



Data Review and Validation Report

Newstead Flood Study and Mitigation Strategy
(M1751-2023)

Mount Alexander Shire Council

26 June 2024



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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.



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

The symbolism in the artwork includes:

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



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GLOSSARY

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



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



1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Mount Alexander Shire Council (MASC) to undertake the Newstead Flood Study and Mitigation Strategy. The project is funded by the Disaster Ready Fund and the Victorian Government. The investigation covers the study area presented in Figure 1-1.

Newstead is a small township in Victoria, located 15 km west of Castlemaine on the banks of the Loddon River. Located within MASC and the North Central Catchment Management Authority (NCCMA) management area. Newstead was established in the mid-19th century as a river crossing point and today hosts a population of approximately 800 people.

No previous flood study has been undertaken for the township of Newstead. There is also no previous hydrologic model covering the upper reaches of the Loddon River. This study will produce reliable flood intelligence for use in emergency management, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Newstead, investigate structural and non-structural mitigation options and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes for the Newstead Flood Study. Each reporting stage is shown below:

R01 – Data Review and Validation Report – This Report

R02 – Hydrology Report

R03 - Draft Hydraulic Modelling Report

R04 – Final Hydraulic Modelling Report

R05 - Design Modelling and Mapping Outputs

R06 – Municipal Flood Emergency Plan (MFEP) Documentation

R07 – Flood Damage and Structural Mitigation Options

R08 – Final Project Report

The data available for this study has been collated and reviewed. This report documents a summary of the available streamflow, rainfall, topographic and structure data (pipes/pits/culverts) as well as the relevant previous projects and other information relevant to the study. Data gaps have been identified, and strategies for obtaining missing data have been outlined. The report details the hydrological and hydraulic modelling approach to be used in the study.

Survey data for specific topographic features, drainage infrastructure, waterway cross sections and ground levels for the purpose of LiDAR verification will be collected after the completion of a draft version of this report, but will be included in the final version.

1.2 Objectives and Outputs

The Newstead Flood Study outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by MASC. The objectives of the investigation are described below:

- Undertake hydrologic and hydraulic modelling to determine flood levels and flood extents for the full range of flood events up to and including the probable maximum flood.
- Calibrate models to historic flood events including the October 2022 flood event.



- Investigate modelling of climate change scenarios.
- Assess the feasibility of a range of potential mitigation options including understanding of the level of protection provided by the existing levee and information to inform necessary upgrades to this levee.
- Analyse the feasibility of establishing effective flood warning, accounting for time available between rainfall and the township flooding, in the context of a total flood warning system.
- Update flood intelligence to be incorporated into the Municipal Flood Emergency Plan.
- Provide recommendations to update the Planning Scheme and ensure it is informed by the best available flood information.

1.3 Study Area

The main flood risk in Newstead is posed by the Loddon River, a levee was constructed in the 1920's that is still protecting the eastern portion of the township from Loddon River flooding. However, a number of smaller catchments generate runoff towards Newstead directly or indirectly, resulting in complex hydrologic and hydraulic conditions to address in planning and emergency response. These catchments include Mia Mia Creek, Muckleford Creek, Larni Barramal Yaluk, Green Gully and Green Gully Creek as shown in Figure 1-1. Additionally, there are several tributaries joining the Loddon River near Newstead further impacting river levels.

Newstead most recently experienced flooding in October 2022, causing flooding to the township located on the western side of the Loddon River. Flooding in Newstead has historically caused levee breaches only contained by sandbags and led to the town being isolated when major traffic routes have been cut off. The Loddon River at Newstead has been subject to considerable physical and ecological modifications due to extensive historic mining activities and other anthropogenic influences since European settlement. In recent years, bank erosion has been an issue for landholders adjacent to the Loddon River.

The Newstead Flood study areas include the following key structures which require consideration as part of the study:

- Main waterway bridges at the following roads:
 - Pyrenees Highway at Loddon River
 - Pyrenees Highway at Green Gully Creek
 - Maldon-Newstead Road at Mia Mia Creek
 - Newstead-Guildford Road at Larni Barramal Yaluk
 - Cemetery Road at Muckleford Creek
- Major and minor culverts throughout the study area
- Stormwater pit and pipe drainage network within Newstead
- Several off-stream dams and ponds
- Levees including the Newstead levee

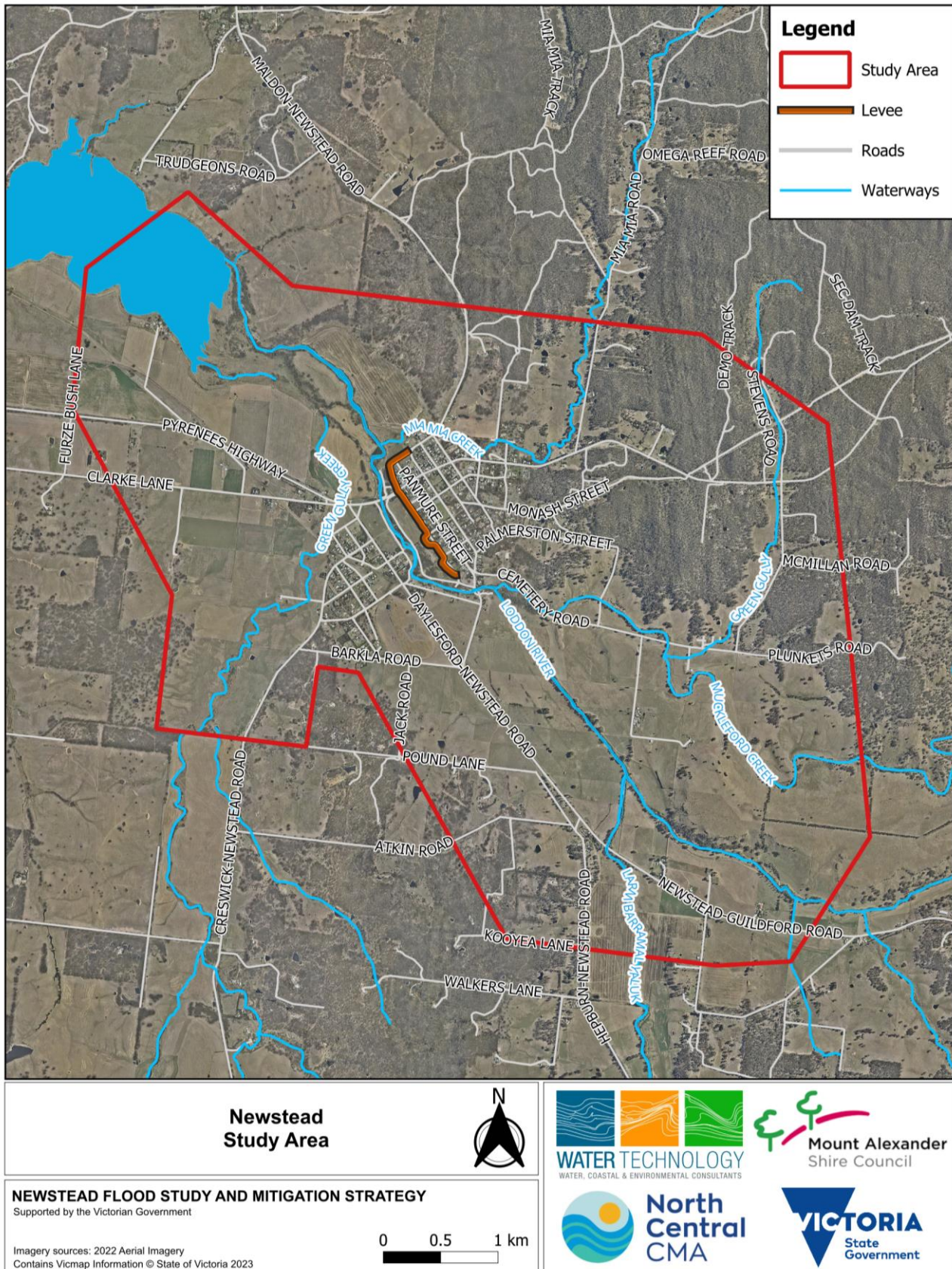


Figure 1-1 Newstead Study Area



2 DATA SUMMARY

2.1 Previous Studies

As previously mentioned, no flood study of Newstead nor any previous hydrologic model covering the upper reaches of the Loddon River have been undertaken. During the data collation and review process the following studies were identified as relevant:

- Newstead Erosion Control – Loddon River Investigation and Design
- Newstead Levee Investigation Report
- Risk Assessment – Newstead Levee
- Newstead Levee Alignment – Modelling Assessment
- Mia Mia Creek Flood Impact Assessment
- North Central CMA Erosion Assessment and Works Prioritisation Project

A synopsis of each study is given below.

Newstead Erosion Control – Loddon River Investigation and Design (Water Technology, 2011)

During the flooding in late 2010 and early 2011, an existing pile field site located on the Loddon River downstream of the Pyrenees Highway was significantly damaged. Water Technology was tasked with undertaking a stream survey at and upstream of the site, a review of the original pile field and develop a detailed design for erosion mitigation. A selection of review findings included that the flood events had contributed to significant bank erosion and subsequent loss of private land, and that the Loddon River channel is over-enlarged, resultantly containing relatively high flow events in-channel but with high erosive energy on bed and banks as a consequence, with continued bank erosion likely. The detailed design options included various techniques for erosion prevention at the site.

Newstead Levee Investigation Report (GHD, 2015)

GHD undertook an investigation of the Newstead Levee in 2014 (report published 2015) with the purpose to document the condition and subsurface profile of the levee and determine the level of flood protection the levee currently provides to the Newstead township. The report provides a thorough description of the levee and its current condition, as well as recommendations for further investigations and remedial works.

Risk Assessment – Newstead Levee and Newstead Levee – Preliminary Design Report (Price Merrett, 2017)

In 2017, Price Merrett conducted a risk assessment based on the information provided in the GHD report. The risk assessment details the risk of failure for different sections of the levee together with recommendations for upgrades and maintenance. The main observation was the Extreme risk of failure identified for the south section of the levee, leading to Price Merrett undertaking re-design and producing a Preliminary Design Report.

Newstead Levee Alignment – Modelling Assessment (Water Technology, 2017)

Water Technology completed the modelling of a proposed levee realignment in the southern part of Newstead. During this project, it was noted that no prior hydraulic modelling existed for Newstead. The project resulted in an impact assessment of the proposed realignment and a better understanding of flooding from the Loddon River in Newstead.



Mia Mia Creek Flood Impact Assessment (Water Technology, 2023)

Water Technology completed a flood risk assessment and flood mapping for a proposed subdivision at 11 Codrington Street, Newstead, Victoria. A hydrologic model was developed for the Mia Mia Creek catchment and a 2D hydraulic flood model was developed for the site, analysing the 1% AEP design storm event.

North Central CMA Erosion Assessment and Works Prioritisation Project (Water Technology, 2024)

Water Technology worked with the NCCMA undertaking erosion assessment and works prioritisation associated with a range of sites reported during and after the October 2022 flood event. Two sites within the Newstead Flood Study area were inspected, the constructed reach of Larni Barramal Yaluk between Newstead-Guildford Road and the Loddon River confluence, and the 1.5 km reach of the Loddon River upstream of the same confluence. For each site, Water Technology provided a description of the site context, recommendations for erosion mitigation works and a risk assessment identifying meander migration, levee bank failure, impact on adjacent farmland and riparian vegetation and water quality issues as potential consequences of continued erosion.

2.2 Flood Records

Newstead has a long history of flooding since the town's establishment in the 1850s. The Newstead Local Flood Guide (developed by the SES) lists records of historic flood levels and impacts, summarised in Table 2-1.

In addition to the above information, investigations of historic news articles identified significant flood events in Newstead in 1870, 1916, and 1934 (see Figure 2-1 to Figure 2-3).

Photographs during and after the 2010, 2011, and 2022 events collected by NCCMA are presented in Figure 2-4 to Figure 2-6. NCCMA have also provided surveyed water levels from the events in 2000, 2010 and 2022, a total of 63 flood marks (as shown in Figure 2-7).

The initial community consultation was undertaken on the 19th of June, 2024. This session generated anecdotal evidence and recollections about past flood events, as well as measurable flood levels. The latter will be captured during the topography survey process. Continuously collected data will be part of the model calibration and included in the modelling reports.

Table 2-1 Flood Records available in Newstead Local Flood Guide by SES

Year	Description
1890	■ 36 mm of rain recorded over 36 hours ■ 900 mm flood depth at the Post Office
1909	■ 1.2 metres of depth on the Main Street
October 1934	■ Flood levels reached within 300 mm of the top of the levee bank. ■ The road between Castlemaine and Newstead was flooded. ■ Significant damage to the bridge in town as documented in a news article, shown in Figure 2-1.
October 24, 2000	■ 103.7 mm of rainfall recorded across 48 hours. ■ Surging water covered the river flats and cut off any access from the western end of the bridge to the town.



Year	Description
January 2011	■ The January 2011 flood event occurred only a few months after the September and November 2010 events. ■ A total of 147.6 mm was received over the three days between the 12th and 14th January. ■ Loddon River peaked at 5.89 metres at Newstead. ■ Southern section of the levee was sandbagged which prevented the levee from being overtopped during the flood event.
October 2016	■ Loddon River peaked at 4.78 metres at Newstead.
October 2022	■ Loddon River peaked at 6.12 metres at Newstead. ■ Some section of the levee was sandbagged which prevented the levee from being overtopped during the flood event.

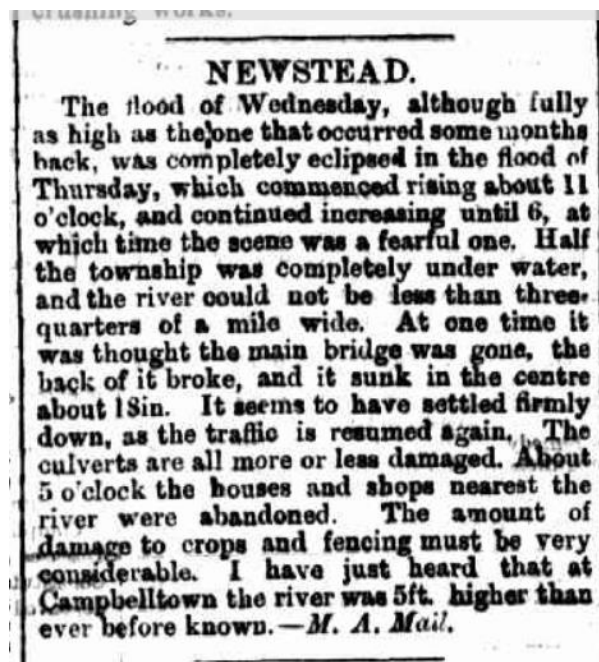


Figure 2-1 News article in The Herald, Saturday evening about flooding at Newstead - September 10, 1870

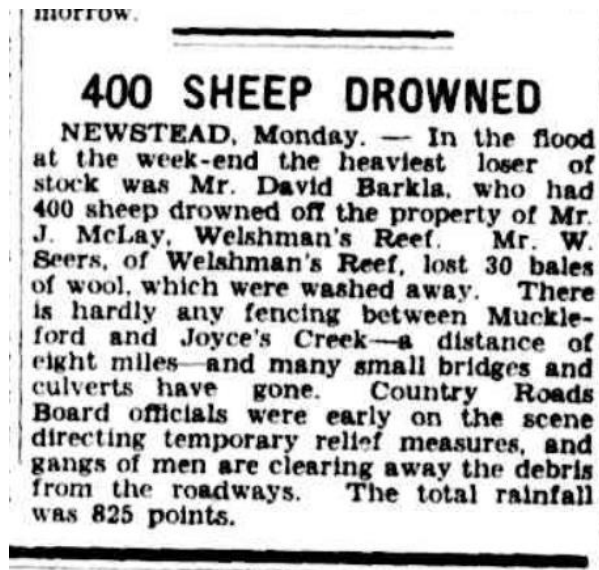


Figure 2-2 News article in The Argus about the flooding in Newstead - Tuesday October 23, 1934

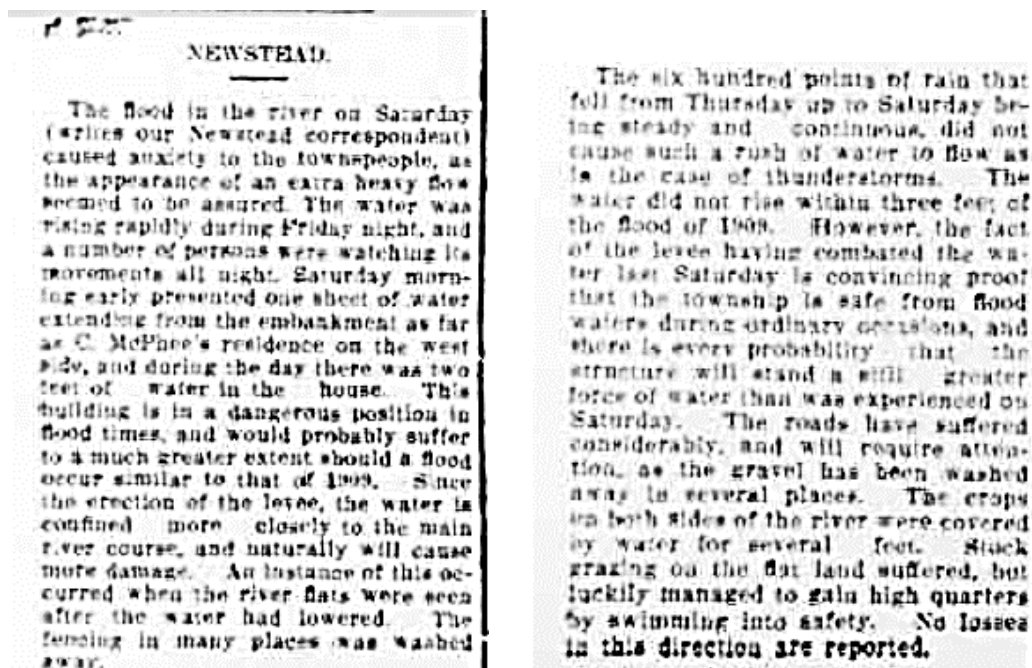


Figure 2-3 News article in Mount Alexander Mail about flooding at Newstead - September 26, 1916



Figure 2-4 Photos of the October 2010 flood event provided by NCCMA



Figure 2-5 Photos of the January 2011 flood event provided by NCCMA with flooded river flats and residents sandbagging the southern end of levee



Figure 2-6 October 2022 flood event provided by NCCMA

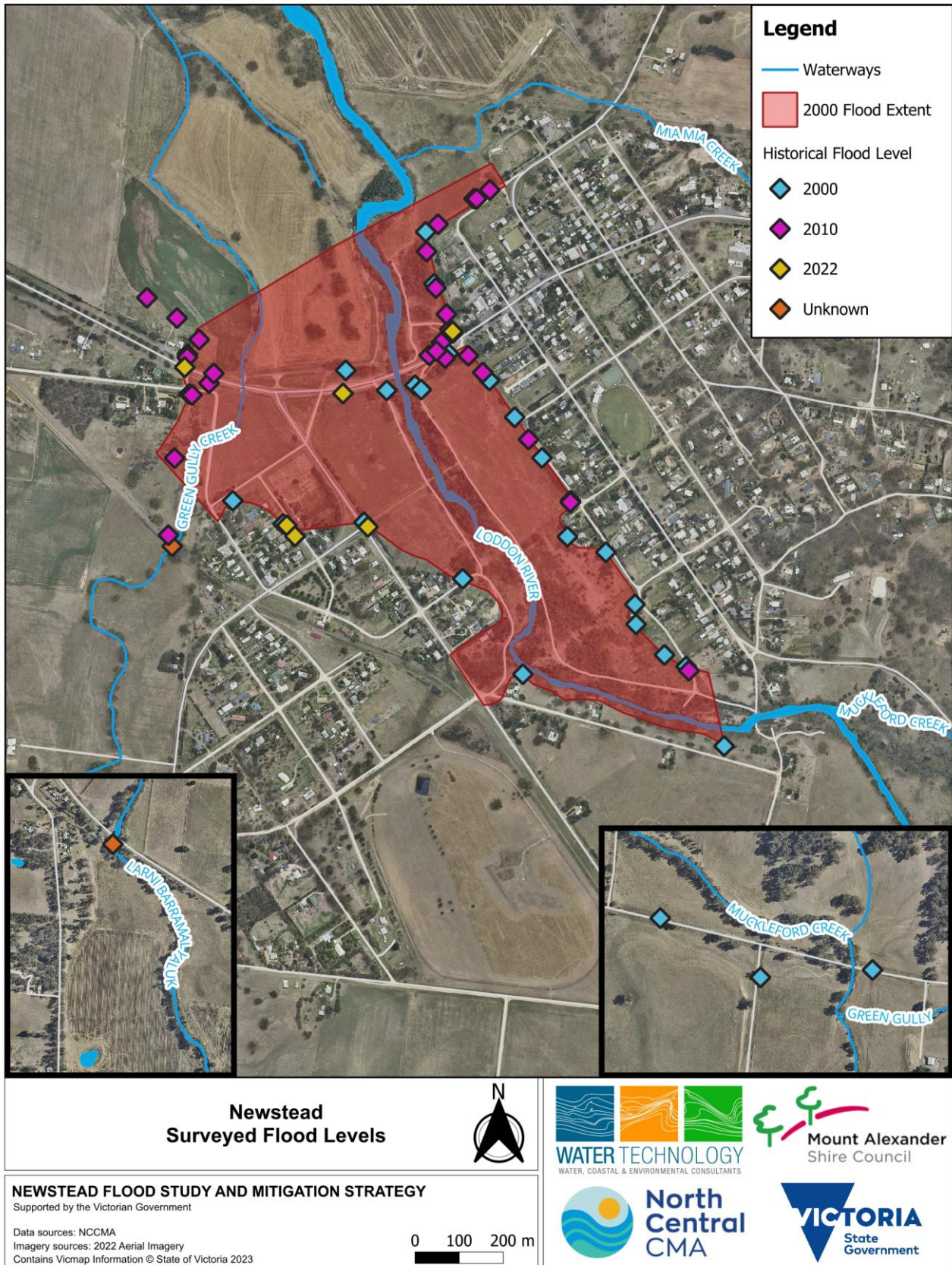


Figure 2-7 Surveyed Historic Flood Level



2.3 Streamflow Data

Four (4) active streamflow gauges are available within the study area with water level and streamflow data available to the present date. The four streamflow gauges information is displayed in Table 2-2 and the available streamflow data for Loddon River at Newstead is displayed in Figure 2-8. The following flood events were identified in the available data at Loddon at Newstead (Station ID: 407215). Peak flood level in local gauge height and flows based on the rating curve are also shown:

- October 24, 2000 (5.64 m, ~49,335 ML/day)
- September 4, 2010 (4.91 m, ~27,492 ML/day)
- November 27, 2010 (5.63 m, ~49,759 ML/day)
- January 14, 2011 (5.89 m, ~62,251 ML/day)
- September 14, 2016 (5.70 m, ~52,836 ML/day)
- October 13, 2022 (6.12 m, ~74,986 ML/day)

Table 2-2 Streamflow gauges information

<i>Station Name</i>	<i>Station No.</i>	<i>Start</i>	<i>End</i>
<i>Loddon River @ Newstead</i>	<i>407215</i>	<i>1973</i>	<i>Current</i>
<i>Larni Barramal Yaluk @ Yandoit</i>	<i>407221</i>	<i>1973</i>	
<i>Loddon River @ Vaughan D/S Fryers Creek</i>	<i>407217</i>	<i>1967</i>	
<i>Muckleford Creek @ Muckleford North</i>	<i>407300</i>	<i>1993</i>	

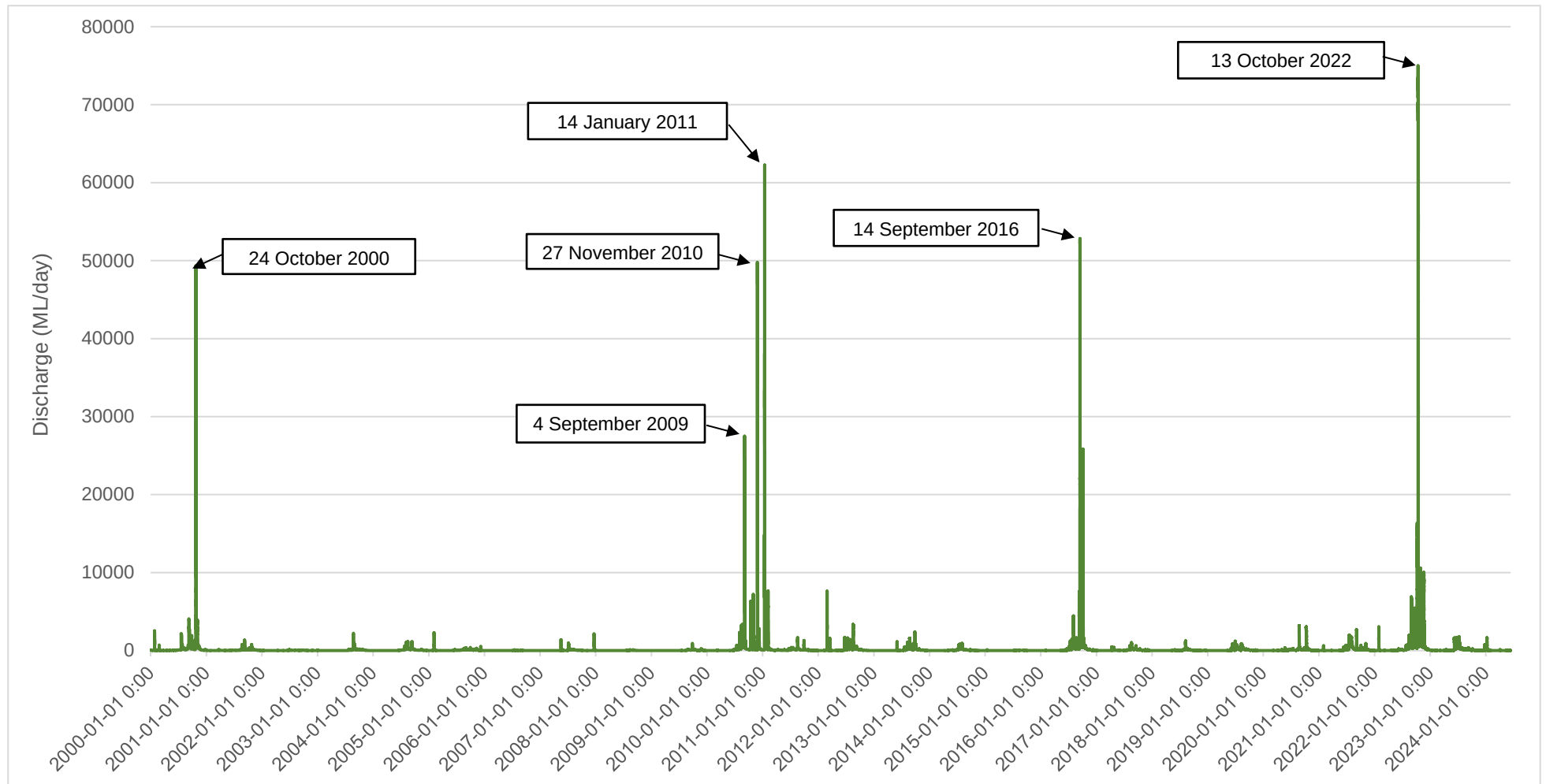


Figure 2-8 Flow rates at Loddon River @ Newstead 407215 (2000-2024)



2.4 Rainfall Data

2.4.1 Overview

Historic daily and sub-daily rainfall data is required for the hydrologic and hydraulic model calibration. Daily rainfall gauges are used to provide a representation of spatial rainfall variation while sub-daily gauges provide a representation of temporal rainfall distribution.

2.4.2 Daily Rainfall

Table 2-3 summarises the daily rainfall information available within a 50 km radius of Newstead. The closest active rainfall gauge is the Newstead township, located 0.6 km southwest of the Newstead Police Station. The locations of the rainfall gauges are shown in Figure 2-9.

Table 2-3 Daily Rainfall Station Information

<i>Station Name</i>	<i>Dist. From Newstead</i>	<i>Station No.</i>	<i>Start</i>	<i>End</i>
<i>Newstead</i>	<i>0.6 km NE</i>	<i>088048</i>	<i>1897</i>	<i>Current</i>
<i>Joyce Creek</i>	<i>6.1 km NW</i>	<i>088032</i>	<i>1907</i>	
<i>Eberys</i>	<i>10.7 km SW</i>	<i>088021</i>	<i>1913</i>	
<i>Yandoit</i>	<i>11.6 km SE</i>	<i>088066</i>	<i>1901</i>	<i>2014</i>
<i>Maldon (Derby Hill)</i>	<i>11.6 km N</i>	<i>088041</i>	<i>1878</i>	<i>2007</i>
<i>Vaughan</i>	<i>14.0 km SE</i>	<i>088108</i>	<i>1958</i>	<i>Current</i>
<i>Campbelltown</i>	<i>15.1 km SW</i>	<i>088011</i>	<i>1889</i>	<i>2011</i>
<i>Cairn Curran Reservoir</i>	<i>15.4 km NW</i>	<i>088009</i>	<i>1949</i>	<i>Current</i>
<i>Castlemaine Prison</i>	<i>16.1 km E</i>	<i>088110</i>	<i>1966</i>	
<i>Shepards Flat</i>	<i>18.6 km S</i>	<i>088054</i>	<i>1928</i>	<i>2023</i>
<i>Baringhup (Blue Hills)</i>	<i>19.4 km NW</i>	<i>088132</i>	<i>1972</i>	<i>2013</i>
<i>Harcourt</i>	<i>21.0 km NE</i>	<i>088188</i>	<i>1968</i>	<i>2016</i>
<i>Smeaton (Blampied (Bardia))</i>	<i>26.1 km SW</i>	<i>088113</i>	<i>1968</i>	<i>Current</i>
<i>Daylesford</i>	<i>27.2 km SE</i>	<i>088020</i>	<i>1867</i>	
<i>Trentham (Post Office)</i>	<i>28.8 km SE</i>	<i>088059</i>	<i>1878</i>	<i>2017</i>
<i>Malmsbury Reservoir</i>	<i>29.3 km SE</i>	<i>088042</i>	<i>1872</i>	<i>Current</i>
<i>Sedgwick</i>	<i>31.2 km NE</i>	<i>081086</i>	<i>1954</i>	<i>2010</i>
<i>Sandhurst Reservoir</i>	<i>32.9 km NE</i>	<i>081121</i>	<i>1986</i>	<i>2012</i>
<i>Lauriston Reservoir</i>	<i>34.3 km NE</i>	<i>088037</i>	<i>1948</i>	<i>2017</i>
<i>Lerderderg (Newbury)</i>	<i>39.6 km SE</i>	<i>088135</i>	<i>1972</i>	<i>2008</i>
<i>Redesdale</i>	<i>40.3 km NE</i>	<i>088051</i>	<i>1903</i>	<i>2017</i>
<i>Moorabool Reservoir</i>	<i>45.0 km S</i>	<i>087045</i>	<i>1912</i>	<i>2017</i>
<i>Blackwood</i>	<i>46.2 km SE</i>	<i>087017</i>	<i>1878</i>	<i>2015</i>



2.4.3 Pluviograph Rainfall

Three (3) of the available daily gauges also record sub daily rainfall, typically every 6 minutes. These are Bendigo Airport, Redesdale, and Ballarat Aerodrome. These gauges are shown in Figure 2-9.

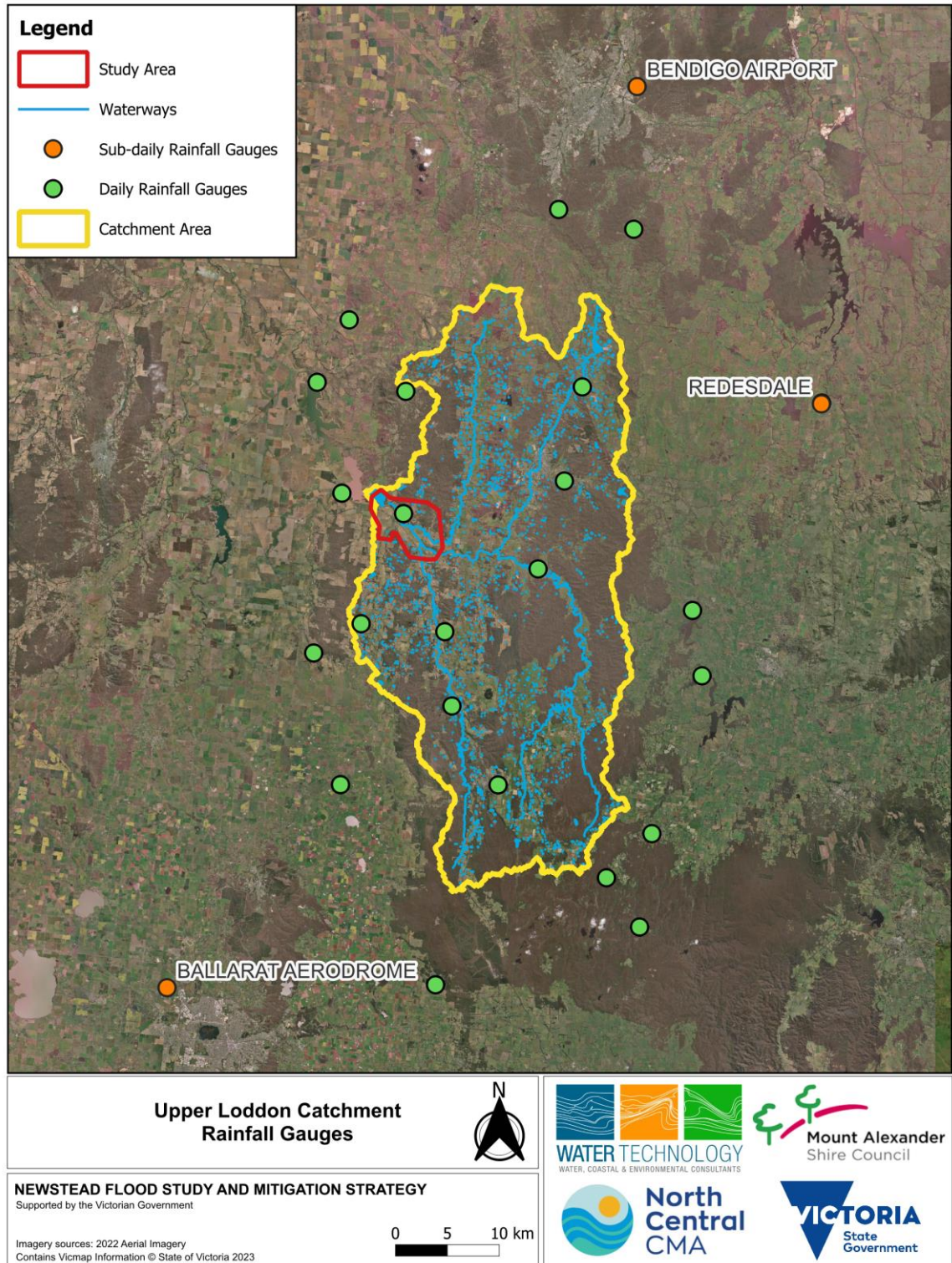


Figure 2-9 Upper Loddon River Rainfall Gauges



2.5 Storages

There are several storages within the study area, including:

- Cairn Curran Reservoir, located downstream of the Newstead Township
- Several water storage dams in open space (e.g., Newstead Racecourse)
- A large number of farm dams upstream of the town.

The dams will not be included within the hydrologic modelling, however will form an important component of the hydraulic modelling. The downstream boundary of the hydraulic model is located within Cairn Curran Reservoir. Other dams located within the study area will likely be modelled as full at the start of the flood event.

2.6 Levees

The Newstead levee was built in the 1920s after the 1909 flood where “twenty-one owners and occupiers” within Newstead were affected by the flood. The levee is located on the east side of the Loddon River stretching from the southern end of Layard Street to the northern end of Panmure Street, with a length of about 1.5 km. The levee has a sluice gate at the north-western end of Panmure Street which allows excess rainwater and stormwater to be drained into the Loddon River when it is open and protects properties on the east side of the levee from Loddon River flooding when it is closed.

Additional levees have been identified through the latest LiDAR along the Loddon River and Larni Barramal Yaluk, located in the upper portions of the study area.

Whilst the Newstead Levee has been surveyed and assessed previously, an updated topographic survey will be undertaken as part of this project to improve the levee representation in the hydraulic model. The levee has been supplemented by sandbagging in a number of flood events. Photos and intelligence from community members will be used to incorporate this information into the hydraulic model calibration including the October 2022 Flood event.

See Figure 2-10 for the Newstead levee alignment and other levee alignments identified within the study area.

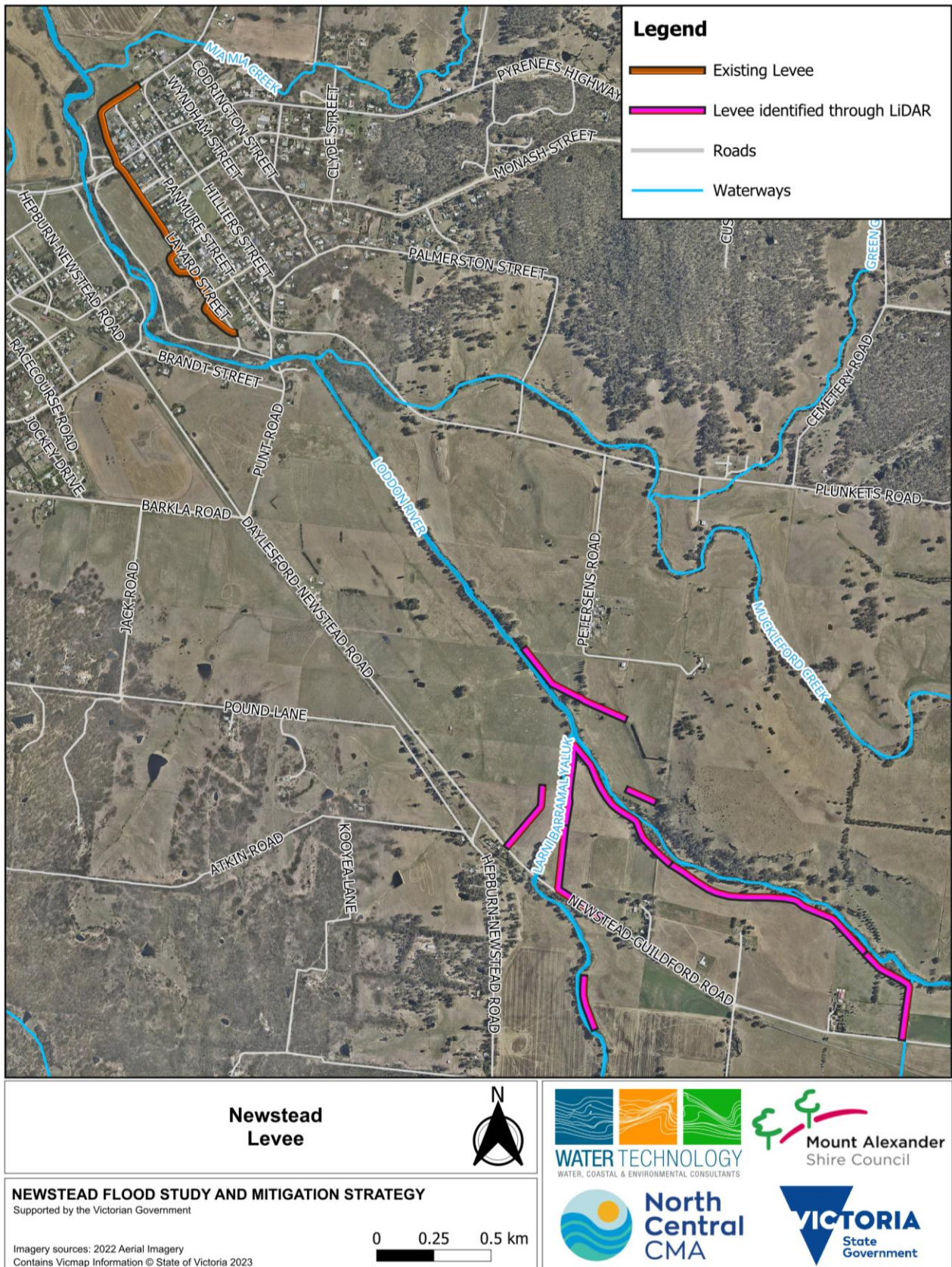


Figure 2-10 Newstead levee alignment



2.7 Road and Drainage Infrastructure

Within the study area, there are significant road structures on Loddon River, Mia Mia Creek, Larni Barramal Yaluk, Muckleford Creek, Green Gully Creek and Green Gully. Major structures are listed in Table 2-4 and highlighted in Figure 2-11.

The listed structures have been identified from aerial imagery, topography data, Department of Transport (DTP) data and council asset data. Detailed information for these structures has been identified as a major data gap, including dimensions and invert levels. This data will be sought from DTP and council, and where not available, captured during topography survey and site visits.

Table 2-4 Waterway structures

Crossing	Owner	Data available	Data missing
Loddon River			
Pyrenees Highway	DTP	As built drawings	
Mia Mia Creek			
Maldon-Newstead Road	DTP	As built drawings	
Cameron Road (2 locations)	MASC		Culvert dimensions, inverts
Larni Barramal Yaluk			
Newstead-Guildford Road	MASC		Inverts, deck level and thickness, piers
Green Gully Creek			
Pyrenees Highway	DTP	As built drawings	
Railway	Unknown		Inverts, deck level and thickness, piers
Creek Lane	MASC		Culvert dimensions, inverts
Muckleford Creek			
Cemetery Road (2 locations)	MASC		Inverts, deck level and thickness, piers
Green Gully			
Pyrenees Highway	DTP		Culvert dimensions, inverts
Cemetery Road	MASC		Culvert dimensions, inverts

Further to the structures listed in Table 2-4, there are several major and minor culverts under roads that may require surveying for inclusion in the hydraulic model. A number of culvert locations have been identified within the Newstead township, connecting the open drains that form the majority of the townships stormwater drainage network.

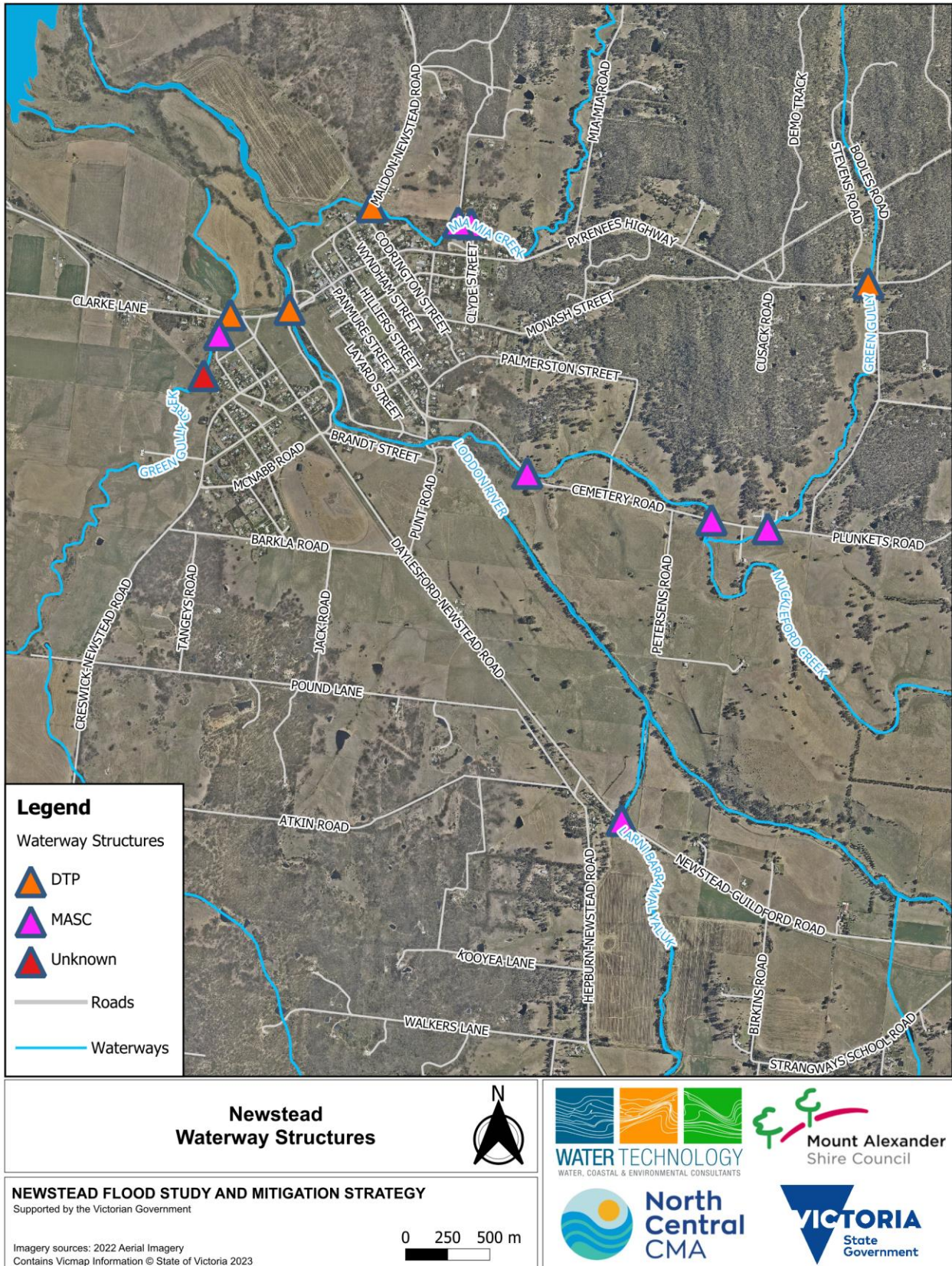


Figure 2-11 Waterways Structures



2.8 Topography and Survey Data

2.8.1 LiDAR Data

2.8.1.1 Overview

Three (3) LiDAR datasets are available for the study area including:

- 2022 Department of Transport (DoT), Digital Twin Project
 - This 1 m LiDAR was captured as part of the largest LiDAR survey project undertaken in Victoria's history and captured over 60,000 km² of high-quality LiDAR data. This data has a vertical accuracy of ± 0.10 m.
- 2009-10 Victorian State Wide Rivers LiDAR Project
 - This 1 m LiDAR was flown for the statewide mapping project undertaken in 2009-12 to accurately map the riparian vegetation and physical form components (metrics) of the Index of Stream Condition (ISC). It has a vertical accuracy of ± 0.10 m and a horizontal accuracy of ± 0.19 m and covers limited areas along the Loddon River and tributaries including Muckleford Creek and Larni Barramal Yaluk.
- VicMap 10m Digital Terrain Model (DELWP)
 - An elevation Digital Terrain Model (DTM) with a 10-metre resolution providing a raster representation of the area. The vertical and horizontal accuracy is coarse at ± 5 m and ± 12.5 m, respectively. The DTM extends across the entire catchment.

Figure 2-12 shows the LiDAR coverage across the study area. The only high-resolution datasets covering the entire hydraulic study area is the 2022 Department of Transport Digital Twin Project, which will be used to form the basis of the hydraulic model terrain and is presented in Figure 2-13.

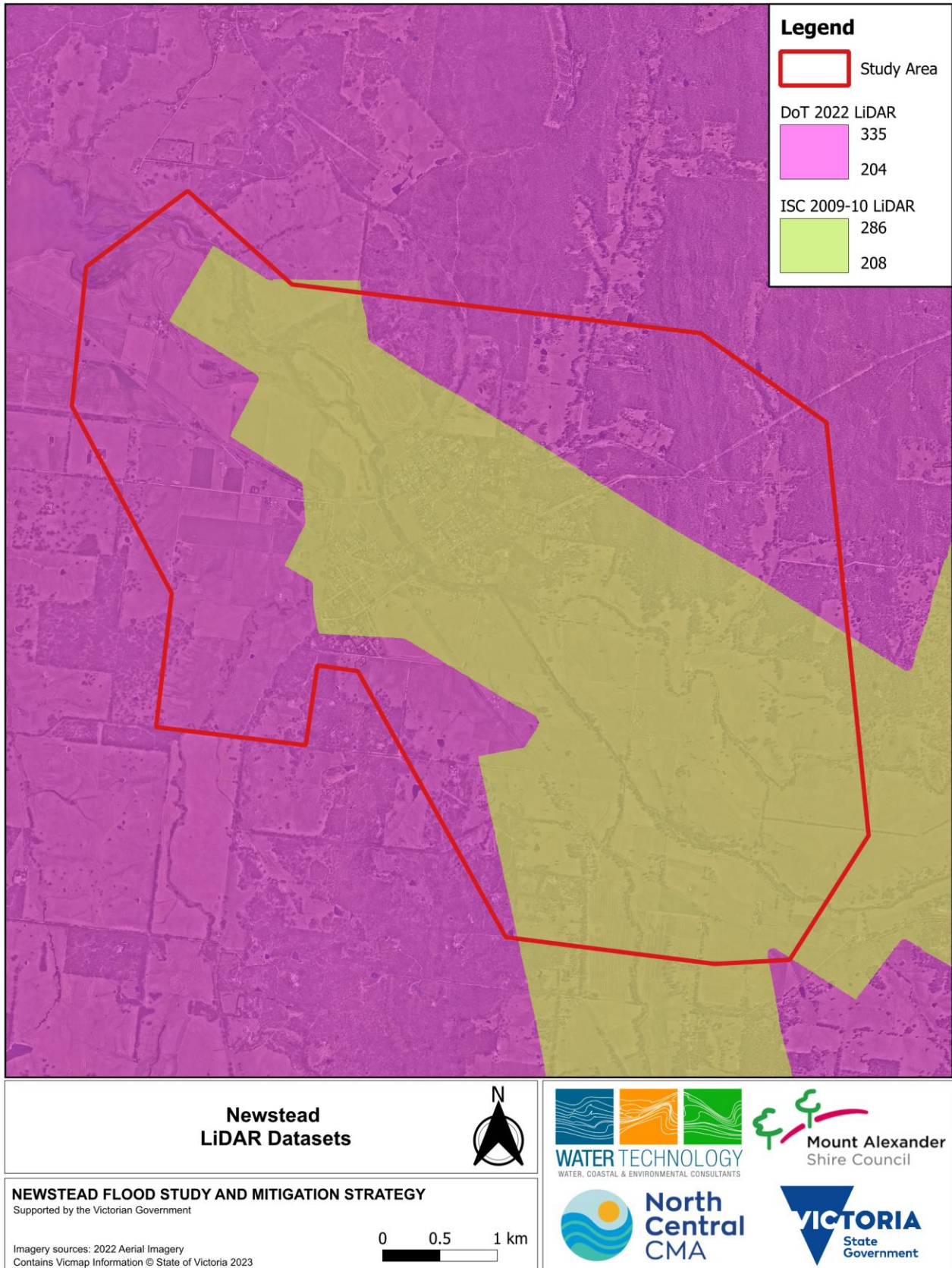


Figure 2-12 LiDAR datasets coverage

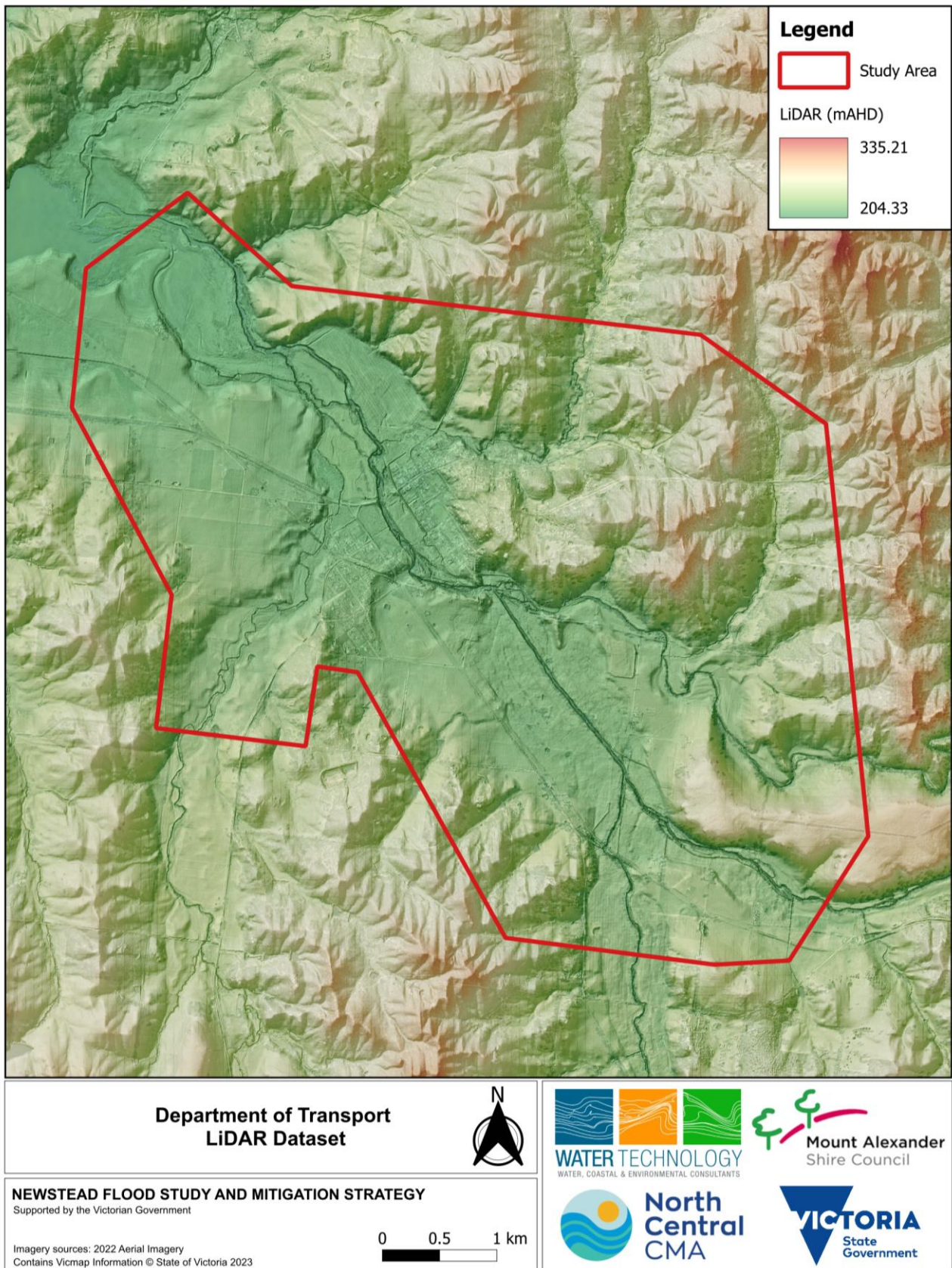


Figure 2-13 Department of Transport LiDAR Dataset



2.8.1.2 LiDAR verification

Topographic data is the major dataset used in this project forming the basis of the hydraulic model terrain. Verification of the dataset is important to ensure the model can accurately replicate observed flooding behaviour within the study area.

The DoT Digital Twin Project 1m LiDAR flown in 2022 covers the entire study area. Verification of this LiDAR dataset will be completed based on a comparison to road transect survey to be collected by Price Merrett as part of the topography and asset survey.

2.8.2 River Cross-sections

Surveyed cross-sections for the Loddon River were available for a small area upstream and downstream of the Loddon River at Newstead streamflow gauge. These were provided by ALS and were captured in 2012. The data will be used to enhance bathymetry of the Loddon River.

2.8.3 Survey Data

Survey will be undertaken by Price Merrett following the initial community consultation session in June 2024. Data captured during survey and the site visit will be presented here in the final version of the report. The following survey data is currently planned for capture (by Price Merrett or Water Technology), the scope will be confirmed post the site visit and community meeting.

- Asset and structure data
 - Newstead levee
 - Township drainage
 - Major and minor road drainage culverts
 - Bridges
- LiDAR verification road transects
- Floor levels
- Observed flood heights (identified during community consultation)

Floor level survey was conducted by NCCMA in 2017 for the properties shown in Figure 2-14. Additional floor level survey will be undertaken by Price Merrett to provide a broader coverage of floor levels within the town.

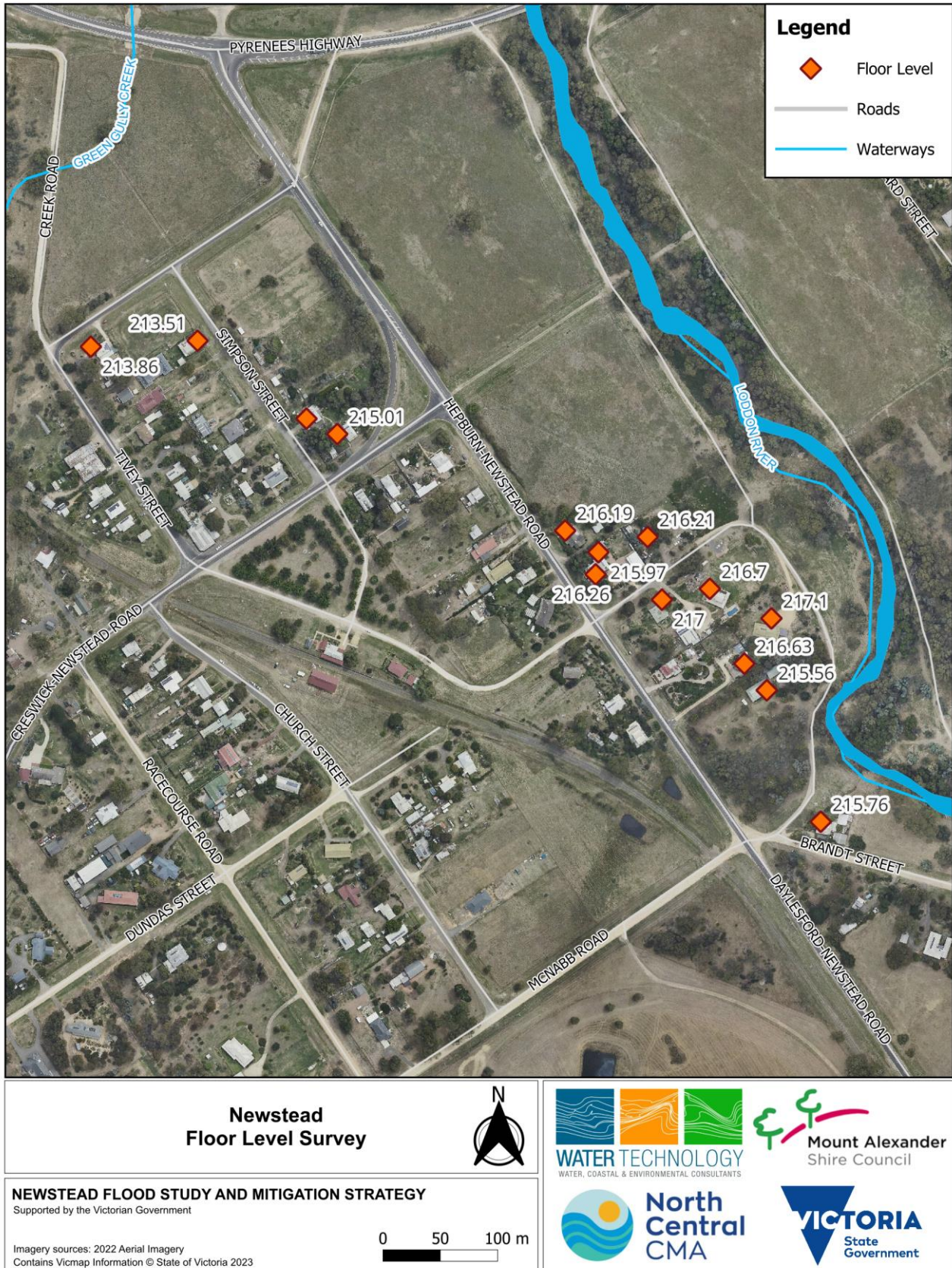


Figure 2-14 Floor level survey conducted by NCCMA in 2017

3 RATING CURVE REVIEW

3.1 Overview

Data from the Loddon River at Newstead streamflow gauge (407215) will be the main source used to calibrate the hydrology model developed as part of this project. A streamflow gauge measures water level and uses an empirical relationship between water level and discharge, developed by hydrographers, to translate the gauged water level into a flow. This empirical relationship is called a rating curve. The rating curve is constructed by fitting a curve through a series of measured water level and discharge points, which are measured over time and across a range of flow magnitudes.

Rating curves are only as good as the accuracy of the water level and discharge measurements taken to construct the curves. In the case of many streamflow gauges, the accuracy of the higher section of the rating curve (i.e. higher water levels and flows) is low, because large floods do not happen frequently and when they do, often hydrographers cannot access the site. In addition, when floodplains are engaged, it can be difficult to accurately measure discharge across the full floodplain where flow is complex.

3.2 Loddon River at Newstead Streamflow Gauge

The Loddon River at Newstead streamflow gauge (407215) has a streamflow record from 1973 onwards. The site hydraulic control is an artificial concrete weir. Figure 3-1 and Figure 3-2 show the control weir and the gauge site.

The published rating table available at the commencement of the flood investigation (rating 19.03, from 24/03/2021) is shown in Figure 3-1. The gauge zero in m AHD is known, at 207.937 m AHD. The rating table notes the rating for flows over 20,500 ML/day are based on measurements more than 20 years old, and that the rating curve is extrapolated beyond 26,400 ML/day. Given that all the significant events listed in Section 2.3 are larger than this, it is crucial to understand the accuracy of the rating curve for high flows.

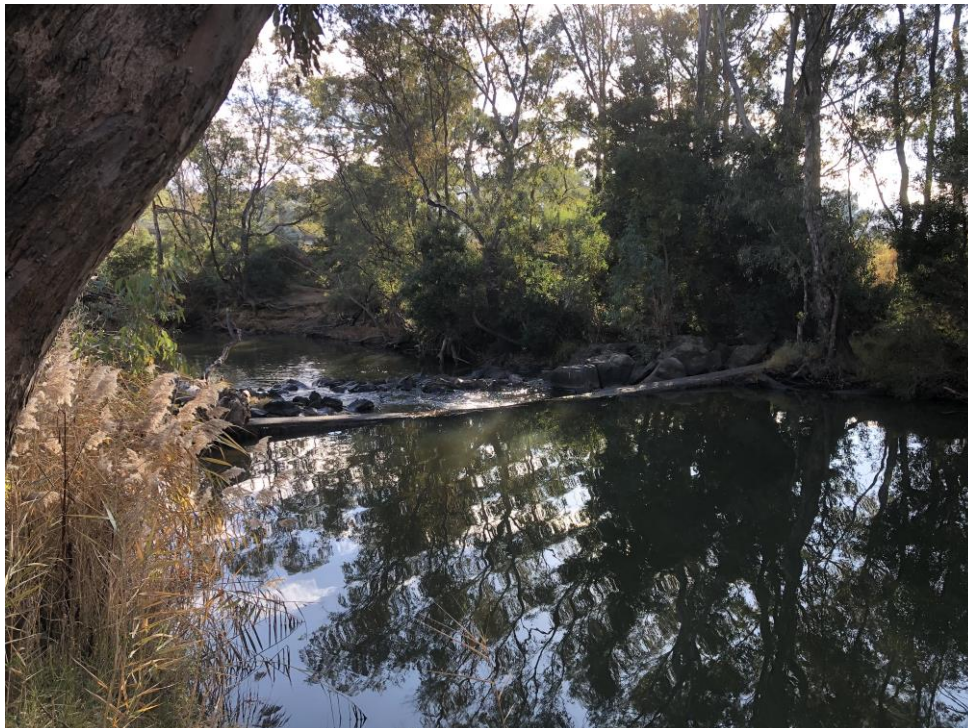


Figure 3-1 Loddon River at Newstead control weir



Figure 3-2 Loddon River at Newstead gauge site

3.3 Hydraulic modelling

A hydraulic assessment for the gauge was conducted using a TUFLOW model. TUFLOW is one of the most widely used hydraulic modelling software packages in Australia and an appropriate choice of modelling tool for developing local 2D models to extract rating curve information for each streamflow gauge site.

The model contained a single 2-dimensional domain (i.e. no 1-D structures or elements), with topography based on the latest 2022 DoT LiDAR dataset. Surveyed cross-sections for the Loddon River were available upstream and downstream of the gauge, and were used to improve the model bathymetry. Lowering of the riverbed was also applied upstream and downstream based on the difference between the cross-section survey and the LiDAR data. Surface lowering was required as the LiDAR derived dataset does not penetrate the water surface. The Pyrenees Highway bridge over Loddon River located just downstream of the gauge was included as a 2-dimensional flow constriction based on as-built drawings provided by the Department of Transport and Planning (DTP).

Model roughness was based on land use as determined by planning layers and aerial imagery, the main types within the floodplain being: river channel, moderate vegetation (trees), pasture, and roads. The model had a single inflow boundary and single outflow boundary, with the boundaries set a significant distance from the gauge site to remove the potential for boundary influences on levels at the gauge. Inflows to the model followed a steady state hydrograph for each inflow magnitude, increasing in increments of 50 m³/s from 50 to 1000 m³/s, holding each flow for 20 hours to allow the model to approach steady state. The model was not intended to refine the rating curve at low flows, for which there are a large number of historic gauges, thus the starting flow of 50 m³/s was deemed appropriate.

The model setup is shown in Figure 3-3 below with roughness values in Table 3-1.

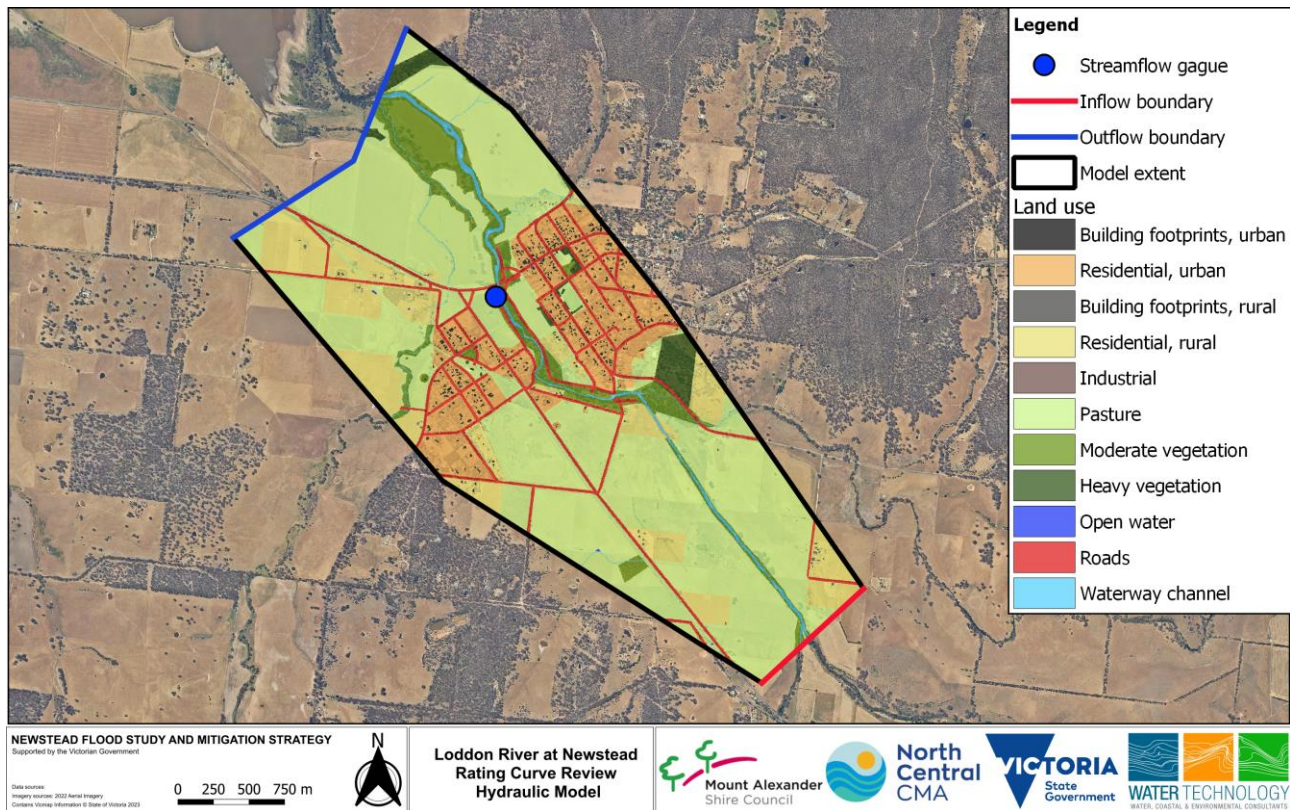


Figure 3-3 Loddon River at Newstead hydraulic model

Table 3-1 Manning's 'n' roughness values used in TUFLOW

Land use type	Manning's 'n' roughness coefficient
Building footprints, urban	0.4
Residential parcel, urban	0.1
Building footprints, rural	0.4
Residential parcel, rural	0.05
Industrial/commercial or large buildings	0.3
Open space – minimal vegetation (pasture)	0.04
Open space – moderate vegetation	0.08
Open space – heavy vegetation	0.12
Open water	0.02
Roads	0.02
Waterway channel	0.04

The model was simulated with a discharge line across the waterway and floodplain at the gauge location as well as a water surface point to allow for the gauge height and flow rate to be analysed. The extracted gauge height and flow rates were plotted along with the existing rating curve table, see Figure 3-4. The results show the baseline conditions hydraulic model results start to differ from the existing rating curve at a gauge depth of around 210.8 m AHD. Above this level, the existing rating curve produces higher flow rates compared with the



hydraulic modelling results. The hydraulic model then approaches the rating curve again at around 213.5 m AHD, and beyond this height the existing rating curve produces lower flows compared to the hydraulic model results.

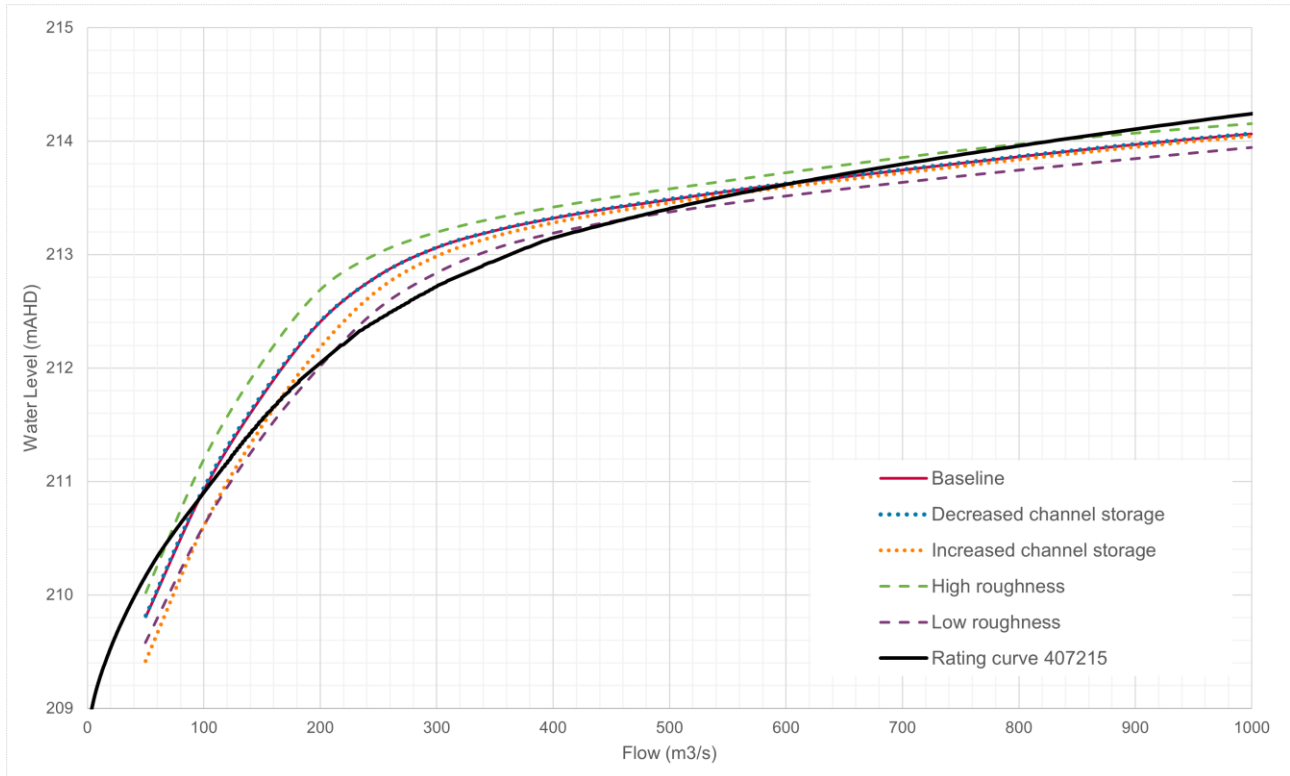


Figure 3-4 407215 modelled rating curves for different scenarios compared to rating table

The effect of the Manning's 'n' coefficient and channel storage was also investigated. The original roughness values shown in Table 3-1, were adjusted by -20% for a low roughness scenario and +20% for a high roughness scenario. For the reduced channel storage scenario, only the LiDAR was used to represent the river topography. For the increased channel storage scenario, the riverbed was lowered 1 m across a 10 m wide area along the river centreline. The results of the modelled rating curves are shown in Figure 3-4 showing that adjusting the model parameters leads to a better match to different sections of the rating curve, depending on parameter. Given that the rating curve shows a reasonably close match for high flows, it is not warranted to adjust the rating curve for this project. While gauged flows will be used for hydrology model calibration, the hydraulic model will be further calibrated to historic observations, surveyed levels, and gauge height, limiting the impact of slight rating curve deviations.



4 MODELLING METHODOLOGY

4.1 Modelling Approach

The Newstead Flood Study and Mitigation Strategy will utilise RORB hydrologic modelling and TUFLOW hydraulic modelling packages. A new RORB model will be developed for the Loddon River catchment, including tributaries, upstream of the Cairn Curran Reservoir. The RORB model will be calibrated to the streamflow gauges within the catchment, focusing on Loddon River at Newstead (407215) gauge. Flow hydrographs from the RORB model will be used as inputs into the hydraulic model at inflow locations. The hydraulic modelling will be completed in TUFLOW software utilising the Heavily Parallelised Computing (HPC).

The following sections contain further detail of the hydrologic and hydraulic model builds, calibration and design modelling methodology.

4.2 Hydrology Modelling

4.2.1 Flood Frequency Analysis

Flood frequency analysis (FFA) will be completed for the Loddon River at Newstead gauge, taking into consideration all available years of data. The FFA will form the basis for flow validation from the RORB model for design events. Design Peak flows from the RORB model will be reconciled with the FFA.

Undertaking FFA at additional gauges in the catchment will be considered as required once the calibration process is underway.

4.2.2 RORB Model

RORB is a hydrology (rainfall-runoff) model that is commonly used throughout Victoria in flood studies. RORB models consist of subareas, storages, reaches, and nodes. The RORB subarea and reach delineation will be completed using the Vicmap 10m DEM. The delineation will consider existing gauging stations such that nodes will be placed at or near to gauging stations to enable calibration and validation of the model.

The key parameters in a RORB model are k_c and m . The k_c parameter impacts the relative delay time of reach storages in the model and m is a representation of the catchment's non-linearity. In accordance with the recommendations of the RORB manual and current standard practice in RORB modelling, the m value is anticipated to be left at the default value of 0.8. The selection of the k_c value will be based on the results of the calibration with consideration of regional values.

Loss values will be calibrated for the historic events, with design losses considering the calibrated loss values, regional values as supplied by Australian Rainfall and Runoff 2019, calibrated values from nearby studies, and reconciliation of design flowrates from RORB with expected flows from the FFA.

The remaining input to the RORB model is rainfall. For historic events such as 2022, recorded daily rainfall totals will be used to determine the spatial distribution of rainfall while sub-daily recordings will be used to determine the temporal distribution. Design rainfalls will be adopted from the Bureau of Meteorology's Intensity-Frequency-Duration data with temporal patterns adopted from the ARR datahub. Given the size of the catchment, spatial variation of design rainfall will be considered.



4.3 Hydraulic Modelling

4.3.1 Hydraulic Model Development

The modelling will utilise the TUFLOW HPC hydraulic modelling package with Graphical Processing Unit (GPU) hardware to keep run times practical while allowing a suitable model resolution to be adopted. The model will utilise TUFLOW's Sub-Grid-Sampling (SGS) capability.

Major bridge structures are proposed to be represented in the 2-dimensional domain as either layered flow constrictions or the new 2d_bg structures introduced in the 2023 TUFLOW release. Culverts will be represented as 1-dimensional elements linked to the 2d domain. Open drains will be modelled in the 2-dimensional domain. With the uses of SGS, it is unlikely the key water way channels will need to be modelled as 1D elements.

Surface roughness values will be applied to the surface types identified by analysis of aerial imagery and VicMap planning layers and modified to match observed flood heights through the calibration process.

The downstream boundary will be located in the Cairn Curran Reservoir. A TUFLOW 2D HQ boundary will be utilised which will allow the water to leave the model without having a set boundary level. The water level within Cairn Curran is to be tested through sensitivity analysis of the design modelling to identify the application of a suitable downstream boundary within the design modelling.

4.3.2 Hydraulic Model Calibration

The hydrology and hydraulic models will be calibrated to a number of historic events, which are to be determined based on calibration information available and discussion with the Project Steering Committee. Furthermore, a validation event may also be selected. A validation event tests the selected design parameters against observations, differing from a calibration event in that the parameters are not adjusted to achieve a close match in the model results and observations.

The RORB model will be calibrated against the available stream gauges for the chosen events, utilising the recorded rainfall at daily and sub-daily rainfall stations. Once good agreement has been reached between the modelled and observed hydrographs, inflow hydrographs will be applied to the TUFLOW model. Modelled flood heights in TUFLOW will be compared to surveyed flood marks and model parameters such as hydraulic roughness adjusted to obtain a suitable match between the observed and modelled heights.

4.4 Design Event Modelling

Design flows produced by the RORB model (with Initial and Continuing Loss values adopted by FFA reconciliation) will be applied to the TUFLOW model for all design AEP events as well as the PMF. The PMF will be determined in line with the method outlined in ARR2019. Design flood extents, heights, depths, velocities and hazard classifications will be determined from the modelling. The impact of climate change will be modelled for a scenario to be determined.

5 COMMUNITY CONSULTATION PLAN

The following community consultation sessions are planned for the project:

- During the project data review – This meeting was held on the 19th of June 2024 to collect historic flood extent and level data from community members, using preliminary 1% AEP and October 2022 flood maps for discussion. The purpose of this meeting was to:
 - Inform the community of the study
 - Gather flood intelligence or other information the community may have, such as historic impacts, extents, flood heights etc.

Information was gathered from the community about:

- peak flood levels and extent in the 2022 event
- road closures during historic events
- timing and flow distribution between waterways during historic events
- topographic features within the waterway and weak points along the levee
- potential sources of flood issues
- stormwater drainage issues within the levee banks



Figure 5-1 Photo taken by council staff during the first community consultation on 19th of June 2024

- At the completion of the calibration modelling and initial design modelling – This meeting will be used to provide further validation of the calibration modelling and mapping to the community and allow community input into what is next for the progress of the project and what it means for them (i.e., planning scheme amendment). It will also be used to seek community feedback regarding mitigation options and flood control changes.
- At the completion of study – defining what is next, now the technical part of the work is done and what the results mean for the Newstead community, as well as answering questions the community may have about the process.

6 SITE VISIT

A site visit was undertaken in conjunction with the first community consultation in June 2024. Representatives of Water Technology, MASC and NCCMA inspected the Loddon River, key waterway structures, local drainage and landform, areas of known issues, and inspected the pit and pipe network. Since topographic survey will be undertaken for the levee and town drainage network, the site visit focused on the waterways entering the Newstead study area and key hydraulic structures. Each structure was visited and measured, with structure inverts in m AHD to be captured during the survey. A number of the inspected structures are presented below.



Figure 6-1 Culvert under Pyrenees Highway/Lyons Street directly east of levee



Figure 6-2 Pyrenees Highway bridge over Loddon River



Figure 6-3 Pyrenees Highway culvert at Green Gully Creek



Figure 6-4 Newstead-Guildford Road bridge over Larni Barramal Yaluk



Figure 6-5 Cemetery Road bridge over Muckleford Creek



Figure 6-6 Muckleford Creek floodway at Palmerston Street



Figure 6-7 Pyrenees Highway culvert at Green Gully



7 SUMMARY AND NEXT STEPS

Data relevant to the Newstead Flood Investigation and Mitigation Strategy has been compiled and reviewed with the key findings presented herein. The data compiled and reviewed broadly fits into the following categories:

- Previous investigations
- Historic flood information
- Streamflow Data
- Rainfall Data
- Hydraulic structures
- Topography

A site visit was undertaken in June 2024, to familiarise key personnel with the area and catchments. The initial community consultation session has been held to inform and gather information from the community. The modelling and calibration approach for the remaining stages of the project has been outlined for review and comment.

The project will now move forward to completing the survey, FFA and RORB model build, with the next major hold point in the project being the draft hydrology report, detailing the hydrology and hydraulic model builds and joint calibration process.



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