Rhelm

Wolumla Flood Study

Draft

Bega Valley Shire Council

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This document does not necessarily represent the opinions of the NSW Government or the NSW Department of Climate Change, Energy, the Environment and Water.

Report Structure

The reporting for the Wolumla Creek Flood Study has been presented in two key documents:

- **Flood Study** – establishes the flood behaviour and risk within the study area.
- **Map Compendium** – a set of A3 maps as referenced in the Flood Study.

Foreword

The primary objective of the New South Wales (NSW) Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) and the NSW State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding, flood risk management, flood emergency management and land-use planning matters.

The *Flood Risk Management Manual* (NSW Department of Planning and Environment, 2023) is provided to assist councils to meet their obligations through the preparation and implementation of floodplain risk management plans, through a staged process. **Figure i**, taken from this manual, documents the process for plan preparation, implementation and review.

The *Flood Risk Management Manual* (NSW Department of Planning and Environment, 2023) is consistent with Australian Emergency Management Handbook 7: *Managing the floodplain: best practice in flood risk management in Australia* (AEM Handbook 7) (AIDR, 2017).

Figure i The Floodplain Risk Management Process (NSW Department of Planning and Environment, 2023)

Bega Valley Shire Council is responsible for local land use planning in its local government area, including in the Wolumla Creek catchment. Council has committed to prepare a comprehensive floodplain risk management plan for the study area in accordance with the NSW Government's *Flood Risk Management Manual* (NSW Department of Planning and Environment, 2023). This document relates to the Flood Study phase of the process.

Executive Summary

The Wolumla Creek Flood Study has been undertaken with Bega Valley Shire Council (Council) to gain an understanding of flood risk in the study area. No prior flood study has been undertaken for the catchment, and as such flood intelligence has been limited to historical observations.

The 2021 census data reveals that approximately 6.7% of the Bega Valley Shire LGA population resides within the rural area surrounding Bega that includes the Wolumla Creek catchment. There is increased development pressure now around the village of Wolumla and it is anticipated that Council will shortly be in receipt of applications for further residential subdivisions.

The Wolumla village and surrounds has been identified for the development of some 700 additional future lots and that Council's adopted affordable housing strategy will also see intensification of development through a proportion of smaller lots.

Flooding is a known risk within the catchment, affecting road access and levels of service (with respect to frequency of inundation), causes nuisance flooding, as well as risk to private and public property. Anecdotal commentary from the local community suggest that regional roads are cut during flood events, which would restricts the response of emergency personnel during emergencies.

This Flood Study represents the first step assessment phase of the floodplain risk management process (discussed in more detail in the Foreword on the preceding page). The Flood Study defines the existing flood behaviour and flood risks present in the study area. This information will feed into a subsequent Floodplain Risk Management Study and Plan which will assess various methods of managing this risk, and ultimately prepare an implementation plan of management options for Council.

Study Area

The study area encompasses the Wolumla Creek catchment, including the tributaries of Frogs Hollow Creek and Greendale Creek. The study area is largely cleared, open space. Dense vegetation remains along the eastern and southern catchment boundaries but does not constitute a large area of the overall catchment.

The catchment discharges to the Bega River, with the Wolumla Creek confluence located approximately 10km upstream of the Bega Township.

The study area experiences flooding from three mechanisms:

- Overland flooding from local rainfall. This is the predominant form of flooding affecting the Wolumla township.
- Mainstream flood and overbank flows. This mechanism characterises the majority of the flood behaviour within the study area.
- Backwater from the Bega River. Backwater may occur independently of flooding along Wolumla Creek, and affects the lower reaches of the study area that interact with the Bega River.

The township of Wolumla lies in the upper reaches of Wolumla Creek, on the southern boundary of the catchment extent. The township is the sole region of low density residential development in the catchment. The township contains the local school, post office, pub, and community hall. The township is primarily affected by overland flow, with two major flowpaths conveying runoff. These flowpaths are located in both open space and residential properties.

The Princes Highway is the key north-south transit route running through the catchment. In addition, two significant Regional Roads transit through the Wolumla Creek catchment, the Candelo-Bega Road and the Candelo-Wolumla Road. Access along all three of these roads is lost in the 2% AEP event.

Project Scope

The overall objective of this study is to improve Council's understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information, and relevant standards and guidelines. The project will also assist Council with planning for future development and will provide flood intelligence to the SES to enable them to progress their emergency management planning for the region.

This report presents the Flood Study, which is a comprehensive technical investigation of existing flood behaviour.

Specifically, the scope of the project involves:

- Construction of hydrological and hydraulic models to model flood behaviour;
- Definition of the existing flood behaviour and associated flood risks;
- Assessment of future flood risk as a result of additional development and climate change; and,
- Providing a robust foundation for the subsequent development of a Floodplain Risk Management Study and Plan, to address the identified flood risks.

The subsequent Floodplain Risk Management Study will utilise this information to develop strategies to manage the flood risks within the Wolumla Creek catchment.

Engagement

Stakeholder engagement was undertaken throughout the flood study. This involved:

- Engaging State Government Agency and industry stakeholders to obtain details of historical flooding, survey data and other relevant data sets.
- Community engagement undertaken through the mail-out of an information brochure and brief survey. Door knocking of the Wolumla township was undertaken during the engagement period. A community drop in session was also held. The purpose of the community engagement was to raise awareness of the study and flood risk in the catchment, as well and obtain observations and experiences of historical flooding to assist in the flood model development.

Public exhibition of the draft Flood Study will provide the community with an opportunity to review and comment on the results of the Flood Study prior to its adoption by Council.

Hydrological and Hydraulic Modelling

Flood modelling has been undertaken using a combination of hydrological and hydraulic models. Hydrological modelling was undertaken for the study area using RAFTS, and catchment flooding was modelled in TUFLOW.

No suitable historical flood data was available for the calibration of the models. Instead, the models were validated against:

- The calibrated Bega River RAFTS model from the Bega and Brogo Rivers Flood Study for the hydrological model; and,
- Community observations on past flood behaviour for the hydraulic model.

Community observations provide useful information on the flood behaviour previously experienced in the catchment. An indirect verification of the modelling was undertaken by comparing the flood behaviour in the model for the 20% AEP event against the observations from the community. The 20% AEP event was used, as the study area has not experienced a major storm in recent years, and so a more modest storm would be more reflective of the community's lived experience.

The model aligned with observations of the community of flood behaviour across the floodplain, namely:

- That the highway remains trafficable during flood events;
- That roads within the Wolumla Township remain trafficable during flood events; and,
- That access to rural properties is lost in minor floods (whether due to road flooding or access road flooding was unclear, but the model shows both being flood affected in the 20% AEP).

The hydrological, hydraulic and hydrodynamic models were analysed for the Probable Maximum Flood (PMF), 0.2% AEP, 0.5% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP, and 20% AEP events. The models were analysed for durations ranging from 60 minutes to 48 hours, using the 10 temporal pattern ensemble approach detailed in ARR2019.

The incised nature of the channel, and relatively steep overbank regions, resulted in a highly confined flood behaviour, characterised by high depth and high velocity flow with little adjacent flood storage or flood fringe. Whilst property lots were flood affected (particularly those adjacent to overland flow paths), there was relatively little flooding of buildings, in events up to and including the PMF.

Access remained relatively open for events up to the 5% AEP. Regional access was lost along the Princes Highway in the 2% AEP.

Conclusion

This report provides a comprehensive investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management study and plan.

The data developed as part of this Flood Study provides a better understanding of the flood behaviour and risks across the full range of flood events. It involved consideration of the local flood history, available flood data, and the development of hydrologic and hydraulic models that are calibrated and verified against historic flood events.

From the hydraulic model results, planning data has been prepared for use by Council.

Table of Contents

Appendices

Maps

These are provided as a separate Map Compendium to this report.

Tables

Figures

Glossary[1]

Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Catchment	The land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Discharge	The rate of flow of water measured in volume per unit time, for example, cubic metres per second (m3 /s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
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 local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

[1] Definitions from the Flood Risk Management Manual (2023)

Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
Hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probability	A statistical measure of the expected chance of flooding (see AEP).
Risk	Chance of something happening that will have an impact. It is measured in of consequences and likelihood. In the context of the manual, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Digital Elevation Model
LGA	Local Government Area
LiDAR	Light Detection and Ranging
mAHD	metres to Australian Height Datum
NSW	New South Wales
PMF	Probable Maximum Flood
SES	State Emergency Service (NSW)

1 Introduction

The Wolumla Creek Flood Study has been undertaken with Bega Valley Shire Council (Council) to gain an understanding of flood risk in the study area. No prior flood study has been undertaken for the catchment, and as such flood intelligence has been limited to historical and anecdotal data.

The 2021 census data reveals that approximately 6.7% of the Bega Valley Shire LGA population resides within the rural area surrounding Bega that includes the Wolumla Creek catchment. There is increased development pressure now around the village of Wolumla and it is anticipated that Council will shortly be in receipt of applications for further residential subdivisions.

The Wolumla village and surrounds has been identified for the development of some 700 additional future lots and that Council's adopted affordable housing strategy will also see intensification of development through a proportion of smaller lots.

This Flood Study represents the first step assessment phase of the floodplain risk management process. The Flood Study defines the existing flood behaviour and flood risks present in the study area. This information will feed into a subsequent Floodplain Risk Management Study and Plan which will assess various methods of managing this risk and ultimately prepare an implementation plan of management options for Council.

1.1 Study Area

The study area encompassed the Wolumla Creek catchment, including the tributaries of Frogs Hollow Creek and Greendale Creek.

The Wolumla Creek catchment is a subcatchment of the wider Bega River catchment. The Wolumla Creek catchment discharges to the Bega River, with the Wolumla Creek confluence located approximately 10km upstream of the Bega Township.

The study area is largely cleared, open space. Dense vegetation remains along the eastern and southern catchment boundaries but does not constitute a large area of the overall catchment.

The township of Wolumla lies in the upper reaches of Wolumla Creek, on the southern boundary of the catchment extent. The township is the sole region of low density residential development in the catchment. The township contains the local school, post office, pub, and community hall.

The catchment contains zoning for several deferred matters that may permit further development within the catchment.

The Princes Highway is a key north-south artery running through the catchment. In addition, two significant Regional Roads transit through the Wolumla Creek catchment, the Candelo-Bega Road and the Candelo-Wolumla Road. Council's traffic count data reveal movements of some 312,000 vehicles annually on the Candelo-Wolumla Road at Wolumla and 269,000 vehicles annually on the Candelo-Bega Road at Candelo.

The study area is shown in **Figure 1-1**.

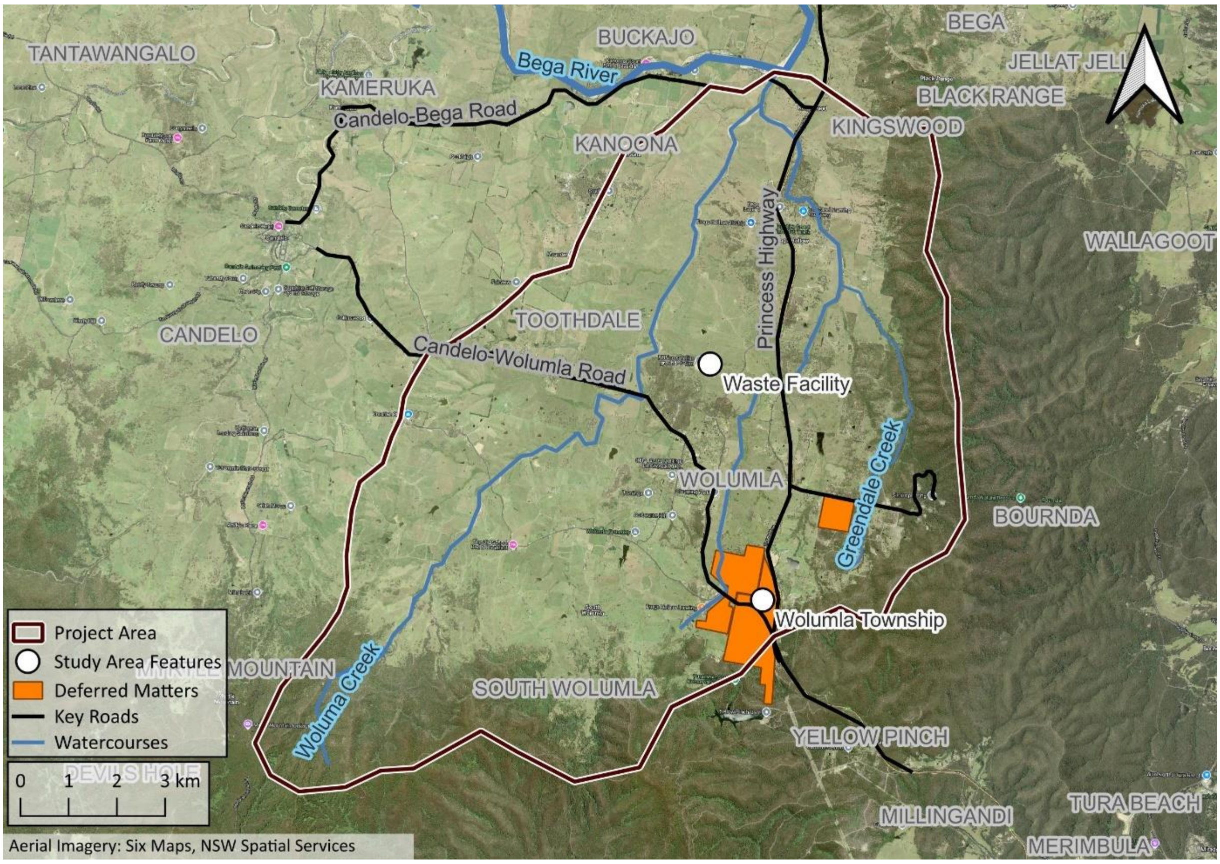

Figure 1-1 Study Area

1.2 Flood Behaviour

The study area experiences flooding from three mechanisms:

- Overland flooding from local rainfall. This is the predominant form of flooding affecting the Wolumla township.
- Mainstream flood and overbank flows. This mechanism characterises the majority of the flood behaviour within the study area.
- Backwater from the Bega River. Backwater may occur independently of flooding along Wolumla Creek, and affects the lower reaches of the study area that interact with the Bega River.

The incised nature of the channel, and relatively steep overbank regions, resulted in a highly confined flood behaviour, characterised by high depth and high velocity flow with little adjacent flood storage or flood fringe. Whilst property lots were flood affected (particularly those adjacent to overland flow paths), there was relatively little flooding of buildings, in events up to and including the PMF.

Access remained relatively open for events up to the 5% AEP. Regional access was lost along the Princes Highway in the 2% AEP.

1.3 Study Objectives and Scope

The overall objective of this study was to improve Council's understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information, and relevant standards and guidelines. The project will also assist Council with planning for future development and will provide flood intelligence to the SES to enable them to progress their emergency management planning for the region.

The flood study provides an understanding of the behaviour and risks associated with a range of flood events, for the existing and future community. Specifically, the study has:

- Reviewed available data from across the catchment and wider region with regard to rainfall and flooding;
- Involved the community in the study through public workshops, surveys, and Council webpages;
- Constructed hydrological and hydraulic flood models, and validated these models to historical data;
- Used the validated models to define design flood event behaviour for events ranging from the 20% Annual Exceedance Probability (AEP) to the Probable Maximum Flood (PMF); and,
- Provided essential information to the NSW State Emergency Service (SES) to enable the effective preparation and implementation of local flood plans to deal with flood emergency response.

2 Available Data

A data compilation and review exercise was undertaken to collect and assess the available data for the catchment. The sections below discuss the data searches undertaken, the data collected, and how this data has been utilised in the study.

2.1 Guidelines

The study has been undertaken in accordance with two key industry guidelines namely, the *Flood Risk Management Manual* (DPE, 2023) and *Australian Rainfall and Runoff* (Commonwealth of Australia, 2019).

2.1.1 Flood Risk Management Manual

The *Flood Risk Management Manual* was published in 2023 by the then Department of Planning and Environment (now Department of Climate Change, Energy, the Environment and Water), to:

> *reduce the impacts of flooding and flood liability on communities and individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. In doing so, community resilience to flooding is improved.*

The policy set out in the manual sets the direction for Flood Risk Management in New South Wales.

To this end, the manual provides 8 principles of flood risk management covering governance, consultation, uncertainty and risk management, a risk management framework for the development and assessment of flood risk management measures, and the roles and responsibilities of local, state and national governments.

The manual was published with a toolkit which includes additional guidance and material for:

- Administration arrangements;
- Understanding and managing flood risk;
- Flood hazard and flood function;
- Support for emergency management planning; and,
- Flood impact and risk assessment.

The methodology adopted in this study is in accordance with the Flood Risk Management Manual.

2.1.2 Australian Rainfall and Runoff

Australian Rainfall and Runoff (ARR) provides the technical and theoretical underpinning for hydrological and hydraulic flood modelling in Australia. The latest version, released in 2019, incorporates contemporary flood modelling techniques developed to provide robust and reliable estimates of flooding across Australia.

The latest Australian Rainfall and Runoff (ARR2019) is presented as a series of 9 books covering all aspects of flood estimation including:

- Rainfall estimation;
- Flood hydrology and hydraulics (including the estimation of very rare to extreme floods); and,
- Climate change.

All flood modelling undertaken as part of this study has been done in accordance with the guidance provided in ARR2019.

2.2 Previous Studies and Reports

Whilst no prior studies have been undertaken for the study area, a prior Flood Study (SMEC, 2014) and Floodplain Risk Management Study and Plan (Cardno, 2017) have been conducted for the Bega River catchment. The Wolumla Creek catchment lies within the larger Bega River catchment.

The study area for these studies was focused on the township of Bega, which is the largest settlement within the Bega River catchment area. The study area extended from Bega township to the outlet of the Bega River at Mogareeka.

The studies assessed flood behaviour for the 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEP events, and the PMF event. The study found that:

- Due to historical flooding experiences, much of the developed areas of Bega are outside of the mainstream 1% AEP flood extent;
- The Brogo River contributes to Bega River flooding as the catchment areas are similar and their flood peaks arrive at similar times;
- The geographic feature, Bottleneck Reach, is a constrained reach of the Bega River that fully contains all events up to and including the PMF, and drives significant upstream ponding in large flood events; and,
- The tidal influence extends approximately 15 km upstream to Jellat Jellat, although in large flood events, the influence of ocean levels extends as far upstream as Bega.

Wolumla Creek was outside of both study areas. However, the Wolumla Creek catchment was incorporated in the calibrated RAFTS hydrological model used in the studies. Reference has been made to this model in establishing the RAFTS hydrological model for this study (refer **Section 4.1**).

2.3 Previous Modelling

No prior hydraulic modelling has been undertaken for the study area.

The study area is covered by the Bega River RAFTS hydrological model, which was developed and calibrated as part of the Bega River Flood Study. However, the catchment mapping was too coarse to adopt this model for use in the study directly.

Model parameters were taken from this larger, calibrated model for use in the local model.

Details of the hydrological model set up are provided in **Section 4.1**.

2.4 Site Inspection

A site visit was undertaken over the 29th and 30th of May 2024 by Rhelm and DCCEEW staff.

The site visit was used to inspect the numerous crossings of Wolumla Creek, both within the township and along the Princes Highway, and to gain an appreciation of the catchment and likely flood risks. Photographs were taken to assist in defining model roughness parameters.

The site visit was also used to collect and confirm available structure data for major crossings.

2.5 Historical Flooding Data

There was no historical recorded flood data available for the site.

Information was collected from the community on their flood observations and experiences which was used to validate the model behaviour.

Further details on the data received from the community are provided in **Section 3** and **Section 4.3.2**.

2.6 Stream Gauge Data

There are no stream gauges located within the study area.

2.7 Rainfall Data

There are no currently active rainfall gauges within the catchment area. The nearest active daily rainfall gauge is at Black Range (Station 69144) approximately 2km north of the catchment area. The nearest pluviograph station is in in Bega (Station 69139) approximately 6km north of the study area. There are a number of decommissioned gauges within and around the catchment area.

The locations of the identified gauges are shown in **Figure 2-1**.

Due to the lack of historical flood data, these gauges have not been incorporated into any assessments in the Flood Study. Use and/or reference to these gauges may be made in the subsequent FRMS for flood warning and flood data management options.

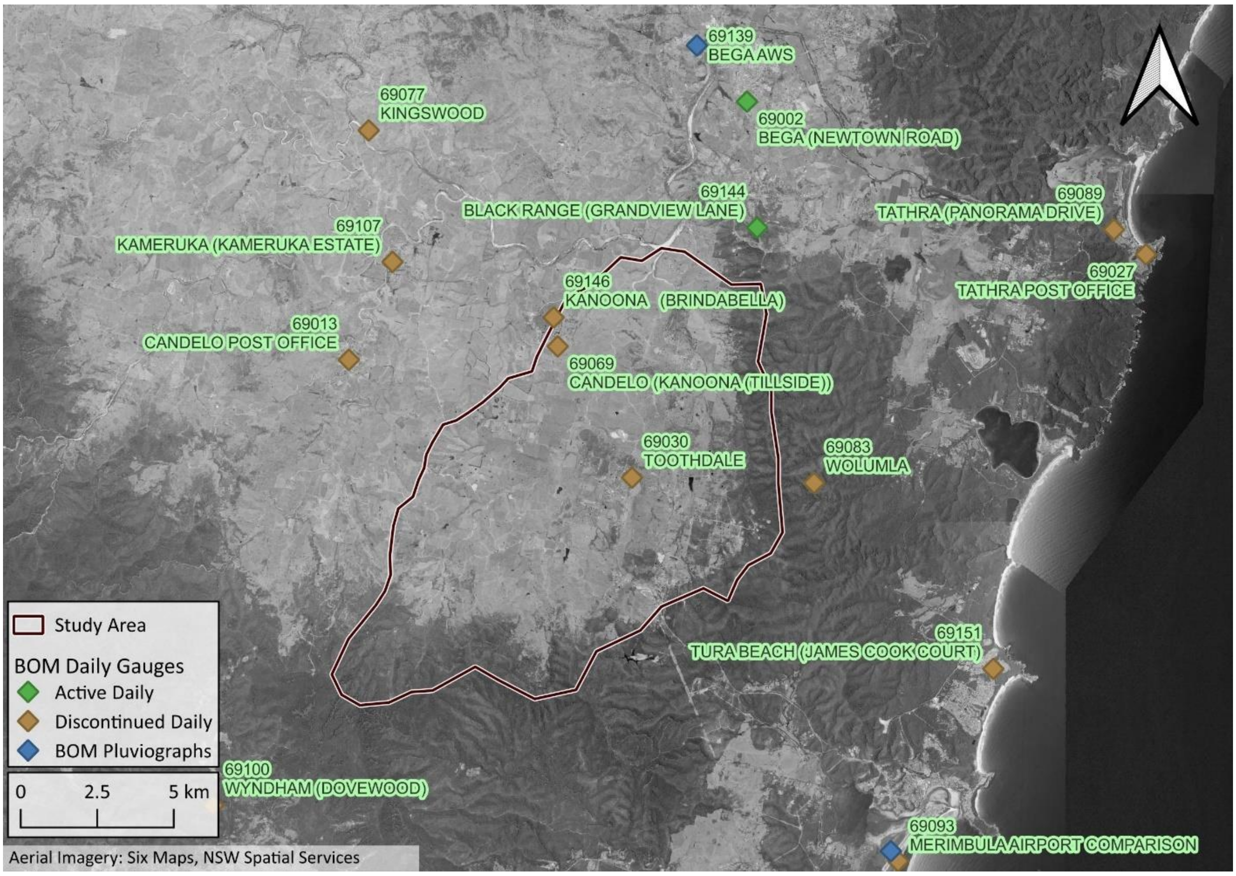

Figure 2-1 Identified Rainfall Gauges

2.8 Available Survey Information

2.8.1 DEM

The full catchment area is covered by 5m LiDAR data provided by Geoscience Australia. The LiDAR data was collected in 2015 and was made available through the "Elvis" Elevation and Depth portal (https://elevation.fsdf.org.au/).

Some additional, more recent data was available at a finer resolution of 1m (from 2013) and 2m (from 2018), but these data sets did not cover the full catchment area. As a 5m grid resolution was considered suitable for the study (refer **Section 4.2.3**) and only three years separated the 5m LiDAR from the latest LiDAR, it was elected to use the data set that covered the full catchment area.

The data has a vertical accuracy of +/- 0.3m and a horizontal accuracy of +/- 0.8m.

2.8.2 Bridges and Culverts

Data on Council owned culverts were provided in Council's GIS asset database.

The Princes Highway crossings owned by Transport for NSW (TfNSW) were measured during the site visit, with inverts estimated from available LiDAR data.

The locations of the structures are shown in **Figure 4-3** as part of the hydraulic model development discussion.

2.9 GIS Data

Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, vegetation communities and soil landscapes were provided by Council in the form of GIS datasets.

3 Consultation

The consultation strategy outlined in **Table 3-1** describes the adopted approach to consultation in accordance with:

- Council's Engagement Policy,
- International Association for Public Participation (IAP2) framework, and
- the requirements of the *Flood Risk Management Manual* (NSW Department of Planning and Environment, 2023).

Table 3-1 Consultation Strategy Outline

IAP2 Engagement Strategy Guide	Flood Investigation
Context *The internal and external drivers, pressures and other background information that is of relevance to the consultation strategy, and in particular how these may influence how the community receives and responds to the consultation program.*	The context of the consultation was defined by the following: • Council's policies; • Flood behaviour; • Past flooding experiences and local regional and national media on flooding; and, • Contact with flood impacted residents.
Scope *The scoping statements are based on the project context and articulate why the consultation is being undertaken for this project, what the desired outcomes would be, and what the limitations of the engagement are.*	The scope of the consultation strategy was to engage with stakeholders and the community to better understand the flood risks within the study area and to develop community understanding, educate, build resilience and ownership of the study outcomes.
Stakeholders *This section provides an overview of the different categories of stakeholders, and their relative level of interest, influence and impact.* *This process is useful in identifying the level of engagement under the IAP2 Consultation Spectrum that may be suitable for different types of stakeholders.*	A stakeholder matrix is provided in **Table 3-1**. This informed level of engagement required with each stakeholder and the selection of appropriate consultation methods.

IAP2 Engagement Strategy Guide	Flood Investigation
Purpose *The purpose relates to the purpose of the consultation not the overall project.* *Stakeholders will be linked to each purpose and the goals within each purpose for each stakeholder will be identified.*	The purpose of the consultation was to: • Inform the community and stakeholders of the study; • Gain an understanding of the community and stakeholders' concerns relating to flooding in the study area; • Obtain historical flood information; • Gather information from the community by participation; • Obtain feedback on the draft reports and outputs; and • Develop and maintain community confidence, build trust and collaboration with the study results.

3.1 Stakeholder Matrix

It is important to ensure that all those who need to be involved in the floodplain management (i.e. those with responsibility for managing flood risk and those with a vested interest in its management, such as property owners) are kept informed and are invited to contribute to the process to establish a common understanding of flood risk and how decisions are made.

Stakeholders may tend to make judgements about risk based solely on their own perceptions. These perceptions can vary due to differences in values, needs, assumptions, concepts, concerns and degrees of knowledge. Stakeholders' views can have a significant impact on the decisions made, so it is important that differences in their perceptions of risk be identified, recorded and addressed.

A stakeholder matrix has been developed to provide an overview of the different categories of stakeholders, and their relative level of interest, influence and impact on the study. Each stakeholder has been assigned a level of engagement based on the IAP2 consultation spectrum, conceptualised in **Figure 3-1**.

The assigned levels of impact, interest and influence, and the recommended approach to consultation for each stakeholder is summarised in **Table 3-2**.

Figure 3-1 IAP2's Public Participation Spectrum

Table 3-2 Stakeholder Matrix

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Impacted Agency Stakeholders				
Council Project Manager	High	High	High	Empower
Councillors	High	Moderate	Moderate	Involve
Department of Climate Change, Energy, The Environment and Water	High	High	High	Empower
Technical Working Group	High	High	Moderate	Collaborate
Floodplain Risk Management Sub Committee	High	High	Moderate	Collaborate
NSW SES	High	High	Moderate	Collaborate
Interested Agency Stakeholders				
Other Council Staff	Moderate	High	Moderate	Involve
Central Waste Facility staff	Low	Moderate	Moderate	Consult
Impacted Community Stakeholders				
Flood affected property owners	High	High	Low	Consult
Flood affected residents	High	High	Low	Consult
Flood affected business owners	High	High	Low	Consult
Residents and owners of properties with flood affected access	Moderate	Moderate	Low	Consult
Hall Committee	Low	Low	Low	Consult
General community	Low	Moderate	Low	Consult

3.2 Website and Media

Council utilised Council's a project website and *Have your Say* webpage hosted on Council's website , media releases, and social media to provide updates and request input to the study.

The webpage provides background information on the project, relevant links and information on how the community has been and can get involved. The website was updated periodically during the project at key milestones.

3.3 Community Mail Out and Survey

A community survey was made available online between 17 May 2024 and 2 June 2024. The survey period was extended by two weeks to collect additional community responses.

A copy of the survey is provided in **Appendix A**.

The survey sought information about historical flooding events and other flooding concerns within the community.

Over the course of the survey period, 10 responses were received (4 of which were received during the two week extension).

A summary of the respondent demographics and flood experience is provided in **Table 3-3**.

The results indicate that most of the respondents are middle aged and are long-term residents. Only one of the 10 respondents reported experiencing significant flooding.

Respondents were provided the opportunity to elaborate on the survey questions. The key themes of the responses were:

- **Development**: development was not supported in flood affected areas.
- **Erosion**: there was a desire to control creek erosion through revegetation and fencing of creeks from livestock.
- **Low Flood Risk**: there was a perception that flood risk in Wolumla was low.

Table 3-3 Community Survey Demographic and Flood Experience Summary

Question	Responses
What is your age group?	<40: 1 40 - 70: 6 >70: 1
How long have you lived at your address?	1-5 years: 1 5-10 years: 1 10-20 years: 3 20+ years: 3
Has your property been previously affected by flooding?	Yes, the building: 1 Yes, the yard: 1 No: 8
How do you anticipate you would respond to a major flood?	Evacuate: 2 Evacuate if directed: 3 Remain: 3 Unsure: 2
What information do you look for during a flood event?	Road closures: 7 Evacuation notices: 5 Flood characteristics: 5
How would you rate the risk of flooding to your personal safety?	No risk: 4 Low Risk: 2 Moderate Risk: 1 High Risk: 1
How would you rate the risk of flooding to the local community?	No risk: 1 Low Risk: 2 Moderate Risk: 2 High Risk: 2

3.4 Door Knocking

Rhelm staff undertook a door knocking program on 29th May 2024. The door knocking focussed on the Wolumla Township.

Rhelm spoke with 14 residents who shared their flooding experiences within the Wolumla Township.

The key themes of the discussions with the community were:

- Concerns around erosion of creeks and tributaries;
- Concern about the impact of further development on flood response due to increased runoff; and,
- Residents were aware of road closures on rural roads but noted that roads within Wolumla and the Princes Highway have remained trafficable during recent flood events. Residents were unable to link these road closures to a specific flood event.

3.5 Public Exhibition

To be completed following completion of public exhibition

4 Model Development

4.1 RAFTS Hydrological

The hydrological modelling has been completed using the RAFTS hydrological model.

The sub catchment delineation has been based on available LiDAR information (refer **Section 2.8**). The sub catchment delineation is shown in **Figure 4-1**.

Inputs to the model and the data sources for those inputs are summarised in **Table 4-1**.

Table 4-1 Hydrological Model Input Data

Parameter	Data Source
Percentage impervious	Percentage impervious areas are largely a factor of development intensity and can be determined from aerial imagery. High resolution aerial imagery has been sourced from freely available online imagery (SIX Maps).
Catchment Runoff & Routing	Flow routing in RAFTS can be done either by a simple 'lag' link, whereby flows are delayed between sub-catchments for a user-specified period, or RAFTS can also automatically calculate lag times if the user enters a channel cross section. The study adopted individual lag times for each sub-catchment based on catchment flow length (the length of the primary flow path through the catchment) and an assumed flow rate through the sub-catchments based on ARR2019 guidance, and validation against the calibrated wider Bega River model (refer **Section 4.3.1**).
Rainfall losses	Under the new methodology set out in ARR2019, rainfall parameters for hydrological modelling are all available from the ARR Data Hub. In the absence of calibrated losses, the ARR2019 Data Hub losses were adopted for the study.
Manning's 'n' roughness	Manning's 'n' roughness values were adopted from the prior Flood Study and Floodplain Risk Management Study RAFTS model for consistency, and also due to these models having been successfully calibrated with these roughness's. Roughness extents were determined based on aerial photography and the site inspection. The following values were adopted for various land use types: • Pasture and open space: 0.045 • Residential lots: 0.1 • Dense vegetation 0.18 • Open, sandy creek bed: 0.06 These values are within typical ranges suggested in ARR2019. Each sub catchment was given a single roughness value, based on an area-averaged value of the above land use values within each sub catchment.
Design Rainfalls	Design intensities and temporal patterns were taken from the ARR Data Hub.

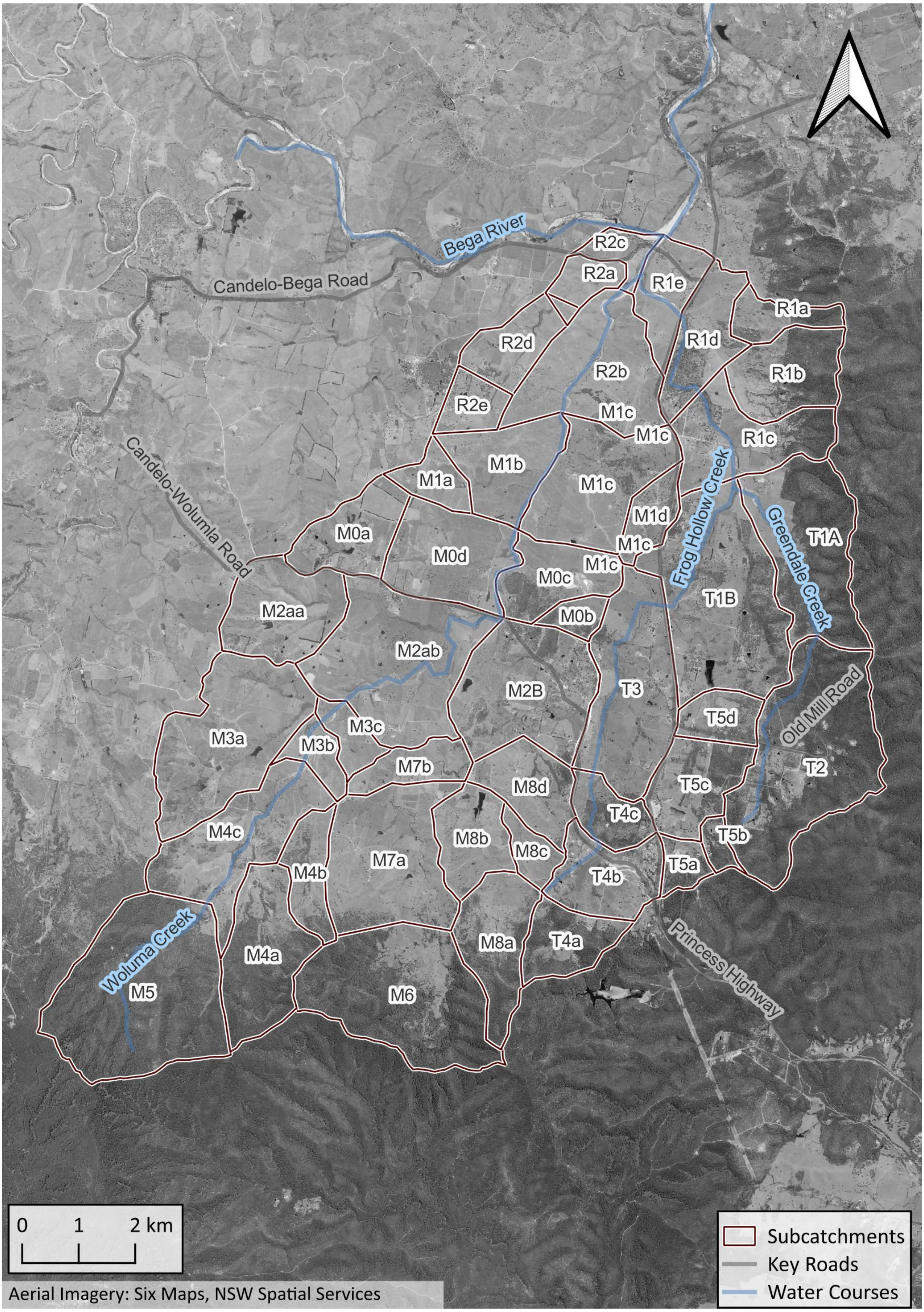

Figure 4-1 Subcatchment Breakdown

4.2 TUFLOW Hydraulic Model

4.2.1 Software

The modelling for the study was undertaken using the latest available TUFLOW version (2023-03-AF), and was run in HPC.

4.2.2 DEM Development and Model Area

A Digital Elevation Model (DEM) has been developed for input into the hydraulic models. This DEM is based on the available 5m LiDAR and covers all the catchment area.

Given the relatively small size of the catchment area, the full catchment area was incorporated within the hydraulic model extent.

The adopted model DEM and model extent is shown in **Figure 4-2**.

4.2.3 Grid Cell Resolution

The adopted LiDAR data was a 5m grid resolution (refer **Section 2.8.1**). As such, a consistent, rectilinear 5m grid was also adopted for the hydraulic model, representing the finest model grid that was achievable with the available data.

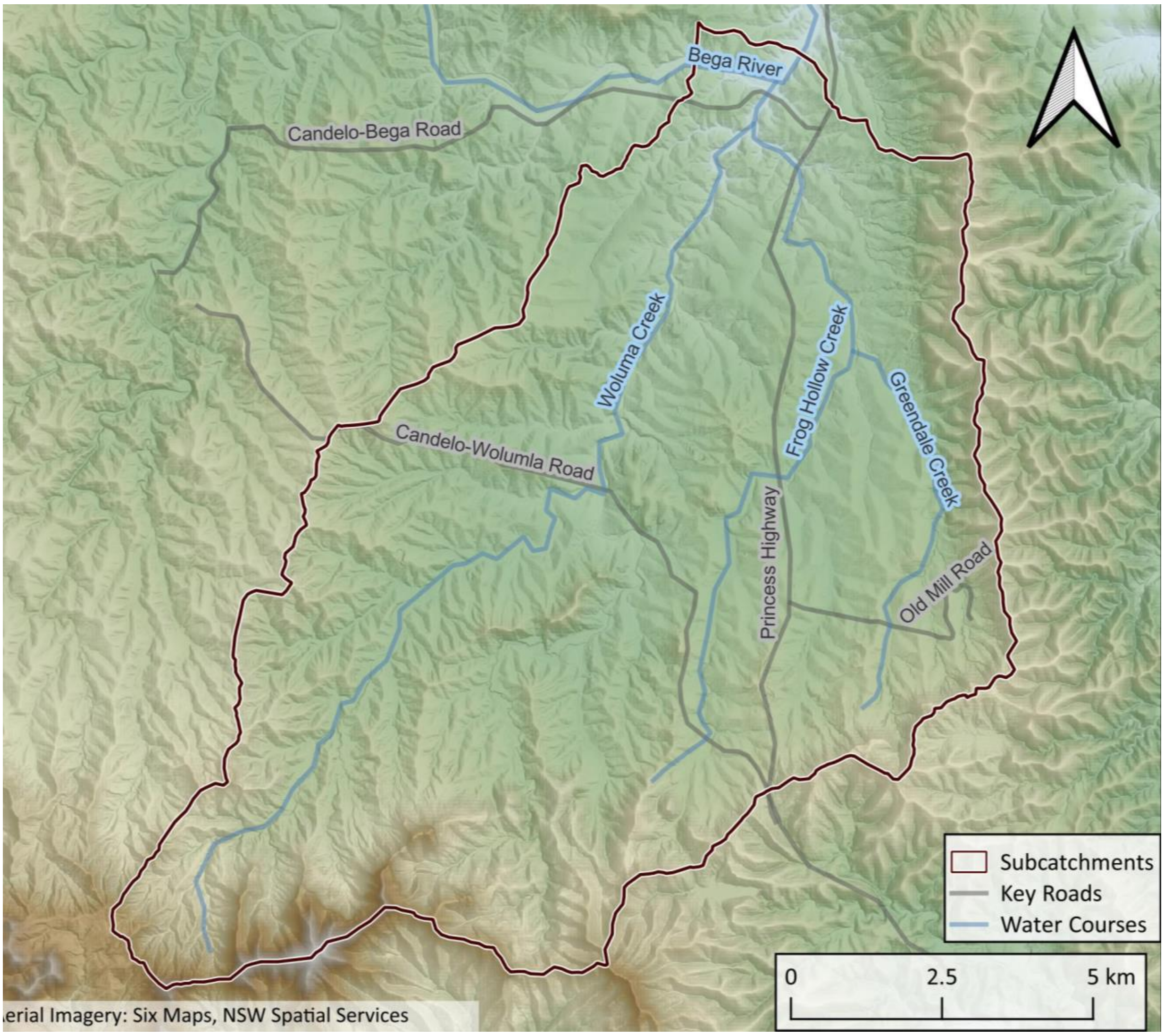

Figure 4-2 **TUFLOW Model DEM**

4.2.4 Hydraulic Structures and Drainage

Key hydraulic structures and drainage elements were incorporated in the model, as shown in **Figure 4-3**.

Bridges were incorporated via layered flow constrictions in the TUFLOW model 2D domain which allow for the definition of the open area, the bridge deck, and any railing or barriers, with individual blockage rates and form loss rates applied for each layer of the structure.

Culverts were incorporated as 1D elements in the TUFLOW model, with sizes and inverts taken from the available data and site inspection.

Stormwater drainage was incorporated as 1D elements in the TUFLOW model. Council's data set was comprehensive in terms of location and pipe size, but invert data was limited. Invert levels were assumed from the LiDAR, based on a minimum 600mm cover. Inverts were then manually reviewed and adjusted to ensure that all pipes had a positive grade of at least 1%.

The model incorporated all the culverts and pipes in Council's data set, regardless of size.

Blockage was applied to all bridges and culverts based on ARR2019 guidelines.

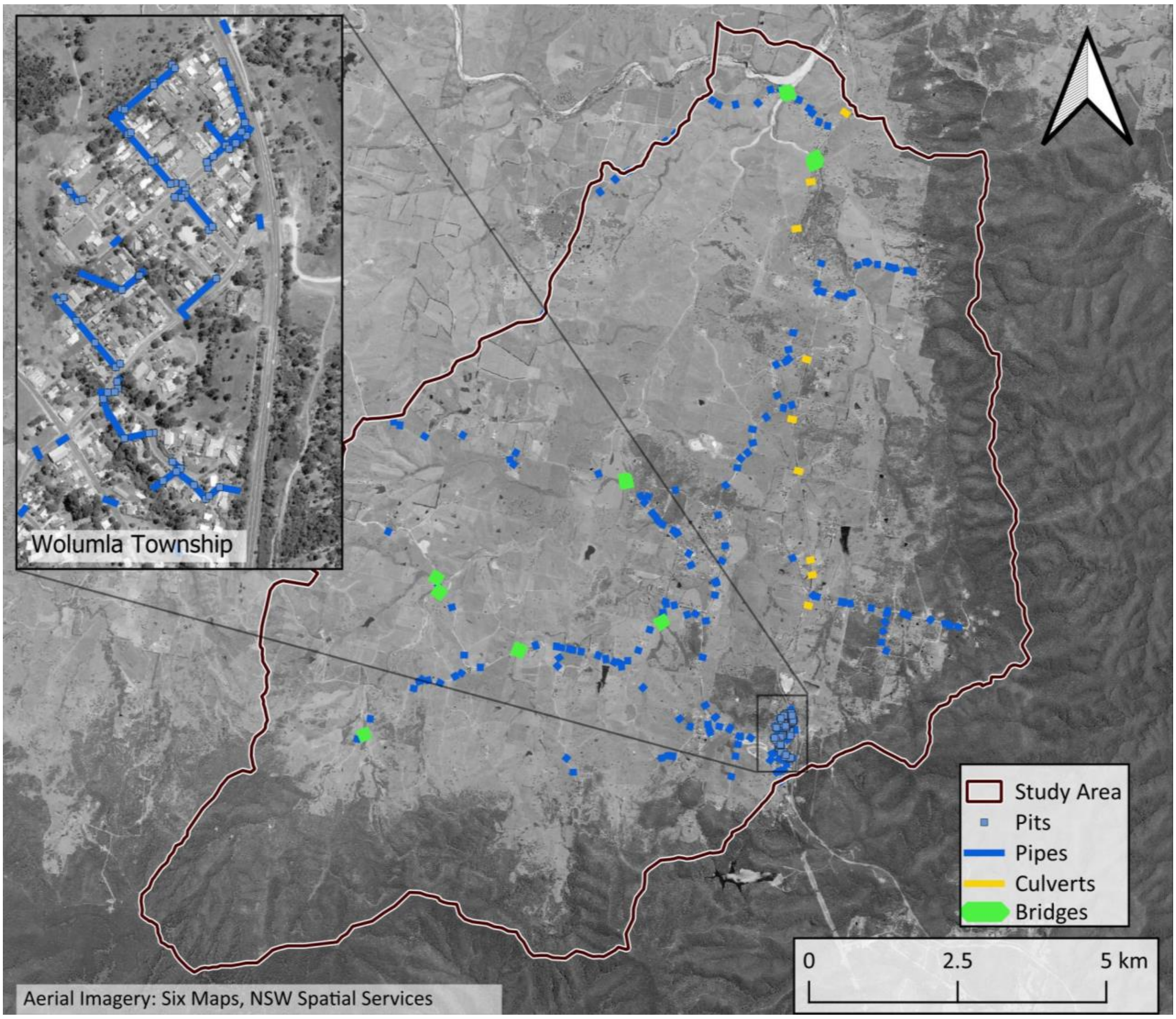

Figure 4-3 **Hydraulic Structures and Drainage**

4.2.5 Roughness

Hydraulic roughness Manning's 'n' values were adopted from the prior Bega River Flood Study and Floodplain Risk Management Study for consistency, and due to these models having been successfully calibrated with these roughness parameters. Roughness zone extents were determined based on land use mapping and aerial photography, with reference made to ARR Guidelines. The values adopted are summarised in **Table 4-2** and shown in **Figure 4-4**.

Table 4-2 Adopted Roughness Values

Land Use	Manning's 'n'
Open Space	0.045
Dense Vegetation	0.18
Open, Sandy Creek Bed	0.06
Residential	0.1

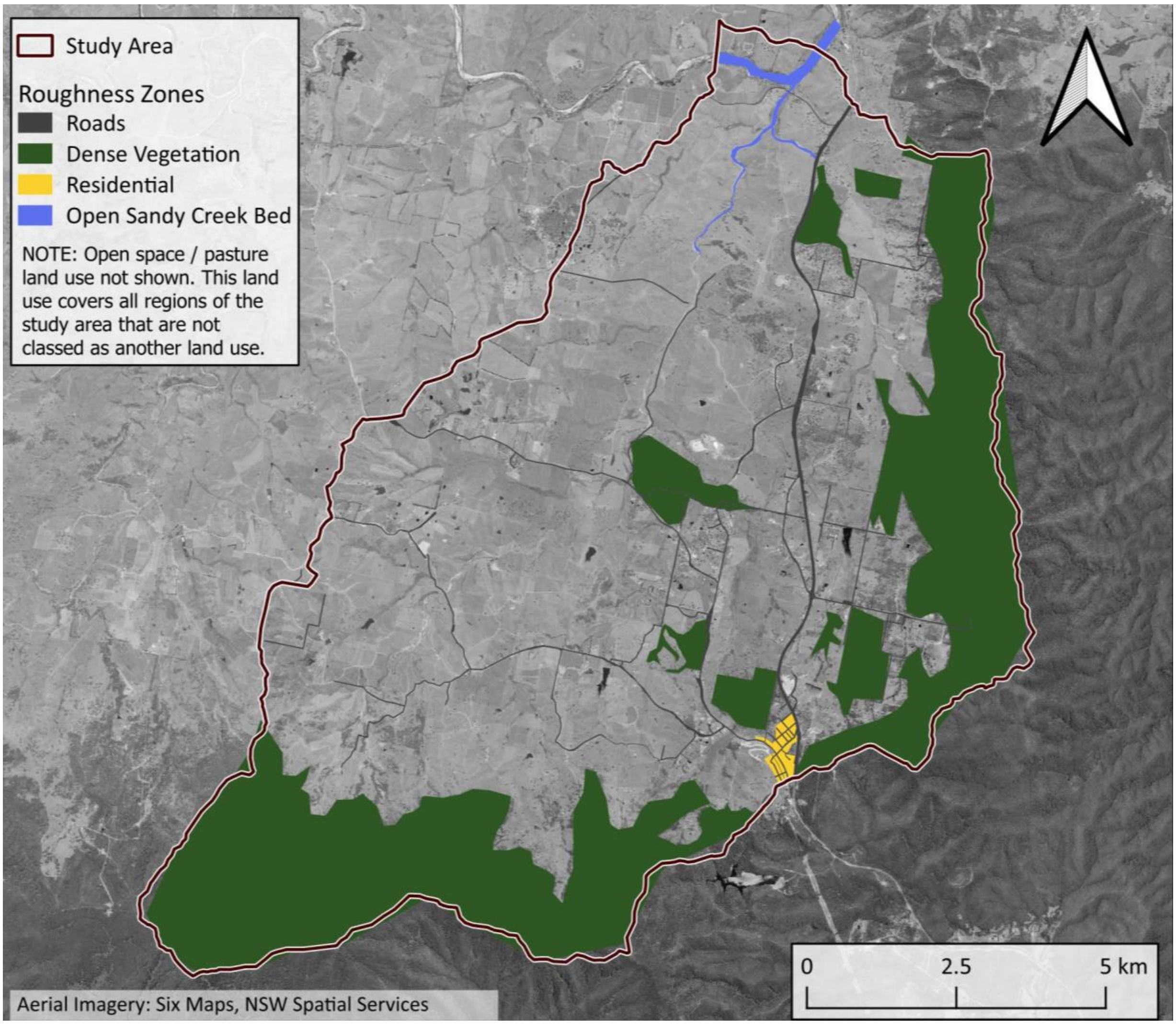

Figure 4-4 TUFLOW Model Roughness

4.2.6 Buildings

Buildings have not been explicitly incorporated into the model. Development is relatively dispersed across much of the catchment, typically involving a small number of structures on a large parcel of land. The exception is the Wolumla Township, which has a greater development density.

Across the large rural lot properties, the land use across these properties has been captured (cleared, vegetated, etc.) but buildings have not been added to the model as they are not expected to significantly impact flood behaviour.

Within Wolumla, where buildings are more likely to impact the flood behaviour, a lot-averaged roughness has been adopted to account for the buildings (“residential” in **Table 4-2**).

4.2.7 Fences

There are numerous ways to incorporate fences within a 2D hydraulic model. While the techniques can be quite advanced, the reality is that the behaviour of fences in flooding can be quite uncertain and difficult to represent appropriately. Fences have been incorporated in the hydraulic model through a property averaged roughness value that accounts for both the buildings, fences and other ancillary structures (“residential” in **Table 4-2**).

4.2.8 Inflows

Inflows to the hydraulic model were applied at hydrological model sub catchment outlets, with hydrographs sourced from the RAFTS hydrological model (refer **Section 4.1** and **Figure 4-1**).

4.2.9 Downstream Boundary Conditions

Coincident flooding of the Bega River was assumed for the design event modelling. The assumed Bega River conditions for each design AEP are summarised in **Table 4-3**.

The downstream boundary is dynamic, with flows applied upstream of the Wolumla Creek confluence. This approach was adopted in preference to a static water level, to better understand the interaction of Wolumla Creek flows with Bega River flooding.

Table 4-3 Downstream Coincident Flooding Assumptions

Local Catchment AEP	Bega River AEP
20% AEP	No Flooding in Bega River
10% AEP	No Flooding in Bega River
5% AEP	No Flooding in Bega River
2% AEP	5% AEP
1% AEP	5% AEP
0.5% AEP	1% AEP
0.2% AEP	1% AEP
PMF	1% AEP

4.3 Model Calibration and Validation

There was insufficient historical data available to enable the calibration of the hydrological and hydraulic models (refer **Section 2**).

Model validation was undertaken by:

- Comparing the discharge hydrograph from the local RAFTS model to the wider, calibrated, Bega River RAFTS model (**Section 4.3.1**); and,
- Comparing the results of the hydraulic model against community observations (**Section 4.3.2**).

4.3.1 RAFTS Validation

To validate the RAFTS model, a comparison was undertaken between the flows at the Wolumla Creek and Bega River confluence between the calibrated Flood Study model, and the local Wolumla Creek model developed for this study.

The comparison is shown in **Figure 4-5**.

The comparison shows a reasonable alignment between the two models. The local model had a slightly slower response on the rising limb, and a slightly longer response on the falling limb. The overall shape and timing were consistent, however, and the peak flows were within 3% of each other.

Given the alignment of the discharge hydrographs, the local RAFTS model is reasonably validated against the wider, calibrated Bega River RAFTS model.

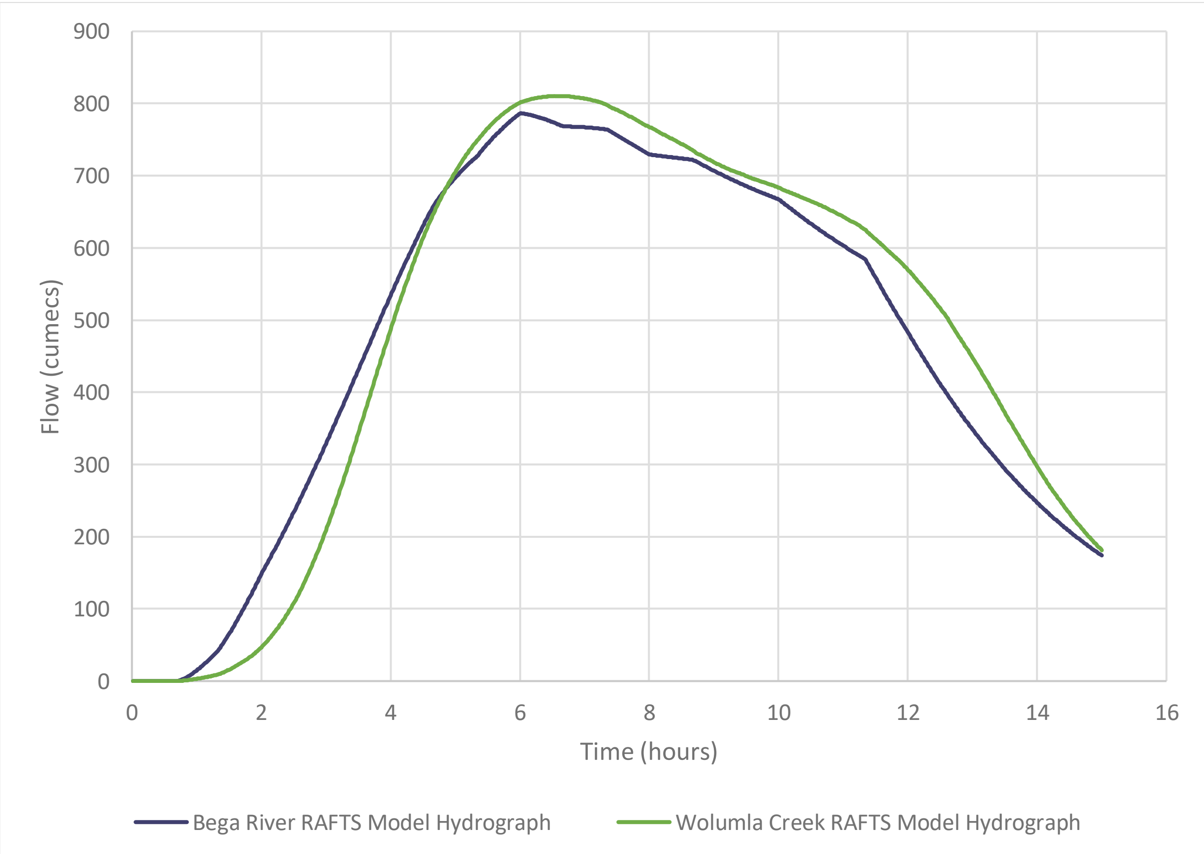

Figure 4-5 RAFTS Hydrograph Comparison

4.3.2 TUFLOW Validation

As a part of the community survey, door knocking and drop-in session, there was information obtained on observations of previous flood behaviour (refer **Section 3.3**).

Whilst the collected data was not sufficient to enable calibration of the flood model (as the responses were unable to accurately assign a month and year to their observations), the community observations provide useful information on the flood behaviour previously experienced in the catchment.

An indirect verification of the modelling was undertaken by comparing the flood behaviour in the model for the 20% AEP event against the observations from the community. The 20% AEP event was used, as the study area has not experienced a major storm in recent years, and so a more modest storm would be more reflective of the community's lived experience.

The model aligned with observations of the community of flood behaviour across the floodplain, namely:

- That the highway remains trafficable during flood events;
- That roads within the Wolumla Township remain trafficable during flood events; and,
- That access to rural properties is lost in minor floods (whether due to road flooding or access road flooding was unclear, but the model shows both being flood affected in the 20% AEP).

The model also replicated observed behaviour within the Wolumla Township. The door knocking focused on the identified flow paths within the township. A comparison between community observations and the model behaviour at two key locations is shown in:

- **Figure 4-6** for flood behaviour at Bridge Street and Bellbird Circuit; and,
- **Figure 4-7** for flood behaviour at Eden Street and Clarke Street.

At Bridge Street and Bellbird Circuit, residents commented that the flow path experienced high velocity flow that was eroding the channel banks downstream of Bega Street. Residents also commented that flow was relatively well contained, and that recent events had never impacted the houses.

The model replicates the above observed behaviour. While depths are modest (typically less than 0.5m downstream of Bega Street), velocities are high, in the order of 1m/s, with isolated regions of up to 2.5m/s. These velocities would be sufficient to drive the observed bank erosion. The depth mapping also indicated that the adjacent properties remained flood free in the 20% AEP.

At the second location, at the corner of Eden Street and Clarke Street, residents had previously observed high velocity flows through the flow path that resulted in the failure of the roadway and the erosion of the downstream channel. It was noted that residents Council had recently upgraded the crossing, and that overtopping was no longer observed in comparable storm events.

The model replicates the above behaviour. Velocities within the channel are in the order of 0.5 – 1m/s, which is sufficient to cause the described and observed channel erosion. The model (which incorporates Council's upgraded culverts) does not show overtopping in the 20% AEP event.

Overall, the comparisons indicate a general level of consistency between the modelling and the observations from the community.

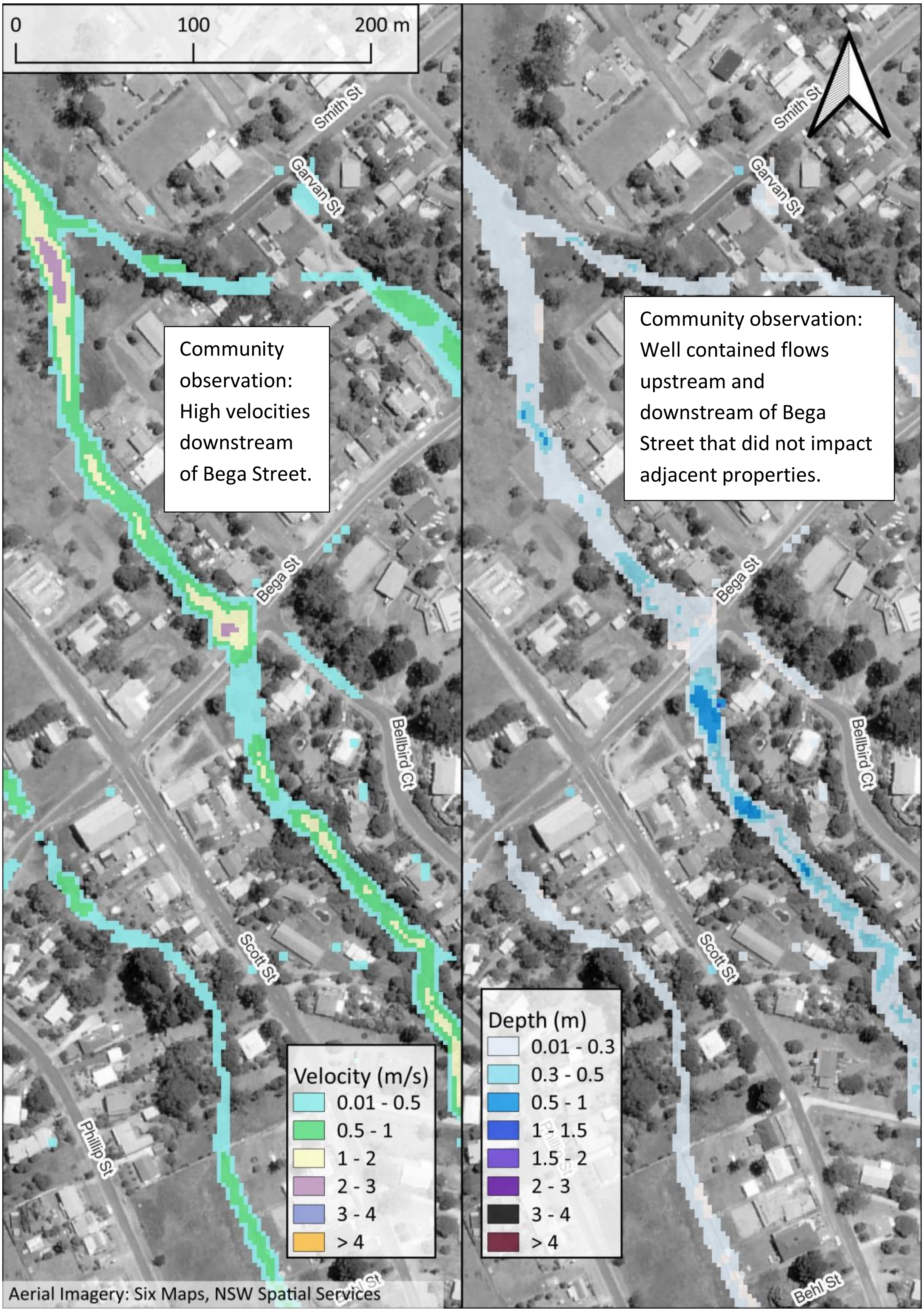

Figure 4-6 20% AEP Flood Behaviour at Bridge Street and Bellbird Circuit

Figure 4-7 20% AEP Flood Behaviour at Eden Street and Clarke Street

5 Flood Behaviour and Risk

5.1 Depths and Velocities

The hydrological and hydraulic models were used to simulate the 50%, 20%, 10%, 5%, 2%, 1%, and 0.2% AEP events and the PMF event.

Design events were determined by:

- In the RAFTS hydrological model, the design events were run for a series of durations ranging from 1-hour up to 18-hour events, and for the full ensemble of 10 temporal patterns as per ARR2019 guidelines.
- From the hydrological results, the critical duration and temporal pattern was determined across each subcatchment. The critical event was determined by:
    - Finding the median flow based on the 10 temporal patterns; then,
    - Comparing the median flow across all durations to find the peak flow.
- The hydraulic model was run for the full set of 10 temporal patterns for each identified critical duration.

The design results are the maximum of these selected critical events.

Results from the design runs are presented in:

- **Maps RG-01-00 – RG-01-07** Peak Flood Depth
- **Maps RG-01-10 – RG-01-17** Peak Flood Level
- **Maps RG-01-20 – RG-01-27** Peak Flood Velocity

Due to the catchment geography, characterised by a narrow, deep channel and steep overbank areas, the flow is relatively constrained within Wolumla township, as well as Wolumla Creek and its tributaries.

Within the Wolumla township, flood depths were relatively modest, due to being located towards the upper reaches of the catchment.

Flood depths increased as flows progressed downstream, north to the Bega River, with depths in the 1% AEP of up to 2m at the confluence of Frog Hollow Creek and Greendale Creek downstream of the township, and over 6m at the confluence of Wolumla Creek and Frog Hollow Creek immediately upstream of the Bega River. In the PMF, these depths increase to over 4m and 10m respectively.

Due to the confined nature of the creeks and flowpaths, velocities were relatively high throughout the catchment, including within with township. Velocities within Wolumla township were typically in the order of 1m/s, although they reached as high as 3m/s in some reaches. Downstream of the township, Frog Hollow Creek and Greendale Creek had typical velocities of 1 – 2m/s, though similar to the township, isolated regions had higher velocities of up to 3m/s. Wolumla Creek had higher velocities, with typical velocities in the order of 3 – 4m/s.

Key crossings in the study area are shown in **Map RG-01-30**. Peak Flood depths above the crossing level at identified crossings are summarised in **Table 5-1**.

The summary shows one identified crossing was inundated in the 20% AEP, and a second crossing becomes inundated in the 10% AEP. There is a step up in affectation in the 2%, after which no new roads are flooded until the PMF. Three of the identified crossings are flood free in the PMF.

A more comprehensive analysis of overtopping behaviour and the impacts on access and evacuation will be undertaken in the Floodplain Risk Management Study (FRMS). This summary, however, highlights the access challenges within the catchment during even relatively minor flood events.

Table 5-1 Flood Depth over Roadway at Identified Crossings

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 in 200 AEP	1 in 500 AEP	PMF
1	Princess Highway at Frogs Hollow Creek (a)	-	-	-	-	-	-	-	-
2	Princess Highway at Frogs Hollow Creek (b)	-	-	-	-	-	-	-	0.3
3	Helmers Crossing at Candelo-Wolumla Rd	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.9
4	Crossing on Bega St	-	-	-	-	-	-	-	0.1
5	Crossing on Garvan St	-	-	-	-	-	-	-	0.1
6	Culvert on Clarke St and Eden St	-	-	-	-	-	-	-	-
7	Crossing on S Wolumla Rd (a)	-	-	-	-	-	-	-	0.3
8	Crossing on S Wolumla Rd (b)	-	0.1	0.2	0.2	0.2	0.3	0.4	0.6
9	Crossing on S Wolumla Rd (c)	-	-	-	-	-	-	-	0.1
10	Crossing on Old Soldiers Rd	-	-	-	-	-	-	-	-
11	Candelo Wolumla Rd on Wolumla Creek	-	-	-	0.2	0.3	0.6	0.8	1.6
12	Candelo-Bega Rd on Wolumla Creek	-	-	-	1.2	1.3	3.0	3.4	4.5
13	Princess Highway on Kingswood Creek	-	-	-	0.5	0.7	2.3	2.8	4.0

5.2 Flood Hazard

Flood hazard varies with flood severity (i.e. for the same location, the rarer the flood the more severe the hazard) and location within the floodplain for the same flood event. This varies with both flood behaviour and the interaction of the flood with the topography.

It is important to understand the varying degree of hazard and the drivers for the hazard, as these may require different management approaches. Flood hazard can inform emergency and flood risk management for existing communities, and strategic and development scale planning for future areas.

The hazard categories mapped are summarised in **Table 5-2** and **Figure 5-1**. These are based on the categories as defined in the AIDR (2017) Guideline.

It should be noted that these classifications are based on the physical flood behaviour in design flood events and do not account for other hazards that may exist (such as, road surface failure) or the variability in real storm events.

Flood hazard using the AIDR categories is provided in **RG-02-00 to RG-02-07**.

The results indicate that the majority of the mainstream flooding is classed as H5 or H6 in all design events, including the 20% AEP. This is due to the highly incised nature of the channels, resulting in riverine flows that are both relatively deep and fast. The steep banks, which serve to drive the confined nature of the flood behaviour, also serve to prevent wide regions of lower hazard flooding adjacent to the banks.

Lower hazard flow was observed in the smaller tributaries, as well as across the Wolumla Township.

Table 5-2 Hazard Categories

Hazard Category	Description
H1	Generally safe for vehicles, people, and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children, and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure

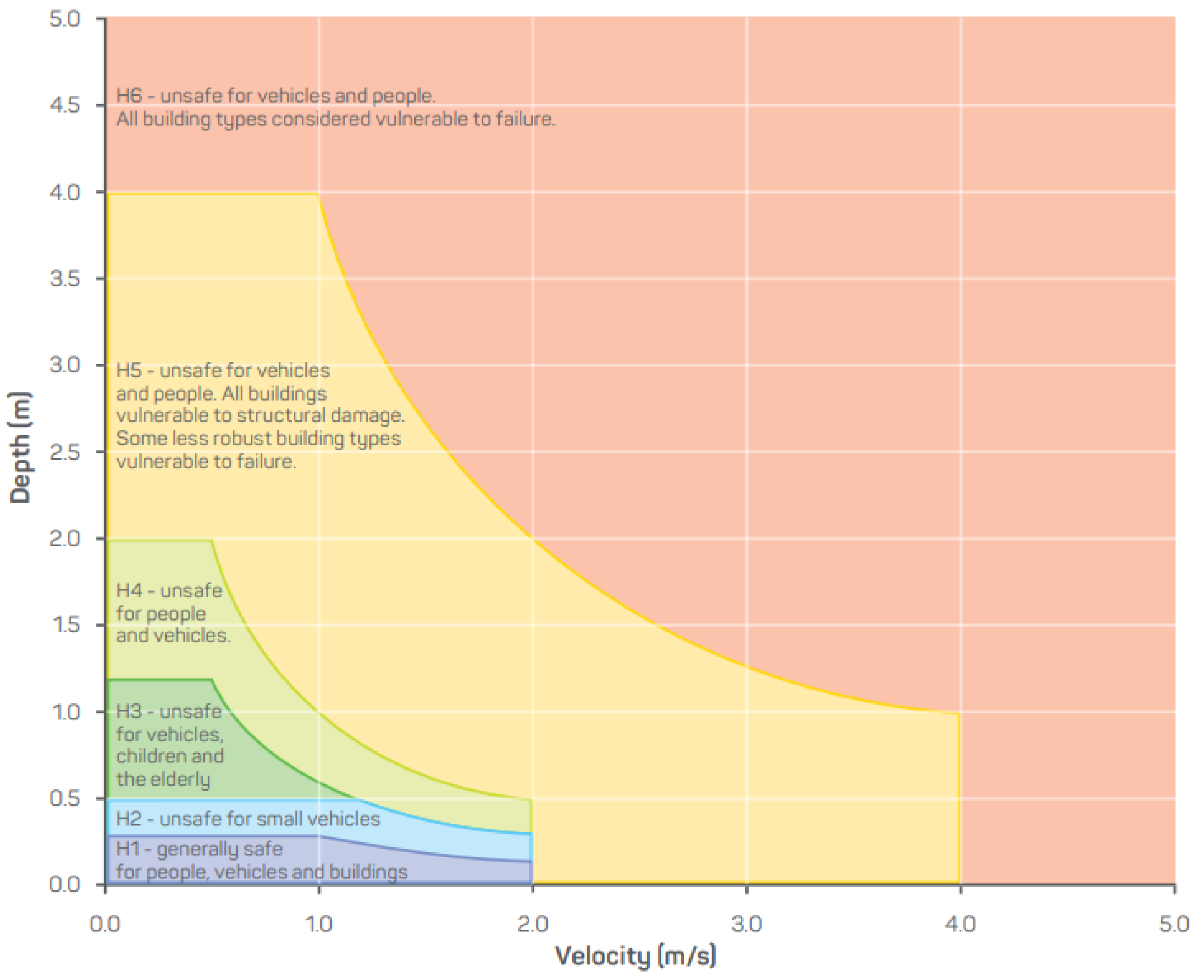

Figure 5-1 Flood Hazard Categories (AIDR, 2017)

5.3 Flood Function

Identifying the flood functions of the floodplain is a key objective of best practice in flood risk management in Australia, because it is essential to understanding flood behaviour. The flood function across the floodplain will vary with the magnitude in an event. An area which may be dry in small floods may be part of the flood fringe or flood storage in larger events and may become an active flow conveyance area in an extreme event. In general flood function is examined in the defined flood event (DFE), so it can be accommodated as part of floodplain development, and in the PMF so changes in function relative to the DFE can be considered in flood risk management.

The hydraulic categories (also known as flood function), as defined in the Flood Risk Management Manual (DPE, 2023), are:

- **Floodway** - areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage** - areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges.
- **Flood Fringe** - remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Preliminary mapping of the floodway was undertaken based on various criteria of floodway indicators, namely:

- VD > 0.2m^2/sec;
- VD > 0.3m^2/sec;
- VD > 0.5m^2/sec; and
- V > 1m/s.

The comparison showed that the floodway extent was generally similar for each criteria within the creeks and channels, due to the highly incised nature of the major flowpaths. The VD > 0.3m^2/sec threshold scenario, coupled with a velocity > 1m/sec threshold provided a more continuous definition of the floodway along the tributaries without significantly increasing the extent of the floodway along Wolumla Creek. It was considered suitable for testing in the hydraulic model.

Encroachment testing was undertaken on the VD > 0.3m^2/sec or V > 1m/sec threshold scenario by increasing the storage and fringe roughness to 0.2, restricting conveyance through these regions and forcing the flow through the nominal floodways. Testing demonstrated that the flood level impacts from this test were less than 0.15m indicating that the floodway definition is reasonable.

Due, again, to the steep topography of both the channel and overbank areas, there was very little storage identified in the model. An initial indicator of depth greater than 0.5m was used to identify storage areas. The only locations with a significant area of flooding based on these criteria, that was not already identified as floodway, were large farms dams, and some occasional ponding upstream of road crossings.

All other flood affected areas were classified as flood fringe.

Testing was undertaken on the flood fringe classification. The fringe areas were removed from the model, forcing all flow through floodway and storage regions. The results of the testing indicated that the classification was suitable, with impacts of less than 0.15m observed across the study area.

The definitions arrived at based on the above methodology were:

- Floodway – Velocity × Depth Product is greater than 0.3m^2/s OR Velocity is greater than 1m/s.
- Flood Storage –Depth is greater than 0.5m and area is not classed as floodway.
- Flood Fringe – areas in the flood extent outside of the above criteria.

Minor revisions were made to the initial classifications as follows:

- Floodways were made continuous.
- Isolated pockets of flood storage (less than 10 grid cells) were converted to flood fringe.

The flood function mapping is provided for the 1% AEP, and the PMF in **Map RG-03-00** to **RG-03-01**.

5.4 Climate Change Assessment

Climate change impacts have been assessed across the study area based on 2050 and 2100 planning horizons. The assessment includes rainfall intensity increases, but not sea level rise, as the Bega and Brogo Rivers FRMSP (2018) indicated that sea level rise impacts did not extend this far upstream.

Rainfall increases were adopted based on the SSP3 scenario for 2050 and 2100 based on the guidance provided in the *Climate Change Considerations* chapter of ARR2019. Based on the guidance in this chapter, the rainfall intensity increases adopted were:

- 15 – 18% (depending on duration) by 2050; and,
- 29 – 35% (depending on duration) by 2100.

Impacts on peak flood levels are shown for the 1% AEP in 2050 and 2100 scenarios are shown in **Maps RG-04-00** to **RG-04-01** respectively.

Note that a more comprehensive assessment of the impacts of climate change on property and infrastructure in the catchment area will be undertaken in the Wolumla Creek FRMSP.

The impact plots show that the effects of climate change vary across the catchment. In the upper reaches, including the Wolumla township, impacts are limited, with water level increases in the 2100 scenario less than 0.1m.

As flow progresses downstream, the additional rainfall depths begin to cause more impacts. Downstream of the township at the confluence of Frog Hollow Creek and Greendale Creek, impacts were observed of 0.3m and 0.5m in the 2050 and 2100 scenarios respectively. Further downstream at the confluence of Frog Hollow Creek and Wolumla Creek, these impacts increased to 0.8m and 1.6m in 2050 and 2100 respectively.

The impact plots also show that due to the steep overbank areas, these increases do not significantly impact flood extents. There is relatively little land that becomes newly flood affected in the climate change scenarios. The key location where a reasonable portion of land becomes newly flooded is at the bends of Wolumla Creek in Taminga, downstream of the Wolumla Cemetery and west of Old Soldiers Lane. At present, this region is undeveloped open space.

5.5 Sensitivity Testing

Sensitivity testing of the hydraulic model was undertaken for the 1% event, to assess how sensitive the TUFLOW model is to changes in:

- Model roughness;
- Model inflows;
- Downstream boundary conditions; and,
- Blockage.

Roughness, inflows and downstream boundary levels was varied by +/-20% and the TUFLOW model re-run. Blockage was assessed for a 0% blockage scenario and a 50% culvert blockage / 20% bridge blockage scenario.

The results of the assessment are presented at the conclusion of Map Compendium in maps:

- **RG-99-00** to **RG-99-01** for the roughness assessment;
- **RG-99-02** to **RG-99-03** for the inflows assessment;
- **RG-99-04** to **RG-99-05** for the downstream boundary assessment; and,
- **RG-99-06** for the 50% culvert blockage / 20% bridge blockage assessment.

Note that no map was prepared for the 0% blockage scenario as the afflux was negligible.

In the upper reaches of the catchment area, including within the Wolumla township, the model was not particularly sensitive to any of the parameters. Afflux for increased and decreased roughness and inflows were less than 0.05m. The upper catchment was sufficiently far upstream to not be affected by changes in the boundary condition.

Impacts arising from changes in roughness and inflows accumulated as flow progressed downstream. The model was more sensitive to changes in roughness than that to changes in flow. At the confluence of Frog Hollow Creek and Greenvale Creek, roughness changes resulted in afflux of +/-0.15 compared to +/-0.05 for flow. Similarly, at the confluence of Wolumla creek and Frog Hollow Creek, roughness afflux was +/- 0.6m, compared to +/- 0.1m for flow.

This response is likely due to the contained nature of the flowpaths. The flowpaths are able to convey additional water relatively easily. However, changes to the underlying roughness results in a significant change in conveyance of these restricted flowpaths, leading to more substantial impacts on peak water levels.

The downstream boundary sensitivity indicated the extent of the influence of the Bega River on catchment flooding. For the 1% AEP, a 20% change in assumed Bega River flow resulted in changes in peak levels in the Bega River of +/- 0.8m at the confluence with Wolumla Creek.

These impacts extended up Wolumla Creek to the confluence with Frog Hollow Creek (900m), and then a further 1.6km up both Wolumla Creek and Frog Hollow Creek. As with the roughness sensitivity, the terrain prevented any significant lateral change in flood extents due to these level changes.

The 0% blockage had a negligible impact on peak flood levels. This was due to most culverts and bridges having a 0 – 10% blockage rate in the 1% AEP due to their relatively large size. As such, the removal of this small amount of blockage had no significant impact on flood behaviour.

There were modest impacts on flood behaviour due to increasing the blockage rates. Whilst impact upstream of major crossings increased by up to 0.15m at Candelo-Wolumla Road and 1.1m at the Frog Hollow Creek crossing of the Princes Highway, these impacts remained well contained due to the topography of the catchment.

Levels reduced along Frog Hollow Creek by 0.02m from the upstream Princes Highway Crossing to 6km downstream.

Similar to the other sensitivity tests, this afflux had little impact on flood extents due to the relatively steep terrain adjacent to these creeks.

6 Conclusions

The Wolumla Creek Flood Study has been prepared for Bega Valley Shire Council to define the existing flood behaviour across the study area, and to establish the basis for subsequent floodplain management activities.

This report presents the flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide a better understanding of the flood behaviour and risks across the full range of flood events. It involved consideration of the local flood history, available flood data, and the development of hydrologic and hydraulic models.

Hydrological modelling was undertaken using RAFTS. Hydraulic modelling was undertaken using TUFLOW.

Validation was undertaken through a comparison to prior modelling, as well as to community observations from past flood events.

The hydrological and hydraulic models were analysed for the Probable Maximum Flood (PMF), 0.2%, 1%, 2%, 5%, 10%, 20% and 50% AEP events. The models were analysed for storm durations from 60 minutes to 18 hours.

Due to creek geography, characterised by a narrow, deep channel and steep overbank areas, the flow is relatively constrained within the study area, both on Wolumla Creek and its tributaries. The majority of the flow is classed as high hazard and floodway, with only relatively small bands of low hazard flow at the edges of the flood extent.

The existing scenario design events resulted in the overtopping of most crossings in the 20% AEP event, all but one are flooded in the 2% AEP, and all are flooded in the 1% AEP event.

Climate change impacts have been assessed across the study area based on 2050 and 2100 planning horizons. The assessment includes both sea level rise and rainfall intensity increases. Rainfall intensity increases were assumed based on the SSP3 scenario set out in the *Climate Change Considerations* chapter of ARR2019. Based on the guidance in this draft chapter, the rainfall intensity increases adopted were:

- 17 – 20% (depending on duration) by 2050; and,
- 32 – 39% (depending on duration) by 2100.

Due to the nature of the topography, climate change had relatively little impact on overall flood behaviour. Flows in both 2050 and 2100 remained well contained with little change in flood extents. There were no new flow paths activated, nor any major change in flood function.

Whilst the behaviour remained similar, there were significant changes in peak flood levels in the downstream regions of the catchment. The incised nature of the channels means that increased flows have a modest impact on behaviour and extent, but a large impact on levels. Typical level increases in the 2100 scenario were observed of:

- 0.3m and 0.5m at the confluence of Frog Hollow Creek and Greendale Creek in the 2050 and 2100 scenarios respectively; and,
- 0.8m and 1.6m at the confluence of Frog Hollow Creek and Wolumla Creek, these impacts increased to in 2050 and 2100 respectively.

The data developed as part of the study provides a better understanding of the flood behaviour and risks across the full range of flood events. It involved consideration of the local flood history, available flood data, and the development of hydrologic and hydraulic models that are calibrated and verified against historic flood events.

The assessment undertaken provides a thorough understanding of the existing flood behaviour in the study area.

7 References

AIDR. (2017). *Australian Disaster Resilience Handbook 7: Managing the Floodplain: A guide to best practice in flood risk management in Australia.* East Melbourne VIC: AIDR, on behalf of the Australian Government Attorney-General's Department.

Cardno. (2017). *Bega and Brogo Rivers Floodplain Risk Management Study and Plan.*

NSW Department of Planning and Environment. (2023). *Flood Risk Management Manual: The policy and manual for the management of flood liable land.* Parramatta NSW: Environment and Heritage Group, Department of Planning and Environment.

SMEC. (2014). *Bega and Brogo Rivers Flood Study.*

Appendix A

Community Survey

Wolumla Flood Study and Risk Management Study – Survey

Bega Valley Shire Council is preparing a flood study and floodplain risk management study and plan for the Wolumla catchment within the Bega Valley Shire Local Government Area.

This survey will take about 10 minutes and your feedback will help us plan and manage existing and future flood risks in the area.

1. *Previous flood experiences*

Q1. Thinking of the <u>worst flood</u> you've experienced in your current home, how serious were the effects of the flood upon the personal safety of households?

- o Not at all serious
- o Slightly serious
- o Serious
- o Very serious
- o Extremely serious

•

Q2a. Still thinking of the worst flood you've experienced, was your property directly affected by flooding? If so, what was the depth of flooding (cm) and duration of flooding (hours)?

____

Q2b. Can you remember when this flood happened? Please include as much detail as you can e.g., month and/or year

____

2. *Preparing for floods*

Q3. How responsible, if at all, do you believe the following groups are for protecting properties against flooding?

	Not at all responsible	Not very responsible	Responsible	Very responsible	Extremely responsible
State government (NSW)	o	o	o	o	o
Bega Valley Shire Council	o	o	o	o	o
Individual households (landlord if rented)	o	o	o	o	o

Q4. To what extent do you intend to do the following in the next 12 months?

	Not at all likely	Not very likely	Likely	Very likely	Extremely likely	Already doing/ done
Assembling an emergency kit (including water, food, a battery powered radio, a first aid kit etc.)	o	o	o	o	o	o
Collecting information about flood consequences, evacuation routes and safe/high locations	o	o	o	o	o	o
Making a plan/ agreements with family, friends and neighbours on how to help each other in case of evacuation/flooding	o	o	o	o	o	o
Renovating building to make it more flood resistant	o	o	o	o	o	o

Q5. How would you rate the risk of flooding:

	No risk	Low risk	Moderate risk	High risk	Very high risk
To your personal safety	o	o	o	o	o
In the local community	o	o	o	o	o

3. *Response to floods*

Q6. How do you anticipate you would respond to a major flood in your area?

- o Evacuate immediately
- o Evacuate only if advised to do so by emergency services
- o Remain at my property
- o Don’t know/unsure
- o Other (please specify)______

Q7. If you were to evacuate, what would be the reasons for you to evacuate?

- Safety of the household
- Discomfort / inconvenience of being isolated by floodwater
- Need for uninterrupted access to medical facilities
- Other (please specify)___________

Q8. If you were to remain at your house, what would be the reasons for you to stay?

- Discomfort/ inconvenience of evacuating
- Need to care for animals
- I know my home cannot be flooded and can cope with isolation
- Concern for security of my property if I evacuate
- Trying to prevent extra damage to property
- I do not know where/have a place to go if evacuating
- Other (please specify)________

Q9. If you had to leave your home on short notice in an emergency, where would you go?

- Home of a family member
- Home of a friend
- An emergency relief centre
- Hotel or short-term accommodation
- I have no plan/do not know
-

Q10. What information do you look for during a flood event?

- Road closures
- Evacuation notices
- Flood characteristics (magnitude, durations, areas impacted, etc.)
- Other (please specify)_________

Q11. Where would you look for updates and information?

- Websites
- Local radio
- TV
- Social media
- Word of mouth

- Smartphone app
- Other (please specify)_________

4. *Management of floods*

Q12. How would you rate the significance of the flood risks below?

	Very Low	Low	High	Very High	Don't know
Inappropriate development	o	o	o	o	o
Isolation, loss of access and inability to evacuate	o	o	o	o	o
Flooding of properties and residencies	o	o	o	o	o
Lack of flood warning	o	o	o	o	o
Lack of flood community awareness	o	o	o	o	o
Lack of guidance prior to and during a flood event	o	o	o	o	o

Q13. As part of this study, a range of options will be assessed for the mitigation and management of flood risk. You will have another opportunity to comment on these options once they are developed. At this early stage, how supportive would you be of the following management options?

	Not at all supportive	Not very supportive	Somewhat supportive	Very supportive	Extremely supportive	Don't know
Raising or lifting crossings to reduce frequency of overtopping	o	o	o	o	o	o
Construction of alternate access routes	o	o	o	o	o	o
Improvements to existing access routes	o	o	o	o	o	o
Improvements to flood forecasting and flood warning	o	o	o	o	o	o
Provision of flood refuge within the Wolumla region	o	o	o	o	o	o
Updates to Council's planning controls to better manage development in the catchment.	o	o	o	o	o	o

Education for the community on flood risk and response	o	o	o	o	o	o
Structural options (such as levees) for the protection of individual properties	o	o	o	o	o	o

Q14. Do you have any suggestions on how flooding in your local area could be managed better?

____

____

____

5. Demographics

Q15. What is your identified gender?

- Male
- Female
- Prefer to self-describe_____
- Prefer not to say

Q16. What is your age group?

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75+

Q17. How long have you lived in this neighbourhood/your current home?

- Less than 5 years
- 5 to 10 years
- 11 to 15 years
- 16 to 20 years
- More than 20 years

Q18. How many people live in your household?

____

Q19. Do you, or anyone in your household, require assistance due to disability or long-term injury or illness?

- Yes
- No

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