

CIVIL | WATER | ENVIRONMENT

SWAN HILL AND ROBINVALE DRAINAGE STRATEGY

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
ARR	Australian Rainfall and Runoff
Council	Loddon Shire Council
DCIA	Directly Connected Impervious Areas
DEM	Digital Elevation Model
EIA	Effective Impervious Area
FI	Fraction Impervious
GIS	Geographic Information System
ICIA	Indirectly Connected Impervious Area
IDM	Infrastructure Design Manual
LiDAR	Light Detection and Ranging
NCCMA	North Central Catchment Management Authority
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCP	Reinforced Concrete Pipe
TIA	Total Impervious Area
VLUIS	Victorian Land Use Information System

EXECUTIVE SUMMARY

The Swan Hill and Robinvale Drainage Strategy project has been prepared for Swan Hill Rural City Council (SHRCC) to address stormwater management challenges in Swan Hill and Robinvale, two townships in northwest Victoria. The primary aim of this study was to assess and upgrade stormwater infrastructure in the urban areas of Swan Hill and Robinvale. This involved establishing hydrologic and hydraulic models for each township and using the results to evaluate the performance of existing drainage systems, including pipes, swales, retarding basins, and pump stations, and identifying priority areas for flood mitigation to ensure compliance with the Infrastructure Design Manual (IDM). It provides a standardized approach to the design and development of infrastructure across SHRCC.

The study also proposed a series of stormwater management solutions and design parameters while recommending targeted infrastructure upgrades with preliminary cost estimates and prioritisation to address current and future challenges. Specifically, the study incorporates:

- Data collection and reviews, including historical flood records, LiDAR topography, and hydraulic structure data.
- Hydrological and hydraulic modelling using TUFLOW to simulate flood behaviour and drainage system performance under 1%, 2%, and 20% Annual Exceedance Probability (AEP) events.
- Community consultation to identify flooding hotspots and validate model outputs.
- Screening and analysis of potential flood mitigation measures.
- Recommendations and next steps.

The modelling methodology adopted for both Robinvale and Swan Hill townships was TUFLOW rain-on-grid hydraulic modelling. The model simulation indicated that Swan Hill and Robinvale are characterised by flat terrain and localised drainage issues, exacerbated by infrastructure limitations and increased urbanisation. Several areas with inadequate drainage capacity were identified, including trapped sags, undersized pits and pipes during recent flood events. Modelling confirmed that the majority of pipes and culverts were at full capacity in a 20% AEP event, with numerous intersections, roadways and properties affected by prolonged ponding over roads.

In November 2023, a significant local flood event in Swan Hill recorded 80.6 mm of rainfall over 9 hours, aligning closely with the 2% AEP design rainfall depth of 79.1 mm. The Swan Hill hydraulic model was validated to this event. Model outputs of the 2% AEP event were compared with site imagery and found to be consistent with observed flood extents, though peak flood depths in the model were slightly higher due to timing uncertainties in the photos.

Model sensitivity testing was conducted to assess the impact of elevated Murray River levels coinciding with local rainfall events (20% AEP event) on the drainage system. In Robinvale, coincident flooding caused minor flood level increases (40–100 mm) near Latje Road, Robin Street, and Lawrence Road, with minimal changes elsewhere. In Swan Hill, high river levels caused backwater flooding, particularly near Milloo and Naretha Streets, with up to 650 mm increases in some areas, affecting the performance of the stormwater network. These results highlight the sensitivity of stormwater systems discharging directly into the Murray River and the need for mitigation measures independent of river tailwater conditions.

Community consultation and stakeholder engagement in Swan Hill and Robinvale identified specific drainage issues and gathered input on potential mitigation measures. The community engagement activities comprised drop-in sessions (19 total attendees) and an online questionnaire (37 responses). In Robinvale, key issues included undersized stormwater pipes, ineffective drainage due to flat terrain, blocked inlets, and recurrent flooding at locations like Robin Street and Caix Square, prompting calls for pipe assessments and pump upgrades. Swan Hill respondents highlighted the absence of a formal drainage system at sites such as Bish Road, Butterworth Street, and Charlie Gray Close, and pump station inadequacies with flooding exacerbated by the decommissioned No. 9 Drain.

The initial mitigation screening assessment developed a 'long list' of options to evaluate their feasibility and potential success before conducting simulations. Following discussions with the council, five mitigation options for each township were implemented into the TUFLOW hydraulic model and simulated to assess the resulting flood impacts and benefits.

In Robinvale, the model results suggested that **Refined Robin Street Stormwater Network Upgrade (R02)** and **Ronald Street Stormwater Upgrade with Swales and Pump Station (R05)** are recommended to move forward. Option R02 was shown to effectively reduce peak flood depths by 130 mm during the 1% AEP event on Robin Street and by 70 mm during the 20% AEP event on Herbert Street. Additionally, it would decrease inundation duration by 7–15 hours in low-lying areas (e.g., Caix Square and Margaret Street), aligning with community needs to address frequent flooding in the town centre and football fields, as reported by residents. Option R05 would decrease peak flood depths by 160–190 mm during the 1% AEP event in eastern Robinvale (Lawrence Road and Alexander Street) and reduce inundation duration by 9–12 hours on Morris Street and Ryan Road.

In Swan Hill, it is essential to release pressure on the Main Drain and provide additional drainage capacity to support future urban growth. The Main Drain Pump Station Upgrade (S03) and Butterworth Street to Main Drain Stormwater Network (S05) are therefore recommended for further investigation. Option S03 would reduce peak flood depths by 110–160mm in the 1% AEP event in the industrial estate near Webster Drive and decrease inundation duration by 6–8 hours at Swan Hill North Primary School. This option would assist in addressing school closures and business disruptions caused by the Main Drain overtopping, particularly in frequent storm events. Option S05 can effectively alleviate localised ponding and achieve 20% AEP flood immunity on Notting Road and Berrybank Drive. Furthermore, it is noted that the Werril Street Drainage Upgrade with Channel Re-establishment and Pump Station (S01) would be implementing in stages to accommodate related costs.

The summarised recommendations with priority for five mitigations for each township are detailed in the table below.

Traffic Light	Priority	Description
	High	Relatively substantial improvement and recommend moving forward. Options can be achieved in stages to accommodate high costs.
	Medium	Only achieve localised benefits in the adjacent streets.
	Not Recommended	Minor reductions in the flood level and time of inundation.

ID	Mitigation Option	Description	Potential Benefits	Concerns	Estimated Costing	Priority	Traffic Light
Robinvale							
R1	Robin Street Stormwater Network Upgrade with Pump Stations	Increase pit and pipe sizes under Robin Street and install a pump station at the end Robin Street.	In the 1% AEP flood event, peak water levels are reduced by up to 90 mm along Robin Street and 40 mm on Herbert Street.	Pump failure risk. Regular maintenance required. Traffic disruptions due to existing pipes being underneath Robin Street.	$282k ex.	Not recommended	
R2	Refined Robin Street Stormwater Network Upgrade	Further refinement of option R01 using alternate pipe, pump seizes.	Offers improved performance with reductions of 130 mm (1% AEP) and 150 mm (20% AEP) along Robin Street, plus enhanced reductions on Herbert Street.	Pump failure risk. Regular maintenance required. Traffic disruptions due to existing pipes being underneath Robin Street.	$500k ex	High	
R3	Williams Road Stormwater Upgrade with Pump Station	Increase pipe sizes under Williams Road and install a pump station.	Minor reductions occur in peak water level in the 1% AEP event across the central and eastern areas of Robinvale. A 280 mm reduction on Morris Street and 110 mm on Rowe Street in the 1% AEP flood event.	Pump failure risk. Regular maintenance required. Existing pipes on Williams Rd are reportedly prone to differential settlement and associated long-term damage.	$360k ex.	Not recommended	
R4	Refined Williams Road Stormwater Upgrade	Further refinement of option R03 using alternate pipe, pump seizes.	In the 1% AEP flood event, peak water levels are reduced by up to 430 mm on Morris Street and 125 mm on Rowe Street in central Robinvale and also improve conditions in eastern areas.	Pump failure risk. Regular maintenance required. Existing pipes on Williams Rd are reportedly prone to differential settlement and associated long-term damage.	$780k ex	Medium	
R5	Ronald Street Stormwater Upgrade with Swales and Pump Station	New drainage pipes starting from the sag in Ronald Street, connecting to the existing drainage network under Alexander Street. New formalised swales along Lawrence Rd and Williams Rd. New pump stations at these two road ends.	Achieves substantial reductions in peak water levels in both central and eastern Robinvale. In the vicinity of Lawrence Road and Alexander Street, 1% AEP peak water levels reduced by 160 – 190 mm.	Pump failure risk. Regular maintenance required. Major earthworks.	Over $1M ex.	High	
Swan Hill							

ID	Mitigation Option	Description	Potential Benefits	Concerns	Estimated Costing	Priority	Traffic Light
S1	Werril Street Drainage Upgrade with Channel Re-establishment and Pump Station	New major stormwater pipes under Werril Street from the intersection with Yana Street east to the Little Murray River. Re-establish and excavate the No. 9 Channel to redirect flows south towards the new Werril Street drainage line. New pipes on the southern half of Yana Street flowing to the new drainage line. New pump station and drainage network on Charlie Gray Close discharging into the Yana Street pipes.	In the 1% AEP event, key residential areas (e.g., near Landy Crescent and Charlie Gray Close) saw reductions of 50–90 mm. Benefits extend to areas west of the racecourse and around community facilities, suggesting a strong overall improvement in southern township drainage.	Pump failure risk. Regular maintenance required. Major earthworks. Relatively expensive	Over $2M ex.	High	
S2	Nalder Drive to Nowie Street Stormwater Upgrade	Upgrade the pit and pipe sizes between Nalder Drive and Nowie Street, and the pipes downstream of these (This option is independent of S01)	Provides moderate reductions along key roadways such as Nowie Street, Cobham Avenue, and Kima Street (50–60 mm in the 1% AEP event).	Likely only localised benefits in the adjacent streets.	$282k ex.	Medium	
S3	Main Drain Pump Station Upgrade	Upgrade existing pump stations at the end of the Main Drain.	Achieves significant flood level decreases (up to 110–160 mm) in the industrial estate north of the Main Drain and near residential areas. Near Swan Hill North Primary School, reductions of 100–150 mm in the 1% AEP event greatly improve conditions for a sensitive community asset.	Increase Swan Hill's reliance on pump stations.	Over $1M ex.	High	
S4	Milloo Street and Chapman Street Pump Station and Drainage Upgrade	Upgrade existing pump stations on Milloo Street and existing drainage network on Chapman Street.	Achieves minor reductions (up to 60 mm in the 1% AEP event) along Chapman, Beveridge, and Campbell Streets.	Likely only localised benefits in the adjacent streets.	$282k ex.	Medium	
S5	Butterworth Street to Main Drain Stormwater Network	New pipe and pit network on Butterworth St, Berrybank, Suttie Dr vicinity draining northwards on Williams Road to Main Drain.	Provides moderate improvements adjacent to Berrybank Drive and Butterworth Street, with particularly strong performance in the 20% AEP event. Notting Road and Berrybank Drive would achieve flood immunity during the 20% AEP event.	Relatively expensive. Somewhat limited by the downstream capacity of the network and could increase runoff into the Main Drain	$825k ex.	High	

1 INTRODUCTION

1.1 BACKGROUND

Swan Hill Rural City Council (SHRCC) has engaged WMS to undertake a drainage study of the Swan Hill and Robinvale townships, located on the southern bank of the Murray River in northwest Victoria. The towns are approximately 300 km northwest of the state capital Melbourne, and 70 to 150 km southeast of the nearest major regional hub, Mildura.

Anecdotally, inadequate drainage infrastructure and flat terrain has been an ongoing challenge in both towns with water ponding for extended periods after moderate storm events. This study involves a review of existing drainage infrastructure, computational modelling and investigating potential options for managing future stormwater drainage requirements. The methodology of the project is as follows:

Stage 1 – Project scoping, inception and site visit

Stage 2 – Data review & survey of drainage infrastructure and site constraints

Stage 3 – Drainage study/Model development

a) Hydrological and hydraulic modelling

b) Community Consultation and Questionnaire

c) Investigation of drainage solutions

d) Reporting

e) Delivery of final report and models

This document outlines the existing case hydrological and hydraulic assessment for the Drainage Strategy and Software Model – Swan Hill and Robinvale. The adopted methodology, key assumptions and parameterisation of models are detailed further below.

1.2 SCOPE OF PROJECT

The primary objective is to determine future stormwater requirements and upgrade priorities for stormwater infrastructure within Swan Hill and Robinvale urban areas.

The scope of works comprises of the following:

- Review existing data including council drainage data, LIDAR, survey and proposed and existing development footprints;
- Develop hydrological (RORB) and hydraulic (TUFLOW) models:
    - 1% and 20% AEP design events for Robinvale;
    - 1%, 2% and 20% AEP design events for Swan Hill;
- Assess existing drainage infrastructure performance including underground drainage networks, swale drains, retarding basins, and pump stations;
    - Note capacity shortfalls for flood mitigation complying with IDM requirements;
- Investigate new stormwater design parameters and drainage management philosophy;
- Identify flood behaviour and key overland flood flow locations;
- Develop and propose an efficient drainage network solution;
    - Including sizing, gradients, location and indicative levels of new and upgraded infrastructure;
    - Identify performance of proposed network in comparison to existing;
    - Identify priority of works and preliminary costs for upgrade of existing infrastructure;
    - Proposed changes to development stormwater control philosophy.

1.3 STUDY AREAS

The town of Swan Hill is situated on the southern bank of the Murray River, adjacent to the Little Murray River, an anabranch of the main river system. The catchment upstream of the township is relatively small and flat, extending from low hills around Woorinen Goschen Road and discharging to the Murray River. Ongoing development has occurred within the town area, particularly over the past 10 years, resulting in increased runoff and drainage challenges. Swan Hill is under the jurisdiction of the North Central Catchment Management Authority (CMA), being within the Loddon-Avoca basin.

The town of Robinvale is located 150 km further downstream of the Murray River. The catchment area is limited, predominately consisting of localised runoff areas. Similar to Swan Hill, the catchment and township are quite flat with only minor changes in elevation. Sitting within the Lower Murray Basin, Robinvale is under the jurisdiction of the Mallee CMA.

Sections of both towns lie within the natural 1% AEP flood extents of the Murray River, however levee developments over the past 150 years has reduced the impact of riverine flooding. The towns are part of the Lower Murray and Loddon-Avoca catchments in the Murray-Darling Basin.

Average annual rainfall for the region is approximately 350 mm with hot summers and cool to mild winters. The study area and drainage network for the Swan Hill township and Robinvale township are presented in Figure 1-1 and Figure 1-2 respectively.

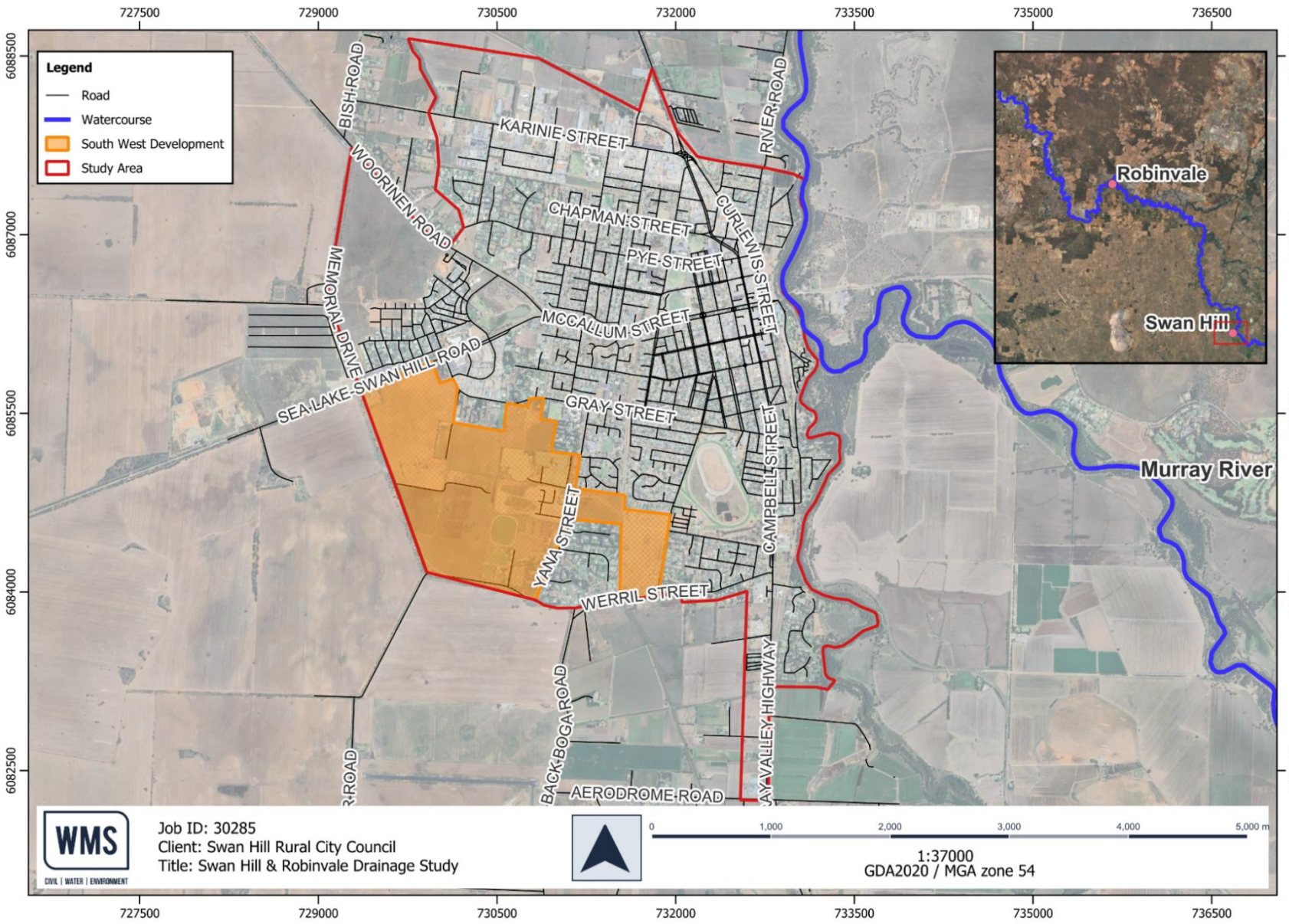


Figure 1-1 Swan Hill Study Area

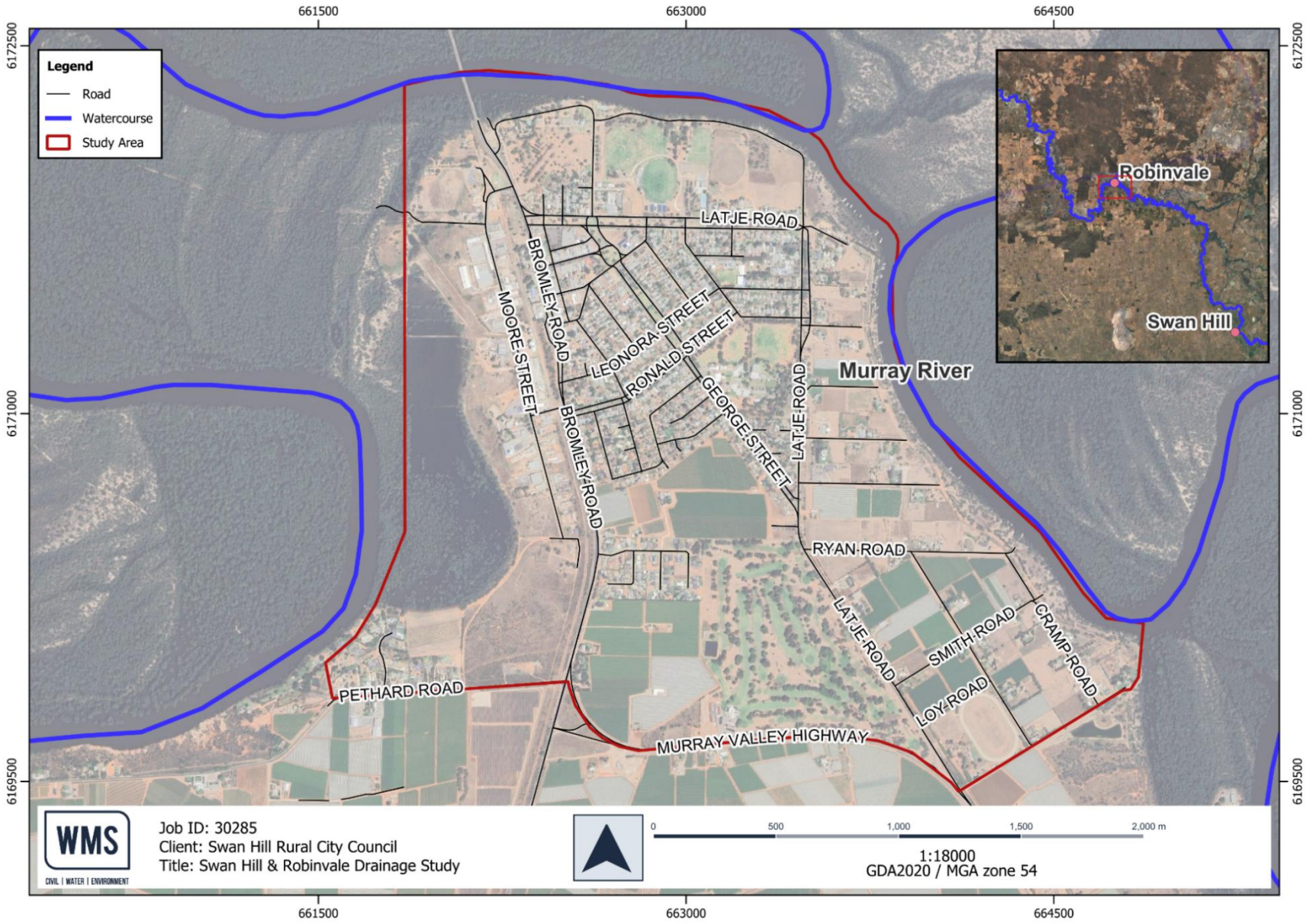


Figure 1-2 Robinvale Study Area

2 AVAILABLE DATA

2.1 PAST STUDIES

Numerous studies have been completed for the Robinvale and Swan Hill townships, which are listed below. Previous models could not be located however reports were reviewed to provide background information and context for the study.

2.1.1 Robinvale

- 2020 – *Management Plan for the Robinvale Constructed Wetland,* Rakali Consulting
- 2003 – *Wetlands for Treatment of Urban Stormwater at Robinvale,* Coomes Consulting
- 2002 – *Robinvale Irrigation District Sections B,C,D & E Stormwater Flooding Strategy,* PPK Environment

2.1.2 Swan Hill

- 2021 – *Regional Flood Mapping Swan Hill Region*, BMT
- 2019 – *Stormwater Management Plan Tower Hill Residential Development,* Heil Engineering Consultants
- 2011 – *South-West Precinct Stormwater Drainage Schematic Design,* Aurecon
- 2005 – *Main Drain Wetlands System,* Coomes Consulting
- 2003 – *Treatment of Urban Stormwater at Swan Hill,* Coomes Consulting
- 2002 – *Tower Hill Estate Stage 1 Stormwater Management Strategy,* Ecological Engineering
- 2002 – *Swan Hill Urban Drainage – Main Drain,* Coomes Consulting
- 2001 – *Stormwater Quality Management Plan for Swan Hill, Nyah and Robinvale,* PPK Environment
- 2001 – *Swan Hill Stormwater Investigation Update,* PPK Environment
- 1998 – *Swan Hill Flood Mitigation Scheme Operations Manual,* Findlay Consulting

2.2 TOPOGRAPHIC DATA

2.2.1 LiDAR Data

LiDAR data for the study areas was sourced from ELVIS and Swan Hill Rural City Council. The source, resolutions and capture dates are provided in Table 2-1. Extents of the LiDAR coverage data sets is presented in Figure 2-1 and Figure 2-2. The VicMaps terrain dataset is a coarse resolution grid but covers the full extents of Victoria.

Table 2-1 Available LiDAR data for Swan Hill and Robinvale

Study Area	Name	Resolution	Capture Date	Coordinate System
Swan Hill	2020 Swan Hill	1 m grid	November 2020	GDA 20 Zone 54
	2019 Swan Hill	1 m grid	September 2019	GDA 94 Zone 54
	2015 Wakool	1m grid	September 2015	GDA 94 Zone 54
	VicMaps	10 m grid	Various	GDA 94
Robinvale	2021 Robinvale	1 m grid	February 2021	GDA 20 Zone 54

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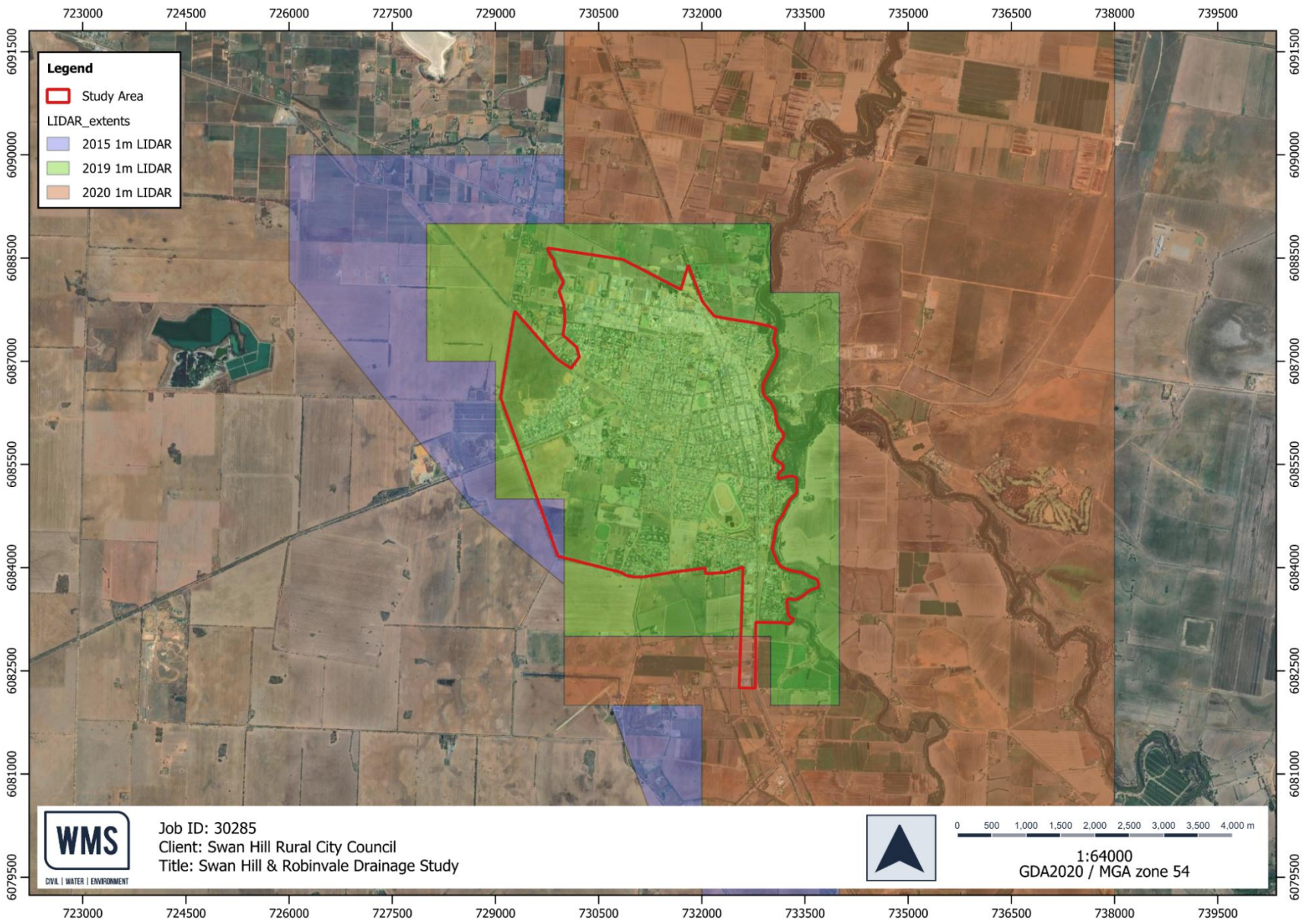


Figure 2-1 LiDAR Extents & Comparison for Swan Hill

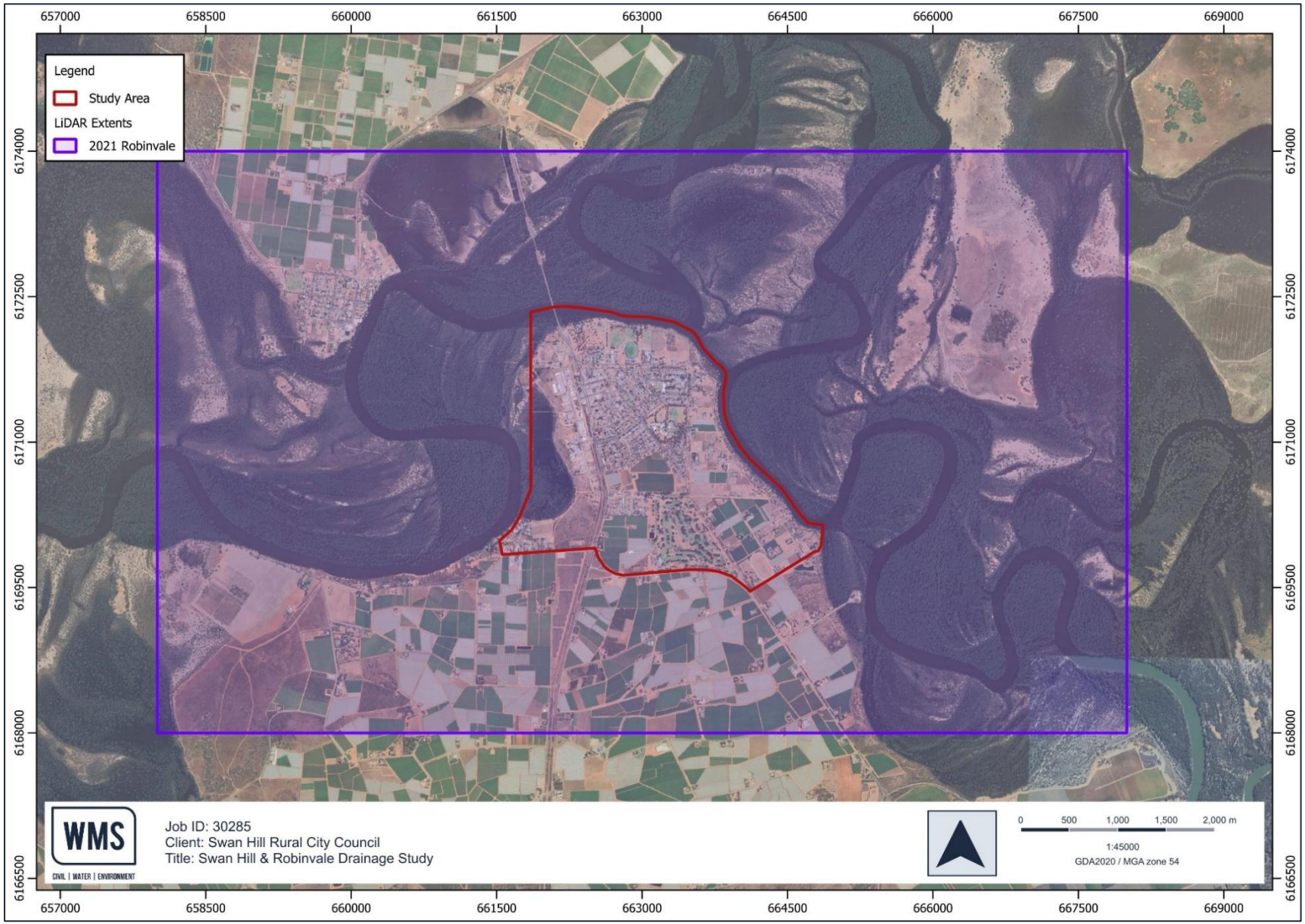


Figure 2-2 LiDAR Extents for Robinvale

2.2.1.1 *Swan Hill LiDAR Comparison*

A comparison of the Swan Hill LiDAR datasets was undertaken through cross sections at various locations throughout the study area. The 2019 and 2020 Swan Hill 1m terrain generally presented similar results at sampled locations. The 2015 Wakool LiDAR is similarly of good quality but appeared to have datum anomalies in comparison with the 2019 and 2020 terrain. Survey outcomes will provide further validation of the LiDAR datasets. Overall, all cross-sections appeared to suitably capture terrain information for hydraulic modelling purposes.

The 10 m gridded data set from VicMaps is of fairly poor quality with inconsistences, low detail, and low resolution. However, it is adequate for hydrological (rainfall routing) analysis where 1 m LiDAR is unavailable. Cross sections are presented in **Figure 2-3**, **Figure 2-4** and **Figure 2-5**. As the 2021 Robinvale LiDAR provides coverage for the full study area at the location, LiDAR validation has been undertaken with surveyed points.

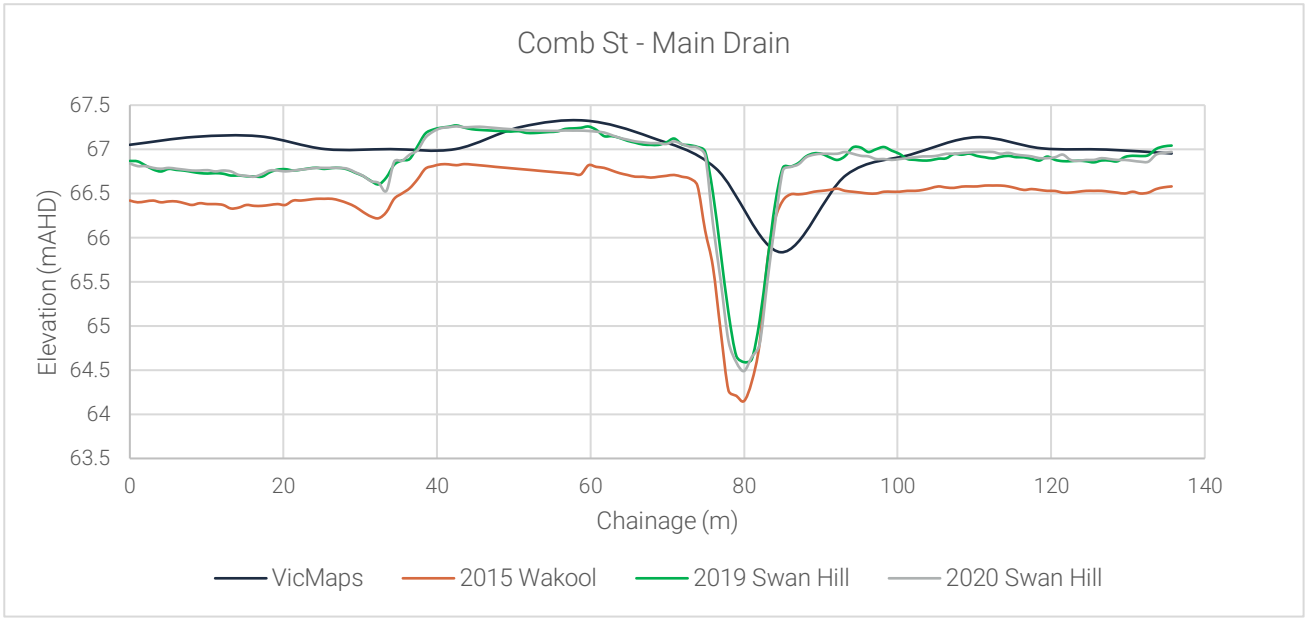


Figure 2-3 Comparison of LiDAR datasets at Comb St - Main Drain, Swan Hill

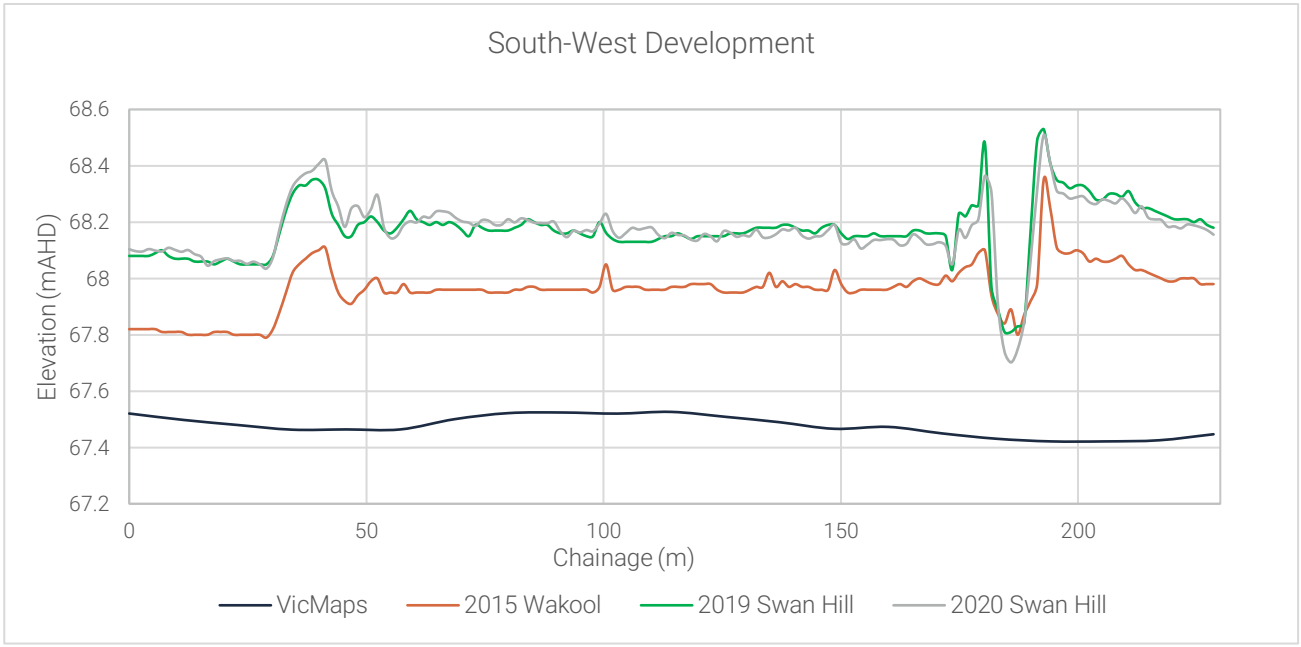


Figure 2-4 Comparison of LiDAR datasets at South-West Development, Swan Hill

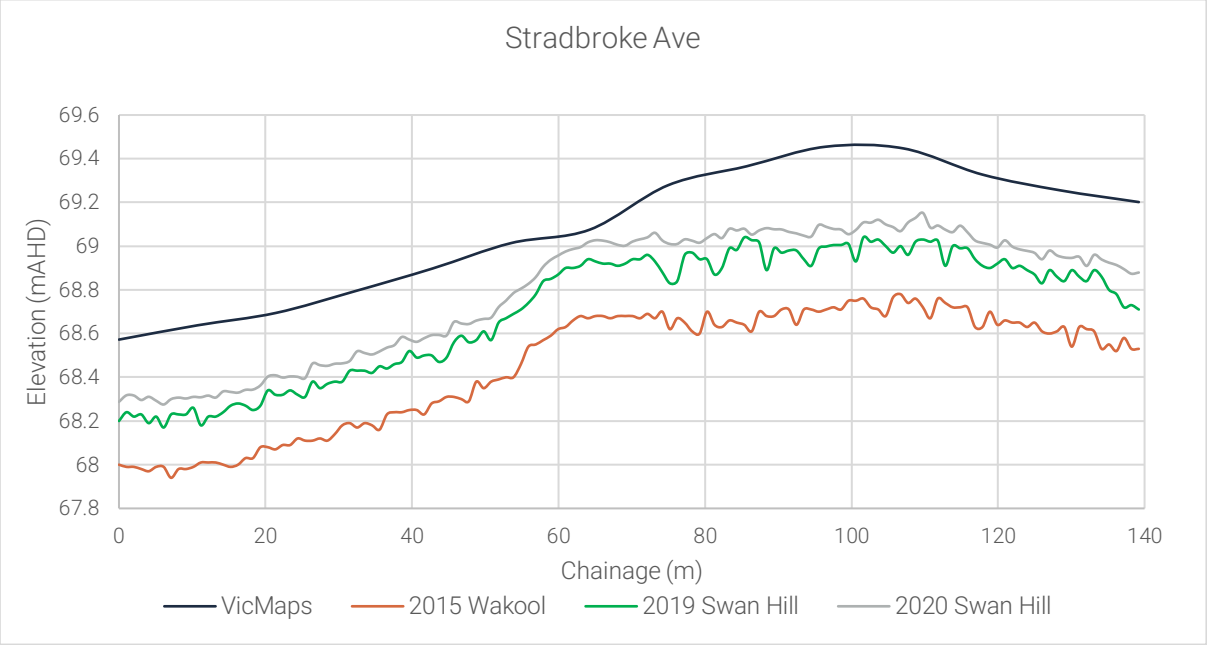


Figure 2-5 Comparison of LiDAR datasets at Stradbroke Ave, Swan Hill

2.2.2 Detailed Survey Verification

Survey was commissioned for select locations across Swan Hill and Robinvale to validate LiDAR data, confirm measurements for hydraulic structures and to identify railway culvert details. The survey locations are presented in Figure 2-6 and Figure 2-7, and resulting comparisons shown in subsequent sections.

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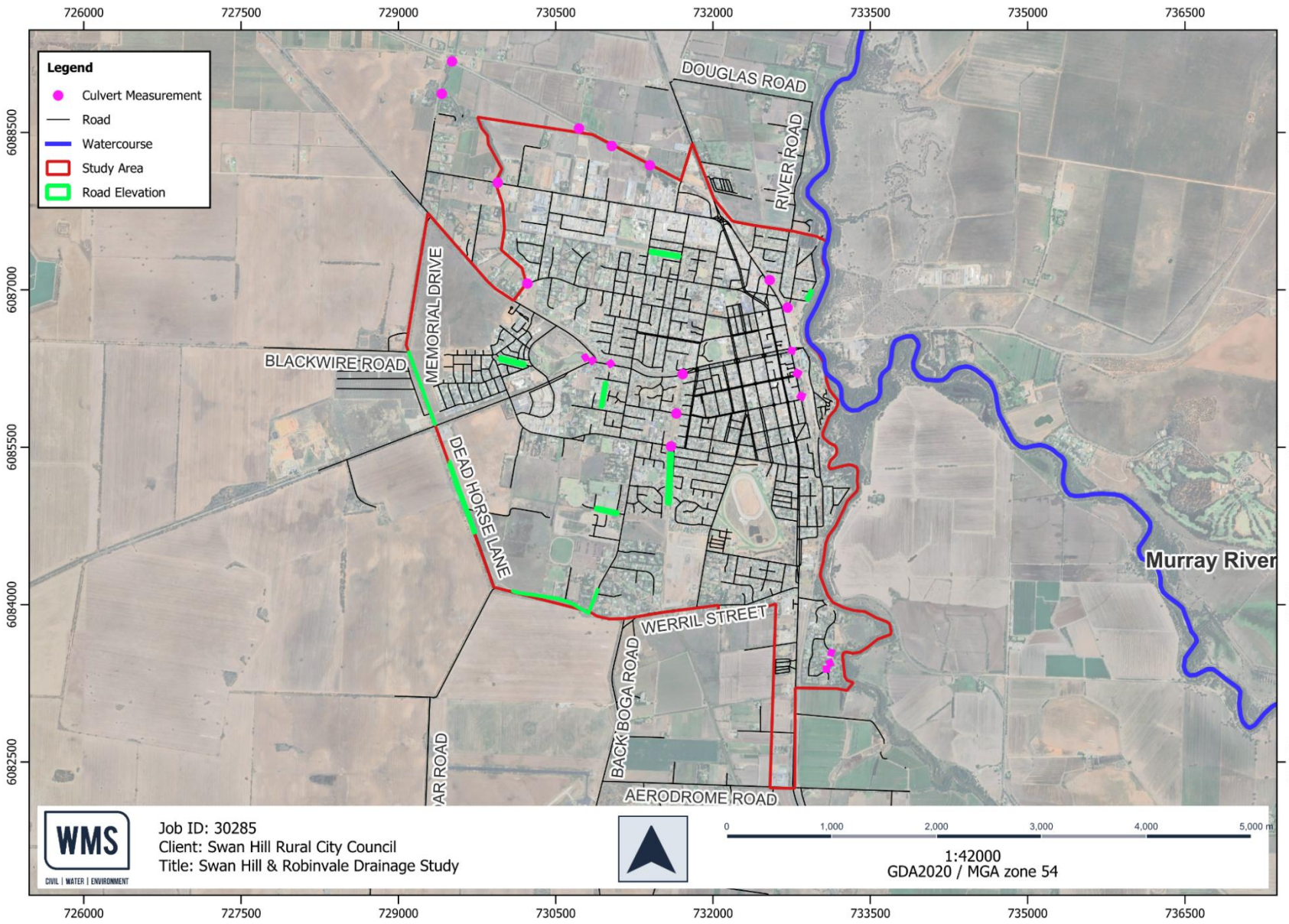


Figure 2-6 Survey locations at Swan Hill

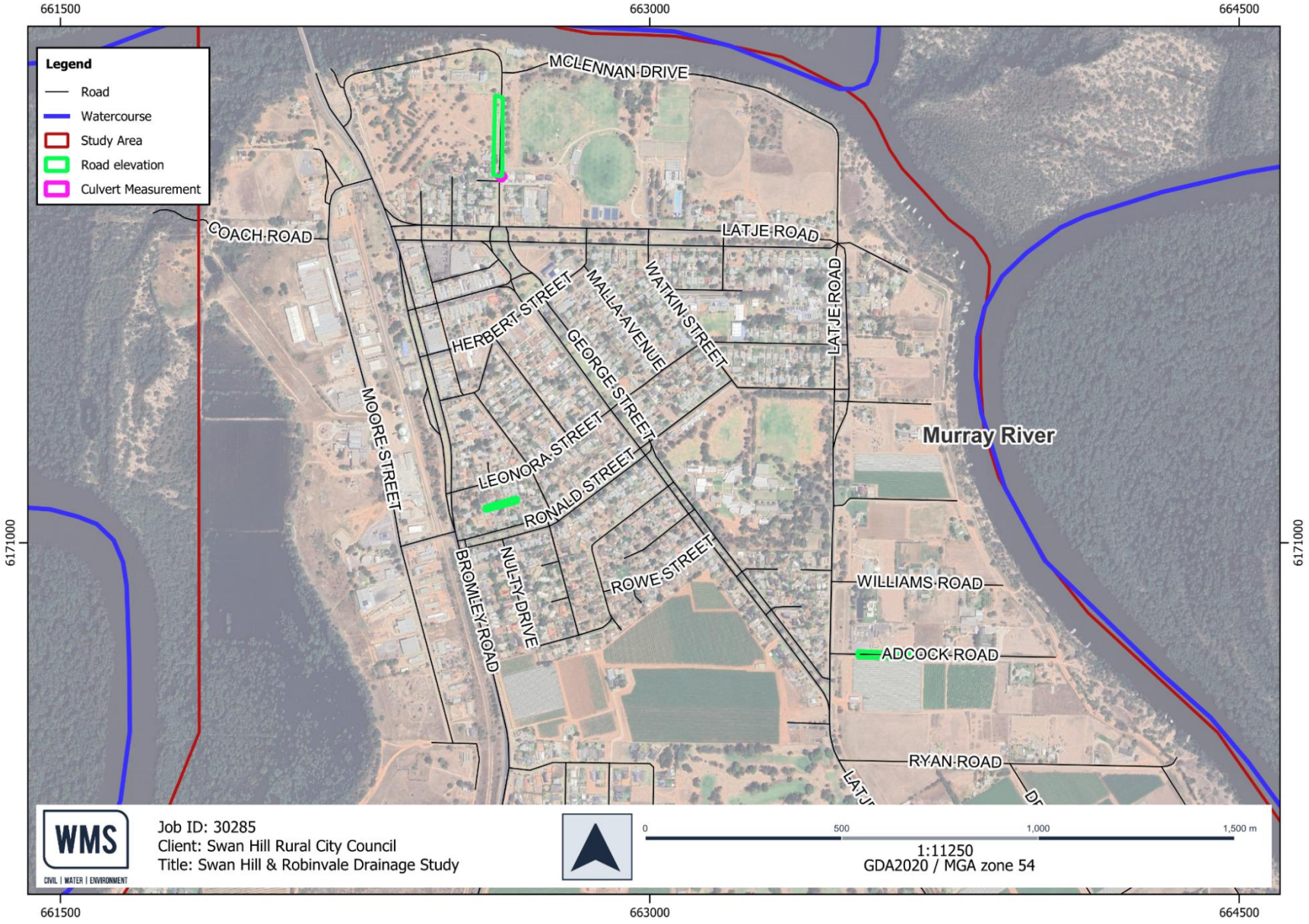


Figure 2-7 Survey locations at Robinvale

2.2.2.1 *Swan Hill*

Comparisons of the LiDAR supplied by Elvis and Swan Hill Rural City Council and survey long sections are illustrated in Figure 2-8 to Figure 2-14. Analysis of the survey shows that surveyed levels in No.9 Main Channel are lower than the LiDAR (0.2m difference), since the LiDAR may capture the top of the vegetation. The Main Drain and road crest between survey and LiDAR them have generally similar levels and gradients. Therefore. the LiDAR data is considered suitable for hydraulic modelling and adjustment of the dataset is not required.

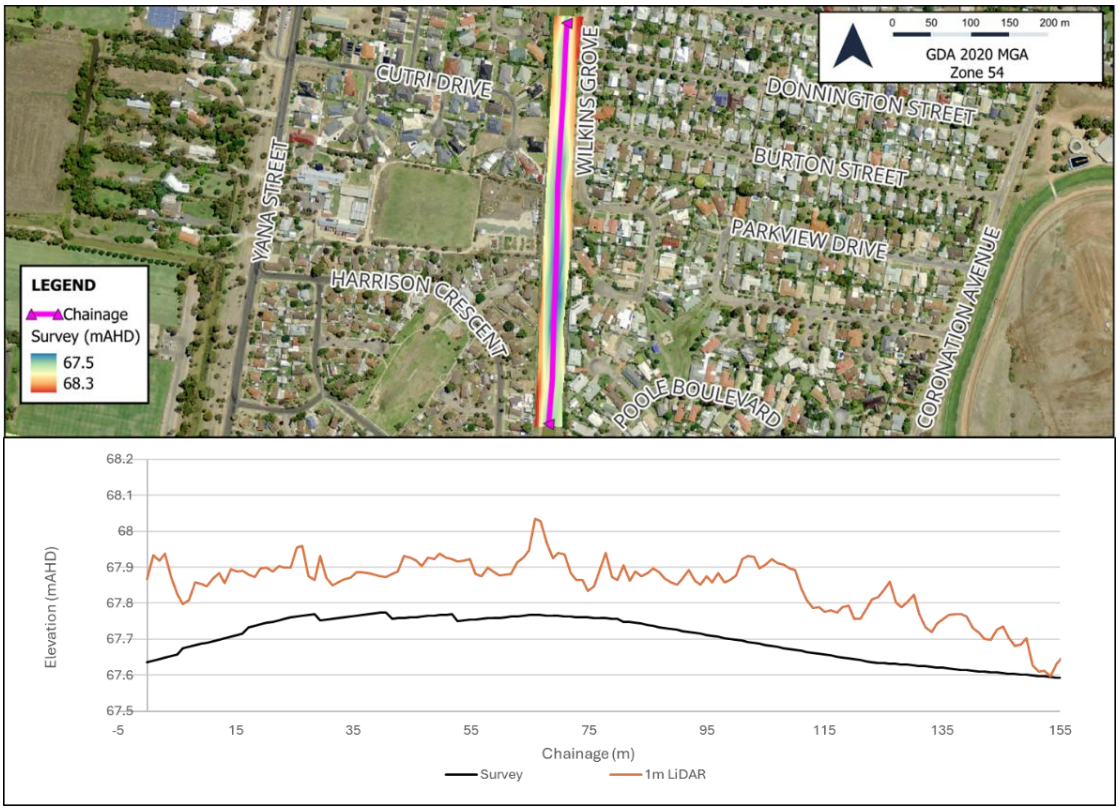


Figure 2-8 LiDAR Verification at No.9 Main Channel, Swan Hill

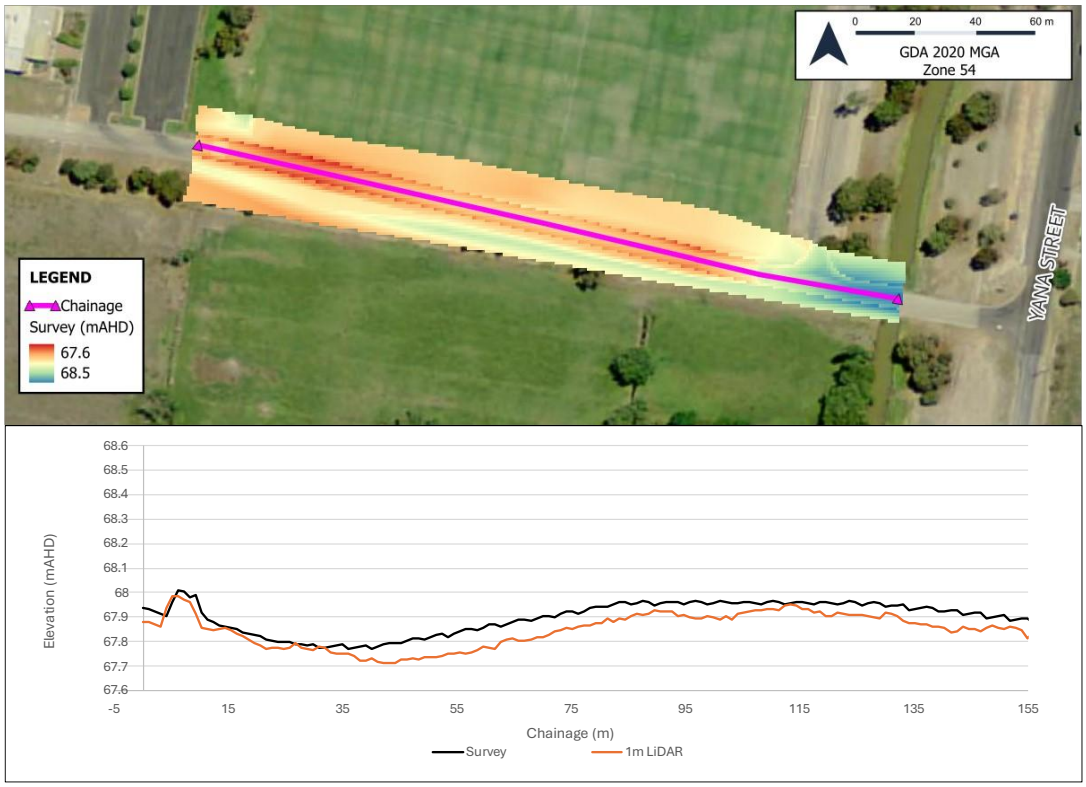


Figure 2-9 LiDAR Verification at Ken Harrison Reserve, Swan Hill

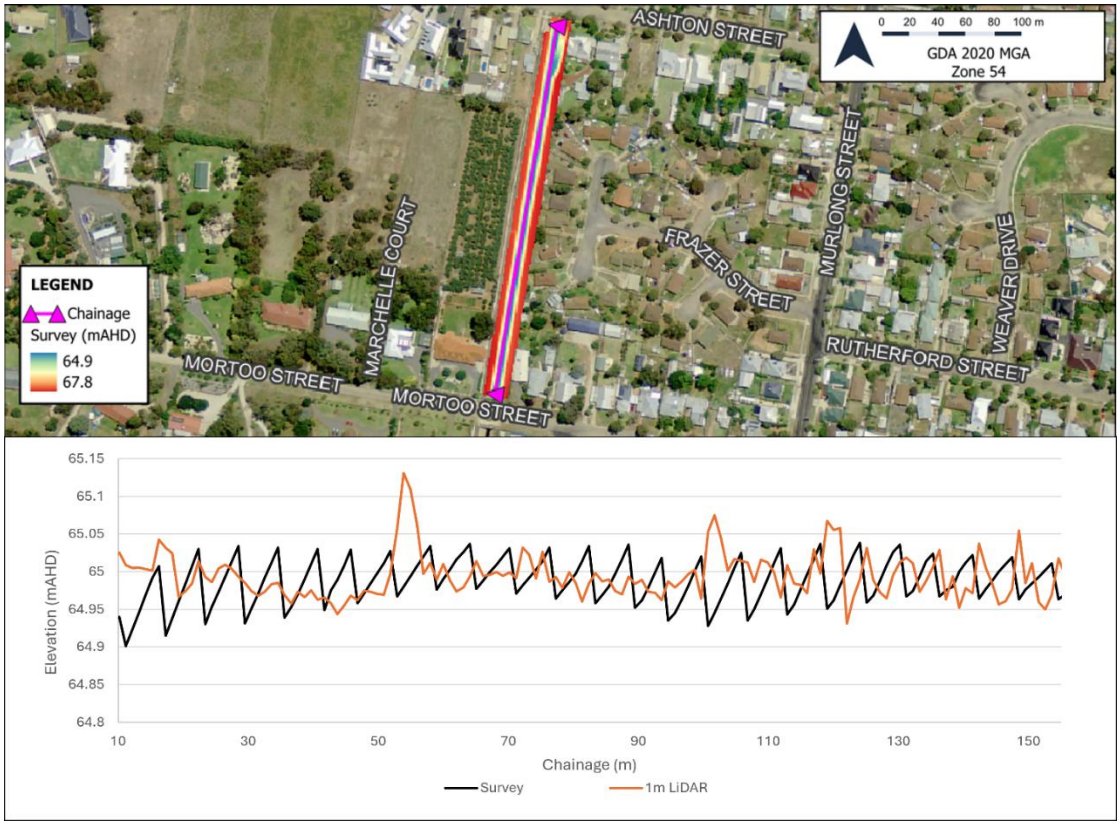


Figure 2-10 LiDAR Verification at Mortoo Street to Ashton Street Main Drain, Swan Hill

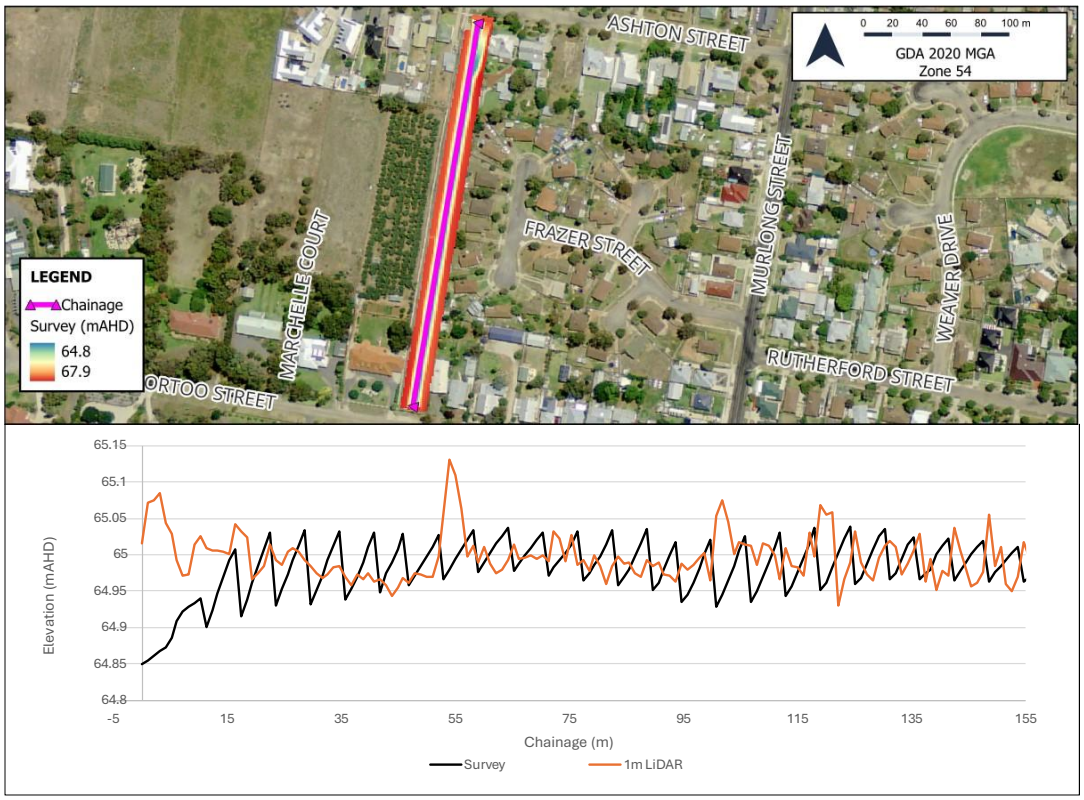


Figure 2-11 LiDAR Verification at Mortoo Street to Ashton Street Main Drain, Swan Hill

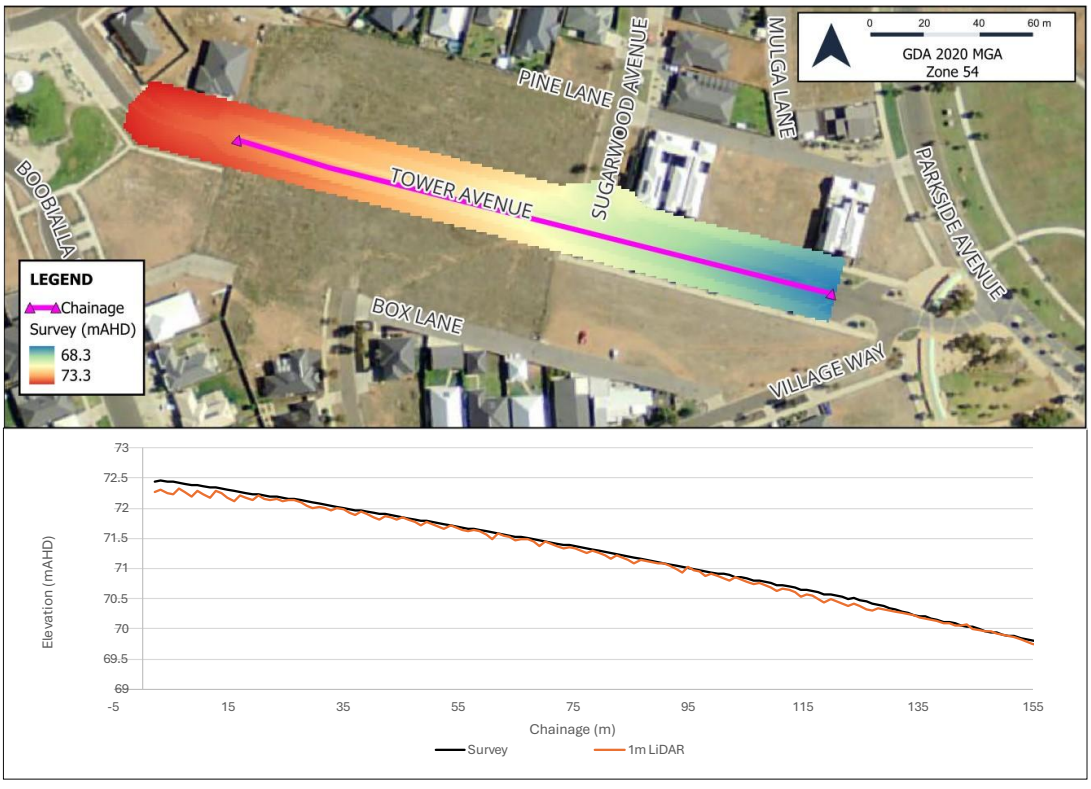


Figure 2-12 LiDAR Verification at Tower Avenue, Swan Hill

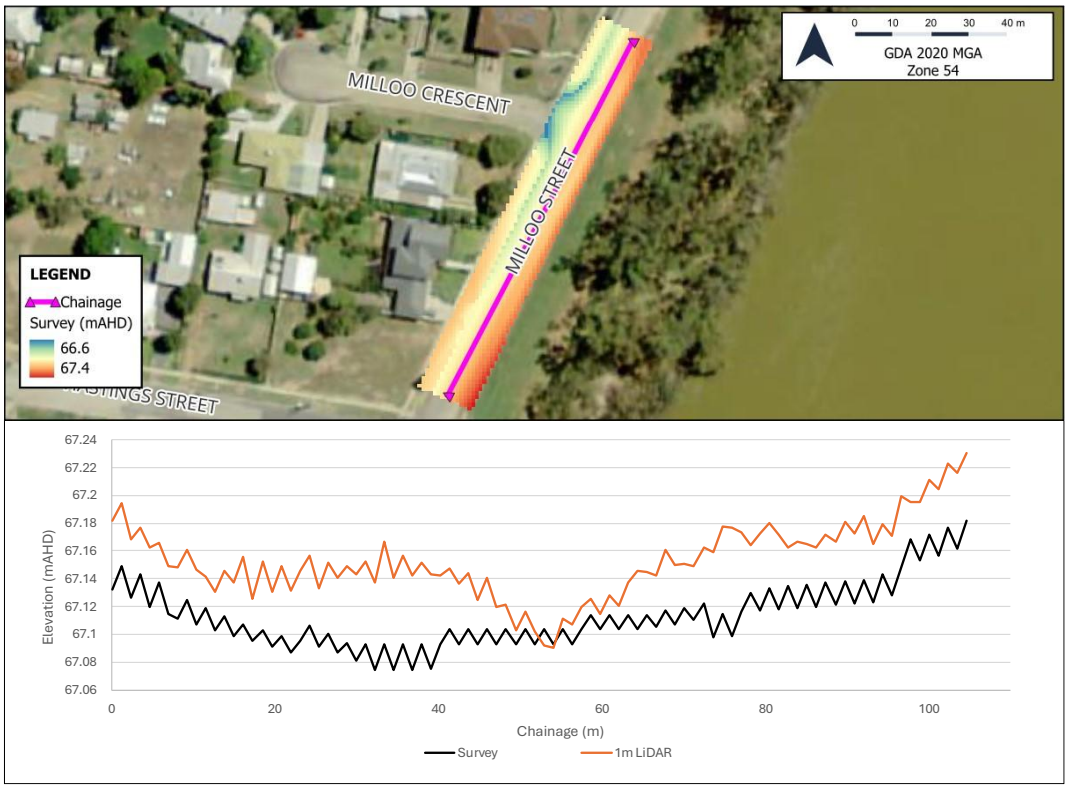


Figure 2-13 LiDAR Verification at Milloo Street, Swan Hill

2.2.2.2 Robinvale

Comparisons of the 1m LiDAR downloaded from Elvis and surveyed long sections are illustrated in **Figure 2-14** to **Figure 2-16.** Analysis of the survey shows that surveyed levels are slightly lower than the LiDAR (approximately up to 0.1m difference). The road crest between survey and LiDAR them have generally similar levels and gradients. Therefore. the LiDAR data is considered suitable for hydraulic modelling and adjustment of the dataset is not required.

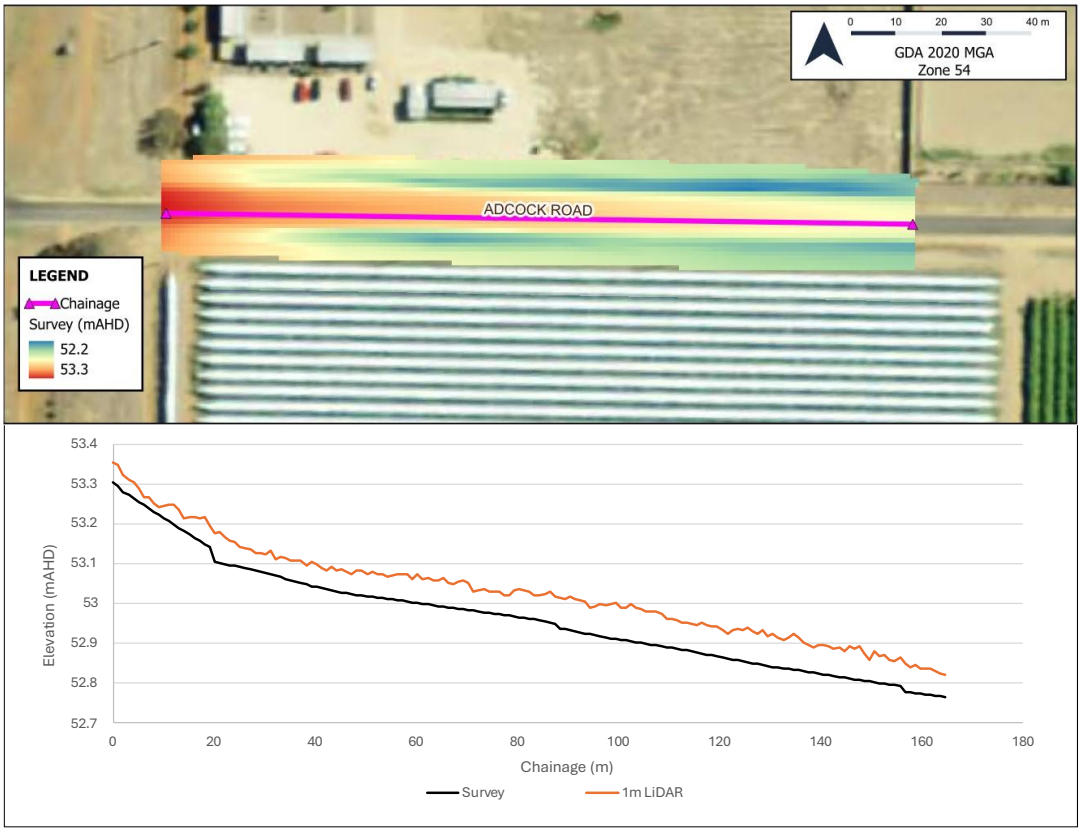


Figure 2-14 LiDAR Verification at Adcock Road, Robinvale

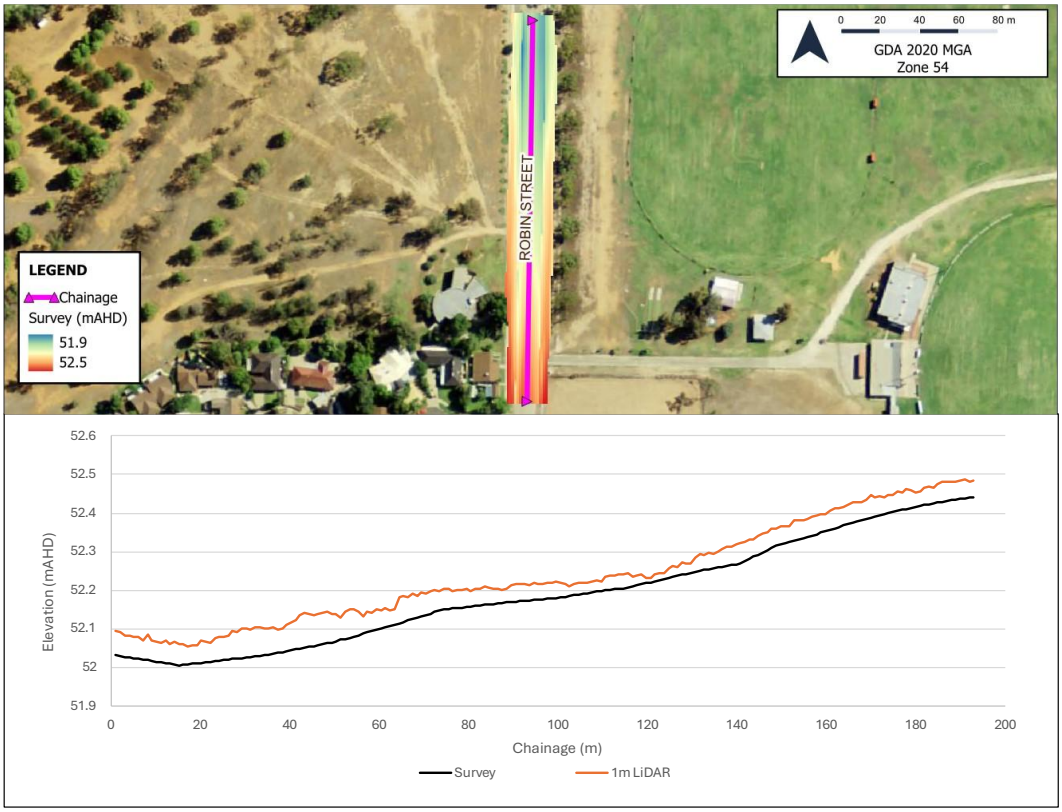


Figure 2-15 LiDAR Verification at Robin Street, Robinvale

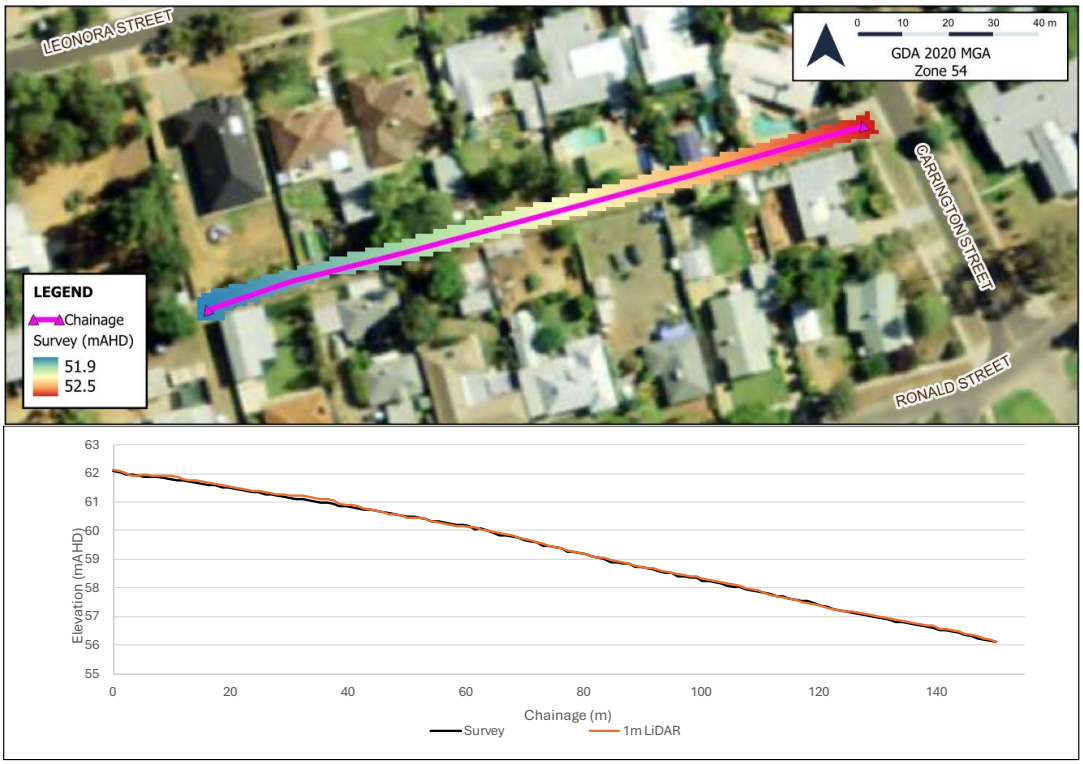


Figure 2-16 LiDAR Verification at Carrington Street Lane, Robinvale

2.3 HYDRAULIC STRUCTURES

Details of existing hydraulic structures have been collated from Swan Hill Rural City Council GIS database, past reports, and documents. A summary is outlined below and locations of key features is presented in Figure 2-17 and Figure 2-18.

2.3.1 Pit and Pipe Network

Pit and pipe data was provided by Swan Hill Rural City Council for both Swan Hill and Robinvale in GIS format. The dataset is reasonably complete with pipe diameters, lengths, and locations available across the study area. Invert data is missing for certain pipe segments; however, this is predominately for short lengths of pipe and/or smaller diameter pipe segments which are unlikely to have any major impacts on the hydraulic modelling. Missing invert levels have been inferred from connecting pipe junctions and minimum cover requirements as per the IDM during the hydraulic modelling process. A summary of the pipe and pit data is presented in Table 2-2 and Table 2-3 respectively.

Table 2-2 Pipe Data Gaps

	Swan Hill		Robinvale	
Diameter (mm)	No. Pipe Segments	% Missing Invert Data	No. Pipe Segments	% Missing Invert Data
≤ 450	2107	40%	314	17%
525	107	30%	21	14%
600	108	31%	25	8%
675	19	26%	4	25%
750	59	32%	14	7%
825	10	40%	-	-
900	56	38%	10	30%
1050	3	0%	-	-
1200	66	38%	10	10%
1350	5	80%	-	-
Total	2540	39%	398	16%

Table 2-3 Pit Data

Asset Type	Number of Assets in Swan Hill	Number of Assets in Robinvale
Junction Pit	683	139
Grated Pit	274	27
Side Entry Pit	1473	208
Grated Side Entry Pit	87	10
Total	2517	384

2.3.2 Additional Culverts

The location of additional culverts not included in SHRCC datasets were identified through desktop review and validated with site survey. Additional culverts are located across the town with the majority being railway culverts along the rail line north of Karinie St. Site survey was commissioned to measure the sizing and invert levels of these culverts, their spatial locations are presented in Figure 2-6 and Figure 2-7.

2.3.3 Retarding Basins and Storages

A lake exists within Barry Steggall Park, which acts as a stormwater retention basin from the neighbouring suburb, Tower Hill. Only approximate storage volume estimates were available for the basin, indicating a volume of 20,000 m^3 (Heil Engineering Consultants, 2019). Stage-storage or bathymetry data for the lake was not available, so storage was estimated using the available LiDAR data.

2.3.4 Pumps and Pump Stations

Swan Hill township has two main pump stations, one located at the northern main drain outlet (Milloo Street) and one at the southern drain outlet off Pental Island Road. These serve as the primary outlets to discharge local stormwater into the adjacent Murray River.

Pump data was provided by Swan Hill Rural City Council through various data formats which included GIS points and historic records. No pumps of note were identified for Robinvale. Cross referencing of various datasets was undertaken to identify key pump specifics for input into hydraulic modelling. The collated pump data is provided in Table 2-4.

Table 2-4 Collated pump data for Swan Hill

ID	Location	Size	Head (MT)	Flow (L/s)	Installation	Comments
DP001	MAIN DRAIN (Milloo Street)	250 MM	7.0	260	1993	
DP002		18 IN	6.0	682	1974	
DP003		24/30	4.4	1300	1993	
DP004			3.5	1100	2012	Pump flow rate determined from pump commissioning report
DP005	MAIN DRAIN WETLANDS	300 MM			2008	
DP006	HASTINGS ST.	150 MM		55	1997	Location based on GIS dataset
DP007		16 IN		310	2011	Location based on GIS dataset
DP009	ELAMAIN AV.	100 MM		31.5	1998	
DP010		100 MM	4	31.5	2008	
DP012	SOUTHERN DRAIN (Pental Island Rd)	9\9	8	190	1989	
DP013		9\11	6	87	1987	
DP014			8.0	18	1987	Location based on GIS dataset
DP015	JENNINGS EST	50 MM			2016	
DP016	JAYCEE PARK	150 MM	9.0	45	1993	
DP017	YANA ST.		2.0	22	1993	
DP018	KEN HARRISON		6.6	18.5	1988	
DP019	RIVERSIDE PARK	80 MM	20.4	10	2000	Location based on GIS dataset
DP023	RIVER OAKS	150 MM	5	20	2001	Location based on GIS dataset

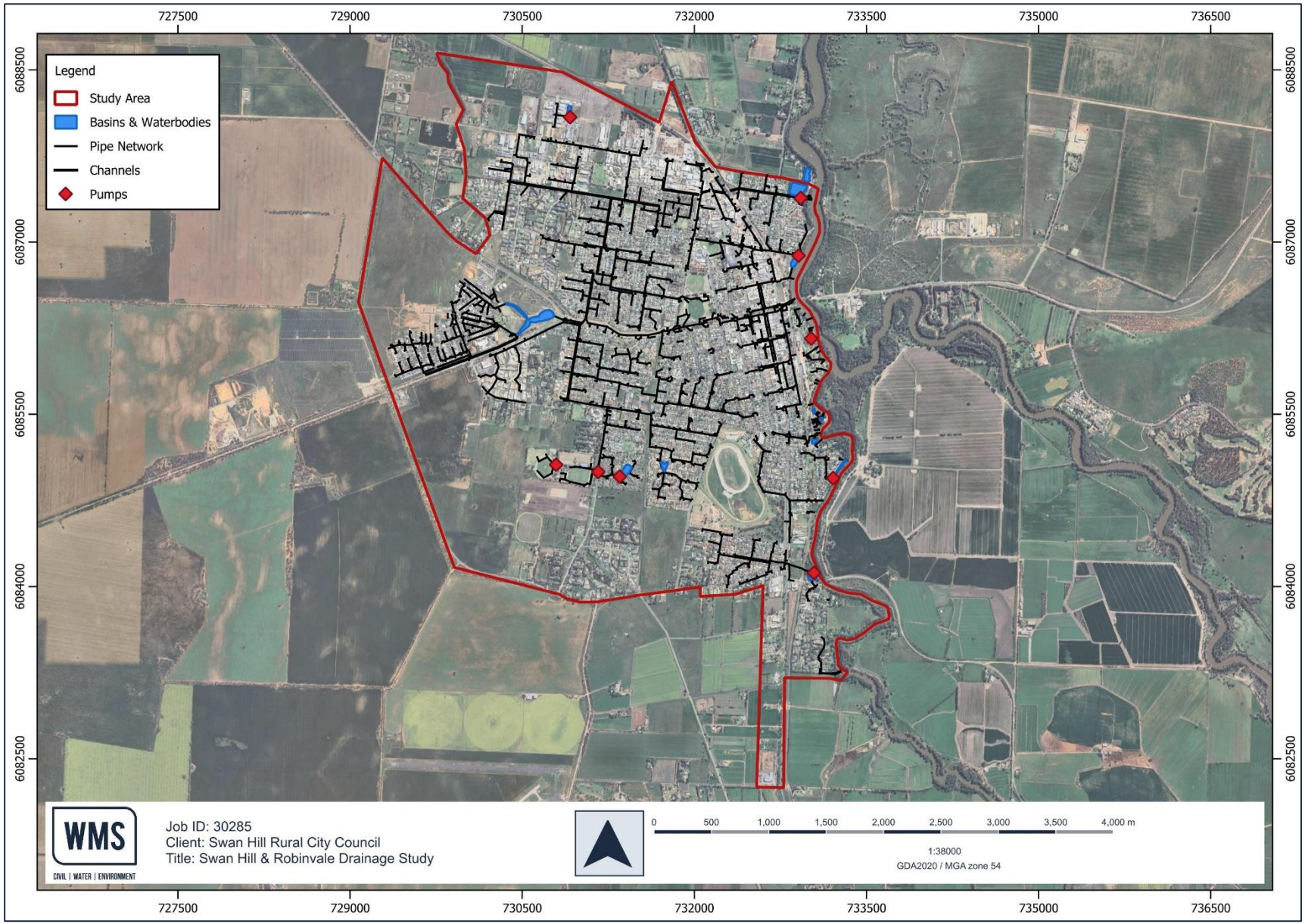


Figure 2-17 Key drainage assets at Swan Hill

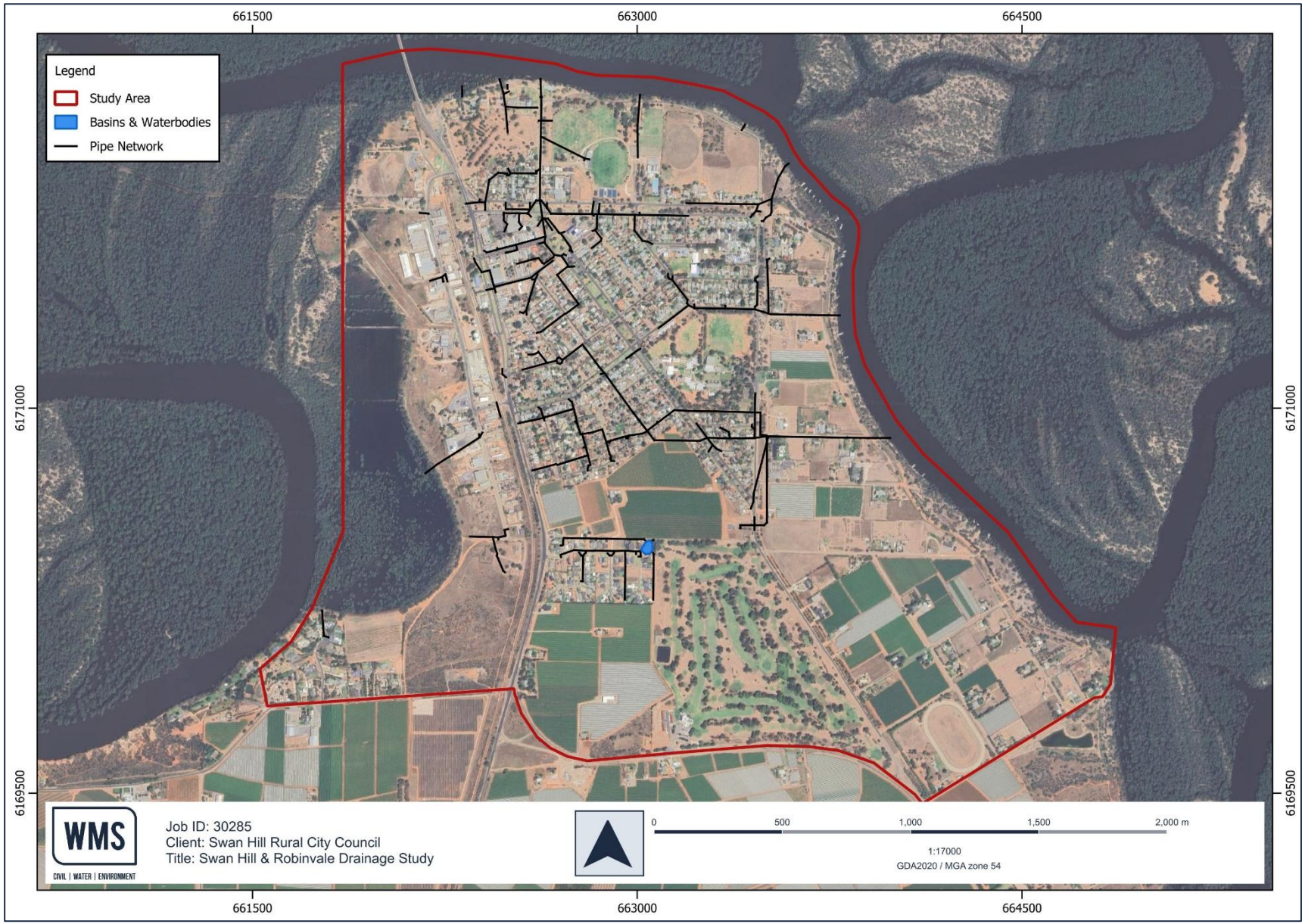


Figure 2-18 Key drainage assets at Robinvale

2.4 OTHER GIS DATA

2.4.1 Cadastre

Parcel and property data was obtained from the Victorian Spatial DataMart in June 2023. It was assumed that the data is up to date and no further adjustments were made.

2.5 SITE VISIT

A site visit was undertaken to Swan Hill and Robinvale by WMS on 8th & 9th August 2023, where key structures and assets within the study area were observed and photos taken. Notes and photographs obtained during the site visit were included as part of the validation process for hydraulic modelling results.

2.6 GAUGE DATA

2.6.1 Rainfall Gauges

Rainfall gauges provide an understanding of rainfall depth totals and distribution of rainfall over time. These are used in flood and stormwater analysis to provide quantitative insight into historic storm events and understand how real site data compares with Bureau of Meteorology (BoM) design rainfall depths. There are several daily rainfall stations near Swan Hill and Robinvale. Selected gauges with long record periods and in close proximity to the study areas are outlined in Table 2-5 and their locations are presented in Figure 2-19 and Figure 2-20.

In contrast to the remaining gauges listed below, Swan Hill Aerodrome (ID 77094) is a pluviograph rainfall gauge which measures continuous, sub-daily rainfall data.

Table 2-5 Daily Rainfall Gauges at Swan Hill and Robinvale

Gauge no.	Location	Commenced	Status
Swan Hill			
77094	Swan Hill Aerodrome	1996	Open
77043	Swan Hill High School	1949	Closed 31 Dec 1951
75048	Swan Hill (Murray Downs)	1865	Closed 05 Jan 2004
77084	Swan Hill SR&WSC	1956	Closed 31 Dec 1982
77042	Swan Hill Post Office	1844	Closed 16 Dec 1996
Robinvale			
76125	Robinvale Consolidated School	1970	Closed 31 Dec 1980
76053	Robinvale	1926	Open
49013	Euston Post Office	1877	Closed 31 Dec 1970
49014	Euston Station	1882	Closed 31 Dec 1940

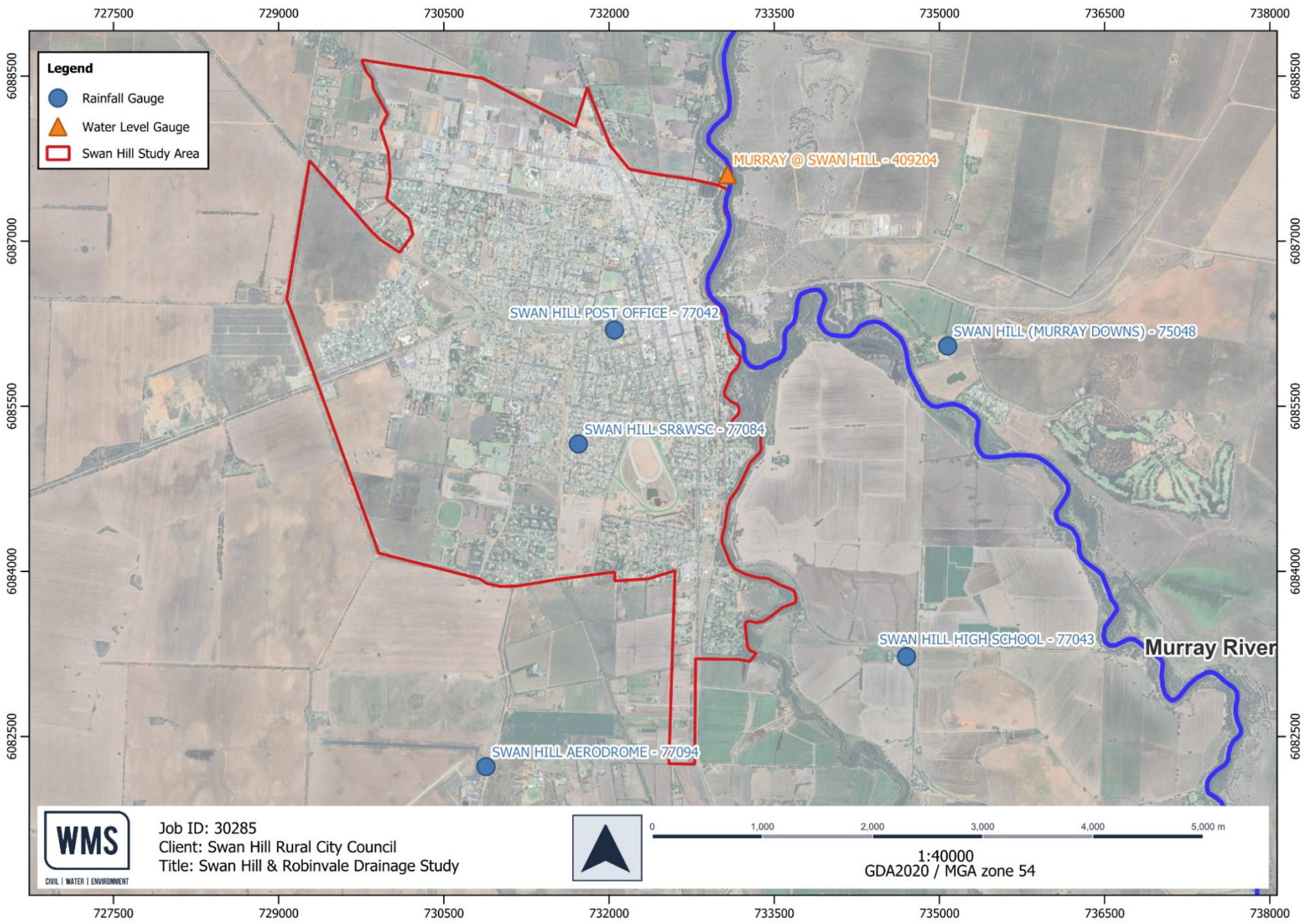


Figure 2-19 Swan Hill Rainfall and Water Level Gauge Locations

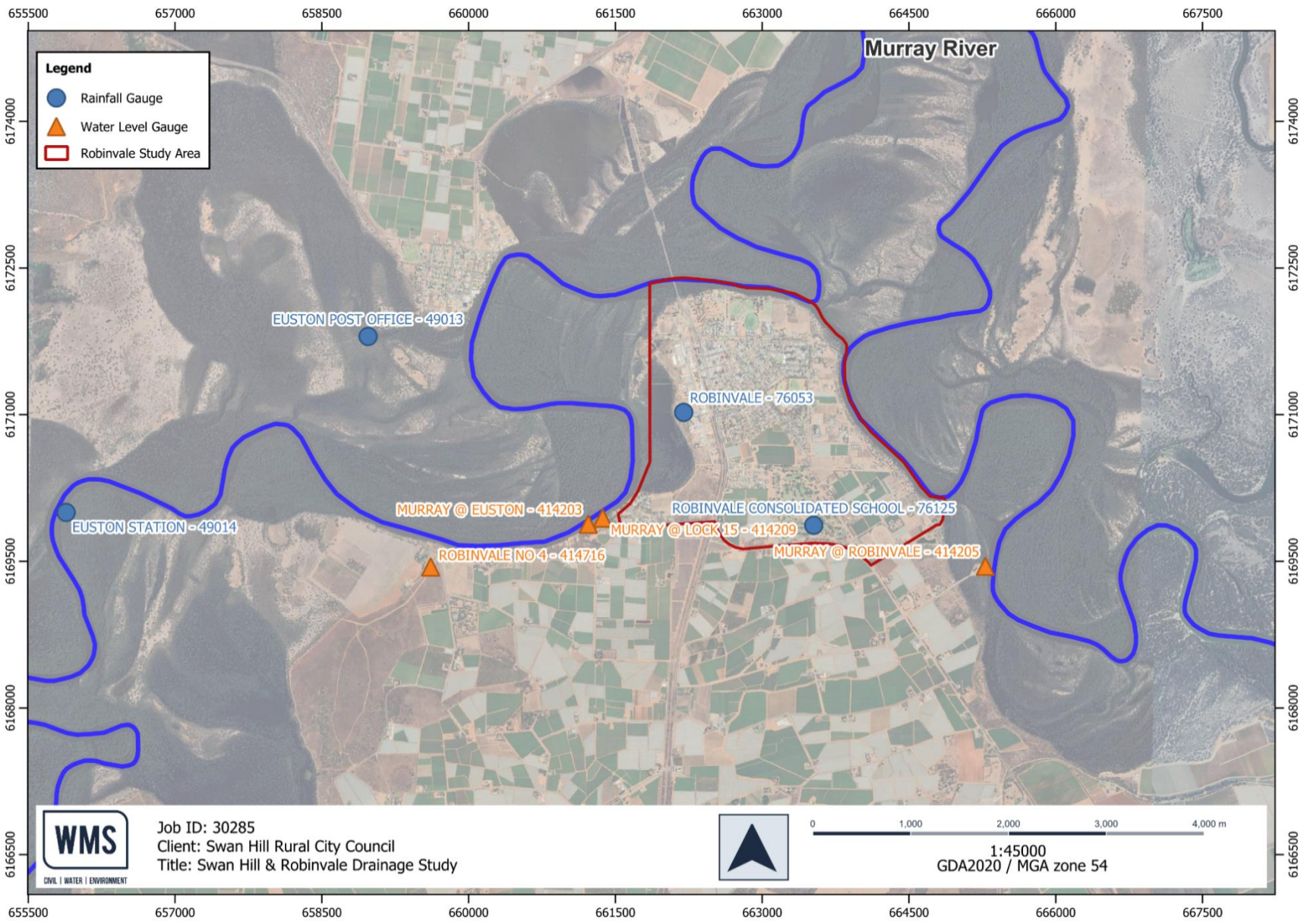


Figure 2-20 Robinvale Rainfall and Water Level Gauge Locations

2.6.2 Streamflow Gauges - Murray River

The Murray River is a highly complex major river with significant catchment and bank developments over time. Both the Victorian and NSW sides of the river neighbouring the study area have been extensively leveed since the 1800s, with significant variation in both height and condition.

Water level gauges for the Murray River are located at Swan Hill township (409204), and Euston Weir (414203), immediately downstream of Robinvale (refer to Figure 2-19 and Figure 2-20). The gauge at Swan Hill has operated continuously since 1909. The Euston Weir was constructed in 1936, with gauging commencing in 1975. The weir maintains adequately high-water levels in the river for navigation and irrigation purposes.

For Robinvale, appropriate flow estimates could not be determined however major, moderate and minor flood levels were extracted from *Robinvale Local Flood Guide* (SES, 2019) and presented in Table 2-7. No other design flood estimates were available from past studies or literature.

No other streamflow gauges exist within the local drainage areas of either township and hence model calibration with gauged data is not possible and was excluded from the project scope.

Table 2-6 Murray River at Swan Hill (409204) Estimated Peak Flows (BMT, 2021) (SES, 2018)

	BMT, 2021			SES, 2018		
	Flow (ML/day)	Gauge Depth (m)	Height (mAHD)	Flow (ML/day)	Gauge Depth (m)	Height (mAHD)
1% AEP	35,000	4.77	67.69	36,200	4.82	67.74
2% AEP	34,000	4.74	67.66	35,800	4.80	67.72
5% AEP	32,000	4.67	67.59	34,800	4.77	67.69
10% AEP	31,000	4.64	67.56	33,600	4.73	67.65
20% AEP	29,000	4.53	67.45	31,500	4.66	67.58

Table 2-7 Murray River at Euston (414203) Flood Levels (SES, 2019)

	Gauge Depth (m)	Height (mAHD)
Major Flood Level	10.30	52.14
Moderate Flood Level	9.80	51.64
Minor Flood Level	9.10	50.94

2.7 HISTORICAL FLOOD RECORDS

In the absence of gauged flood data within the town, photographs and anecdotal information from historic flood events were used to validate hydraulic modelling results at key inundation locations. Photographs of past flooding events reveal potential flood levels and drainage extents. Given significant catchment changes throughout the years, floods during recent years with appropriate data were prioritised.

2.7.1 13th October 2022

Photographs of the October 2022 flood event was provided by Swan Hill Rural City Council. This event occurred from 13 October to 14 October 2022 with flooding observed across both Swan Hill and Robinvale. This period saw riverine flooding of the Murray River across the region, with simultaneous local catchment flooding at Swan Hill. Swan Hill Aerodrome rainfall gauge (Station ID 77094) received a total of 85.2 mm over a period of 30 hours. Rainfall intensity remained relatively consistent over the course of the storm, ranging between 3 – 7 mm/hr. Hourly and cumulative rainfall totals for this event are presented in Figure 2-21.

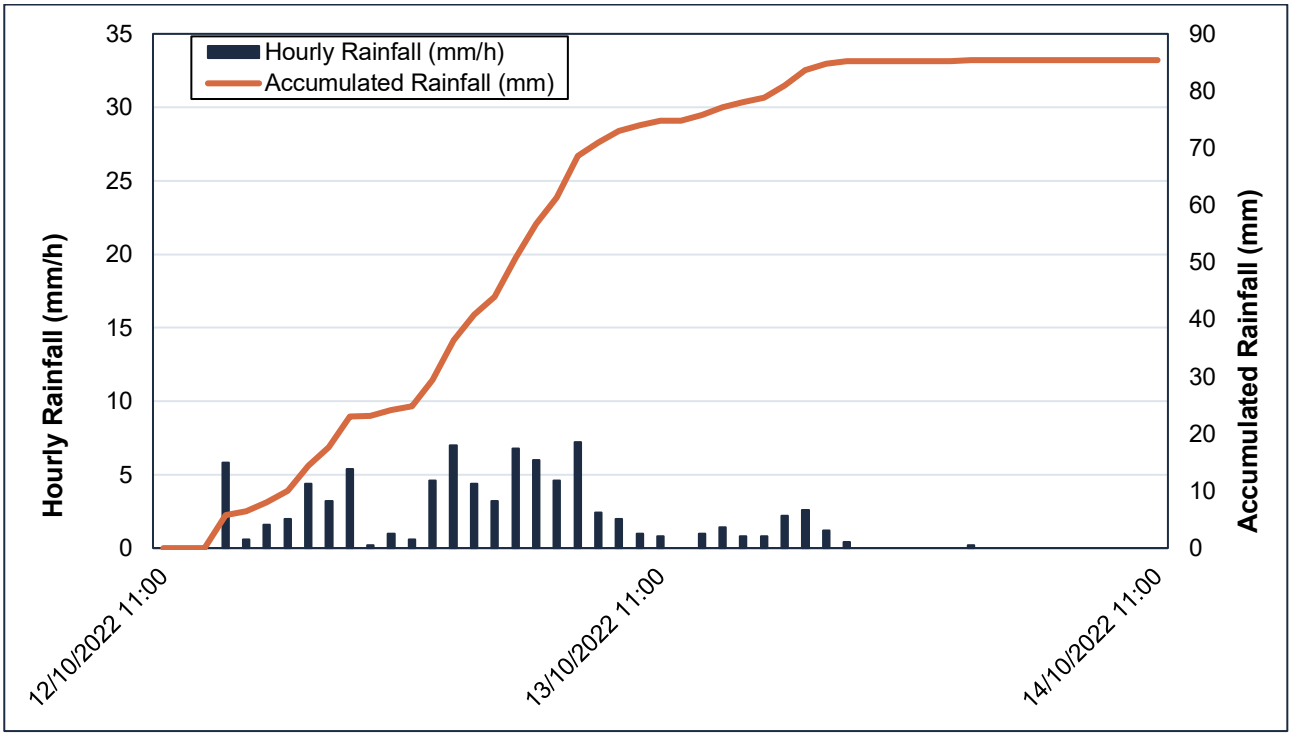


Figure 2-21 Cumulative and Hourly Rainfall Totals at Swan Hill Aerodrome Gauge (ID 77094) in the October 2022 Event

Rainfall intensities for this event approximately equalled a 20% AEP design rainfall event for a 9-hour duration, however this increased to a 3% AEP rainfall event for a 30-hour storm duration. Measured rainfall intensities at Swan Hill Aerodrome relative to design rainfall intensities are presented in Figure 2-22.

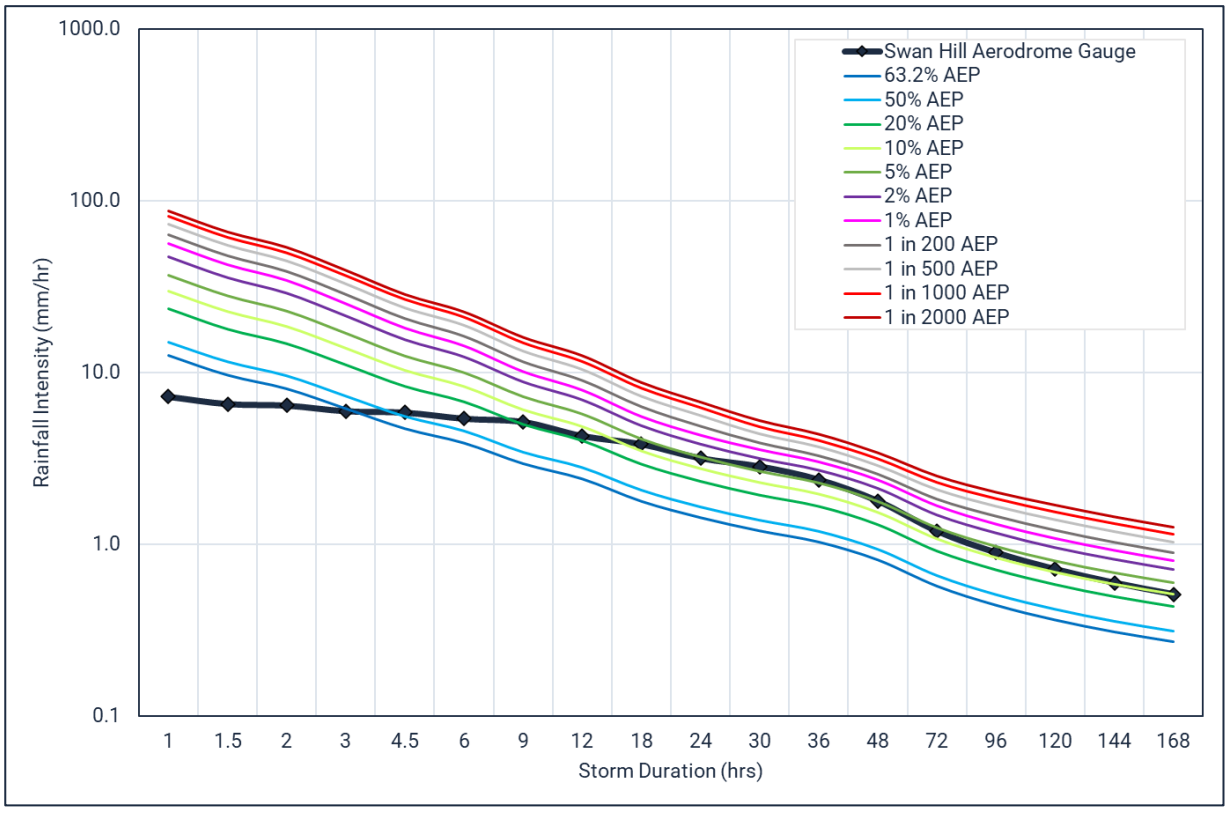


Figure 2-22 Measured Site Rainfall Intensities at Swan Hill Aerodrome Gauge (ID 77094) in the October 2022 Event

Several locations within Swan Hill experienced local catchment flooding during this event. WMS was informed during the August 2023 site visit that the Main Drain pump station failed during this storm event, which is expected to have worsened overland flooding within the township. Photos captured during and after the event were provided to WMS, indicating flood extents at key locations within the township.



Figure 2-23 October 2022 Overland Flooding at the Intersection of McCallum Street and Stradbroke Avenue



Figure 2-24 October 2022 Overland Flooding at Butterworth Street



Figure 2-25 October 2022 Overland Flooding of Naretha Street (Left) and Milloo Crescent (Right)

2.7.2 29th November 2023

During the commissioning of this drainage study, a major flood event occurred at Swan Hill on 29 November 2023. This event resulted in significant flash flooding across the township with several areas of inundation. Media coverage of the event recorded several photographs of the storm aftermath including the major inundation areas. Swan Hill Aerodrome rainfall gauge (Station ID 77094) received a total of 80.6 mm of rainfall over a 9-hour period, which is more than the 2% AEP design rainfall depth for Swan Hill for a 9-hour storm. This event was chosen as a validation event for the Swan Hill TUFLOW model. Refer to Section 4 for comparison of photography captured during the event with hydraulic model outputs. Hourly and cumulative rainfall totals for this event are presented in Figure 2-26.

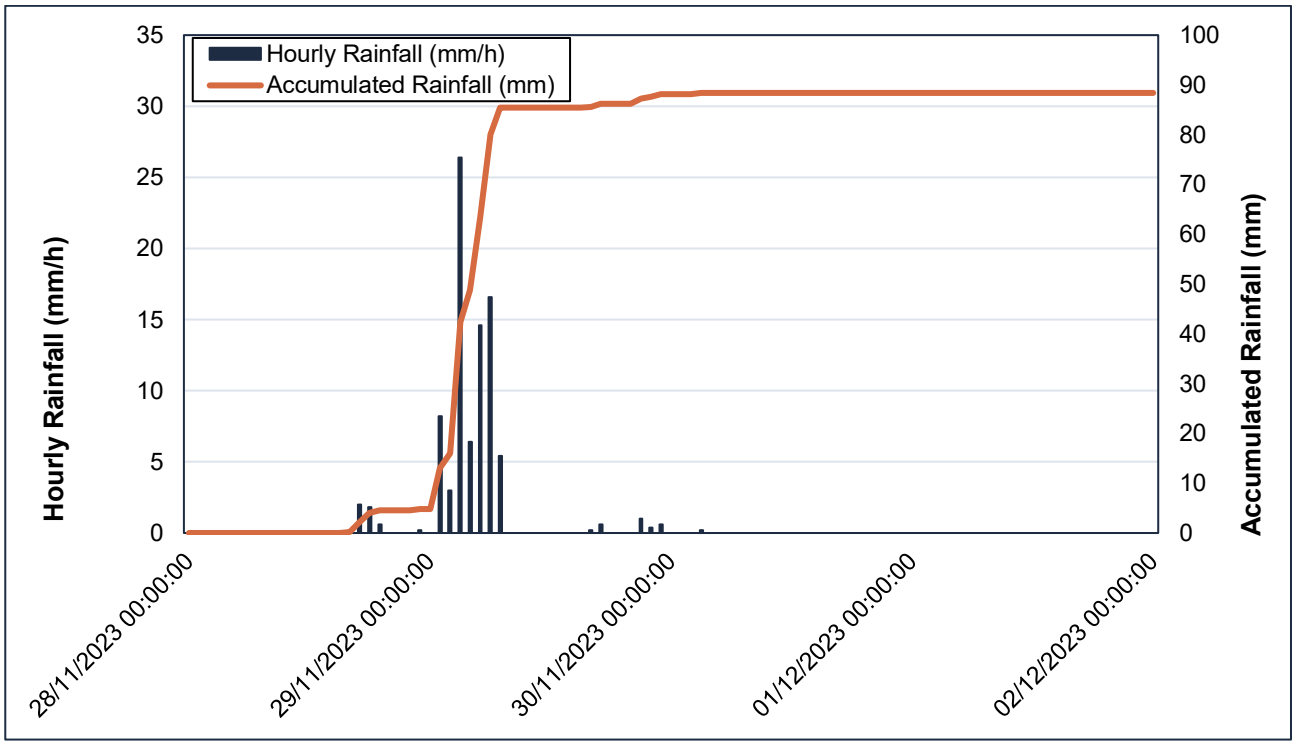


Figure 2-26 Cumulative and Hourly Rainfall Totals at Swan Hill Aerodrome Gauge (ID 77094) in the November 2023 Event

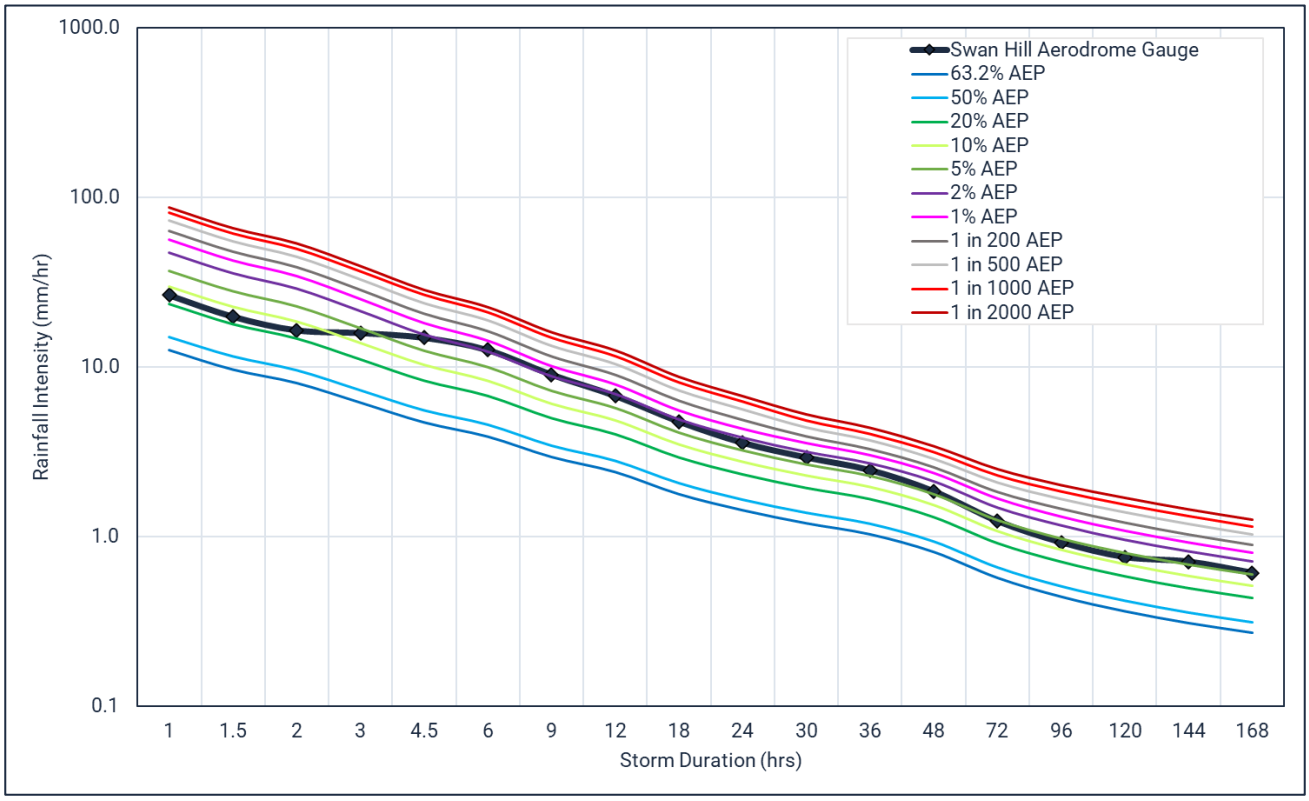


Figure 2-27 Measured Site Rainfall Intensities at Swan Hill Aerodrome Gauge (ID 77094) in the November 2023 Event

3 HYDRAULIC MODEL DEVELOPMENT

The modelling methodology adopted for both Robinvale and Swan Hill townships was TUFLOW rain-on-grid hydraulic modelling. This methodology was selected based on the availability of high-quality topographic data for suitable for hydraulic modelling and with consideration of limited upstream catchment areas for each township. The following section outlines the TUFLOW model development.

TUFLOW is a 2D hydraulic modelling software used extensively across Australia to simulate the hydrodynamic behaviour of rivers, floodplains, and urban drainage environments. The software is ideal for large scale catchment studies, such as the Swan Hill and Robinvale studies, as it is equally capable of overland flow paths as well as the urban drainage environment such as pits, pipes and culverts. The latest TUFLOW HPC (Heavily Parallelised Compute) model was used in this study, which delivers a 10-100 times simulation speed increase compared to the standard CPU version.

The rain-on-grid modelling approach applies direct rainfall across cells in the modelling domain and simulates flow behaviour between cells using an explicit finite volume scheme. The extents of modelling domains were determined by delineating local catchment for each town. The TUFLOW software outputs floodplain mapping results, ideal for model validation when using historic photographs. Hydraulic modelling development and results for each township are discussed in detail in Section 3.1 and Section 3.2

3.1 ROBINVALE HYDRAULIC MODEL

The Robinvale township is generally low lying along the banks of the Murray River, with a small ridge to the south creating the local catchment divide. It is protected from the Murray River with a town levee however, due to the limited variation in gradients, river tailwater levels are known to impact the town stormwater drainage during major events.

The Robinvale hydraulic model was developed using TUFLOW rain-on-grid to simulate localised flood behaviour for the 1% and 20% AEP design storm events. The hydraulic model setup and extents are presented in Figure 3-1. and the model development is detailed below.

3.1.1 Model Extent, Resolution and Topography

The TUFLOW model extent was delineated to capture the full extents of the town's local catchment, covering the urban development areas bounded by the Murray River and the catchment boundary to the south. The 2021 Robinvale 1m LiDAR was used as the underlying DEM and a grid resolution of 2 m was selected to balance model detail with suitable run times. Surveyed strings at Adcock Road, Carrington Street and Robin Street were converted to terrain surfaces and overlayed in the model.

3.1.2 Inflow Boundaries - Design Rainfall

A rainfall polygon was delineated around the full model extents to apply direct rainfall to all cells in the model domain.

Design rainfall data was extracted from the ARR Data Hub using the TUFLOW ARR plugin tool for QGIS. The tool interfaces directly with the ARR 2019 Data Hub and obtains the relevant Intensity-Frequency-Duration (IFD) rainfall depth data and temporal patterns at the catchment location. The data is output as hyetographs for rain-on-grid modelling. The datasets were based on the catchment centroid coordinates (34.5957, 142.7764).

Design rainfall was derived for the 1%, and 20% AEP events at 30-minute to 540-minute storm durations and included all temporal patterns. No other inflows were included in the model.

3.1.2.1 Design Storm Losses

Storm losses represent rainfall losses that occur due to factors such as interception by vegetation, soil infiltration, and/or depression storage. The Robinvale catchment is designated as an arid region, as such, no initial loss or continuing loss values are available from ARR Data Hub. No calibration or historic data could be accessed to determine suitable storm losses for Robinvale. Hence, the adopted design storm losses were derived from the Swan Hill catchment given their relatively close proximity and similar characteristics. The applied initial loss was 25 mm and continuing loss was 0.3mm/hr. Median pre-burst values for each AEP and duration were also applied to the initial losses to account for pre-storm rainfall.

3.1.2.2 *Areal Reduction Factors (ARF)*

Areal reduction factors as outlined in the ARR 2019 Guidelines, provide a correction factor to design rainfall on the basis that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole catchment area. ARFs are recommended for catchment areas greater than 1 km^2 in area. Due to the variance in catchment area for key locations in the Robinvale model, and many areas of town have less than 1 km^2 in catchment area, an ARF of 1.0 was chosen. This ensured that all locations within the Robinvale model had a reasonable representation of runoff volume and overland flows.

3.1.3 Outflow Boundaries

Normal flow (HQ) boundaries were adopted around most of the model perimeter to allow water to flow out of the mode and prevent artificial ponding of flows. HQ boundaries are based on a stage-flow relationship derived from a defined water profile slope; these slopes have been estimated based on the terrain slope at the boundary location. A slope of 0.001 m/m was selected for this model. Locations of outflow boundaries are illustrated in Figure 3-2.

3.1.4 Hydraulic Network

The pit and pipe network for the town were provided by SHRCC as shape files which included pipe sizes, number of pipes, and some invert levels. Estimates were undertaken from adjoining pipes to fill data gaps where invert levels were missing. The hydraulic features were included in TUFLOW as a dynamically linked 1D network using their inbuilt ESTRY solver, their locations are illustrated in Figure 3-3. No other hydraulic features were included as the model resolution was deemed sufficient in representing other hydraulic controls.

3.1.5 Tailwater Conditions

The town stormwater network discharges to the Murray River at 5 gravity-fed outlet locations. Tailwater levels representing Murray River water level conditions were extracted from *Robinvale Local Flood Guide* (SES, 2019) and presented in Table 2-7. No other design flood estimates were available from past studies or literature.

Table 3-1 Murray River at Euston (414203) Flood Levels (SES, 2019)

	Gauge Depth (m)	Height (mAHD)
Major Flood Level	10.30	52.14
Moderate Flood Level	9.80	51.64
Minor Flood Level	9.10	50.94

Two separate tailwater conditions representing a 'Low River Level – No Riverine Flood' and a 'High River Level – SES Major Flood' scenarios were applied to these outlet pipes. The 'Lower River Level' scenario was chosen for use in the overland flow assessment, with the 'High River Level' scenario being used in sensitivity testing to understand the effect Murray River flooding on performance of Robinvale's stormwater network. Refer to Section 6 for sensitivity analysis of high Murray River levels on Robinvale local catchment flooding. The tailwater elevation for each scenario is presented in Table 3-2.

Table 3-2 Robinvale Tailwaters

Scenario	Elevation (mAHD)	Approx. Depth at Gauge (m)
Low River Level (No Flood Scenario)	48	6.16
High River Level (SES Major Flood Level)	52.14	10.30

3.1.6 Manning's Roughness

The Manning's roughness values were selected to comply with the ARR2019 Guidelines as per Table 6.2.1 – Values of Roughness Coefficient n for different channel conditions and Table 6.2.2 – Valid Manning 'n' Ranges for Different Land Use Types, with both tables and references cited in (Lambert, M. B. Cathers & R Keller, 2019). The planning scheme zones were used to obtain the land use types and were adjusted as required based on aerial imagery and site visit photography.

The adopted values for hydraulic roughness were generally taken as the median of the range of recommended values. The adopted Manning's 'n' hydraulic roughness values for different land use types are listed in Table 3-3 and illustrated in Figure 3-4.

Table 3-3 Robinvale Adopted Manning's Roughness Values

Material ID	Land Use Type	Manning's Roughness
2	Residential Rural (Higher Density) – Building footprints and parcels combined	0.10
5	Building footprints	1.00
6	Residential: Rural (Lower Density) – Building footprints and parcels separate	0.05
9	Open Pervious Areas: Minimal Vegetation (Grassed)	0.03
10	Open Pervious Areas – Moderate Vegetation (Shrubs)	0.06
11	Open Pervious Areas – Heavy Vegetation (Trees)	0.08
14	Car Park / Pavement / Driveway / Road	0.025

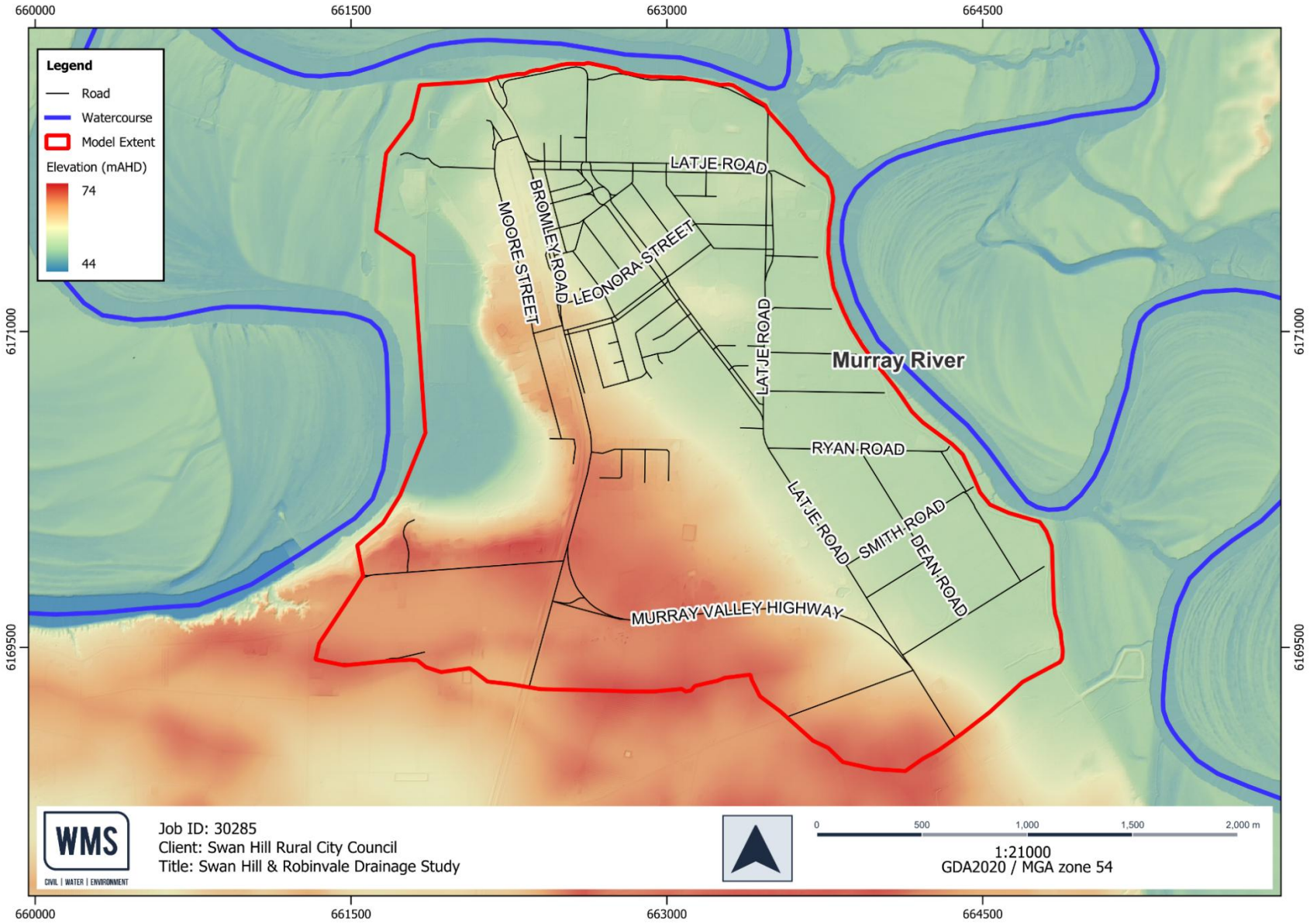


Figure 3-1 Robinvale Model Extent and Topography

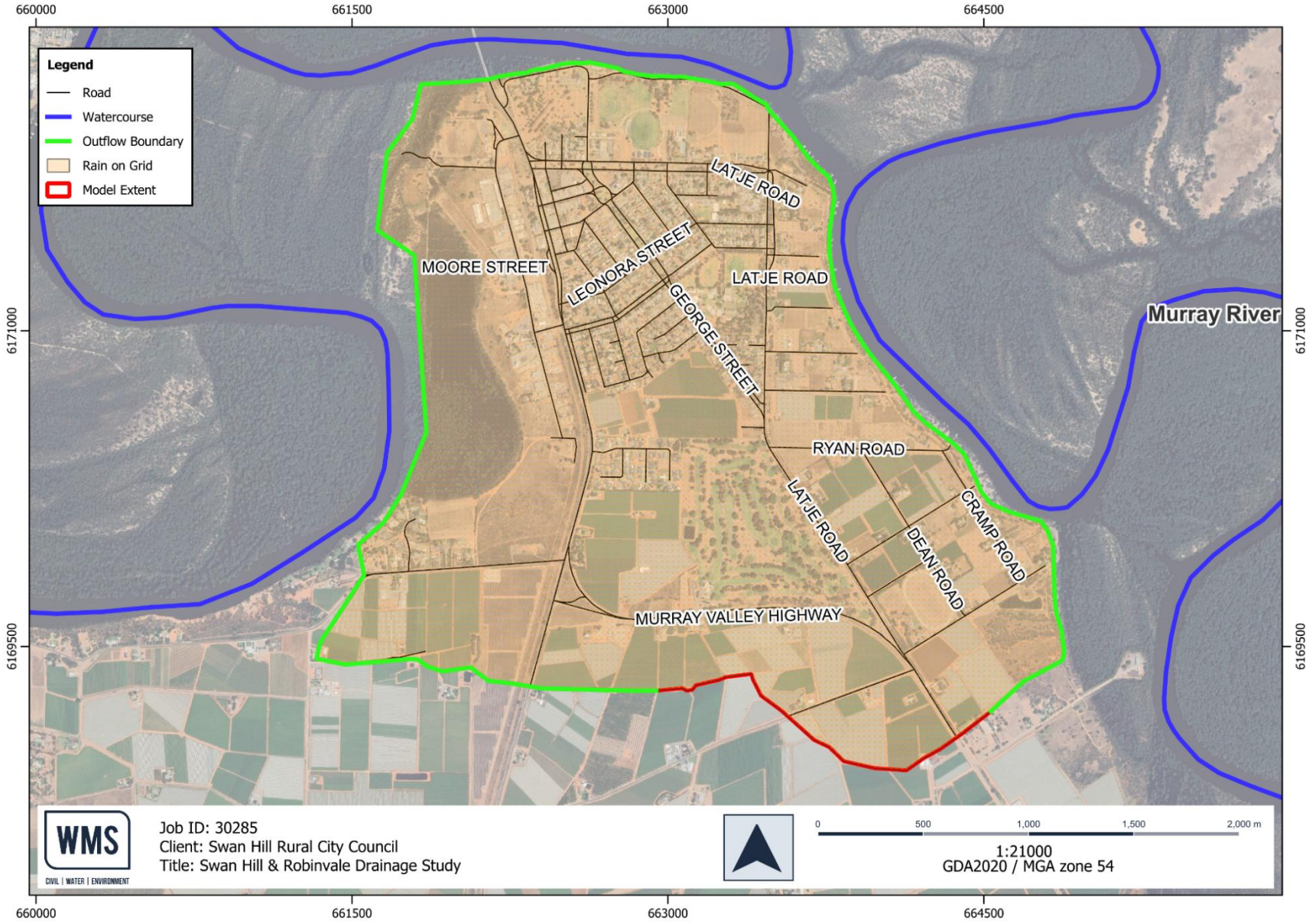


Figure 3-2 Robinvale Inflow and Outflow Boundaries

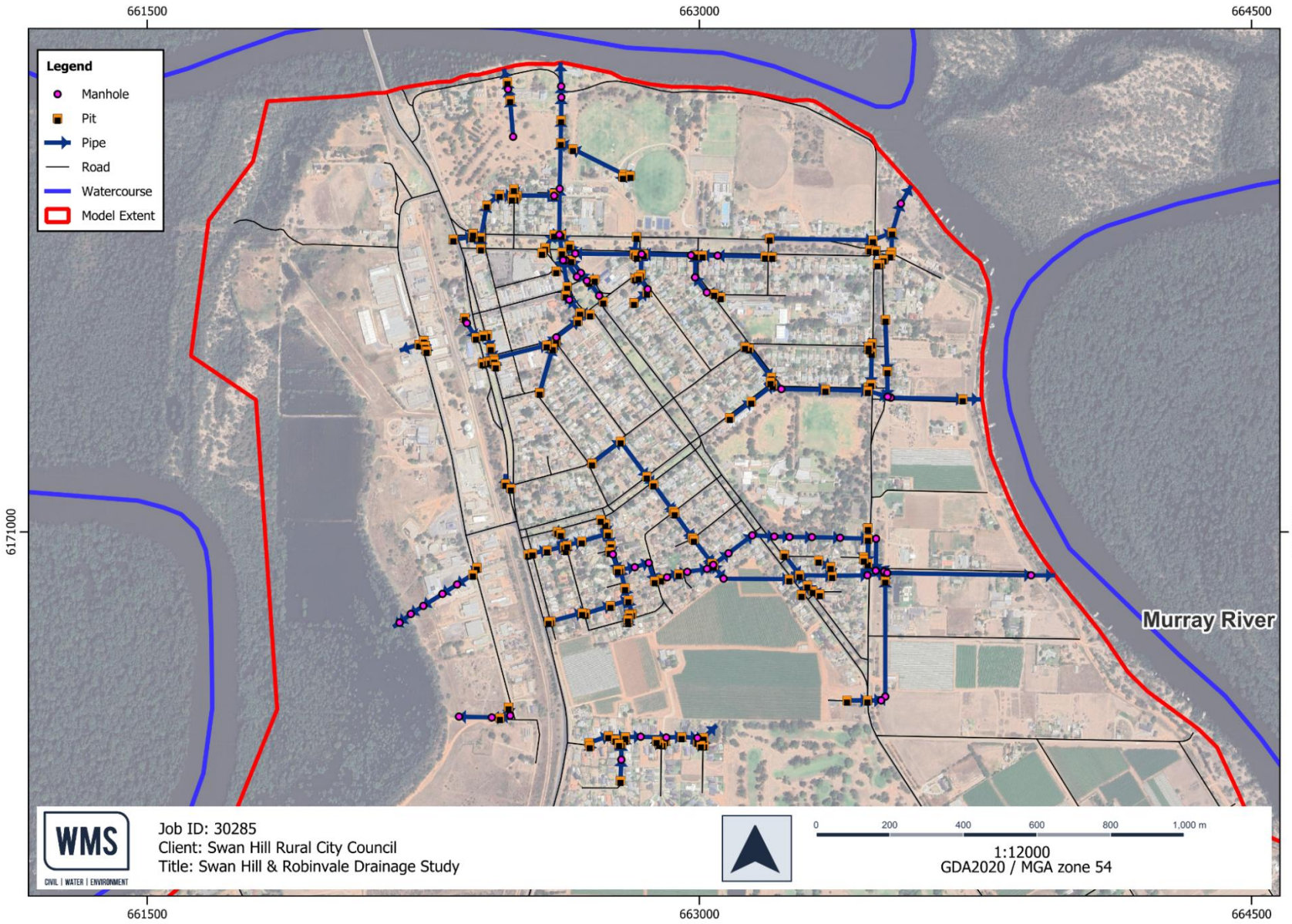


Figure 3-3 Robinvale Hydraulic Network

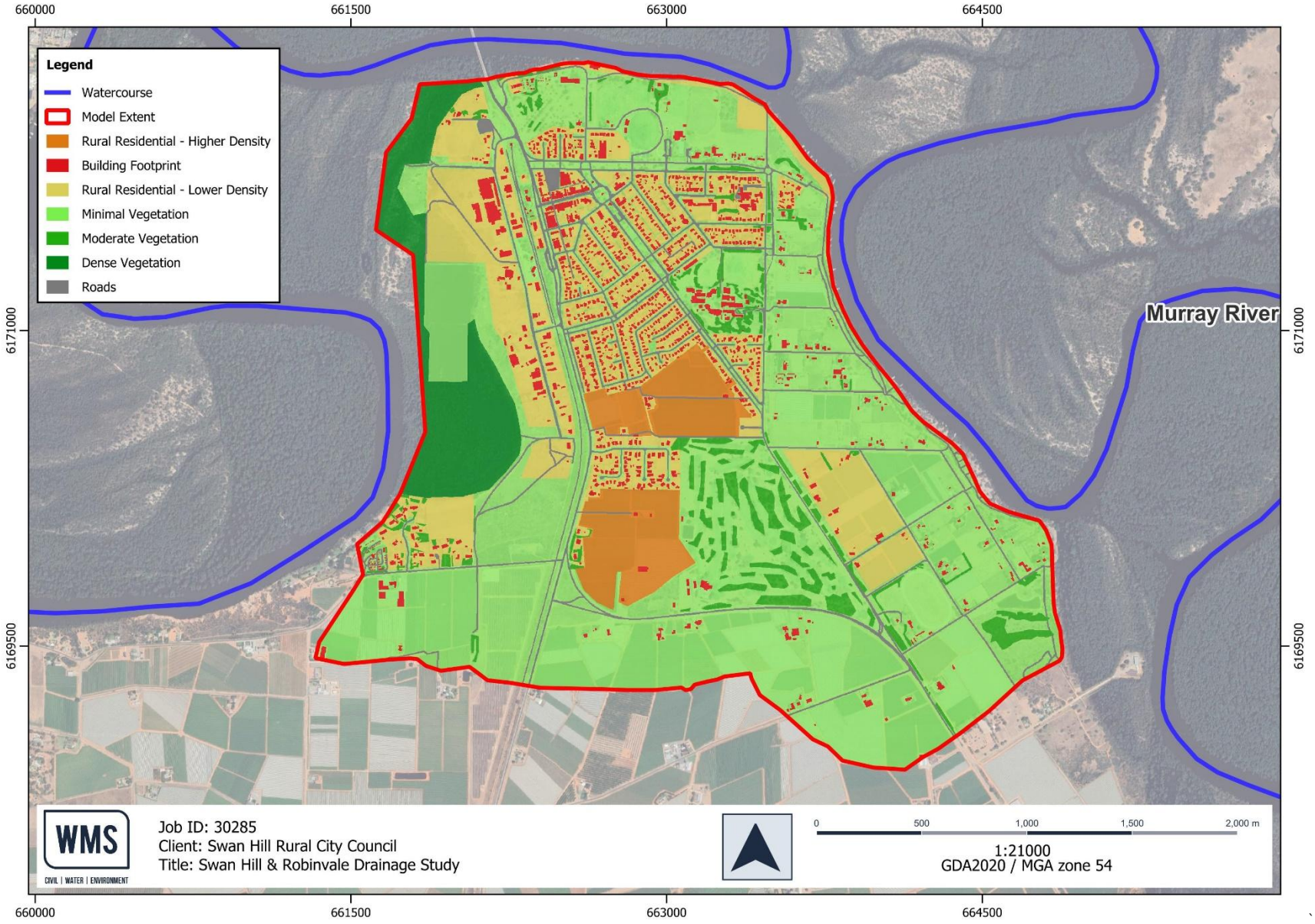


Figure 3-4 Robinvale Manning's Hydraulic Roughness Map

3.1.7 Ensemble Simulation

The design event modelling at Robinvale utilised ARR2019 methodologies with an ensemble event analysis. An ensemble approach involves simulating all temporal patterns and relevant storm durations to determine the critical storm event for each design storm AEP.

As described above, the design rainfall is derived by the Bureau of Meteorology and accessed from ARR Data Hub. It provides rainfall totals for each AEP and each critical duration. The Robinvale rain-on-grid model was simulated for the 30-minute, 45-minute, 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour, 6-hour and 9-hour durations using all 10 temporal patterns. The ensemble simulation was run for the 1% and 20% AEP events. Post-processing was then undertaken to extract the median temporal patterns for each duration to identify the critical duration for the catchment.

3.1.8 Critical Duration Assessment

The critical storm duration is identified in ARR2019 as the storm duration which produces the highest median peak water surface level out of ten temporal patterns. Critical duration typically depends on the catchment size and shape upstream of the location of interest. In the case of Robinvale, the whole township required assessment, thus different locations in the town had different critical durations which needed consideration.

WMS assessed initial model results and communicated with SHRCC to identify local flooding hotspots and key areas of interest within the town. These discussions were used in conjunction with feedback from the community consultation to inform selection of priority zones within the town. Three priority areas were chosen, named the "Northern Zone", "Central Zone" and the "Eastern Zone." The critical durations at these locations were nominated as the primary storm events of interest for the purposes of the overland flooding and flood mitigation assessments. These zones are presented in Figure 3-5.

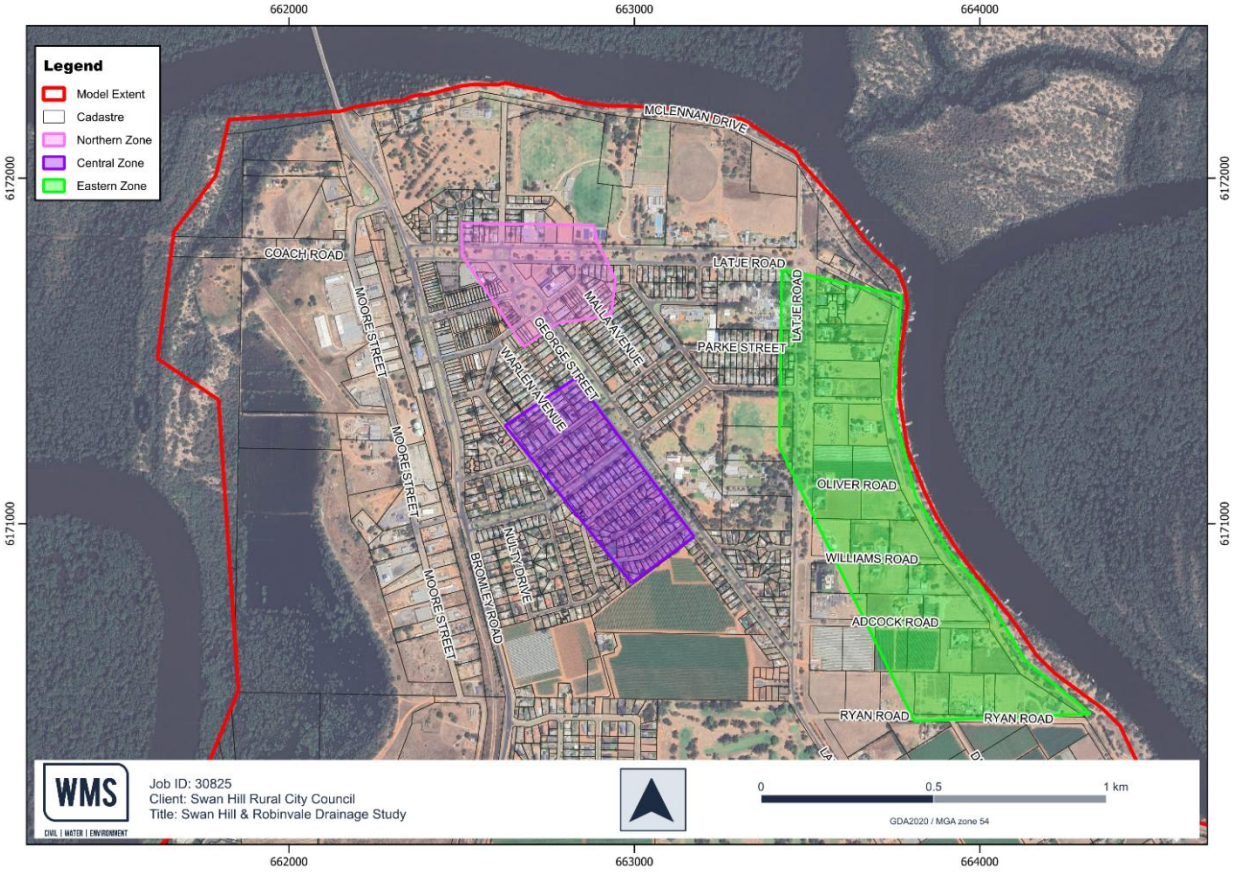


Figure 3-5 Robinvale Priority Zones for Critical Duration Selection

Critical durations for each priority zone are listed in **Table 3-4** for the 20% and 1% AEP events. Critical duration maps for the 20% AEP and 1% AEP events are presented in **Figure 3-6** and **Figure 3-7** respectively.

Table 3-4 Robinvale Adopted Design Storm Events

	Northern Zone		Central Zone		Eastern Zone	
Design Storm	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP
Critical Duration	6-hour	4.5-hour	6-hour	3-hour	9-hour	9-hour
Temporal Pattern	TP02	TP04	TP09	TP06	TP07	TP02
Murray River Water Level Condition	Low River Scenario	Low River Scenario	Low River Scenario	Low River Scenario	Low River Scenario	Low River Scenario



Figure 3-6 Robinvale Critical Duration Map for the 20% AEP Event

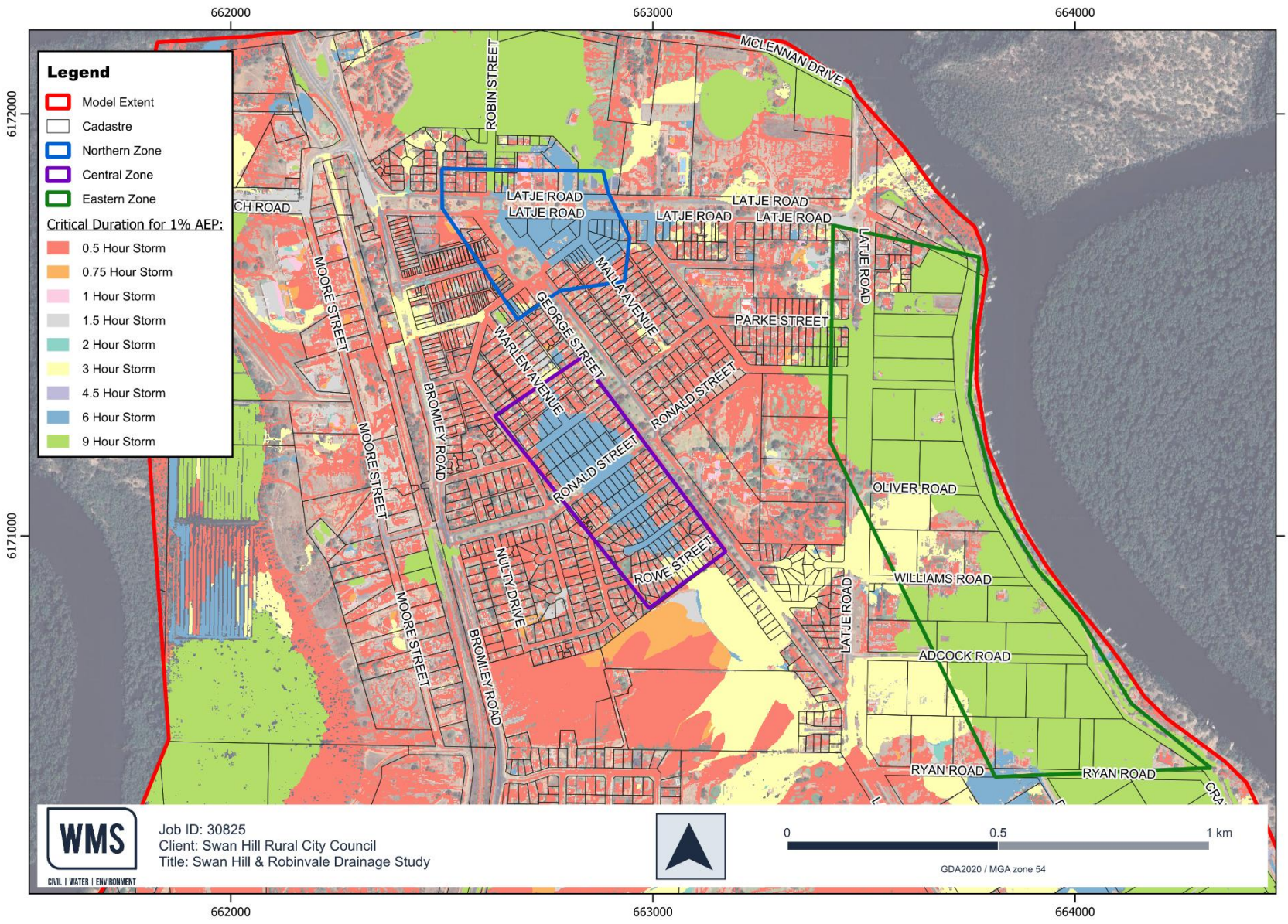


Figure 3-7 Robinvale Critical Duration Map for the 1% AEP Event

3.2 SWAN HILL HYDRAULIC MODEL

The Swan Hill township is located along the banks of the Murray River near the confluence with the Little Murray River. The hydraulic model was developed using TUFLOW rain-on-grid to simulate localised overland flood behaviour for the 1%, 2% and 20% AEP design storm events. The hydraulic model setup and extents are presented in Figure 3-8 and the model development is detailed below.

3.2.1 Initial Modelling and Catchment Delineation

The Swan Hill Catchment was initially delineated using industry standard methods by analysing the available topographic data. However, the resulting modelled flood behaviour in Swan Hill appeared to be grossly overestimated compared to historic flood events and the lived experience of Council staff involved in the study. WMS undertook a detailed review of topographic information, aerial imagery, land usage, hydraulic structures and the CMA boundaries, in addition to advice from Council based on its own local knowledge and experience of past flood events.

The outcome of this assessment resulted in the adoption of a smaller catchment area for Swan Hill, excluding flows from areas west of Dead Horse Lane. The investigation was supported with hydrologic and hydraulic modelling, in which the 2% AEP event was used as a proxy for the November 2023 event to validate the modelled flood behaviour. This assessment is described in detail in the technical memorandum *Swan Hill Drainage Study – Catchment Delineation*, produced by WMS in May 2024. The resulting catchment utilised for this assessment is shown in Figure 3-8.

3.2.2 Model Extent, Resolution and Topography

The TUFLOW model extents were delineated to capture the town's urban development areas bounded by the Murray River and a ridgeline to the west. Several topographic data sets were available within the model extents and were layered based on the date captured as follows:

1. 10 m VicMaps topography as the base map where no other terrain data was available;
2. 1 m Wakool LiDAR captured in 2015;
3. 1 m Swan Hill LiDAR captured in 2019;
4. 1 m Swan Hill LiDAR captured in 2020;
5. Surveyed terrain data for Ashton to Mortoo Drain, Ken Harrison Reserve, Milloo Street, Murlong to Thurla Drain, Tower Avenue, Wilkins Road Reserve

Where datasets join, checks were performed to ensure no artificial restrictions to flow occurred and some datum shift adjustments were undertaken to rectify any inconsistencies. A modelling grid resolution of 2m was selected to balance model detail with suitable run times.

3.2.2.1 Topographic Modifications

Additional topographic modifications were undertaken using TUFLOW Zshps which changes elevations along a certain line or within a polygon. Survey points were undertaken by council along Dead Horse Lane and Memorial Drive to capture the road and bund elevations. These points and lines were added to the model as topographic modifications.

3.2.3 Inflow Boundaries - Design Rainfall

A 2d_rf rainfall polygon was delineated around the full model extents to apply direct rainfall to all cells in the model domain. Design rainfall data was extracted from the ARR Data Hub using the TUFLOW ARR plugin tool for QGIS. The tool interfaces directly with the ARR2019 Data Hub and obtains the relevant Intensity-Frequency-Duration (IFD) rainfall depth data and temporal patterns at the catchment location. The data is output as hyetographs for rain-on-grid modelling. The datasets were based on the coordinates of the catchment centroid (-34.5957, 142.7764).

Design rainfall was derived for the 1%, 2% and 20% AEP events at 10-minute to 9-hour storm durations, with ten temporal patterns extracted for each duration. No other inflows were included in the model.

3.2.3.1 *Design Storm Losses*

Storm losses represent rainfall losses that occur due to factors such as interception by vegetation, soil infiltration, and/or depression storage. In the absence of gauged calibration data, storm losses for Swan Hill were accessed from ARR Datahub. The adopted initial loss was 25 mm and continuing loss was 0.3mm/hr. Median pre-burst values for each AEP and duration were also applied to the initial losses to account for pre-storm rainfall.

3.2.3.2 *Areal Reduction Factors (ARF)*

The entire township of Swan Hill was subject to assessment of overland flow flooding as part of this study. ARR2019 guidelines recommend implementing an ARF for catchments greater than 1 km^2 in area. Due to the large extent of the assessment, catchment areas at different locations of interest within the town varied from 0.1 km^2 to 4 km^2. To avoid underestimating runoff volume and overland flows at locations with smaller catchment areas, an ARF of 1.0 was chosen. Whilst conservative, this ensured no areas had inadequate representation of flood levels, and provided acceptable validation results as detailed in Section 4.

3.2.4 Outflow Boundaries

Normal flow (HQ) boundaries were adopted along the northern and eastern perimeter of the model to allow water to exit and prevent artificial ponding within the model. HQ boundaries are based on a stage-flow relationship derived from a defined water profile slope; these slopes have been estimated based on the terrain slope at the boundary location. The slopes of 0.01 m/m and 0.005 m/m were selected for this model. Locations of outflow boundaries are illustrated in Figure 3-9.

3.2.5 Hydraulic Network

The pit and pipe network for the town were provided by SHRCC as shape files which included pipe sizes, number of pipes, and some invert levels. Estimates were undertaken from adjoining pipes to fill data gaps where invert levels were missing. Hydraulic structures were included in TUFLOW as a dynamically linked 1D network using TUFLOW's 1D solver, ESTRY. The hydraulic structure network featured in the model is illustrated in Figure 3-10 and Figure 3-11. No other hydraulic features were included as the model resolution was deemed sufficient in representing other hydraulic controls. The town stormwater network is predominately gravity-fed and discharges to the Murray River at 8 locations and the Little Murray River at 6 locations. These outlet locations are known to be impacted by river water levels during significant flood events. Several pump stations are located near the river to supplement the gravity-fed network, particularly when Murray River water levels are high.

3.2.6 Tailwater Conditions

Estimated design flows for Swan Hill were derived from *Regional Flood Mapping Swan Hill Region* (BMT, 2021) and based on flood frequency analyses taken at the Swan Hill gauge on the Murray River. These estimates are in line with a previous assessment, *Murray Downs Flood Study* (GHD, 2014) and indicates the major flood event from 2011 was comparable with a 20% AEP storm and the largest storm on record from 1975 was comparable with a ~1.25% (1:80) AEP storm. *Municipal Flood Emergency Plan - Swan Hill Rural City* (SES, 2018) provides alternative, more conservative estimates for Swan Hill. The respective river depth and heights were interpolated from the gauge rating curve by Victorian Department of Environment, Land, Water and Planning. The estimated peak flows for Murray River at Swan Hill (409204) are presented in Table 2-6.

Table 3-5 Murray River at Swan Hill (409204) Estimated Peak Flows (BMT, 2021) (SES, 2018)

	BMT, 2021			SES, 2018		
	Flow (ML/day)	Gauge Depth (m)	Height (mAHD)	Flow (ML/day)	Gauge Depth (m)	Height (mAHD)
1% AEP	35,000	4.77	67.69	36,200	4.82	67.74
2% AEP	34,000	4.74	67.66	35,800	4.80	67.72
5% AEP	32,000	4.67	67.59	34,800	4.77	67.69
10% AEP	31,000	4.64	67.56	33,600	4.73	67.65
20% AEP	29,000	4.53	67.45	31,500	4.66	67.58

Two tailwater conditions were considered for use in the Swan Hill study. One was to represent a 'Low River Level – no riverine flood' and another as a 'High River level – SES major flood' scenario. As the primary focus of the study is on overland flow/stormwater flooding, the 'Low River Level' tailwater scenario was chosen for use in the overland flow assessment. The higher river level scenario was used in model sensitivity testing to understand areas in the town that are vulnerable to coincident local catchment and Murray River flooding. Refer to Section 6 for sensitivity analysis of high Murray River levels on Swan Hill local catchment flooding. The tailwater elevation for used in the Swan Hill hydraulic model is presented in Table 3-2.

Table 3-6 Swan Hill Tailwater

Scenario	Elevation (mAHD)	Approx. River Depth at Gauge (m)
Low River Level (No Flood Scenario)	64.50	1.58
High River Level (Major Flood Scenario)	67.74	4.82

3.2.7 Manning's Roughness

The Manning's roughness values were selected to comply with the ARR2019 Guidelines as per Table 6.2.1 – Values of Roughness Coefficient n for different channel conditions and Table 6.2.2 – Valid Manning 'n' Ranges for Different Land Use Types, with both tables and references cited in (Lambert, M. B. Cathers & R Keller, 2019). The planning scheme zones were used to obtain the land use types and were adjusted as required based on aerial imagery and site visit photography.

The adopted values for hydraulic roughness were generally taken as the median of the range of recommended values. The adopted Manning's 'n' hydraulic roughness values for different land use types are listed in Table 3-7 and illustrated in Figure 3-12.

Table 3-7 Swan Hill Adopted Manning's Roughness Values

Material ID	Land Use Type	Manning's Roughness
2	Residential: Rural (Lower Density) – Building footprints and parcels combined	0.15
3	Building footprints	Depth-varying: 0.02 for depths < 30 mm 0.1 for depths > 30 mm
4	Residential: Urban (Higher Density)	0.09
6	Residential: Rural (Lower Density)	0.05
9	Open Pervious Areas: Minimal Vegetation (Grassed)	0.03
10	Open Pervious Areas – Moderate Vegetation (Shrubs)	0.06
11	Open Pervious Areas – Heavy Vegetation Trees)	0.1
13	Waterway: Vegetated	0.08
14	Car Park / Pavement / Driveway / Road	0.025
16	Concrete Lined Channels	0.018
17	Waterbodies/Lakes: No Emergent Vegetation	0.02
18	Wetlands: Emergent Vegetation	0.065

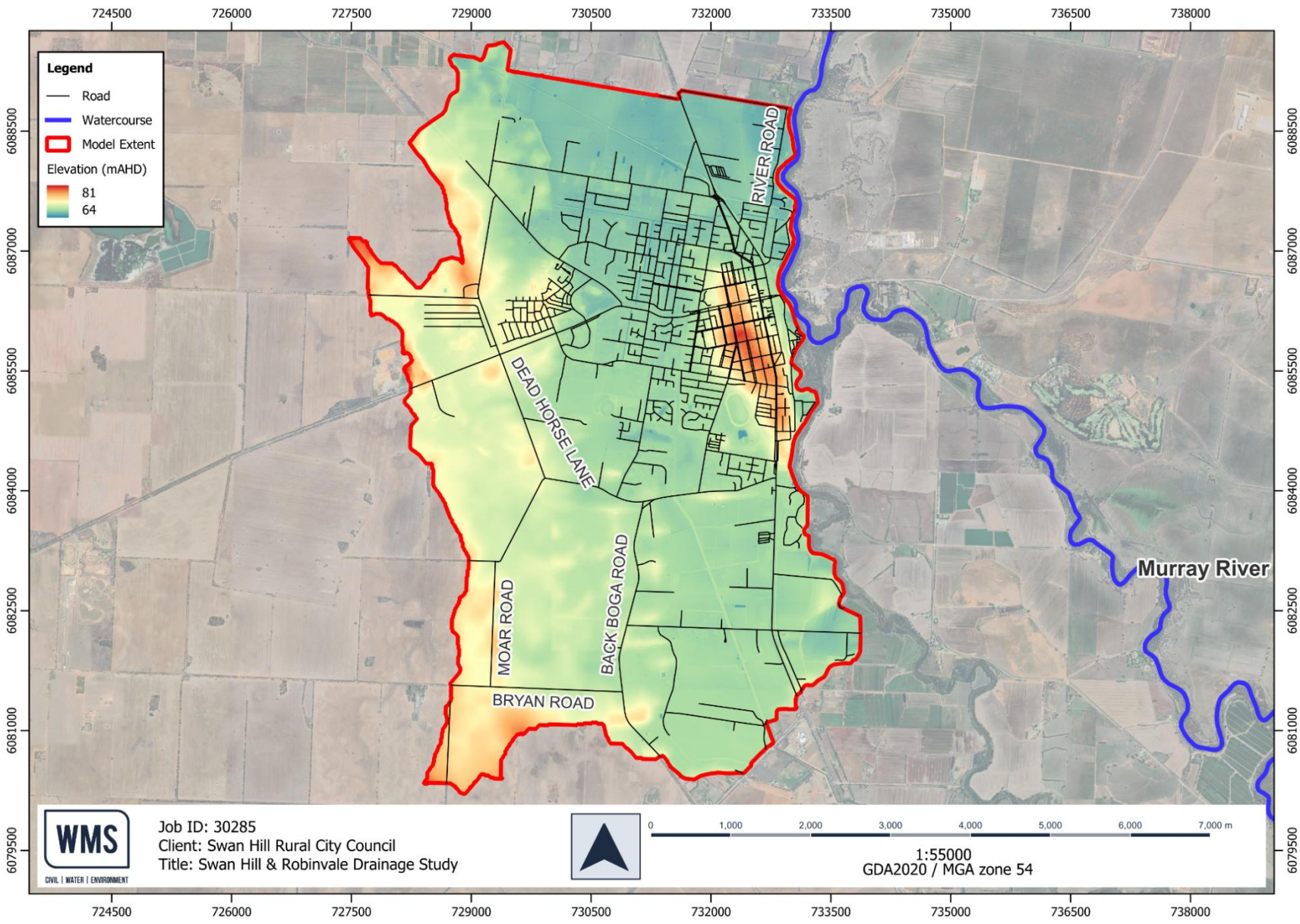


Figure 3-8 Swan Hill Model Extent and Topography

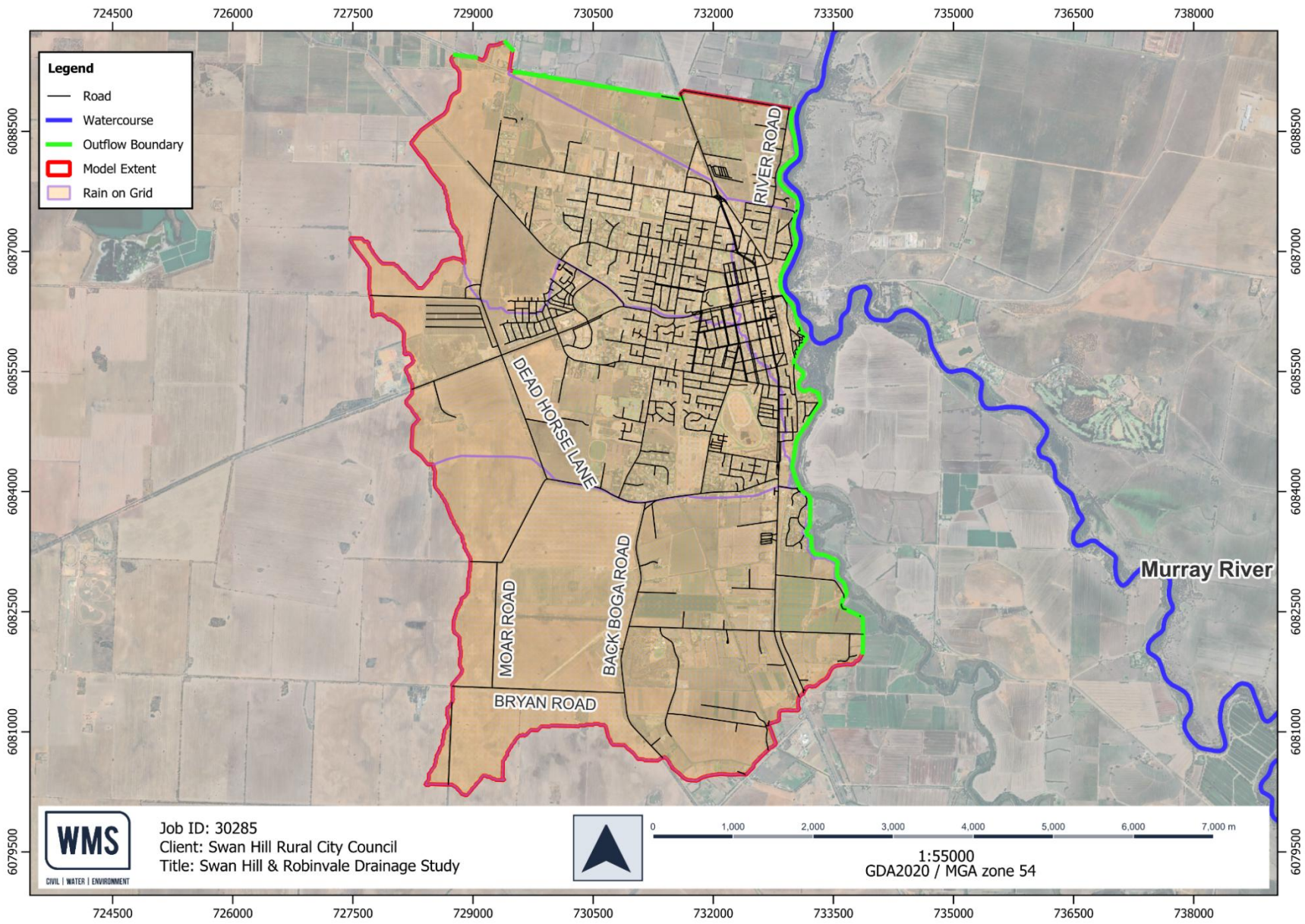


Figure 3-9 Swan Hill Inflow and Outflow Boundaries

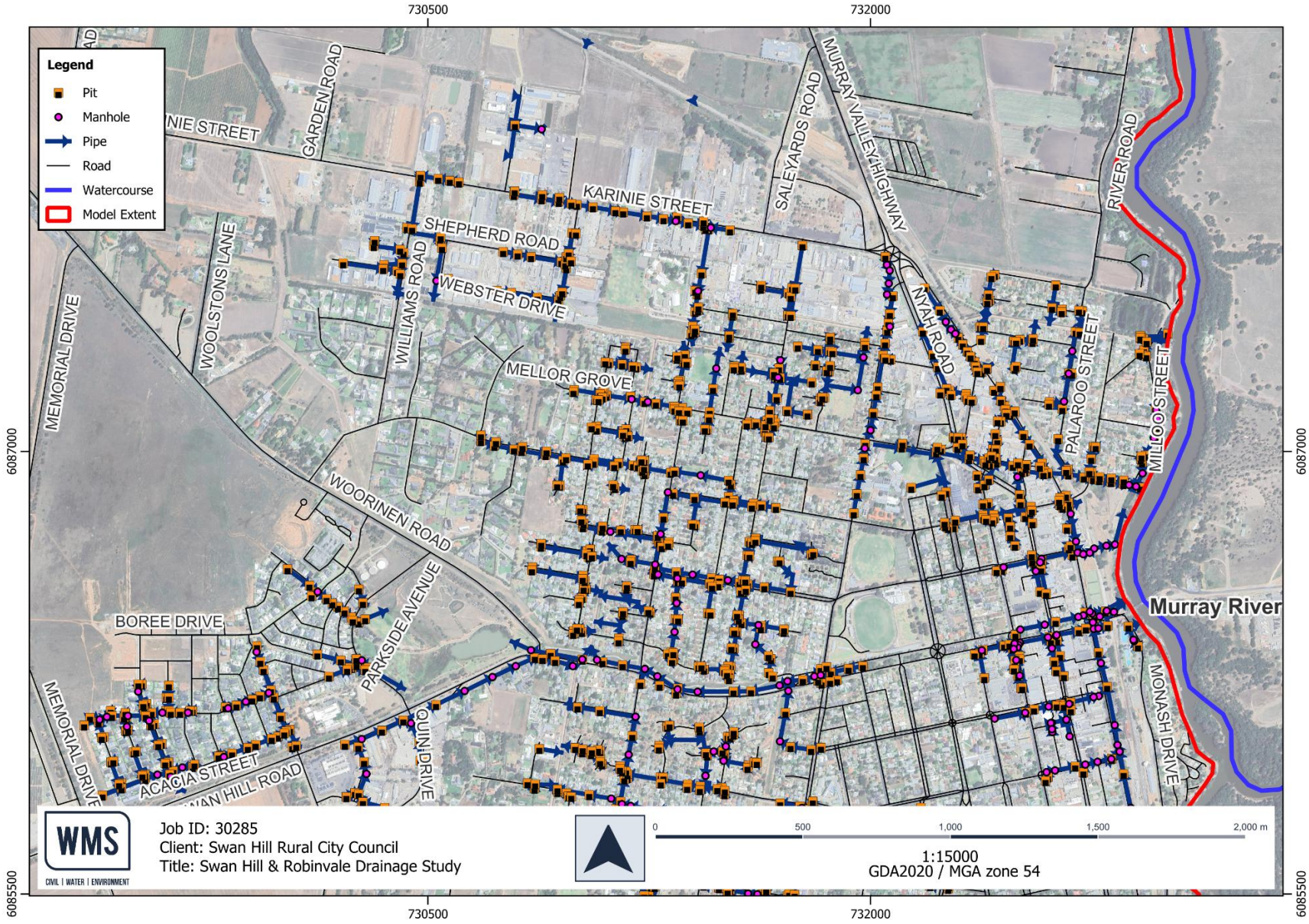


Figure 3-10 Swan Hill Hydraulic Network (Township Upper Part)

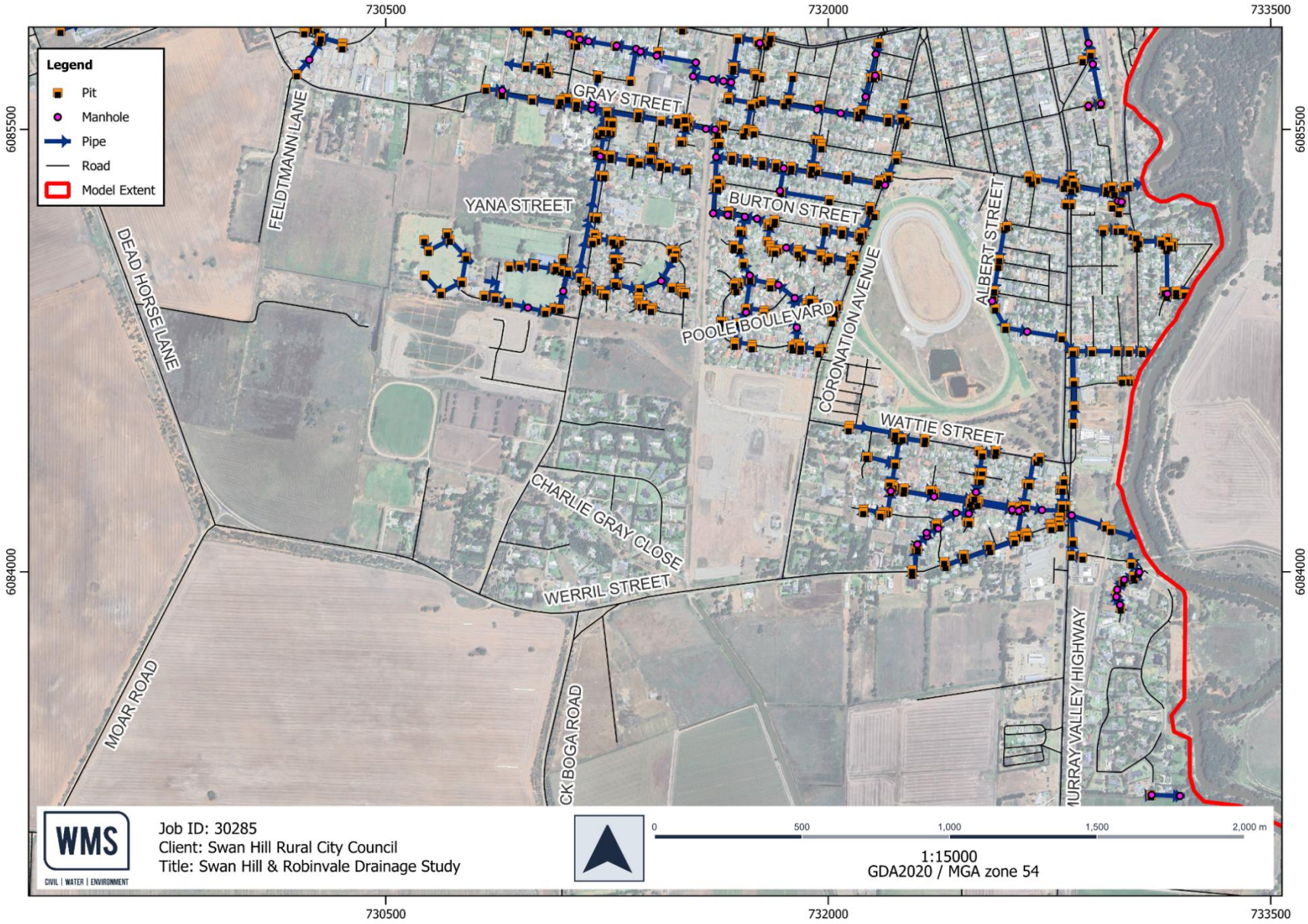


Figure 3-11 Swan Hill Hydraulic Network (Township Lower Part)

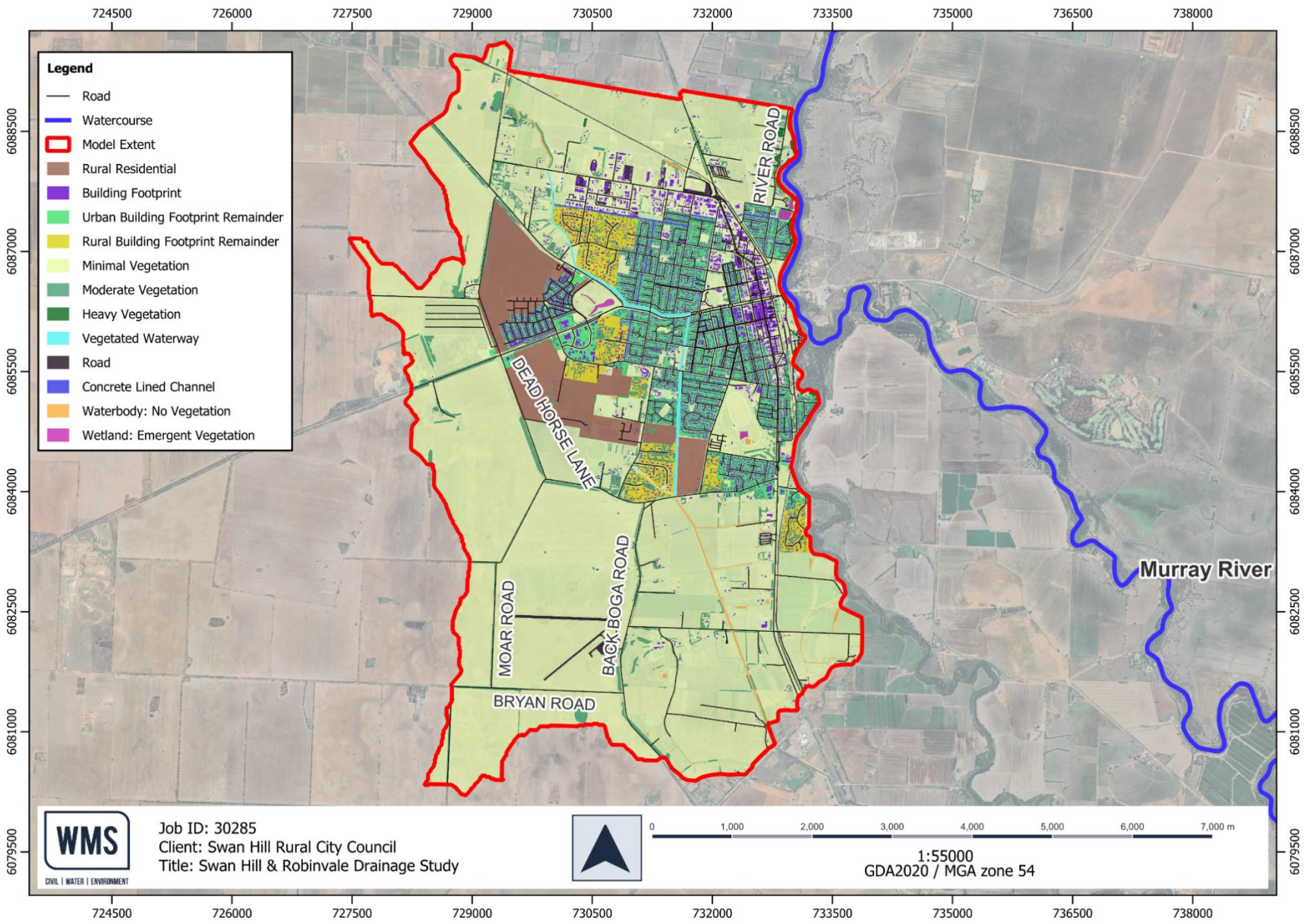


Figure 3-12 Swan Hill Manning's Hydraulic Roughness Map

3.2.8 Ensemble Simulation

The design event modelling at Swan Hill utilised the ARR2019 ensemble event analysis. An ensemble approach involves simulating ten nominal rainfall temporal patterns and all relevant storm durations to determine the critical storm event for each design storm AEP. At each location within the model, the median temporal pattern was recorded for each duration based on peak water surface level. Out of these median temporal patterns, the critical storm duration was selected based on the maximum resultant water surface level at each location.

Design rainfall depths were sourced from the BOM. Rainfall temporal patterns were accessed from the ARR Data Hub for the 30-minute, 45-minute, 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour and 9-hour storm durations. Simulations were completed for the 1%, 2% and 20% AEP events. Post-processing was then undertaken to extract the median temporal patterns for each duration to identify the critical duration for key locations within the catchment.

Critical duration maps for the 1%, 2% and 20% AEP events are illustrated in Figure 3-13, Figure 3-14, and Figure 3-15 respectively.

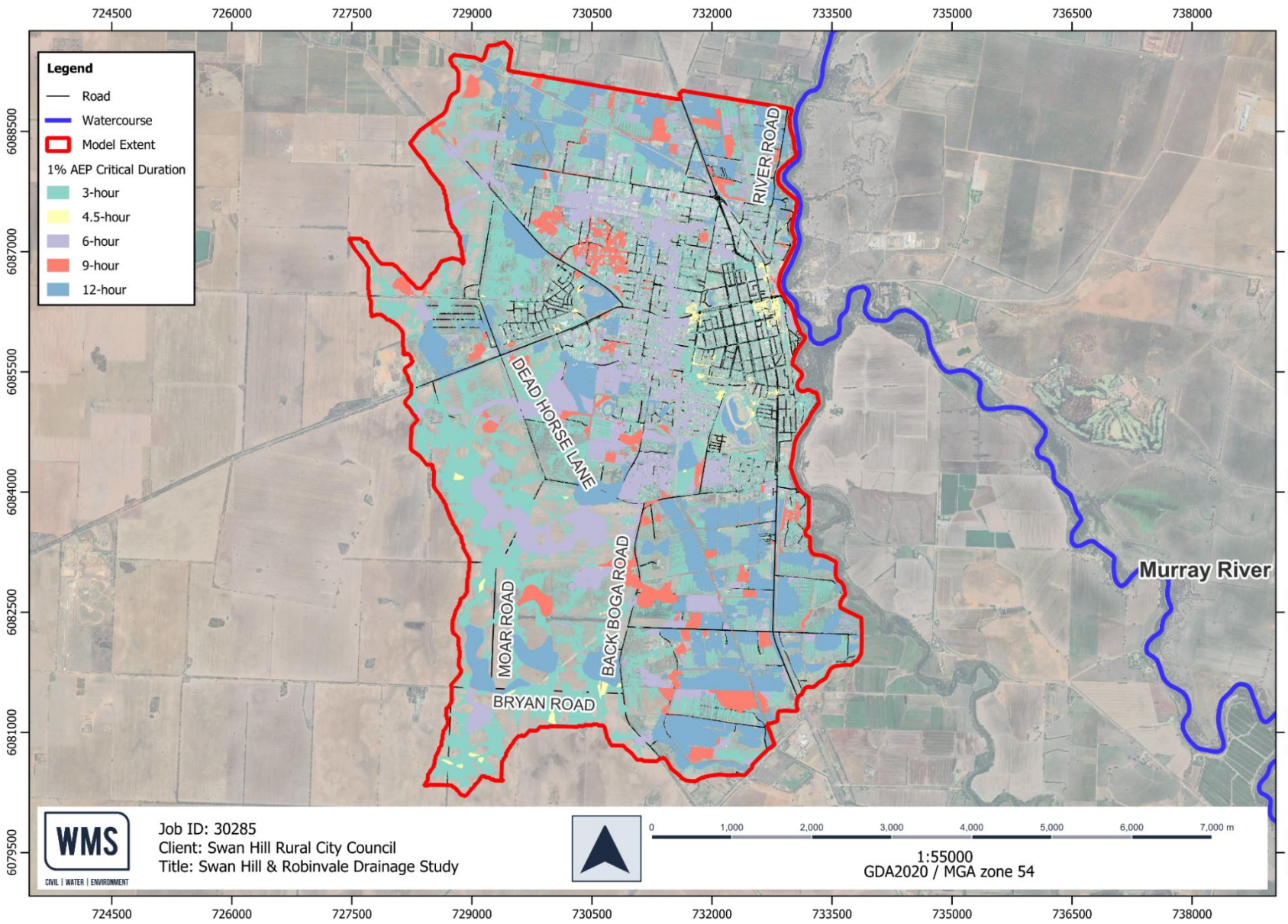


Figure 3-13 Critical Duration Map of Swan Hill for the 1% AEP Storm Event

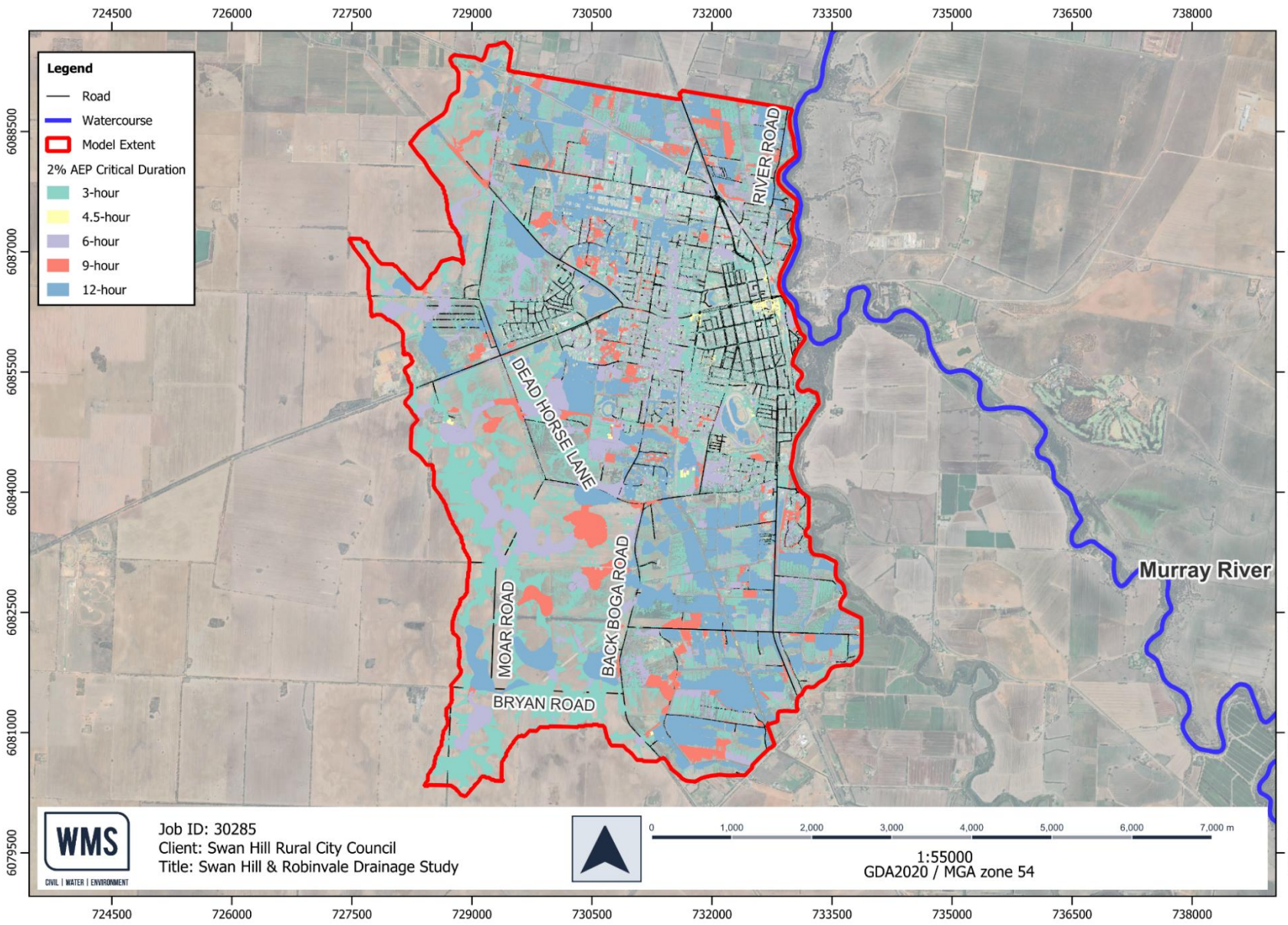


Figure 3-14 Critical Duration Map of Swan Hill for the 2% AEP Storm Event

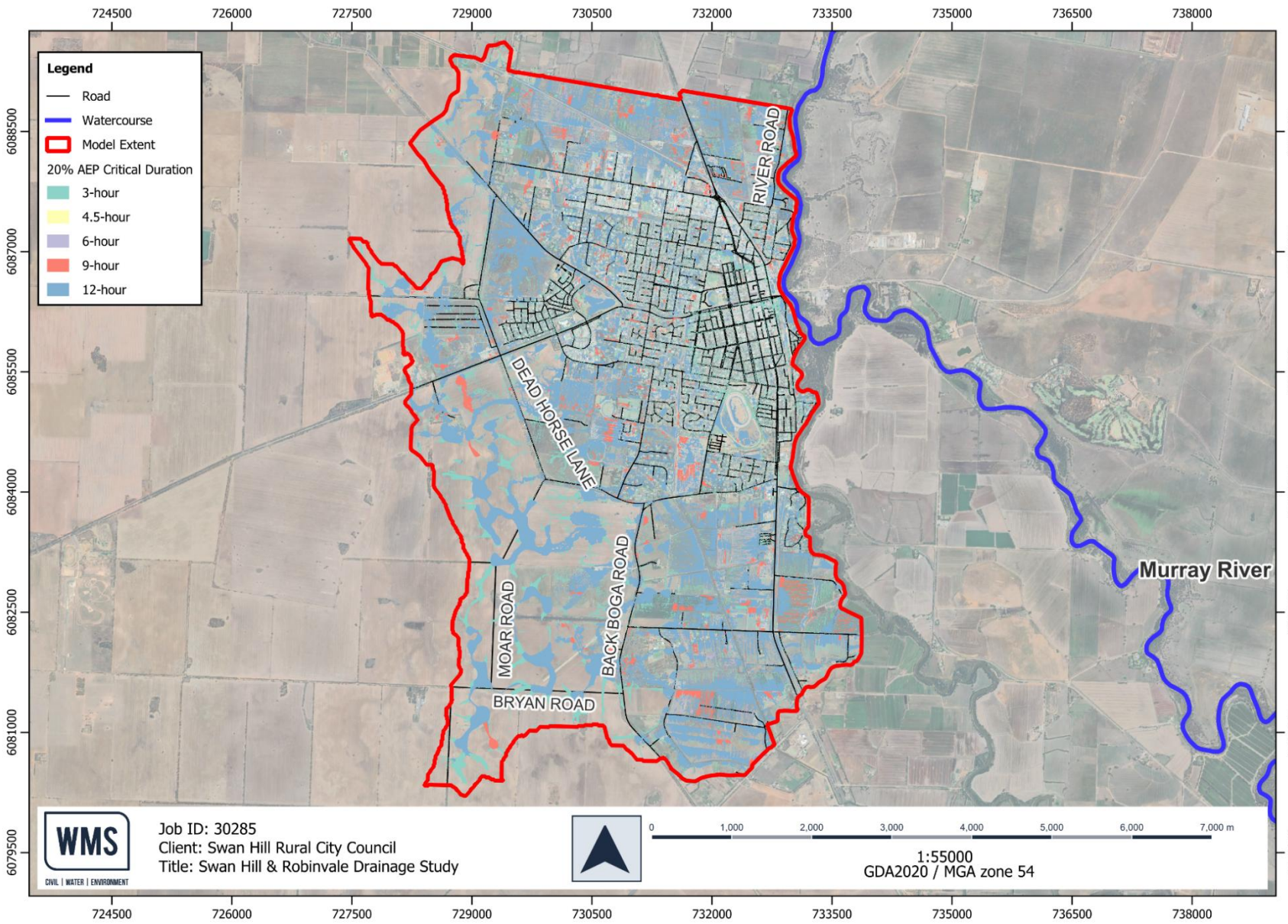


Figure 3-15 Critical Duration Map of Swan Hill for the 20% AEP Storm Event

4 MODEL VALIDATION

In November 2023 a significant local flood event occurred in Swan Hill in which substantial site imagery was captured. At the Swan Hill Aerodrome rainfall gauge, 80.6 mm of rainfall was recorded over a 9-hour period. This is approximately equal to a 2% AEP 9-hour design rainfall event at Swan Hill with a 79.1 mm design rainfall depth. Due to the similarity in rainfall depth and duration, the 2% AEP event was chosen as a validation event. Outputs of the 2% AEP model simulations were compared against site photos captured at various locations within Swan Hill during the November 2023 local catchment flood. Refer to Table 4-1 for comparison of recorded and design storm rainfall events.

Table 4-1 Comparison of Recorded November 2023 Storm Rainfall Depths with Swan Hill Design Storm Rainfall Depths

November 2023 - Swan Hill Aerodrome Gauge 9-hour Rainfall Depth (mm)	2% AEP 9-hour Design Rainfall Depth (mm)	1% AEP 9-hour Design Rainfall Depth (mm)
80.6	79.1	90.5

Flood extents were generally found to be consistent with site imagery of the November 2023 event. Peak flood depths were typically greater higher in the hydraulic model than site photos. This is partly attributed to uncertainty regarding the timing of the site photos, which may not have coincided with the flood peak at every location (whereas the hydraulic model outputs specify the peak at every location). Refer to Figure 4-1 through to Figure 4-5 for comparisons of the modelled 2% AEP design storm event with site photos captured during/following the November 2023 event.

The 2% AEP design event results are considered to appropriately represent the observed flooding in the November 2023 event, particularly at the key locations shown in the subsequent figures. This provides confidence in the selected modelling approach and parameters and suggests the Swan Hill hydraulic model is sufficiently representative of current conditions for the purposes of this Drainage Study, and can be used as the basis for design flood event modelling.



Figure 4-1 Comparison of Modelled Results with Site Photo of Coronation Avenue, Swan Hill, looking towards the Racecourse



Figure 4-2 Comparison of Modelled Results with Site Photo of Chapman Street from Nyah Road

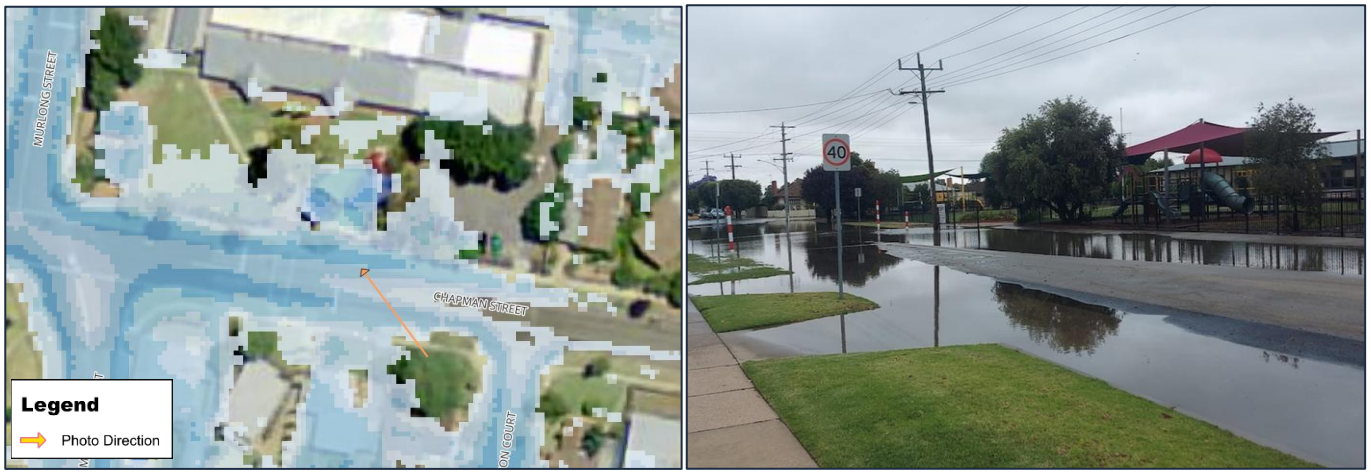


Figure 4-3 Comparison of Modelled Results with Site Photo of Swan Hill North Primary School (From Chapman Street)



Figure 4-4 Comparison of Modelled Results with Site Photo of Flood Water at St Mary's Primary School (From Murlong Street)

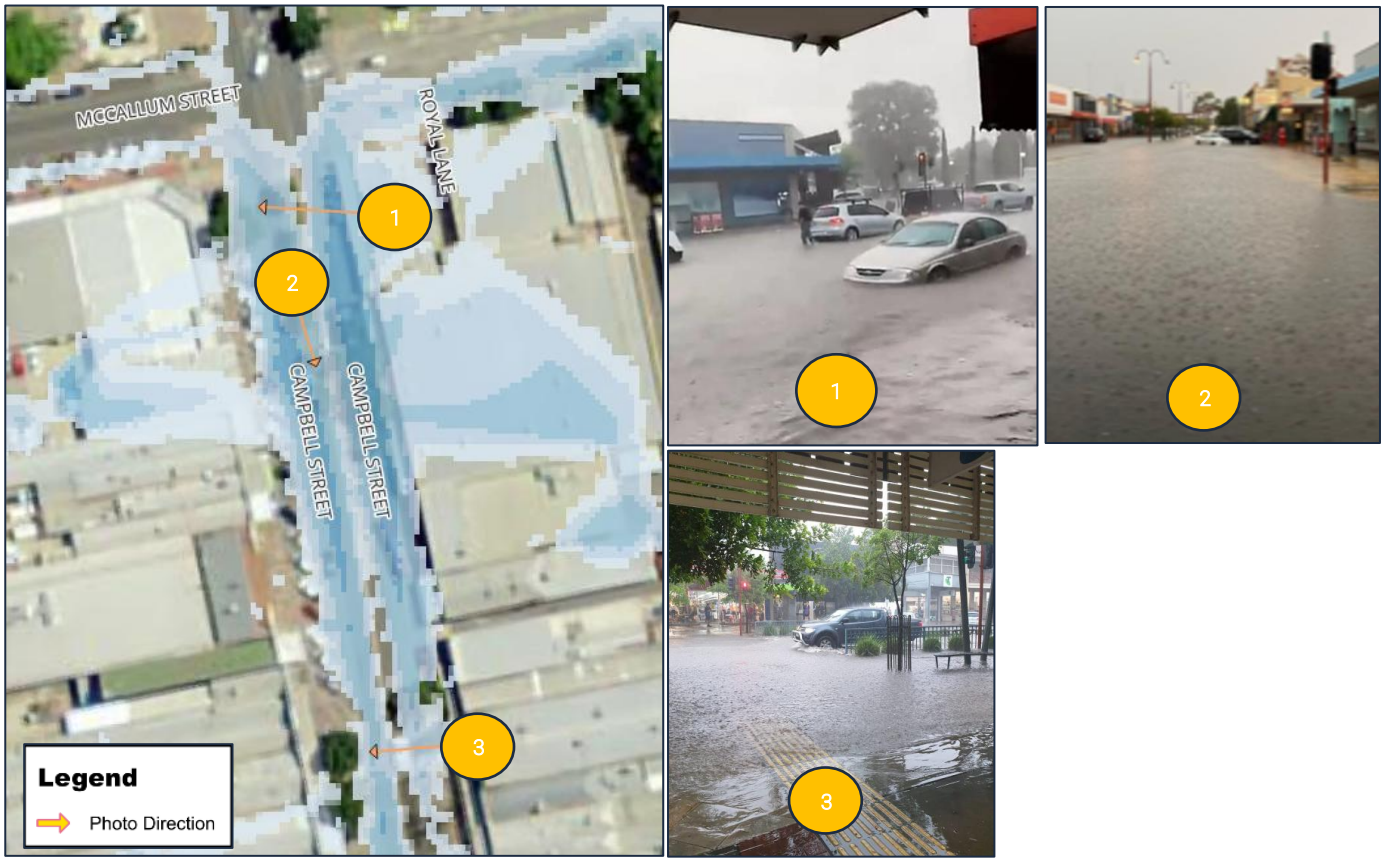


Figure 4-5 Comparison of Modelled Results with Site Photos Captured on Campbell Street in the November 2023 Event

5 FLOOD MODELLING RESULTS

5.1 ROBINVALE MODEL RESULTS

5.1.1 Local Catchment Flood Behaviour

Overland flow behaviour in Robinvale is characterised by relatively flat, semi-urbanised catchments bounded by small hills. The town can be broadly split into three main catchments which loosely reflect the three priority zones of the town listed in Section 3.1.8. These three catchments have been identified as the following:

- Northern Catchment – this catchment includes the main township and economic centre of town including Perrin and Herbert Street. Most of the catchment drains to the low point at the intersection of Herbert Street and Latje Road, before either spilling over Latje Road or moving through the stormwater pipes to Robin Street. Underneath Robin Street is a stormwater pipe which discharges to the Murray River. An overview of this catchment is presented in Figure 5-1.
- Central Catchment – bounded by the Murray Valley Highway and Moore Street to the west and George Street to the east, this catchment includes several residential streets, vineyards and part of the Robinvale golf course. Runoff in this catchment accumulates in the flat, low residential streets between Leonora and Rowe Street, before crossing George Street and flowing east. An overview of this catchment is presented in Figure 5-2.
- Eastern Catchment – dominated by flat farmland and low-density residential areas, this catchment is bounded by hills to the south and Robinvale's flood levee to the east. Overland flow accumulates on the low-lying farmland adjacent to the river, relying on stormwater pipes and culverts under the levee to drain away. The Eastern Catchment receives overland flow and piped stormwater from the Central Catchment near Vine and Maston Court. An overview of this catchment is presented in Figure 5-3.

The following sections describe flood behaviour at key locations within the township. Flood mapping for the study area is presented in Appendix A.



Figure 5-1 Overview of the Robinvale Northern Catchment

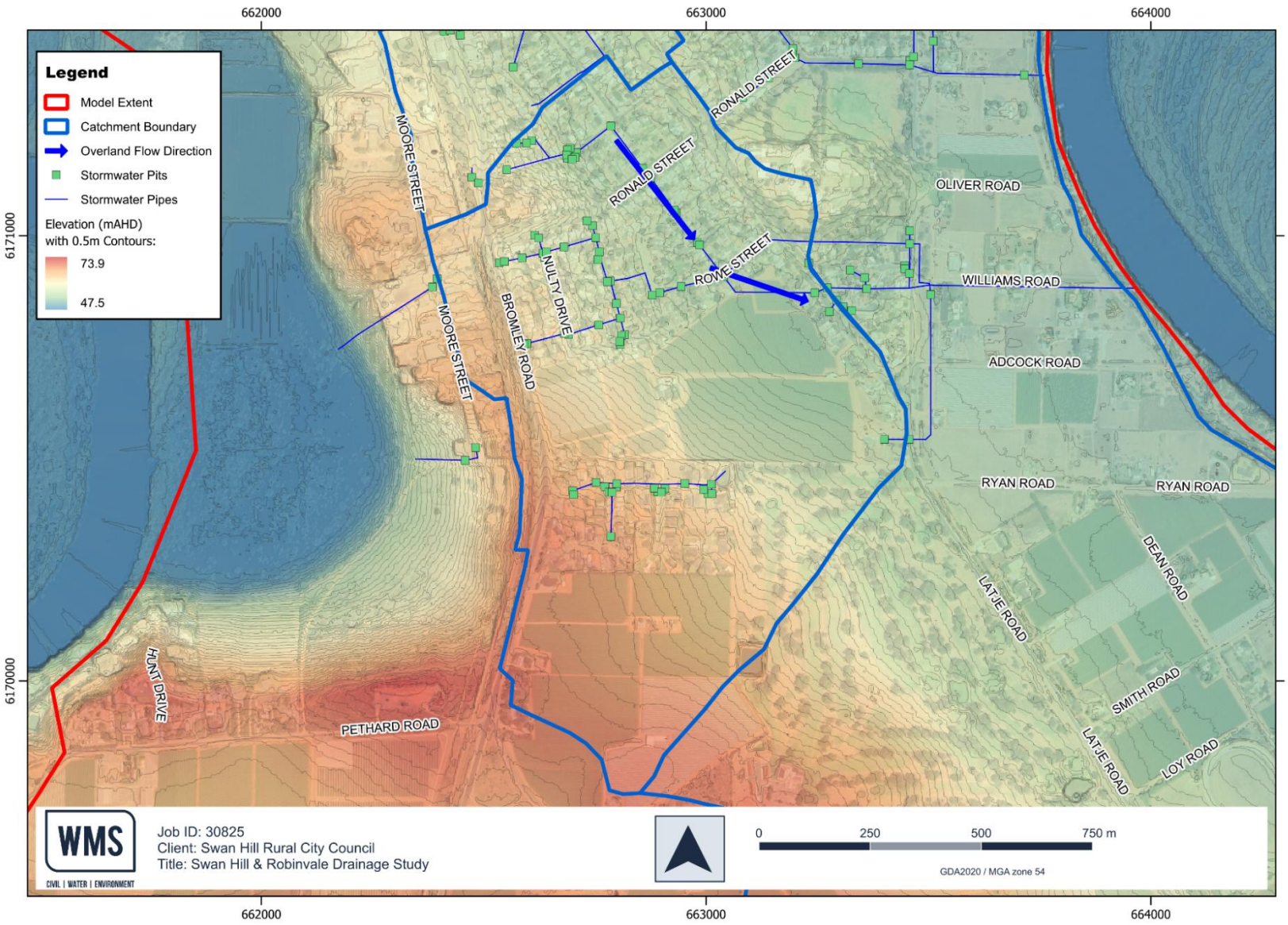


Figure 5-2 Overview of the Robinvale Central Catchment

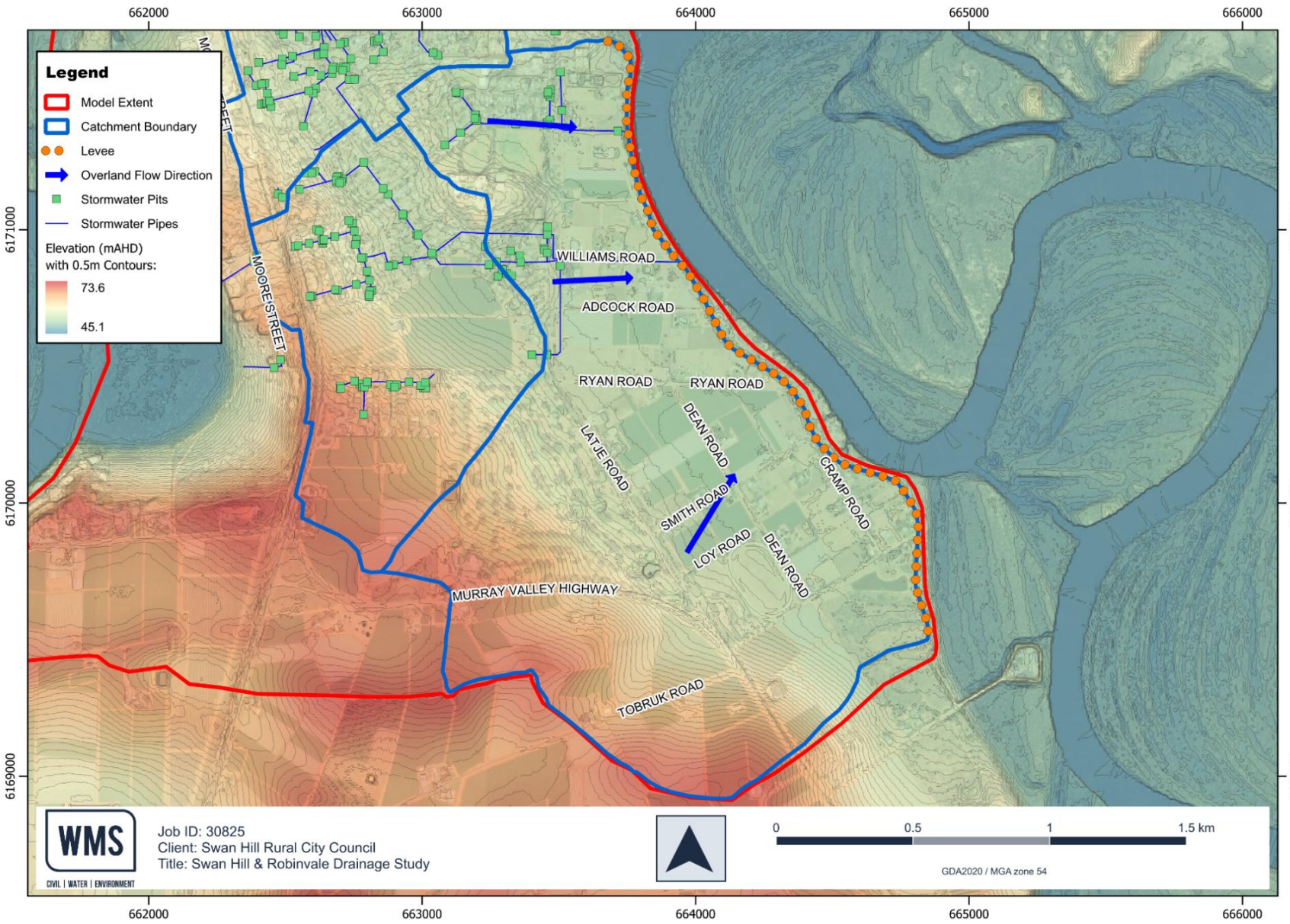


Figure 5-3 Overview of the Robinvale Eastern Catchment

5.1.1.1 Flood Behaviour in the 20% AEP Event

In the 20% AEP storm event, the Northern Catchment experiences minor flooding at the intersection of Herbert Street and Latje Road. Much of Herbert Street, Latje Road and Malla Avenue are inundated with depths exceeding 0.4 m. This extends to the neighbouring properties at the intersection. Low lying sections of George Street also experience ponding with depths ranging from 100 – 180 mm. Refer to **Figure 5-4** for the peak flood depths at these locations in the 20% AEP.



Figure 5-4 Peak Flood Depth at Herbert Street in the 20% AEP Event

Further north on Robin Street, there is significant inundation of the roadway and surrounding parklands. Flood depths range from 0.05 – 0.6 m. Robin Street forms a trapped sag at this location and relies on the stormwater pipe beneath the road to drain water northwards to the river. There are inlet pits in the vicinity, but the capacity of the drainage network is insufficient to prevent significant inundation. Refer to **Figure 5-5** for the peak flood depths at Robin Street in the 20% AEP.

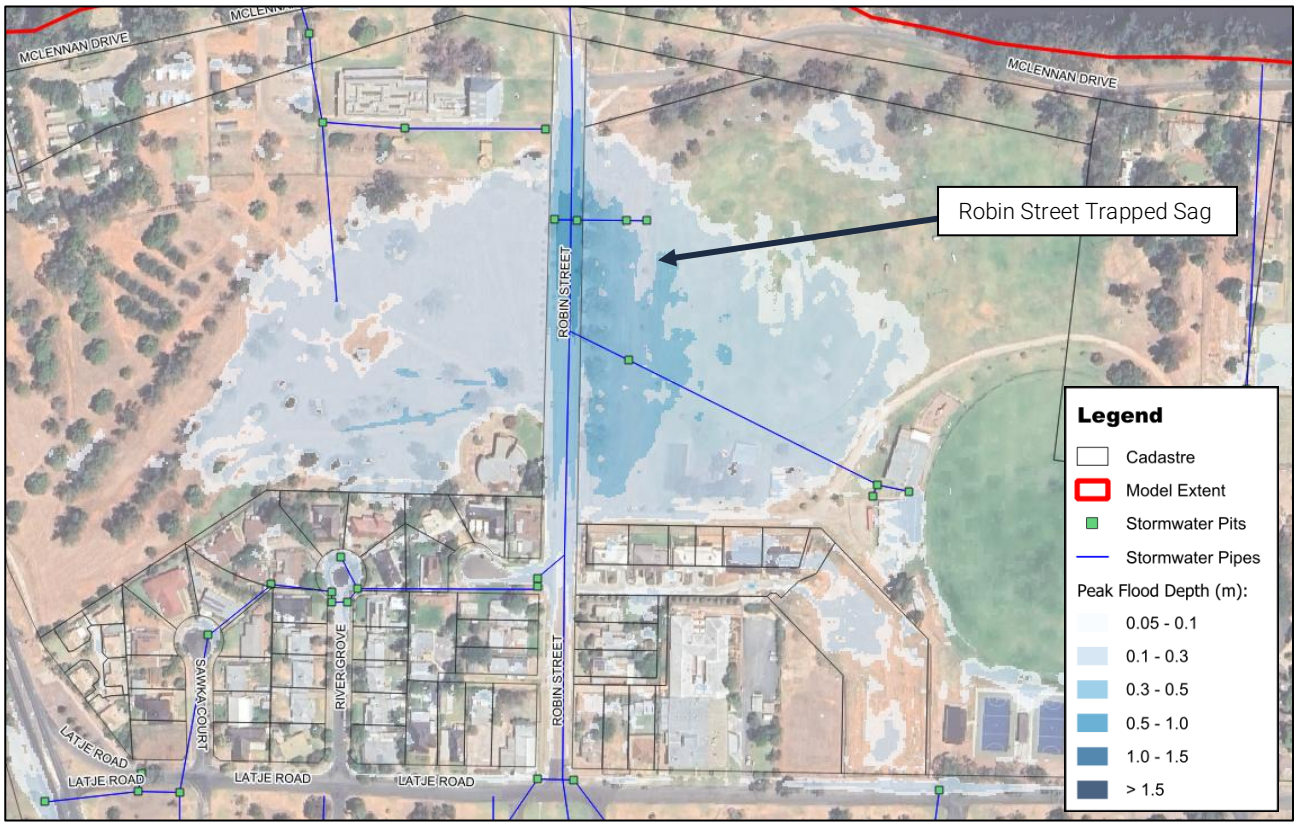


Figure 5-5 Peak Flood Depth on Robin Street in the 20% AEP Event

In the Central Catchment, minor flooding occurs at the low points of several residential streets including Leonora, Ronald, Kennedy, Morris, and Rowe Street. The worst affected roads are Leonora Street and Warlen Avenue with flood depths exceeding 0.3 m depth. Further downstream, there is significant inundation of George Street and the surrounding residential properties. Flood depths on both George Street and Maston Court exceed 0.5 m in depth. Several residential properties at this location experience flood depths between 0.1 and 0.25 m in depth. Refer to Figure 5-6 and Figure 5-7 for the 20% AEP flood depths at Leonora Street and George Street respectively.



Figure 5-6 Peak Flood Depth on Leonora Street and Warlen Avenue in the 20% AEP Event

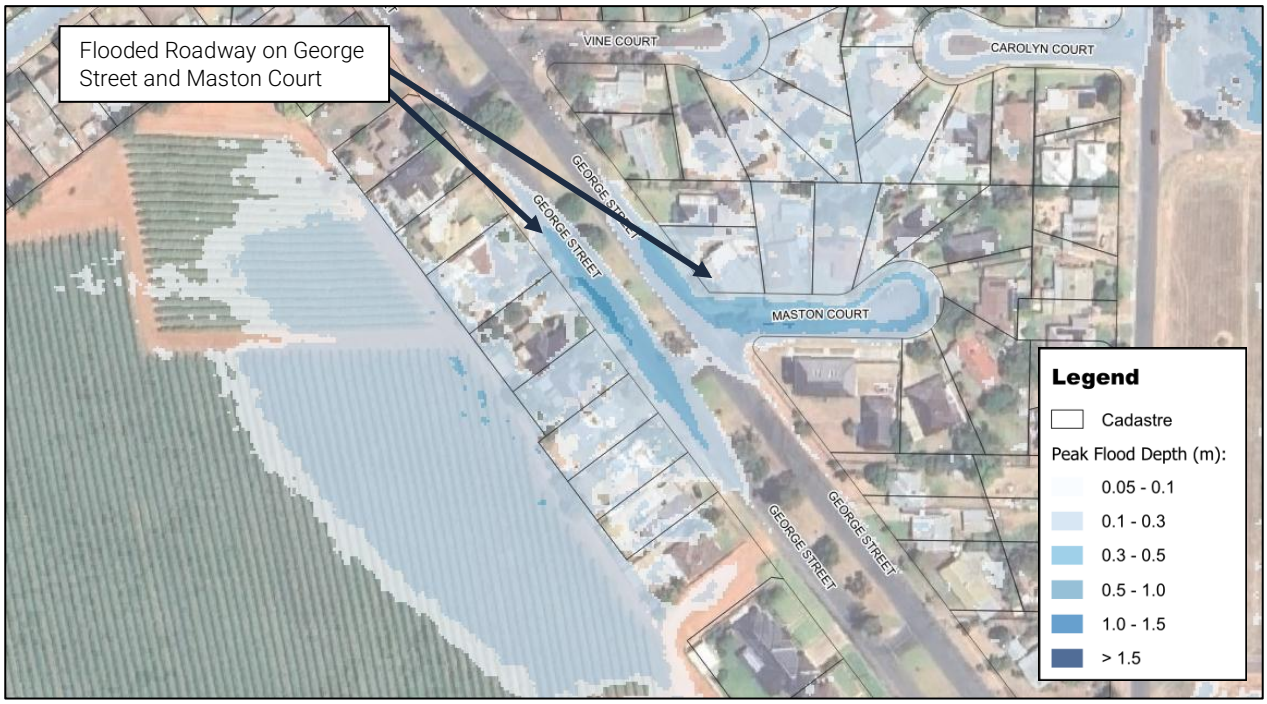


Figure 5-7 Peak Flood Depth at the George Street Sag in the 20% AEP Event

In the Eastern Catchment, the low-lying areas between Latje Road and the levee experience widespread flooding up to 0.4 m in depth. Overland flow accumulates in the swale parallel to the levee, exceeding 1 m in depth at several locations. At the intersection of Alexander Street and Latje Road, both roadways are completely inundated with flood depths ranging from 0.1 to 0.4 m. One property at the eastern end of Higgins Road (adjacent to the town levee) is almost completely inundated. Figure 5-8 presents the 20% AEP peak flood depths across the Eastern Catchment. Figure 5-9 presents 20% AEP peak flood depths in the vicinity of Alexander Street, Latje Road and Higgins Road.



Figure 5-8 Flooding of Low-Lying Areas Adjacent to the Levee in the 20% AEP Event

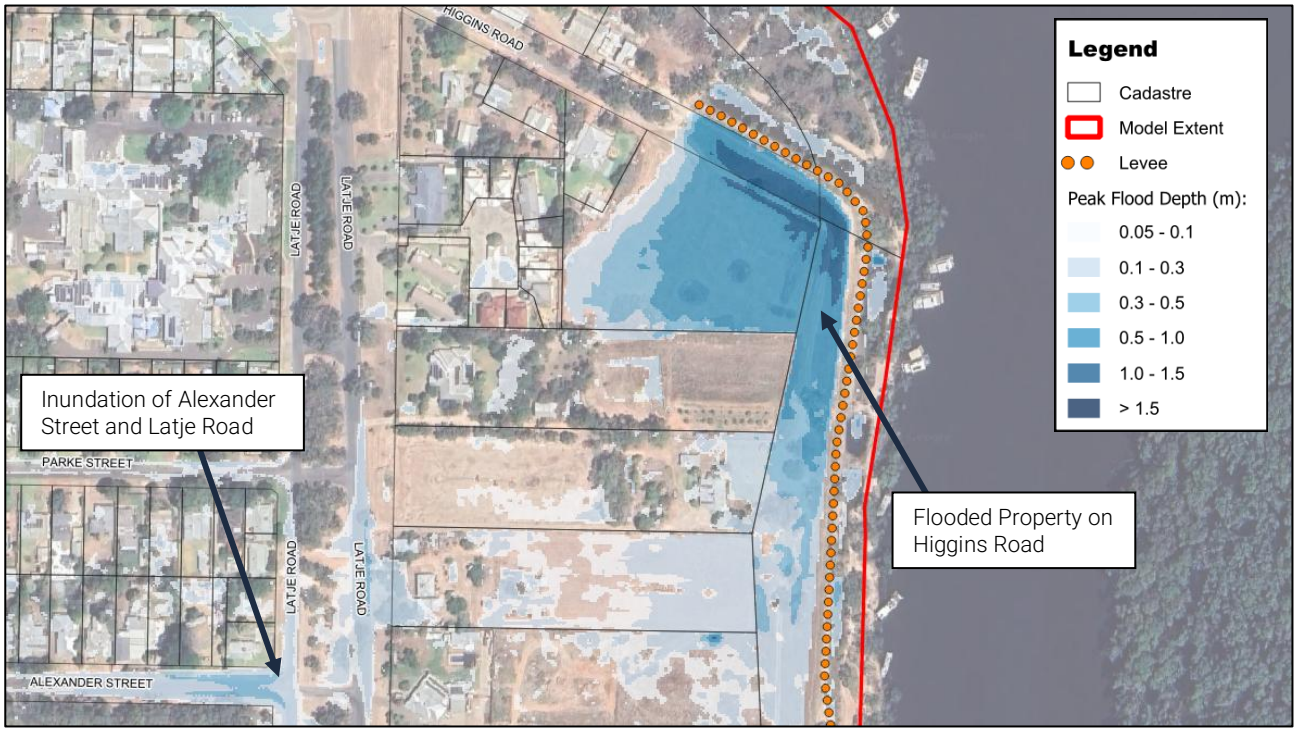


Figure 5-9 Peak Flood Depth on Alexander Street, Latje and Higgins Road in the 20% AEP Event

Flow velocities are generally low in the 20% AEP flood event, with most flood waters across the township peaking at less than 0.3 m/s. Any areas of greater flow velocity are typically restricted to drainage structures such as roadside longitudinal drains. There is a small number of exceptions to this. At the intersection of Herbert and George Street, the roadway experiences peak velocities of up to 0.7 m/s as the overland flow travels north-west towards Malla Avenue. This elevated velocity in the 20% AEP event is presented in Figure 5-10.

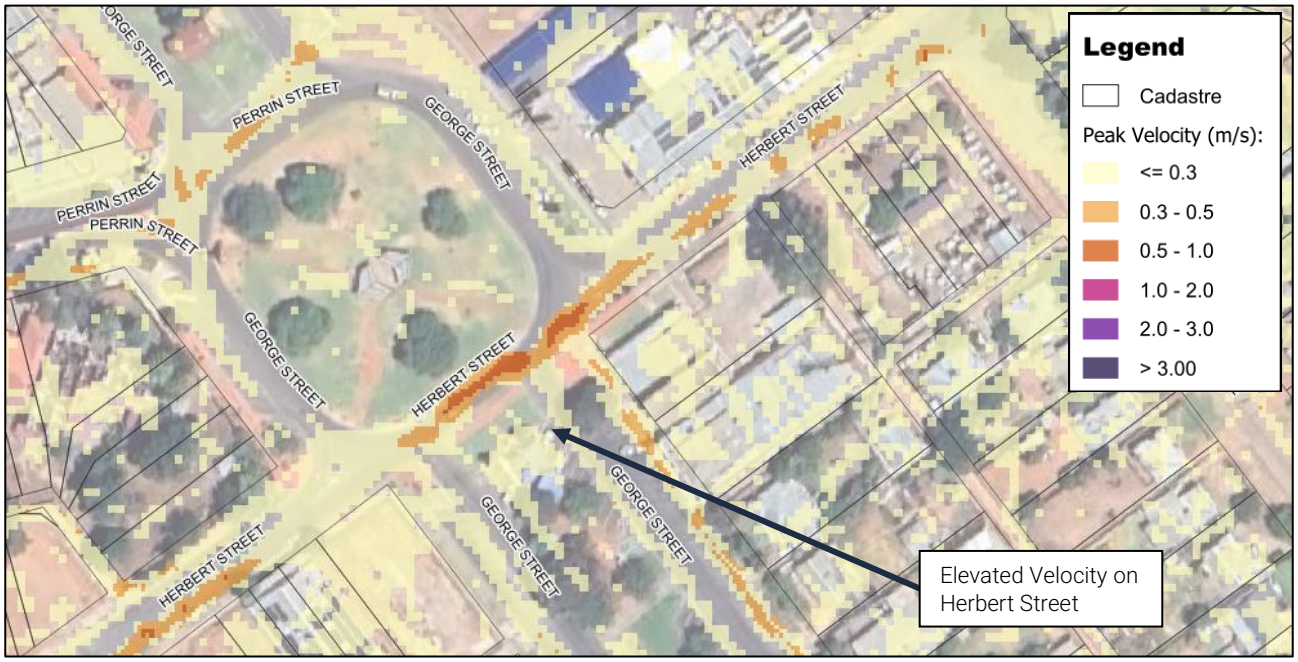


Figure 5-10 Peak Velocity on Herbert Street in the 20% AEP Event

Two sections on Latje Road experience relatively high flow velocities in the 20% AEP, where overland flow paths cross over the road crest. These locations include the roadway near the intersection with Carolyn Court, and further south between Carrazza Court and Ryan Road. Peak velocities at these crossings reach 0.7 and 1.1 m/s respectively and are presented in Figure 5-11

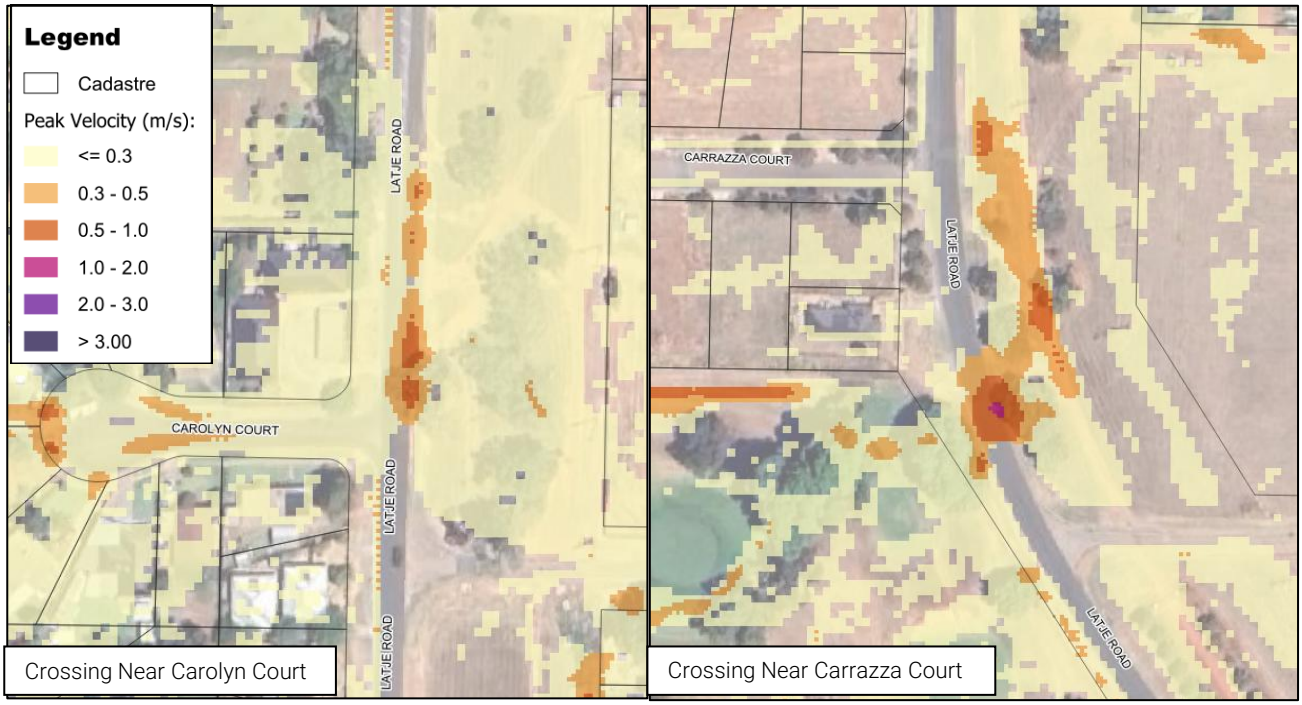


Figure 5-11 Peak Velocities in the 20% AEP Event at Overland Flowpath Crossings of Latje Road

5.1.1.2 Flood Behaviour in the 1% AEP Event

In the 1% AEP flood event, the Northern Catchment experiences flooding in the same areas as the 20% AEP but to a much greater extent. Near the town centre, large sections of Herbert Street, George Street, Malla Avenue and Latje Road are inundated. Flood depths on the roadways range from 0.15 m to 0.7 m in depth. Several commercial and residential properties on Herbert Street and Latje Road experience flooding of up to 0.5 m depth. Peak flood depths experienced in the 1% AEP event at these locations are presented in Figure 5-12.



Figure 5-12 Peak Flood Depth on Herbert Street in the 1% AEP Event

Further north on Robin Street, widespread inundation of the roadway and adjacent parkland occurs to depths up to 0.9 m. This flooding extends up Robin Street to the roadway and residential properties on Margaret Street. Peak flood depths in the vicinity of Robin Street in the 1% AEP event are presented in Figure 5-13.

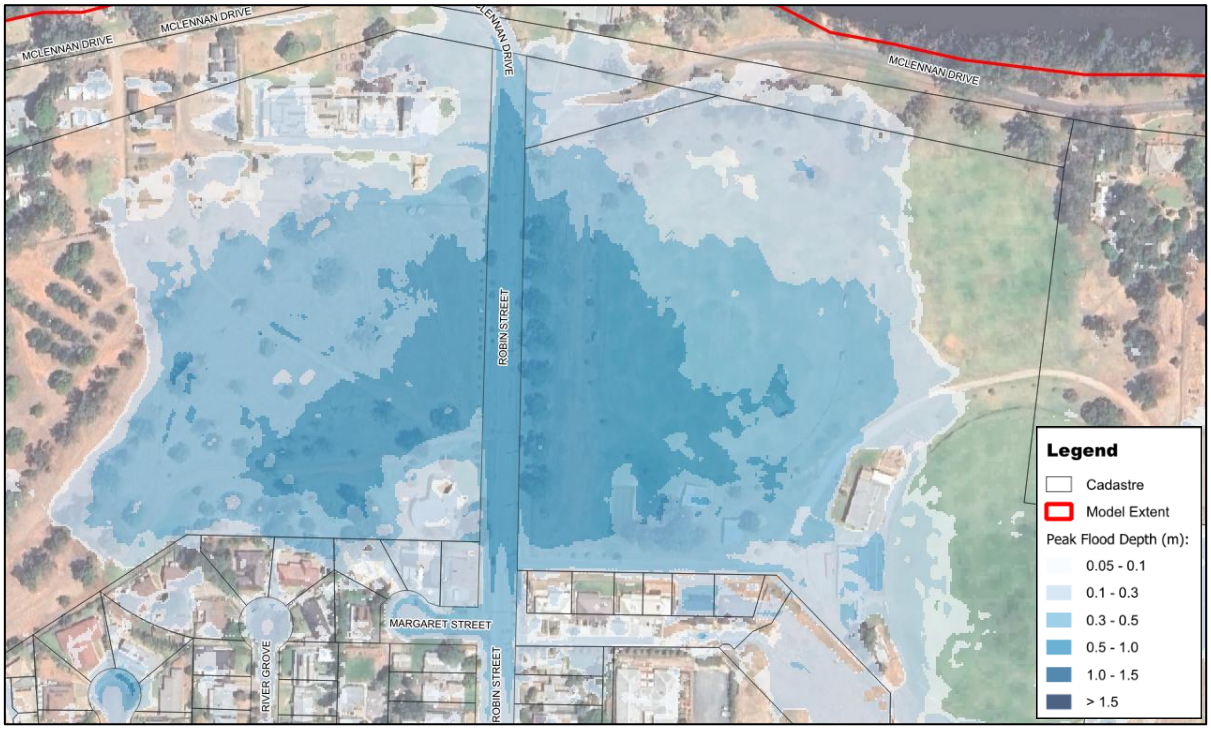


Figure 5-13 Peak Flood Depth on Robin Street in the 1% AEP Event

In the Central Catchment, widespread inundation occurs on several streets and residential properties along the overland flowpath shown in the catchment overview in Figure 5-2. The entirety of the roadway on Warlen Avenue is flooded, along with much of Leonora, Ronald, Kennedy, Morris and Rowe Street. Residential properties in the vicinity experience flood depths ranging from 0.1 to 0.4 m. Refer to Figure 5-14 for peak flood depths in the vicinity in the 1% AEP event.

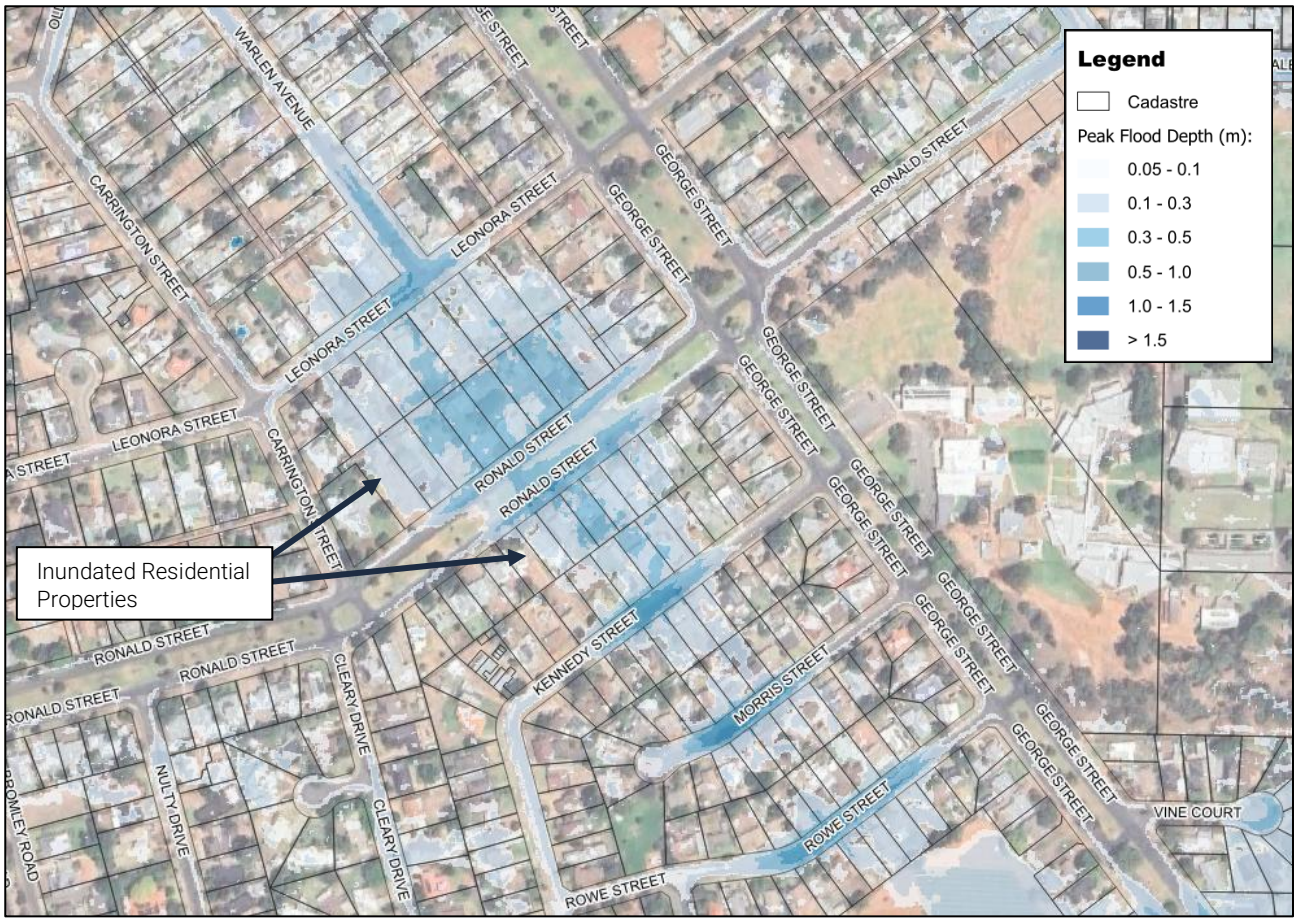


Figure 5-14 Peak Flood Depth in the Vicinity of Leonora Street in the 1% AEP Event

Further downstream, the roadways of both George Street and Maston Court are inundated by over 0.6 m of flood water. Numerous residential land parcels on George Street, Maston Court, Vine Court and Carolyn Court are inundated. Peak flood depths at these locations are presented in Figure 5-15.

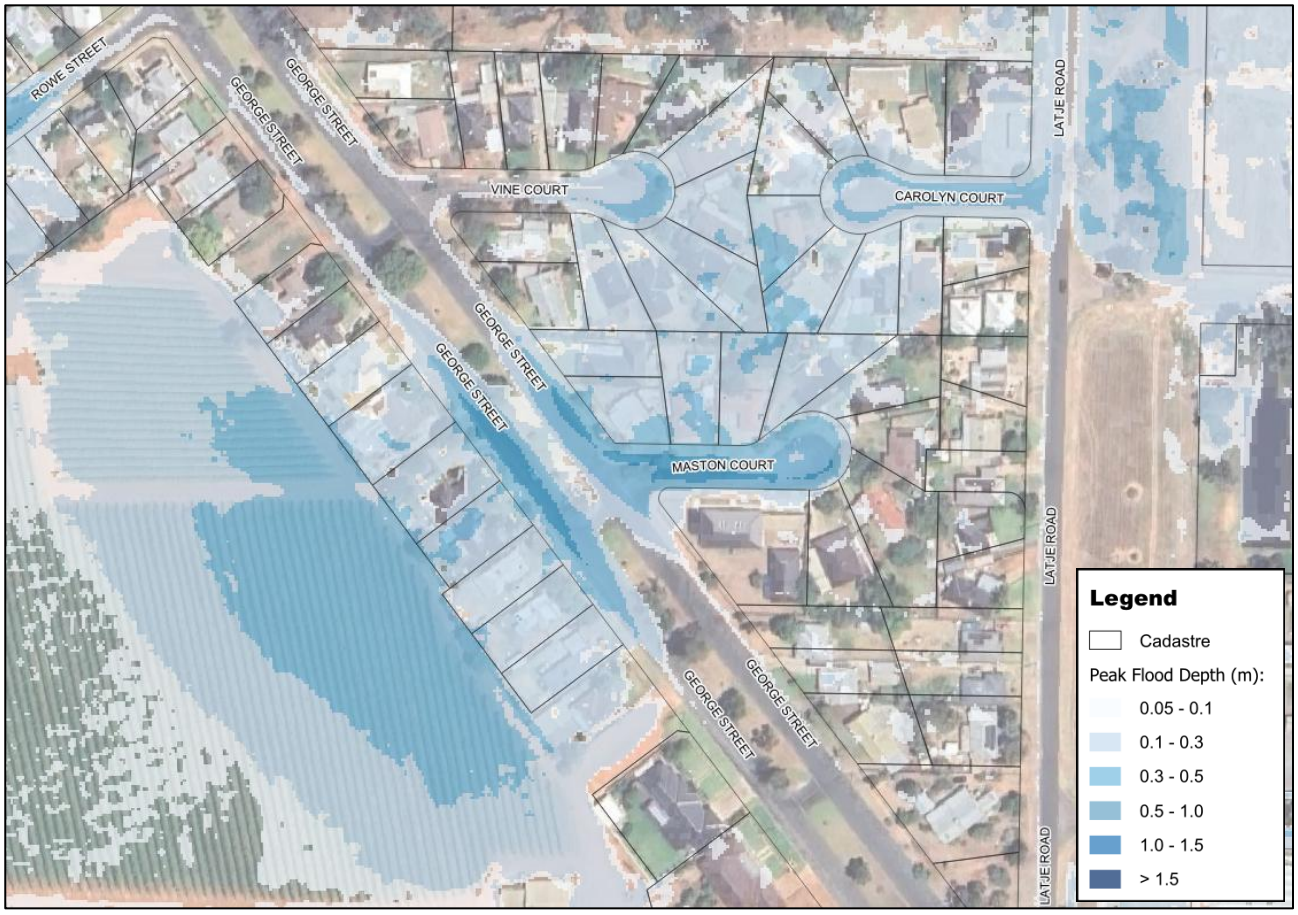


Figure 5-15 Peak Flood Depths at George Street and Maston Court in the 1% AEP Event

Low-lying areas of the Eastern Catchment experience significant, widespread inundation. Overland flow accumulates on the western side of the levee as outflow is limited to pipe outlets on Lawrence and Williams Road. Upstream of the levee, numerous rural-residential properties are inundated by over 0.5 m of water depth. Large sections of Lawrence, Oliver, Williams, Adcock, Ryan, Cramp, Smith, and Smythe Road are inundated. Refer to Figure 5-16 for the peak 1% AEP flood depths in the Eastern Catchment.

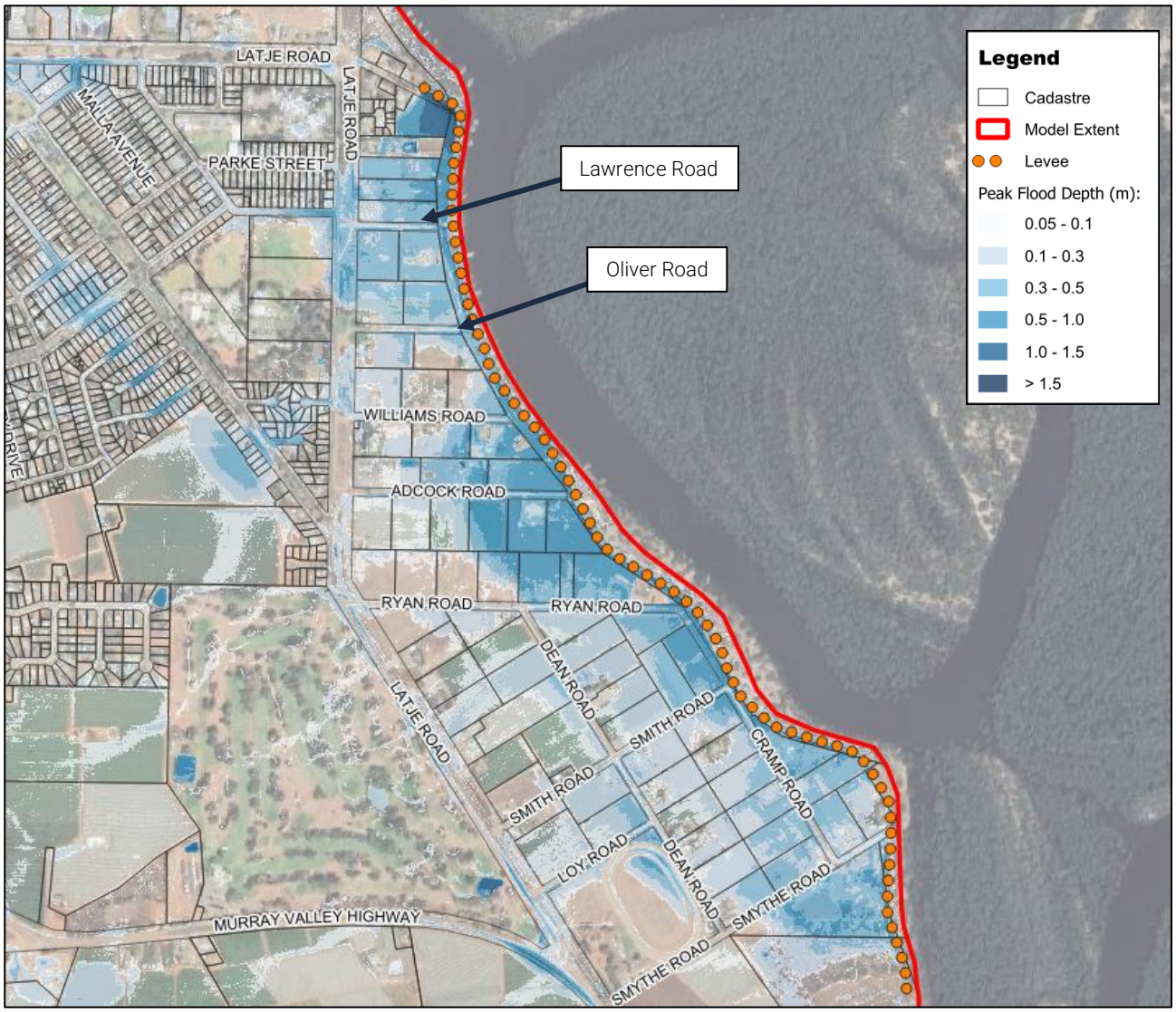


Figure 5-16 Peak Flood Depth in the Eastern Catchment in the 1% AEP Event

The entirety of Alexander Street, along with sections of Watkin and Parke Street, are inundated. Peak flood depths over the road on Alexander Street exceed 0.6 m in depth. Adjacent to the intersection with Alexander Street, approximately 400 m of Latje Road is also inundated by flood waters. Refer to Figure 5-17 for peak flood depths in the 1% AEP event for the areas described above.

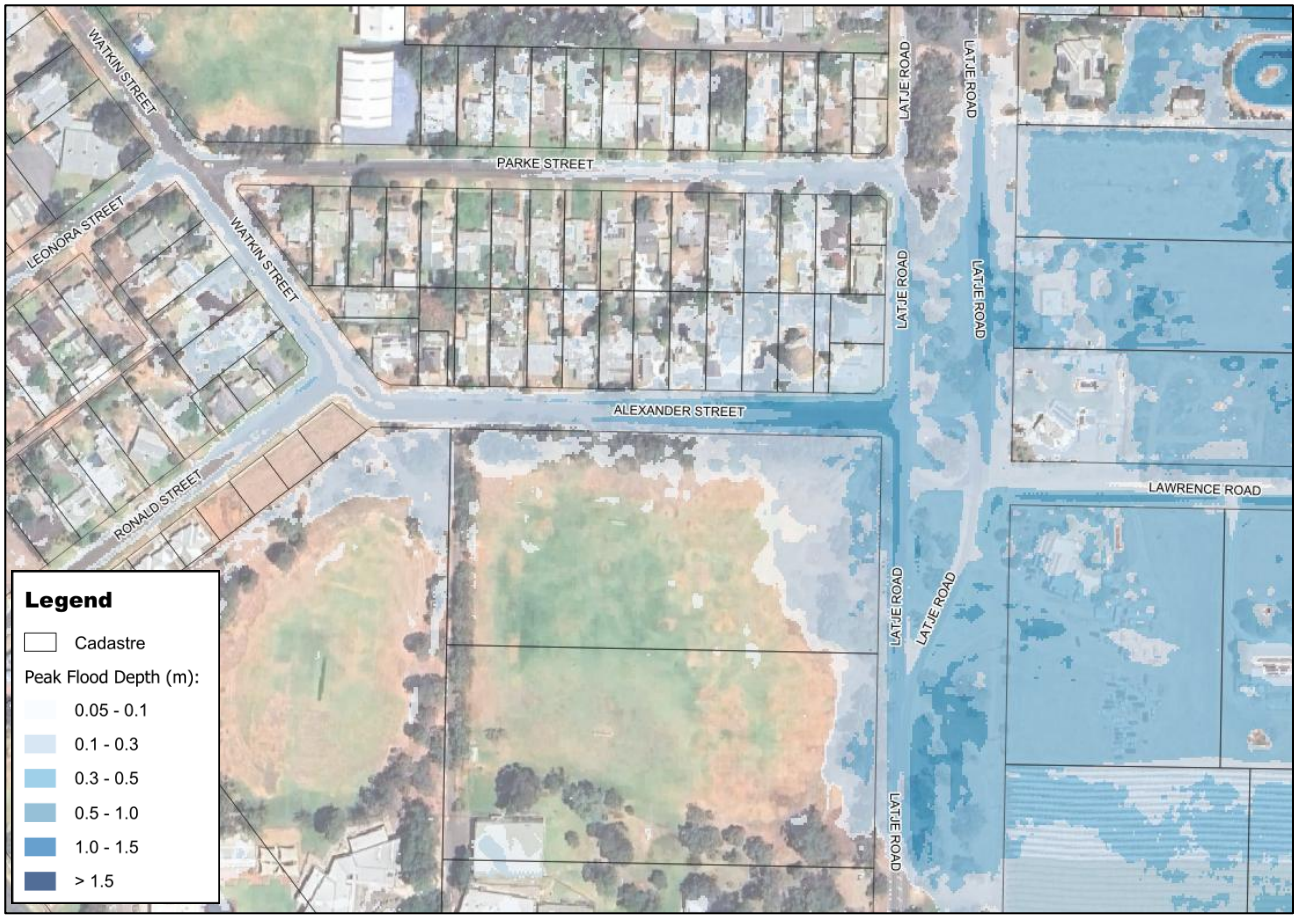


Figure 5-17 Peak Flood Depth in the Vicinity of Alexander Street in the 1% AEP Event

Peak flood velocities in the 1% AEP are typically less than 0.3 m/s throughout Robinvale. There are isolated areas within overland flow paths that experience higher velocities. One such location is Herbert Street, which sees a considerable amount of flow exceeding 0.5 m/s on the roadway itself. Immediately north on the intersection of Perrin Street and George Street there are also velocities on the roadway exceeding 0.5 m/s. Refer to Figure 5-18 for the 1% AEP peak velocities on Herbert Street.

On Alexander Street, the majority of the roadway forms an overland flowpath, with velocities ranging from 0.5 – 0.8 m/s. Refer to Figure 5-19 for the 1% AEP peak velocities on Alexander Street.

Between Loy Road and the Murray Valley Highway, a major overland flow path crosses Latje Road causing velocities exceeding 1.8 m/s. Refer to Figure 5-20 for the 1% AEP peak velocities on the southern end of Latje Road.

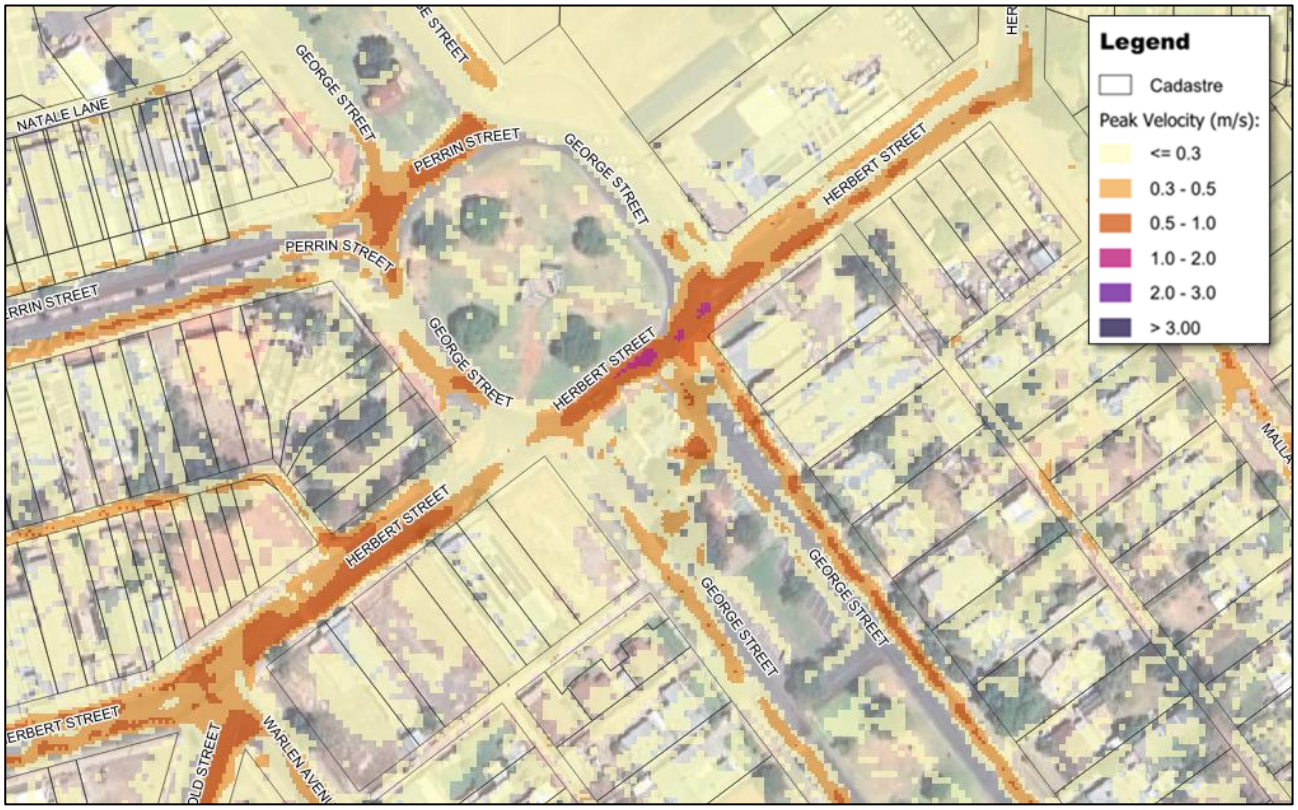


Figure 5-18 Peak 1% AEP Velocity on Herbert Street



Figure 5-19 Peak 1% AEP Velocity on Alexander Street

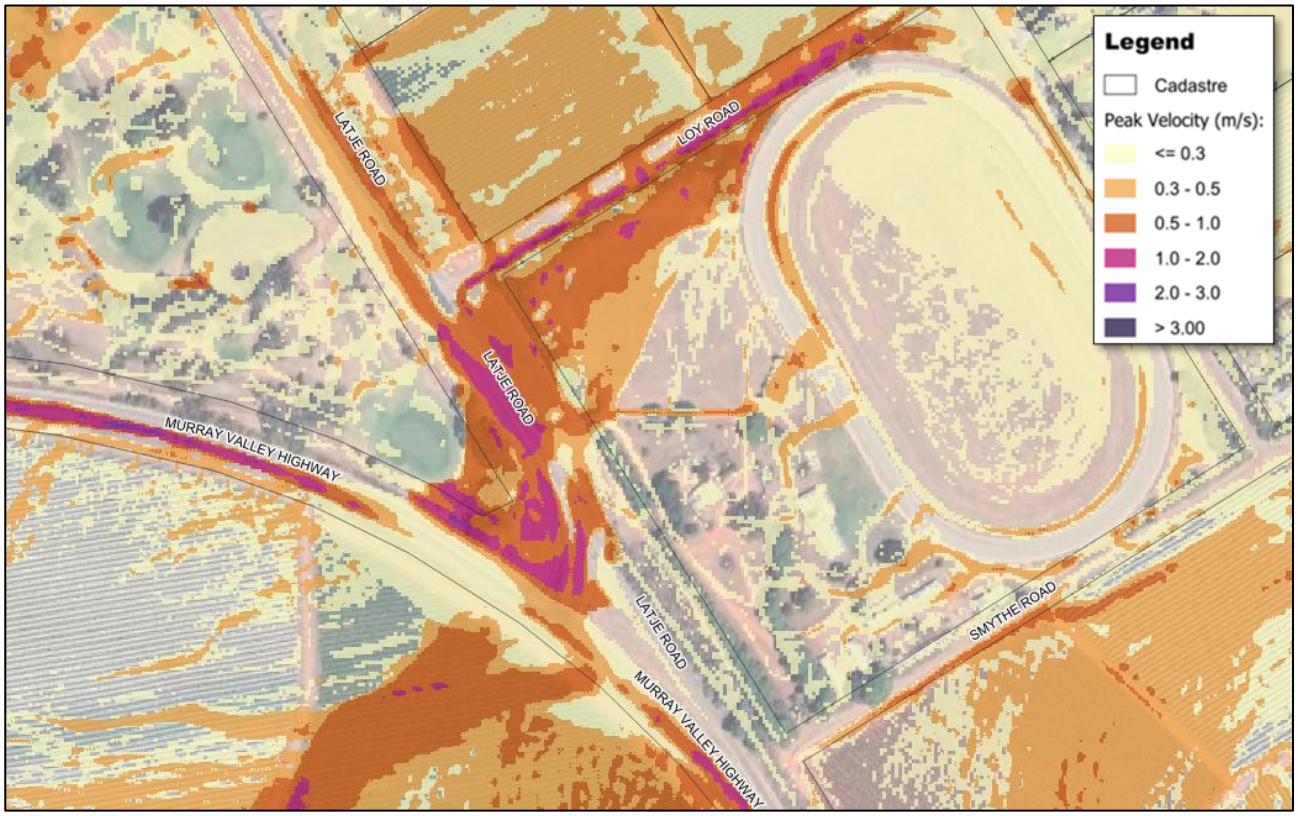


Figure 5-20 Peak 1% AEP Velocity on (South) Latje Road

Peak modelled flood depths and velocities on prominent roads within Robinvale are summarised in Table 5-1. Note that peak depth and peak velocity on each road may not occur at the same location. Refer to mapping of results in Appendix A for peak depths and velocities in Robinvale.

Table 5-1 Summary of Peak Depths and Velocities on Prominent Robinvale Roads for the 20% and 1% AEP Events

Road Name	20% AEP Event		1% AEP Event	
	Peak Depth (m)	Peak Velocity (m/s):	Peak Depth (m)	Peak Velocity (m/s):
Robin Street	0.64	0.33	0.94	0.52
Latje Road (North)	0.31	0.65	0.58	0.86
George Street (North)	0.21	0.27	0.36	0.81
Perrin Street	0.07	0.38	0.33	0.72
Herbert Street	0.42	0.71	0.70	1.20
Watkin Street	0.15	0.43	0.39	0.64
Warlen Avenue	0.33	0.53	0.50	0.67
Leonora Street	0.37	0.70	0.56	1.10
Ronald Street	0.24	0.60	0.58	0.98
Kennedy Street	0.26	0.47	0.77	1.08

Road Name	20% AEP Event		1% AEP Event	
	Peak Depth (m)	Peak Velocity (m/s):	Peak Depth (m)	Peak Velocity (m/s):
Morris Street	0.19	0.66	0.72	0.67
Rowe Street	0.37	0.53	0.75	1.04
George Street (South)	0.56	0.40	0.66	0.75
Maston Court	0.51	0.89	0.64	1.17
Vine Court	0.35	0.41	0.50	0.84
Carolyn Court	0.30	0.63	0.40	0.89
Latje Road (South)	0.31	1.08	0.39	1.53
Watkin Street	0.24	0.44	0.35	0.58
Alexander Street	0.45	0.58	0.72	0.82
Lawrence Road	0.67	0.49	1.12	0.94
Williams Road	0.20	0.18	0.54	0.51

5.2 SWAN HILL MODEL RESULTS

The following sections detail flood behaviour at key locations within the township of Swan Hill. General flood mapping for the study area can be found in Appendix B.

5.2.1 Local Catchment Flood Behaviour

Overland flow behaviour in Swan Hill is characterised by the town's relatively flat, urbanised catchments bounded by small hills. The town can be broadly split into three catchments. The largest is the northern catchment, in which flows either traverse overland or travel through the stormwater network to the Main Drain before being pumped out to the Murray River at the pump station on Milloo Street. This catchment stretches from Karinie Street on the northern end of the town down to Harrison Crescent and Poole Boulevard near the racecourse. The southern area of Swan Hill drains east towards the Little Murray River predominately via overland flow, with sections aided by the stormwater pipe network. The eastern slopes of the town's most prominent hill, occupied by the town centre, flows east towards the Murray via several overland flow paths and stormwater networks.

An overview of these catchments is presented in Figure 5-21.

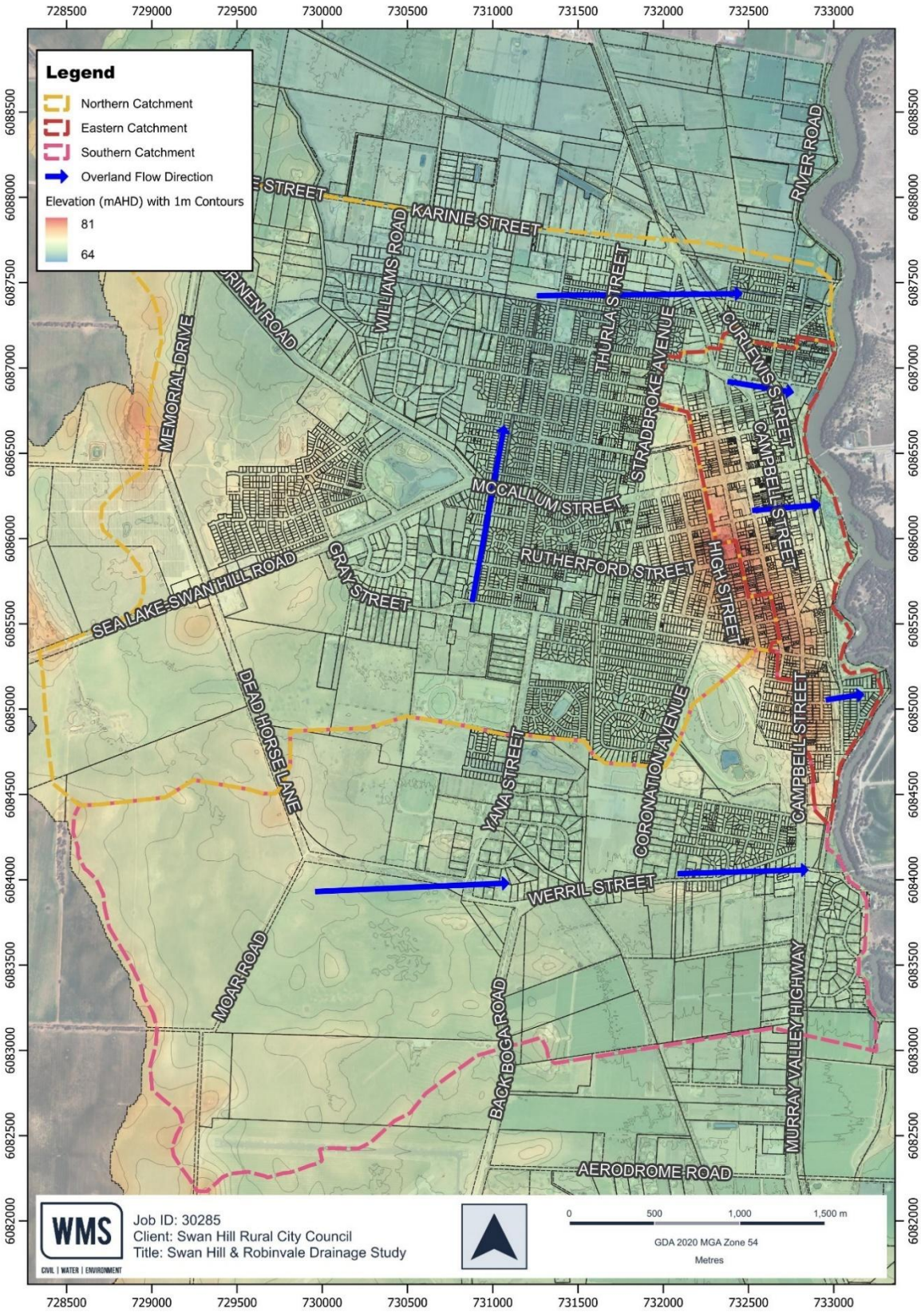


Figure 5-21 Overview of Swan Hill Overland Flow Catchments

5.2.1.1 *Flood Behaviour in the 20% AEP Event*

Swan Hill's northern catchment experiences isolated minor flooding in the 20% AEP event, predominately within road corridors which form overland flow paths or localised sags. Low points along Burton Street and Parkview Drive experience flood depths of up to 350 mm. Similar flood depths occur on low-lying areas on Gray, Wanera, Willick, and Wallace Street. These flood depths are presented in Figure 5-22 and Figure 5-23.



Figure 5-22 Flooding of Burton Street and Parkview Drive in the 20% AEP Event



Figure 5-23 Peak Flood Depths in the Vicinity of Gray Street and Willick Street in the 20% AEP Event

Remaining areas of the northern catchment typically do not experience flood depths greater than 150 mm outside of road shoulders and longitudinal drains.

In the eastern catchment, sections of the town centre experience flooding of roadways and adjacent buildings. Peak flood depths on Chapman Street reach up to 0.4 m adjacent to Gurnett Oval. Flood depths on Beveridge and Pye Street reach up to 0.25 m. Parts of Campbell and Curlewis Street reach flood depths up to 0.35 m, just south of McCallum Street. Peak flood depths at these locations are presented in Figure 5-24 and Figure 5-25. Note that the large area with flood depths exceeding 1 m is the Swan Hill Outdoor Pool.



Figure 5-24 Peak Flood Depths on Chapman and Pye Street in the 20% AEP Event



Figure 5-25 Peak Flood Depths on Beveridge, Campbell and Curlewis Street in the 20% AEP Event

Flooding in the southern catchment is minor and typically restricted to low points of roadways in the 20% AEP event. Several sections of Wattie Street are inundated by up to 0.2 m of flood water. At the bend in the road of Nalder Drive (adjacent to Guastalegname Park), flood depths exceed 0.3 m. These flood depths are presented in Figure 5-26.

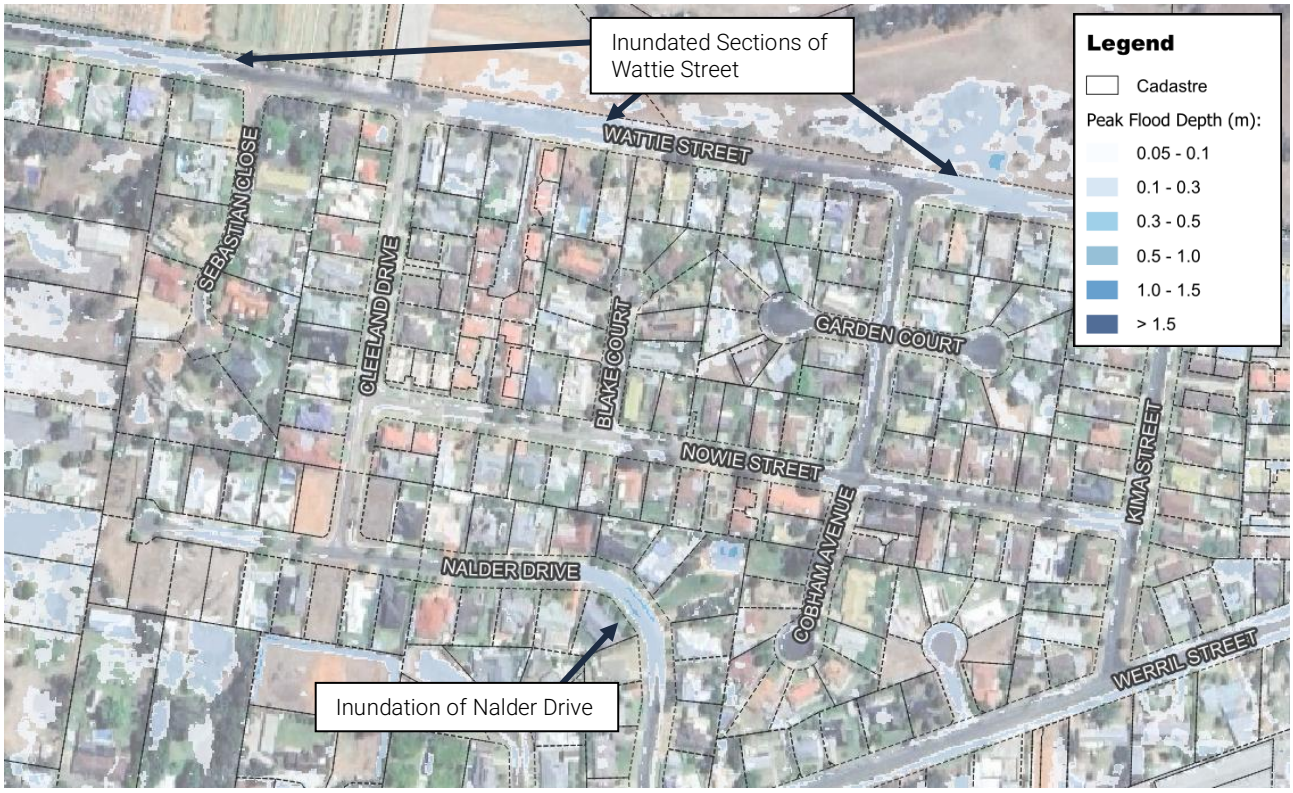


Figure 5-26 Peak Flood Depths on Wattie Street and Nalder Drive in the 20% AEP Event

Peak flow velocities in the 20% AEP event are typically low across the township, with only isolated areas exceeding 0.3 m/s. Within the Main Drain, velocity ranges from 0.5 – 1.0 m/s. In the northern catchment, parts of McCallum Street at the intersection with Stradbroke Avenue reach up to 1.2 m/s. Refer to Figure 5-27 for the peak 20% AEP velocity at this location.



Figure 5-27 Peak 20% AEP Velocity on McCallum Street

In the eastern catchment, flow velocities are generally high within longitudinal drainage of the CBD. This is most notable along sections of Campbell, Beveridge, McCrae and Rutherford Street where many flow paths exceed 0.7 m/s. These velocities are presented in Figure 5-28.

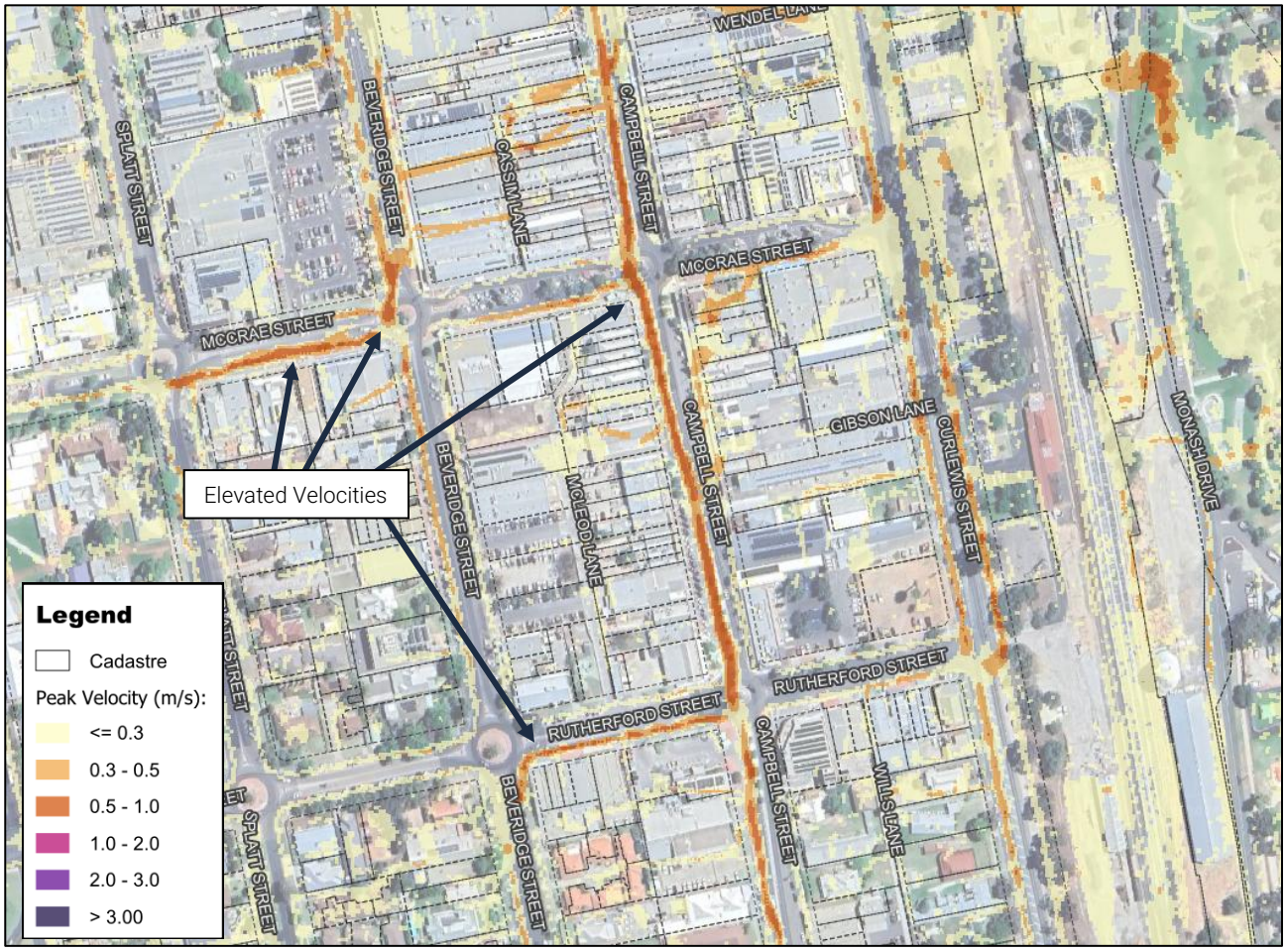


Figure 5-28 Peak Velocity Within the Town Centre in the 20% AEP Event

The southern catchment generally experiences flow velocities less than 0.3 m/s. An exception to this is an overland flow path that forms on Gray Street and Coronation Avenue, where flow velocity exceeds 1 m/s at several locations and generally peaks above 0.7 m/s. Velocity at this location in the 20% AEP event is presented in Figure 5-29.

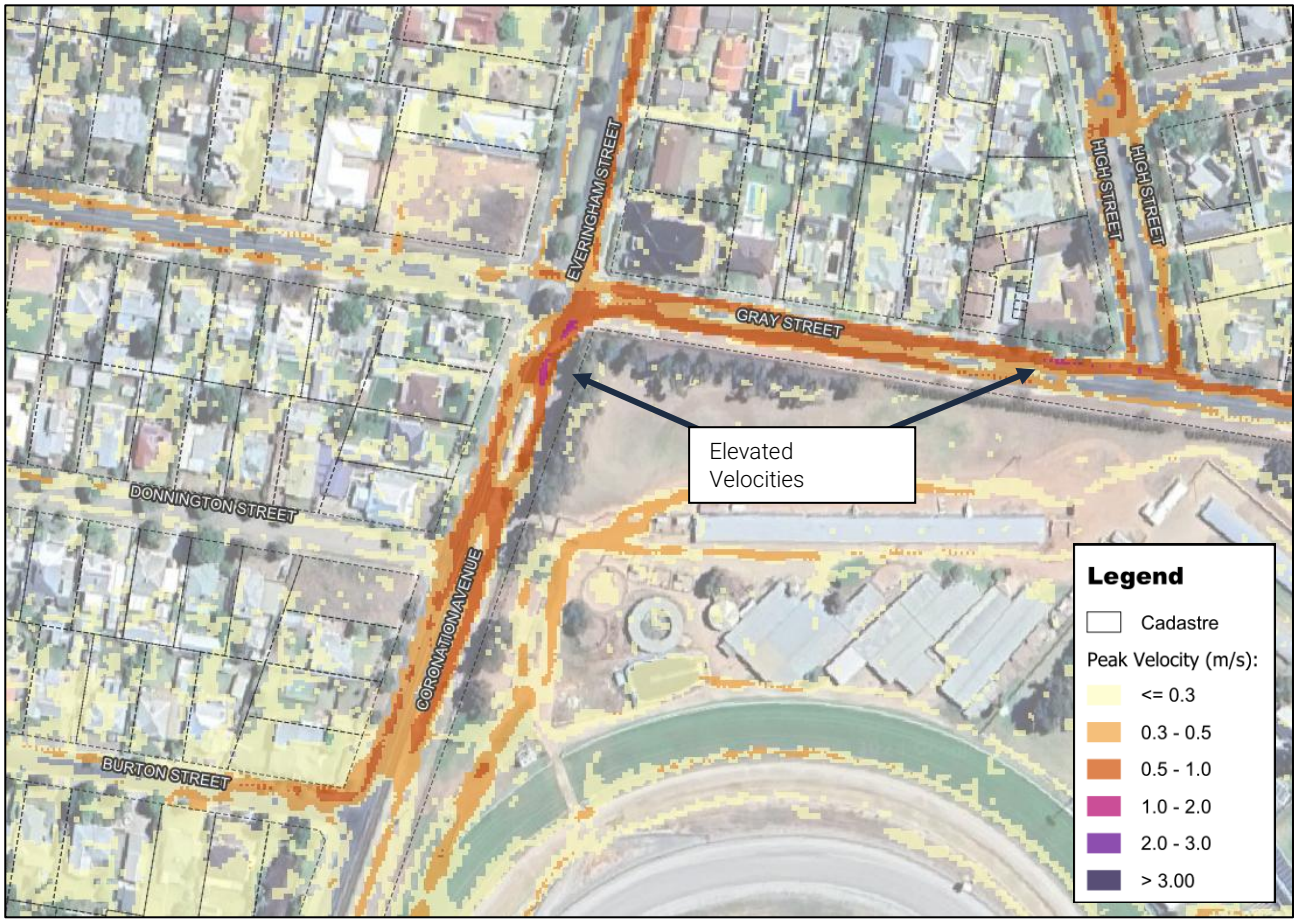


Figure 5-29 Peak Velocity Along the Overland Flow Path on Gray Street and Coronation Avenue in the 20% AEP Event

5.2.1.2 *Flood Behaviour in the 1% AEP Event*

The 1% AEP sees significant, widespread inundation of much of Swan Hill's roadways and low-lying areas. In the northern catchment, areas adjacent to the Main Drain are the worst-affected. At several locations, either the stormwater network reaches capacity and cannot convey the local runoff, or the Main Drain overflows and causes backwater flooding. One such example of this is the industrial estate in the vicinity of Webster Drive. Flood depths on Webster Drive and Sheperd Road exceed 0.7 m. At the crossing of the Main Drain, Williams Road is overtopped by over 0.4 m. This flooding extends south of the Main Drain to Hocking Drive, as presented in Figure 5-30.

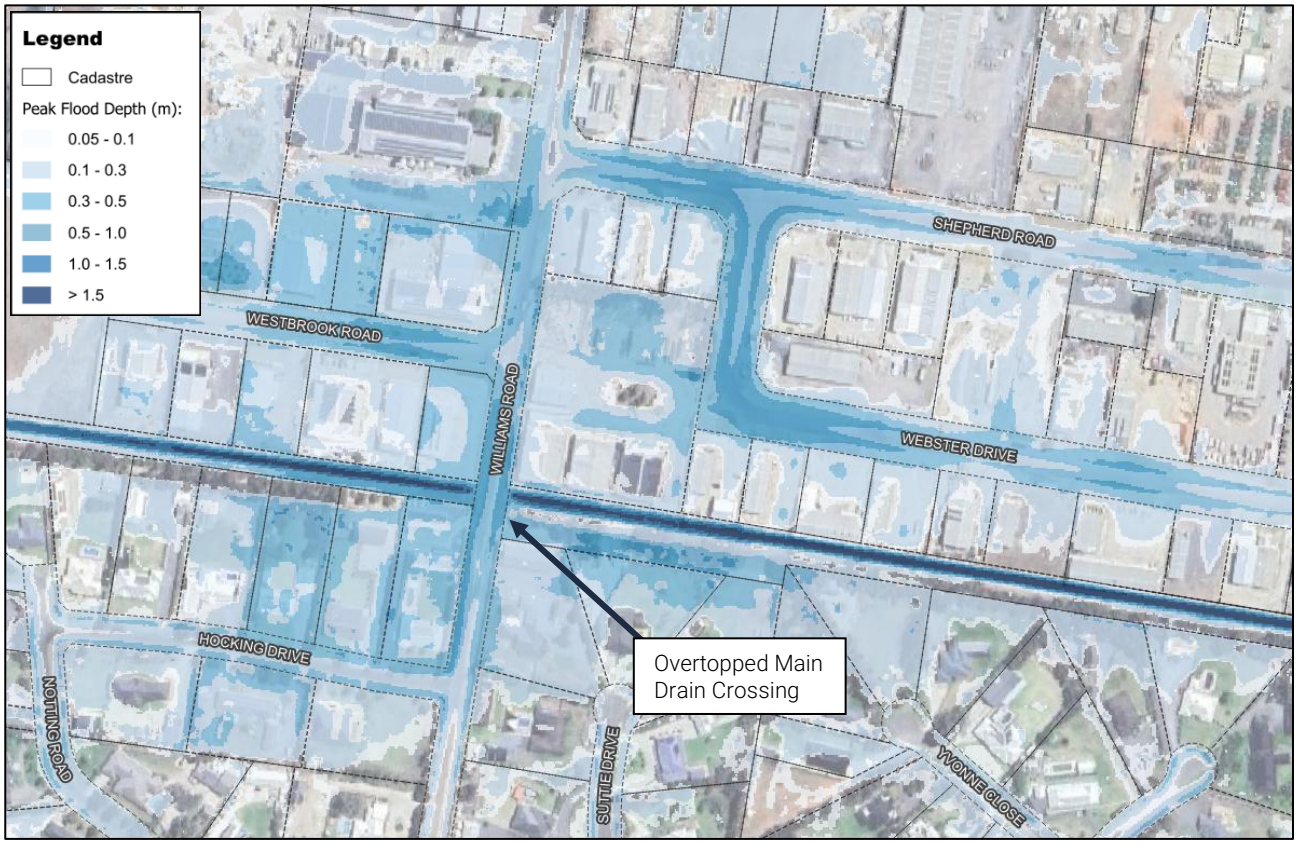


Figure 5-30 Flood Depths in the Vicinity of Webster Drive in the 1% AEP Event

At Murlong Street in the vicinity of Swan Hill North Primary School, most of the roadways are inundated by over 0.4 m of flood water. The majority of the school grounds are inundated, along with the Main Drain crossing on Murlong Street. Refer to Figure 5-31 for peak flood depths at this location.

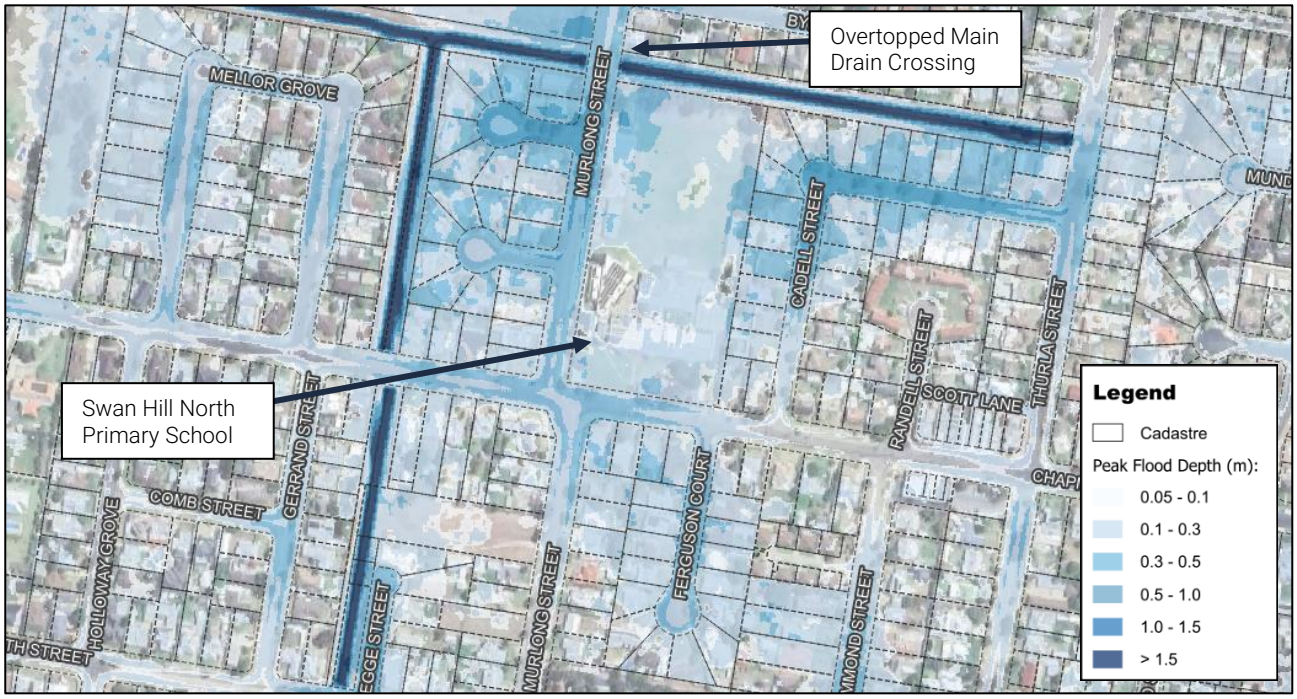


Figure 5-31 Peak Flood Depths in the 1% AEP on Murlong Road and Swan Hill North Primary School

Parallel to the southern branch of the Main Drain, Dunstone, Drummond and Thurla Street form a major overland flow path. This inundates a combined length of approximately 900 m of roadway along the three streets. Peak flood depths on these roadways are presented in Figure 5-32.



Figure 5-32 Overland Flow Path Formed on Dunstone, Drummond and Thurla Street in the 1% AEP

In the eastern catchment, several streets within the town centre experience inundation exceeding 0.2 m including Chapman, Queen, Beveridge, Pye, and Campbell Street. Refer to Figure 5-33 for peak flood depths at these locations in the 1% AEP event. Flood waters in other streets of the CBD are typically restricted to road shoulders and do not exceed 0.2 m in depth.



Figure 5-33 Peak Flood Depths in the Swan Hill Town Centre in the 1% AEP Event

In the southern catchment, flood behaviour generally mirrors that of the 20% AEP event albeit with increased flood depth magnitude. One such exception so this is the collection of residential lots on Peppercorn Mews, Charlie Gray Close and Settlers Court. These areas experience widespread flooding of both the roadways and private lots themselves. Peak flood depths at this location are presented in Figure 5-34.

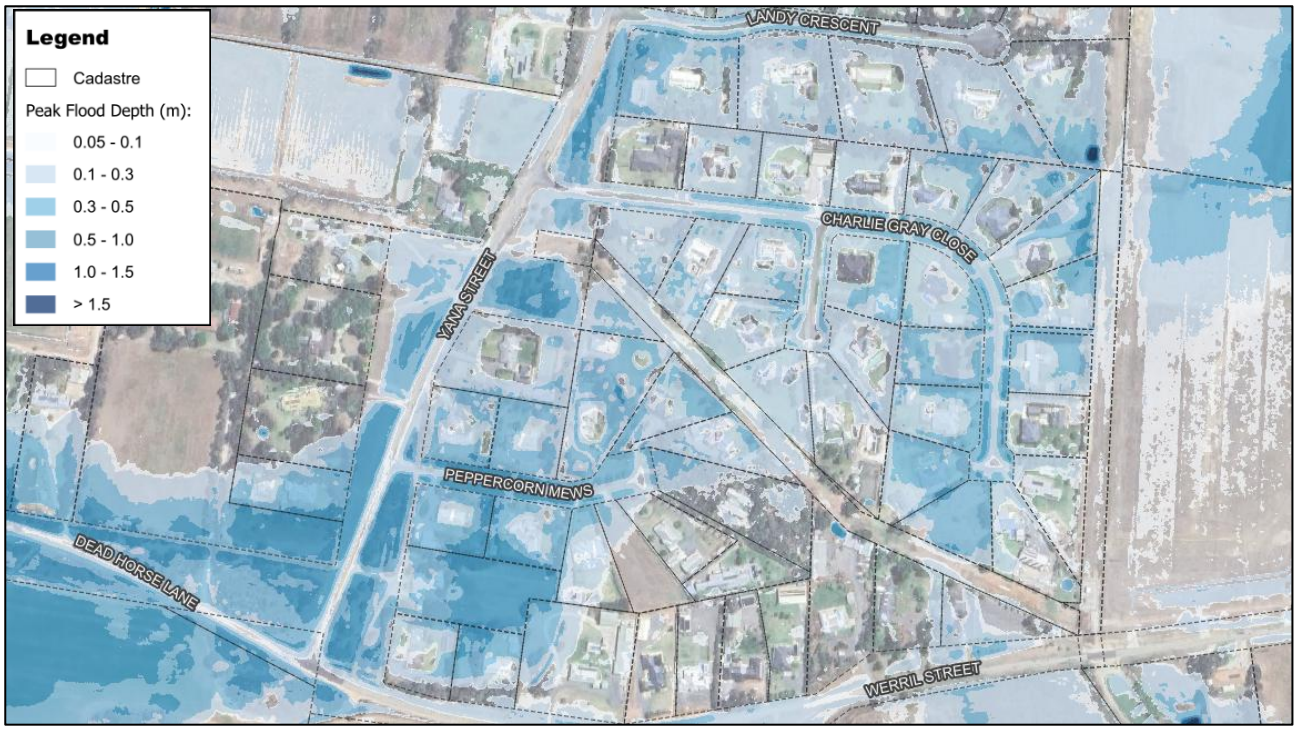


Figure 5-34 Peak Flood Depths on Peppercorn Mews and Charlie Gray Close in the 1% AEP Event