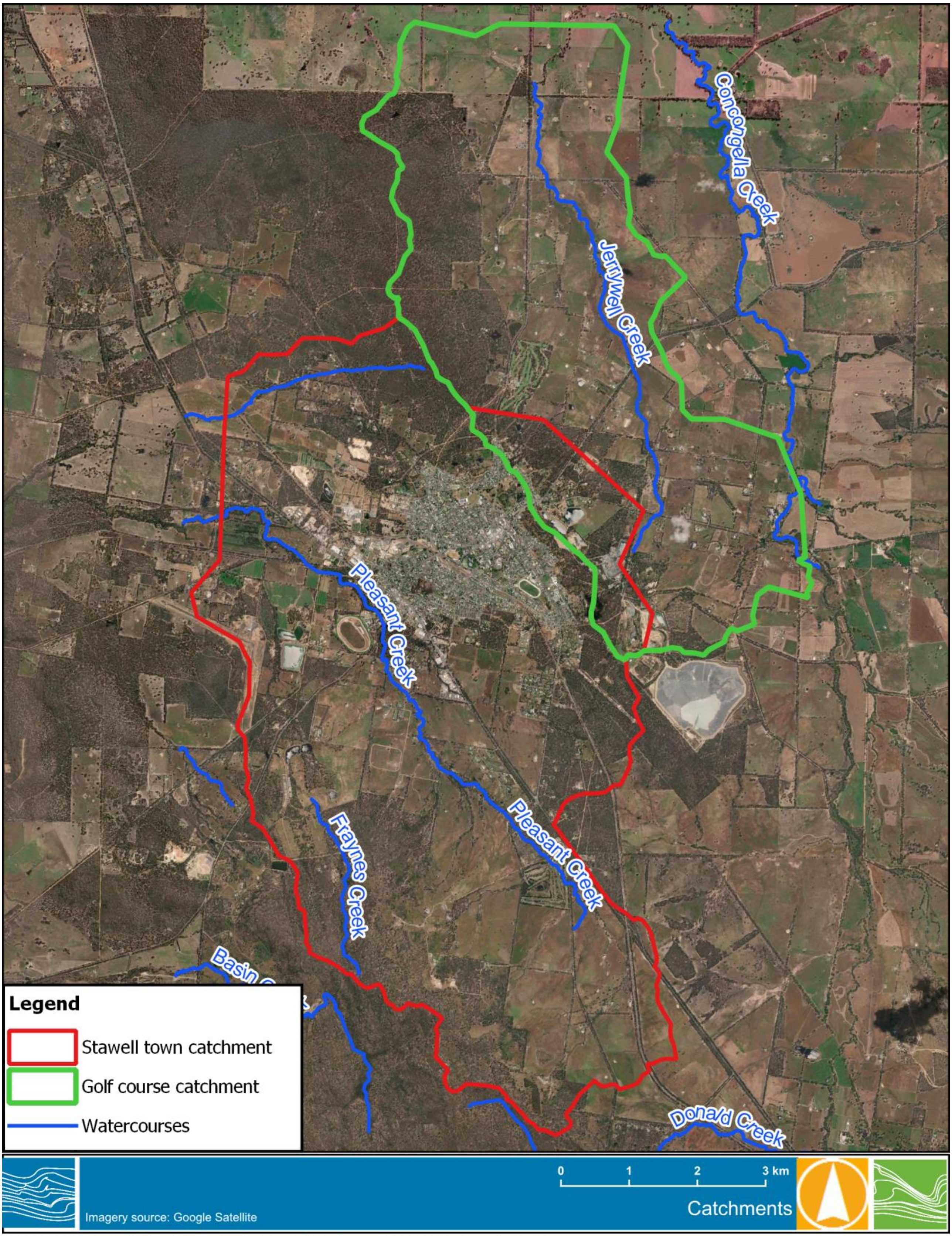

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Figure 1-2 **Stawell catchments**

2 HYDRAULIC DESIGN MODELLING

2.1 Overview

The Stawell Flood Investigation has adopted a direct rain on grid (RoG) hydraulic modelling approach utilising 1D/2D TUFLOW software. Two hydraulic models were developed, covering the Pleasant Creek catchment including the Stawell township and the golf course catchment respectively, as depicted in Figure 1-2. The hydraulic model developed during the Big Hill assessment[1] was used as a basis for the current Stawell model. It was expanded and upgraded with the data collected during the data review phase of the project.

The models were built using the TUFLOW HPC hydraulic modelling software. A gridded model was developed per catchment with a direct rainfall boundary applied to represent calibration and design rainfall events. The underground pit and pipe network within the town was incorporated as 1D structures, with the model topography developed and modelled in 2D.

Land use roughness and rainfall loss parameters were adjusted to validate the flood model against community observations during the model calibration. The calibration was completed for the Stawell catchment, with the calibrated parameters adopted for the golf course catchment based on the proximity and similar characteristics of the upper catchments.

For the design modelling, an ensemble approach was adopted to determine the design peak flows and the corresponding critical duration and temporal pattern producing the median peak flow at model key locations, as outlined in Australian Rainfall and Runoff 2019 (ARR2019)[2]. Spatial variations, event duration and temporal patterns were also analysed by comparing maximum depth results.

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[1] Water Technology, 2022, Stawell Flood Investigation

[2] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

2.2 Design modelling parameters and inputs

Table 2-1 summarises the key model parameters/inputs adopted for the TULFLOW modelling. Further details on the TUFLOW model inputs are described in detail in the Model Development and Calibration Report (R02).

Table 2-1 Key TUFLOW parameters summary

Parameter	Value
Model build	2023-03-AC-iSP-w64
Model precision	Single precision
Model base topography	2005-2006 GWMWater Wimmera Mallee Pipeline project LiDAR (2 m x 2 m) – lowered based on LiDAR verification
Topography adjustment	Point cloud data and topographic survey of areas developed since LiDAR flown
Grid cell size	5 metres with Quadtree refinement down to 5/6 m in Stawell township
Sub grid sampling	1 m
Solution scheme	HPC
Inflows	Rainfall polygon with uniform pluviograph
Outflows	Height-flow slope of 1%
Hydraulic roughness	Manning's 'n', varies with land use
2D structures	12 bridges modelled as bridge flow constrictions
1D elements	Culverts and pipes linked to 2D domain

2.2.1 Storm losses

Storm losses of 20 mm initial loss (IL) and 4 mm/hr continuing loss (CL) were adopted based on the outcome of the iterative calibration approach. Losses were adjusted based on land use type.

2.2.2 IFD design rainfall depths

The design rainfall depths were downloaded via Bureau of Meteorology (BoM) website using the centroid of each sub-catchment. The spatially varying design rainfall depths across each catchment were applied in conjunction with subarea weighting to produce an IFD table with one design rainfall depth for each AEP and duration for the entire catchment. Table 2-2 shows the design rainfall depths for each AEP and event durations for the Stawell model.

Table 2-2 IFD design rainfall depth (mm)

Duration	20%	10%	5%	2%	1%	0.5%	0.2%	0.05%
30 min	17.5	21.5	25.7	32	37.3	42.2	48.9	60.3
1 hr	13.8	15.7	22.1	27	32.3	40	46.5	75.6
2 hr	27.5	33.4	39.6	48.7	56.3	63.6	73.9	91.3
3 hr	31.3	37.9	44.7	54.6	62.7	70.8	82.1	101
6 hr	39.7	47.5	55.5	66.9	76.2	85.9	99.3	122
9 hr	45.7	54.5	63.5	76	86.3	97.1	112	137
12 hr	50.6	60.2	69.9	83.5	94.6	107	123	150
18 hr	58.2	69.2	80.1	95.7	108	122	141	173
24 hr	64	76	88.1	105	120	135	157	193

2.2.3 Temporal patterns

Temporal patterns were obtained via the ARR Data Hub using the catchment centroid. Temporal patterns were selected from the “Murray Basin region”. Given the limited size of each catchment, and in line with the recommendations of ARR2019, point temporal patterns were adopted. To reduce computational time, the ensemble of temporal patterns modelled for each duration consisted of three patterns: a front loaded, median and back loaded. The front loaded pattern had most of the rainfall occurring within the first third of the storm, the median had most in the middle third and the back loaded in the last third. The patterns modelled are listed in Table 2-3.

2.3 Critical duration

A range of durations were modelled to determine the critical event durations across each model extent. Using peak flows from the three temporal patterns selected for each duration, a representative temporal pattern was selected based on median peak flow at key locations throughout the models.

Further to assessing peak flow at key locations across each model extent; the critical duration and temporal pattern was also analysed by comparing maximum depth results. The analysed storm durations and temporal patterns for the 1% AEP event are listed in Table 2-3, with the selected critical durations and temporal patterns for the Stawell catchment highlighted. This was done for each group of temporal patterns (rare, intermediate and frequent) for each model extent. As an example, comparison of modelled flow hydrographs in Pleasant Creek downstream of Grampians Road is shown in Figure 2-1. Solid lines represent the temporal pattern resulting in the median peak flow for each modelled duration, indicating that the critical duration in Pleasant Creek location is 6 hours, with the median temporal pattern TP03. Figure 2-2 shows the critical duration in central Stawell overland flow paths is 1 hour with median temporal pattern TP08. Table 2-4 shows the adopted critical duration and representative temporal patterns for each AEP and catchment area.

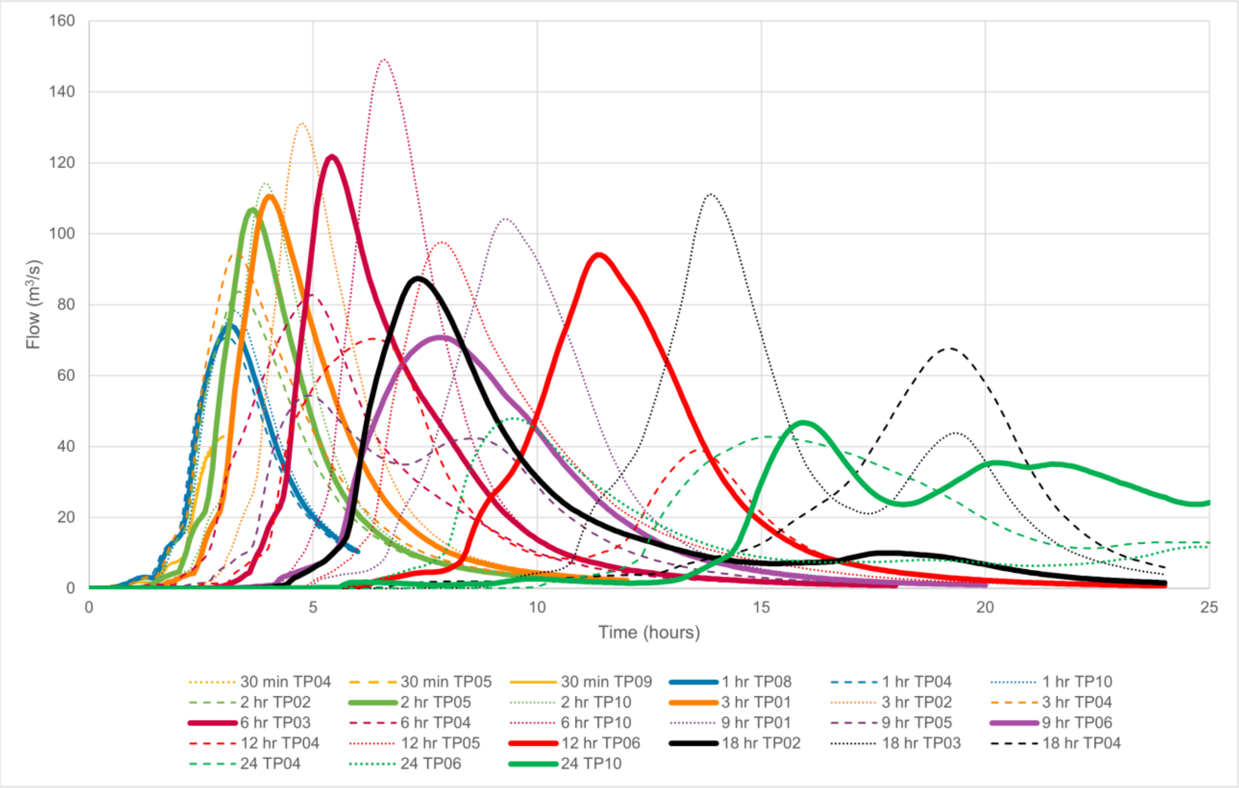

Figure 2-1 Modelled 1% AEP flows in Pleasant Creek DS Grampians Road (m^3/s)

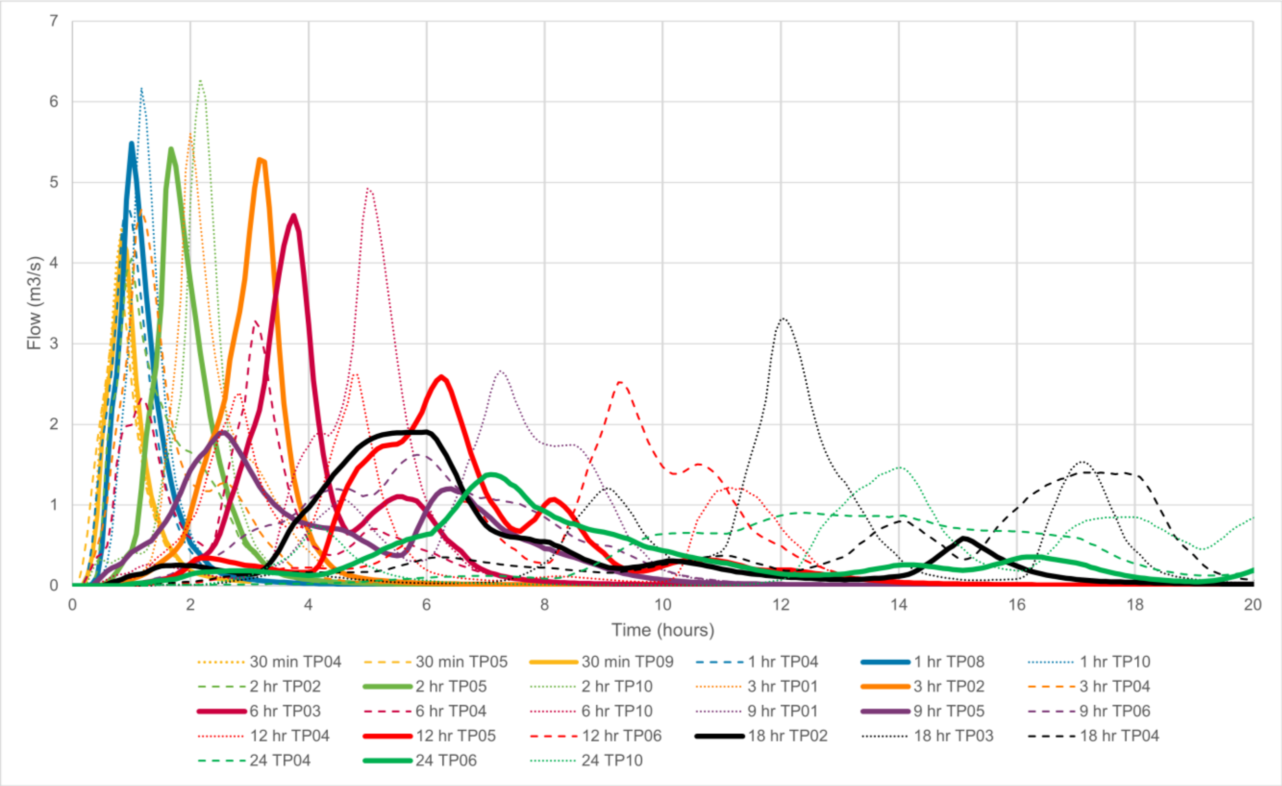

Figure 2-2 Modelled 1% AEP flows in overland flow path east of hospital towards Maud Street Dams (m^3/s)

Table 2-3 1% AEP analysed durations and temporal patterns

Duration	Front loaded	Median	Back loaded
30 min	TP05	TP04	TP09
1 hr	TP04	TP08	TP10
2 hr	TP02	TP05	TP10
3 hr	TP04	TP01	TP02
6 hr	TP04	TP03	TP10
9 hr	TP05	TP06	TP01
12 hr	TP04	TP05	TP06
18 hr	TP02	TP03	TP04
24 hr	TP06	TP04	TP10

Table 2-4 Adopted critical durations and median temporal patterns

Stawell			
AEP group	**Adopted storm events**		
Rare (0.05, 0.2, 0.5, 1, 2%)	1 hr - TP08	3 hr - TP01	6 hr - TP03
Intermediate (5, 10%)	6 hr - TP01		
Frequent (20%)	3 hr - TP08	12 hr - TP08	
Stawell Golf course			

AEP group	Adopted storm events		
Rare (0.05, 0.2, 0.5, 1, 2%)	3 hr - TP01	6 hr - TP03	
Intermediate (5, 10%)	6 hr - TP01		
Frequent (20%)	12 hr - TP08		

2.4 Probable maximum flood

The Probable Maximum Precipitation (PMP) was interpolated between depths estimated by the Generalised Short Duration Method (GDSM) and the Generalised Southeast Australia Method (GSAM). The rainfall depths were modelled utilising the 'rare' temporal patterns obtained from the ARR datahub. An Initial loss of 0mm and a continuing loss of 1mm/hr was applied. The adopted storm events for the 'rare' AEP events outlined in Table 2-4Table 2-4 were modelled for each catchment area.

2.5 Developed conditions model

A developed conditions scenario of the Stawell model was prepared by incorporating future changes in land use according to the Stawell Structure Plan[3] . Future growth areas include both high- and low density residential zones and industrial zones, see Figure 2-3 and Figure 2-4. For areas with changed land use, the Manning's 'n' roughness and rainfall losses were modified to suit the proposed land use. Most of the areas were previously defined as open space. Table 2-5 shows the hydraulic roughness coefficients and rainfall losses, and the areas of change are highlighted in Figure 3-8.

Table 2-5 Developed land use types and Manning's 'n' values

Land use	Manning's 'n'	Initial loss (mm)	Continuing loss (mm/hr)
Open space, minimal vegetation	0.04	20	4
Built-up and residential areas – high density	0.35	20	3
Built-up and residential areas – low density	0.15	20	3
Commercial/industrial areas	0.30	2	0.5
Open space, moderate vegetation	0.08	20	4

The developed conditions model was run for the events adopted for the existing conditions model as listed in Table 2-4.

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[3] Hansen Partnership, Tim Nott & Martyn Group, 2021, Stawell Structure Plan

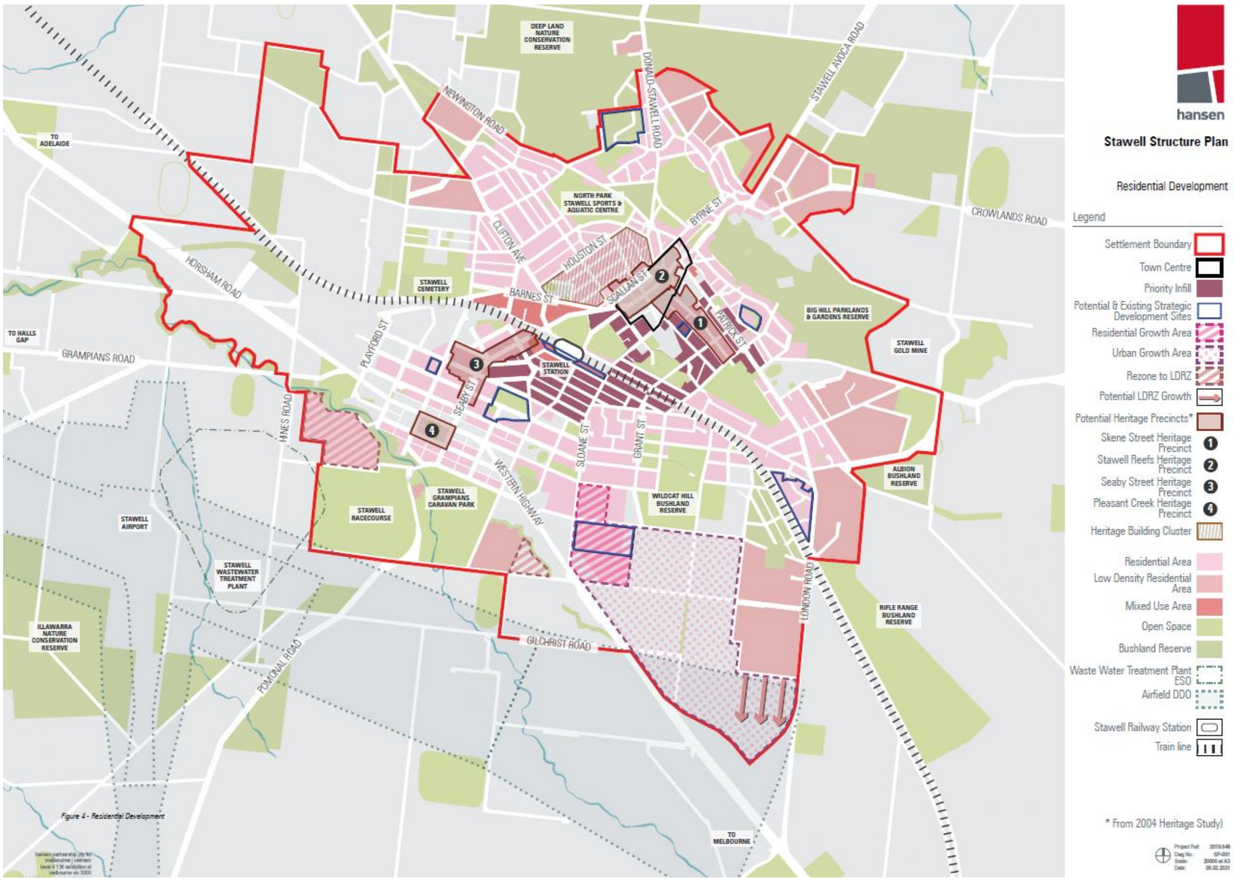

Figure 2-3 Stawell Structure Plan (Hansen Partnership, Tim Nott & Martyn Group, 2021)

Figure 2-4 Stawell Growth Area (Hansen Partnership, Tim Nott & Martyn Group, 2021)

3 RESULTS

3.1 Existing conditions

Design flood modelling for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and 0.05% AEP events and the PMF event was completed using the validated hydraulic models. Flood modelling outputs will be applied for flood emergency response improvement and planning, and flood maps will be used as guidance for future land use development.

The final flood maps for each event were created by the maximum of all the runs for each AEP event, including the critical durations and the chosen temporal patterns as summarised in Table 2-4. The maximum flood extents for the full range of modelled AEP events for each catchment area are shown in Figure 3-2 and Figure 3-3, and the 1% AEP maximum depth is shown in Figure 3-4 to Figure 3-6. All gridded results were filtered to only include areas where the flood depth is >0.05 m or flood velocity >0.5 m/s, to include areas of shallow but high velocity flow.

Flood depth maps for the full range of AEPs and the PMF event are provided in Appendix A and GIS deliverables (grids and extents) were provided to Council and Wimmera CMA.

Flood hazard mapping was prepared in line with ARR2019 and the Australian Disaster Resilience Guideline 7-3 Flood Hazard[4]. The hazard classifications are based on the peak depth, velocity and product of depth and velocity. The classifications are shown in Figure 3-1.

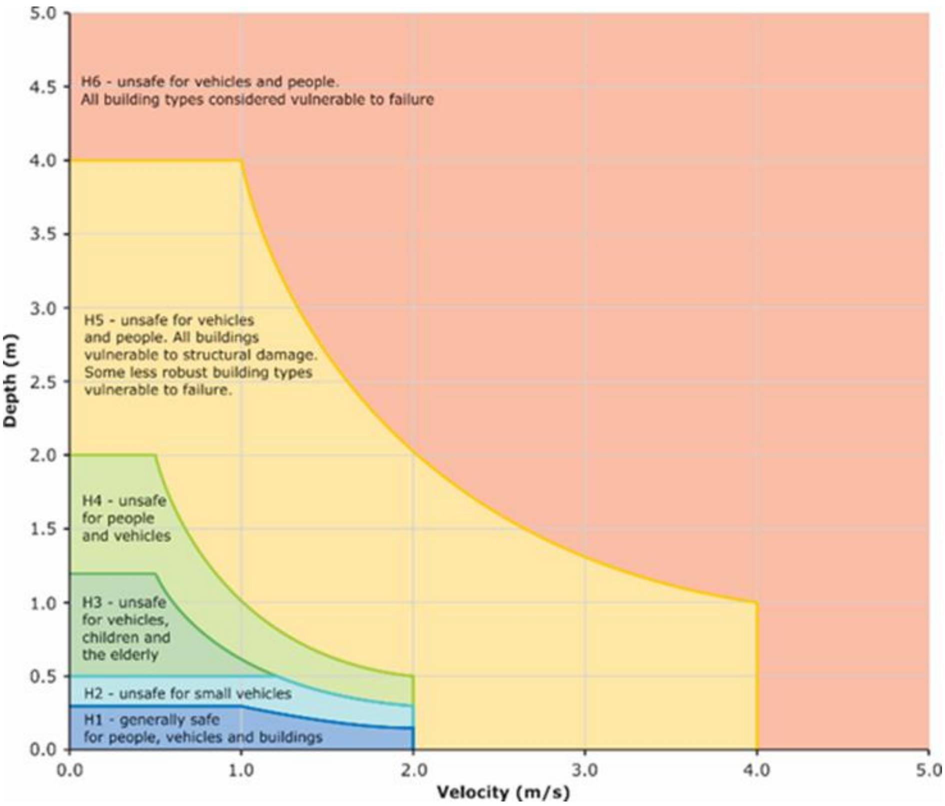

Figure 3-1 Flood hazard classifications

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[4] Australian Disaster Resilience Guideline 7-3 Flood Hazard, 2017, Australian Institute Disaster Resilience

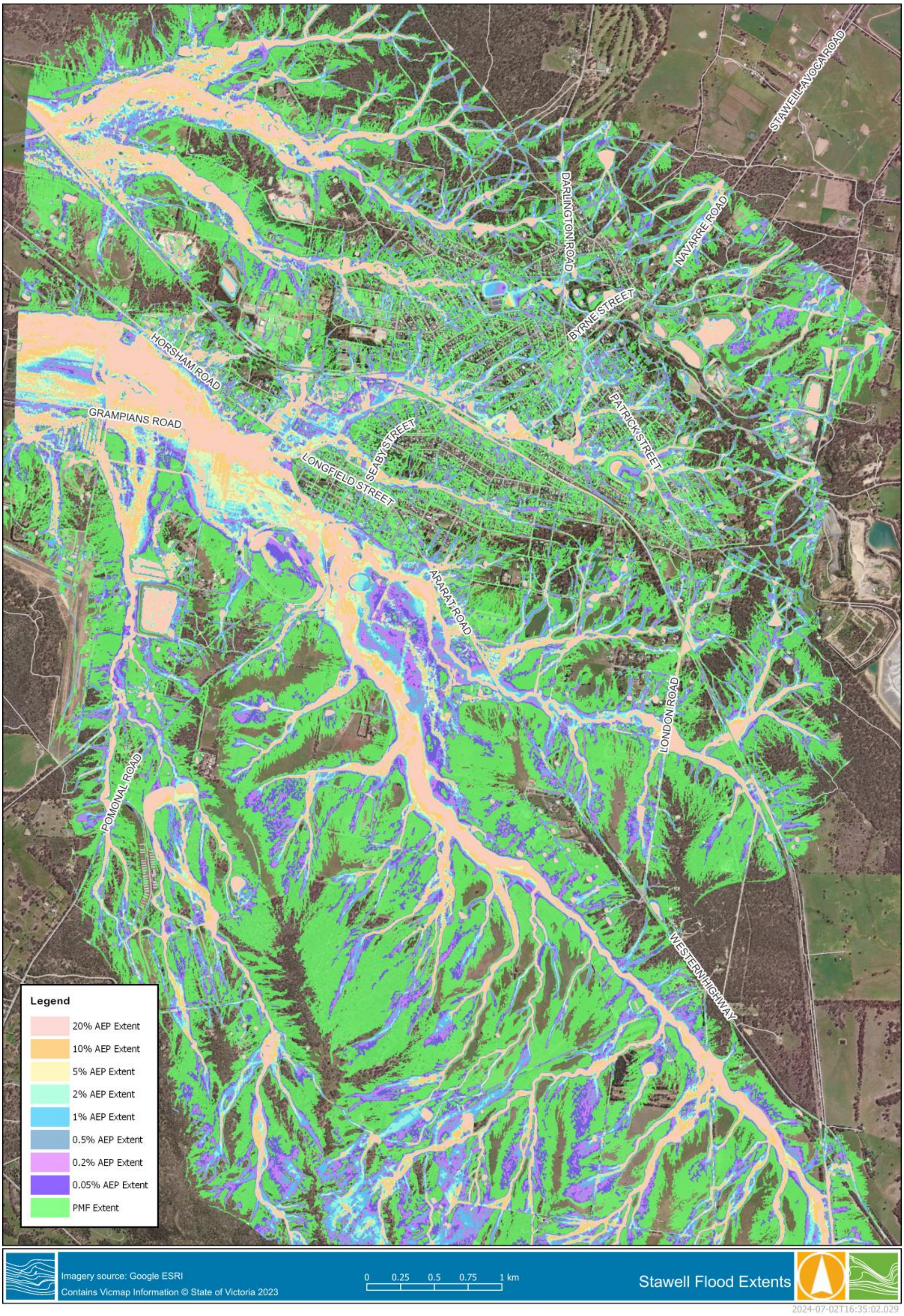

Figure 3-2 Design modelling extents – Stawell

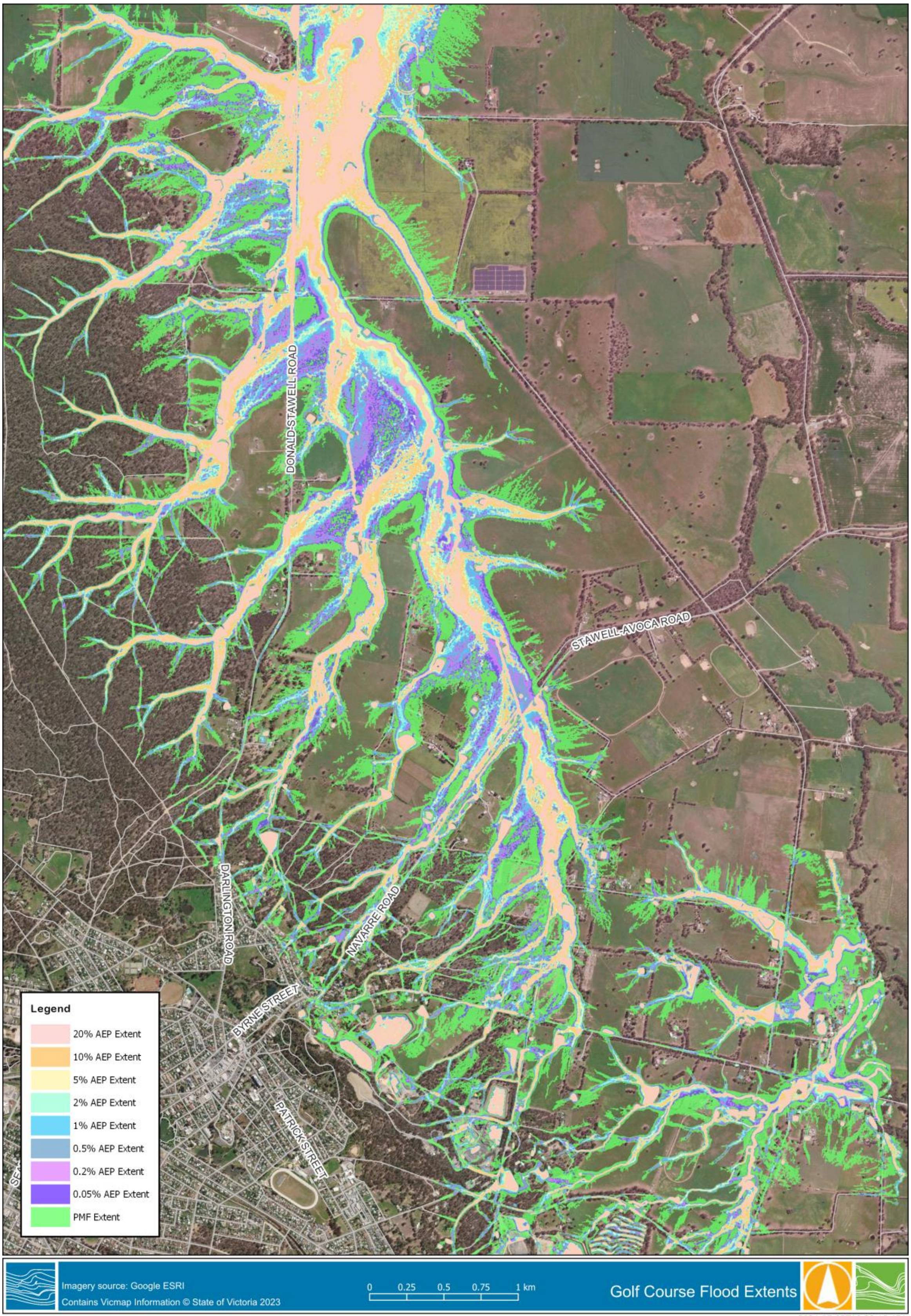

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Figure 3-3 Design modelling extents – Stawell Golf course

Data sources: Stawell_01_00p_Ex_v09_d_max_filt.tif
Imagery source: Google ESRI
Contains Vicmap Information © State of Victoria 2024

Figure 3-4 1% AEP depth – Stawell

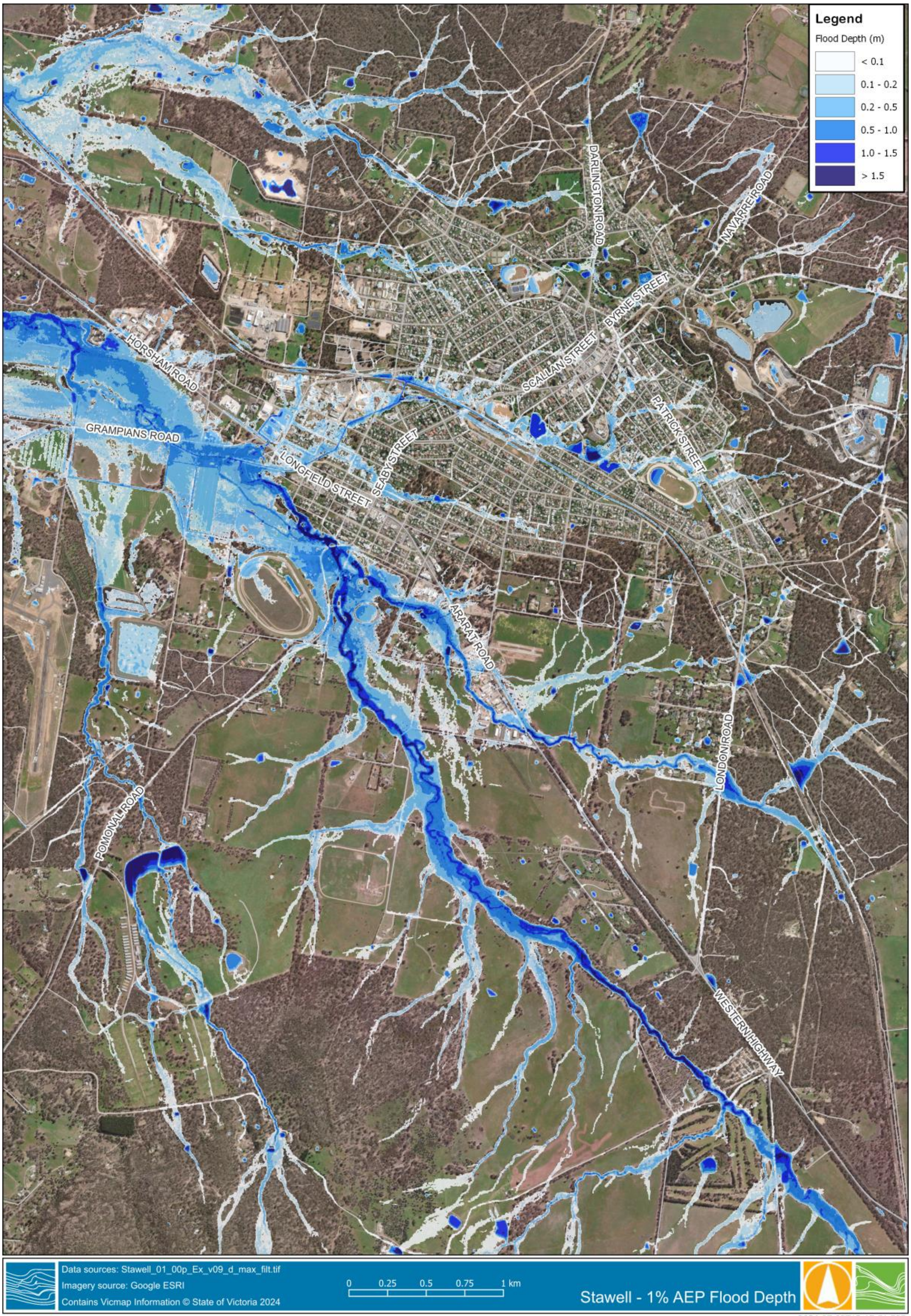

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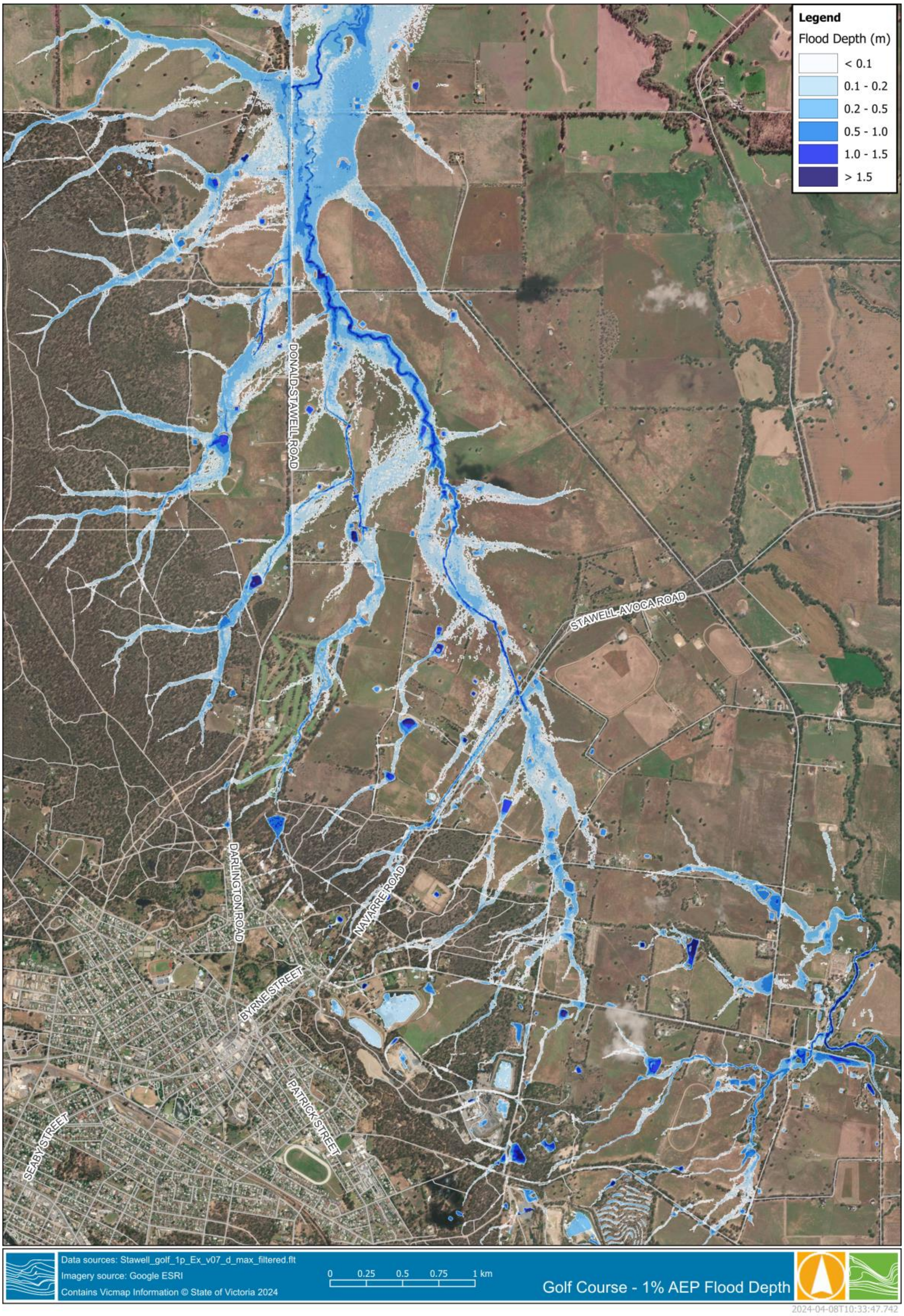
Figure 3-5 1% AEP depth – Stawell township



Data sources: Stawell_golf_1p_Ex_v07_d_max_filtered.flt
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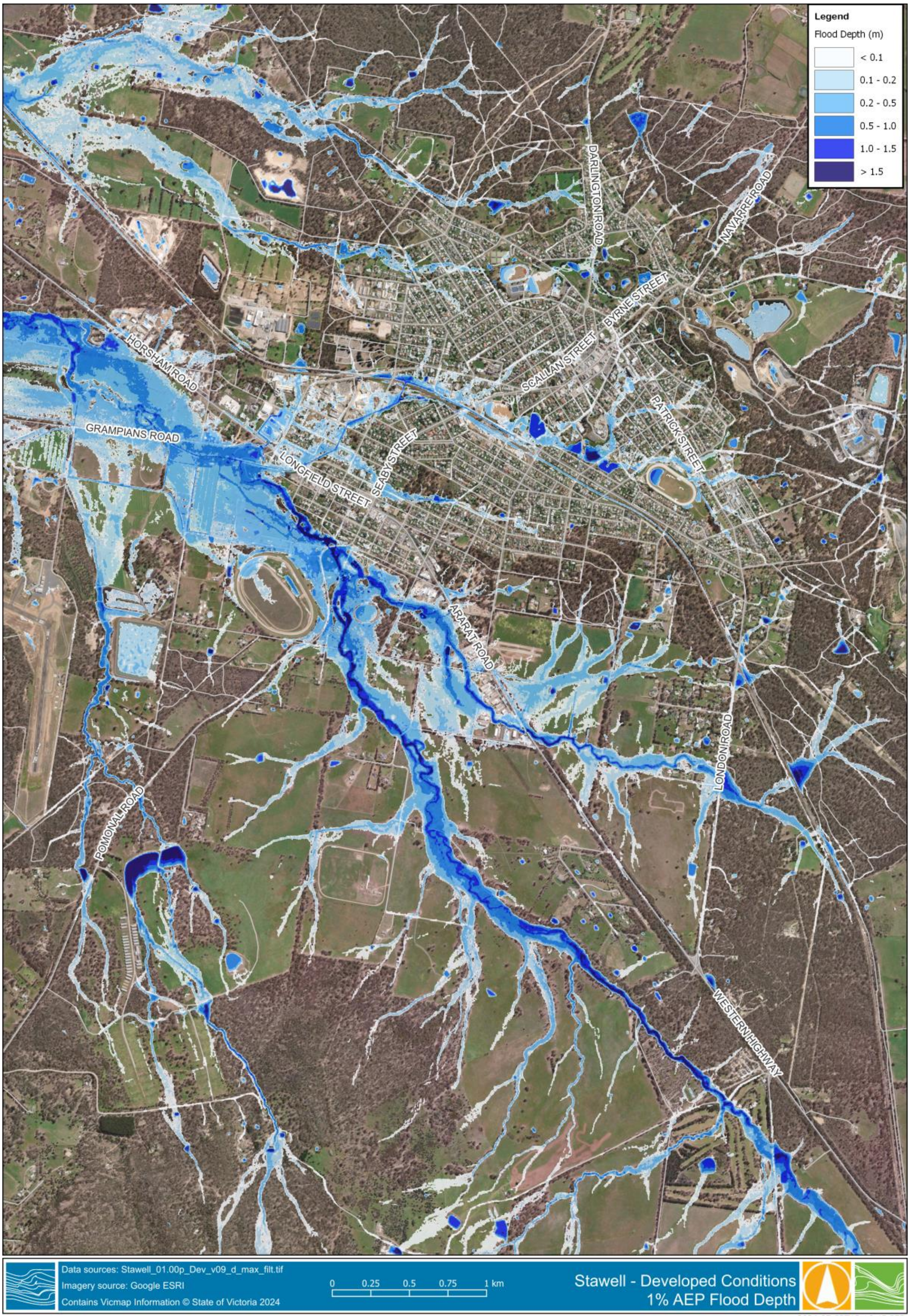
Figure 3-6 1% AEP depth – Stawell Golf Course

3.2 Developed conditions

Developed conditions flood modelling was undertaken for all the events modelled under existing conditions, and final flood maps were created based on the maximum of adopted critical durations and the chosen temporal patterns as summarised in Table 2-4.

The 1% AEP maximum depth is shown in Figure 3-7 and a difference in water level is shown in Figure 3-8. The increased land use roughness in the development areas result in increased flood extents and depths within and directly upstream of these areas. Consequently, flood levels downstream of these areas decrease as a result of the changed timing of flows through the rougher developed areas. Flood extent increases are mostly confined within the development area boundaries. The modelling did not adopt any mitigation measures that would typically be associated with land development (e.g. peak flow retardation, underground and open drain stormwater infrastructure, basins or bunds). It would be expected that individual subdivisions would assess peak flow reduction and provision of overland flow paths as part of a subdivision stormwater management plan.



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Imagery source: Google ESRI
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Figure 3-7 1% AEP depth - Developed conditions

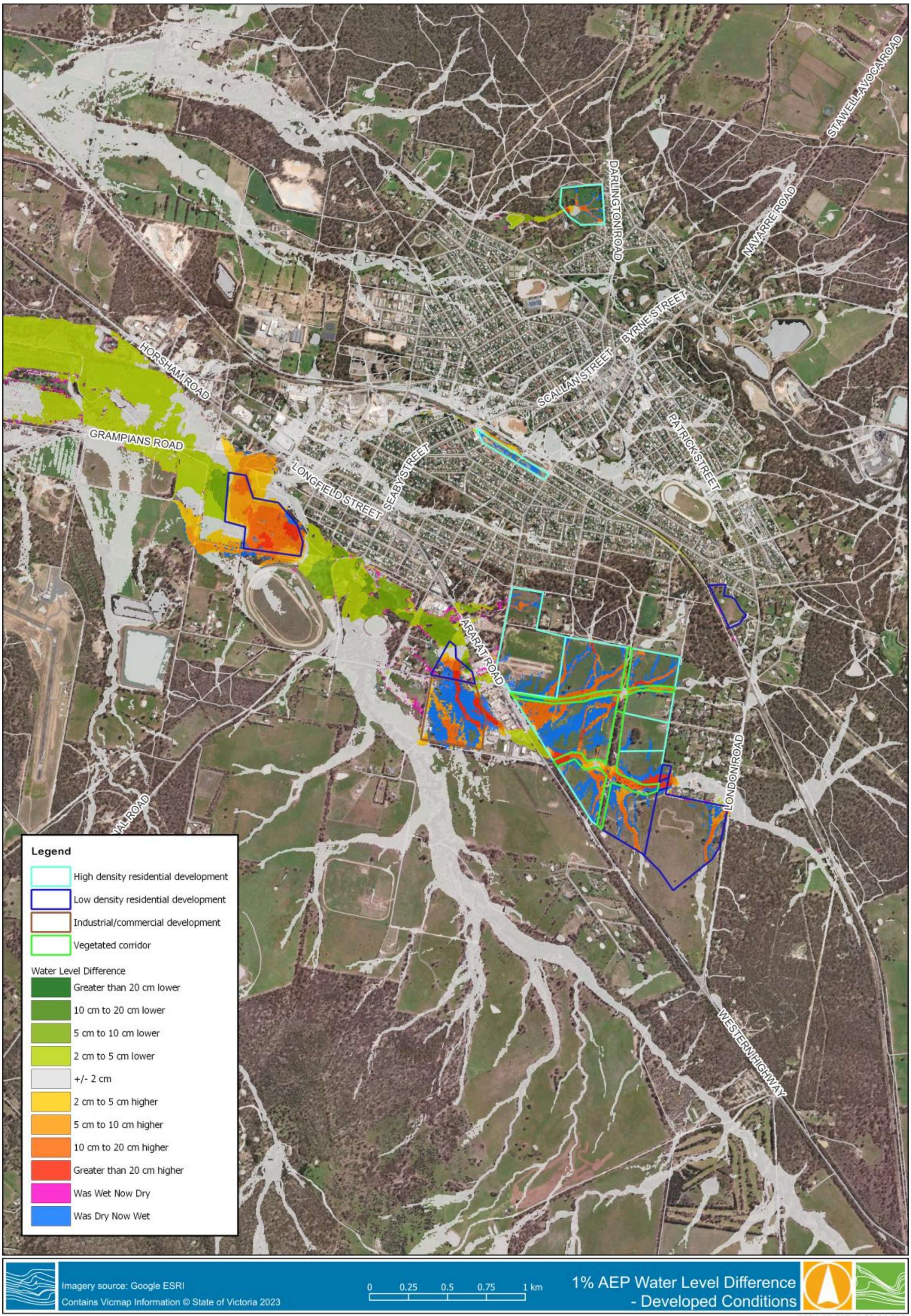

Figure 3-8 1% AEP water level difference – Developed conditions model

3.3 Stormwater network utilisation

The pipe capacity utilisation for the township underground pit and pipe network is show in Figure 3-9 for the 1% AEP storm event under existing conditions. Results are displayed for the critical duration within the Stawell township catchment. The pipe network is running at full or near full capacity in most areas, in particular major trunk drains. Underutilised pipes are observed in the most upstream network branches within residential areas. This may be due to the modelling technique which does not account for directly connected areas (houses, sheds) which are plumbed directly to the underground drainage network. Figure 3-10 shows the difference in pipe capacity utilisation between developed and existing conditions for the 1% AEP event. Since the proposed development areas are mostly outside of the existing network area very little change is observed.

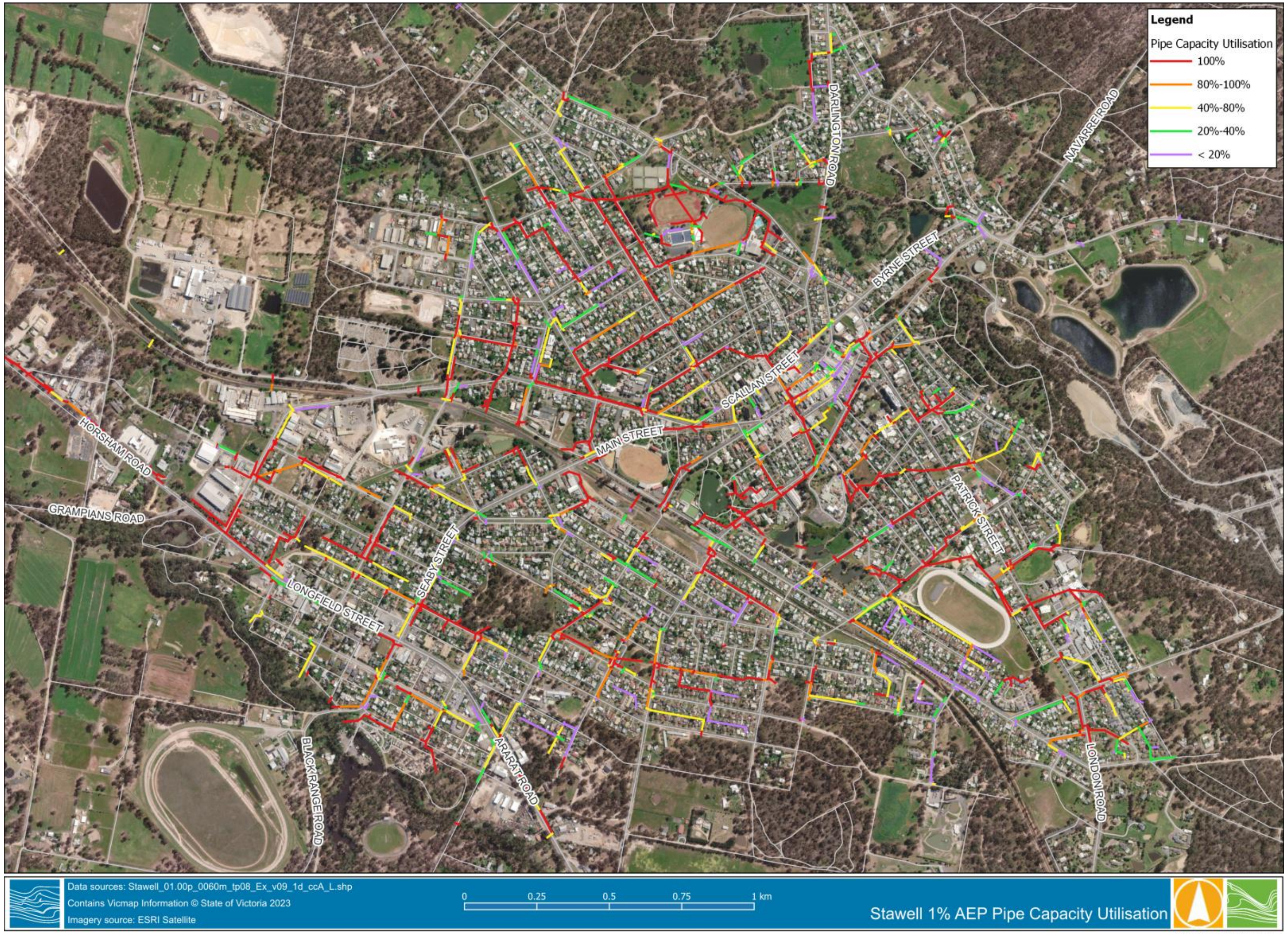

Figure 3-9 1% AEP stormwater network capacity utilisation

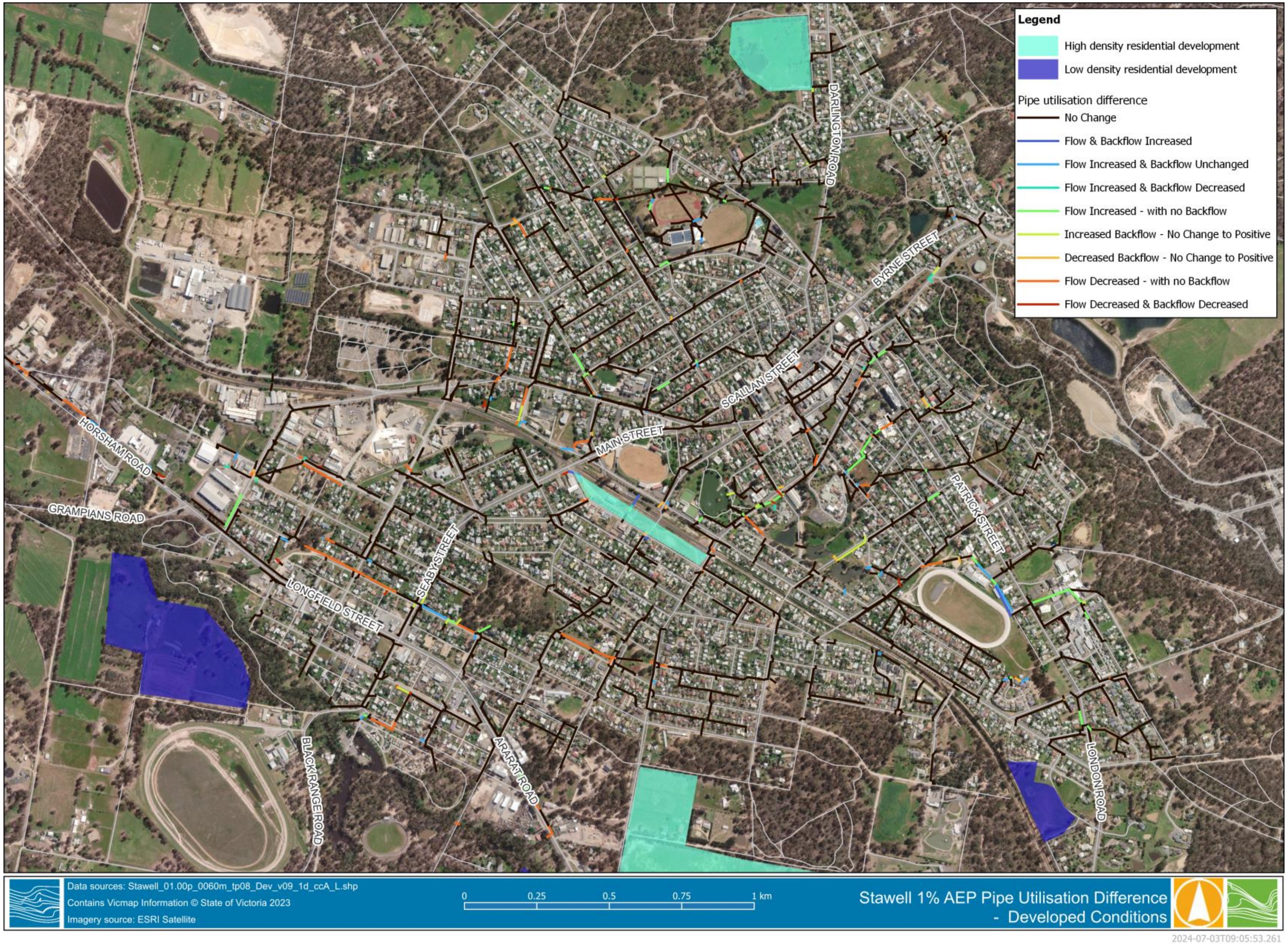

Figure 3-10 1% AEP pipe capacity utilisation difference – Developed conditions model

4 SENSITIVITY ANALYSIS

Sensitivity testing of flood models consists of altering an input or parameter and comparing results to the base case, revealing the sensitivity of the model results to that input or parameter. Sensitivity testing of the model was undertaken for a range of parameters and inputs as described below. Sensitivity testing of the model was completed for the Stawell model for the 1% AEP event only. Afflux mapping (flood level difference) of the sensitivity tests compared to the design mapping is shown for each sensitivity test undertaken. Note that the mapping shows sensitivity analysis undertaken for a previous model version (with the exception of climate change modelling). The model updates incorporated since the sensitivity analysis were minor changes to local areas and have no impact on the sensitivity analysis conclusions.

4.1 Catchment storage

A sensitivity test was undertaken to determine how varying antecedent conditions could impact 1% AEP flood levels and extents. This was done by assuming catchment storages (dams, lakes, depressions, channels) were already full by including a short rainfall burst prior to the start of the 1% AEP storm event. Figure 4-1 shows the difference in water level in Stawell with the prefilled storages. The results show water levels increase up to 0.1 m in the waterways and main overland flow paths, with larger increases in individual storages and ponded areas. Despite this, the flood extent remains largely unchanged indicating that the catchment is not overly sensitive to full or empty catchment storage conditions.

4.2 Roughness coefficients

Sensitivity to roughness within the hydraulic model was tested by lowering and raising the Manning's 'n' roughness. The roughness values in the model were multiplied by 0.8 and 1.2 for the low and high tests respectively. Figure 4-2 and Figure 4-3 show the difference in water level in Stawell for each test. The largest flood level changes were observed in the upper reaches of the Pleasant Creek catchment, but overall changes in water level and extent are limited. Within Stawell, the largest changes are observed in the area surrounding the railway/Griffith Street intersection where the Main Drain overflows; however, the water level difference is within +/- 0.05 m.

4.3 Structure blockage

Blockage factors were applied to culverts, pipes and bridges as follows:

- 20% blockage applied to the bridge openings (i.e. underneath the deck) and 100% blockage applied to the bridge railings for all modelled bridges.
- 50% blockage applied to all culverts.
- 50% blockage to all pits connected to the pipe network in the township (including headwall openings).

Figure 4-4 show the difference in water level in Stawell obtained using the blockage factors. Applying blockage factors cause localised change upstream of a handful of major culverts, in particular along the railway and Western Highway. Negligible changes are observed inside Stawell, indicating that the pipe network is already running above full capacity in the 1% AEP event and is not significantly impacted by additional blockage.

4.4 Boundary conditions

The model has a number of outflow boundaries, the main one being where Pleasant Creek exits the model. All outflow boundaries adopted a slope of 1% based on the slope of Pleasant Creek at the boundary location. Changing the downstream boundary slope to 5% lowered flood levels in the vicinity of the boundary, see Figure 4-5. Flood levels in Stawell were unaffected by the change, confirming the boundaries were set a sufficient distance from the township to not impact results.

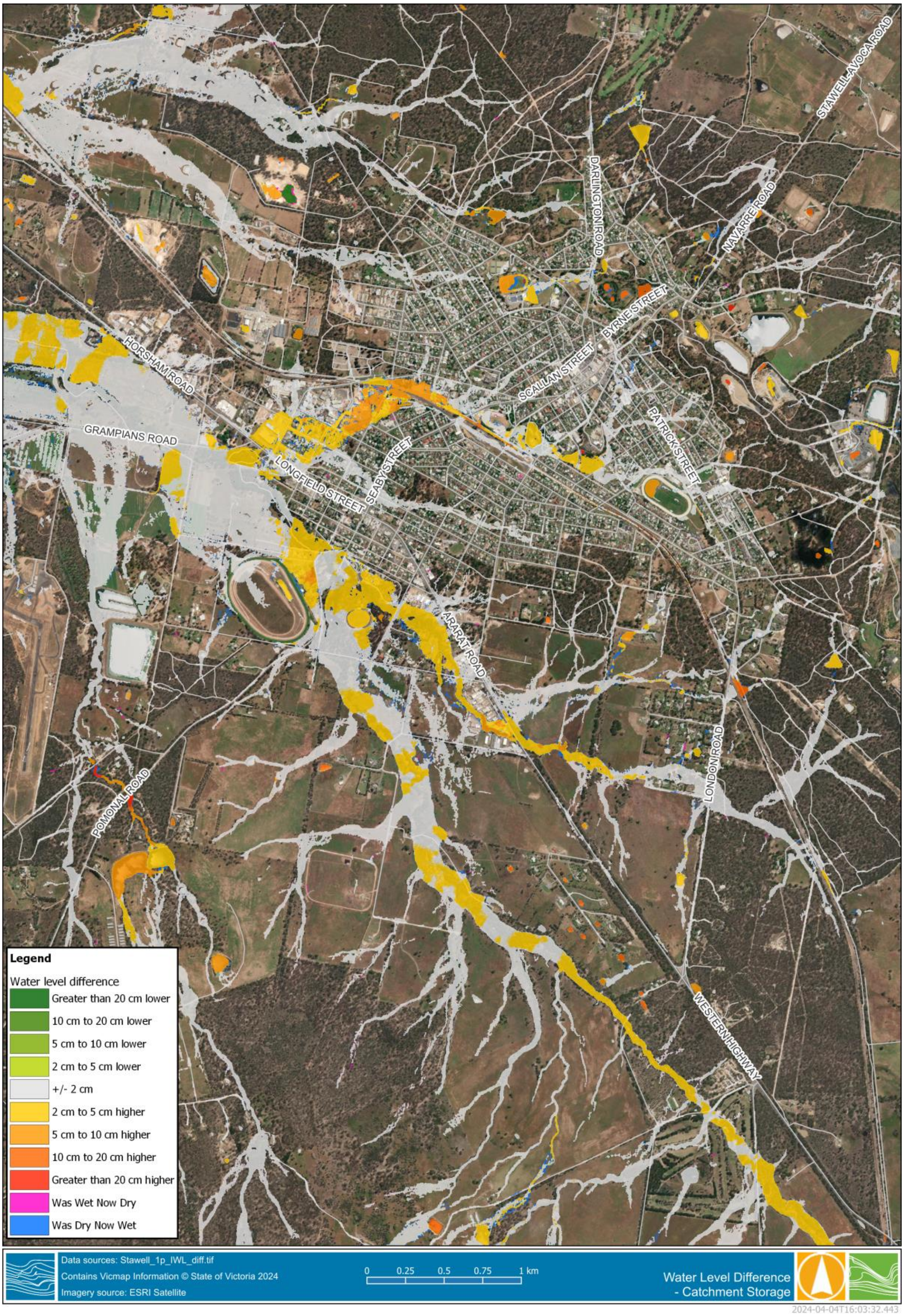

Figure 4-1 1% AEP water level difference – Prefilled catchment storage

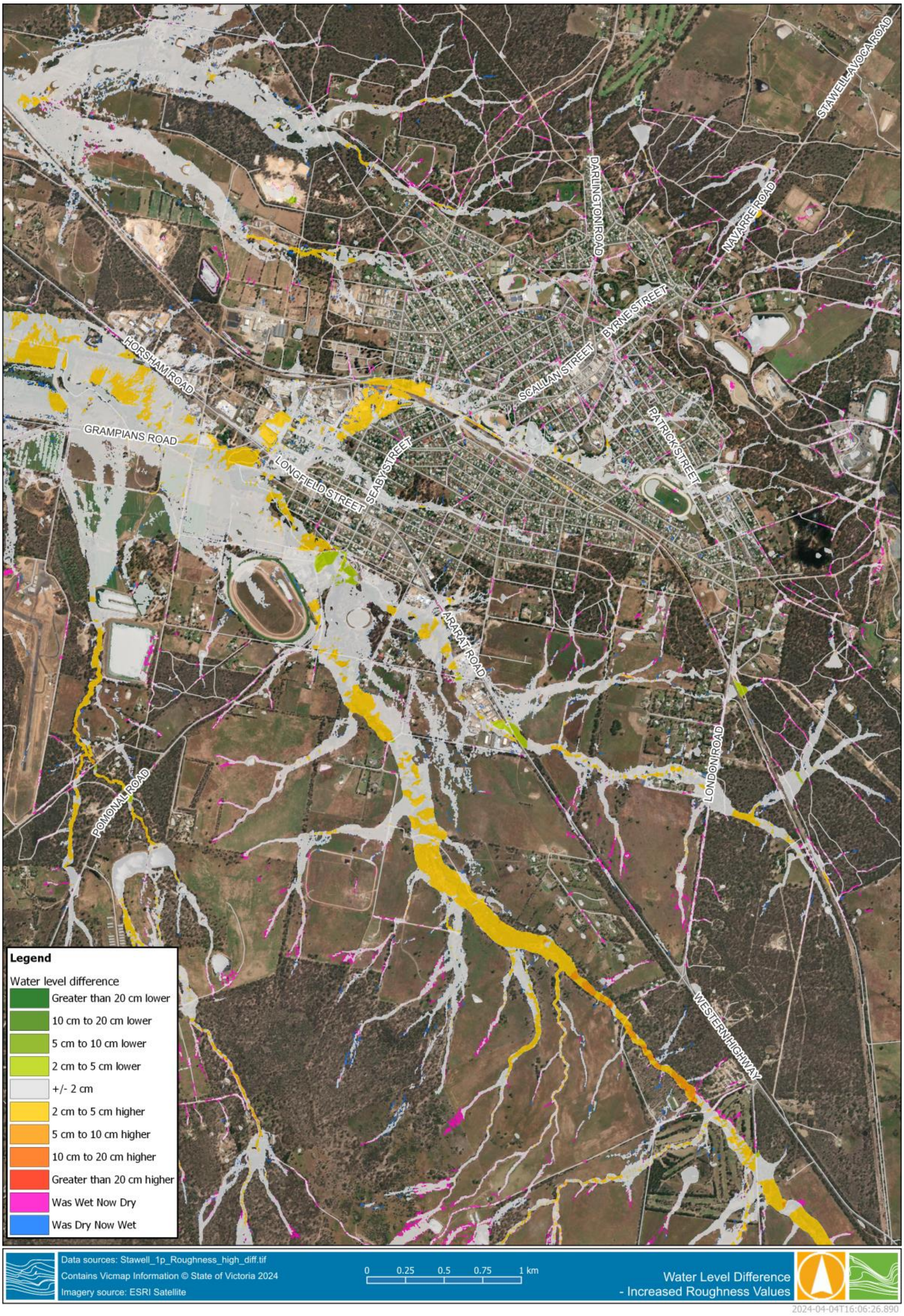

Figure 4-2 1% AEP water level difference – Increased roughness values

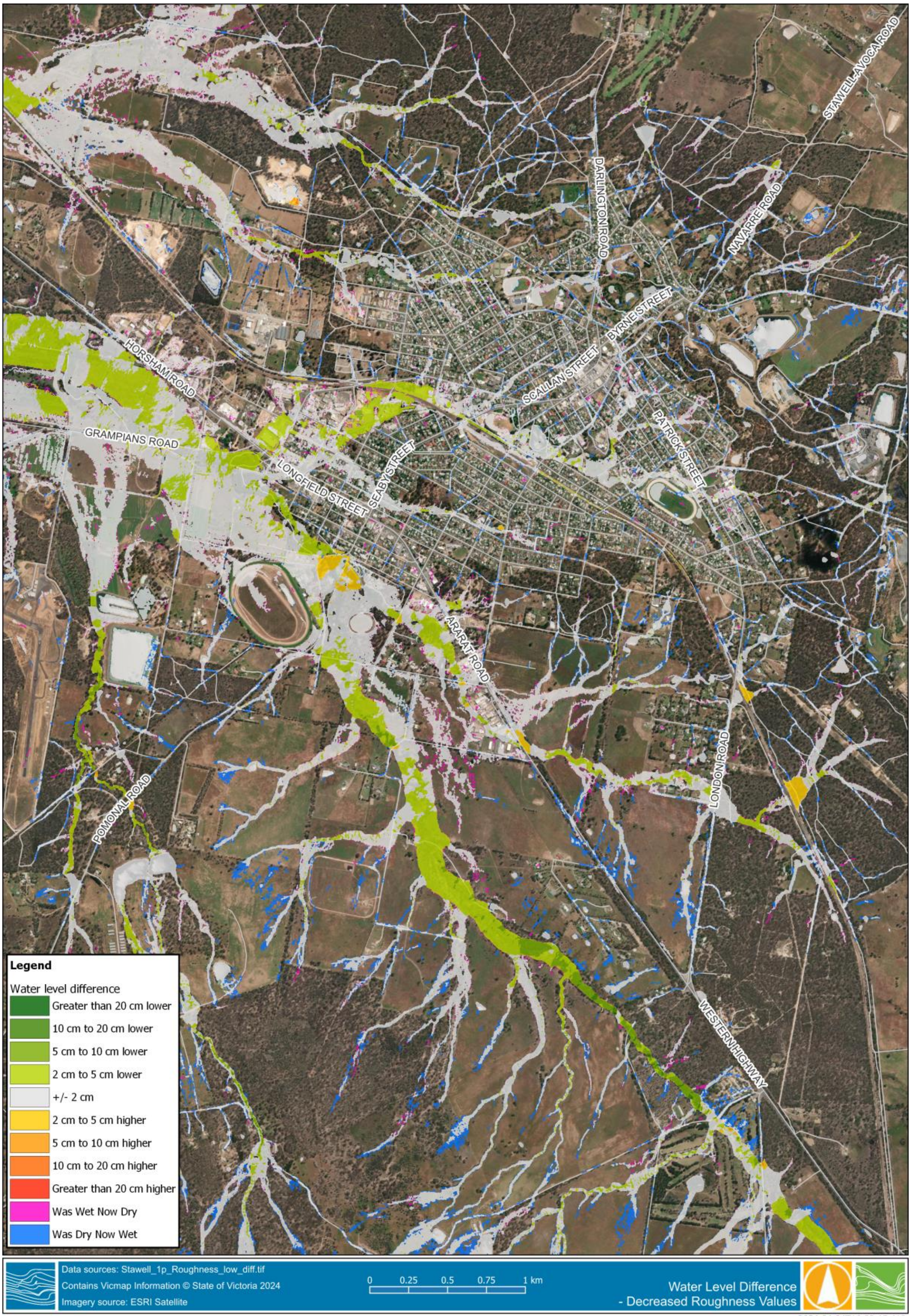

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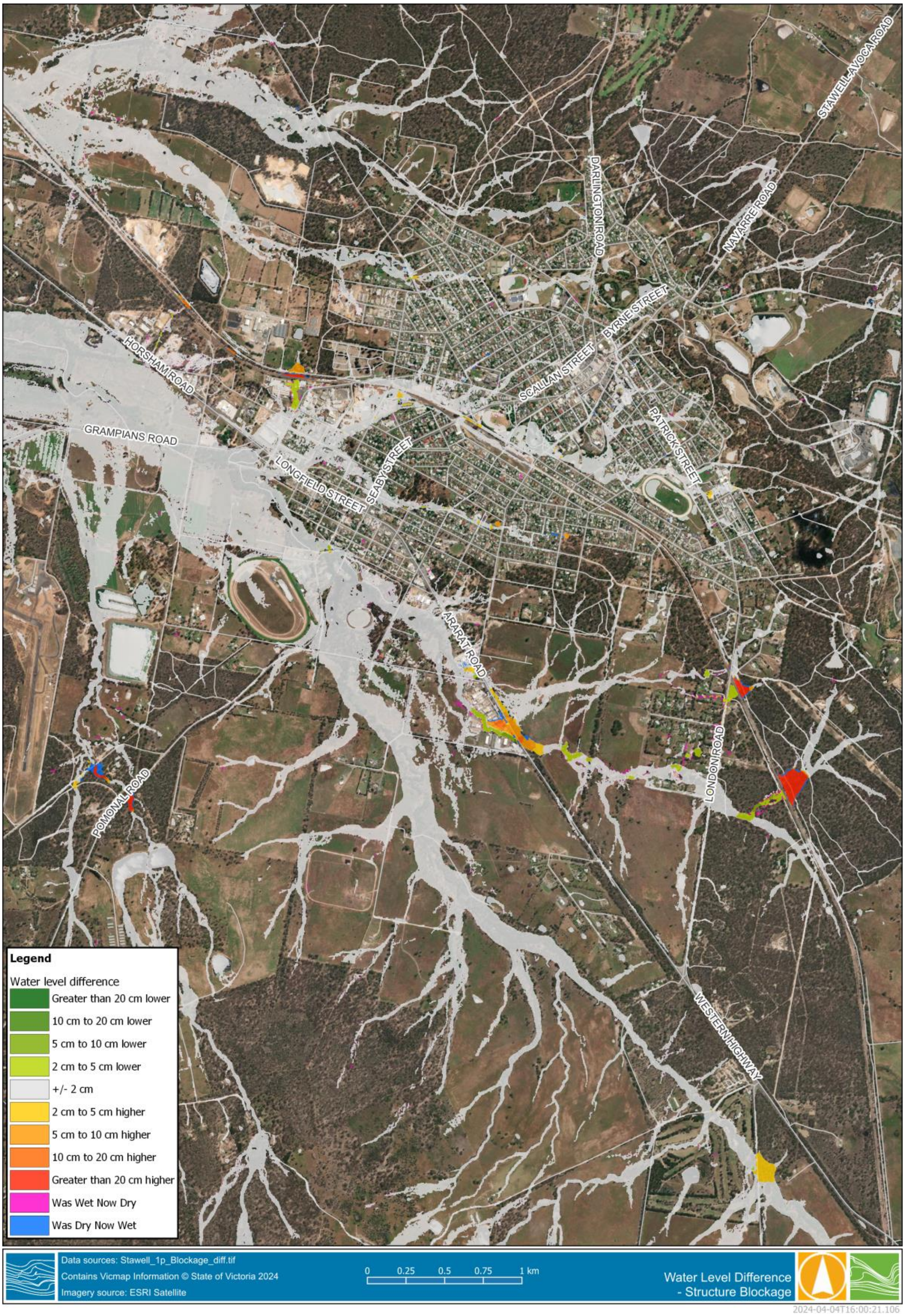
Figure 4-3 1% AEP water level difference – Decreased roughness values



Data sources: Stawell_1p_Blockage_diff.tif
Contains Vicmap Information © State of Victoria 2024
Imagery source: ESRI Satellite

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Figure 4-4 1% AEP water level difference – Structure blockage

Figure 4-5 1% AEP water level difference – Increased boundary slope

4.5 Climate Change modelling

The 20%, 10% and 1% AEP events were modelled with increases in rainfall intensity associated with climate change. Modelling considered Representative Concentration Pathways (RCP) 4.5 and 8.5 under projections to the year 2100 in line with the ARR guidelines with rainfall scaling factors obtained from the ARR Data Hub[5], extrapolated from the year 2090. The increased rainfall depths were applied to the hydraulic model. The resultant rainfall depths and hydraulic model peak flows at a downstream location are shown in Table 4-1. The 6 hr or 12 hr duration rainfall depths were provided for comparison, but increases were applied to all modelled durations.

The model results indicate that climate change scenarios cause an increase in peak flow for both models. The 1% AEP flows under an RCP8.5, 2100 scenario are increased by 51% and are between present day 0.5% and 0.2% AEP flows. The 10% AEP flows for the same climate scenario are increased 41% and are between present day 10% and 5% AEP flows. The difference in water level for the RCP8.5, 2100 1% AEP event is shown in Figure 4-6 and complete results are included in Appendix A.

As expected, the increased rainfall intensity RCP8.5, 2100 scenario produces an increase in flood levels across the study areas. In the township, levels increase up to 0.3 m with larger increases in and around Pleasant Creek.

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[5] ARR Data Hub, accessed from https://data.arr-software.org/

Table 4-1 Climate change assessment summary

1% AEP (6 hr duration)	RCP4.5 (Year 2100)	RCP8.5 (Year 2100)
Current IFD rainfall (mm)	76.2	76.2
% increase	9.60	23.33
Projected rainfall depth (mm)	83.5	94.0
Peak flow Pleasant Creek DS Grampians Road (m/s)	149	176
% flow increase	19	41
10% AEP (6 hr duration)	**RCP4.5 (Year 2100)**	**RCP8.5 (Year 2100)**
Current IFD rainfall (mm)	47.5	47.5
% increase	9.60	23.33
Projected rainfall depth (mm)	52.1	58.6
Peak flow Pleasant Creek DS Grampians Road (m/s)	54	70
% flow increase	32	71
20% AEP (12 hr duration)	**RCP4.5 (Year 2100)**	**RCP8.5 (Year 2100)**
Current IFD rainfall (mm)	50.6	50.6
% increase	9.60	23.33
Projected rainfall depth (mm)	55.5	62.4
Peak flow Pleasant Creek DS Grampians Road (m/s)	30	40
% flow increase	36	82

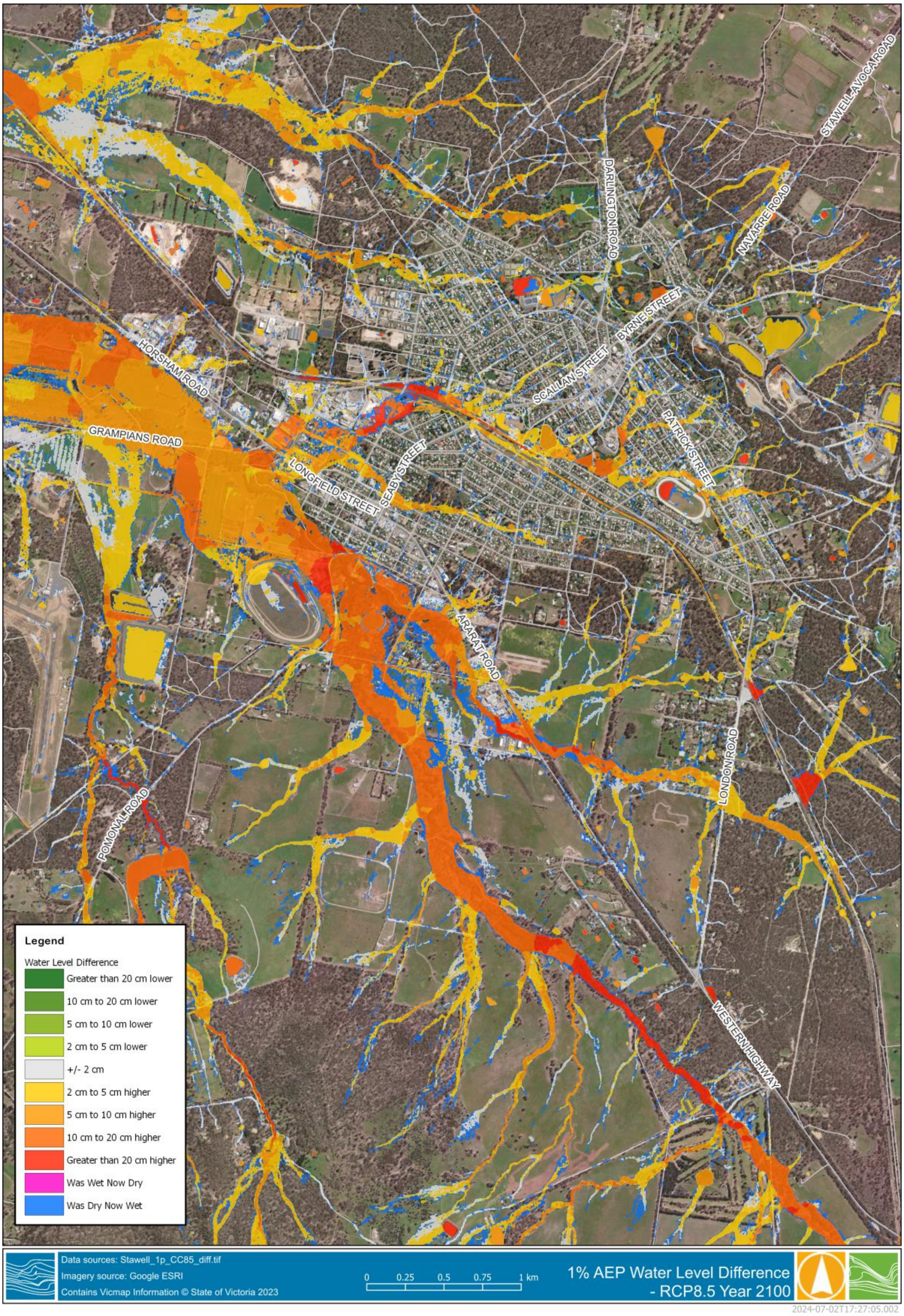

Figure 4-6 1% AEP water level difference - Climate change RCP8.5 2100

5 SUMMARY AND DISCUSSION

Design modelling and sensitivity testing of the hydraulic models built as part of the Stawell Flood Investigation has been completed and detailed in this report. Design flood mapping outputs have been provided digitally along with this report.

The models have been simulated for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.05% AEP and PMF events. The 20%, 10% and 1% AEP events were simulated with projected climate change increased rainfall intensity under RCP4.5 and RCP8.5 for the year 2100.

The modelling shows limited sensitivity to hydraulic roughness and catchment storage conditions. For the 1% AEP event, structure blockage and boundary conditions were not shown to be influential on results in the township aside form localised increases upstream of blocked culverts.

Flood mapping was produced in line with industry standards and the current Australian Rainfall and Runoff guidelines. The mapping is fit for the purposes of informing land use planning in Stawell through the development of draft overlays for a future planning scheme amendment. As part of this study, model outputs will be used to assess average annual flood damages for the township and the models utilised to assess potential structural mitigation options. Flood intelligence products will be developed to inform emergency management planning and response including updated content for the Municipal Flood Emergency Management Plan.

APPENDIX A
FLOOD MAPPING

WATER TECHNOLOGY
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Telephone (07) 3105 1460

Adelaide

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Eastwood SA 5063
Telephone (08) 8378 8000

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Geelong

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Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera

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Stawell VIC 3380
Telephone 0438 510 240

Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

watertech.com.au