



Model Calibration Report

Edenhope and Apsley Flood Investigation

West Wimmera Shire Council

4 June 2026



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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.

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



4 June 2026

Edwin Irvine
Senior Planning Officer
West Wimmera Shire Council
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Via email: EdwinIrvine@westwimmera.vic.gov.au

Dear Edwin

Edenhope and Apsley Flood Investigation

Please see the attached Model Calibration Report for the Edenhope and Apsley Flood Investigation. This report documents the following:

- Data collation.
- Stage 1 community consultation.
- Model schematisation.
- Calibration modelling.
- Preliminary design modelling.

The intent of this report is to document the studies ongoing progress. There are likely to be some changes in the content of the report post the second round of community consultation, adjusting design modelling parameters.

Yours sincerely

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CONTENTS

1	INTRODUCTION	7
1.1	Overview	7
1.2	Study Area	7
2	DATA COLLATION AND REVIEW	11
2.1	Streamflow Data	11
2.2	Storage Data	11
2.3	Rainfall Data	15
2.4	Drainage Infrastructure	17
2.5	Topography Data	17
2.6	Stage 1 Community Consultation	17
2.6.1	Overview	17
2.6.2	Edenhope	17
2.6.3	Apsley	18
3	CATCHMENT ANALYSIS	19
3.1	Catchment and Characteristics	19
3.2	Historic Events	22
3.3	Antecedent Conditions	23
4	HYDRAULIC MODELLING	29
4.1	Model Extent and Structure	29
4.2	Model Topography	32
4.3	Model Roughness	33
4.4	Model Structures	36
4.5	Rainfall Losses	39
5	MODEL CALIBRATION	41
5.1	Overview	41
5.2	January 2011 Event	41
5.2.1	Event Overview	41
5.2.2	Modelled Rainfall	46
5.2.3	Calibration data	47
5.3	Modelled Event & Scenarios	51
5.4	Apsley – 2011 Flood Results	52
5.5	Apsley – 2011 Calibration Discussion	58
5.6	Edenhope - 2011 Flood Results & Discussion.	60
6	PRELIMINARY DESIGN MODELLING	65
7	SUMMARY AND NEXT STEPS	72



LIST OF FIGURES

Figure 1-1	Edenhope and Apsley with respect to western Victoria	8
Figure 1-2	Edenhope Study Area	9
Figure 1-3	Apsley study area	10
Figure 2-1	Edenhope – Lake Wallace flood record	11
Figure 2-2	Edenhope – Lake Wallace Overflow Record	12
Figure 2-3	Rainfall gauges relevant to Edenhope and Apsley	16
Figure 3-1	Edenhope Catchment and Topography	20
Figure 3-2	Apsley Catchment and Topography	21
Figure 3-3	Antecedent Conditions - Comparison	25
Figure 3-4	DEA Water Observation – 1% Return Frequency	26
Figure 3-5	DEA Wetness Percentile – 10 th , 50 th and 90 th for Water Bodies	27
Figure 3-6	Comparison of Datasets	28
Figure 4-1	Model Schematic – Edenhope	30
Figure 4-2	Model Schematic – Apsley	31
Figure 4-3	Model Topography Methodology	32
Figure 4-4	Apsley – Model Roughness	34
Figure 4-5	Edenhope – Model Roughness	35
Figure 4-6	Apsley Modelled Structures	37
Figure 4-7	Edenhope Modelled Structure	38
Figure 4-8	Rainfall Loss Processes (Source: ARR2019, Book 5)	39
Figure 5-1	January 2011 event temporal pattern – Edenhope Airport, 079099	43
Figure 5-2	IFD curves for Edenhope and observed rainfall intensities – January 2011	44
Figure 5-3	IFD curves for Apsley and estimated rainfall intensities – January 2011	45
Figure 5-4	Interpolated Rainfall Depths – Edenhope and Apsley	46
Figure 5-5	Flooding at residences along Townsend Street	48
Figure 5-6	Flooding at Wallace Street Crossing	49
Figure 5-7	Observed flood behaviour within Apsley	50
Figure 5-8	Scenario 1 (Prior Rainfall) January 2011– Flood Depth	53
Figure 5-9	Scenario 2 (Dry Catchment) January 2011– Flood Depth	54
Figure 5-10	Scenario 3 (Wet Catchment) January 2011– Flood Depth	55
Figure 5-11	Extent Comparison – January 2011	56
Figure 5-12	Key Locations of Flood Behaviour	59
Figure 5-13	Scenario 1 (Prior Rainfall) January 2011– Flood Depth (Edenhope)	61
Figure 5-14	Scenario 2 (Dry Catchment) January 2011– Flood Depth (Edenhope)	62
Figure 5-15	Scenario 3 (Wet Catchment) January 2011– Flood Depth (Edenhope)	63
Figure 5-16	Extent Comparison – January 2011 (Edenhope)	64
Figure 6-1	Apsley 10% AEP – Preliminary Mapping	66
Figure 6-2	Apsley 1% AEP – Preliminary Mapping	67
Figure 6-3	Edenhope 10% AEP – Preliminary Mapping	68
Figure 6-4	Edenhope 1% AEP – Preliminary Mapping	69
Figure 6-5	Apsley 10% AEP – Extent Comparison	70
Figure 6-6	Edenhope 10% AEP – Extent Comparison	71



LIST OF TABLES

Table 2-1	Collated Lake Hydrology Data	13
Table 2-2	Summarised Lake Wallace Lake Level Information	14
Table 2-3	Daily rainfall station information	15
Table 3-1	Apsley Rainfall Records	22
Table 3-2	Edenhope Rainfall Records	23
Table 3-3	Rainfall and Catchment Conditions Analysis	24
Table 4-1	Land Use Manning's 'n' Roughness values	33
Table 4-2	Edenhope and Apsley Infiltration Loss Values	40
Table 4-3	Apsley Depression Loss - Estimation	40
Table 5-1	January 2011 event rainfall totals	42
Table 5-2	January 2011 Event – Rainfall AEP	43
Table 5-3	Rainfall Losses Applied to Scenarios	51
Table 5-4	Modelled Flood Depths at Assessed Locations	57



1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by West Wimmera Shire Council to undertake the Edenhope and Apsley Flood Investigation. Both Edenhope and Apsley are within West Wimmera Shire Council, located in Victoria's Wimmera region approximately 100 km southwest of Horsham. Both townships are also within the Wimmera Catchment Management Authority (CMA) management area and the Millicent Coast basin. Edenhope is the larger of the two townships with around 1,000 residents, located on the banks of Lake Wallace. Apsley is located 20 km west of Edenhope and has around 300 residents.

Both townships are known to be prone to stormwater flood events, with events recorded in 1971, 1973, 1975, 1981, 1991, 1993, 2011, 2016 and 2022. Edenhope is at risk from overland flow from a series of local undefined waterways and wetlands located to the southeast. Apsley is impacted by local waterways and drainage lines flowing towards Newlands Lake west of the township.

There is no current flood study for either of the townships, and current flood risk information is based on information from council, SES and the Wimmera Wetland Hydrology Investigation completed by Water Technology in 2019.

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 Edenhope and Apsley, investigate structural and non-structural mitigation options for each township. It will also produce planning scheme overlays for inclusion in the West Wimmera Shire Council planning scheme.

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

- **R01 – Data Collation, Model Development and Calibration Report – This report.**
- R02 – Design Modelling Report.
- R03 – Flood Intelligence Report & Municipal Flood Emergency Plan (MFEP) Documentation.
- R04 – Summary Report.

1.2 Study Area

Edenhope and Apsley are both are located within western Victoria. Their locations with respect to western Victoria is shown in Figure 1-1, with the study area for Edenhope and Apsley shown in Figure 1-2 and Figure 1-3 respectively.

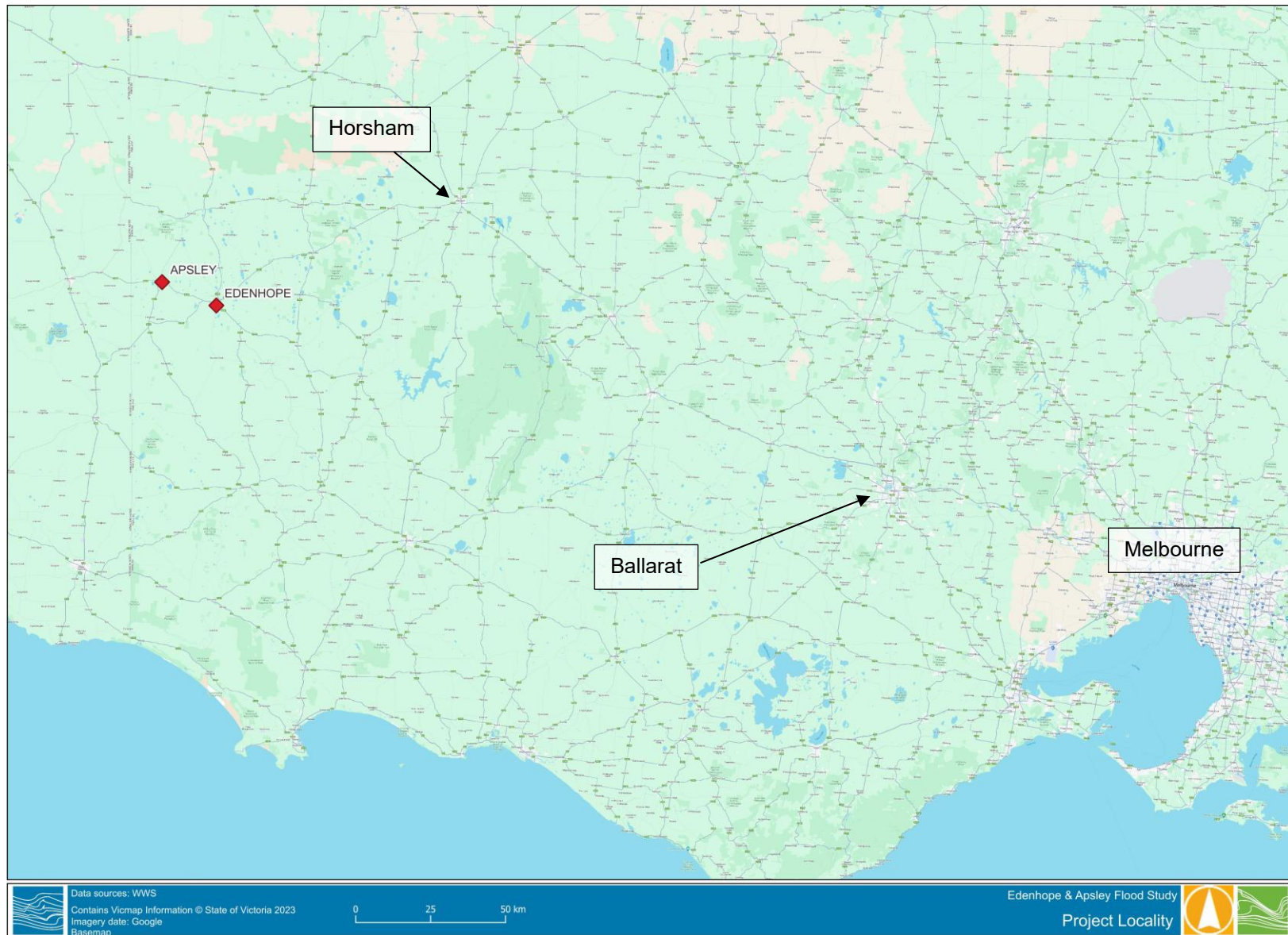


Figure 1-1 Edenhope and Apsley with respect to western Victoria



Figure 1-2 Edenhope Study Area

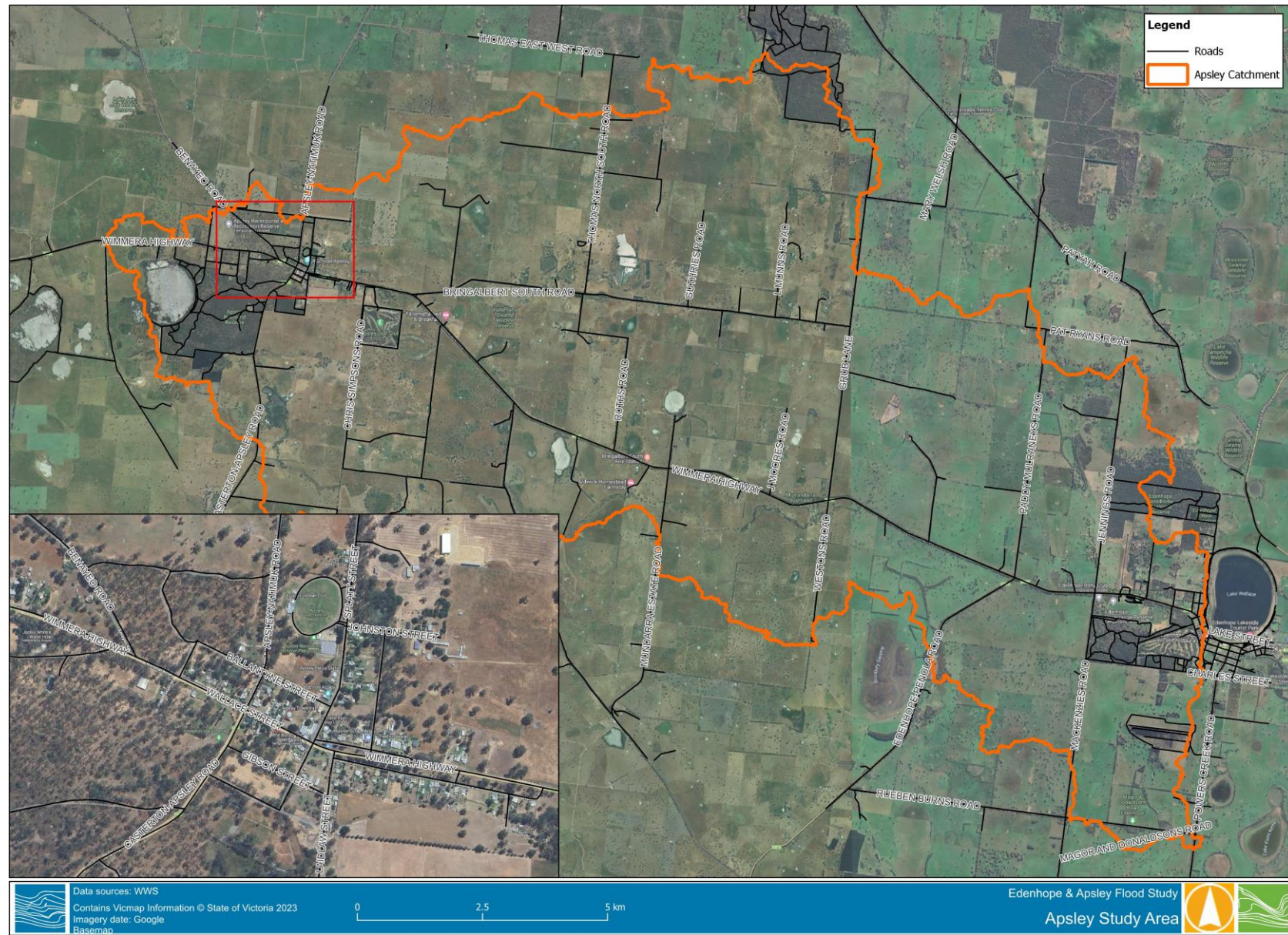


Figure 1-3 Apsley study area



2 DATA COLLATION AND REVIEW

2.1 Streamflow Data

There are no active or non-active streamflow gauges within the study areas or in any adjoining catchments.

2.2 Storage Data

There are two major water storages across the study area; Lake Wallace, within Edenhope and Newlands Lake immediately downstream of Apsley. There is limited recorded water level information available across both lakes but Lake Wallace does have opportunistic water level records or observed dates when the lake was either empty, full or overflowing. Most of this record has been extracted from newspaper articles/photos. Examples of this for Lake Wallace are shown in Figure 2-1 and Figure 2-2.

Key dates, data available and data source for each of the three wetlands are shown in Table 2-1.



Figure 2-1 Edenhope – Lake Wallace flood record



Figure 2-2 Edenhope – Lake Wallace Overflow Record



Table 2-1 Collated Lake Hydrology Data

Lakes Hydrology		
Lake Wallace		
Date	Date type	Source
1890 – 2018	Rainfall	BoM
1996 – 1997	Streamflow	Fawcett and Huggins
Drought (00 – 10)	Lake Dried	Lake Signage
2 Oct 1992	Overflow Flood	Lake Signage
19 Sept 1991	Overflow Flood	Lake Signage
27 June 1988	Overflow Flood	Lake Signage
7 Aug 1987	Overflow Flood	Lake Signage
20 Sept 1984	Overflow Flood	Lake Signage
19 Aug 1981	Overflow Flood	Lake Signage
4 Aug 1974	Overflow Flood	Lake Signage
27 Oct 1970	Overflow Flood	Lake Signage
7 Sept 1965	Overflow Flood	Lake Signage
27 Aug 1955	Overflow Flood	Lake Signage
11 Aug 1953	Overflow Flood	Lake Signage
10 Jul 1950	Overflow Flood	Lake Signage
23 Jul 1946	Overflow Flood	Lake Signage
17 Aug 1923	Overflow Flood	Lake Signage



Table 2-2 Summarised Lake Wallace Lake Level Information

Date	Level
1923-1946	Lake did not overflow
Sept 1984	'lake almost full to overflowing', good inflows
Oct 1984	Lake overflows
April 1987	Lake looks full
July 1987	Head of the Lake Regatta
Nov 1987	Lake full for sailing
? 1996	Lake almost full
Jan 2003	Shallow water in the middle, 'expected to go dry in a week'. 'Lowest in living memory'
Feb 2003	Dry for Henley on Lake Wallace
Feb 2003	Went dry on 7 Feb
March 2003	Dry, event on dry lake bed
Oct 2003	No water visible in photo of southern part of lake
Sept 2004	Shallow water in lake, drain flowing well into lake
Jan 2005	Photo of shallow water in the lake
Jan 2007	Lake burnt for fairy grass
June 2007	No water visible in photo of southern part of lake
Sept 2007	Small area of shallow water with swans building nests
Dec 2007	Dry Lake sprayed for fairy grass
Sept 2008	Back Swamp full but not much in Lake Wallace
March 2009	Aerial photo shows lake is dry
Oct 2009	No water visible in photo of northern part of lake
Nov 2009	No water visible in photo of southern part of lake
May 2010	Small concrete barrier built in virtually dry drain into lake to retain water in drain
Sept 2010	'About 4 foot deep'
Oct 2010	Shallow water visible in photo
Dec 2010	Shallow water visible in photo
Feb 2011	'About 1/3 full'
March 2011	'About 6 feet of water'
Jan 2014	Photo of shallow water in the lake
April 2014	Photo of shallow water in the lake
Oct 2014	Water in the lake near the bottom of the pier, 'about half full'
Feb 2015	Water in the lake about 30 m from the bottom of the pier



2.3 Rainfall Data

Historic daily and sub daily rainfall data is required for the hydrologic and hydraulic model calibration. Daily rainfall gauges are used to provide a representation of spatial rainfall variation while sub daily gauges provide a representation of temporal rainfall distribution. Daily gauges used in this investigation are outlined in Table 2-3 and Figure 2-3, with only Edenhope Airport (bolded) recording sub-daily information.

Table 2-3 Daily rainfall station information

Station Name & No.	Dist. From Apsley	Dist. From Edenhope	Start	End
Apsley Post Office, 079071	0.6 km	19.9 km	1953	Open
Apsley, 079001	3.4 km	17.3 km	1883	1947
Edenhope Airport, 079099	13.1 km	2.9 km	2005	Open
Edenhope Elizabeth Street, 079011	16.6 km	1.0 km	1890	Open
Benayeo, 079083	13.1 km	31.1 km	1972	Open
Patyah, 079107	22.9 km	25.3 km	1998	Open
Poolaijelo, 090164	23.5	24.8 km	1974	Open
Karnak (Rosedale), 079025	37.4	25.2 km	1890	2014
Harrow (Pine Hills), 079021	44.5	30.1 km	1884	2011

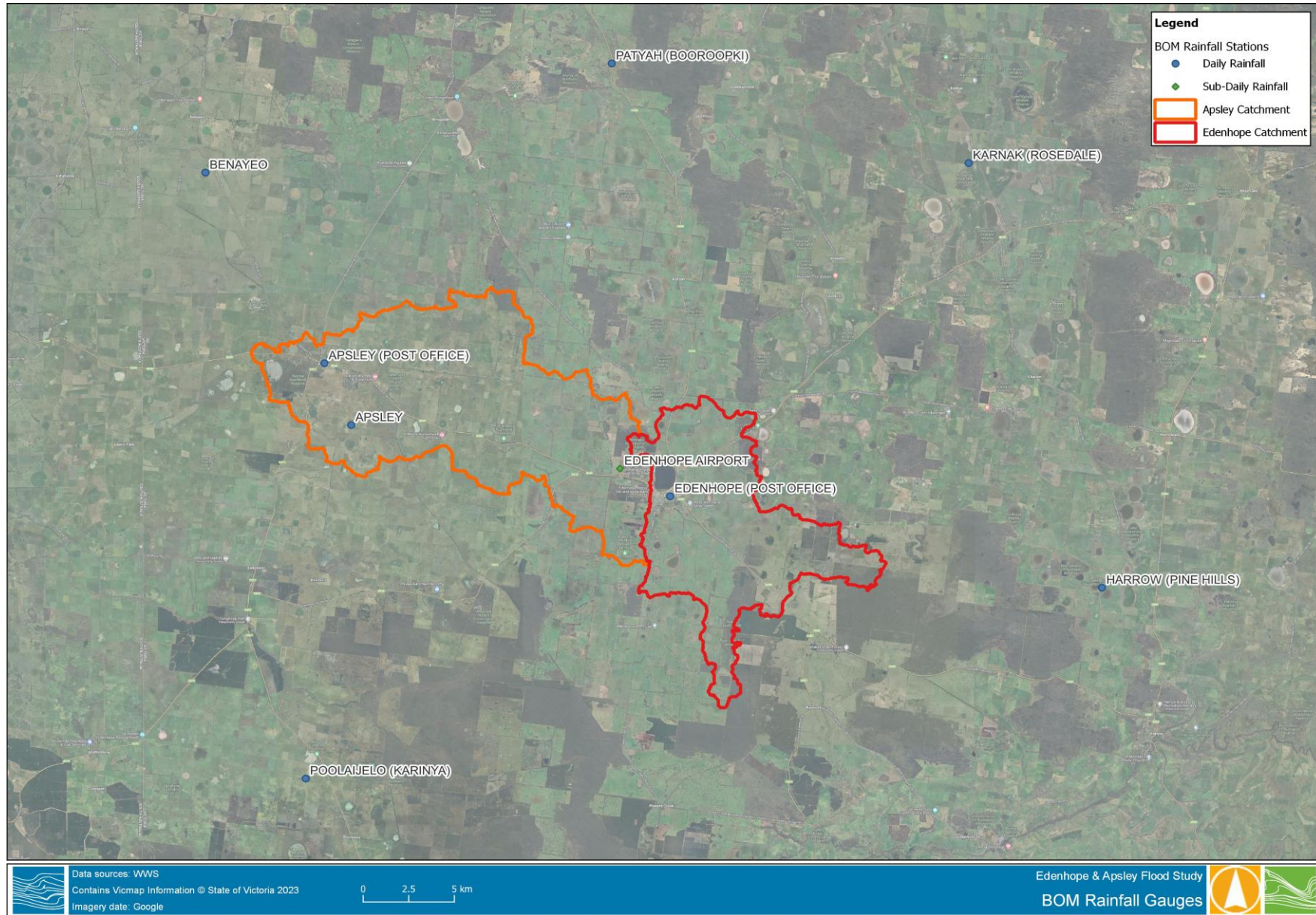


Figure 2-3 Rainfall gauges relevant to Edenhope and Apsley



2.4 Drainage Infrastructure

Both Edenhope and Apsley have township scale stormwater infrastructure. The infrastructure within Apsley is generally limited to open roadside drainage and bridges/culverts under roads. Given Edenhope is larger, it has a more developed infrastructure system with an interconnected pipe and pit network. The drainage infrastructure is discussed later as part of the model schematisation in Section 4.4.

2.5 Topography Data

There were two topographic datasets available for development of the Edenhope and Apsley hydraulic models:

- VicMap 10m digital terrain model
 - Elevation digital terrain model (DTM) with a 10-metre resolution providing a raster representation of the broader area. The vertical and horizontal accuracy is coarse at ± 5 m and ± 12.5 m, respectively, relative to the Australian Height Datum (AHD). The DTM extends across the entire catchment.
- The 2006 Wimmera CMA -Wimmera Mallee Pipeline Project LiDAR.
 - Elevation DTM with a 2 metre resolution providing a raster representation of the area. The vertical and horizontal accuracy is ± 0.4 m and ± 0.15 m, respectively, relative to AHD. The DTM extends across the entire catchment.

The 2006 Wimmera CMA LiDAR was used as the primary topography in this project. The topography in the Edenhope and Apsley catchments is shown in Figure 3-1 and Figure 3-2 respectively.

2.6 Stage 1 Community Consultation

2.6.1 Overview

Community consultation was held in both Edenhope and Apsley over alternate afternoons. The intent of the consultation was to inform the community of the study and to gather any information the community may have on historic flooding, frequency of flooding, any specific areas which are at a particular risk of flooding and potential flood mitigation ideas.

2.6.2 Edenhope

A community consultation session for Edenhope was held in the Edenhope Community Centre, on the 27th of November 2023. During the consultation two members of the community attended, residents of Laidlaw Avenue. The residents had moved to Edenhope recently and did not provide information on historic flooding within Edenhope. They were able to provide insight on flood behaviour on Laidlaw Avenue, with it understood that the local drainage network results in water pooling on the upstream side of Laidlaw Avenue and Macquarie Street.



2.6.3 Apsley

A community consultation session for Apsley was held in the Apsley Hall, on the 28th of November 2023. This community consultation was attended by with multiple residents. The attendees were able to provide significant insights into flood behaviour within the township, providing information on inundation mechanisms, consequences and mitigation options. The following information was gained and corroborated by multiple members of the community:

- The township of Apsley has an extensive history of flooding as “it was built in a swamp”. When first settled the creek that is now diverted under the Wimmera Highway, flowed through the township. This led to regular flooding, with the school having to be moved as a result. Since this time, the creek diversion was constructed, with flows from Edenhope intended to be diverted to Lake Newlands around the township. It is noted that during significant flood events the capacity of this diversion is exceeded, exacerbated by a loss of capacity of the diversion via silting, vegetation and a lack of continued maintenance.
- The most recent flood events occurred in 2011 and 2016, with 2011 representing the largest of the two. During this flood it is understood the following occurred:
 - Parts of Apsley Football Club rooms were inundated, with sandbagging required.
 - Properties along Wallace Street were inundated, some protected via sandbagging and pumping.
 - Fences along flow paths were cut to remove blockages.
 - Properties on the southern side of Ballantyne Street, experienced flooding as the channel that drains around town, backed up and overtopped flowing into the township.
 - Properties along Splatt Street experience overland flow spilling from the Church Water Hole.
 - Blockages and inefficiency in the drainage network led to a worsening of flood conditions. Several members of the community explained that when the drains were regularly maintained the issues experienced in 2011 and 2016 were not as severe.



3 CATCHMENT ANALYSIS

3.1 Catchment and Characteristics

Apsley and Edenhope have two unique catchments, with several depressions located upstream of both townships scattered throughout the catchments. The size of these depressions varies with some relatively shallow and others covering a significant area. The nature of the township's catchments has been formed over thousands of years, with both catchments located within North Western Dunefields and Plains¹².

The Northwestern Dune fields and Plains cover north-western Victoria as part of the Murray Basin. This area was once submerged by the ocean, with the series of ridges and depressions across the landscape formed as the ocean retreated. Through this process, the series of depressions and ridges that are scattered across the township's catchments were formed³. These series of depressions have resulted in both catchments having significantly more storage, than other catchments in Victoria. As such, the amount of run-off flowing toward the townships is dependent upon the connectivity of these depressions and their antecedent water levels prior to a flood event.

The larger ridgelines surrounding Edenhope to the south and west, provide evident catchment divides for the two townships. The identified catchments and topography for Edenhope covering 98 km² and Apsley covering 168.7 km² are provided in Figure 3-1 and Figure 3-2, respectively. However, for both townships the actual area contributing to run-off is dependent upon the upstream connectivity, with many potential semi-terminal depressions located within the catchments. There are locations within the catchment, that require metres of water prior to spilling into the downstream catchment. Further discussion around the influence of these depressions are provided Section 3.3.

¹ https://vro.agriculture.vic.gov.au/dpi/vro/wimregn.nsf/pages/soil_landform_apsley_plains

² https://vro.agriculture.vic.gov.au/dpi/vro/wimregn.nsf/pages/soil_landform_edenhope

³ https://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphological_framework_5

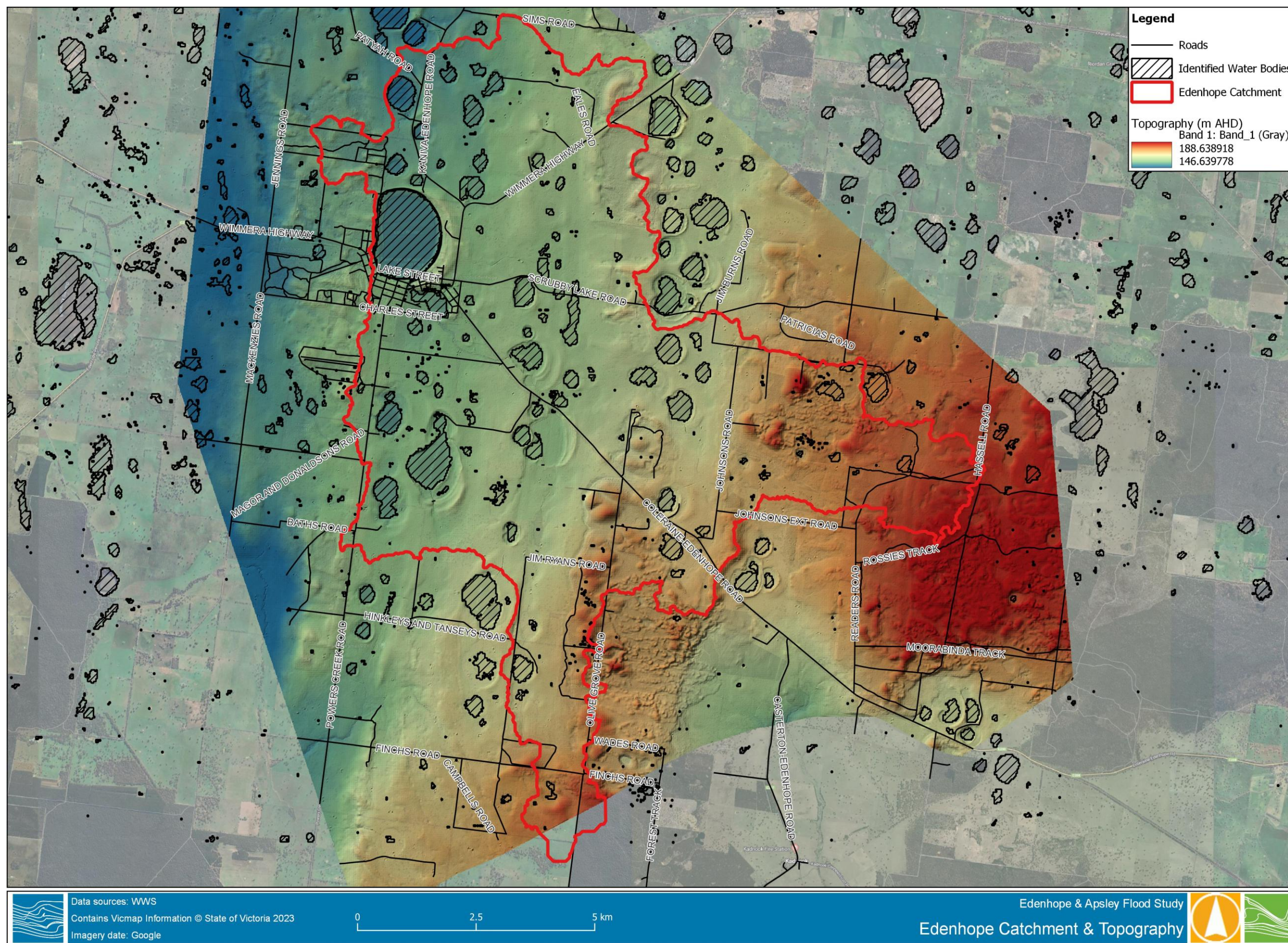
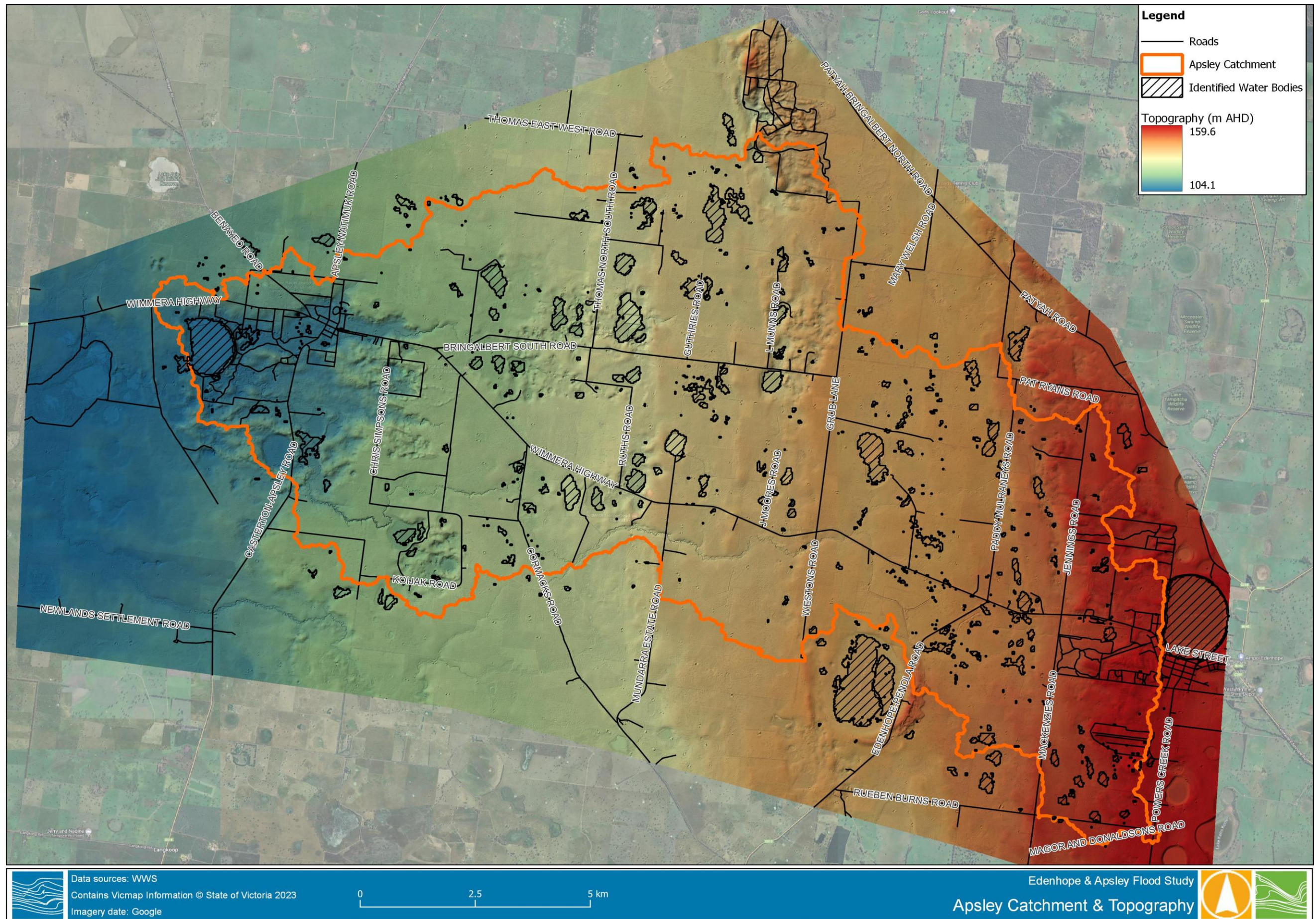


Figure 3-1 Edenhope Catchment and Topography



324-03-14T15:20:08.572

Figure 3-2 Apsley Catchment and Topography



3.2 Historic Events

As discussed in Section 2.1, there are no stream gauges located within the two catchments of interest, as such historic flood events have been identified based upon local rainfall gauges, Lake Wallace water level records and consultation with the community. During the initial community consultation, there was little information gained on prior flood events within Edenhope. Whereas several members of the Apsley community were able to provide a vast history of flooding within the township.

The community were able to provide outstanding historic flood information for Apsley, with the original school having to be moved, after it was impacted multiple times in the late 1800's. The local community explained prolonged wet periods and rainfall events have a significant impact on the township.

The following recent flood events have also impacted the township of Apsley:

- September 2016.
- January 2011 – understood to be the largest flood in recent times.

Rainfall records for Apsley and Edenhope are provided in Table 3-1 and Table 3-2 respectfully. This demonstrates the January 2011 event was the largest event on record within Apsley, while in November 1970 both townships experienced significant rainfall. However, it is noted the impact of the 1970 event is unknown for both townships.

Table 3-1 Apsley Rainfall Records

Event Rank	Date of Rainfall	Gauge	Total (mm)
1	14/01/2011	Apsley Post Office, 079071	115
2	16/11/1970	Apsley Post Office, 079071	96.8
3	8/12/1986	Apsley Post Office, 079071	78
4	16/12/1930	Apsley, 079001	76.7
5	20/03/1941	Apsley, 079001	76.7
6	6/06/1988	Apsley Post Office, 079071	64.4
7	22/01/2007	Apsley Post Office, 079071	62
8	5/04/1907	Apsley, 079001	59.4
9	8/06/1889	Apsley, 079001	56.9
10	20/07/1906	Apsley, 079001	56.6
11	14/12/2008	Apsley Post Office, 079071	55.5
12	15/10/1889	Apsley, 079001	54.6
13	22/04/1896	Apsley, 079001	53.8
14	1/04/3789	Apsley, 079001	53.3
15	26/04/1971	Apsley Post Office, 079071	51.6



Table 3-2 Edenhope Rainfall Records

Event Rank	Date of Rainfall	Gauge	Total (mm)
1	16/11/1970	Edenhope Elizabeth Street, 079011	100.6
2	9/06/1980		88
3	6/03/1910		81.8
4	21/04/1980		77
5	27/10/1973		73.7
6	18/04/1938		72.4
7	14/01/1974		69
8	22/01/2007		67.8
9	16/03/1946		66.5
10	10/04/1978		66
11	5/06/1988		64.8
12	19/01/1946		63
13	19/01/1946		63
14	8/12/2010		61.4
15	14/01/2010		61.4

3.3 Antecedent Conditions

As discussed in Section 2.5, the Edenhope and Apsley catchments contain multiple depressions creating a series of swamps, wetlands and lakes all which provide significant catchment storage. Many of these depressions are ephemeral, only experiencing pooling water in periods of prolonged rainfall. The complex connectivity of these wetlands influences flood behaviour within both townships.

In general, major flood events within south-eastern Australia are more likely to occur in periods of prolonged rainfall and wet climatic conditions. While no stream flow gauges are available, an analysis of the record rainfall totals at Apsley against climatic conditions and prior rainfall, indicate that record totals tend to occur during La Nina periods and when there has been a period of rainfall (Table 3-3). Normally, flood modelling and analysis considers this weighting toward wet conditions and adjusts parameters accordingly to produce mapping that is representative of the joint probability of the many variables when an event occurs. For this reason, design mapping will always vary from historical events. While this approach is appropriate in standard catchments, where flood consequences are primarily driven by runoff volume, for Edenhope and Apsley upstream flooding is more likely driven by the connectivity of the upstream system during an event.

For example, the largest flood (in recent times) experienced within Apsley is understood to be the January 2011 event. Prior to this event occurring, the largest monthly total for December (2010) was recorded. Satellite imagery captured on the 3rd of January 2011, identified water within most of the upstream depressions (Figure 3-3). In comparison, satellite imagery captured on the 16th of January 2007, prior to the rainfall event in January 2007, which occurred after a dry period, captures significantly less water in the upstream catchment (Figure 3-3). Further indication of the sensitivity due to variation in catchment conditions, is the flooding experienced in September 2016. While the recorded rainfall was relative frequent, the upstream catchment conditions evidently had a significant impact on flood behaviour and consequence.

This variation of catchment storages volume, vegetation and soil, has implications on flooding within the townships and while flooding has the tendency to occur during wet conditions, there is always the potential for



a rainfall event to occur during a dry period. To account for this uncertainty sensitivity analysis will be required during design modelling. Satellite imagery will be used to provide an understanding of potential antecedent catchment conditions. The datasets proposed to be used for the sensitivity analysis include:

- Digital Earth Australia (DEA) Water Observation Multi Year⁴ – this dataset provides the frequency at which satellite imagery captured water within the various depressions. It is proposed to be used to assess extreme conditions, adopting water where observations have occurred less than 1% of the time, Figure 3-4.
- DEA Wetness Percentiles⁵ – this dataset provides 10th, 50th and 90th percentiles of “wetness” within the area. It is proposed to be used as the basis of sensitivity analysis, with the three used to identify starting conditions within the depressions. The 90th percentile output is provided in Figure 3-5, noting that this output will be filtered to water bodies only.
- Note, the DEA Water Observation dataset, could also be varied to capture initial conditions for a range of conditions. A comparison of the two datasets is provided in Figure 3-6. It demonstrates that the datasets reasonably align with one another.

It is considered likely that flood response planning in Apsley and Edenhope will likely have to consider both forecast rainfall and antecedent conditions to accurately assess the risk of inundation. This assumption will be analysed in the design modelling phase of this investigation.

Table 3-3 Rainfall and Catchment Conditions Analysis

Date	Highest Rainfall Recorded at Apsley Post Office	24hr IFD	Edenhope (Elizabeth)	24hr IFD	Prior Month Total Apsley Post	Prior Month Percentile for Apsley	Climate Condition
14/01/2011	115	~ 0.5%	61.4	~ 10%	135.90	Largest	La Nina
16/11/1970	96.8	~ 1%	100.6	~ 1%	23.90	50th	La Nina
8/12/1986	78	~ 2%	8.8	~ 12EY	15.80	50th	Negative
6/06/1988	64.4	~ 5%	20.6	~ 4EY	124.60	Largest	La Nina
22/01/2007	62	~ 10%	67.8	~ 5%	6.20	25th	Negative
14/12/2008	55.5	~ 10%	0	N/A	27.10	75th	La Nina
26/04/1971	51.6	~ 20%	34.3	~ 50%	25.70	90th	La Nina
14/01/1974	49	~ 20%	69	~ 5%	27.20	75th	La Nina
8/12/2010	48.4	~ 20%	61.4	~ 10%	51.00	90th	La Nina
13/07/1964	47.5	~ 20%	57.2	~ 10%	102.40	95th	La Nina
9/09/2016	37.5	~ 50%	46.0	~ 20%	115.20	Largest	Positive

⁴ <https://knowledge.dea.ga.gov.au/data/product/dea-water-observations-statistics-landsat/?tab=overview>

⁵ <https://maps.dea.ga.gov.au/#share=s-mYmYKh57NcZV7nUN8vaV52ZNO5S>

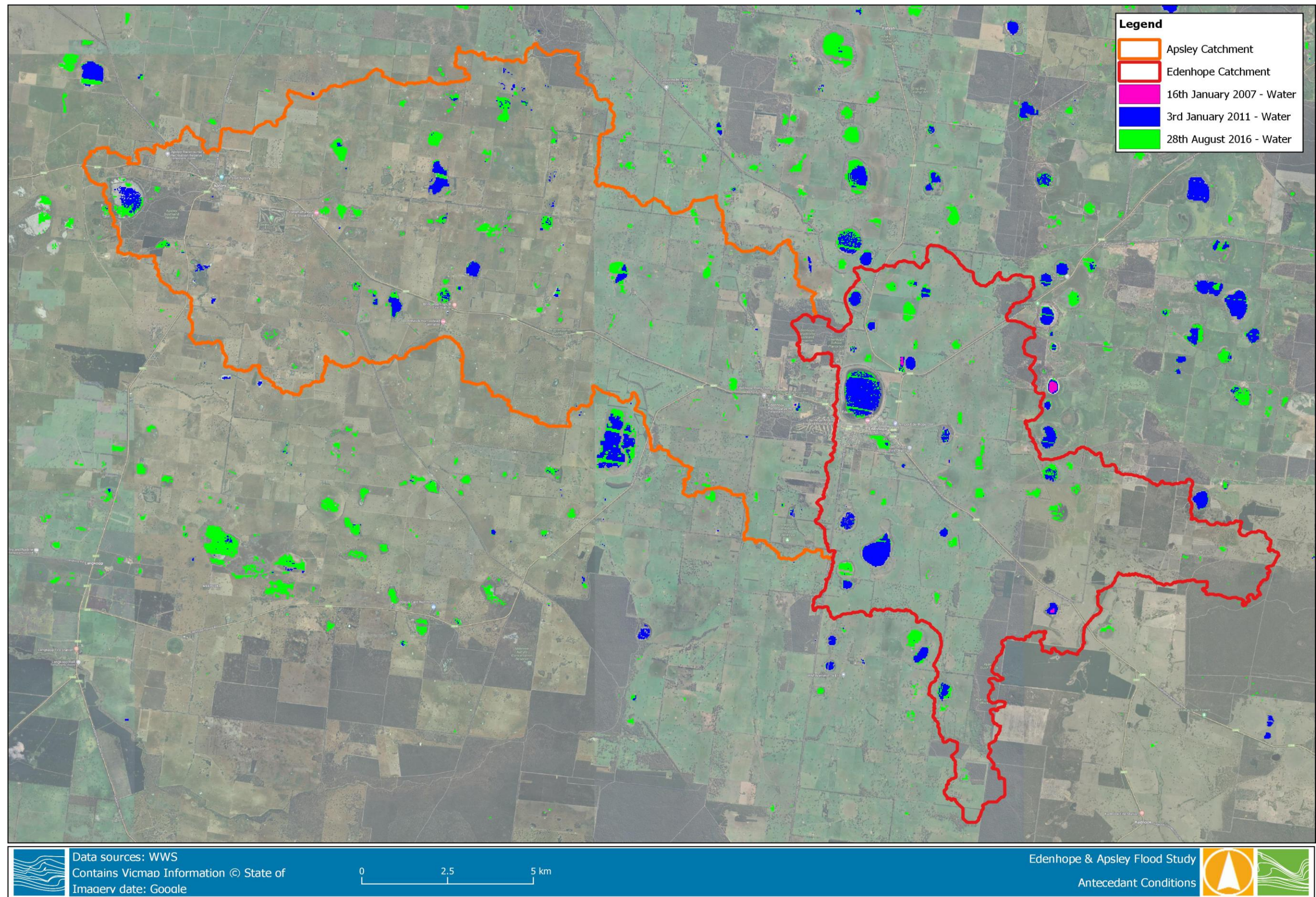


Figure 3-3 Antecedent Conditions - Comparison

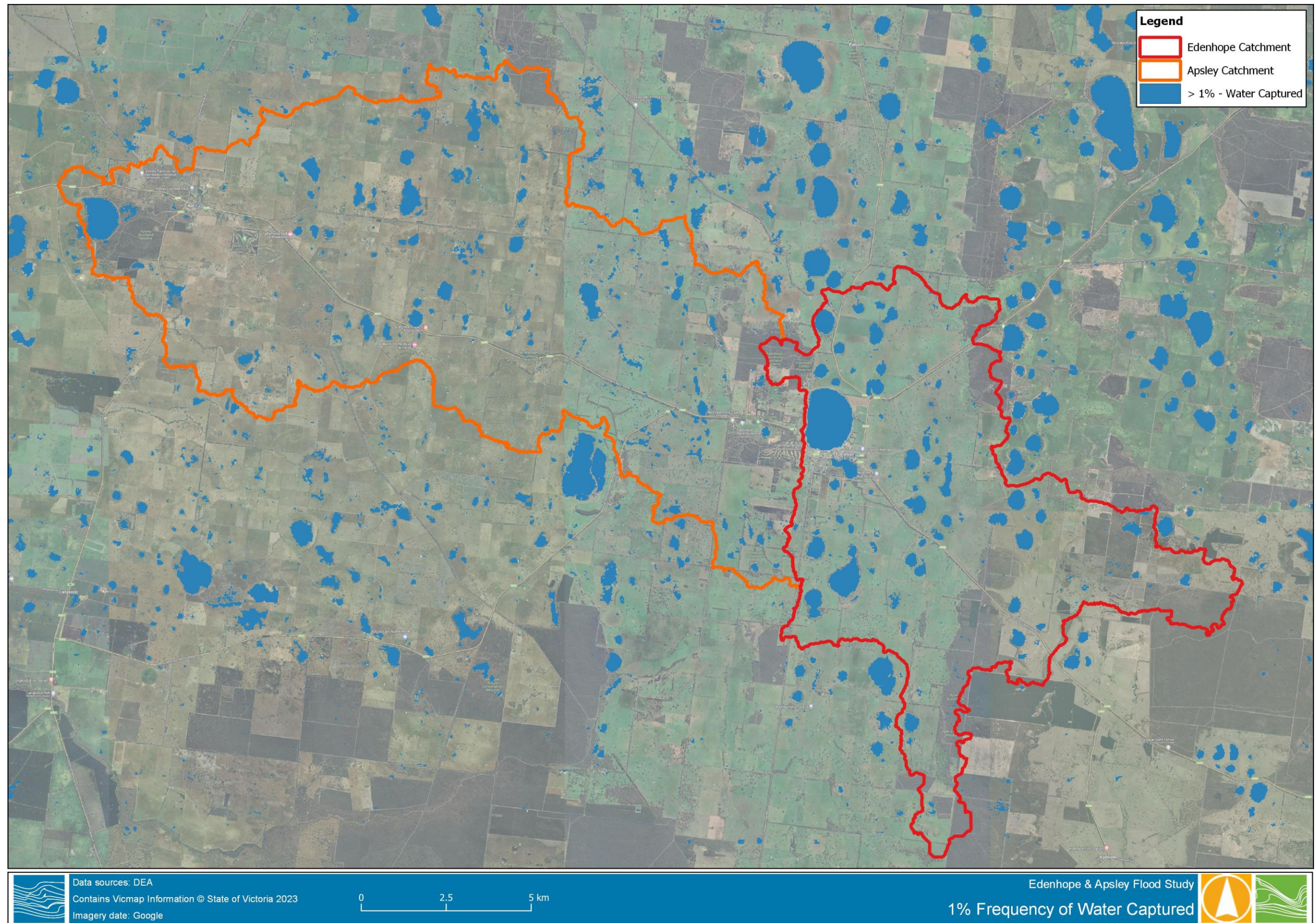


Figure 3-4 DEA Water Observation – 1% Return Frequency

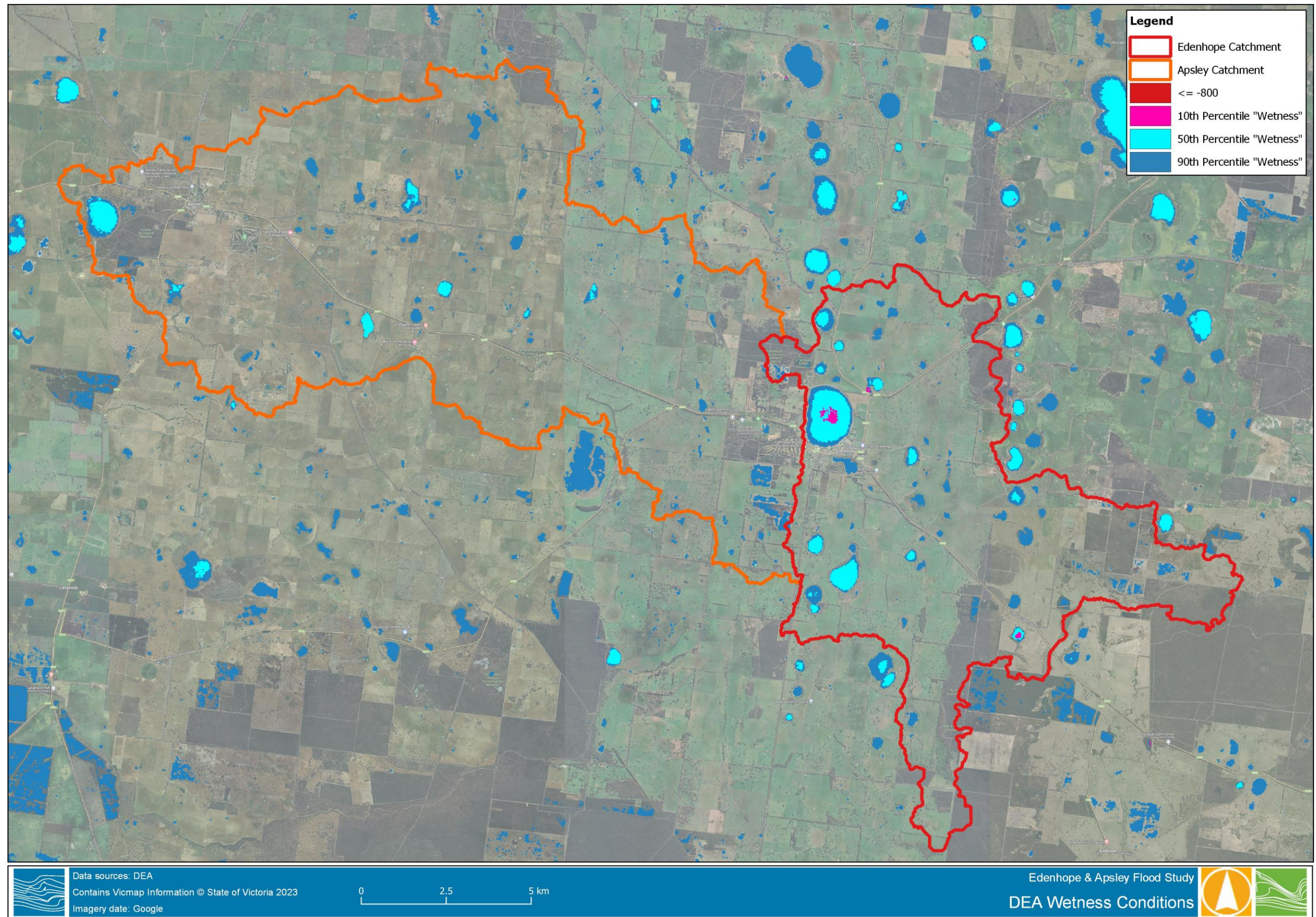


Figure 3-5 DEA Wetness Percentile – 10th, 50th and 90th for Water Bodies

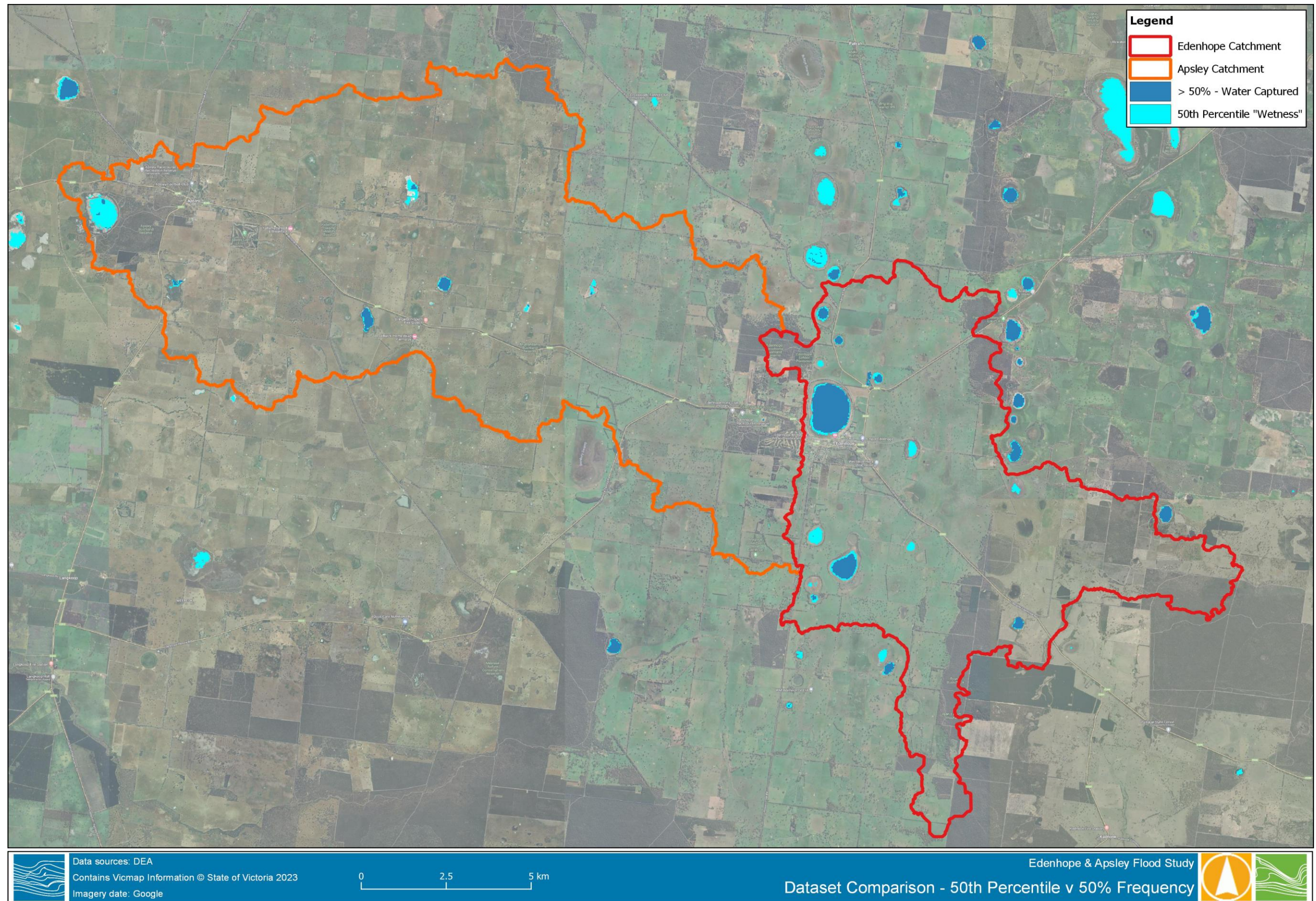


Figure 3-6 Comparison of Datasets



4 HYDRAULIC MODELLING

4.1 Model Extent and Structure

A 1D/2D TUFLOW model was developed for each study area, encompassing the catchments upstream of both Edenhope and Apsley. The model extents were determined based on the topography, ensuring the entire upstream catchments were included.

The models were developed for use in the TUFLOW HPC hydraulic modelling software. The model topographies were represented with a varying resolution (using Quadtree), with a cell size of 12 m outside of the township and 3 m within the township and local catchment. The ability for the resultant model grid to capture finer details was supported by Sub-Grid-Sampling (SGS) of the underlying topography datasets, which is based on detailed 2 m LiDAR.

The models adopted a Rain-on-Grid (RoG) approach will be used to directly apply rainfall to the study areas. This modelling approach will provide a better understanding of overland flow and drainage paths through the townships. RoG was considered more appropriate than standard hydrologic models, due to the complexities around connectivity created by the various upstream storages. The adoption of RoG modelling identifies how these storages connect based on the topography.

The models adopted outflow boundaries at the downstream extent, located downstream of Newlands Lake Reserve and Lake Wallace, respectively. These outflow boundaries adopted a water level vs flow (stage-discharge) curve calculated from the topography. The influence of these boundaries was controlled by the two upstream lakes, which both act as natural controls to upstream flooding.

The two model schematics are presented in Figure 4-1 and Figure 4-2.

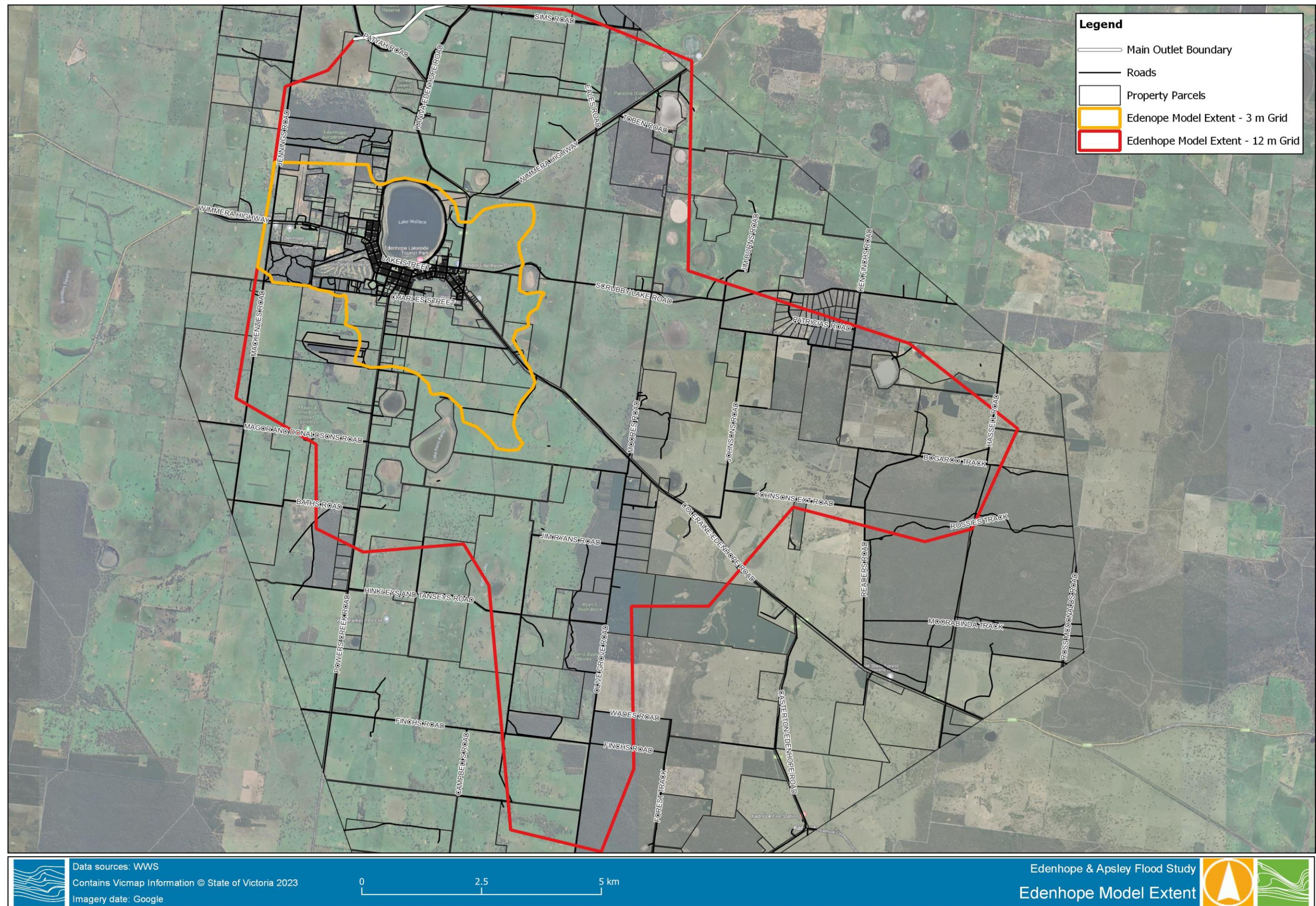


Figure 4-1 Model Schematic – Edenhope

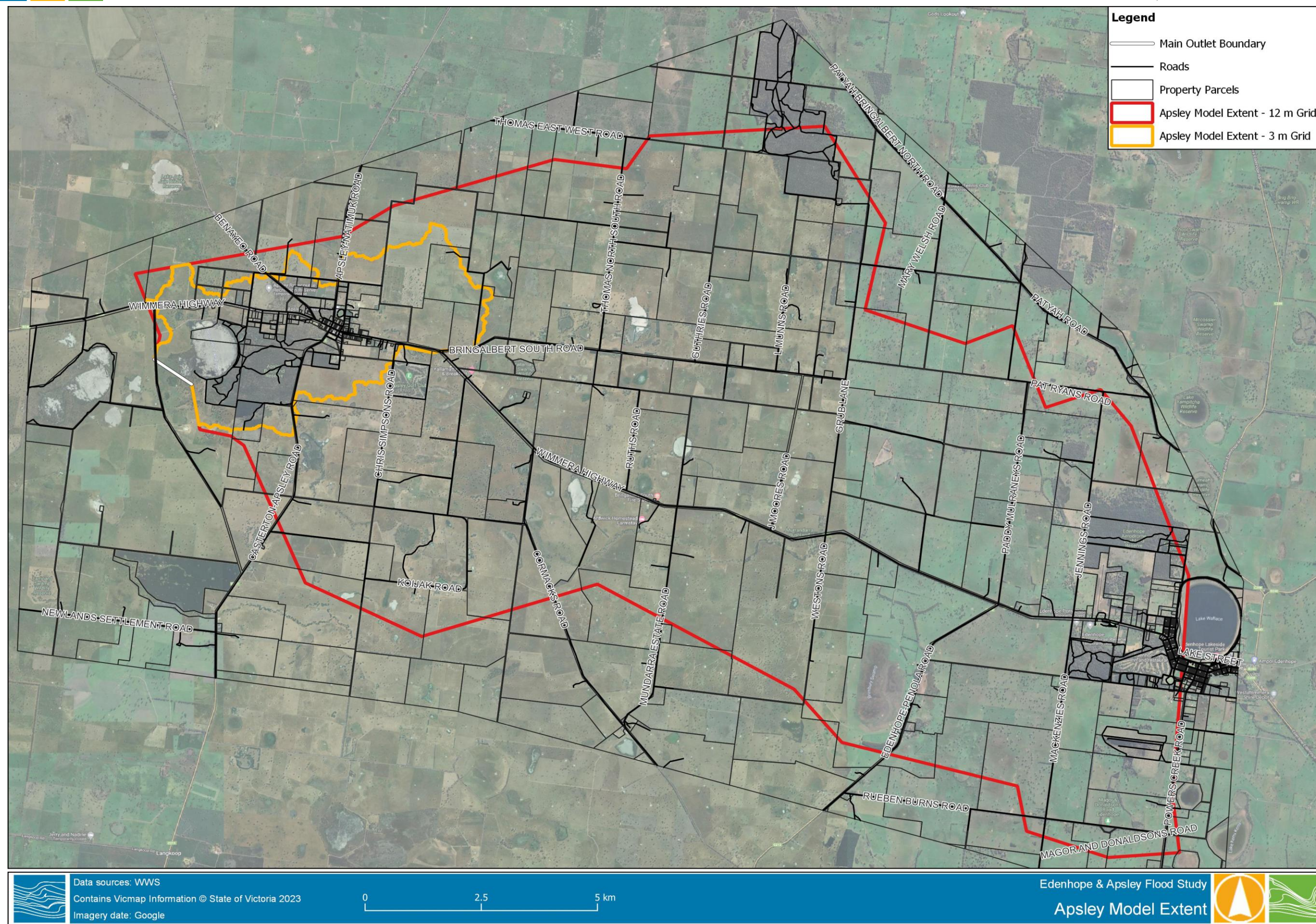


Figure 4-2 Model Schematic – Apsley



4.2 Model Topography

The model was primarily based upon the Wimmera CMA LiDAR dataset (2006). The Wimmera CMA LiDAR covered the entirety of the townships and most of their respective catchments. Areas not covered by the Wimmera CMA LiDAR adopted the VicMap 10m DEM. While the LiDAR was the primary source of topographic information, the model topography was further refined where more accurate or appropriate data was available. The main adjustment made to the LiDAR was the removal of water from storages or works known to have been undertaken. Figure 4-3 provides an overview of the model topography development.

The topography of the catchments was previously shown in Figure 3-1 and Figure 3-2.

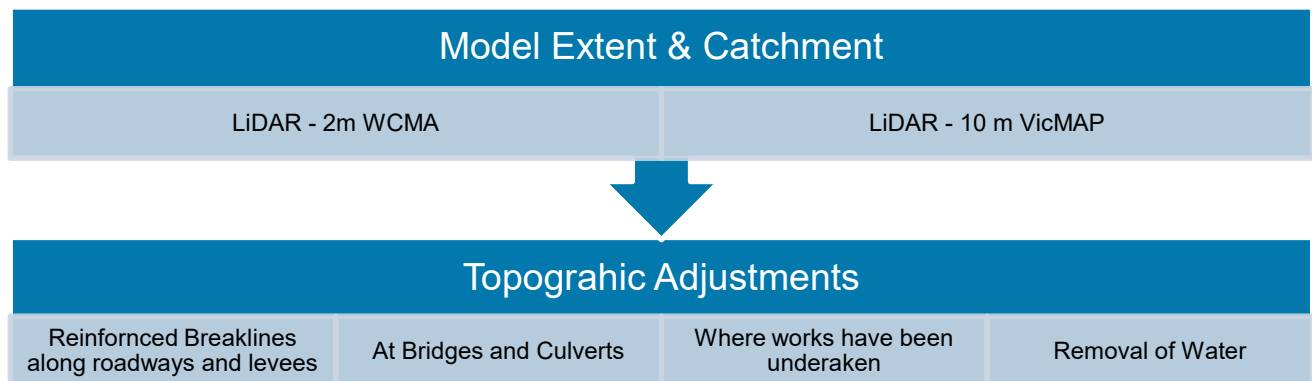


Figure 4-3 Model Topography Methodology



4.3 Model Roughness

A key component of a hydraulic model is the land use types represented with a 2D materials layer, determining the Mannings 'n' roughness (surface resistance) for each part of the TUFLOW model. The roughness value varies between land uses. In general terms, a lower Manning's 'n' value represents a more efficient flow surface (e.g. a roadway), while a higher Manning's 'n' value represents a rougher and slower surface (e.g. dense vegetation). For this investigation, a roughness map was developed based upon aerial imagery. The adopted Manning's 'n' values are presented in Table 4-1 and shown spatially in Figure 4-4 and Figure 4-5.

Table 4-1 Land Use Manning's 'n' Roughness values

Material	Manning's 'n' value
Rural Residential	0.1
Pasture	0.04
Dense Vegetation	0.095
Waterway Channel	0.03
Roadway (Paved)	0.025
Roadway (Unpaved)	0.035
Lake / Swamp / Wetland	0.05

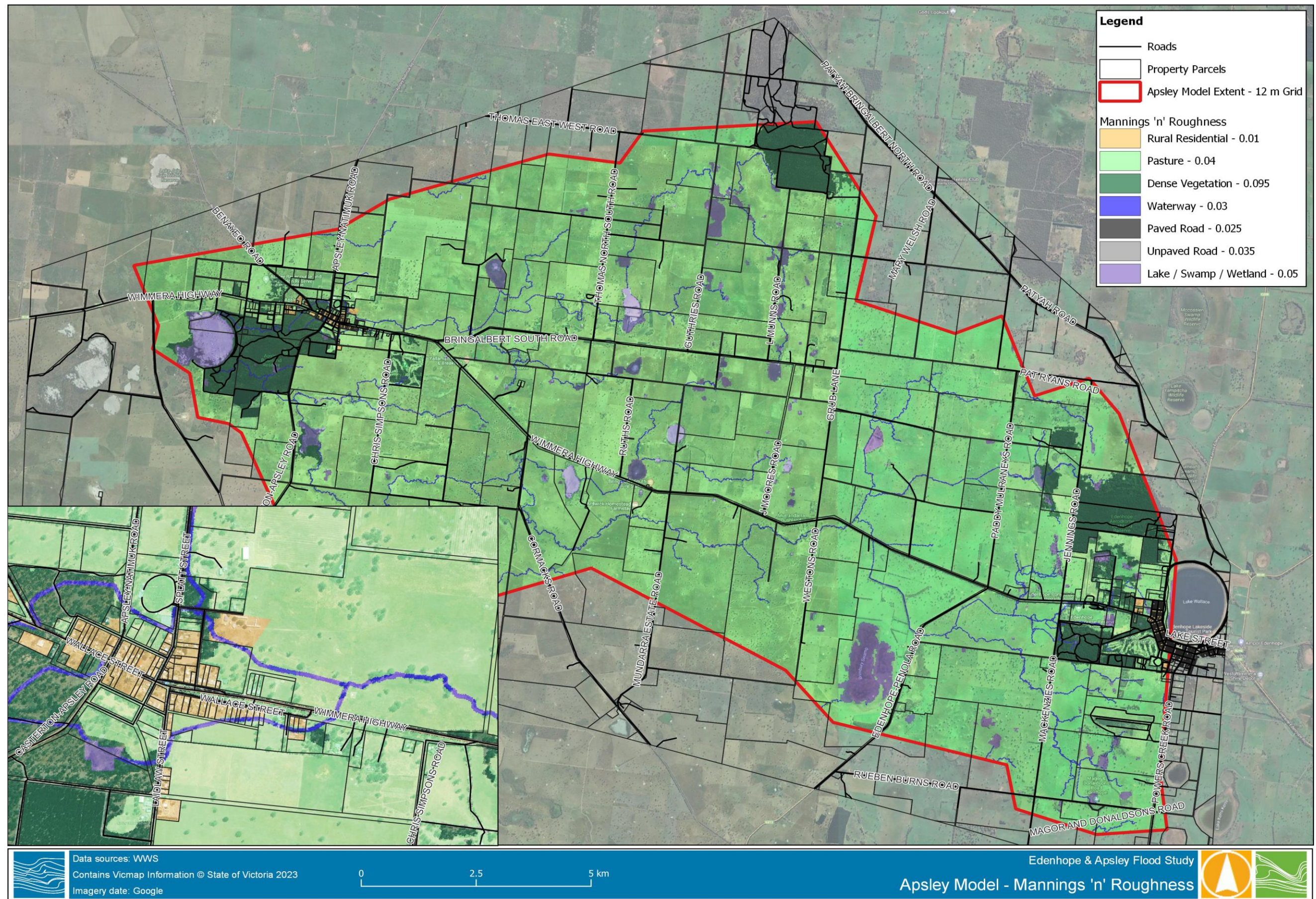


Figure 4-4 Apsley – Model Roughness

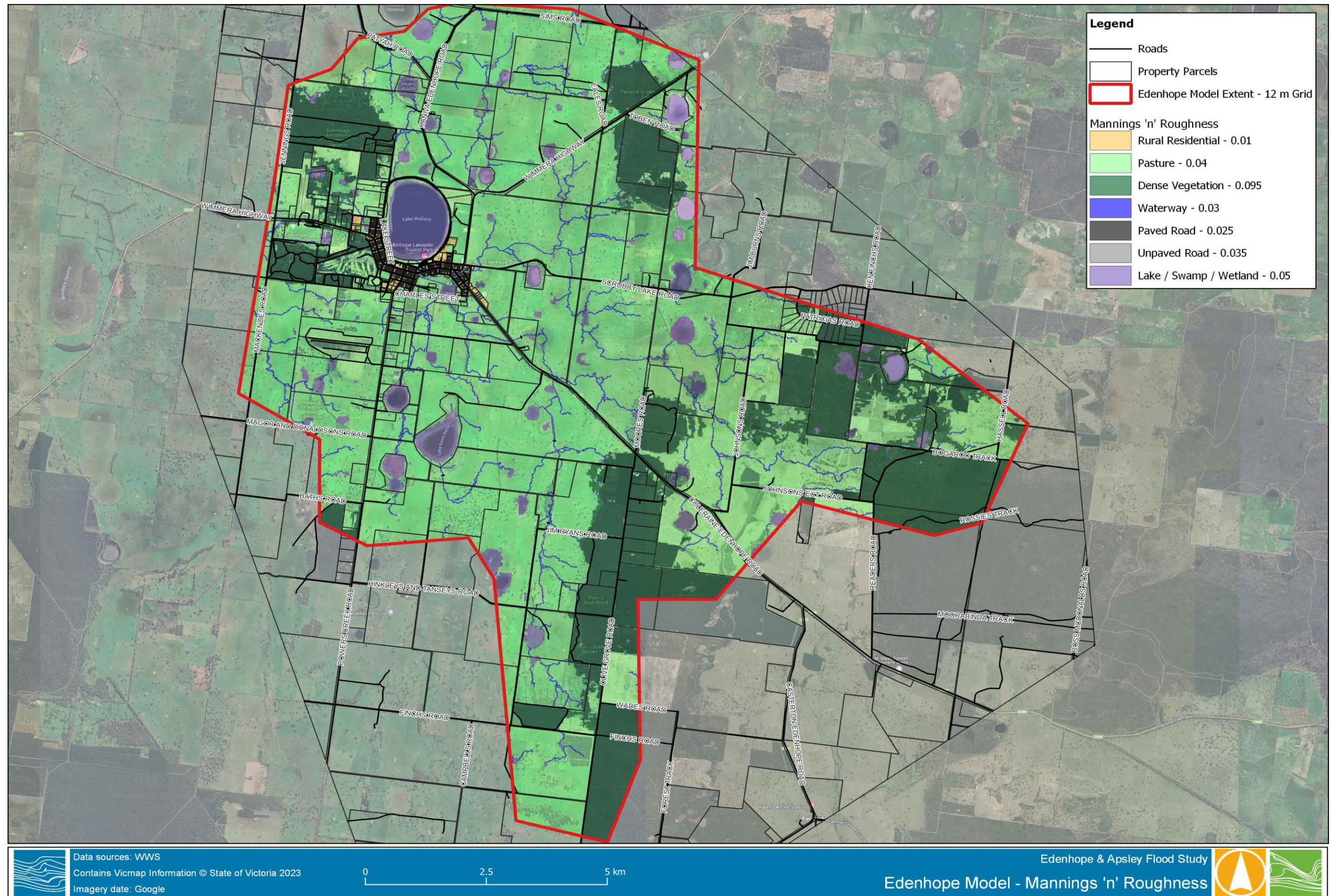


Figure 4-5 Edenhope – Model Roughness



4.4 Model Structures

The drainage infrastructure in both Edenhope and Apsley consists of open drains, pipes, pits and bridges. The major drainage network (pits and pipes) was provided by WWSC, with the invert levels estimated based on the topography, incorporating a standard cover. Additional bridge and culvert measurements were obtained during the site visit. In total, the Edenhope model incorporates 211 pipes, 150 pits and 5 bridges. While the Apsley model incorporated 42 pipes and 13 pits. Upstream of the two townships where flow paths intercepted roadways crossing were artificially removed to ensure connectivity, unless other information was known. The blockage from the roads was incorporated by applying additional bridge structure at these locations. The modelled (township) infrastructure is provided in Figure 4-6 and Figure 4-7.



Figure 4-6 Apsley Modelled Structures



Figure 4-7 Edenhope Modelled Structure

4.5 Rainfall Losses

Rainfall losses are an important component of flood modelling. The standard approach to simplify the complex relationship between rainfall and runoff, is the empirical method of Initial Loss (IL) and Continuing Loss (CL). This method primarily focuses on the resultant flow and does not represent the processes. Adjusting these losses determines the volume of rainfall that is converted to runoff. The processes represented by the losses are (Figure 4-8):

- Initial Loss – represents rainfall captured at the beginning of the event captured by:
 - Interception from vegetation.
 - Retention by storages on surface.
- Continuing Loss – represent rainfall lost during an event:
 - Infiltration and Evaporation⁶.

This method is widely adopted for flood investigations and is the recommended procedure in Australian Rainfall Runoff guidelines, with recommended design losses available online⁷. The recommended losses for Edenhope and Apsley are provided in Table 4-2. These losses have been determined based on a regression analysis of 11 catchments within Region 3, using soil moisture in winter, design rainfall and the soil storage as variable to calculate IL and CL. While this method is appropriate for many catchments, the Apsley and Edenhope catchments are expected to have significantly higher retention losses.

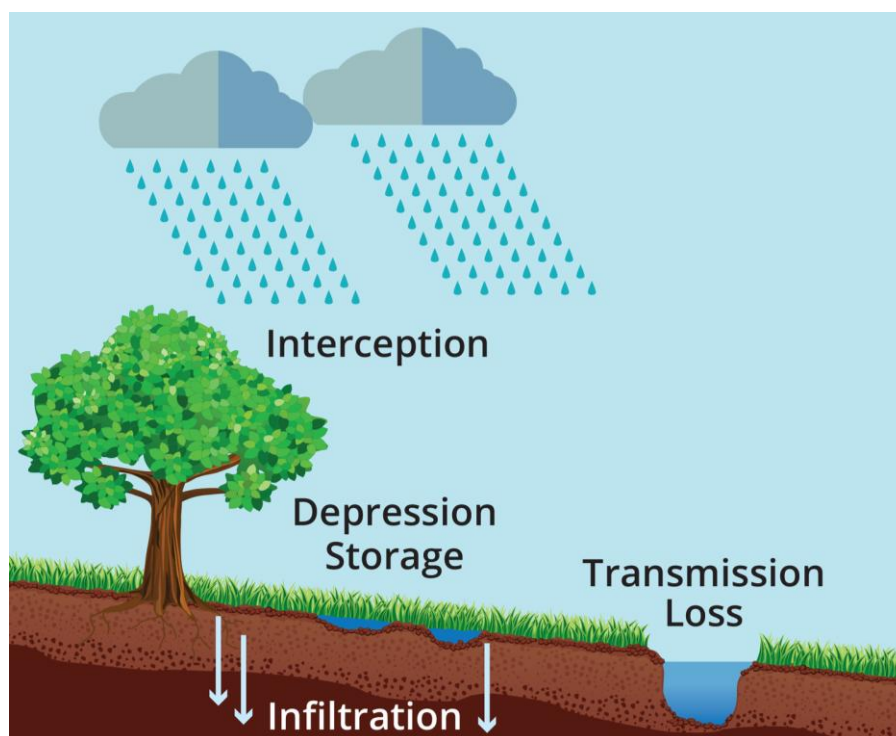


Figure 4-8 Rainfall Loss Processes (Source: ARR2019, Book 5)

⁶ Chapter 3, Book 5: <http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/>

⁷ <https://data.arr-software.org/>



Table 4-2 Edenhope and Apsley Infiltration Loss Values

	Initial Loss (mm)	Continuing Loss (mm/hr)
ARR Recommendation	21	4.8

To analyse the depression loss potential within the Apsley catchment the catchment topography, preliminary mapping and DEA water observations datasets were used to identify potential water storages and their respective volumes. The volumes were calculated for a range of starting conditions and were then divided by the overall Apsley catchment area. The result provided an estimation of the potential depression losses for the entire catchment under a variety of starting conditions. The result of this analysis is provided in Table 4-3 and identified areas previously provided in Figure 3-4.

While the analysis is high-level, it demonstrates that depending on antecedent conditions, the expected initial losses may exceed those recommended by ARR. Particularly once additional loss mechanisms are considered. It also demonstrates that antecedent conditions influence the expected losses and that the two are not independent. Therefore, sensitivity testing will be required on the influence of rainfall losses for a variety of antecedent conditions.

Table 4-3 Apsley Depression Loss - Estimation

Scenario	Total Number of Depressions	Total Volume (m3)	Catchment Area (ha)	Estimated Loss (mm)
Depressions Empty	552	5.04×10^6	16,867	29.9
Depressions @ Average Elevation within area		4.37×10^6		25.9
Depression Almost Full		2.38×10^6		14.1



5 MODEL CALIBRATION

5.1 Overview

The model calibration and validation primarily focussed on the township of Apsley and consequences of the January 2011 event. This event was a focus of the community feedback within Apsley, as discussed in Section 2.6. Several members of the community were able to provide recollections of the events behaviour and consequences. In some cases, their recollections were supported by photography. While no streamflow gauges or surveyed levels within either of townships were available, the anecdotal information within Apsley was considered sufficient to validate the model.

As there is minimal information regarding flooding within Edenhope, the adopted model parameters for Apsley were also adopted for the Edenhope model. This was considered adequate given the lack of specific observations within Edenhope and the similarities between the catchments.

The January 2011 event was modelled iteratively in TUFLOW. Calibration of the model had three primary variables, these included:

- Rainfall infiltration losses.
- Antecedent conditions - note will also influence rainfall losses.
- Mannings 'n' roughness values.

The above parameters were adjusted until the best overall match observations was achieved. The full details of each model simulation are not documented in this report due to the number of iterations. However, the influence of individual parameters is be discussed in design modelling sensitivity in later reporting. It should be noted that the calibration is not considered final, and adjustments are still able to be made once further discussion with the community is complete.

5.2 January 2011 Event

5.2.1 Event Overview

January 2011 was the wettest January on record across many parts of Victoria, causing flooding in over 100 towns. The highest local monthly total was recorded at Halls Gap with 297.0 mm, followed by Mount William with 289.6 mm. Rainfall was concentrated over the north-central and western regions and fell between January 9 and January 15. The event occurred after the wettest December (2010) on record within Apsley.

In Apsley and Edenhope, the storm event primarily occurred in the 24 hours prior to 9 am, January 14, in this period 115 mm and 68.2 mm fell at the two townships respectively. At least 24 hours prior to this rainfall, 25.6 mm and 39 mm was experienced in the 24 hours prior to 9 am, January 12 at Apsley and Edenhope respectively. The recorded rainfall over the period of the 11th - 15th of January at various gauges is presented in Table 5-1. The rainfall temporal patterns recorded at Edenhope are presented Figure 5-1.

Rainfall prior to January 12 was below a 50% AEP event, while the rainfall experienced after exceeded a 1% AEP event at Apsley and peaked around the 5% AEP event at Edenhope. While no sub-daily rainfall data was available at Apsley, it is likely that the rainfall fell at similar times but with varying intensities between the townships. It is expected that both townships experienced most of the rainfall over a 12-hour period, as captured at Edenhope.

The recorded intensities at Edenhope, in comparison to Bureau of Meteorology (BoM) Intensity Frequency Data (IFD), is presented in Table 5-2 and Figure 5-2. While extrapolated rainfall intensities for durations not recorded (< 24 hrs) at Apsley are provided in Figure 5-3.



Table 5-1 January 2011 event rainfall totals

Station Name, Station No.	Rainfall (mm)					
	11/01	12/01	13/01	14/01	15/01	Total
Edenhope Airport, 079099	4.8	39.0	0.0	62.8	0.2	106.8
<i>Apsley Post Office, 079071</i>	0.6	25.6	0.0	115.0	0	141.2
Edenhope Elizabeth Street, 079011	9.0	45.6	0.0	61.4	0.0	116
Benayeo, 079083	0.	14.6	>	117.0	0.0	131.6
Patyah, 079107	0.0	38.0	0.0	49.2	0.0	87.2
Poolaijelo, 090164	>	31.6	0.2	100.0	0.0	131.8
Karnak (Rosedale), 079025	0.0	47.0	0.0	33.8	0.0	80.8
Harrow (Pine Hills), 079022	0.0	67.2	0.0	75.0	0.0	142.2

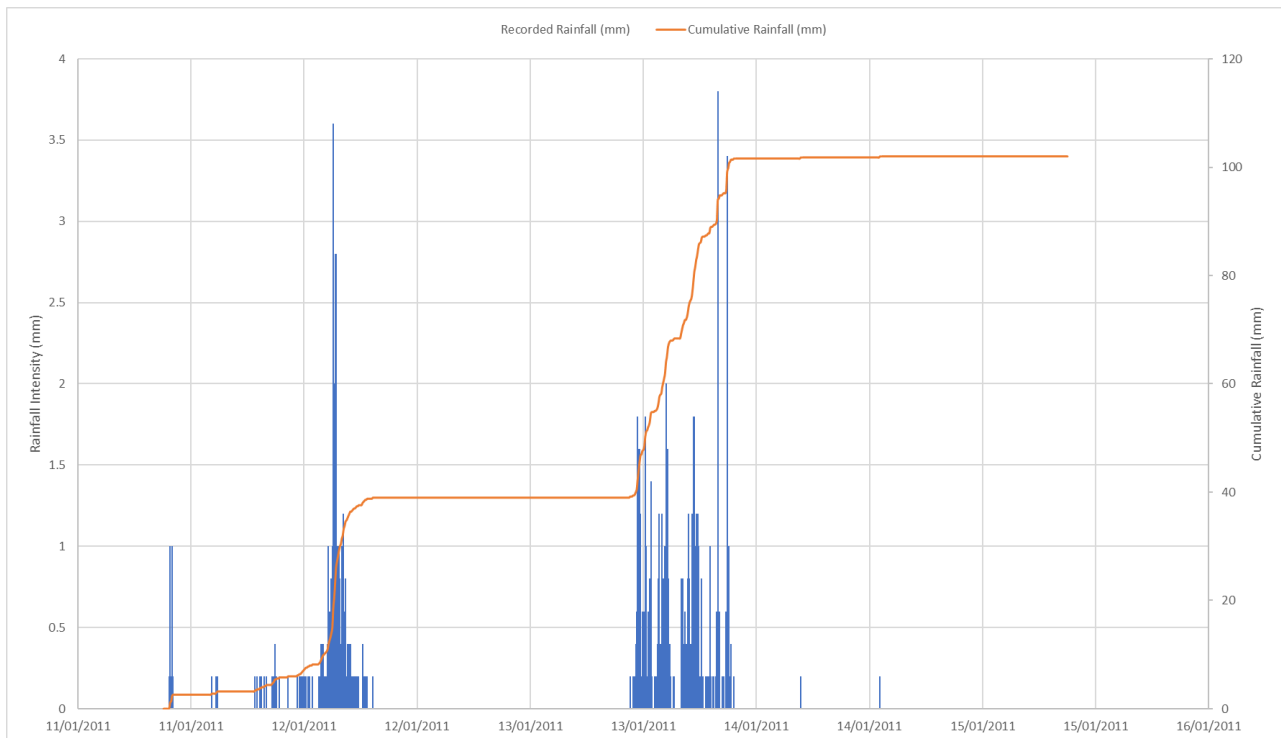


Figure 5-1 January 2011 event temporal pattern – Edenhope Airport, 079099

Table 5-2 January 2011 Event – Rainfall AEP

Period	AEP	
	Prior to January 13 th	All data
5 minutes	< 63.2%	< 63.2%
30 minutes	50% - 20%	50% - 20%
1 hour	50% - 20%	50% - 20%
2 hour	20%	20%
3 hour	20%	20%
4.5 hour	50% - 20%	20%
6 hour	50% - 20%	20% - 10%
9 hour	50% - 20%	5%
12 hour	50% - 20%	5%
18 hour	50%	10% - 5%
24 hour	50%	10%
48 hour	63.2-50%	5%
72 hour	< 63.2%	5%

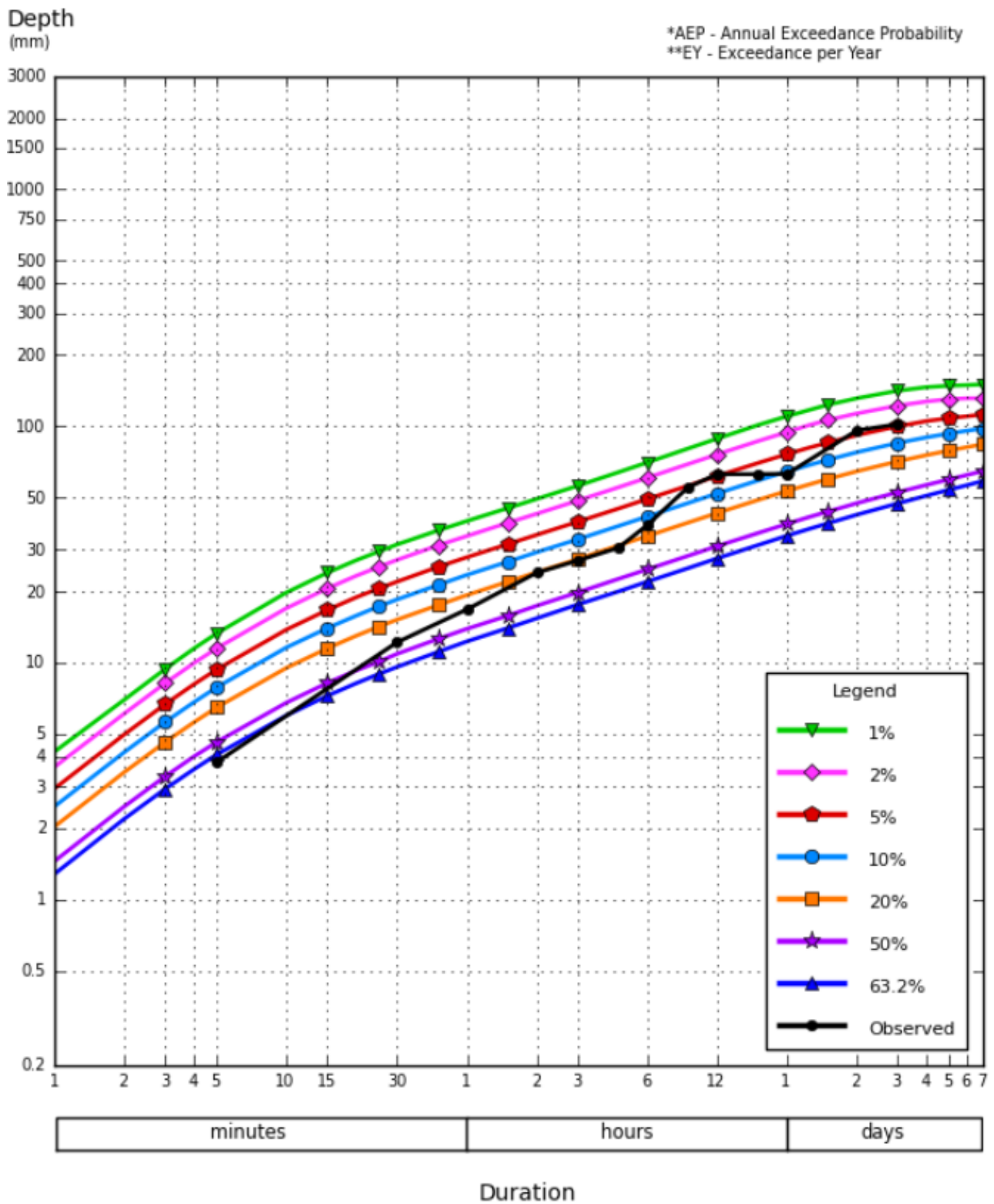


Figure 5-2 IFD curves for Edenhope and observed rainfall intensities – January 2011

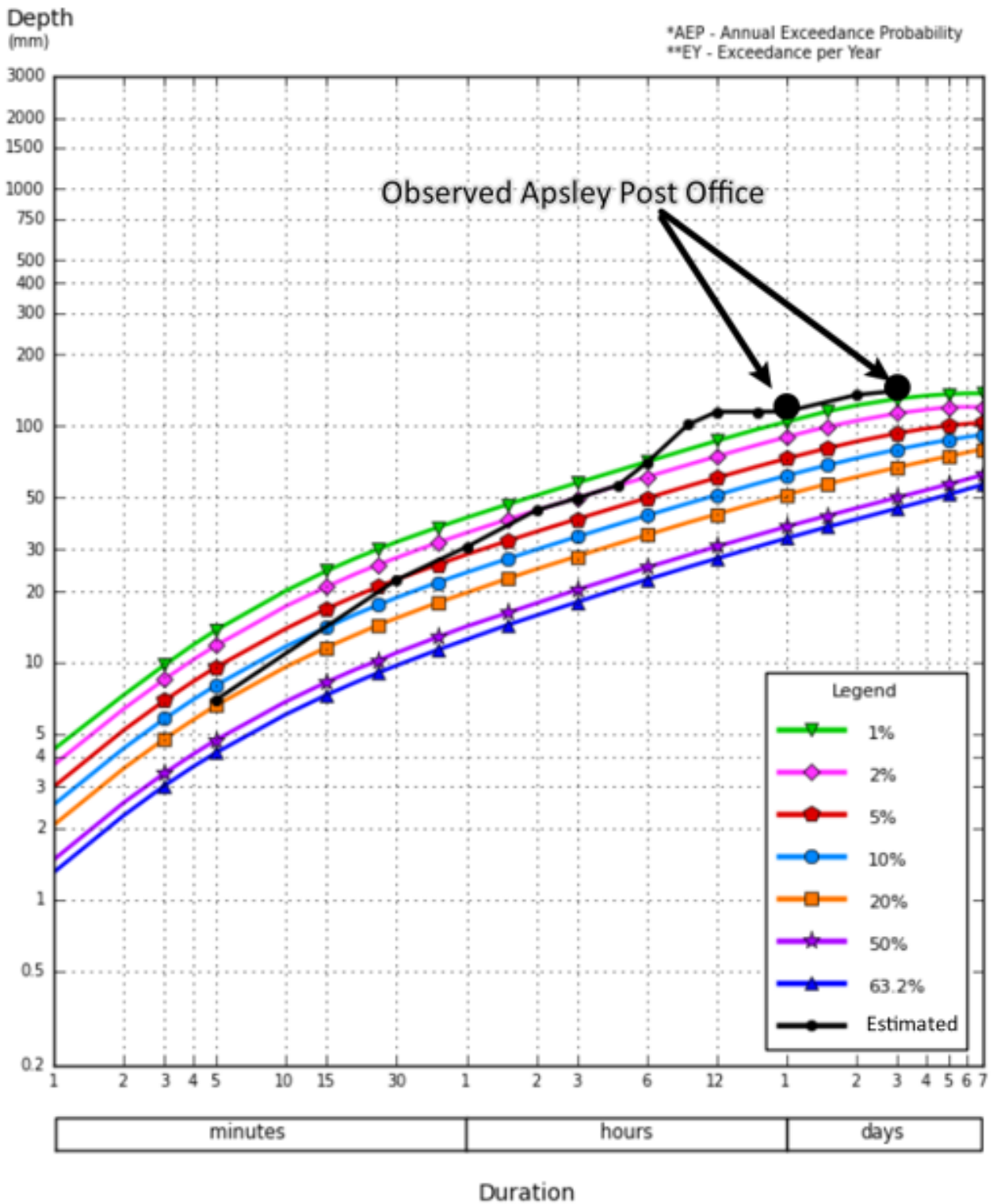


Figure 5-3 IFD curves for Apsley and estimated rainfall intensities – January 2011

5.2.2 Modelled Rainfall

A rainfall spatial distribution was generated using eight rainfall gauges, for rainfall bursts occurring on January 12 and 14, spatially adjusting the temporal pattern recorded at the Edenhope Gauge (079099). The daily totals at the eight gauges were used to interpolate rainfall depth across the catchment, as shown in Figure 5-4. The temporal pattern was based upon the recorded rainfall depth at Edenhope Airport. It is noted the modelling assumes the temporal pattern at Edenhope is representative of the event experienced at Apsley.

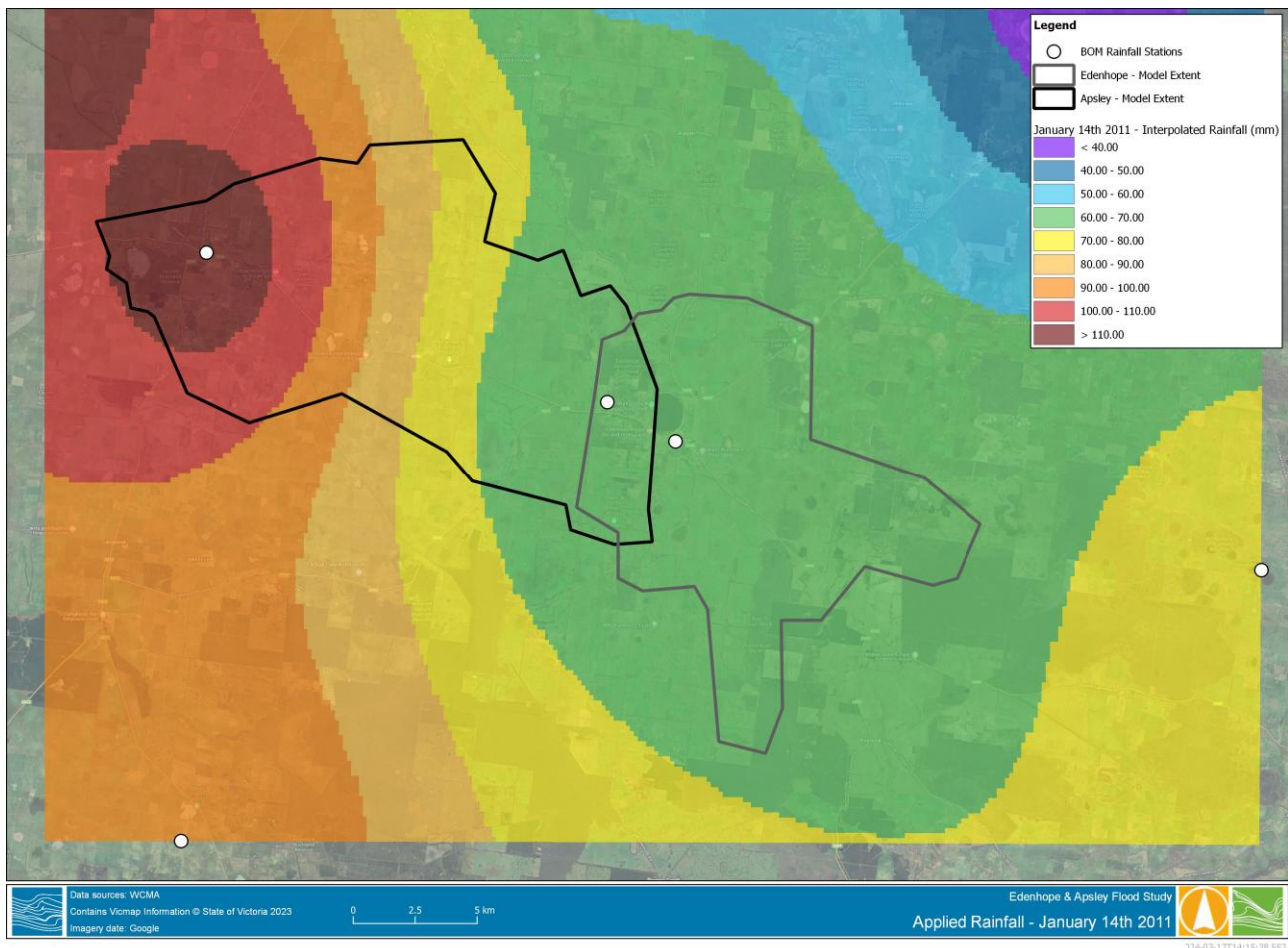


Figure 5-4 Interpolated Rainfall Depths – Edenhope and Apsley



5.2.3 Calibration data

Calibration data for the January 2011 event mainly included anecdotal evidence from community members, with some photographs taken during the event. Community consultation and phone interviews indicated the January 2011 event impacted Apsley significantly. It is understood that the following occurred during the event:

- Clubrooms at Apsley Reserve: was protected by sandbags, with inundation around ankle deep experienced. It is understood that Apsley Reserve is impacted from the north, prior to the flow the east. Once flow from the east reaches Apsley, this then proceeds to flow over Splatt Street and into the reserve.
- Properties Along Splatt Street from Johnson Street to around Ballantyne Street: flow from the east (via Church Water Hole) spill toward the reserve, threatening houses in this area. It is understood that most water was directed over the vacant land at 28 Splatt Street, with 32 Splatt Street experiencing inundation and requiring protection via Sandbags.
- Properties south of the main drain alignment between Apsley-Natimuk Road and Benayeo Road: during the 2011 event this drain exceeded its capacity, exacerbated by its inability to drain freely. Excess water drained over Ballantyne Street and to the west of Townsend Street. Photographs and accounts by residents in this area indicate the flood depth likely reached between 200-500 mm deep, described as knee deep at the intersection of Townsend Street and the Wimmera Highway. Figure 5-5 and Figure 5-6 provide some guidance of the inundation experienced; however, it is expected that these were not taken during the peak of the event.
- Properties east of Laidlaw Street, along Wallace Street: this area was heavily impacted by flows from the east. During the 2011 event, several properties, particularly from 1 to 35 Wallace Street, experienced some form of inundation. It is known that the vacant land on Wallace Street experienced inundation, with neighbouring properties requiring protection from sandbagging and pumping. Some discussion with community members indicate that Wallace Street may not have overtopped in the January 2011 event; however, this is not clear. Importantly, it is understood that flooding in this area is solely related to water draining under the Wimmera Highway and not overtopping of the highway from the north into the properties.
- The Apsley Post Office: while this location is understood not to have been inundated in 2011, it served as a key location where flood behaviour was known. It is understood that inundation did occur outside of the Post Office and it was under threat of inundation in 2011.
- The Appley Pub: on the higher side of the Wimmera Hwy and did not experience inundation in the 2011 event.

A summary of the flood behaviour and areas impacted during the 2011 flood event is provided in Figure 5-7. Unfortunately, a lack of survey water levels has meant calibration of the modelling was reliant on anecdotal evidence and an understanding of the flood behaviour.



Figure 5-5 Flooding at residences along Townsend Street



Figure 5-6 Flooding at Wallace Street Crossing

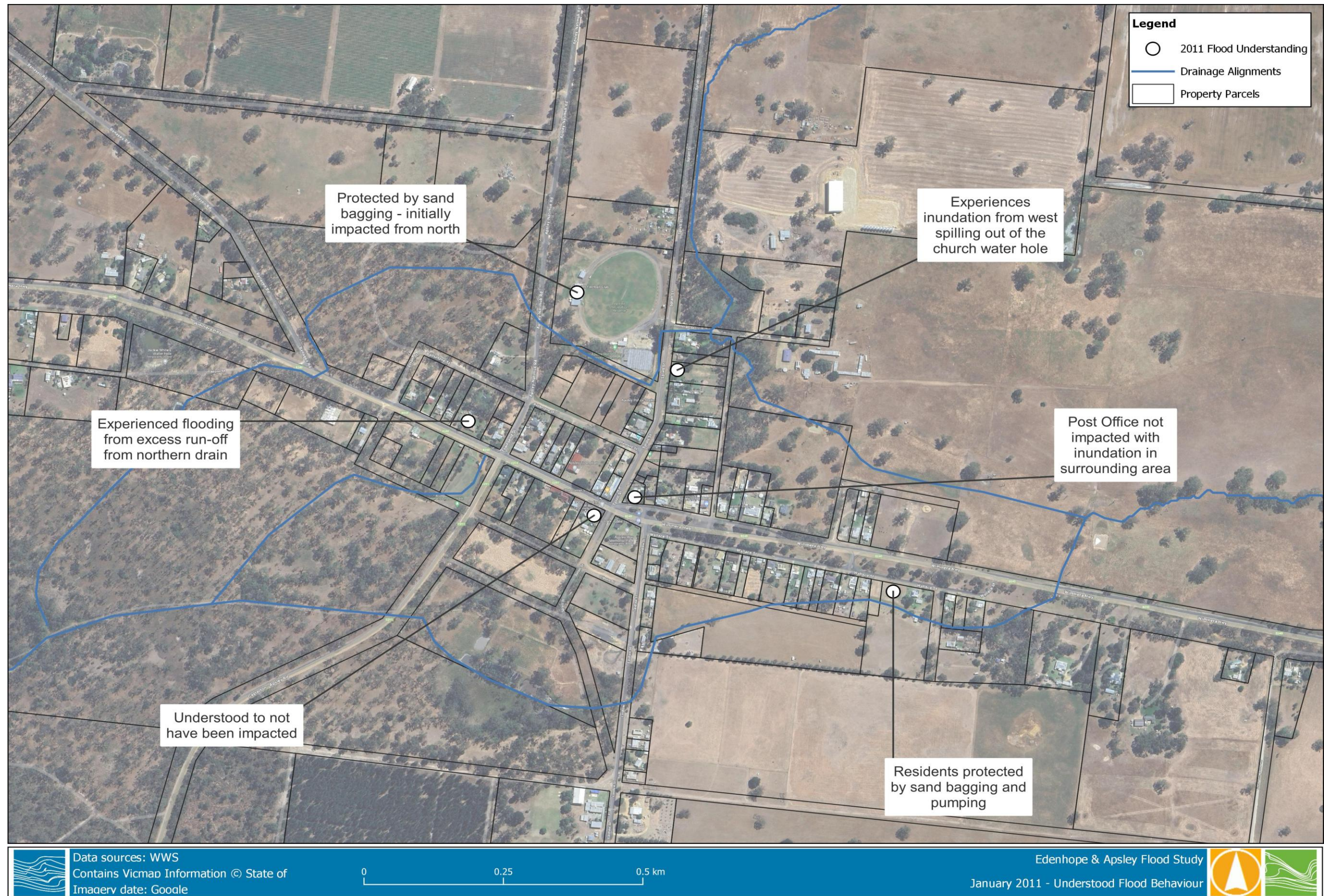


Figure 5-7 Observed flood behaviour within Apsley



5.3 Modelled Event & Scenarios

As flooding within Apsley and Edenhope is expected to be heavily reliant upon upstream antecedent conditions, the following scenarios and events were modelled:

- Scenario 1 - January 12th event to pre-wet the catchment, followed by January 14th event. This included the following:
 - Simulation of the January 12th event from 9 am on the 11th of January to 9 pm on the 12th of January (36 hours). This event adopted lower rainfall losses than Scenario 2 & 3, as it is known that the catchment had experienced significant rainfall in December 2010.
 - Simulation of the January 14th event from 9 pm on the 12th of January to 12 pm on the 14th of January (40 hours). Further lowered losses to those applied during the January 12th event.
 - Note for this event varied rainfall losses, to aid in assessing the relationship between antecedent conditions and rainfall losses. Losses were also reduced for this event to ensure the January 12th event resulted in run-off.
- Scenario 2 – January 14th event, adopting a dry upstream catchment.
- Scenario 3 – January 14th event, adopting a wet catchment (DEA 1% Return Frequency – Figure 3-4).
 - Both Scenario 2 and 3, were simulated from 6 am on the 13th of January to 12 pm on the 14th of January (30 hours).
 - Note Scenario 2 and 3 adopted the same losses, this was done so it was easier to assess the sensitivity of a wet catchment. Scenario 1 allowed the assessment of both catchment wetness and variation of rainfall losses.

Losses adopted for the three scenarios are provided in Table 5-3.

Table 5-3 Rainfall Losses Applied to Scenarios

Material	Scenario 1 – January 12		Scenario 1 – January 14		Scenario 2 – January 14		Scenario 3 – January 14	
	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)
Rural Residential	10.0	2.0	5.0	1.0	15.0	3.0	15.0	3.0
Pasture	15.0	3.0	5.0	1.0	30.0	4.0	30.0	4.0
Dense Vegetation	20.0	4.0	10.0	2.0	30.0	5.0	30.0	5.0
Waterway Channel	15.0	2.0	5.0	1.0	15.0	2.0	15.0	2.0
Roadway (Paved)	5.0	1.0	5.0	1.0	5.0	1.0	5.0	1.0
Roadway (Unpaved)	10.0	1.0	10.0	1.0	10.0	1.0	10.0	1.0
Lake / Swamp / Wetland	10.0	1.0	0.0	0.0	10.0	1.0	10.0	1.0



5.4 Apsley – 2011 Flood Results

Flood depth mapping for the three scenarios in Apsley is presented in Figure 5-8 to Figure 5-10, with a comparison of the flood extents presented in Figure 5-11. A summary of the key locations and flood results for each scenario is provided in Table 5-4. The locations assessed are provided in Figure 5-8.

The flood results at these locations demonstrates that the flooding experienced within Apsley has a degree of sensitivity to antecedent conditions. While the depth range is within 100 mm and flooding in these locations is controlled by the natural topography and structures, the difference in flood extent upstream of Splatt Street (toward Edenhope) highlights the sensitivity of the catchment, with a significant increase in flood extent between a dry catchment and the two scenarios considering antecedent conditions. Importantly, results of Scenario 1, which lowers rainfall losses with catchment conditions results in the largest flood extent. This indicates that flooding within Apsley is most sensitive when rainfall losses and catchment condition are considered together. The difference in flood extent indicates that during design modelling, sensitivity testing will be required for antecedent conditions. A summary of the flood behaviour at each location is provided below:

- Apsley Reserve – during the 2011 event, works downstream of Apsley-Natimuk Road were not complete, with the drain known to have limited capacity. This limitation meant during 2011 water filled the reserve until it overtopped (around 105.1 m AHD), along the main drain and along the southern bank of the drain upstream of Apsley-Natimuk Road. These controls cause flooding at the reserve to be driven by the volume of water, and there is a negligible difference in flood depths between scenarios.
- Splatt Street – inundation at Splatt Street is controlled by the available storage in the depression directly to the west, it is referred to as the Church Water Hole. These depressions, in combination with Splatt Street, control flooding in this area. The increased runoff from wet antecedent conditions, increases the extent of which Splatt Street is overtopped and the amount of water directed toward the Post Office.
- 72 – 88 Wallace Street – flooding to the rear of these properties is controlled by the amount of water spilling from the main drainage alignment over Ballantyne Street. While there is some variation in flooding at the rear of these properties, flood depths are controlled by the hydraulic controls in Apsley Reserve. However, for the front of these properties, flooding is dependent on antecedent conditions. In the wet condition scenarios, Newlands Reserve fills up to a level that exceeds the road crest of the Wimmera Highway / Wallace Street, controlling flooding on the front of these properties.
 - **IMPORTANT** – the behaviour of Newlands Reserve on flooding at this location, provides an opportunity to validate the modelling to community experiences. For example, Figure 5-6 previously presented, does not indicate that there is significant inundation on the Newlands Reserve side of the roadway. This image best aligns with the results of the “dry” upstream catchment, confirmation of the behaviour at this location will enable the modelling to be refined.
- 1 – 35 Wallace Street – flooding at this location is primarily controlled by the upstream culverts, under the Wimmera Highway. While in wet antecedent conditions, significantly more water is flowing from east, the capacity of the culverts and the upstream channel control the amount of water directed south of the Wimmera Highway. Once downstream of the culverts, controls appear to exist within the channel with the upstream water level significantly higher than the downstream of the controls. Based upon the modelling results a significant control impacting the residents upstream of 29-31 Wallace Street, exists within the channel in this location. While this could be an error in the topographic data created by the trees. After discussions with community members, it is far more likely that these controls exist throughout the channel due to degradation over time.
 - During community consultation several members of the community demonstrated interest in walking this section of the channel to aid identifying these controls and explaining the flood behaviour. This is recommended to occur during the next community engagement, as confirming the locations of controls will benefit both the flood modelling and identification of mitigation options.

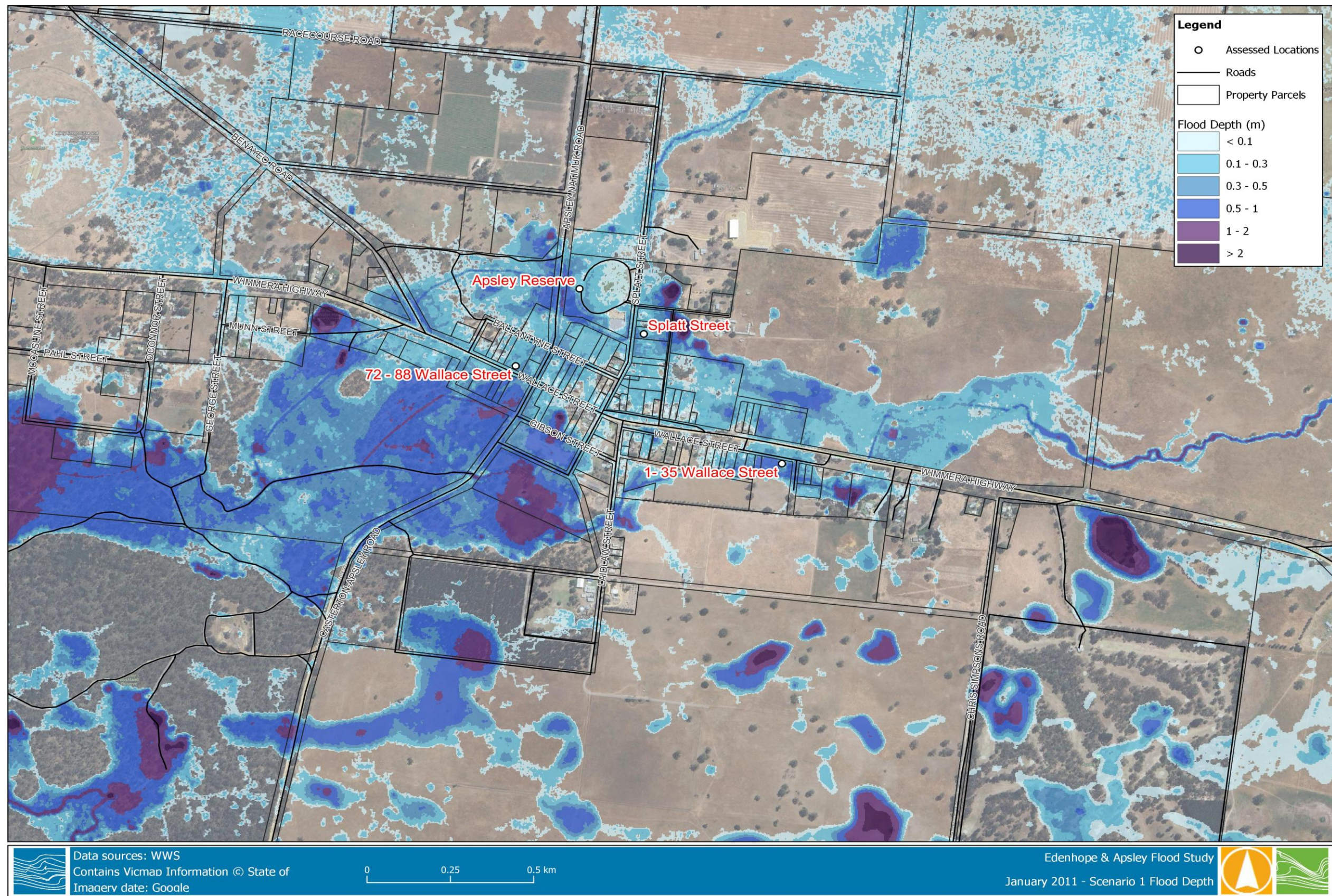


Figure 5-8 Scenario 1 (Prior Rainfall) January 2011– Flood Depth

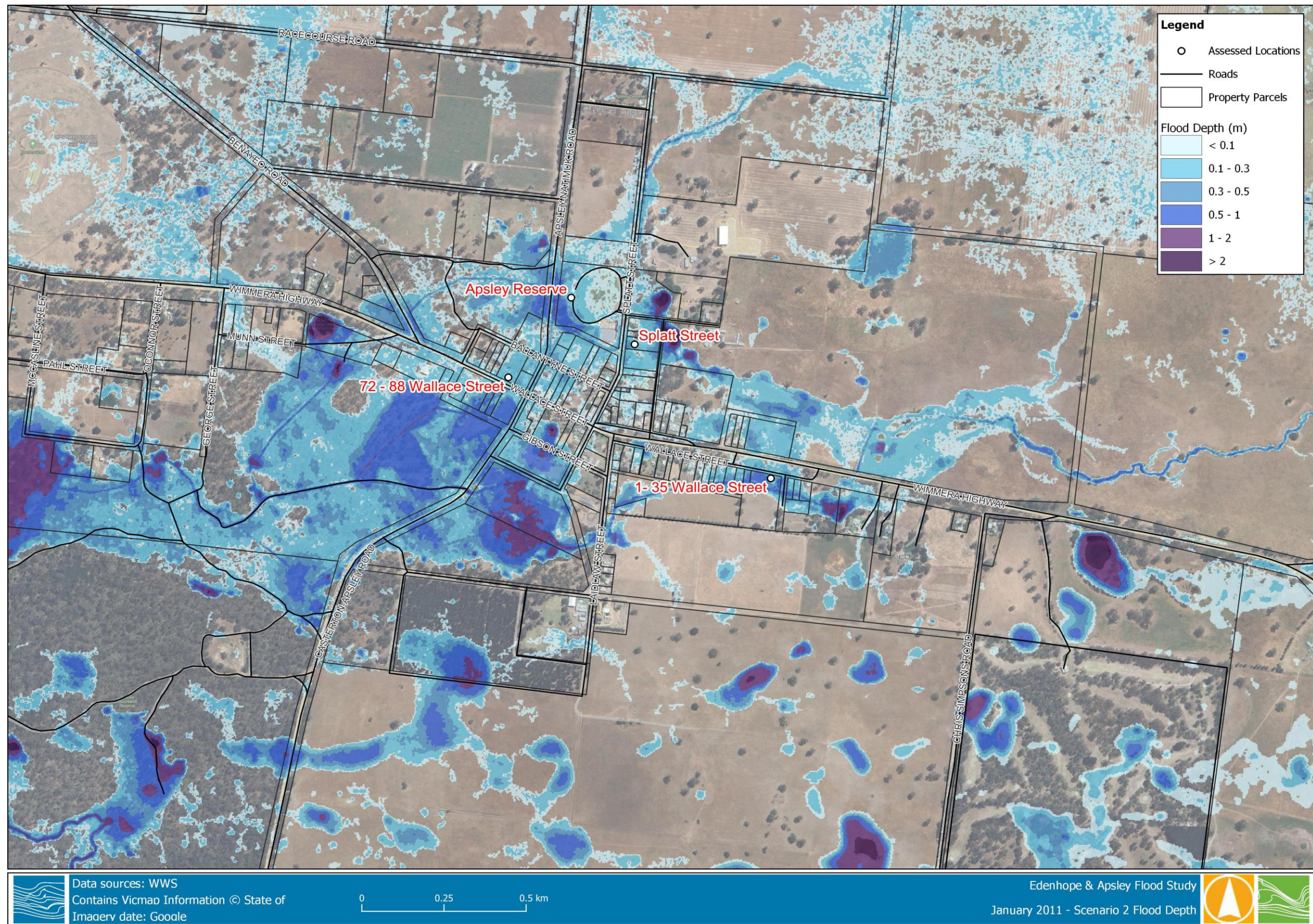


Figure 5-9 Scenario 2 (Dry Catchment) January 2011– Flood Depth

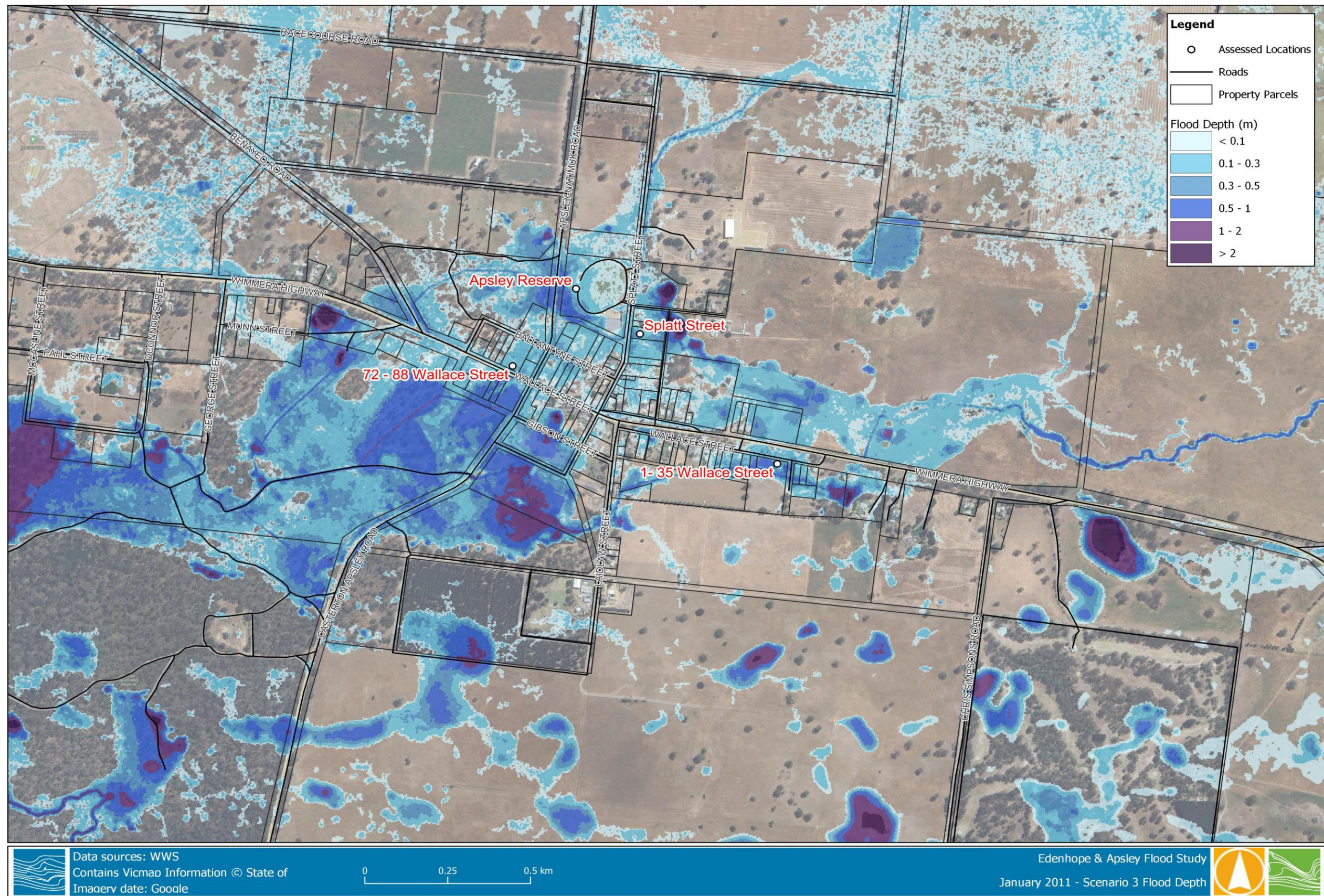


Figure 5-10 Scenario 3 (Wet Catchment) January 2011– Flood Depth

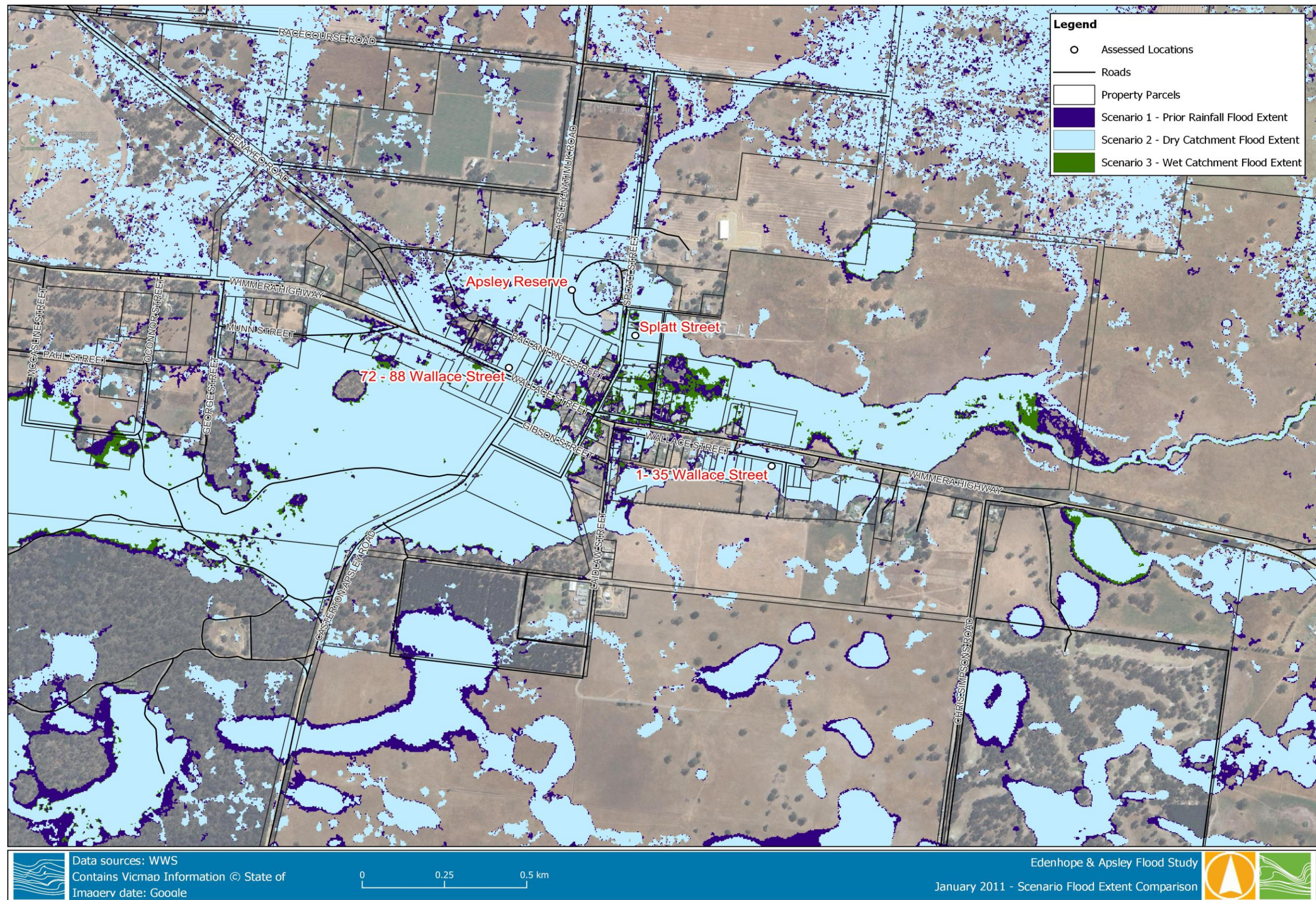


Figure 5-11 Extent Comparison – January 2011



Table 5-4 Modelled Flood Depths at Assessed Locations

Location	Address Assessed	Understood Flood Impact	Expected Flood Depth	Scenario 1 – Flood Depth	Scenario 2 – Flood Depth	Scenario 3 – Flood Depth	Range
Apsley Reserve	Apsley Reserve, Clubrooms	Required sandbagging, with ankle depth inundation experienced in surrounded areas	50-100 mm	135 mm	75 mm	80 mm	60 mm
Splatt Properties	28 Splatt Street	Flow occurring from east to west through properties with vacant parcel inundated	200 – 500 mm	305 mm	220 mm	255 mm	85 mm
72 – 88 Wallace Street	76 Wallace Street	Excess flow from intended drainage route, flowing south inundated properties in this location.	200 – 500 mm	280 mm	200 mm	205 mm	80 mm
1 – 35 Wallace Street	11 Wallace Street	Flow from Edenhope under Wimmera Highway exceeding capacity of channel toward Lake Newlands, impacting residents between 1 to 35 Wallace Street. Potentially exacerbated by backwatering from downstream.	100 – 300 mm	245 mm	180 mm	190 mm	65 mm



5.5 Apsley – 2011 Calibration Discussion

The various model scenarios for the January 2011 event capture similar flood depths to those experienced. The adoption of wet antecedent conditions results in a slight increase in flood depth and increased areas which experiences shallow inundation. Due to the nature of both the upstream catchment and topography within the township the modelled flood behaviour during large flood events suggests flooding is not as sensitive to antecedent conditions as expected. While the sensitivity in terms of flood depth is less than expected, the consideration of catchment conditions and rainfall losses does increase the flood extent both within town and particularly upstream of the township. Whereas within the township there are various controls which attenuate the implications of additional surface water run-off in large events.

Even though the change in flood depth as a result of the variable antecedent conditions is not as significant as anticipated, the initial catchment conditions do alter the flood behaviour in locations within Apsley. The location sensitive to these changes will allow community members to identify the accuracy of the modelling. The locations which can aid in improving the modelling include:

- Water level within Newlands Reserve: both scenarios demonstrate that the Wimmera Highway would have been overtopped due the water level within the reserve, exacerbating flooding to the residents. While the dry conditions modelling, demonstrates that flooding to residents between 72 – 88 Wallace Street, would have solely been the result of flow from the Apsley Reserve. The confirmation of the mechanism will identify whether the two wet conditions scenarios is exaggerating the amount of run-off within the catchment.
- Water level experienced around the Post Office: this location experiences flooding from overtopping of the Church Street Water Hole and flow exceeding the capacity of the channel from Edenhope. Both these mechanisms are the dependent upon the amount of run-off from the east, if the community can identify which scenario best represents flooding around this location, the modelling can be further validated.
- Water level over Wallace Street from 1 – 35 Wallace Street: all scenarios modelled demonstrate Wallace Street would have been inundated, with inundation experienced on the southern side of the Wimmera Highway. This flooding is controlled by a blockage within the channel directly south of 29-31 Wallace Street, where large gums are present. This control in the model, holds water up inundating residents and overtopping Wallace Street. From discussions with community members, it is unclear whether Wallace Street was overtopped in the January 2011 event. Confirmation of this behaviour will further improve the accuracy of the modelling and confirm whether the identified control is exaggerated in the topographic data.
 - Noting that from discussions with community members controls exist to some degree in this channel.
- Water levels experienced upstream at Bringalbert Road and Simpsons & Fosters Road: upstream conditions significantly influence the water entering Apsley from Edenhope. If the community can confirm the behaviour of flooding in this area, during the January 2011 event it will aid the modelling in understanding the influence of the upstream catchment. For example, the wet conditions scenarios have these roads overtopping to depths up to 200 mm, while the dry catchment is primarily controlled by the culverts under the roadway.

While the above locations are identified as key locations to improve the modelling it is noted that any commentary on the accuracy of the modelling and further information on the flood behaviour from community will be beneficial for the investigation. It is noted that a lack of surveyed flood levels means the model accuracy is reliant upon community experiences and anecdotal evidence. Therefore, additional information can always allow for the improvement of the modelling presented. A summary of the identified locations where community insight can aid the modelling is provided in Figure 5-12.

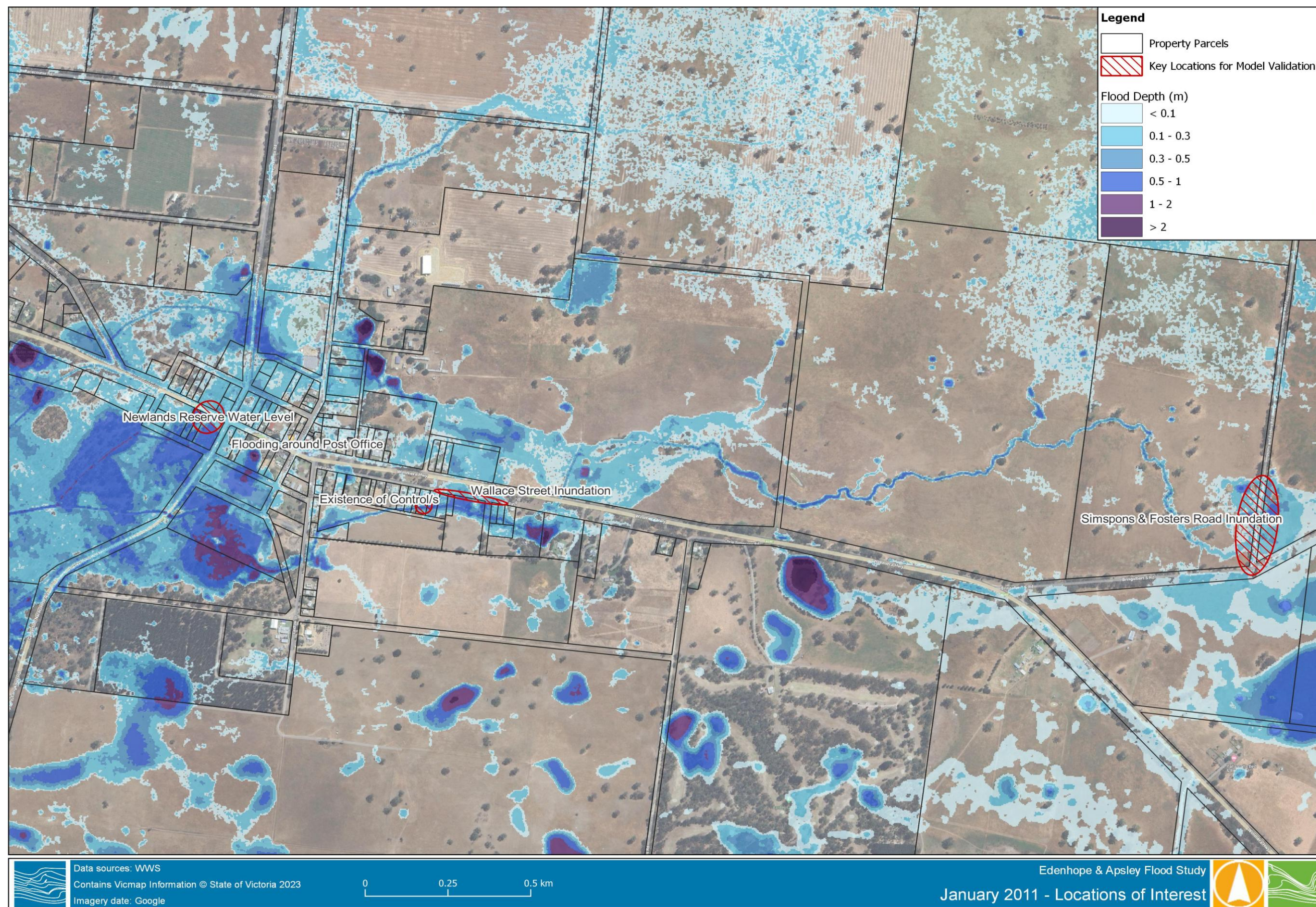


Figure 5-12 Key Locations of Flood Behaviour



5.6 Edenhope - 2011 Flood Results & Discussion.

Flood depth mapping for the three scenarios in Edenhope is presented in Figure 5-13 to Figure 5-15, with a comparison of the flood extents presented in Figure 5-16. As there is little information available or obtained for the consequences of the January 2011 event within Edenhope, the ability for this investigation to assess the accuracy of the results presented is limited.

However, based upon the flood modelling results and scenarios run, it is evident that flooding from the upstream catchment within the township is heavily controlled by the topography. The primary flow path is controlled by the natural swamp upstream of Edenhope Lions Park, with little impact to surrounding areas. Therefore, it is expected that residents in the town are likely more impacted but shorter intense events where the local stormwater network is exceeded. It should be noted that for Edenhope the 2011 event was only around a 10% AEP rainfall event.

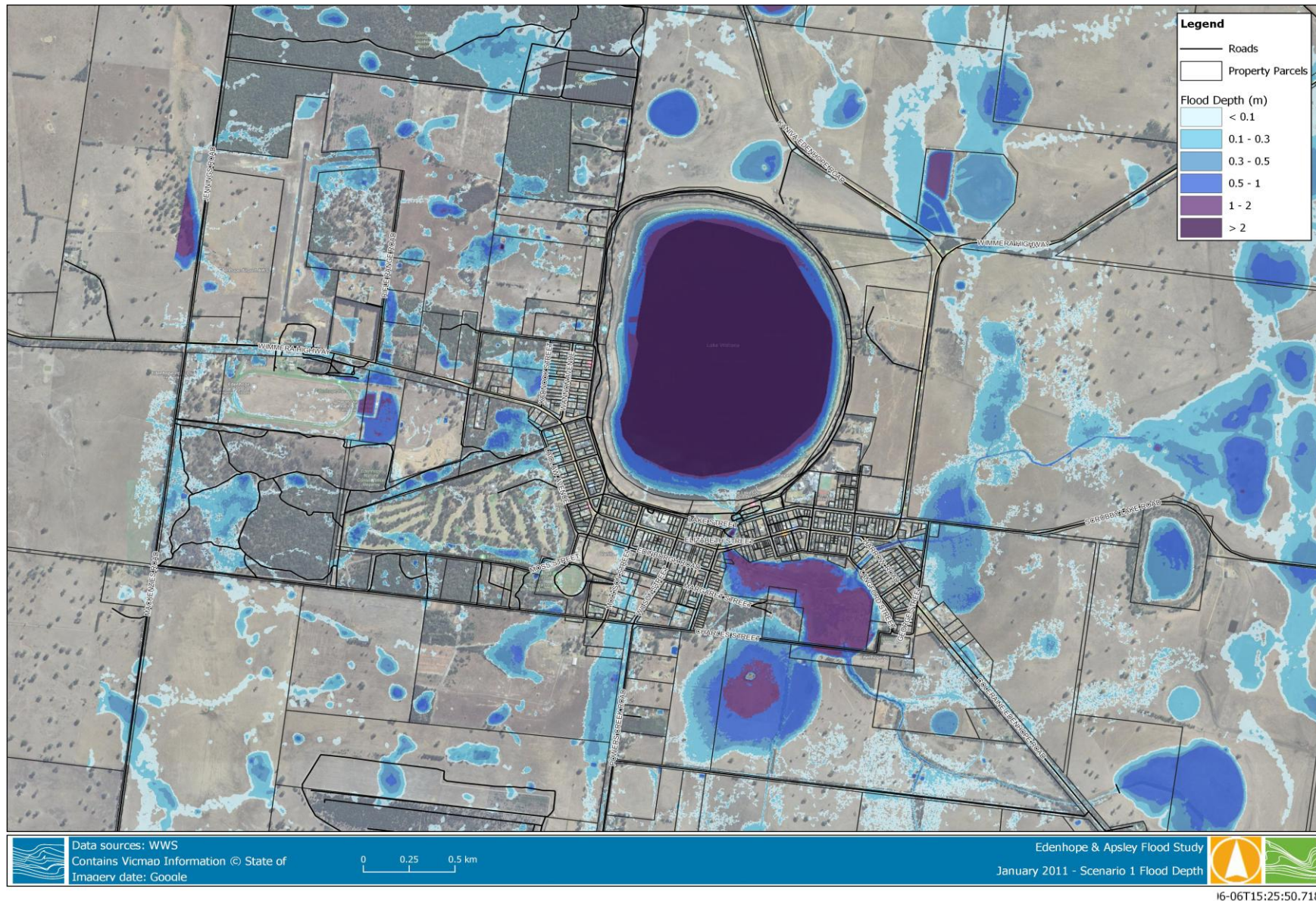


Figure 5-13 Scenario 1 (Prior Rainfall) January 2011– Flood Depth (Edenhope)

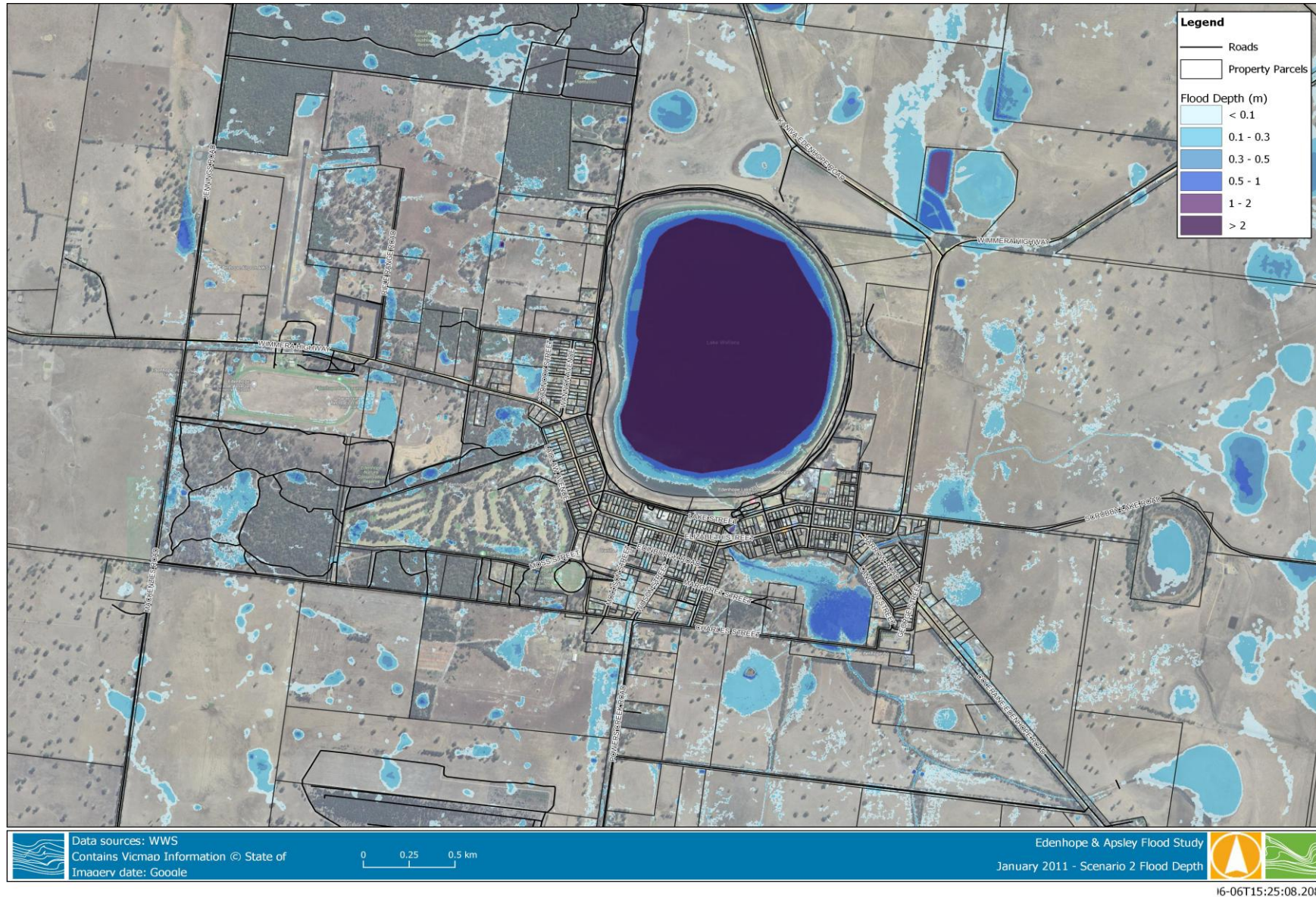


Figure 5-14 Scenario 2 (Dry Catchment) January 2011– Flood Depth (Edenhope)

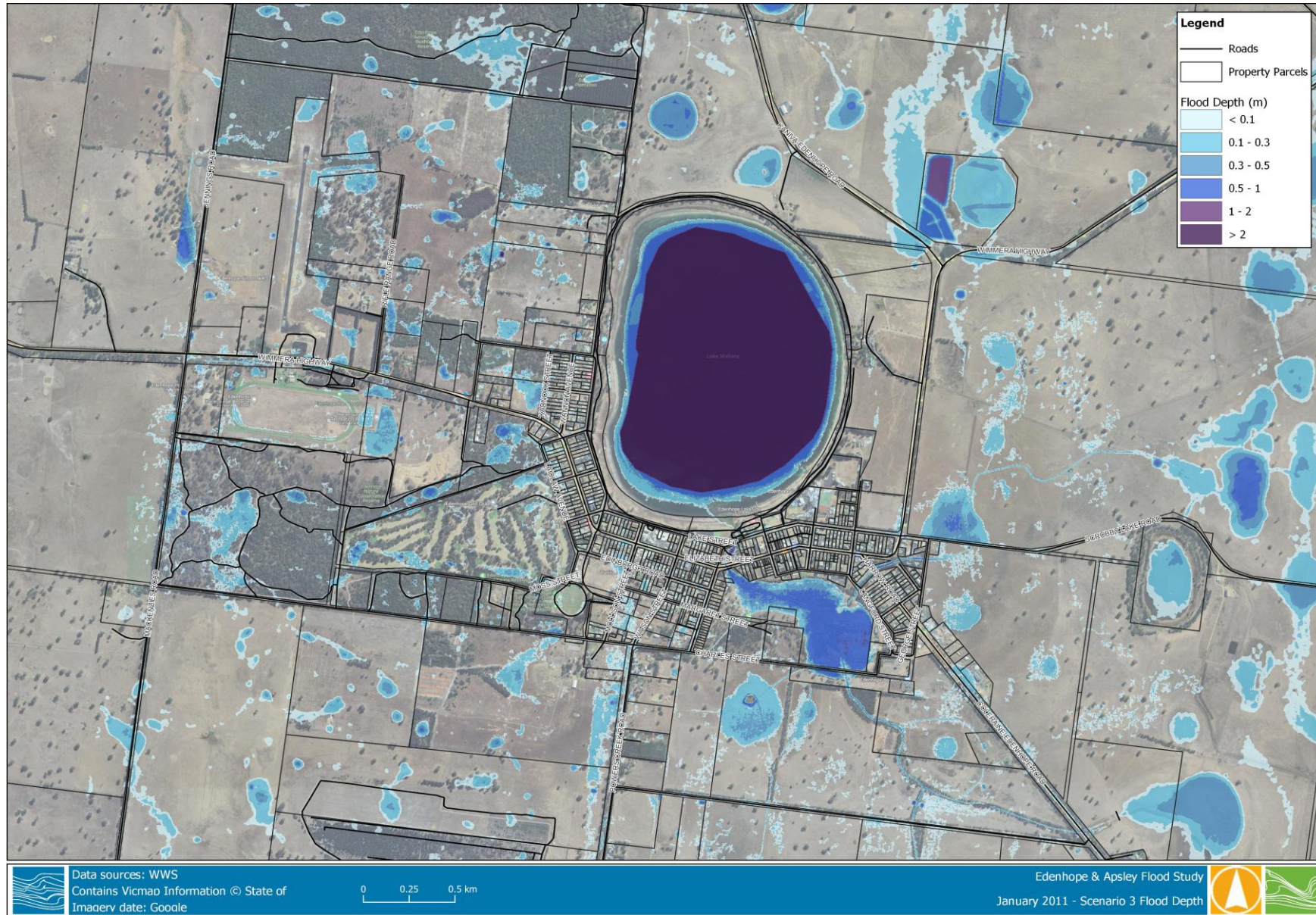


Figure 5-15 Scenario 3 (Wet Catchment) January 2011– Flood Depth (Edenhope)

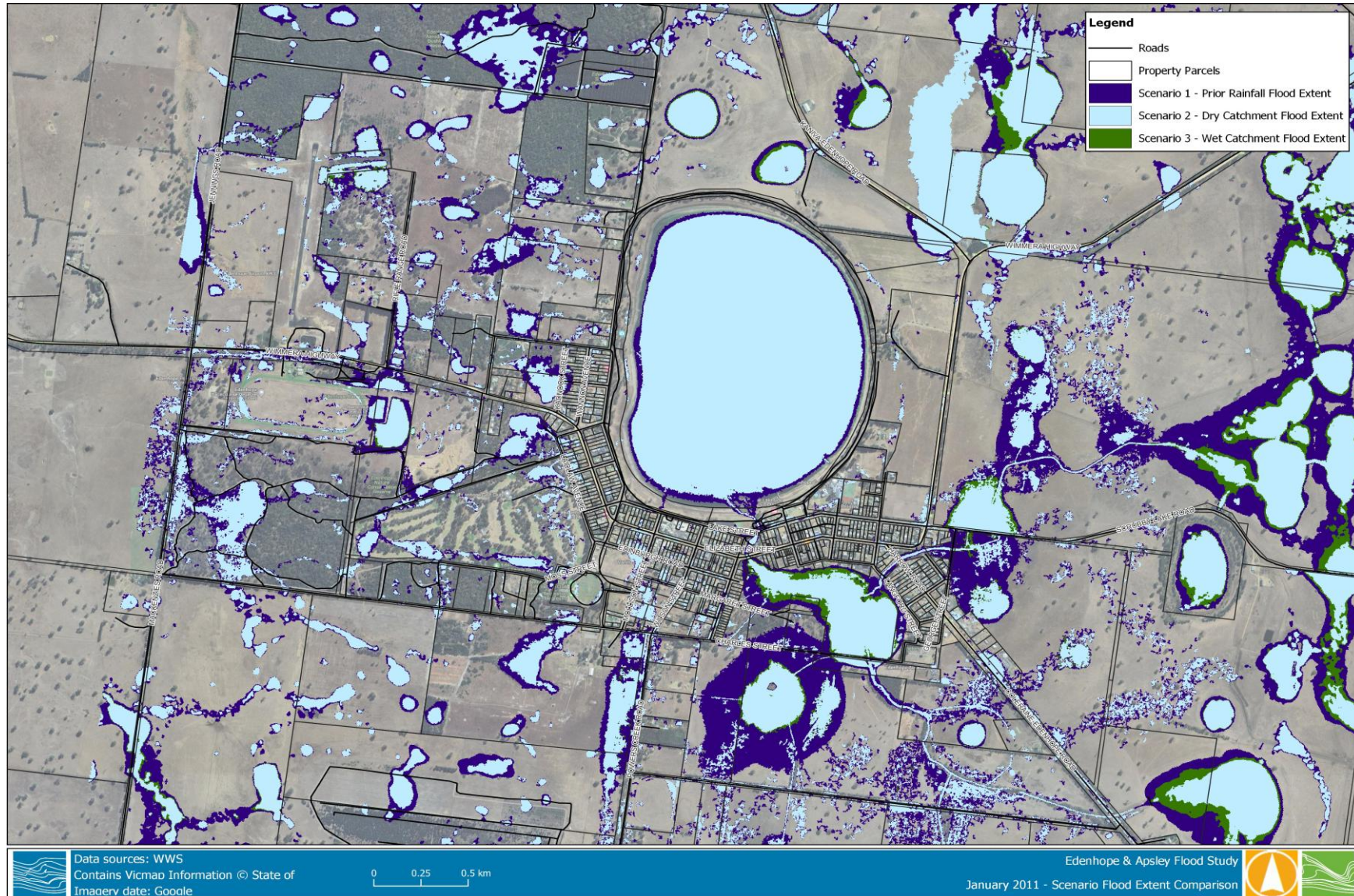


Figure 5-16 Extent Comparison – January 2011 (Edenhope)



6 PRELIMINARY DESIGN MODELLING

The calibrated hydraulic model was used to produce preliminary flood mapping for the 10% and 1% AEP events. The preliminary flood depth mapping for the two townships was produced from a single temporal pattern for the 12-hour storm duration and is presented in Figure 6-1 to Figure 6-4. It is noted that the mapping produced adopted a wet upstream catchment.

Figure 6-5 and Figure 6-6 for the 10% AEP event demonstrates the increased extent when rainfall losses are lowered with antecedent conditions. The appropriate rainfall losses for design modelling will be determined in the next stage of this project.

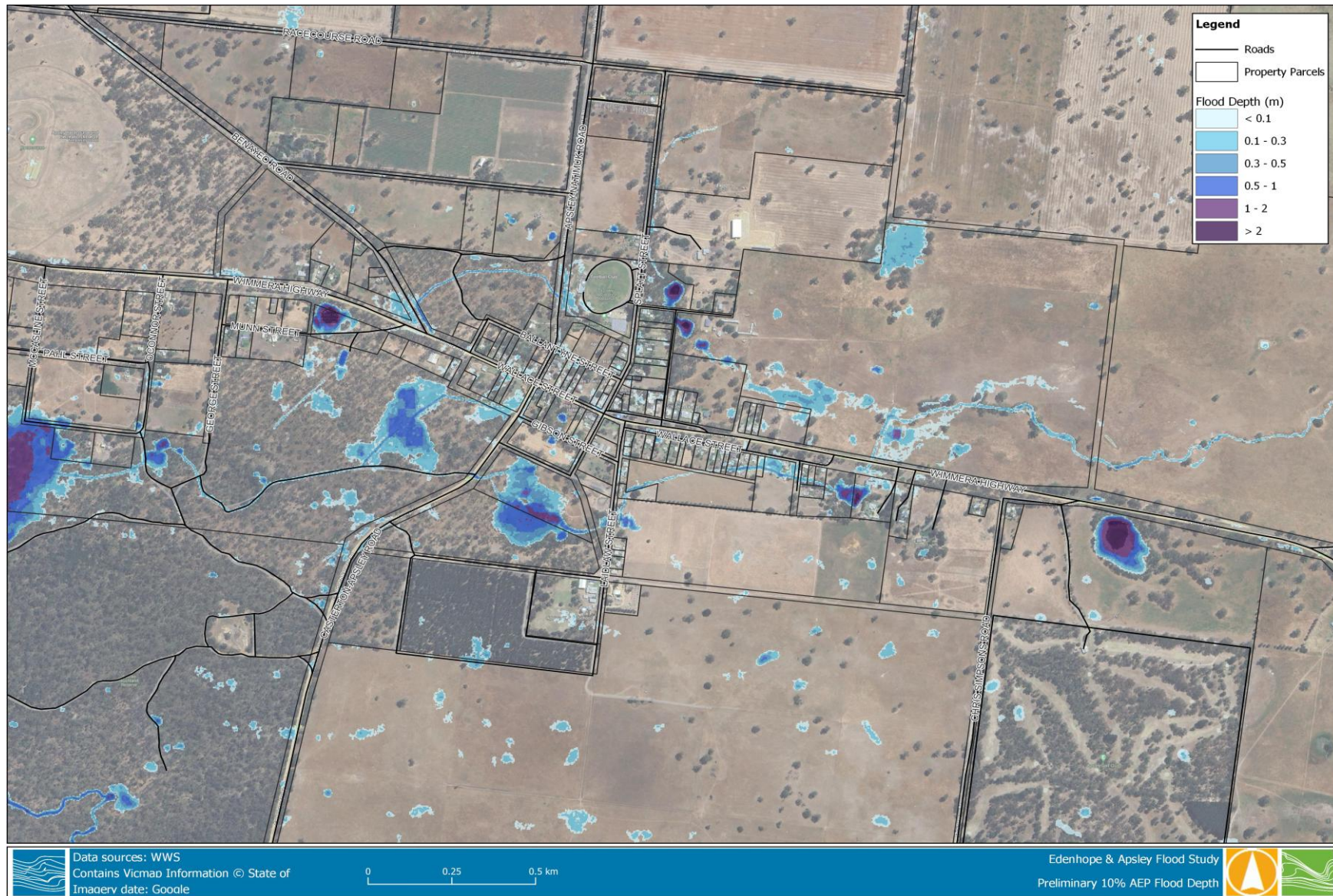


Figure 6-1 Apsley 10% AEP – Preliminary Mapping

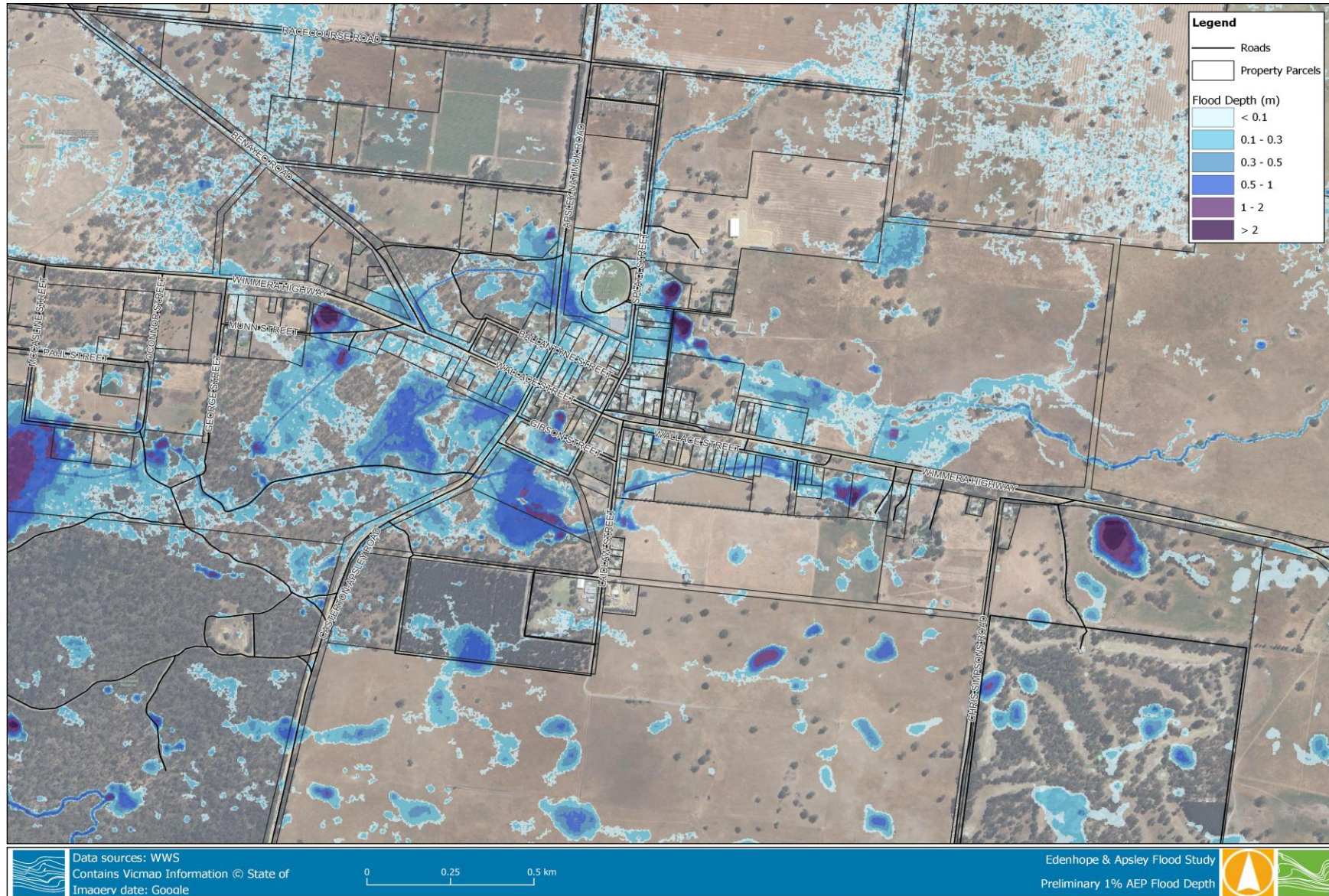
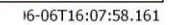


Figure 6-2 Apsley 1% AEP – Preliminary Mapping



West Wimmera Shire Council | 4 June 2026
Edenhope and Apsley Flood Investigation

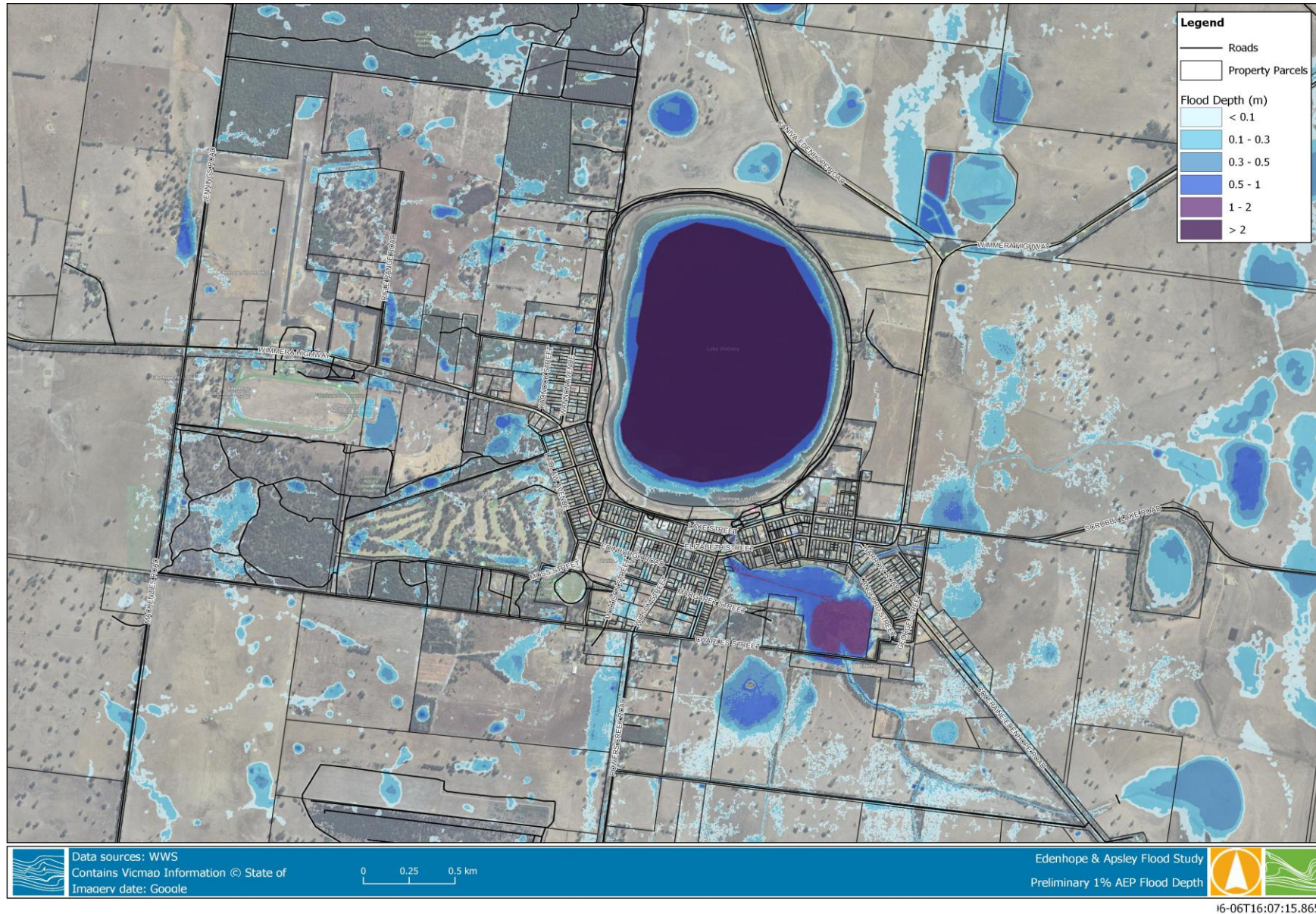


Figure 6-4 Edenhope 1% AEP – Preliminary Mapping

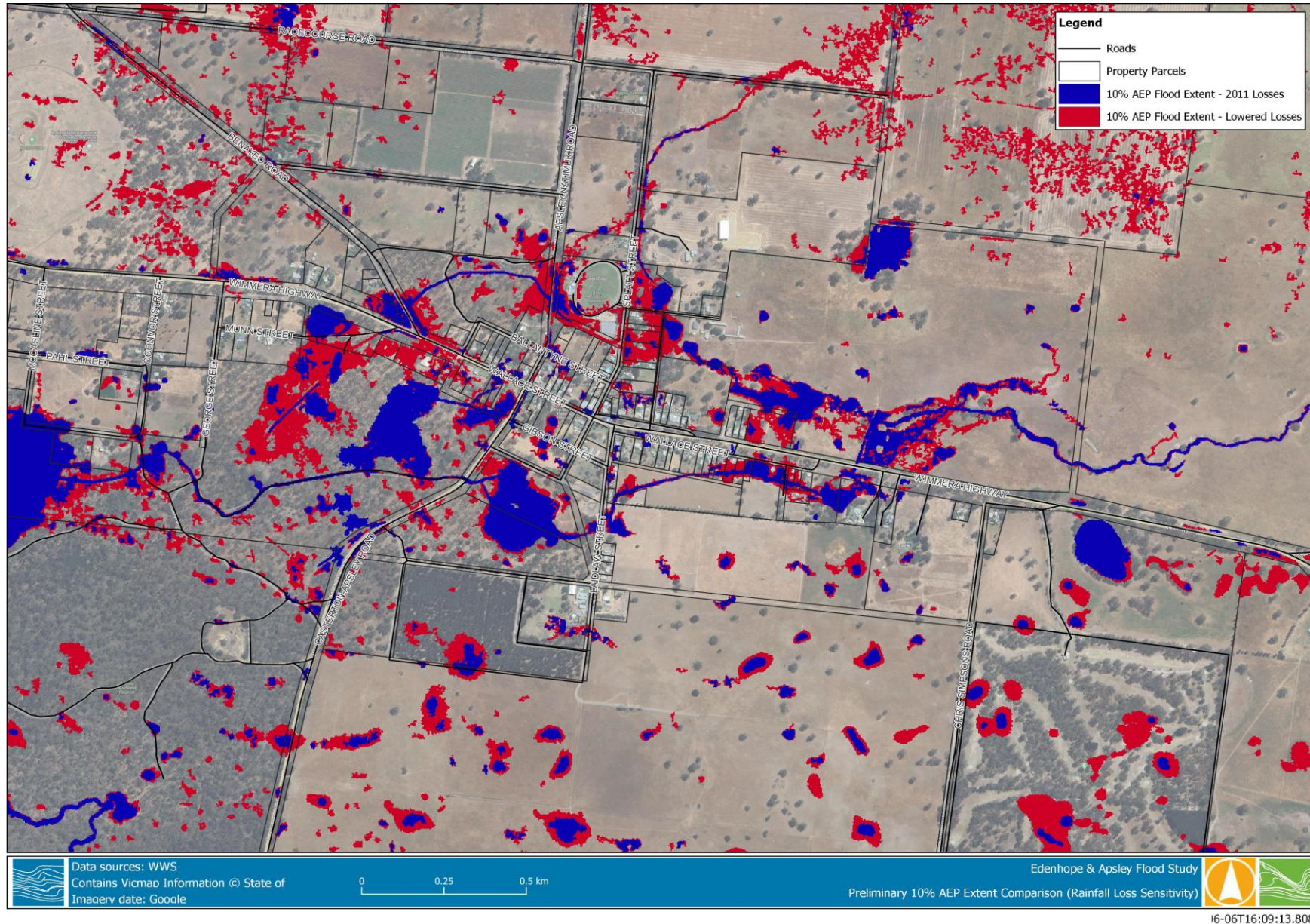


Figure 6-5 Apsley 10% AEP – Extent Comparison

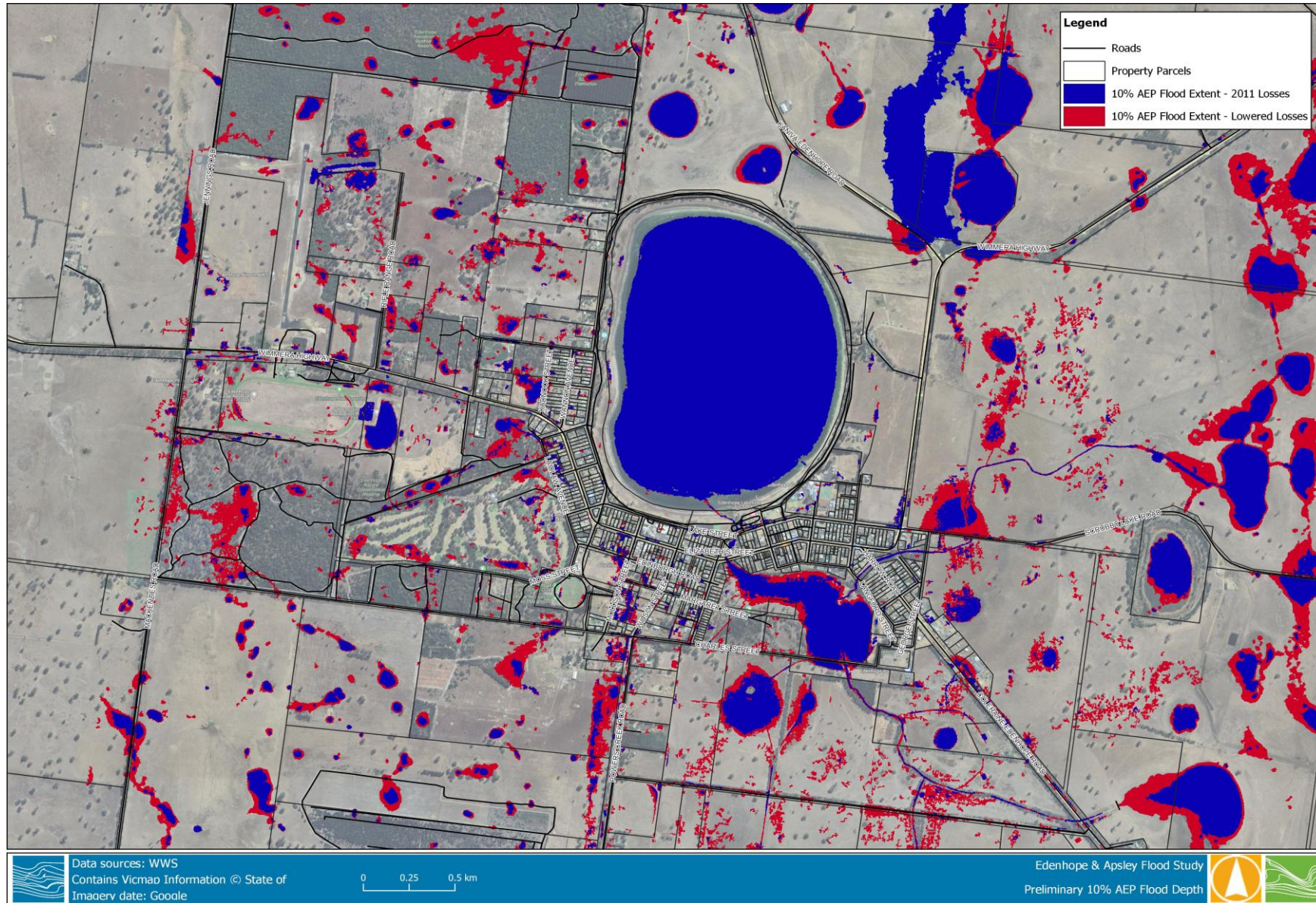


Figure 6-6 Edenhope 10% AEP – Extent Comparison



7 SUMMARY AND NEXT STEPS

This report provides detail of the data collation and flood model calibration for Edenhope and Apsley. These townships are in ungauged catchments, with an understanding of flood behaviour heavily reliant upon community engagement and knowledge. From initial community engagement, where valuable information was gathered particularly for Apsley, it was determined that the January 2011 event would be used to validate the hydraulic modelling.

Flood modelling has been developed based upon information provided by WWSC, community members and on-site observations. The unique nature of the topography surrounding both townships led to the consideration of the influence of antecedent conditions on flood impacts. Antecedent conditions were considered and investigated for several starting conditions, with rainfall losses iteratively adjusted to match observed flood consequences within Apsley and then adopted for Edenhope.

The findings of this report will be used to develop design modelling for the two townships. The design modelling will likely adopt a single antecedent condition, with consideration of antecedent conditions used for discussion purposes only. It is expected that the degree of consequence for a rainfall event will have a large range as modelling of the 2011 event and preliminary design modelling has shown that antecedent conditions influence flood extents and depths. This is proposed to be considered within later stages of the flood study, specifically the flood response and risk assessments.

It is recommended a community meeting be held in Apsley to confirm the model results outlined in this report.

Post confirmation of the calibration modelling, the design modelling is proposed to adopt the following methodology:

- Initial Water – a single run for the 10% and 1% AEP events considering a range of conditions to understand impact. All design modelling outputs will adopt the 90th percentile upstream water level based upon DEA observations.
- Rainfall Losses – a single run for the 10% and 1% AEP events adopting the calibrated losses and a scenario adopting half these losses to understand impact. All design modelling outputs will adopt lower losses than the 2011 calibrated losses, to ensure a conservative analysis.
- Pre-Burst – the event considering the prior rainfall for the January 2011 event, demonstrating this had an impact on flood depth and extent. As such pre-burst rainfall (75th Percentile) will be incorporated into the design modelling.
- Temporal Patterns – for the 10% and 1% AEP all 10 temporal patterns will be run for a short duration and long duration event. It is expected that this will identify that the catchments are sensitive to a particular temporal pattern (likely rear-loaded). Once determine three temporal patterns for other design modelling will be adopted based upon the catchment sensitivity. If the sensitivity is not evident a front-loaded, middle and rear will be adopted instead.
- Durations – for all design modelling a single temporal pattern will be run for all durations to identify their respective critical duration/s. Once determined that additional temporal patterns will be run.

Design modelling and the next stages of the project will commence once the modelling presented within this report is approved.

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